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Human impact on the forest line

A pollen analytical study in connection to stalo dwellings in Vindelfjällen nature reserve, northern Sweden.

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Abstract

The vegetation in the Swedish Scandes has been considered to be mostly unaffected in the past by humans. Thus, the region has been regarded as important when studying how climate chang affects forest line vegetation. However, recent evidence from archaeological surveys in the Scandes show that the area have been used to a much larger extent than previously belived. The aim of this study was to examine past vegetation changes at the forest line right next to seven stalo dwellings in the Vindelfjällen area, northern Sweden, by the use of pollenanalysis. The results show that around the dwellings a deforestation occurred locally and the altitude of the forest line was lowered. Also, a chatastophic shift in the ecosystem might have occured that reduced the ability of the forest to regenerate. To understand how climate affects the forest line today we have to choose study areas where past human impact has been minimal.

Sammanfattning

Vegetationen i den svenska fjällkedjan har tidigare ansetts vara i stort sett skonad från mänsklig påverkan. Nyligt genomförda arkeologiska inventeringar visar däremot att fjällkedjan varit utnyttjad i större utsträckning än vad man tidigare trott. Målet med denna studie var att undersöka vegetations förändringar i anslutning till stalotomter i Vindelfjällens naturreservat med hjälp av pollenanalys. Resultaten visar att området runt stalotomterna blev avskogat och att skogsgränsen sänktes. Dessutom kan den mänskliga påverkan ha orsakat en förändring i ekosystemet som ledde till att möjligheten för återbeskogning minskade. Därför är det viktigt att, när man studerar hur skogsgränsen påverkas av klimat förändringar, välja studieområden med tidigare minimal mänsklig påverkan.

Introduction

During the last century the global air temperature has increased in response to higher concentrations of CO_2, creating a greenhouse effect. The average temperature in the Swedish Scandes has increased with 1^oC during the last 100 years (Kullman 2003), and in northern Alaska and northern Canada it has risen 2 to 4^oC (Oechel & Vourlitis 1994). This is one of the most important environmental aspects of today. Many researchers are studying what effect this climate change has on the composition and distribution of vegetation. The forest line is one such study area as it is supposed to change its distribution towards higher altitudes with increasing temperatures. In the Northern hemisphere tree seedlings and saplings emerge further north and at higher elevations (Kullman 2002). In many mountain areas in Europe, like the Alps, Scotland and Iceland, the recent altitudinal increase of forest line distribution has been explained as an effect of ceased land use (Kullman 1976, Wick & Tinner 1997, Aradottir & Arnalds 2001). Thus, in these areas it has been difficult to investigate the effects of solely climate during the last 2000 years (Wick & Tinner 1997). The Swedish Scandes, on the other hand, with its extensive mountain birch (*Betula pubescens ssp. czerepanovii*) forest belt, has been considered to be unaffected by human impact and that natural causes, e.g. climate, have created the subalpine landscape we see today. But even in the Swedish Scandes past human impact on the forest line can be larger than we think.

The term forest line in this study will be defined as the upper limit for a closed forest (Kullman 1976), and should be distinguished from the term tree line that describes isolated birches (>2m height) that grows above the forest line. The zone between the forest line and the tree line is called the “kampfzone”.

Early humans

Humans that followed the retreating ice into northern Scandinavia 10000 years ago lived on hunting and fishing. From 500 BC – 400 AD a specialisation towards reindeer hunting occurred in northern Sweden and the amount of hunting pits close to the forest line increased during this time (Mulk 1994). The alpine area was part of a large resource area, mostly used during the summer (Bergman 1997). Around 700 AD a new settlement pattern emerged. In the inland new settlements where not only built close to water but also on dry sand heaths (Bergman 1997). At the same time in the sub-alpine area, stalo dwellings (fig. 1 and front cover) appeared in places where no previous settlements had been found.

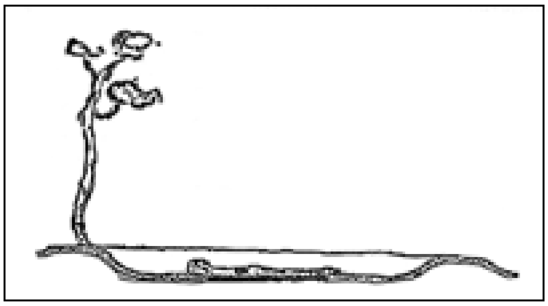

Figure 1. Stalo dwelling from the side. The floor is slightly dug into the ground creating a peat wall around the dwelling (Manker 1960).

