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Lotte Selsing

Intentional fire management in the Holocene with emphasis on hunter-gatherers in the Mesolithic in South Norway

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The font page: Old pine forest. Westward view past the forest lake of Fagerlitjørna from Gygrestølen, Husefjell – Bjørnhuskkollen, Bø in Telemark, 29 September 2010. Photo: Tom Hellik Hofton.
The back page: Old pine tree in Trollheimen, Nordmøre/Sør-Trøndelag. Photo: Morten Gåsvand.

Abstract

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The geographical and altitudinal distribution of the data from 68 palynological sites has allowed the synthesis of a relationship between the microscopic charcoal curves and people over time. Most of the selected sites were of archaeological interest. Quantitative methods, qualitative methods and topics about the relation between fire, charcoal, nature and people in a forested landscape were used. Palynological sites are better suited to revealing fire management activities in the Mesolithic than archaeological sites because intentional burning of vegetation was carried out in areas related to lakes and mires.

Climate is ruled out as the cause of the charcoal occurrence because there are no correlations between inferred regional climatic changes and the charcoal. This suggests that an anthropogenic explanation for the charcoal occurrence is the most plausible.

There are many indications that hunter-gatherers in the Mesolithic used fire management and that fire was an important part of cultural practice associated with settlement, population density and resource needs. Fire management was a common and regular work task integrated with other activities. The traditional lifestyle of foragers may have included customary controlled burning practices as a part of manipulating the ecological succession and the modification of vegetation communities. Burning may have been central to hunting and gathering practices and the key to many social and cultural activities. The timing of burns may have been related to weather conditions, time of year and annual cultural events.

The different pattern of temporal changes in charcoal abundance suggests that no widespread burning (i.e. on a regional or landscape-scale) had taken place. The anthropogenic burning was different from natural fires. The fires set by people were smaller and less intense. Selected areas of vegetation were burnt on a recurrent basis. They were predictable, almost immediately productive, creating mosaics in a complex pattern of vegetation of burnt and unburnt patches. Because they reduced available fuel, they provided protection against the disruptions of natural fires. The occurrence of natural fires is irregular, often with long intervals in between; they are uncontrolled, unpredictable, destructive to the vegetation and potentially dangerous for people. In order for the recorded charcoal occurrences to be considered the result of natural fires, sites close to each other should have had similar charcoal occurrences, but this is not the case. An often low and continuous charcoal presence in a more or less dense forest in the Mesolithic indicates a continuous production of charcoal, which is better interpreted as people's use of fire than continuous natural fires.

The data confirm that anthropogenic fires were much more frequent than natural fires in the Mesolithic. Foragers did not simply adjust to their environment, but had an active, dynamic relationship with nature, using intentional burning both to modify and to maintain the environment.

Intentional burning of vegetation during the Mesolithic is suggested to have been enacted by foragers who controlled fire for many purposes and widened its application to preserve their basis of existence, for instance to improve the outcome of hunting and for communication.

Two periods with a high frequency of maximum values of charcoal in the pollen diagrams are recorded in the early (9800–6000 cal yr BP) and the late part of the Holocene (younger than 2400 cal yr BP), respectively, and not at the transition to the Neolithic. This shows that early farmers did not produce as much charcoal—measured in maxima—as the hunter-gatherers did before the transition to the Neolithic, and confirms foragers' intentional burning as part of Mesolithic land-use in South Norway.

The first occurrences and high frequency of maximum values of charcoal pre-date the transition to the Neolithic and thus it can be ruled out that they were correlated with agrarian cultures in South Norway. It is possible that the selective burning carried out by foragers in vegetation paved the way for pioneer farmers to convert land for agricultural purposes. In that sense, the neolithisation was not very revolutionary, as the knowledge of using fire to manipulate and open the forest had a long pre-agrarian history.

As the path of the charcoal curve following the transition to the Neolithic is often interpreted as the result of forest clearance by farmers, a fire-related woodland change interpretation for the Mesolithic might also be used. After the transition to the Neolithic, the density of the forest in many areas decreased and allowed more charcoal deposition. The density of the forest affected the charcoal curve resulting in low values before the transition to the Neolithic compared to the values after the transition. This is a strong indication that the charcoal curve during the Mesolithic mainly originated as an effect of human activities. That the density of the forest in the Mesolithic changed more than the traditionally accepted view is probably the result of intentional fire management.

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Key words: Mesolithic, hunter-gatherer, intentional burning, fire management, South Norway, palynological analysis, microscopic charcoal, ethnographical analogy

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1 Introduction

This paper is based on the hypothesis that hunter-gatherers in the Mesolithic had a culture of environmental management, which included the strategic, intentional and controlled use of fire to improve their lifestyle. The aim of the paper is to document and disclose the strategies and methods of hunter-gatherers with regard to the intentional use of fire, and describe how fire management may have been an important and integrated part of their culture in the Mesolithic in South Norway.

Fire is a natural phenomenon that constitutes one of the major disturbance agents shaping vegetation (Chandler *et al.* 1983:293, Bond & Keeley 2005, Bond *et al.* 2005, Montoya & Rull 2011). Natural fires occurred before the arrival of people and forests experienced lightning fires (Rowe & Scotter 1973:447). The reduction of trees by fire has resulted in the development of some of the most biodiverse ecosystems in the world (Bond *et al.* 2005). Non-catastrophic fires are considered a normal process in the history of a forest rather than a special event (Uggla 1958:4, Frissell 1973:397, Wright & Heinselman 1973:321–322).

People needed fire in many contexts, such as cooking, heating, lighting, signalling, combating insects, preparing raw materials, clearing settlement areas and burning vegetation to provide browse for animals and to enhance food production (Rick *et al.* 2012:353).

The commonest form of pre-agricultural land management was burning and anthropogenic fire influences whole ecosystems, not only individual species (Mellars 1976, Pyne 1993:250). Flammable ecosystems, such as boreal forests, are characterised by their vastness and few species, where *Pinus* and *Picea* are the main types of trees (Steven & Carlisle 1959, Chandler *et al.* 1983:274, Bond & Keeley 2005:389). Many forms of hunting and gathering in the northern boreal areas relied on management of the landscape through selective forest burning (Simmons & Innes 1987, 1996:190). Generally, fire produces a forest with increased productivity and species diversity in the early phases of ecosystem development, resulting in an increase in the total biomass and net productivity of the animal populations. Generally, fire improves conditions for seedlings; it recycles nutrients, modifies the conditions that influence animals, and shapes the mosaic of age classes in the vegetation. Recently burnt areas are covered by lush vegetation, primarily herbs, because fire reduces the need for plants to compete for moisture (Ahlgren 1960, Loope & Gruell 1973:439). Animals rely on a certain number of different habitats for different purposes and they move from resource-poor towards resource-rich environments as a self-reinforcing mechanism of herbivores (Gautestad & Mysterud 2013). The mixture of successional phases and plant societies decides the pattern of herbivore animal behaviour and the regulation of their numbers. Recently burnt areas also increase the number of suitable hiding places for many of the animals that are basic food resources for carnivores and for people (Heinselman 1973:378, Lewis 1982:339) and for people.

To move through dense forest, hunter-gatherers need a network of paths as markers in the landscape, which could also enable them to concentrate activities outside the settlement site. Fire may increase the mobility of people and animals, allowing for the utilisation of considerably larger areas for collecting resources compared to a dense forest without paths. Fire may have been an important tool for maintaining the paths in the forest, facilitating communication and improving visibility during the hunt. Fire makes it easier to gather roots and tubers and fire management may also have contributed to maintaining and increasing access to edible berries, nuts and other plants that could be used as food (Simmons 1975, Göransson 1986, Smart & Hoffman 1988, Simmons & Innes 1996:191, Brody 2002a:193 [1981], Davies *et al.* 2005:284–285).

The distribution, mobility and movements of the animals are controlled, while also improving security in the hunt and reducing the energy and effort needed to gather food resources (Mellars 1976:36). Likely, there were openings in the forest in the Mesolithic and anthropogenic activity continuously formed and maintained the openings (Davies *et al.* 2005:280). Burning reduced the element of uncertainty and unpredictability in the hunt; fire may have resulted in a more intensive relationship between people and the selection of individual preys (Mellars 1976:36–37). With regard to Mesolithic forests in Scandinavia, the existence of clearings has been suggested by e.g. Göransson (1982, 1986), Groenman-van Waateringe (1983) and Welinder (1983b).

The practice of burning by foragers is a neglected topic in Scandinavian natural science. The influence of people on the ecosystems in Scandinavia during the Mesolithic has been recorded as less than that of wild vertebrates, except near the settlements where they could change the vegetation (B.E. Berglund 1969:12, B.E. Berglund *et al.* 1991:427). Woodburn (1980:110) stated that the ecological effects from the systematic, controlled and deliberate use of fire by hunter-gatherers, burning vegetation in order to drive game or to attract game by improving pastures, are sometimes far more substantial than the ecological effects of a farmer's clearance and cultivation.

There is a long tradition in Norwegian vegetation history of interpreting the charcoal curve in palynological analyses after the transition to the Neolithic as caused by agrarian people. They cleared the forest using the slash-and-burn method to open the vegetation for agricultural purposes (Moe *et al.* 1978, Kaland 1979, 1986, Prøsch-Danielsen 1990, Høeg 1996, Prøsch-Danielsen & Simonsen 2000a, 2000b, Høgestøl & Prøsch-Danielsen 2006). Prescribed burning also resulted in the development of the Norwegian coastal heaths (e.g. Kaland 1986, Prøsch-Danielsen & Simonsen 2000a, 2000b) and is used as a tool to manage heathlands (Måren 2009, Velle 2012:16).

The subject of the impact of pre-Neolithic hunter-gatherers in pollen diagrams of South Norway is often ignored. There are some records of anthropogenically pre-agrarian fire disturbances in Finland and Scandinavia, which have been proposed to have improved hunting (M. Tolonen 1978, 1983, 1985a, Vuorela 1981, K.-D. Vorren 1986, 2005, Høeg 1990:133, 1996:83, 127, Hicks 1991, 1993, Solem 2003:26–27, Hörnberg *et al.* 2005, Prøsch-Danielsen & Selsing 2009:85–86). Welinder (1979, 1983a, 1983b:38–42, 1989) ascribed traces of intentional forest clearance before the neolithisation of Norway, Sweden and Finland to improve the pastures for ungulates and thus to improve the possibilities for successful hunting (see also Selsing 2010:297–298). Even if the palaeoecological records provide evidence that can be interpreted as the effects of the utilisation of the environment by hunter-gatherers (see Edwards 1988:257), an obvious reason for not commenting the Mesolithic charcoal occurrence may be that it is often not or only weakly correlated with other changes in the pollen diagrams that could be related to people.

2 Methods

Quantitative and qualitative methods are used, in addition to methods for correlating fire in a forested landscape.

2.1 Quantitative methods

Palynological and charcoal analysis

Preparation of the samples followed the acetolysis method (Fægri & Iversen 1975). Samples rich in inorganic material were treated with hydrofluoric acid. The percentage of aquatic pollen, spores, algae and charcoal are based on ∑P+x where x is the palynomorph in question. Charcoal analysis was carried out during the pollen analysis and counted on the pollen slides in the same size range as pollen. This is the norm because of the comparability (Rhodes 1998). In some investigations, absolute pollen was estimated by using the procedure of Stockmarr (1972) and is presented in influx diagrams.

The taxa names are presented in Latin in the text (for English names see Table 1) using Lid & Lid (2005).

Charcoal analysis of deposits would seem to offer perhaps the most comprehensive means of reconstructing fire events (Patterson *et al.* 1987:20). The causes, frequency and effects of fires in the Holocene are often determined based on analyses of microscopic charcoal in palynological investigations (e.g. Swain 1973, Wein & MacLean 1983, M. Tolonen 1985a, We-linder 1989, Edwards 1990). Even though the review of Patterson *et al.* (1987) indicated that the taphonomic processes affecting charcoal are less well-understood than for pollen, charcoal counts have been performed along with other palynomorphs and properties such that the relative changes in abundance can be assessed (M. Tolonen 1985a). The main difference compared to pollen counts is breakage of charcoal, which will increase the number of particles (Patterson *et al.* 1987:10, see also K. Tolonen 1986 and Théry-Parisot *et al.* 2010) and presupposes that the samples are prepared with care to avoid this problem.

Radiocarbon dating

Radiocarbon dates are calibrated using OxCal v3.9 (Ramsey 2003), based on atmospheric data from Stuiver *et al.* (1998). The manuscript work has run for a couple of years, and meanwhile the calibration program has shifted to OxCal v4.2, which is now the current version. A test with 95.4% probability was carried out to evaluate the age difference between the two versions (Ramsey 2013, 2015) based on atmospheric data from Reimer *et al.* (2013). Ages between 9100 and 300 yr BP (19 pages of the manuscript) have been recalibrated with the new version showing a difference from -49 to +25 years (87% of the samples from -9 to +14 years). These small age differences confirm that using the new version of the program would not have consequences for the results in this paper. The ages given to a sample level are based on an interpolation of radiocarbon dated levels or, in a few cases, a rise in the tree pollen curves and, in these instances, there is a possibility that levels have been assigned to a too young or too old age. Each age are given in calibrated yr BP.

Geological chronology

The use of the formal stratigraphic units follows Mangerud *et al.* (1974).

Archaeological chronology

The archaeological chronology in yr BP, cal yr BP and cal yr BC/AD (Table 2) is based on Nærøy (1987, 1994:19, 2000:4), Selsing *et al.* (1991), Olsen (1992:123–127), Vandkilde *et al.* (1996), Bergsvik (2002:14–15) and Høgestøl & Prøsch-Danielsen (2006) (see also Bang-Andersen 1995:Table 1, 2008 and Ballin 2000:136–138, Fig. 4). The transition Mesolithic/Neolithic follows Indrelid (1976). Modified from Selsing (2010:Table 4). In the text years are presented as cal yr BP.

2.2 Qualitative methods

Ethnographical analogy

Ethnographic analogies of burning are an important basis for interpreting the palynological investigations.

The record of ethnographic studies in fire ecology adds important dimensions to the understanding of the relationship between the use of fire by hunter-gatherers and the vegetation history. Ethnographical analogy is used in the analyses of natural and cultural contexts (e.g. Jordan 2003) in South Norway in the Mesolithic period. Using a procedure of approach by generalising from a wide range of studies of contemporary hunter-gatherers, limited generalisations about people with similar modes of subsistence may be possible (Woodburn 1980:96). Ethnographic observations can provide insight into past behaviours and ethnoarchaeology is a useful approach to the study and extension of the archaeological record (Kramer 1979). Ethnoarchaeological research has often focused on hunter-gatherers i.a. because most of the time during which hominids have evolved they were foragers rather than food producers (Kramer 1979).

Table 1. The English taxa names are presented in Latin in the text.

Latin name	English name
Alnus sp.	alder
Alnus incana	grey alder
Betula pubescens or *B. pendula*	tree-birch
Betula nana	dwarf-birch
Calluna vulgaris	common heather
Cladium mariscus	fen sedge
Corylus avellana	hazel
Cyperaceae	sedges
Empetrum	crowbetrry
Equisetum fluviatile	water horsetail
Ericales	Rhododendron order incl. unid. Ericaceae and Empetraceae
Hippophaë	common sea buckthorn
Juniperus communis	juniper
Lycopodium annotinum	stiff club moss
Melampyrum sp.	cow-wheat
Onagraceae (cf. *Chamerion angustifolium*)	evening primrose family (cf. fireweed)
Phragmites australis	common reed
Picea abies	Norway spruce
Pinus sylvestris	Scots pine
Plantago lanceolata	ribwort plantain
Plantago major	broadleaf plantain
Poaceae	grasses
Polypodiaceae	fern family
Populus tremula	aspen
Pteridium aquilinum	bracken fern
Quercus robur or *Q. petraea*	oak
Salix sp.	willow
Sphagnum mosses	peat mosses
Tilia cordata	lime
Ulmus glabra	elm
Urtica sp.	nettle
Vaccinium uliginosum	bog blueberry

Burning has affected the ecology of entire continents (Lewis & Ferguson 1988, Adam 1992, Bowman 1998, Jackson & Brown 1999). Where European colonists approached unknown coasts, they were met with columns of smoke (Bean & Lawton 1973:xix–xx, Mellars 1976:15–16, Lewis 1982:31) and hunter-gatherers' use of fire to improve benefits from nature can be traced back to the beginning of the European colonisation of other continents. Almost everywhere, indigenous hunter-gatherers deliberately have set fires to improve their supply of resources and drive game during the hunt (Stewart 1956:120). Ethnographically, traces of fire are widely interpreted as active burning by hunter-gatherers (Stewart 1955, 1956, 1963, Viereck 1973:469, Brody 2002b:148 [2000]). Conscious, controlled and delimited burning of vegetation by hunter-gatherers has been a near-universal practice with significant consequences (Mellars 1976), as indicated by many examples worldwide (e.g. Maloney 1980, Kershaw 1983, Inoue *et al.* 2012).

Based on ethnographical analogy, hunter-gatherers in the Mesolithic probably had substantial experience with the use of fire, as indicated by numerous records of fireplaces, pits, and macroscopic and microscopic charcoal remains common at archaeological and palynological sites in South Norway. Charcoal is the most frequent botanical remain found at archaeological sites, and palynological-related microscopic charcoal may be the only indication of the presence of people in an area (Solem 1991, Bennett *et al.* 1992, Gelabert *et al.* 2011).

The terms culturing the landscape and domesticating the landscape are used about people's influence on nature. As these terms can be misunderstood as Neolithic cultivation, the term fire management is used as a neutral term in this paper for the relationship hunter-gatherers had to the landscape and is intended to formulate the extent of the relationship between people and nature.

Table 2. The archaeological chronology is based on Nærøy (1987, 1994:19, 2000:4), Selsing et al. (1991), Olsen (1992:123–127), Vandkilde et al. (1996), Bergsvik (2002:14–15) and Høgestøl & Prøsch-Danielsen (2006), see also Bang-Andersen (1995:Table 1, 2008 and Ballin 2000:136–138 and Fig. 4). The transition Mesolithic/Neolithic follows Indrelid (1976). The chronology is presented in yr BP, cal yr BP and BC/AD. Modified from Selsing (2010:Table 4).

Period/subperiod	Age yr BP	Age cal yr BP	Age yr BC/AD
Newer times	Younger than 370	Younger than 435	Younger than 1535
Middle Ages			
Late	610–370	600–435	1350–1535
Middle	840–610	750–600	1200–1350
Early	970–840	920–750	1000–1200
Late Iron Age			
Viking period	1200–970	1100–920	800–1000
Merovingian period	1500–1200	1400–1100	600–800
Early Iron Age			
Migration period	1700–1500	1600–1400	400–600
Roman period	2000–1700	1900–1600	1–400
Preroman Iron period	2400–2000	2500–1900	600 BC–AD 1
Late Bronze Age			
Period VI	2500–2400	2600–2500	700–600
Period V	2800–2500	2900–2600	900–700
Period IV	2900–2800	3000–2900	1100–900
Early Bronze Age			
Period III	3000–2900	3200–3000	1300–1100
Period II	3200–3000	3500–3200	1500–1300
Period I	3500–3200	3700–3500	1800–1500
Neolithic			
Late Neolithic II	3600–3500	3900–3700	2000–1800
Late Neolithic I	3900–3600	4400–3900	2400–2000
Middle Neolithic II	4200–3900	4700–4400	2800–2400
Middle Neolithic I	4700–4200	5400–4700	3500–2800
Early Neolithic	5200–4700	6000–5400	4000–3500
Mesolithic			
Late Mesolithic	7500–5200	8400–6000	6400–4000
Middle Mesolithic	9000–7500	10,200–8400	8300–6400
Early Mesolithic	10,000–9000	11,400–10,200	9500–8300

2.3 Topics about the relation between fire, charcoal, nature and people in a forested landscape

Before discussing the occurrences of charcoal in the 68 pollen sites in a chronological context, different aspects of fire, charcoal, nature and people in a forested landscape are presented.

2.3.1 Forests without fires

A prolonged lack of forest burning results in a considerable loss of diversity, productivity and niches for game animals, and thus the stock is reduced (Rowe & Scotter 1973:461, Flannigan *et al.* 2009:554). Without fire, the organic refuse from the vegetation will accumulate and will function as fuel if fire develops (Rowe & Scotter 1973:450–452).

A "climax" forest is a forest community that represents the final stage (climax community) of natural forest succession (Sprugel 1991:2). When a forest is protected against fire, it results in impoverishment and the assumed preservation of natural forest conditions is not achieved (Wright & Heinselman 1973:325, Lewis 1977:26). Nearly all types of forest are dependent on disturbances and fire has a dominating role (Frissell 1973:397). The "good" or "right" vegetation is not old climax vegetation as indicated by the climax theory axiom, with interferences considered as unfortunate because they disturb a theoretical balance (Rowe & Scotter 1973:460).

Probably, few areas ever reached the postulated state of climax vegetation in the Holocene and fire has a role as an integrated part of many natural forest successions, including the development of Nordic coniferous forests (Heinselman 1973, Wright & Heinselman 1973:327). Attempts of fire exclusion have had profound and quite often undesirable effects upon the management of wilderness areas (Lewis 1977:26).

2.3.2 The benefit of fire in the forest

Forest fire is a significant natural element and a stand-renewing agent in the circumboreal forest (Flannigan *et al.* 2009:549). Much of the complexity in the present boreal forest relies on fire (Rowe & Scotter 1973:444). The partitioning between surface and crown fires in the circumboreal forest is largely a species effect (Wirth 2005:325).

During a wildfire, the organic material will contribute to the flames reaching the crown-layer and result in an uncontrolled fire. This can damage the vegetation in a large area so that the positive effects of fire are reduced or counteracted. The succession pattern following such a fire in a coniferous forest is markedly different from that which follows lower intensity fires (Lewis 1973:33). A high intensity, uncontrolled crown-fire may kill many trees and can delay or reduce the possibility of a successful regeneration because the seeds necessary for a successful regeneration are spoiled. Seeds spread from other areas, resulting in new vegetation can take at least 10–15 years (Frissell 1973:404, Lewis 1973:33–39, cf. Figs. p. 37 and 39 in Loope & Gruell 1973:431 and Schimmel & Granström 1993).

Uggla (1958:10) recorded that *Pinus* is Sweden's most fire-resistant tree, when the fire is not too violent. This was opposite to Rackham (1980:103–104), who stated that *Pinus* is the only tree that can easily be burnt while it is still standing. *Pinus* forest in particular has a tendency to burn where living understorey is scarce because, below the open crowns, the ground dries quickly and a developing fire meets little resistance (Rowe & Scotter 1973:451). The litter of the needles increases the probability of fire because of high flammability. The crown-layer and structure is ideal for ignition and development of fire in the crown may proceed down to the forest floor (Ahlgren 1974:200, Chandler *et al.* 1983:274–275). This may have influenced the *Pinus* dominated boreal forest in South Norway during the Mesolithic.

In coniferous forests with only small amounts of deciduous trees, fire spreads more easily than in deciduous woodlands (Heinselman & Wright 1973, Rowe & Scotter 1973:460, Talon *et al.* 2005). Even if forest fires occur today in regions of deciduous forest (Clark & Robinson 1993:200), Rackham (1980) is often referred to in order to exclude natural fire in deciduous trees and it is impossible to ascertain the pattern of natural fires unaffected by human intervention (Rackham 2008:575). Rackham (1980:103) stated, "The woodlands in England are more difficult to burn than almost any of the world's forests". The native forests are almost fireproof even in exceptional droughts with the exception of the Boreal, with its drier climate; the forest sometimes became combustible during droughts (Rackham 1980:103–104). Based on forest ecology, forest fire ecology and through the application of ethnographic studies, Moore (1996) analysed the statement made by Rackham (1993:72 [1986]): "British woodlands (except *Pinus*) burn like wet asbestos". Moore (1996:62–63, see also discussion in Tipping 1996:52) pointed out that these assertions have become an obstacle in evaluating the potential for human use of fire in the forest. Moore (1996:63, 65) also pointed to the issue of fire being both a part of the natural forest ecology, and a tool for human management of forest resources. For Norway, Botnen (2013:11) reported that deciduous trees burn more poorly than conifers; in the event of a fire in a deciduous forest, generally only the undergrowth will burn. As no references were used, the base of this statement is uncertain. To the best of my knowledge, it is not documented that deciduous trees burn poorly.

Wirth (2005) classified major forest-forming tree species of the circumboreal zone according to the features relevant for fire adaption, including the two most common trees in the Mesolithic in South Norway. *Betula pubescens* and *Pinus sylvestris* were defined as invaders/endurers and resisters, respectively. Invaders are killed by even light burns but have specialised in re-colonising burnt areas from outside. Endurers survive and resprout from below ground, while resisters are able to survive surface fires of low to medium intensity (Wirth 2005:313).

The prevalence of either surface or crown fires should generate distinct patterns in the structure of boreal forest ecosystems. Surface fires consume only part of the forest floor fuels and hardly any canopy fuels (Wirth 2005:327). The distribution of microscopic charcoal produced by a surface fire in a dense forest will be small. In surface fires, sub-canopy regeneration is suppressed and trees that lack sufficient thermal protection due to their thin bark are selectively killed.

Most importantly, recurring surface fires keep the load of surface fuels low, reducing the risk of crown fires (Wirth 2005:328) which may have been known by hunter-gatherers. Their selective burning promoted the mosaic quality of ecosystems, creating forests in many different states of ecological successions (Cronon 2003:51 [1983], Bowman *et al.* 2004 for Australian Aborigines). It is likely that hunter-gatherers in the Mesolithic observed the connection between the burning of vegetation and the improvement of the outcome and therefore would use fire strategically (Simmons *et al.* 1981:103).

Only little light reaches the field layer in a dense forest, which is sparse of fodder to offer to herbivorous animals. Openings in the crown cover allow light to the forest floor and result in the growth of herbs and foliage on low hanging branches on the trees. This situation may develop naturally by windfall and breakage in old and dead trees because of wind, snow and/or ice. People can also contribute to opening the forest by cutting down the vegetation at places that are strategically located in relation to the settlement and the biotopes of animals, or the settlement can be situated at a favourable location compared to the habitats and movements of the animals (Binford 1980, see also Grøn 2012:180–181).

Preston (2009:675) stated (based on Wirth 2005, Balshi *et al.* 2007 and Ohlson *et al.* 2009) that the fire regime in boreal North America is dominated by high-intensity crown fires, which destroy the majority of trees. Landscape burning in boreal Eurasia generally has a patchy, low-intensity nature, with fires that mainly run along the surface of the forest ground and do not destroy the majority of the full-sized trees. They cover small areas relative to other regions in the boreal zone and are generally less damaging (Ohlson *et al.* 2009, 2011:401). Non-pyrogenic boreal forest stands seem to have been more common in Fennoscandia than in North America and Russia (Ohlson *et al.* 2009).

Burning was the commonest form of pre-agricultural land management (Mellars 1976). Mellars & Reinhardt (1978:260) summed up research in England on early Holocene settlements, which probably is also transferrable to other areas in Northern Europe. They concluded that natural vegetation was greatly affected by the activities of the Mesolithic societies and that modification could largely be attributed to the systematic, careful and controlled use of fire in many kinds of forest.

2.3.3 Frequency of natural fires

The interval between two natural fires can vary greatly, with a range of 25–500 years in boreal forests (Chandler *et al.* 1983:159–160, 162–166, Table 6.1, see also Zackrisson 1977, Niklasson & Granström 2000). Estimates based on palaeoecological studies in boreal peatlands in Canada and Fennoscandia are significantly longer (200–1500 years) (K. Tolonen 1986:Table 23.1, Kuhry 1994:905–906, Ohlson *et al.* 2006, Carcaillet *et al.* 2007, Camill *et al.* 2009:6, Magnan *et al.* 2012). The macroscopic charcoal record in boreal-forested peatlands in Southeast Norway for the last 10,200 calendar years is highly individualistic and unpredictable (Ohlson *et al.* 2006:736–738 and Table 5). Fire has played a subordinate role in this area, considerable areas remained unburnt after each fire event and fire frequency is among the longest recorded for boreal forests. Most likely, this pattern is brought about by the prevalence of low-intensity fires. Each fire event only affects a small part of the peatland area because of the spatial variability of surface peat topography, variation in hydrology and moisture levels, including the distribution of woody plants (Ohlson *et al.* 2006:737, 740).

Granström (1993:Fig. 1.a.) studied the density of lightning ignitions in Sweden in the period 1953–1975. The very low values (0.03–0.24 per 10,000 hectares per year) are probably representative for Norway as well. In the Swedish boreal forest, new fires are unlikely for the first 20 years after a fire because of the scarcity of fuel, increasing in the following decades. It takes approximately 50 years for surface fuel to recover to a level of balance between fuel on the ground and the fire potential (Schimmel 1993, Schimmel & Granström 1993, 1997). Ignition by humans dominated over lightning ignition by a factor of 19 in the period AD 1600–1800 (Hellberg *et al.* 2004:337).

By comparison, agrarians established the Norwegian coastal heaths since the Neolithic by using fire to clear the forest and establish pastures for animal husbandry and cropland. The fire management has been managed and maintained until recently with burning intervals of 2–20 years (Gimingham 1972:202–203, Bakkevig 1981:115, Kaland 1999:121–125, Ely-Aastrup & Sand 2012:9). If it is not managed, the forest will immigrate again (e.g. Kaland 1986, 1999, Velle 2012:Fig. 3).

Most of the investigations cited above did not inform of the reason for the recorded fires and did not consider anthropogenic fire activity. Natural fires can ignite vegetation everywhere and the sizes of the fires vary from the smallest ones put out immediately to megafires nearly impossible to stop. On the other hand, anthropogenic fires are, by intention, limited. If not, the control is lost, which is proposed to have been rare. Fires ignited by lightning strokes inform about natural factors, such as vegetation and moisture, in contrast to fires ignited by people, which inform about cultural choices in nature. The maintenance and management of a cyclical fire system in South Norway may have been dependent on the composition of the forest and the specific purpose of the burning. With this in mind, hunter-gatherers during the Mesolithic in South Norway could have used fire management to produce a partial opening of the forest and achieve the benefits with regard to vegetation as described above (e.g. Mellars 1976).

2.3.4 Natural and anthropogenic fires in the Mesolithic revealed by palynological investigations

It is difficult to achieve concrete results from palynological investigations regarding the use of fire management in pre-agrarian cultures. It is also difficult, if not impossible, to detect traces left by the intentional fires set by hunter-gatherers in the archaeological material. The burning of vegetation might have been practiced to a greater extent than is possible to predict from palynological data (Mellars 1976:34). Edwards (1996, 2001), considered that fire was the most important aspect of Mesolithic impact on vegetation, in some cases being inferred as the only evidence for the presence of hunter-gatherers. The zone between the forest-edge and the open water represented optimal pasturing conditions for ungulates (Bay-Petersen 1978:128) and therefore palynological sites may be qualified for detecting intentional burning.

B.E. Berglund (1966:127) suggested that if charcoal in pollen diagrams was recorded in an area with no traces of Mesolithic sites, natural fire is very often concluded to have been the reason for the fire. This argument is not convincing because hunter-gatherers are proposed to have left few, small, local and sporadic traces in the vegetation and their sites have not yet been discovered or did not leave any traces in the landscape (e.g. Bennett *et al.* 1992, Greisman & Guillard 2009:595). It depends on luck if they are to be traced through palynological analyses (Mellars 1976:34). This is confirmed in e.g. West Norway where archaeological excavations have revealed many new Mesolithic sites in recent decades (e.g. Gjerland 1990, Bjørgo *et al.* 1992, Olsen 1992, Nærøy 1994, Ballin & Jensen 1995, Høgestøl 1995, Juhl 2001, Bergsvik 2002, Skjelstad 2011). If the charcoal in pollen diagrams of the early Holocene does not derive from natural or anthropogenic forest fires, it can perhaps originate from domestic fires burning over long periods at the settlement site (Edwards & Ralston 1984, Bennett *et al.* 1990b:639, Edwards 1990). Moore (1996:64) questioned how it is possible to differentiate between deposition from these domestic fires and small-scale fire clearances of marginal forest scrub, which implies that the last proposal is as reliable as the first one. If the charcoal record reflects the burning of woodland by people, then the record could be different at different sites, depending on local population densities and land use (Bennett *et al.* 1990b:639).

A fire caused by lightning is a short event, at most some days or weeks. The charcoal from a natural fire is produced in a very short period compared to the temporal dissolution in palynological analysis. This means that a natural fire may be difficult to disclose by the charcoal curves, depending on the size of the fire and the amount of charcoal produced. In reality, it is even more complicated because pollen samples are not often collected continuously, but rather there is a sampling interval (e.g. every five cm). This is often not taken into consideration in the interpretation of the material. Small natural fires with little production of charcoal should be impossible to disclose if they were not close to the site where the pollen samples were collected.

Large wildfires with a big production of charcoal should be possible to disclose, depending on their distance from the pollen site. In the last few decades, increases in wildfires in Eurasian boreal forests are primarily attributable to humans (Mollicone *et al.* 2006:437). There is a close relationship globally between forest wildfires and human activities, which may result in high-severity megafires (Meyn *et al.* 2007, Hanson *et al.* 2013, Ryan & Opperman 2013, San-Miguel-Ayanz *et al.* 2013, Chas-Amil *et al.* 2015, see also Pyne 1993:258). Based on quantitative evidence, global area burnt appears to have declined overall over the past decades (Doerr & Santín 2016).

Usually, the results of palynological analyses are presented as curves, where a sample makes up a point in the curve, even if it represents one centimetre. Using 1 mm samples (Simmons & Innes 1996:185–187) allows for a greater degree of resolution in the interpretation. The results indicated disturbance-recovery phases and charcoal coinciding with high levels of disturbance indicators, of which *Melampyrum* is perhaps the best single indicator. This was not carried out in any of the 68 investigations.

There are two types of maxima in the 68 charcoal curves, a single spectrum peak and a maximum of more than a single spectrum peak. A single spectrum peak of charcoal is often referred to as potentially representing a severe fire (Moore 1996:65) caused by natural forest fire. A single spectrum peak of charcoal may also have been caused by people's fire management of the vegetation, which came out of control or was close to the sampling site; as stated by Blackford (2000:41), high charcoal concentrations are indicative of fires at the sampling point. The charcoal curve resulting from natural fires should theoretically be characterised by a single spectrum peak. A maximum spanning more than a single spectrum peak of charcoal is most probably the result of a regular anthropogenic intentional fire regime in the surroundings, meaning that natural fire as the main agent for charcoal may be ruled out because the maxima cover many years. People may have caused the occurrence of partly high levels of charcoal even if the population during the Mesolithic was small.

Generally, the origin of the charcoal may primarily have been from people's intentional use of fire in vegetation and, to a lesser degree, natural fires (Edwards 1990, see also Bishop *et al.* 2015:70). Through anthropogenic fires, people may alter the availability of fuel such that natural fires become much less frequent and increased human ignitions may decrease the area burnt by lightning fires (Kauffman *et al.* 1993:376).

In summary, a continuous charcoal curve with low values may not have been the result of natural fires, especially not in a dense forest. The course of most of the charcoal curves in the 68 pollen diagrams indicates that they primarily originated from human-induced fires because the curves reflect more or less continuous fires. In contrast, natural fires without human intervention are characterised by long fire intervals (Nik-lasson & Nilsson 2005). In Norway today, people cause nearly all fires (Botnen 2013:10).

2.3.5 Charcoal production and dispersal

The discussion above gives several indications that the charcoal curves originated primarily from human activities—but how was the charcoal produced and dispersed?

The sites in this study are grouped as lakes (19), infilled basins (20) and mires (29). As the infilled basins are overgrown lakes, they first functioned as lakes and thereafter they were transformed into mires. The lake sites are surrounded by vegetation, while vegetation grows on and surrounds the mires.

Generally, charcoal is a result of fire in wood and woody vegetation. The type of fire and the way in which charcoal is transferred from production to deposition is of importance in the evaluation of the charcoal data.

It is difficult to make general interpretations concerning local, on-site fire managements (Hörnberg *et al.* 2011). Low values of charcoal in pollen slides do not necessarily indicate the lack of fire indicated by a striking discrepancy between the occurrence of macroscopic and microscopic charcoal (Solem 1991, Eide *et al.* 2006, Ohlson *et al.* 2006, 2013, Olsson *et al.* 2010, Hörnberg *et al.* 2011). The different implications are recorded in the processes of production, dispersal, deposition and post-deposition. The macroscopic charcoal used by Ohlson *et al.* (2009, 2011) in their studies behaves differently from the microscopic charcoal that is used in the present study. A co-occurrence of macroscopic charred particles and changes in the pollen record suggests local on-site fires, even if it is difficult to formulate general rules regarding the correlation between charred particles and their origin (Hörnberg *et al.* 2011:208–210).

Models of charcoal transport and deposition show that fires release more heat as they increase in size, as with intense crown fires (Chandler *et al.* 1983, Clark 1988a, 1988b, Odgaard 1994:127–128). A critical phase may be reached in terms of heat output, above which a movement of air masses injects fire plumes into higher layers of the convective boundary layer, or even into the free troposphere. During this process, microscopic charcoal can be transported to heights of several kilometres and may travel over long distances (Wirth 2005:335). In contrast, plumes generated by surface fires remain close to the surface and smoke contents may be recycled in the vicinity of the source (Wirth 2005:335).

Mires form a potential firebreak (Granström 1993: 742). Open peatlands are naturally resistant to fire because the ground is moist year round. They often remain unaffected by fire, especially when local water tables are high and trees are sparse but, under drought conditions, fires can also affect these peatland ecosystems (Kuhry 1994:909, Zoltai *et al.* 1998:15). Fires sometimes burn on the mire surface itself, which may be the effect of a long period of drought, when moss dries out and forms a continuous fuel bed that can carry a fire (Hellberg *et al.* 2004:336). These fires may be local, depending on the fuel load. Fire also affects boreal peatland ecosystems (Kuhry 1994:899, Flannigan *et al.* 2009:552–553), where other types of fuel than woody plants may burn, resulting in a lack of charcoal in spite of the presence of fire since wooded fuel is a prerequisite for charcoal production (Ohlson *et al.* 2006:739). In other words, if no woody plants are burnt, the fire will not add to the charcoal curve. Dry biomass of standing dead litter of graminoid-dominated peatlands may be completely consumed by fire, leaving no burnt charcoal residue (Zoltai *et al.* 1998:16). With favourable fuel continuity and weather conditions, patchy surface fires can sweep across almost any wetland, consuming aboveground biomass (Zoltai *et al.* 1998:16). Small amounts of fuel, fuel that produces no charcoal and low fire intensity most likely explain the lack of charcoal occurrence, which sometimes results in changing and discontinuous charcoal curves from mires and the margins of lakes. The frequency and severity of fires across wetlands are virtually unknown, despite the likelihood that wetter fen communities may burn less frequently and severely than drier sites (Camill *et al.* 2009:2). Increased nutrient availability due to the distribution of ash etc. following burning may enhance plant productivity in peatlands (Zoltai *et al.* 1998:21); in boreal peatlands dominated by moss, the nutrients that are released are quickly leached out (Kuhry 1994:909).

Local peatland fires burn the peat surface or, if there are trees, may affect the tree canopy only (K. Tolonen 1983, Kuhry 1994:902–903). The roots of many ericaceous shrubs, *Salix*, and *Betula* survive and resprout vigorously soon after a fire (Zoltai *et al.* 1998:18).

Charred peat identifying a peatland fire event has been recorded from North Norway and is associated with a strong anthropogenic signal and the occurrence of Onagraceae in the period 8500–3100 cal yr BP (Jensen 2004:275). Charred peat in combination with microscopic charcoal is also recorded from the present study (sites 42–43, Kalvheiane a and 2). Since this kind of vegetation does not burn easily, it may indicate that people strategically burnt the mire regularly and recurrently to improve pastures and attract herbivores close to a dwelling area since the Early Mesolithic (Solem 2000, see also Lewis 1973, 1982 and Simmons *et al.* 1981). The mires in South Norway are generally characterised by a sparse field layer above a *Sphagnum* mat. The fuel loads in the field layer are often low and discontinuous. Hather (1998:195–196) reported charred plant remains from the Mesolithic site of Star Carr in England. They were interpreted as regular *in situ* burning, largely from *Phragmites* reed beds fringing the lakeshore with overhanging trees.

The relationship between charcoal production from fires and charcoal deposition in lakes is poorly understood (M. Tolonen 1985a:16, Lynch *et al.* 2004). Lakes are fed by a supply of palynomorphs through input streams, and the local deposition of microscopic particles is supplemented with pollen and charcoal transported by the wind, while in mires the deposition is primarily by wind and reworking processes are absent or rare (e.g. Fægri & Iversen 1975:50–71, Clark & Patterson 1997). In lakes, reworking of the sediment often occurs with redistribution of the palynomorphs from shallow to deeper water (Davis *et al.* 1984:288–289, M. Tolonen 1985a:16). The pollen assemblage is increasingly influenced by extra local and regional components, with increasing basin size and mainly regional sources of charcoal (Jacobson & Bradshaw 1981, Clark 1988a). The differences between influx measures for total pollen and charcoal in a small lake in Scotland indicate that probably the charcoal floats or is suspended in a manner different from that of pollen (Edwards & Whittington 2000:83–84). Thus, mires reflect local fire events, both natural and anthropogenic, better than lakes.

In a dense forest, intentional fire will not necessarily affect the pollen flora because the density of the forests most places in South Norway in the Mesolithic was relative high, with limited local openings. This yielded poor conditions for the dispersal of pollen from the bottom floor vegetation. The extent of intentional burning may often be so small that it will not necessarily change the composition of trees. Even if the vegetation changed to a limited extent in space and time, it may often be difficult to detect through ordinary palynological investigations (e.g. Edwards 2004:61). Fire management in the Mesolithic will not necessarily result in changes in the composition of the pollen deposition because it usually would have taken place in the form of small, local interferences, as a limited and regular part of a cultural strategy.

Fires from domestic hearths in human settlements in East England may have been burning more or less continuously during the early Holocene (Bennett *et al.* 1990b:639–640). They were compared with forest fire by using the calculations of Clark (1988a). The domestic hearths would have sent a plume to an altitude of only about 18 metres and most macroscopic charcoal particles tend to be deposited rather close to the source; about 90% of the charcoal particles were already deposited within 50 m from the fire (Welinder 1989, Solem 1991). The distance between settlement and palynological sites is usually more than 50 m, which complicates the possibility of tracing people and their use of fire. Bennett *et al.* (1990b) concluded that the charcoal from domestic fires would be deposited locally, within 200 m from the fireplace, whereas the charcoal from forest fires may be dispersed to distances of many kilometres (Clark 1988a). The key point of this argument is that small fires differ from large ones in the nature of charcoal dispersal, not just the amount of it. Charcoal from small fires will be deposited locally, and give records that differ from site to site, depending on occupation frequency and intensity, and charcoal from large fires will be widespread, giving more homogeneous records that are similar from site to site (Bennett *et al.* 1990b:640, see also Caseldine & Maguire 1986, Caseldine & Hatton 1993, 1994, Caseldine 1999).

The marked variations in the charcoal records indicate a profound variability in the fire regime across forest sites. The study of Tryterud (2003) indicated that South Norway experienced a variety of fire regimes. Fire disturbance is not a ubiquitous phenomenon in boreal European forests, in contrast to the common view that wildfire is a generally important and a frequent disturbance agent (Ohlson *et al.* 2011:400). Forest fires have never been a ubiquitous ecological phenomenon in the Scandinavian boreal forest with large variation in the natural conditions (Zackrisson 1977, Tryterud 2003).

In the present paper, an attempt has been made to eliminate uncertainties by using many sites in a large area with differentiated geography. This was also the implication of Tryterud (2003:166), who suggested that the use of one single sampling point might result in underestimation of fire events. The use of microscopic charcoal is in most cases a more robust indicator of local fire occurrence than the use of macroscopic charcoal. Identification of the species-origin of microscopic charcoal might add to the understanding of distribution of charcoal and fire regimes. To the best of my knowledge, no attempt has been made to identify species in microscopic charcoal.

This review indicates that the charcoal records in this study are mainly a result of people's use of fire in the vegetation, but also at the settlement sites, in an effort to facilitate a variety of favourable outcomes, and to a lesser extent, the result of natural fires.

2.3.6 Fire, climate and human impact

In general, many sites in Europe indicate greater-than-present or near-present fire activity during the Holocene until recently (Power *et al.* 2008). Based on a view of changes in global fire regimes, these complex patterns can largely be explained in terms of large-scale climate controls modified by local changes in vegetation and fuel load (Power *et al.* 2008:887). On the other hand, no significant interactions of climate on fire regimes could be detected in the circumboreal forest based on the analysis of Wirth (2005:320).

Vegetation change combined with climate change could produce ecological changes of much greater magnitude than would be expected from climate change alone (Ohlson *et al.* 2011:396). The aim of Olsson *et al.* (2010) was to separate climate from human-induced fire activity during the last 10,600 calendar years, by comparing macroscopic and microscopic charcoal in a mire and lake sediment deposit in southern Sweden. Most fire episodes were probably of regional character with three major phases, 10,600–10,300 cal yr BP, 9200–6000 cal yr BP and 2700 cal yr BP to the 19th century. Olsson *et al.* (2010:139) concluded that fire was an important disturbance factor in the past, controlled by climate during the early and middle Holocene, because the warmer and drier climate caused frequent and intensive natural fires, and primarily by the activities of people in the last part of the Holocene. This was also the result of Greisman & Gaillard (2009), who based their study mainly on microscopic and macroscopic fragments of charcoal. They concluded that high fire activity was related to a dry and warm climate and low fire activity to wetter and cooler conditions. On the other hand, Kasin *et al.* (2013:1063) reported from boreal forest sites in Southeast Norway that macroscopic charcoal accumulation rates per 1000 years were higher during cold than warm climatic periods. Nor is the lack of a general expansion in the charcoal curves across several sites in a Scottish lake for the first half of the Holocene suggested to be related to dry climate (Edwards & Whittington 2000:81). This suggests that high fire activity (and possibly more frequent fires) is not necessarily coupled with the deposition of large amounts of charcoal or possibly that cold climatic periods improve charcoal preservation in peat. Even if some of these authors recorded the known archaeological remains in the area of investigation, they did not take into consideration that foragers could have used a fire management technique as indicated by ethnographic analogies and which is not disclosed by archaeological remains.

Both directly and indirectly, climate is probably the single most important factor governing the occurrence of natural fire (Moore 1996:64). Temperature is the most important predictor of the area affected by a fire in Canada and Alaska, i.e. higher temperatures will increase the area burnt (Flannigan *et al.* 2005). Lucas

& Lacourse (2013) recorded, for example, a higher frequency of fires during the Medieval Warm Anomaly with warm, dry conditions compared to the Little Ice Age. Climate is related to forest fires by determining the length and severity of fire seasons and it determines the amount of forest fuel in an area; a drier climate may also result in increased fire frequency and intensity, even in peatlands (Zoltai *et al.* 1998, Talon *et al.* 2005). These authors and many others reporting about climate related to fire and fire frequency in the past (e.g. Filion 1984, Kuhry 1994, Briles *et al.* 2005, Bond-Lamberty *et al.* 2007, Bellen *et al.* 2012, Mustaphi & Pisaric 2013) did not include indigenous people's use of intentional fire. They looked for the reasons in nature, mostly the climate, in areas where hunter-gatherers had lived since the last deglaciation.

The main problem when using the literature about natural versus anthropogenic fires is that it is very often based on data from investigations that focus either on natural or on anthropogenic causes—not both. Another variant of this subject is Rius *et al.* (2012), who based the comparison of climate-driven and human-driven fire regimes on both pollen and macroscopic charcoal analysis as well as archaeological data but did not specify the cultural aspects of fire managements. Probably, the anthropogenic factor in foragers' fire regimes on vegetation was underestimated or unknown. It is often not possible to separate natural and anthropogenic fire factors based on the literature, and it is difficult or impossible to sort out hunter-gatherers' use of fire and its influence on the vegetation during the Mesolithic.

Many researchers underestimate indigenous people's influence on nature in prehistory and historical times (e.g. Smith 1970, Lewis 1973:85–86, 1982:3). The reason is probably that knowledge of ethnographical literature on the use of fire by hunter-gatherers has not been included (Lewis 1982) or is not known. The study of Holz & Veblen (2011) from Patagonia confirms that fires set by indigenous people prior to any likely influence by Euro-Chilean settlers were much more common (and sometimes even more widespread) than previously known. Presumably, most researchers find it difficult to envisage a small Mesolithic population affecting the forest, when the vast areas that would have been involved are taken into consideration (Smith 1970:83). The tendency of researchers to conceive people in the past as primitive may also still be an obstacle when interpreting natural historical data.

Some examples illustrate the argument used to compare climate and people's influence on nature and hunter-gatherers as the reason for fires during the Holocene. One example is from the Late Mesolithic in North East England with repeated fire events within a cycle of disturbance and regeneration (Innes *et al.* 2010:448). The authors concluded that the anthropogenic explanation for the charcoal events is probably the most plausible because the phase of burning does not correlate well with regional climatic wet and dry phases. Another example is from Edwards & Whittington (2000). Here the results of the detailed study of fire ecology and human impact as recorded in sediments in a small Scottish lake did not support the suggestion that fire incidence was related to warmer and drier climatic phases in the first half of the Holocene as proposed by Tipping (1996) for northernmost Scotland. Bishop *et al.* (2015:69) suggested an anthropogenic rather than a natural origin for many "disturbance phases" to explain the lack of clear correlation between fire frequency and dry periods in Scotland. A last example compares the relative timing of changes in charcoal, pollen and other proxies in Big Woods, Minnesota, USA, over the past 2000 years. The changes in the selected proxies differed from site to site, suggesting no one single response to climatic change (Umbanhowar 2004).

To sum up, the influence of hunter-gatherers on vegetation through fire is underestimated and should be considered when interpreting climate change studies of the past. Some examples indicate that fire regimes varied with climate and vegetation in ways that suggest indirect responses to climate change (Clark & Robinson 1993). Climate-induced fire regimes, especially in the early Holocene warm period, were probably more frequent than during the late Holocene, at least in Europe, but also in the western USA (Tipping 1996:53, Rius *et al.* 2011, Morris *et al.* 2013). Even if some authors recorded the known archaeological remains in the area of investigation, they did not take into consideration that foragers could have used a fire management technique in vegetation as indicated by ethnographic analogies and not disclosed by archaeological remains.

This review gives several indications that the charcoal curves primarily may have originated from human activities.

3 Plants favoured by fire

Any given fire regime will favour some species at the cost of others in relation to time since the fire (Duff *et al.* 2013). The plant species may be sorted into fire tolerant and intolerant taxa (Bond *et al.* 2005), and the relatively few species that establish themselves early at burnt sites can maintain a dominant position for several years (Ahlgren 1960). Some plants whose pollen can be identified in palynological analyses in South Norway are tied to the activities of hunter-gatherers (Vuorela 1981, Hicks 1993). Characteristics of anthropogenic forest fire are charcoal, dynamic changes in the composition of the forest, such as a rise in deciduous trees and light-demanding herbs, while *Melampyrum* sp., *Pteridium aquilinum* and Onagraceae, which are favoured by fire, may indicate local use of fire (Vuorela 1982:182, Hicks 1993:141, Simmons & Innes 1996). They are used as possible indicators of fire because they invade open areas that may follow fires or other open areas.

In the Norwegian flora, Onagraceae contain many species (Lid & Lid 2005:556–567). Its pollen is common in palynological analyses in Northern Europe and usually interpreted to be from *Chamerion* (formerly *Epilobium*) *angustifolium* (fireweed) (Godwin 1956:129, Fægri & Iversen 1975:245, 252, Vuorela 1983:65, Lid & Lid 2005:564). The flower is self-fertilised or insect pollinated, mostly by bees, and the pollen is heavy (Fægri 1970, 2:54, Husband & Sabara 2003:706) resulting in limited spreading. The plant is circumboreal and frequent in Norway up to 1780–1840 m asl in the middle alpine zone (Jørgensen 1933, Lid & Lid 1994:407, Klanderud 2000:103) and probably even higher during the early Holocene warm period. It has been gathered for food and used as a medicine plant (O.A. Høeg 1975:278–279, Røthe 2007:8, Urtekildens planteleksikon 2013). It may have been used in prehistory. The occurrence may have an anthropogenic origin because the taxa frequently occur in palynological samples collected in archaeological contexts (B.E. Berglund 1969, Vuorela 1972:4, 1985:123, Kvamme *et al.* 1992, Jensen 2004:275, 282, Selsing 2010:Chap. 4 and 5.6).

Chamerion angustifolium invades freshly burnt peatlands (Zoltai *et al.* 1998:18). It grows fast in full light and is adapted to fast invasion both vegetative and by seeds, at the same time as fire stimulates production of flowers and seeds (Hafsten 1956:119, Ahlgren 1960:439, O.A. Høeg 1975:278–280, Hicks 1991, Lid & Lid 1994:407). This species may both survive the fire and colonise the burnt area from outside (Uggla 1958:16). Within 3–6 years after a fire, the burnt areas may be dominated by among others *Chamerion angustifolium*, which may still bloom 25 years after a fire (Uggla 1958:14, Viereck 1973:473). Its presence in palynological analyses may be a result of a useful plant which occurrence was benefited by fire.

Melampyrum sp. is ruderal open ground taxa. It flowers well when the forest has been opened and the ground layer burnt both in the *Betula* forest and at the edge of the forest or mires (e.g. Iversen 1949:17, Hafsten 1956:101, 115, 117, Florin 1958:232, 236, 242, M. Tolonen 1985b, Moore *et al.* 1986:214–215, Simmons & Innes 1996:185, Blackford *et al.* 2006). These insect-pollinated or self-fertilised herbs have limited distribution of pollen (Fægri 1970, 2:217–218, Kwak & Jennersten 1991).

It is perhaps the best single indicator of disturbances in the pollen diagrams, charcoal may coincide with high values of this indicator and it is frequently recognised in the post-fire field layer (Simmons & Innes 1987:395, 1996:185, Innes *et al.* 2010). The coincidence of charcoal and *Melampyrum* has often been observed in pollen diagrams of the Mesolithic (e.g. Simmons & Innes 1988, Hörnberg *et al.* 2005, Blackford *et al.* 2006). In South Norway, *Melampyrum* is normal up to 1230 m asl (Lid & Lid 1994:544) and probably even higher during the early Holocene warm period.

Pteridium aquilinum is a pioneer plant benefiting from open places in a forest. It may be a sensitive indicator of forest fires and clearance (e.g. Iversen 1958:140, Oinonen 1967b, Vuorela 1978:49, 1985:123). It is a very successful cosmopolite with a competitive power and a high productivity (Smith & Taylor 1995, Le Duc *et al.* 2003, G. Stewart *et al.* 2008:957). In South

Norway, *Pteridium* is normal up to about 830 m asl (Lid & Lid 1994:17–18) and probably even higher during the early Holocene warm period. Spore production may be extremely variable, both from year to year and from place to place, depending on local environmental factors (Conway 1957:284). This fern often increases in woodland gaps and clearings, but can survive in conditions ranging from heavy shade to full sunlight and expands markedly in areas where there is human activity (Florin 1958:234, Fægri 1970:330, O.A. Høeg 1975:534, Måren *et al.* 2008a, 2008b).

In the dense forests of the pre-Neolithic, *Pteridium* could be expected at sites with open-canopied woods (Marrs & Watt 2006:1283, 1308), e.g. around mires and lakes. Vuorela (1981:56) recorded fires combined with disturbances in the vegetation and plentiful occurrence of spores from *Pteridium* in the period 7900–6300 cal yr BP in a pollen diagram from southern Finland. This was suggested to reflect periodic burning, at least in part attributable to the effects of human activity, extending for the duration of reforestation, with the aim of improving the conditions for various animals hunted by the population for food.

When *Pteridium* is cut, regrowth is the result (Marrs *et al.* 1998). Cutting twice within a year would probably reduce the growth (Stewart *et al.* 2008). Patches can persist on the same site for a considerable period, at least 1500 years in Finland (Oinonen 1967a:38–41). In the past, this fern was an important resource and people used it for a range of purposes e.g. as food, fuel, bedding for people and animals, animal food, medicine and insect repellent (Fægri 1970:330, O.A. Høeg 1975:534–535, Rymer 1976, Simonsen 1985:Appendix 1, Marrs & Watt 2006:1309).

4 The geographical setting and hunter-gatherers' relationship to nature

Norway has a varying nature, with many islands along the coast and deep, long fjords especially in the west. The interior is mountainous, with peaks up to nearly 2500 m asl. The vegetation varies with altitude, latitude and climate. Generally, the mean temperature in the east is higher than in the west. In the west, the Atlantic Ocean and the Gulf Stream cause a maritime climate with a general westerly circulation and higher precipitation than east of the main water divide, where there is a more continental climate (Selsing & Wishman 1984, Moen 1999:22–25). Temperature decreases with elevation above sea level and humidity is higher in the west than in the east.

The stable climate in the early Holocene warm period (about 10,000–7500 cal yr BP ago) was characterised by the immigration of flora and fauna following the deglaciation. The summer temperature is estimated to have been about 1–2 ˚C higher than today (1971–2000) (Paus 2013, Hanssen-Bauer *et al.* 2015:28). Later the climate was more unstable, cooler and humid. These changes influenced the forest limits, which were higher during the early Holocene than today.

Hunter-gatherers have a detailed knowledge about and insight into the nature where they live. All contemporary hunter-gatherers are highly skilled and selective users of their environment, and choices are constantly being made (Woodburn 1980:100). Their understanding of landscape differs from the scientific, systematic ecological analyse (Welinder 1992:63). Their general knowledge about nature and local weather signs, and their cognitive approximation to movements, were a basic tactic in order to extend their settlement area. People had knowledge about the geography and nature of large areas, far outside their own yearly round. The hunter-gatherer culture is complicated and their cognitive approach to the landscape is associated with specific conceptions, and represents mythological, ritual, ideological, historical and social relations based on knowledge and experiences (Knutsson 1995:Fig. 2, Mulk & Bayliss-Smith 1999, Fuglestvedt 2000:59). The nature influences a region's culture and the people are experts on the use of resources in their territory (Kelly 1995, Brody 2002a:26 [1981], 2002b:105 [2000]). As an example, the Evenki hunter-gatherers in Siberia possessed a dynamic understanding of their environment, comparable to that of modern ecologists (Grøn 2012:176–177).

Hunter-gatherers are more or less mobile, with a yearly round founded on their culture and their experience; the way they use different landscapes primarily depends upon activities that can change in the details, but not in broad outline (Brody 2002a:191 [1981]). The system is based on free access, flexible use and rotational preservation. Depending upon the evaluation of a resource within the territory, the same areas were not used year after year (Brody 2002a:87, 90, Fig. 1–3 [1981]).

