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The deforestation patterns
and the establishment of the coastal heathland
of southwestern Norway

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&
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Abstract



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Palynological data collected over a period of 60 years have been compiled and re-interpreted in order to reveal the deforestation patterns and heath establishment in the southwestern Norwegian coastal heathland. This heathland area has been divided into four sub-regions based on topography, bedrock and coverage of Quaternary deposits. The palynological sites represent different sizes of catchments reflecting both local, extra-local and regional pollen source areas. They are represented by ancient monuments, soil profiles, bogs and lakes. The palynological signals of deforestation and heathland establishment can be described by different models indicating an abrupt, gradual or stepwise deforestation. The differences between these models can be explained by the size of the catchments. The deforestation seems to have been metachronous, leading to a regional mosaic pattern of different vegetation types. The process spanned more than 3600 years, from 4000 cal BC to 400 cal BC, with three pronounced clearance periods: 4000–3600 cal BC (Mesolithic/ Early Neolithic transition), 2500–2200 cal BC (Middle Neolithic II/ Early Late Neolithic transition), and 1900–1400 cal BC (Late Neolithic to Bronze Age period II). The development of heathland in the outer coastal area that followed deforestation has also been metachronous and took place over a period of approximately 4000 years from 4000 cal BC to 200 cal BC, but was mainly completed during the Bronze Age. Regional differences in the deforestation pattern and heathland establishment are discussed with respect to chronology. The progression of the deforestation can best be explained by the interaction of human manipulation, topography and edaphic conditions. Climatic variations seem to be of less importance.

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Introduction

The coastal heathland is a threatened ecosystem in Rogaland and Vest-Agder as in the rest of Norway. Today only 10% of the Norwegian heathland is left (Hjeltnes 1997). They have been a dominant feature in that part of the country which border the North Sea and the Atlantic for several millennia. The coastal heathland had its maximum extent in the mid-nineteenth century. Since then, the balance of the heathland ecosystem has been changed, mainly as a result of human exploitation. The heather has lost its role as winter fodder and the heathlands have been converted into tilled fields, cultivated pastures, conifer plantations and urban areas. This change was promoted by land ownership regulations in the nineteenth century and further extended by the import of fertilisers. In recent years the heathland has been extensively converted to fertilised pasture or been used as a dispersal area for excess manure. The coastal heathland is also threatened by natural regrowth of shrub and woodland, and by high exposure to airborne nitrogen compounds during the last decades (Fremstad 1992, Aerts & Heil 1993).

This study was partly initiated by the project «Contact-Conflict: Cultural Heritage and Cultural Perception. Analyses of Outlying Fields and Heather Lands in Hå Municipality, Rogaland County, Norway» (Lillehammer 1996), which is part of the national research program «Cultural Heritage and Environment».

There are distinct conflicts of interest between the protection of the natural environment and cultural heritage and local agriculture and industry, particularly in the farming districts of Jæren. The modern cultural landscape in the region is still rich in ancient monuments, which can be «linked» to the heathland: for example, some groups of anonymous monuments; stone-walled enclosures (cattlepens) and «alvedanser» («fairy-circles»). These small earth constructions mostly rectangular, are found exclusively in the heathland on Jæren and on some of the islands further to the north in the Boknafjord. Knowledge about the heathland history may give information leading to the interpretation of these cultural monuments.

Since a regional synthesis was prepared in the early 1940's (Fægri 1940, 1941, 1944a,b), little work had been done on the history of the Norwegian coastal heathland until the Lindås project in the 1970's. This was initiated by P.E. Kaland (1979, 1986) to study in detail the origin and management of the coastal heathland on the Lindås peninsula and the archipelago in the county of Hordaland.

In this paper special attention is given to the deforestation history and development of *Calluna* heathland further south on the southwestern coast of Norway. The objective of the present study is to:

- date the start and progression of the deforestation
- date the establishment of the heathland and discuss the temporal and spatial variations
- understand the relationship between different palynological deforestation signals and the deforestation process

In this paper we have chosen to present separately the descriptive and chronological aspects of the deforestation and heath expansion. The ecological and cultural aspects are the subjects of an ongoing comprehensive interdisciplinary study, which will be presented later.

The investigation is based on 58 sites with palaeobotanical information, dates etc., studied during the last 60 years. All the investigated sites are situated below the climatic tree limit (*sensu* Aas & Farlund 1988, Strand 1998).

The southwestern «coastal section»

In this study we focus on the southwestern part of the *lowland belt* of «the coastal section» in the county of Rogaland and Vest-Agder as defined by Dahl et al. (1986) and Moen (1999). This section is generally characterised by the predominance of open heathland where *Calluna vulgaris* is the dominant species (Kaland 1986, Moen 1987, Steinnes 1988, Fremstad et al. 1991, Fremstad &

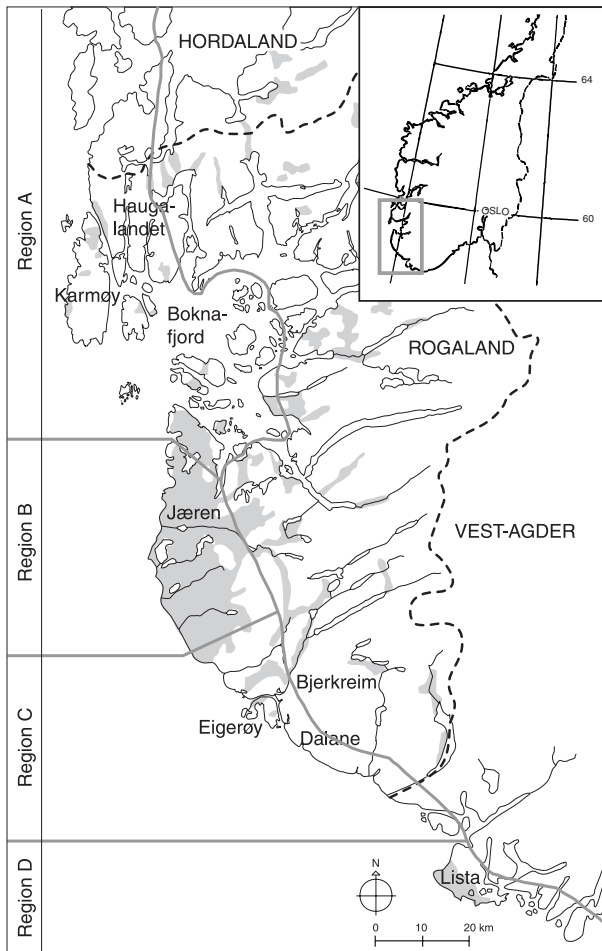


Fig. 1a. Distribution of till and Quaternary deposits (marked grey) (after Thoresen 1990). The eastern limit of the southwestern coastal heath section and the division into four regions are shown.

Kvenild 1993, Kaland & Vandvik 1998). Although it is commonly accepted that the Norwegian coastal heathland are anthropogenic in origin, the heathland vegetation consists of species that are not intentionally introduced, with oceanic and sub oceanic species in abundance. Small stands of natural woodland may occur. The belt is restricted to «The strong oceanic section (O3)» characterised by a mild, humid climate limited inland by the January mean 0°C isotherm (Moen 1999).

In Vest-Agder, the coastal heathland is located within the nemoral region (the temperate deciduous forest region), characterized by oak forests, warmth-demanding and frost-sensitive species. In Norway, this nemoral region is found exclusively in a narrow belt along the coast of Sørlandet. In Rogaland, however, the heathland merges into the boreonemoral region (forests with deciduous and conifer tree species). In Rogaland, this region covers the outer low-lying coastal area and stretches up to ca. 150 m asl in the fjord areas. This region forms a transition between the typical nemoral and southern boreal (southern

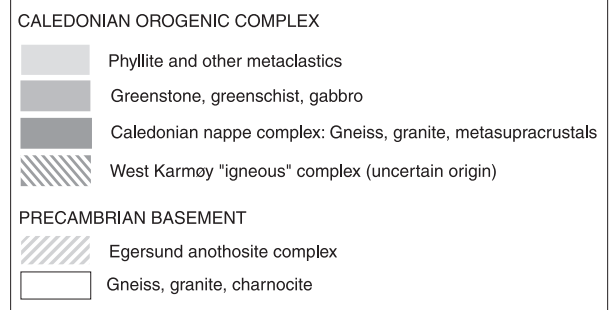
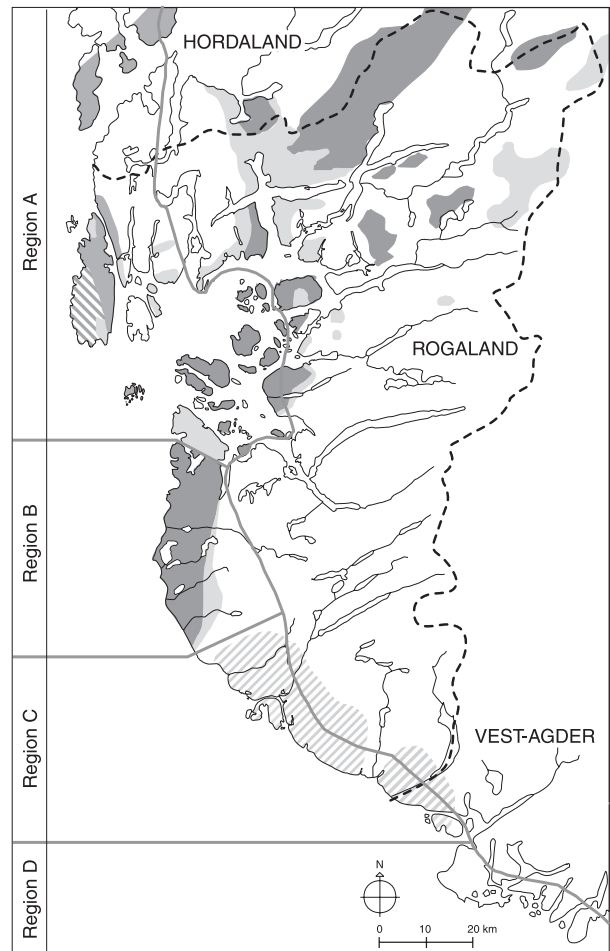


Fig. 1b. A simplified bedrock map of Rogaland and adjacent areas.

conifer) regions found further inland (Dahl et al. 1986, Moen 1999).

We have chosen four geographical regions for Rogaland and Lista in Vest-Agder for our lowland heath belt investigation. The regions from north to south are (Fig. 1a):

- A. The Karmøy, Haugalandet and Boknafjord region, the «Strandflaten» region with upland
- B. South Jæren, low-lying part and coastal upland region
- C. The Dalane coastal region
- D. The Lista coastal region

This division is mainly based on local topographical and geological parameters (Figs. 1a,b). Special attention has been paid to: 1. Whether it has an archipelagic appearance (regions A and D) or not (B and C). 2. Whether the bedrock is Precambrian (regions C and D) or Caledonian orogenic complex (A and B) and 3. General thick coverage of Quaternary deposits (regions B and D) or not (A and C).

The lowland belt of the heather zone gradually merges into the *inland heath belt*, which is fully developed in the Dalane and Bjerkreim regions (Steinnes 1988). However, this inland belt is not the subject of this paper, but for comparative studies we have included some localities where pollen diagrams have been made from this inland belt.

Region A. The Karmøy, Haugalandet and Boknafjord region, the «Strandflaten» region with upland

The northernmost region with its archipelagic appearance belongs to the so-called «Strandflaten», a geomorphologic feature that can be followed from the coast of Troms to Jæren. Only small parts of the «Strandflaten» reach above 100 m asl (Larsen & Holtedahl 1985).

The Caledonian bedrock of the island of Karmøy (Fig. 1b) is rather complex, but there is a distinct difference between the northeastern and southwestern parts of the island. Metamorphic lavas and phyllite dominate the northeastern part, which produce a very fertile soil (Menuge et al. 1989). In southwestern Karmøy a granitic bedrock gives a more acid soil of lower fertility. This is also reflected in the natural vegetation cover (Lundberg 1998). The exposed bedrock of the mainland «Haugalandet» east of Karmøy is dominated by Precambrian gneiss and granite with hilltops reaching 100–150 m asl (Rønnevik 1971, Sigmond et al. 1984). The islands between Karmøy and the mainland of Jæren consist of soft phyllite, meta-basalt and trusted Precambrian rocks of different composition. We have found the northern part of Jæren, even though it is not an island, to be topographically and geologically more similar to region A than to the rest of the Jæren area, which is almost completely covered by thick Quaternary deposits. In this northern part of Jæren the phyllite bedrock can be exposed as rocks or rocky hills.

