THE NATURAL HOLOCENE VEGETATION DEVELOPMENT AND THE INTRODUCTION OF AGRICULTURE IN NORTHERN NORRLAND, SWEDEN.

STUDIES OF SOIL, PEAT AND ESPECIALLY VARVED LAKE SEDIMENTS.

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Dissertation May 1990

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The natural Holocene vegetation development and the introduction of agriculture in northern Norrland, Sweden. Studies of soil, peat and especially varved lake sediments.

When the interior parts of the Luleälv valley were deglaciated about 9500 BP, an open ecosystem formed dominated by shrubs and dwarf-shrubs. A few hundred years later Betula and Pinus invaded and rapidly formed forests, and by 9000 BP Alnus had immigrated and become common in most of Norrland. With climatic improvement Betula and Alnus increased in abundance, and nemoral broad-leaved trees colonized from south to north: between 6000-3500 BP Ulmus and Corylus had become common as far north as Västerbotten. In Norrbotten, however, Betula and Alnus were the dominant deciduous trees.

Around 3400 BP Picea abies reached the coast of Norrland from Finland, established itself and within 300 years became the major forest tree along a coastal zone. It occupied the moist, fine sediment substrates in those areas which earlier had been mainly dominated by Alnus and Betula. Climatic deterioration resulted in a steady retreat of the more southerly forest elements, and by 2000 BP only small, remnant stands at isolated sites were left. Over the last 2000 years little natural change has occurred in the forest vegetation.

Man invaded the area soon after the deglaciation. These first occupants were hunters and fishermen, however, and their impact on the vegetation development was minor and restricted to small camp clearings. Not until an agricultural economy became established, did the influence of man become pronounced. In coastal Västernorrland and Västerbotten, traces of agriculture and animal husbandry occurred between 4700-2500 BP, but these first cereal cultivations were temporary, short-lived and occurred primarily at coastal sites. In those areas, permanent cultivation developed due to changed settlement structure during the first centuries AD. In the Luleälv valley in Norrbotten, cereal cultivation and animal husbandry was introduced between 500-1000 AD, although the hunter/gatherer economy continued to dominate, as it did in most of interior Norrland. Concomitant with the general agricultural expansion in Västernorrland and Västerbotten between 1000-1200 AD, permanent field cultivation developed in the coastal parts of the Luleälv valley. In the interior of northern Norrland, however, agriculture did not become important until the 17th-19th centuries.

Key words: holocene vegetation, agriculture history, ancient cultivation, cereals, anthropochores, pollen analysis, soil pollen, varves, sediment.
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This thesis is based on four papers, listed below, and includes a summary of the earlier investigations undertaken to study the vegetation history and the introduction of agriculture in Norrland. It consists of: 1) A brief description of pollen analyses undertaken in Norrland before 1970. 2) The Holocene forest history of northern Norrland, as interpreted from these and the modern pollen analyses made after 1970. 3) The development of agriculture in northern Norrland, as deduced from multidisciplinary projects which attempted to describe the role of man in ancient Norrland. 4) A brief summary of the four papers listed below.


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Abstract

The Holocene vegetation history of northern Norrland was studied by pollen analysis of sediment, peat and soil samples, with the aim to improve our knowledge about vegetation development in northern Norrland, and also about the history of man and the introduction of agriculture in the area. Earlier made pollen analyses from the four northernmost provinces were summarized and a series of new analyses from northern Norrland added. Pollen analyses were conducted on sediment and peat profiles from four sites in the Luleälv valley, in Norrbotten, and from Kassjön in coastal Västerbotten. Furthermore, the hypothesis was tested that pollen analysis of thin mor humus soils could be used to trace and identify ancient cultivated fields.

When the interior parts of the Luleälv valley were deglaciated about 9500 BP, an open ecosystem formed dominated by shrubs and dwarf-shrubs. A few hundred years later Betula and Pinus invaded and rapidly formed forests, and by 9000 BP Alnus had immigrated and become common in most of Norrland. With climatic improvement Betula and Alnus increased in abundance, and nemoral broad-leaved trees colonized from south to north: between 6000-3500 BP Ulmus and Corylus had become common as far north as Västerbotten. In Norrbotten, however, Betula and Alnus were the dominant deciduous trees.

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This thesis is based on four papers, listed below, and includes a summary of the earlier investigations undertaken to study the vegetation history and the introduction of agriculture in Norrland. It consists of: 1) A brief description of pollen analyses undertaken in Norrland before 1970. 2) The Holocene forest history of northern Norrland, as interpreted from these and the modern pollen analyses made after 1970. 3) The development of agriculture in northern Norrland, as deduced from multidisciplinary projects which attempted to describe the role of man in ancient Norrland. 4) A brief summary of the four papers listed below.


These papers will be referred to by their Roman numerals.
Reference sources for the study sites illustrated (left)

SWEDEN
1. Königsson 1970
2. Tolonen 1972
3. Huttunen & Tolonen 1972
4. Sonesson 1974
5. Engelmark 1976
6. Engelmark 1978
7. Engelmark 1979
8. Miller & Robertsson 1979
9. Segerström 1982
10. Königsson 1984
11. Küttel 1984
12. Wallin 1983
13. Wallin 1986a, b
14. Wallin 1989
15. Segerström II
16. Segerström III

FINLAND
17. Hjelmroos 1978
18. Reynaud & Hjelmroos 1980
19. Tolonen 1979
20. Vuorela 1986
21. Hicks 1988
22. Segerström & Wallin 1988

NORWAY
23. Vorren 1979

Figure 1. Location of pollen profiles from Sweden made after 1970, and those from Finland and Norway referred to in the text, and at which early agriculture has been inferred.
1. POLLEN ANALYSES IN NORTHERN SWEDEN BEFORE 1970

Since the beginning of this century when pollen analysis was invented (v. Post, 1916), it has been frequently used as a tool for studying past vegetation and climatic changes. However, in Sweden most work has been made on sites in the southern and central parts, and there have been few detailed studies focused on the northerly areas. For long, it was thought that during prehistoric time only a sparse population of hunter-gatherers had moved around in Norrland, and thus northern Sweden was regarded uninteresting from an archaeological point of view. Since it was usually the archaeological interests which initiated the studies of vegetation history in different areas, little or no effort was paid to use pollen analysis to identify prehistoric man in Norrland. Malmström (1923, 1927, 1932) studied soil hydrological changes and peatland expansion, and Lundqvist (1927) focused on the tapping catastrophe of Örträsket. They both used pollen analyses to obtain chronologies when interpreting changes in peat growth and lake level changes, and often divided the studied period into the sections before and after the establishment of *Picea abies*. Sandegren (1924) studied the post-glacial vegetation history of the Ragunda area and included five pollen analyses which mainly covered the time period prior to the *Picea* establishment. Aiming to correlate the post-glacial vegetation and mire development in the western parts of Norrland with the chronology in the eastern coastal parts, v. Post (1930) published a chain of pollen analyses from the coast of Hälsingland to the mountains of Härjedalen and defined a number of pollen levels general to the natural development.