The description of four vegetation zones below is related to the hunter-gatherer way of life. The vegetation limits were important to hunter-gatherers because they delimit areas with different access to resources, which also vary with altitude. Hunter-gatherers used several types of biotopes, but not necessary all the four South Norwegian vegetation zones in the Mesolithic.

4.1 The coastal forest zone

Along the coast, broad-leaved deciduous woodland occurred many places in the Mesolithic, even if *Pinus* forest dominated, often mixed with *Betula* and other deciduous tree species. Thermophilous deciduous trees were especially *Quercus* in the west and *Tilia* in the east (for further information, see Moen 1999). The forest was as dense as the topography allowed and probably the early Holocene forest was open. Along the coast, the wind could affect the vegetation and open forest also developed because of management (e.g. Hjelle 2002:342, Prøsch-Danielsen & Selsing 2009:79–80, 90). This zone was rich in resources, characterised by its proximity to the sea, and foragers had access to both terrestrial and marine resources. Usually the pastures were best where the forest was open close to the coast.

The main terrestrial prey resources were red deer *(Cervus elaphus)* and elk *(Alces alces),* maybe without a marked geographical differentiation as today (see Selsing 2010:287–289). The elk population achieves the highest density in forests opened by fire or other forms of disturbances that allow regeneration of *Salix*, *Betula* and *Populus* (Uggla 1958:11). Like many other animals, beaver (*Castor fiber*) is affected by fire because it is tied to early stages of the forest succession (Viereck 1973:485–486). Wild boar (*Sus scrofa*), brown bear (*Ursus arctos*), wolf (*Canis lupus*) and wolverine (*Gulo gulo*) also lived in the forest along with small game. Large and strategically located archaeological sites in areas along the coast and fjords are good examples of how easy available economic resources may have been the basis for more permanent hunter-gatherer sites (e.g. Bjørgo 1981, Olsen 1992, Bergsvik 2002).

There are landscape elements in the mountain area that are open and perspicuous and have similarities with the landscape along the coast (Gundersen 2004); the aim of burning dense forest is to create such openings in the forest. Seen from this perspective, hunter-gatherers may have settled these areas because they did not need extensive intentional fire management of vegetation.

4.2 The boreal forest zone

South Norway is located in the circumboreal forest zone, where coniferous forests dominate. The flora is naturally poor and resources are relatively scarce. The boreal forest zone was dominated by *Pinus* mixed to a varying degree with *Betula* in the Mesolithic. Deciduous trees were more numerous than today, especially during the early Holocene warm period. The forest was probably rather dense (Selsing 2010:295–296), with more uniform vegetation and resources than the other vegetation zones. The wildlife was very much the same as in the coastal forest zone, but the low degree of openness entailed a reduced diversity of grazing animals (Aaris-Sørensen 1998). This is perhaps an important reason why hunter-gatherers in the boreal forest generally have great mobility (Kelly 1995:123). Hunting and, to a lesser extent, gathering were the dominating adjustment strategies in the boreal forest (Lewis 1982:19). According to Lewis (1982), the use of fire to maintain corridors and yards in regions of low primary production is clearly a feature shared by hunter-gatherers in distinct regions and different parts of the world.

The mosaic of a boreal forest that has been subject to burning compared to unburnt regions provides a favourable range of environments for the greatest number and populations of species (see Lewis 1982:16) compared to unburnt regions, which may have been avoided by people as uninhabitable (see Pyne 1993:251). Intentional burning would have been of importance for maintaining a varied forest mosaic ecosystem, giving advantages to the indigenous people in South Norway, who may effectively have related to this forest type. This may have been important for the foraging groups who had to cross the boreal forest during the seasonal migrations from settlement sites at the coast to settlement sites in the mountain area and back again (see Selsing 2010:328–330).

4.3 The subalpine forest zone

During the early Holocene warm period, *Pinus* dominated, especially in the east, mixed to varying degrees with *Betula*, which dominated in the west. The forest limit was located higher than today and large areas, which today are above the forest limit, were included in the subalpine forest. The dominance of *Pinus* started to decline around 7600 cal yr BP, corresponding with a decline in the forest limit and a less stable climate. *Betula* gradually became the dominant tree at higher levels and the subalpine *Betula* forest was established 6500–5000 cal yr BP, with decreasing temperatures and a declining forest limit. The forest density varied and decreased towards the forest limit, with a relatively rich under-storey of herbs and shrubs (see Selsing 2010:Chap. 6 and 7.5, Table 31). The vegetation changes in the last part of this period occurred earlier in western areas than in eastern areas and earlier in higher areas than in lower areas (Selsing 1996).

Animals from both the alpine zone and boreal forest zone met here. Reindeer may have grazed in this zone, especially when the forest limit was high and the pastures in the alpine zone were restricted. Access to the three big ungulates was better in the subalpine forest than in the other vegetation zones and they could be hunted more or less at the same time in this zone, which was rich in resources.

The elk population is dependent on fire (Uggla 1958:5, Viereck 1973:484, 489, Mellars 1976:30). The effect of fires can improve the environment for elk for 25–50 years, mainly because of better productivity, with the development of good winter pastures. In contrast to reindeer, elk prefer young forests (Chandler *et al.* 1983:239). Arboreal lichen, which grows on old trees, can be alternative fodder for reindeer, especially late in the winter season when snow is deep (Heinselman 1973:378). In the Mesolithic, when the forest probably was characterised by different year classes of trees, old trees with lichens may have been widespread and good winter fodder for reindeer.

Upland areas may have been particularly attractive for hunters because of the greater variety of habitats they contained, especially at the forest edge, compared to the forests below, which were broken only by rivers (Simmons 1975:11). Burning of the margins of the subalpine forest may have started at the time of the maximum altitudinal extension of the forest limit (Simmons *et al.* 1983).

4.4 The alpine zone

Herbs, shrubs, dwarf shrubs and sporadic trees with large variations within short distances and a mosaic of landscape elements dominate the vegetation above the forest limit. Vegetation assemblages and associated disturbances are spatially heterogeneous in mountain ecosystems due to the complex terrain and strong environmental gradients (Mustaphi & Pisaric 2013).

Reindeer (*Rangifer tarandus)* is the only widespread ungulate, while important prey resources such as elk and red deer sporadically cross the transition from the subalpine forest zone. The carnivorous brown bear (*Ursus arctos*), wolf (*Canis lupus*) and wolverine (*Gulo gulo*) have reindeer as important food in competition with people.

The need for fire management was small in the open landscape above the forest limit because it naturally had many of the characteristics that the burning had the intention to create. During the early Holocene warm period, with restricted areas above the forest limit, the foragers may have used fire management.

The effects of burning in this zone last long after a fire because the temperature is low, the processes are slow, and the growth season is short (Frissell 1973:417, Loope & Gruell 1973:440). Therefore, intentional burning by hunter-gatherers was probably not widespread. Fire can cause serious damage to winter reindeer pastures of lichens (mainly *Cladonia*), which burn easily and are destroyed for a long period because regrowth is very slow (40–150 years, Hustich 1951:33–36, Viereck 1973:473, 481, 484, 489, Andersen & Hustad 2004:18, Andersen *et al.* 2006:16). If an intentional fire comes out of control, it will cause significant damage to winter reindeer pastures (Rowe & Scotter 1973:450). The summer pastures, which consist of different herbs and shrubs will improve considerably even with low-intensity fires (Mellars 1976:17). Other plants, such as the moss *Sphagnum*, may also suffer and regrowth may be delayed more than thirty years after fire (Qiu 2009).

Firewood is restricted above the forest limit. People that live temporarily in a forest can be selective in their choice of firewood (Smart & Hoffman 1988:169, 190–191), but probably the physical character of the firewood is less important above the forest limit. Firewood may have been important in the choice of location for hunter-gatherer settlements sites with few woody plants (Bergman 1927:150, 179, Rasmussen 1927:141, 147 [1915], 1955:89, 93, 105–106, 108 [1932], Ingstad 1975:98, 121, 129, 154, 163, 230 [1951], Brody 1987:41).

4.5 The density of the forest

Traditionally, the forest environment during the Mesolithic has been supposed to be dense, and the development of more open areas was not assumed until the onset of the Neolithic. This view has changed recently and there are different views of the density of the pre-Neolithic forests.

Vera (2000) assumed that the forests of West Europe in the period 9500–6300 cal yr BP had similarities to open parklands maintained by the intensive pasturing of herbivorous mammals. Mitchell (2005), on the other hand, compared the changes in the forest on the Continent with the Irish forests of the same period. Because this area was isolated, the forests were characterised by the absence of many of the herbivorous animals. His analysis showed no significant difference between the forest developments in the two areas. He was convinced that the forests were dense and that herbivorous mammals played a limited role in the dynamic of the forests. The study of Nielsen *et al.* (2012:142) could neither rule out nor confirm that large grazing animals affected the pre-agricultural landscape openness.

Using quantitative reconstructions, the regional vegetation openness was 10–20% across much of North Germany and Denmark about 8700 cal yr BP (Nielsen *et al.* 2012). The forest cover was most dense 8000–6000 cal yr BP. It increased in much of the region 7700–6700 cal yr BP and was the densest at the same time as the first evidence of agriculture (Nielsen *et al.* 2012:136). The analyses indicate that the variation in openness at the regional scale are related to soil types and degree of continentality (Nielsen *et al.* 2012:142).

Without human activity, central Europe would most likely have been dominated by woodland, although lakes, wetlands, etc. would have provided open habitats (Nielsen *et al.* 2012:132).

Fyfe *et al.* (2013) carried out the same kind of study in Britain and Ireland with the main conclusion that this area had higher levels of landscape/woodland openness at the regional scale than elsewhere on the European mainland. The openness was particular in the first half of the Holocene and the general decline in woodland cover began at c. 6000 cal BP. The results show a significantly higher level of landscape/woodland openness than has previously been suggested from pollen percentage data (Fyfe *et al.* 2013:138). The reason may be that the used sites are largely from areas rich in extensive wetlands, or uplands and the results are probably reasonable for the landscapes from which the sites derived and may not be for other parts of the British Isles. The openness at the regional scale includes the development of heath and bog during the Holocene, as well as anthropogenic changes (Fyfe *et al.* 2013:139–140). The activities of prehistoric societies were not uniform in either space or time, and the pattern of temporal and spatial variability in woodland decline points towards human agency as a major driver of regional vegetation cover (Fyfe *et al.* 2013:144).

Based on the approaches mentioned above, the complexity of this subject is clear. The studies did not take openings in the forest caused by people's fire management in the Mesolithic into consideration. Difficulties with regard to determining the density of the forest include that it was not homogenous, the population in the Mesolithic was generally small and the location of settlement sites and communication systems compared to the pollen sites was not touched on. The presence of over-mature and old-growth stands during the Mesolithic may have resulted in openings in the forest canopy. Most of all, the subject of possible fire management activities by hunter-gatherers was not discussed. To sum up dense forests were probably prevalent in the Mesolithic even if e.g. people, topography, downfalls of trees or mires created areas of open forest.

5 Site descriptions

The data used in this project is from 68 sites where palynological analyses have been carried out (Appendix A, Fig. 1 and Table 3). The palynologists responsible for these analyses are experienced established researchers. The sites have been selected based on the following criteria:

1. The data material includes a charcoal curve.
2. The sediments are radiocarbon dated (or dated by correlation with sites close by).
3. The bottom of the diagram is older than the transition to the Neolithic.

Most of the pollen diagrams were produced in connection with archaeological investigations that were required under the terms of the Norwegian Cultural

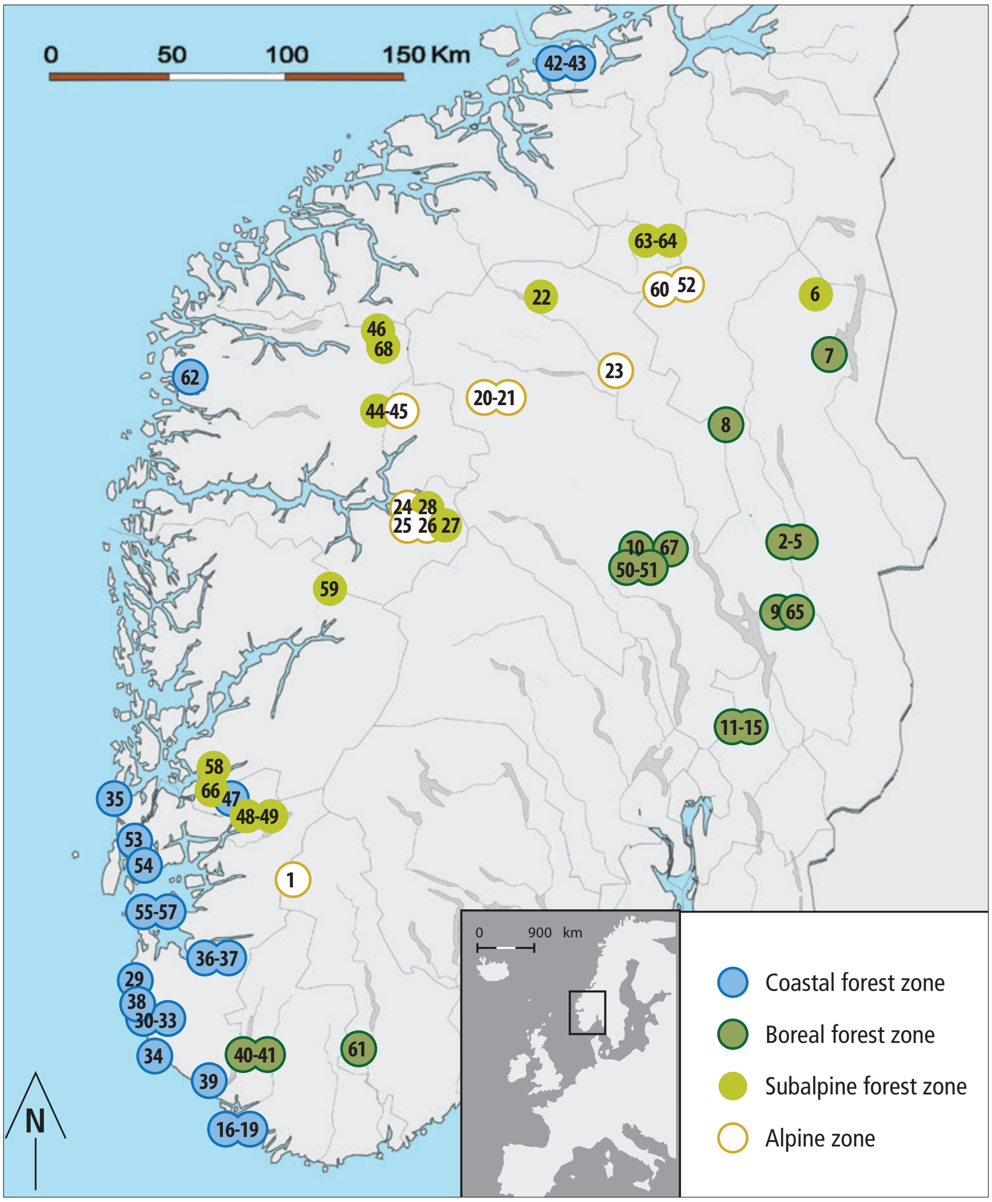


Fig. 1. Location of the 68 pollen sampling sites in South Norway used in this study and their present-day vegetation zone. Graphic design: Martin Blystad.

*Table 3. The 68 palynological sampling sites from South Norway with information on accumulation rate, age of the earliest deposition of organic material in the basin, age of the first occurrence of charcoal dust, age of the first occurrence of three taxa indicating fire or open vegetation, age of the earliest palynological recorded agricultural activity (pasturing and cereal type pollen) and reference. Abbreviations: occ.=occurrence. Scale of occ.: - =no occ., 1 occ., 2 occ., scarce >2 occ. and clear discontinuous, sporadic: several occ. and discontinuous. *=site represented as figure.*

13.12.201613.12.2016	Site, municipality, county (m asl)	Sediment thickness cm	Accumulation rate cm/ 10 cal yr	Age bottom pollen diagram yr BP/cal yr BP	Age first occ. charcoal yr BP/ cal yr BP	Charcoal curve pattern no. 1–4 (cf. Table 7)	Age first occ. *Melampyrum* sp. yr BP/cal yr BP	Age first occ. Onagraceae yr BP/ cal yr BP	Age first occ. *Pteridium* aquilinum yr BP/cal yr BP	Age first occ. *Plantago lanceolata* yr BP/ cal yr BP	Age first occ. cereal pollen type yr BP/ cal yr BP	Reference
1	Locality J, Øvre Storvatnet, Bykle, Aust-Agder (980)	141	0.170	8600/9600	8600/9600	4	8600/9600 sporadic	8600/9600 sporadic	-	3400/3700	-	Blystad & Selsing 1988:77, 80–81, Selsing 2010:38–39
2*	Persmyra, Åmot, Hedmark (304)	145	0.183	8200/9100	8200/9100	3	8000/8900 sporadic	-	8200/9100 sporadic	4000/4500	3200/3400	Høeg 1996:19–25
3	Ulvehammeren, Åmot, Hedmark (292)	145	0.142	9000/10,200	8800/9800	3	7300/8100	9000/10,200 1 occ.	8700/9600 sporadic	3700/4000	300/400	Høeg 1996:25–30
4	Dulpmoen, Åmot, Hedmark (273)	339	0.381	8000/8900	8000/8900	2	6900/7700 sporadic	7300/8100 sporadic	7500/8300	2600/2700	4200/4800	Høeg 1996:30–35
5	Ottersmyra, Åmot, Hedmark (273)	245	0.250	9100/10,200	8800/9800	1	9100/10,200 sporadic	-	6400/7300	3200/3400	800/700	Høeg 1996:35–40
6	Kåsmyra, Tolga, Hedmark (925)	325	0.357	8200/9100	7800/8600	4	8200/9100 sporadic	-	7200/8000 sporadic	2900/3000	1500/1400	Høeg 1996:63–68
7	Lille Sølensjøen, Øvre Rendal, Hedmark (705)	127	0.172	6500/7400	6500/7400	3	6500/7400	-	6500/7400	2000/2000	1600/1500	Høeg 1996:79–84
8	Hirsjøen, Ringebu, Oppland (729)	650	0.637	9000/10,200	8800/9800	2	7700/8400	6400/7300 sporadic	6900/7700	5700/6500	2400/2400	Høeg 1996:102–109
9	Engelaug, Løten, Hedmark (184)	290	0.276	9700/11,200	9200/10,300	4	9300/10,500 sporadic	7200/8000 sporadic	8700/9600 sporadic	3400/3700	3800/4200	Høeg 1996:125–131
10	Kittilbu, Nordre Land, Oppland (820)	210	0.236	8000/8900	8000/8900	2	8000/8900	-	7700/8500	2800/2900	1200/1100	Høeg 1990:51–58
11	Rud Øde, Nannestad, Akershus (200)	175	0.164	9500/10,700	9500/10,700	4	9500/10,700 sporadic	9000/10,200 scarce	9300/10,500 sporadic	4400/5000	2200/2200	Høeg 1997:21–30
12*	Danielsetermyr, Ullensaker, Akershus (175)	565	0.785	6300/7200	6300/7200	4	6000/6800 sporadic	6200/7100 2 occ.	6300/7200	4800/5500	3500/3800	Høeg 1997:30–36

13	Svenskestutjern, Ullensaker, Akershus (198)	283	0.382	6500/7400	6500/7400	2	3600/3900 scarce	-	6500/7400	4500/5200	2100/2100	Høeg 1997:36–41
14	Bånntjern, Ullensaker, Akershus (196)	497	0.700	6200/7100	6200/7100	1	4000/4500 scarce	2700/2800 scarce	6200/7100	4400/5000	4000/4500	Høeg 1997:41–46
15	Skånetjern, Ullensaker, Akershus (191)	680	0.747	8200/9100	8000/8900	1	3800/4200 sporadic	1000/900 1 occ.	7100/7900 sporadic	4300/4900	3700/4000	Høeg 1997:47–51
16	Skjoldnes myr I, Farsund, Vest-Agder (3.8)	1006	0.645	13,200/15,600	13,200/15,600	3	9300/10,500 sporadic	11,500/13,500 sporadic	7400/8200	4800/5500	7400?/8200	Høeg 1995:272–283
17	Fjellestad myr I, Farsund, Vest-Agder (4.5)	240	0.276	12,300/14,400	12,300/14,400	2	10,400/12,400 sporadic	11,600/13,600 scarce	3200/3400	3200/3400	3200/3400	Høeg 1995:288–294
18	Fjellestad myr II, Farsund, Vest-Agder (4.9)	500	0.394	10,800/12,700	10,800/12,700	4	9200/10,300 sporadic	7600/8400 scarce	8300/9300 sporadic	3800/4200	(5200/6000) 1700/1800	Høeg 1995:294–301
19	Jølletjønn, Farsund, Vest-Agder (110)	935	0.599	13,200/15,600	13,200/15,600	4	8800/9700 sporadic	11,200/13,200 2 occ.	12,900/15,200 spordaic	(8800) 4800/ (9700) 5500	3900/4400	Høeg 1995:301–309
20	Foss-Setri, Lom, Oppland (1220)	100	0.099	8900/10,100	8400/9500	4	-	8900/10,100 scarce	-	-	-	Gunnarsdóttir 1996:233–255
21	Illmyri, Lom, Oppland (1250)	170	0.159	9500?/10,700	8000/8900	2	-	7200/8000 scarce	-	-	-	Gunnarsdóttir 1996:233–255
22	Ølstadsetri, Lesje, Oppland (820)	110	0.116	8500/9500	1900/1900	4	7900/8700	-	-	1200/1100	1200/1100	Gunnarsdóttir & Høeg 2000:21–28
23	Dovrehytta, Dovre, Oppland (950)	173	0.201	7800/8600	7800/8600	4	7400/8200 scarce	-	-	-	1100/1000	Gunnarsdóttir & Høeg 2000:28–33
24	Urutlekråi-1, Årdal, Sogn og Fjordane (965)	84	0.094	8000/8900	8000/8900	2	8000/8900	8000/8900 scarce	4300/4900 sporadic	4400/5000	-	Kvamme *et al.* 1992:29–39
25	Riskallsvatn-tuft loc. 1, Årdal, Sogn og Fjordane (950)	100	0.143	6100/7000	6100/7000	4	6100/7000 sporadic	2700/2800 1 occ.	6100/7000 sporadic	4000/4500	-	Kvamme *et al.* 1992:63–69
26	Riskallsvatn mire, Årdal, Sogn og Fjordane (948)	220	0.210	9300/10,500	9300/10,500	4	8800/9800 sporadic	9000/10,200 1 occ.	3200/3400 2 occ.	3500/3800	2200/2200	Kvamme *et al.* 1992:70–75
27	Skarhaugfossen-2, Årdal, Sogn og Fjordane (915)	18	0.023	7000?/7900	7000?/7900	3	7000?/7900 sporadic	6700/7600 scarce	7000/7900 sporadic	-	-	Kvamme *et al.* 1992:76–84
28	Skarhaugfossen (core 1 and 2), Årdal, Sogn og Fjordane (945)	310	0.525	8000/8900	8000/8900	4	8000/8900	5000/5700 scarce	8000/8900 scarce	2500/2600	-	Kvamme *et al.* 1992:85–98
29	Alvevatn, Klepp, Rogaland (10)	186	0.204	8200/9100	8200/9100	1	8200/9100 sporadic	-	8000/8900 sporadic	4300/4900	2000?/1900	Fægri 1940, Prøsch-Danielsen & Simonsen 2000:32, 49

13.12.201613.12.2016	Site, municipality, county (m asl)	Sediment thickness cm	Accumulation rate cm/ 10 cal yr	Age bottom pollen diagram yr BP/cal yr BP	Age first occ. charcoal yr BP/ cal yr BP	Charcoal curve pattern no. 1–4 (cf. Table 7)	Age first occ. *Melampyrum* sp. yr BP/cal yr BP	Age first occ. Onagraceae yr BP/ cal yr BP	Age first occ. *Pteridium* aquilinum yr BP/cal yr BP	Age first occ. *Plantago lanceolata* yr BP/ cal yr BP	Age first occ. cereal pollen type yr BP/ cal yr BP	Reference
30*	Obrestad Harbour, Hå, Rogaland (18)	70	0.074	8400–8200/9500–9100	8400–8200/9500–9100	2	8400-8200/9500–9100	-	8400–8200/9500–9100 sporadic	1700?/1600	-	Prøsch-Danielsen & Simonsen 2000:28, 35, 50
31	Kviamyra,Hå, Rogaland (43)	115	0.124	9000/10,200	9000/10,200	2	9000/10,200	-	8600/9600 sporadic	1900/1900	1900/1900	Prøsch-Danielsen & Simonsen 2000:50
32	Stavnheimsmyra, Hå, Rogaland (21)	123	0.156	7000/7900	6000/6800	2	7000/7900 sporadic	-	6000/6800 sporadic	4500/5200	-	Prøsch-Danielsen & Simonsen 2000:33, 35, 40, 51
33*	Romamyra, Hå, Rogaland (265)	105	0.133	7000/7900	7000/7900	1	7000/7900	-	6400/7400	3000/3200	-	Prøsch-Danielsen & Simonsen 2000:35, 40, 51
34	Vodlamyr, Egersund, Rogaland (4)	262	0.349	7700/8500	7700/8500	4	7700/8500 sporadic	-	7700/8500	3700/4000	-	Prøsch-Danielsen & Simonsen 2000:52
35*	Vassnestjern, Bømlo, Hordaland (52)	435	0.366	10,600/12,600	10,600/12,600	2	10,400/12,400	10,000/11,500 scarce	10,200/11,900 sporadic	4800/5500	-	Midtbø 1999:104–105, 107
36	Åsen, Forsand, Rogaland (100)	250	0.227	9600/11,000	9600/11,000	4	9400/10,600	9600/11,000 1 occ.	8700/9600	3500/3800	2800/2900	Høeg 1999:156–162
37	Åsheim, Forsand, Rogaland (115)	950	0.766	10,400/12,400	9000/10,200	4	8800/9800 sporadic	10,200/11,900 1 occ.	8900/10,100 sporadic	4000/4500	3000/3200	Høeg 1999:162–169
38	Håtjern, Hå, Rogaland (8.5)	268	0.288	13,500/16,000	10,600/12,600	4	9800/11,200 sporadic	10,600/12,600 scarce	12,600/15,400 sporadic	1700/1600	1300/1200	Høeg 1999:176–184
39	Svartetjørn, Sokndal, Rogaland (250)	410	0.315	10,900/13,000	10,900/13,000	4	9900/11,300 sporadic	10,400/12,400 scarce	8700/9600 sporadic	6800/7600	3600/3900	Høeg 1999:184–190
40	Ersdal myr, Flekkefjord, Vest-Agder (410)	280	0.277	8900/10,100	8900/10,100	4	8900/10,100	8200/9100 1 occ.	8600/9600	8300 (4600)/9300 (5300)	500/500	Høeg 1999:197–202
41	Ersdal Fiskelausvann, Flekkefjord, Vest-Agder (410)	321	0.401	7200/8000	7200/8000	4	7200/8000	2500/2600 scarce	3900/4400	4900/5600	2500/2600	Høeg 1999:202–207

42	Kalvheiane A, Tjeldbergodden, Aure, Møre og Romsdal (50)	57	0.285	9600/11,000	9600/11,000	3	9500/10,700	8800/9800 scarce	-	-	-	Solem 2000:76–79
43	Kalvheiane 2, Tjeldbergodden, Aure, Møre og Romsdal (50)	75	0.087	7800/8600	7800/8600	3	7800/8600	7800/8600 1 occ.	7800/8600 2 occ.	1800/1700	3600/3900	Solem 2000:79–82
44	Fåbergstølen 1, Luster, Sogn og Fjordane (515)	270	0.318	7700/8500	7700/8500	1	7700/8500	7200/8000 scarce	7500/8300 sporadic	3800/4200	Top	Kvamme 1982:138–141, Kvamme & Randers 1982:98–103
45	Sætrehaug-I, Luster, Sogn og Fjordane (840)	95	0.106	8100/9000	8100/9000	2	8100/9000	7300/8100 1 occ.	6400/7300 sporadic	3000/3200	400/500	Kvamme & Randers 1982:106–107
46	Gamle Sæterkulen-I, Stryn, Sogn og Fjordane (660)	110	0.149	6500/7400	6500/7400	2	6500/7400	6500/7400 2 occ.	3400/3700 scarce	1200/1100	1000/900	Randers & Kvamme 1982:120–124
47	Rødstødno, Sauda, Rogaland (41)	452	0.435	9200?/10,400	9200?/10,400	4	8500/9500 sporadic	4000/4500 1 occ.	8400/9400 sporadic	4300/4900	-	Prøsch-Danielsen 1990:part I
48	Breidastølen, Suldal, Rogaland (700)	130	0.183	6200/7100	6100/7000	4	2700/2800	-	6200/7100	4800/5500	1200/1100	Prøsch-Danielsen 1990:part II
49	Hidlerberget, Suldal, Rogaland (680)	142	0.149	8500/9500	7900/8700	3	8500/9500	8200/9100 1 occ.	7800/8600 sporadic	4000/4500	-	Prøsch-Danielsen 1990:part III
50	Liumholseter, Nordre Land, Oppland (745)	260	0.255	9000/10,200	9000/10,200	2	7800/8600	2300/2300 2 occ.	6800/7600	2500/2600	2700/2800	Høeg 1990:44–51
51	Dokkfløy syd, Nordre Land, Oppland (696)	215	0.239	8100/9000	8100/9000	3	7100/7900	2200/2200 1 occ.	8100/9000	2200/2200	1400/1300	Høeg 1990:37–44
52*	Flåfattjønna, Tynset, Hedmark (1110)	165	0.128	11,000/12,900	9800/11,200	1	9800/11,200 sporadic	9800/11,200 scarce	7600/8400 sporadic	4800/5500	800/700	Paus 2010
53	Skumpatjørna, Tysvær, Rogaland (11.6)	296	0.269	9600/11,000	9600/11,000	2	8500/9500	-	8600/9600	3400/3700	-	Midtbø 2000:17–52
54	Sandvikvatn, Tysvær, Rogaland (127)	276	0.165	13,900/16,700	13,000/15,600	4	8500/9500	13,900/16,700 scarce	8200/9100	4700/5400	2700/2800	Eide & Paus 1982:34–35, Simonsen & Prøsch-Danielsen 2005:20
55	Flekkstadmyra 1–3, Rennesøy, Rogaland (80)	365	0.367	11,700/13,700	11,700/13,700	1	11,700/13,700 sporadic	9900/11,300 scarce	8100/9000 sporadic	3800/4200	-	Prøsch-Danielsen 1993:part I
56	Kådastemmen, Rennesøy, Rogaland (29)	253	0.575	13,000?/15,600	11,300?/13,300	4	-	-	-	-	-	Prøsch-Danielsen 1993:70–79
57	Jubemyr I–II, Finnøy, Rogaland (6.7)	35	(0.230)	9500?/10,700	9500?/10,700	4	9300/10,500 sporadic	8100/9000 1 occ.	9400/10,600 scarce	4100/4700	-	Prøsch-Danielsen 1993:93–101
58	Vestre Øykjamyrtjørn, Matre, Hordaland (570)	356	0.310	10,000/11,500	3800/4200	1	-	-	-	4000/4500	-	Bjune *et al.* 2004, 2005
59	Trettetjørn, Upsete, Aurland, Hordaland (810)	270	0.318	7700/8500	2300/2300	2	-	-	-	3900/4400	-	Bjune *et al.* 2005

13.12.201613.12.2016	Site, municipality, county (m asl)	Sediment thickness cm	Accumulation rate cm/ 10 cal yr	Age bottom pollen diagram yr BP/cal yr BP	Age first occ. charcoal yr BP/ cal yr BP	Charcoal curve pattern no. 1–4 (cf. Table 7)	Age first occ. *Melampyrum* sp. yr BP/cal yr BP	Age first occ. Onagraceae yr BP/ cal yr BP	Age first occ. *Pteridium* aquilinum yr BP/cal yr BP	Age first occ. *Plantago lanceolata* yr BP/ cal yr BP	Age first occ. cereal pollen type yr BP/ cal yr BP	Reference
60	Råtåsjøen, Folldal, Hedmark (1169)	189	0.173	10,100/11,600	9800/11,200	2	-	-	-	-	-	Eide 2003, Velle *et al.* 2005
61	Grostjørna, Birkenes, Aust-Agder (180)	350	0.285	10,400/12,300	10,200/11,900	4	-	-	-	4400/5000	5200/6000	Eide *et al.* 2006
62	Botnaneset, Flora, Sogn og Fjordane (11)	182	0.204	8000/8900	8000/8900	4	8000/8900	3500/3800 2 occ.	8000/8900	6400/7300	2600/2700	Bostwich Bjerck 1983
63*	Frengstadsetra, Innerdalen, Tynset, Hedmark (800)	170	0.159	9500/10,700	9500/10,700	3	8200/9100 sporadic	9500/10,700 2 occ.	-	-	-	Paus & Jevne 1987:21–32
64	Flonan, Innerdalen, Tynset, Hedmark (780)	127	0.142	8000?/8900	8000?/8900	2	8000?/8900	6800/7600 scarce	7600/8400 scarce	4400/5000	4100/4700	Paus & Jevne 1987:70–80
65	Hellemundsmyra, Elverum, Hedmark (190)	478	0.469	9000/10,200	8700/9600	1	9000/10,200 sporadic	4000/4500 1 occ.	9000/10,200	4000/4500	3200/3400	Høeg 1996:117–123
66	Flaatevatn, Etne, Hordaland (570)	334	0.304	9600/11,000	9000/10,200	1	9600/11,000	9600/11,000 2 occ.	6500/7400 2 occ.	2300/2300	0/0	Sivertsen 1985:98–124
67	Brynnsmyra, Snertingdal, Gjøvik, Oppland (725)	218	0.273	7300/8100	7300/8100	4	6900/7700	6900/7700 1 occ.	6700/7600	2900/3000	2500/2600	Høeg 2007:181–186
68*	Sygneskardsvatn, Sunndalen, Stryn, Sogn og Fjordane (690)	329	0.313	9300/10,500	9300/10,500	4	9300/10,500 sporadic	8900/10,100 scarce	4700/5400 scarce	9000 (4900)/10,200 (5600)	-	Kvamme 1984:238–266

Heritage Act (*Lov om kulturminner*). A minority were associated with natural science projects.

The investigated sites are, with few exceptions, restricted to mires and lakes. Most of the 68 sites are located a distance close enough to the archaeological sites that they may disclose human activity in the vegetation.

The charcoal curve is described for each site. A maximum in the curve is defined as one or more spectra with high values compared to the surrounding samples. Sometimes it is the highest charcoal value in the pollen diagram, but often there is no marked maximum. The maximum recordings are relative compared to the charcoal spectre below and above, and do not give information about the amount (the percentage value) of charcoal.

The traditional palynological indications of agricultural activity are cereal-type pollen, which can indicate cultivation (Firbas 1937, Iversen 1941:39, 48–49), and the pollen of *Plantago lanceolata*, as a weed of pastures associated with Neolithic clearance phenomena (Iversen 1941:39–41, see also Behre 1981, Prøsch-Danielsen & Simonsen 2000a, 2000b).

Mire is used as a general term for all kinds of wetland, such as bogs, fens or combinations of mires (Moen 1999:73–76).

The accumulation rate is presented as cm/yr of sediment. The diameter of a pollen sample is normally 1 cm.

6 Results

The geographical and altitudinal distribution of the 68 pollen sites is used to evaluate the representatives of the pollen diagrams with regard to fire management in South Norway during the Mesolithic (Fig. 1 and 2). Compared to the climate regions in South Norway (Hanssen-Bauer 2005:Fig. 1 and 8), 28 of the sites are located in the eastern region and 40 in the western region. The altitudinal distribution is 4–1250 m asl. The sites are not equally distributed with regard to altitude.

6.1 Accumulation rate

The accumulation rate was calculated without consideration of the sediment type and excluding basal minerogenic deposits. It is a mean of the organic deposit from the bottom to the top in the pollen diagrams, independent of peat, gyttja etc (Fig. 3). The accumulation rate of the individual sample is used to interpret the charcoal occurrences.

6.2 The age of the bottom of the organic sediments

The age of the bottom of the organic sediment in the pollen diagrams is 16,700–7000 cal yr BP, of which the bottom age of 14 sites is older than the transition to the Holocene (Fig. 4 bottom). The frequency of sites with the age of the bottom of the organic sediment in the period 16,700–13,000 cal yr BP is low, becoming higher in the period 13,000–12,300 cal yr BP. After a gap, the frequency increases around 11,600 cal yr BP and is high, but fluctuating, until 7000 cal yr BP.

6.3 The age of the first occurrence and maximum in the charcoal curves

The age of the first occurrence of charcoal spans the period 15,600–2300 cal yr BP, with 10 sites being older than the transition to the Holocene and two sites younger than 7000 cal yr BP (Fig. 4 centre and Table 4). Charcoal was present continuously at most sites since

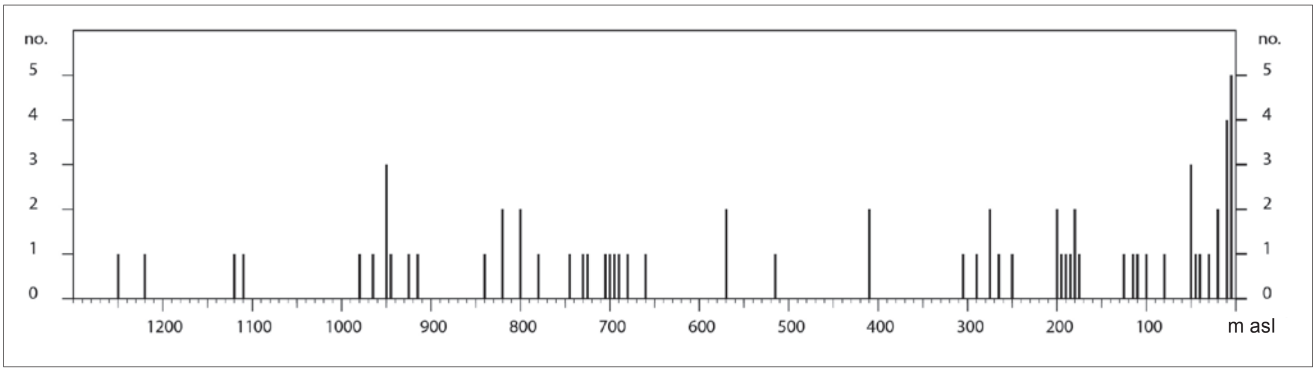


Fig. 2. The altitudinal distribution of the 68 pollen sampling sites in South Norway, located 4–1250 m asl. Drawing: Martin Blystad.

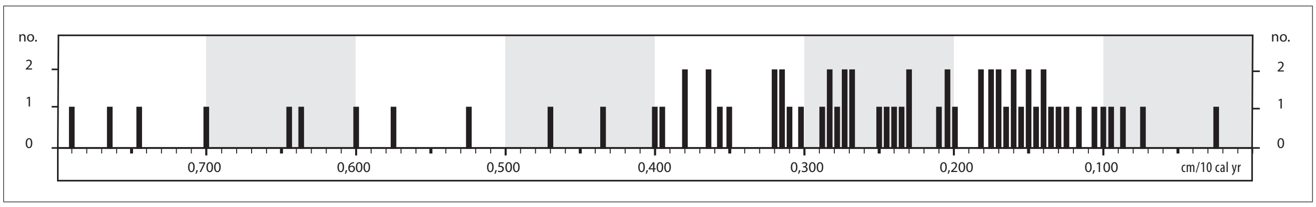


Fig. 3. The accumulation rate cm/10 yr of the 68 pollen diagrams. Drawing: Martin Blystad.

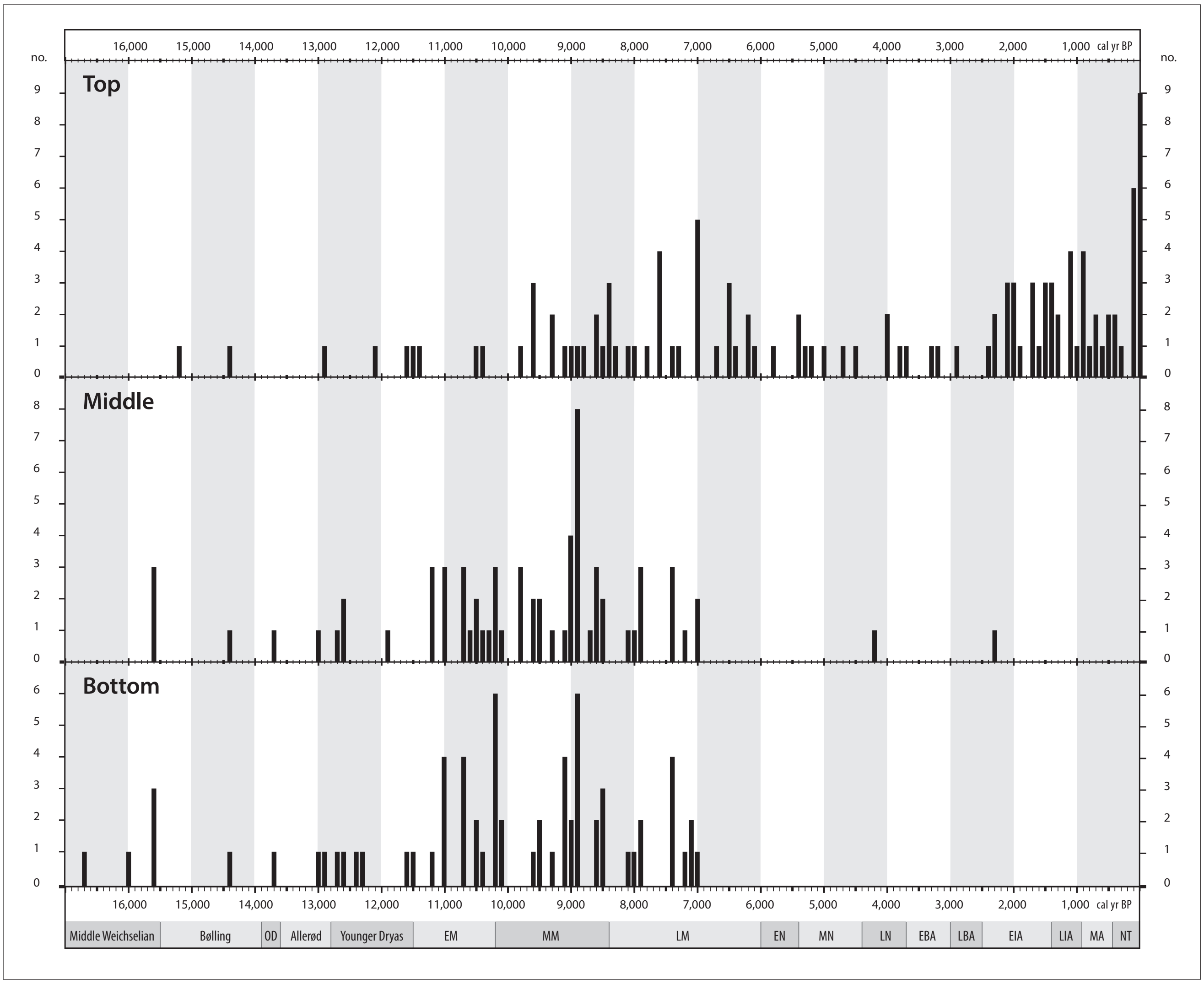


Fig. 4. Bottom: the age of the bottom of the organic sediment in the 68 pollen diagrams. Centre: the age of the first occurrence of the charcoal. Top: the age of the maximum occurrence of the charcoal curve (maximum means one or more spectre with high values compared to the surrounding samples). Abbreviations: OD=Older Dryas, EM=Early Mesolithic, MM=Middle Mesolithic, LM=Late Mesolithic, EN=Early Neolithic, MN=Middle Neolithic, LN=Late Neolithic, EBA=Early Bronze Age, LBA=Late Bronze Age, EIA=Early Iron Age, LIA=Late Iron Age, MA=Middle Ages, NT=Newer times. Drawing: Martin Blystad.

the beginning of organic deposition. The frequency of sites with the age of the first occurrence of charcoal in the period 15,600–11,200 cal yr BP is low, high in the period 11,200–8500 cal yr BP and none the next 400 cal yr BP. A short period with a low frequency 8100–7900 cal yr BP was followed by a hiatus 7900–7400 cal yr BP and a new period with low occurrence was 7400–7000 cal yr BP.

The age of maximum in the charcoal curves is recorded between 15,200 cal yr BP and the present-day, with two periods of high frequency, the oldest from 9800 to 6000 cal yr BP and the youngest from 2400 cal yr BP to the present-day (Fig. 4 top and Table 4). There are two periods with a low frequency of maximum values in the charcoal curve: 15,200–9800 cal yr BP and 6000–2400 cal yr BP. In the oldest one of these two periods, there are two gaps with no maximum in the charcoal curve: 14,400–12,900 cal yr BP and 11,400–10,500 cal yr BP. In the younger of these two periods there are also two gaps 4500–4000 cal yr BP and 2900–2400 cal yr BP.

6.4 The frequency of the use of terms to describe the charcoal curves

The 68 charcoal curves are characterised by using the frequency of the terms used subjectively to describe the lapse of the curves in Appendix A. The most used terms are *maximum*, *continuous*, *low (values)* and *rise (upwards)/increase* (Table 5). Other terms are used more rarely. *Minimum*, *hiatus*, *peak*, *regular* and *culmination* are used only a few times.

Table 4. The age of the first occurrence and the maximum occurrence of charcoal for the 68 palynological sampling sites in South Norway compared to calendar years BP and the archaeological chronology.

Archaeological chronology	First occurrence charcoal	Age cal yr BP	Age cal yr BP	Maximum occurrence charcoal	Archaeological chronology
Late Palaeolithic	Low frequency	*15,600–11,200*			
			15,200–9800	Low frequency	Last part of Late Palaeolithic and first part of Early Mesolithic
Early and Middle Mesolithic	High frequency	11,200–8500			
			9800–6000	High frequency	First part of Early Mesolithic to the transition to the Neolithic
Transition to and early part of Late Mesolithic	No occurrences	8500–8100			
Early part of Late Mesolithic	Low frequency	8100–7900			
Early part of Late Mesolithic	No occurrences	7900–7400			
Middle part of Late Mesolithic	Low frequency	7400–7000			
Late part of Late Mesolithic to the present time	Two occurrences	7000–0			
			6000–2400	Low frequency	Transition Mesolithic/Neolithic to start Early Iron Age
			2400–0	High frequency	Start Early Iron Age to the present time

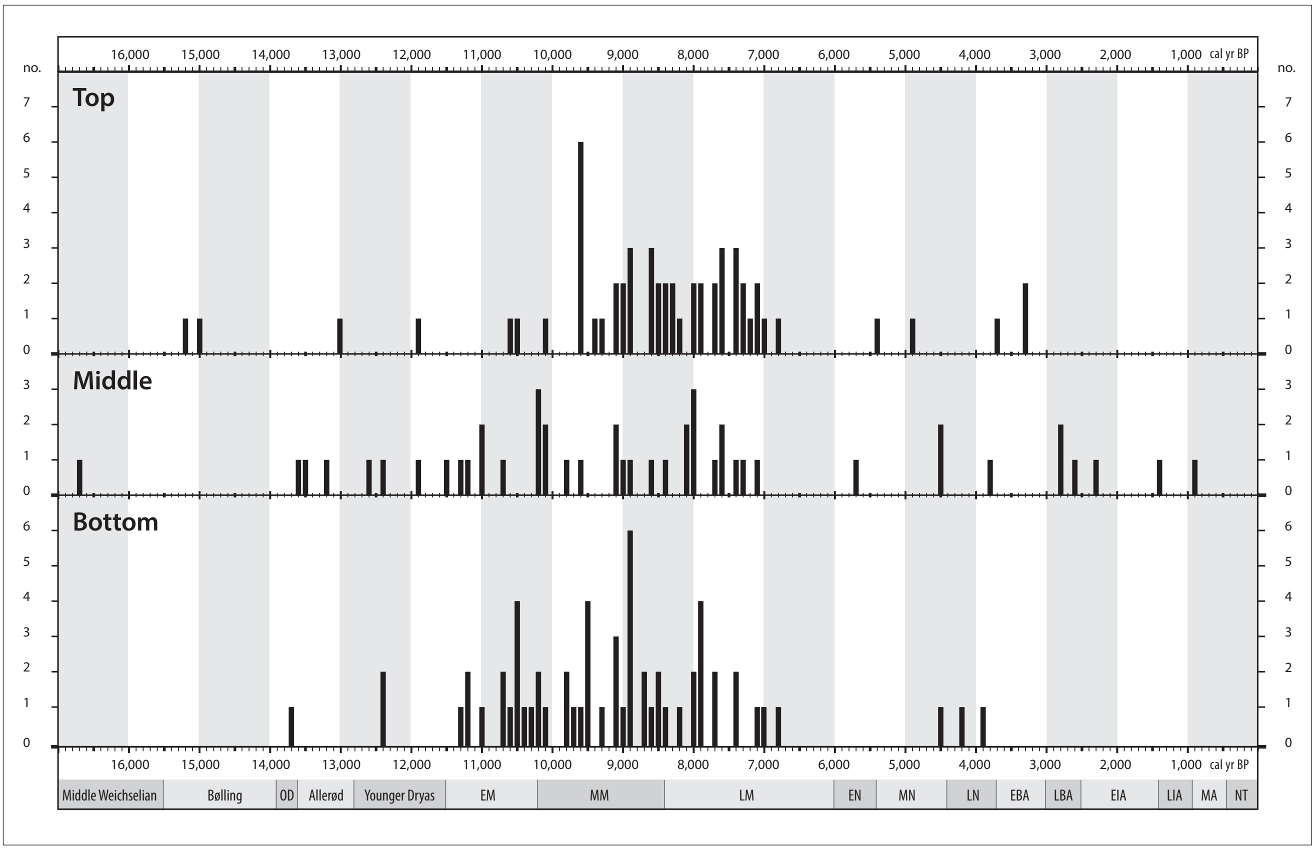


Fig. 5. The age of the first occurrence of pollen from Pteridium aquilinum (top), Onagraceae (centre) and Melampyrum sp. (bottom) from the 68 pollen diagrams. Abbreviations see Fig. 4. Drawing: Martin Blystad.

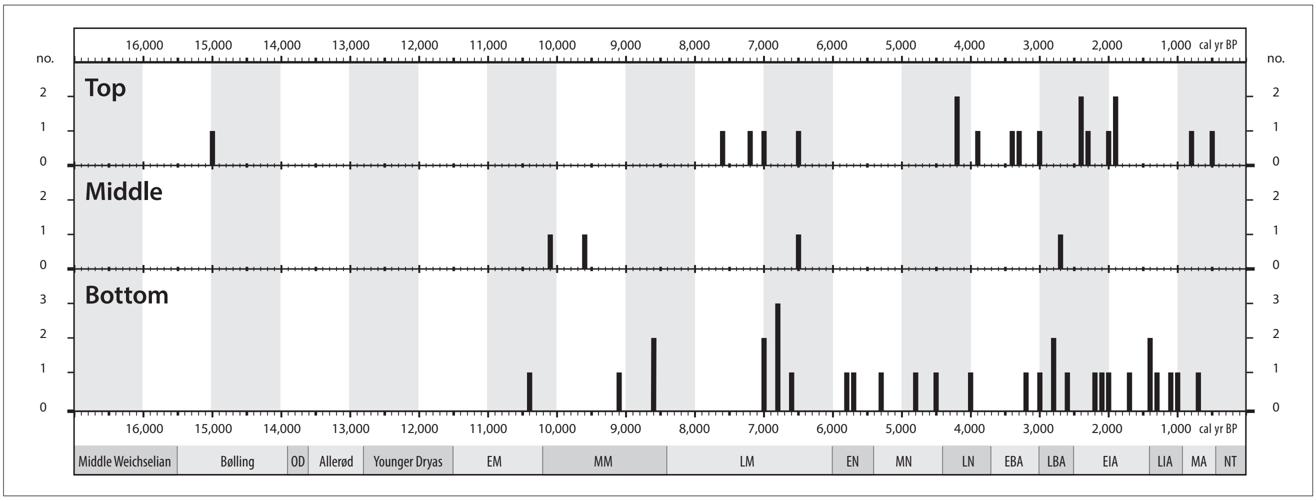


Fig. 6. The age of the maximum occurrence of pollen from Pteridium aquilinum (top), Onagraceae (centre) and Melampyrum sp. (bottom) from the 68 pollen diagrams. Abbreviations see Fig. 4. Drawing: Martin Blystad.

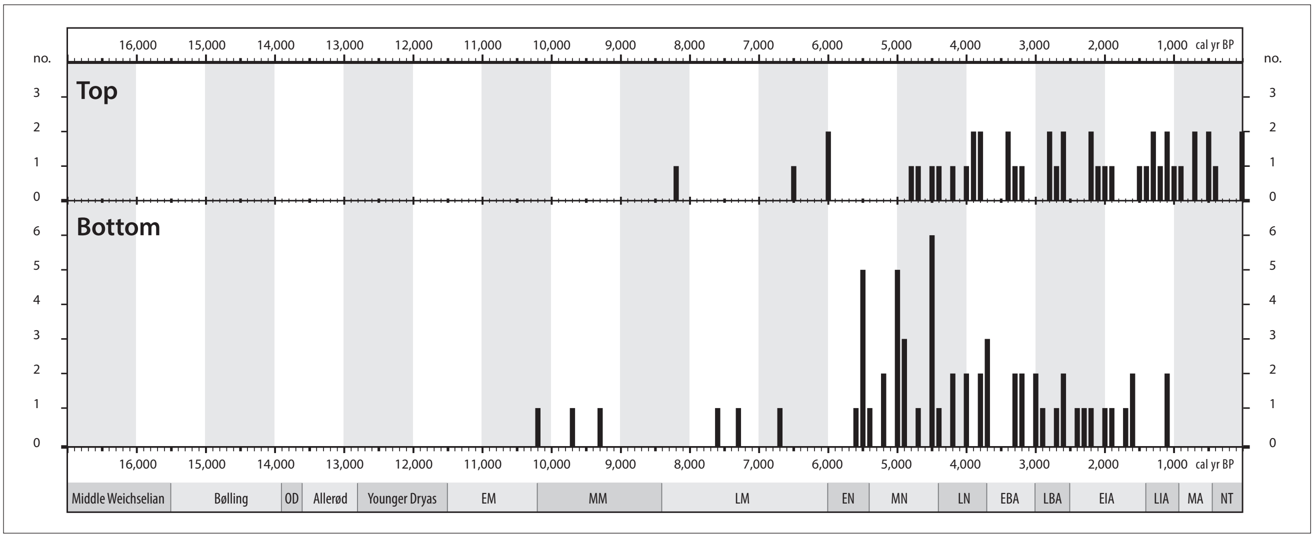


Fig. 7. The age of the first occurrence of pollen from the traditional palynological indicator of agricultural activity Plantago lanceolata (pasturing) (bottom) and (top) cereal type pollen (cultivation) from the 68 pollen diagrams. Abbreviations see Fig. 4. Drawing: Martin Blystad.

6.5 The age of the first occurrence and the maximum occurrence of fire indicators

The age of the first occurrence of *Pteridium*, Onagraceae and *Melampyrum* is presented in Fig. 5 and the maximum occurrence in Fig. 6. The values of the three taxa appear in Appendix A and Table 6.

6.6 The age of the first occurrence and frequency of pollen from *Plantago lanceolata* and cereal-type pollen

The age of the first occurrence and frequency of pollen from *Plantago lanceolata* from the 68 pollen diagrams (Fig. 7 bottom) is spread in the period 10,200–1100 cal yr BP. A marked increase in frequency of the first occurrence is in the period 5600–1600 cal yr BP and the highest frequency in the period 5600–3700 cal yr BP.

The age of the first occurrence of cereal-type pollen (Fig. 7 top) is spread in the period 8200–0 cal yr BP, with the highest frequency in the period 4800–0 cal yr BP.

6.7 Changes in the vegetation density

The temporal and spatial changes in the vegetation density revealed in the 68 pollen sites (dense forest, open forest and open vegetation) are presented in Fig. 8. The temperature and precipitation regions in South Norway have an effect on the vegetation density (Hanssen-Bauer 2005:Fig. 1 and 8).

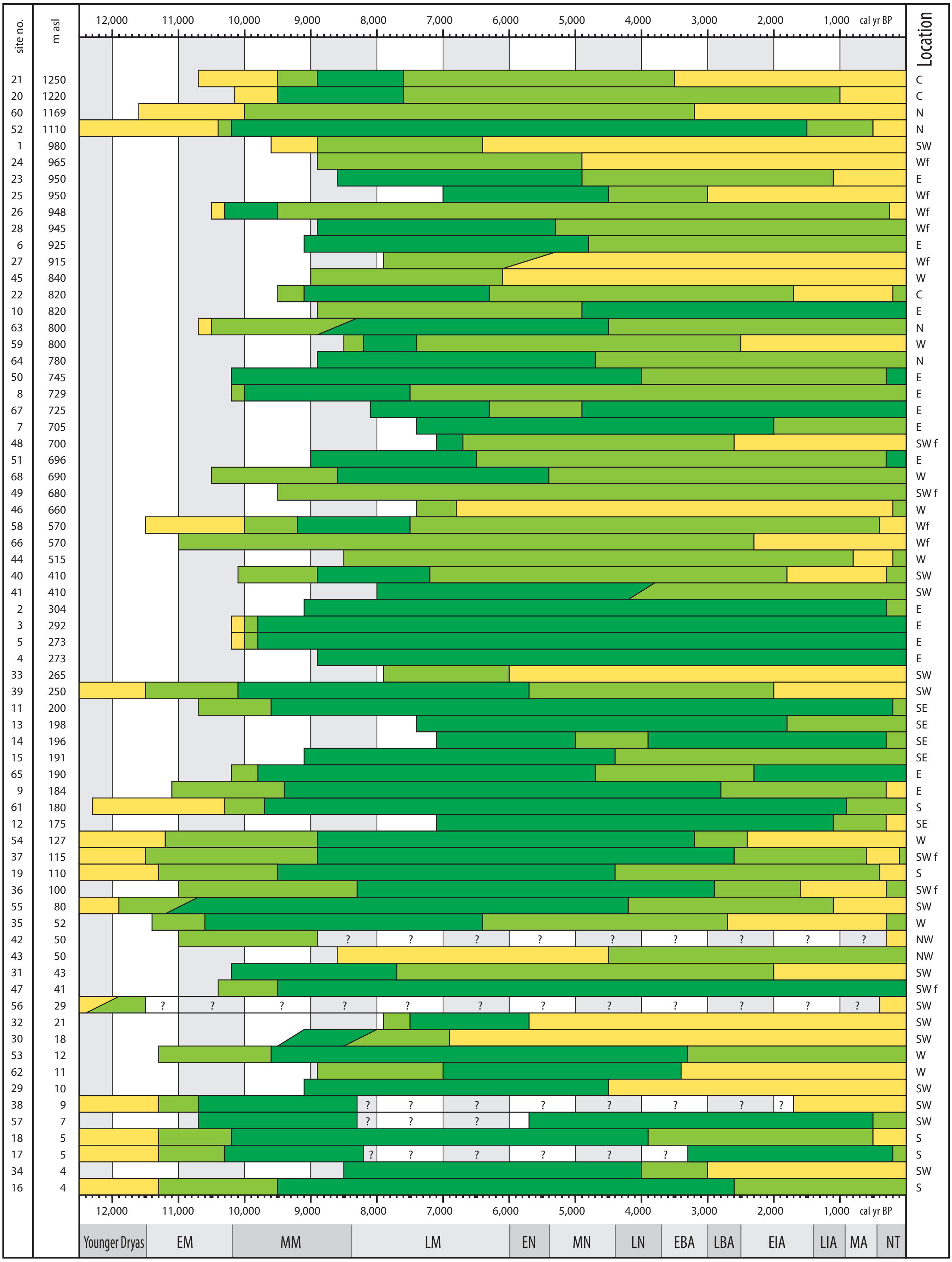


Fig. 8. The temporal and spatial changes in the vegetation density of the 68 pollen diagrams (yellow=open vegetation such as alpine vegetation above the forest limit and agricultural landscape including coastal heaths in the west, light green=open forest and dark green=dense forest). Uncertainties and hiatuses are marked with question marks. To the left, site no. and m asl (bottom upwards). To the right, the geographical location of the site: C=central part, E=east, N=north, NW=northwest, S=south, SE=southeast, SW=southwest, SWf=southwestern fiord district, W=west and Wf=western fiord district. Graphic design: Martin Blystad.