Since there is no strong resemblance between the traditional stalo dwellings and Sámi huts, there is an ongoing debate about who lived in these dwellings and what kind of life they had. The stalo dwellings are oval and approximately 3-6 meter in diameter. The floor is dug into the ground creating a low peat wall around the dwelling (Manker 1960). They were established during the period, 700 – 1500 AD. Today they are mostly found above the forest line at 550-800 m.a.s.l., usually on shrub heaths, 2 to 8 in a row (Bergman 1997). The name "Stalo" derives from ancient Sámi myths. The stories are different in different parts of the Sámi area. One myth derives from Karesuando and southwards where the Stalo was considered to be a cruel giant who fought the Sámi people, but usually he was beaten by his own stupidity and by the more intelligent Sámi (fig. 2). The fact that the myth portraits Stalo as a giant have led to some speculations that Stalo was in fact Vikings who sometimes harassed the Sámi (Manker 1960). However, the connections between the name "Stalo" and the stalo dwellings are vague. In the area around Arjeplog the stalo dwellings are called *ednamisgoahte* by the Sámi, which means "soil-hut" (Mulk 1994).

Figure 2. Woodcut by Emelie Demant Hatt that depict the Sámi boy Askovis and the Stalogiant on the edge of a steep mountain side. Askovis have tricked Stalo to put down his bag with silver and rest on the edge and then pushes him over the side (Manker 1960).

Archaeologists have long discussed the question about who lived in the dwellings. Kjellström (1975) thought that the Vikings lived in the dwellings during 800-1100 AD followed by a void phase until the Sámi utilized them around 1600 AD. According to him the Norwegian Vikings used the alpine area for hunting and also for collecting taxes from the Sámi. He interpreted the word "stalo" as the word "steel" and related this to the armour made of steel that was worn by the Vikings. However, today most researchers argue that the Sámi used the stalo dwellings. Aronsson (1991) and Storli (1991) claim that the Sámi people lived there and they think that the dwellings can be connected with an early domestication of the reindeer. According to them the dwellings where used seasonally in connection to summer grazing for reindeers. Mulk (1994) believes that the Sámi people regularly lived in the stalo dwellings until 1500 AD, they used systems of hunting pits close to the forest line and that captured reindeer were utilized as hunting decoys and for transport.

The time when the Sámi people initiated the intensive form of reindeer husbandry (the old form of husbandry prior to 1900 AD, the modern reindeer husbandry is called extensive) is important because this is also the time when the impact on the forest would have increased. Some researchers suggest that the intensive form of reindeer herding became common during 500 AD (Aronsson 1991), others during 1200 – 1300 AD (Storli 1993) and still others during 1400 – 1600 AD (Mulk 1994). During this form of intensive reindeer herding the animals where tame and herded in small groups close to the forest line (Aronsson 1991). The forest line gave a good supply of firewood, the camp was protected against strong winds and the grazing areas were close (Emanuelsson 1987).

The aim of this study was to examine past vegetation changes with pollenanalysis at the forest line right next to seven stalo dwellings in the Vindelfjällen area, northern Sweden. Around the stalo dwellings the forest line is considerably lower than in the surrounding area (fig. 4). I wanted to answer these questions; How did the people that lived in the dwellings affect the surrounding vegetation? How did they affect the forest line? I have also discussed how climate affects the forest line and evaluated the importance of its past history when it was used as a climatic indicator in the Swedish Scandes.

Material and method

Study area
The study area is situated in the northern part of Vindelfjällen nature reserve about 7 km southeast of the Vindelkroken Sámi settlement (fig. 3). Vindelfjällen nature reserve is the largest reserve in Sweden with it's 550 000 hectare. The area consists of both high alpine mountains about 1700 m.a.s.l., like Ammarfjället and Norra Storfjället, and valleys located 400 m.a.s.l. The Vindelvalley is a productive valley where mountain birch forms the forest line at about 700-750 m.a.s.l. On the east side of the valley, parallel to the creek and overgrown with *Betula nana*, lies seven Stalo dwellings (fig. 4). They are situated 680 m.a.s.l. and the area around them (about 200 m x 700 m) remains treeless even though trees grow on the same altitude in the surrounding area. When Ernst Manker examined the dwellings he concluded that they had all the common characteristics; i.e. oval peat wall, lowered floor plan and a hearth in the middle (Manker 1960). He also measured the width and length of the dwellings and the space between them.