Region B. South-Jæren, low-lying part and coastal upland region

Jæren is a undulating lowland exposed to the North Sea without protecting skerries and islands. In contrast to the rest of western Norway, Jæren south of Stavanger is almost completely covered with thick glacial deposits (Fig. 1a), varying in thickness up to 130 m (Sejrup et al. 1998). The general stratigraphy of the glacial deposits is

characterised by shifting series of glaciofluvial deposits, glaciomarine clays and diamicton (Semb 1978, Andersen et al. 1987). A late Weichselian erosion has exposed these series in a mosaic pattern resulting in the subsoil's of the Jæren region having very diverse fertilities (Semb 1962). Near the coast there are also areas with aeolian sand that have been stabilised with forest plantations during the last century (Wishman 1990). The Jæren landscape has experienced repeated sequences of marine transgressions and regressions. Due to the low relief, the coastline has shifted repeatedly during the last 12 000 years (Thomsen 1982a, b, Bird & Klemsdal 1986). Many of the land-locked water bodies were earlier parts of a complex fjord system that divided the land into a series of peninsulas, particularly the northern part of Jæren.

The underlying bedrock belongs to the Caledonian nappe complex with trusted gneiss, granite and meta-supracrustals with an exposed rim of phyllite to the east (Birkeland 1981).

Region C. The Dalane coastal region

The Dalane coastal region differs strongly from the Jæren region in that it is a mountainous area dominated by rocks poor in plant nutrients, especially potassium and phosphate. The dominating rock is anorthosite with narrow bands of more nutrient-rich norite (Michot 1966). Loose deposits are rare and thin, usually in the bottoms of valleys. On the island of Eigerøy the farms are mainly located on rather small drumlins (Garnes 1976).

Region D. The Lista coastal region

Lista is a peninsula located on the extreme southern coast of Norway. The peninsula is divided into a low-lying outer coastal area and an inner mountainous area with a low relief (up to 350 m asl). In many ways Lista resembles the Jæren region being a sediment-dominated rim of lowland in front of a mountainous inland. The outer coastal area consists mainly of reworked Weichselian till and glaciofluvial deposits (Andersen 1979). The *in situ* till deposits have a varying sand and clay content (Bjørlykke 1929). The low-lying part of Lista has changed its appearance from an archipelago to a lowland peninsula due to the movement of loose deposits and a changing sea-level (Prøsch-Danielsen 1997). The bedrock consists of Precambrian metamorphic rocks belonging to the Egersund complex (Falkum 1982), and consists of acid gneisses and granitic igneous rocks.

Previous and new palaeobotanical investigations

Sampling sites

The studies by Kaland in Nordhordland (1979, 1986) were based on pollen analyses from peat bogs in the outfield areas close to prehistoric or historic farms, which had been archaeologically dated. His study was carried out in a relatively small and geomorphologically homogeneous area with a significant W-E climatic gradient.

The background for our study is somewhat different. Our research area is topographically and geologically very heterogeneous. Pollen analysis has been carried out from many localities during the last sixty years in this area. There is much potential information in these investigations and, to a great extent, these researches have therefore been

included in this study. It is no longer possible to choose new sampling sites freely as most of the basins and bogs have been drained, filled in, or otherwise disturbed. The spatial distribution of the sampling sites is not optimal since they were chosen for very different reasons, usually dictated by public development demands. The new investigations have been concentrated in region B as the remaining heathland in this region are those most threatened by modern human activity. Until now our knowledge of this region has also suffered from the lack of radiocarbon-dated pollen diagrams.

The sampling sites in region A.

No	Site	Sediment type	Pollen catchment area	Number of C-14 dates	Reference(s)
1	Vassnestjern	gyttja	local	2	Midtbø 1995, 1999
2	near Akسدalsvatn	peat	local	1	Prøsch-Danielsen & Øvstedal 1994
3	Gjerdsvatn	gyttja	regional	1	Midtbø 2000
4	Skumpatjørna	gyttja	extra-local	2	Midtbø 2000
5	Valborgmyr	peat	regional	0	Gramstad Eide & Paus 1982
6	Sandvikvatn	gyttja	extra-local/ regional	3	Gramstad Eide & Paus 1982
7	Husøy 2	carr peat	local	1	Lindblom et al. 1997
7	Husøy 4	carr peat	local	1	Lindblom et al. 1997
8	Håvik II	infill peat	extra-local	2	Hafsten 1964-79 (this volume)
9	Tjødnå	gyttja	extra-local	1	Prøsch-Danielsen 1993a
10	Flekkstadmyra I	gyttja	regional	1	Prøsch-Danielsen 1993a
11	Flekkstadmyra II	peat	local	1	Prøsch-Danielsen (this volume)
12	Golhaugen	peat	extra-local	1	Prøsch-Danielsen in Høgestøl 1995
13	Storhagen	peat	extra-local	1	Prøsch-Danielsen in Høgestøl 1995
14	Voll	peat	local	1	Prøsch-Danielsen in Høgestøl 1995
15	Børe Askje	charcoal	local	1	Prøsch-Danielsen in Høgestøl 1995
16	Tunge	peat	local	1	Fægri 1940
17	Ytre Bø	peat	local	1	Fægri 1940
18	Breiavatn	gyttja	extra-local	2	Simonsen 1971
19	Lassatjern	diatomite	regional	1	Fægri 1940, 1944a

The sampling sites in region B.

No	Site	Sediment type	Pollen catchment area	Number of C-14 dates	Reference(s)
20	Sola airport	peat	local	3	Prøsch-Danielsen 1993b
21	Solavika	peat	local	0	Ugland 1984, Danielsen 1986
22	Alvevatn	gyttja	extra-local/ regional	2	Prøsch-Danielsen (this volume), Fægri 1940
23	Stormyra	peat	regional	1	Fægri 1940
24	Eigebakken	gel-mud	regional	1	Fægri 1940
25	Orstad	charcoal	local	3	Hemdorff et al. 2000
26	Line	charcoal	local	1	Simonsen 1983 (unpubl.)
27	Trolltjern	gyttja	extra-local	1	Gunnarsdottir 1997 in Hemdorff et al. 2000
28	Hanalandstjønn	gyttja	extra-local	2	Prøsch-Danielsen 1999, (this volume)
29	Obrestad harbour	gyttja	extra-local	1	coll. Thomsen 1987, Prøsch-Danielsen (this volume)
30	Søylandsvann	gyttja	regional	2	Prøsch-Danielsen (this volume)
31	Bø in Nærbø	peat	extra-local	1	Fægri 1941
32	Audemotlandstjønn	gyttja	extra-local	1	Prøsch-Danielsen (this volume)
33	Kviamyra	peat	extra-local	2	Prøsch-Danielsen (this volume)
34	Stavnheimsmyra	peat	local	1	Prøsch-Danielsen (this volume)
35	Rugland	charcoal	local	1	Lindblom 1982
36	Aniksdalsheia	peat	extra-local	1	Prøsch-Danielsen (this volume)
37	Romamyra	peat	extra-local	1	Prøsch-Danielsen (this volume)

Region A

From region A nineteen localities have been included in this study (localisation see Fig. 14). The establishment of major industrial enterprises and other construction works such as gas pipelines and road construction has been the main factor for choosing sampling sites in the Tysvær, Karmøy and Rennesøy districts. These environmental encroachments had to be preceded by archaeological surveys and investigations, and the main objective of the pollen analyses was to provide environmental backgrounds for the investigated archaeological sites. The palynological signals from these sites have therefore preferably a local or extra-local significance as defined by Jacobson & Bradshaw (1981). Although some pollen diagrams are regional, pollen analyses from sites within the main heathland areas are missing, e.g. from the island of Bokn and the eastern part of Rennesøy. On the Stavanger peninsula the situation is somewhat different: here all the selected sites have been chosen to give the general vegetation history or the shoreline displacement history. The regional vegetation development is well represented in these investigations.

Region B

This region is covered by palynological data from eighteen sites rather evenly distributed mainly over the lowland part of the region. The upland part is only represented by two pollen diagrams, both with local catchments areas. The sampling history covers the time-span from the pioneer work of Fægri (1940, 1941) to recent investigations in connection with pipeline projects, road constructions and farming activity. Supplementary studies have been made where data were missing or to confirm older analyses (Alvevatn). This region is considered to have the best data in our study and to have the best distribution of local, extra-local and regional pollen diagrams.

Region C

This region is very poorly covered by palynological data. Of the eight localities used only five represent pollen diagrams from sedimentary sequences. No pollen diagram is evaluated as being of regional significance. Except for Svartetjørn, all the investigated sites are from the north-western part of the region and were selected to answer specific local environmental problems. No supplementary sampling has been carried out in this region.

Region D

From 1955 to 1957 Hafsten investigated several basins on the low-lying outer coastal area at Lista. Seven of these localities have been further analysed, dated and published (Prøsch-Danielsen 1996a, 1997). This material is incorporated in this study as Lista represents the south-eastern fringe of the coastal heath section. Two localities analysed by Høeg are also included in the study. Five of the eight sites used in the study are evenly distributed over the Lista lowland and three represent the upland part of the Lista peninsula. All but one are evaluated as having a regional pollen catchment.

Inland heath belt

For comparison, information from pollen analyses published recently from the adjacent inland heath belt has also been included. From Forsandmoen in the Forsand district the development of the heathland vegetation has been thoroughly studied by Høeg (1984, 1999) and Prøsch-Danielsen (1996b) with analysed samples from peat bogs and soil profiles. Høeg (1999) has also investigated peat bogs and a small basin at Moi and Ersdal respectively, in the counties of Rogaland and Vest-Agder. The pollen catchment areas of the Forsand diagrams are local and extra-local. For the Moi and Ersdal diagrams information is missing.

The sampling sites in region C.

No	Site	Sediment type	Pollen catchment area	Number of C-14 dates	Reference(s)
38	Bø	charcoal from soil profile	local	1	Lillehammer & Prøsch-Danielsen unpubl.
39	Røymyra	gyttja	extra-local	1	Fægri 1940
40	Slettabø	organic layer in sand	local	2	Skjølsvold 1977, Selsing 1984
41	Salthelleren	carr peat	local	2	Selsing 1984, Skar Christiansen 1985, Selsing & Mejdahl 1994
42	Vodlamyr	peat	extra-local	1	Simonsen (this volume), Bang-Andersen 1988
43	Podlamyr	peat	extra-local	1	Simonsen (this volume), Bang-Andersen 1988
44	Gjedlestadvika	charcoal in peat	local	2	Simonsen 1972
45	Svartetjørn	gyttja	extra-local	2	Griffin & Høeg 1990, Høeg 1999

The sampling sites in region D.

No	Site	Sediment type	Pollen catchment area	Number of C-14 dates	Reference(s)
46	Jølletjønn	gyttja	extra-local	3	Høeg 1995
47	Monatjønn	gyttja	regional	1	Prøsch-Danielsen 1996a
48	Hallandsvann	gyttja	regional	1	Prøsch-Danielsen 1996a
49	Præstvann	gyttja	regional	4	Prøsch-Danielsen 1996a
50	Hanangervann	gyttja	regional	1	Prøsch-Danielsen 1997
51	Kviljotjønn	diatomite	regional	1	Prøsch-Danielsen 1997
52	Braastadvann	gyttja	regional	1	Prøsch-Danielsen 1997
53	Skjoldnesmyr I	peat	local	0	Høeg 1995

Sampling sites from the inland heath belt.

No	Site	Sediment type	Pollen catchment area	Number of C-14 dates	Reference(s)
54	Åsen	peat	local/extra-local	3	Høeg 1984, 1999
55	Forsandmoen	peat	local	3	Prøsch-Danielsen 1996b
56	Moi	peat	?	2	Høeg 1999
57	Ersdal	peat	?	0	Høeg 1999
58	Ersdal, Fiskeløsvann	gyttja	?	4	Høeg 1999

Methods

The raw data in this study represent more than sixty years of development of sampling, soil sample treatment, pollen identification and dating methods. This heterogeneity had to be taken into consideration during the compilation of the data and implies that the information potential of the recent material cannot be fully utilised for comparative studies.

Field work

During this sixty-year time span several types of sampling equipment and procedures have been used. In the early days the Hiller corer dominated, but also different kinds of piston corers. Sediments from the most recently sampled lakes (sites no. 22, 28, 30 and 32) were obtained by using a 7.5 or 10 cm diameter «Russian peat corer» with a chamber length of 100 cm. Coring was carried out from a raft specially designed for this purpose. Peat samples from bog sections were either taken directly from a trench wall or sampled by hammering 10 cm PVC drainpipes into the peat. Charcoal and samples for pollen analysis from ancient monuments were collected directly from the soil profile into plastic bags and test tubes respectively.

Laboratory procedures and pollen identification

The pollen samples were treated according to a standard acetolysis method described by Fægri & Iversen (1950, 1975). Samples from minerogenic layers were also treated with hydrofluoric acid (HF) when necessary.