Table 5. Terms used to describe the lapse of the charcoal curves for the 68 palynological sampling sites in South Norway in the site descriptions in Appendix A.

Term	Number of the term used	Age cal yr BP
Maximum	55	15,600–11,200
Continuous	46	
Low (values)	41	11,200–8500
Rise (upwards)/increase	26	
Fluctuation	11	8500–8100
Nearly continuous	10	8100–7900
Sporadic	9	7900–7400
Discontinuous	8	7400–7000
Gap	8	7000–0
High(er) values	7	
Decrease (upwards)	6	
Irregular	5	
Minimum	3	
Hiatus	2	
Peak	2	
Regular	2	
Culmination	1	
Sum	242	

Table 6. The occurrence of three taxa indicating fire or open vegetation from the 68 palynological sampling sites in South Norway: Melampyrum sp., Pteridium aquilinum and Onagraceae. Scale of occurrence: - =no occ., scarce >2 occ. and clear discontinuous, sporadic: several occ., but discontinuous, regular: several occ. and at least parts of curve continuous.

Occurrence frequency	*Melampyrum* sp.	Onagraceae	*Pteridium aquilinum*
No occurrence	7	21	12
1 occurrence	-	15	-
2 occurrences	-	7	3
Scarce	3	20	6
Sporadic	29	5	24
Regular	29	-	23
Total	68	68	68

7 People and fire managements

Most of the 68 sites represent a single-sequence approach, which is insufficient to reveal spatial patterns in past fires and to reconstruct realistic long-term fire histories (Ohlson *et al.* 2006:731). When all the sites are examined together, they represent a good basis for reconstructing how people used fire as part of their culture in the Mesolithic (as well as after agrarian culture developed in South Norway). The pre-Holocene results are discussed in a separate paper (Selsing in manuscript).

Most sites (48) have an accumulation rate between 0.07 and 0.32 cm/10 years (Fig. 3). One site has a lower accumulation rate, while eight sites have an accumulation rate of 0.35–0.40 cm/10 years and eleven sites have an accumulation rate of 0.43–0.79 cm/10 years. For comparison, the accumulation rate of anthropogenically affected sediments in harbours in West Norway in the Middle Ages and more recent times is 1.4–5.07 cm/10 years (Simonsen 1978, Mathisen & Prestmo 1999, Hansen 2003:87). Not surprisingly, this is much higher than the accumulation rate recorded in the present study as the supply of anthropogenic organic material is added to the natural organic deposition. The rate of accumulation close to the coast may often be high, particularly where the sediments are influenced by anthropogenic activity and deposition compared to natural accumulation alone. Elvestad *et al.* (2009:150–151, Table 1, three of the sites from which are also used in the present study) calculated the rate of accumulation for natural marine gyttja and freshwater gyttja without any known anthropogenic elements, mainly from isolated basins close to the coast in South Norway. This calculation showed a variation in the rate of natural accumulation rate from 0.1 cm/10 years to more than 1.0 cm/10 years, with an average of about 0.4–0.5 cm/10 years. The average of the 68 sites in the present study is below 0.29 cm/10 years, which is considerably lower. This is, for example, comparable to the accumulation rate (0.27 cm/10 years) before 6300 cal yr BP at a site in central South Finland (104 m asl) enclosed by forest, with no cultivated fields or settlement in its immediate vicinity today (Vuorela 1981:50–51). The reason for this result is probably that the present data set comprises all types of sites, from sea level to the mountain area. At higher altitudes and especially above the forest limit, but also at other sites with nutrient-poor environments, organic production and deposition has been low. This indicates that, as a group, the 68 sites are not or very little affected by nearby anthropogenic sources as e.g. rubbish from settlements.

Quantitatively, the most used of the selected terms (*maximum*, *continuous, low* (*values*) and *rise* (*upwards*)/*increase*) in the description of the 68 charcoal curves make up more than two-thirds of the terms used to characterise the charcoal curves (Table 5). Qualitatively, the terms may be divided into two groups used to indicate fluctuations (205 instances) and breaks (37 instances) in the course of the charcoal curves. This indicates that the vast majority of the charcoal curves or parts of them are continuous with fluctuations and maxima. The two terms *low values* and *rise* (*upwards*)/*increase* supplement each other because low values are often followed by rising values. Interestingly, the curves of the three fire indicating taxa (see below) are more predictable than the charcoal curves, which is also an indication of anthropogenic factors being an important reason for the course of the charcoal curves.

Generally, the vegetation was open during the pioneer period while soil was established (Fig. 8) and development followed the well-known pattern in Northern Europe. The vegetation became gradually denser, open forest took over (usually *Betula* forest) at the transition to the Holocene, followed by dense forest, usually from the transition to the Boreal chronozone (traditional *Pinus* forest with deciduous mixed forest during the early Holocene warm period at lower altitudes). The forest opened over a long period, starting before the transition to the Neolithic some places. It was succeeded by open vegetation in many places towards the present time. This general pattern of vegetation changes had regional and altitudinal deviations, such as open vegetation in the west (and the mountain area) at least since the transition to the Iron Age. Dense coniferous boreal forest dominated in the east up to about 400 m asl. The changes in vegetation density were not as homogeneous as previously proposed. The complexity may be site-dependant, confirmed by the fact that most sites were selected because of archaeological purposes. Anthropogenic factors, such as the use of fire in vegetation and agriculturally induced changes may have played a role in forest density as it appears in the pollen analyses.

7.1 The first occurrence of charcoal

Considering the 68 sites, 58 of the first occurrences of charcoal are younger than the transition to the Holocene (Fig. 4 centre). The frequency of first occurrences is high in the period 11,200–8500 cal yr BP and there are no first occurrences later than 7000 cal yr BP (Table 4). The earliest possibility of organic deposition in the basins is normally a little delayed compared to deglaciation (Cotter *et al.* 1984). The similarities between the pattern of the age of the bottom of the organic material (Fig. 4 bottom) and the pattern of the first occurrence of charcoal shows that deposition of charcoal at about two thirds of the sites started simultaneously with organic production. This shows that charcoal deposition started very early in many parts of South Norway, much earlier than the transition to the Neolithic. The final retreat of the melting ice after the Late Weichselian Substage occurred during the period 11,600–10,400 cal yr BP in the interior of South Norway (Vorren & Mangerud 2006:Map p. 514).

Generally, the climate in South Norway in the early Holocene was rather stable, dry and with temperatures higher than today. If the frequency and pattern of lightning strokes had been similar in the area of many of the 68 pollen diagrams, natural fires should have been the reason for the recorded pattern in the first occurrence of charcoal, including the early course of the charcoal curves. There ought to have been some parallels and/or similarities between the charcoal occurrences at the sites, at least for those in the same climate regions (see maps in Hanssen-Bauer 2005:Fig. 1 and 8) and the same vegetation zone. This is not the case. The early courses of the curves are different from site to site, as are the percentage values of charcoal occurrence. Based on these statements, it is unlikely that natural fires were the main reason for the first occurrence and the early course of the charcoal curves even if natural fires sometimes may have added to the charcoal deposition in some places.

The period 11,200–8500 cal yr BP, with a high frequency of first occurrences of charcoal, was characterised by the immigration of the trees. Open forest, primarily with *Betula*, were gradually replaced by dense *Pinus* forest with some *Corylus* from around 10,200 cal yr BP until about 8900 cal yr BP. Mixed and more variable forests dominated from about 9400 cal yr BP at least at lower levels. This means that there was a high frequency of first occurrences of charcoal deposited at the same time as the forest grew dense, which should have prevented deposition from the air.

In a forested landscape, which was the case for most sites at least until the end of the Middle Neolithic (Fig. 8), the deposition of long-distance transported microscopic particles constituted only a very small part of the total pollen deposition (Fægri & Iversen 1975:62, 175, Hjelle *et al.* 2006:151). This reflects an origin from below the crown layer and production of charcoal inside the forest in the area in question.

The expansion of settlements over vast areas during the residential camp phase (Housley *et al.* 1997) at the transition to the Holocene is well correlated with the oldest period with a high frequency of first occurrences of charcoal, starting around 11,200 cal yr BP. This period is the main immigration phase after the last ice age, and the entire Scandinavian Atlantic coast was occupied with many small sites within 200–300 years after the transition to the Holocene, based mainly on marine resources (Bjerck 1995, 2007, 2008, see also Fuglestvedt 1999, 2005). During this phase, the social pattern changed. Small and very mobile social units had high settlement mobility and little differentiated settlement sites. The regional variations in the material culture and the geographical differences between the sites were few, at the same time as the social territories were little developed until about 8500 cal yr BP (Bjerck 2007:19, 2008:78, 84, 90). A change in the social pattern resulted in a broader subsistence foundation than earlier, with the use of both marine and terrestrial resources (Bjerck 2007:21). This last part of the period with a high frequency of first occurrences of charcoal was characterised by a marine-oriented location pattern that included the use of the mountain area and the forests within large geographical areas through more complex, structured and well-organised seasonal migrations in the landscape (Boaz 1999a, 1999b). An increase in the regional differentiation of sites and the material culture characterised the settlement structure (Bjerck 2007:Table 2.3. p. 17 and 21–22, 2008:78, 94). Social units were larger, with an increased diversity of economic strategies that included seasonal activities

(Bjerck 2007:22). Both reuse of sites and differentiated sites may have been an obvious and integrated part of the mobile hunter-gatherer culture characterised by seasonal travels, with the expansion into the mountain area perceived as settlement in new areas and not a population expansion (Selsing 2010:209).

The period 8500–8100 cal yr BP with no first occurrences of charcoal and no sites with the bottom age of the pollen diagrams was characterised by mainly dense forest at lower levels. The dense canopy may have hindered both deposition of charcoal from the atmosphere as well as emission of charcoal produced below the canopy. About 8500 cal yr BP, a marked large and rather abrupt expansion and the start of the culmination of the settlement of the mountain area was recorded (Selsing 2010:218, 221, Fig. 45–47 and Table 31). The reason may have been improved economic possibilities in the mountain forest due to the culmination of the forest limit, which allowed all three of the big ungulates to be hunted more or less at the same time in the upper part of the subalpine forest. An increase in the total population was recorded, at least in the west (Nygaard 1990:234) for the period 8900–7800 cal yr BP. This period may have been characterised by few new migrations in the lowland, where most sites were located, and therefore no new first occurrences of charcoal at the pollen sampling sites.

The period 8100–7000 cal yr BP with a low frequency of first occurrences of charcoal, including a hiatus 7900–7400 cal yr BP, may find an explanation in the marked culmination in the seasonal yearly settlement of the mountain area, which lasted until 7600 cal yr BP (Selsing 2010:221, Fig. 45–47 and Table 31). Probably few new migrations and settlements in the lowland, combined with mainly dense forest, caused few new first occurrences of charcoal. This can also explain that six of eleven of the recordings from this period are from higher areas (660–950 m asl) because an expansion and culmination of the settlement in the mountain area implies that the settlement in the higher areas between the lowland and the mountain area also increased. At this level, the deposition of charcoal particles was facilitated because the forest was more open compared to the mostly dense forest at lower levels (Fig. 8).

The first occurrence of charcoal is severeal thousand years older than the transition to the Neolithic, which is much earlier than the archaeological record of agrarian cultures. It can be ruled out that the first period with a high frequency of first occurrence of charcoal is correlated with agrarian cultures in South Norway. Nor is it possible that natural fires could have been an important agent in the environment. The pattern of first occurrences of charcoal strongly indicates an anthropogenic origin from a hunter-gatherer culture.

7.2 The maximum occurrence of charcoal

The older of two periods with a high frequency of maximum occurrences of charcoal is 9800–6000 cal yr BP (Fig. 4 top and Table 4). Preceding this period, a low frequency of maximum values of the charcoal curve is recorded since the beginning of the Bølling chronozone 15,200–9800 cal yr BP. Compared to the first occurrence of charcoal (Fig. 4 centre), the first recording of maximum occurrence is delayed by only 400 calendar years.

7.3 An early period with a low frequency of maximum values of the charcoal curve

The pattern of the maximum occurrences since the earliest record and the continuation into the Holocene provides additional information. If the origin was long-distance transport, it should be expected that charcoal was deposited at all sites, only dependant of the density of the forest. This is not the case. Natural fires would probably give a sporadic pattern of charcoal occurrence, while many charcoal curves are more or less continuous. It could be that local fires in the woody shrubs and dwarf shrubs added to the maxima. Thus, the reason for the delay of 400 calendar years may have been that the areas empty of people were characterised by long-distance transported charcoal and were initially used sporadically by few people (Selsing in manuscript).

The approaches of Fuglestvedt (2009) and Selsing (2012) provide a basis for understanding the cultural strategies needed to profit from new landscapes in South Norway. Probably, the mobile people during the early part of the residential camp phase developed and established a culturally defined fire management of the vegetation to improve their profit from nature during the early period of the immigration of the trees and the forest.

7.4 The oldest period with a high frequency of maximum occurrences of charcoal

The period of high frequency of maximum occurrences of charcoal, 9800–6000 cal yr BP, is delayed about

1400 calendar years compared to the beginning of the highest frequency of first occurrences of charcoal. This period was characterised by new settlements along the coast by a small and increasing mobile population of hunter-gatherers, who soon used the forests and the mountain area over large geographical areas, through systematic migrations in the landscape. The use of fire management in the vegetation may have been adapted to the natural conditions with still denser forest. One of the cultural strategies to ensure the basis of subsistence was to develop and expand the use of marine resources (Bjerck 1995, 2007, 2008). Another was to follow the old reindeer hunting traditions from the Continent, as long as the animals lived in the lowlands, which, based on radiocarbon dates from Denmark (Aaris-Sørensen *et al.* 2007), probably lasted until as late as the last part of Preboreal chronozone (Selsing 2010, 2012). Just like conscious burning of vegetation was a way to increase the concentration of ungulates, the reindeer herds on the European Continent before the Holocene—compared to other ungulates—may have functioned mentally as an ideal to the people, who also lived in groups. The refuge of the reindeer herds in the open areas of the mountains in Scandinavia may have had a special role at least in some hunter-gatherer societies (Selsing 2012). When the forest gradually dispersed during the Preboreal chronozone, non-gregarious ungulates immigrated together with other terrestrial animals (Lie 1986, 1988, Grøndahl *et al.* 2010).

Foragers' intentional burning during the Mesolithic is recorded in South Norway and other places in northwest Europe. Mikkelsen (1982:131, 1989:60, 284) interpreted layers and particles of charcoal and charred pollen in Telemark as traces of burning for forest clearing. Fuglestvedt (1992:178) regarded the burning of woodland to improve the vegetation for game animals as a reliable situation in the Late Mesolithic around the Svevollen site, East Norway. Three sites in Southwest Norway (Prøsch-Danielsen & Simonsen 2000a:28, 35, 50) show that pre-Neolithic heathland establishment may have started as early as 8600 cal yr BP (two of these sites are included in this study and are situated close to known Mesolithic dwelling sites). The very early deforestation may have been facilitated because of the location close to the exposed North Sea coast (Prøsch-Danielsen & Selsing 2009:85–86).

Also at the coast of the Baltic Sea in South Sweden, data might add to the idea of the use of fire before the *Ulmus* decline (Håkansson & Kolstrup 1987:6, 15). A sudden, high percentage of charcoal indicates fire near the site caused by people intentionally opening the surrounding forest. At the South Swedish site Sturup, foragers' use of fire management probably occurred in the forest close to two Mesolithic sites (10,200–8900 cal yr BP) (Welinder 1971:193–195, 1983b:40–42, 1989:363). This is at the same time as the beginning of the high frequency of maximum values recorded in this paper. At the Dalkarlstorp site, close to a Mesolithic site in South Sweden, either forest fires or charcoal blown from the domestic hearth occurred 7400–6800 cal yr BP (Welinder 1989:364–365). The increase of red deer in the Atlanticum chronozone at an archaeological site in Sweden (Liljegren & Lagerås 1993:34) was attributed to people's ability to secure the availability of the prey. The ungulates that were utilised by people in the Mesolithic in Denmark all prefer open areas in the forest created by burning (Bay-Petersen 1978:127–128).

Human activities in the Mesolithic on the British Isles may have had considerable effects and there is clear evidence of human influence on the vegetation and the constitution of the flora (Smith 1970:86, 88, Blackford *et al.* 2006). From early in the Atlantic period onwards, people's activities affected the vegetation well outside the immediate vicinity of their living places (Smith 1970:90). There is commonly evidence of fire in Mesolithic settlements and, in some instances, in places where little indication of the presence of people has been found (Smith 1970:93). The disturbances were suggested to have been caused by human activity with fire as an integral part of the Late Mesolithic economy. The study of Jacobi *et al.* (1976) supported strategic regular and recurrent burning in North England, implying perhaps one tenth of a given area of range per season. Burning the vegetation is suggested to have led to a permanent suppression of a closed tree cover over large areas above an altitude of about 350 m asl. For Southwest England, a record of charcoal about 8500 cal yr BP was attributed to the activities of Mesolithic communities (Caseldine & Maguire 1986, Caseldine & Hatton 1993, 1994:40, Caseldine 1999:577–578). Fire events were regionally continuous in English uplands from about 7000 cal yr BP but ceased thereafter until later prehistoric times (Simmons 1969, Innes *et al.* 2010:448). Innes & Blackford (2003) tested fire disturbance in the Late Mesolithic in North East England that offered support for environmental manipulation of woodland with widespread burning which ended in the Neolithic.

7.5 The youngest first occurrences of charcoal

The youngest first occurrences of charcoal in the pollen diagrams are 7000 cal yr BP, which is 1000 calendar year older than the transition to the Neolithic. All charcoal curves began well before the Neolithic and the first occurrences are not correlated with neolithisation, nor do they add information about the early development of agrarian cultures in South Norway. The charcoal deposition had started all over South Norway a thousand calendar years before the end of the oldest period with a high frequency of maximum occurrences.

7.6 A late period with a low frequency of maximum values of charcoal

The transition to the Neolithic 6000 cal yr BP is characterised by a change from a high to low frequency of maximum values in charcoal that lasted until 2400 cal yr BP. The traditional Norwegian archaeological transition between foragers in the Mesolithic using fire management and the Neolithic, with agrarian people using slash-and-burn technique that involves the cutting of forest and fire for agricultural purposes, is possible to identify in the charcoal occurrence in South Norway (Fig. 4 top). This transition may also have involved the change from hunting wild game to primarily domesticated livestock after the Mesolithic. One reason for decrease in charcoal maximum values may be that, once the forest was cut and burnt, the pasturing livestock reduced the possibility of forest expansion and frequent burning was not necessary unless pastures needed to be expanded.

Comparable results were recorded in East England, where the lowest rates of charcoal deposition in the Holocene are immediately after 5700 cal yr BP with an increase in charcoal deposition much later in the Holocene. In this case, Bennett *et al.* (1990b:637, 639–640, see also Edwards 1985, 1988:81 and Innes *et al.* 2010:448) suggested that the origin of the early Holocene record of charcoal probably originated from domestic fires from settlements near lake margins. The low rates of charcoal deposition may be seen as a shift in settlement pattern from lakesides occupied by hunter-gatherers to upland agricultural sites occupied by early farmers. The record from 5700 cal yr BP onwards may be explained by increasing use of fire as a land clearance tool in areas remote from the lake basins used for pollen analysis.

The change of land-use strategy in the English uplands between the Mesolithic and Neolithic caused "[…] changes in the location, availability and size of exploited herbivore populations and so the end of any requirement for widespread woodland burning." (Innes *et al.* 2010:448). This change in land-use strategy probably also occurred in South Norway and caused a decrease in the requirement for woodland burning at the same time as the location of fire management may have changed geographically because the aim of the burning changed. However, geographical changes in location did not always occur (Hjelle *et al.* 2012:1378). At the coast of central Norway, during the first phase of agriculture, settlement sites from the Mesolithic were resettled, used for cultivation, and grazing. Moore (2003:143) argued for England that the transition to the Neolithic was not only a simplistic removal of forest, clearing the land for agriculture, but also a shift from interaction with nature to domination of nature, i.e. a shift in culture and ideology.

The deforestation process is well-known in Southwest Norway, where it seems to have been metachronous, leading to a regional mosaic pattern of different vegetation types (Prøsch-Danielsen & Simonsen 2000a, 2000b, see also Mehl 2014:20 Fig. 7). The three clearance periods, all in the time interval between 5800 and 3300 cal yr BP correspond to the first part of the last period with a low frequency of maximum values of charcoal in the present study. The charcoal curves are characterised by a more or less continuous increase upwards, as a response of anthropogenically induced clearance, deforestation and heathland establishment, which became permanent mainly because of repeated burning.

To sum up, the charcoal occurrences recorded in this paper started already during the Late Weichselian Substage, quite earlier compared to a model of non-intentional burning of the vegetation before the transition to the Neolithic. The two periods with high occurrences of maximum values of charcoal were separated into an early period, in the early Holocene, and a later one, in the late part of the Holocene, respectively, and not in the middle part. The transition to the Neolithic is characterised by a decrease in maxima in the charcoal occurrence. The generally dense forest in the Mesolithic and opening of the forest after the transition to the Neolithic actually indicate more intense burning during the Mesolithic than otherwise indicated from the charcoal occurrences. If the charcoal curves should be interpreted in the same objective way throughout the Holocene, this result shows that the charcoal curve during the Mesolithic (mainly) originated as an effect of human burning activities.

7.7 The occurrences of pollen from *Plantago lanceolata* and cereal-type pollen compared to the occurrence of charcoal

The early occurrences of *Plantago lanceolata* in South Norway since 10,200 cal yr BP (Fig 7 bottom and Table 3) may have been the result of transport in the fur of pasturing ungulates from the coast, where the plant is assumed to have grown soon after deglaciation (Iversen 1954, Simonsen 1980). These sporadic occurrences may have had their origin in small clearances in the forests made by purposeful alteration of the vegetation towards the forest margins (Simmons 1975:7).

A marked increase in the frequency of the first occurrence of *Plantago lanceolata* is in the period 5600–1600 cal yr BP with the highest frequency in the period 5600–3700 cal yr BP. The pollen appears in small quantities before the generally archaeologically accepted breakthrough of agriculture about 4400 cal yr BP (Prescott 2009, Høgestøl & Prøsch-Danielsen 2006, see also Smith 1970:88 for The British Isles). The first small-scale agricultural activities may not be reflected in the pollen spectra, but *Plantago lanceolata* could be traced (M. Tolonen 1983:167, see also Behre 1981:229, 234–235 and Kolstrup 1990:253–254). Hjelle *et al.* (2006:152), assuming that the agricultural activity probably was small and had little effect on the traditions of the hunter-fisher economy at the coast.

The earliest indication of cereal cultivation is dated to the Early Neolithic along the coast of central Norway, indicating that knowledge of agriculture arrived early in this area (Hjelle *et al.* 2012:1377), confirmed by early finds from the south coast and eastern part of South Norway (Prøsch-Danielsen 1996:95, Høeg 2005:36). On the other hand, early occurrences of cereal-type pollen may be ascribed to the large pollen of natural grasses (Fægri & Iversen 1966:195–197). Compared to *Plantago lanceolata*, the frequency of the first occurrence of cereal-type pollen is generally low. The start of maximum in first occurrences of cereal-type pollen is 800 calendar years later than the start of maximum in first occurrences of *Plantago lanceolata*. This may indicate that animal husbandry had long been successful in a number of areas before cereal was successfully grown in more places. The reason for the long period of cereal-type pollen may be that attempts at growing cereal may have been carried out occasionally but without success. Many of the sites may not have been suitable for cereal growing.

The neolitisation process in South Norway was earliest in East Norway, and later and less clear in the west (Østmo 1988, Høgestøl & Prøsch-Danielsen 2006). A probable change in the utilisation of resources, resulting in animal husbandry in West Norway, was traced from the Early Neolithic (Hjelle *et al.* 2006:150–152). Early traces were also recorded around the coast to Telemark in the southeast and in the inner part of the country. This corresponds to the first part of the last period with a low frequency of maximum values in the charcoal occurrence and the first occurrences of *Plantago lanceolata*. A gap without maxima in the charcoal curves found in the time interval 4500–4000 cal yr BP might be an indication of the end of any requirement for widespread woodland burning (Innes *et al.* 2010:448). This period corresponds to a change towards an agrarian economy in the Middle Neolithic II (4500–4200 cal yr BP). The end of this period was probably the final phase of the indigenous forager-culture in West Norway (Bergsvik 2012). The process that resulted in the general breakthrough and establishment of agriculture happened in the lowlands at the transition to the Late Neolithic about 4200 cal yr BP and 100–300 years earlier in Southwest Norway (Hjelle *et al.* 2006:154–155, 165, Høgestøl & Prøsch-Danielsen 2006, Prescott 2009, Glørstad 2012, Prescott & Glørstad 2012:4). The traces of people in the mountain area slowly also included activities connected to an agricultural culture (Boaz 1998, Bang-Andersen 2008, Selsing 2010:244–245). The palynological, archaeological and domesticated animal bones data presented in Hjelle *et al.* (2006) confirm the establishment of an agrarian society in the Late Neolithic.

In general, farmers may have taken over for hunter-gatherers in the period 4500–4200 cal yr BP, perhaps with a weak start already from 6000 cal yr BP. The location of the settlement sites changed from places where the natural economic resources were available for the hunter-gatherer economy to places where it was appropriate to keep husbandry and/or grow cereals close to the settlement site. Such changes would result in a change in the use of fire, from selective small-scale and local fire management to improve and concentrate access to natural resources to forest clearance for agricultural purposes, using e.g. slash-and-burn technology close to the settlement sites. In general, the charcoal curves changed from low, but changing values with maxima to charcoal curves characterised by an increase in the charcoal with few maxima.

7.8 The last period of a high frequency of maximum values in the charcoal curves

The last period of a high frequency of maximum values in the charcoal curves started around 2400 cal yr

BP at the transition to the Early Iron Age. This is the most intense period of maximum values in charcoal, increasing towards the present. This corresponds with the complete, or nearly complete, clearance of the forest for agricultural purposes in parts of South Norway and other parts of Northern Europe and expansion in man-made heathland in the west (e.g. Moe *et al.* 1978, Kaland 1979, 1986, Håkansson & Kolstrup 1987, Peglar *et al.* 1989, Høeg 1995:299, 305, 1996:120, Prøsch-Danielsen & Simonsen 2000a, 2000b, Nielsen *et al.* 2012, Fyfe *et al.* 2013).

7.9 The occurrences of three selected pollen taxa favoured by fire

Generally, the occurrences of *Pteridium,* Onagraceae and *Melampyrum* are discontinuous with low values and few maxima, especially for Onagraceae (Table 6).

The age of the first occurrence of *Pteridium* is 15,200–3300 cal yr BP with the highest frequency of first occurrences in the period 9600–6800 cal yr BP (Fig. 5 top). The age of the maximum value is within the period 15,000–500 cal yr BP with a tendency to higher frequency clustered around 7600–6500 cal yr BP and 4200–1900 cal yr BP (Fig. 6 top). This shows a weak indication of *Pteridium* being associated with agriculture rather than a forager culture.

The age of the first occurrence of Onagraceae is 16,700–900 cal yr BP with the highest frequency in the period 13,600–7100 cal yr BP (Fig. 5 centre). The four observations of maximum values are scattered in the period 10,100–2700 cal yr BP (Fig. 6 centre). This shows a weak indication of Onagraceae being associated with hunter-gatherer culture rather than agricultural activities.

The age of the first occurrence of *Melampyrum* is 13,700–3900 cal yr BP with the highest frequency in the period 11,300–6800 cal yr BP and only three first occurrences younger than 4500 cal yr BP (Fig. 5 bottom). The maximum value is scattered from 10,400 to 700 cal yr BP with a tendency to increasing frequency 7000–700 cal yr BP (Fig. 6 bottom). This indicates that the occurrence of *Melampyrum* is primarily associated with agriculture rather than hunter-gatherer culture even if the maxima in the first occurrences are associated with the early part of the Mesolithic.

The distribution of the first occurrence of *Melampyrum* and *Pteridium* has similarities with the distribution of the first occurrence of charcoal, but with some few first occurrences after 7000 cal yr BP. The distribution of the first occurrence of Onagraceae is not as concentrated as *Melampyrum* and *Pteridium.*

The correlation between one or more of these selected taxa and fire is generally weak. Only a few sites may indicate an obvious correlation between the occurrence of one or more of the selected taxa and the charcoal curves. Nor is their occurrence well correlated with changes in the vegetation. The sporadic occurrence may be attributed to dense forests, insect-pollination or self-fertilising and therefore limited dispersal of pollen and spores.

8 Proposal for a fire management model for hunter-gatherers in the Mesolithic

In this chapter, ethnographical analogy is used to put the results into a cultural frame.

All anthropogenic fires defined the relationship between people and the lands they lived on (Pyne 1993:248). Archaeological evidence suggests that most of the basic technical equipment available to modern hunters was already available in the pre-Neolithic period (Woodburn 1980:113). This theoretical model of the impact of foragers is based on several authors e.g. Cronon 2003 [1983] and most of all Lewis (1973, 1977, 1982) because his studies concerning the indigenous peoples of California, USA, and Alberta, Canada, contain many details about the burning traditions of foragers. In addition, the Canadian study was carried out in the boreal forest zone. Indigenous people also utilised fire in their management of the deciduous forest in New England, USA (Moore 1996:66–67) and many other places in the world.

The indigenous people of South Norway did not simply use the habitat as they found it. They probably had a full understanding of the systemic, relational effects of burning and of the variable ecological relationships that result from both natural and man-made fires (see Lewis 1982:46–47). It was vital that the fire neither failed nor ran wild, and they had to maintain the fires they lighted (Pyne 1993:246, 248). Foragers' organisation of knowledge about boreal forest adaptations involved a complex, systematic structure of ideas about environmental relationships (Lewis (1973, 1977, 1978:3, 1982:17, 48). They may also have had knowledge about what we today would call the ecological succession of plant species that grow after a fire and the responses from the fauna (Clarke 2011:65 [2007]). Species structure and community processes change as well as the complex networks of the relationship between plants, herbivores and predators (see Lewis 1977:20–21, 1982:9, Lewis & Ferguson 1988:70). Their knowledge of the multifaceted role of burning and control mechanisms is confirmed by present-day ecological knowledge. It is the same as modern fire fighters consider being the best (Lewis 1977:24, see also Botnen 2013) and the recommendations of contemporary science being superior. Lacking a scientific terminology, foragers enveloped their knowledge in a "spiritual" framework (Grøn 2012:177).

People in the Mesolithic had the equipment to improve the environment for the animals, especially fire, and it would be naive to suppose that fires would be started by accident (Simmons *et al.* 1981:103). Hunting and gathering were not simple, unorganised activities but involved a dynamic manipulative land-use strategy. The object of using controlled burning may have had the same main purposes everywhere, i.e. to alter local habitats through systematic burning to create and maintain herb vegetation and open forests with a grassy floor and controlled small-scale fire mosaics. Fire has an ambiguous nature; it is both an important tool and a potentially dangerous hazard. It reduces the possibility of catastrophes caused by uncontrolled wild fires over a large area, which may have been viewed as dangerous and potentially destructive (Lewis 1982:1, 27, 33–34, Grøn 2012:178–179).

Fires were not just started anywhere, anytime and seasonality may have been the most basic control (see Lewis 1973:79, 1977:15, 23). Regularity and the frequency with which fires were set were important considerations, not too often and not too seldom, annually or even several times a year if necessary. Foragers in South Norway may have taken into account the general weather conditions when determining when and when not to burn. The weather conditions, not the calendar, determined the schedule for burning (Lewis 1982:25). Wind regime and directions may dictate when to burn, as it was the singularly most important consideration with regard to burning conditions; there must not be too much wind. At the same time, controlled fires will not develop if it is too wet.

For security, the settlement areas were probably located in, or transformed into, open places and not in the dense forest. Annual burning of ground cover around and at settlement areas and campsites may have made them fireproof (see Lewis 1977:26, 1982:29, 38, Lewis & Ferguson 1988:69). An archaeological site is traditionally defined through the presence of material traces after people and does not include the surrounding areas, which in most cases were also in use and not a wild, unorganised tract surrounding settlement sites (Grøn *et al.* 1999:20, Sjurseike 1999, Berg-Hansen 2001). The archaeological site is normally regarded as a unit where a number of daily activities took place, while the concept of settlement site used within ethnography emphasises the human relationship to, and the use of, the landscape in a larger area (Grøn *et al.* 1999, Berg-Hansen 2001:183, 2009, Jordan 2001, 2003, Grøn & Kuznetsov 2003:219). By including the surrounding areas in the archaeological site as an extended settlement site, the intentional burning of the vegetation on and surrounding the settlement sites becomes a part of the archaeological site and not simply vegetation that could have been influenced by people.

Probably the clearings for grazing areas did not contain any habitation or settlement sites i.e. because it would have disturbed the ungulates. Regular fires promoted what ecologists call the "edge effect", the boundary areas between vegetation types such as forest and grassland (Cronon 2003:51 [1983]). Probably, the foragers did not set fire to large areas of forest, but regularly and systematically expanded the naturally created openings such as the edges of streams and other corresponding environments (Lewis & Ferguson 1988:57, Moore 2003:140). The pyrotechnology contributed to an overall fire mosaic that formerly may have characterised northern boreal forests. The Norwegian foragers may have had insight into food chains and they probably created a variety of local ecotones, diversified available natural resources and facilitated cross-country travel (see Lewis 1982:7, 29).

It was probably well-known to the foragers in South Norway that the annual yield is larger during the early stages of succession, characterised by species most important to people (see Lewis 1977:21, 1982:12). The foragers may have prepared the ground to receive seeds from the natural vegetation, recognising that some species require fire to germinate seeds and initiate new plant growth (see Lewis 1973:73).

If an area was to be maintained as pastures, subsequent small fires could have taken place when the winter snow was melted and the grass was sufficiently dry (see Lewis 1973:72, 1982:37, Lewis & Ferguson 1988:64, 70). Foragers in South Norway who burnt a site probably planned to go back to hunt there because they had already invested in the site (see Lewis & Ferguson 1988:70–71). They may have named the places to inform each other about the hunt (see Lewis 1982:31–32).

Hunter-gatherers in South Norway could have repeatedly set fire to wood piled around the base of standing trees, which would have destroyed the bark and killed the trees completely; a simple method used by indigenous people in New England, East USA (Cronon 2003:48 [1983]). Probably, the hunter-gatherers in the Mesolithic were aware that deadfall-windfall forests devoid of game could be a serious threat to the surrounding forest if ignited by lightning (see Lewis 1982:36–37, 43, Lewis & Ferguson 1988:68, 70–71, 74). It was impossible to travel in the areas with a tangle of fallen trees, which represent a much greater risk for natural wildfires than periodic intentional burning because of the greater flammability of the fuels. Annual fires set within windfall and deadfall forests may have been recognised as a necessary feature in the Mesolithic. These fires may have burnt for a long time, with the people often returning the next year to burn it more; then after some years, this place would become open.

Probably, the South Norwegian foragers had the same experience regarding firewood as the Canadian indigenous people, where a frequently mentioned reason for burning trees was to obtain firewood (Lewis 1982:37, 54). Fresh cut wood takes a long time to dry out thoroughly, while partially burnt wood is excellent, pre-dried fuel. People in the Mesolithic could have burnt the trees growing at the edge of the grassy openings and the fringe areas of the settlement area repeatedly. This would scar and subsequently kill the trees growing there. Another way to obtain firewood was recorded by Grøn *et al.* (1999:23) from an Evenki settlement to the northeast of Lake Baikal in eastern Siberia. Here, the bark was stripped off to dry out the trees, which were later cut down.

The density of the forest (see Chapt. 4.5 and Fig. 8) influenced movement and communication in the landscape. Burning may have resulted in a combination of different sizes of openings, corridors and mosaics of these within the forested area and the repeatedly burnt areas would have made movements and hunting in the forest much easier (see Lewis 1982:39, Lewis & Ferguson 1988:69). In this way, utilisation and activities were concentrated in predictable places in larger areas outside the settlement site. Without doubt, the South Norwegian hunter-gatherers would have kept a network of paths to increase the mobility of people and animals and to improve information exchange (Selsing 2012:191–194). Actually, pastures, watercourses, and paths may have constituted a network of fire-maintained habitats. Fire corridors may have made up the margins and fringes of streams, lakes and mires, ridges and paths, while densely forested areas may purposefully have been left unburnt (see Lewis & Ferguson 1988:60–61). People would have used narrow corridors connecting their extraction areas at strategic points or zones (Grøn 2012:178). If their chief mode of transportation was water transport, they had less need of paths (see Cronon 2003:50 [1983]). Animal paths may have been enlarged simply through continued human use as footpaths. By using fire, paths were kept exposed to sunlight and free of underwood, thus keeping the walking surfaces relatively dry (see Lewis 1982:40, Cronon 2003:28, 47, 49 [1983]).

People in the Mesolithic in South Norway may have had traplines used for fur hunting as a part of the annual cycle (see Hufthammer 1988, Lewis & Ferguson 1988:69, 71, Gustafson 1989:22–23, 1990, Mikkelsen 1989:Table 9). They knew where to trap the important fur animals, such as beaver, and the yearly trapping trips were easier if burning was used. Frequent burning favours beaver, which disappear in the late succession stage if there are no fires for a long period (Loope & Gruell 1973:440, Rowe & Scotter 1973:460). The traplines often may have been maintained as corridors, and paths following the watercourses, where the vegetation provides a suitable habitat for selected fur-bearing species (see Lewis 1982:31–32). An appropriate fire method could follow the pattern used by the indigenous people of Alberta, Canada (see Lewis 1982:32, Lewis & Ferguson 1988:68, 70, 72). Annual fires set right on the path were recognised as a necessary feature of their strategy and the following year, they returned to the same path. Path-side fires may have been set at the end of the trapping season, when they were on their way home from spring hunting, just before all of the snow melted. The burning vegetation along the lines while the surrounding forests were still damp could result in a string of small fires that burnt to the wetter part of vegetation and went out.

Ethnographical sources indicate that the drainage systems were important communication systems, constituting cores for social territories, or borders, or meeting points in no-man's land (Rogers 1969:43–44, Osgood 1970:5 [1936], Forsberg 1985, Vorren & Eriksen 1993, Fuglestvedt 1998:68, Brody 2002a:175–176, 195 [1981], Selsing 2010:309, 2012, Hadler *et al.* 2012). Mires, lakes and rivers constituted openings in the forest canopies and important routes of communication may have included these natural openings in the Mesolithic path-systems. Important resources, such as fish, game and birds are concentrated here. Probably, systematic burning of the vegetation took place before nesting during spring, since they may have profited by an influx of more ducks and geese (see Lewis 1982:41–42, Lewis & Ferguson 1988:65). The right time of the year for burning was when the new vegetation and animal breeding would not be destroyed, resulting in a missed season.

The practice of signal fires could have been used by the hunter-gatherers in South Norway, following the same strategy as the indigenous Canadians in Alberta. They set fire to individual isolated trees to make a lot of smoke, always on high ground, where they were visible for long distances (see Lewis 1982:44–45). No examples were found of signal fires having been used in flat landscapes, with the continuity of vegetation cover preventing such practices.

People in the Mesolithic in South Norway may have calculated the frequency of burning in terms of the relative build-up of fuel strategies. Burnings in the forest probably took place, whenever a sufficient fuel load accumulated to carry a fire through one stand to another. Regular fires reduced fuel loads and prevented or reduced the severity of high-intensity fires that could spread widely (Førland *et al.* 1974, Sow *et al.* 2013). By removing underwood and fallen trees, the Norwegian hunter-gatherers may have acted as the indigenous people in New England, USA. Accumulated fuel was reduced by ground fires and, with little vegetation to consume, the annual fires moved quickly, at low temperatures, and soon extinguished themselves (Cronon 2003:50 [1983]).

Forest fires may have been viewed as essentially destructive (see Lewis 1982:33–34) because they would have destroyed the soil, including roots and other overwintering organs. New vegetation would then only spread with seeds and regrowth would take perhaps 10–15 years or more. Without fires, trees invaded most areas within a few decades (Granström 1993:737, 743). The indigenous people probably knew that strong fire easily develops into a crown-fire that spreads quickly at high intensity and may develop into megafires (Stocks *et al.* 2004:1543, Leys *et al.* 2013). Hunter-gatherers may have used natural firebreaks (e.g. streams, lakes, headwind and wet vegetation such as mires or recently burnt areas) when burning as a possible means of stopping the movement of fires if necessary (see Lewis 1982:13).

8.1 Consequences of intentional burning for the culture of hunter-gatherers

Included in controlled burning was the dynamic for cultural change for the people who mastered it (Mellars 1976:40). It was probably an integrated part of the daily life of hunter-gatherers in South Norway and an important part of their cultural practice. This resource strategy had important implications for foragers' culture with regard to settlement, population density and control over resource needs (see Lewis 1973:85). The processes were not only mental, but also involved the physical transformation of particular locations (Jordan 2003:137).

The mobility of the hunter-gatherers in South Norway affected different aspects of their lives (e.g. Kelly 1995:111, Knutsson 1995:199, 203). Their way of living left few material traces, especially as long as they were mobile, because they had to carry all their possessions on their yearly round (Knutsson 1995:181). The cultural landscape they left was nearly free of monuments, artefacts and other cultural structures. The traces they left—garbage of long-lasting stones from production and use, and most of all charcoal – must be interpreted in relation to their culture. People could have used the Western Isles of Scotland at the transition to the Holocene, as indicated by charcoal, but there are no supporting archaeological data (Bennett *et al.* (1990a:296). Following Moore (1996:70), the recording of microscopic charcoal could identify areas of activity without the presence of artefacts.

Charcoal inevitably occurs at nearly all archaeological sites indicating the use of fire. It is a good indicator of Mesolithic hunter-gatherers in South Norway. Anthropogenic use of fire may have included more or less permanent repeated and recurrent burning. Places of burning may have changed over time because of changes in the mobility and yearly round with a cultural and empirical foundation. In the later part of the Mesolithic, the settlement system was more permanent, with reduced or little mobility. One reason may have been that the fire regime resulted in the concentration of resources and thus predictability, resulting in a concentration of people and a more sedentary life.

The intensity and changes in mobility affected how stable the settlement sites were and where to burn. Probably, different groups of South Norwegian foragers had different traditions of mobility and migration cycles, but as a rule, they moved around according to their traditions and the availability of resources, i.e. from the coast to the mountain area in the west and from coast to the inland areas in the east. The timing of the burnings may often have been related to these annual cultural events.

Intentional burning was performed as a permanent, moderate, repeated and regular strategy in the same way as the coastal heather has been managed later (see e.g. Bird *et al.* 2005, Grøn 2012). That is why it is impossible to identify single short-term intentional fire events in the vertical resolution of the pollen diagrams.

The ability of fire to produce changes and local concentrations of resources may have become important for social organisation, settlement strategies, economic organisation and the long-term economic development of the Norwegian hunter-gatherer cultures. It allowed an increase in population compared to areas without fire management. Another effect is the minimising of the distance between the location of a settlement and concentrations of resources (Mellars 1976:35). This reduction in distance could be achieved either by moving the settlement close to concentrations of resources in burnt areas or, alternatively, by using burning as a means to get concentrations of special resources close to the selected settlement site (Mellars 1976:35). The latter strategy has the advantage that the location of the settlement can be chosen to achieve an effective utilisation of other resources that are not directly under human control, such as fresh water, special raw materials and resources from rivers or the coastal environment (Mellars 1976:36). Collaboration among people may have been key in their culture, as more than one person would usually have been needed to carry out the burning.

Generally, hunter-gatherers do not practice ownership of their territory and the borders are not marked; sharing of collective goods is also valid in other areas (Brody 2002b:118, 190 [2000]). They rarely accept individual rights to areas (Broch 1982:41) and usually they do not legitimise possession of an area; on the contrary, they rather avoid it. This reflects that they do not divide the landscape in relation to power strategies (see Selsing 2010:274–275). The maintenance of the pastures may have been seen as a form of public domain with community interests and community responsibilities involved.

Energy may have been used to manage, maintain and improve the available resources by fire. Ownership may have developed in relation to the areas as well as the larger animals in the area and the plants that grew there (Mellars 1976:39). The origin of the idea of ownership of animals, or at least of defined areas, was a condition for the change in the precautions taken to maintain the resources (Mellars 1976:41). It is a question if this happened first when the population grew and resources were stressed. The tendency of animals to concentrate in areas of recently burnt vegetation could also result in a form of common hunt (Mellars 1976:39). Burning, however, could contribute to the process that gave hunter-gather groups common usage of areas by tradition (Mellars 1976:38–39), and which could develop into territories (Selsing 2010:275) because the labour input may have contributed to the establishment of a right to the managed areas. Increased population density may have been an incentive to define distinct territorial limits and fire management may have resulted in ownership to economic resources in the end.

This study has proposed a fire management model for the Mesolithic in South Norway, but the results are probably applicable to foragers in the past in other areas of the boreal forest zone. It concerns Europe in particular but probably also applies to Siberia as well as North America (e.g. Brody 2002a:1 [1981], 2002b:255 [2000], Grøn 2012). Results of the discussion by several authors concerning density of the forest would have been more constructive if they had included fire management in pre-agrarian cultures in their discussion. It should have been possible as so many of the references used in this study are earlier than the author's discussion. However, as recorded by Lewis (1977, 1982), the inclusion of hunter-gatherer fire management has only been sporadic and peripheral in the running discussion among researchers within vegetation history, archaeology, ethnography and ecology.

9 Regional distribution of patterns of fire management in South Norway

Because of the varied geography in South Norway, the impact of intentional burning may have been different in different regions. The forest during the Mesolithic in South Norway is considered to have been mainly dense even if the present palaeoecological archive demonstrates that the temporal and spatial variations in the forest density were more variable, with more open forests and clearings in the forests than traditionally viewed (Fig. 8). This was confirmed by Hjelle *et al.* (2012:1378), who concluded for the coast of central Norway that a high degree of heterogeneity in the vegetation was found, with a change from forests with openings in the Mesolithic to larger openings in the Late Neolithic and Bronze Age. This corresponds to the description of the British forests in the Mesolithic, which did not form a solid cover across the country but were characterised by edge habitats, patches and openings originating from natural and anthropogenic actions (Moore 2003:140, Fyfe *et al.* 2013). Nielsen *et al.* (2012) also confirmed this for Denmark and North Germany. This more nuanced picture of the variations in forest density than earlier indicates that human impact may be in combination with instability in the natural state of ecosystems (Tipping 2004). Figure 8 also indicates the differences in density from sea level to the mountain area. The forest density during the Mesolithic was highest in the east, up to about 400 m asl, while many sites in the west, especially the fjord districts, had forests that were more open, probably due to the often rocky topography.

The hunter-gatherers of South Norway probably moved in and out of areas of variable productivity. The population may have been too small to be able to burn regularly in larger areas; extensive fire management was unnecessary and their impact on the physical environment was not widespread. Localised burning was apparently well distributed at all elevations and frequent on a regular and consistent basis at strategic places, leaving large, more remote areas unused (see Lewis 1973:65, 70, 84). These forest modifications probably included many open patches with herbs, as a rule small in size, but stable over time (Davies *et al.* 2005:286).

Probably, foragers in South Norway depended on more than two major vegetation zones for their subsistence and made use of several vegetation sub-types and microhabitats in these zones (see Lewis 1973:14, 16, 82–83). The most fundamental component of this interchange between varieties of zones was the intentional employment of fire. Generally, transition areas between two zones in nature such as the edge environments of the forest or a riverbank, have an especially rich flora and fauna: the greater the difference between two areas, the richer the flora and fauna in the ecotone. The people may have been aware of and able to utilise and benefit from the ecotones in their subsistence patterns.

The charcoal curves are grouped in four patterns (Table 7). Below, they are compared with other palynological information, vegetation zones, geographical

Table 7. The charcoal curves from the 68 palynological sampling sites in South Norway are grouped in four patterns compared to the present forest type.

Pattern no. → Vegetation zone↓	Number of sites	Pattern 1: classical, site no.	Pattern 2: extended classical, site no.	Pattern 3: opposite classical, site no.	Pattern 4: maxima bottom and top or no marked changes, site no.
Coastal forest	24	*29, 33, 55*	17, 30, 31, 32, 35, 53	16, 42, 43	18, 19, 34, 36, 37, 38, 39, 47, 54, 56, 57, 62
Boreal forest	20	5, 14, 15, 65	4, 8, 10, 13, 50	2, 3, 7, 51	9, 11, 12, 40, 41, 61, 67
Subalpine forest	14	44, 58, 66	46, 59, 64	27, 49, 63	6, 22, 28, 48, 68
Alpine	10	52	21, 24, 45, 60	–	1, 20, 23, 25, 26
Sum	68	11	18	10	29

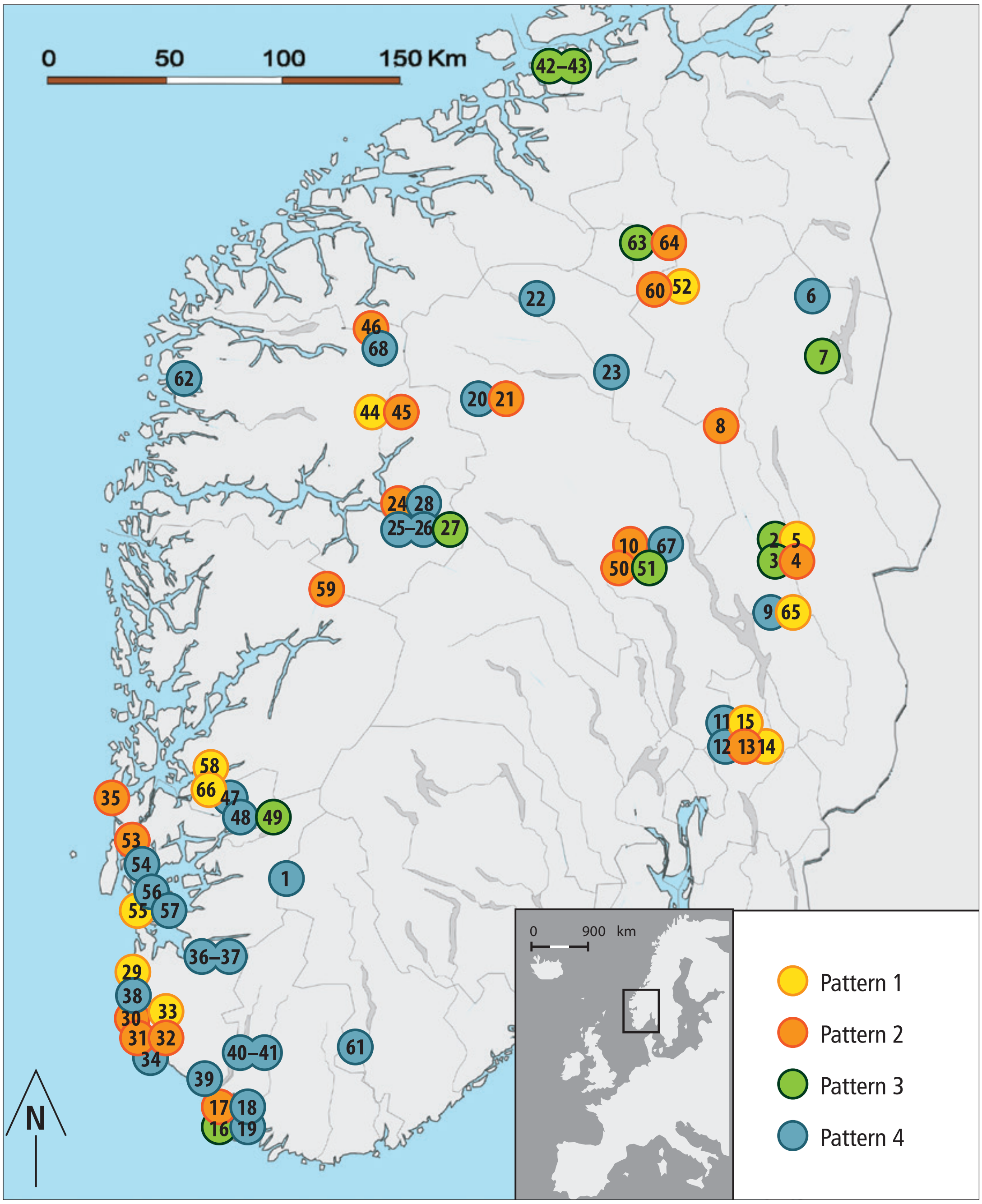


Fig. 9. The distribution of the 68 pollen diagrams correlated with charcoal curve patterns 1–4 (pattern: 1 the "classical", pattern 2 the "extended classical", pattern 3 the "opposite classical", pattern 4 "maxima bottom and top". Graphich design: Martin Blystad.

location, density of the forest and archaeological sites:

- Pattern 1) the *classical*: low occurrences of charcoal during the Mesolithic and a rise at or soon after the transition to the Neolithic (>3900 cal yr BP).
- Pattern 2) the *extended classical*: increase in charcoal during the Mesolithic and/or long after the transition to the Neolithic (<3900 cal yr BP).
- Pattern 3) the *opposite classical*: the opposite situation of patterns 1 and 2, with higher values of charcoal during the Mesolithic than after the transition to the Neolithic.
- Pattern 4) *maxima bottom and top*: high values in the bottom and the top and low levels between the maxima, no marked changes and other patterns.

The 68 sites are sorted based on the present altitudinal vegetation zone because they are not possible to sort according to the altitudinal vegetation zone to which each of them belonged in the Mesolithic as the vegetation changed during the Holocene (Appendix B).

9.1 Discussion of the regional distribution of fire management

The degree to which locally produced charcoal is mixed with long-distance transported charcoal from the air is dependent on the openness of the forest; the more open, the higher the deposition of long-distance transported microscopic particles. The tree crowns of the dense forests may have prevented the deposition of charcoal from long-distance transported particles to the ground. In dense forest, charcoal could hardly have reached the ground surface if it had not come from a place in the vicinity, primarily from below the crown layer. This indicates that, in dense forest, much of the recorded charcoal may have been produced locally. It may have originated from the use of fire at settlement sites and people's fire management of the vegetation. The pollen sampling sites were mostly lakes and mires, which constitute different sizes of openings in the canopy and therefore deposition of long-distance transported microscopic particles cannot be ruled out completely. Sites 40 (Ersdal mire) and 41 (Ersdal Fiskelausvann), located close to each other, show that there can be significant variations in charcoal within short distances, indicating an anthropogenic origin. Another reason may be that the mire (site 40) mainly reflects the local environment, while the lake (site 41) is representative of regional fire managements.

The subalpine forest was usually open or partly open *Betula* forest and the open crown-layer could not effectively prevent deposition of long-distance transported charcoal, which may have been mixed with locally produced charcoal. The need for fire management was less in this forest compared to the dense forest because the open crown-layer resulted in light to the ground vegetation of herbs and shrubs and thus naturally had some of the characteristics that burning was intended to create. The access to prey was probably better here than in the dense forest and the mountain area because all the three important ungulates may have been available (Selsing 2010:288, 295).

During the early Holocene warm period, the forest limit was higher and the mountain area, with alpine vegetation, was much smaller than today. The foragers may have focused on fire management around this limit to try to prevent the progress of forest (see Selsing 2010 with many references about the settlement in the mountain area). In the open vegetation above the forest limit, the local anthropogenically produced charcoal may have been mixed with long-distance transported charcoal. Therefore, charcoal does not always indicate burning activities in the mountain area even if charcoal were produced at fireplaces and from fire management by burning selected parts of the lignose vegetation for example close to the forest limit. The generally low levels of the charcoal occurrence may have been due to the scarcity of woody plants to burn and the limited need for fire management. Also, little use of fire could have been the result of limited seasonal use during summer slack and the reindeer hunting period in the late summer and autumn, which may have been a part of the seasonal yearly cycle for some groups of foragers (Selsing 2010:312–313). Natural fire may have added to the charcoal occurrence, but fire management was without doubt also used in open vegetation when necessary. Foragers' use of intentional fire in the mountain area may have been the main origin of the charcoal, also because people were familiar with fire management technology and probably did not hesitate to use it when they met new challenges. However, hunter-gatherers are expected to have affected this environment with fire less than at lower altitudes.

The distribution of sites correlated with charcoal curve patterns 1–4 (Fig. 9) indicates that they are all well distributed all over South Norway, without any clear system. This shows that the pattern types are not dependent upon the geography and vegetation zone. More likely, the local topography, people's culture, migrations and movements, the location of and the distance from the pollen sampling sites to archaeological sites and the specific location of the burning are factors that influence the charcoal curve pattern.

Pattern 4 is the most frequent pattern in South Norway (Table 7). The reason may be that it represents a more diffuse and variable pattern than patterns 1, 2 and 3, which are more strictly defined. In general, pattern 1, with a rise in the charcoal deposition correlated to the transition to the Neolithic, makes up less than one fifth of the sites. Pattern 2 is the second most frequent pattern, representing the norm of recording agricultural activity compared to pattern 1. Pattern 3 is not recorded in the mountain area and has the same frequency in the three other altitudinal vegetation zones. Pattern 4 is, in per cent, most frequent in the coastal forest and the mountain area.