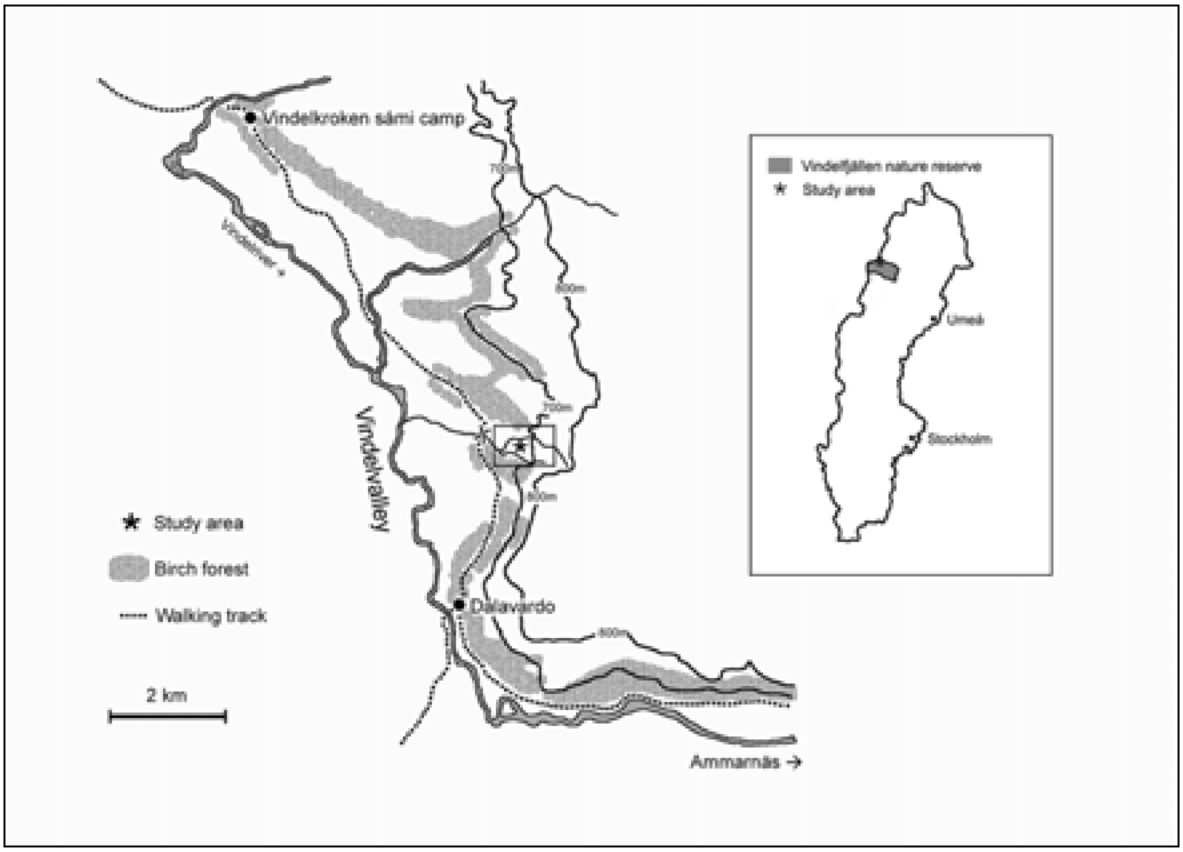

Figure 3. Map over the Vindelvalley and the study area. In connection with the distribution of birch forest, two elevation lines have been added (700m and 800m). The inserted map show where in Sweden Vindelfjällen nature reserve is located.

Pollenanalysis
Pollenanalysis is a method developed to study vegetation composition and changes in the past by identifying and quantifying pollen (Moore et.al. 1991). Because of the resistant outer coat of the pollen grain it can be preserved in anaerobic environments like mires, lake sediment and humus in the ground. Pollen grains at different depth of a sediment/peat core is studied and counted under a microscope. By presenting the results in a pollen diagram it is possible to interpret the pollen assemblages and reconstruct the vegetation history. Pollen analysis has several applications, including reconstruction of vegetation history, past climate and human impact on vegetation.

