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The role of human disturbance in the local Late Holocene establishment of Fagus and Picea forests at Flahult, western Småland, southern Sweden

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Abstract. A pollen record from a small alder carr located in the centre of a *Fagus* stand near the hamlet of Flahult in southern Småland has shown that *Fagus* became established in a semi-open cultural landscape about 900 B.P. Human disturbance seems to have controlled the local establishment of *Fagus* at this site through an expansion of pastoral farming. The *Fagus* dominance in the present stand seems to be of recent origin, as *Fagus* pollen percentages and influx values have increased considerably only during the last 50 years. The modern composition and structure of the *Fagus* stand are probably an effect of changes in land-use and decreased human activity at the end of the last century. Today, only occasional *Picea* individuals occur in the studied stand, and *Picea* does not appear to have been more abundant in the recent past. The regional expansion of *Picea* has probably occurred during this century and has been favoured by modern forestry during the last 50 years.

Key words: Pollen analysis – Forest dynamics – *Fagus sylvatica* – *Picea abies* – Southern Sweden

Introduction

The present distribution of *Fagus sylvatica* in Sweden is well-established (e.g. Lindquist 1931, 1959; Hjelmqvist 1940; Lindgren 1970; SOU 1971). Its main distribution occurs in the nemoral vegetation zone (*sensu* Sjörs 1965) where it is normally a dominant forest tree. It also extends into the southernmost part of the boreo-nemoral zone, where the natural ranges of *Fagus* and *Picea abies* overlap (Fig. 1). Within this overlap zone *Fagus* generally has a patchy occurrence.

Fagus immigrated into Sweden from the south (Huntley and Birks 1983; Huntley 1988), but our knowledge about its immigration and establishment is limited. Several regional-scale pollen-stratigraphical studies (e.g. Nilsson 1964; Berglund 1966; Digerfeldt 1972, 1974, 1982; Regnéll 1989; Thelaus 1989; Lagerås 1996) have described when *Fagus* started to expand regionally in southern Sweden, but we still know very little about how it became established, particularly at a stand-scale. The lack of detailed information about its establishment is due to the fact that most pollen diagrams available for the area are from large lakes or bogs. These diagrams have the disadvantage that they represent a large pollen source area with a mixture of vegetation types. They provide therefore an 'average picture' of the landscape. They give very little information about landscape patchiness, or the extent of open vegetation, and do not allow conclusions to be drawn concerning stand-scale development. If we want to understand processes that lie behind vegetation history, we need to complement regional pollen diagrams with local-scale pollen studies. With the help of local diagrams we can study vegetation changes within a limited area, i.e. within a forest stand or less (Bradshaw 1988). If we want to investigate the establishment of *Fagus* within an area where it today has a scattered distribution, we can use small wet hollows close to existing *Fagus* stands (e.g. Björkman 1996).

This study focuses on the history of establishment of *Fagus* and *Picea* at stand-scale in western Småland. These trees are today important forest constituents in this area. A small peatland near the hamlet of Flahult was selected because it lies in the middle of a *Fagus* stand. The study aimed to provide answers to the following questions:

1) When did *Fagus* immigrate into this locality?
2) When and how did the rather pure *Fagus* stands presently occurring in the locality originate?
3) When did *Picea* became established in this locality?

The history of Fagus forest in western Småland

Several studies of historical documents and maps have demonstrated that *Fagus* was more abundant and widespread in southern Sweden during the Middle Ages and early Modern Time than today (e.g. Wibeck 1909; Malmström 1937, 1939; Troedsson 1966; Svenningsson 1992; Brunet 1995). The past and present distribution of *Fagus* in western Småland was thoroughly investigated

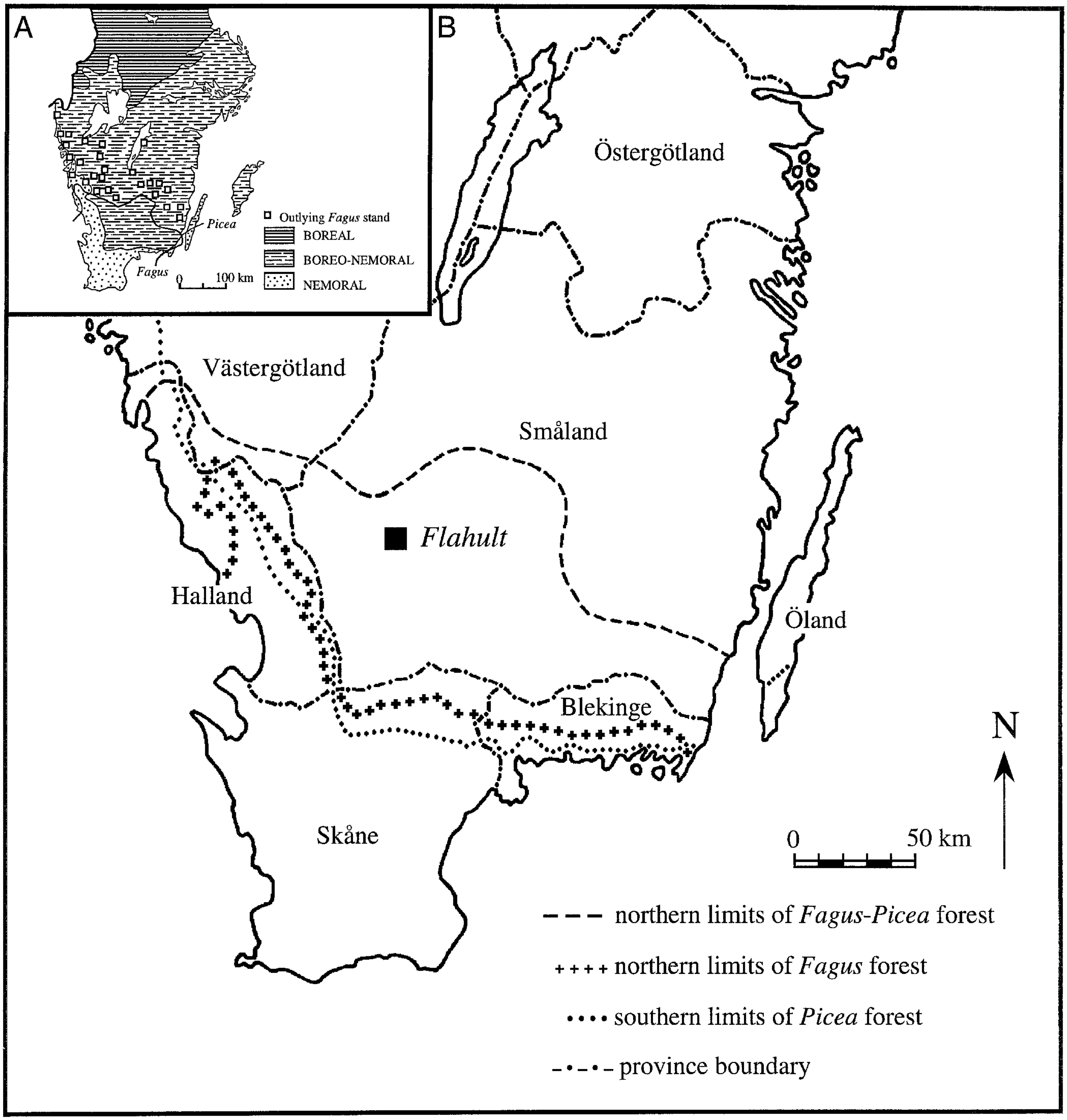


Fig. 1. A The forest regions of southern Sweden according to Sjörs (1965). **B** Detailed map of southernmost Sweden showing the distribution limits for *Fagus* and *Picea* forests according to Lindquist (1931, 1959). Provinces and place names referred to in the text are also indicated. Note that isolated *Fagus* stands occur north of the northern limits of the *Fagus-Picea* forest as indicated in **A**