Before 1975 pollen identification mainly followed the pollen keys of Fægri & Iversen (1950) and Erdtman et al. (1961). Otherwise pollen identification is according to Fægri & Iversen (1975, 1989) and spores follow Sorsa (1964) and Moe (1974), together with «modern» reference collections.

The early pioneer works from Jæren mainly concentrated on arboreal pollen (Fægri 1940). Identification of non-arboreal pollen types was limited, and an analysis of

species diversity could not be made. Fægri as well as Hafsten (1950 and unpubl. data) did not routinely distinguish ericaceous genera. Nevertheless, these studies provide sufficient information for identifying the deforestation and the establishment of the coastal heathland.

More recent studies show that in the Subboreal (SB) and the Subatlantic (SA) periods, ericaceous pollen is totally dominated by *Calluna vulgaris* originating from heathland and heather moorland. In a forested landscape these vegetation types are scarce. The Ericales group can therefore be used to identify heathland during the SB and SA. The problem of local over-representation of *Calluna* in samples from peat bogs has been evaluated but not quantified for each site.

However, in the early Preboreal sequences in Rogaland (Gramstad Eide & Paus 1982, Paus 1988, Braaten & Hermansen 1985, Prøsch-Danielsen 1993a), *Empetrum*-dominated heathlands were common. In this study the nomenclature has been updated following Lid & Lid (1994) in order to compare old and new pollen diagrams.

Pollen diagrams and zonation

The results from Fægri's and Hafsten's analyses were partially available as composite pollen diagrams with arboreal ($\Sigma AP=100\%$) and non-arboreal ($\Sigma NAP=100\%$) pollen types presented separately. As composite diagrams are no longer routinely used in Norwegian pollen analysis, the diagrams have been recalculated and redrawn for a more easy comparison. The new percentage values are calculated on the basis of ΣP (total terrestrial pollen) and plotted using the computer program CORE 2.0 (Natvik & Kaland 1994). The percentages of spores, algae, aquatic pollen and charcoal dust particles are based on $\Sigma P+X$, where X is the actual constituent. Only terrestrial taxa are shown on the diagrams. The pollen taxa are grouped according to ecology.

The diagrams made by Fægri and Hafsten do not include charcoal curves. In Simonsen's early studies (1971, 1972) charcoal particles were registered qualitatively, semi-

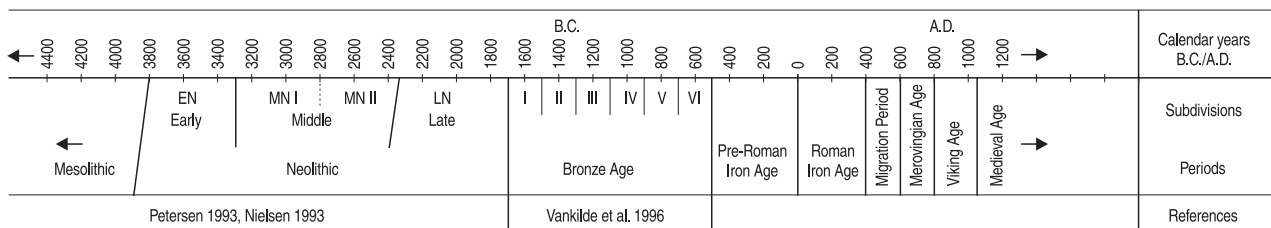


Fig. 2. Chronology of Mesolithic, Neolithic, Bronze Age and Iron Age as calibrated radiocarbon years BC/AD.

quantitatively or quantitatively (sites no 42, 43). In recent pollen diagrams quantitative charcoal curves are routinely included.

Local biostratigraphical zones (PAZ's) are based on the terrestrial pollen and spore assemblages that characterise the various sections of the diagrams. Otherwise the pollen diagrams are divided into deforestation stages, assigned A,B and C. Diagrams not published earlier are available as fold outs in this paper.

Radiocarbon dates and chronology

Both Fægri's and Hafsten's diagrams from Rogaland suffered from a lack of radiocarbon dates. They were chronologically zoned according to their biostratigraphy but this was incorrect as biological changes did not occur simultaneously. Recently, 11 bulk sediment samples of terrestrial or limnic origin have been radiocarbon dated by means of accelerator mass spectrometry (AMS). The results are given in Table 1.

To test the quality of the sediments in the stored samples, a new sediment section was pollen analysed and dated from one of Fægri's localities, Alvevatn (site no 22) in Klepp. The correlation between the two diagrams was very good. The overall deforestation and subsequent establishment of the *Calluna* heaths was dated to 3860±85 BP, 2479–2208 cal BC (TUa-1577A) and 3805±125 BP, 2470–2060 cal BC (T-12550A) according to Fægri and Prøsch-Danielsen's samples respectively (Table 1).

Recently, 7 AMS and 9 conventional radiocarbon dates have been carried out on terrestrial and limnic material sampled by Prøsch-Danielsen. All results, listed in Table 1, are expressed in conventional ¹⁴C years BP (radiocarbon years before present = 1950) and calibrated age calculated according to Stuiver & Reimer (1986), method A, using the program CALIB 86 (version 2.0). Gyttja and peat samples have been calibrated within a time-span of 100 years.

The graphical display of the radiocarbon datings are calculated and plotted with the OxCal v. 2.18 program (Bronk Ramsey 1995) using the calibrated data set according to Stuiver & van der Plicht (1998).

All radiocarbon datings of charred wood have been carried out on shortlife-span species from well-sealed strata according to the recommendations of Simonsen (1983).

The Radiological Dating Laboratory in Trondheim, Norway made the conventional radiocarbon dates, the AMS dates by the Svedberg Laboratory at the University of Uppsala, Sweden and Beta Analytic Inc. Florida, USA.

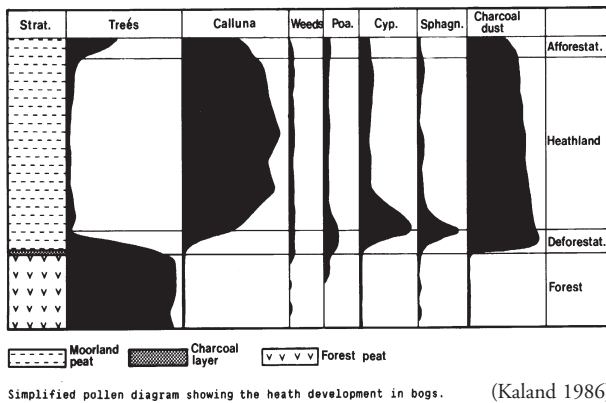
The chronological subdivision of the Mesolithic and the Neolithic (Fig. 2) follows Nærøy (1987, 1993). This chronology for western Norway is based on local artefact assemblages with data compiled primarily from Hordaland county. This is correlated with the south Scandinavian chronology and periodization proposed by Petersen (1993) and Nielsen (1993). The Bronze Age chronological subdivision follows Vandkilde et al. (1996) while the traditional Norwegian way of subdividing the Iron Age is used (cf. Slomann 1971).

Identification of deforestation, deforestation steps and establishment of the heath vegetation

In western Norway, Holmsen (1923) and Fægri (1940, 1941, 1944a,b) were the first to identify the development of the heathland by means of pollen analysis. Fægri's diagrams indicated a sudden change from forested vegetation to heathland (the zone X-XI boundary). The transition to zone XI was marked by a rise of the NAP curve to dominance together with a parallel increase in the amount of *Sphagnum* spores. Fægri suggested that this *Sphagnum* increase was associated with a general humidification of the terrestrial heathland rather than a result of local spore dispersal from the basins and mires (Fægri 1940). In some diagrams he recognised a small-scale rise in the NAP curve in the upper part of zone X before the «catastrophic» heath development. Fægri's interpretation model was also used by Hafsten (1950 and unpubl. data).

Later Kaland (1979, 1986) combined information from pollen analysis, registration of microscopic charcoal particles and radiocarbon dates with lithostratigraphic observation to provide data about the heathland establishment. His *local pollen diagrams*, almost exclusively

based on peaty soil profiles, turned out to be highly uniform independent of time. Based on this material Kaland constructed a simplified pollen diagram summing up the deforestation/heathland development on peaty soils. This «model» is only valid for local sites with small catchments representing local pollen deposition and not for those with larger catchments representing regional pollen deposition. The diagram is separated into three different stages: A. the forest stage, B. the deforestation stage, and C. the heathland stage.



With few modifications, Kaland identified a similar deforestation development in the regional pollen diagrams analysed from the tarns and lakes in Nordhordland. So far, only the regional pollen diagram from Longstjørn has been published (Kaland 1974, 1979, 1986). This makes it difficult to compare the regional development

in this area of Nordhordland with the development in southwestern Norway.

Although Kaland is aware of a possible time lapse between the deforestation, identified as a charcoal layer, and the later establishment of *Calluna* heathland, he uses the radiocarbon dates as if these two processes were one episodic event (Kaland 1979, 1986). As his radiocarbon dates are carried out on charred wood lying on top of stage a, he is actually dating the end of the forest stage or the start of the deforestation process rather than the establishment of the *Calluna* heathland which is therefore younger than these dates (Fig. 13).

In Denmark, Odgaard (1992, 1994) combined Kaland's methods with a widespread use of quantitative data (concentrations and accumulation rates) and multivariate techniques to detect «disturbances» in lakes caused by human impact in Western Jutland. In addition redundancy analysis (RDA) was used to describe the correlation between fire intensity and vegetation response as reflected by pollen assemblages. The model explains regional *Calluna* heathland expansion on mineral soils as a result of intentional vegetation burning. Odgaard also estimated «palynological richness» (diversity), which he uses as an indicator of human impact or «disturbances».

With the establishment of heathland, Odgaard generally detected an increase in sediment accumulation rate (course detritus), and a rise in mineral content, charred particles and palynological diversity simultaneously with a decrease in pollen concentration and pollen influx in the lake sediments.

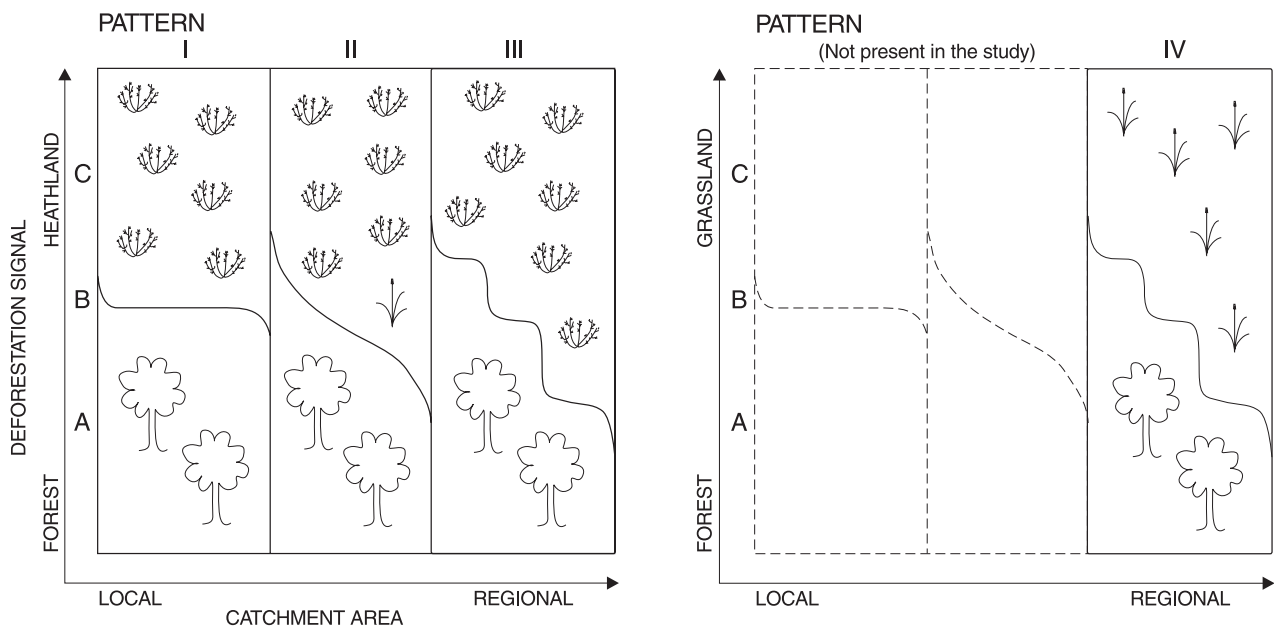


Fig. 3. A schematic pattern of the deforestation patterns as seen from the «pollen signals» in the study area. The changes follow two main courses; either towards heathland or grassland and permanent infields.

Due to the large time span in sampling history, we have found in this study that our data is too heterogeneous for advanced multivariate methods. Kaland's general «abrupt» deforestation model with a distinct charcoal layer is only

represented in the diagrams from Husøy (site no. 7) and Gjedlestadvika (site no. 44), both having a local pollen catchment area. Generally our study illustrates a different pattern particularly in the deforestation stage. We therefore find it more appropriate to distinguish between the deforestation event(s) and the final establishment of heathland.