Booberg's (1930), study of Gisselåsmyren presented the first detailed division of post-glacial forest development in northern Sweden. He identified six main pollen zones; the oldest (VI) in which *Hippophae* was present (vaguely divided into three sub-zones); a period dominated by *Pinus* (V); a *Betula* period with various QM-species (IV); a second *Pinus* period (III); the *Picea* period (II) and the youngest period with increased *Betula* (I).

Granlund (1932) focused on the history of Swedish ombrotrophic mires, although very little attention was paid to the development of the mires in the northern parts of the country (but Tavelsjömossen, near Umeå). In southern Sweden, he identified five recurrence surfaces (ca. 2300 BC, 1200 BC, 600 BC, 400 AD and ca. 1200 AD), indicating increased precipitation. At sites along the river Ångermanälven eight pollen analyses were dated by varve-counting of clay varves (Fromm 1938), which was the first study to give a detailed chronology of the post-glacial vegetation development in northern Sweden. He dated the expansion of *Alnus* to ca. 6300 BC, the thermal optimum to ca. 5000-3500 BC and the *Picea abies* expansion to about 1000 BC (Fromm 1938). Erdtman (1943) analysed soil pollen content to study the relationship between the local pollen accumulation and the vegetation at the actual sites. He stressed the importance of taking into account the herb pollen when discussing local vegetation development. Further, Erdtman (1943) also suggested that the development of
the podzol mor humus soils in Lapland had started with the establishment of 
Picea abies forests. Granlund (1943) included 20 pollen diagrams in the 
description accompanying the map of the Quaternary deposits of the southern 
part of Västerbotten. Four distinct forest development phases were identified, 
which fairly well matched those of Booberg (1930). Further, Granlund (1943) 
noted that two major recurrence surfaces (at ca. 500 BC and ca. 3500 BC) were 
common to most profiles studied. From Norrbotten, Eneroth (1951) presented 
three pollen diagrams and identified the different sub-fossil Betula species, and 
aimed to discuss post-glacial climatic variations. Lundqvist (1951) published two 
pollen diagrams from Kebnekaise in order to study the development of palsas. 
Arnborg (1952) briefly discussed the forest history at Frostviken, northwestern 
Jämtland.

The first 14C dated pollen analysis from Norrland was presented by Östlund et 
al. (1956) and Lundqvist (1957), and dated the Alnus rise to ca. 6600 BC and the 
Picea expansion to ca. 1000 BC at Adak, Västerbotten. Lundqvist (1963) 
discussed 12 pollen analyses from southern Norrland (most of them 14C dated), 
and he definitely questions the possibility to use recurrence surfaces as a means 
of dating horizons. Fromm (1965) included 18 pollen analyses in the description 
to the map of the Quaternary deposits of the southern parts of Norrbotten. His 
conclusion was also, contradictory however, to earlier suggestions (e.g. v. Post 
1930, Booberg 1930, Granlund 1943), that no recurrence surfaces, nor any clear 
pollen zonation could be identified except for the Picea expansion at ca. 1000 
BC.

The studies referred to above, although commonly based on a relatively low 
number of pollen grains counted, and most of them indirectly dated only by 
shore-line displacement data and pollen zones, gave a remarkably consistent 
view of the Holocene forest development in northern Sweden. The basis, 
however, for the vegetational and climate history of all Scandinavia, had been 
formalized earlier by peat-stratigraphical analyses (cf. v. Post 1906). 
Furthermore, the schemes proposed by Malmström (1923), v. Post (1930) and 
Booberg (1930) for the main northern vegetational shifts, and the general 
conclusions of v. Post (1944) about long-term post-glacial forest development and 
climatic changes, were mainly obtained by merely transferring knowledge about 
the past conditions in southern Sweden to the newly analysed sites in Norrland. 
For decades pollen analysis was an instrument used mainly for indirect dating, 
and for confirming environmental changes, which had been first identified by 
means of other techniques. Common, however, to all of these older pollen 
analyses which focused on northern Sweden was that almost none of them 
cluded non-arboreal pollen.

Among the first to include the non-arboreal pollen component was Fries (1956, 
1962) in the studies from Bensjö, southern Jämtland, and Hornavan, 
Norrbotten. However, not until the analyses by Sonesson (1968) in northern 
Norrbotten were made, was a real attempt made to interpret the general forest
development together with detailed information about changes among other floral elements. Sonesson (1968) proposed a new $^{14}C$ dated zonation of the pollen diagrams, that would fit better the changes specific to northern Scandinavia. The four phases in vegetation development were: the early Betula period (T1) before 7000 BC with high frequencies of Betula, Juniperus, Salix and Hippophae; the Betula/Alnus period (T2) ca. 7000-4500 BC; the Pinus period (T3) between 4500-1500 BC during which the first Picea pollen occurred; and finally the late Betula period (T4). Lundqvist (1969) included the main non-arboreal components in the 15 pollen diagrams in the descriptions accompanying the map of the Quaternary deposits of Jämtland. Most of the profiles were radiocarbon dated on several individual levels. Instead of adopting the zones proposed for northern Sweden by previous researchers, Lundqvist (1969) used the zonation concept valid for southern Sweden (cf. Nilsson 1964), i.e. the Blytt-Sernander climatic scheme (cf. Mangerud et al. 1974). According to Lundqvist (1969) recurrence surfaces (cf. Granlund 1943), were difficult to identify clearly in the fifteen studies.

From this stage on, the pollen analyses were of a "modern kind", with a relatively high number of pollen grains counted (500-1000 AP), and in which also the non-arboreal pollen were given a high interpretative value. Since then the role of man, fire and climate in northern Sweden have been discussed in more detail in the interpretation of pollen diagrams.