by Wibeck (1909), and recently this investigation was followed up by Svenningsson (1992). The earliest history of *Fagus* in western Småland is, however, not well known as *Fagus* was already present in the area when the oldest documents were written. According to regional pollen diagrams an expansion of *Fagus* occurs in many areas in southern Sweden ca. 2200–1500 B.P., particularly in northern Skåne, Halland, and Blekinge (e.g. Digerfeldt 1974, 1982; Berglund 1966), but if this also applies to western Småland is uncertain.

Fagus is a masting tree and its nuts have been highly valued, especially for pig breeding. As a consequence of this, many historical documents describe *Fagus* stands and their usage (Wiebeck 1909). The oldest preserved documents from western Småland describing *Fagus* stands date from the 12th and 13th centuries. These documents clearly demonstrate that *Fagus* stands were important for feeding pigs. The legislation affecting stands with *Fagus* (and *Quercus robur*) was strict during the Middle Ages and early modern time. For instance, the Forest Act of 1647 prescribed that every individual of *Fagus* and *Quercus* felled should be replaced with the same species. This legislation was, however, not strictly followed, and during the latter part of the 18th century, the use of masting forests became freer with more liberal legislation.

Throughout the Middle Ages and even later, the value of a *Fagus* stand was determined by the number of pigs that could feed within the stand during years with a large mast. Later on, when the areas with *Fagus* forests decreased, the importance of pig breeding also declined. The breeding of pigs probably had a positive effect on the regeneration of *Fagus*, as rooting pigs created seed beds that where favourable for *Fagus* seeds. The canopy of a *Fagus* stand used for pig breeding was probably held rather open so as to increase the production of nuts. It is very likely that such stands had an open structure with both old and young *Fagus* individuals intermixed.

Wibeck (1909) made a thorough study of historical documents from western Sweden. Between 1680 and 1909 the area with *Fagus* forest decreased from ca. 7400–8000 ha to 455 ha, which implies a nearly 95% reduction of the area during a period of ca. 230 years. Several factors probably contributed to this decline. The major factor has been the increase in tilling and grazing, occurring during the 18th and 19th centuries. When new land was cultivated, fertile soils with deciduous trees were selected, as these soils gave the best yield. Regeneration of the forests was also reduced by a heavy grazing regime, as numerous cattle, sheep, and goats freely roamed in the outfield areas. Before the re-distribution and enclosure reforms of the 19th century, these outfield areas were commonly used for grazing. These areas were not fenced, and could be heavily grazed in some parts. This certainly prevented forest regeneration, especially for many deciduous species. Other factors partly responsible for the decline of *Fagus* forests were building activities, production of potash (which required enormous amounts of wood), and the use of *Fagus* wood as raw material for items such as barrels. All these activities together contributed to the rapid decline of *Fagus* forest in the area. These activities also made the existing *Fagus* stands less resistant to invasion of other vegetation communities. This decline was probably most rapid during the 18th and the beginning of the 19th centuries.

Picea is a late immigrant into western Småland, and its expansion may be a further factor that contributed to the decline of *Fagus* forests. *Picea* migrated southwards from central Sweden (e.g. Moe 1970; Tallantire 1972, 1977; Persson 1975) at approximately the same time as *Fagus* migrated northwards from central Europe. Both species can flourish under similar conditions, and consequently there is strong competition between these two potential forest dominants when they meet in the same stand. In undisturbed forest stands the outcome of this competition is uncertain, but in areas that are influenced by cultural activities, for instance grazing, *Picea* is most likely favoured.

Wibeck (1909) made many ecological observations when he travelled in western Småland during the beginning of this century. Many of these observations concern *Fagus*, particularly its stand-scale dynamics with other tree species. Some of these observations are worth presenting to the general reader as previously they have only been available in Swedish. The following paragraph is a verbatim translation of some important parts of Wibeck's original text: "*Fagus* is one of our most shade-giving trees. In closed-canopy stands dominated by *Fagus* very little light is available for the ground vegetation, and it is therefore not possible for *Fagus*, or other trees, to regenerate under such dense stands. In clear-cut areas *Picea*, *Fagus*, *Betula*, and *Pinus* quickly regenerate. *Picea* is often the victorious species in this competition. The major part of the area with *Fagus* forest that disappeared during the last centuries has been converted in such a way that *Picea* has regenerated in thinned *Fagus* forests, and when old remaining *Fagus* individuals have been cut down, or rotted away, the forests turned into pure *Picea* stands. The last stages in this transformation are possible to observe in the area, i.e. stands were single old *Fagus* individuals are found within stands dominated by a young *Picea* generation. An establishment of *Picea* is found in many gaps (and at most edges) in the existing *Fagus* stands in the area. *Picea* individuals may stand suppressed as long as the canopy in the *Fagus* stand is intact, but when gaps occur *Picea* quickly uses these for regrowth. *Picea* grows fast on ground previously occupied by *Fagus*, but its wood then becomes rather soft. *Picea* can also establish locally if the ground for some reason becomes water-logged. As *Fagus* avoid wet habitats it rarely grows at the edges of peatlands. In some cases a predominant *Fagus* regeneration occurs in gaps, or in thinned forests, which means generations of *Fagus* can replace each other. If one considers that *Fagus* in the area sets seed more seldom than *Picea*, that it has fewer possibilities for seed dispersal, and that its seedlings are much more susceptible to insects, grazing and ground frost than *Picea*, and that it has an equal competitor in *Picea*, it is obvious that *Fagus* has little chance of winning the long-term competition with *Picea*."

About 85 years after Wibeck's study, Svenningsson (1992) investigated changes in the extent of *Fagus* forests during this century in western Småland. Using forest inventories from the 1980s, it was possible for Svenningsson to follow up Wibeck's earlier study. Svenningsson found that the area covered with *Fagus* forests in the 1980s was ca. 820 ha, which implied an increase compared with the 1909 situation. The decrease in the area of *Fagus* forests observed by Wibeck (1909) had probably ceased during the latter part of the 19th century, when reorganisation of land ownership led to reduced human impact on the forest. The Forest Act of 1903 probably also contributed to this change. This change is well expressed in the age structure of the present stands in the area. Nearly 90% of these stands originated after ca. 1880 when cultural activities decreased.