Our criteria for forest clearance and heath establishment are mainly in accordance with Jonassen (1950), Aaby (1994) and Andersen (1995). In Danish surface pollen samples the ratio between AP/NAP decreases as the tree vegetation opens up as follows: AP= 80–90% in deciduous woodland, 50–70% in glades, 50% in farmland and between 50–20 % in heathland areas (Jonassen 1950). The final heathland establishment in SW-Norway is also reflected in a high influx of charcoal particles combined with pollen from anthropogenic species such as *Plantago lanceolata* and species characteristic of regularly burnt heather in this region (Sundve 1977, Øvstedal 1985, Kaland 1986).

Deforestation patterns

This study is based on palynological analyses and radiocarbon dates from 58 sites. We have chosen not to display a complete set of pollen diagrams from the sites, but rather present and discuss a subset of four diagrams representing the four main types of deforestation patterns interpreted from the palynological signal. These patterns include: A. the forest stage, B. an intermediate or deforestation stage, and C. the heathland stage or grassland and permanent infields.

Fig. 3 shows a schematic model of the deforestation patterns. The changes in the pollen signal follow two main directions: either towards taxa indicative of open heathland, or those indicative of open grassland at sites where heathland never fully developed.

In stage A the original forest density may vary. In some of the pollen diagrams from local mires or lakes stage B is absent with an abrupt transition from stage A to stage C. In other diagrams, mainly from sites with an extra-local or regional pollen source area, stage B may proceed continuously or stepwise. Usually the deforestation leads to the establishment of heathland, but in some highly cultivated areas, the heathland is never fully developed.

Pollen analysis from soil profiles and ancient monuments have not been easy to classify, as pollen spectra are totally dominated by local pollen. Normally these diagrams show a very abrupt deforestation signal reflecting a small local area, and very often these diagrams also represent only a short time sequence (these sites are marked with an asterisk in the «pattern» column in Table 1).

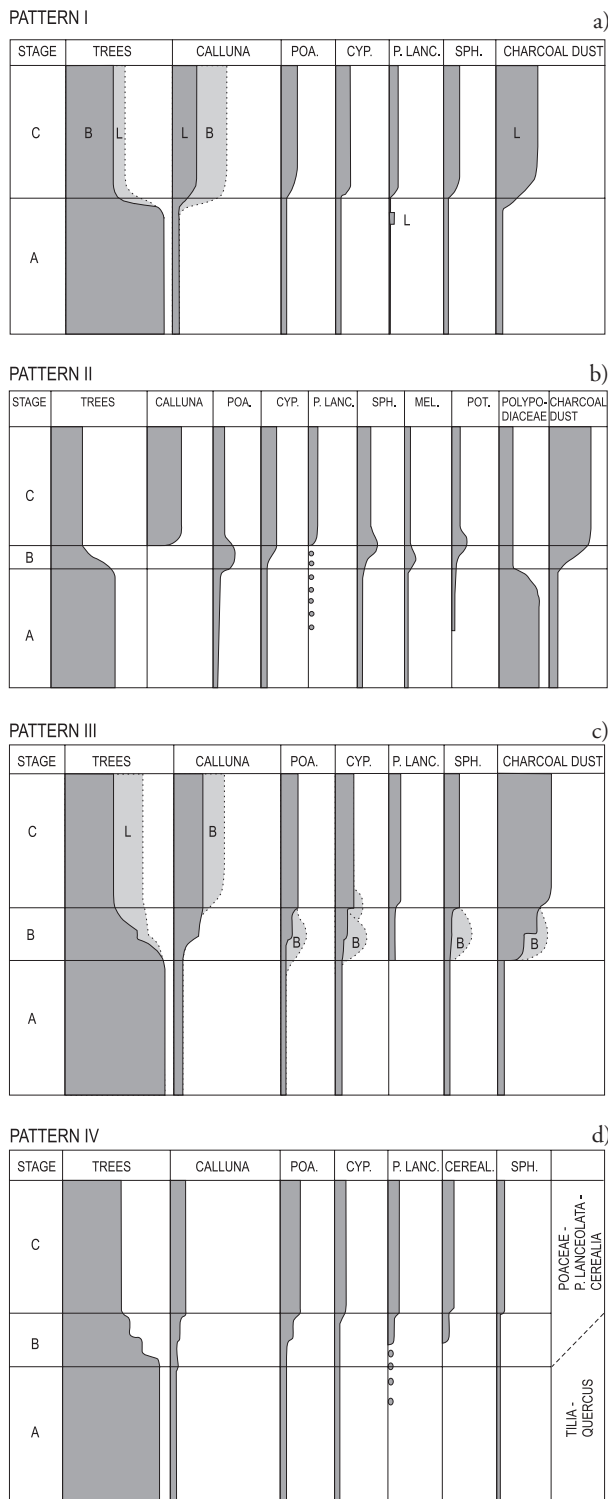


Fig. 4a-d. The four deforestation patterns interpreted from the «pollen signals», showing an abrupt (I), gradual (II) or stepwise deforestation (III and IV).

A3-ark med 2 pollendiagram (fig. 5 og 6)

Fig. 5. Percentage pollen diagram from Audemotlandstjønn, Hå (region B), representing deforestation pattern I.

Fig. 6. Percentage pollen diagram from Aniksdalsheia, Hå (region B), representing deforestation pattern II.

A3 ark med 2 pollendiagram (fig. 7 og 8)

Fig. 7. Percentage pollen diagram from Lassatjern, Stavanger (region A), representing deforestation pattern III.

Fig. 8. Percentage pollen diagram from Breiavatn, Stavanger (region A), representing deforestation pattern IV.

Pattern I. Abrupt deforestation from a closed woodland stage to heathland (Figs. 3, 4a)

Main characteristics

Stage A: Closed woodland. AP ca. 90%, Ericales <5%.

Calluna present before deforestation.

Bogs: Forest succession from QM (Quercetum-Mixtum) and local *Alnus* stands to *Betula* dominance.

P. lanceolata present at Podlamyr (Simonsen this volume).

Lakes: *Quercus-Tilia* PAZ

Stage B: Absent

Stage C: Heathland. Marked drop in AP to below 50% (bogs) and 60% (lakes). Increases in the curves for Poaceae, Cyperaceae and *Sphagnum* spp. Rise in the charcoal dust curve.

Bogs: Ericales 40–60%. First *P. lanceolata* at the A/C transition in the diagrams made by Fægri (1940).

Lakes: Rapid rise in *Calluna* to ca. 20%. Continuous occurrence of anthropogenic species such as *P. lanceolata* and from species characteristic of *Calluna* heath in this region e.g. *Potentilla*-type and *Lotus*-type (Sundve 1977, Øvstedal 1985).

Locality Audemotlandstjønn, Hå

(Fig. 5, Prøsch-Danielsen this volume)

Audemotlandstjønn (site no 32) is a small tarn 30 m asl with a mainly extra-local pollen source area situated in the low-lying part of Jæren in region B, characterised by a hillocky, undulating morainic landscape. Audemotlandstjønn is situated on the northern border of the Hanabergsmarka cultural heritage and recreation area closely connected to the «Jærmuseet». Just south of this area lays the largest remnant of heathland in the Jæren low-lying region. This site is of special interest, as the ancient agricultural landscape still lies virtually undisturbed, and can be seen as a series of superimposed artificial landscape features, ranging in time from Bronze Age burial mounds to the present heavily fertilised grazed fields.

The sediment sequence is shown in the pollen diagram (Fig. 5). Audemotlandstjønn represents a site dominated by local and extra-local pollen (see Fig. 9) where the pollen diagram depicts changes in the nearby vegetation cover.

The pollen diagram covers a time span of at least eight thousand calendar years starting with a drop in the curves for *Pinus* and *Corylus* simultaneously with the introduction and rise of *Alnus* pollen. A closed forest stage (stage A) with a mixed deciduous forest is reflected up to level 105 cm.

At level 105 cm there is a sudden drop in the AP curve and a corresponding rise in the curve for *Calluna*, Poaceae, Cyperaceae and charcoal dust particles. These curves, as well as the curves for pastoral indicators such as

P. lanceolata, are found continuously from this level upwards indicating deliberate use of the area. This event is dated to 3850±65 BP, 2458–2221 cal BC (TUa-1668A) and represents the early and final Middle Neolithic deforestation and heathland establishment in this area.

This abrupt deforestation signal, as seen from the pollen diagram, may be the result of a rapid and massive clearance in the area or simply the appearance of a gradual process strongly compressed by a low sedimentation rate in the basin. However, there are few indications of a change in sedimentation rate at this level so we wish to explain this abruptness as a reflection of a *local* deforestation at the site.

Pattern II. Gradual deforestation from open wet woodland to heathland with abrupt *Calluna* establishment (Figs. 3, 4b). Only bogs and mires

Main characteristics

Stage A: Open wet woodland. AP < 70%, *Calluna* almost absent. Field layer with Polypodiaceae and *Filipendula* decreasing towards the end of the stage.

Stage B: Shift in dominance or co-dominance in deciduous forest types, here *Betula* and *Alnus*. Rise in charcoal dust followed by a rise in Poaceae, Cyperaceae, *Potentilla*-type and locally *Melampyrum*. Rise in *Sphagnum* spores throughout this stage with a maximum at the transition to stage C.

Stage C: Heathland. Marked drop in AP to less than 40%. *Calluna* rises from B/C to more than 20%. Rise in charcoal dust. *P. lanceolata* present throughout this stage (not at site no 33), but may occur as early as stage A (site no 36).

Locality Aniksdalsheia, Hå

(Fig. 6, Prøsch-Danielsen this volume)

The locality Aniksdalsheia (site no. 36) is situated inside the Landscape Protected Area of Synesvarden 235 m asl, a 14 km² large heathland in the Jæren coastal upland region. The landscape is patchy with kames, eskers, ridges and hummocks as well as kettle holes (Andersen et al. 1987). This is the most typical dead-ice landscape seen in Rogaland. The area has been extensively exploited for peat cutting with few untouched peat sequences.

The sediment sequence is shown in the pollen diagram (Fig. 6). The pollen diagram from Aniksdalsheia is locally influenced and depicts natural and manipulated forest succession prior to the establishment of the heathland.

The two lowermost strata, which represent the oldest humus-building forest stage, depict wet woodland of alder carr with a field layer characterised by *Filipendula*,

Equisetum (including evidence from macrofossils) and Polypodiaceae. Here, pollen of the pastoral plant *P. lanceolata*, has been recorded in the pollen diagram during this stage (stage A).

At the transition to stage B, there is a decrease in the *Alnus* curve followed by a rise in the *Betula* curve. In the field layer the tall herb and fern vegetation is gradually replaced by more open ground species such as *Potentilla erecta*, *Cornus* and *Melampyrum*. There is also an increase in charcoal dust. This shift from an alder forest to a mixed birch-dominated forest may reflect a natural succession towards a more acid community caused by environmental changes.

At the start of stage C, there is an abrupt, well-marked rise in the curves of *Calluna* and pollen of open vegetation species. The influx of charcoal dust is high. AP is still decreasing. The heathland establishment is dated to 2470 ±50 BP, 773–450 cal BC (T-13496). Birch stands can survive or even be favoured for a period and form a mosaic pattern within the cultivated (regularly burnt) heathland.

Pattern III. Gradual or stepwise deforestation from closed woodland to heathland (Figs. 3, 4c)

Main characteristics

Stage A: Closed woodland. AP ca. 90% (normally mixed deciduous forest, but with *Pinus* as one of the dominant tree species in some regions) and Ericales <5%. *Calluna* present before deforestation.

Stage B: Gradual or stepwise deforestation with subsequent rise in Ericales (between 5–10%) and the curve for charcoal dust (if registered). Increases in Poaceae, Cyperaceae, *Sphagnum* spp. and species diversity. *P. lanceolata* pollen usually registered from the transition A/B and with scattered occurrences or continuous presence from this stage onwards.

Stage C: Marked drop in AP < 50–60%, *Calluna* (Ericales in the oldest diagrams) >10%. Normally between 10–20% in pollen diagrams from lakes. Rise in charcoal dust (if registered), Poaceae, Cyperaceae, *Sphagnum* spp. and continuous occurrence of anthropogenic species such as *P. lanceolata* and species characteristic of burnt *Calluna* heath in this region; *Potentilla*-type, *Succisa*, *Lotus*-type and species in the family Asteraceae (Sundve 1977, Øvstedal 1985, Kaland 1986).

