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Environment and Man

Current Studies in Vegetational History at the Geological Survey of Denmark

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Very soon after its establishment 1888, the Geological Survey of Denmark employed a young botanist, N. Hartz, whose primary task was to investigate the plant remains found in peat bogs. This initiative should be seen on a background of the great attention paid to the geology of bogs in Denmark during the 19th century. The interest in peat bogs was promoted by concern about the fuel supply, especially due to overexploitation of the forests and the loss of Norway 1814. The government therefore initiated a survey of the Danish peat resources, which resulted in the first scientific description of bogs in Denmark: *Über die Torfmoore Seelands* published by J.C. Dau 1829. Dau's work was continued by Japetus Stenstrup, and later by C. Vaupell and other famous botanists. It was therefore natural for the new Geological Survey to include bog investigations in its activity.

N. Hartz extended the study of peat bogs to comprise interglacial deposits; his work at the Geological Survey was continued by K. Jessen and J. Iversen. Jessen introduced pollen analysis in Denmark, and Iversen elaborated this method to a high degree of perfection. Their work is being continued at the Geobotanical Department. J. Troels-Smith, originally a collaborator of Iversen's, transferred to the National Museum. There he founded the Department of Natural Science, where archaeology and natural sciences work closely together.

The study of plant remains in Quaternary deposits thus has a long tradition at the Geological Survey. The methods employed have, however, improved continuously, and the objects and potentials of the studies have been increasingly widened.

Today, the primary purpose of the geobotanical studies at the Geological Survey is to elucidate vegetational change throughout the Quaternary, and to understand their underlying causes. Whereas peat-bogs at first were a main object of investigation, the studies now also comprise plant remains in lake deposits, marine deposits, and in terrestrial soils.

Changes in vegetation have proved useful for the establishment of chronologies for the Quaternary and the dating of deposits; this purpose has been greatly advanced by the introduction of methods of absolute dating, of which the radiocarbon dating-method extends 30–40,000 years back in time, and newly developed methods even 200–300,000 years (Vogel 1982).

Reconstruction of former vegetation provides a picture of former landscapes and environments. Changes in landscape and environment – including climate and soils – can therefore be elucidated by studies of vegetational history. At times when Man was present, studies of the former vegetation thus highlight his living conditions. As originally shown by J. Iversen, Man has actively interfered with plant life in Denmark throughout 6,000 years and has changed the vegetation to suit his purpose. The changing methods and intensity of human exploitation, and the response of vegetation, are, therefore, inevitable facets of the geobotanical studies.

The landscape in Denmark today reflects former and modern exploitation in varying degrees. The vegetation thus reflects past and present interaction between Nature and Man. Studies of current vegetation types and their history therefore provide a basis for the conservation of vegetation, which today illustrates conditions of the past.

STUDIES OF VEGETATIONAL HISTORY AT THE GEOBOTANICAL DEPARTMENT

Throughout nearly a hundred years geobotanical studies at the Geological Survey of Denmark have elaborated the knowledge of Quaternary vegetation in the

