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Lars-Göran Ek

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Photo: Lars-Göran Ek

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Abstract

The general migration model for Norway spruce (*Picea abies)* suggests that it arrived and established in Sweden along the Bothnian coast about 3500 years ago. Spruce thereafter spread westwards and southwards in Sweden, and it is suggested to have become established in the Scandes mountains about 1300-1600 years ago. Recent macrofossil finds in the Scandes mountains have challenged this theory. Two macrofossils of Norway spruce dated to 11 020 and 10 250 ^{14}C yr BP have been found on Mt Åreskutan that is a mountain top in the south-western Swedish Scandes.

The aim of this study was to find out if this early establishment of Norway spruce on Mt Åreskutan could be verified with pollen analysis. Two mires where selected for the study on two adjacent mountains, Årebjörnen and Totthummeln 6,5 km and 3,5 km distant from Åreskutan. The pollen diagrams reveal that Norway spruce was established on these two mountains about 4000 years cal. BP. This much later establishment of spruce on Årebjörnen and Totthummeln compared to Mt Åreskutan show that the establishment of spruce in an area can vary strongly in time plausibly due to differences in local climate and due to competition from already established vegetation. The reason for the absence of spruce pollen from Mt Åreskutan in the Årebjörnen and Totthummeln peat stratigraphies, can be that the population on Åreskutan was to small and the distance between the two mountains and Åreskutan is to long for spruce pollen to be dispersed. Still the establishment on the studied mountains occurred ca 2500 years earlier than postulated by the former model. The stand of *Ulmus* that can be found on the south side of Totthummeln today has most likely been established during the post glacial temperature optima and is thus a relict that has survived for 7000 years.

Sammanfattning

Enligt den gängse modellen för granens (*Picea abies*) invandring etablerades granen vid Bottniska kusten för ca 3500 år sedan. Därefter spred den sig västerut och söderut i Sverige. Etableringen i Skanderna skedde för mellan 1300-1500 år sedan. Makrofossilfynd av gran i fjällen har ifrågasatt detta.Två makrofossil av gran daterade till 11 020 ^{14}C år före nutid och 10 250 ^{14}C år före nutid hittades på Åreskutan, ett fjäll beläget i den sydvästra delen av fjällkedjan.

Syftet med föreliggande studie var att undersöka om den tidiga kolonisationen av gran på Åreskutan kunde verifieras med pollenanalys. Två myrar på de två närmaste bergen, Årebjörnen och Totthummeln, valdes för studien. Årebjörnen är beläget ca 6,5 km sydväst om Åreskutan och Totthummeln är beläget ca 3,5 km söder om Åreskutan. Pollendiagrammen visade att gran blev etablerad på dessa berg för ca 4000 år sedan, avsevärt tidigare än den gängse modellen säger, men också betydligt senare än makrofossilen från Åreskutan. Detta visar att etableringen av gran inom en region kan variera i tid. Det kan i sin tur bero på klimatiska skillnader mellan de olika lokalerna och konkurrens från redan etablerad vegetation. Orsaken till att pollen saknas från granarna på Åreskutan i pollenanalyserna från Årebjörnen och Totthummeln tyder på att granarna på Åreskutan var för få, eller att avståndet mellan Åreskutan och Årebjörnen och Totthummeln var för stort för pollen att spridas dit. Beståndet av alm (*Ulmus glabra*) som idag finns på den södra sidan av Totthummeln har troligen blivit etablerad under den postglaciala värmeperioden och pollenanalysen stödjer att det är en relikt som har överlevt under ca 7000 år.

Introduction

On Mt Åreskutan, a mountain top in the south-western Swedish Scandes, several macrofossil finds of Norway spruce (*Picea abies* (L.), Karst.), Scots pine (*Pinus sylvestris)* and Downy birch (*Betula pubescens*) dated to the late glacial period have been found (Kullman, 2000; 2002). These finds challenge not only the general model of tree migration and early Holocene vegetation development, but also the suggested deglaciation pattern. Two issues that have been in focus regarding the Holocene vegetation history is the migration and population development of Norway spruce. It has been suggested that Norway spruce migrated from east to west due to climatic change (Fægri, 1950; Moe, 1970; Tallantire, 1980). Earlier pollen analyses have revealed that Norway spruce first became established along the Bothnian coast about 3500 years ago and spread to southern and western Scandinavia (Huntley and Birks, 1983). Thus Norway spruce has been regarded as a late-Holocene immigrant (Moe 1970; Tallantire 1977; Huntley and Birks 1983; Hafsten 1992). It has been suggested that spruce in the Åre region was established about 1300-1600 ^{14}C yr BP (Tallantire, 1980). Macrofossil finds on Mt Åreskutan challenge this general view. On 1340 m a.s.l. two subfossil spruce stems dated to 11 020±90 ^{14}C yr BP and 10 250 ±90 ^{14}C yr BP respectively and a spruce cone dated to 8650 ±60 ^{14}C yr BP have been found. In addition to the spruce finds, macrofossils of Scots pine dated to 11 720±90 ^{14}C yr BP and a stem of a Downy birch dated to 14 020±80 ^{14}C yr BP were found on the same site (Kullman, 2002).