Locality Lassatjern, Stavanger (Fig. 7, Fægri 1940, 1944)

Lassatjern was a lake 30 m asl in northern Jæren now filled in and used as a sports field. The pollen source area is regional/extra-local. The lake sediments were sampled by Fægri (1940) in the late 1930's and analysed in order

to throw light upon the general vegetation history of northern Jæren. Later (1944a) Fægri re-analysed the samples to gain a more accurate record of the earliest indications of agriculture in this area. The site is situated in a gently undulating landscape of phyllite covered by a rather thin layer of loose deposits. Until recently the Lassatjern area has been in a typical outfield location.

The sediment sequence at the sampling point is shown in the pollen diagram (Fig. 7). The time span of the diagram is from the Preboreal to the present. The forested stage (stage A) is represented by a lower *Pinus-Betula-Corylus* local pollen assemblage zone (LPAZ) followed by an *Alnus-Betula* LPAZ and an upper *Quercus-Corylus* LPAZ. The transition stage (stage B) 420–310 cm is represented by a *Quercus-Tilia* LPAZ. A pronounced step in the deforestation can be seen at 360 cm with decreasing values of *Quercus* and *Tilia* and slightly increasing values of Ericales, Poaceae and Cyperaceae. *Calluna* is not differentiated from the other Ericales constituents in this diagram.

The transition to the deforested stage with heathland (stage C) is at 310 cm and is radiocarbon dated to 2585 ±65 BP, 826–772 cal BC (TUa-1581A) with drops in *Betula* and *Corylus* pollen values. The percentages of Ericales, Cyperaceae and Poaceae increase. Cerealia and *P. lanceolata* pollen are present, but scarce throughout the upper part of the diagram from the transition A/B.

Pattern IV. Gradual or stepwise deforestation from closed woodland to grassland and permanent infields. Heathland are never fully developed (or are not the dominant feature) (Figs. 3, 4d)

Main characteristics

Stage A: Closed woodland. AP ca. 90% (normally mixed deciduous forest, *Tilia-Quercus* PAZ, but with a significant amount of *Pinus* in the diagram from Breiavatn). Ericales almost absent. *P. lanceolata* may be present at this stage. Charcoal dust was not quantitatively registered in these pollen diagrams (Lista-type).

Stage B: Gradual or stepwise deforestation with a subsequent rise in NAP. At one of the steps there is a marked decrease in the AP/NAP ratio, with a decrease in the QM constituents and a simultaneous rise in *Betula* and Poaceae pollen followed by increasing pollen diversity. There is also a rise in anthropogenic indicators, and the curves of *P. lanceolata* and Cerealia are almost continuous from this level upwards. This marks the onset of the local Poaceae – *P. lanceolata* – Cerealia PAZ.

Stage C: Grassland and permanent infields. AP values

between 50–70%. A rise in the Ericales curve (*Calluna* curve at Breiavatn), although with relatively low values (<10%), can be seen from the onset of the Poaceae – *P. lanceolata* – Cerealia PAZ in some of the diagrams (from the sites Hallandsvann, Kviljotjønn and Breiavatn). In other diagrams Ericales rise from the second or third deforestation step in this local PAZ (Præstvann, Braastadvann, Jølletjønn, Monatjønn and Hanangervann). Unlike models I and III from other lakes, a marked rise in the curves for Cyperaceae and *Sphagnum* spp. is not registered.

Locality Breiavatn, Stavanger (Fig. 8, Simonsen 1971)

Breiavatn is a small lake with a local and extra-local pollen source area. Lying 4 m asl on the northern Jæren peninsula the lake is today located in the very centre of Stavanger city. The sediment series was sampled and analysed in 1971 in an attempt to throw light on the settlement history of Stavanger. The lake lies in the northern part of a rather narrow valley in a rocky phyllite landscape with a patchy morainic cover. In the valley there are thick deposits of a rather complex glacial origin. These sediments consist of glaciomarine clays and glaciofluvial sands with a diamicton cover. The top layers have been reworked by marine activity. The rich soil cover in the depressions is fertile and easily farmed.

The sediment sequence is shown in the pollen diagram (Fig. 8). The pollen diagram covers a time span of approximately six thousand calendar years. The closed forest stage (stage A) is represented by the three lowermost spectra in a *Quercus-Tilia* LPAZ. From 670 cm this dense deciduous mixed forest opens up stepwise to more or less open vegetation where an early occurrence of *P. lanceolata* indicates influence by human activity. The transition to this stage B and a local *Betula-Corylus-Alnus* PAZ is estimated to 5000 radiocarbon years BP. This local PAZ has a pronounced step at 630 cm with an increase in NAP from 5–20% associated with an increase in *P. lanceolata* pollen, and with Cerealia pollen detected from 590 cm. This sub-stage is not radiocarbon dated. A further deforestation at the transition to stage C and a local Poaceae-*P. lanceolata*-Cerealia PAZ at 530 cm is dated to 1780±290 BP, 100 cal BC – cal AD 580 (T-1164), and represents the main land clearance. From this level Cerealia pollen occurs continuously and to rather high values (Simonsen 1971). In the 1970's, when the analysis was carried out, charcoal dust was not routinely counted and displayed in the diagram. In this area it seems that heath has never developed as a continuous plant cover. This can possibly be explained as a result of the topography, local favourable soil conditions, and heavy grazing pressure.

Each of the pollen diagrams has been categorised according to the deforestation pattern types and included in Table 1.

Site type and deforestation patterns

In our study area the evidence for vegetation changes is based on pollen diagrams from sites representing local, extra-local or regional pollen source areas as discussed by Jacobson & Bradshaw (1981).

Such a combination of sites is necessary to understand both the details and the complexity of the deforestation process (*sensu* Bradshaw 1991, Edwards 1991). The general pictures of the palynological deforestation patterns and the heathland establishment thus seem to be strongly influenced by the pollen catchment area.

Jacobson & Bradshaw (1981) in their theoretical model define «local pollen as originating from plants within 20 m of the edge of the sampling basin, extra-local pollen as coming from plants growing between 20 and several hundred meters of the basin, and regional pollen as derived from plants at greater distances».

Infill basins, lakes and mires (bogs) with continuous sedimentation have been preferentially chosen, but other «short time» deposits such as soil profiles from open fields or from ancient monuments have also been combined to achieve a complete record of the deforestation and heathland establishment.

Local and extra-local sites

To obtain more precise information about spatially detailed and distinct events we have focused on sites with small pollen catchment areas. Pollen in soil samples from ancient monuments (in-context sampling, *sensu* Bostwick Bjerck 1988) and from soil profiles, derive mainly from vegetation growing on the sampling site or within 20–30 metres distance (Janssen 1973, Raynor et al. 1974, 1975, Bradshaw 1988, Andersen 1992). Pollen from more distant sources (extra-local pollen, *sensu* Janssen 1973) may be present in low amounts.

Within closed canopy forests as, for example, wet woodlands (alder carr, birch stands), studies by Andersen (1970, 1973) and Bradshaw (1981) have shown that most pollen does not travel beyond 20–30 m from its source. In more recent investigations however, it is argued that this distance is underestimated (Jackson & Wong 1994, Calcote 1995). As the canopy opens, the pollen catchment area increases (Janssen 1973, Berglund et al. 1986, Edwards 1991, Andersen 1992).

The opposite phenomenon is found in infill basins where the pollen diagrams will represent more local vegetation as the site is reduced in size (peat's overly lake sediments). The authors have been aware of these problems in defining the size of the sites in Table 1.

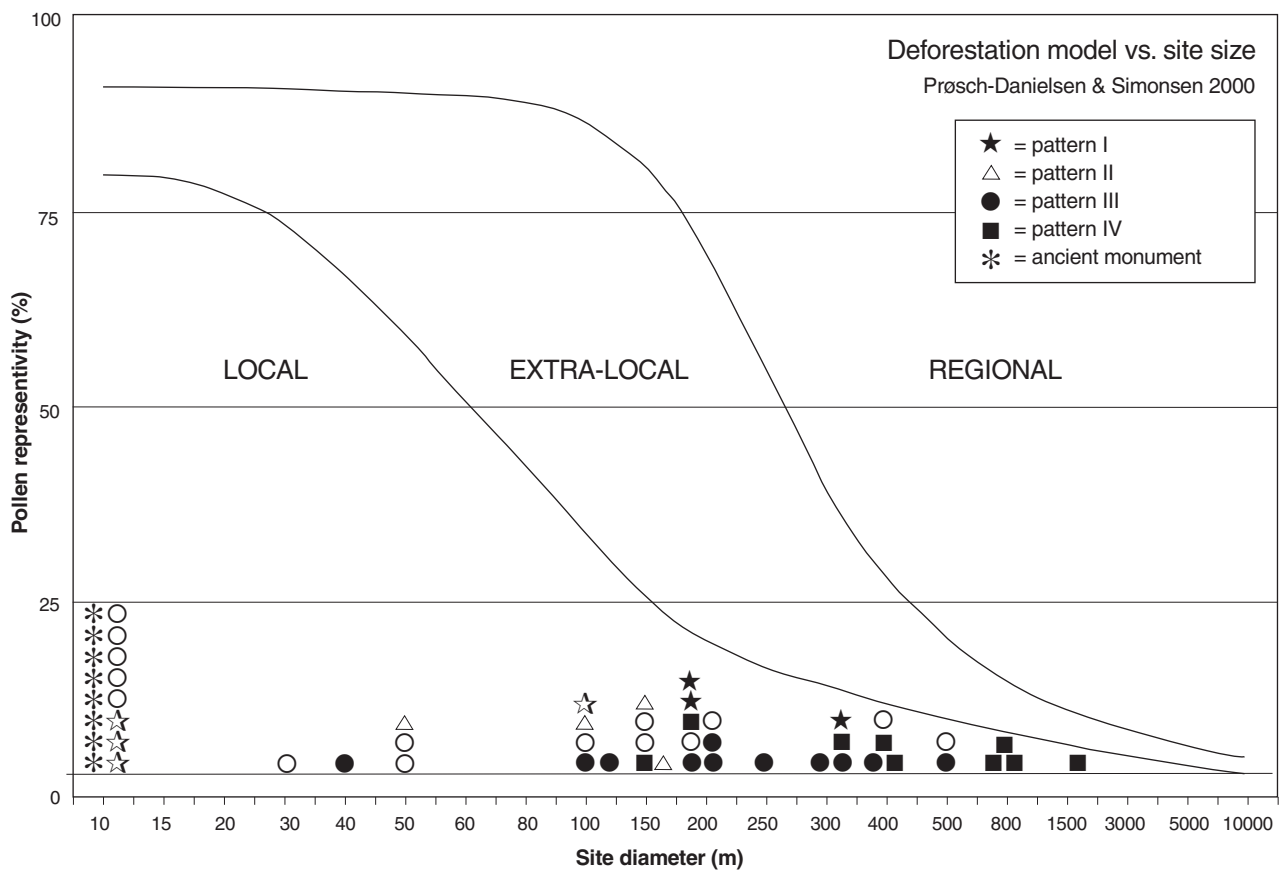


Fig. 9. The sites plotted in a modified Jacobson & Bradshaw diagram (1981), showing the relationship between pattern, site size and the relative proportions of local, extra-local and regional pollen. Black symbols = lakes, open symbols = bogs.

Small-scale sites, local or extra-local will generally fit into the deforestation patterns I or II, Figs. 3, 4a,b.

Regional sites

Pollen analyses from small tarns and larger lakes may be interpreted by using Jacobson & Bradshaw's (1981) simplified and arbitrary model that relates basin size to the pollen source area, Fig. 9. According to this model, the pollen assemblage is increasingly influenced by extra-local and regional components with increasing basin size. For small tarns (20–200 m in diameter) there is a substantial input of both local and extra-local pollen. However, Jackson (1990, 1991) showed that the regional pollen contribution from the canopy component was greatly underestimated in this arbitrary model. Never-

theless, the pollen diagrams from our small sites give a clear picture that is consistent with the deforestation and heathland establishment criteria.

Pollen diagrams from larger bogs and lakes (> 200 m in diameter) provide a smoothed picture on a larger areal scale. These regional pollen diagrams do not point to specific ecological/historical events, but rather reflect the sum of changes in mosaic vegetation within an ecologically complex pollen source area (*sensu* Odgaard & Rostholm 1987, Andersen 1988). The regional pollen diagrams will also show the final completion of the deforestation process.

Large-scale sites, representing the regional and some extra-local vegetation, generally fit into the deforestation patterns III and IV, Figs. 3, 4c,d.

Results and discussion

Chronology

Metachroneity and steps

Both Fægri (1940) and Hafsten (1950) considered the biostratigraphic transition from woodland to a deforested area to be a result of climatic deterioration and therefore synchronous in the area. Fægri (1940, p. 62) found the rise in NAP pollen to be synchronous with the establishment of *Calluna* heathland in the area. In Denmark however, Jonassen (1950) concluded that the heath formation was highly metachronous, and this was confirmed by Odgaard (1994). Kaland (1979, 1986) showed that for Nordhordland this biostratigraphical transition was also highly metachronous, spanning a time interval of 3000 years. This is confirmed by our study.