Sampling site and preparation of pollen
The wet hollow (66^{o}12'944N/ 15^{o}40'471E) where the sample was taken lies 130 m to the SE of the stalo dwellings (fig. 4). Today the vegetation around it consists mostly of *Betula nana*, *Empetrum nigrum*, *Vaccinium vitis-idaea*, *Carex bigelowii*, *Vaccinium uliginosum*, *Salix*, *Caltha palustris*, *Salix*, *Alchemilla*, *Solidago virgaurea*, *Geranium sylvaticum*, *Eriophorum vaginatum* and *Equisetum*. In the hollow a 50 cm deep peat core was collected in September 2002 with a Russian peatcorer (Moore et al. 1991). It was wrapped in plastic film and stored in a freezer (-20 ^{o}C). The core was sampled at 1 cm intervals from 5 cm to 27 cm and at 5 cm intervals in the top and bottom (0 to 5 cm and 30 to 45 cm). One cm^3 was extracted from each level of the peat core and treated with the standard method using KOH and acetolysis to "clean" the samples from organic matter other than pollen and spores (Moore et. al. 1991). For preparation of microscopic slides the pollen were mounted in saffranin-stained glycerine. For each level, at least 500 pollen and some spores were counted. The keys in Moore et. al. (1991) and a reference collection at the Department of Forest Vegetation Ecology, SLU in Umeå, were used for identification of pollen and spores.

To be able to distinguish the shrub *Betula nana* from mountain birch trees and thereby discuss the deforestation process, the birch pollen were divided in size groups, <25µm and >25µm. In the pollendiagram, "shrubs" is the pollensum of *Salix* and *Betula*<25µm. The size of birch pollen was measured from the pore to the outer surface of the opposite wall. Even though variations occur it has been shown that among the birch species *Betula nana* pollen occur more frequently in the smaller size group (<25µm) and mountain birch in the larger size group(>25µm) (Mäkelä 1999). The percentages of each taxa were put together in a pollen diagram using the computer programs Tilia and Tilia graph (Grimm 1990). In the diagram some pollen have been divided into a group called apophytes; i.e. plants that occur naturally but are benefited by human influence. Included in this category is Asteraceae, *Plantago lanceolata*, Poaceae, Caryophyllaceae, *Artemisia vulgaris*, Chenopodiaceae and *Rumex* (Hicks 1996). Charred particles and some spores were also counted. The charred particles were also divided in size groups, >25 -<50µm and >50µm. Large charred particles has a shorter dispersal distance and thus indicate a more local origin (Patterson et. al. 1987). *Gelasinospora* is a fungi who lives on coal and animal feces and can be used as an indication of fire if it occures together with coal. (van Geel 1978).

