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The Environmental Aspects and Palynological Signals of the "Fairy-Circles" – Ancient Earthworks linked to Coastal Heathland in South-Western Norway

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Abstract

The fairy-circles, a group of mysterious earthworks, are restricted to the coastal heathland of Jæren, south-western Norway. They are the result of a specialised farming practice adapted to local environmental conditions and are often situated on convex landforms of Quaternary deposits. These earthworks comprise an enclosure defined by a bank and an oval or rectangular ditch in loose deposits. They have been recorded, archaeologically investigated and debated since the 1820s. Problems concerning their form, function and period of use have until now been unsolved.

Factors such as climate, Quaternary deposits, vegetation cover and land-use were recorded to put the fairy-circles into an environmental context. Principal components analysis (PCA) was performed on fossil pollen data from structures within 16 of these man-made constructions and compared to modern and fossil analogues. This study reveals a change in the pollen taxa throughout the period of use of these historic relics suggesting that the wet heaths and mires found on the slopes and concave landforms were used for haymaking, and that the fairy-circles served as bases for haystacks. The onset of this activity may be dated back to the Late Iron Age while the upper age limit is tentatively put at AD 1835.

Keywords: South-western Norway, Heathland, Land-use, Haymaking, Fairy-circles, Haystack Bases

Introduction

A characteristic feature of the Norwegian landscape is the diversity of environments resulting in a variety of cultural landscapes reflecting local natural conditions, civilisation and history.

The most prominent feature of the west Norwegian coast is the "coastal heath section" (def. Dahl *et al.* 1986; Moen 1999, 131), the most important part of the outlying land in this part of the country (Fig.1). This heathland belt is especially wide in the Jæren region in Rogaland and has dominated the landscape for several millennia with a maximum extent in the mid-nineteenth century (Flor 1995 [1811] 53,59,72; Kraft 1830). However, since World War II, economic activity and especially the recent use of artificial fertilisers, has changed this picture considerably, and only 10 % of the original Norwegian heathlands are left (Hjeltnes 1997). One reason for this is that this type of outlying land has been regarded as a low productive vegetation type in modern times. Today, only patches of the formerly common heathland with its cultural environment remain as islands within the modern and highly effective farmland of the Jæren region.

Human exploitation threatens both the natural resources and cultural monuments within the heathland ecosystem, including a group of mysterious earthworks called fairy-circles (in Nor-

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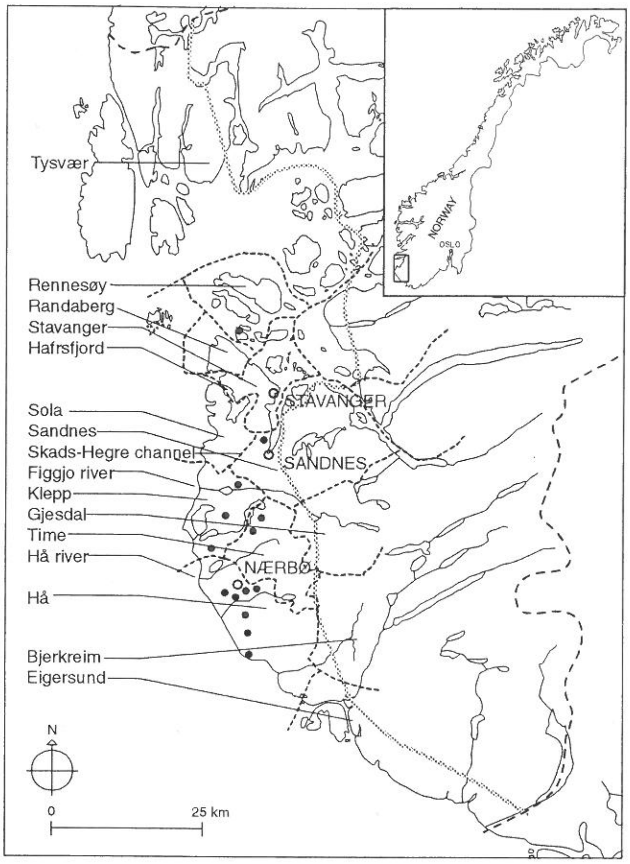


Figure 1. Rogaland county with district boundaries and localities of sites mentioned in the text. The eastern limit of the south-western coastal heath section is shown. • = Fairy-circles investigated.

wegian referred to as "alvedanser"). These small (usually 5 to 15 m diameter) earthworks consist of an enclosure defined by a bank and an oval or rectangular ditch in loose deposits (Fig. 2). The fairy-circles are exclusively 'associated with' the heathlands and thus to the former use of this outlying land.

Since the mid-nineteenth century the fairy-circles have been historically and archaeologically recorded and are believed to have played a part in the harvesting of outfield resources, either as peat, hay, cereal or heatherstacks (Kraft 1830; Nicolaysen 1866; 1869; Mauland 1923; Skjøldsvold 1962; Møllerop 1965; Myhre 1966; Danielsen 1984; Lillehammer 1996). They have also been linked to cults involving fairies and sun worship (Rønneseth 1959a; 1959b). However, even by the 1830s their traditional use had been forgotten. There has been an aura of mystery surrounding the fairy-circles, and several questions concerning their form, function and time of use have been unresolved until now. The author suggests that they are the result of a specialised traditional farming practice, well suited to the specific environmental conditions and local resources found in this part of the west Norwegian heathland. Circles similar to these have been found in the Jutland heathlands, Denmark (Uldall 1930; Andersen 1977).

The main objectives of this paper are to:

- Describe the physical environmental factors characteristic of the Jæren region, putting the fairy-circles into an environmental context

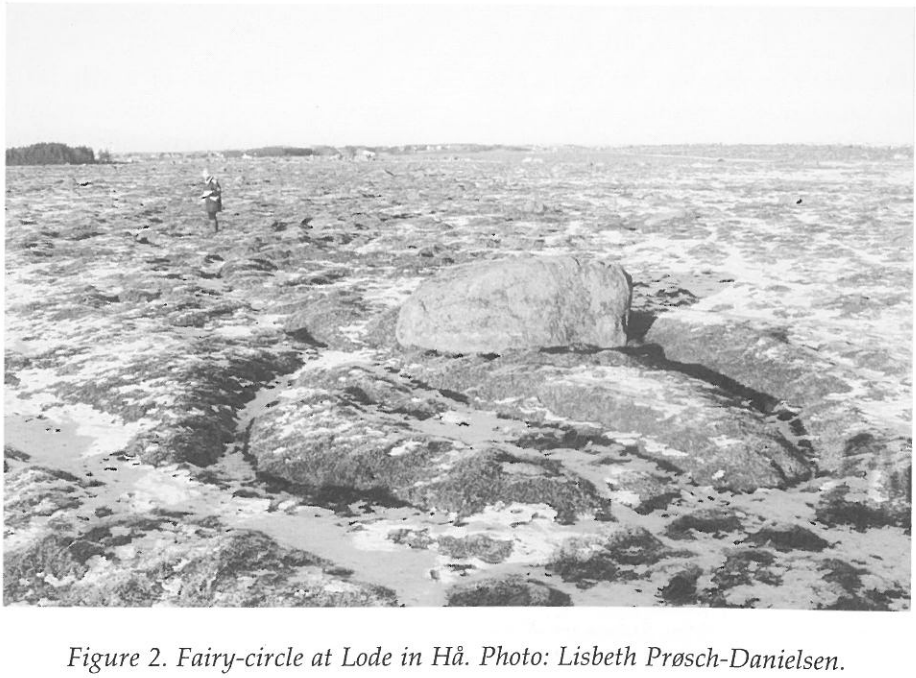


Figure 2. Fairy-circle at Lode in Hå. Photo: Lisbeth Prøsch-Danielsen.

- Study the palynological signals of the earthworks in order to understand their function and period of use

Until now our knowledge of the heathland in Norway, its land-use history, farming practice and ancient monuments, has been based on the studies and results from the Lindås project in the county of Hordaland in the 1970s (Kaland 1979; 1986). Fortunately, in 1996, the national research program "Cultural Heritage and Environment" provided an opportunity to study different aspects of the coastal heathland further south in Norway. This program led to the initiation of the project "Contact-Conflict: Cultural Heritage and Cultural Perception. Analyses of Outlying Fields and Heather Land in Hå municipality, Rogaland County, Norway" which included archaeological, palynological and geological investigations (Lillehammer 1996; Prøsch-Danielsen and Simonsen 2000a; 2000b; Lillehammer in prep.).