The history of Fagus at Flahult

The investigated site at Flahult lies in the parish of Tannåker. The oldest map giving information about the distribution of *Fagus* in this parish is from 1799 (Wibeck 1909; Svenningsson 1992). This map also shows the outfield area belonging to the hamlet Flahult. On this outfield area, situated south of Flahult, an area with ca. 175 ha *Fagus* forest is indicated. At the beginning of this century almost the whole area previously occupied by *Fagus* had disappeared (Wibeck 1909), and only a few and small *Fagus* stands remained. According to local farmers in Flahult, this outfield area was mainly covered with grassland vegetation during the 19th century. At the end of that century, only single *Fagus* individuals remained and a thin forest of young *Picea* and *Pinus* individuals started to develop. It was also stated that during the 1860s this outfield area was a "grassland with wild strawberries", and that it could "feed many times more cattle than during the beginning of this century" (Wibeck 1909). This area is today mostly covered with a dense, homogeneous *Picea* forest, but single *Fagus* individuals occur in places (personal observation).

A map depicting the distribution of *Fagus* forests in western Småland during historical time is attached to Wibeck's (1909) publication. In the Flahult area several small stands of *Fagus* are indicated. One of these stands probably corresponds to the *Fagus* stand surrounding the sampled site. In the description accompanying Wibeck's map there is unfortunately no further account of this stand. According to Wibeck's investigation, *Fagus* had a patchy occurrence in the parish of Tannåker but it had been more abundant in the recent past. Today, there are ca. 100 ha of deciduous forests dominated by *Fagus* in the parish (Svenningsson 1992). This area is divided into approximately 60 small stands. The largest *Fagus* stands in the parish lie close to Flahult, and at least two of these have an area of ca. 6 ha.

Material and methods

Site description

The investigated site lies close to the hamlet Flahult in western Småland (56°58'N; 13°50'E) (Fig. 1). The site lies within the boreo-nemoral vegetation zone (*sensu* Sjörs 1965) and the *Fagus-Picea* region (*sensu* Lindquist 1931, 1959). Granite forms the local bedrock. Regional soils are dominated by a sandy to fine sandy till (Daniel 1986). Small isolated, and often ridge-shaped, glaciofluvial deposits also occur in the vicinity of Flahult. Mean annual precipitation is between 700 and 800 mm. The mean annual temperature is between 5 and 6°C, with the July mean between 15 and 16°C, and the January mean between -2 and -3°C (Ångström 1974; Sveriges Nationalatlas 1995).

A larger area of *Fagus* forest occurs immediately northeast of the hamlet Flahult. It includes mainly younger *Fagus* stands, but in the southern part somewhat older *Fagus* individuals are present. The sampled site (Fig. 2) is a small peatland (ca. 20x40m) located in the centre of a *Fagus* stand in the southern part of the area with *Fagus* forest. The maximum depth of the peat deposit, which is dominated by carr peat, is ca. 105 cm (Table 1). Traces of mineral material were visible in the lower part of the profile (below 90 cm). The sampled site can be described as an mesotrophic alder carr. It is surrounded on all sides by rather steep and esker-like ridges, except in the NE corner where the ground is flatter. These ridges consist of glaciofluvial deposits (mainly gravel), and are orientated towards the north-north-east (Daniel 1986). The major part of the local *Fagus* stand grows on glaciofluvial deposits, where the topsoil is dominated by a rather weak podsol. The centre of the stand lies at ca. 185–195 m asl. The sampled site is today situated under a closed canopy of alder. The nearest *Fagus* individual stands ca. 10 m from the coring point. The ground flora in the upland *Fagus* stand is sparse, as the ground is almost completely covered with leaf litter.

Table 1. The lithostratigraphy of the studied profile at Flahult

Depth (cm)	Sediment description
0 – 10	Highly humified carr peat
10 – 20	Moderately humified *Sphagnum*-peat
20 – 105	Highly humified carr peat

Field and laboratory methods

The top 95 cm of peat was sampled in October 1994 with a Wardenaar corer (Wardenaar 1987) in the central part of the peatland where the peat was thickest. The sediments were ca. 105 cm deep at this point. Only the topmost 81 cm of the profile has been used for pollen analysis. The monolith taken from this site was stored at 8°C, and subsequently divided into two parts. A smaller part (a 9-cm^2 section) was reserved for pollen and charcoal analysis, and a larger part for radiocarbon dating. The section selected for pollen and charcoal analysis was frozen at -20°C, and cut into thin subsamples (3.5-5-mm thick) using an electric kitchen slicing machine with a serrated rotating blade. To avoid contamination during cutting the blade in the slicing machine was carefully cleaned after cutting each subsample. Small samples (0.5-1 cm^3) were taken from the centre of these subsamples for pollen analysis. The surface layers of these thin subsamples were also removed before pollen preparation in order to avoid contamination during handling and storage of the samples. *Lycopodium* tablets were added to the subsamples. The volume of each subsample was measured by water displacement.

The samples were prepared for pollen analysis following standard methods (Berglund and Ralska-Jasiewiczowa 1986). Microscopic slides were prepared from the residue and scored for pollen (at least 1000 pollen in each subsample) and microscopic charcoal (25–250 µm). Pollen keys in Moore et al. (1991) and the reference collection at the Laboratory of Palaeoecology, Lund University, were used for pollen identification. Macroscopic charcoal was counted from samples that would not pass trough a 250 µm mesh during the preparation procedure for pollen analysis. Four bulk peat sections of the remaining monolith (1-1.3-cm thick) were submitted for conventional radiocarbon dating at the Radiocarbon Dating Laboratory in Lund.