2. HOLOCENE FOREST HISTORY OF NORTHERN SWEDEN

As a result of the large-scale exploitation of the big rivers in Norrland, for hydro-electric power, numerous archaeological exploitation digs have been conducted since 1942. At these investigations thousands of prehistoric sites and remnants after human life were registered, and therefore, the role of early man in northern Sweden was reconsidered. A number of palaeoecological projects were initiated, with the aim to study the natural vegetation development, the environmental conditions for human subsistence and to assess the establishment and impact of an agricultural economy in Norrland.

Norrland is a very large area (almost 60% of Sweden), extending over 1000 km on a north-south axis and includes various climatic and vegetational regions. The following discussion will, therefore, mainly concern the northern parts of the area, i.e. the provinces of Västernorrland, Jämtland, Västerbotten, and Norrbotten (Fig. 1). It is, however, in this context appropriate to consider a few analyses from northern Finland too, especially those from the Torneälv valley although the pollen analyses are from sites which lie on the Finnish side of the river. The dates are, if not announced otherwise, given as uncalibrated $^{14}C$ years as given by the authors. When "calendar years" is suggested, it has been obtained by varve-counts.
After the ice-retreat, the Ancylus Sea reached its maximum areal extension, and the coast-line was in places more than 100 km to the west of the present day coast (Lundqvist & Nilsson 1959). Fjords stretched along the river valleys far into the interior of Sweden, and also, in Finland the sea reached about 100 km farther east than today. The sea was very large and, therefore, probably affected climatic conditions even more than today.

At first, when the land was exposed after the ice, open, unshaded ecosystems were formed (Sonesson 1974, Saarnisto 1981, cf. also Vasari 1962, Hyvärinen 1975). Lichens, herbaceous plants, grasses and sedges mixed with patches of shrubs and dwarf-shrubs occupied vast areas (Engelmark 1978). Important early immigrants in northern Sweden were Hippophae rhamnoides and Salix species (Tolonen 1972, Sonesson 1974, Engelmark 1978, Küttel 1984, Segerström II), which were abundant during a few hundred years until Pinus and Betula forests developed. In Västernorrland Corylus appeared early, indicating warm conditions, similarly, the early dominance of Pinus at inland localities in Västernorrland indicated dry summer conditions (Engelmark 1978).

Around 9000 years ago (calendar years) Alnus expanded rapidly in northern Sweden (cf. Tallantire 1974, Saarnisto 1981, Segerström II), and both Alnus and Betula became common for a period, between ca. 9000-6000 BP. In northern Sweden these two genera were of major importance (Engelmark 1979, 1982, Segerström II), and on the badly drained fine grained soils they dominated locally until about 3500 BP (calendar years, Segerström II, III). Corylus and Ulmus reached their northern limits in Västerbotten (Andersson & Birger 1912, Hultén 1971, Huntley & Birks 1983). In the Umeå area Corylus and Ulmus were well established as early as 6300 years ago, and for Ulmus a maximum representation was reached around 6000 BP (calendar years, Segerström III). The climatic conditions between 9000-6000 BP, particularly during the later half of this period, became more maritime with increased summer moisture and increased winter precipitation (Engelmark 1978).

Gradually, with land upheaval, the shoreline retreated eastwards and Norrland became larger, and the impact of the sea decreased correspondingly in those parts which became the interior of northern Sweden. In the inland areas the climate became more continental between 6000-4000 BP, with drier summers and more severe winters, with a concomitant decrease in temperature (Engelmark 1978). Sonesson (1974) concluded, for the northernmost areas that the temperature during growing season was at an optimum during the early pine period (T3a, around 6000 BP), and that generally dry conditions prevailed at that time.

Along the coast the forests generally changed little during this period, probably because of the more stable maritime influence (Engelmark 1979, Segerström III). At Kassjön and Lundfors many herbaceous plants were more common than later, and were probably associated with the light deciduous forests, which were
locally very common. For example, at Kassjön, *Humulus lupulus* (wild hop) grew within the moist *Alnus* forest close to the lake. Fries (1958) suggested the same kind of natural *Humulus lupulus* occurrence in southern Sweden. *Urtica dioica*, a nitrophilous species was probably abundant on more nutrient rich soils in the area (Segerström III). *Polypodiaceae* species also became common in the wet forests or swamps, as at many sites in Fennoscandia (Engelmark 1978, 1979, Huttunen 1980, Segerström II and III).

Between 6000-4000 BP *Picea abies* expanded in east and central Finland (Tolonen & Ruuhijärvi 1976, Huntley & Birks 1983), and the earliest finds of *Picea* pollen in northern Sweden date to that period, although always at low frequencies (Fromm 1938, Granlund 1943, Sonesson 1974, Segerström II, III, cf. also Tallantire 1980). Pollen distribution over long distances is a well known phenomenon (Hesselman recorded *Pinus* pollen far out over the sea as early as in 1919), and most of the early occurrences are probably due to long-distance dispersal. For example, in northern Finland *Picea abies* pollen occur in lake sediments far north of its present day limits (Hyvärinen 1975). However, it still must be considered possible that *Picea*, which has seeds that are easily spread over long distances by wind (cf. Tallantire 1980), may have become established in northern Sweden at that time, but only as small isolated stands or single trees. However, according to Tallantire (1972a, 1977) it was when the winters became more severe, *Picea* became competitive enough to establish itself on a larger scale.


The expansion of *Picea* was a major vegetational change and was also accompanied by other changes. The soils were affected by increased podzolisation (Tamm 1920, Erdtmann 1943, Schmidt-Vogt 1986), and consequently there was a decrease in soil fauna, and the mineralisation processes in the soils became probably mainly fungal (cf. Schmidt-Vogt 1986, Bridges 1986). Light demanding herbaceous plants, which had been common in the open *Betula* forests were replaced by *Vaccinium myrtillus* and *Vaccinium vitis-idaea*, which were better adapted to the closed ecosystems dominated by *Picea*. In the interior of northern Sweden, *Picea* expanded about 500-1000 years later (Huttunen & Tolonen 1972, Engelmark 1978, Königsson 1984, Olofsson &
Widell 1986, Wallin 1986a, b, Segerström II). At the westernmost and northernmost sites, however, it never gained the same importance as at more coastal sites (Robertsson 1971, Sonesson 1974, Segerström II).