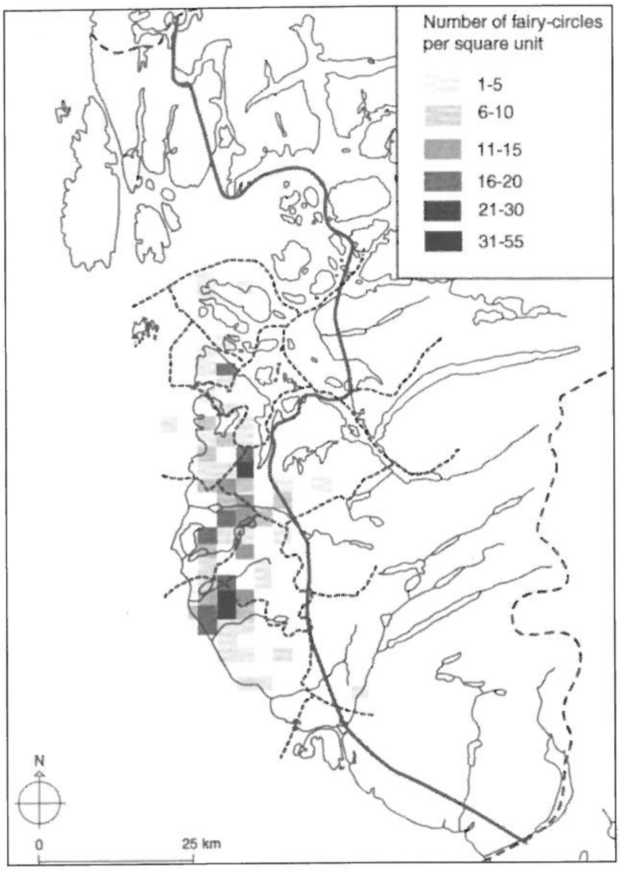


Figure 3. The distribution pattern of the fairy-circles. Number(s) of registered earthworks per square unit (according to land-use mapping) is given in the legend.

The Fairy-Circles and their Environment

Distribution pattern

337 localities with one or more fairy-circles have so far been registered (Land-use mapping, Museum of Archaeology, Stavanger, files) and Fig. 3 shows their distribution. However, several localities have been destroyed and new ones will probably be added in the future. The main distribution is located in the low-lying part of Jæren with three marked concentrations: one close to the Skads-Heigre channel, and the others by the Figgjo and Hå rivers (Fig. 1), areas with a thick soil cover (Wangen *et al.* 1987). The number of localities decreases both south and north in Jæren and is relatively rare on the Stavanger peninsula. Its northernmost outpost is found on the island of Rennesøy, situated in the Boknafjord area.

Climate

The fairy-circles are restricted to "the highly oceanic section (O3)" (def. Moen 1999, 131), characterised by a humid climate with relatively cool summers (July and August monthly mean 14–15°C) and mild winters (mean January temperature up to +2°C). This section is limited inland by the January 0°C isotherm. Within this geographically restricted area, winter temperatures vary noticeably along a gradient from coast to inland and with altitude, but not in a south – north direction as temperature gradients run parallel to the coast. Mean annual precipitation is about 1100 mm in the Jæren lowland with increasing annual precipitation and frequency inland due to changes in relief. Maximum precipitation is found in a region 30–50 km from the sea (Lye 1970). The prevailing winds in summer are north-westerly (onshore), while those of winter are mainly south-easterly (Wishman 1990, 107–11). Oceanic regions of Norway are considerably windier than continental regions and in the absence of forest are very exposed to strong winds.

Geomorphological features and Quaternary deposits

Geomorphologically, the northern part of Jæren including the islands of Rennesøy, belongs to the so-called "Strandflaten", a geomorphological feature that can be followed from the coast of Troms to Jæren (Larsen and Holtedahl 1985) where sediment cover is discontinuous and bedrock is exposed as rocks or rocky hills.

The southern part of Jæren is characterised by thick Quaternary deposits (Wangen *et al.* 1987; Andersen *et al.* 1987; Janocko 1997) (Fig. 4) that record at least four glaciations and partly record

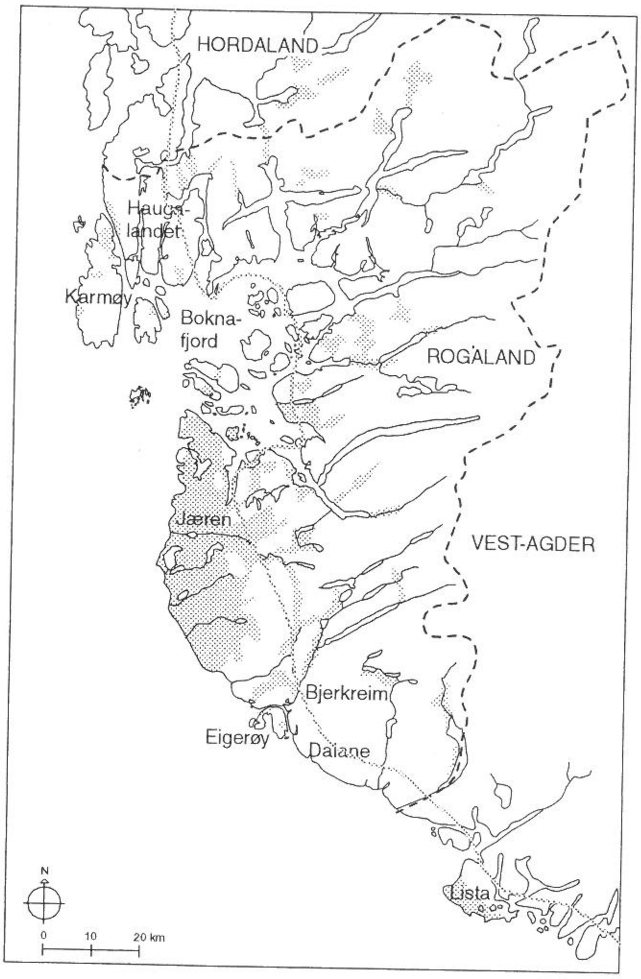


Figure 4. Distribution of till and Quaternary deposits (marked grey) (modified after Thoresen 1990 in Prøsch-Danielsen and Simonsen 2000a).

"ice-free" periods in which glaciomarine clays were deposited by a Norwegian Channel Ice Stream (Sejrup *et al.* 1998; Stalsberg *et al.* 1999). This has resulted in huge series (up to 130 m) of tills and glaciofluvial deposits interbedded with marine sediments. Late Weichselian erosion has exposed these series in a mosaic pattern (Grimnes 1910; Wangen *et al.* 1987) resulting in the subsoils of Jæren having a very diverse soil fertility (Semb 1962). As a result of recent studies (e.g. Sejrup *et al.* 1998; Stalsberg *et al.* 1999; Jónsdottir *et al.* 1999) the southern part of Jæren has been separated into three geomorphological areas.

1. A hummocky lowland area (north of Nærbø) (Fig. 1)
This area is relatively flat but with an undulating and hummocky landscape with shallow lakes. It is covered by glaciofluvial deposits and a sandy and gravely till interpreted as having been deposited during the last glaciation, and it has ridges running in an E–W direction as a result of ice lobes flowing from the east. The soils are well drained. The majority of fairy-circles are found in this area.

2. A smooth lowland area with streamlined morphology (south of Nærbø)
The area has ridges running predominantly NW–SE parallel to the coast, that have been interpreted as drumlins formed by ice flowing along the Norwegian Channel. Superimposed on these is a weaker imprint of later E–W flowing ice. This southern part of Jæren is also covered by sand and gravely till but has a pronounced clay till content on the ridges. Fewer fairy-circles are found in this area.

3. Coastal upland region
The upland area (between 180 and 250 m asl) is characterised by a very flat landscape covered by a fine-grained till matrix. The eastern part (above 200 m asl) is more hummocky with till and glaciofluvial deposits and dead-ice topography.

In contrast to the southern part of Jæren, the inland areas to the east are almost lacking in Quaternary deposits due to Late Weichselian erosion (Janocko 1997, 58). The fairy-circles lie west of this marked border. They are also found in areas with Quaternary deposits in the northern part of Jæren and on the islands of Rennesøy. Thus Quaternary deposits seem to be a prerequisite for the formation of the fairy-circles.

Coastal heathlands – general features and major types

Within this geographically limited area there is a gradual change in the *Calluna* heaths due to the climatic coast to inland gradient. Frost-sensitive communities with *Erica cinerea* are confined to the outer Boknafjord district, on the islands of Rennesøy and in the northern part of Jæren (Lye 1970; Steinnes 1988b, 31; Fremstad *et al.* 1991, 32) (Fig. 1). Further inland, the heaths consist of eu- and sub-oceanic species with broad distributions. The sub-oceanic heaths are often composed of grasses, sedges, rushes and species of wet and damp substrates. Important species are the sub-oceanic *Erica tetralix, Narthecium ossifragum, Myrica gale* and *Juncus squarrosus* and eu-oceanic *Polygala serpyllifolia* and *Galium saxatile.* Other important species often found in the grass heaths are *Plantago lanceolata* and *Succisa pratensis.*

The lowland belt of the heather zone gradually merges into the inland heath belt that is fully developed in the Dalane and Bjerkreim region (Steinnes 1983) where fairy-circles are almost absent.

The phytosociology of the coastal heaths in

Rogaland has been studied by Fægri (1952), Semb and Nedkvitne (1957), Steinnes (1983; 1988a; 1988b; 1988c), Fremstad Hansen (1991) and Prøsch-Danielsen and Øvstedal (1994). As part of the project "Atlantic heaths" Steinnes (1988b) described thirteen types of coastal heath vegetation with both wet and dry heaths. He concluded that within a geographically small area, the drainage capability of the soils and their wetness are the most important environmental factors for heath-type differentiation. Earlier and later phytosociological studies in Rogaland, which included measurements of several environmental variables, have confirmed these results (Semb and Nedkvitne 1957; Fremstad Hansen 1991).