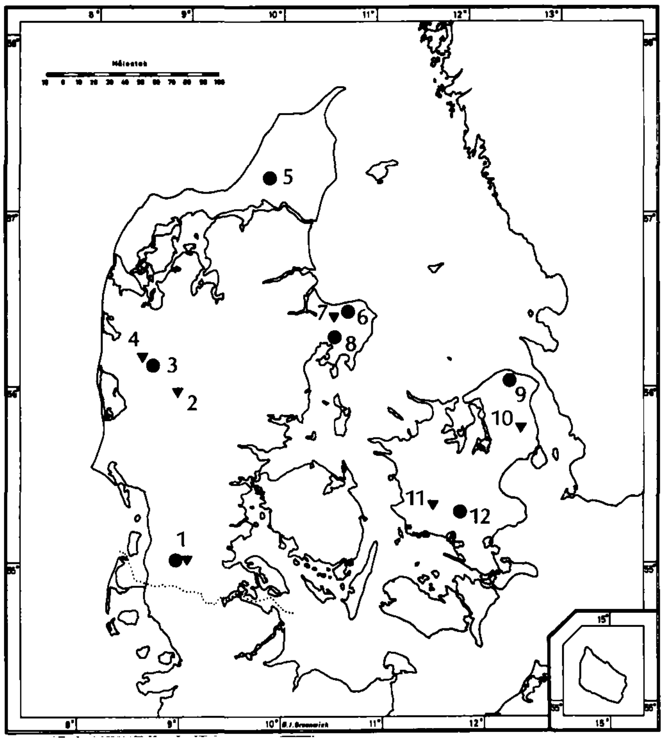

Fig. 1. Sites currently under investigation by pollen analysis at the Geobotanical Department. Dot: regional pollen diagram (bog or lake); triangle: local pollen diagram (wet-hollow site or soil). 1, Draved Bog and Forest. 2, Skarrild. 3, Lake Solsø. 4, Grøntoft. 5, Store Vildmose. 6, Fuglsø Bog. 7, Løvenholm. 8, Korup Sø. 9, Søborg Sø. 10, Geel Forest. 11, Næsbyholm Forest. 12, Holmegård Bog.

light of new discoveries and improvements of methods. General surveys of the subject were presented in 1967 in *Danmarks Natur* (Andersen 1967, Iversen 1967). Since then, new developments and discoveries have revealed that our picture of the past is still imperfect and can be greatly improved. In 1967, only a few pollen diagrams which illustrate the general development of vegetation since the last ice age existed; none of them were dated by the radiocarbon method. Furthermore, better understanding has been reached of the transfer of pollen from vegetation to deposit and better tools have been evolved for the quantative reconstruction of vegetation. Finally, new potentials for studying narrow-scale vegetational change have been discovered.

Pollen diagrams reflect the vegetational development on varying areal scales, according to the object chosen for study (see also Andersen 1970, 1978, Janssen 1973, Webb *et al.* 1978). Pollen diagrams from sites with a large receptive surface – lakes or bogs – and distant from local vegetation (100m or more) reflect vegetation on a large scale, probably within up to ten kilometers. On this scale an average of the vegetation mosaic in a large area, about 300km^2, is obtained. General trends in vegetational change – and intensity of human occupation – are revealed; however, vegetational diversity, dependant on topographical variation, is masked, and human activity cannot be localized or described in detail.

In recent years it has proved possible to elucidate vegetational change on a narrow areal scale by the study of very small ponds or bogs, and soil sections. Sites in woodland covered by tree canopy – small wet hollows or soils – receive pollen from a very narrow range of vegetation, within 30m. In this way only a single forest community, the one which prevailed around the site, is recorded. Furthermore, new correction factors make it possible to reconstruct the areal composition of the tree community precisely (Andersen 1970, 1980). If the forest around such a site was changed by Man or cleared, these events will manifest themselves clearly in the pollen spectra. One can say, accordingly, what the composition of the forest was on uplands in contrast to low-lying areas at varying times, how Man changed the vegetation, what purpose he possibly had with his activity, and for how long he persisted. Studies from small kettle-holes and soil sections can therefore pinpoint the activity of Man and elucidate its nature; the extent and intensity of human activity must, on the other hand, be traced at the sites that record vegetation on a large scale.

At the Geobotanical Department it has been a major task in recent years to study regional vegetational development especially in the Holocene and to study local sequences at small-hollow sites and soil sections. The former activity of Man and its interaction with nature are inevitable features of these studies.

As lake deposits often are unsuitable for radiocarbon dating, regional vegetational change is being studied at the raised bogs Draved Bog, Store Vildmose, Fuglsø Bog and Holmegård Bog (B. Aaby, Fig. 1). Furthermore, regional vegetational history is studied in marine deposits at Søborg Sø and Korup Sø (H. Krog). Pollen diagrams from soils and wet hollows are worked out from Draved Forest (B. Aaby), Løvenholm (Eldrup Forest), Geel Forest and Næsbyholm Forest (S.T. Andersen). The history of the heaths in western Jutland is studied at Lake Solsø and in soil sections at Skarrild and Grøntoft (B. Odgaard, Fig. 1). Some results from these investigations will be mentioned below.