Between 3000-2000 BP (calendar years), both Ulmus and Corylus disappeared from most of Västerbotten. Only a few small stands remained at isolated localities in Jämtland and Västerbotten, where localized climatic and soil conditions favoured these thermophilous species (Andersson & Birger 1912, Malmström 1934).

During the last 2000 years the boreal forests have undergone little natural change. The main cause to disturbance and change has been the increasing impact of man, both in terms of cultivation and animal husbandry, and during the last two centuries as a result of the increasingly important forest industry.

An important aspect of the vegetational development is that Norrland includes areas, which primarily were deglaciated and have not been under the sea, and areas which have been formed later, due to isostatic land upheaval. In the areas above the highest shore-line a certain long-term stability in the forest vegetation was achieved soon after the ice-retreat. The initial, open and tree-less ecosystems prevailed only for a few hundred years, with the exception of the westernmost mountain areas. Betula and Pinus rapidly invaded and formed a mosaic of dry Pinus forests and moister vegetation characterized by Betula stands. Below the highest shore-line, however, there has been a continuously eastwards moving frontier at the rising sea-shore where the vegetation has been continually dynamic, to a certain degree similar to the early ecosystem type of the inland areas.

However, after this short-lived, highly dynamic phase was over, most of the herbaceous plants and bushes disappeared. When pollen from these kinds of plants later occur in peat and lake sediments, they probably reflect temporary openings in the forests, for example after forest fires or storm fellings, or originate from the vegetation close to the lakes and rivers. Such indications of disturbance occur only sparsely prior to land-use.

3. HUMAN IMPACT AND AGRICULTURE IN NORTHERN SWEDEN

At the end of the last glaciation, as the ice retreated from Fennoscandia, both plants and animals rapidly immigrated and established themselves on the newly exposed land areas. With the improving climate, Norrland became rich in natural resources, such as large terrestrial animals, birds, seal, fish and edible plants. The first humans which invaded these northern areas were hunters and fishermen; more than 5000 sites have been found which can be related to hunting cultures dating to the 6000 year period before Christ (Baudou 1990). Very little is, however, known about how and to what extent these early cultures affected natural vegetation development and the boreal ecosystem. The
non-cultivating hunter-gatherers, probably only changed their environment locally, i.e. at camps by tree felling for constructions and firewood. They may also have known how to increase local production of fodder, to attract wild animals such as elk, although for that we have no clear evidence in the pollen records. A moderate impact on the local vegetation, as of a hunters' camp, is difficult to detect in regional pollen analyses made from large influx basins (Andersen 1970, Hicks 1988) mainly because the small-scale local changes become hidden by regional pollen input (cf. Jacobson & Bradshaw 1981). Pollen analysis of thick, well stratified mor humus profiles (cf. Bradshaw 1988) or thin mor humus soils as described by Segerström (IV) is one method to identify the local impact of man, and to investigate the extent of the areas affected. However, also when analysing more locally derived pollen assemblages the impact of a hunting society on the vegetation must be difficult to identify with any certainty. It may be reflected in the pollen spectrum, for example by a change in the tree pollen composition and an increase in herbaceous, light demanding and nitrophilous species. Such a change, however, could be natural as well, for example near the coast or the river shores, and after storm felling or forest fires. Therefore, there are only a couple of pollen profiles from northern Sweden, with indications of disturbance, which can be unambiguously related to the early hunting cultures.

Two pollen diagrams from the Lundfors area, Västerbotten were interpreted to obtain a detailed description of the local vegetation conditions that had prevailed at a Mesolithic dwelling site (Engelmark 1979). The study at Lundfors included a close co-operation between archaeology and palaeoecology (Broadbent 1979), and pollen and macrofossil analyses contributed to a detailed description of the past natural environmental conditions of the area, with special respect to the human requirements (Engelmark 1979). Some of the potential natural food resources of the boreal coniferous ecosystem and their probable utilisation were also assessed (Engelmark 1979). Wallin (1989) suggested human impact of non-cultivating hunters at Juvuln, in Jämtland about 740 BC and 300 AD. He based his conclusions on increased frequencies of apophytic species in the pollen assemblages, probably as a result of small clearances at the dwelling. In northern Finland (at Iso-Mustajärvi in the Torneälv river valley, at the Swedish border), finds of Plantago major and Urtica pollen, dated to ca. 3400 BC, have been interpreted as indications of hunter settlements (Hjelmroos 1978, Reynaud & Hjelmroos 1980).

With cultivation, cereals and weeds were introduced and these produce pollen evidence of a more direct nature. However, questions still remain: what interpretative value should single or a few finds of indicator pollen be given; what source area do they represent; and how large cultivations are they representing?

The pollen diagrams which are published have provided quite a good picture of the spread of sedentary farming in northern Sweden, although the analyses only
assess the development in a few areas, most of them along the coast. Königsson (1970) attempted to give a full evaluation of the local vegetation changes at Bjurselet, Västerbotten, and to identify the very early localized human impact on the boreal ecosystem. It was the first pollen analysis in northern Norrland to confirm the archaeological conclusions of an early important human influence this far north, and the earliest traces of cultivation of *Hordeum* were dated to ca. 1500 BC (radiocarbon years). At Iso-Mustajärvi, at the Finnish border the first cereal pollen were registered about 2500 BC, indicating clearances and cultivation, dated to about the same time as in southern Finland (Hjelmroos 1978).

The study by Huttunen & Tolonen (1972) in Ångermanland (including eight pollen analyses), stressed the potential of interpreting the occurrence of various apophytes and anthropochores and also discussed the importance of early agricultural influence on the natural vegetation development. It was a large-scale regional study of agricultural development, in an area ranging from the Bothnian coast to localities more than 100 km inland. Huttunen & Tolonen (1972) showed that there was apparently no Early Neolithic "Landnam" phase corresponding to the South Swedish development, although some agricultural activities dated to a time-period about 2500-2000 BC were recorded. These early cultivations, which were indicated by low occurrences of *Hordeum* and *Triticum* type pollen grains and by a few other anthropochores and apophytes, were probably very localized and small-scale and restricted to coastal sites. At the end of the Bronze Age (1000-500 BC) the indications of human influence in Ångermanland decreased, although pollen from plants indicating grazing still were found.