The selected radiocarbon dates have been sorted by decreasing age and used as input data to the OxCal v. 2.18 program (Bronk Ramsey 1995). This program produces calibrated ages with two level confidence intervals, 68% and 94%. We have chosen calibration according to Stuiver & van der Plicht (1998). Fig. 10 illustrates the initial deforestation and deforestation steps from all regions. It shows that the deforestation process for all regions followed a stepwise development for at least 3600 calendar years from approximately 4000 cal BC to approximately 400 cal BC.

Fig. 11 shows the sorted dates for heathland or grassland establishment in all regions. It reveals a metachronous development in the heathland establishment taking place during at least 4000 calendar years from approximately 4000 cal BC to 200 cal BC at the outer coastal area.

This metachroneity and stepwise pattern is more accurately displayed in compressed diagrams of calibrated ages BC/AD (Figs. 12, 13).

The deforestation shows a gradual development with some pronounced clearance periods.

Period 1 from 4000–3600 cal BC (The Mesolithic/ Early Neolithic transition). During this period, deforestation has taken place at 35% of the sites.

Period 2 from 2500–2200 cal BC (The Middle Neolithic III/ Early Late Neolithic transition). During this period deforestation is registered at 60% of the sites. A pronounced substage can be seen at approximately 2300 cal BC (Early LN).

Period 3 from 1900–1400 cal BC (The Late Neolithic to Bronze Age II). During this period, deforestation has occurred at approximately 80% of the sites. From the OxCal plot, Fig. 10, this period can be further subdivided with the most pronounced substage at approximately 1900 cal BC (LN).

It is also possible to separate a fourth and fifth period around 800 cal BC (Late Bronze Age V, VI) and 400 cal BC (Early Pre-Roman Iron Age) respectively, but the significance is low because of several estimated dates. Here, one has to be aware of the pitfall concerning plateau phases.

In our material period 1 in the deforestation process is only encountered in regional diagrams representing models III and IV. Periods 2 and 3 are seen in pollen diagrams representing both local, extra-local and regional pollen sources where all models are represented.

The development of heathland seems to be a more or less continuous process. Although clear events (corresponding to periods 1 and 2 in the deforestation process) can be identified, nothing dramatic seems to happen until the Bronze Age period V (900–700 cal BC). In the period from 900–400 cal BC (The Bronze Age V-VI/ Pre-Roman Iron Age transition) there is a threefold increase in the heathland establishment rate. Later the heathland development continues, but at a somewhat lower rate. The process seems to have come to an end at approximately 200 cal BC (Pre-Roman Iron Age) in the lowland belt of «the coastal section» and at cal AD 1000–1100 (Iron Age/ Medieval Age transition) in the inland heath belt.

Pollen diagrams showing the earliest heathland establishment are all from sites representing local and extra-local pollen sources, while those showing the latest heath-

land establishment are normally from those representing a regional pollen source area. This tendency is as expected. The onset of deforestation will probably first be observed in regional diagrams, while these diagrams will be the last to show heath as the final regional vegetation pattern.

Pre-Neolithic deforestation and heath development

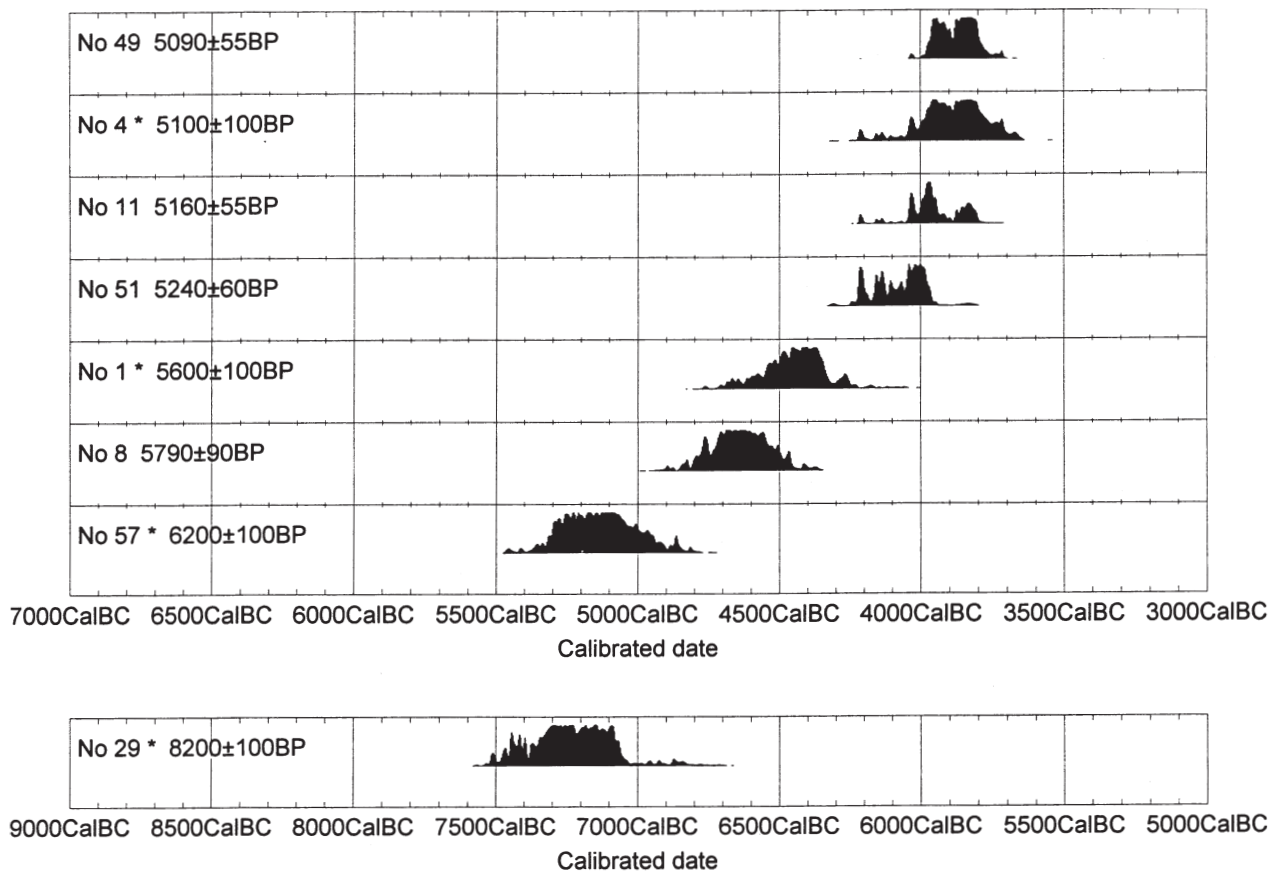
Figs. 10 and 11 show the deforestation and the establishment of heathland develop mainly after the defined transition between the Mesolithic and the Early Neolithic around 3900/3800 cal BC.

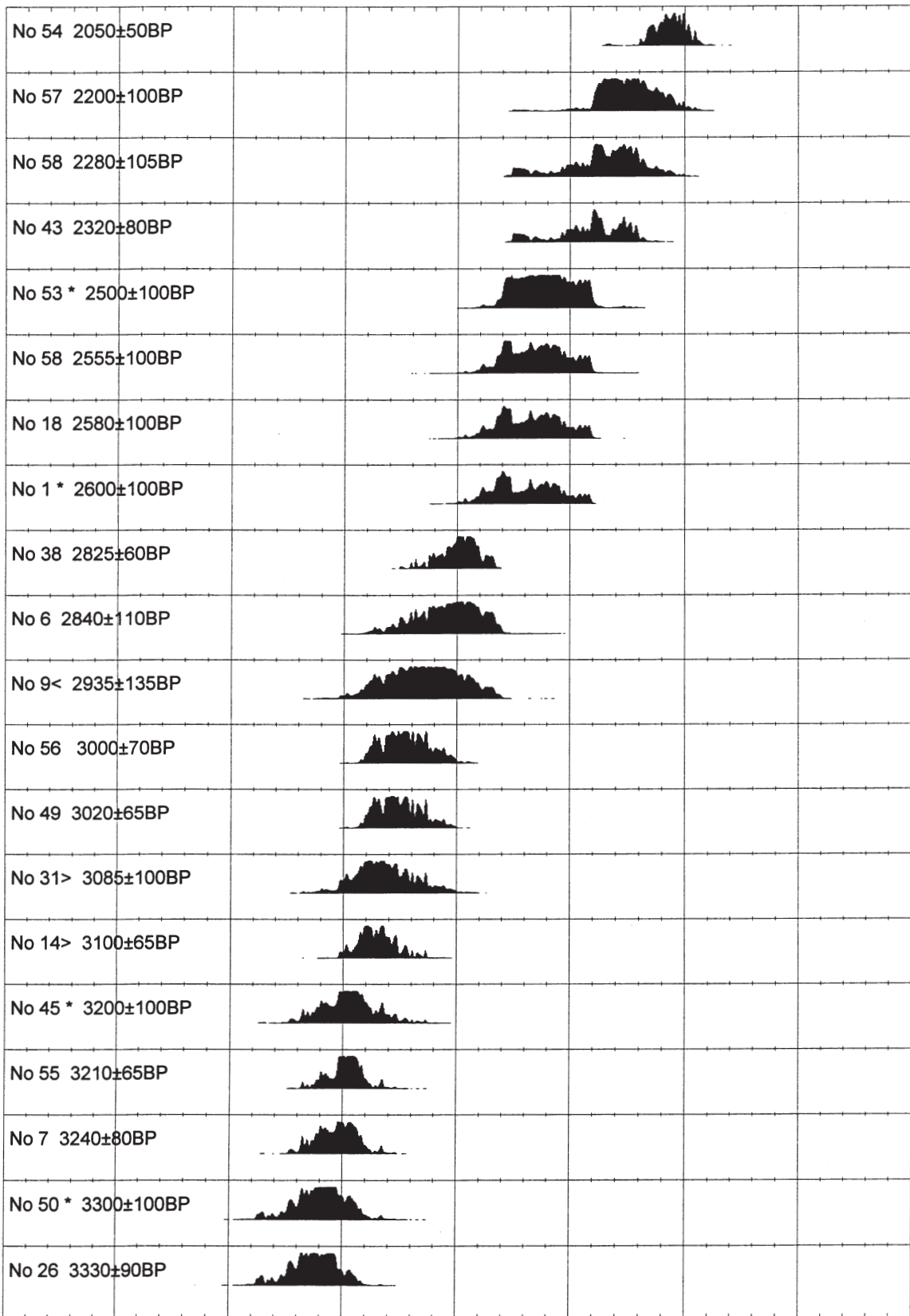
However, *Calluna* has been a natural constituent of the West Norwegian coastal vegetation since Late-Weichselian times (Gramstad Eide & Paus 1982), but probably not as a dominant species. *Calluna* is associated with acid mineral soils of low nutrient content. However, the Late-Weichselian – early Holocene soils had a low organic content and acid soils had not yet developed. The occurrence of *Calluna* in this environment can be explained by the high chemical buffer ability of these fresh mineral soils with a «floating» acidity (pH). Additionally,

Calluna seems to have a wide tolerance for soil acidity (Semb & Nedkvitne 1956). On such kinds of soil, plants of different soil preferences could have grown in mixed communities (Fægri 1933).

In the early Holocene, *Calluna* communities are considered to have been rather common in patchy pattern mainly on acid mineral soils, in oligotrophic mires and later on raised bogs, as can be observed in recent vegetation (Aaby 1988, Odgaard 1994). Larger early Holocene heaths, obviously not manmade, have been recorded from north mainland Scotland (Peglar 1979, Birks 1996) and the Western Islands of Scotland (Birks & Madsen 1979) as early as 9000–8600 BP, and in the Faroes from ca. 6000 BP (slow rise from 7000 BP) (Jóhansen 1985, 1996). On Hoy, Orkney, heath establishment is recorded as early as 7000 BP (Bunting 1996). These heath establishments are attributed to such factors as extreme wind exposure and salt spray. In western Norway heath development has also been recorded this early. On the island of Utsira heath development has been dated to 7200±30 BP, 6101–6011 cal BC (T-6346A), but estimated to 9500 BP (Paus

Fig. 10 (page 24–27). Onset of deforestation and deforestation steps in the southwestern coastal heath section. Probability distribution of calibrated radiocarbon dates (sorted by B.P. age) according to Stuiver & van der Plicht (1998), OxCal v. 2.18 (Bronk Ramsey 1995). Localities with estimated age are marked with an asterisk.