The aim of the study was to find out if the early spruce establishment on Mt Åreskutan could be verified and quantified by pollen analysis. On Mt Åreskutan no appropriate study site could be found in the vicinity of the site where the macrofossils had been retrieved. Therefore alternative high elevation sites were selected. Peat cores for pollen analysis were taken from two lower mountains, Årebjörnen and Totthummeln close to Mt Åreskutan. The main questions were; is the establishment of spruce, as suggested by the macrofossils of spruce found on Mt Åreskutan (Kullman 2001a), a general phenomena in the region and can it thus be verified by pollen analyses from nearby mountains; or are there any differences in establishment of spruce on Årebjörnen, Totthummeln and Åreskutan? Did the general vegetation development differ during Holocene between Årebjörnen and Totthummeln?

Material and Method

Study area

The study sites are located on the two mountains Årebjörnen (728 m a.s.l) and Totthummeln (1120 m a.s.l) and situated in mid-western Sweden in the direct vicinity of mount Åreskutan (Fig. 1). The present forest limit in the area is about 850 m a.s.l and formed by Mountain birch (*Betula pubescens* Ehrh. ssp. *tortuosa* (Ledeb.) Nyman). Below ca. 600 m, the forest is dominated by spruce and pine. Locally, the coniferous forest can reach higher elevation. The bedrock in the area consists of Seve amphibolite and schist (Lundqvist, 1969; 1986). According to Lundqvist (1969; 1986), the area was deglaciated about 9000 years cal. BP.