The border between dry heaths, wet heaths and mires is not always clear-cut in this landscape. Generally, dry heaths, characterised by the dominance of *Calluna vulgaris* with *Arctostaphylos uva-ursi* (Steinnes 1988b, 24), are found on convex landforms and on steep slopes where the soils are well-drained and usually podzolised. Therefore they are often the most visually prominent vegetation type in the landscape. Heaths totally dominated by *Calluna vulgaris* are now rare in Rogaland and only found in the Karmøy-Haugesund area. Dry heaths were most prominent in the coastal upland region, but due to high grazing pressure, they have been converted into grass heaths dominated by *Nardus stricta* (Skogen 1989).

The wet heaths, characterised by species such as *Trichophorum caespitosum, Molinia caerulea, Narthecium ossifragum* and *Myrica gale* are usually associated with concave landforms. However, in the southernmost part of Jæren wet heaths are also found on the convex landforms with fine-grained substrate ridges. Generally, the wet heaths cover large areas in this region, as they require gentle slopes and some water movement (Øvstedal 1985, 397). Soligenous mire communities, distinguished from wet heath communities by the occurrence of *Eriophorum* spp. and with the accumulation of peat, are found in places with a high groundwater level and stagnant water.

The development and management of the heathlands

The development of the coastal heathland was a gradual man-made process in western Norway (Kaland 1979; 1986). In Rogaland deforestation was metachronous, spanning over more than 3600 years from 4000 to 200 cal BC (Prøsch-Danielsen and Simonsen 2000a; 2000b), leading to a regional mosaic pattern of different vegetation types. The development of the heathland paralleled deforestation. North of Hafrsfjord (Fig. 1) heath establishment occurred gradually from 4000 cal BC, but was fully developed by approximately 200 cal BC (Pre-Roman Iron Age). Further south in Jæren, deforestation started at the end of the Middle Neolithic II around 2500 cal BC. Here, clearance was extensive and rapid, and permanent heaths developed before the end of Bronze Age V (900–700 cal BC) (Prøsch-Danielsen and Simonsen 2000a; 2000b).

The heaths have been maintained by burning, cultivation, winter pasturage and heather cutting. Burning and winter pasturage are the oldest forms of land-use practice. Due to the mild climate, a prerequisite for the formation of coastal heaths, there are few days with snow cover in this region (Stavanger 20 days) (Steinnes 1988c, 12) and therefore sheep and cattle can feed outside throughout the year (Kaland 1986, 20; Fremstad *et al.* 1991, 13).

In Rogaland, grazing and regular heath burning have been recorded from 4000 cal BC up to the present (Prøsch-Danielsen and Simonsen 2000a). The effect of burning and the subsequent characteristic succession, is thoroughly documented in Gimingham (1972) and Webb (1986) and, of Norwegian heaths in Sundve (1977, 226) and Øvstedal (1985, 395–7). Generally, with increasing grazing pressure, the heaths are converted into oceanic grass heaths.

Heather mowing has been dated back to the Viking age in Hordaland (Kaland 1986) but not yet to prehistoric times in Rogaland. According to ethnological and historical evidence in Hordaland, the heather was mown every third year and brought home as additional fodder for winter, especially for cattle. In the twentieth century, heather was only mown as emergency supplies in springtime (Malmin 1973; Gjertsen 1975). From interviews with local people in Rogaland, Høeg (1976, 101, 257–61) found that, up until the 1920s, heather was mown either for use as firewood for baking or as fodder for cattle, and was mown throughout the winter during snow-free periods.

The Palynological Signals from Fairy-Circles

Material

Although archaeological investigations of fairy-circles have been made since the 1860s (Nicolaysen 1866, 1869), sampling for pollen analysis was only routinely included a hundred years later when Stavanger Museum collaborated with natural scientists. Since then, a total of 34 fairy-circles have been excavated and investigated palynologically. The investigations have been concentrated in the central agricultural areas of Rogaland. In addition one earthwork has been investigated from the northern border of distribution (Fig. 1). The locations of excavations have primarily been dictated by conflicts in interest between the management of the protected earthworks and farming activity, but some have been chosen exclusively for this project. A set of 19 of these fairy-circles (pollen data-set 1), all with well-documented distinct structures, were selected for further study and listed in Table 1.

Knowledge of Jæren's coastal heathland is based on palynological studies from sites representing local, extra-local, and regional pollen source areas, as discussed in Prøsch-Danielsen and Simonsen (2000a). However, for comparative studies, this work requires sites with a local pollen source area, as discussed by Jacobson and Bradshaw (1981), Bradshaw (1988), Bostwick Bjerk (1988) and Andersen (1992) since it is necessary to distinguish between different local vegetation types within the heathland (e.g. between dry and wet heaths/mires). From the coastal heath section in Rogaland a number of surface pollen spectra supplemented with fossil pollen spectra (below) are available and some are published (Prøsch-Danielsen and Øvstedal 1994; Gunnarsdottir 1997). These are from ancient monuments like clearance cairns (dry heaths), peaty soils and small bogs (wet heaths/mires). Clearance cairns have been selected because they serve as pollen-traps with a local pollen source area (Prøsch-Danielsen 1999). As ancient monuments they are also automatically protected by the Cultural Heritage Act, and seem to have survived modern encroachments.

In addition, surface pollen samples collected from characteristic dry and wet heaths in Lindås in Hordaland have been included. This is due to the virtual absence of "uncultivated heathland" on the low-lying parts of Jæren. All sites and samples (pollen data-set 2) for comparative studies are listed in Table 2.

Field work and identification of soil structures

To obtain maximum information on the extent, form and soil structures of the fairy-circles, a trench was excavated either by hand or by a hydraulic excavator across the earthworks. The soil structures, both natural and man-made, were identified, interpreted and later documented by profile drawings in the field. The topsoil was not removed mechanically.

The fairy-circles are usually situated on convex landforms or gentle slopes on sandy or gravelly tills or glaciofluvial sediments. The topsoil is well drained and usually podzolised with a distinct top layer of black raw-humus, followed by a greyish leached stratum, a humic sandy soil, and a mottled yellow and rust-coloured precipitated layer at the base. Fairy-circles numbers 2, 4, 8, 9, 16 and partly 15, lack the leached stratum, and the profiles can be interpreted as humic podzols. Fairy-circle 16 from Kvia south of Nærbø, is the only one from a rather wet locality. Here the raw humus is rather thick and of a peaty character and the basal layer consists of a greyish till with high clay content. These soils bear the stamp of

Site	Farm no – district	Excavator and sampler, year	Pollen analyst, year
1	Nedre Åse 37/3, Klepp (no. 1)	GL and LP-D 1987	LP-D 1996
2	Nedre Åse 37/3, Klepp (no. 2)	GL and LP-D 1987	LP-D 1996
3	Sørbø 23/4, Klepp (no. 77)	GL and LP-D 1987	LP-D 1996
4	Sørbø 23/4, Klepp (no. 83)	GL and LP-D 1987	LP-D 1996
5	Sørbø 23/4, Klepp (no. 86)	GL and LP-D 1987	LP-D 1996
6	Stangeland 6/2, Klepp	OO and AS 1969	AS 1969
7	Bryne 1/1, Time	EØ and AS 1974	LP-D 1999
8	Soma 65/21, Sandnes (no. 3)	EH and HG/E-CS 1996	LP-D 1998
9	Bru 44/7, Rennesøy	MH and LP-D 1998	LP-D 1998
10	Skrettingland 52/9, Hå	AET/ ØL and ØL 1998	LP-D 1999
11	Bø 110/3, Hå	GL and LP-D 1997	LP-D 1998
12	Lode 17/2, Hå (no. 2, 1996)	GL and LP-D 1997	LP-D 1998
13	Lode 17/2, Hå (X16)	AJN and LP-D 1999	LP-D 1999
14	Lode 17/2, Hå (new 1997)	AJN and LP-D 1999	LP-D 1999
15	Kvia 19/6, Hå (no. 14)	GL and LP-D 1996	LP-D 1996
16	Kvia 19/5, Hå (no. 2)	GL and LP-D 1997	LP-D 1997
17	Serigstad 20/2, Time	AL and AS 1976	
18	Ævestad 67/8, Hå	KV and E-CS 1998	
19	Kvassheim 103/2,18, Hå	GL, AL and AS 1975	

Table 1. The investigated fairy-circles. HG= Helga Gunnarsdottir, EH= Elisabeth Holst, MH= Mari Høgestøl, ØL= Øystein Lia, AL= Arnvid Lillehammer, GL= Grete Lillehammer, AJN= Arne Johan Nærøy, OO= Oluf Olsen, LP-D= Lisbeth Prøsch-Danielsen, AS= Asbjørn Simonsen, E-CS= Eli-Christine Soltvedt, AET= Alma Elisabeth Thunstad, KV= Kjersti Vevatne, EØ= Einar Østmo.