Results and interpretation

Dating and chronology

Four radiocarbon dates were obtained from the topmost 50 cm of the peat profile (Table 2). These dates show that this part of the profile developed during the last 2500 radiocarbon years approximately (equivalent to the last 2700 calendar years). The chronology for the lowermost part of the profile (50–81 cm) is uncertain. A

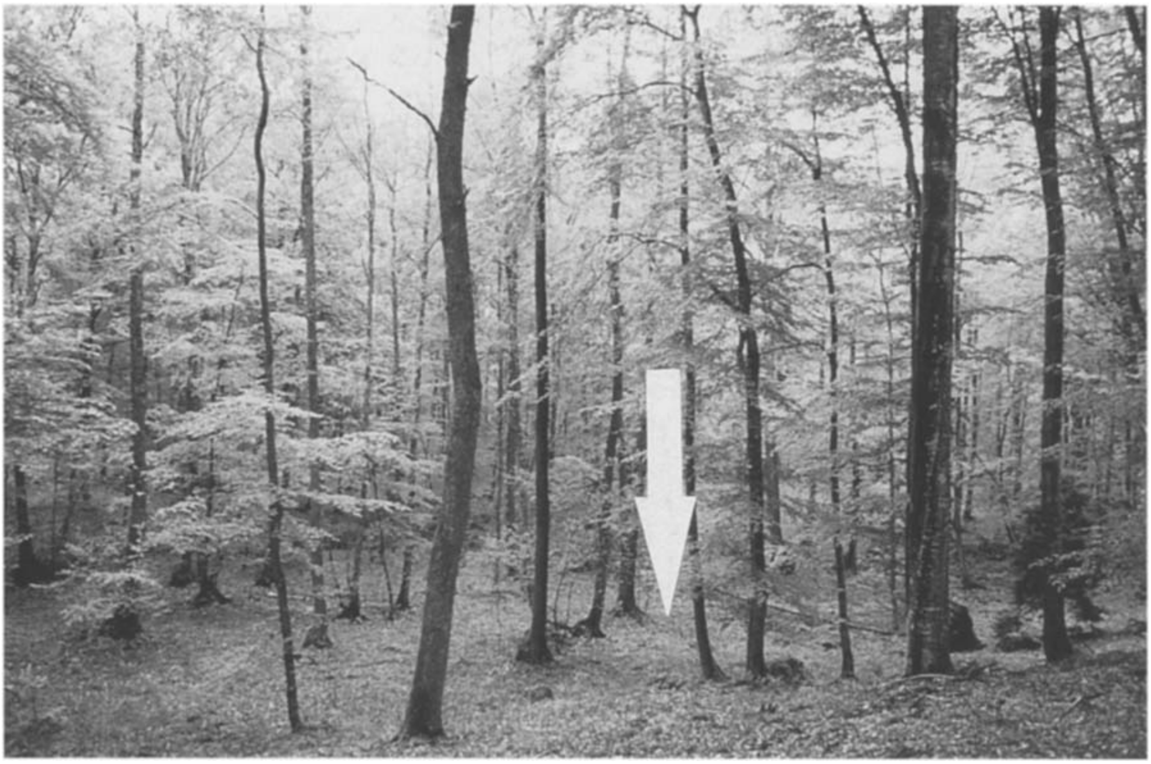


Fig. 2. View of the studied peatland near the hamlet Flahult. View towards the east. The sampling point is located in the centre of the peatland (indicated with an arrow)

tentative timescale has been established for this part by extrapolation, and that chronology can only be regarded as showing minimum ages.

Root penetration can be a serious problem when using bulk samples for radiocarbon dating, particularly when studying sections from small peatlands where trees may have grown, as for instance in a alder carr. If roots are incorporated in the sediment these may give bulk samples an age that is younger than the age for the peat itself. This problem may have affected the dates used for this study, but it is, however, impossible to quantify what effect, if any, this might have had.

Fire history

The analysis of two charcoal size-fractions (25–250 μm; >250 μm) revealed that fire has not been an important factor at this site. There were no visible charcoal layers in the core, and only a few scattered charcoal particles larger than 250 μm were found in some subsamples. The frequencies of microscopic charcoal particles are generally low and there are no clear peaks in the diagram (Fig. 3). The frequencies are slightly higher during the last 300 years, which is a period of more open vegetation. This implies that the microscopic charcoal probably had a regional origin and was not produced locally (Patterson et al. 1987; Clark 1988).

Vegetational history

The pollen data are presented in a percentage diagram with all pollen types included in the calculation sum (Fig. 3). Only dominant or indicator taxa are presented. Pollen influx data were only calculated for *Fagus* and *Picea*, as these taxa occur during the well dated part of the profile.

Table 2. Radiocarbon dates from the profile at Flahult. Calibrated ages at $\pm 1\sigma$ as derived by CALIB program (Stuiver and Reimer 1993) are also given

^{14}C Lab. No.	Depth (cm)	Age (B.P.)	Age (cal. B.C./A.D.)	Material dated
Lu-3920	9.0 - 10.0	90 ± 50	A.D. 1689 - 1955 *	Alder carr peat
Lu-3921	18.0 - 19.0	320 ± 55	A.D. 1484 - 1652	*Sphagnum* peat
Lu-3922	33.0 - 34.3	920 ± 55	A.D. 1029 - 1213	Alder carr peat
Lu-3923	50.0 - 51.3	2540 ± 70	799 - 532 B.C.	Alder carr peat