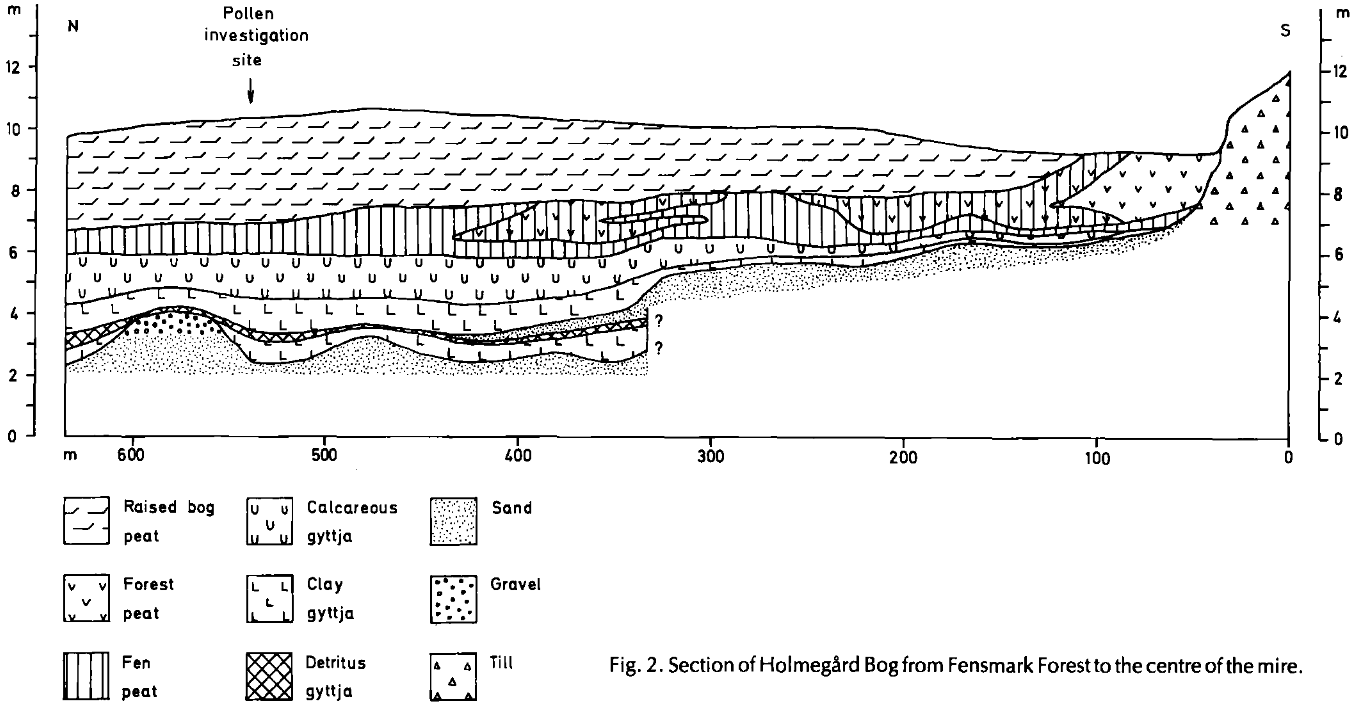

Fig. 2. Section of Holmegård Bog from Fensmark Forest to the centre of the mire.

REGIONAL POLLEN DIAGRAMS

Holmegård bog

In the need for accurate dating of the Holocene vegetational development in eastern Denmark, attention was drawn to Holmegård Bog, an extended raised bog in southern Zealand (Fig. 1, 12). The bog is part of a larger mire complex in a glacigenic landscape, with deposits dominated by clayey till.

The bog has previously been analysed from a pollen-analytical point of view and knowledge about the vegetation in limited periods has been published by Jessen (1925, 1935) and Nilsson (1937). Indeed, the Holmegård Bog was among the first sites, where co-operation between archaeology and geobotany was practiced, providing important knowledge and inspiration to both subjects.

A transect from the southern border to the centre of the bog is shown in Fig. 2. In late Weichselian and early Holocene time a lake was found in the area. Sheltered areas along the margin of the lake were overgrown by mosses, sedges, and grasses in the early Preboreal. In early Boreal time, a peat zone, 2–300m wide, was formed along the southern margin of the lake. The overgrowing of the lake was completed in the early Atlantic; alder forest occurred along the marginal part of the bog, whereas the central area remained treeless. In late Atlantic time, raised bog vegetation was established in the central part of the mire, and gradually expanded to form a large pillow-shaped bog, which was surrounded by birch and alder carr, as also seen today.

The pollen diagram, derived from the central part of the bog, illustrates the vegetational history throughout the Holocene (Fig. 3). The chronology back to the early Atlantic is based on 26 radiocarbon dates, whereas older calcareous sediments are tentatively dated by correlation with well-dated vegetational events within the same region (Krog 1973, Fredskild 1975). Juniper, crowberry (***Empetrum nigrum***), and meadow-sweet (***Filipendula ulmaria***) characterized the vegetation at the transition from the late Weichselian to the Preboreal. The ground flora was still favoured by ample light in the preboreal birch-pine forest. Hazel immigrated in early Boreal time and soon became the dominant tree species. Pine and birch are light-requiring and could not hold their ground against the advancing hazel. The luxuriant herb flora also vanished and was of no regional importance until the Subboreal.