Site	Farm no – district	Site-type	Pollen sampler and analyst, year	Sample no. (ref to Fig. 8)
20	Lygra 57/1–5, Lindås	wet heath, surface pollen samples	DOØ 1999, LP-D 1999	146–150
21	Lygra 57/1–5, Lindås	dry heath, surface pollen samples	DOØ 1999, LP-D 1999	151–154
22	Kvia 19/5, Hå	clearance cairn (dry heath), section	LP-D 1997, 1998	155–163
23	Skjæveland 52/7, Sandnes	clearance cairn no. 60a (dry heath), section	HG 1996	164–169
24	Skjæveland 52/7, Sandnes	clearance cairn no. 86 (dry heath), section	HG 1996	170–176
25	Håbakken V, Norheim 19/7,11, Time	clearance cairn (dry heath), section	IM 1998	177–178
26	Kvia 19/5, Hå	peat bog /wet heath sequence	LP-D 1996	179–181
27	Stavnheimsmyra 70/1, Hå	peat bog/wet heath sequence	LP-D 1997	182
28	Gismarvik, Håstø 61/2,6, Tysvær	peaty soil/wet heath sequence	LP-D 1988	183–187

Table 2. Selected sites for comparative studies of heath types/mires. HG= Helga Gunnarsdottir, IM= Inger Midtbø, LP-D= Lisbeth Prøsch-Danielsen, DOØ= Dag Olav Øvstedal.

the climate and of the length of time since soil formation began.

However, the ditches and banks are artificial structures. Earthworks have either outer or inner banks or both. The ditches are clearly visible, with depths of approximately 50 cm. They were later filled with dark brown well-humified soils (soil-structure F), with a raw-humus layer on top (soil-structure T) (Figs. 5 and 6). These soils are most probably developed *in situ*. Ditches with heterogenous infills have been avoided for pollen sampling. The material dug from the ditch was used to create the bank and appears in the profile as a heterogeneous layer where humus and mineral content are intermixed (soil-structure X). The bank was later covered by a sandy humic layer with a raw-humus layer on top (soil-structures Y and T) (podzolisation has been recorded above the banks in some fairy-circles).

The original soil-profile (soil-structure S) has been sealed underneath the banks and provides the best opportunity for studying the local fossil pollen assemblage contemporaneous with or prior to the construction of the fairy-circles. This reflects the local resources available at that time. The ditches serve as pollen traps with a local catchment area, and represent the local fossil pollen assemblage after the construction of the earthwork. If both are available they give an excellent opportunity for studying environmental changes and thus changes in land-use.

Figure 5. Photograph of a soil section showing the ditch cut down in the soil profile. From a fairy-circle at Kvia in Hå. Photo: Lisbeth Prøsch-Danielsen.

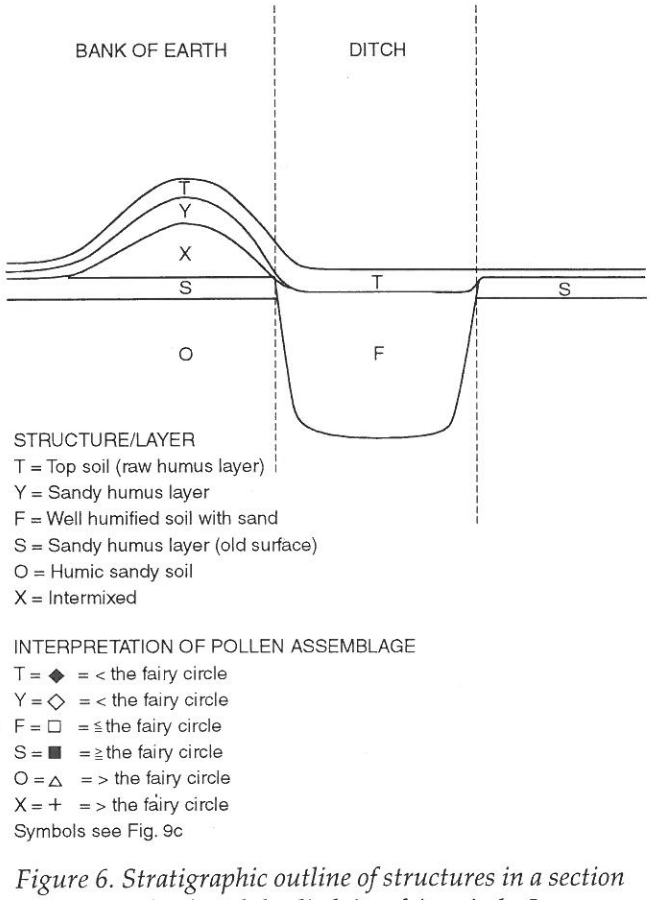


Figure 6. Stratigraphic outline of structures in a section through the bank and the ditch in a fairy-circle. Interpretation of the structures is given in the legend, including reference to various symbols used in Fig. 9 c (diamonds, squares and triangles). > and < indicates pollen assemblages older and younger respectively than the fairy-circle.

Soil samples for pollen and charcoal analyses were sampled from all the different soil structures as seen from the stratigraphic outline in Fig. 6. Interpretation of the pollen assemblages are included in the legend.

Pollen samples from the clearance cairns were sampled directly into plastic tubes from open soil sections in the field. Samples from peat bogs and peaty soils were sampled from open sections or by hammering down 10 cm PVC drainpipes into the peat. Surface pollen samples were collected from the litter (raw-humus) layer (depth 2 cm).

Laboratory procedures, radiocarbon dating and identification of heathland and major heath types

The pollen samples were treated according to a standard acetolysis procedure and identified according to Fægri and Iversen (1989). Spores follow Sorsa (1964) and Moe (1974). Plant nomenclature follows Lid and Lid (1994). Charcoal dust particles were counted quantitatively or semi-quantitatively (sites 20, 21) at all sites except site 6.

7 AMS and 2 conventional radiocarbon dates were made on peat, wood, charred wood and charred seeds. All results are expressed in conventional ^{14}C years BP and calibrated ages calculated according to Stuiver and Reimer (1986), method A, using the program CALIB 86 (version 2.0). Charred wood and seeds from soil horizons and structures do not appear as distinct, well-sealed strata within the fairy-circles. The dates may therefore only serve as stratigraphical markers, being contemporaneous with, younger than, or older than the date of the man-made structures.

The criteria used for established heathland in this study are in accordance with Jonassen (1950), Janssen (1973), Aaby (1994), Andersen (1995) and Prøsch-Danielsen and Simonsen (2000a), the ratio between AP/NAP being between 20–50% in heathland areas. The ericaceous pollen is totally dominated by *Calluna vulgaris* originating from heathland or heather moor (wet habitats).

The criteria used for identifying burnt heather are in accordance with Sundve (1977), Øvstedal (1985) and Kaland (1986). Pollen samples from burnt heather show a high influx of *Calluna* pollen and charcoal dust combined with pollen from anthropogenic species such as *Plantago lanceolata* (Behre 1981) and species characteristic of regularly-burnt heather: *Potentilla*-type, *Erica*-type, *Lotus*-type, Asteraceae sect. Asteroideae and Asteraceae sect. Cichorideae. *Juniperus* pollen is virtually absent.