* upper end of this range influenced by bomb ^{14}C

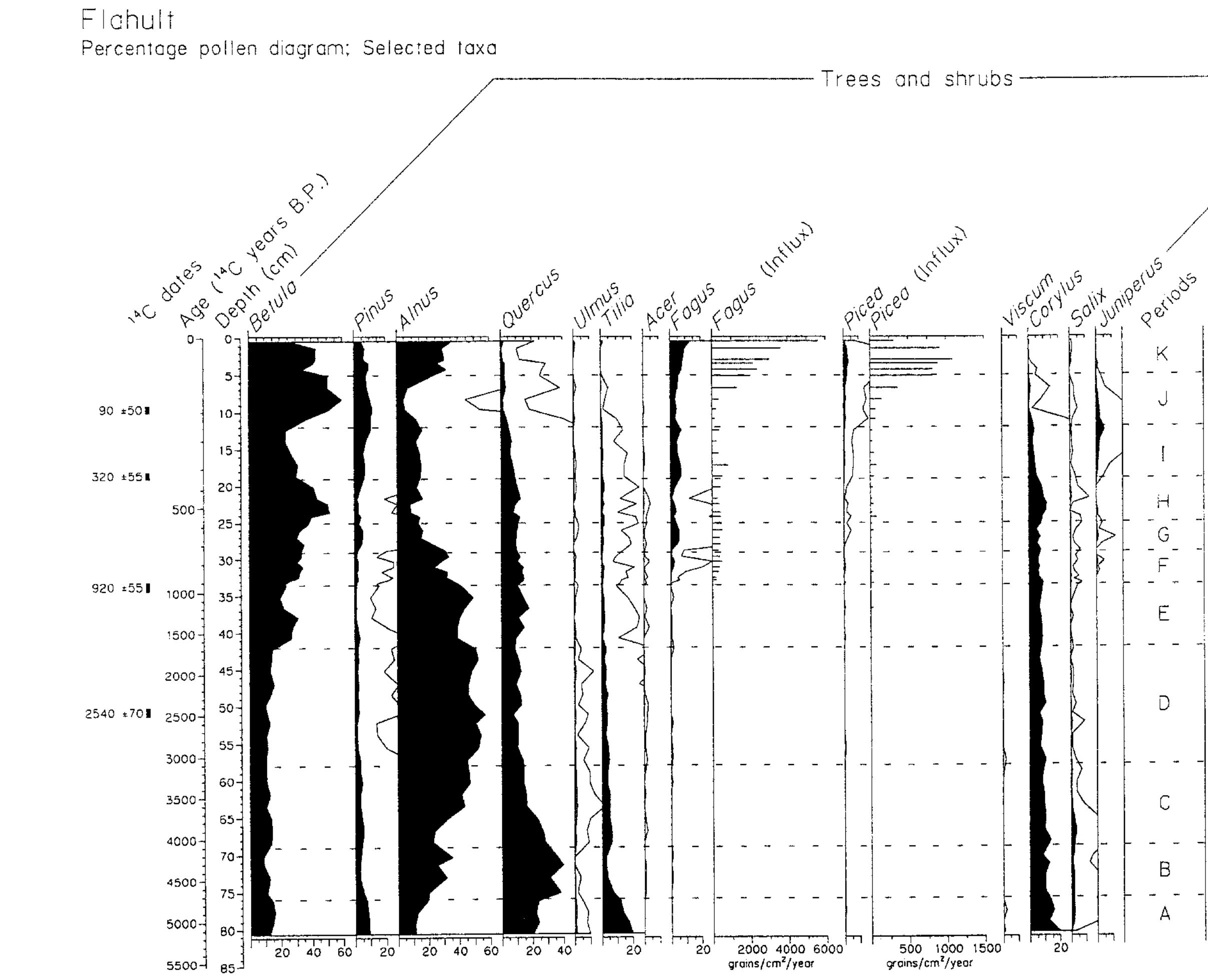


Fig. 3. A, B Percentage pollen diagram from the studied site in Flahult with selected taxa presented on a linear depth scale. Radiocarbon dates and a non-linear time scale (tentative for ages older than 2500 B.P.) are shown on the left of the diagram. Pollen influx data, expressed as grains/cm^2/^{14}C-year, are shown for *Fagus* and *Picea*. Percentages for Polypodiaceae undiff., *Sphagnum*, and charcoal particles (25–250 µm) are calculated outside the pollen sum

The interpretation of the pollen diagram in terms of forest and land-use history led to the identification of eleven different landscape periods (A–K). These periods are used in the following description and discussion.

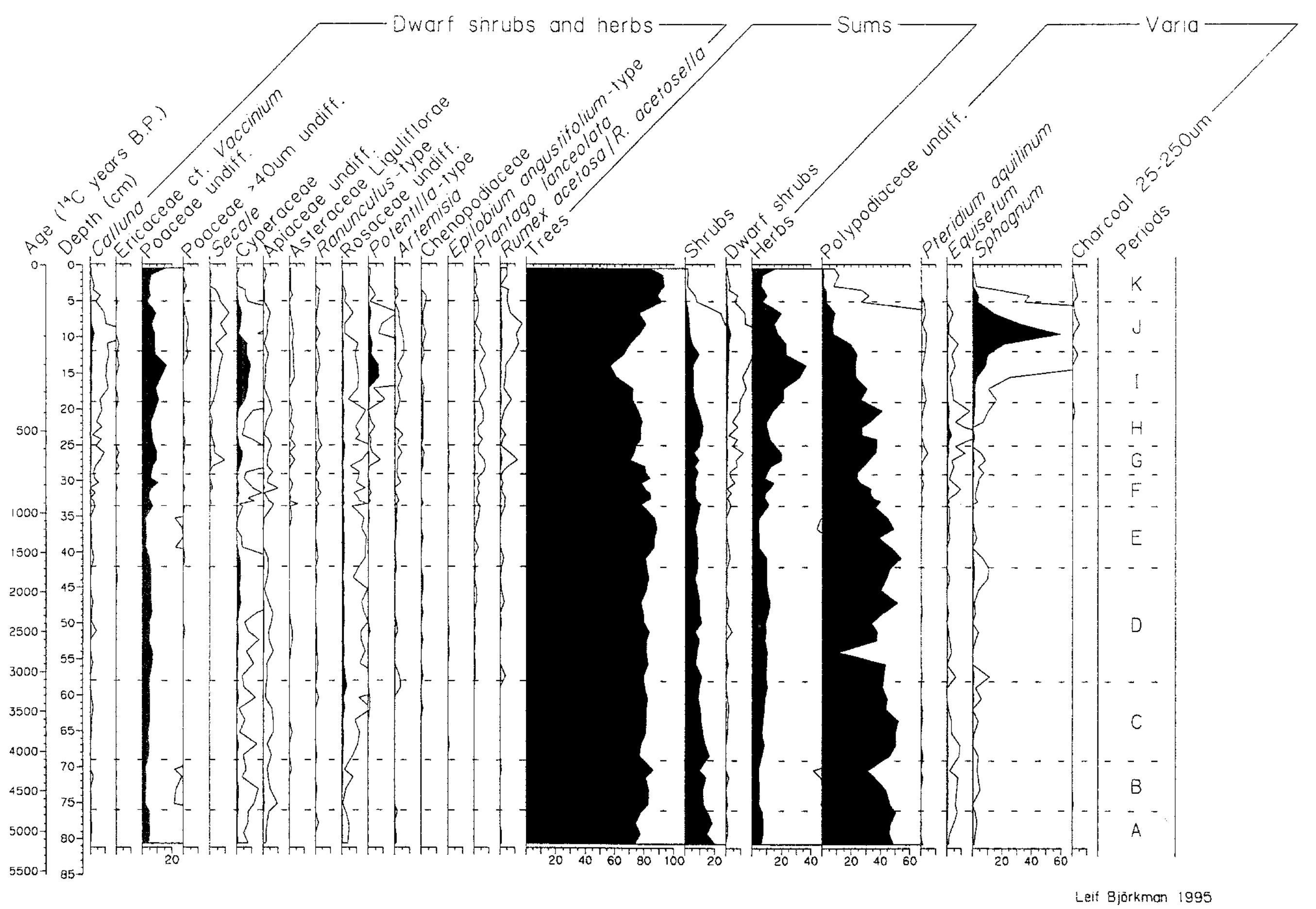
The vegetation surrounding the studied peatland has consisted of at least two major vegetation components, i.e. the plant communities on the alder carr itself and at its margin (pollen taxa such as *Alnus*, *Salix*, *Potentilla*-type), and the upland vegetation on well-drained ground (all tree pollen except *Alnus*).

Period A (minimum age ca. 5100–4700 B.P.). This period is characterised by high percentages for tree and shrub pollen, particularly for *Quercus*, *Tilia*, and *Corylus*. *Tilia* is at ca. 20% at the beginning of this period, but has decreased to 12–13% at the end. A slight increase in *Quercus* percentages is recorded as well as a slight decrease for *Corylus*. *Betula*, *Pinus*, and *Alnus* have percentages around or above 10%, which could imply these trees were present in the local vegetation. *Ulmus* has low percentage representation that decreases at the end of this period.