Around Umeå, in coastal Västerbotten pollen analyses indicated an early agricultural phase at ca. 900-700 BC (Tolonen 1972, Engelmark 1976). Pollen grains of *Hordeum*, *Triticum*, *Avena* and *Secale cereale* were found. This first phase of agriculture, however, was followed by a regression ca. 400 BC. Engelmark (1976) considered short-term vegetation changes both natural as well as human induced, and discussed the importance of very local small-scale differences in vegetation development between adjacent study sites. Engelmark (1976) also discussed several "hemerophilous" pollen types, and the validity of interpretation in terms of agricultural impact in the boreal coniferous ecosystem. At Kassjön, a lake only 11 km from Tolonen's and Engelmark's study sites, no local cultivation and only a few weed pollen were registered for this period (Segerström III). It is likely that this phase of settlement was still closely attached to the coast or rivers, leaving Kassjön outside the settlement zone because of its location within the forest a few km from the river.

In middle Norrland the earliest finds of agriculture are traces of stock-breeding, and cereal cultivation (*Triticum*) registered ca. 2700 BC and 1800 BC at coastal sites in Ljungan river valley, Medelpad, in Västernorrland (Engelmark 1978). The study included six pollen analyses at both coastal and inland sites.
However, no traces of Neolithic agriculture were found at the inland sites. In this comprehensive study by Engelmark (1978) attempts to interpret the small-scale vegetational changes were enhanced and a comparison between inland and coastal sites was made. Differences in settlement patterns between the sites were explained as being a result of local environmental and climatic differences. Engelmark (1978) concluded that in interior Norrland, fertile soils were considerably less common than along the coast, and the maritime impact near the coast made cereal cultivation less hazardous than at the more continental inland sites.

In the Anundsjö region, in coastal Västernorrland 16 pollen analyses were undertaken within a small area (Miller & Robertsson 1979). The results showed the development of the local forest as well as described the stages of the long-term development of the Baltic. Very few signs of early agriculture were recorded, with the exception of two sites where finds of cereal type pollen were dated to ca. 1000 BC (Miller et al. 1979). In Fjällnäs in the southern part of the Scandes Mountains, the first sporadic cultivation and impact from grazing was dated ca. 2000-1500 BC, although a long period with little or no human impact followed after that (Königsson 1984).

In conclusion, the first phase of agricultural development in northern Norrland was characterized by small-scale cereal growing or extensive animal husbandry introduced at scattered sites. The settlements were short-lived, sporadic and attached to the coast where the sea-shore meadows provided natural fodder, pasture and easily cultivated productive land. Agriculture during this phase probably was never of a major importance for subsistence, instead it was a complement to hunting and fishing. This phase proceeded until about the first centuries AD.

The second phase of the development of an agricultural economy in Norrland started during the first centuries AD. Agriculture occurred at an increasing number of sites and became permanent in some areas. At that time permanent cultivations developed at Bjurselet, Västerbotten (Königsson 1970). Between 400-600 AD the agriculture indicators increased also in Ångermanland (Huttunen & Tolonen 1972) and the first Secale cereale pollen were found. In the Umeå area permanent settlement became established between 500-750 AD (Tolonen 1972, Engelmark 1976). At Kassjön, no cereals were registered for this period, but certain forest changes were identified and found to be common for the region, and further, finds of Plantago lanceolata and Plantago media/major indicated an increased human impact in the local forests (Segerström III). At Edefors in the Luleälv valley, vague indicators of animal husbandry and a few cereal type pollen grains were found, but at this time (during the first 1000 years AD), no permanent agriculture developed into the Luleälv valley (Segerström II).
The agricultural influences apparently spread, however, as a wave all along the Bothnian coast. At sites in Ångermanland and Västerbotten it occurred as sedentary farming, and farther north and inland up along the river valleys probably as introduction of animal husbandry and small temporary cultivations. Also, in the Torneälv valley the impact of man increased during the first centuries AD (Hjelmroos 1978).

Around 1000 AD the third phase in the development of agriculture appeared in northern Norrland (Sundström 1983). In the Umeå area there was a remarkable increase in cereal cultivation, and forests were cleared for pasture (Engelmark 1976). At Kassjön, cultivation became permanent from about 1200 AD (calendar years, Segerström III). According to Huttunen & Tolonen (1972) marked settlement and agricultural expansion in coastal Ångermanland was identifiable from about 800-1000 AD onwards. A similar picture applies for Medelpad too (Engelmark 1978), with an increasing impact at those sites which had become exploited during earlier phases, and with new clearances at a number of other sites. In the southern Scandes Mountains cereals occur again, and both Hordeum and Secale were cultivated (Königsson 1984). In the Luleälv valley permanent agriculture was established at Heden, near the coast, and farther up the valley the impact of man grew stronger (Segerström II).

During the period of the 15th-18th centuries a major increase occurred over most of Norrland, including many inland and mountain areas. The inland colonisation and cultivation was supported by the government (cf. Egerbladh 1987), and it appears that in many of the inland areas cultivation then occurred for the first time on a larger scale, at least according to the pollen analyses. Besides the formerly mentioned studies, this is also revealed from a series of pollen analyses made in the 1980's in order to describe the vegetational development at a number of pre-historic dwelling sites, and to assess if any impact of man could be identified. Six studies were in Västerbotten located in the Åsele area (Segerström 1982, Wallin 1983), Vojmsjön and Stalon (Wallin 1986a, b) and in Jämtland, in Juvuln (Wallin 1989). All profiles covered more than the last 8000 years. Indications of agricultural impact were very weak at all sites, and mostly of a late date (17-19th centuries). The earliest signs were registered at Åsele, where permanent cereal cultivation was dated to early Medieval time (Segerström 1982).

The most recent studies are from coastal Ångermanland where a number of varved lake sediments have been found and analysed, providing new details on the chronology of the land uplift in the area and about the local vegetational development (Wallin, work in progress). In this thesis my studies from the Luleälv river valley and from the Umeå area are presented and they are summarized below.
4. SUMMARY OF PAPERS I-IV INCLUDED IN THE PRESENT THESIS


A method for quantitative sub-sampling of fresh sediment cores and an alternative method for calculating net annual accumulation rates of different sediment constituents is presented.