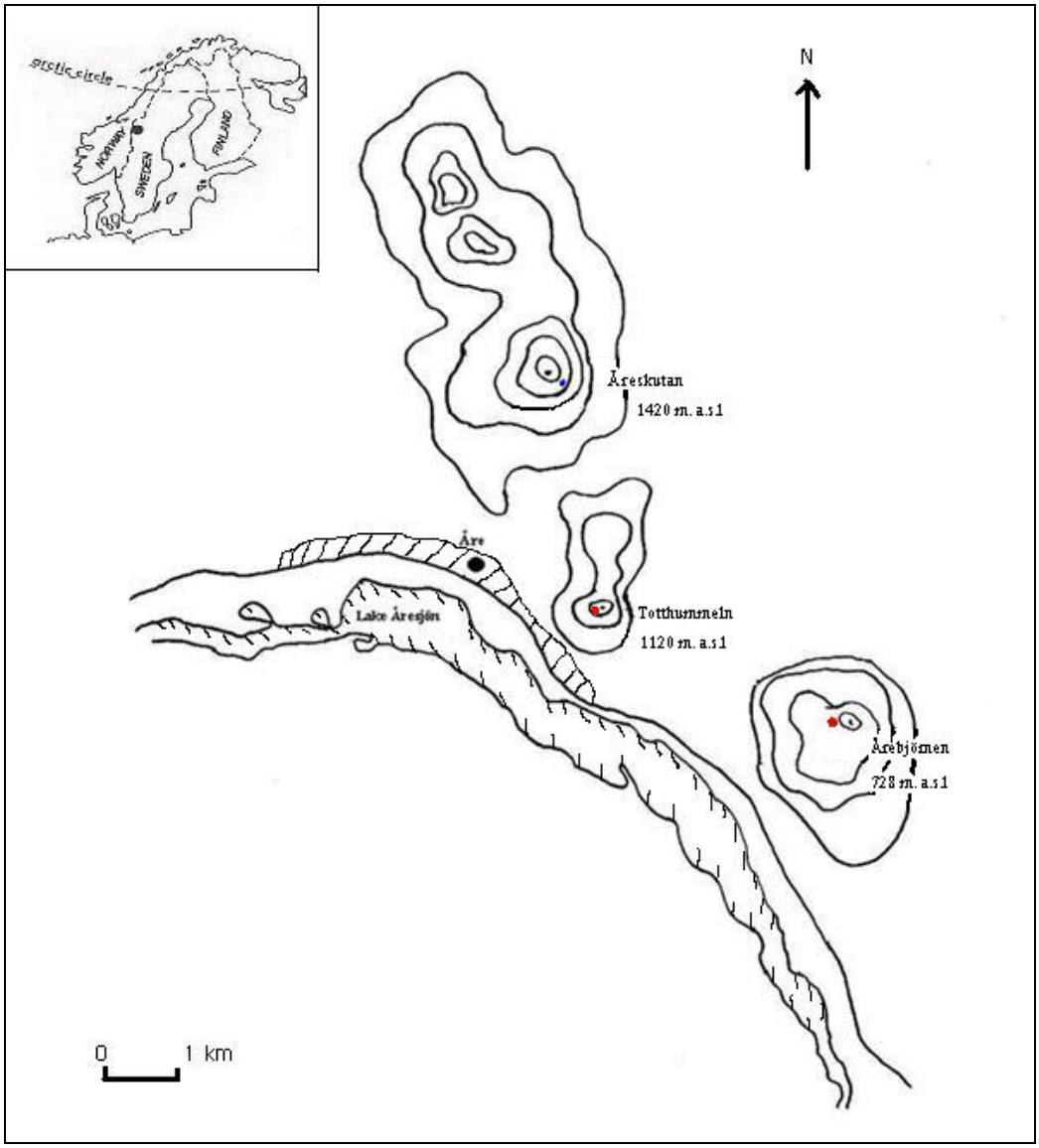

Figure 1. Map showing the study sites on Mt Årebjörnen and Mt Totthummeln respectively and their location in the Åre area. Insert map shows the geographical location of the study area in Fennoscandia.

Two series of peat cores, one from each mountain, were taken with a Russian peat corer (cf. Jowsey, 1966) with a length of 50 cm and a width of 5 cm. The 175 cm peat core from Årebjörnen was taken on a small mire (63º23´N, 13º10´E) ca. 700 m a.s.l. Årebjörnen is situated approximately 6,5 km southeast of mount Åreskutan. The ground vegetation surrounding the mire consists of dwarf shrubs like *Betula nana* and Ericaceae species. The vegetation on the mire consists mostly of Cyperaceae species and peat mosses (*Sphagnum spp*.). The forest surrounding the mire is dominated by spruce (Fig. 2).

Figure 2. The sampling site on Årebjörnen.

The sampling site on Totthummeln has an alpine character with vegetation consisting of dwarf shrubs, Cyperaceae species and some widely dispersed stands of krummholz spruce (Fig.3). Totthummeln is situated about 3,5 km south of mount Åreskutan. The 145 cm peat core on Totthummeln was taken from a small mire ca. 1100 m a.s.l (63º24´N, 13º05´E).

Pollen analysis

From the Årebjörnen peat core 40 samples, each representing 1 cm, were analysed for pollen. From 175 to 100 cm every second cm was analysed, from 100 cm to 50 cm every fourth or every sixth cm was analysed, and from 50 cm to 10 cm every tenth cm was analysed. From the Totthummeln 145 cm peat core every fourth cm was analysed, in all 30 samples.

The preparation of the samples included digestion in 5% potassium hydroxide, hydrofluoric acid treatment and acetolysis (cf. Moore *et al*., 1991). The samples were stained with safranine and mounted in glycerine on microscope slides. From each sample a minimum of 500 pollen were counted, and the percentage frequencies were calculated based on the total terrestrial pollen sum including Cyperaceae. For the pollen identification a pollen key (Moore *et al*., 1991) was used, and for critical examinations a collection of reference pollen was available.

Figure 3. The sampling site on Totthummeln. In the background mount Åreskutan.

Dating

The age determinations were made by AMS ^{14}C-dating on selected samples consisting of terrestrial macrofossils, mainly moss and Ericaceae-leaves and bulk-peat samples. For both sites Årebjörnen and Totthummeln two samples were dated; one sample from the bottom to date the initiation of peat accumulation; and one sample at the level where spruce pollen was continually recorded. The ^{14}C-datings from the Årebjörnen core were performed at the Ångström Laboratory in Uppsala and the calibrations were made using Calib 4,0 (Int.cal 93, probability data, method B) (Stuiver and Reimer, 1993). The samples from Totthummeln were ^{14}C-analysed at the Beta Analytic Radio carbon Dating Laboratory in Court, Miami Florida. Calibrations were made using Calib 4,0 (Int.cal. 98 Radiocarbon Age Calibration) (Stuiver, et. al., 1998).

Results

Dating

The ^{14}C datings (table 1) show that peat initiation on Årebjörnen started between 10 150 and 9550 years cal. BP and thus the peat core covers more or less the entire Holocene. The 56 cm level was dated 4150-3460 years cal. BP. The ^{14}C dating from the bottom of the Totthummeln peat core shows that peat initiation started between 7240 and 6990 years cal. BP. The 73 cm level from Totthummeln was dated 2470-2330 years cal. BP. The degree of humification is high in both peat cores and no major changes in humification could be detected in either of the peat cores, and that may imply a rather steady peat accumulation over time in both peat cores. Age estimates in the text are based on the age/depth curves (figure 4).

Table 1 Radiocarbon dates from the study sites.