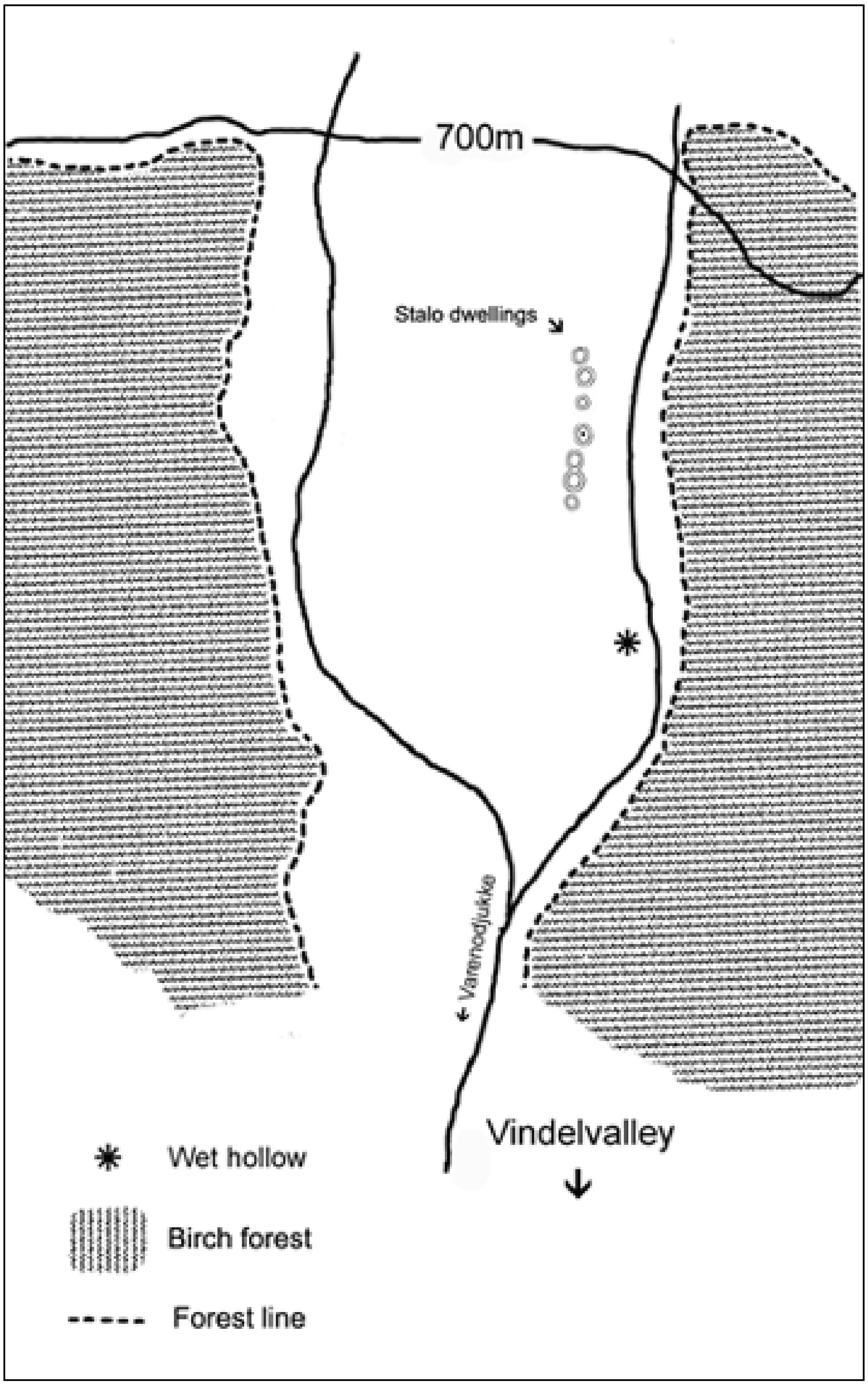

Figure 4. Map over the study area that shows the distribution of birch forest and the altitude of the forest line. The distance between the wet hollow and the stalo dwellings is about 130m. The Vindelvalley is located at the bottom of the map. The direction of north is to the left.

Results and discussion

The result is presented in a pollendiagram (fig. 5) that has been divided into three different zones, each reflecting major changes in the vegetation in more than one pollen taxa. Both latin and common names are presented in the pollendiagram.

Phase A – Forest dominated landscape
This phase was characterized by large amounts of tree pollen. Pine (*Pinus sylvestris*) pollen is the dominating pollen type. Alder (*Alnus sp*.) and birch pollen were present in equal amounts in the beginning of this phase but in the end of the phase the amount of alder pollen decreased and birch pollen increased. Pine decreased in the end of the phase. Other pollen types that were present include Cyperaceae and *Filipendula*. Polypodiaceae spores were also present in considerable amounts but decreased in the end of the phase.

High amounts of tree pollen indicate that a mix of alder, birch and pine forest dominated the area. Pine was growing at higher altitudes during this phase because of a more favourable climate (Aas & Faarlund 2001). During this time the wet hollow could be considered to be a "closed canopy site" because it was surrounded by trees. In a closed canopy site the pollen influx area is small, the site receive less long-distance dispersed pollen and most pollen originate from within 20 to 30 m (Bradshaw 1988). Thus, the results reflect very local vegetation changes. This is especially important when trying to trace human impact. High amounts of tree pollen indicate that the forest line was situated above the sampling site (Hicks & Birks 1996). It probably consisted of both birch and pine or only birch as some evidence suggests that a birch belt occurred above the pine-birch forest around 4000 BC in the Scandes (Kullman 1988). The decrease of pine in the end of the phase could be due to a initial human impact; i.e. the establishment of the stalo dwellings. Presence of alder, Cyperaceae, *Filipendula* and high amounts of Polypodiaceae spores showed that the area was fairly wet and productive initially. The fact that alder decreased in the end of the phase suggest that the area became drier.

Phase B – Human impact.
The amount of pine pollen decreased gradually during this phase with a sharp decline at 14 cm. The amount of birch pollen was quite constant while there was an increase in spruce (*Picea abies*) pollen. The pollen curve for shrub species shows a slight increase. Many of the apophytic pollen types increased. The amount of Polypodiaceae spores is less in this phase than in the previous. *Gelasinospora* and charred particles now occurred for the first time.