As a standard, the patterns of charcoal may be interpreted from a cultural perspective:

- Pattern 1 indicates often low-intensity of fire management during the Mesolithic and farmers' increased intentional use of fire at, or rather some time after, the transition to the Neolithic for clearing the forest, which was not the purpose of foragers.

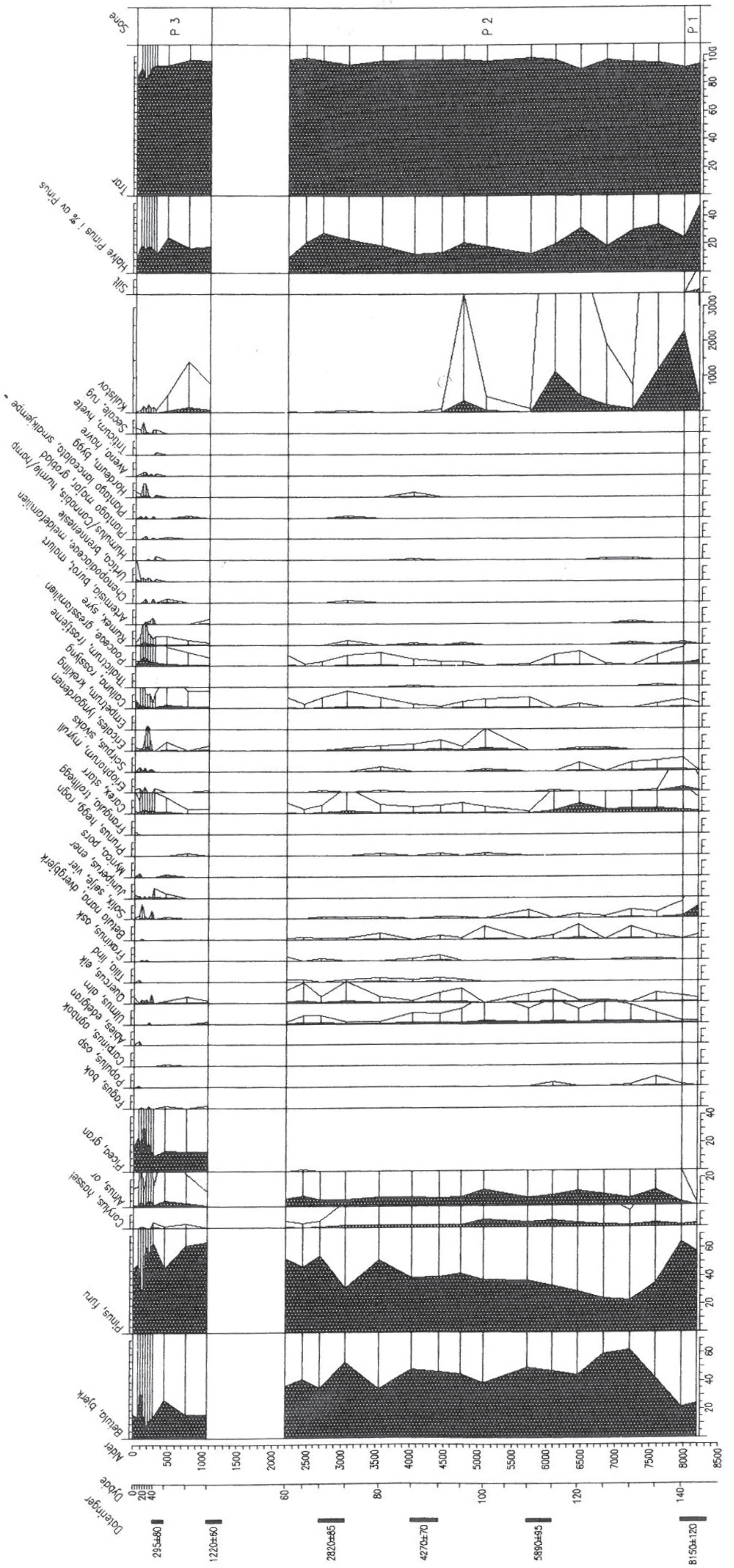
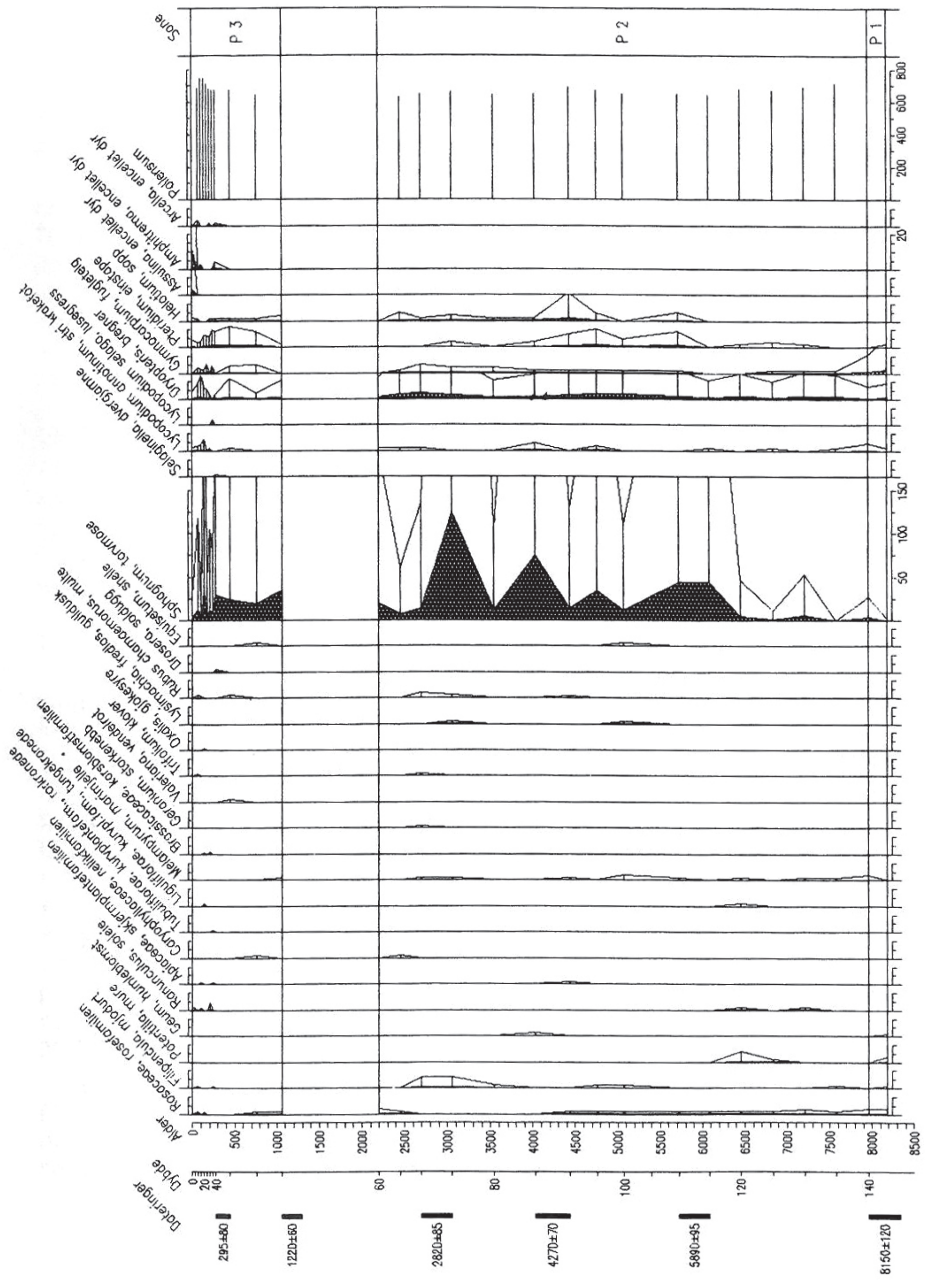


Fig. 10a-b. Pollen diagram from site 2, Persmyrkoia in East Norway from the boreal forest zone with a pattern 3 charcoal curve (kullstøv=charcoal). From Høeg (1996:20–21).



- Pattern 2 indicates often low-intensity of fire management during the Late Mesolithic and farmers increased intentional use of fire for forest clearing more than 2000 calendar years after the transition to the Neolithic.
- Pattern 3 indicates that the sites represent areas that were attractive for hunter-gatherers and not very much for farmers.
- Pattern 4 is representative for sites from areas attractive early for hunter-gatherers and very late, when the number of farmers increased so much that the areas became attractive, but not attractive between the two maximum periods or not attractive for people at all.

Intentional burning in the boreal forest may have created a mixture of different types of habitats and the specific patterns of burning may well have varied from one subtype to another, given regional variations (see Lewis & Ferguson 1988:73). Maxima in the charcoal curves are less common in the boreal forest zone than in the other altitudinal vegetation zones and in some cases the areas around the pollen sites only saw little use by hunter-gatherers or farmers. It is likely that the boreal forest in many cases was only seasonally exploited by the South Norwegian foragers, due to the scarcity of resources. It may only have supported few people, as evidenced both ethnographically and archaeologically by Lewis (1973:71) for the coniferous forest in California.

A few sites in South Norway are presented below because they supplement information from the 68 sites used in this paper. Other sites show that the four charcoal curve patterns are also recorded outside South Norway.

9.1.1 Interpretation of the different types of charcoal patterns

Generally, anthropogenically controlled fires produce less charcoal than uncontrolled natural fires because natural uncontrolled landscape fires burn more dead biomass than controlled patch fires, and the latter tend to suppress the development of large amounts of dead biomass (Grøn 2012:184). If the charcoal had resulted from a sequence of natural fire events, it could potentially have resulted in more variation in the pollen spectra (Moore 1996:70) than recorded from the 68 pollen sampling sites. Natural fires will result in fluctuations, irregularities and discontinuities in the charcoal curves, and the continuous and low occurrence of charcoal is unlikely to be the result of natural fires alone, as confirmed by e.g. Granström (1993) and Carcaillet *et al.* (2007). A combination of continuity and changes in the charcoal curves, which is common in the present dataset, indicate that they may have originated from both anthropogenic and natural fires with the anthropogenic factor as the dominating one.

Steadily maintained levels of charcoal without changes in the pollen assemblage, are more informative as to people's fire maintenance activity (Moore 1996:72, see also e.g. Edwards 2004:Fig. 4.5) and natural fires were probably not important for the charcoal occurrences. These results agree with Caseldine & Hatton (1994:41) for Southwest England. They recorded that the difference between the occurrence of charcoal before and after the neolitisation is microscopic charcoal during the Mesolithic, which usually does not show a sudden increase and decrease, but is present throughout in a small, sporadic form and at low-intensities. Therefore, it does not have an identifiable effect below the treeline.

Pattern 3 and pattern 4 charcoal curves are representative for sites from areas that were attractive for hunter-gatherers and not very much for farmers or not attractive for people at all, or they were attractive for foragers very early and for farmers very late, when the population increased so much that the areas were put in use for their purposes. This is in accordance with Sørensen (2014 part 1:8 with reference to Moen 1999:269), who pointed to reasons for unsuccessful establishments of agrarian societies and why the agrarian expansion stopped in southern Norway. These reasons included a shorter growing season, lower population density, limited areas of easily worked arable soils and that it may have been difficult for such societies to maintain regular social relations and participate in the agrarian network in the early phase, as they were located in the border zone of their culture. Climate and vegetation may have been a general natural obstacle for farming at that time, beyond the limit of the boreonemoral vegetation zone.

The pollen sampling sites with pattern 3 charcoal curves constitute 10 of the 68 sites, the smallest pattern group (Table 7, Fig. 10a-b and 11a-b). These charcoal occurrences have the highest values before the Neolithic and indicate that they represent areas that were attractive for hunter-gatherers and to a lesser degree for farmers or not at all. One example of a pattern 3 charcoal curve not included in Appendices A and B is the pollen site *Styggdalssetra* in the boreal forest zone less than ten kilometres northeast of sites 2 and 3 (Persmyrkoia and Ulvehammeren) (Bjune 2000:144–145). This may indicate that this region seems to have been attractive for hunter-gathers and not for farmers.

While patterns 1, 2 and 4 do not show any identifiably geographical distribution picture, the pattern 3 sites tend to be located in the inland or at typical Mesolithic locations at the outer coast. The missing representation in the alpine zone implies that hunter-gatherers' need for fire managements here was small, compared to the forest zones. Probably, long-distance transported charcoal particles comprised part of the alpine charcoal occurrences. The foragers used continuous, regular and limited burning at the settlement sites and the extended areas of their settlements. Within the boreal forest, small openings may have been maintained strategically and in some cases, fires were set around lakes and mires (see Lewis & Ferguson 1988:68, 70–71).

Continuous, changing charcoal curves—or parts of a curve—as those classified as pattern 3 may have been caused by hunter-gatherers' continuous use of burning in the area, with changing intensity, ruling out natural fire as the main agent because of the continuity, but depending on the density of the forest. Another possibility is that foragers may have used the area intensively close to the pollen sampling site for periods, which may have resulted in increases and maxima in the charcoal curve.

The forest density could be oscillating, confirming an anthropogenic origin of the charcoal from a place in the vicinity. There is no good correlation between the pattern 3 charcoal curves, the earliest traditional palynological indications of agricultural activity (pollen of *Plantago lanceolata* and cereals) and opening of the forest. This indicates that these sites may have been considered unproductive for existing farming technology and traditions. In the cases where the palynological traces of husbandry farming occurred without change in the level of charcoal, the charcoal does not confirm agricultural activity.

Pattern 3 charcoal occurrences are recorded at sites not included in Appendices A and B and a few of them are discussed here.

The archaeological sites at Skatestraumen in Sogn og Fjordane, West Norway, are located in the coastal forest zone and were settled for a long period (Bergsvik 2002). The settlement pattern was characterised by the use of sites at the coast, in the forest and in the mountain area with a specialised adaptation in the interior that included hunting of terrestrial animals and gathering places (Bergsvik 2002:304, see Selsing 2010:223–224). In the Late Mesolithic, settlements were considered to have been semi-sedentary or sedentary. The open forest with *Betula* at Havnen (site 17) had open herb-dominated vegetation before 7800 cal yr BP (Hjelle 2002:343). The open area was described as "rydning" (clearing) and thus probably was created by people (Hjelle 2002:342). These sites are considered a pattern 3 charcoal occurrence because clearing of vegetation around the settlement was carried out in the Mesolithic.

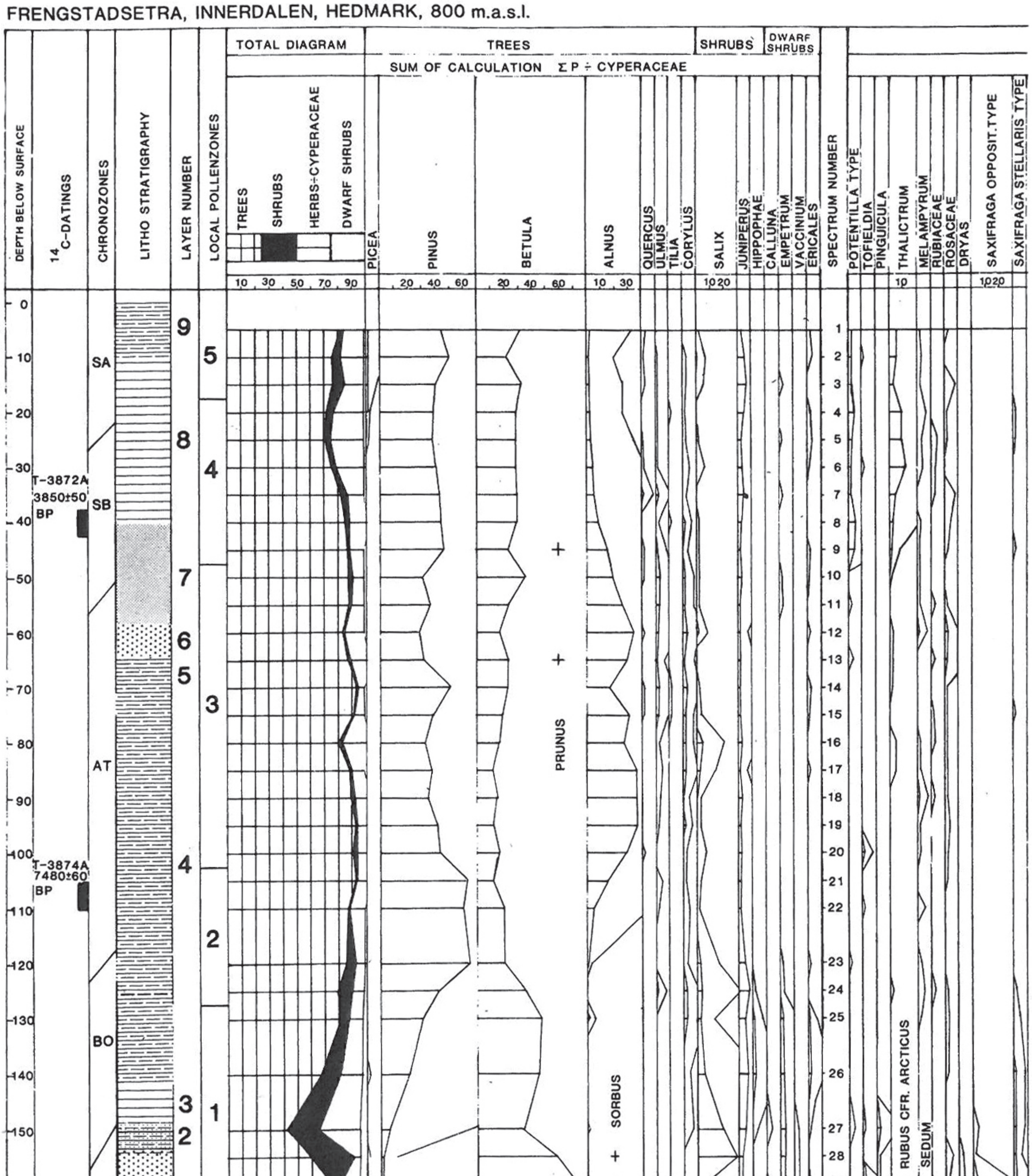
Macroscopic charcoal from peat in a mire at the edge of the archaeological site Hovatn III (690 m asl) in the boreal forest zone in the southern part of South Norway was radiocarbon dated to 8100 cal yr BP (see Selsing 2010:Appendix 2). The sample was collected from the periphery of a Stone Age site without a distinct stratigraphic relation between the Middle Neolithic archaeological material and the charcoal in the peat (Martens in Nydal *et al.* 1972:438). The occurrence is considered a pattern 3 site, where hunter-gatherers probably burnt the local vegetation intentionally in the early part of the Late Mesolithic to extend open vegetation at the margin of the mire to attract game.

Barth (1979:146–148) described a pitfall in Trangdalen in East Norway in the subalpine forest zone with radiocarbon dated charcoal from a sealed soil. The age 7400 cal yr BP was much higher than other pitfalls, which only rarely are older than the Iron Age. Barth (1979:147) proposed that the charcoal could be from a tree or a forest fire ignited from lightning long before the pit was dug. Later excavations demonstrated that this could not be the case because the limits of the charcoal layer excluded that it could have originated in a forest fire, which should have been traced over a larger area. Barth's other proposal (1979:148) was that one or more dead trees and shrubs had fallen and were burnt long before the pit was dug for the first time. An alternative and simpler explanation is that it can be the result of hunter-gatherers' clearance of scrub and trees using intentional fire on a reindeer path to improve hunting success around the path by improving their overview of the movements of the animals around this strategically located place where the pit was constructed much later. This is considered a pattern 3 occurrence as it is a specialised hunting site and is mentioned as one way of using fire management during the Mesolithic, i.e. to burn off the underbrush in certain localities to facilitate hunting (see e.g. Lewis 1973:75).

The pollen diagram from the mire Mabo Mosse in the boreal forest zone of eastern South Sweden had a charcoal occurrence during the Mesolithic with large changes and lower values later (including a hiatus), which is considered a pattern 3 charcoal curve. Göransson (1977:110) supposed that most probably it was a consequence of local forest fires in the surrounding of the site. Probably, hunter-gatherers used fire management at and around this mire during the Mesolithic.

The most commonly recorded charcoal curve—pattern 4—is seen in all the altitudinal vegetation zones. This pattern also includes sites with deviating charcoal curves. The curves are usually continuous, low and regular with small changes and often with maximum in the bottom and the top (Fig. 12a-b and 13a-b). The ages of the maximum in the bottom of the curves are (with one exception) from the Late Weichselian Substage or the Mesolithic and the ages of the maximum values in the top of the curves are (with one exception) from the Iron Age until the present time. The continuous production of charcoal is usually independent of changes in the density of the forest. During the Mesolithic, the charcoal may have originated from pre-agrarian peoples' regular, continuous and low-intensive use of fire in vegetation in the area but probably not close to the sampling site. A good proof of charcoal indicating intentional fire (site 45, Sætrehaug-I) was within an open *Betula* forest. There were no changes in the charcoal occurrence, while the forest limit decreased below the site. This type of charcoal curve indicates that the foragers usually may have been dependent on only limited use of intentional

FRENGSTADSETRA, INNERDALEN, HEDMARK, 800 m.a.s.l.



fire to change vegetation for their purposes.

Pattern 4 charcoal curves—or parts of a curve—can also be characterised by sporadic and irregular curves with low values. They indicate that the area was used low-intensive, sporadic or not in use with regard to foragers' fire management, maybe because the natural conditions were evaluated as not attractive for their purposes. It may indicate that foragers did not use the same area for longer periods; they may have migrated and changed their annual cycles over the years. Natural fires may also have added to the charcoal occurrence. There may have been many places that were not burnt.

The pattern 4 charcoal curves indicate that possible scouting expeditions of migrating pioneering farmers and attempts to establish agrarian societies in the areas represented by this pattern in periods later

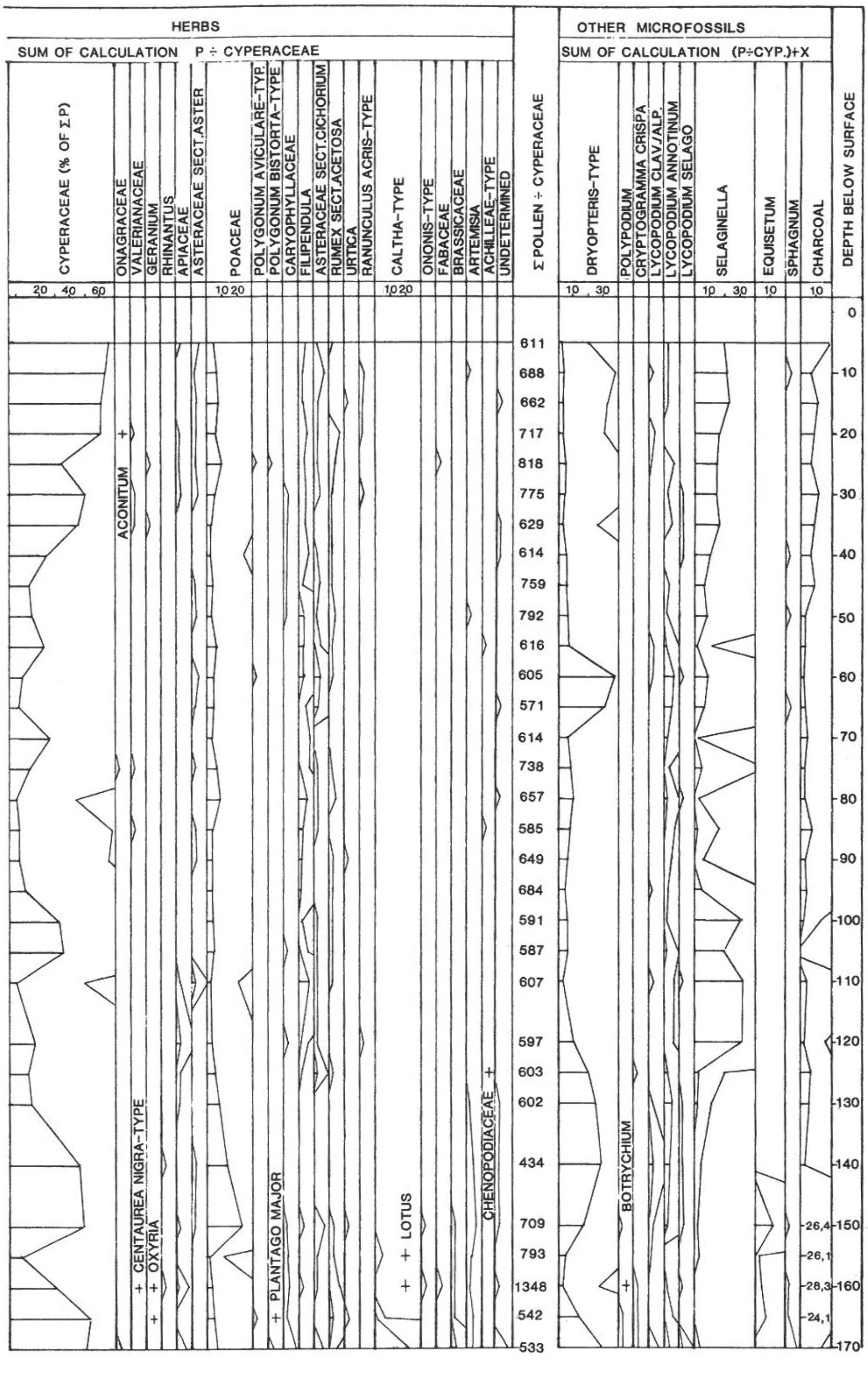


Fig. 11a-b. Pollen diagram from site 63, Frengstadsetra in the northern part of South Norway from the subalpine forest zone with a pattern 3 charcoal curve. From Paus & Jevne (1987:24–25).

than the Neolithic may have been unsuccessful until the Iron Age or later. Experiment migrations were not only towards the north, but probably also from agrarian centres to the surrounding areas in more remote and, for agriculture, sometimes unproductive areas. This is in accordance with Moen (1999:159), who calculated areas in Norway suitable for agriculture today to be only three percent of the total area.

Pattern 4 charcoal occurrences are recorded at sites not included in Appendices A and B and one of them is discussed here.

The pollen diagram from Lake Vån is located in the boreal forest zone of eastern South Sweden (Göransson 1977). The pattern 4 charcoal curve is continuous and low with the highest levels at the transition to the Holocene and at the top, but slowly increasing since

6800 cal yr BP. The forest was dense except very early and for the last thousand years. This indicates that the area was most attractive very early and may-be for the last 3000 years

A single spectrum peak is often interpreted as the result of the vegetation ignited by a lightning stroke (e.g. Kvamme 1984:238–266, Høeg 1999:202–207). Compared to the accumulation rate, a single spectrum peak of charcoal usually spans a long time compared to a short natural fire event—even if this does not exclude natural fire because of secondary movements of particles in the sediments. Natural fire may usually be ruled out as the main agent when the forest was dense, but may otherwise have contributed to these maxima. Natural fires are excluded when there is more than a single spectrum peak of charcoal, which spans a long period (see Fig. 10a-b, 11a-b and 14a-b).

Maxima in the charcoal curves are common during the Mesolithic (Fig. 4 top). They may span a peak or several spectra, even over a period of more than thousand years. If the forest was dense, the peaks indicate marked fire events (see e.g. Fig. 13a-b), when the foragers' fire regime was more intense for a shorter period. They may have used the area more intensively than earlier, burning at and around the pollen sampling site for a while or they may have lived close to the pollen site and burnt the vegetation at and around the settlement site or it originated from intentional burning that came out of control. These are the most likely reasons for maxima, while natural fires may have influenced the curves at irregular intervals, the amount dependent on the local circumstances and the extent of the wild fire. Maxima occur also in the mountain area, even if woody plants were present only to a limited degree, and indicate people's use of fire.

9.1.2 The relationship between the charcoal curves and the transition to the Neolithic

The relationship between the charcoal curves and the transition to the Neolithic has special interest. There is often no close relationship between the earliest traditional pollen-recorded agricultural activity (*Plantago lanceolata* and cereals) and the charcoal curves. The rise in the charcoal correlated with the transition to the Neolithic may indicate a change from foragers to farmers' use of intentional fire (pattern 1, Fig. 15 and 16a-b). This pattern is recorded in all the vegetation zones, but mostly below the forest limit while continuous and regular charcoal curves crossing this transition are more common and recorded in all the vegetation zones (pattern 2, see also e.g. Edwards 2004:Fig. 4.6 from Shetland). It may indicate people's continuous use of fire in the area without cultural changes in the period, which should reflect the change from foragers to farmers. This implies that the activities of farmers and hunter-gatherers resulted in the same charcoal deposition level even if the activities, purposes and places may have been different. This may be exemplified by the English settlers in New England, USA, who applied the use of fire for different purposes and on an extensive scale in clearing land. They burnt to remove the forest itself opposite to the indigenous people who burnt the forest to remove undergrowth as a tool in the regenerative process (Cronon 2003:118 [1983]).

An increase in charcoal indicates a change in the deposition situation. It may have been the result of either foragers' intensified burning activities or clearing by early farmers for agricultural purposes, resulting in opening of the forest. Based on the present charcoal record, it cannot be excluded that foragers continued to use fire management after the transition to the Neolithic. The traditional pollen pasturing-indicator may have been the result of pastures made for ungulates and/or pasturing husbandry in an early phase. The location of burning for the ungulates may have been at other sites than for husbandry animals—especially because on the one hand they should not be disturbed, while on the other hand the husbandry animals should be protected against carnivores. The early farmers could have brought their own fire management traditions from abroad with the slash-and-burn technology. Maybe in some areas, they also adapted to the foragers' technology and knowledge, traditions and strategies of using fire management for the same purposes as the foragers and without leaving other palynological traces than the charcoal. This may be confirmed by ethnographical examples, which show that it is very common for farmers to supplement their food supply with foraging practices (e.g. Hartz & Schmölcke 2013, Sørensen 2014:32). For West Norway, Prescott (1995) pointed out that this combination in the use of nature has continued until the present time, with hunting, trapping, fishing and gathering as important parts of the economy in many rural districts, in combination with farming activities.

Recent investigations of ancient DNA suggest a key role for migration in association with the neolithisation process. A subsequent Neolithic or post-Neolithic population replacement is proposed in Scandinavia. A group of people that was genetically distinct from resident hunter-gatherers brought farming practices to Northern Europe. Migration from the Aegean area and Southern Europe catalysed the spread and expansion of agriculture (Malmström *et al.* 2009, 2015, Skoglund *et al.* 2012, 2014, Hofmanová *et al.* 2016:5). The conclusions of Sørensen (2014 part 1:263–269 and part 2:71) confirmed that the agrarian expansions in South Norway were a result of migrations. It excluded that agriculture could have been spread as an idea because it is very complex, takes time to learn and requires insight into farming. This is opposite to the conclusions of Hofmanová *et al.* (2016:1) that "farming spread into and across Europe via the dissemination of ideas but without, or with a limited, migration of people."

Migrating farmers may have brought their own fire management practices adjusted to their agricultural activities, and they may have been influenced by impressions from other European farming groups and their strategies during the migrations. However, the hunter-gatherers had detailed experience in the use of fire in the vegetation of their own environment. Probably, the population replacement by farmers included transfer of useful and important knowledge from the foragers. Hjelle *et al.* (2012) confirmed that the early farmers in the northwestern part of South Norway might have used the same sites as the foragers. However, in general, the farmers later gradually settled sites best suited for farming purposes, i.e. exemplified by the pollen sampling sites with pattern 1 and later also pattern 2 charcoal curves.

Pattern 1 and 2 charcoal occurrences are recorded at sites not included in Appendices A and B and a few of them are discussed here.

The pollen diagram from Lake Ämmen in the boreal forest zone in eastern South Sweden has a regular and continuous classical pattern 1 charcoal curve with a rise about 6000 cal yr BP. Göransson (1977:115) supposed that this rise reflects the first clearance fires, but did not comment the charcoal curve before the rise. Hunter-gatherers likely used fire management during the Mesolithic in this area.

Møllermosen in Southeast Norway, close to the Swedish border (Høeg 2002) has a pattern 1 occurrence in the coastal forest zone. Low-intensity of fire management dominated the Mesolithic, while farmers increased intentional use of fire about 4400 cal yr BP followed by several high maxima. This occurred shortly before the first occurrence of *Plantago lanceolata* and opening of the forest, indicating agricultural activities.

Two sites are from Stord in West Norway in the coastal forest zone (Overland & Hjelle 2009). The typical pattern 2 charcoal curves indicate foragers' low-intensity use of fire until increases about 3500 cal yr BP and 3200 cal yr BP, respectively, and followed by several high maxima. This occurred at the same time as a continuous curve of *Plantago lanceolata* and a marked opening of the forest, indicating agricultural activities with forest clearance during the Bronze Age. There were no traditional traces of agriculture before the increase in charcoal indicating intentional use of fire long after the transition to the Neolithic.

The pollen diagram Lake Skånsø in the coastal forest zone in northern West Denmark has a pattern 2 charcoal curve with high values in the late Younger Dryas chronozone (Odgaard 1994:149). Probably, foragers used low-intensity fire management in the area until the forest was denser in the Preboreal chronozone, at a time when reindeer still lived here (see Aaris-Sørensen *et al.* 2007). Odgaard (1994:84–85, 96) suggested that the low values of charcoal recorded since the Early Preboreal chronozone originated from local woodland fires, but was puzzled by the absence of synchronous changes in the charred particle values in the three diagram types. In my opinion, this indicates that foragers' use of intentional fire may have been local around the lake and therefore resulted in different spatial deposition. Odgaard (1994:97) supposed, as a tentative explanation of the Mesolithic part of this charcoal occurrence with a rise in the charcoal curve about 7700 cal yr BP and fluctuations, that drier climate would have increased the frequency of fires caused by lightning. As an alternative, Odgaard proposed (1994:154) that the observed increase in fire intensity were ignitions made by people to improve hunting. The charcoal occurrence had fluctuations up to newer times, with decreasing density of the forest and heathland establishment.

A pattern 2 charcoal occurrence in the coastal forest zone in northeast Shetland has greatly varying charcoal accumulation rates and a rise 8400 cal yr BP (Bennett *et al.* 1992:257). Even if there was no dated archaeological evidence for the presence of people earlier than 5700 cal yr BP (Bennett *et al.* 1992:264), the fires of red deer hunters were suggested to have produced the charcoal during the Mesolithic. This was a period when tree cover changed little, but the herb and fern communities were replaced by plants of heathland and mires (Bennett *et al.* 1992:259–260, 267–268). Most likely, the hunter-gatherers used fire managements in the vegetation to improve the availability of their preferred resources such as red deer.

A rise in charcoal during the Late Mesolithic (a small

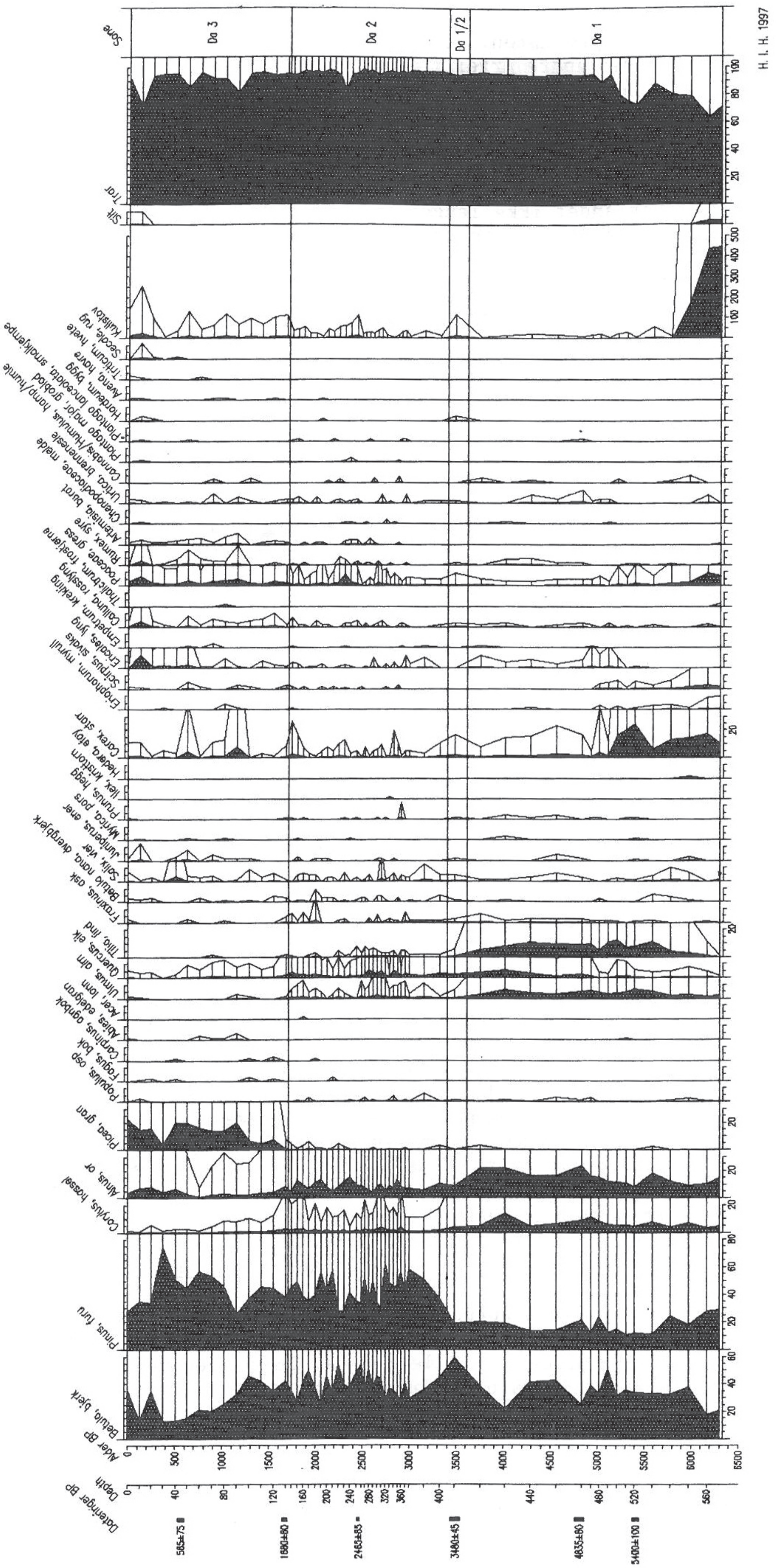
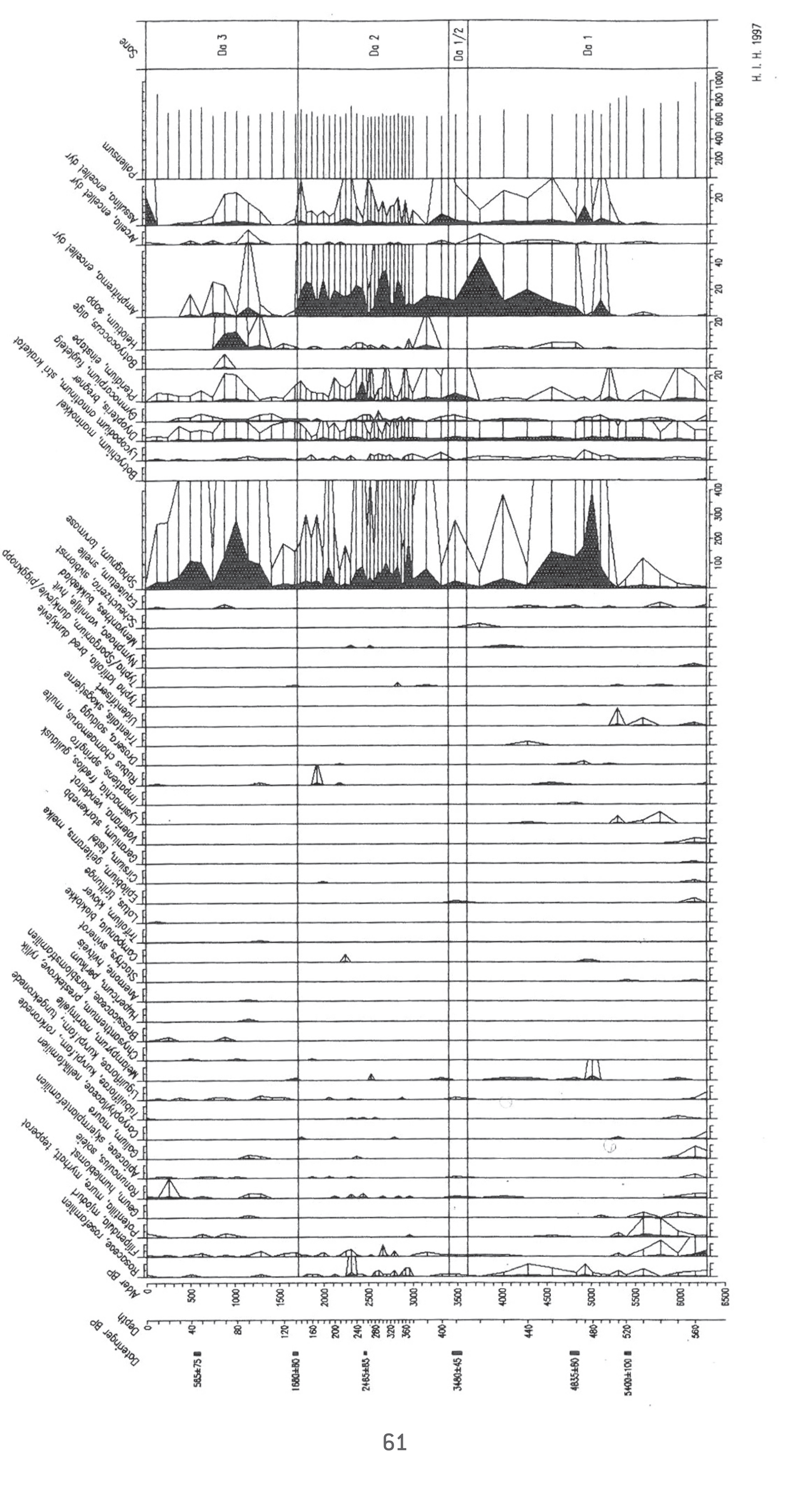


Fig. 12a-b. Pollen diagram from site 12, Danielsetermyr in Southeast Norway from the boreal forest zone with a pattern 4 charcoal curve (kullstøv=charcoal). From Høeg (1997:32–33).



Sone
Da 3
Da 2
Da 1/2
Da 1
H. I. H. 1997
Pollensum
Assulina, encellet dyr
Arcella, encellet dyr
Amphitrema, encellet dyr
Helotium, sopp
Botryococcus, alge
Pteridium, einstape
Gymnocarpium, fugletelg
Dryopteris, bregner
Lycopodium annotinum, stri kråkefot
Botrychium, marinøkkel
Sphagnum, torvmose
Equisetum, snelle
Scheuchzeria, sivblomst
Menyanthes, bukkeblad
Nymphaea, vannlilje, hvit
Typha/Sparganium, dunkjevle/piggknopp
Typha latifolia, bred dunkjevle
Uidentifisert
Trientalis, skogstjerne
Drosera, soldogg
Rubus chamaemorus, multe
Impatiens, springfrø
Lysimachia, fredløs, gulldusk
Valeriana, vendelrot
Geranium, storkenebb
Cirsium, tistel
Epilobium, geitrams, mjølke
Lotus, tiriltunge
Trifolium, kløver
Campanula, blåklokke
Stachys, svinerot
Anemone, hvitveis
Hypericum, perikum
Brassicaceae, korsblomstfamilien
Chrysanthemum, prestekrave, ryllik
Melampyrum, marimjelle
Liguliflorae, kurvpl.fam., tungekronede
Tubuliflorae, kurvpl.fam., rørkronede
Caryophyllaceae, nellikfamilien
Galium, maure
Apiaceae, skjermplantefamilien
Ranunculus, soleie
Geum, humleblomst
Potentilla, mure, myrhatt, tepperot
Filipendula, mjødurt
Rosaceae, rosefamilien
Alder BP
Depth
Dateringer BP
565±75
1680±80
2465±85
3460±45
4835±60
5400±100

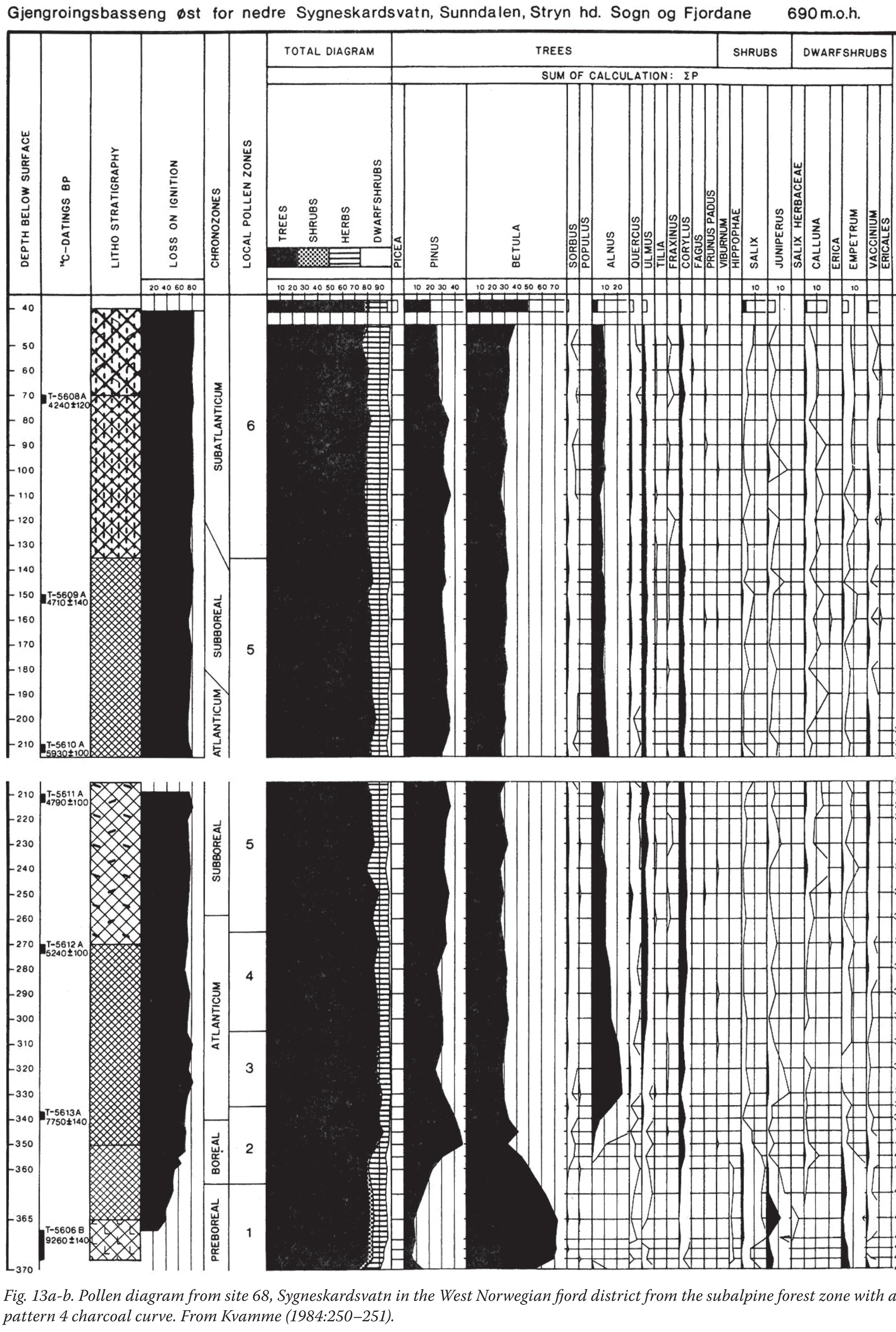
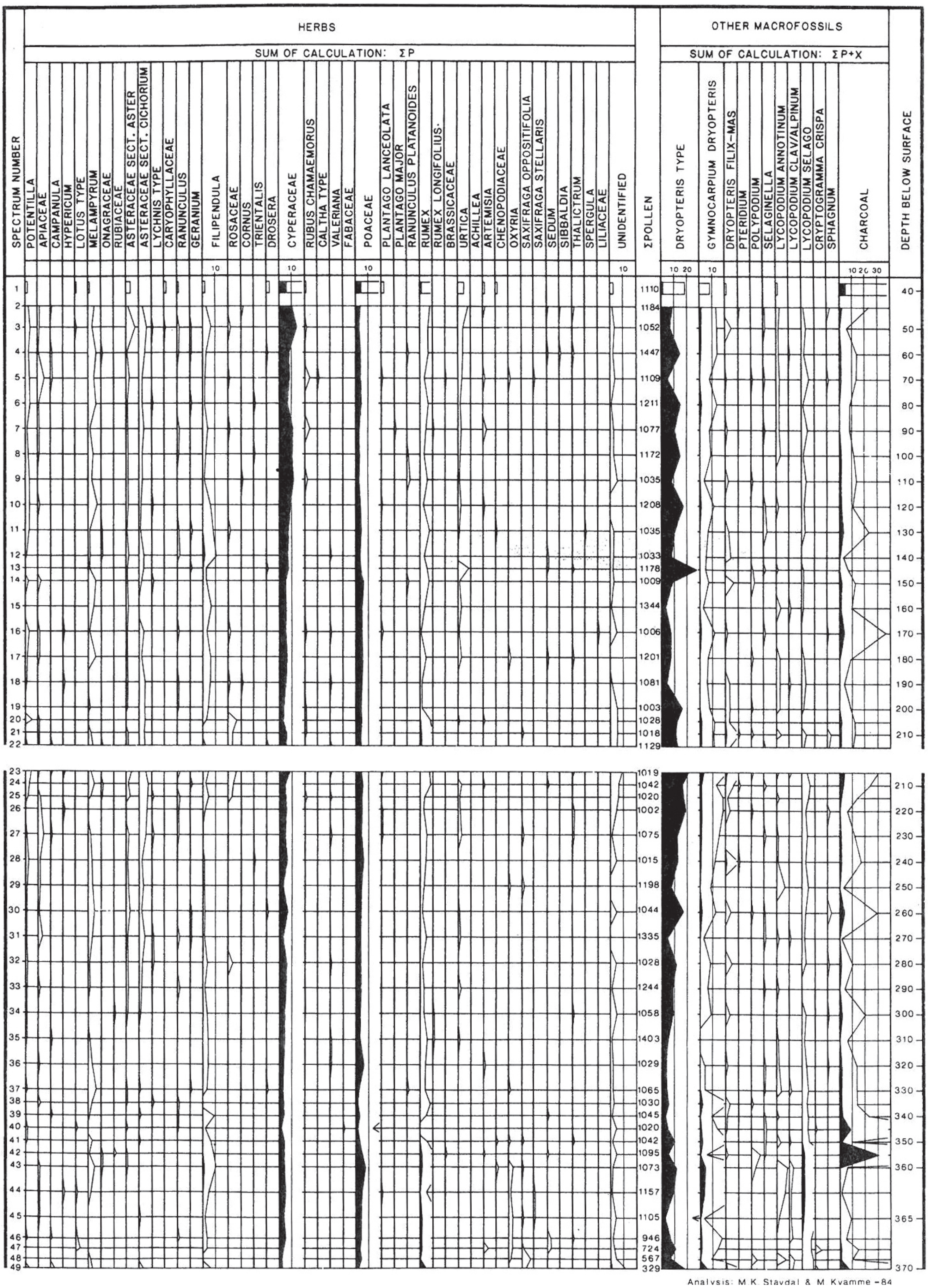


Fig. 13a-b. Pollen diagram from site 68, Sygneskardsvatn in the West Norwegian fjord district from the subalpine forest zone with a pattern 4 charcoal curve. From Kvamme (1984:250–251).


HERBS
SUM OF CALCULATION: ΣP
OTHER MACROFOSSILS
SUM OF CALCULATION: ΣP+X
SPECTRUM NUMBER
POTENTILLA
APIACEAE
CAMPANULA
HYPERICUM
LOTUS TYPE
MELAMPYRUM
ONAGRACEAE
RUBIACEAE
ASTERACEAE SECT. ASTER
ASTERACEAE SECT. CICHORIUM
LYCHNIS TYPE
CARYOPHYLLACEAE
RANUNCULUS
GERANIUM
FILIPENDULA
ROSACEAE
CORNUS
TRIENTALIS
DROSERA
CYPERACEAE
RUBUS CHAMAEMORUS
CALTHA TYPE
VALERIANA
FABACEAE
POACEAE
PLANTAGO LANCEOLATA
PLANTAGO MAJOR
RANUNCULUS PLATANOIDES
RUMEX
RUMEX LONGIFOLIUS-
BRASSICACEAE
URTICA
ACHILLEA
ARTEMISIA
CHENOPODIACEAE
OXYRIA
SAXIFRAGA OPPOSITIFOLIA
SAXIFRAGA STELLARIS
SEDUM
SIBBALDIA
THALICTRUM
SPERGULA
LILIACEAE
UNIDENTIFIED
ΣPOLLEN
DRYOPTERIS TYPE
GYMNOCARPIUM DRYOPTERIS
DRYOPTERIS FILIX-MAS
PTERIDIUM
POLYPODIUM
SELAGINELLA
LYCOPODIUM ANNOTINUM
LYCOPODIUM CLAV/ALPINUM
LYCOPODIUM SELAGO
CRYPTOGRAMMA CRISPA
SPHAGNUM
CHARCOAL
DEPTH BELOW SURFACE
Analysis: M.K. Stavdal & M. Kvamme -84

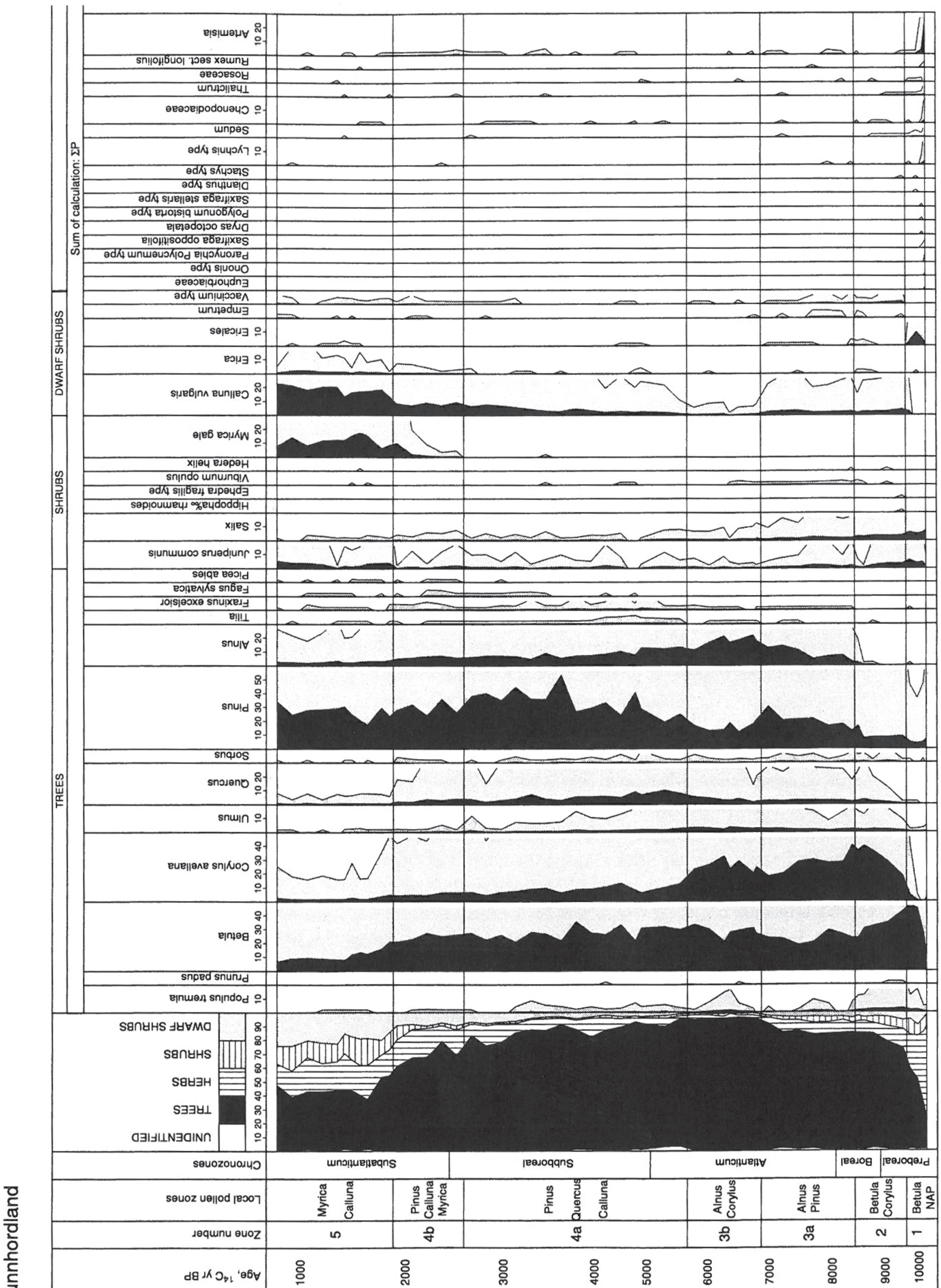
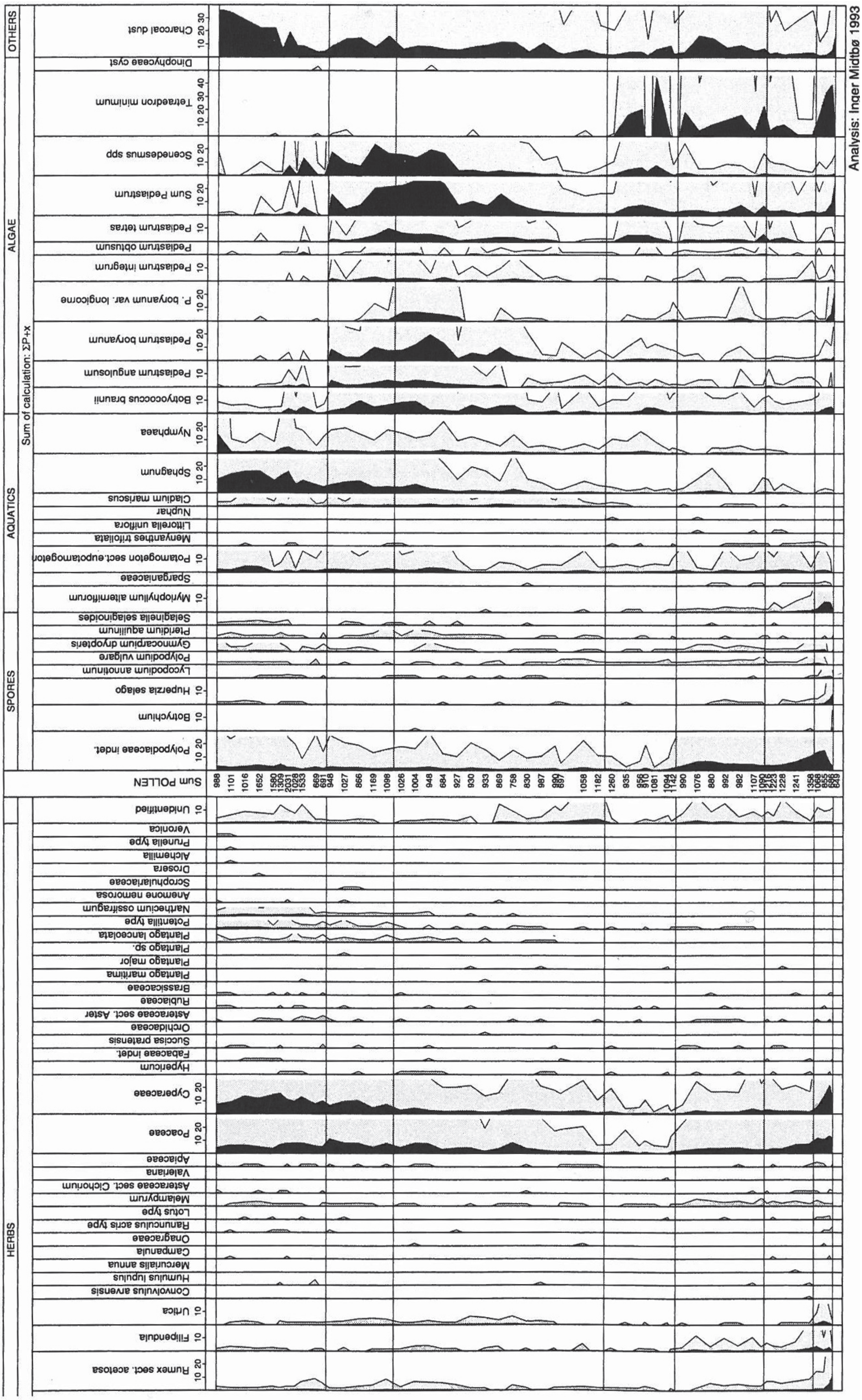


Fig. 14a-b. Pollen diagram from site 35, Vassnestjern in West Norway from the coastal forest zone with a pattern 2 charcoal curve. From Midtbø (1999:104–105).