Material for radiocarbon dating	Laboratory code	Site	Depth (cm)	^{14}C age BP	Calibrated age ranges (cal. BP) at 2 σ
Moss and Ericaceae leaves	Ua-21758	Årebjörnen	174-175	8750 ± 65	10 150 - 9550
Moss and Ericaceae leaves	Ua-22118	Årebjörnen	54,5-56,5	3595 ± 50	4150 - 3460
Bulk peat samples	Beta-191079	Totthummeln	143,5-144	6200 ± 40	7240 - 6990
Bulk peat samples	Beta-191078	Totthummeln	73-73,5	2370 ± 40	2470 - 2330

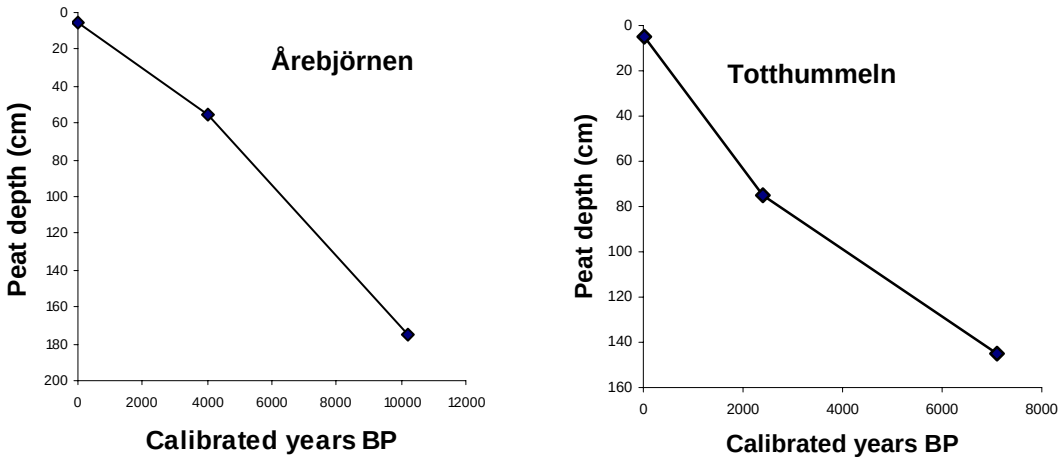

Figure 4. Age-depth curve based on calibrated ^{14}C dates.

The vegetation history on Årebjörnen and Totthummeln

The Årebjörnen diagram has been sub-sectioned into three main periods (A, B, C) based on major vegetation changes. The most recent period (C) is subdivided into two minor periods (CI and CII) according to minor changes in the pollen composition (Fig 5). The Totthummeln diagram (Fig 6) does not extend as far back in time as Årebjörnen and it is sub-sectioned into two main periods which correspond to the periods B and C (subdivided into CI and CII) on Årebjörnen.

Årebjörnen

(A) The *Hippophae-Betula-Pinus*-Cyperaceae period (ca. 10 000-7000 years cal. BP) was initially characterized by alpine-tundra or open shrub-like vegetation. *Pinus* became the most frequent tree, and dominated the forest in the region. *Alnus* was present but was not an important part of the vegetation. *Betula* was common and probably formed the tree-line in the region. *Hippophae rhamnoides* and *Salix* forming an important part of the vegetation, indicates that the vegetation on Årebjörnen was rather open. The vegetation on the mire is suggested to have been open sedge mire due to the relatively high percentage of Cyperaceae pollen. It is also suggested that the occurrence of *Menyanthes* indicates that the site was wetter than today (Kilander, 1955). Other common herbaceous plants on the site were *Filipendula*, Rosaceae, *Ranunculus*, *Melampyrum*, Asteraceae and Apiaceae. At the end of the period *Hippophae rhamnoides* disappeared likely due to increased shading from the trees.One *Picea* pollen grain is recorded about 9000 years cal. BP.

(B) The *Alnus-Betula-Pinus-Ulmus* period (7000-4000 years cal. BP) begins with an increase in *Alnus*, *Ulmus* and *Betula* pollen and a sharp decrease in *Pinus* pollen. *Betula* pollen gradually increases during the entire period. *Alnus* pollen increases in the beginning and decreases slightly thereafter, but it is suggested that *Alnus* was an important species around the site. The occurrence of *Ulmus* pollen is not likely to represent on site origin, rather a more regional presence during the post glacial temperature optimum c. 8000-4000 years BP (Königsson, 1980). Overall it seems clear that during this period deciduous trees were a more important part of the vegetation around the site than coniferous trees. From the middle of the period *Salix* decreased which could be an effect of competition by the increase of deciduous trees. Only one pollen grain from *Menyanthes* was recorded and Cyperaceae species decreased at the same time as Ericaceae increased, reflecting drier conditions on the mire. Asteraceae pollen was only sporadically found. *Melampyrum*, *Compositae* and Rosaceae increased in the beginning. Polypodiaceae increased in the beginning, peaked in the middle of the period and decreased slightly towards the end of the period. All together these changes suggest that the local conditions on the mire became drier. Two *Picea* pollen grains where recorded, about 5000 years cal. BP.

(C) The period (4000 years cal. BP to present) is mainly characterized by the establishment and continual presence of *Picea* forest. However, some features in the vegetation changes divide the period in two sections and therefore the period is presented in two, CI and CII respectively.