The first signs of human impact occured when the stalo dwellings where established as pine continued to decreased gradually and many of the apophytes increased at the same time. The people who settled in the area probably cut down pine for building material and for firewood. The sharp decrease of pine around 14 cm could indicate that the area around the stalo dwellings became completely deforested at this time. This could have

Vindelkroken, Vindelfjällens nature reserve

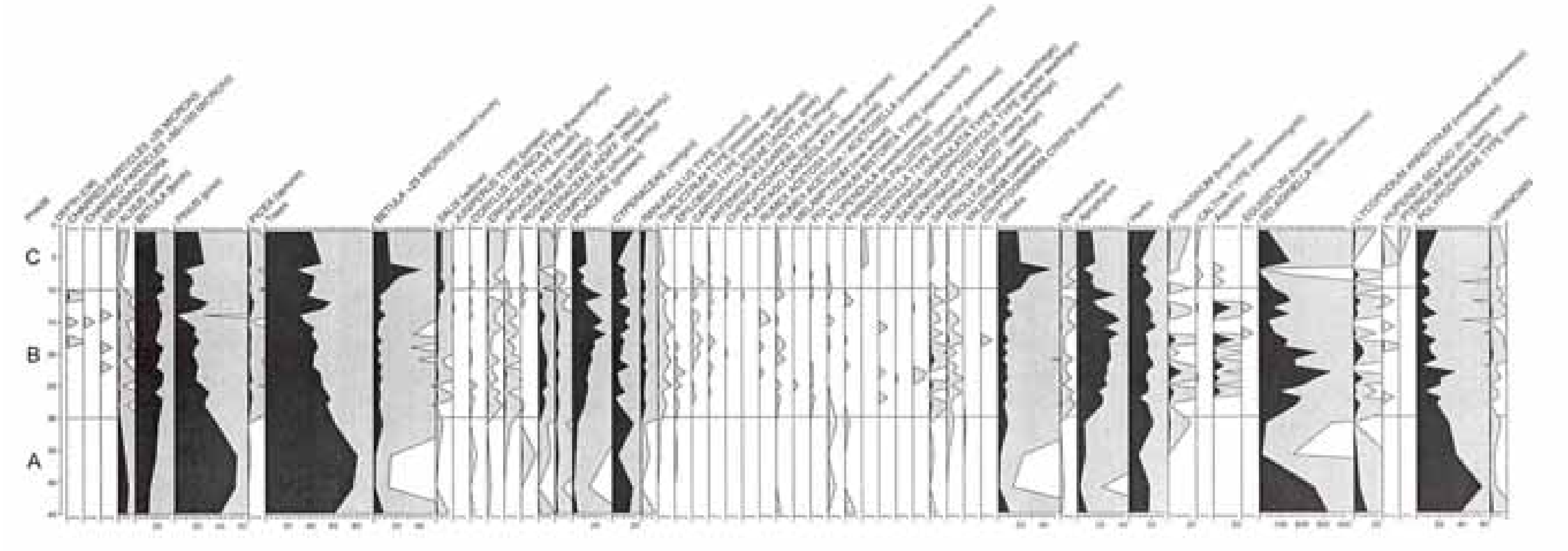

Figure 5. Pollendiagram from the wet hollow. The numbers on the vertical line to the left show the depth (cm) of the peat core. The horizontal lines divide the pollendiagram into three phases (A – Forest dominated landscape, B – Human impact and C – Continued human activity). The black fields show pollenpercentage amounts and grey fields show parts per mille amounts.

lead to erosion of the area and a lower productivity. The increase of spruce pollen and the fact that birch didn't decrease could represent an increased regional influx because the amount of trees around the wet hollow decreased. Birch was still present in the area around the dwellings. Also supporting the interpretation of human impact is the increase of apophytic plants like Asteraceae, *Plantago lanceolata*, *Artemisia vulgaris*, *Rumex*, *Polygonum bistorta* and *Epilobium* (Räsänen 2001, Hicks & Birks 1996). They reflect a more open landscape with a greater influx of light. According to a study made by Räsänen (2001) *Rumex acetosa/acetosella* is strongly correlated with settlements. Poaceae pollen has been connected with both trampling and grazing (Räsänen 2001), although this has been contradicted by Hicks and Birks (1996) who claim that Poaceae can only be regarded as an indicator of open unforested conditions. With more open conditions the amount of light increased and created a less favourable environment for Polypodiaceae, which decreased. Presence of *Gelasinospora* and charred particles can be attributed to human impact. Humans could have used fire to change the vegetation to attract animals for hunting or to provide better grazing grounds for the domesticated animals (Hörnberg 1999). Also, the charred particles could derive from the dwelling hearths. Bennett et. al (1991) have demonstrated that charred particles can spread 100 m from small campfires. Because of the low frequency of natural fires in the alpine area (Granström 1993), human impact seem to be the most probable reason for the presence of Gelasinospora and charred particles. Altogether this points toward an increased anthropogenic influence, vegetation changes in the forest floor and a depressed forest line.