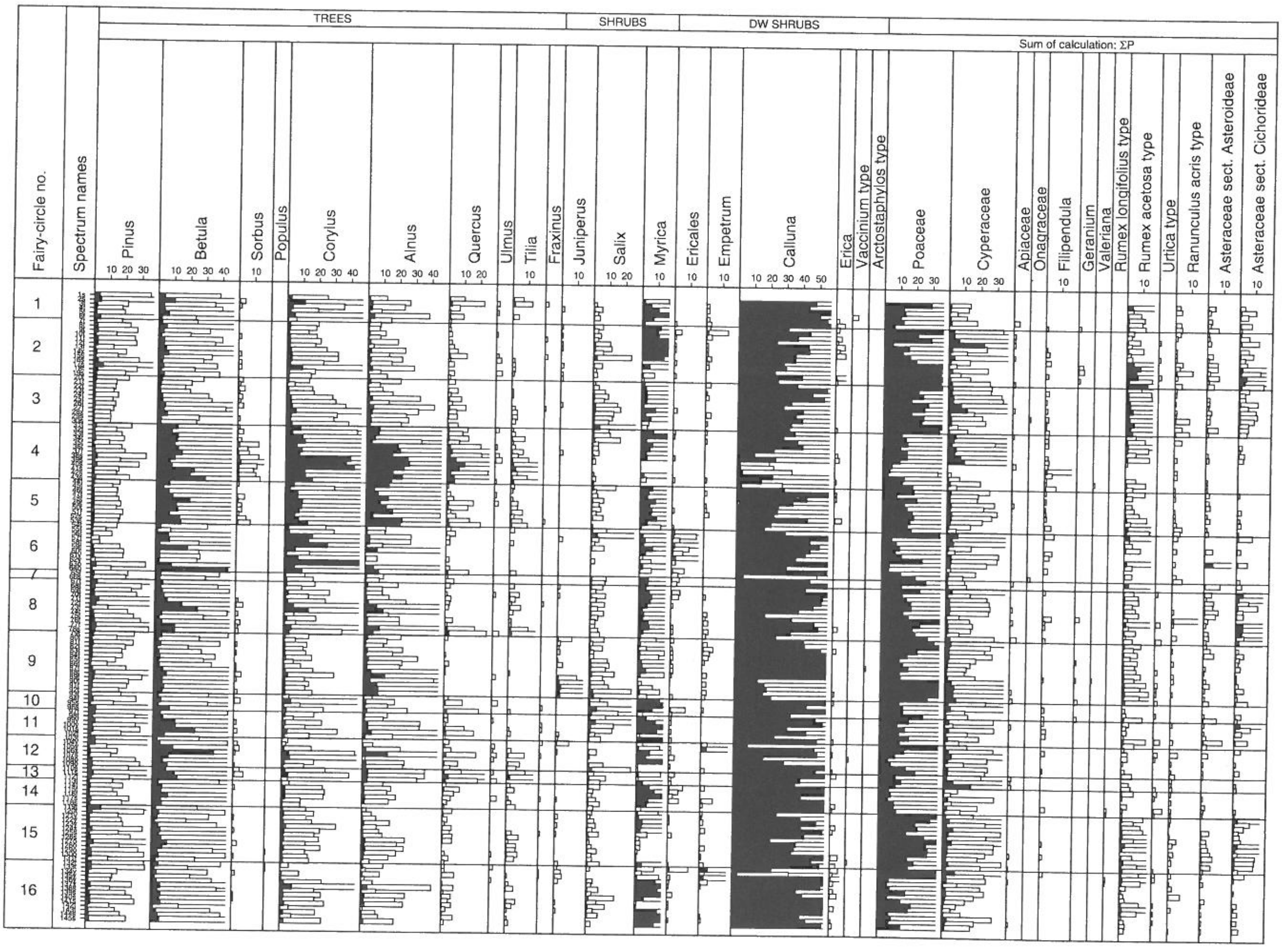


Figure 7. The total pollen data from the investigated fairy-circles.

Mown heather can be identified by high pollen values of *Calluna* and Cyperaceae combined with high frequencies of *Empetrum* and low frequencies of charcoal dust (Kaland 1986), and the virtually absence of *Potentilla*-type pollen.

Wet and dry heaths have earlier been studied palynologically from 28 podzol profiles at Forsandmoen, in the middle fjord district in Rogaland (Prøsch-Danielsen and Simonsen 1988; Prøsch-Danielsen 1996). In addition, the plant sociology of wet heaths dominated by *Molinia caerulea* has been studied together with pollen analyses from sites on the Tysvær peninsula (Prøsch-Danielsen and Øvstedal 1994). The interpretation of these fossil pollen assemblages is based on knowledge of present-day plant communities and of the ecological demands of different plant species. Wet lowland heaths are characterised by a dominance of ericaceous pollen of *Calluna vulgaris* and *Erica tetralix* and high pollen values of *Myrica gale*, *Narthecium ossifragum* and Cyperaceae. Palynologically it is difficult to differentiate between wet heath communities and peat bogs as the peat-producing communities are differentiated from the wet heaths by the occurrence of *Eriophorum* spp. (Prøsch-Danielsen and Øvstedal 1994), which can not be differentiated within the Cyperaceae pollen type. Dominant *Calluna* pollen and the virtual absence of shrub pollen is characteristic of dry heaths. Herbaceous pollen is dominated by Cyperaceae and Poaceae taxa.

Pollen diagrams, data-sets used and numerical analysis

The two pollen data-sets, from the earthworks and from selected dry and wet heaths/mires, were plotted using the computer program CORE 2.0 (Natvik and Kaland 1994) and calculated as percentages of P (total terrestrial pollen) with spores and charcoal dust particles as percentages of ΣP + total spores or charcoal dust (Figs. 7 and 8). A total of 94 pollen taxa were identified.

AP is rather low (10–20% ΣP) in the data-sets, representing open treeless vegetation types. However, in some samples the AP values reach 50–60%. These pollen assemblages derive from soil horizons below the man-made constructions, and may reflect local stands of *Betula* and *Alnus*. At Sørbø, site 4, the area may possibly have been densely forested (AP values 90%) prior to the construction. Fern spores are generally present in low amounts, or are associated with high AP values.

Other characteristics of the pollen diagrams are

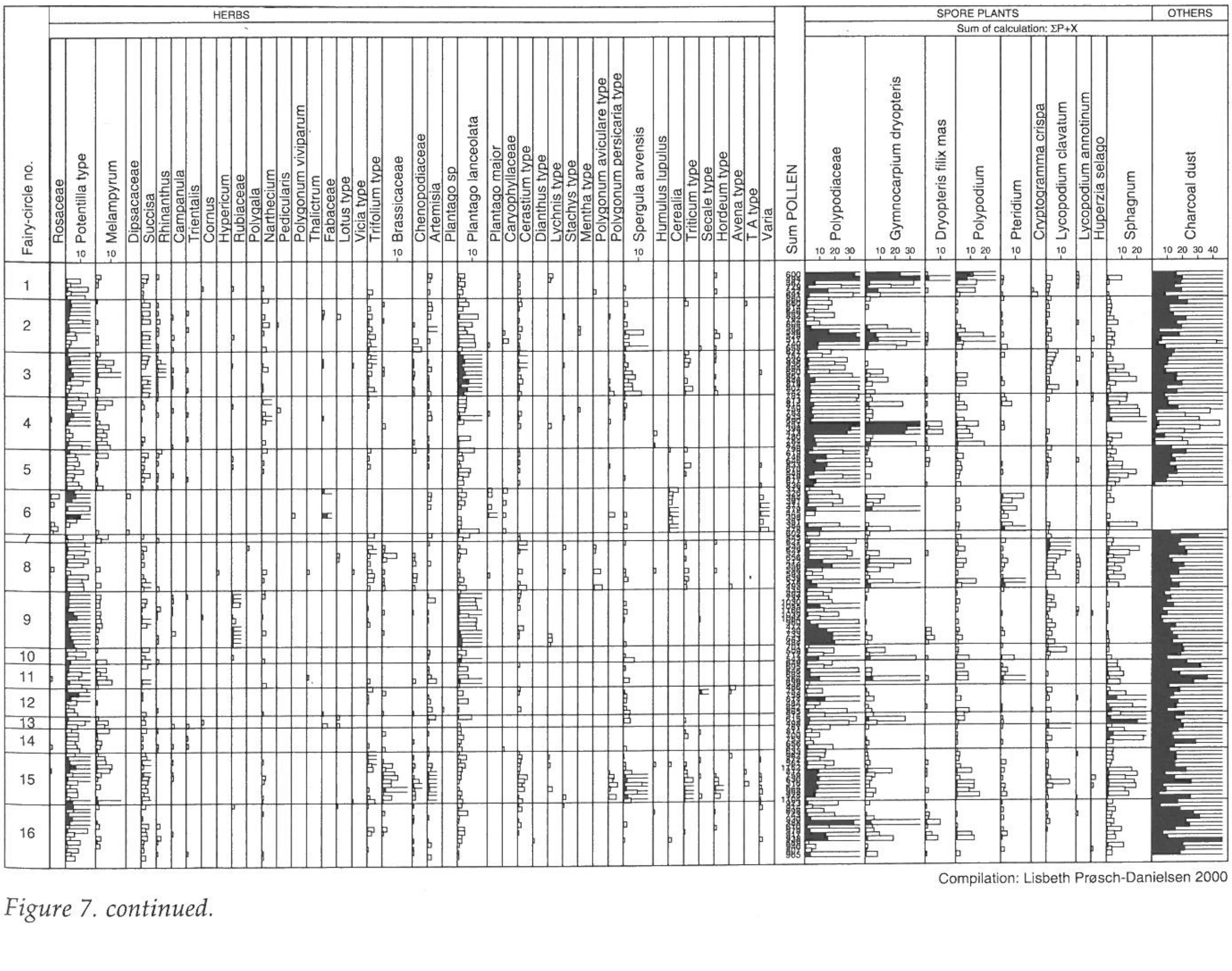
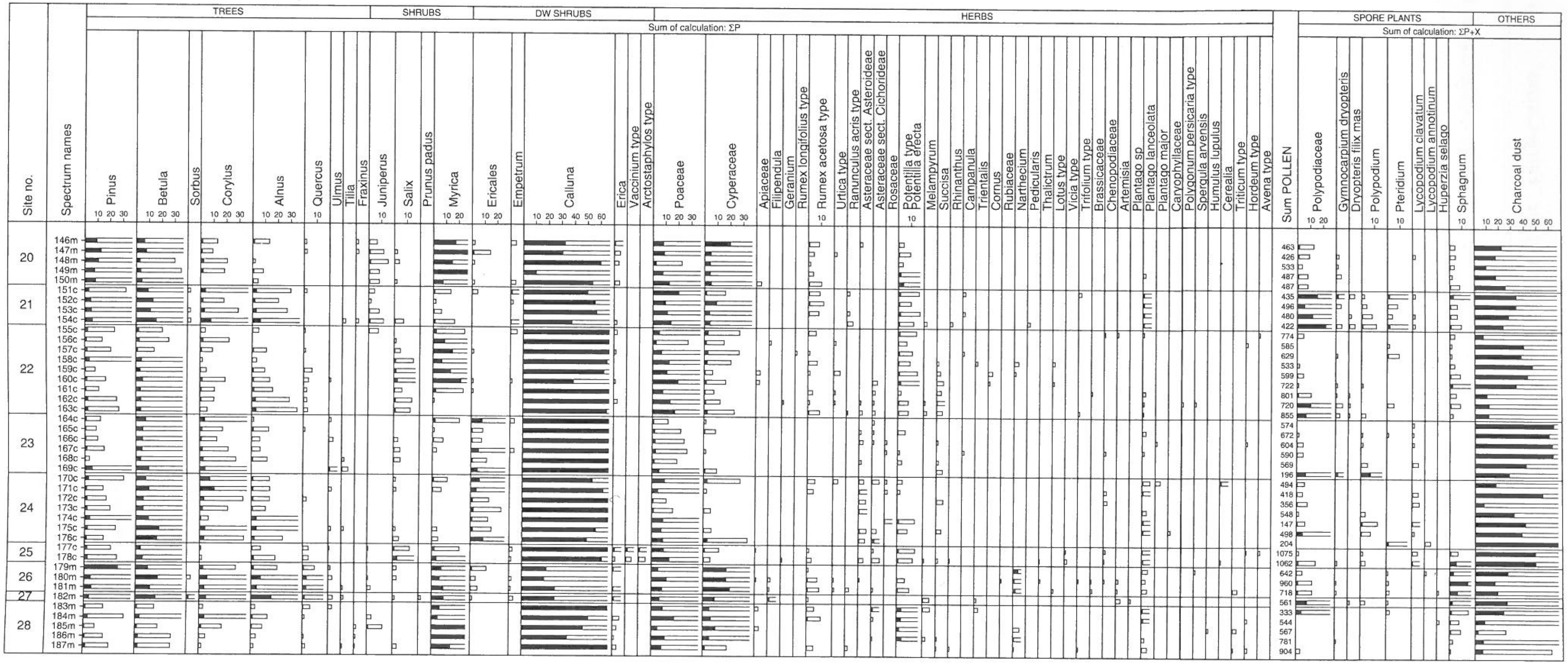