Pollen percentages for Poaceae undiff. are relatively high (ca. 5%) and represent the major part of the herb pollen sum. There is no obvious indication of human interference at the local stand level during this period. Single pollen grains of *Artemisia* and *Rumex acetosa*/*R. acetosella* may be of regional origin, or originate from natural openings in the forest. *Viscum album* was recorded in some samples from this period. These records clearly indicate that *Viscum* grew as a semi-parasite in the area, most likely on *Tilia*, which was abundant in the local forest stand. *Viscum* today, at close to its northern European distributional limits, has a preference for *Tilia* as host (Walldén 1961).

It seems that the local forest stand on well-drained ground during this period was dominated by *Tilia*, but there was also substantial amounts of *Quercus* and *Corylus*. The field layer was probably sparse as indicated by low herb pollen percentages. Pteridophytes may have been abundant on the peatland.

Period B (minimum age ca. 4700–4100 B.P.). This period is characterised by generally higher tree pollen percentages than during the preceding period. *Quercus*



and *Alnus* are better represented than earlier, while *Tilia*, *Betula*, *Pinus*, *Ulmus* and herbs, mainly Poaceae undiff., are somewhat lower. The *Quercus* curve rises rapidly at the transition to this period and peak values around 40% are reached subsequently. The decrease for *Tilia* that began during the previous period continues, and minimum values of ca. 5% are reached during the middle part of the period. *Ulmus* has very low pollen percentages, and the absence of *Ulmus* pollen in some samples may indicate that during certain periods none or very few mature and pollen-producing *Ulmus* individuals occurred in the vicinity of the sampling point.

There is no clear indication of human influence at the local stand during this period. Pollen percentages for Poaceae undiff. and other herbs are lower than previously, except for Apiaceae undiff. and Cyperaceae. *Quercus* was probably the dominant tree species in the local forest stand on well-drained ground during this period. *Corylus* was as abundant as earlier in the understorey, while the population of *Tilia* had become more restricted. *Alnus* now continuously exceeds 20% and these values may imply it now grew locally on the peatland. It is probably during this period that the peatland became an alder carr.

Period C (ca. 4100–3100 B.P.). *Alnus*, *Quercus*, *Betula*, and *Corylus* are important pollen types during this period. Pollen percentages for *Quercus* decrease throughout the period and during the latter part they average around 15%. *Alnus* percentages increase up to around 45% near the end of this period. However, *Alnus* was now more abundant than ever, while *Quercus* was only as abundant as during period A. At the transition to this period both *Tilia* and *Ulmus* seem to regenerate. *Ulmus* percentages recover to the same values it had in period A, and even reaches its highest value in the profile. In contrast, *Tilia* does not recover to its previous values.

Even during this period, no apparent indication of human interference at local stand level are found. Single pollen of *Artemisia*, Chenopodiaceae, and *Epilobium angustifolium*-type are difficult to interpret. The pollen percentages for Poaceae undiff., and the sum of herb pollen, are as high during this period as during period A, which suggests a similar structure of the local forest stand, i.e. a rather open forest type.

The local forest stand on well-drained ground was most likely dominated by *Quercus*, *Tilia*, and *Corylus*, but some scattered *Ulmus* individuals may have occurred as well. *Alnus* became dominant on the peatland during this period. Its high percentages at the end of this period certainly depress all other values.

Period D (3100–1700 B.P.). This period is characterised by high pollen percentages for *Alnus*, which continuously reaches values exceeding 45%. Percentages for *Quercus* and *Corylus* are relatively constant throughout the period and lay on average close to 10%, but the percentages for *Quercus* are considerably lower than earlier. Percentages for *Tilia* (ca. 4%) and *Ulmus* (ca. 0.5%) are lower than during the preceding period. The few grains of *Viscum* indicate that it still grew locally, most likely on *Tilia*.

Herb pollen percentages increased somewhat and reached values that are consistently higher than earlier. Several herb taxa are better represented, for example Poaceae undiff., Cyperaceae, Rosaceae undiff. This period is also characterised by a more regular occurrence of *Artemisia*, Chenopodiaceae, and *R. acetosa/R. acetosella*. At the beginning of this period, *Plantago lanceolata* is first recorded, as single pollen. This may be interpreted as the first sign of human interference in the local forest, most likely as forest grazing. The higher percentages for Poaceae undiff. may also indicate that the structure of the forest had became somewhat more open than earlier.

The local forest stand on well-drained ground was still dominated by *Quercus*, *Tilia*, and *Corylus* and some occasional *Ulmus* individuals. *Alnus* was a dominant species on the peatland. *Salix* had become less abundant. Percentages for Polypodiaceae undiff. fluctuate markedly during this period, but Pteridophytes were still certainly important in the local mire vegetation.

Period E (1700–900 B.P.). This period is characterised by higher pollen percentages than earlier for trees, but also by considerably lower herb pollen percentages. The period starts with a rapid increase of *Betula*, and a rapid decrease of *Alnus*. Percentages for *Betula* increase from ca. 15% at the transition to this period and reach ca. 30% during the middle part. This change is reversed at the end when *Betula* decreases to 20–25% and *Alnus* increases to ca. 50%. Percentages for *Quercus* increase slightly, whereas *Corylus* remains fairly constant. *Tilia* has lower values than during period D. A more regular occurrence, though with low values, of *Fagus*, may indicate a generally more open landscape during this period, or a regional occurrence of few and scattered *Fagus* individuals.

Percentages for Poaceae undiff. and Cyperaceae decreased notably during this period. *P. lanceolata* and other anthropogenic pollen indicators still occur with low percentages. Two pollen grains of Poaceae >40 µm have been found during this period but it is uncertain if these grains belong to the Cerealia group.

The sudden change in the tree pollen curves at the beginning of this period certainly indicate a significant modification of the composition of the local forest stand. This change may be an effect of some kind of disturbance, e.g. increased forest grazing triggering a succession of *Betula*. *Quercus*, *Tilia*, and *Corylus* were probably still important in the local forest stand on well-drained ground, but *Betula* also seems to have become a major constituent of these stands.

Period F (900–750 B.P.). This period is characterised by a sudden increase in percentages for *Fagus*, and this increase clearly indicates the local establishment at ca. 900 B.P. This period is also characterised by decreasing percentages for *Alnus* and Polypodiaceae undiff., and considerably increasing values for *Betula* and Poaceae undiff. *Quercus*, *Tilia*, and *Corylus* have percentages that are only slightly lower than earlier.

Herb pollen percentages increase at the beginning of this period, as well as many anthropogenic indicators, i.e. *Calluna*, *Artemisia*, *P. lanceolata*, and *R. acetosa/R. acetosella*. Other herbs such as Asteraceae, Liguliflorae and *Ranunculus*-type are also more common and the first regular occurrence of *Juniperus* and *Secale* also occur. The first single *Secale* pollen was found at a level dated to ca. 900 B.P. The presence of *Secale* and the increase of ruderal taxa, e.g. Asteraceae, Liguliflorae, *Artemisia* and *R. acetosa/R. acetosella* are the first signs of cultivated fields close to the site. *Juniperus* is an indicator of cleared areas close to the site that were used for grazing.