From a varved sediment core taken with a large Russian peat corer samples which comprise a known number of years (e.g. 10 years) and in which each varve represent a given area of the lake bottom (e.g. 1 cm²) can be cut out. Freeze cores can be sub-sampled following the same principle (see Renberg 1981).

The samples taken for pollen analysis must be boiled in 5% KOH, treated with hydrofluoric acid (if necessary), and then with the acetolysis mixture (standard procedure for pollen preparation, e.g. Moore & Webb 1978). The residue is then diluted with water and weighed. After careful homogenisation sub-samples are transferred to plankton chambers and weighed. After filling up the chambers with water they must be left to allow pollen to sediment for at least 12 hours, after which all pollen of some easily identifiable pollen type (e.g. Pinus) in the chamber are counted with an inverted microscope. On the basis of the counts the total number of that pollen type (here Pinus) in the sediment sample can be estimated.

To determine the dry matter content of the sediment and the organic and mineral matter content, the samples taken must be dried, weighed, combusted and weighed (following standard methods, see e.g. Bengtsson & Enell 1986).

To estimate the mean net annual accumulation rate, the values obtained for pollen, organic and mineral matter content in the sediment sample are divided by the number of years and the area of the sediment sample. Tests presented in the paper clearly show the precision and repeatability of the method. The method has been used in two of the papers referred to below (papers II and III).


The paper includes five pollen analyses from a 150 km stretch of the river Luleälv in northern Sweden, and is the first series of modern pollen analyses along this major and important river. The study is a sub-project of "The Luleälv Project" (cf. Baudou 1980), and the aim was to use palaeoecological methods including pollen analyses of lake sediments and peat profiles to investigate the local and regional vegetation development at a series of sites along the river
valley. Of main interest were the natural resources and the human impact during the last two thousand years in the river valley.

Fisktjärnen, the site at Heden (Case study A), is a former coast locality. The sediment sequence is partially varved and was dated by means of varve-counts and three $^{14}$C dates. The development of the lake began with the formation of a river-side lagoon around 2600-2500 BP, which was entirely isolated from the river impact at about 2200-2000 BP. As a result of a rich nutrient state during the isolation phase, and the nearness to the river and to the sea, large areas which were affected by flooding formed open sea-shore meadows with abundant grasses, sedges and herbs. When the river impact ceased around 2000 BP, forest vegetation expanded on the formerly open shore areas and the lake became completely enclosed. At this stage Picea abies, which established itself in the region between 3000-2600 BP, represented ca 50% of the forest trees in the area. Whether there was any human impact during this early stage (late Bronze Age to early Iron Age) was difficult to assess. However, natural sea-shore meadows could have provided both winter fodder and pasture, as well as areas suitable for cereal cultivation. Although no clear evidence for agriculture at Fisktjärnen was found, human presence around 2000 BP in the area cannot be ruled out.

A permanent agricultural settlement and expansion took place at late Iron Age (ca. 1000-1200 AD), and both crop cultivation and animal husbandry probably became important. At that time a marked decline of Picea was registered, reflecting the increasing human impact in the area. Around the 16th-17th centuries Secale cereale was introduced in the area, but in general animal husbandry became more important than crop growing.

At Edefors (Case study B), two proximal varved lake sediments (Kroktjärnen and Strömbackatjärnen) were analysed. Standard pollen analyses, varve-thickness measurements, and determinations of mean net annual accumulation rates of pollen, organic and mineral matter were made.

Both lakes were initially riverside lagoons and strongly affected by the flooding river. Kroktjärnen was isolated from the river about 3000 BP and Strömbackatjärnen about 2000 BP, i.e. at about the same time as Fisktjärnen ca. 60 km downstream. At first, during the period before Christ both Betula and Pinus were abundant, but the latter became more dominant, at least during the last 2000 years. In general, the results are similar to those from coastal parts of Norrland. Picea was established between 2750-2500 BP and although common from ca. 2300 BP, was less important at Edefors than nearer the coast. During the last 1500 years Picea probably represented less than 20% of the forest trees in the area.

The initial impact of the river on the vegetation, i.e. hindering a closed forest development was indicated by erratic oscillations in the tree pollen curves, and regular occurrences of herbaceous plants such as Artemisia, Asteraceae,
Apiaceae, Chenopodiaceae, Humulus, Ranunculus, Rosaceae and Rumex species. After the lakes had been isolated from the river the forest encircled both lakes, as at Fisktjärnen.

Human impact is very weak throughout the studied period, but the first possible traces date ca. 1500-1000 BP. The fens and the shore-meadows around lakes in the area may have been used for winter fodder or summer grazing in a mixed economy with extensive animal husbandry. During the 13th century small-scale, temporary cereal growing occurred in an area close to Kroktjärnen (cf. Segerström IV). From approximately the 17th century onwards agriculture became permanently established near the river in an area ca. 5 km north of the lakes. At Strömbackatjärnen a settlement was established in late 19th century, as verified by the documentary records (The Archives of the Tresuary Board for the Rating of Property, Stockholm, and The Provincial Archives, Härnösand).

The fen Kvarnmyran at Vuollerim (Case study C), is close to a Stone-Age dwelling site (Loeffler & Westfal 1985). The oldest part of the profile from Kvarnmyran, a mineral rich sediment originating from a temporary river branch or a lake-like phase which existed prior to the fen dates about 6000 BP (calibrated $^{14}$C), i.e. a period contemporaneous with the dwelling. In the forest composition a long-term successional pattern was recorded. At first, Betula and Alnus dominated, and there were also more abundant bushes and herbaceous species than later. Successively, however, Pinus became dominant, and between 2800-2500 BP Picea established itself at Vuollerim.

Human impact in terms of cereal cultivation is not detected in the analyses. The occurrence of, herbs such as Artemisia, Asteraceae, Alchemilla, Chenopodiaceae, Galium, Humulus and Sinapis species and abundant Poaceae spp. in the oldest layers may indicate settlement disturbance, but such an interpretation would not be undisputable. These species were not necessarily there due to man, but could have occurred naturally along the river shores at that time. However, the vegetation was more open, light and patchy, and the nutrient state probably better than today, as indicated by the aquatic flora which included Typha spp. and Polygonum amphibium.