Figure 7. continued.



Compilation: Lisbeth Prøsch-Danielsen 2000

Figure 8. The total pollen for comparative studies from selected dry and wet heaths/mires.

the high frequencies of either *Calluna* or its obvious counterpart Poaceae, representing heathlands and/or grasslands. In general there is a high diversity of pollen of vascular plants, some of them the typically sub- and eu-oceanic heathland species mentioned above. Another striking feature is the high frequency of indicator taxa for different anthropogenically-influenced vegetation types, such as *Plantago lanceolata, Rumex acetosa*-type, *Ranunculus acris*-type, Asteraceae sect. Cichorideae (Behre 1981; Prøsch-Danielsen 1988; Prøsch-Danielsen and Simonsen 1988; Hjelle1997) and taxa representing cultivated land. There seems to be a correlation between low AP values, high *Calluna* values and a high content of charcoal dust (Fig. 7), although this feature is not always obvious. However, the constant occurrences of pollen of *Plantago lanceolata, Potentilla*-type and Asteraceae indicate regularly burnt heather (see above). As charcoal dust was not routinely counted in all the investigations, this data had to be omitted from the final data-sets used for numerical analysis.

As the main objective of this study was to identify the different vegetation types within the heathland on a local scale, arboreal pollen and fern spores were omitted from the final data-sets as discussed in Caseldine and Pardoe (1994) and Hjelle (1999, 60) and a pollen sum of shrubs, dwarf-shrubs and herbs has been used. The number of pollen taxa has been reduced from 94 to 71.

The data-files were converted from CORE 2.0 (Natvik and Kaland 1994) to CORNELL CONDENSED format using TRAN 1.3 (Juggins 1991). Ordination of the final data-set was made using the program CANOCO version 3.12 (ter Braak 1988; 1990). CANOCO is an extension of Cornell Ecology program DECORANA (Hill 1979). Ordination was made in order to visualise the structure of the complex dataset and to help the interpretation of vegetation types in terms of environmental gradients. Indirect ordination was carried out. Prior to the analysis the species data were square root transformed.

Detrended correspondence analysis, DCA, with down weighting of rare taxa, was used to measure the length of the gradient in standard deviation (SD) units (ter Braak and Prentice 1988). This resulted in a gradient length of 1.59 SD-units for the vegetation data, justifying the further use of a linear taxon-response model and thus the selection of principal components analysis (PCA). Using PCA the ordination axes (PCA axes) can be considered as latent variables or hypothetical environmental variables constructed to optimise the fit of the species to a particular statistical model of how species abundance varies along gradients (Prentice 1986; ter Braak and Prentice 1988). The new species variables are called Principal Components (PC) and are ranked according to the fraction of the total variance each of them represents. This fraction can be found from the so-called "eigenvector table".

To visualise the PCs it is convenient to produce biplots or scatter-plots between two PC axes. In biplots each sample is marked by a point and each pollen taxon by an arrow. PCs with high positive or high negative loadings in the "eigenvector table" (Table 3) are the most important for indicating sample differences, while those near the centre are of minor importance. The results were plotted using the program CanoDraw version 3.0 (Smilauer 1992).

The second data-set (from selected dry and wet heaths/mires) are positioned passively onto the ordination plane formed by the data-set from the fairy-circles, in order to reveal any similarity between the two data-sets which could suggest different heath types involved in the fairy-circle study.

Results and discussion

pollen and PCA analysis

The first two principal components account for 55% of the total variance in the pollen assemblages from the fairy-circles. Fig. 9a, a plot of the first (eigenvalue 0.392) and second (eigenvalue 0.157) principal components, shows the relationships between pollen taxa. The selected variables with highest

First principal component		**Second principal component**	
Positive scores		*Positive scores*	
Poaceae	0.945	*Myrica*	0.610
Rumex acetosa-type	0.462	Cyperaceae	0.370
Asteraceae sect. Cichor.	0.382	*Narthecium*	0.271
Cerastium-type	0.374	*Trientalis*	0.216
Juniperus	0.342	Poaceae	0.209
Ranunculus acris-type	0.299	*Juniperus*	0.152
Melampyrum	0.279	*Lonicera*	0.131
Rubiaceae	0.274	*Potentilla*-type	0.116
Plantago lanceolata	0.273	*Pedicularis*	0.098
Spergula arvensis	0.269		
Asteraceae sect. Aster.	0.265		
Negative scores		*Negative scores*	
Myrica	−0.780	*Calluna*	−0.639
Calluna	−0.743	*Spergula*	−0.235
Erica	−0.124	Cerealia	−0.185
Trientalis	−0.113	Brassicaceae	−0.160
Vaccinium-type	−0.105	*Dianthus*-type	−0.154
Pinguicula	−0.089	*Plantago* sp.	−0.150
Pedicularis	−0.086	*Succisa*	−0.146
		Hordeum	−0.137

Table 3. Variables with the largest positive and negative eigenvector scores on the first and second principal components.