OTHERS
ALGAE
AQUATICS
SPORES
HERBS
Sum of calculation: ΣP+x
Charcoal dust
Dinophyceae cyst
Tetraedron minimum
Scenedesmus spp
Sum Pediastrum
Pediastrum tetras
Pediastrum obtusum
Pediastrum integrum
P. boryanum var. longicorne
Pediastrum boryanum
Pediastrum angulosum
Botryococcus braunii
Nymphaea
Sphagnum
Cladium mariscus
Nuphar
Littorella uniflora
Menyanthes trifoliata
Potamogeton sect. eupotamogeton
Sparganiaceae
Myriophyllum alterniflorum
Selaginella selaginoides
Pteridium aquilinum
Gymnocarpium dryopteris
Polypodium vulgare
Lycopodium annotinum
Huperzia selago
Botrychium
Polypodiaceae indet.
Sum POLLEN
Unidentified
Veronica
Prunella type
Alchemilla
Drosera
Scrophulariaceae
Anemone nemorosa
Narthecium ossifragum
Potentilla type
Plantago lanceolata
Plantago sp.
Plantago major
Plantago maritima
Brassicaceae
Rubiaceae
Asteraceae sect. Aster
Orchidaceae
Succisa pratensis
Fabaceae indet.
Hypericum
Cyperaceae
Poaceae
Apiaceae
Valeriana
Asteraceae sect. Cichorium
Melampyrum
Lotus type
Ranunculus acris type
Onagraceae
Campanula
Mercurialis annua
Humulus lupulus
Convolvulus arvensis
Urtica
Filipendula
Rumex sect. acetosa
Analysis: Inger Midtbø 1993

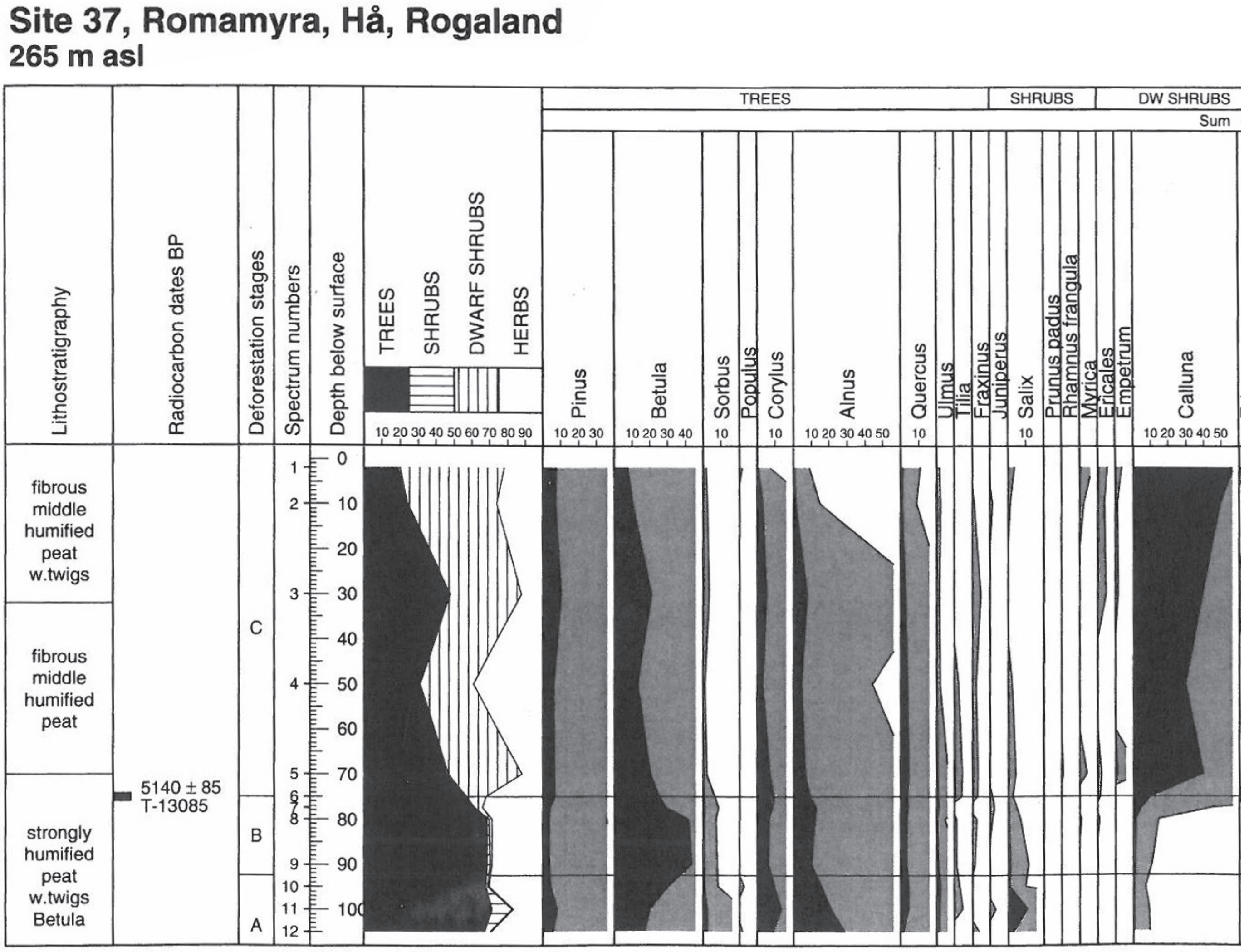
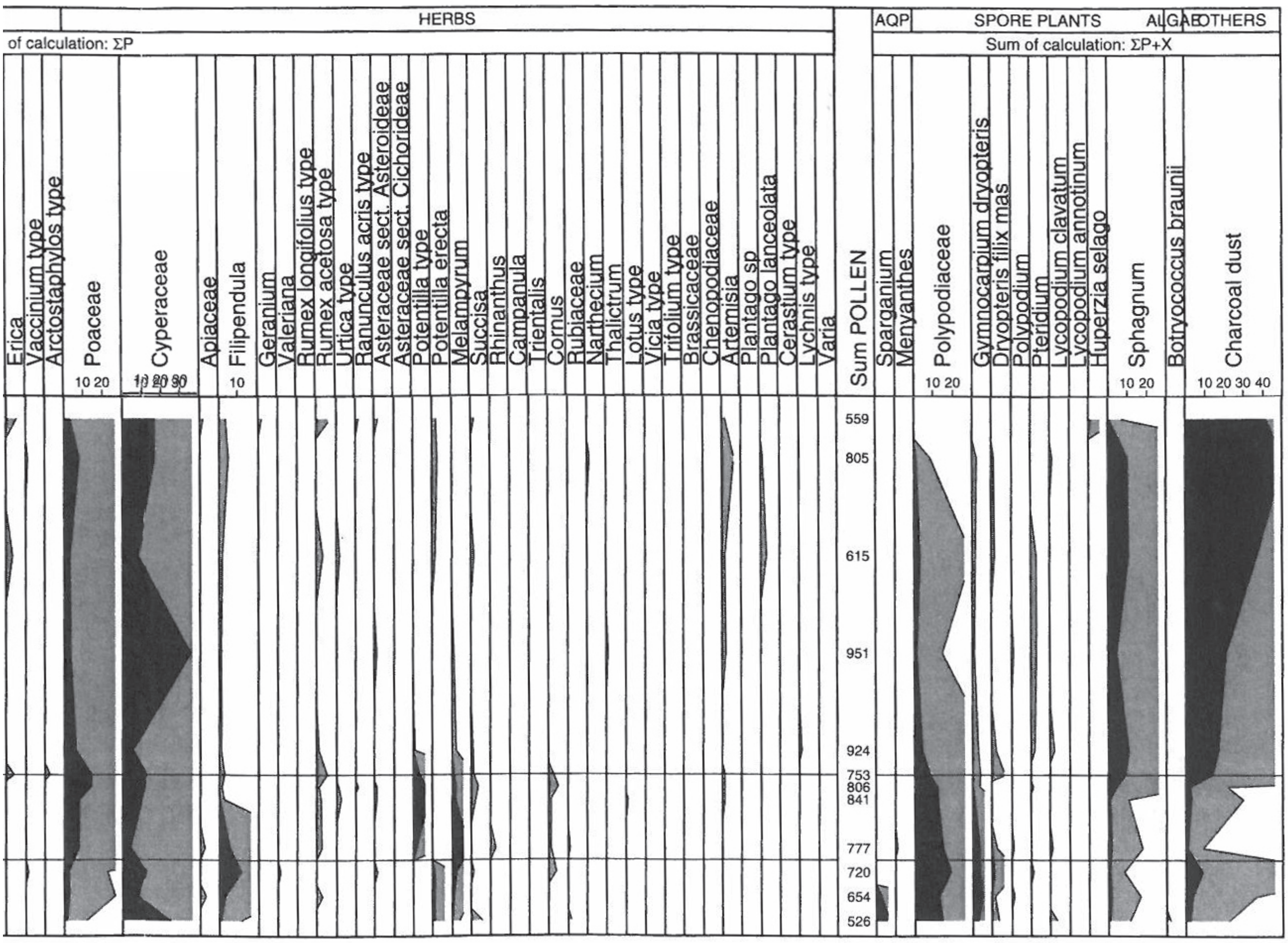


Fig. 15. Pollen diagram from site 33, Romamyra in Southwest Norway from the coastal forest zone with a pattern 1 charcoal curve. From Prøsch-Danielsen & Simonsen (2000a:51).

part of the pattern 2 sites) in dense coastal and boreal forest indicates a change in the charcoal deposition situation, which probably was the result of intensified burning activities by foragers to improve the pastures for their prey, likely close to the pollen sampling site (Fig. 17). Alternatively, it cannot be excluded that early pioneer farmers on scouting or migration expeditions conducted their own sporadic burning experiments before they took over from the foragers. Nor can it be excluded that pre-Neolithic occurrences of the traditional palynological indication of husbandry pasturing may have been the result of such a situation.

The Late Mesolithic settlement site Salthelleren in Southwest Norway (7400–6300 cal yr BP) was located on the seashore in the coastal forest zone (Skar Christiansen 1985, Prøsch-Danielsen & Selsing 2009:73–81). The pollen record showed an environment with a seashore meadow and a sporadic tree cover, which resulted in rich ground vegetation with herbs and shrubs, vegetation attractive to grazing animals such as ungulates, a principal prey of Mesolithic hunters. Human impact caused aeolian activity traced back to about 7400 cal yr BP, indicating a pattern 2 occurrence. People probably influenced the environment by intentional burning and otherwise managing the vegetation. The improved pastures would have increased the quantity and quality of game (Prøsch-Danielsen & Selsing 2009:86).

Sørensen (2014 part 1:256, 269) proposed small groups of scouting expeditions, or even migrations of pioneering farmers to gather information among the indigenous foragers and to find suitable areas for establishing agrarian societies. They could establish social relations with the hunter-gatherers and train them through praxis communities, which would have changed the identity and material culture for both groups. In this way, the early farmers may have tried to establish an agrarian society in parts of South



Analysis: Lisbeth Prøsch-Danielsen 1997

Norway already during the Early Neolithic (Sørensen 2014 part 1:269), while the suggestions of Hofmanová *et al.* (2016:4) indicate sporadically mixing between migrating farmers and local foragers. This may explain how the cultural elements of the late hunter-gatherers existed in parallel to early farmers for a long time (Malmström *et al.* 2009, 2015 with references, Sørensen 2014 part 1:263–269). The changes towards an agrarian economy in South Norway resulted in the general breakthrough and establishment of agriculture at the transition to the Late Neolithic. This means that the farming enculturation process may have lasted for about two thousand years, during which the cultures of hunter-gatherers and farmers in one form or another may have existed together in parts of South Norway. The period of overlap between the two cultures corresponds to the period covered by pattern 1. Most of the sites with pattern 2 charcoal curves may represent areas where farmers' fire regimes increased late because they were not considered as well-suited for the farming traditions that dominated in the early phase. Both the immigrating farmers and the indigenous population were involved in the creation of agrarian societies and interaction between these communities changed the material culture as well as the identity, ideology and power relationship of the participating people from the two cultures (Sørensen 2014 part 1:263–264).

This confirms the suggestion by Grøn (2012:185), that indications of systematic resource manipulation by foragers, including burning of the vegetation will tend to undermine an operable economic definition of the Mesolithic-Neolithic transition, regarded as a discontinuous progressive step.

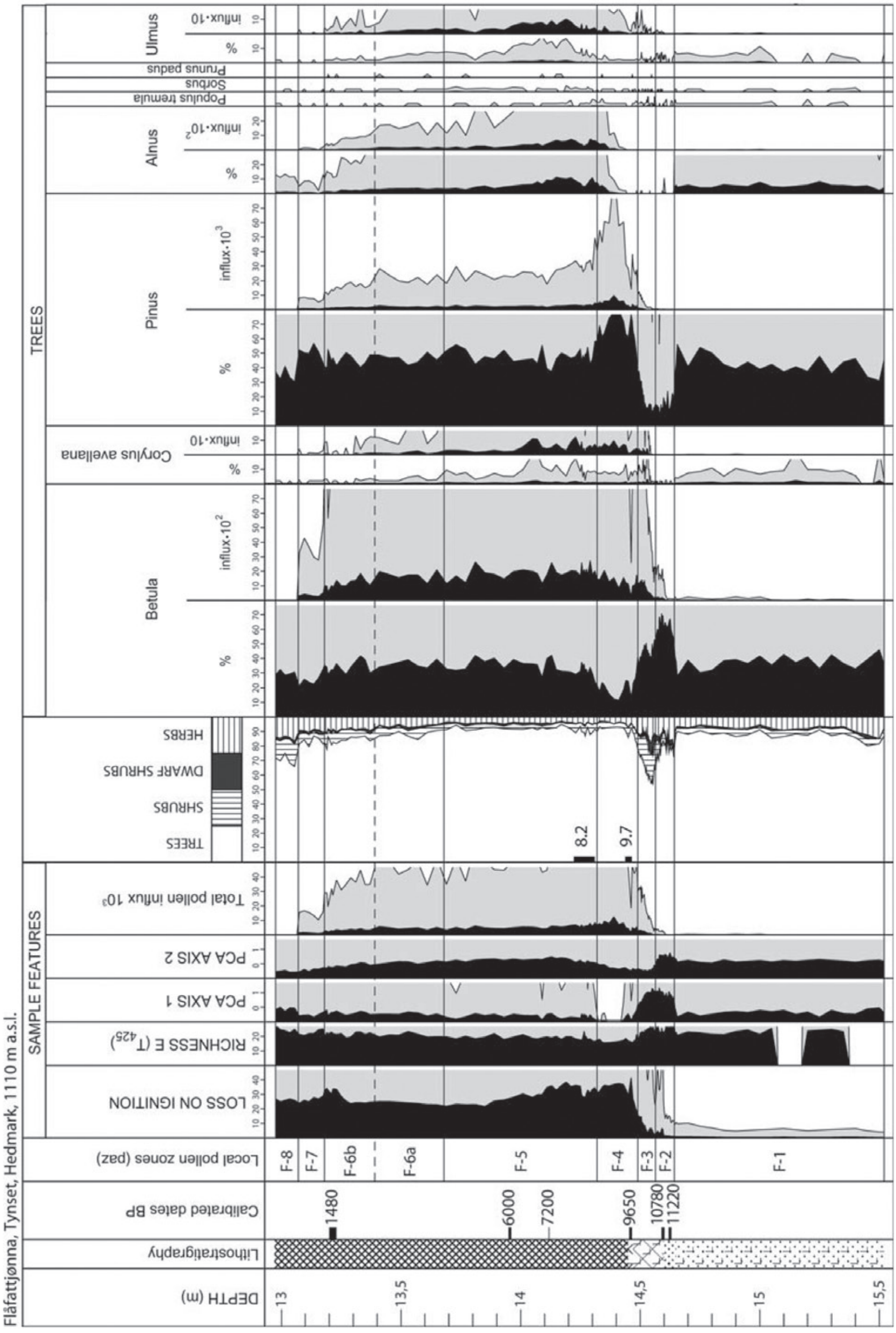
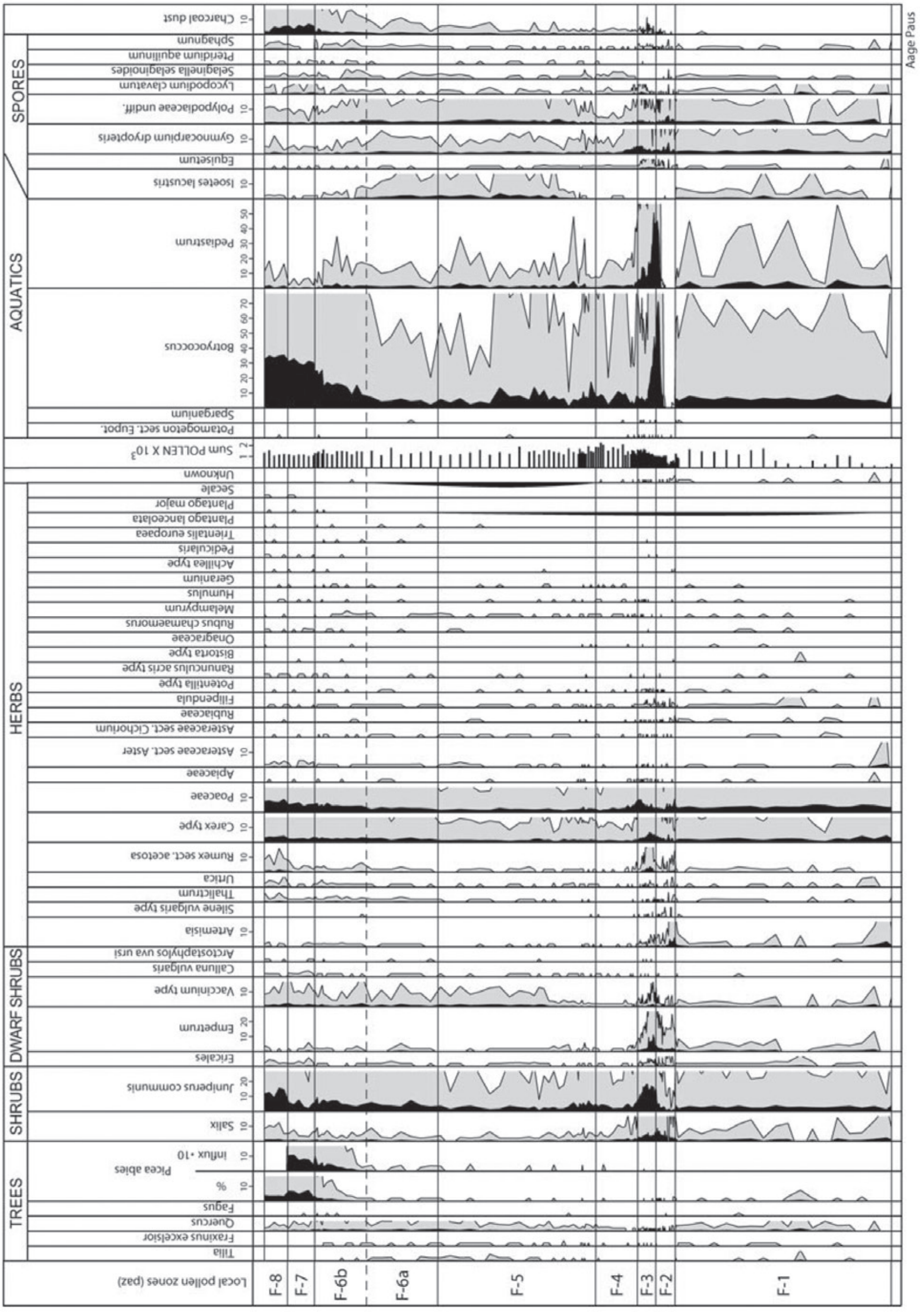


Fig. 16a-b. Pollen diagram from site 52, Flåfattjønna in the northern part of South Norway from the alpine zone with a pattern 1 charcoal curve. From Paus (2010:36–37).


Aage Paus
SPORES
Charcoal dust
Sphagnum
Pteridium aquilinum
Selaginella selaginoides
Lycopodium clavatum
Polypodiaceae unidiff.
Gymnocarpium dryopteris
Equisetum
Isoetes lacustris
AQUATICS
Pediastrum
Botryococcus
Sparganium
Potamogeton sect. Eupot.
Sum POLLEN X 10^3
Unknown
HERBS
Secale
Plantago major
Plantago lanceolata
Trientalis europaea
Pedicularis
Achillea type
Geranium
Humulus
Melampyrum
Rubus chamaemorus
Onagraceae
Bistorta type
Ranunculus acris type
Potentilla type
Filipendula
Rubiaceae
Asteraceae sect. Cichorium
Asteraceae sect. Aster
Apiaceae
Poaceae
Carex type
Rumex sect. acetosa
Urtica
Thalictrum
Silene vulgaris type
Artemisia
DWARF SHRUBS
Arctostaphylos uva ursi
Calluna vulgaris
Vaccinium type
Empetrum
Ericales
SHRUBS
Juniperus communis
Salix
TREES
Picea abies
influx • 10
%
Fagus
Quercus
Fraxinus excelsior
Tilia
Local pollen zones (paz)
F-8
F-7
F-6b
F-6a
F-5
F-4
F-3
F-2
F-1

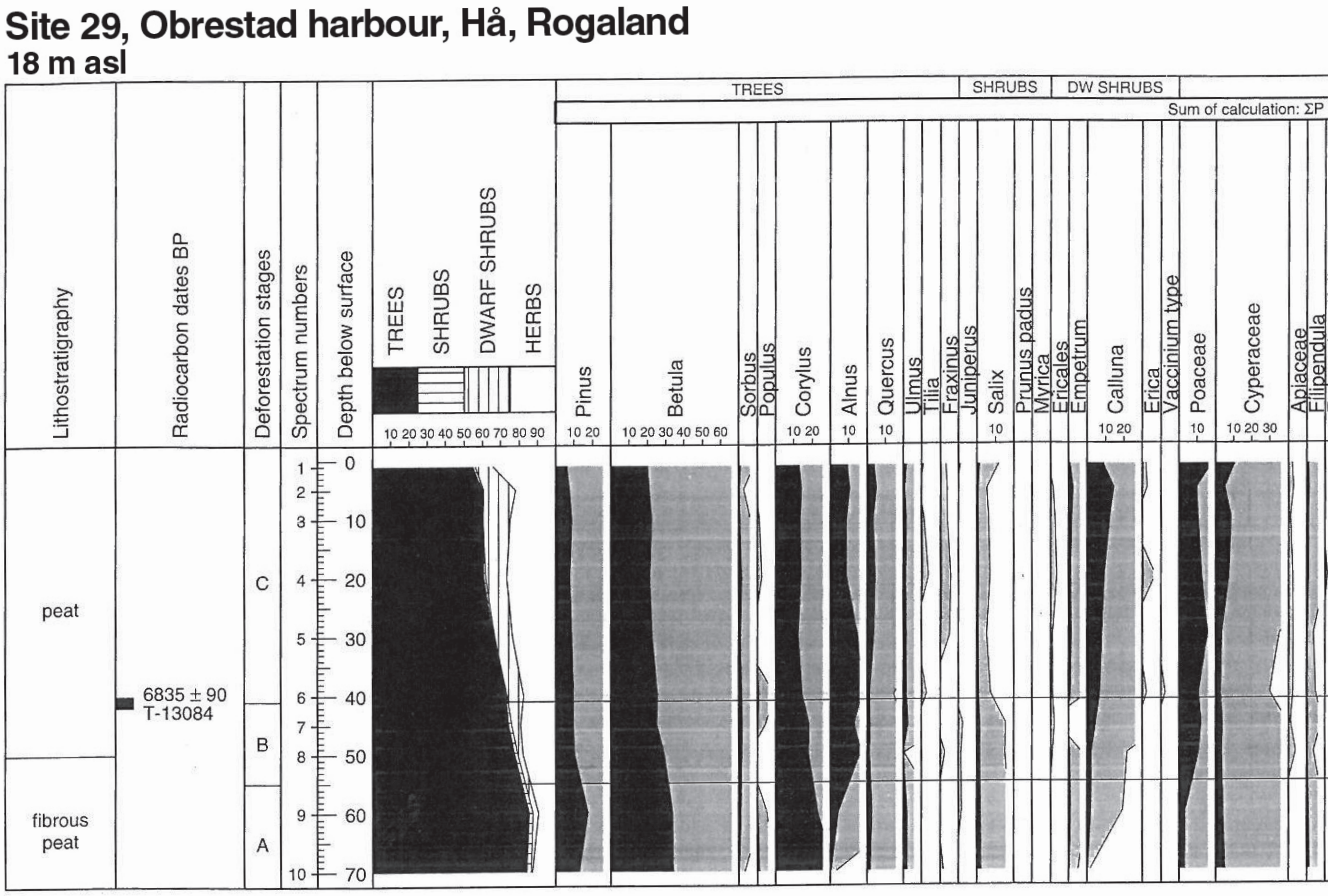
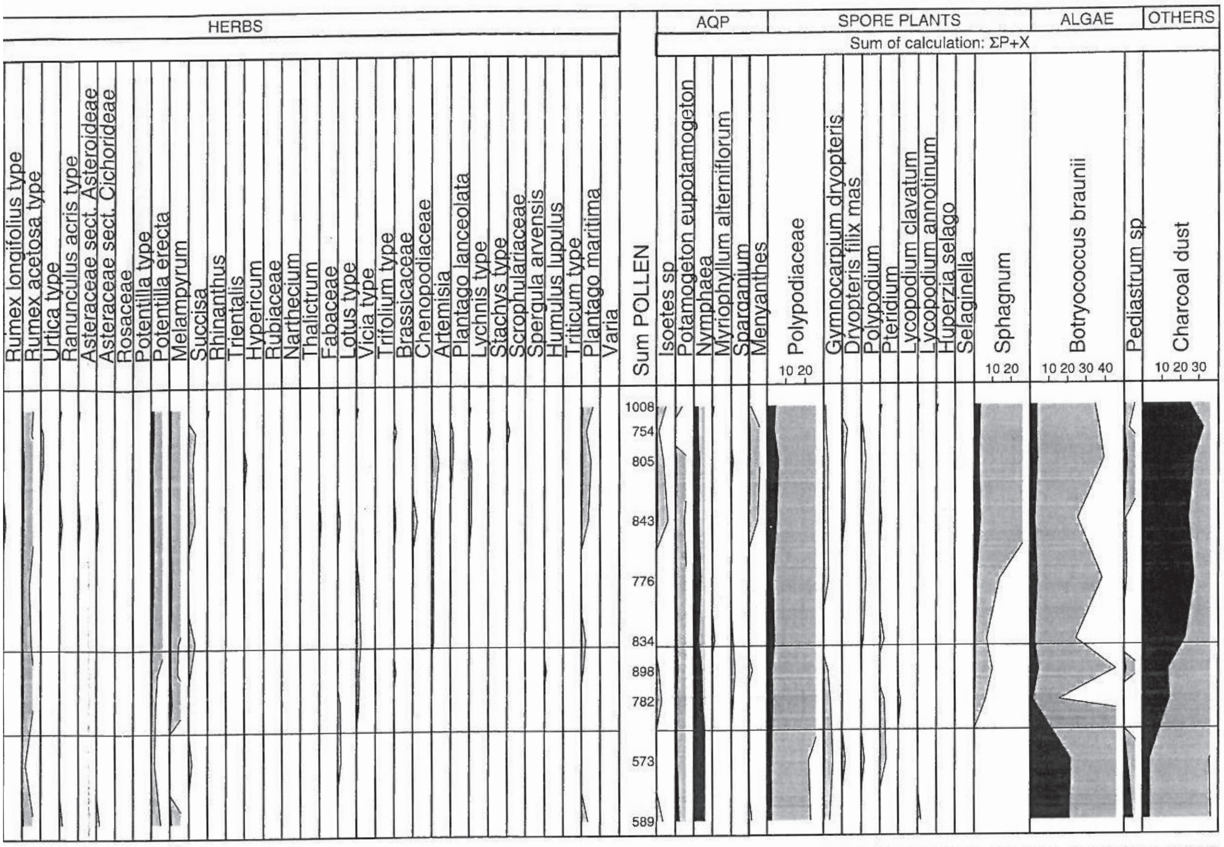


Fig. 17. Pollen diagram from site 30, Obrestad Harbour in Southwest Norway from the coastal forest zone with a pattern 2 charcoal curve. From Prøsch-Danielsen & Simonsen (2000a:50).



Analysis: Lisbeth Prøsch-Danielsen 1997

10 Final comments and conclusions

It has often been assumed that hunter-gatherers adjusted to their environment and that human-environmental relationships were simply passive, where people collected the products of nature with little or no impact upon natural phenomena (see Lewis 1977:16–17, Moore 2003:139). Environments limit culture, but usually it has not been accepted that foragers affect nature. Foragers' culture has been regarded as a form of symbioses between culture and nature. To a large degree, this was also the case for South Norway, where the nature was usually poor in many places and the particular plants and animals the foragers sought were scattered and not in great abundance—except marine resources, which are not discussed in this paper. Especially naturally dense forest may strongly have limited access to necessary resources and the ability to profit from nature without any manipulation or interferences. However, this attitude towards hunter-gatherers is changing (e.g. Innes *et al.* 2010, Grøn 2012, Bishop *et al.* 2015), as is also the attitude towards fire as a management tool (Seijo *et al.* 2015, Doerr & Santín 2016:1–2).

Burning was an important strategy and an essential and integral part of hunter-gatherers' culture of shaping their environment. Foragers have used fire in a variety of ways to modify and to maintain local environments to improve their yield from nature. They possessed important knowledge of the circumstances that created the required fire behaviour in order to reach their management and resource objectives. The use of fire may have given foragers the ability to change the environment in a purposeful way (Simmons *et al.* 1981:124). By the use of intentional burning, which involved a technologically sophisticated control of natural resources, the foragers in the Mesolithic in South Norway (and many other places) may have shaped plant and animal communities radically. They played significant roles in shaping their environments.

The reasons for neglecting the subject of intentional use of fire as part of foragers' adaptation of their environment was summed up by Lewis (1977:16–17, 1978:2, see also Bowman *et al.* 2004:208). They include 1) our own cultural traditions with an outdated view of how fire affects environments, 2) our own value-laden assumptions that foragers do not exert control over natural resources and 3) the perspective until recently that environments influence the behaviour of foragers and not the opposite. Many researchers lack the knowledge, have little attention of or ignore foragers' use of fire to transform natural environments (Lewis 1982:3). It is also thought provoking that the environment, of which much is today regarded as wilderness, was once exploited, used by means of well-organised activities and manipulated with fire by indigenous people (Lewis & Ferguson 1988:60, Grøn *et al.* 1999:23). As maintained by Pyne (1993:261), "Contemporary philosophies of primitivism typically deny anthropogenic fire a role in the management of parks, wilderness, or natural reserves."

The view of the climax forest as the optimal goal could have developed because the burning practices of the indigenous people in for instance North America were eliminated by governmental fire regulations (Lewis 1978:2). The effects of the sophisticated way that hunter-gatherers around the world handled fire in nature were not understood by the colonisers, likely because the hunter-gatherers were considered as primitive, without knowledge of burning.

The research on an expected increase in wildfires in the future should include anthropogenic fire impact on vegetation, which may have been more extensive than presumed and highly underestimated (Crawford *et al.* 2015, Lightfoot & Cuthrell 2015:1585). However, new research indicates that global area burnt appears to have declined over past decades (Doerr & Santín 2016).

The main conclusion is that the occurrence of charcoal in the pollen diagrams throughout the Mesolithic originated from hunter-gatherers' intentional use of fire and from natural fires only to a limited degree. People used fire management at settlement sites, but especially in the vegetation to improve the benefit of nature and maximise their aims, particularly to improve the yield of hunting ungulates. Frequent ground fires of low-intensity may have been a common feature. They may only have resulted in no or small changes in the pattern of the local pollen production and therefore would be difficult, if not impossible, to detect even in a detailed pollen diagram (Mellars 1976:34). Fire management activities resulted in an overall reduction of accumulated fuel in the vegetation because the intentional fires were small, very frequent and consequently less intense than natural fires. If the recorded charcoal occurrence was the result of natural fires, sites close to each other would have had charcoal occurrences similar to each other, but this is not the case. The different pattern of temporal changes of charcoal abundance suggests that no widespread burning took place, i.e. regionally on a landscape scale. This confirms that natural fires were much less common compared to anthropogenic fires.

There are many other convincing indications that hunter-gatherers in the Mesolithic used fire management in the vegetation in South Norway.

Other comments and conclusions:

1. The sites selected for palynological investigations, such as lakes and mires are usually better for disclosing fire management activities than traditional archaeological sites (settlement sites, burial mounds etc.). The banks of the lakes and the rims of the mires were probably burnt regularly in many places to improve pastures for ungulates that used them to graze and drink water.
2. Most of the 68 sites were selected because of archaeological aims located close to cultural activity. Spatial differences between the sites are almost entirely a function of their different local fire histories. The sites have been a good base for the present study to disclose intentional fire managements because the burning of vegetation was carried out in the landscapes used during the foragers' yearly rounds.
3. The present kind of investigation, using many pollen diagrams to disclose the foragers' fire regime in the past, is rare. All the sites taken together represent a good base for reconstructing whether and how foragers have used fire management as an important part of their cultural practice in the Mesolithic.
4. Burning was a part of and influenced daily life because fire management was a common and regular work task integrated with other doings. Burning may have been central to the hunting and gathering lifestyle and the key to many social and cultural activities. The timing of the burnings may have been related to the weather situation, time of the year and annual cultural events.
5. The charcoal curves have to be interpreted in the same way before and after the transition to the Neolithic, i.e. high values mean high activity independent of the time in the Holocene. There are no systematic differences in the charcoal occurrences before and after this transition that should require different interpretations. The charcoal curves after the transition have traditionally been interpreted as the result of intentional burning to clear the forest for agricultural purposes, ending up in deforestation many places, while this was not the case before the Neolithic. The forest was usually dense in many places during the Mesolithic, which prevented the deposition of long-distance transported charcoal particles from the air, resulting in low values of charcoal from the intentional burning. After the transition to the Neolithic, the forest opened, with increasing depositions of long-distance transported microscopic charcoal. This actually indicates more intense burning during the Mesolithic than indicated from the charcoal occurrences and compared to the period after the transition to the Neolithic.
6. The forest density during the Mesolithic was not as homogenous as traditionally viewed. Probably, the variations and changes in forest density were primarily the result of a forest mosaic caused by fire management activities, not so much in terms of a natural fire regime. Furthermore, the density of the forest often did not influence the variation in the charcoal curves, which can be small or large even if the forest density was unchanged, resulting from small fires below the crowns of the trees or at the edges of mires and lakes. In an area with dense forest, charcoal primarily had a local origin. Low and continuous charcoal curves, which are common and correspond to more or less dense forest, indicate a continuous production of charcoal, which is best interpreted as foragers' continuous use of fire with only local spreading and not natural fires.
7. The relative timing of changes in charcoal during the Mesolithic differed from site to site, suggesting no response to climatic change. The results do not support a suggestion that incidences of fire correlate with Holocene climatic changes, such as the early Holocene warm period. This strengthens the interpretation of an anthropogenic origin of the charcoal occurrences as the most plausible.
8. The first occurrences of charcoal in the pollen diagrams are much older than the transition to the Neolithic and there were no first occurrences after 7000 cal yr BP. It can be ruled out that the

first occurrences of charcoal can be correlated with agrarian cultures in South Norway. The pattern of first occurrences of charcoal strongly indicates an anthropogenic origin in hunter-gatherer culture.

9. The two periods with high frequency in maximum values of charcoal in the pollen diagrams are in the early (9800–6000 cal yr BP) and late part of the Holocene (after 2400 cal yr BP) with two periods of low frequency of maximum values (15,200–9800 cal yr BP and 6000–2400 cal yr BP). The oldest in the Late Weichselian Substage and the youngest between the two periods with high frequency in maximum values. Thus, the transition to the Neolithic is marked by a decrease in frequency of maxima in the charcoal occurrences. This shows that early farmers did not produce as much charcoal—measured in maxima—as the hunter-gatherers did before the transition to the Neolithic and confirms foragers' intentional burning as part of Mesolithic land-use in South Norway.
10. When the forest was denser in South Norway, in the Preboreal and Boreal chronozones, fire management was increasingly important for concentrating resources in selected areas.
11. Intentional burning may have taken place below the forest limit and to a lesser degree in the mountain area, where the need for fire management was limited because of open vegetation. The need for fire management was also reduced in the open subalpine *Betula* forest because the forest naturally had many of the characteristics that burning had the intention to create.
12. The correlation between the fire indicators *Melampyrum*, *Pteridium* and Onagraceae, and charcoal in the 68 palynological sites is weak. The sporadic occurrences may be attributed to often dense forests, insect-pollination or self-fertilising and limited dispersal of pollen and spores.
13. The results confirm the idea that hunter-gatherers' universal practice of controlled burning to create and maintain open pastures paved the way for pioneer farmers to convert land for agricultural purposes. This entails that neolitisation was not revolutionary, as the knowledge of using fire to open the forest had a long pre-agrarian history.
14. The main problem when using the literature about natural versus anthropogenic fires is that it is nearly always based on data from investigations that focus either on natural or on anthropogenic causes—not both. Thus, in the first case, anthropogenic factors are not taken into consideration and no or little information or references are available. In the last case, there are no estimates of, or references to, natural factors such as climate. That is a reason why, it is often not possible to separate natural and anthropogenic fire factors based on the literature and thus difficult or impossible to sort out the hunter-gatherers' fire regime and its influence on the vegetation during the Mesolithic.
15. Using qualitative and not only quantitative methods, gives a fuller understanding of the relation between people and nature.
16. The paper adds to the understanding of the important question: what is natural? As pointed out by Sprugel (1991) defining the "natural" vegetation is challenging, "because the vegetation in any given area would not be stable over long periods of time even without man's influence."

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Appendix A

Sites that focus on the Mesolithic and indications of fire. The vegetation development for each site is based on the descriptions of the original author. Eight pollen diagrams are selected to represent the four vegetation zones and the four charcoal curve patterns in Chapter 9 (Table 3 with asterix).

Site 1: Øvre Storvatnet loc. J, Bykle, Aust-Agder (980 m asl) (Blystad & Selsing 1988:77, 80–81, Selsing 2010:38–39)

The mire is an in-filled basin surrounded by open low-alpine vegetation characterised by heather and grass moors. 141 cm of sediment (gyttja covered by peat from 130 cm to the top) deposited over 9600 cal yr means an accumulation rate of 1 cm/68 cal yr. A hiatus of about 1300 cal yr (approximately 8000–6700 yr BP, 8900–7600 cal yr BP) means that a more correct accumulation rate is 1 cm/59 cal yr or 0.170 cm/10 cal yr. The investigation was carried out because of Late Mesolithic settlements in the area (Bang-Andersen 2008).

Charcoal curve: Continuous and low from the bottom, with maxima (5–7%) at bottom and top, and a very low level 6300–4400 yr BP (7200–5000 cal yr BP).

The three taxa favoured by fire and openings in the forest:

1) Onagraceae: Sporadic with maximum (0.5%) at bottom
2) *Melampyrum*: Sporadic from the bottom
3) *Pteridium*: None

Vegetation development: Open vegetation dominated by *Salix*, *Rumex* and other herbs (bottom 8600 yr BP, 9600 cal yr BP) soon after deglaciation. The charcoal occurrence indicates that hunter-gatherers used the area with low intensity and this is confirmed by the presence of Onagraceae. The decrease of *Rumex* and increase in *Corylus* was followed by a rise in *Betula* and a decrease in *Corylus* about 8500 yr BP (9500 cal yr BP), followed by a rise in *Alnus* around 8000 yr BP (8900 cal yr BP). Pollen from both *Corylus* and *Alnus* was probably transported from lower altitudes. Open mixed forest of *Pinus* and *Betula* characterised the vegetation, with a relatively rich under-storey of e.g. *Melampyrum* and higher values of Cyperaceae. Charcoal occurs at about 2%, indicating that people still used the area with low intensity, probably mostly for hunting reindeer. After the hiatus, *Alnus* and herbs increased 6700 yr BP (7600 cal yr BP), dominated by Cyperaceae and followed by an increase in species from the *Rhododendron* order at the same time as the forest limit decreased. About 5600 yr BP (6400 cal yr BP), the *Pinus* forest limit decreased to below the site. The open mixed forest changed to open vegetation with scattered trees and shrubs of *Betula*. This is confirmed by the identification of *Betula*, *Juniperus*, *Pinus* and *Salix* from macroscopic charcoal from archaeological sites from the period 7000–6000 yr BP (7900–6800 cal yr BP) (Bang-Andersen 1986). The continuous and low occurrence of charcoal indicates that people may still have used the area with low intensity. The earliest palynological traces of agricultural activity, pollen of ribwort plantain, are indicated 3400 yr BP (3700 cal yr BP). Low-alpine vegetation was dominated by heather and grass moors at the same time as the forest limit continued to decline.

Site 2: Persmyrkoia, Åmot (Rødsmoen), Hedmark (304 m asl) (Høeg 1996:19–25) (Fig. 10a-b)

The mire is situated in an open *Pinus* forest with *Picea*. 145 cm of peat deposited over 9100 cal yr means an accumulation rate of 1 cm/63 cal yr. A hiatus of about 1200 cal yr (2200–1100 yr BP, 2200–1000 cal yr BP) means that a more correct accumulation rate is 1 cm/54 cal yr or 0.183 cm/10 cal yr. The investigations were conducted because of the construction of military facilities (Boaz 1997:141). The archaeological record shows settlement since the Middle Mesolithic (Boaz 1997:34, 38, 137, see Bergstøl 1997 for younger archaeological sites and Narmo 1997 for iron extraction sites)

Charcoal curve: Continuous and irregular from the bottom, maximum (>2000%) bottom to 7600 yr BP (8400 cal yr BP), gap from 4400–3000 yr BP (5000–3200 cal yr BP) and very low until 1100 yr BP (1000 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Sporadic <8000 yr BP (8900 cal yr BP), maximum (<1%) 5000 yr BP (5700 cal yr BP)
3) *Pteridium*: Sporadic from the bottom, maximum (~2%) 500 yr BP (500 cal yr BP)

Vegetation development: Dense mixed *Pinus* and *Betula* forest with *Corylus* (bottom 8200 yr BP, 9100 cal yr BP) with high values of charcoal indicate that people lived in the area, using burning close to or at the site. *Alnus* increased with changing amounts of *Betula* and *Pinus*. Burning occurred until 4600 yr BP (5300 cal yr BP) with varying intensity, which influenced the forest. Probably, people lived in the area until this time. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4000 and 3200 yr BP (4500 and 3400 cal yr BP), respectively.

Site 3: Ulvehammeren, Åmot (Rødsmoen), Hedmark (292 m asl) (Høeg 1996:25–30)

The present vegetation around the small mire (in-filled basin) is *Pinus* forest with *Picea* and *Betula*. 145 cm of sediment (gyttja covered by peat from 127 cm to the top) was deposited over 10,200 cal yr, with an accumulation rate of 1 cm/70 cal yr or 0.142 cm/10 cal yr. The investigations were conducted because of the construction of military facilities (Boaz 1997:141).

Charcoal curve: Continuous, with large fluctuations from 8800 yr BP (9800 cal yr BP), maxima 7900–7300 yr BP (8700–8100 cal yr BP) and 6100 yr BP (7000 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence at the bottom
2) *Melampyrum*: Sporadic 7900 yr BP (8700 cal yr BP), continuous >7300 yr BP (8100 cal yr BP)
3) *Pteridium*: Sporadic <8700 yr BP (9600 cal yr BP), maximum (~1%) 6100 yr BP (7000 cal yr BP)

Vegetation development: Soon after deglaciation (bottom 9000 yr BP, 10,200 cal yr BP), the vegetation was dominated by herbs and shrubs. *Pinus* increased in the open *Betula* forest. About 8800 yr BP (9800 cal yr BP), a small maximum in charcoal indicates that fire reduced the forest, followed by other fires, probably in the catchment area of the mire. People may have caused the fires intentional or they may have been unintentionally. The mixed *Betula* and *Pinus* forest was dense, with small fluctuations. The high but fluctuating charcoal values indicate that fires may have influenced the forest at least until 5400 yr BP (6200 cal yr BP). The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 3700 yr BP (4000 cal yr BP) and 300 yr BP (400 cal yr BP), respectively.

Site 4: Dulpmoen, Åmot (Rødsmoen), Hedmark (273 m asl) (Høeg 1996:16, 30–35)

The mire (in-filled basin) is surrounded by a mixed *Pinus-Picea* forest with *Betula*. 339 cm of sediment (gyttja from the bottom covered by peat from 175 cm to the top) was deposited over 8900 cal yr, with an accumulation rate of 1 cm/26 cal yr or 0.381cm/10 cal yr. The investigations were conducted because of the construction of military facilities (Boaz 1997:141). The site was situated about two kilometres northeast of site 3 and close to three archaeological sites from the Stone Age (Boaz 1997:34, see Bergstøl 1997 for younger archaeological sites and Narmo 1997 for iron extraction sites).

Charcoal curve: Nearly continuous from the bottom, with large fluctuations, maximum (>1800%) 5400 yr BP (6200 cal yr BP), five younger maxima.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Sporadic <7300 yr BP (8100 cal yr BP)
2) *Melampyrum*: Sporadic <6900 yr BP (7700 cal yr BP), nearly continuous <5200 yr BP (6000 cal yr BP), maximum (~10%) 1100 yr BP (1000 cal yr BP)
3) *Pteridium*: Nearly continuous <7500 yr BP (8300 cal yr BP)

Vegetation development: The dense forest was mixed with *Betula* and *Pinus*, with short periods of reduced density (bottom 8000 yr BP, 8900 cal yr BP). *Alnus* grew at moist places. *Corylus* grew in the area and occasionally *Quercus*. The charcoal curve is low during the Mesolithic, with the oldest marked maximum about 5400 yr BP (6200 cal yr BP). The earliest palynological recorded agricultural activity (cereal pollen and pasturing) is indicated about 4200 yr BP (4800 cal yr BP) and 2600 yr BP (2700 cal yr BP), respectively.

Site 5: Ottersmyra, Åmot (Rødsmoen), Hedmark (273 m asl) (Høeg 1996:35–40)

The larger mire (in-filled basin) is surrounded by *Pinus* forest with *Picea* and *Betula*. 245 cm of sediment (gyttja covered by peat from 190 cm to the top) was deposited over 9800 cal yr, with an accumulation rate of 1 cm/40 cal yr or 0.250 cm/10 cal yr. The investigations were conducted because of the construction of military facilities (Boaz 1997:141). The site was situated close to seven archaeological sites from the Stone Age (Boaz 1997:36, see Bergstøl 1997 for younger archaeological sites and Narmo 1997 for iron extraction sites).

Charcoal curve: Low and continuous <8800 yr BP (9800 cal yr BP), generally <4% until 4200 yr BP (4800 cal yr BP), rise 1500 yr BP (1400 cal yr BP) and maximum 900 yr BP (800 cal yr BP).

The three taxa favoured by fire or openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Sporadic from the bottom
3) *Pteridium*: Nearly continuous <6400 yr BP (7300 cal yr BP)

Vegetation development: Vegetation of herbs and shrubs (bottom 9100 yr BP, 10,300 cal yr BP) was replaced by a forest of *Betula* and later also *Pinus*. The dense mixed *Betula-Pinus* forest existed 8300–2100 yr BP (9300–2100 cal yr BP). The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 3100 yr BP (3300 cal yr BP) and 800 yr BP (700 cal yr BP), respectively.

Site 6: Kåsmyra, Tolga, Hedmark (925 m asl) (Høeg 1996:63–68)

The 250 m long mire (in-filled basin) is surrounded by open *Betula* forest. 325 cm of sediment (gyttja replaced by peat at 313 cm to the top) was deposited over 9100 cal yr, with an accumulation rate of 1 cm/28 cal yr or 0.357 cm/10 cal yr. The vegetation history investigation was initiated in connection with the writing of local history.

Charcoal curve: Sporadic <7800 yr BP (8600 cal yr BP) with three small maxima (<2%) two of them 7800–7500 yr BP (8600–8300 cal yr BP) and 5700–5400 yr BP (6500–6200 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Sporadic from the bottom
3) *Pteridium*: Sporadic <7200 yr BP (8000 cal yr BP)

Vegetation development: The dense forest was mixed with *Betula* and *Pinus* from the bottom (8200 yr BP, 9100 cal yr BP) with *Alnus*. The two occurrences of charcoal were probably caused by hunters using the area at the edge of the forest. *Alnus* declined and *Pinus* increased 5500 yr BP (6300 cal yr BP). The forest became gradually more open from 4100 yr BP (4700 cal yr BP) and *Picea* probably immigrated. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 2900 yr BP (3000 cal yr BP) and 1500 yr BP (1400 cal yr BP), respectively.

Site 7: Lille Sølensjøen, Øvre Rendal, Hedmark (705 m asl) (Høeg 1996:79–84)

The small mire is surrounded by *Pinus* forest with *Betula*. 127 cm of peat was deposited over 7400 cal yr, with an accumulation rate of 1 cm/58 cal yr or 0.172 cm/10 cal yr. The pollen investigation was initiated because of the close proximity of burial mounds from the Late Iron Age (Høeg 1996:59, 62 with reference to Skjølsvold 1958, 1981).

Charcoal curve: Continuous and low (<3%) from the bottom, hiatus 4300–2100 yr BP (4900–2100 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Nearly continuous from the bottom, maximum (1%) 800 yr BP (700 cal yr BP)
3) *Pteridium*: Nearly continuous from the bottom

Vegetation development: Mixed dense forest of *Betula* and *Pinus* with a little *Alnus* (bottom 6500 yr BP, 7400 cal yr BP) existed until 5000 yr BP (5700 cal yr BP) when *Alnus* decreased. *Picea* immigrated 2000 yr BP (2000 cal yr BP) at the same time as the opening of the forest with changing amounts of *Pinus* and *Betula*. The deposition of charcoal was probably caused by people's activity in the area. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 2000 yr BP (2000 cal yr BP) and 1600 yr BP (1500 cal yr BP), respectively, confirmed by the archaeological record.

Site 8: Hirsjøen, Ringebu, Hedmark (729 m asl) (Høeg 1996:99, 102–109)

The mire (in-filled basin) is surrounded by mixed *Picea* and *Pinus* forest, with *Betula* and pastures. 650 cm of sediment (gyttja with sporadic sand layers to 175 cm covered by peat to the top) was deposited over 10,200 cal yr, which means an accumulation rate of 1 cm/16 cal yr or 0.637 cm/10 cal yr (high values i.a. caused by the sand layers). The site is situated in Hirkjølen, forest and climate test area since 1929 (see Mork & Heiberg 1937), chosen as a demonstration area for multiple use of the mountain forest by the Ministry of Agriculture.

Charcoal curve: Sporadic and low <8800 yr BP (9800 cal yr BP), continuous from 7900 yr BP (8700 cal yr BP) and maximum (>400%) 1000 yr BP (900 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Sporadic <6400 yr BP (7300 cal yr BP)

2) *Melampyrum*: Sporadic <7700 yr BP (8400 cal yr BP), continuous <6400 yr BP (7300 cal yr BP), maximum (1%) 2200 yr BP (2200 cal yr BP)
3) *Pteridium*: Low and nearly continuous <6900 yr BP (7700 cal yr BP), maximum (<1%) 900 yr BP (800 cal yr BP)

Vegetation development: Open *Betula* forest with herbs and shrubs (bottom 9000 yr BP, 10,200 cal yr BP) was followed by a gradually denser *Pinus* forest with some *Betula* 8600 yr BP (9600 cal yr BP). The charcoal curve indicates the occurrence of people earlier than indicated by the archaeological record from Atnasjøen northwest of the site, where people lived about 6500 yr BP (7400 cal yr BP) ago (Mikkelsen 1980). The forest was characterised by *Betula* and *Pinus* with some *Alnus* 7500–5100 yr BP (8300–5800 cal yr BP) and the occurrence of charcoal indicates the regular presence of people. The density of the forest decreased about 6900–6400 yr BP (7700–7300 cal yr BP). The earliest palynological recorded agricultural activity (cereal pollen and pasturing) is indicated about 5700 yr BP (6500 cal yr BP, maybe large grass pollen) and 2400 yr BP (2400 cal yr BP), respectively.

Site 9: Engelaug, Løten, Hedmark (184 m asl) (Høeg 1996:125–131)

The small mire (in-filled basin) is surrounded by *Betula* in an agricultural landscape. 348 cm of sediment (348–290 cm inorganic material with little pollen covered by gyttja 290–265 cm (this level corresponds to 9300 yr BP, 10,500 cal yr BP) and peat to the top) was deposited over 11,200 cal yr, with an accumulation rate of 1 cm/32 cal yr or 0.031 cm/10 cal yr. Without the inorganic material, which influences the accumulation rate, the values are changed to 1 cm/36 cal yr or 0.276 cm/10 cal yr. Archaeological excavations were carried out close to the palynological site. The pit with burnt bones from elk indicates mobile hunter-gatherers' use of the area (Risbøl 1997:8).

Charcoal curve: Continuous with large fluctuations, maximum (2600% and 4500%) 8600 yr BP and 8200 yr BP (9600 cal yr BP and 9100 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Sporadic <7200 yr BP (8000 cal yr BP)
2) *Melampyrum*: Sporadic <9300 yr BP (10,500 cal yr BP)
3) *Pteridium*: Sporadic <8700 yr BP (9600 cal yr BP), maximum 6600–4800 yr BP (7500–5500 cal yr BP)

Vegetation development: Open *Betula* forest with herbs and shrubs dominated from the bottom (9700 yr BP, 11,200 cal yr BP). The charcoal curve indicates the presence of hunter-gatherers in the area from shortly after 9200 yr BP (10,400 cal yr BP). Natural fire was excluded because deciduous trees burn poorly (Rackham 1980). *Pinus* increased and dominated, mixed with *Betula* 9100–8100 yr BP (10,200–9000 cal yr BP). The two very high maxima in charcoal may have resulted from fires, either natural or intentional, caused by people. The density of the *Pinus* forest with *Betula* was changing until 3900 yr BP (4400 cal yr BP). The charcoal occurrence is so high that without doubt natural or intentional fires occurred at least until 5000 yr BP (5700 cal yr BP) and especially in the period 8500–7700 yr BP (9500–8500 cal yr BP), but also later until 1500 yr BP (1400 cal yr BP). Regular fires occurred throughout this period and people probably kept openings in the landscape by using fire. The earliest palynological recorded agricultural activity (cereal pollen and pasturing) is indicated about 3800 yr BP (4200 cal yr BP) and 3400 yr BP (3700 cal yr BP), respectively.

Site 10: Kittilbu, Nordre Land, Oppland (820 m asl) (Høeg 1990:51–58)

The mire (60x200 m, part of a larger mire) is situated in *Picea* forest. 210 cm of peat was deposited over 8900 cal yr, which means an accumulation rate of 1 cm/42 cal yr or 0.236 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required in conjunction with hydroelectric power plans (see Boaz 1998). The site was situated only 2–6 km north of archaeological sites from 8000–2500 yr BP (8900–2600 cal yr BP, Boaz 1998:Chapter 18, iron extraction sites see Larsen 1991).

Charcoal curve: Continuous and low from the bottom, rising from 1600 yr BP (1500 cal yr BP), maximum 1500 yr BP (1400 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Nearly continuous and low from the bottom
3) *Pteridium*: Scarce <7700 yr BP (8500 cal yr BP)

Vegetation development: The *Pinus* forest was open with *Betula* and *Alnus* (bottom 8000 yr BP, 8900 cal yr BP). *Betula* increased and *Pinus* had two minima about 5900 yr BP (6700 cal yr BP) and in the period 4300–4100 yr BP (4900–4700 cal yr BP). From this time, the forest was mixed with *Betula* and *Pinus*. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 2800 yr BP (2900 cal yr BP) and 1200 yr BP (1100 cal yr BP), respectively.