Elm was the next tree to arrive followed by lime, oak,

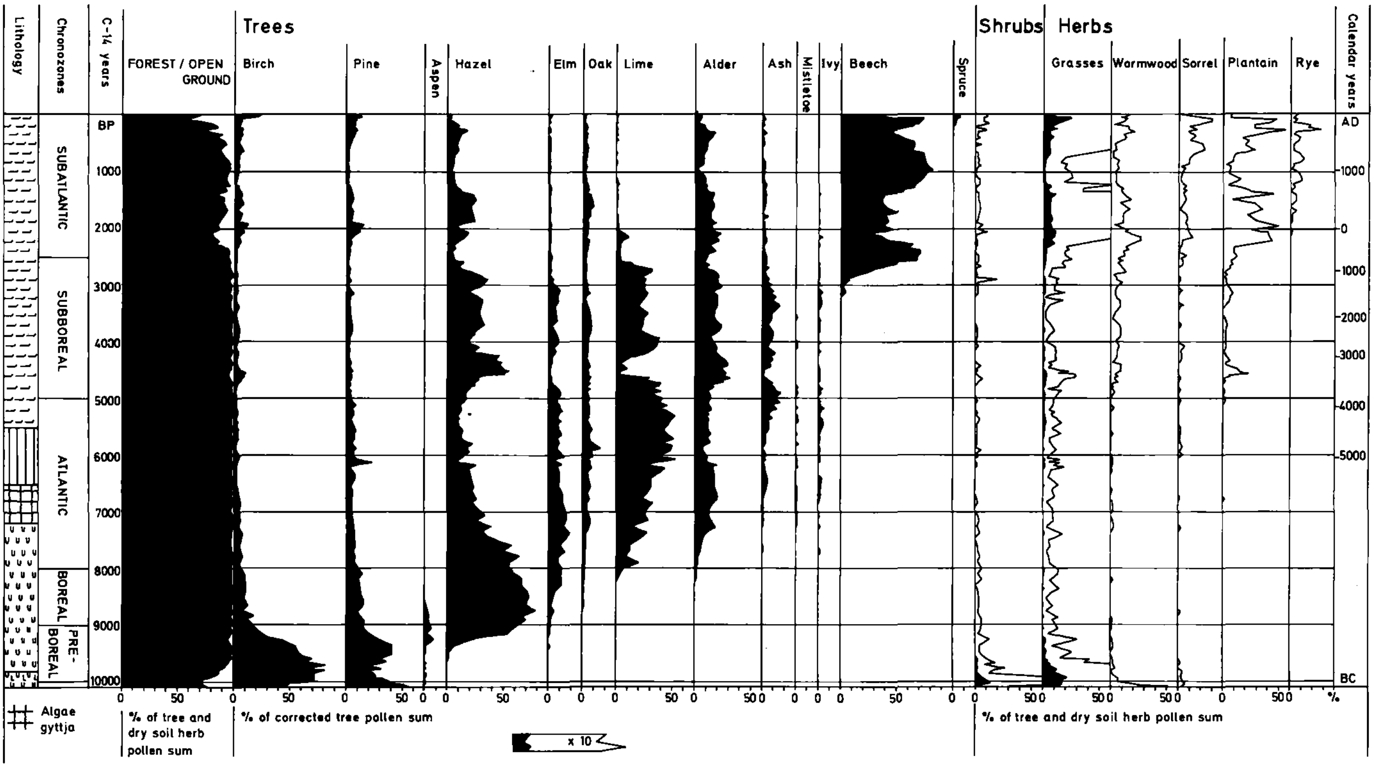

Fig. 3. Holocene pollen diagram from Holmegård Bog. The diagram shows the occurrence of trees and open land (survey diagram) and separate curves for trees and categories of herbaceous plants. The tree pollen frequencies were corrected according to Andersen (1970, 1980). Calendar years are calibrated according to Clark (1975).

ash, and alder and the Boreal hazel forest was gradually succeded by a more complex tree vegetation. The pollen curves stabilize by the middle of the Atlantic, indicating that a competitive equilibrium between the various species or plant communities was established. The spatial distribution of the tree species was possibly determined mainly by the soil conditions, as they are today, but the regional pollen diagrams allow only little insight into the forest structure. No doubt lime was dominant on well-drained soil, whereas hazel, elm, oak and ash probably were found mainly on damp ground, and alder exclusively on peaty soil (compare Iversen 1960, Andersen 1980).