The rapid decrease of *Alnus*, the expansion of *Betula*, and the increase of Poaceae undiff. indicate that some forest stands were cleared away. Clearly a semi-open cultural landscape came into existence during the transition to this period, and this seems to have favoured the establishment of *Fagus*. However, some forest stands remained where *Quercus*, *Tilia*, and *Corylus* dominated, but their populations probably diminished throughout the period. The declining percentages for *Alnus* may have been caused by a disturbance of the vegetation on the peatland or at its margin. This probably made it possible for *Salix* to regenerate.

Period G (750–550 B.P.). This period is characterised by a slight expansion of the open vegetation as shown by increasing percentages for *Betula*, *Pinus*, *Fagus*, and herb pollen, and decreasing values for *Alnus*. *Alnus* seems to have already decreased notably at the transition to this period, and this decrease was probably caused by a clearing. Higher percentages for *Fagus* are not followed by higher influx values, which may indicate that the local population was rather stable and did not expand. *Picea* pollen starts to occur regularly throughout this period. However, its percentages are probably too low to indicate a local presence.

A slight expansion of the cultivated fields is indicated by higher percentages for *Secale*, as well as for *R. acetosa/R. acetosella*. It is also evident that the grazed areas expanded somewhat, as indicated by a slight increase in percentages for *Juniperus* and *Calluna*. The vegetation at the study area was still of a semi-open type, but the openness had probably increased considerably. The peatland had now lost its character of an alder carr as *Alnus* was probably cleared away. The increase of Cyperaceae are probably due to a local succession when *Alnus* was cleared.

Period H (550–350 B.P.). This period is characterised by a conspicuous increase in *Betula* and *Corylus*, which reach peaks of over 50% and 10%, respectively. At the same time, the anthropochores have considerably lower percentages than earlier.

The local human interference declined obviously over ca. 200 years, which made it possible for *Betula* and *Corylus* to expand on abandoned pastures and cultivated fields. However, the study area may not have been abandoned completely as single pollen of *Secale* are found throughout the period, and percentages for Poaceae undiff. and *P. lanceolata* only show slight decreases. But the expansion of *Betula* and *Corylus* indicates a general cessation of the local land-use.

It is interesting to note that the abandonment of the area did not create possibilities for *Alnus* to re-establish on the peatland, or for *Fagus* to expand on well-drained ground. Influx values for *Fagus* are fairly constant and largely in the same order as during the preceding period. *Alnus* had probably during this period only minor importance in the local vegetation. *Fagus* was probably not particularly abundant in the local forest stand, as its pollen percentages are comparatively low. However, the occurrence of macroremains of *Fagus* dated to ca. 500 B.P. (part of a nut and bud scales; identified by G. Hannon) prove that it was present locally.

The local forest stand on well-drained ground most likely consisted during this period of a mixture of *Quercus*, *Tilia*, *Corylus*, and *Fagus*. *Betula* and *Corylus* dominated areas that previously had been grazed or cultivated. *Acer* probably had a restricted population in the area as it is first during this period that its pollen became more frequent. It may have been favoured by the decline in human activity at the site.

Period I (350–150 B.P.). This is a new clearance period and is characterised by low percentages for tree pollen, and decreases in *Betula*, *Quercus*, *Tilia*, and *Corylus*. Herb representation increases strongly and peak values above 35% are reached at ca. 200 B.P. The anthropochores that occurred before the decline in human activity during period H re-expanded, implying the same type of land-use as earlier with cultivated fields and open pastures with *Juniperus*. The extent of open areas reached its maximum during this period. The populations of *Quercus*, *Tilia*, and *Corylus* were reduced further throughout this period, and at its end they probably only occurred as occasional individuals in the vicinity. The increase in percentages for *Pinus* is also an effect of these open conditions.

There is a slight increase of influx values for *Fagus* during the beginning of this period, and this might reflect an expansion of *Fagus* which was favoured by a renewed openness of the landscape. This expansion was, however, halted later on and followed by decreasing values. The land-use practices in the area were most likely intensive, especially during the latter part of the period, and this may have prevented a further expansion of *Fagus*.

The peatland may have been nearly treeless during this period, as indicated by high percentages for Cyperaceae and *Potentilla*-type. A succession of *Sphagnum* begins during the middle part of the period. This succession may have been initiated by a local clearance of trees that led to a raised groundwater table favouring *Sphagnum*.

Period J (150–50 B.P.). This period is characterised by an increase in tree pollen percentages and decreases for herb pollen, particularly for Poaceae undiff., Cyperaceae and *Potentilla*-type, and for Polypodiaceae undiff. spores. There is also a conspicuous peak of *Sphagnum* spores during the earliest part of the period.

The considerable increase in tree pollen percentages is mostly an effect of increasing *Betula* percentages. *Betula* increases from about 25% at the beginning of the period and reach a peak value of about 60% during the middle part. *Alnus*, *Quercus*, *Fagus*, and *Corylus* show decreasing pollen percentages during the middle part of the period, but these decreasing values are probably an effect of the strong increase in percentages for *Betula*.

Betula experienced a considerable expansion during this period. This expansion was probably caused by changes in land-use at the transition to this period. Pastures near the study site may have become abandoned, and this caused a rapid regeneration of *Betula*. The regeneration of *Betula* was followed by an expansion of *Fagus*, and eventually also by the local establishment of *Picea*. *Fagus* was present with a rather stable but restricted population during the first part of this period. Influx values for *Fagus* do not show any significant change until the middle part of the period when they start to increase considerably.

Picea individuals probably first became established in the local forest stand during the middle part of this period. *Picea* has rather low pollen percentages throughout this period, and these values alone can probably not be used as evidence for a local presence of *Picea*, as they may equally have been an effect of long-distance transport. However, influx values for *Picea* show a strong increase during this period, and this increase may imply a local establishment. If *Picea* became established during this period it was certainly not an important species in the local forest stand.

Even if the pastures close to the sampling point were abandoned during this period it is obvious that cultivated fields were maintained in the area. This cultivation may have been more intense during the latter part of this period than during the preceding period, when land-use practices also were intensive and the area with open vegetation peaked. The intensive cultivation is clearly indicated by peak percentages for *Secale* and Poaceae undiff. However, these fields probably did not lie close to the studied peatland as the pollen record indicates an expansion of trees at this time.

Another conspicuous feature in the pollen diagram is the peak value for *Sphagnum* during the earliest part of this period. Increase in *Sphagnum* began during the preceding period but local conditions must have been optimal during this period. Percentage values for Polypodiaceae undiff. also show a notable decrease coinciding with the peak value for *Sphagnum*. Conditions for Pteridophytes seem to have rapidly deteriorated, but the reason for this is not clear. The expansion of *Sphagnum* indicates wetter conditions in the peatland, and these conditions were most common during the earliest part of this period.