(C I) Around 4000 years cal. BP *Picea* forest was established at the site. *Alnus* decreased possibly due to competition from *Picea.* *Ulmus* diminished, plausibly reflecting the end of the warm period. *Betula* and *Pinus* were the most common trees during this period. *Salix*, Rosaceae, *Compositae*, *Filipendula* and *Melampyrum* decreased most likely as an effect of the forest composition changes. Asteraceae increased slightly towards the end of the period.

(CII) About 1500 years ago a shift in the coniferous trees is recorded; spruce increased and pine decreased. *Betula* decreased about 1000 years cal. BP probably as an effect of the increase of *Picea*. At the end of the period *Ulmus* pollen is recorded again but it is still considered to reflect the presence of *Ulmus* in the region rather than on the site. *Salix* disappeared from the site likely due to denser forest. Asteraceae, *Melampyrum* and *Filipendula* increased, and others like Caryophyllaceae, *Rubus chamameorus*, *Artemisia*

Årebjörnen

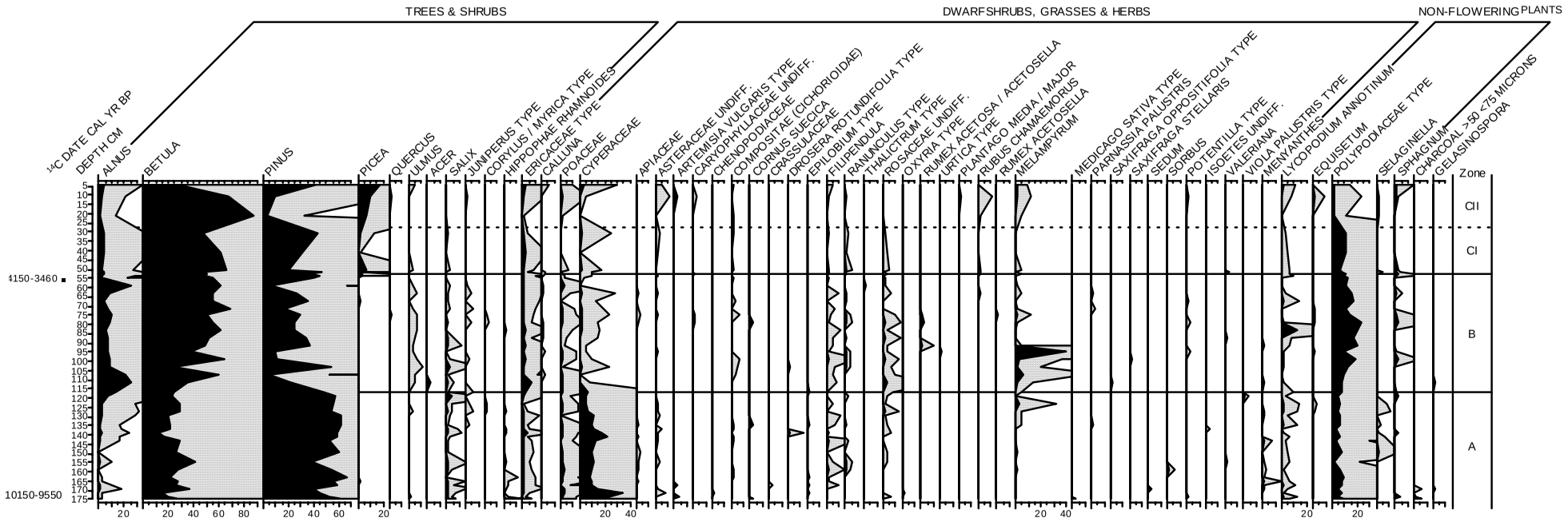

Figure 5. Pollendiagram from Årebjörnen. The numbers on the x-axis to the left show the depth (cm) of the peat core and calibrated ^{14}C dates with ranges at 2 σ. The horizontal lines divide the pollen diagram into three main zones (A, B and C), zone C is divided into two minor zones (CI and CII). The black fields represent pollen percentage and grey fields represent a X 10 exaggeration of the percentage values. Only the pollen types important for the discussion are shown, while other pollen types occurring in low frequencies have been omitted from the diagram.

vulgaris and *Potentilla* were established on the site. *Ranunculus* decreased and Rosaceae disappeared from the site. Polypodiaceae decreased in the beginning of the period.

Regarding the top most part of the diagram one has to consider that for the last three or four decades the area has been highly influenced by human activities that have affected the vegetation. Årebjörnen is an important recreational area with downhill skiing slopes that are managed by removing bushes and trees every year, which is beneficial for some herbs and graminoids, and detrimental for much other vegetation.

Totthummeln

(B) In the beginning of the *Alnus-Betula-Pinus-Ulmus* period (about 7000-4000 years cal. BP) *Alnus* was very common and *Pinus* was less abundant. Later *Alnus* declined and *Pinus* increased gradually. *Ulmus* is recorded relatively frequent, and is thus suggested to have been locally present. *Ulmus* that can be found in the Scandes today belongs to the westerly subspecies, *Ulmus glabra* ssp. *Montana* (With.). *Betula* pollen increased to some extent from the beginning and Betula was probably the most common tree. Due to the warm mid Holocene period and a plausibly higher tree limit it is suggested that the site on Totthummeln was forested during this period. Polypodiaceae species formed an important part of the vegetation. *Salix* was common in the beginning but decreased in the end.