Site 11: Rud Øde, Nannestad, Akershus (200 m asl) (Høeg 1997:21–30)

The very small mire is surrounded by a mixed *Pinus-Picea* forest with *Betula* and agricultural areas. 175 cm of peat (some places with a little sand) was deposited over 10,700 cal yr, with an accumulation rate of 1 cm/61 cal yr or 0.164 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required during the construction of the Oslo Airport, Gardermoen (Helliksen 1997). The archaeological record indicates settlement from the Late Bronze Age to the Middle Ages with burial mounds and pits from the Roman period until Late Middle Ages. The closest archaeological sites are 1–3 km from the pollen sampling site (Early Iron Age and Middle Ages) (Gustafson 1995:169, Helliksen 1997:8–9, 15).

Charcoal curve: Irregular and discontinuous from the bottom, three maxima periods 8900–7800 yr BP (10,000–8600 cal yr BP), 4800–4600 yr BP (5500–5300 cal yr BP) and 2100–500 yr BP (2100–500 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <9000 yr BP (10,200 cal yr BP)
2) *Melampyrum*: Sporadic from the bottom
3) *Pteridium*: Sporadic <9300 yr BP (10,500 cal yr BP), nearly continuous <6400 yr BP (7300 cal yr BP)

Vegetation development: Open *Betula* forest with herbs and shrubs dominated (bottom 9500 yr BP, 10,700 cal yr BP). The *Pinus* forest was dense with *Betula* and *Corylus* about 8700 yr BP (9600 cal yr BP). The oldest maximum period in charcoal was probably caused by hunters and not by natural fire. *Pinus* declined about 7800 yr BP (8600 cal yr BP) at the same time as an increase in *Betula* and *Corylus* and rise in *Alnus* may have been caused by forest fire. The dense forest was mixed with *Pinus*, *Alnus*, *Betula* and *Corylus* until 6600 yr BP (7500 cal yr BP). The low charcoal occurrence indicates only little use by people in this period. The dense *Betula* forest was mixed with *Alnus*, *Corylus* and *Pinus* until 5200 yr BP (6000 cal yr BP) with no traces of people. *Betula* dominated but varied in the dense forest with *Tilia*, *Corylus* and *Alnus* and a high amount of Polypodiaceae in the field layer. The charcoal maximum period may indicate people's attempts with pasturing animals (earliest record of *Plantago lanceolata* 4400 yr BP, 5000 cal yr BP). After about 3700 yr BP (4000 cal yr BP), the dense *Betula* forest was mixed with *Quercus*, while *Alnus* grew close to the mire with Polypodiaceae in the field layer. The earliest palynological recorded cereal pollen is 2200 yr BP (2200 cal yr BP). The upper maximum period in charcoal is interpreted as caused by intentional use of fire for clearing for pasturing husbandry and cultivation.

Site 12: Danielsetermyr, Ullensaker, Akershus (175 m asl) (Høeg 1997:30–36) (Fig. 12a-b)

The mire is surrounded by *Picea* forest with some *Betula* and agricultural areas. 565 cm of peat was deposited over 7200 cal yr, which means an accumulation rate of 1 cm/13 cal yr or 0.785 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required during the construction of the Oslo Airport, Gardermoen (Helliksen 1997).

Charcoal curve: Continuous from the bottom with maximum (450%) until 6000 yr BP (6800 cal yr BP) followed by low values rising upwards from 3600 yr BP (3900 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <6200 yr BP (7100 cal yr BP)
2) *Melampyrum*: Sporadic <6000 yr BP (6800 cal yr BP)
3) *Pteridium*: Nearly continuous from the bottom, rise 3500 yr BP (3800 cal yr BP), maximum >10% 2400 yr BP (2400 cal yr BP)

Vegetation development: The forest was a mixture of *Betula*, *Pinus* and *Alnus* (bottom 6300 yr BP, 7200 cal yr BP). Maximum in charcoal over about 300 years in the partly open forest is consistent with people living in the area and not natural forest fires. The *Betula* forest changed, with decreasing *Pinus* and increasing *Corylus*, *Ulmus*, *Quercus* and *Tilia* (maximum 15%), until about 3600 yr BP (3900 cal yr BP). At this time, the charcoal curve and *Pteridium* rose. *Betula* had a maximum and decreased together with the other deciduous trees at the same time as *Pinus* increased markedly in the dense forest, with *Alnus* close to the mire. The opening of the forest started about 1200 yr BP (1100 cal yr BP). The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4800 yr BP (5500 cal yr BP) and 3500 yr BP (3800 cal yr BP), respectively.

Site 13: Svenskestutjern, Ullensaker, Akershus (198 m asl) (Høeg 1997:36–41)

Mixed forest of *Pinus* and *Picea* surround the lake. 283 cm of gyttja was deposited over 7400 cal yr, with an accumulation rate of 1 cm/26 cal yr or 0.382 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required during the construction of the Oslo Airport, Gardermoen (Helliksen 1997).

Charcoal curve: Continuous from the bottom, irregular with large fluctuations, increase 5300 yr BP (6100 cal yr BP) and maximum (65%) 4700 yr BP (5400 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Scarce <3600 yr BP (3900 cal yr BP)
3) *Pteridium*: Nearly continuous <6500 yr BP (7400 cal yr BP)

Vegetation development: Dense *Betula* forest (bottom 6500 yr BP, 7400 cal yr BP) with *Corylus*, *Ulmus*, *Quercus* and *Tilia* dominated by *Alnus* at moist places. *Betula* had a maximum 4000–3700 yr BP (4500–4000 cal yr BP) and then decreased together with thermophilous, deciduous trees and the charcoal at the same time as *Pinus* increased. Probably, agrarian people used the area in the period 4700–2800 yr BP (5400–2900 cal yr BP) using fire with changing intensity. *Picea* increased about 2300 yr BP (2300 cal yr BP) and 1700 yr BP (1800 cal yr BP) the vegetation was considerably more open. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4500 yr BP (5200 cal yr BP) and 2100 yr BP (2100 cal yr BP), respectively.

Site 14: Bånntjern, Ullensaker, Akershus

(196 m asl) (Høeg 1997:41–46)

Mixed forest of *Pinus* and *Picea* surround the lake. 497 cm of gyttja was deposited over 7100 cal yr, with an accumulation rate of 1 cm/14 cal yr or 0.700 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required during the construction of the Oslo Airport, Gardermoen (Helliksen 1997). The archaeological record indicates settlement that varies from the Late Bronze Age to the Middle Ages. The closest archaeological sites were situated 2–4 km from the pollen sampling site (Late Bronze Age and Middle Ages, Helliksen 1997:8–9, 15).

Charcoal curve: Continuous from the bottom with fluctuations from 4400 yr BP (5000 cal yr BP), rising upwards with maximum (>3500%) 1600 yr BP (1500 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <2700 yr BP (2800 cal yr BP)
2) *Melampyrum*: Scarce <4000 yr BP (4500 cal yr BP)
3) *Pteridium*: Nearly continuous from the bottom

Vegetation development: Dense *Betula* forest with *Corylus*, *Quercus* and *Tilia*, and *Alnus* at moist places (bottom 6200 (8200) yr BP (7100 (9100) cal yr BP) opened at the same time as the earliest palynological indication of agricultural activity (pasturing and cereal pollen), 4400 yr BP (5000 cal yr BP) and 4000 yr BP (4500 cal yr BP), respectively, and an increase in charcoal deposition. This indicates clearings, pasturing and cereal growing near the site. Probably people did not use the area before this time. *Betula* rose to a maximum and then decreased at the same time as *Pinus* increased about 3600 yr BP (3900 cal yr BP) The dense mixed forest with changing dominance of *Betula* and *Pinus* and few other deciduous trees, except from *Alnus* at moist places, was dominated by changing but generally increasing charcoal deposition. *Picea* increased about 1600 yr BP (1500 cal yr BP) and a *Pinus-Picea* forest with *Betula* opened towards the present.

Site 15: Skånetjern, Ullensaker, Akershus

(191 m asl) (Høeg 1997:47–51)

The lake is surrounded by mixed forest with *Betula*, *Pinus* and *Picea* with a little *Alnus*. 680 cm of gyttja was deposited over 9100 cal yr which means an accumulation rate of 1 cm/13 cal yr or 0.747 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required during the construction of the Oslo Airport, Gardermoen (Helliksen 1997).

Charcoal curve: Discontinuous and low (0–3%) <8000 yr BP (8900 cal yr BP), rising from 3700 yr BP (4000 cal yr BP) with fluctuations, maximum (420%) 1200 yr BP (1100 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence <1000 yr BP (900 cal yr BP)
2) *Melampyrum*: Sporadic <3800 yr BP (4200 cal yr BP)
3) *Pteridium*: Sporadic <7100 yr BP (7900 cal yr BP), nearly continuous <6400 yr BP (7300 cal yr BP)

Vegetation development: Mixed *Betula* and *Pinus* forest with *Corylus* (bottom 8200 yr BP, 9100 cal yr BP) grew dense and *Alnus* increased. About 6300 yr BP (7200 cal yr BP) the dense *Betula* forest was mixed with *Pinus* and warmth-demanding deciduous trees and *Alnus* grew at moist places. *Tilia* and *Alnus* rose and about 4600 yr BP (5300 cal yr BP) *Betula* increased markedly, at the same time as a rise in *Quercus*. At 3900 yr BP (4400 cal yr BP), the dense forest was dominated by *Betula*, followed by a decrease at the same time as a rise in *Pinus* and charcoal in the *Betula* forest. Probably, people used the area for agricultural purposes. *Picea* increased about 2800 yr BP (2900 cal yr BP), at the same time as decreasing density of the forest and rise in charcoal, which indicates agrarian people. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4300 yr BP (4900 cal yr BP) and 3700 yr BP (4000 cal yr BP), respectively.

Site 16: Skjoldnes myr I, Farsund, Vest-Agder
(4 m asl) (Høeg 1995:272–283)

The mire (in-filled basin) is surrounded by a *Betula* forest. 1006 cm of sediment (in the bottom 856 cm of gyttja, partly with silt and clay, was covered by 150 cm of peat to the top) was deposited over 15,600 cal yr, with an accumulation rate of 1 cm/16 cal yr or 0.645 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required because of a local development plan (Ballin & Jensen 1995). The site was situated about 3 km to the southeast of archaeological sites from the Middle Mesolithic until the Roman period (Ballin & Jensen 1995:21, 25).

Charcoal curve: Discontinuous, with three maxima, the earliest one (500–2700%) from the bottom to 11,200 yr BP (13,200 cal yr BP), the second one 7400–4100 yr BP (8200–4700 cal yr BP) and the third one 800–300 yr BP (700–400 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Sporadic <11,500 yr BP (13,500 cal yr BP)
2) *Melampyrum*: Sporadic <9300 yr BP (10,500 cal yr BP)
3) *Pteridium*: Continuous <7400 yr BP (8200 cal yr BP)

Vegetation development: Open pioneer vegetation of herbs and shrubs (bottom 13,200 yr BP, 15,600 cal yr BP) with long-distance transported and or redeposited taxa dominating until 12,300 yr BP (14,400 cal yr BP). The open vegetation lasted until about 11,500 yr BP (13,500 cal yr BP) when open *Betula* forest spread during the Allerød chronozone, to disappear again during the Younger Dryas chronozone. The earliest charcoal maximum was probably the result of hunter-gatherers, who used the area during the Late Weichselian Substage, especially parts of the Bølling chronozone and less intensively during the Younger Dryas chronozone. At the transition to the Holocene *Betula* forest with shrubs spread. First *Corylus* and later *Alnus* increased and dominated, as the forest grew denser. The mixed *Quercus* forest increased, with *Quercus* as the dominating taxa together with warmth-demanding deciduous taxa in the dense forest. The second charcoal maximum, which started with a peak (2200%) in the middle of this period, probably had an anthropogenic origin. The mixed *Betula-Quercus-Alnus* forest opened with oscillations about 2500 yr BP (2600 cal yr BP). The earliest palynological recorded agricultural activity (cereal pollen and pasturing) is about 7400 yr BP (8200 cal yr BP, maybe a large grass pollen) and 4800 yr BP (5500 cal yr BP), respectively.

Site 17: Fjellestad myr I, Farsund, Vest-Agder
(4.5 m asl) (Høeg 1995:288–294)

The small mire (in-filled basin) is surrounded by *Pinus* forest with *Betula*, *Picea*, *Quercus*, *Juniperus* and *Salix*. 240 cm of sediment, in the bottom clay to 208 cm covered by gyttja (partly with sand) to 167 cm and peat to the top, was deposited over 14,400 cal yr, which means an accumulation rate of 1 cm/60 cal yr or 0.167 cm/10 cal yr. A hiatus of 5700 cal yr (8200–3200 yr BP, 9100–3400 cal yr BP) means that a more correct accumulation rate is 1 cm/36 cal yr or 0.276 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required because of a local development plan (Ballin & Jensen 1995).

Charcoal curve: Continuous from the bottom, low values (<10%) until 8200 yr BP (9100 cal yr BP) followed by a hiatus. Higher values with fluctuations from 3200 yr BP (3400 cal yr BP), maximum (600%) 1200 yr BP (1100 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Sporadic <11,600 yr BP (13,600 cal yr BP)
2) *Melampyrum*: Continuous 10,400–9000 yr BP (12,400–10,200 cal yr BP), otherwise sporadic
3) *Pteridium*: Continuous <3100 yr BP (3300 cal yr BP)

Vegetation development: Herbs and shrubs dominated the open vegetation (bottom 12,300 yr BP, 14,400 cal yr BP). *Betula* increased, with a field layer of herbs and shrubs in the open forest during the Allerød chronozone. *Betula* decreased during the Younger Dryas chronozone. The charcoal curve indicates that people used the area during the Late Weichselian Substage. The density of the *Betula* forest increased 9200 yr BP (10,400 cal yr BP) together with *Corylus* and people still used the area. After a hiatus, *Alnus* dominated the vegetation, with *Betula* from 3100 yr BP (3300 cal yr BP) and palynological indications of agricultural activity (pasturing and cereal pollen). The charcoal occurrence indicates people's use of fire. Hunter-gatherers probably used low-intensity fire management in the area during the Late Weichselian Substage and until at least 8200 yr BP (9100 cal yr BP) confirmed by the site's location immediately to the west of archaeological sites from the Middle Mesolithic until the Roman period (Ballin & Jensen 1995:21, 25).

Site 18: Fjellestad myr II, Farsund, Vest-Agder (4.88 m asl) (Høeg 1995:294–301)

The mire (in-filled basin) is surrounded by *Betula* forest with *Pinus* and agricultural areas. 500 cm of sediment (clay 500–472 cm below gyttja to 49 cm and peat to the top) was deposited over 12,700 cal yr, with an accumulation rate of 1 cm/25 cal yr or 0.394 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required because of a local development plan (Ballin & Jensen 1995). Archaeological sites from the Middle Mesolithic until the Roman period are located immediately to the northwest of the pollen sampling site (Ballin & Jensen 1995:21, 25).

Charcoal curve: Nearly continuous from the bottom, fluctuating with maxima from the bottom to 10,000 yr BP (11,500 cal yr BP) and about 1800 yr BP (1700 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <7600 yr BP (8400 cal yr BP)
2) *Melampyrum*: Sporadic <9200 yr BP (10,400 cal yr BP)
3) *Pteridium*: Sporadic <8300 yr BP (9300 cal yr BP)

Vegetation development: Herbs and shrubs dominated the open vegetation (bottom 10,800 yr BP, 12,700 cal yr BP). The high amount of charcoal indicates the presence of people in the vicinity. No or very little charcoal was observed during the Preboreal chronozone, with still denser *Betula* forest. *Corylus* increased and dominated in the dense forest during the Boreal chronozone, with increasing charcoal indicating the presence of people in the area. *Alnus* increased 8200 yr BP (9100 cal yr BP) and dominated the dense forest together with *Corylus*. In the period 7000–3600 yr BP (7900–3900 cal yr BP), the mixed forest was dominated by *Alnus* with *Corylus*, *Quercus* and *Tilia*, characterised by 30–60% charcoal, interpreted as marine over-representation. *Alnus* dominated the still more open forest with minimum in charcoal increasing to maximum about 1800 yr BP (1700 cal yr BP). The earliest palynological recorded agricultural activity (cereal pollen interpreted as wild grass and pasturing) is indicated about 5200 yr BP (6000 cal yr BP) and 3800 yr BP (4200 cal yr BP), respectively, while cereal pollen occurred 1700 yr BP (1800 cal yr BP).

Site 19: Jølletjønn, Farsund, Vest-Agder (110 m asl) (Høeg 1995:301–309)

The mire (in-filled basin) is surrounded by treeless agricultural vegetation. 935 cm of sediment (clay 120 cm below 40 cm of gyttja with clay, followed by gyttja 775–32 cm and peat to the top) was deposited over 15,600 cal yr, with an accumulation rate of 1 cm/17 cal yr or 0.599 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required because of a local development plan (Ballin & Jensen 1995). Archaeological sites from the Middle Mesolithic until the Roman period (Ballin & Jensen 1995:21, 25) are located about 15 km southeast of the pollen site.

Charcoal curve: Nearly continuous from the bottom, maximum with peak (1200%) 12,900 yr BP (15,200 cal yr BP), lower values until minimum 11,000 yr BP (12,900 cal yr BP), low values until 8200 yr BP (9200 cal yr BP), discontinuous low until marked rise 3900 yr BP (4400 cal yr BP) with maxima 2400 yr BP (2400 cal yr BP) and 500–200 yr BP (500–100 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Two occurrences, oldest 11,200 yr BP (13,200 cal yr BP)
2) *Melampyrum*: Sporadic <8800 yr BP (9700 cal yr BP), continuous and increasing <4500 yr BP (5200 cal yr BP)
3) *Pteridium*: Sporadic <12,900 yr BP (15,200 cal yr BP), continuous <4500 yr BP (5200 cal yr BP)

Vegetation development: Open vegetation (bottom 13,200 yr BP, 15,600 cal yr BP) was replaced by open *Betula* forest, which dominated in the Allerød chronozone, followed by treeless vegetation in the Younger Dryas chronozone. People in the area probably caused the charcoal occurrence during the Late Weichselian Substage. Open *Betula* forest in the Preboreal chronozone was followed by an increase in *Corylus* at the same time as the forest gradually became dense during the Boreal chronozone. *Alnus* increased 8200 yr BP (9100 cal yr BP) and dominated the dense forest mixed with *Betula* and *Corylus* and followed by increase in *Ulmus* and *Quercus*, parallel with a decrease in *Alnus* and *Corylus*. *Quercus* increased further in a mixed dense deciduous forest. Until about 3900 yr BP (4400 cal yr BP) the occurrence of charcoal is sporadic later than the earliest palynological recorded agricultural activity (pasturing and cereal pollen) which is indicated about 4800 (8800) yr BP (5500 (9700) cal yr BP) and 3900 yr BP (4400 cal yr BP), respectively. The deciduous forest opened gradually, at the same time as agricultural indications and charcoal increased.

Site 20: Foss-Setri, Lom, Oppland (1220 m asl) (Gun-narsdóttir 1996:233–255)

The mire is situated in low-alpine treeless vegetation. 100 cm of peat was deposited over 10,100 cal yr, with an accumulation rate of 1 cm/101 cal yr or 0.099 cm/10 cal yr. The pollen diagram was produced with the aim of investigating vegetation history and forest-limit fluctuation reconstruction.

Charcoal curve: Sporadic <8400 yr BP (9400 cal yr BP), maximum 6400 yr BP (7300 cal yr BP), top of diagram about 5500 yr BP (6300 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Maximum bottom <5%, otherwise scarce
2) *Melampyrum*: None
3) *Pteridium*: None

Vegetation development: Ericales dominated the open vegetation (bottom 8900 yr BP, 10,100 cal yr BP). Mixed *Pinus* and *Betula* forest developed about 8600 yr BP (9600 cal yr BP) and 8400 yr BP (9400 cal yr BP) dense *Pinus* forest took over, mixed with *Betula* and some *Alnus* until 6700 yr BP (7600 cal yr BP), the period with the highest Holocene *Pinus*-forest limit. At this time, a *Betula* forest with *Pinus* and *Alnus* developed and the forest opened.

Site 21: Illmyri, Lom, Oppland (1250 m asl) (Gunnarsdóttir 1996:233–255)

The large mire (400x500 m) is situated in low-alpine treeless vegetation. 170 cm of peat was deposited over 10,700 cal yr, with an accumulation rate of 1 cm/63 cal yr or 0.159 cm/10 cal yr. The pollen diagram was produced with the aim of investigating vegetation history and forest-limit fluctuation reconstruction.

Charcoal curve: Continuous and rising upwards <8000 yr BP (8900 cal yr BP), maximum (60%) 1000 yr BP (900 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <7200 yr BP (8000 cal yr BP)
2) *Melampyrum*: None
3) *Pteridium*: None

Vegetation development: Open vegetation (bottom estimated 9500 yr BP, 10,700 cal yr BP) dominated with *Salix* shrubs and Cyperaceae and gradually with some *Betula*. Mixed *Pinus* and *Betula* forest developed about 8600 yr BP (9600 cal yr BP). Scattered *Pinus* forest took over 8100 yr BP (9000 cal yr BP), with some *Alnus* 7200 yr BP (8000 cal yr BP) and *Betula* during the highest Holocene *Pinus*-forest limit. 6700 yr BP (7600 cal yr BP) a *Betula* forest with *Pinus* and *Alnus* took over and the forest opened. About 4700 yr BP (5400 cal yr BP) the subalpine *Betula* forest was established and low-alpine vegetation developed about 3300 yr BP (3500 cal yr BP)

Site 22: Ølstadsetri, Lesja, Oppland (820 m asl) (Gun-narsdóttir 1999, Gunnarsdóttir & Høeg 2000:11, 21–28)

The mire is situated in open subalpine *Betula* forest with scattered *Pinus* trees and infields with a *Pinus* forest limit about 900–950 m asl. 110 cm of peat was deposited over 9500 cal yr which means an accumulation rate of 1 cm/86 cal yr or 0.116 cm/10 cal yr. The aim of this study was to investigate the Holocene vegetation history and human impact. Archaeological observations were recorded by Skjølsvold (1976), Hofseth (1980, 1981, 1988, 1992) and Fossum (1995).

Charcoal curve: Continuous from the bottom with rise 1900 yr BP (1900 cal yr BP), two maxima 8300 yr BP (9300 cal yr BP) (80%) and 1000 yr BP (900 cal yr BP) (100%).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Nearly continuous <7900 yr BP (8700 cal yr BP)
3) *Pteridium*: None

Vegetation development: The density of the *Pinus* forest increased (bottom 8500 yr BP, 9500 cal yr BP) and the maximum in charcoal occurrence at the same time as maximum in Polypodiaceae indicates human activity, which decreased and disappeared about 7000 yr BP (7900 cal yr BP). Dense *Pinus* forest 8200 yr BP (9100 cal yr BP) with maximum (>5%) of *Lycopodium* *annotinum* was mixed with *Betula* and *Alnus* 7300 yr BP (8100 cal yr BP) and the forest opened 5500 yr BP (6300 cal yr BP) at the same time as an increase in apophytes. Vegetation changes might be associated with long-term seasonal settlement from hunter-gatherers. Subalpine *Betula* forest developed 3700 yr BP (4000 cal yr BP), with indications of intensified human activity, including charcoal from 1900 yr BP (1900 cal yr BP), suggesting that fire was used to clear land, resulting in deforestation. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 1200 yr BP (1100 cal yr BP). The indications of human activity in the pollen diagram are not correlated with the archaeological record (most related to reindeer hunt) from the Late Mesolithic and possibly year-round settlement during the Neolithic (Hofseth 1980, 1981, 1992), Iron Age and Middle Ages (Skjølsvold 1976, Hofseth 1988, Fossum 1995) except for the period since the Late Iron Age.

Site 23: Dovrehytta, Skogsetrin, Dovre, Oppland (950 m asl) (Gunnarsdóttir 1999, Gunnarsdóttir & Høeg 2000:28–33)

The mire is situated in open vegetation close to the forest limit with a few scattered trees of *Betula* and *Pinus*. 173 cm of peat was deposited over 8600 cal yr, with an accumulation rate of 1 cm/50 cal yr or 0.201 cm/10 cal yr. The aim of this study was to investigate the Holocene vegetation history and human impact.

Charcoal curve: Continuous from the bottom with three maxima (<15%) 7500–7000 yr BP (8300–7900 cal yr BP), (<25%) 2700–1200 yr BP (2800–1100 cal yr BP) and (<40%) 300 yr BP (400 cal yr BP), with one short gap 4100 yr BP (4700 cal yr BP) and low values (<5%) 6200–3000 yr BP (7100–3200 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Scarce <7400 yr BP (8200 cal yr BP)
3) *Pteridium*: None

Vegetation development: Dense mixed *Pinus-Betula* forest with *Alnus* (bottom 7800 yr BP, 8600 cal yr BP) lasted until 4300 yr BP (4900 cal yr BP). The records of charcoal might relate to hunting camps. Maximum in charcoal in the early part of the period indicates human activity (hunters) in the area. The density of the *Pinus-Betula* forest decreased at the same time as apophytes increased, indicating human activity or climate changes. Soil erosion may have been due to intensified human utilisation of the area, perhaps caused by grazing domestic animals and resulting in deforestation 1200 yr BP (1100 cal yr BP). The earliest palynological recorded agricultural activity (cereal pollen) is indicated about 1100 yr BP (1000 cal yr BP). There are no records of archaeological remains at Skogsetrin.

Site 24: Urutlekråi-1, Årdal, Sogn og Fjordane (965 m asl) (Kvamme *et al.* 1992:29–39)

The mire is situated in open low-alpine vegetation with scattered *Betula* trees. 84 cm of peat was deposited over 8900 cal yr, with an accumulation rate of 1 cm/106 cal yr or 0.094 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required in conjunction with hydroelectric power plans.

Charcoal curve: Low (5%) from the bottom, two maxima (75%) around 2300 yr BP (2300 cal yr BP) and (20%) 200 yr BP (100 cal yr BP), weakly rising from 1600 yr BP (1500 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce from the bottom
2) *Melampyrum*: Continuous from the bottom, maximum 3% <4000 yr BP (4500 cal yr BP) and sporadic <1000 yr BP (900 cal yr BP)
3) *Pteridium*: Sporadic <4300 yr BP (4900 cal yr BP)

Vegetation development: Open vegetation with *Juniperus*, *Pinus* and increasing *Betula* to dominance without indications of human impact (bottom 8000 yr BP, 8900 cal yr BP). Decrease in *Betula* 4200 yr BP (4800 cal yr BP), increase in apophytes and about 3000 yr BP (3200 cal yr BP) a small single spectrum peak (<20%) of charcoal. This is interpreted as caused by pasturing and clearing of the forest. A new decrease in trees, increase in apophytes, a marked maximum in charcoal (around 2300 yr BP, 2300 cal yr BP) and sand in the peat are correlated with a settlement phase. This is followed by changes in *Betula* and anthropocores. A decrease in charcoal was followed by a slow rise towards the present. Patchy burning of the vegetation for pasturing husbandry purposes may have caused the changes. The earliest palynological recorded agricultural activity (pasturing) is about 4400 yr BP (5000 cal yr BP). The site was chosen because of the archaeological record (Late Stone Age, Early Iron Age and Viking Age, Prescott 1991, 1995, Bjørgo *et al.* 1992).

Site 25: Riskallsvatn-tuft (old monument), loc. 1, Årdal, Sogn og Fjordane (950 m asl) (Kvamme *et al.* 1992:63–69)

The small mire (peat section 5x10 m) is situated in low-alpine vegetation with shrubs and scattered *Betula* trees. 100 cm of peat was deposited over 7000 cal yr, with an accumulation rate of 1 cm/70 cal yr or 0.143 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required in conjunction with hydroelectric power plans.

Charcoal curve: Continuous from the bottom with two maxima (30%) 5300 yr BP (6100 cal yr BP) and (65%) 1600 yr BP (1500 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 2700 yr BP (2800 cal yr BP)
2) *Melampyrum*: Sporadic from the bottom, maximum (9%) 6100 yr BP (7000 cal yr BP)
3) *Pteridium*: Sporadic from the bottom

Vegetation development: *Betula* forest with *Pinus* (bottom 6100 yr BP, 7000 cal yr BP) grew around the site. Maximum in charcoal 5300 yr BP (6100 cal yr BP) at the same time as opening of the forest indicates that people used the area close to the site. *Betula* decreased and more light-demanding vegetation increased. In general, pasturing elements changed the vegetation from about 4000 yr BP (4500 cal yr BP), indicated by the earliest palynological recorded agricultural activity (pasturing). The site was chosen because of the archaeological record of Early and Late Iron Age settlement (loc. 26, Bjørgo *et al.* 1992), correlated with the upper charcoal maximum.

Site 26: Riskallsvatn mire, Årdal, Sogn og Fjordane (948 m asl.) (Kvamme *et al.* 1992:70–75)

The large mire complex is situated in open vegetation with *Betula* trees. The present *Pinus* forest limit is 850 m asl. 220 cm of peat was deposited over 10,500 cal yr, with an accumulation rate of 1 cm/48 cal yr or 0.210 cm/10 cal yr. A hiatus of several thousand years decreased the accumulation rate. The pollen diagram was produced in connection with archaeological investigations that were required in conjunction with hydroelectric power plans.

Charcoal curve: Continuous and low (3–8%), maximum (41%) at bottom and a maximum plateau (~10%) in the upper part.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 9000 yr BP (10,200 cal yr BP)
2) *Melampyrum*: Sporadic <8800 yr BP (9800 cal yr BP)
3) *Pteridium*: Two occurrences, oldest 3100 yr BP (3300 cal yr BP)

Vegetation development: Open vegetation (bottom 9300 yr BP, 10,500 cal yr BP) with *Betula* and shrubs dominated soon after deglaciation. *Pinus* forest with changing density covered large areas before 8500 yr BP (9500 cal yr BP) with *Betula* and scattered *Alnus*. Open *Betula* forest dominated with an increase in Polypodiaceae and charcoal about 7100 yr BP (7900 cal yr BP) to a small maximum in charcoal about 6200 yr BP (7100 cal yr BP interpolated). *Pinus* increased after 6000 yr BP (6800 cal yr BP) and probably the *Pinus* forest disappeared from the area after 5600 yr BP (6400 cal yr BP). The earliest palynological recorded agricultural activity (pollen of *Plantago lanceolata* and cereals) is indicated about 3500 yr BP (3800 cal yr BP) and 2200 yr BP (2200 cal yr BP).

Site 27: Skarhaugfossen-2, Årdal, Sogn og Fjordane (915 m asl) (Kvamme *et al.* 1992:76–84)

The vegetation around the peat section is shrubs and *Betula* forest. 18 cm of peat (above 7 cm of inorganic material) was deposited over 7900 cal yr (stipulated), with an accumulation rate of 1 cm/439 cal yr or 0.023 cm/10 cal yr. Because of the low accumulation rate and only one radiocarbon date, it is difficult to date important changes in the pollen diagram and to correlate with the archaeological sites. The pollen diagram was produced in connection with archaeological investigations that were required in conjunction with hydroelectric power plans.

Charcoal curve: Continuous with maximum period (<42%) bottom to about 5300 yr BP (bottom–6100 cal yr BP) and maximum about 1600 yr BP (1500 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One period 6700–4700 yr BP (7600–5400 cal yr BP) with maximum 2%
2) *Melampyrum*: Sporadic from the bottom, maximum 3% 2500 yr BP (2600 cal yr BP)
3) *Pteridium*: Sporadic from the bottom

Vegetation development: Mixed *Alnus-Betula* forest (bottom stipulated to 7000 yr BP, 7900 cal yr BP) dominated by a high amount of Polypodiaceae in the field layer and charcoal. The forest opened gradually 5300–4600 yr BP (6100–5300 cal yr BP) at the same time as *Alnus*, Polypodiaceae and charcoal decreased. The marked changes to vegetation types rich in herbs with fewer trees than today started in this period, caused by a combination of pasturing and increased landslide activity. Three archaeological sites 83 (correlated to this palynological site), 88 and 84 were dated to c. 5300 yr BP (6100 cal yr BP), 4600 yr BP (5300 cal yr BP) and 2100–2500 yr BP (2100–2600 cal yr BP) (Bjørgo *et al.* 1992). Site 83 has probably had only little impact on vegetation recorded in the pollen diagram apart from the charcoal occurrence. The marked changes in the vegetation and start of pasturing are correlated with site 88, typologically dated to Early Neolithic (Bjørgo *et al.* 1992:90). Vegetation was dominated by cultural impact also during the Early Iron Age (site 84), correlated with the youngest charcoal maximum.

Site 28: Lake east of Skarhaugfossen (core 1 and 2), Årdal, Sogn og Fjordane (945 m asl) (Kvamme *et al.* 1992:85–98)

The lake (40x60 m) is located 200 m southeast of Skarhaugfossen and is surrounded by open *Betula* forest close to the forest limit. 310 cm of gyttja was deposited over 5900 cal yr, with an accumulation rate of 1 cm/19 cal yr or 0.525 cm/10 cal yr. Reaccumulation may have caused the large changes in accumulation rate from 0.048 cm per year in the oldest part and in the upper part an average of 0.032 cm per year (see Kvamme *et al.* 1992:Fig. 43). The pollen diagram was produced in connection with archaeological investigations that were required in conjunction with hydroelectric power plans.

Charcoal curve: Continuous and low from the bottom, two maxima (10%) 6700 yr BP (7600 cal yr BP) and (12%) 3500 yr BP (3800 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <5000 yr BP (5700 cal yr BP), maximum 3% 2600 yr BP (2700 cal yr BP)
2) *Melampyrum*: Continuous from the bottom, maximum 1% 6000 yr BP (6800 cal yr BP)
3) *Pteridium*: Sporadic from the bottom

Vegetation development: *Pinus* decreased in the mixed, gradually denser *Pinus-Betula* forest (bottom 8000 yr BP, 8900 cal yr BP). In the period 7500–7000 yr BP (8300–7900 cal yr BP) *Alnus*, *Ulmus* and *Corylus* established in the forest and charcoal had a single spectrum peak 6700 yr BP (7600 cal yr BP) caused by reaccumulation or more probably anthropogenic activity. About 4600 yr BP (5300 cal yr BP, maybe later) *Betula*, *Quercus* and the charcoal increased at the same time as deforestation probably started. The earliest palynological recorded agricultural activity (pasturing) is indicated about 2500 yr BP (2600 cal yr BP).

Site 29: Alvevatn, Klepp, Rogaland (10 m asl) (Fægri 1940, Prøsch-Danielsen & Simonsen 2000a:7, 32, 49)

The lake (diameter 330 m) is situated close to the coast and pastures dominate the vegetation. 186 cm of gyttja deposited over 9100 cal yr means an accumulation rate of 1 cm/49 cal yr or 0.204 cm/10 cal yr. The study by Prøsch-Danielsen & Simonsen (2000a) was partly initiated in conjunction with the national research programme *Cultural Heritage and Environment*. Attention was given to the deforestation history and development of *Calluna* heathland.

Charcoal curve: Continuous and low from the bottom, increasing 4500 yr BP (5200 cal yr BP) to maximum level (10%) <3700 yr BP (4000 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Sporadic from the bottom
3) *Pteridium*: Sporadic <8000 yr BP (8900 cal yr BP), nearly continuous <5500 yr BP (6300 cal yr BP)

Vegetation development: The mixed *Pinus-Betula-Corylus* forest was dense (bottom 8200 yr BP, 9100 cal yr BP). *Pinus* and *Corylus* decreased at the same time as *Betula* and *Alnus* increased. Before 6500 yr BP (7400 cal yr BP) *Corylus* rose again together with *Quercus*, *Alnus* decreased and later also *Betula*. The dense deciduous forest, dominated by *Betula*, *Corylus*, *Alnus* and *Quercus*, opened about 3800 yr BP (4400 cal yr BP), with decreasing *Corylus* and increasing *Pinus*. The deforestation and subsequent establishment of coastal heathland were dated to 3900 and 3800 yr BP (4400 and 4200 cal yr BP), respectively, which is correlated with the increase in the charcoal curve. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4300 yr BP (4900 cal yr BP) and probably 2000 yr BP (2000 cal yr BP), respectively.

Site 30: Obrestad Harbour, Hå, Rogaland (18 m asl) (Prøsch-Danielsen & Simonsen 2000a:28, 35, 50) (Fig. 17)

The mire (diameter 110 m) is situated close to the exposed seashore in an open pasturing landscape. 70 cm of peat was deposited over maximum 9500 cal yr, with an accumulation rate of 1 cm/maximum 136 cal yr or 0.074 cm/10 cal yr; however, the age of both bottom and top is uncertain. The study by Prøsch-Danielsen & Simonsen (2000a) was partly initiated in conjunction with the national research programme *Cultural Heritage and Environment*. Attention was given to the deforestation history and development of *Calluna* heathland.

Charcoal curve: Continuous rising from the bottom (3%) to maximum (>30%) close to the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Nearly continuous from the bottom
3) *Pteridium*: Sporadic from the bottom

Vegetation development: With only one radiocarbon date (6800 yr BP, 7600 cal yr BP dating heath establishment), it is difficult to calculate the age of the changes in the pollen diagram. The increase in *Corylus* is 9200 yr BP (10,400 cal yr BP) and in *Alnus* 8400–8200 yr BP (9500–9100 cal yr BP) in Jæren (interpolated between Lista and Rennesøy, Prøsch-Danielsen 1993, 1996). Maximum or decrease in *Corylus* and increase in *Alnus* at bottom indicates an age of about 8400–8200 yr BP (9500–9100 cal yr BP). *Betula* and *Corylus* dominated dense, mixed deciduous forest. The start of the deforestation 7700 yr BP (8500 cal yr BP) is correlated with a decrease in *Betula* and *Corylus* and increase in *Alnus* and *Calluna*. Deforestation continued to the top of the pollen diagram with establishment of the coastal heathland and continuous increase in charcoal from at least 7200 yr BP (8000 cal yr BP). This indicates pre-Neolithic heathland establishment and anthropogenic induced deforestation. The heathland establishment became permanent mainly because of repeated burning. The earliest palynological recorded agricultural activity (pasturing) is indicated 10 cm below the top of the pollen diagram (probably 1700 yr BP, 1600 cal yr BP).

Site 31: Kviamyra, Hå, Rogaland (43 m asl) (Prøsch-Danielsen & Simonsen 2000a:50)

The mire (diameter 160 m) is situated in an open agricultural landscape. 115 cm of peat was deposited over 9300 cal yr, with an accumulation rate of 1 cm/81 cal yr or 0.124 cm/10 cal yr; the age of both bottom and top is uncertain. The 2000 study was partly initiated in conjunction with the national research programme *Cultural Heritage and Environment*. Attention was given to the deforestation history and development of *Calluna* heathland.

Charcoal curve: Continuous and rising from the bottom with a small culmination (12%) estimated 7800 yr BP (8600 cal yr BP) and maximum (25%) at the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Continuous from the bottom, maximum >10% 7800 yr BP (8600 cal yr BP) followed by sporadic occurrence
3) *Pteridium*: Sporadic <8600 yr BP (9600 cal yr BP)

Vegetation development: The bottom is estimated to be about 9000 yr BP (10,200 cal yr BP) based on the rise of *Corylus* in Jæren (interpolated between Lista and Rennesøy, Prøsch-Danielsen 1993, 1996). *Betula* dominated the vegetation followed by an increase in *Corylus* and maximum in *Pinus*. The small culmination in charcoal 7800 yr BP (8600 cal yr BP) occurred at the same time as maximum in *Melampyrum* and *Calluna*. Before maximum in *Alnus* and *Betula,* Polypodiaceae had a marked maximum. A small increase in charcoal about 6900 yr BP (7700 cal yr BP) indicates anthropogenic induced deforestation and pre-Neolithic heathland establishment, which became permanent mainly because of repeated burning. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 1900 yr BP (1900 cal yr BP).

Site 32: Stavnheimsmyra, Hå, Rogaland (21 m asl) (Prøsch-Danielsen & Simonsen 2000a:33, 35, 40, 51)

The peat formation (diameter 50 m) is situated close to the sea, surrounded by pastures outside the central agricultural areas. 123 cm of peat was deposited over 7900 cal yr, with an accumulation rate of 1 cm/64 cal yr or 0.156 cm/10 cal yr; the age of the bottom and the top is uncertain. The study by Prøsch-Danielsen & Simonsen (2000a) was partly initiated in conjunction with the national research programme *Cultural Heritage and Environment*. Attention was given to the deforestation history and development of *Calluna* heathland.

Charcoal curve: Decrease from the bottom, increase >6000 yr BP (6800 cal yr BP) after a gap and maximum 5100 yr BP (5800 cal yr BP), later values about 20%.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Sporadic from the bottom
3) *Pteridium*: Sporadic <6000 yr BP (6800 cal yr BP)

Vegetation development: With only one radiocarbon date (5000 yr BP, 5700 cal yr BP); it is difficult to calculate the age of the changes in the pollen diagram. The bottom is younger than the *Alnus* rise, maybe about 7000 yr BP (7900 cal yr BP). The density of the open *Betula* forest increased in the lower part of the pollen diagram, followed by a single spectrum peak of the charcoal curve at the same time as *Betula* decreased and *Alnus* increased to a maximum about 5700 yr BP (6500 cal yr BP). The reappearance of charcoal occurred at the same time as maximum in *Alnus* and opening of the forest. Maximum in the charcoal curve 5000 yr BP (5700 cal yr BP) is correlated with a total deforestation, maximum in Poaceae and increase in *Calluna*. Coastal heathland developed with few other changes in the vegetation until the top of the diagram. This development occurred in areas far from where the main agricultural activities later took place. The earliest palynological recorded agricultural activity (pasturing) is indicated about 4500 yr BP (estimated, 5200 cal yr BP). Sites 30–32 are situated close to Mesolithic dwelling sites outside the central agricultural areas.

Site 33: Romamyra, Hå, Rogaland (265 m asl)
(Prøsch-Danielsen & Simonsen 2000a:35, 40, 51)
(Fig. 15)

The peat formation (diameter 100 m) is situated in an outfield pasturing landscape, outside the central agricultural areas. 105 cm of peat was deposited over 7900 cal yr, with an accumulation rate of 1 cm/75 cal yr or 0.133 cm/10 cal yr; the age of the bottom and the top is uncertain. The 2000a study was partly initiated in conjunction with the national research programme *Cultural Heritage and Environment*. Attention was given to the deforestation history and development of *Calluna* heathland.

Charcoal curve: Continuous from the bottom with a small maximum (10%) estimated 6400 yr BP (7400 cal yr BP) followed by a minimum period (2%) until 5100 yr BP (5800 cal yr BP) from where the charcoal increased to >40% at the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Continuous from the bottom to 3400 yr BP (3700 cal yr BP), maximum 6100 yr BP (7000 cal yr BP)
3) *Pteridium*: Sporadic <6400 yr BP (7400 cal yr BP)

Vegetation development: With only one radiocarbon date (5100 yr BP, 5800 cal yr BP), it is difficult to calculate the age of the changes in the pollen diagram. The decrease of *Alnus* in the bottom is probably younger than 7000 yr BP (7900 cal yr BP). Open *Betula* forest with *Alnus* and a small maximum in charcoal 6400 yr BP (7400 cal yr BP) was followed by decreasing *Alnus* and *Corylus* at the same time as a marked maximum in *Betula* and *Melampyrum*, corresponding to a minimum period in charcoal until 5100 yr BP (5800 cal yr BP). Increase in the charcoal and *Calluna* and opening of the forest characterise the period at the transition to the Neolithic. The appearance of anthropochorous pollen types indicates human impact and the development of pastures and coastal heathland. The maintenance of the heathland in the outfields area continued to the top of the pollen diagram at this site, far from areas later developed into the main agricultural areas. The earliest palynological recorded agricultural activity (pasturing) is estimated to about 3000 yr BP (3200 cal yr BP).

Site 34: Vodlamyr, Egersund, Rogaland (4 m asl)
(Prøsch-Danielsen & Simonsen 2000a:52)

The mire (in-filled basin) is situated in an outfield pasturing landscape. 262 cm of sediment (gyttja 290–136 cm covered by peat to 60 cm and gyttja to 28 cm below the surface, estimated at 1000 yr BP, 900 cal yr BP) was deposited over 7500 cal yr, with an accumulation rate of 1 cm/29 cal yr or 0.349 cm/10 cal yr; the age of both bottom and top is estimated. The pollen diagram was original produced in connection with archaeological investigations that were required because of zoning for industrial purposes.

Charcoal curve: Continuous from the bottom, irregular with four maxima >50%, 7100–6400 yr BP (7900–7300 cal yr BP), 5900 yr BP (6700 cal yr BP), 4500 yr BP (5200 cal yr BP) and one at the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Sporadic from the bottom, maximum <2% 3700 yr BP (4000 cal yr BP)
3) *Pteridium*: Nearly continuous from the bottom, maximum 2% 3600 yr BP (3900 cal yr BP)

Vegetation development: The bottom of the sediments is younger than the rise in *Alnus* (8400–8200 yr BP, 9400–9100 cal yr BP) in Jæren (interpolated between Lista and Rennesøy, Prøsch-Danielsen 1993, 1996) and older than 7100 yr BP (7900 cal yr BP), estimated to be 7700 yr BP (8500 cal yr BP). *Betula* and *Corylus* dominated mixed deciduous and dense forest with Pinus. Peak in *Alnus* occurred before a marked increase in charcoal to a maximum period 7100–6400 yr BP (7900–7300 cal yr BP) when *Betula* and *Alnus* declined and *Pinus* and *Quercus* increased in the dense forest with *Corylus*. High values of charcoal continued with a maximum 5900 yr BP (6700 cal yr BP) at the same time as *Pinus* increased mixed with *Corylus* and *Quercus* to dominance in the dense forest, with a new maximum in the charcoal curve 4500 yr BP (5200 cal yr BP). Maximum in the dense *Pinus* forest was at the same time as a marked decrease in the charcoal curve 4400 yr BP (5000 cal yr BP) and maximum in *Quercus*. The dense *Pinus* forest with deciduous trees declined about 3700 yr BP (4000 cal yr BP) when the charcoal curve increased and at the same time as the earliest palynological recorded agricultural activity (pasturing). The first occurrence of cereal pollen is about 1400 yr BP (1300 cal yr BP).

Site 35: Vassnestjern, Bømlo, Hordaland (52 m asl) (Midtbø 1999:99–112) (Fig. 14a-b)

The vegetation around the lake (25x40 m) is *Pinus* forest with *Calluna* in the field layer. 435 cm of gyttja was deposited during 11,900 cal yr, with an accumulation rate of 1 cm/27 cal yr or 0.366 cm/10 cal yr. The pollen diagram was produced with the aim of vegetation history reconstruction with special attention to fen sedge (*Cladium mariscus*).

Charcoal curve: Continuous and slowly rising with maximum (15%) 7200 yr BP (8000 cal yr BP) and the last 1400 yr BP (1300 yr cal BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <10,000 yr BP (11,500 cal yr BP)
2) *Melampyrum*: Continuous <10,400 yr BP (12,400 cal yr BP), sporadic <6800 yr BP (7600 cal yr BP)
3) *Pteridium*: Sporadic <10,200 yr BP (11,900 cal yr BP), nearly continuous <3800 yr BP (4200 cal yr BP)

Vegetation development: Herbs dominated the vegetation (bottom 10,600 yr BP, 12,600 cal yr BP) and were replaced by *Betula* forest. *Corylus* immigrated in the dense forest 9500 yr BP (10,700 cal yr BP). *Pinus* established in the region with *Melampyrum* in the field layer. *Pinus* and *Alnus* increased 8400 yr BP (9400 cal yr BP) in the forest that was mixed with *Betula* and warmth-demanding deciduous trees, with a charcoal maximum 7200 yr BP (8000 cal yr BP). *Betula* and *Corylus* with *Alnus* dominated the mixed dense forest close to the lake and *Pinus* with local occurrence from 6900 yr BP (7700 cal yr BP). The forest changed 5600 yr BP (6400 cal yr BP) to an open *Betula-Pinus* forest. The heathland expanded and the forest declined from 2600 yr BP (2700 cal yr BP). Charcoal increased towards the top of the diagram (800 yr BP, 700 cal yr BP). The earliest palynological recorded agricultural activity (pasturing) is indicated about 4800 yr BP (5500 cal yr BP).

Site 36: Åsen, Forsand, Rogaland (100 m asl) (Høeg 1999:156–162)

The small mire (70 m east-west) is surrounded by *Betula* forest. 250 cm of peat (sandy in the bottom) was deposited over 11,000 cal yr, with an accumulation rate of 1 cm/44 cal yr or 0.227 cm/10 cal yr. The aim of this study was to investigate the vegetation history and human impact correlated with the settlement archaeologically recorded from the Late Neolithic to the Migration period (Løken 1987, 1991, 1999).

Charcoal curve: Continuous and low (1–3%) from the bottom with two gaps 9300–8100 yr BP (10,500–9000 cal yr BP) and 5400 yr BP (6200 cal yr BP), and two maxima (4%) 8000 yr BP (8900 cal yr BP) and (5%) 1800 yr BP (1700 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence, bottom
2) *Melampyrum*: Nearly continuous <9400 yr BP (10,600 cal yr BP), two maxima (1%) 9200 yr BP (10,400 cal yr BP) and (2%) 8200 yr BP (9100 cal yr BP)
3) *Pteridium*: Sporadic <8700 yr BP (9600 cal yr BP), continuous <4700 yr BP (5400 cal yr BP) maximum (10%) 2300 yr BP (2300 cal yr BP)

Vegetation development: *Betula* forest dominated the vegetation from the bottom (9600 yr BP, 11,000 cal yr BP). *Corylus* immigrated 9400 yr BP (10,600 cal yr BP) and was mixed with *Betula* in the deciduous forest. *Pinus* immigrated in the *Betula*-dominated forest 8500 yr BP (9500 cal yr BP) and *Alnus* immigrated 8000 yr BP (8900 cal yr BP) and rose to a local maximum 6100 yr BP (7000 cal yr BP) on the mire, with *Corylus* and *Pinus* in the surroundings. Probably, the forest was dense about 7500 yr BP (8300 cal yr BP) with immigration of *Quercus* 5800 yr BP (6600 cal yr BP) and with *Betula* as the dominating constituent. *Betula* declined 3700 yr BP (4000 cal yr BP), at the same time as *Quercus* increased. From 2800 yr BP (2900 cal yr BP), the heathland developed with an increase in *Calluna*, opening of the forest, but no increase in the charcoal curve. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 3500 yr BP (3800 cal yr BP, at the same time as an increase in *Melampyrum*) and 2800 yr BP (2900 cal yr BP), respectively. Probably, people used the area since 10,000 years ago except in the period 9300–8100 yr BP (10,500–9000 cal yr BP). Agrarian people used the area since 3500 yr BP (3800 cal yr BP) when the forest changed. The area was deforested 1600 yr BP (1500 cal yr BP).

Site 37: Åsheim, Forsand, Rogaland (115 m asl) (Høeg 1999:162–169)

The vegetation around the mire (in-filled basin) is *Betula* forest with *Quercus*, *Corylus*, *Ulmus* and

Pinus. Gyttja from the bottom 950 cm was covered by peat from 195 cm to the top and was deposited over 12,400 cal yr, with an accumulation rate of 1 cm/13 cal yr or 0.766 cm/10 cal yr. No radiocarbon dates of the sediments were carried out because the mire was situated only 800 meters from site 36, Åsheim, and could be correlated with this site. The aim of this study was to investigate the vegetation history and human impact correlated with the settlement archaeologically recorded from the Late Neolithic to the Migration period (Løken 1987, 1991, 1999).

Charcoal curve: <9000 yr BP (10,200 cal yr BP), low and continuous <7800 yr BP (8600 cal yr BP) with a small maximum (2%) about 7600 yr BP (8400 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 10,200 yr BP (11,900 cal yr BP)
2) *Melampyrum*: Sporadic <8800 yr BP (9800 cal yr BP)
3) *Pteridium*: Sporadic <8900 yr BP (10,100 cal yr BP), nearly continuous <5400 yr BP (6200 cal yr BP), maximum ~2% 2400 yr BP (2400 cal yr BP)

Vegetation development: Open, treeless vegetation dominated (bottom 10,400 yr BP, 12,400 cal yr BP), with immigration of *Betula* about 10,000 yr BP (11,500 cal yr BP) and *Corylus* 9400 yr BP (10,600 cal yr BP). *Betula* dominated in the mixed open deciduous forest, with immigration of *Pinus* 8800 yr BP (9800 cal yr BP) and the earliest occurrence of charcoal shortly before. With the immigration of *Alnus* 8000 yr BP (8900 cal yr BP), the forest grew dense with *Betula* as the dominant constituent and some *Pinus*. *Betula* declined markedly 6800 yr BP (7600 cal yr BP), with a decline of *Pinus* 6300 yr BP (7200 cal yr BP) and a marked increase in *Quercus* 5800 yr BP (6600 cal yr BP). A marked decline of *Quercus* 2500 yr BP (2600 cal yr BP) occurred at the same time as an increase in *Calluna* and opening of the forest, which was dominated by *Betula*. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated 4000 yr BP (4500 cal yr BP) and 3000 yr BP (3200 cal yr BP), respectively.

Site 38: Håtjern (lake), Hå, Rogaland (8.5 m asl) (Høeg 1999:176–184)

Open agricultural landscape without forest dominates around the lake, which is exposed close to the North Sea coast. 268 cm of sediments (sand, clay and gyttja up to 83 cm covered by peat and sand) had a hiatus of 6700 cal yr (7500–1700 yr BP, 8300–1600 cal yr BP). The age of the bottom is 16,000 cal yr, i.e. the sediments were deposited over 9300 cal yr, with an accumulation rate of 1 cm/35 years or 0.288 cm/10 cal yr. The pollen record is correlated with e.g. Brønnmyra (Chanda 1965) not so far from the site as no radiocarbon dates of the sediments were carried out. The aim of this study was to investigate the Holocene vegetation history and human impact.

Charcoal curve: Nearly continuous <10,600 yr BP (12,600 cal yr BP), low (<2%).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <10,600 yr BP (12,600 cal yr BP)
2) *Melampyrum*: Sporadic <9800 yr BP (11,200 cal yr BP)
3) *Pteridium*: Sporadic <12,700 yr BP (15,000 cal yr BP), maximum 1% 12,700 yr BP (15,000 cal yr BP)

Vegetation development: Probably, the two maxima of *Betula* 12,600–12,400 yr BP (15,400–14,600 cal yr BP) and 11,500–10,800 yr BP (13,500–12,800 cal yr BP) represent the Bølling and Allerød chronozones, with an age of the bottom 13,500 yr BP (16,000 cal yr BP). *Betula* probably first immigrated in the Allerød chronozone and the *Betula* correlated with the Bølling chronozone may have originated in *Betula nana*. After a cold period with open vegetation during the Younger Dryas chronozone, *Betula* established in two stages about 10,000 yr BP (11,500 cal yr BP) and as a dense forest 9500 yr BP (10,700 cal yr BP). *Corylus* and *Alnus* immigrated 9400 yr BP (10,600 cal yr BP) and 8200 yr BP (9100 cal yr BP), respectively. Betula dominated the mixed deciduous forest. After the hiatus 7500–1800 yr BP (8300–1700 cal yr BP), open heathland vegetation dominated. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated 1700 yr BP (1600 cal yr BP) and 1300 yr BP (1200 cal yr BP), respectively.

Site 39: Svartetjørn, Sokndal, Rogaland (250 m asl) (Høeg 1999:184–190)

The lake is surrounded by heathland. 410 cm of gyttja was deposited over 13,000 cal yr, with an accumulation rate of 1 cm/32 cal yr or 0.315 cm/10 cal yr. The pollen diagram was carried out with the aim of vegetation history reconstruction because the area was to be used for storage of scrap-stones.

Charcoal curve: Continuous and generally slow rising from the transition to the Holocene with large fluctuations. Remarkably high (>1000%) before 10,000 yr BP (11,500 cal yr BP) with maxima 11,000 yr BP

(12,900 cal yr BP), 10,100 yr BP (11,600 cal yr BP), 4400 yr BP (5000 cal yr BP), 2000 yr BP (2000 cal yr BP) and (1000%) 800 yr BP (700 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <10,400 yr BP (12,400 cal yr BP)
2) *Melampyrum*: Sporadic <9900 yr BP (11,300 cal yr BP)
3) *Pteridium*: Sporadic from the bottom, nearly continuous <8700 yr BP (9600 cal yr BP), maximum ~1% 3100 yr BP (3300 cal yr BP)

Vegetation development: Open treeless vegetation dominated (bottom 10,900 yr BP, 13,000 cal yr BP) because of the cold climate during the Younger Dryas chronozone. Remarkably high maximum in charcoal indicates that people lived at the lake. *Betula* immigrated about 10,000 yr BP (11,500 cal yr BP) and a rather dense forest developed. *Corylus* immigrated 9400 yr BP (10,600 cal yr BP) and decline in charcoal indicates that people probably used the area continuously with low and changing intensity. *Corylus* increased 8900 yr BP (10,100 cal yr BP) and the dense forest consisted of *Betula* and *Corylus*. *Pinus* was a part of the forest from 8800 yr BP (9800 cal yr BP) and *Alnus* immigrated 8300 yr BP (9300 cal yr BP). A combination of high levels of charcoal and the earliest occurrence of *Plantago lanceolata* was interpreted as the result of people's use of fire 6800 yr BP (7600 cal yr BP) to make openings in the forest, thus improving pasturing for the game. An alternative interpretation was pasturing of domestic animals earlier than the Neolithic. *Quercus* increased 5700 yr BP (6500 cal yr BP) with a maximum 5000 yr BP (5700 cal yr BP) when the density of the forest gradually decreased at the same time as *Plantago lanceolata* occurred, with a continuous curve and *Calluna* and charcoal increased interpreted as a result of pasturing of domestic animals, burning of forest and development of the present-day heathland. The landscape was open from 2000 yr BP (2000 cal yr BP). The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated 6800 yr BP (7600 cal yr BP) and 3600 yr BP (3900 cal yr BP), respectively.

Site 40: Ersdal myr, Flekkefjord, Vest-Agder (410 m asl) (Høeg 1999:197–202)

The small mire (in-filled basin) at the end of a lake is surrounded by open mixed *Pinus* and *Betula* forest. 280 cm of sediment (gyttja covered by peat from 272 cm to the top) was deposited over 10,100 cal yr, with an accumulation rate of 1 cm/36 cal yr or 0.277 cm/10 cal yr. The pollen diagram was produced in connection with the Surface Water Acidification Programme directed by Rosenqvist (1987).