Phase C – Continued human activity
After the sharp decline in pine pollen the amounts recovered to some extent. The amount of birch and spruce pollen was stable. In the beginning of the phase pollen from the shrub species *Salix* and *Betula*<25µm (interpreted as *Betula nana*) sharply increased at the same time. Pollen from the apophytic plants decreased but there are still occurrences of Asteraceae, Poaceae, *Artemisia vulgaris* and *Rumex* during the whole phase. Low amounts of *Juniperus* pollen also occured.

The results indicate that the area around the dwellings was overgrown by *Salix* and later *Betula nana*. Although the stalo dwellings had been abandoned, the intensive reindeer herding in the area still affected the vegetation. Occurrences of Asteraceae, Poaceae, *Artemisia vulgaris*, *Rumex* and *Juniperus* indicate that the area was still used. Because of the proximity of the Norwegian border the valley has been an important trade route to Mo I Rana and the Atlantic coast during 1800 AD and widely populated. Today the area consists of numerous traces of reindeer enclosures and areas of park like mountain birch forest.

Response to a changing environment
In a long time scale the position of the forest line is determined by climate related mechanisms (Hofgaard 1999). In Scandinavia, throughout the Holocene, gradually lowered summer temperature and greater snowfall has caused the pine to retreat to lower altitudes while the subalpine birch forest emerged (Kullman 1995). In a shorter time scale the tree line position is a result of factors like seed production, seedling and tree survival

and tree vitality (Hofgaard 1999). These factors are determined by variations in temperature and precipitation, frost damage, snow depth, soil nutrients, insect outbreaks, grazing and human impact. These factors have caused the tree line to fluctuate back and forth in altitude trough time. The tree line is continuously in a process of recovering from past disturbances and thus in a non-equilibrium state in relation to climate. In the Abisko area, northern Sweden, an expansion of the tree line has been recorded in spite of a cooling trend after the mid 20th century (Emanuelsson 1987). Since the area has been subjected to strong human influence in the past it is probably an effect of ceased human impact.

During 2001 the office of Custodian of National Antiquities and Västerbottens museum searched the area around Vindelkroken for ancient remains (Andersson et. al. unpublished). Stone age settlements were found in the alpine zone and findings of quarts and a boot shaped shale knife indicate that the area were used around 5000 BC. Conclutions can also be drawn, from remains of reindeer enclosures, hearths and areas of open park like mountain birch forests, that the study area have been used during the intensive reindeer herding, i.e. from 1600 AD. Because the the human activities seems to have been concentrated close to the forest line, both during the stalo period and the intensive reindeer herding period, the human impact in the Vindelkroken area has caused the tree line to be in non-equilibrium with the climate.

Grazing animals

In the Vindelkroken area, from 1600 AD, the grazing animal that has affected the vegetation the most is the reindeer. It is difficult to discuss previous impact by reindeer or how the vegetation looked like before humans influenced reindeer densities, as reindeer and humans have interacted continuously since the most recent Ice Age. Humans and reindeer arrived to Scandinavia at approximately the same time immediately after the inland ice melted (Suominen & Olofsson 2000).

Oksanen et. al. (1995) have shown that grazing by reindeer is the major determining factor, together with edaphic and climatic factors, modifying the mountain birch forest structure. When predicting the impact of grazing animals on vegetation diversity the most well known model is called the "intermediate disturbance hypothesis" (Connel 1978, Fox 1979). When grazing is low, plant diversity is low due to competitive exclusion, intermediate grazing pressure leads to high diversity and high grazing leads to low diversity due to stress. Studies show that grazing can improve the early phase of tree regeneration by providing patches of bare soil for the seedlings. On the other hand, seedling survival in grazed areas has been shown to be poorer compared to fenced areas. Helle and Kajala (1992) showed that on heavy grazed summer pastures the leaf biomass decreased with as much as 90% of the total biomass in the field layer up to 130cm in height. These effects by grazing animals is often apparent at the forest line (Hofgaard 1999).

The concentrated use of the forest line area during the intensive form of reindeer herding (prior to 1900 AD) created a open forest structure with good food availability and less insect attacks. When the intensive reindeer herding was abandoned and replaced by the modern extensive form of reindeer herding the impact on the forest line decreased which favoured regrowth of the birch forest in most areas.