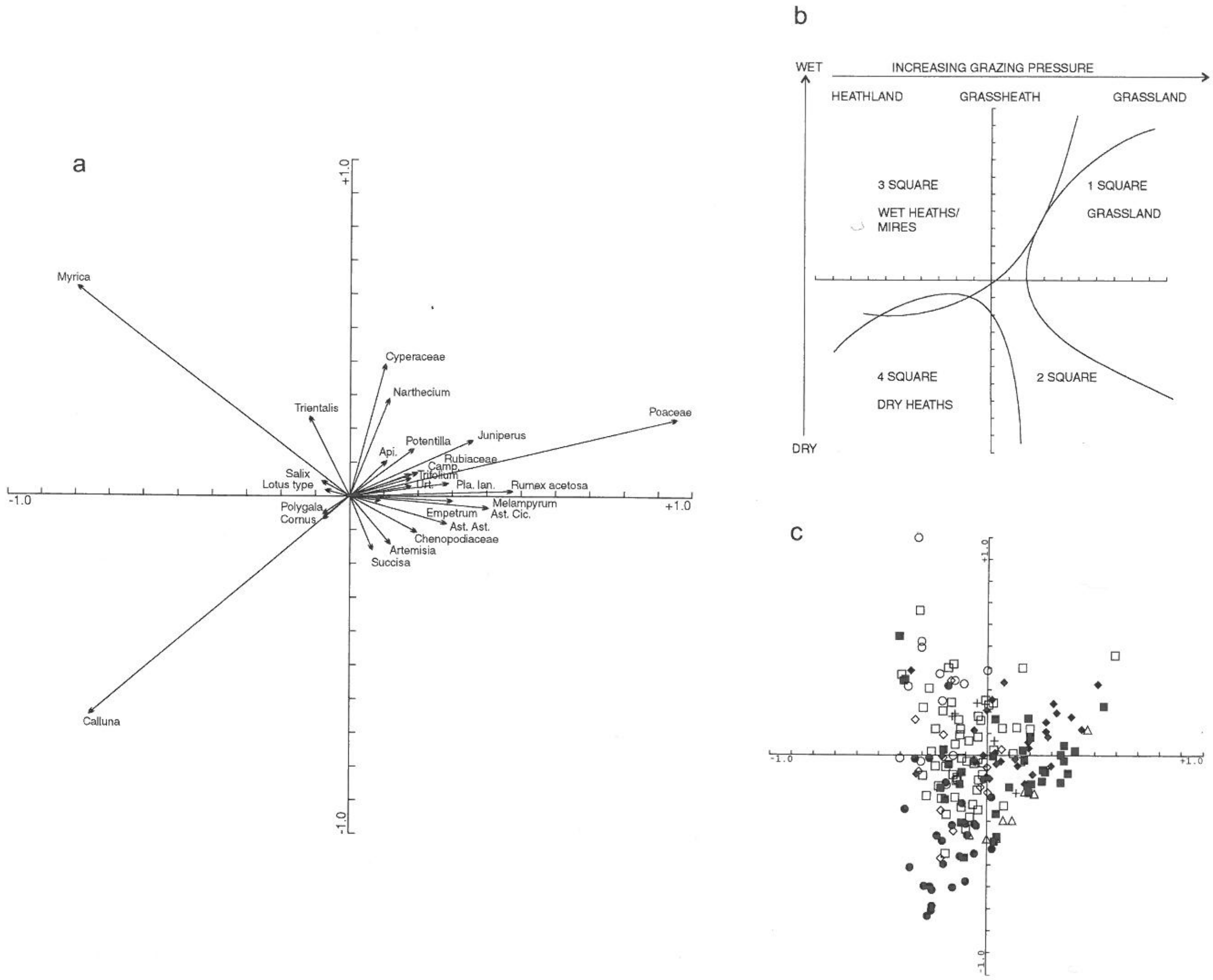


Figure 9. Principal components analysis (PCA). (a) Plot showing the relationship between pollen taxa in the samples from the fairy-circles. (b) The ecological interpretation of the plot. (c) Plot showing the samples coded according to soil structures within the fairy-circles. The samples from selected dry (filled circles) and wet heaths/mires (open circles) are positioned passively in the correlation plot. The legend for the other symbols is presented in Fig. 6 and explained in the caption for that figure.

positive and negative scores on the first and second principal components from the eigenvector table are listed in Table 3.

The first principal component in the ranked list shows a clear trend starting with Poaceae as the most important variable indicating grassland on the positive side. The next variables are characteristic of heavily grazed heaths, *Plantago lanceolata*, Rubiaceae (probably *Galium saxatile*), *Ranunculus acris*-type and *Potentilla*-type, and of cultivated land, such as *Rumex acetosa*-type and *Spergula arvensis* (Steinnes 1988c; Prøsch-Danielsen 1988; Prøsch-Danielsen and Simonsen 1988; Hjelle 1999). *Juniperus* also has a high score on the positive side possibly as it is usually left untouched in grazed heathlands and therefore is a high pollen producer. Variables with negative scores are taxa with no direct connection with typical grasslands or agricultural activity. The ranked list is headed by shrub and dwarf shrub species followed by western species characteristic of coastal heaths such as *Trientalis europaea* and *Pedicularis cf. sylvatica.* The first principal component appears to express a gradient from heathlands on the negative side to grasslands on the positive side of the axis, i.e. it expresses an increase in grazing pressure or cultivation (Fig. 9b).

The group of taxa with negative scores along the first principal component axis can be further differentiated by their scores along the second principal axis (Table 3). The ranked list with positive scores is headed by variables characteristic of wet heaths in Rogaland: *Myrica gale, Narthecium ossifragum,* sedges and grasses. Unfortunately it is impossible to distinguish pollen of sedges and grasses to species level, but *Trichophorum caespitosum* and *Molinia caerulea* may be the most likely species regarding wet heath and mires in Rogaland. *Molinia caerulea* is sometimes also dominant on dry heaths particularly where grazing pressure has decreased (Steinnes 1988b, 18). Other variables on the positive side of the list include *Erica tetralix* and *Pedicularis* (probably *P. sylvatica*), both characteristic species of the wet heaths in Jæren (Fægri 1952; Semb and Nedkvitne 1957; Steinnes 1988b). Taxa representing dry heaths and cultivated land now have negative scores. The most important variable is *Calluna*, which is also the dominant species in dry heaths. However, the arrows of the cultivation taxa, weeds and cereals, are narrow and centred near the zero point indicating that these are of minor importance for differentiating between samples.

Thus, the second principal component detects differences in heath types which may be interpreted in ecological terms by a gradient from wet heath/mire communities on the positive side of the axis to dry heath communities on the negative side (Fig. 9b). This interpretation is also confirmed by the pollen assemblages from the known dry and wet heath/mire types that have been positioned passively on the ordination plane (Fig. 9c). All samples, marked by a distinct point in the plot, are clustered on the negative side of the first principal component axis in agreement with heathland taxa. Their scores on the second principal component further differentiate the samples; dry heath/mire samples clustered on the negative side and wet heath samples mainly on the positive side. Some wet heath samples collected from Lygra and Gismarvik are centred on the zero point. This may be explained by the local small-scaled patchy pattern of wet and dry heaths found on these sites where *Calluna* (having a high pollen production and good pollen dispersal, Hjelle 1997, 10) may be the dominant species in pollen assemblages from wet as well as dry heaths.

Fig. 9c also shows a plot of the first and the second principal components with the samples identified by their origins related to the soil structures (see Fig. 6). Only 8 samples from earthworks 6, 12 and 15 are represented in the dataset from soil-structure O, deposited prior to the constructions. These samples are mainly identified in the second square of the plot, associated with cultivated land, dry or heavily grazed heaths. The results are not surprising – for example, earthwork 15 at Kvia was constructed within a field system dating back to the Middle Ages.

The 33 samples from soil-structure S, representing the old soil surface sealed underneath the banks are mainly found in the first, second and fourth squares associated with grasslands, heavily-grazed heaths, cultivated land or dry heaths. Only 3 samples are associated with wet heaths. It can therefore be concluded that the fairy-circles were preferably constructed on well-drained soils and on earlier cleared sites, prepared for cultivation, or used as pastures. This accords with field observations (Lillehammer 1996).

The 55 samples from the humified soils in the ditches (soil-structure F) and therefore post-dating the constructions, are mainly clustered on the negative side of the first PC axis, in the third and fourth squares associated with dry and wet heaths/mires respectively. However, the majority of the samples are clustered within the range of the wet heaths/mires (Fig. 9b). Some samples are identified with low scores on the positive side of the first PC axis (square one), associated with wet heaths or heavily grazed heaths.

The samples from soil-structure Y, covering the banks of the fairy-circles, are identified on the negative side of the first PC axis in both the third and fourth squares, and are associated with heathlands, though dominantly dry heaths.

The raw humus on top (soil-structure T), representing the modern soil surface, is mainly clustered within the range of the grassland which also reflects the modern vegetation.

The plots indicate a shift from mixed pollen assemblages associated with dry ground anthropogenically-influenced plant communities prior to the man-made construction, via wet ground and mire plant communities in a period after the fairy-circle had been constructed or was still in use, to the present dry ground heath and grassland communities. This pattern signals a major change towards a wet heath plant community caused by the introduction of the man-made structure. Wet heaths though are not usually associated with convex landforms (where the fairy-circles are situated) and well-drained soils, and may therefore be interpreted as an alien element brought in by man. This leads us to conclude that the plants from the wet heaths/mires have been used for haymaking and that the fairy-circles have served as bases for haystacks or alternatively served as bases for peatstacks. Both alternatives are feasible. However, high frequencies of *Sphagnum* spores, that would indicate stacking of peat for fuel, are almost absent from the dataset and peat as a resource was available throughout most seasons and could be dried on top of the mires directly which would take less time and effort. In addition, protecting peatstacks by digging ditches and banks seems meaningless. On the other hand, with regard to haystacks, the livestock (at least the sheep) could feed outside during winter and the haystack had to be protected against grazing animals. The ditch and bank(s) may have been built up and functioned as a form of defence (see e.g. Nielsen 1997, 30–1), probably with twigs woven together on top (Påhlsson 1999). Haymaking was of importance in enabling farmers to survive and the hay may have served as an additional resource, especially for cattle, in unfavourable years where periods of low winter temperatures and snow-cover prevented the livestock from staying outside.

Traditionally the dry heaths have been interpreted as being the "hearth" of the coastal heaths, especially in areas north of Jæren where rock outcrops are characteristic (Fremstad *et al.* 1991). In Hordaland, wet heaths and bogs cover about 20% of the area and are subordinate elements in the coastal heaths (Øvstedal 1985, 397) where "the heath outfields were used for pastures all the year through, and to improve the quality of the vegetation heath burning was used extensively and heather was mown as additional winter fodder for the cattle" (Kaland 1986). There is no evidence of haymaking in the investigations from the Hordaland section.

In Jæren the pattern is somewhat different. Here, dry and wet heaths have existed equally in a patchy mosaic pattern due to the gently undulating landscape. Integrated in this landscape were the atlantic bogs, which earlier covered the depressions. However, the heathland has been modified step-by-step and the peat bogs have been destroyed by peat cutting, draining, and so on. As a consequence the visual landscape has changed and knowledge of the former traditional utilisation of this specific heathland has been lost. The importance of the wet heath and peat bogs in the outlying land and in supplying winter fodder has probably been underestimated in this region, despite the fact that the proportion of the outlying land used for haymaking was still greater in Rogaland then in other Norwegian counties as late as around 1900 AD (Moen 1970). In this landscape, heather was mown and traditionally brought in as required during the winter and especially in early spring (Høeg 1976). There is no tradition of drying heather on a stack. Heather had to be soaked, cooked or mixed with hay before feeding to the cattle. Palynologically, only criteria for regularly burnt heather, but not for heath mowing (as recorded from Hordaland, Kaland 1986), are met in this investigation from Rogaland.