Charcoal curve: Low and discontinuous from the bottom with a gap 6600–4700 yr BP (7500–5400 cal yr BP) and two maxima (<5%) 7500 yr BP (8300 cal yr BP) and 1700–400 yr BP (1600–500 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 8200 yr BP (9100 cal yr BP)
2) *Melampyrum*: Continuous from the bottom, maxima (10%) 4600 yr BP (5300 cal yr BP) and (8%) 3000 yr BP (3200 cal yr BP)
3) *Pteridium*: Sporadic <8600 yr BP (9600 cal yr BP), continuous <4600 yr BP (5300 cal yr BP), maximum (>1%) 2100–1800 yr BP (2100–1700 cal yr BP)

Vegetation development: *Betula* and *Corylus* dominated the forest (bottom 8900 yr BP, 10,100 cal yr BP). The occurrence of *Plantago lanceolata* 8300 yr BP (9300 cal yr BP) at the same time as the occurrence of charcoal was interpreted because of people in the area. *Alnus* immigrated 8000 yr BP (8900 cal yr BP) and *Betula* and *Alnus* were the main constituents in the dense deciduous forest. Charcoal indicates the presence of people in the area until a gap 6600–4700 yr BP (7500–5400 cal yr BP). *Alnus* declined markedly to a minimum 6300 yr BP (7200 cal yr BP) followed by opening of the forest. At the same time Poaceae increased markedly, which may have been caused by the growing of *Phragmites* on the mire. Charcoal increased 4700 yr BP (5400 cal yr BP) at the same time as *Calluna*. Open *Betula* forest, maybe with some *Pinus*, dominated the vegetation. Pasturing possibly occurred already 5600 yr BP (6400 cal yr BP), at least from 4600 yr BP (5300 cal yr BP). The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated 8300 (4600) yr BP (9300 (5300) cal yr BP) and 500 yr BP (500 cal yr BP), respectively.

Site 41: Ersdal Fiskelausvann, Flekkefjord, Vest-Agder (410 m asl) (Høeg 1999:202–207)

Even though this site is situated close to site 40, there are differences between the results from the two sites. The lake is surrounded by mixed forest with *Pinus* and *Betula*. 321 cm of gyttja was deposited over 8000 cal yr, with an accumulation rate of 1 cm/25 cal yr or 0.401 cm/10 cal yr. The pollen diagram was produced in connection with the Surface Water Acidification Programme directed by Rosenqvist (1987).

Charcoal curve: Continuous from the bottom with fluctuations and several one and two sample maxima 6800 yr BP (7600 cal yr BP), (~60%), 6100 yr BP (7000 cal yr BP), (~70%) 5700 yr BP (6500 cal yr BP), 4600 yr BP (5300 cal yr BP), 3100 yr BP (3300 cal yr BP), 1900 yr BP (1900 cal yr BP) and the highest (~250%) 300 yr BP (400 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <2500 yr BP (2600 cal yr BP)
2) *Melampyrum*: Nearly continuous from the bottom (<1%)
3) *Pteridium*: Nearly continuous from the bottom, rising 3900 yr BP (4400 cal yr BP), maximum (4%) 1900 yr BP (1900 cal yr BP)

Vegetation development: The dense forest consisted of *Betula*, *Corylus*, *Alnus* and *Quercus* with some *Pinus* (bottom 7200 yr BP, 8000 cal yr BP). *Alnus* started to decline 6000 yr BP (6800 cal yr BP) while *Pinus* increased. *Betula* had a small decline 5200 yr BP (6000 cal yr BP) while *Pinus* increased. A single spectrum peak of charcoal may have been caused by natural fire. The continuous occurrence of charcoal most probably derives from people's activities because natural fire is rare in deciduous forests. The forest was dense until 3800–3500 yr BP (4200–3800 cal yr BP). The general long-term course of *Calluna* and charcoal compared to the decline in tree pollen indicates development of cultural heathland landscape formed by regular burning of vegetation. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4900 yr BP (5600 cal yr BP) and 2500 yr BP (2600 cal yr BP), respectively.

Site 42: Kalvheiane A (125 m SW of a Mesolithic dwelling site), Tjeldbergodden, Aure, Møre og Romsdal (50 m asl) (Solem 2000:76–79)

The large mire (in-filled basin) is situated in open landscape with mires, woodland and exposed bedrock. 57 cm of sediment (above two cm of inorganic sediment follow 225–205 cm of gyttja covered by peat to the top which is 8000 yr BP (8900 cal yr BP) was deposited over 2000 cal yr, with an accumulation rate of 1 cm/35 cal yr or 0.285 cm/10 cal yr. The investigation was carried out in order to link the indications of people in the Mesolithic in the natural archive with archaeological finds (B. Berglund 2001).

Charcoal curve: Continuous and changing from the bottom, with one gap (9500 yr BP, 10.700 cal yr BP) and maximum 8800 yr BP (9800 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <8800 yr BP (9800 cal yr BP)
2) *Melampyrum*: Nearly continuous <9500 yr BP (10,700 cal yr BP)
3) *Pteridium*: None

Vegetation development: Open *Betula* forest with lush ground vegetation dominated the area (bottom 9600 yr BP, 11,000 cal yr BP). Charred fragments of *Equisetum fluviatile* 9600–8500 yr BP (11,000–9500 cal yr BP) confirm wet, swampy conditions. Ericales established before 9400 yr BP (10,600 cal yr BP) and the dwelling site was situated close to the sea 9300 yr BP (10,500 cal yr BP), emphasised by shore vegetation. From this strategic place, it was possible to overlook the coastline in all directions. Peak in Ericales about 9200 yr BP (10,400 cal yr BP) at the same time as a minimum in *Betula* is followed by maxima in the charcoal and *Betula* curves and Ericales nearly disappeared about 9100 yr BP (10,300 cal yr BP). This shows fire near the site, indicating that the vegetation was burned when swamp vegetation took over. A large charcoal maximum about 8800 yr BP (9800 cal yr BP) probably represents campfires, since there was hardly any combustible vegetation present. Minimum values of pollen 8700 yr BP (9600 cal yr BP) are a possible effect of a major fire at the same time as the charcoal curve is low, indicating that there was little activity producing charcoal. Possibly, people left the area for some time. *Betula* re-established together with *Pinus* and *Calluna* about 8500 yr BP (9500 cal yr BP). The general disturbance of the vegetation resulted in a short-lived maximum of *Alnus* and *Corylus* 8400 yr BP (9400 cal yr BP). Extensive fire would have had a favourable effect for the establishment and spread of *Corylus* (Solem 2000:78 with reference to Smith 1970 and Huntley 1993). High values of charcoal and charred particles in the peat 8100 yr BP (9000 cal yr BP) indicate fire/campfire very close to the site. The area was, indeed, practically a larder.

Site 43: Kalvheiane 2 (mire 25 m SW of a Mesolithic dwelling site), Tjeldbergodden, Aure, Møre og Romsdal (50 m asl) (Solem 2000:79–82)

Present vegetation is a mosaic of open *Pinus* forest with *Calluna* and mires. The chronology is obtained by interpolating between top assumed 0 year and 35 cm radiocarbon dated to 4200 yr BP (4800 cal yr BP), and for the lower part to interpolate between this age and the bottom radiocarbon dated to 7800 yr BP (8600 cal yr BP). 75 cm of peat was deposited over 8600 cal yr, with an accumulation rate of 1 cm/115 cal yr or 0.087 cm/10 cal yr. The investigation was carried out in order to link the indications of people in the Mesolithic in the natural archive with archaeological finds (B. Berglund 2001).

Charcoal curve: Continuous, maximum (90%) at bottom, decreasing upwards.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence at bottom (5%)
2) *Melampyrum*: Nearly continuous from the bottom, maximum (4%) 6000 yr BP (6800 cal yr BP)
3) *Pteridium*: Scarce from bottom

Vegetation development: The charred peat in the bottom (7800 yr BP, 8600 cal yr BP) may indicate that the coring site was in a dwelling area. Open *Betula* forest with understorey of Polypodiaceae and tall herbs reflects a continuation of the local *Betula* zone recorded in Kalvheiane A, which had already existed for 2400 cal yr. The site was still relatively close to the sea. *Pinus* was part of the *Betula* forest 7400–6000 yr BP (8200–6800 cal yr BP) with increasing *Calluna* and high values of charcoal at the same time as charred material shows fire/campfire close to the site. *Pinus* and *Calluna* dominated 6000–4200 yr BP (6800–4800 cal yr BP), mires became more extensive and the charcoal curve was still high, indicating regular fire/campfire in the area. About 4200 yr BP (4800 cal yr BP), charred peat indicates that vegetation had been burned at the site. *Pinus* dominated (>50%) and the vegetation was much as today since about 4000 yr BP (4500 cal yr BP). The earliest palynological recorded agricultural activity (cereal growing and pasturing) is indicated 3600 yr BP (3900 cal yr BP) and 1800 yr BP (1700 cal yr BP), respectively, indicating that farming apparently occurred somewhere in the area. The results of site 42 and 43 indicate that people were present in the area since about 9600 yr BP (11,000 cal yr BP). The vegetation burned several times. Since this kind of vegetation does not burn easily, people probably used regular and recurrent strategic burning to improve the pastures and attract herbivores (Simmons *et al.* 1981, Solem 2000). This continued until the present time after the introduction of animal husbandry.

Site 44: Fåbergstølen 1, Luster, Sogn og Fjordane (515 m asl) (Kvamme & Randers 1982:98–103)

Present vegetation around the mire (diameter 50 m) is open *Betula* forest and pastures around the summer farms. Radiocarbon dates from Kvamme (1998, pers. comm.): bottom 7700 yr BP (8500 cal yr BP), 235 cm 7100 yr BP (7900 cal yr BP) and 30 cm 2700 yr BP (2800 cal yr BP). 270 cm of peat was deposited over 8500 cal yr, with an accumulation rate of 1 cm/31 cal yr or 0.318 cm/10 cal yr. The investigation was carried out to compare the vegetation development in the outskirts of a summer farm area with changes inside the summer farm area. Mesolithic sites were recorded 5–10 km northeast of the site (Randers 1986:29, 66–67, 78–80).

Charcoal curve: Nearly continuous and low (~5%) from the bottom, higher level (5–15%) 3900 yr BP (4400 cal yr BP), maximum top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce >7200 yr BP (8000 cal yr BP)
2) *Melampyrum*: Nearly continuous from the bottom, rise <2300 yr BP (2300 cal yr BP) to maximum (10%) 1800 yr BP (1700 cal yr BP)
3) *Pteridium*: Sporadic <7500 yr BP (8300 cal yr BP)

Vegetation development: *Pinus* forest with *Betula* (bottom 7700 yr BP, 8500 cal yr BP) was followed by the establishment of *Alnus* forest with Polypodiaceae 7300 yr BP (8100 cal yr BP). *Betula* mixed with *Alnus* in the forest took over 6700 yr BP (7600 cal yr BP). At 6000 yr BP (6800 cal yr BP) the forest was mixed of *Pinus* and *Betula* until 2700 yr BP (2800 cal yr BP) when *Pinus* decreased, increase in herbs and *Melampyrum*, indicating opening of vegetation as a result of the rise in summer farming. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 5900 yr BP (6700 cal yr BP) and in the top sample, respectively.

Site 45: Sætrehaug-I, Luster, Sogn og Fjordane (840 m asl) (Kvamme & Randers 1982:106–111)

The peat deposit (2x1½ m, perhaps a remnant of a larger mire) is surrounded by open low-alpine vegetation dominated by shrubs and dwarf shrubs. With only one radiocarbon date, the chronology is obtained by interpolating between top assumed 0 year and the radiocarbon date 5300 yr BP (6100 cal yr BP at 60–65 cm), and for the lower part to extrapolate using the same accumulation rate as above the radiocarbon date. Based on this 95 cm of peat was deposited over 9000 cal yr, with an accumulation rate of 1 cm/95 cal yr or 0.106 cm/10 cal yr. The investigation was carried out to determine when the area was put to use and the age of the nearby remnants of a house site monument.

Charcoal curve: Continuous from the bottom (2%), increasing slowly (up to 11%) with a small decrease 3800 yr BP (4200 cal yr BP) and a peak (<20%) 3000 yr BP (3200 cal yr BP), maximum close to the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 7300 yr BP (8100 cal yr BP)
2) *Melampyrum*: Nearly continuous from the bottom with maximum (15%) 5100 yr BP (5800 cal yr BP), lower values <4700 yr BP (5400 cal yr BP)
3) *Pteridium*: Sporadic <6400 yr BP (7300 cal yr BP)

Vegetation development: Open *Betula* forest just below the forest limit was dominated by herbs (e.g. Poaceae and *Melampyrum*) in the field layer from the bottom (8100 yr BP, 9000 cal yr BP). About 5300 yr BP (6100 cal yr BP), the forest limit decreased below the site at the same time as Poaceae decreased and Cyperaceae increased. A marked increase in Cyperaceae before 3800 yr BP (4200 cal yr BP) indicates the establishment of vegetation similar to the present. At the same time, taxa indicating agricultural activity increased. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 3000 yr BP (3200 cal yr BP) and 400 yr BP (500 cal yr BP), respectively.

Site 46: Gamle Sæterkulen-I, Stryn, Sogn og Fjordane (660 m asl) (Kvamme & Randers 1982:120–124)

Present vegetation around the remnants of the eroded mire is *Betula* forest. The chronology is obtained by interpolating between top assumed 0 year and the radiocarbon date of the bottom. 110 cm of peat was deposited over 7400 cal yr, with an accumulation rate of 1 cm/67 cal yr or 0.149 cm/10 cal yr. The investigation was carried out to reconstruct the environment related to the old house site monuments nearby dated to the Merovingian period and charcoal pits dated to the Roman period. Late Mesolithic and younger records are confirmed by the archaeological investigations (Randers 1986:29, 66–67, 78–80).

Charcoal curve: Continuous, regular and low (<8%) from the bottom with an increase to higher levels and maximum (22%) 3400 yr BP (3700 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Two occurrences bottom and 1200 yr BP (1100 cal yr BP)
2) *Melampyrum*: Continuous from the bottom with a gap 4100–2500 yr BP (4700–2600 cal yr BP) and maximum (26%) 1400 yr BP (1300 cal yr BP)
3) *Pteridium*: Scarce <3400 yr BP (3700 cal yr BP)

Vegetation development: Open mixed forest of *Betula* and *Alnus* with Poaceae in the understorey (bottom 6500 yr BP, 7400 cal yr BP) was followed by a decrease in *Alnus* 6000 yr BP (6800 cal yr BP) and a marked increase in Cyperaceae 4700 yr BP (5400 cal yr BP) at the same time as Poaceae decreased. Unstable vegetation in the period 3700–1500 yr BP (4000–1400 cal yr BP) was perhaps because of people's use of the area. Weak indications of agricultural activity from 3400 yr BP (3700 cal yr BP), with an increase 2800 yr BP (2900 cal yr BP), were interpreted as a result of activity at lower altitudes in the valley, which is also the reason for the changes in tree species as *Pinus* and *Ulmus*. The vegetation was characterised by more intensive pasturing and removing of the trees around the summer farm after 1500 yr BP (1400 cal yr BP). The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated 1200 yr BP (1100 cal yr BP) and 1000 yr BP (900 cal yr BP), respectively. The cereal pollen could have been transported with people and animal husbandry from the lowland (Kvamme & Randers 1982 with reference to Moe 1973:70).

Site 47: Rødstjødno, Sauda, Rogaland (41 m asl) (Prøsch-Danielsen 1990:part 1)

The small lake is surrounded by deciduous forest. 452 cm of gyttja was deposited over 10,400 cal yr, with an accumulation rate of 1 cm/23 cal yr or 0.435 cm/10 cal yr. The palynological investigation was initiated by a local history project for Sauda in order to reconstruct the vegetation history.

Charcoal curve: Between the maximum in the bottom (14%) and top (18%) the continuous occurrence is low (<1–<10%).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 4000 yr BP (4500 cal yr BP)
2) *Melampyrum*: Sporadic <8500 yr BP (9500 cal yr BP)
3) *Pteridium*: Sporadic <8400 yr BP (9400 cal yr BP), continuous <4400 yr BP (5000 cal yr BP) (<2%)

Vegetation development: Open *Betula* forest dominated when marine clay was deposited (bottom estimated 9200 yr BP, 10,400 cal yr BP). The lake was isolated from the sea 8700 yr BP (9600 cal yr BP) shortly after a marked maximum in *Pinus*, followed by immigration of *Corylus* which increased in the mixed dense *Betula-Pinus* forest to maximum 8500 yr BP (9500 cal yr BP). *Alnus* immigrated to maximum 7500 yr BP (8300 cal yr BP) at the same time as *Ulmus* increased. This dense deciduous forest with some *Pinus* lasted until the immigration of *Quercus* and *Tilia* 5400 yr

BP (6200 cal yr BP) and the mixed *Quercus* forest took over with *Pinus* and *Betula*. The warmth-demanding trees declined after 3000 yr BP (3200 cal yr BP) and the forest was a mixture of *Pinus*, *Betula* and *Alnus*. The earliest recording of pasturing indicated by *Plantago lanceolata* occurred 4300 yr BP (4900 cal yr BP), while archaeological finds indicate livestock husbandry first in the Bronze Age (Lillehammer 1991:50–51) well correlated with the cultural influence on vegetation which increased 3400 yr BP (3700 cal yr BP) and again 2500 yr BP (2600 cal yr BP).

Site 48: Breidastølen, Suldal, Rogaland (700 m asl) (Prøsch-Danielsen 1990:part 2)

The mire (70x15–40 m) is surrounded by open vegetation with *Betula* trees. The treelimit is about 850 m asl and the site is above the *Betula* forest limit. The bottom is obtained by using the same accumulation rate as between the two oldest radiocarbon dates. 130 cm of peat was deposited over 7100 cal yr, with an accumulation rate of 1 cm/55 cal yr or 0.183 cm/10 cal yr. The palynological investigation was carried out in conjunction with hydroelectric power plans.

Charcoal curve: Discontinuous and low <6100 yr BP (7000 cal yr BP), maximum (>5%) close to the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: Nearly continuous from the bottom (2%) to about 2700 yr BP (2800 cal yr BP) with maximum (7%)
3) *Pteridium*: Sporadic and low (<1%) from the bottom (rising upwards)

Vegetation development: The open forest was dominated by *Alnus* with some *Betula*, Polypodiaceae and tall herbs in the field layer (bottom 6200 yr BP, 7100 cal yr BP). *Alnus* declined. Open *Betula* forest took over 5900 yr BP (6700 cal yr BP) with field layer dominance of Poaceae. The field layer changed 4800 yr BP (5500 cal yr BP) with declining Poaceae and increase in other herbs, dwarf shrubs and shrubs at the same time as the earliest recording of *Plantago lanceolata* and increase in the frequency of other cultural indicating plants. The mires expanded 3600 yr BP (3900 cal yr BP) and dwarf shrubs and shrubs increased. The forest disappeared about 2500 yr BP (2600 cal yr BP) and the mires expanded at the same time as dwarf shrubs decreased. Cereal pollen occurs from 1200 yr BP (1100 cal yr BP).

Site 49: Hidlerberget, Suldal, Rogaland (680 m asl) (Prøsch-Danielsen 1990:part 3)

The mire with open water is surrounded by open *Betula* forest with dwarf shrubs and herbs. 142 cm of peat was deposited over 9500 cal yr which gives an accumulation rate of 1 cm/67 cal yr or 0.149 cm/10 cal yr. The palynological investigation was carried out in conjunction with hydroelectric power plans.

Charcoal curve: Discontinuous and low (<2%) <7900 yr BP (8700 cal yr BP), sporadic from 6900 yr BP (7700 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 8200 yr BP (9100 cal yr BP)
2) *Melampyrum*: Continuous from the bottom (10%) with two gaps, maximum (13%) 6000 yr BP (6800 cal yr BP)
3) *Pteridium*: Sporadic <7800 yr BP (8600 cal yr BP), maximum (>1%) 3800 yr BP (4200 cal yr BP)

Vegetation development: The field layer in the relatively open *Betula* forest with some *Pinus* and *Salix* (bottom 8500 yr BP, 9500 cal yr BP) was tall herbs and Polypodiaceae. *Betula* forest with increasing *Pinus*, *Alnus* and tall herbs took over from 7700 yr BP (8500 cal yr BP) and Poaceae dominated the field layer. *Betula* dominated in the forest with increasing *Pinus* and a field layer of Polypodiaceae, Poaceae, *Vaccinium uliginosum* and *Calluna*. *Melampyrum* probably grew in open areas in and at the edge of the *Betula* forest. Mires expanded and *Alnus* in the open *Betula* forest. *Pinus* disappeared from the area 6600 yr BP (7500 cal yr BP). Open mixed *Betula* and *Alnus* forest was replaced by open *Betula* forest 4000 yr BP (4500 cal yr BP) equivalent to the vegetation around the site today at the same time as the earliest palynological recorded agricultural activity of pasturing (*Plantago lanceolata*) occurred together with an increase in other cultural indicating taxa. This was interpreted as people's regular use of the area until today.

Site 50: Liumholseter, Nordre Land, Oppland (745 m asl) (Høeg 1990:44–51)

The present vegetation around the mire (in-filled basin) (120x60 m) is *Picea* forest with some *Pinus* and *Betula*. Burnt peat in the bottom is covered by gyttja to 145 cm and peat to the top. 260 cm of sediment was deposited over 10,200 cal yr, with an accumulation rate of 1 cm/39 cal yr or 0.255 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required in conjunction with hydroelectric power plans. The site was situated 3–7 km north of archaeological sites from 8000–2500 yr BP (8900–2600 cal yr BP, Boaz 1998:Chapter 18, iron extraction sites see Larsen 1991).

Charcoal curve: High at bottom (8100 yr BP, 9000 cal yr BP), otherwise sporadic, continuous <1200 yr BP (1100 cal yr BP) with maximum 400 yr BP (500 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Two occurrences, oldest 2300 yr BP (2300 cal yr BP)
2) *Melampyrum*: Nearly continuous 7200 yr BP (8000 cal yr BP) with maximum (<2%) 7800 yr BP (8600 cal yr BP)
3) *Pteridium*: Nearly continuous from 6900 yr BP (7700 cal yr BP) with maximum (<1%) <6800 yr BP (7600 cal yr BP)

Vegetation development: *Betula* and soon *Pinus* immigrated in the open vegetation (bottom 9000/8100 yr BP, 10,200/9000 cal yr BP). *Pinus* with *Alnus* dominated at the mire from 7900 yr BP (8700 cal yr BP). *Betula* was mixed with *Pinus* and other deciduous trees 7300 yr BP (8100 cal yr BP). *Pinus* forest dominated until 6200 yr BP (7100 cal yr BP) mixed primarily with *Betula* until 5800 yr BP (6600 cal yr BP). The deciduous trees decreased 5800 yr BP (6600 cal yr BP) and the *Pinus-Betula* forest was more open towards the present time. *Picea* appeared 1800 yr BP (1700 cal yr BP). The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 2500 yr BP (2600 cal yr BP) and 2700 yr BP (2800 cal yr BP), respectively. Since 4000 yr BP (4500 cal yr BP), the area was used more or less continuously until the present with forest opening 3700 yr BP (4000 cal yr BP).

Site 51: Dokkfløy syd, Nordre Land, Oppland (696 m asl) (Høeg 1990:37–44)

Picea forest with *Betula* surrounds the mire (600x250 m). 215 cm of peat was deposited over 9000 cal yr, with an accumulation rate of 1 cm/42 cal yr or 0.239 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required in conjunction with hydroelectric power plans. The site was situated 2–5 km north of the archaeological sites from 8000–2500 yr BP (8900–2600 cal yr BP, Boaz 1998:Chapter 18, iron extraction sites see Larsen 1991).

Charcoal occurrence: Sporadic and low from the bottom with a gap 5600–2700 yr BP (6400–2800 cal yr BP), continuous from 2200 yr BP (2200 cal yr BP), maximum 1500 yr BP (1400 cal yr BP)

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Two occurrences, oldest 1500 yr BP (1400 cal yr BP)
2) *Melampyrum*: Continuous <7100 yr BP (7900 cal yr BP), maximum (<2%) 2100 yr BP (2100 cal yr BP)
3) *Pteridium*: One occurrence, bottom, nearly continuous <6100 yr BP (7000 cal yr BP)

Vegetation development: Dense *Pinus* forest (bottom 8100 yr BP, 9000 cal yr BP) was dominated by *Salix* at the mire. *Alnus* and especially *Betula* increased in the mixed *Pinus-Betula* forest with *Alnus* growing around the mire and Cyperaceae and Poaceae at the mire. *Alnus* decreased 5700 yr BP (6500 cal yr BP), with changing amounts of *Pinus* and *Betula* in the more open forest. *Picea* appeared 2600 yr BP (2700 cal yr BP) and increased 1500 yr BP (1400 cal yr BP) to dominance with *Pinus*. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 2200 yr BP (2200 cal yr BP) and 1400 yr BP (1300 cal yr BP), respectively.

Høeg (1990:94–95) interpreted the charcoal curve as the use of the area by people more or less on a yearly basis 8200–5800 yr BP (9100–6600 cal yr BP), based on dense forest where charcoal could hardly have reached the mire surface if it had not come from a place in the vicinity. The archaeological record (Boaz 1998) confirmed this. New traces of people occurred 4400–4000 yr BP (5000–4500 cal yr BP) after a gap, and, after a new gap, people used the area continuously from 3000 yr BP (3100 cal yr BP).

Site 52: Flåfattjønna, Tynset, Hedmark (1110 m asl) (Paus 2010) (Fig. 16a-b)

The lake (425x225 m) is surrounded by lichen-dominated dwarf shrub tundra vegetation in the low-alpine zone. 165 cm of gyttja was deposited over 12,900 cal yr, with an accumulation rate of 1 cm/78 cal yr or 0.128 cm/10 cal yr. The pollen diagram was carried out with the aim of determining vegetation history and environment reconstruction.

Charcoal curve: One occurrence >9800 yr BP (11,200 cal yr BP), continuous <9500 yr BP (10,700 cal yr BP), increases (<1%) 4900 yr BP (5600 cal yr BP) and (<10%) 2500 yr BP (2600 cal yr BP), maximum (~10%) <1400 yr BP (1300 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce, earliest occurrence >9800 yr BP (11,200 cal yr BP)

2) *Melampyrum*: Sporadic, earliest occurrence >9800 yr BP (11,200 cal yr BP)
3) *Pteridium*: Sporadic <7600 yr BP (8400 cal yr BP)

Vegetation development: Open vegetation of grasslands, heath shrub and snow beds (bottom estimated 11,000 yr BP, 12,900 cal yr BP) was replaced by mineral-soil pioneers and dwarf shrubs and increasing vegetation density 9500 yr BP (10,700 cal yr BP). *Betula* was established 9200 yr BP (10,400 cal yr BP). The *Betula* forest was dense, with *Pinus* locally 8900 yr BP (10,200 cal yr BP), increasing to dominance 8800 yr BP (9900 cal yr BP). Decrease in *Pinus* 7700 yr BP (8500 cal yr BP) marks the end of *Pinus* dominance, which lasted up to the present with local and stable *Pinus* vegetation until approximately 2600 yr BP (2700 cal yr BP) mixed with *Betula*. The forest was dense until about 1600 yr BP (1500 cal yr BP). The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4800 yr BP (5500 cal yr BP) and 800 yr BP (700 cal yr BP), respectively.

Site 53: Skumpatjørna, Tysvær, Rogaland
(11.6 m asl) (Midtbø 2000:17–52)

The lake (100x200 m) is surrounded by pastures and mixed *Alnus* forest. 296 cm of gyttja was deposited over >11,000 cal yr which gives an accumulation rate of 1 cm/37 cal yr or 0.269 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required for the construction of a gas pipeline from the North Sea to processing plants on land (Kårstø).

Charcoal curve: Continuous and low from bottom (~1%), higher level (5–10%) from 3100 yr BP (3300 cal yr BP), maximum (12%) 2100 yr BP (2100 cal yr BP).

The three taxa favoured by fire and other openings in the forest:
1) Onagraceae: None
2) *Melampyrum*: Continuous <8500 yr BP (9500 cal yr BP), higher level (~2%) <3100 yr BP (3300 cal yr BP)
3) *Pteridium*: One occurrence 8600 yr BP (9600 cal yr BP), continuous <8100 yr BP (9000 cal yr BP), maximum (~2%) 3200 yr BP (3400 cal yr BP)

Vegetation development: Open *Betula* forest dominated (bottom >9600 yr BP, 11,000 cal yr BP), with *Juniperus* and herbs in the field layer. *Corylus* and *Pinus* established and expanded at the same time as *Betula* and *Juniperus* decreased in the period 9600–8500 yr BP (9500 cal yr BP). *Alnus* established 8700 yr BP (9600 cal yr BP) and rose to a maximum in the dense forest. From 6300 yr BP (7200 cal yr BP), the mixed *Quercus* forest culminated with maximum in *Quercus* (10%) in the dense forest at the same time as *Corylus* and *Alnus* decreased. A weak opening of the forest is indicated 5100 yr BP (5800 cal yr BP). *Pinus* dominated and the warmth-demanding deciduous trees declined in the more open forest. *Calluna* increased and the charcoal curve at the same time as the forest opened 3100 yr BP (3300 cal yr BP). The earliest palynological recorded agricultural activity (pasturing) is indicated about 3400 yr BP (3700 cal yr BP).

Site 54: Sandvikvatn, Tysvær, Rogaland (127 m asl) (Eide & Paus 1982, Paus 1988, Simonsen & Prøsch-Danielsen 2005:20)

The lake (130x450 m) is surrounded by heathland. 276 cm of gyttja was deposited over 16,700 cal yr, with an accumulation rate of 1 cm/61 cal yr or 0.165 cm/10 cal yr. The pollen diagram was carried out with the aim of vegetation history reconstruction in connection with archaeological investigations that were required for the construction of a gas pipeline from the North Sea to processing plants on land (Kårstø).

Charcoal curve: The record starts about 13,000 yr BP (15,600 cal yr BP) with maximum >30% decreasing to about 10–15% 10,400 yr BP (12,400 cal yr BP) with continuous increase 5100 yr BP (5800 cal yr BP) to two maxima 2300 yr BP (2300 cal yr BP) and (50%) 1800 yr BP (1700 cal yr BP).

The three taxa favoured by fire and other openings in the forest:
1) Onagraceae: Scarce from the bottom
2) *Melampyrum*: Nearly continuous <8500 yr BP (9500 cal yr BP), maximum (<2%) 2700 yr BP (2800 cal yr BP)
3) *Pteridium*: Scarce, nearly continuous <8200 yr BP (9100 cal yr BP), maximum (<2%) 2000 yr BP (2000 cal yr BP)

Vegetation development: Scattered steppe vegetation >13,900 yr BP (16,700 cal yr BP) indicates a recently deglaciated area. Long-distance transport and or redeposited pollen characterises the pollen assemblage. Denser local vegetation dominated by *Salix*, different herbs and snow bed vegetation until 12,800 yr BP (16,700–15,100 cal yr BP), followed by *Salix* and increase in *Betula* and *Juniperus* until 12,400 yr BP (14,600 cal yr BP). Vegetation expanded, characterised by *Betula*, *Salix* and *Empetrum*. *Betula* forest established 11,700 yr BP (13,700 cal yr BP) and culminated in a well-developed vegetation during the Allerød chronozone until 11,000 yr BP (12,900 cal yr

BP). *Betula* and *Empetrum* decreased and the vegetation was dominated by herbs and snow bed vegetation during the Younger Dryas chronozone, with marked climate decrease until 10,000 yr BP (11,500 cal yr BP). Temperature increased and continuous vegetation developed with an increase in *Betula*, *Empetrum*, and Polypodiaceae at the same time as light-demanding species were shaded out. Denser *Betula* forest with a *Juniperus* maximum took over 9800 yr BP (11,200 cal yr BP). *Corylus* established in the area and made up the forest with *Betula*, probably with a little *Pinus* 9000–8000 yr BP (10,200–8900 cal yr BP) when the *Alnus* increased to dominance at least around the lake. Dense forest was dominated by *Betula* and *Corylus* with representation of warmth-demanding *Quercus* and *Ulmus* in the mixed deciduous forest, while *Alnus* grew close to the lake with *Melampyrum* at the edge of and in open areas in the forest 7600–5300 yr BP (8400–6100 cal yr BP). The charcoal curve increased 5100 yr BP (5800 cal yr BP), indicating slash-and-burn agriculture. A *Pinus* forest with *Quercus* took over. Deforestation and establishment of heathland started 3000 yr BP (3200 cal yr BP) and was characterised by increase in charcoal and pasturing-indicating taxa dominated up to the present time. Further deforestation took place 2400 yr BP (2500 cal yr BP). The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4700 yr BP (5400 cal yr BP) and 2700 yr BP (2800 cal yr BP), respectively.

Site 55: Flekkstadmyra 1–3, Rennesøy, Rogaland
(80 m asl) (Prøsch-Danielsen 1993:9–37)

The mire (in-filled basin) (500x150 m) is surrounded by coastal heathland vegetation, pastures and *Picea* plantation. 365 cm of gyttja was deposited over 9700 cal yr, with an accumulation rate of 1 cm/27 cal yr or 0.376 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required because of the road/tunnel connection from the mainland to Rennesøy.

Charcoal curve: Continuous from the bottom, varying (5–10%) >9800 yr BP (11,200 cal yr BP) with maximum (<20%) about the transition to the Holocene, low values (<1–2%) increasing <3800 yr BP (4200 cal yr BP) to maximum (5%) with a decrease towards the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <9900 yr BP (11,300 cal yr BP)
2) *Melampyrum*: Sporadic from the bottom, continuous <4200 yr BP (4800 cal yr BP), maximum (2%) about 1500 yr BP (1400 cal yr BP)
3) *Pteridium*: Sporadic <8100 yr BP (9000 cal yr BP)

Vegetation development: Open discontinuous mosaic vegetation of herbs and shrubs dominated (bottom >11,700 yr BP, 13,700 cal yr BP) during the Older Dryas chronozone. During the warmer Allerød chronozone, *Betula* forest with *Empetrum* and some *Juniperus* developed. The cold Younger Dryas chronozone was characterised by a decrease in *Empetrum* and especially *Betula*. Dry open plant societies, grass fields and snow bed vegetation dominated open vegetation without trees. *Betula* increased about 10,200 yr BP (11,900 cal yr BP), followed by an increase in *Empetrum* and the establishment of *Empetrum* heathland in the *Betula* forest 10,000–9800 yr BP (11,500–11,200 cal yr BP) during the warmer climate. *Juniperus* increased 9800–9500 yr BP (11,200–10,700 cal yr BP) in the dense *Betula* forest at the same time as *Empetrum* decreased. *Corylus* rose 9500–8100 yr BP (10,700–9000 cal yr BP) in dense forest, with *Betula* and some *Pinus*. *Alnus* increased 8100 yr BP (9000 cal yr BP) in the mixed forest with *Betula*, *Pinus*, *Alnus* and *Corylus*. *Ulmus* increased and from about 6500 yr BP (7400 cal yr BP), the mixed *Quercus* constituents had their maximum in the *Betula* forest, with varying amounts of *Pinus*, *Alnus*, *Corylus* and *Tilia*. At the transition to the Neolithic, *Betula* increased while *Corylus* and *Ulmus* decreased. Deforestation started 3800 yr BP (4200 cal yr BP), at the same time as the earliest recording of *Plantago lanceolata* and increase in the charcoal curve, indicating a slash-and-burn agricultural management of the forest resulting in pastures in the *Betula* dominated forest. The mixed *Quercus* constituents decreased and *Pinus* and *Betula* increased. Probably, common heathland vegetation dominated since 1200 yr BP (1100 cal yr BP)

Site 56: Kådastemmen, Rennesøy, Rogaland
(29 m asl) (Prøsch-Danielsen 1993:70–79)

Pastures and heathland surround the lake (100x200 m). Calculation of the accumulation rate is based on the age of the bottom 13,000 yr BP (15,600 cal yr BP) and the top 9800 yr BP (11,200 cal yr BP) of the pollen diagram (extrapolation based on three radiocarbon dates between top and bottom using the same accumulation rate). 253 cm of gyttja was deposited over 4400 cal yr, with an accumulation rate of 1 cm/17 cal yr or 0.575 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required because of the road/tunnel connection from the mainland to Rennesøy.

Charcoal curve: Sporadic, low (<1%) <10,300 yr BP (12,600 cal yr BP)

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: None
3) *Pteridium*: None

Vegetation development: Discontinuous mosaic vegetation with herbs, especially Poaceae and *Rumex*, and shrubs such as *Salix*, dominated until 11,700 yr BP (13,700 cal yr BP). *Salix* decreased. Open *Betula* forest dominated, with a later dominance of *Empetrum* when soil was stable. Increase in herbs occurred in a mosaic with snow beds from 11,000 yr BP (12,900 cal yr BP) in the treeless vegetation that characterised the cold Younger Dryas chronozone. Temperature increased 10,400–10,200 yr BP (12,400–11,900 cal yr BP), with an increase in trees, *Empetrum*, Poaceae and *Juniperus* at the transition to the Holocene.

Site 57: Jubemyr I–II, Finnøy, Rogaland (6.7 m asl) (Prøsch-Danielsen 1993:93–101)

The mire (in-filled basin) (75x250 m) is surrounded by pastures, heathland and patches of *Betula*. The accumulation rate is only calculated of the gyttja between the two radiocarbon dates 9170±100 yr BP (10,400 cal yr BP, T-9750A, 309–315 cm) and 8050±100 yr BP (8900 cal yr BP, T-9751A, 274.5–280.5 cm), which is 1 cm/43 cal yr or 0.230 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required because of the road/tunnel connection from the mainland to Rennesøy.

Charcoal curve: Sporadic, low from the bottom, maximum (1–2%) >4100 yr BP (4700 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 8100 yr BP (9000 cal yr BP)
2) *Melampyrum*: Sporadic <9300 yr BP (10,500 cal yr BP)
3) *Pteridium*: Scarce <9400 yr BP (10,600 cal yr BP)

Vegetation development: Dense deciduous forest was dominated by *Corylus* and *Betula* (bottom probably >9500 yr BP, 10,700 cal yr BP) with local stands of *Hippophaë* at open areas. The location close to the beach caused a beach meadow to develop 9200 yr BP (10,400 cal yr BP). *Alnus* immigrated 8100 yr BP (9000 cal yr BP) in the forest and dominated around the site. The two pollen diagrams do not cover the period about 7500–>5000 yr BP (8300–5700 cal yr BP). Dense forest with species from the mixed *Quercus* forest and other deciduous trees was dominated by *Alnus* around the site. *Alnus* decreased 4100 yr BP (4700 cal yr BP). The warmth-demanding deciduous trees were reduced and partly replaced by *Pinus* in the dense forest. Towards the top of the pollen diagram, Cyperaceae took over around the lake. The earliest palynological recorded agricultural activity (pasturing) is >4100 yr BP (4700 cal yr BP).

Site 58: Vestre Øykjamyrtjørn, Matre, Hordaland (570 m asl) (Bjune *et al.* 2005)

The lake is situated at the present-day treeline formed by *Betula* and *Alnus*.

356 cm of gyttja was deposited over 11,500 cal yr, with an accumulation rate of 1 cm/32 cal yr or 0.310 cm/10 cal yr. The pollen diagram was carried out with the aim of climate reconstruction.

Charcoal curve: Nearly continuous, low <3800 yr BP (4200 cal yr BP), maximum (1%) close to the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: None
3) *Pteridium*: None

Vegetation development: Open shrub vegetation (bottom 10,000 yr BP, 11,500 cal yr BP) was replaced by *Betula* and gradually by *Pinus* from 8900 yr BP (10,100 cal yr BP). *Alnus* increased 8200 yr BP (9200 cal yr BP) and the forest was at its densest. *Pinus* started to decrease 7200 yr BP (8000 cal yr BP) and the forest opened 6600 yr BP (7500 cal yr BP). *Betula* dominated the still more open forest until about 300 yr BP (400 cal yr BP). The earliest palynological recorded agricultural activity (pasturing) is indicated about 4000 yr BP (4500 cal yr BP).

Site 59: Trettetjørn, Upsete, Aurland, Hordaland (800 m asl) (Bjune *et al.* 2005)

The lake is surrounded by open vegetation with scattered *Betula* trees, situated in the low-alpine vegetation zone. 270 cm of gyttja was deposited over 8500 cal yr, with an accumulation rate of 1 cm/31 cal yr or 0.318 cm/10 cal yr. The pollen diagram was carried out with the aim of climate reconstruction.

Charcoal curve: Nearly continuous <2300 yr BP (2300 cal yr BP), rising and low, maximum (>40%) close to the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: None

3) *Pteridium*: None

Vegetation development: *Betula* dominated the forest (bottom 7700 yr BP, 8500 cal yr BP), *Pinus* increased to a maximum 7400 yr BP (8200 cal yr BP) and then decreased markedly in the relatively dense forest. *Alnus* increased 7100 yr BP (7900 cal yr BP) to a maximum 6500 yr BP (7400 cal yr BP) and decreased markedly at the same time as the *Betula* forest gradually opened with some *Pinus* and Cyperaceae increased in the field layer. Open vegetation existed from 2400 yr BP (2500 cal yr BP). The earliest palynological recorded agricultural activity (pasturing) is indicated about 3900 yr BP (4400 cal yr BP).

Site 60: Råtåsjøen, Folldal, Dovre Mountains in Hedmark (1169 m asl) (Velle *et al.* 2005)

The lake (250x500 m) is situated in the low-alpine vegetation zone above the treeline. 189 cm of gyttja was deposited over 10,900 cal yr, with an accumulation rate of 1 cm/58 cal yr or 0.173 cm/10 cal yr. The pollen diagram was carried out with the aim of environmental history and climate reconstruction.

Charcoal curve: Sporadic <9800 yr BP (11,200 cal yr BP), nearly continuous and low <7600 yr BP (8400 cal yr BP), increasing 2400 yr BP (2500 cal yr BP) to maximum (>2%) close to the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: None
3) *Pteridium*: None

Vegetation development: Open treeless vegetation indicates a cool and unstable ground dominated by scattered and sparse vegetation (bottom 10,100 yr BP, 11,600 cal yr BP). Open alpine vegetation was dominated by *Salix*, herbs such as Poaceae, and increase in *Juniperus* and *Empetrum* from 9600 yr BP (11,000 cal yr BP). Probably both *Betula nana* and tree-birch *Betula* sp. immigrated 8900 yr BP (10,100 cal yr BP). An open *Betula* forest established around the lake and denser vegetation cover developed. *Pinus* advanced altitudinally 8100 yr BP (9000 cal yr BP), while *Salix*, Poaceae, *Juniperus* and *Empetrum* were typical plants in this area. *Pinus* trees occurred locally from 7400 yr BP (8200 cal yr BP) at or near its upper limit. Open *Betula* forest, with a field layer of *Betula nana* and *Juniperus*, and some *Empetrum* together with tall herbs (6400–3900 yr BP, 7400–4400 cal yr BP), dominated the vegetation. *Pinus* had receded from the catchment 3900–3700 yr BP (4400–4000 cal yr BP) when climate cooling started with tree decline and instability and 3000 (3200 cal yr BP) tree-birch receded. Since this time, the landscape opened and present-day low-alpine heath and grassland vegetation gradually developed, with opening of the local vegetation cover and increased distance to the treeline. Today, tree-birch and *Pinus* trees grow 170 m and 370 m, respectively, below the lake.

Site 61: Grostjørna, Birkenes, Aust-Agder (180 m asl) (Eide *et al.* 2006)

The lake is surrounded by open *Pinus* forest with scattered *Picea* and *Betula*. 350 cm of gyttja was deposited over 12,300 cal yr, with an accumulation rate of 1 cm/35 cal yr or 0.285 cm/10 cal yr. The pollen diagram was carried out with the aim of forest development reconstruction.

Charcoal curve: Sporadic <10,200 yr BP (11,900 cal yr BP), continuous <9000 yr BP (10,200 cal yr BP) with a maximum period (2–15%) 8300–6600 yr BP (9300–7500 cal yr BP). Increase in the charcoal curve <2600 yr BP (2700 cal yr BP) to maximum 18% 2100 yr BP (2100 cal yr BP). The maximum occurrence of macroscopic charcoal is 6500–4800 yr BP (7400–5500 cal yr BP), with low values nearly to the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: None
2) *Melampyrum*: None
3) *Pteridium*: None

Vegetation development: Open vegetation dominated by herbs characterised the last part of the Younger Dryas chronozone (bottom 10,400 yr BP, 12,300 cal yr BP). Rise in species from the Ericales and *Salix* 10,000 yr BP (11,500 cal yr BP) was followed by a mosaic of *Betula*, *Salix*, heaths and Polypodiaceae. *Corylus* immigrated about 9300 yr BP (10,500 cal yr BP) and increased to a maximum 8900 yr BP (10,100 cal yr BP). *Pinus* arrived 8800 yr BP (9900 cal yr BP) and the forest became denser, dominated by *Betula* and *Pinus*, with *Alnus* that increased 8500 yr BP (9500 cal yr BP). Mixed deciduous forest established around the lake 7200 yr BP (8000 cal yr BP), with *Quercus* as a common constituent from 6100 yr BP (7000 cal yr BP) and an increase 4500 yr BP (5200 cal yr BP), at the same time as human activity increased. Macroscopic charcoal is most frequent in the period (6500–4800 yr BP, 7400–5500 cal yr BP) is delayed compared to the maximum period in charcoal (8300–6600 yr BP, 9300–7500 cal yr BP) without overlap. Macroscopic charcoal suggests local burning, while charcoal may originate in a larger area recording a regional fire regime. A slight increase in microscopic charcoal 4400 yr BP (5000 cal yr BP) might have resulted from nearby human settlement. The forest was dominated by *Betula*, *Pinus*, *Alnus* and *Quercus* from 2900 yr BP (3000 cal yr BP) and *Picea* occurred after 1700 yr BP (1600 cal yr BP). Forest diversity and density was reduced about 1000 yr BP (900 cal yr BP), followed by a gradual decline in *Betula*, leaving *Pinus* as the dominant tree as today. The earliest recorded palynological agricultural activity (cereal pollen and pasturing) is indicated 5200 yr BP (6000 cal yr BP) and 4400 yr BP (5000 cal yr BP), respectively.

Site 62: Botnaneset mire, Flora, Sogn og Fjordane (11 m asl) (Bostwich Bjerck 1983)

Open *Pinus* forest surrounded the mire. 182 cm of peat was deposited over 8900 cal yr (extrapolation based on two radiocarbon dates using the same accumulation rate), with an accumulation rate of 1 cm/49 cal yr or 0.204 cm/10 cal yr. The pollen diagram was produced in connection with archaeological investigations that were required for the construction of a supply base for the oil fields in the North Sea and for other industry (Olsen 1983).

Charcoal curve: Continuous from the bottom with large fluctuations, two maxima (75%) 7200–6800 yr BP (8000–7600 cal yr BP) and (85%) 1700 yr BP (1600 cal yr BP) and lowest values (<10%) 6100–5300 yr BP (7000–6100 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <3500 yr BP (3800 cal yr BP)
2) *Melampyrum*: Nearly continuous from the bottom, three maxima (13–21%) 5800 yr BP (6600 cal yr BP), 4200 yr BP (4800 cal yr BP) and 2000 yr BP (2000 cal yr BP)
3) *Pteridium*: Nearly continuous from the bottom, maximum (42%) 3800 yr BP (4200 cal yr BP)

Vegetation development: Open forest was dominated by *Betula*, *Salix*, *Juniperus*, *Empetrum* and herbs (bottom 8000 yr BP, 8900 cal yr BP) and influenced by the transgressing sea. *Pinus* and *Alnus* were mixed in the open *Betula* forest at the maximum transgression 7000 yr BP (7900 cal yr BP), correlated with the oldest maximum in charcoal and the oldest settlement phase at Botnaneset. The charcoal occurrence was low 6100–5300 yr BP (7000–6100 cal yr BP), indicating low human activity and a period with dense forest of *Betula* with *Alnus*. High values of *Melampyrum* were probably caused by opening of the vegetation caused by fire. Increase in *Pinus*, *Quercus* and *Lycopodium annotinum* and decrease in *Betula* in the dense forest 4700 yr BP (5400 cal yr BP) is correlated with the archaeological phase 3 at Botnaneset (approximately 5000 yr BP, 5700 cal yr BP). The forest was gradually more open 3900 yr BP (4400 cal yr BP), with high values of e.g. *Melampyrum* caused by burning to increase the pastures. Reduction in *Pinus* and increase in *Betula*, *Alnus* and *Pteridium* indicate deforestation 3400 yr BP (3700 cal yr BP), followed by increase in *Calluna* with changes in the human impact which, however, became more intense. Further increase in *Calluna*, *Juniperus* and charcoal occurred 1800 yr BP (1700 cal yr BP) at the same time as *Quercus* disappeared. The development of coastal heathland was characterised by continuous and intensive pasturing combined with burning. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 6400 yr BP (7300 cal yr BP) and 2600 yr BP (2700 cal yr BP), respectively.

Site 63: Frengstadsetra, Innerdalen, Tynset, Hedmark (800 m asl) (Paus & Jevne 1987:21–32) (Fig. 11a-b)

Betula forest with *Vaccinium myrtillus* and Polypodiaceae dominated the vegetation around the mire but the site is now part of a dammed lake. 170 cm of peat was deposited over 10,700 cal yr, with an accumulation rate of 1 cm/63 cal yr or 0.159 cm/10 cal yr. The archaeological and palynological investigations were carried out in conjunction with hydroelectric power plans. The archaeological record indicates settlement during most of prehistoric and historic times, with 142 archaeological sites (radiocarbon dated 7400–240 yr BP, 8200–290 cal yr BP, Gustafson 1987).

Charcoal curve: Continuous from the bottom with a single spectrum gap 7400 yr BP (8200 cal yr BP). Maximum from the bottom to 8900 yr BP (10,100 cal yr BP) (24–28%), generally 2–5% with a weak increase <4200 yr BP (4800 cal yr BP) to the top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Two occurrences, bottom and 5700 yr BP (6500 cal yr BP)
2) *Melampyrum*: Sporadic <8200 yr BP (9100 cal yr BP)
3) *Pteridium*: None

Vegetation development: Light-demanding herbs and shrubs established after deglaciation in a mosaic with snow bed vegetation (bottom 9500 yr BP, 10,700 cal yr BP). Vegetation became closer and more continuous. *Salix* and *Empetrum* were well represented before the development of *Betula* forest. *Plantago major* and *Urtica* occurred at the same time as high values in charcoal not caused by people. Long-distance transport was considered a more likely interpretation i.a. because the low pollen deposition was the reason for high charcoal values. *Pinus* established and depressed the *Betula* in a gradually denser *Pinus* forest with maximum 8000–7500 yr BP (8900–8300 cal yr BP). *Alnus* (probably *A. incana*) immigrated about 7900 yr BP (8700 cal yr BP) and increased to dominance at the same time as rise in moisture-indicating taxa. *Alnus* and *Betula* made up the deciduous forest with *Pinus* at dry growing places. The Holocene Thermal Maximum was indicated by increase in the warmth-demanding taxa. *Alnus* and tall-herbs disappeared. Open subalpine *Betula* forest established, with some *Pinus* and increase in *Juniperus* and *Melampyrum*. Increase in *Pinus* and charcoal was interpreted as the result of opening of the forest and therefore increase in long-distance transport of microscopic particles. Weak anthropogenic traces are present. Rise in *Picea* resulted in a few stands in the still more open forest.

Site 64: Flonan, Innerdalen, Oppdal, Sør-Trøndelag (780 m asl) (Paus & Jevne 1987:70–80)

The mire was surrounded by pastures at the summer farm and open *Betula* forest but the site is now part of a dammed lake. 126.5 cm of peat was deposited over probably 8900 cal yr, with an accumulation rate of 1 cm/70 cal yr or 0.142 cm/10 cal yr. The archaeological and palynological investigations were carried out in conjunction with hydroelectric power plans.

Charcoal curve: Continuous and low (1–10%) from the bottom, increase 2200 yr BP (2200 cal yr BP) to ~20% to the top with maximum (22%) 1500 yr BP (1400 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <6800 yr BP (7600 cal yr BP)
2) *Melampyrum*: Continuous and low from the bottom, maximum (>1%) 1500 yr BP (1400 cal yr BP)
3) *Pteridium*: Scarce <7600 yr BP (8400 cal yr BP)

Vegetation development: *Pinus* dominated the dense forest (bottom probably 8000 yr BP, 8900 cal yr BP by comparison with site 63). *Alnus* increased to dominance 7500–4000 yr BP (8300–4500 cal yr BP). A pasturing phase started 4100 yr BP (4700 cal yr BP), when *Betula* forest expanded and *Alnus* decreased. The forest opened at the same time as the charcoal curve and taxa indicating pasturing increased. Pasturing continued until 2600 yr BP (2700 cal yr BP) when charcoal declined and the forest was denser. A more intense cultural phase started 2000 yr BP (2000 cal yr BP) with e.g. marked rise in charcoal. The occurrence of *Picea* started 1300 yr BP (1200 cal yr BP), probably long-distance transported. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4400 yr BP (5000 cal yr BP) and 4100 yr BP (4700 cal yr BP), respectively.

Site 65: Hellemundsmyra, Elverum, Hedmark (190 m asl) (Høeg 1996:117–123)

The mire (in-filled basin) is surrounded by *Pinus* forest with *Betula* and *Picea*. 478 cm of sediment (gyttja 478–230 cm covered by peat to the top) was deposited over 10,200 cal yr, with an accumulation rate of 1 cm/21 cal yr or 0.469 cm/10 cal yr. The site was chosen for palynological analysis because of the close proximity of the archaeological site of Svevollen from the latest phase of the Late Mesolithic period (5500–5000 yr BP, 6300–5700 cal yr BP, Fuglestvedt 1992).

Charcoal curve: Nearly continuous, low and regular <8700 yr BP (9600 cal yr BP), increase 5200 yr BP (6000 cal yr BP), maximum (~2000%) 2000 yr BP (2000 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 4000 yr BP (4500 cal yr BP)
2) *Melampyrum*: Sporadic from the bottom
3) *Pteridium*: Continuous <7800 yr BP (8600 cal yr BP), maximum (<1%) 6300 yr BP (7200 cal yr BP)

Vegetation development: Open *Betula* forest with shrubs and herbs dominated (bottom 9000 yr BP, 10,200 cal yr BP) with no indications of people. *Pinus* immigrated 8600 yr BP (9600 cal yr BP) and became dominating at the same time as the forest became denser and *Betula* decreased. The low occurrence of charcoal indicates that people had possibly started to use the area. *Alnus* immigrated 7900 yr BP (8700 cal yr BP), while *Betula* and *Corylus* increased at the same time as a marked decrease in *Pinus*. *Quercus* immigrated in the dense forest about 7500 yr BP (8300 cal yr BP). *Tilia* immigrated 6400 yr BP (7300 cal yr BP) and *Pinus* increased until 5000 yr BP (5700 cal yr BP) while *Corylus* and *Alnus* decreased in the dense *Pinus* forest with *Betula*. A small increase in charcoal 5700 yr BP (6500 cal yr BP) was followed by a larger one 5200 yr BP (6000 cal yr BP), which indicates that people used the area. *Pinus* increased to maximum 4400 yr BP (5000 cal yr BP) followed by a marked decrease at the same time as herbs increased on the mire after the tarn was overgrown 4100 yr BP (4700 cal yr BP). The mixed forest of *Betula* and

Pinus with a little *Alnus* was gradually more open. Occurrence of silt indicates erosion from fires or wear and tear on the vegetation from people staying at the mire. The forest was dense again 2400 yr BP (2400 cal yr BP). *Picea* immigrated 2000 yr BP (2000 cal yr BP) and the forest was mixed with *Betula*, *Pinus* and *Picea*. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 4000 yr BP (4500 cal yr BP) and 3200 yr BP (3400 cal yr BP), respectively. Probably the charcoal originated from people's regular use of fire for firewood and burning in the area since 4000 yr BP (4500 cal yr BP).

Site 66: Flaatevatn, Etne, Hordaland (570 m asl) (Sivertsen 1985:98–124)

A mosaic of mires and *Betula* forest surrounds the lake. 334 cm of sediment (gyttja 334–177 cm covered by peat to the top) was deposited over 11,000 cal yr, with an accumulation rate of 1 cm/33 cal yr or 0.304 cm/10 cal yr. The pollen diagram was carried out with the aim of vegetation history reconstruction.

Charcoal curve: Discontinuous and low values (<1%) <9000 yr BP (10,200 cal yr BP), continuous <5400 yr BP (6200 cal yr BP) with a small increase 4500 yr BP (5200 cal yr BP), maximum (12%) top.

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Two occurrences, oldest bottom
2) *Melampyrum*: Continuous from the bottom (½–2%), sporadic <4500 yr BP (5200 cal yr BP)
3) *Pteridium*: Two occurrences, oldest 6700 yr BP (7600 cal yr BP)

Vegetation development: *Betula* dominated in the open forest with *Corylus* (bottom 9600 yr BP, 11,000 cal yr BP). *Melampyrum* and other herbs grew in the field layer. *Betula* decreased and *Alnus* increased 8500 yr BP (9500 cal yr BP) in the open forest, with Poaceae and Cyperaceae in the field layer and tall herbs probably at the edge of the forest. *Alnus* increased to culmination 7000–6300 yr BP (7900–7200 cal yr BP) and the rather open *Alnus* forest was mixed with *Betula*. *Melampyrum* and Polypodiaceae were among the taxa in the field layer. *Alnus* decreased and *Quercus* increased 5900 yr BP (6700 cal yr BP) in the mixed open *Betula* and *Alnus* forest, with stands of *Quercus* and *Ulmus* and other deciduous trees, while Cyperaceae dominated in the field layer locally. *Pinus* increased 4300 yr BP (4900 cal yr BP); *Quercus* culminated by 6% and a mixed *Quercus* forest was established. In the field layer, tall herbs decreased and Cyperaceae increased. The earliest palynological recorded agricultural activity (pasturing and cereal pollen) is indicated about 2300 yr BP (2300 cal yr BP) and in the top sample, respectively. People's use of the area from 2300 yr BP (2300 cal yr BP) is indicated by e.g. deforestation, which occurred at the same time as shrubs and dwarf shrubs established with *Juniperus*, *Calluna* and other Ericales.

Site 67: Brynnsmyra, Snertingdal, Gjøvik, Oppland (725 m asl) (Høeg 2007:181–186)

The mire is surrounded by *Picea* forest with a little *Betula*. It is located 50 m from a summer farm used AD 1669–1946. 218 cm of peat was deposited over 8000 cal yr, with an accumulation rate of 1 cm/37 cal yr or 0.273 cm/10 cal yr. The pollen diagram was carried out to reconstruct the vegetation history for Snertingdal historical society. The archaeological record indicates people's use of the area since the Early Bronze Age (Gustafson 2007, Larsen 2007).