Period K (50 B.P. to present time). This period is characterised by high tree pollen percentages. Tree pollen percentages around 90% or more is reached in all pollen samples except the surface sample. *Betula*, *Alnus* and *Fagus* are important pollen types during this period.

The expansion of *Fagus* that started during the preceding period continued and became even more marked, as is clear from the influx data. The major part of the present *Fagus* stand consists of young individuals indicating a notable expansion during this century and particularly during the last 50 years.

Picea has its highest pollen percentages and influx values in the pollen record during this period, but these values are still comparatively low (pollen percentages only reach just above 3%). Today, only a few *Picea* individuals occur in the local forest stand which is dominated by *Fagus*. Some *Picea* individuals have also been cut down recently (the same is true for *Fagus*), and this felling may explain the somewhat lower influx value for *Picea* in the surface sample. Even today, *Picea* has a rather restricted abundance in the regional vegetation which is still largely dominated by deciduous forest stands. However, its importance has increased recently with the introduction of intensive forest management, particularly since the 1950s. *Pinus* is not present in the local forest stand although its pollen percentages reach nearly 10%.

Pollen from *Juniperus* and *Calluna* and many herb pollen types indicating cultural activities show low percentages during this period. These low percentages may indicate that the local forest stand on well-drained ground has not experienced any form of land-use during this period. However, pollen percentages for Poaceae undiff. has a peak value in the surface sample and this increase may coincide with a recent thinning of the local forest stand when some *Picea* and *Fagus* individuals were cut down. This felling certainly favoured graminids as more light became available for the ground flora.

Alnus show a considerable expansion during the transition to this period. *Alnus* once again re-established a viable population on the peatland. Today, there are no *Alnus* individuals older than ca. 40–50 years to be found on the peatland, and this also indicates that the present population became established during the beginning of this period. *Alnus* had probably been more or less absent from the peatland since the earliest part of period G, i.e. for a period of ca. 650 years.

Sphagnum representation is much lower during this period than earlier. This decrease may indicate a change in the local groundwater table towards drier conditions. Percentages for Polypodiaceae undiff. also decreased which suggests that Pteridophytes became even rarer in the local vegetation. The return of forested conditions and the re-establishment of *Alnus* on the peatland itself did not obviously favour Pteridophytes, which earlier had been an important constituent of the local mire vegetation.

Discussion

Fagus became established in the local forest stand at ca. 900 B.P. Its pollen percentages are, however, low at this time, and values continuously exceeding 2% are not reached until ca. 750 B.P. These percentages indicate a local presence of *Fagus* since 900 B.P., but it was certainly not a dominant tree until rather recently. It was during this century, and probably during the last 50 years, that *Fagus* expanded considerably and become a forest dominant. This relatively late expansion is particularly evident in the pollen influx data, where its values are comparatively low and stable until this century.

Fagus may have been present in western Småland before 900 B.P. Single *Fagus* pollen grains are found regularly before 900 B.P., but these grains may be of long-distance origin. Regional pollen diagrams from southern Småland and Halland (e.g. Digerfeldt 1972, 1982; Svensson 1988) indicate that *Fagus* expanded regionally ca. 1500–1100 B.P. Pollen diagrams showing a more local picture from the same area (e.g. Königsson 1989; Lindbladh and Bradshaw 1995; Björkman and Bradshaw 1996; Björkman, unpublished material) indicate that the local expansion of *Fagus* occurred during a relatively extended period, mainly between 1500 and 800 B.P. It is speculative to draw conclusions based on single pollen grains of any taxon occurring in regional pollen diagrams well before its main expansion. Single *Fagus* pollen may derive from scattered *Fagus* individuals in the local vegetation (e.g. Lagerås 1996), or may have been transported to the site from populations some distance away. If *Fagus* was present in the study area before 900 B.P., it was obviously not abundant in the vegetation.

It is significant that the establishment of *Fagus* occurred near the sampling point at ca. 900 B.P., i.e. at the same time as an expansion of open pastures and cultivated fields also occurs. Forest grazing had probably been practised earlier in the area, but this form of disturbance alone does not seem to have been sufficient to favour the local establishment of *Fagus*. It is well-known from other studies that regeneration of *Fagus* is favoured by ground disturbance (e.g. Watt 1923; Röhrig et al. 1978; Bjerregaard and Carbonnier 1979; Björkman and Bradshaw 1996). This knowledge is also used within contemporary forestry to assist *Fagus* regeneration. Many recent palaeoecological studies in Denmark and Sweden have also shown a close relationship between cultural influence and *Fagus* expansion (e.g. Iversen 1969, 1973; Aaby 1983, 1986, 1988; Andersen et al. 1983; Andersen 1984, 1988; Regnéll 1989; Berglund et al. 1991; Lindbladh and Bradshaw 1995; Björkman 1996). However, in areas with a strong cultural influence *Fagus* expansion was restricted (e.g. Aaby 1986, 1988; Odgaard 1994).

It is obvious from the pollen diagram that *Fagus* did not expand notably until this century. Its failure to expand at the site until the last 100 years is related to continuous land-use, especially grazing. It failed to expand during a period of decreased land-use (ca. 550–350 B.P.), possibly because the open areas were rapidly overgrown by *Betula* and *Corylus*. During the latter part of the 19th century land-use changed, mainly due to a reorganisation of land ownership. Some areas that previously had been intensively used were abandoned, or became less intensively used. These changes in land-use, particularly in the grazing pressure, probably created possibilities for *Fagus* to regenerate. This shift in land-use is also well expressed in the present age structure of the local *Fagus* stands. They are almost completely dominated by young *Fagus* individuals, and *Fagus* trees older than 100 years are rare.

According to Wibeck (1909), an area with *Fagus* forest was present some kilometres to the south of the sampled peatland. This area held forests dominated by *Fagus* at least until the end of the 18th century. In the pollen diagram from Flahult, *Fagus* pollen percentages are low, except during the last 100 years. These low percentages do not support the hypothesis that widespread *Fagus* forests occurred in the area before the 19th century. The pollen diagram is either too 'local' to detect vast *Fagus* forests some distance away, or the extent of these supposed forests has been exaggerated.

The local establishment of *Picea* probably occurred during the last 100 years. *Picea* pollen percentages are low and reach 3% at most. *Picea* probably did not build up a significant population until very recently. Even today the studied region is mainly characterised by mixed deciduous forests, but *Picea* has started to become more important as it is favoured by modern forestry. Clear-cut deciduous stands are nowadays often replaced by *Picea* plantations. An investigation of another small peatland (located in a former out-field area), some kilometres south of Flahult, confirmed that the local *Picea* expansion is very recent (Björkman, unpublished). In that case also, the shift in forest composition from a deciduous to a coniferous type occurred during this century. The late expansion of *Picea* in this area was most likely a consequence of land-use changes during the latter part of the 19th century, and the increased economic importance of *Picea* products during this century.

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