Juokojauratj 25 km west of Jokkmokk is a proper inland locality (Case study C). It was never affected by the river or the sea, but the early vegetation development in this part of the Luleälven valley was influenced by dead-ice (cf. Karlén 1981). The sediment in Juokojauratj covers the entire post-glacial vegetation development, starting with initial plant colonisation after the deglaciation ca. 9500-9000 BP. Initially, Hippophae rhamnoides was abundant, indicating an open vegetation type dominated by bushes, and rich in dwarf-shrubs and various herbs (Hafsten 1966). In a few hundred years Pinus became abundant, which corresponds closely to late Boreal conditions identified further east and south (Robertsson 1971). With the onset of warmer and more moist climatic conditions Betula and Alnus began to increase, and replaced Pinus as
the dominant forest tree. *Alnus* and *Betula* became the very northernmost representatives of deciduous vegetation of the post-glacial thermal optimum; nemoral broad-leaved trees never grew this far north. *Corylus, Ulmus* and *Tilia* are, however, recorded at very low percentages. At Juokojaratj they represent back-ground components due to long-distance dispersal, but when they decrease in the pollen diagram they, nevertheless, reflect the large scale changes of the Holocene climate.

At the climatic deterioration some 5000-4000 years ago *Pinus* increased again. At Juokojauratj *Picea* probably colonized between 3000-2500 BP, although it never became abundant at this site. No human impact was registered at Juokojaratj. Apparently, there were never any cultivations in the area, and the results do not indicate any disturbances which could be related to animal husbandry or even moderate impact of local hunters' settlements.

The agricultural development in the Luleälv valley has followed the general scheme put forward by Engelmark (1982), i.e. Bronze Age (1500-500 BC) and Iron Age (500 BC - 1000 AD) agriculture was only small-scale and temporary, permanent settlements were established during late Iron Age or early Middle Age (around 1000-1200 AD), and finally a major expansion took place around the 16-17th centuries.

(III) The vegetational and agricultural history of a northern Swedish catchment, studied by analyses of varved lake sediments. *By Segerström, U. 1990. (manuscript).*

The varved lake sediment from Kassjön, near Umeå in coastal Västerbotten, is one of the best preserved long sequences of varved lake sediment found in Sweden (ca. 6300 years). Varve counts, varve-thickness measurements and calculations of mean net annual accumulation rates of organic and mineral matter, made on two separate sediment profiles, show excellent agreement, and demonstrate the precision of the varve sequences.

The lake was isolated from the sea about 6300 years ago, and at that time *Betula* and *Alnus* dominated the surrounding moist fine-grained soils. *Pinus* was common on the drier sandy or blockish substrates in the area. The dominance of the deciduous trees was a result of the climatic conditions during the post-glacial thermal optimum, the local soils and the influence of the sea. *Ulmus* and *Corylus* grew locally and were probably, here in the Umeå area, near their northern limits. In the moist, fertile and open deciduous forests both Polypodiaceae species, *Humulus lupulus*, *Urtica* sp. and various herbaceous plants were common.

About 3400 BP, *Picea abies* invaded from Finland and expanded rapidly to become 60-70% of the forest trees in the area, and both *Betula* and *Alnus* became successively less important. As a result many herbaceous plants
common to the deciduous forests disappeared, and instead species such as *Vaccinium myrtillus* and *Vaccinium vitis-idaea* became common. Between 3000-2000 BP both *Corylus* and *Ulmus* disappeared from most of their northernmost sites, probably because of changed climatic conditions, but also as a result of the increased competition from *Picea abies*.

For early settlers, game, seal and fish were the most important natural resources. For animal husbandry, the nearness to productive pasture land was essential (Frödin 1952). Therefore, the settlements commonly lay at the coast or along the large and important rivers where resources were optimized. The rivers were also important as a means of transport (Hoppe 1945).

At Kassjön, however, which was situated several km from the river and the coast, and was completely encircled by forest there was no local agriculture established during the Bronze Age or the early Iron Age, such as at Hamptjärnen (Tolonen 1972) and Prästsjön (Engelmark 1976). Hamptjärnen and Prästsjön were both situated near the coast, at the river mouth 11 km to the south. In Kassjön a few indications were, however, registered (i.e. two pollen grains of cereal type at 850 and 50 BC, and a few apophytic pollen types), but these were probably derived from settlements which were established along the river.

Around 1200 AD a localized cereal cultivating settlement became established at Kassjön. *Hordeum* was the first cereal to appear, but from about the 16th century *Secale cereale* was also cultivated. The major expansion of field area around the lake took place between the 17th-19th centuries, with a 500% increase in 200 years.

A comparison of the tree pollen curves from Kassjön with the previously mentioned analyses from Prästsjön (Engelmark 1976) and Hamptjärnen (Tolonen 1972) suggest that at least 5 pollen zones during the last 3500 years are a result of regionally general changes. It is noteworthy, however, that the changes in the tree pollen curves about 400 BC, which were suggested by Engelmark (1976) to be caused by localized land-use at Prästsjön, also are identified in Kassjön, although land-use, is not clearly identified in the pollen record. Therefore, some of the conclusions of Tolonen (1972) and Engelmark (1976) about early agricultural impact on the forest development, are reconsidered and are instead given a climatic explanation.

For the interpretation of the climatic and vegetational changes the varve thicknesses and the mean net annual accumulation rates obtained for pollen, mineral and organic matter, proved to be valuable.

This paper presents a new approach of identifying small ancient arable patches, later abandoned and overgrown by closed forest. Series of pollen analyses were made on thin mor humus deposits from three different forest sites, all with varying agricultural histories.

The youngest study site, at Svarttjärnen near Leksand, in Dalarna, was abandoned more than 80 years ago. The agricultural history of the area is well documented and the pollen analyses show good accordance with the old land-use maps. Samples taken within the formerly cultivated areas contained abundant pollen of Poaceae and other apophytic species, as well as various cereal pollen. The samples taken 20 m outside the former cultivated land contained very few pollen indicative of agriculture.

At Kroktjärnen, Edefors, Norrbotten, pollen analysis of the varved lake sediment indicates that small-scale cultivation had taken place close to the lake in the 13th, 15th and 17th centuries (paper II, Case study B). According to the local farmers and the maps dated 1671 and 1846, no cultivated field should have existed at Kroktjärnen. Close to the lake soil samples were taken on a grid basis. In several samples cereal pollen, various field herbs and high frequencies Poaceae and Epilobium pollen were registered. Samples taken for controls 200-400 m away, to the west, south and east, contained no pollen which could indicate agriculture. The results show that a small area in the immediate vicinity of the lake had been cultivated, and were previously unknown. The patches which were identified, were probably the sites for some of the temporary cereal cultivations that are indicated in the sediment profile from the lake, and which date to Medieval time.