Ericaceae pollen increases gradually and peaks towards the end. Poaceae pollen disappears in the end of the period. Cyperaceae pollen is continuously recorded but decreases in the end of the period. This shift from Cyperaceae to Ericaceae species might reflect a change to drier conditions in the vicinity of the mire. Apiaceae, *Artemisia*, *Potentilla* and *Ranunculus* were an important part of the vegetation in the beginning. *Compositae*, Rosaceae and *Filipendula* were common, but a decrease is recorded in the end of the period. *Melampyrum* pollen is recorded in the middle of the period but disappears in the end. The suggested drier condition in the vicinity of the mire is probably the reason for the overall decrease of herbaceous plants towards the end of the period.

(C) The period (4000 years cal. BP to present) is mainly characterized by the establishment of *Picea* in the area at about the same time as *Ulmus* became less important. *Alnus* pollen is recorded but is not considered to be an important part of the vegetation. Some features in the vegetation changes divides the period in two sub-section, CI and CII.

(CI) The *Picea-Betula-Pinus* period about 4000-2200 years cal. BP begins with the occurrence of *Picea* pollen suggesting that *Picea* was growing in the area. Due to the relatively low percentage of *Picea* pollen it is suggested that *Picea* was not abundant here. *Ulmus* pollen was regularly recorded but the pollen signal was weaker than during the previous period reflecting the end of the warm period. *Juniperus* pollen is regularly recorded *Salix* increases. Ericaceae pollen decreases and Cyperaceae pollen increases suggesting drier conditions on the mire. Poaceae species increased and were common on the site. Apiaceae and *Artemisia* pollen increase in the end of the period. Asteraceae and *Potentilla* became more common than during

Totthummeln

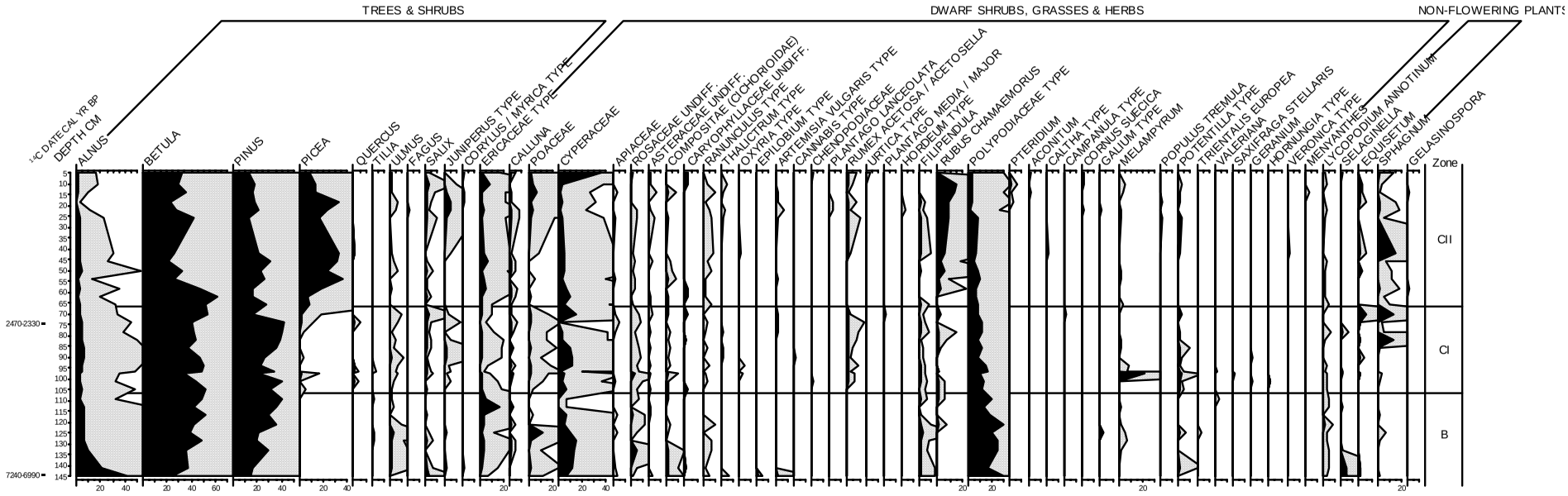

Figure 6. Pollendiagram from Totthummeln. The numbers on the x-axis to the left show the depth (cm) of the peat core and calibrated ^{14}C dates with ranges at 2 σ. The horizontal lines divide the pollen diagram into two main zones (B and C), zone C is divided into two minor zones (CI and CII). The black fields represent pollen percentage and grey fields represent a X 10 exaggeration of the percentage values. Only the pollen types important for the discussion are shown, while other pollen types occurring in low frequencies have been omitted from the diagram.

the previous period. *Filipendula*, *Ranunculus* and *Compositae* are regularly recorded, but were probably less important in the vegetation than during the previous period. *Melampyrum* became very common for a short period around 3800 years ago, at the same time as an increase in Rosaceae, *Potentilla* and *Compositae* is recorded. *Rubus chamaemorus* became established on the mire and *Rumex* species became established in the area. In general there was an increase in herb species. Polypodiaceae decreased slightly but was still common.