Charcoal curve: Continuous and low (<0.5–3%) from the bottom with maximum (5%) 6700 yr BP (7600 cal yr BP) and increase to maximum (18%) 1100 yr BP (1000 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: One occurrence 6900 yr BP (7700 cal yr BP)
2) *Melampyrum*: Nearly continuous <6900 yr BP (7700 cal yr BP), maxima (8%) 2900 yr BP (3000 cal yr BP) and (10%) 1200 yr BP (1100 cal yr BP), respectively
3) *Pteridium*: Discontinuous and low values <6700 yr BP (7600 cal yr BP), maximum (1%) 2900 yr BP (3000 cal yr BP)

Vegetation development: The forest was mixed with *Betula*, *Pinus* and *Alnus* (bottom 7300 yr BP, 8100 cal yr BP) with *Alnus* at the mire and shrubs, Polypodiaceae and *Lycopodium annotinum* in the understorey. The charcoal occurrence indicates that few people used the area, but not every year. *Alnus*, *Corylus*, Polypodiaceae and *Lycopodium annotinum* decreased at the same time as Cyperaceae increased 5500 yr BP (6300 cal yr BP) and the forest was more open. The dominance of *Betula* in the forest was replaced by permanent dominance of *Pinus* from 4300 yr BP (4900 cal yr BP). Cyperaceae decreased and Ericales and *Sphagnum* increased. The forest was mixed by *Pinus* and *Betula* with a little *Alnus* at moist places from 3000 yr BP (3200 cal yr BP). *Sphagnum*, *Lycopodium annotinum* and *Pteridium* increased in the field layer. Agrarian people used the area indicated by the earliest palynological recorded agricultural activity (pasturing and cereal pollen) about 2900 yr BP (3000 cal yr BP) and 2500 yr BP (2600 cal yr BP), respectively. *Picea* immigrated about 1300 yr BP (1200 cal yr BP) and soon dominated in the forest. The sampling site was situated close to a pitfall system for elk dated to the Bronze Age until newer times. Iron production sites and charcoal pits have also been identified in Snertingdal from the transition to the Iron Age until newer times (Gustafson 2007, Larsen 2007).

Site 68: Sygneskardsvatn, Sunndalen, Stryn, Sogn og Fjordane (690 m asl) (Kvamme 1984:238–266) (Fig. 13a-b)

The mire at the lake (15x30 m, in-filled basin) was surrounded by *Betula* forest with Ericales and tall herbs. It is located 2–3 km from the glacier margin of Jostedalsbreen. 329 cm of gyttja was deposited over 10,500 cal yr, with an accumulation rate of 1 cm/32 cal yr or 0.313 cm/10 cal yr. The pollen diagram was carried out with the aim of vegetation history reconstruction.

Charcoal curve: Continuous and low (<1–2%) from the bottom with maximum (31%) 8600 yr BP (9600 cal yr BP).

The three taxa favoured by fire and other openings in the forest:

1) Onagraceae: Scarce <8900 yr BP (10,100 cal yr BP)
2) *Melampyrum*: Sporadic from the bottom, continuous <5300 yr BP (6100 cal yr BP) (<1%)
3) *Pteridium*: Scarce <4700 yr BP (5400 cal yr BP)

Vegetation development: *Betula*, probably mostly *Betula nana*, dominated the vegetation with *Juniperus*, *Salix* and *Empetrum* (bottom 9300 yr BP, 10,500 cal yr BP dating deglaciation). *Hippophaë* grew in the area. One pollen of *Plantago lanceolata* was recorded 9000 yr BP (10,200 cal yr BP) at the same time as a marked increase in *Pinus*, which culminated 8400 yr BP (9400 cal yr BP). This early occurrence of *Plantago lanceolata* was, with reference to Iversen (1954, see also Simonsen 1980), interpreted as an element in the flora that followed the melting ice margin. The relatively open forest was mixed with *Pinus* and *Betula*. The maximum in charcoal 8600 yr BP (9600 cal yr BP) was interpreted as caused by local natural fire because there are no other palynological or archaeological indications of people from the area with recorded effect on vegetation. *Alnus* (probably *A. incana*) established 7800 yr BP (8600 cal yr BP) in the dense mixed *Pinus-Betula* forest. *Alnus* decreased at the same time as *Ulmus* increased and was a constituent in the forest 6500 yr BP (7400 cal yr BP). The opening of the mixed *Pinus-Betula* forest increased slowly 4700 yr BP (5400 cal yr BP) at the same time as Polypodiaceae and Cyperaceae increased and Poaceae decreased somewhat. The earliest palynological recorded agricultural activity (pasturing) is indicated about 9000 (4900) yr BP (10,200 (5600) cal yr BP).

Appendix B

The interpretation of the data in Appendix A as it pertains to fire management. Eight pollen diagrams are selected to represent the four vegetation zones and the four charcoal curve patterns in Chapter 9 (Table 3 with asterix).

The coastal forest zone

Pattern 1

The small changes in the low and continuous charcoal curve at *site 29* (Alvevatn), on the coast of Southwest Norway indicate that people used the area since 9100 cal yr BP with low-intensity until about 4200 cal yr BP. The dense deciduous forest was mixed with changing amounts of *Pinus* but opened at this time with deforestation and the subsequent establishment of *Calluna vulgaris*. The rise in charcoal is 700 cal yr later than the earliest traditional palynological indication of pasturing, which is correlated with a small increase in the charcoal level 5200 cal yr BP, indicating agriculture. Before this time, foragers may have dominated the burning regime.

The occurrence of charcoal at *site 33* (Romamyra) (Fig. 15) in Southwest Norway indicates low and continuous intentional use of fire during the Mesolithic, at the same time as the relatively open deciduous forest indicates that it may have been a good place to hunt ungulates. The small maximum in charcoal about 7400 cal yr BP indicates a fire event. This is confirmed by the occurrences of *Melampyrum* and *Pteridium aquilinum*. An increase in fire management in the area could have been the result of settlement close to the site; natural fire may be excluded because burning in a deciduous forest is rare (Rackham 1980, see Clark & Robinson 1993:200 and discussion Chapter 2.3.2). The rise in charcoal occurred at the transition to the Neolithic and was characterised by an increase in *Calluna vulgaris* and opening of the forest. The appearance of anthropochorous pollen types indicates the impact of farmers on vegetation and the development of pastures. Otherwise, the development at the site has many similarities with sites 30–32 (Obrestad Harbour, Kviamyra and Stavnheimsmyra) but, because of a rise in the charcoal curve in the Mesolithic, these sites are placed in pattern 2.

The charcoal occurrence at *site 55* (Flekkstadmyra 1–3) at the island Rennesøy in Southwest Norway indicates that hunter-gatherers used intentional fire from the earliest record around 13,700 cal yr BP until 11,200 cal yr BP, with a maximum before the transition to the Holocene. This was followed by a long period with people's low-intensive use of fire in the area before an increase about 4800–4200 cal yr BP, when farmers opened the forest using intentional fire for a slash-and-burn cultural management of the forest, resulting in pastures for husbandry. The minor changes in the charcoal curve indicate small changes in fire management and low-intensive occurrences of people in the area for a very long period.

This is in contrast to the two neighbouring islands of Mosterøy (*site 56*, Kådastemmen) and Nord-Talgje (*site 57*, Jubemyr I–II, actually pattern 4 for both sites), at a distance of only 3–4 km and 5 km, respectively, as the crow flies. The very low and sporadic occurrences of charcoal, giving no (or low) indication of hunter-gatherers' use of these two sites. The three islands are separated by sounds. A possible scenario is that foragers regularly used sites at Rennesøy during the Late Weichselian Substage and the earliest part of the Holocene because they were better situated to exploit and utilise both marine and terrestrial resources than the two other islands, which were maybe not settled in this period. The scarce traces of charcoal at the sites on Mosterøy and Sør-Talgje may have originated from the intentional use of fire on Rennesøy. This strategy may have developed as a tradition in the mobile way of life, using intentional burning that may have been introduced as a strategy developed in the area of origin on the Continent (see Selsing 2012). The archaeological evidence (Høgestøl 1995, Høgestøl *et al.* 1995, Prøsch-Danielsen & Høgestøl 1995) confirms the results.

Pattern 2

Based on the regular values of charcoal at *site 17* (Fjellestad myr I) the hunter-gatherers probably used low-intensity fire management in the area during the Late Weichselian Substage and until at least 9100 cal yr BP. This is confirmed by the site's location immediately to the west of archaeological sites from the Middle Mesolithic until the Roman period (Ballin & Jensen 1995:21, 25). The charcoal curve indicates that farmers used the area for pasturing husbandry at least since 3400 cal yr BP.

Three sites (30–32, Obrestad Harbour, Kviamyra and Stavnheimsmyra) are from the Jæren area in the southwest. Until the Neolithic, the area was more or less densely forested by mixed deciduous forest grading into *Pinus* dominance in the southern part of this area (Prøsch-Danielsen & Selsing 2009:85). Some areas close to the coast had more open vegetation than areas further from the sea.

The process of anthropogenically induced pre-Neolithic deforestation, rise in the charcoal curve and increase in *Calluna vulgaris* at *site 30* (Fig. 17) started at least 8500 cal yr BP in a dense, mixed deciduous forest. This very early deforestation may have been facilitated by the location close to the exposed North Sea coast. It also indicates that people used the area rather intensively from this time on. The increase in the charcoal curve is 2500 cal yr earlier than the transition to the Neolithic in South Norway. The early coastal heathland establishment about 7600 cal yr BP and anthropogenically induced deforestation may show that foragers opened the landscape by using fire to improve the pastures for ungulates because their culture was favoured by this change (see also Prøsch-Danielsen & Selsing 2009:85–86). The coastal heathland establishment became permanent because of repeated burning until the present time. This may confirm that the use of fire by hunter-gatherers and early farmers was a continuous process. This interpretation is strengthened by the first occurrence of pollen of *Plantago lanceolata* as late as 4300 cal yr after the transition to the Neolithic. This development occurred in areas far from where the main agricultural activities later took place.

Site 31 and to a certain degree site 32 reflect the same general conditions as site 30. At site 31, the continuous charcoal curve indicates the presence of hunter-gatherers in the area from about 10,200 cal yr BP. The correlation between the small culminations in charcoal estimated 8600 cal yr BP and maximum in *Melampyrum* and *Calluna vulgaris* indicates opening of the vegetation and the presence of people close to the site. Probably, foragers changed the vegetation by the use of intentional fire. At this site, the earliest palynological occurrence of agricultural activity is as late as about 1900 cal yr BP while the increase in the charcoal curve is estimated to be more than 3000 cal yr earlier than the transition to the Neolithic in South Norway. In general, this indicates that people used this area very early, but that farmers may have affected the pollen assemblages very late.

At *site 32*, the transition to the Neolithic is recorded by a maximum in the charcoal 800 cal yr before the earliest pollen indication of agricultural activity (pasturing). Probably, it was caused by human impact through the development and maintenance of heathland for pasturing. This may show that farmers used areas in this region early, while other areas may still have been used by hunter-gatherers (e.g. around site 30 and 31). The sites are situated close to Mesolithic dwelling sites outside the central agricultural areas and most probably, the record indicates hunter-gatherers fire activities.

The charcoal curve at *site 35* (Vassnestjern, Fig. 14a-b) in West Norway shows that hunter-gatherers probably used fire in the area since the Younger Dryas chronozone, with an intensive phase after which the continuous use of fire in the area was low-intensive. Increasing use of fire culminated 8000 cal yr BP based on a maximum in the charcoal curve, indicating hunter-gatherers' intensive use of fire in the area or close to the site within a rather dense forest. This long period of foragers using fire management to make openings in the forest is confirmed by a continuous *Melampyrum* curve until 7600 cal yr BP. The earliest indication of pasturing and a weak increase in *Calluna vulgaris* may imply farmers in the area from 5500 cal yr BP. Heathland expanded and the forest declined nearly 3000 cal yr later.

The charcoal curve at *site 53* (Skumpatjørna) in West Norway indicates people's regular, continuous and low-intensive use of fire in the area since the Early Mesolithic until an increase in charcoal to a higher level from 3300 cal yr BP. Heathland developed, indicating pasturing for husbandry well correlated with the earliest traditional indication of agricultural activity (*Plantago lanceolata*). The generally low occurrence but increase of *Melampyrum* and *Pteridium aquilinum* through the whole period confirms the use of fire management and opening of the landscape.

Pattern 3

The charcoal occurrence at *site 16* (Skjoldnes myr I) on the south coast is irregular with a high maximum in the Late Weichselian Substage and a low one in newer times. The early charcoal maximum may have originated in a large area, when the interior was still mainly covered by inland ice. The charcoal curve indicates people's use of intentional fire during the Late Weichselian Substage, from the beginning of the Late Mesolithic to the beginning of the Middle Neolithic II (8200–4700 cal yr BP) and 700–400 cal yr BP. The site was situated about 3 km to the southeast of archaeological sites from the Middle Mesolithic until the Roman period (Ballin & Jensen 1995:21, 25). The maximum periods are separated by periods of sporadic occurrences of charcoal, indicating low-intensive or no use of fire, showing that the area was probably not settled continuously and separated by periods of intensive use probably close to the pollen sampling site. The earliest palynological indication of cereal growing and the beginning of a continuous curve of *Pteridium aquilinum* are well correlated with the beginning a period of maximum in charcoal, which started with a marked peak 8000 cal yr BP. This may indicate that foragers or early groups of farmers experimented with cereal growing and using fire management, even if it cannot be excluded that the early cereal type pollen was a large grass pollen. The earliest traditional palynological indication of husbandry pasturing indicates traces of farming without changes in the level of charcoal.

Sites 42–43 (Kalvheiane A and 2), close to the sea in the northwestern part of South Norway, are located close to Early and Middle Mesolithic sites, confirming the use of intentional fire in the extended areas of the settlements. This influenced the charcoal curve, which has high and changing values. The investigation was carried out in order to link the indications of people in the Mesolithic in the natural archive with the archaeological record by i.a. using the charcoal occurrence in the interpretation about foragers' use of the area (Solem 2000:76–82 with a detailed interpretation of the sites, see also B. Berglund 2001). The detailed interpretation of the relationship between the vegetation, people and fire was based on goal-oriented efforts. Use of fire near the pollen sampling site indicates that the vegetation was burnt when swamp vegetation took over. Charred fragments of *Equisetum fluviatile*, indicating burning of wet vegetation also confirm this. High values of charcoal and charred particles in the peat 9000 cal yr BP indicate fire, maybe a campfire very close to the site or intentional burning in the vegetation. The charred peat 8600 cal yr BP may indicate a dwelling area or burning the mire to improve the pastures for ungulates. Campfires or burning of vegetation close to the site 8200–6800 cal yr BP were indicated by an increase in *Calluna vulgaris*, high values of charcoal and charred material. Regular intentional burning of vegetation and campfires in the area continued until 4800 cal yr BP, based on high values of *Calluna vulgaris* and charcoal. The earliest palynological recorded agricultural activity (cereal growing and pasturing) is 3900 cal yr BP and 1700 cal yr BP, respectively, indicating farming in the area. Based on this, foragers could have used the area until the Late Neolithic II. The results indicate that people were present in the area and used intentional burning since the Early Mesolithic. Charred peat shows that vegetation was burnt at the mire several times.

Pattern 4

The high charcoal values at *site 18* (Fjellestad myr II) on the south coast indicate locally produced charcoal by hunter-gatherers, who used the area from 13,300 cal yr BP to the transition to the Holocene (see Høeg 1995:295). The period of maximum in *Corylus* is correlated with a minimum and a hiatus in the charcoal curve, which may be interpreted as being because people did not carry out burning in the area where *Corylus* grew. Archaeological sites from the Middle Mesolithic until the Roman period are located immediately to the northwest of the pollen sampling site (Ballin & Jensen 1995:21, 25). This is not in agreement with the view that burning favoured the growth of *Corylus* (Smith 1970), however, it is in agreement with e.g. Bennett *et al.* (1990b) and Edwards (1990) who found no correspondence between *Corylus* and charcoal peaks. Noteworthy is the continuous and regular charcoal curve during the period 7900–3900 cal yr BP crossing the Mesolithic/Neolithic transition without any changes.

The high occurrence of charcoal at *site 19* (Jølletjønn) on the south coast during the Late Weichselian Substage is most probably due to people's fire activity in the area, except perhaps for the Younger Dryas chronozone (Høeg 1995:304). The charcoal occurrence after the transition to the Holocene decreased to low and discontinuous values until 4400 cal yr BP, when the charcoal curve show a marked rise. Archaeological sites from the Middle Mesolithic until the Roman period (Ballin & Jensen 1995:21, 25) are located about 15 km southeast of the pollen site. The dense deciduous forest may have been a reason for the low values of charcoal; both because the crown layer of the forest prevented the deposition of microscopic particles from the air but also because deciduous trees burn poorly except when conditions are very dry. The location close to the sea may be responsible for very early occurrence of *Plantago lanceolata* (9700 cal yr BP) because it grew naturally there. The earliest palynological indication of agricultural activity (*Plantago lanceolata* and cereal type pollen) is about 5500 cal yr BP and 4400 cal yr BP, respectively. The continuous and increasing occurrence of *Melampyrum* and *Pteridium aquilinum* since 5200 cal yr BP confirms burning and opening of the forest. The first occurrence of cereal type pollen is well correlated with an increase in the charcoal curve, indicating clearing for cereal growing close to the site. Probably, this was an area of low-intensive and sporadic use by hunter-gatherers, with intentional burning until at least the Early Neolithic when farmers probably took over.

On the southwest coast (*site 34*, Vodlamyr), foragers probably managed the dense mixed deciduous forest with *Pinus* continuously, intensively and fluctuating with intentional burning at least since 8500 cal yr BP, including the maximum in charcoal 5200 cal yr BP. The amount and continuity of charcoal in the dense forest shows that the area may have satisfied the demands of hunter-gatherers (see Bang-Andersen 1981:115). A maximum in the dense *Pinus* forest with deciduous trees occurred at the same time as a marked decrease in the charcoal curve 5000 cal yr BP that may indicate a transfer from foragers to farmers. An increase in the charcoal curve, the earliest palynological recorded agricultural activity (pasturing) and maxima of *Melampyrum* and *Pteridium aquilinum* confirm the opening of the forest by farmers about 4000 cal yr BP.

The low occurrence of charcoal with only small changes at *sites 36–37* (Åsen and Åsheim) in the southwestern fjord district indicates that hunter-gatherers probably used low-intensity intentional fire in the dense forest since about 10,200 cal yr BP. The earliest palynological recorded agricultural activity did not influence the charcoal curve, nor was the curve influenced by the burning at and around the extensive settlement archaeologically situated about 1050 m and 800 m, respectively, from the pollen sampling sites recorded from the Late Neolithic to the Migration period (Løken 1987, 1991, 1999). Based on the palynological indicators, farmers used the area since about 4500 cal yr BP, when the forest opened. Since 2900 cal yr BP, the heathland developed but without any increase in the charcoal curve.

The charcoal curve at *site 38* (Håtjern) in Southwest Norway may indicate people's low-intensive use of fire in the area since 12,600 cal yr BP with a hiatus in the sediments of 6700 cal yr (8300–1600 cal yr BP), after which open heathland vegetation dominated.

The continuous charcoal curve with large fluctuations at *site 39* (Svartetjørn) in Southwest Norway has maxima during the Younger Dryas chronozone and in newer times. This indicates that mobile foragers probably lived around the lake during the Younger Dryas and that people used intentional burning for 13,000 cal yr. A marked decrease at the transition to the Holocene was followed by a weak increase in the charcoal curve, indicating that foragers probably used the area continuously with changing low-intensity in the rather dense forest. A combination of high levels of charcoal and the occurrence of *Plantago lanceolata* already 7600 cal yr BP may have been caused by early farmers, but most probably by hunter-gatherers. The density of the forest gradually decreased 5700 cal yr BP and *Plantago lanceolata* occurred 5000 cal yr BP with a continuous curve. *Calluna vulgaris* and charcoal increased. These changes were a result of farmers with pasturing domestic animals, burning of forest and development of heathland.

The charcoal curve at *site 47* (Rødstødno) in the southwestern fjord district indicates that the maximum around the transition between the Early and Middle Mesolithic was caused by hunter-gatherers' use of fire managements in the open forest around the pollen sampling site which was a bay of the fjord at that time. A phase of people's continuous, low-intensive use of fire took over. The maximum in charcoal at the top indicates farmers' increased use of the area in newer times. Between the bottom and the top of the pollen diagram, the changes in the charcoal curve are small and there are no correlations with the earliest palynological recording of pasturing (4900 cal yr BP) or the archaeological finds. This indicates livestock husbandry since the Bronze Age (Lillehammer 1991:50–51) and is well correlated with the palynological indications of farming, which increased 3700 cal yr BP and again 2600 cal yr BP.

The continuous and regular charcoal curve at *site 54* (Sandvikvatn) in West Norway since 15,600 cal yr BP indicates that mobile hunter-gatherers used intentional burning around the lake during the Late Weichselian Substage. The decrease in the charcoal curve after the transition to the Holocene when the trees immigrated was because the still denser crown layer of the forest prevented the deposition of microscopic particles from the air. The alternative is that the burning became less intensive because the mobile foragers did not use this area as intensively as earlier. The charcoal curve increased continuously from 6400 cal yr BP, when the forest was still dense, to a maximum close to the present time. The increase indicates a change in the charcoal deposition situation, which may have been the result of either foragers' intensified burning activities around the lake or early farmers, who took over this area from the foragers. The earliest traditional palynological indication of pasturing husbandry is indicated about thousand cal yr later. Deforestation and establishment of heathland started 3200 cal yr BP and cereal type pollen (2800 cal yr BP) occurred at the same time as a marked increase in charcoal and pasturing-indicating taxa.

The charcoal curve with large fluctuations at *site 62* (Botnaneset) in West Norway indicates foragers' continuous use of fire management in the area with varying intensity since 8900 cal yr BP. The charcoal curve was characterised by maxima in the period 8000–7600 cal yr BP, which indicates foragers' increased intensity in the use of intentional burning correlated with large changes in the forest density and maximum in the sea level transgression. This period is correlated with the earliest settlement phase at Botnaneset (Olsen 1983:88–91). The earliest traditional palynological indication of husbandry pasturing is about 7300 cal yr BP, a little earlier than the period with the lowest occurrence of charcoal 7000–6100 cal yr BP. This indicates low activity using intentional fire during a period with dense deciduous forest. After 6100 cal yr BP, single spectra peaks characterised the charcoal occurrence. Natural fires may have been the reason for these maxima because combustible *Pinus* dominated the dense forest. More reasonably, people's changing settlements were responsible for these charcoal occurrences, as confirmed by the many archaeological sites recorded in the area (Olsen 1983:88–91). The forest was gradually more open 4400 cal yr BP with high values of *Melampyrum* and a peak in *Pteridium aquilinum* caused by burning and opening of the vegetation. Deforestation 3700 cal yr BP was followed by an increase in *Calluna vulgaris* and more intense human impact. The development of coastal heathland was characterised by continuous and intensive burning and pasturing.

The boreal forest zone

Pattern 1

The lapse of the charcoal curve at *sites 5, 14 and 65* (Ottersmyra, Bånntjern and Hellemundsmyra) in East and Southeast Norway indicates hunter-gatherers' low-intensive, continuous or nearly continuous intentional but limited and local use of fire managment of the dense forest in the Mesolithic. Natural fires are excluded, as they do not occur continuously, but irregularly. A small increase in charcoal 6500 cal yr BP at site 65 was followed by a larger one 6000 cal yr BP, which rose to extreme maxima and large fluctuations in the charcoal curve. Early farmers may have caused this development, but the close proximity of the archaeological site of Svevollen from the latest phase of the Late Mesolithic period (Fuglestvedt 1992) most probably indicates foragers' intentional use of fire in the forest. The charcoal may have originated from people's regular burning of the vegetation since 4500 cal yr BP when the lake was overgrown, which may have increased the use of the site. The rise in the charcoal and the earliest palynological indication of agricultural activity shortly after the transition to the Neolithic indicate a change in the approach to intentional fire from foragers to farmers, with different purposes and therefore probably also the use of different places at least gradually. The farmers may have burnt for clearings in the forest for animal husbandry and growing of cultural plants, but maybe also for hunting ungulates. Site 5 was situated close to seven archaeological sites from the Stone Age (Boaz 1997:36, see Bergstøl 1997 for younger archaeological sites and Narmo 1997 for iron extraction sites). The archaeological record from the area around site 14 indicates settlement that varies from the Late Bronze Age to the Middle Ages. The closest archaeological sites were situated 2–4 km from the pollen sampling site (Late Bronze Age and Middle Ages, Helliksen 1997:8–9, 15).

The classical charcoal curve is well exemplified by *site 15* (Skånetjern) in Southeast Norway. The very low charcoal values during the Mesolithic in nearly dense forest are followed by a marked rise and oscillations in the Late Neolithic I. It corresponds to the earliest recorded cereal type pollen, while the earliest recorded palynological indicator of pasturing was in the Middle Neolithic before the rise in charcoal. However, based on the palynological data, this may indicate agriculture from this time on. However, based on the palynological record, it cannot be excluded that foragers lived in the area until the Middle Neolithic. The archaeological record indicates settlement that varies from the Late Bronze Age to the Middle Ages. The closest archaeological sites are 1–2 km from the pollen sampling site (Late Bronze Age and Middle Ages, Helliksen 1997:8–9, 15).

Pattern 2

The charcoal curve at *site 4* (Dulpmoen) in East Norway indicates low-intensive and continuous use of the area by hunter-gatherers, at least since 8900 cal yr BP until a marked increase about 6200 cal yr BP. The density of the forest showed few and small changes before 1100 cal yr BP. The charcoal may have originated from local intentional burning of the vegetation to improve the pastures for ungulates, but also from the settlement areas. Large fluctuations and extreme maxima in charcoal followed after the marked increase and started before the earliest palynological recorded agricultural activity (cereal type pollen and pasturing) indicated about 4800 cal yr BP and 2700 cal yr BP, respectively. This indicates intensive and changing use of the area for farming activities at least since the Middle Neolithic I. The site was situated close to three archaeological sites from the Stone Age (Boaz 1997:34, see Bergstøl 1997 for younger archaeological sites and Narmo 1997 for iron extraction sites).

The continuous, regular and low charcoal occurrence at *site 8 and site 10* (Hirsjøen and Kittilbu) in East Norway is not influenced by changes in the density of the forest. It indicates people's regular and low-intensive presence in the area and use of intentional fire in the Mesolithic. Natural fire is excluded as the main reason because of the regular lapse in the charcoal curves. The occurrence of *Melampyrum* and *Pteridium aquilinum* confirms the use of fire in the more open forest. There are few other changes in the charcoal curve than one in the Late Iron Age. In addition, the earliest palynological recorded agricultural activity is late (except from a pre-Neolithic occurrence of cereal type pollen, maybe a large grass pollen). This opens the question of when farmer activity replaced foragers. The charcoal curve indicates that this site was not attractive for either foragers or farmers, except maybe from the last 1500 cal yr, even if site 10 was situated only 2–6 km north of archaeological sites from 8900–2600 cal yr BP (Boaz 1998:Chapter 18, iron extraction sites see Larsen 1991). The activities connected with these sites may not have produced much charcoal.

The continuous charcoal curve with large fluctuations at *site 13* (Svenskestutjern) in Southeast Norway may have resulted from hunter-gatherers' continuous use of fire with changing intensity. They may have lived in the area since the Late Mesolithic at the same time as the forest was dense. Natural fire is ruled out as the main agent because the crown-layer in the dense forest would effectively have reduced the charcoal deposition from the air. The earliest palynological record of agricultural activity about 5200 cal yr BP may indicate farmers' use of the area with changing intensity since the Middle Neolithic I. The archaeological record indicates settlement that varies from the Late Bronze Age to the Middle Ages. The closest archaeological sites are 1–2 km from the pollen site (Bronze Age and Middle Ages, Helliksen 1997:8–9, 15).

It could be that the charcoal occurrence in the bottom of the pollen diagram at *site 50* (Liumholseter) in East Norway was the result of a natural fire as it consists of only the bottom sample. Alternatively, it resulted from mobile people's use of intentional fire in a period with open vegetation at the transition to the Middle Mesolithic or perhaps intentional burning that came out of control. Høeg (1990:95) interpreted the charcoal curve as the early presence of hunters in the area and after a gap again 6800 cal yr BP. Except from the bottom occurrence, the charcoal curve is sporadic, indicating sporadic or low-intensive use of fire management. Openings in the forest made by fire during the late Mesolithic are indicated by the continuous occurrence of *Melampyrum* and *Pteridium aquilinum*. Since 4500 cal yr BP, the area was used more or less continuously until the present with forest opening 4000 cal yr BP. The earliest palynological recorded agricultural activity is indicated at the transition to the Iron Age, while the charcoal curve indicates that farmers used the area continuously at least since the Viking Age. The site was situated 3–7 km north of the archaeological sites from 8900–2600 cal yr BP (Boaz 1998:Chapter 18, iron extraction sites see Larsen 1991).

Pattern 3

The occurrence of charcoal at *site 2* (Persmyra, Fig. 10a-b) in East Norway is continuous, high and changing at least during the Middle and Late Mesolithic, even though the forest was dense. This indicates that natural fire can be excluded and that people used intentional burning regularly in the area close to the site with changing intensity until 5300 cal yr BP, as confirmed by the archaeological record (Boaz 1997:34, 38, 137, see Bergstøl 1997 for younger archaeological sites and Narmo 1997 for iron extraction sites). After this, the charcoal curve indicates little or no use of fire in the area until 1000 cal yr BP, which is much younger than the earliest traditional palynological indication of agricultural activity (cereal type pollen and pasturing, 4500 and 3400 cal yr BP, respectively). Farmers may have used the area 1500 cal yr after the transition to the Neolithic in South Norway, but probably with low-intensity. The site represents areas that seem to have been attractive for hunter-gatherers and not for farmers.

The situation at *site 3* (Ulvehammeren) in East Norway has similarities with site 2 (Persmyra), but with a continuous charcoal curve with high-level, large fluctuations and two marked maxima during the Middle and Late Mesolithic confirmed by the archaeological record (Boaz 1997:34, 38, 137). Foragers' continuous intentional burning in the catchment area of the mire with large changes was probably the main reason for this record of charcoal. The burning may have resulted in openings in the mixed *Betula* and *Pinus* forest. A marked decrease in the charcoal curve indicates that fires may have influenced the vegetation at least until 6200 cal yr BP but without influencing the density of the forest noticeably. The marked change in the fire regime after this time also resulted in only small changes in the forest density. Low values of charcoal lasted until the present time with some changes in the forest density. The earliest traditional palynological indication of agricultural activity (*Plantago lanceolata* and cereal type pollen) is indicated about 4000 cal yr BP and 400 cal yr BP, respectively. The charcoal curve does not confirm agricultural activity.

The low charcoal occurrence at *site 7* (Lille Sølensjøen) in East Norway during the last part of the Late Mesolithic was continuous. This indicates few people's continuous but low-intensive use of intentional fire, and not natural fires because of the regularity of the charcoal occurrence and dense mixed forest of *Pinus* and *Betula*, as confirmed by the regularity of *Pteridium aquilinum* indicating fire and open areas. This lasted until a hiatus in the charcoal curve 4900–2100 cal yr BP. The charcoal indication of a very late agrarian occupation is confirmed by the record of the earliest traditional palynological indication of agricultural activity and opening of the forest. The site was situated 50 m east of seven small burial mounds from the Late Iron Age (Høeg 1996:59, 62 with reference to Skjølsvold 1958, 1981). It also opens the question if foragers used the area until the hiatus and left the area unused by people until farmers took over after the transition to the Iron Age.

The charcoal occurrence at *site 51* (Dokkfløy syd) in East Norway indicates hunter-gatherers' sporadic and low-intensive use of fire in the area 9100–6400 cal yr BP. The site was situated 2–5 km north of the archaeological sites from 8900–2600 cal yr BP (Boaz 1998:Chapter 18, iron extraction sites see Larsen 1991). In this period, *Pinus* dominated with changing amounts of *Betula* and the forest density was oscillating, which confirms an anthropogenic origin of the charcoal. Høeg (1990:94–95) interpreted the charcoal curve as the use of the area by people more or less on a yearly basis in this period, based on the forest density where charcoal could hardly have reached the mire surface if it had not come from somewhere in the vicinity. A high amount of charcoal shortly after deglaciation occurred at the site Dokkfløy north (Høeg 1990:26–37), only three km north of site 51. This indicates that mobile hunter-gatherers used the area already then, which is in agreement with the archaeological record (Boaz 1998, see Selsing 2010:198–199). It cannot be excluded that the early high occurrence of charcoal may have been caused by natural fires or, more probably, by human induced intentional burning which may have come out of control because it spanned more than one sample. The forest was more open 6500 cal yr BP. Traces of farmers were recorded from 4900 cal yr BP, even if the earliest traditional palynological indication of agricultural activity (pasturing and cereal type pollen) is as late as 2200 cal yr BP and 1300 cal yr BP, respectively. After a hiatus in the charcoal curve, fire in the vegetation is indicated again 2800 cal yr BP, when the area may have been used for pasturing husbandry and more intensively from 2200 cal yr BP. This is well correlated with the archaeological record (Boaz 1998).

Pattern 4

The continuous, changing and high charcoal occurrence with extreme maxima at *site 9* (Engelaug) in East Norway, in a forest with changing density, indicates hunter-gatherers' continuous presence with the use of sometimes intensive intentional burning since the middle part of the Middle Mesolithic may be close to the pollen sampling site. They may have kept more or less permanent openings in the forest, especially in the period 9500–8500 cal yr BP. An investigated archaeological site, a pit with burnt bones from elk, indicates mobile hunter-gatherers' use of the area (Risbøl 1997:8). The described charcoal and forest situation also indicate that natural fires may have added to the burning regime. The two very high single spectra peaks of charcoal may have resulted from either natural or intentional fires close to the site perhaps coming out of control (accumulation rate is one sample in 32 cal yr). Natural fire may be excluded as a main agent at least until 5700 cal yr BP because fire in a deciduous forest is rare. The density of the *Pinus* forest with *Betula* was changing until 4400 cal yr BP after which time it opened. The earliest palynological recorded agricultural activity (cereal type pollen and pasturing) is indicated about 4200 cal yr BP and 3700 cal yr BP, respectively, at the same time as a maximum period in the charcoal, which indicates farming. Regular use of intentional fire occurred throughout this period and people probably kept openings in the landscape by using fire until about 1400 cal yr BP when the charcoal declined.

The discontinuous and irregular occurrence of three periods of charcoal (lasting 1400, 200 and 1600 cal yr) from the very small mire at *site 11* (Rud Øde) in Southeast Norway has maxima periods in the lower and the upper part of the pollen diagram. Long-lasting periods of very low or no occurrence of charcoal indicate that natural fire as a main reason may be ruled out because natural fires would not produce such long maximum periods in a discontinuous charcoal curve. The oldest maximum period in the Middle Mesolithic with dense forest indicates cultural activity (in two main periods) with intentional burning. The middle maximum period, with the lowest values of the three periods, is correlated with the earliest occurrence of pollen of *Plantago lanceolata* indicating pasturing husbandry. These two periods were separated by a period with the sporadic occurrence of charcoal that indicates little or no use of intentional burning by people in this period, and that foragers probably did not use the same site for long periods, but migrated and changed their annual cycles over the years. The upper maximum period in charcoal is interpreted as caused by intentional use of fire for clearing for pasturing husbandry and cultivation, which corresponds well with the archaeological record. The archaeological record indicates settlement that varies from the Late Bronze Age to the Middle Ages with burial mounds and pits from the Roman period until the Late Middle Ages. The closest archaeological sites are 1–3 km from the pollen sampling site (Early Iron Age and Middle Ages) (Gustafson 1995:169, Helliksen 1997:8–9, 15).

The continuous, regular and low charcoal occurrence at *site 12* (Danielsetermyr, Fig. 12a-b) in Southeast Norway with maxima in the bottom and the top indicates that foragers used burning in the area intensively in the period 7200–6800 cal yr BP with open forest. Based on the charcoal curve, this was followed by a period of dense forest and with continuous but low-intensive use of fire managements with few changes until an increase 3900 cal yr BP. This is 1600 cal yr later than the earliest palynological recorded agricultural activity (pasturing) 5500 cal yr BP. Cereal growing occurred for the first time about 3800 cal yr BP and is confirmed by the rise of the charcoal curve and *Pteridium aquilinum*. The opening of the forest started about 1100 cal yr BP and the charcoal curve increased. The archaeological record indicates settlement that varies from the Late Bronze Age to the Middle Ages. The closest archaeological sites are 1–3 km from the pollen site (Iron Age and Middle Ages) (Helliksen 1997:8–9, 15), which confirms the younger part of the palynological record.

The continuous and fluctuating charcoal curve at the lake *site 41* (Ersdal Fiskelausvann) in Southwest Norway indicates hunter-gatherers' continuous use of intentional fire in the area with varying intensity, to improve the vegetation for the demands of their culture during the Late Mesolithic in the dense deciduous forest. At the close by mire at *site 40* (Ersdal mire), the charcoal occurrence is discontinuous with low values since the Middle Mesolithic, a small maximum 8300 cal yr BP and a gap 7500–5400 cal yr BP. This shows that the difference in charcoal deposition can be large within short distances. The main reason may be that the mire mainly reflects the local environment in this case with generally little or no activity, while regionally the activity was continuous with fluctuating intensity represented by the lake. Natural fires may have caused some one and two sample maxima at site 41. Alternatively, the samples that comprise these maxima (one cm accumulated over 25 years) may have been short periods with hunter-gatherers' intensified use of fire around the lake. The continuous occurrence of charcoal indicates most probably that it derived from people's activities, also because natural fire is proposed to be rare in deciduous forests. Another argument against natural fire is that these maxima are not reflected in the charcoal curve at site 40. Here, the forest opened 7200 cal yr BP during the gap in charcoal but at the same time as a marked increase in grasses. If this increase was caused by the *Phragmites australis*, it was not suited for pasture, meaning that hunting had to be carried out other places. *Phragmites australis* is, however, suited for roofing. The area may have been used, but not for purposes that resulted in the deposition of charcoal on the mire. The palynological recorded agricultural activity – husbandry pasturing – is indicated about 5600–5300 cal yr BP at the two sites at the transition to the Middle Neolithic. At site 40, charcoal increased 5400 cal yr BP at the same time as *Calluna vulgaris* and *Melampyrum* increased to a maximum in open *Betula* forest. At site 41, the forest was dense until 4200–3800 cal yr BP. Regular intentional burning of vegetation, confirmed by the increase in *Pteridium aquilinum* 4400 cal yr BP., formed the cultural heathland landscape. The very early occurrence of *Plantago lanceolata* at site 40 (9300 cal yr BP) at the same time as the occurrence of charcoal may have been the result of hunter-gatherers burning the vegetation around the mire, thus opening the forest for the purpose of improving the pastures for the prey. Alternatively, this one pollen occurrence may have originated in long-distance transport, as may be the traditional palynological view. The increased values of charcoal in the upper part of the pollen diagram correspond to an increase in agricultural indicators.

The record of charcoal at the lake *site 61* (Grostjørna) in the southern part of South Norway indicates that hunter-gatherers' may have already started using the area around 11,900 cal yr BP, but at least 9300–7500 cal yr BP, when the open forest had changed to a dense *Pinus-Betula* forest. The use of the area may have been close to the pollen sampling site until 5500 cal yr BP when mixed deciduous forest had established around the lake. This is confirmed by macroscopic charcoal, suggesting local burning based on a forest that is a little more open. Based on the earliest traditional palynological indication of agricultural activity and the increase in the charcoal curve, the area was used by farmers since the transition to the Neolithic. A slight increase in microscopic charcoal 5000 cal yr BP might have resulted from a nearby human settlement. Farmers were responsible for the increase in the charcoal curve about 2700 cal yr BP, rising to a maximum around 2100 cal yr BP. The occurrence of macroscopic charcoal nearly at the top of the pollen diagram indicates people's activities close to the site.

Probably, hunter-gatherers used the area at and around the mire at *site 67* (Brynnsmyra) in East Norway regularly but with low-intensive burning, maybe not every year, at least since 8100 cal yr BP, as indicated by the charcoal curve. The charcoal occurrence indicates an increase of the intensity of people's use of fire from 7600 cal yr BP in a dense *Betula-Pinus* forest with *Alnus*, which opened 6300 cal yr BP. From the Late Bronze Age, about 3000 cal yr BP, farmers used intentional burning for pasturing and shortly after also for cereal growing, as confirmed by a maximum in *Melampyrum*, while the archaeological record indicates people's use of the area since the Early Bronze Age (Gustafson 2007, Larsen 2007). The very late increase in the charcoal curve in the Viking Age indicates intentional burning and opening of the vegetation, as confirmed by a maximum in *Melampyrum*.

The subalpine forest zone

Pattern 1

The charcoal curve at *site 44* (Fåbergstølen 1) in West Norway indicates foragers' low-intensive and nearly continuous use of the area during the Late Mesolithic, in a forest with changing density and varying dominance of *Pinus* and *Betula*. Mesolithic sites are recorded 5–10 km northeast of the site (Randers 1986:29, 66–67, 78–80). The earliest traditional palynological indication of agricultural activity is about 6700 cal yr BP, i.e. well before the transition to the Neolithic. This occurrence may have originated in long-distance transport. An increase in the charcoal curve 4400 cal yr BP was followed by opening of the vegetation 2800 cal yr BP, when *Pinus* decreased and herbs and *Melampyrum* increased because of the rise in summer farming.

The charcoal curve at *site 58* (Vestre Øykjamyrtjørn) in the western fjord district, selected for climate change purposes, indicates no use of the area by foragers. The forest opened already 7500 cal yr BP. Farmers may have used the area at least since 4200 cal yr BP, as indicated by a rise in the charcoal curve, or may be already 4500 cal yr BP, when the earliest record of pasturing occurs.

The charcoal curve at *site 66* (Flaatevatn) in the fjord district of West Norway indicates that, since the Early Mesolithic, the area was used only sporadically (or not at all) by foragers with low-intensity in the open forest. About 5200 cal yr BP, a small increase in charcoal may indicate farmers' use of intentional fire in the area. The open forest may have allowed deposition of charcoal from the air and therefore long-distance transported charcoal originating in other areas from both anthropogenic and natural fires. Farmers' use of the area since 2300 cal yr BP is indicated by e.g. deforestation, which occurred at the same time as the earliest palynological record of pasturing. Shrubs and dwarf shrubs established with *Juniperus communis*, *Calluna vulgaris* and other Ericales.

Pattern 2

The charcoal curve at *site 46* (Gamle Sæterkulen-I), West Norway, indicates foragers' continuous, regular and low-intensive use of the area at least since the Late Mesolithic, as confirmed by the archaeological record (Randers 1986:29, 66–67, 78–80). Probably, foragers were dependent on only limited use of intentional fire to change vegetation for pasturing ungulates because of the open forest. Indications of agricultural activity since about 4200 cal yr BP, increasing to a higher level with a maximum in charcoal 3700 cal yr BP, were followed by a further increase in agricultural activity 2900 cal yr BP. It was presumably related to summer farming, which increased after 1400 cal yr BP, when also the earliest palynological recorded agricultural activity occurred.

The charcoal curve at *site 59* (Trettetjørn) in West Norway, selected for climate change purposes, indicates no use by foragers in the relatively dense forest during the Mesolithic and farmers' use of low-intensive intentional fire management since 2300 cal yr BP, more than 2000 cal yr after the earliest palynological recorded agricultural activity (pasturing). The traces indicate only low agricultural use of the area since Late Neolithic I, increasing in newer times.

The charcoal curve at the mire at *site 64* (Flonan) in the northern part of South Norway indicates hunter-gatherers' continuous, regular and low-intensive use of fire in the dense mixed *Pinus* and *Alnus* forest at least since the last part of the Middle Mesolithic. Probably, farmers used the area since the earliest recorded agricultural activity (pasturing and cereal type pollen) indicated about 5000 cal yr BP and 4700 cal yr BP, respectively. Farmers used the area more intensively from 2200 cal yr BP, as indicated by a marked rise in charcoal (Paus & Jevne 1987). The charcoal curve had approximately the same values from the bottom of the pollen diagram until this marked rise, which implies that the activities of farmers and hunter-gatherers resulted in the same charcoal deposition until 2200 cal yr BP, even if the activities may have been different.

Pattern 3

The charcoal curve at *site 27* (Skarhaugfossen-2) in the fjord district of West Norway, with a marked maximum period in the Late Mesolithic (7900–6100 cal yr BP) and low values until a rise and maximum 1500 cal yr BP, was probably the result of people's use of the area continuously with changing intensity. The early maximum period in charcoal within a dense mixed *Alnus-Betula* forest was probably caused by people who used the area intensively, or an area close to the site, even if this maximum is a little older than the oldest recorded archaeological site. Natural fires are excluded both because natural fires may be rare in deciduous forest, which dominated, but most of all because a more than a single spectrum peak of charcoal combined with an accumulation rate of 1 cm/439 cal yr make a more detailed interpretation impossible. The marked changes in the vegetation and start of pasturing are correlated with the typologically dated site 88 to the Early Neolithic (Bjørgo *et al.* 1992:90). Vegetation was influenced by cultural impact also during the Early Iron Age (site 84), correlated with the youngest charcoal maximum.

The charcoal curve at *site 49* (Hidlerberget) in the fjord district of Southwest Norway indicates foragers' low-intensive and sporadic use of fire management in the area since about 8600 cal yr BP, when partly open *Betula* forest with increasing *Pinus* and *Alnus* took over. The sporadic occurrence of charcoal indicates very low or no use of fire since 7700 cal yr BP. Because of the open forest, it cannot be excluded that long-distance transported charcoal added to the occurrence of charcoal. Since 4500 cal yr BP, the pollen record indicates that people used the open *Betula* forest for pasturing husbandry until today.

The charcoal curve at *site 63* (Frengstadsetra, Fig. 11a-b) in the northern part of South Norway is characterised by low and nearly continuous occurrence, except from the maximum in the early part of the Mesolithic and increase in the upper part of the pollen diagram. The maximum in the lower part was probably caused by hunter-gatherers' use of intentional fire, which is confirmed by the occurrence of *Plantago major* and *Urtica*. This interpretation does not agree with Paus & Jevne (1987:26–27), who considered long-distance transport from areas where the development of vegetation and soil had reached a more advanced phase a more likely interpretation. After that phase, the forest was dense and use of fire managements in the area became low-intensive and nearly continuous until a weak increase in the charcoal curve about 4800 cal yr BP until the top. The archaeological record indicates settlement during most of prehistoric and historic times, with 142 archaeological sites (radiocarbon dated 8200–290 cal yr BP, Gustafson 1987). It was not expected to find Stone Age sites without markings at the surface during the field work because the area was expected not to have had particular interest for hunters. Traces from the Stone Age are probably underrepresented (Gustafson 1987:109). Probably, the archaeological remains from the Early and Middle Mesolithic were not brought to light during the excavations.

Pattern 4

The two charcoal occurrences in the Mesolithic at *site 6* (Kåsmyra) in East Norway overlap more than one sample and they may have been caused by hunter-gatherers' low-intensive and sporadic use of the area, which stands in contrast to no use after the transition to the Neolithic, except for one sporadic charcoal occurrence in newer times. The earliest palynological indications of agricultural activity (pasturing and cereal type pollen) are indicated about 3000 cal yr BP and 1400 cal yr BP, respectively. The record indicates that the area has not been attractive for people's use since the deglaciation.

The charcoal curve at *site 22* (Ølstadsetri) in the central part of South Norway shows maximum values in the lower and upper part of the pollen diagram with low and oscillating values between the maxima. Dense forest and high values of Polypodiaceae in the period 9500–7800 cal yr BP confirm intentional use of burning by foragers in the Mesolithic. This indicates long-term seasonal settlement. This occurred in an area that is today characterised as a particularly rich biotope for reindeer (Gunnarsdóttir 1999, Gunnarsdóttir & Høeg 2000:21, 23). The charcoal recording indicates cultural activity earlier than known from archaeological observations (Hofseth 1980, Gunnarsdóttir 1999, Gunnarsdóttir & Høeg 2000:21, 23, 40). The period between the maxima indicates low-intensive and changing use of intentional fire in the area, first by foragers and later by farmers. The increase in apophytes 6300 cal yr BP may have been the result of neolitisation processes or repeated seasonal settlement by hunter-gatherers (see Hicks 1993). The rise in anthropogenic indicators after the Early Iron Age was caused by agricultural activity. The earliest traditional palynological indication of agricultural activity is very late (800 cal yr BP) at the same time as the increase in the charcoal curve to a marked maximum. The indications of human activity in the pollen diagram are not correlated with the archaeological record (Skjølsvold 1976, Hofseth 1980, 1981, 1988, 1992, Fossum 1995), except for the period since the Late Iron Age.

The charcoal curve at *site 28* (Skarhaugfossen) in the fjord district of West Norway indicates continuous, regular and low-intensive use of burning by foragers in the dense Mesolithic forest. The single spectrum peak of charcoal 7600 cal yr BP comprises 19 cal yr. It occurs at the same time as the forest was a little more open than earlier with increased occurrence of shrubs and followed by charcoal at a higher level than earlier. The crown-layer of the forest may to a large degree have prevented deposition of long-distance transported dust and the occurrence of charcoal may have been produced locally. It is therefore most probably the result of hunter-gatherers' intentional use of fire, using the area more intensively than earlier or living close to the tarn for a period, ruling out resedimentation, natural fire, and human initiated fire coming out of control. A local small natural fire cannot be excluded. There are no differences between the charcoal record before and after the transition to the Neolithic, which indicates no difference in the use of fire even if people's purposes may have changed. Farming is indicated since 3800 cal yr BP with a small charcoal maximum and correlated with anthropogenic pollen indicators showing agricultural activity.

The charcoal curve at *site 48* (Breidastølen) in the fjord district of Southwest Norway probably indicates the sporadic and low-intensive use of the open forest by foragers before the Neolithic. The crown-layer of an open forest could not effectively prevent deposition from long-distance transported charcoal, which may have been responsible for at least parts of the sporadic deposits of charcoal. The earliest traditional palynological indication of agricultural activity is 5500 cal yr BP, at the same time as an increase in the frequency of other cultural indicating plants. Farmers may primarily have used the area sporadically for husbandry pasturing since then.

The charcoal curve at *site 68* (Sygneskardsvatn, Fig. 13a-b), West Norway, indicates people's continuous and low-intensive use of fire management in the area since deglaciation 9300 yr BP (10,500 cal yr BP). The forest grew dense with changing *Pinus* and *Betula*. The single spectrum peak of charcoal 9600 cal yr BP (Middle Mesolithic) comprises 32 years and may have been caused by natural fire. More probably, the intentional burning of vegetation by hunter-gatherers may have come out of control or they may have lived close to the site. Such an interpretation may be confirmed by the very early occurrence of the traditional palynological indication of agricultural activity (*Plantago lanceolata* 10,200 cal yr BP), which may have been the result of transport in the fur of ungulates or it may have originated in long-distance transport. There are no changes in the charcoal curve since this early maximum. The earliest traditional palynological indication of agricultural activity (*Plantago lanceolata*) is indicated 5600 cal yr BP, followed by opening of the mixed *Pinus-Betula* forest.

The alpine zone

Pattern 1

The *Betula* forest at *site 52* (Flåfattjønna, Fig. 16a-b) in the northern part of South Norway was dense with *Pinus* locally since 10,200 cal yr BP. The dense forest lasted until 1500 cal yr BP. The tree crown-layer may have prevented deposition of air-borne microscopic particles and the charcoal may primarily have been produced locally. The charcoal curve indicates a low-intensive and continuous use of intentional fire in the area by foragers since 10,700 cal yr BP when the forest density increased. The two increases in charcoal are delayed compared to the transition to the Neolithic by 400 and 3400 cal yr, respectively. The earliest one is well correlated with the earliest palynological indication of pasturing, which may show that farmers had settled the area, or likely at lower levels because of long-distance transport of charcoal.

Pattern 2

The forest at *site 21* (Illmyri), the highest (1250 m.a.s.l.) in the present investigation located in the central part of South Norway, was dense about 9600 cal yr BP until 7600 cal yr BP when it opened. The charcoal deposition started when the forest was dense, indicating that it is the result of local production of charcoal and not long-distance transport from other areas. Probably, foragers used fire management around the mire in a continuous and low-intensive manner since 8900 cal yr BP to improve the pastures for ungulates and for other purposes to favour their lifestyle. A small decrease in the tree pollen and a small increase in *Salix* sp. and Ericales are correlated with the single sample maximum about 7400 cal yr BP, which indicates a fire event. Even if the accumulation rate shows that one sample comprises 63 cal yr, the origin may have been natural fire. More probably – because the forest was still rather dense – it may have been caused by foragers' intentional use of fire in the vegetation, living close to the pollen site for a short period or their intentional burning of vegetation that came out of control. There are no pollen indications of farmers' use of the area except for rising values of charcoal (a rise to about 12% 5000 cal yr BP) and a maximum about 900 cal yr BP, which may indicate pasturing husbandry.

The charcoal curve at *site 24* (Urutlekåi-1) in the fjord district of West Norway may indicate people's continuous, regular and low-intensity use of intentional fire in an open forest at least since 8900 cal yr BP. The use of the area for farming purposes started during the Middle Neolithic I. A small single spectrum peak of charcoal about 3200 cal yr BP and a marked maximum about 2300 cal yr BP correspond to changes in the vegetation and indicate farmers' intentional burning close to the site, fire coming out of control, natural fires or long-distance transport because of the open vegetation. An accumulation rate of one sample deposited in 106 cal yr is much longer than the duration of a natural fire. Even if natural fire cannot be excluded, a cultural origin is more probable because people already used the area. An increase in the charcoal indicates an increase in agricultural activity 1500 cal yr BP during the Migration Period, using intentional burning.

The charcoal curve at *site 45* (Sætrehaug-I) in West Norway is continuous, low and slowly increasing. The open *Betula* forest dominated by herbs in the field layer opened for deposition of long-distance transported charcoal, which may have added to the charcoal occurrences. On the other hand, foragers may have used intentional burning in the area at least since 9000 cal yr BP continuously, low-intensive and slowly increasing. The forest limit decreased below the site at the transition to the Neolithic, with no changes in the charcoal occurrence. This may also be an indication of locally produced charcoal. Taxa indicating agricultural activity occurred since Late Neolithic I, a thousand cal yr earlier than the earliest traditional palynological recorded pasturing, which is well correlated with a peak in the charcoal. This indicates an anthropogenic origin, maybe a short period (the accumulation rate is 1 cm in 95 years) with more intensive agricultural use of the site and with a later marked increase in the Middle Ages, which is in agreement with the archaeological record (Kvamme & Randers 1982:65–68).

The charcoal curve at *site 60* (Råtåsjøen) in the Dovre Mountains in the northern part of South Norway indicates foragers' nearly continuous and low-intensive use of the area at least since 8400 cal yr BP. *Pinus* increased and open *Betula* forest dominated the vegetation 7400–4400 cal yr BP. The need for fire management was smaller in the open forest because the open crown-layer resulted in ground vegetation of herbs and shrubs. The landscape opened 3200 cal yr BP, present-day low-alpine heath, and grassland vegetation gradually developed. The increase in the charcoal curve indicates farming activity in the area since the transition to the Iron Age.

Pattern 4

The charcoal curve at *site 1* (Locality J, Øvre Storvatnet) in Southwest Norway has maxima at the lower part and at the top part of the pollen diagram. Hunter-gatherers may have used continuous and low-intensive intentional fire in the area soon after deglaciation, confirmed by Høeg (1991:19, unpublished:59, 66–77) for Hovden, 40 km northeast of the site. The crown-layer of the open forest could not effectively have prevented deposition from long-distance transported charcoal, which may have added to the charcoal occurrence. The need for fire management may have been small in the open forest as mentioned above. A period of very low and continuous charcoal occurrence since 7600 cal yr BP, when the forest limit decreased – and after a hiatus – until 5000 cal yr BP, partly confirmed by the archaeological record (Selsing 2010:Table 18, see also Bang-Andersen 2008). Probably, the charcoal may have originated from both fireplaces and fire management by burning selected parts of the vegetation. About 6400 cal yr BP, the *Pinus* forest limit decreased to below the site. The earliest palynological indication of agricultural activity (*Plantago lanceolata*) is 3700 cal yr BP.

The low and sporadic charcoal occurrence at *site 20* (Foss-Setri) in the central mountain area, Jotunheimen, most probably indicates people's sporadic and low-intensive use of the area during the Mesolithic, confirmed by the high values of Onagraceae in the oldest part. Long-distance transport of charcoal can be excluded, as the forest was rather dense and changing. The mixed *Pinus* and *Betula* forest (9600 cal yr BP) was followed by dense *Pinus* forest with *Betula* and some *Alnus* 9400 cal yr BP to 7600 cal yr BP. *Betula* forest with *Pinus* and *Alnus* developed and opened shortly before a maximum in the charcoal curve 7300 cal yr BP. This may indicate foragers' more intense use of the area for a short period, with fire management around the mire, even if natural fire cannot be excluded. As for site 1 and 60 (Locality J, Øvre Storvatnet and Råtåsjøen), the open crown-layer could not effectively have prevented deposition from long-distance transported charcoal, and the need for fire management was small in the open forest because of rich ground vegetation.

The charcoal occurrence at *site 23* (Dovrehytta) in East Norway indicates that hunter-gatherers used fire management in the area in the Mesolithic continuously with varying intensity at least since 8600 cal yr BP. The density of the forest was changing. Probably, foragers used the area close to the site at least 8300–7800 cal yr BP, when the charcoal had maximum values. As for other sites mentioned above, open forest opened for the deposition of long-distance transported charcoal, and also the need for fire management was small because of rich ground vegetation. Low values in charcoal 7100–3200 cal yr BP indicate low-intensive use of fire. A marked increase in charcoal 2800 cal yr BP and pollen suggesting increased impact of farmers is much earlier than the earliest palynological recorded agricultural activity (cereal type pollen) 1000 cal yr BP. The indications of human impact from the beginning of the Early Iron Age can be associated with pasturing or seasonal settlement (Gunnarsdóttir 1999, Gunnarsdóttir & Høeg 2000:40).

The charcoal curve at *sites 25–26* (Riskallsvatn-tuft and Riskallsvatn mire) in West Norway indicates people's continuous, regular and low-intensive use of fire in the area, more intense in the Early Mesolithic and after the transition to the Iron Age. The density of the forest was changing and, in the periods with more open forest, long-distance transported charcoal may have deposited and added to the charcoal curves. They are likely dominated by charcoal from intentional burning. Two settlement sites (5600 cal yr BP) 400 m from site 25 indicate that people used the area at the same time as the forest opened, which may be correlated with a maximum in charcoal. Early and Late Iron Age settlement (loc. 26, Bjørgo *et al.* 1992) is correlated with the upper charcoal maximum at site 25. In general, pasturing elements changed the vegetation from about 4500–3800 cal yr BP, earlier than indicated by the charcoal occurrence and the archaeological record.

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