The wet heaths in the low-lying part of Jæren are dominated by *Myrica gale, Erica tetralix, Narthecium ossifragum, Trichophorum caespitosum* and *Calluna vulgaris.* With increasing grazing pressure the dwarf shrubs almost disappear, and the wet heaths become dominated by grasses and sedges such as *Trichophorum caespitosum, Nardus stricta* and *Juncus squarrosus*. The variation within the wet heaths is considerable (*cf.* Røsberg 1982; Øvstedal 1985; Steinnes 1988b; Prøsch-Danielsen and Øvstedal 1994). The wet heaths with *Myrica* recognised here are quite common in the lowland areas up to at least 350 m in the coastal upland region and 450 m in the Dalane region (Steinnes 1988b, 27–28), but are quite rare in north-Rogaland. At Hidra in West-Agder the *Myrica* wet heaths are peat-producing (40–175 cm depth) (Brandsberg Drangeid 1980, 96). According to local farmers, both mires and wet heaths ("bakkar") have been regularly mown in Rogaland (Steinnes 1988b, 11). However, there seems to be a good correlation between the *Myrica* wet heaths and the distribution of the fairy-circles.

Scything and haymaking activities involve grasses, sedges and herbs and explain the high pollen content of these taxa in the samples, as their pollen would easily be spread locally during haystack preparation. Nevertheless, haymaking does not necessarily include shrubs. A reasonable explanation for the high pollen values of *Myrica* identified in the pollen assemblages may be that twigs of bog myrtle were used in the woven fence on top of the banks or actually used in the haystack construction itself. Moen (1990, 73–5) has studied constructions of haystacks in detail (Fig. 10). When the hay was stored on a stack pole, it was supported by split poles. To provide a dry foundation on which to start laying the dried grass, twigs were laid around the base. In forested areas twigs of *Betula pubescens* and *Juniperus communis* were preferred, but in the absence of trees as in Jæren, the next best material, twigs of *Myrica gale,* was probably chosen. If the haystacks were very short or smooth, a further layer of twigs was added after the pole was half full. This layer was termed the "middle wood" and

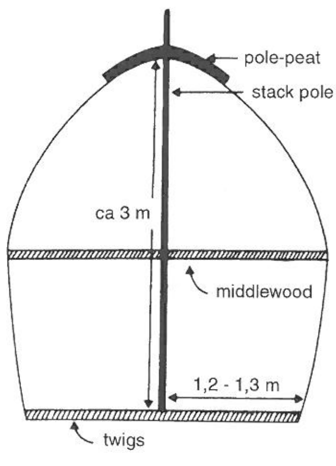


Figure 10. Schematic representation of a typical haystack, as seen in vertical section (from Moen 1990, 75).

allowed the hay to remain dry and further served to bind the stacked hay together. On top of the stack pole a pole-peat was impaled, to prevent rain from running down the pole into the interior of the stack and to keep the upper hay firmly in place. Up to the 1950s in Rogaland, twigs were put on top of the haystack and tied to prevent the hay blowing away (Visted and Stigum 1971, 286–289). Again, in the absence of trees, twigs of *Myrica gale* may have been used for this purpose.

An alternative interpretation could be that *Myrica gale*, which was quite abundant, was also intentionally gathered and traded to provide extra income for the local farmers. *Myrica* (bog myrtle) had a wide range of uses in medieval times, but was most important as a flavouring for beer (von Hofsten 1960, 49; Høeg 1976; Behre 1999). Both the female catkins and the fruits (especially rich in aromatic resins) were used, and sometimes also the male catkins. Very little information is available on how the plant was handled, but there are some records. Literature from Sweden (von Hofsten 1960) confirms that *Myrica* was dried and used in a similar way to *Humulus lupulus*, indicating a working practice involving threshing. Large amounts of *Myrica* in the medieval layers from Bryggen in Bergen, Hordaland, suggest that *Myrica* must have been specially gathered throughout the season, brought to the site and stored for use or for sale (Krzywinski and Soltvedt 1988, 59). Documents from the time of Håkon V and Håkon VI show that around 1300 AD, *Myrica* was an important commercial product in Norway (von Hofsten 1960, 27).

age estimates

The radiocarbon dates relevant to this study are presented in Table 4. The first three dates, sampled from soil horizons below the banks, give maximum ages for the fairy-circles. The dates from Bø (11) and from Serigstad (17), dated to 2825±60 BP, 1025–905 cal BC (TUa-1945) and 2605±65 BP, 815–770 cal BC (TUa-1574) respectively, probably represent the final deforestation at the sites. Heathland was well established by Bronze Age V (900–700 cal BC) in the Jæren region (Prøsch-Danielsen and Simonsen 2000a; 2000b). The material dated from Kvia (15) and Ævestad (18) is charcoal sampled from structures interpreted as being contemporaneous with or younger than the man-made constructions. The dates fit into the Late and Younger Iron Age. The manufactured wood penetrating the fairy-circle at Kvia (16) has been dated to younger than AD 1700. This probably represents remains of activities by the Germans in that area during World War II.

The dated peat bog sequence, situated 150 m east of the fairy-circle at Kvia (16), gives the onset of the wet heath/mire type with *Myrica* (published in Prøsch-Danielsen and Simonsen 2000a) and thus indirectly gives a maximum age for the construction of 1885±65 BP, AD 47–199 (T-13495). However, charred seeds of *Myrica* found in the lower part of the infill in a clearance cairn next to the fairy-circle, are dated to 1250±100 BP, cal AD 670–900 (TUa-2220). From this level and upwards throughout the clearance cairn, there is also a marked increase in *Myrica* pollen. This date may represent the onset of a clearance prior to the earthwork. In western Norway, the expansion of *Myrica* seems to be promoted by periods of increased cultural activity, heathland development with subsequent abandonment, and utilisation of uncultivated rural land (Kaland 1974; Moe 1996; Overland 1999).

In general, indirect evidence for mowing (probably grass cutting) in western Norway is based on the presence of the scythe in archaeological contexts dating back to 550–800 AD (Petersen 1951; Sølvberg 1976). In the Jæren region, the fairy-circles are often found on sites that had earlier been cleared and settled, and within sites with traces of earlier land-use practices. There are also examples of fairy-circles overlapping burial mounds ranging in age from the Migration Period to the Viking Age (Lillehammer 1996; Museum of Archaeology, Stavanger, files). Yet it is impossible to establish the period of use of the fairy-circles by archaeological or palynological investigations alone. Nevertheless, fences built due to land ownership changes in the 1830s cover some fairy-circles, giving the main historical evidence and upper age limit. At the same time, an incipient interest in the earthworks arose among the antiquarians in the late nineteenth century.

At some time the practical use of the fairy-circles came to an end and the knowledge about their traditional use was forgotten. Since then, these mysterious earthworks have been attributed to local tradition of fairy belief. Today, the fairy-circles are put out of their environmental context and stand out as relicts in the highly effective farmland of Jæren. To approach the fairy-circle problem, analyses using archaeological and palynological resources have been necessary. This study confirms that the fairy-circles are the result of a specialised outland farming practise, involving haymaking, connected to the coastal patchy-patterned heathland of Jæren in south-western Norway. It also emphasises the importance of protecting the monuments in their environmental setting and not keeping them as isolated objects in the modern cultural landscape.

Site no	Farm no – district	Site-type	Structure (Fig. 6)	Material	Lab. ref.	Radiocarbon age (yr BP)	Calibrated age range cal BC/cal AD	Dated event in relation to the fairy-circle >older than < younger than
3	Sørbø 23/4, Klepp	fairy-circle no. 77	O/S	charcoal (*Pinus*)	TUa-1777	7910 ± 70	BC 7000–6605	>
11	Bø 110/3, Hå	fairy-circle	O	charcoal (*Betula*)	TUa-1945	2825 ± 60	BC 1025–905	>
17	Serigstad 20/2, Time	fairy-circle	O	charcoal (*Quercus*)	TUa-1574	2605 ± 65	BC 815–770	>
26	Kvia II 19/5, Hå	peatbog sequence	–	peat 25–27 cm below surface	T-13485	1885 ± 65	AD 47–199	≥
15	Kvia II 19/6, Hå	fairy-circle no. 14	S	charcoal (*Betula*)	TUa-1573	1595 ± 65	AD 410–550	≥
18	Ævestad 67/8, Hå	fairy-circle	F	charcoal (*Betula*)	TUa-2214	1395 ± 55	AD 625–670	≤
22	Kvia 19/5, Hå	clearance cairn	infill	charred seeds (*Myrica gale*)	TUa-2220	1250 ± 100	AD 670–900	≥
16	Kvia 19/5, Hå	fairy-circle no. 2	–	wood (*Pinus*)	T-13325	70 ± 45	Y. than AD 1700	?
19	Kvassheim 103/2,18, Hå	fairy-circle	F	charcoal	ß-135254	32040 ± 90	–	<

Table 4. Radiocarbon dates with relevance to this study. The conventional radiocarbon dates (Lab. ref. T) were made by the Radiological Dating Laboratory in Trondheim, Norway, the AMS dates by the Svedberg Laboratory at the University of Uppsala, Sweden or by Beta Analytical Inc. in Miami, Florida, USA (Lab. ref. TUa or ß).

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