(CII) The period begins with an increase in *Picea* and a decrease of *Betula* about 2000 years ago. *Salix* decreases in the beginning of the period. *Juniperus* pollen is only recorded in the latter half of the period. Poaceae increases towards the end of the period. *Rubus chamaemorus* and *Ranuculus* species increased except for in the end of the period, but in general there was a trend that herbaceous plants decreased. Pollen of Apiaceae, Asteraceae, *Filipendula*, *Melampyrum* and *Potentilla* are only sporadically found. Rosaceae and *Compositae* decreased but were still growing in the area. It is suggested that the site got more forested during this period, probably due to a change in the climate.Towards the end of the period though, *Picea* pollen decrease, reflecting the supressed *Picea* trees growing on the top today. *Pinus* pollen also decrease slightly towards the end of the period. Cyperaceae increase in the end of the period. The shift in the vegetation with the increase of Cyperaceae species and the decrease of herbs is suggested to reflect wetter conditions.

Discussion

The local establishment of Picea abies

The results showed that spruce became established on Totthummeln (1120 m a.s.l) and Årebjörnen (728 m a.s.l) ca. 4000 years BP. The oldest spruce macrofossil finds on mount Åreskutan (1340 m a.s.l.) date ^{14}C 11 020±90 yr BP, and spruce macrofossils dated to ^{14}C 8650±60 yr BP suggest that spruces have been growing on mount Åreskutan during a period of at least 3000 years in late glacial and the early Holocene (Kullman, 2002). Thus the tree limit during this period was 400-500 m higher than the present day tree limit (Kullman, 2000).

A recent review article have shown that spruce reached its maximum abundance during the last 4000 years in northern Europe (Giesecke and Bennett, in press). The results from Årebjörnen and Totthummeln ad further to this conclusion. The distinct start of the spruce curve on Årebjörnen suggests that the local establishment of spruce was more marked on Årebjörnen than on Totthummeln. However, considering the results of Segerström and von Stedingk (2003) also the weak records of spruce pollen on Totthummeln most likely represent local spruce there.

However, to explain the much later establishment on Årebjörnen and Totthummeln compared to Mount Åreskutan one has to consider both local climate conditions such as strong winds and hydrology but also competition from already established vegetation. To withstand the harshness on alpine altitudes tree growth is strictly confined to thermally favorable and wind sheltered places. Such sites can maintain a large accumulation of snow that prevents ground frost, which in turn will make water more accessible for the trees. On more open areas with strong winds and a sparse snow cover, the ground frost is deep and the water is only available a shorter period during the growing season. No megafossil wood remnants have been found on such open areas (Kullman, 2001b). The establishment of spruce can thus depend on the difference in the local climate on each site although competition from already established vegetation is plausibly also an important factor. On Årebjörnen it is suggested that *Alnus* was a relatively common species before spruce became established. The establishment of spruce had to involve competition with *Alnus* and probably also other tree species that were growing there. On Totthummeln *Alnus* was not that important when spruce became established and thus the local climate situation may have been the most plausible explanation for the relatively late establishment of spruce. Around 4000 years ago it is suggested that the climate got colder and moister, and since the site on Totthummeln is situated on much higher altitude than the Årebjörnen site the local conditions there were probably more crucial for forest development than on Årebjörnen. The establishment of spruce on Totthummeln took place during this climatic shift, about 4000 years ago. However, spruce did not establish as fast and distinct as on Årebjörnen, and did not become an important forest constituent on Totthummeln until 1500 years later.

Local Picea pollen

Macrofossils are more directly linked to the flora on the site than pollen. However since macrofossils are not usually preserved in high abundance and therefore are rarely found, it is difficult to quantify the vegetation in an area and to be sure that the macrofossils that are found represent the oldest specimen at the site (Birks and Birks, 2000). By using pollen analysis it is possible to find more taxa like grasses and herbs that rarely preserve as macrofossils, and therefore makes it possible to interpret the vegetation in terms of both local and regional abundance.

The local dispersal of spruce pollen has been examined by Segerström and von Stedingk (2003) who made pollen analyses combined with macrofossils in the Handöl-valley ca 50 km to the west of Åre. Three local pollen analyses along a 10 km stretch through the valley revealed no common background pollen signal from spruce. The low frequency of pollen that were recorded in the most northern part of the valley were thus not long distance spread background pollen, as it would have been interpreted in accordance with Fægri (1950) and Moe (1970). Instead it was suggested to reflect the first stands of spruce on the site (Segerström and von Stedingk, 2003). The poor spruce representation on both Totthummeln and Årebjörnen in the early Holocene further enhances the conclusion that spruce pollen is rather poorly dispersed and that the background spruce pollen load is negligible in situations like these.