Catastrophic ecosystem shift in Vindelkroken

Many human disturbances can be considered to be episodic and succeeded by a period of recovery (Hofgaard 1999). In this study, the recovery has not occurred in the area around the stalo dwellings. If disturbances are strong and persistent, a catastrophic shift in the ecosystem can occur. The fact that there is a large open *Betula nana* heath in the proximity of the stalo dwellings at Vindelkroken today instead of birch forest gives us a clue about the magnitude of past impact on the forest vegetation that the climate is not responsible for. The results show large human impact on the vegetation. Since the dwellings were at least abandoned by the end of 1600 AD the trees have not been able to regenerate for 300 years. Studies have shown that ecosystems can, if subjected to severe "pressure", shift to an alternative but contrasting state (Scheffer et. al. 2001). When the pressure reaches a certain level an ecosystem passes a threshold and makes a "catastrophic" transition to an alterative state.

In the case of Vindelkroken this alternative state could be the *Betula nana* heath. Cutting of trees and overgrazing could have caused soil erosion close to the stalo dwellings. Nitrogen is one of the most limiting nutrient in alpine soil. The symbiosis with the nitrogen fixation bacteria *Nostoc sp.* and the moss *Pleurozium schreberi* has been found to be an important source of nitrogen (DeLuca et. al. 2002). However, the cryptogamic crust of lichens, mosses and cyanobacteria is dependent on the availability of surface moisture (Wookey & Robinson 1997). When the area around the stalo dwellings was deforested, erosion occurred, it became drier and the source of nitrogen fixation, one of the most important factors for ecosystem production and the base for successional development, disappeared. An event that could have further sustained and accelerated the degradation process in the study area is the "Little ice age"; i.e. in 1350 AD a climatic detoriation started with lowered temperatures that in Scandinavia culminated around 1600-1700 AD (Grove 2001). The low temperatures lead to a descending forest line and advancing glaciers. During this time period the intensive reindeer herding could also have had a large impact. The harsh climate of the "Little Ice Age" together with continued grazing pressure, less snow cover (more open conditions) and loss of nitrogen fixating bacteria hindered new tree seedlings to emerge and recover to the previous state, birch forest.

A similar shift might have occurred in Iceland (Aradottir & Arnalds 2001). In Iceland the birch forest today covers 1165 km^2 but it has been estimated that it once covered as much as 40 000 km^2. Soon after the Viking settlement (around 850 AD) in Iceland there was a rapid population increase wich lead to deforestation and a widespread ecosystem degradation. The settlers cleared large areas of woodland for building material, fuel and iron making. At the same time the grazing pressure by especially sheep increased in the birch forest. Sheep grazed on the basal sprouts of the birch and since basal sprouting is an important regeneration strategy for birch this had large negative effects on the birch forest. The clearing of the forest by the settlers and the effects of grazing resulted in an ecosystem shift and a total barren land with very low productivity. This means that the recovering of birch woodland on Iceland may take a very long time. Although the conditions in Iceland differ from the conditions in the Scandes, high mountain vegetation is especially sensitive to erosion processes. Studies have shown increased erosion and a decreased lichen and vegetation cover in some areas in Sweden, changes that are similar to those in Norway, Finland, Greenland and Canada (Allard et.al 1998). It seems like the process of degradation is accelerated at higher elevations caused by shorter growing season, slower soil forming processes and windier conditions (Allard 2003).

The response of the alpine environment to a climate change is difficult to predict. No single limiting environmental factor that constrains ecosystem function exists (Wookey & Robinson 1997). Instead they are often highly coupled which makes it difficult to evaluate the effects of a single one. Furthermore, climate data and forest line position are rarely published together and climatic recording stations are usually not located close to the natural forest line (Körner 1998). There is no doubt that climate does affect the vegetation cover, but the speed of these changes at the forest line will be difficult to predict if human impact has been large in the past . The tree line, on the other hand, may react more quickly to climate change. However, in the “kampfzone” tree seedlings is constantly colonizing and retreating. Temporarily trees in the “kampfzone” and above the tree line may look vigorous and appear to colonize new area and temporarily look suppressed and appear to be retreating (Hofgaard & Wilmann 2002).

The recent archaeological investigations in the Scandes show that these mountains have been used to a much larger extent than was previously believed. Many new remains from stone age settlements and the Sámi culture, have been found. To investigate how climate effects the forest line vegetation it is important to choose study areas where past human impact has been minimal. This might be a difficult task in many areas so we also have to understand how humans have affected the forest line in the past, as well as today. This study show that previous humans in the Swedish Scandes have locally changed the altitude of the forest line and affected it to such a large extent that tree regeneration was haltened. Thus, the perception of the Swedish Scandes as a “wilderness” area is a view that belongs to the past.

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