3000CalBC 2500CalBC 2000CalBC 1500CalBC 1000CalBC 500CalBC CalBC/CalAD 500CalAD 1000CalAD
 Calibrated date

A3-ark med tabell 1, del A

A3-ark med tabell 1, del B

A3-ark med tabell 1, del C

A3-ark med tabell 1, del D

indicating anthropogenically induced deforestation, and the heathland establishment becomes permanent mainly because of repeated burning. Appearances of other anthropogenic indicators cannot be detected in the pollen diagrams at this early stage.

At Håvik, a short episode of heathland establishment is estimated to 7000–6500 BP. Forest vegetation is soon re-established. All these sites are situated close to known Mesolithic dwelling places.

Neolithic and later deforestation and heath development

Throughout northern Scotland and in the Orkneys heath vegetation and blanket bog formation expanded after about 5000–4500 BP. This expansion is mainly attributed to Neolithic human activity, possibly accelerated by climatic deterioration (Birks 1996, Bunting 1996). In Shetland the development is more unclear, but Jóhansen (1985) suggests that the heathland expansion from 4650 ±80 BP, 3525–3346 cal BC, reflects human impact possibly due to increased grazing intensity.

In West Jutland the expansion of heath vegetation occurs after the introduction of agriculture around 4000 cal BC with the first permanent expansion from around 3000 cal BC (Odgaard 1994). Odgaard (1992, 1994) points to a strong correlation between charred particles and *Calluna* pollen, indicating that heathland expanded and was maintained by regular burning. The development of heathland was also influenced by soil type.

Since the early 1920's there has been an extensive debate in Norway on the relationship between heathland vegetation, farming and climate, summed up by Kaland (1979, 1986) and Fremstad et al. (1991).

In Nordhordland, except for two exposed and isolated localities, the heathland expansion in that area is greatly delayed compared to the «generally accepted» (see below) introduction of agriculture (Bakka & Kaland 1971). Despite these facts, the investigations from Nordhordland show that the development of heathland has a strong connection to farming, especially the use of outfields and that it is also influenced by climatic stress.

In 1940 Fægri postulated that «Die Heide ist – auf Jæren! – ein in erster Linie klimatisch bedingter Vegetationstypus. Dafür spricht erstens die Gleichzeitigkeit womit sie entsteht.» Fægri also maintains this climatic explanation for the heath formation in his work from Bømlo (1944b), but is now ready to consider human impact as an additional agency of vegetation change.

The first signs of human impact in our data occur at the transition between the Mesolithic and Early Neolithic (4000–3600 cal BC) as an opening in the forest together

with the first appearance of anthropochorous pollen types indicating the presence of pastures. However, heathland has only developed at three new localities during that period: Flekkstadmyra II, Stavnheimsmyra and Romamyra. These localities have, in common, an exposed position far outside the central agricultural areas. Here an increase in charcoal dust indicates *active human impact* and maintenance of the heathland in the outfields area.

At the Middle Neolithic II/ Early Late Neolithic transition (2500–2200 cal BC), the next main deforestation period opens up almost the entire landscape of SW-Norway (60% of the localities have been affected) with further permanent heath establishment. This event occurs simultaneously with the «generally accepted» introduction of a Neolithic agro-pastoral economy in western Norway at the transition MN II/ LN around 2400 cal BC (Prescott 1996). The mid- to late-Holocene climatic deterioration proposed by Anderson et al. (1998) and identified from changes in peat humification and lake level fluctuations ca. 3900–3500 BP (2400–1800 cal BC) in Scotland, does not seem to be of any significance with respect to heathland establishment pattern in our area.

Archaeological chronology and environmental changes

From the Mesolithic/ Early Neolithic transition the deforestation and heathland development is a continuous, but nevertheless, stepwise process, and very few regression events have so far been observed (Simonsen 1969, 1971). The stepwise pattern of these processes and expansions may reflect a general increase in agricultural pressure as a result of settlement expansion due to population rise, immigration of new population groups, or simply a change in economy and land use. How do these vegetation changes match the archaeological chronology based on technology and typology?

From the Mesolithic/Early Neolithic transition until the end of the late Middle Neolithic II there is a good «correlation» between environmental impact periods, clearance period 1 and 2, caused by human activities and changes in artefact inventory in western Norway. This correspondence may be due to the fact that the artefact inventory of the Neolithic settlement sites represents or reflects daily life activities connected to environmental manipulation and subsistence activities. However, the Bronze Age chronology is mainly based on artefacts connected to religious ceremonies or activities displaying political and social power. Therefore, a similar correspondence between the archaeological inventory, on which the chronology is based, and subsistence activities cannot be expected for the Bronze Age. The significance of the Bronze Age landscape is the landscape of prestige

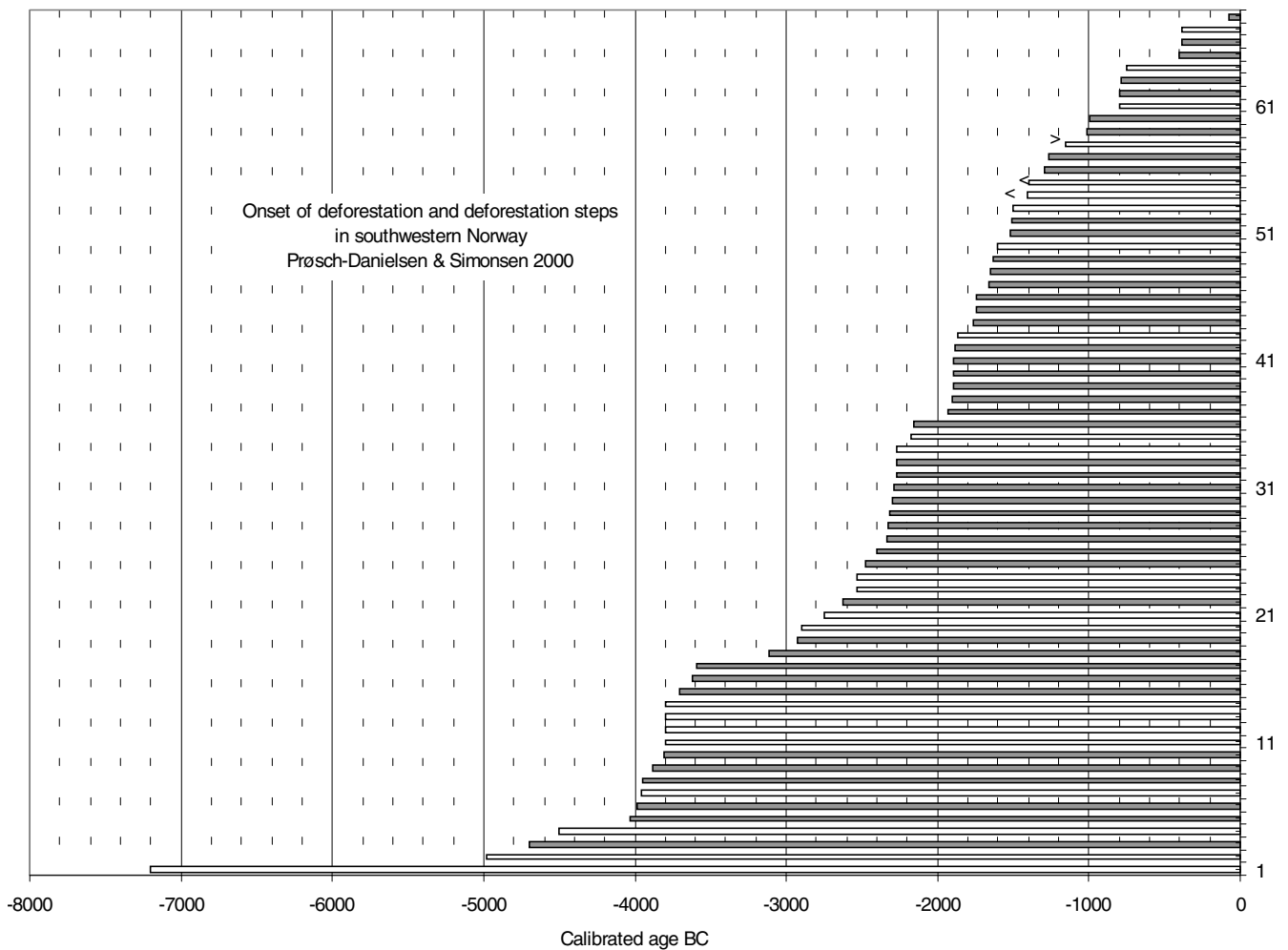


Fig. 12. Onset of deforestation and deforestation steps in the southwestern coastal heath section. Fixed dates are mean values of calibrated ages according to Stuiver & Reimer (1986), bold in Table 1. Shaded bars: calibrated ages. Unshaded bars: estimated ages. < earlier than, > later than.

compared to the everyday landscape as proposed by Lillehammer (1994).

Clearance period 1, corresponds with the Mesolithic/ Early Neolithic transition from 4000–3600 cal BC and there are no further extensive vegetation changes until the end of the late Middle Neolithic II, at approximately 2500 cal BC. This period is archaeologically considered to represent a transition phase with a change to artefacts showing a strong south Scandinavian influence. Our data (Fig. 12) show this period to be very important for the structural outline of the landscape with significant forest clearance pointing to the introduction of an agro-pastoral economy. In this period we also recognise the second heathland expansion indicating a more active use of the land for grazing.

The subsequent vegetation development only partially fits into the traditional archaeological chronological scheme for western Norway. Our data show a considerable

human impact on forest vegetation from the second half of the Late Neolithic to the Bronze Age II (1900–1400 cal BC), with the most pronounced substage in the Late Neolithic. This human impact can be associated with the earliest finds of two-isled houses in Rogaland. The heathland expansion on the other hand shows a more gradual development. The traditional LN/BA transition at 1700 cal BC is not distinct in our data.

In the first part of the Bronze Age however, it is not possible to trace any abrupt vegetation change. Since 1980, extensive archaeological excavations at Forsandmoen in Rogaland have revealed the remains of 250 prehistoric house foundations where radiocarbon dates from postholes range from the Bronze Age period II up to the Migration Period (Løken 1998a). This represents a perfect opportunity for estimating changes in social organisation and agricultural practices, in other words in daily life. It is therefore of special interest that there seems to be a shift in the Bronze Age social organisation in the Bronze Age

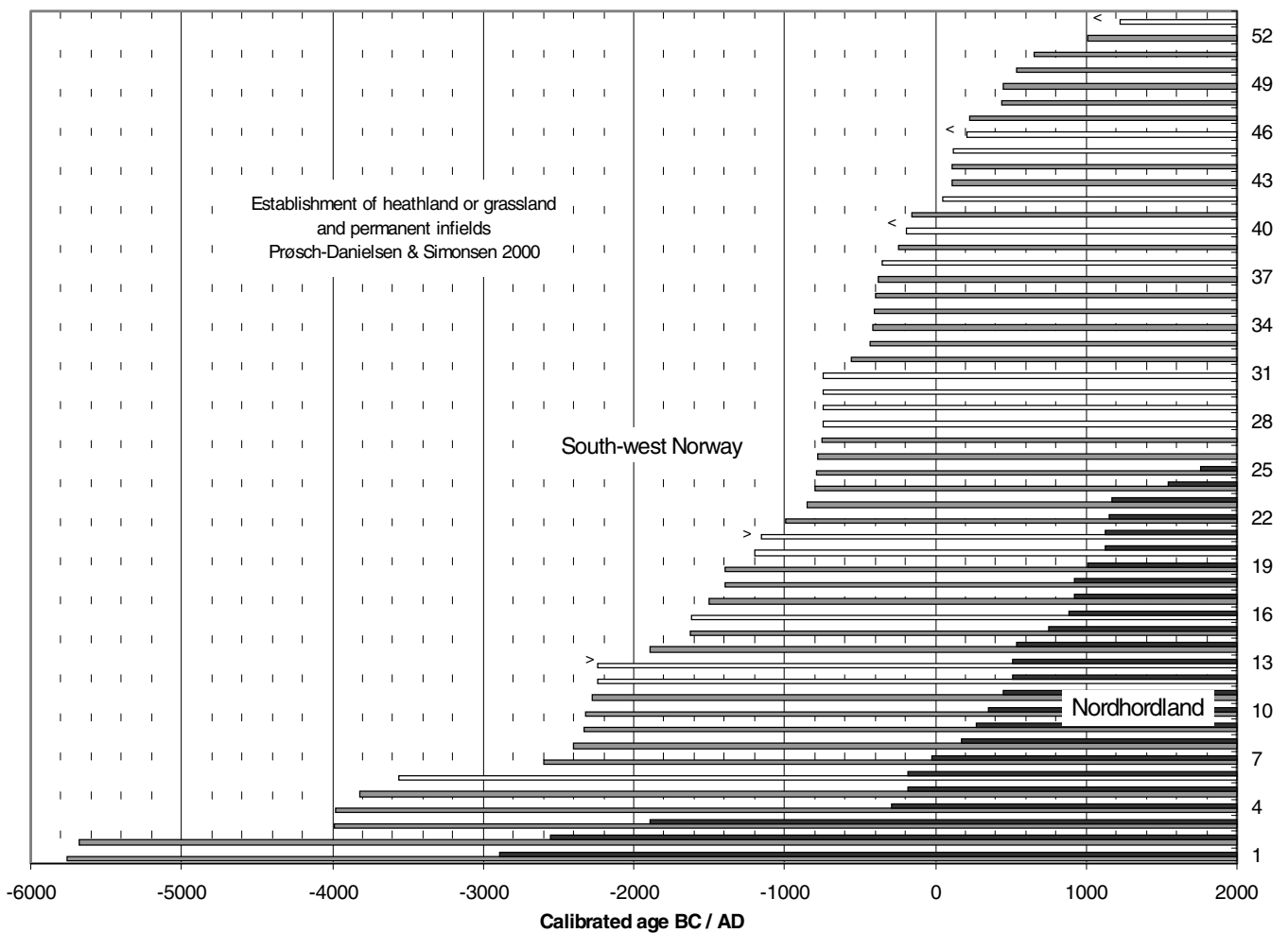


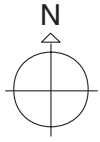
Fig. 13. Final establishment of heathland or grassland and permanent infields in the southwestern coastal heath section. Heath establishments in Lindås, Nordhordland, are marked with black bars (based on Kaland 1986, Waaler 1997). Fixed dates are mean values of calibrated ages according to Stuiver & Reimer (1986). Shaded bars: calibrated ages. Unshaded bars: estimated ages. < earlier than, > later than.