On Totthummeln a weaker spruce pollen signal is recorded in period CI compared to CII. This is thus suggested to reflect that the first spruce on Totthummeln where only small stands or only scattered single spruce trees. Spruce became most abundant in period CII about 2000-1000 years BP. Towards the end of the period the pollen frequencies decrease, reflecting the few spruces that are growing on Totthummeln today. On Årebjörnen the spruce pollen record starts distinctly about 4000 years BP and reveals a stable increase from about 3000 years BP towards the end of the period reflecting the spruce forest that is growing there today. The few single spruce pollen grains that are recorded at ca 9000 years BP and 5000 years BP respectively, may possibly represent spruces that where growing on Mount Åreskutan or elsewhere in the area during this time.

Early Holocene vegetation establishment

Generally it is suggested that the last glacial period terminated ca. 10 000 years ago and before that ice covered most of this region. The glaciation and deglaciation of Scandinavia is usually considered to have started and ended in the Scandes Mountains (Lundqvist, 2002). In the county of Jämtland glacial-geomorphologic reconstructions and models suggest that deglaciation of this part of the Scandes took place around 9300-8800 years ago (Lundqvist, 1986). This is questioned by the macrofossil finds in the area, of which many are much older than 9000 years. This early establishment of vegetation on a mountain like Åreskutan has been suggested to originate from full glacial refuges in the west (Kullman, 2001b).

No early Holocene dated macrofossils of trees have been recovered at relatively low elevations and no wood or peat has been radiocarbon dated older than 8300 years on the valley-bottom mires (Lundqvist, 1969; Kullman and Kjällgren, 2000). This corresponds well with other macrofossil finds which together show that the oldest tree macrofossils are found on high elevation (Kullman, 2000). To explain this it is suggested that in the valleys there were ice remnants and ice-dammed lakes still in the early Holocene that delimited the establishment of vegetation and thus the first trees and other plants colonized the higher mountain tops. This would have contributed to a rapid regional spread when the vegetation later migrated downhill (Kullman and Kjällgren, 2000). This leads to the nunatak theory discussed by Blytt (1876) and Sernander (1896). Nunataks on Greenland have been shown to have a surprisingly rich flora (Gjaerevoll and Ryvarden, 1977) and recent evidence for plant survival during the whole Weichselian has been found on Icelandic nunataks (Rundgren and Ingolfsson, 1999). Mount Åreskutan may have been a nunatak in late glacial and early Holocene and could thus have been the first place in the region where vegetation became established (Kullman, 2000).

It is suggested that the vegetation on Årebjörnen initially was more open, treeless, and that the area became forested about 8000 years ago. On Totthummeln the peat formation started about 7000 years ago and it is suggested that the site was more or less forested already

at that time due to the plausibly higher tree limit during a climatically favourable period. The few krummholz type spruces that grow on Totthummeln today are most likely remnants after a denser spruce forest that established on Totthummeln about 4000 years ago. Today these spruces are living on the margins of their habitat.

On the south west side of Totthummeln there is a small stand of *Ulmus glabra* ssp. *Montana* (With.). *Ulmus* was most common during the warm period 8000-4000 years ago (Königsson, 1980) but on suitable places *Ulmus* seems to have survived in small stands until today. *Ulmus* pollen is frequently recorded in the older part of the Totthummeln peat record and pollen is recorded through the entire peat record and therefore it is likely that *Ulmus* has been growing close to the site during the last 7000 years.

Conclusion

- The establishment of spruce on Årebjörnen and Totthummeln about 4000 years ago challenge the prevailing theory that spruce first became established in Sweden along the Bothnian coast about 3500 years ago and in the Åre area 1300-1600 years ago.

- The local differences in climate, and competition from already established vegetation is the plausible explanation for the much later establishment of spruce on Årebjörnen and Totthummeln compared to Mount Åreskutan.

- The *Ulmus* population on Totthummeln today is most likely a relict from the warm period about 8000-4000 years ago.

- The distance between Mount Åreskutan and the mountains Årebjörnen and Totthummeln is too long to reflect the spruce that grew on Åreskutan. It also implies that the spruce population at Åreskutan was only small and locally delimited, and therefore has not become regionally recorded at the surrounding nearby sites.

Future studies

The early Holocene history of spruce and its migration pattern from the west should be more thoroughly investigated. Both pollen analyses and macrofossil analyses should be carried out on westerly sites that may have been ice free during late Pleistocene. The few spruces on Totthummeln should be dated to see if they are old clones originating from the first spruces established on Totthummeln. Molecular biological tests could be a helpful tool; with DNA analyses it may be possible to see if different spruce populations have a different migration pattern, and in that way trace the origin of the first spruce populations in Sweden.

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