The analyses of organic and phosphate contents in the soil at an Iron Age dwelling at Västibäcken near Hög, Hälsingland (Fulks et al. 1985) suggested that a small area had been cultivated. Pollen analyses of soil samples taken along transects through the area south of a house foundation show high frequencies of cereal pollen (Hordeum type) and Poaceae and other apophytes. The pollen analyses confirm the suggestions made by the archaeologists, and show that pollen from the cultivations are preserved in the soil although the cultivations were abandoned 1000 years ago.

The three studies, provide an interesting application of soil pollen analysis. The problem of identifying and delimiting ancient fields is of archaeological and cultural interest, and the method certainly is applicable at a number of sites in the boreal region. Moreover, the very local establishment and spread of any plant species may be studied in detail with this method.
4. DISCUSSION

The development of an agricultural economy in Norrland, as in southern Sweden took place stepwise. In southern Sweden up to six phases have been identified (Berglund 1988). In contrast, in coastal Ångermanland and Västerbotten there are only three to four phases, and in the Luleälv region three phases. It is the first phase, characterized by spread and temporary cultivation or indications of animal husbandry, which lasted much longer in northern Sweden, thus reducing the number of phases. In interior Norrland the first phase continued until about the 16th-19th centuries before permanent agriculture became established. Prior to agricultural development the economy was entirely based upon natural resources, such as game, seal, fish and wild plants.

Studies from the Lofoten islands in northern Norway, and from Ostrobothnia in northern Finland show similar development trends. At Lofoten three to four phases were identified, with the first signs of forest clearance around 3500 BC (Vorren 1979, 1986, Nilssen 1988). Between 2200 BC - 200 AD sporadic cerealia occurred, and after ca 200 AD the cultivation became permanent. Along the Oulujoki river valley in northern Finland the first traces of possible human impact were dated to about 4000 BC (Reynaud & Hjelmroos 1980). According to Reynaud & Hjelmroos (1980) the economy based on hunting and fishing continued until about 500 AD, but was supplemented by animal husbandry and small-scale shifting cultivation. Around 500 AD there was a simultaneous development of permanent field agriculture at most of the study sites. For southern Ostrobothnia the picture is not as simple, mainly because of the rapid shore-line displacement. It has been shown, however, that field cultivation was established in the coastal region by at least the first century AD (Tolonen 1979, Vuorela 1986, Engelmark 1989, Segerström & Wallin 1988, 1989). In south-western Finland the first indications of agriculture occurred between 2000-1000 BC, and a major increase took place about 500-800 AD (Vuorela 1982).

It appears that the development of agriculture proceeded very similarly in the three countries, although agriculture apparently was less important in northern Norrland. The reasons for this difference are not clear and the discussion of three possible explanations must only remain speculative. 1) The natural conditions (e.g. climate and soils) for the development of an agricultural economy may have been better in the other areas. Ostrobothnia is today a much more pronounced agricultural region than the adjacent areas. In Norway the spread of agriculture was probably supported by the more favourable maritime climatic conditions along the Atlantic coast. 2) The present picture of northern Norrland is based upon rather few modern pollen analyses. Most of these analyses are not directly connected to known archaeological sites, or settlements. They rather reflect regional development, and small-scale, temporary cultivations may, therefore, not be found by the analyses. 3) Problems with the interpretation of the pollen diagrams. Most of the early
settlements lay along the coast, the rivers or the lakes. The pollen assemblages, therefore, contain pollen from a shore flora and also reflect natural disturbances, which can largely resemble the conditions caused by early agriculture. Such circumstances can cause both over- and underestimations of the prehistoric human impact.

The spread of the agrarian economy in northern Europe has been suggested by Zvelebil & Rowley-Conwy (1984) to follow a three-phase model: Knowledge available; transition phase; and consolidation. They found the model valid for Denmark and southern Finland, and suggested that the transition was caused by deficient availability in local marine sources (oysters in Denmark ca. 3000 BC, and seal in Finland ca 1500 BC). For northern Sweden the validity of the model has been discussed by Baudou (1989). Baudou suggests that, if the agrarian culture had become adopted by the original population, then the agriculture would have become more important and the evidences should have been stronger and more common in the pollen diagrams. Baudou (1989a, b) further suggests that from an archaeological viewpoint, the cultivations seem to have been connected to the Battle Axe culture, which in south Scandinavia was connected to the middle Neolithic agricultural expansion. To explain the pattern in Norrland, with relatively few, widely spread and weak indications of Neolithic agriculture, Baudou (1989a) suggested the following hypothesis: During the Stone Age and Bronze Age until about BC/AD small groups of immigrants came from the south and bringing the agricultural knowledge with them. This practice was not, or was only to a minor extent accepted by the original population. As regards the consolidation of the agricultural economy in Norrland during the first century AD and later, Baudou (1989a) suggested that this phase was also a result of strong impact from southern Scandinavia, and not purely an internal process.

Baudou's (1989a) conclusion, therefore, is that the development in Norrland is difficult to fit into the model of Zvelebil & Rowley-Conwy (1984). Agricultural development was a result of years of moulding in southern Scandinavia, and later modifications depending on the local conditions in Norrland. Baudou also suggested that the spread of agricultural practices probably was similar in northern Norway and coastal south-western Finland.

As has been shown by this review there are still many "grey" areas (Fig. 1), where the details of the forest history and more important, the role of man are largely unknown. To be able to clarify the details of the hunter-gatherer/farming economy and the slow spread of agriculture and its consolidation in northern Sweden, future pollen analytical research must to a greater extent become focused on studies from small influx basins were the regional influx is less important. Therefore, pollen analyses of thick mor humus profiles (cf. Bradshaw 1988), such as those from islands in Uddjaur, northern Norrland (R. Bradshaw, ms in prep.) or even thin mor humus soils such as presented in this thesis (Segerström IV) will, if closely connected to an ancient cultivation or dwelling be
most likely to reflect local changes both in natural vegetation and caused by agriculture. Furthermore, Norrland is rich in varved sediments and varve-counting and pollen analyses from these can provide more detailed chronologies for different areas in Norrland.

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