period V, 900–700 cal BC, probably from a clan-based house structure to a more nuclear family-based house structure where each family had its own cattle and fields (Løken 1998a). This change in social structure is also illustrated by a study made by Nordenborg Myhre (1998). She found that on Karmøy and northern Jæren, the collective construction of huge burial mounds came to an end during this period. This change in social organisation from large to small farming units, also implies an expansion in outfield exploitation. The change is well in accordance with the vegetation development observed from the heathland region. The outfield heath areas are well established from this time onwards and expand greatly in all regions. Region C however, has a somewhat delayed heathland development. The process of heathland formation is completed during the Pre-Roman Iron Age in the lowland belt of «the coastal section».

Geographical variations

In Fig. 14, the deforestation and final heathland or grassland establishment dates are displayed in a regional context. A brief evaluation seems to reveal a regional pattern. Although it is now obvious that the deforestation and heath establishment are caused by human impact on the vegetation, it is necessary to analyse whether this pattern also is a result of geographical parameters or simply due to the pollen catchment area described by the models. For simplification, only localities deforested after the Mesolithic/ Early Neolithic transition at 3900/3800 cal BC are discussed.

Region A. The first clearance period (4000–3600 cal BC) has been recorded in nine pollen diagrams (including Vassnestjern in Hordaland, site no 1), but at only one locality (Flekkstadmyra II, site no 11) far from the settlement areas (*sensu* Høgestøl 1995) has human impact led



VASSNESTJERN

NEAR AKSDALSVATN
SKUMPATJØNN
GJERDESVATN
HUSØY
SANDVIKVATN
VALBORGMYR

HÅVIK II

TJØDNÅ

VOLL
STORHAGEN
FLEKKSTADMYRA II
FLEKKSTADMYRA I
BØRE ASKJE
GOLHAUGEN
TUNGE
YTRE BØ
LASSATJERN
BREIAVATN

SOLAVIKA
SOLA AIRPORT

ORSTAD I, II, III
ALVEVATN
STORMYRA
EIGEBAKKEN
TROLLTJERN

HANALANDSTJØNN
LINE
SØYLANDSVANN
BØ IN NÆRBØ
AUDEMOTLANDSTJØNN
OBRESTAD HARBOUR
KVIAMYR
ROMAMYR
ANIKSDALSHEIA
RUGLAND
STAVNHEIMSMYR

BØ
SLETTABØ
RØYRMYRA
SALTHELLEREN
VODLAMYR
PODLAMYR
GJEDLESTADVIKA
SVARTETJØRN

ÅSEN
FORSANDMOEN
MOI
ERSDAL, FISKELØSVANN
ERSDAL

HALLANDSVANN
JØLLETJØNN
MONATJØNN
PRÆSTVANN
BRAASTADVANN
HANANGERVANN
KVILJOTJØNN
SKJOLDNESMYR I

HORDALAND

ROGALAND

VEST-AGDER

0 20 km

to permanent heathland establishment. In the pollen diagrams from the northern Jæren region (sites no 16,17) evidence for human impact occurs relatively late (see also region B), first in the Middle Neolithic II and Late Neolithic. The landscape was gradually deforested throughout the Neolithic, and by the beginning of the Bronze Age, 1700 cal. BC, all sites appear to have been affected by human activity. The deforestation process continued gradually throughout the Bronze Age so that heathland had become established by the Pre-Roman Iron Age, approximately 200 cal BC, in the pollen diagrams extending back this far.

At the localities Gjerdesvatn (site no 3) and Breiavatn (site no 18) the heathland vegetation never fully developed. On the islands in the southern part of this region it has been extremely difficult to find complete sediment series due to peat cutting, which gives an incomplete picture of the general deforestation.

Region B. At the beginning of the Early Neolithic heath development had begun at two localities, Stavnheimsmyra (site no 34) and Romamyra (site no 37), far from areas that were later to develop into the main agricultural areas. Before the second deforestation period 2500–2200 cal BC, only small environmental changes can be inferred from the pollen diagrams in this region, but before the end of the Neolithic Age all the sites show human impact on the forest vegetation. Throughout the Bronze Age this impact continued so that nearly all localities had developed into heathland by BA V (900–700 cal BC) prior to the beginning of the Pre-Roman Iron Age.

Region C. So far in this region no pronounced traces of human impact have been recorded before the Late Neolithic period. During the Late Neolithic and the Bronze Age there was a gradual opening of the forest, ending in heathland vegetation during the Pre-Roman Iron Age, before 200 cal BC.

Region D. The Lista region is characterised by very early human impact from the beginning of the Early Neolithic (3900–3600 cal BC) recorded in the pollen diagrams as an opening of the local *Tilia-Quercus* forest. A second phase of deforestation is seen in the MN II approximately 2500 cal BC. The deforestation continued throughout the Bronze Age, but in this region heathland never fully developed. Instead rough grass-dominated pastures and permanent infields developed rather than heathland. The process was completed during the Bronze Age V (900–700 cal BC) (Prøsch-Danielsen 1996a, 1997).

The inland heath belt. Deforestation can be recognised in some of the pollen diagrams from the Early Neolithic. In

the early Bronze Age all localities were affected by human impact. Thus in this region the development of heathland vegetation started rather late and proceeded continuously from the Roman Iron Age to the Viking Period (cal AD 0–1000).

Deforestation

From the regional display, Fig. 14, the earliest signs of Neolithic human impact can be seen in regions A and D as onset of deforestation from clearance period 1 (4000–3600 cal BC). In region A the timing of this gradual impact is spread over at least 2300 year (from the Early- to the Late Neolithic), while in region D this early impact seems to be more concentrated in the Early- and Middle Neolithic. In southwestern Norway the earliest signs of farming thus appear to be associated with a heterogeneous landscape with a diverse potential for human exploitation.

At the Mesolithic/Early Neolithic transition these regions have in common a complex landscape of loose deposits, rocks, fjords, sounds and small islands, wetlands and lakes. The archipelagic appearance of this landscape is more pronounced in region A, but can also be seen on a smaller scale in region D, especially in the eastern part characterised as a «fjord and fjård» coast landscape (Klemsdal 1982). Such a landscape is considered favourable for a mixed economy based on hunting, fishing and gathering and possibly small-scale farming. The general picture of this early deforestation indicates a mixed economy gradually shifting to one with more emphasis on terrestrial resources similar to the situation described from Hordaland by Bakka & Kaland (1971) further north in western Norway.

The early onset of deforestation can also be interpreted in terms of deforestation models depicting different catchment areas of the sampling sites. All sites in region D and most of the sites in region A are lakes with a rather large catchment area where even distant human impact on the vegetation can be traced.

In region B, however, the first signs of forest clearance start at the end of the Middle Neolithic II, around 2500 cal BC. It is generally accepted that an agro-pastoral economy was fully established at the end of this period in western Norway (Bakka 1993, Solberg 1993, Prescott 1996). Prior to this stage the lowland region B was densely forested with mixed oak woodland that had probably been exploited quite extensively by migrating groups, but of which there is little or no trace in the pollen record. Traces of these groups are mainly encountered at localities along the main watercourses and larger water bodies. However, the clearance starting at MN II was massive and rapid, leaving a patchy landscape with woodland and fields. It is difficult to understand such a sudden overall environ-

mental change without considering the immigration of a farming population at that time (as also suggested by Bakka 1993 and Solberg 1993). The rather broad lowland rim of loose deposits was well suited for a dense population of farmers.

In region C and the inland heath belt, there are no signs of distinct clearance periods. The timing is scattered with both early and very late traceable human impact. Rocks and mountains lacking in nutrients produce a soil unsuitable for farming. Only small patches of loose deposits occur, e.g. at Forsandmoen. However, at the end of LN, 1700 BC, human impact can be traced in all regions, including the inland heath belt.

Heathland establishment

A prominent feature of the diagrams is the early and massive final establishment of heaths in region B, South Jæren, where all sites show complete deforestation and permanent heath development before the end of the Bronze Age V (900–700 cal BC). A similar pattern is seen in region D, Lista, but in this region the deforestation did not lead to heathland but rather to mosaic vegetation with *Calluna* patches in a more grass-dominated open vegetation with permanent infields.

In both regions B and D there was considerable farming pressure throughout the LN and BA periods (Bakka 1993, Solberg 1993, Johansen 1986, Bjarke Ballin & Lass Jensen 1995, Løken 1998b). The vegetation response to this pressure was the development of a «pure» heathland in region B, South Jæren, where large areas of loose deposits provided space for scattered farming, and where single household units could optimise the use of outfield resources. Here the heathland establishment seems to have been the result of intentional maintenance more than a gradual deterioration of the soil or accidental forest fires. However, in region D, Lista, space was limited and therefore farmed differently. High-density farming was unable to expand freely to exploit large outfields nearby, so the pressure on these fields was too high for heathland vegetation to be maintained (see also Odgaard 1994, Semb & Nedkvitne 1956). If heath was preferred as winter fodder, this resource may have been exploited in the nearby upland area.

In Denmark different vegetation responses to soil type are more pronounced mainly because of a large-scale soil substrate homogeneity (Odgaard 1994, Aaby & Andersen 1986). Jæren is more dominated by a small-scale mosaic soil pattern where vegetation responses to soil conditions are difficult to discriminate palynological. However, in Jæren the variable drainage capability of the diverse soil types seems to be more important to heath development and vitality of *Calluna* than the chemical

properties of the soil substrate (Semb & Nedkvitne 1956). *Calluna vulgaris* has a maximum constancy on well-drained soils and those with a somewhat impeded drainage.

Early heath establishment can also be seen in region A, but the onset was more scattered in time. The heathland was fully developed by approximately 200 cal BC, before the end of the Pre-Roman Iron Age. However, at a few localities, Breiavatn (site no 18) and Gjerdesvatn (site no 3), heathland never developed completely. At Gjerdesvatn, however, newly emerged marine deposits probably led to poorly drained soils with high clay content unfavourable to heath development.

Both in the more unfavourable anorthosite region C, and the inland heath belt the development of the heathland started rather late. This can best be explained by the limited farming of these areas, thus been the last to be cleared for extensive grazing.

The general picture from our study suggests a deforestation and heath establishment considerably earlier than previously anticipated. Kaland's investigations from Nordhordland show this process to have occurred mainly throughout the Iron Age with two main steps: Pre-Roman Iron Age 300–0 BC and the Viking Age/ Early Medieval AD 900–1100 (Fig. 13). Our data show that 50% of the sites had developed into heaths at approximately 800 BC compared with approximately AD 500 for Nordhordland. In our study heathland was already well established in the Bronze Age V (900–700 cal BC) in regions B and D, and prior to 200 cal BC in region A.

One of the main objectives of Kaland's investigations was to study heath formation around prehistoric and historical farms of different sizes and ages in a marginal farming area. Thus the obtained ages of the heath formation is only representative for this particular area and cannot be generalised to the southwestern Norwegian heath section as such. The heath development delay in Nordhordland can be explained by access to alternative, mainly marine resources that may have been used in preference to intensive farming. Except for some local areas with rich Quaternary deposits, Nordhordland is considered to be less favourable to farming and may have been rather weakly exploited until a population growth in the Iron Age led to a more intensive pressure on the outfield areas.

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