The occurrence of Man in Atlantic time and earlier is very difficult to detect outside dwelling places. A few peaks in the grass pollen curve and the finding of microscopic charcoal may reflect the presence of the Maglemose people in Boreal-early Atlantic time, when open water still occurred.

In early Subboreal time, definite signs of human activity were registered. Pollen of plantain (*Plantago lanceolata*), was found at three levels below a well-marked decline in the elm pollen curve. The amount of grass pollen also increases before the elm decline, which was dated to 3600 B.C. (in calibrated calendar years). This date is later than the elm decline elsewhere in Denmark (Andersen 1978) and southern Sweden (Nilsson 1964). The herb pollen found below the elm decline at Holmegård may be due to long distance transport, reflecting neolithic clearances, but may also be considered local, indicating cultural influence in the vicinity of the bog.

An increase in the herb pollen curve shows that larger areas were cleared shortly after the elm decline and the landscape attained a nemoral character. Plantain (*Plantago lanceolata*), bracken (*Pteridium aquifolium*) and grasses were common on open ground. A few cereal pollen grains indicate the presence of fields. The early peasant culture strongly hampered the lime, elm, and ash populations and their pollen producing capacity remained low, whereas birch and especially hazel were favoured and probably occurred also on the dry soil. The cultural disturbance was low in the moist and peaty areas with oak, pine, and alder, as their pollen curves remain almost stable from the end of the Atlantic. The nemoral character of the vegetation was maintained for about 500 years (34–2900 B.C.).

The progress of the early Subboreal vegetational development in the Holmegård area is similar to most other regions in eastern Denmark, indicating common farming practice at that time.

After 2900 B.C. the Holmegård area was abandoned by Man and the forest adopted a composition similar to that of Atlantic time, except that hazel stabilized on a higher level and pine became a subordinate element. The original ecosystem equilibrium thus remained stable although the peasants had strongly interfered with the vegetation for five hundred years.

Beech immigrated about 15–1400 B.C. and expanded about 2–300 years later, reaching values unique for Danish and even northwest European pollen diagrams in the Subboreal. Beech forest thus occurred earlier than formerly supposed. The composition of the forest on high ground was drastically changed at the expansion of beech, as lime and especially hazel were suppressed.

The pollen diagram next reflects distinct changes in the landscape about 5–400 B.C. The beech forest was strongly reduced and extended open areas appeared for the first time. Perennial weeds, such as plantain, sorrel (*Rumex acetosella*), wormwood (*Artemisia*), and grasses, were common, indicating extensive land-use. Cereal pollen, mainly of barley-type, is scattered in the pollen spectra. Rye appeared about 2000 years ago but was of little importance during the Iron Age.

The landscape again changed radically about A.D. 4–500. The beech forest expanded contemporaneously with a lowering in the frequency of weeds. These vegetational variations signify a depopulation of the Holmegård area. The same phenomenon also occurred in other regions in eastern Denmark (Mikkelsen 1949, Andersen 1954).

There is good evidence that the Holmegård area was settled again in early Medieval time, A.D. 11–1200. Rye was commonly grown, and grassland occupied larger areas. Buckwheat (*Fagopyrum* sp.) and cornflower (*Centaurea cyanus*) were found somewhat later, about A.D. 1400. The well-documented desertion of farms in late Medieval time (Gissel *et. al.* 1981) is rather difficult to trace in the Holmegård area, and the farming intensity seems to have been almost stable throughout the Middle Ages and until about A.D. 16–1700. At that time the frequency of weed pollen rose to a significant maximum, which lasted until modern time. Intensified farming in the 18th century thus had a distinct influence on the landscape. The low herb pollen values in the uppermost pollen spectra reflect the major influence of modern agriculture on the weed flora.

The Holmegård area has possibly been a marginal area from an agricultural point of view. Colonization and desertion have been registered in the pollen diagram several times since the first large land occupation, six thousand years ago. Stages with cultural influence occurred particularly during the Neolithic (34–2900 B.C.), the early Iron Age (500 B.C.–A.D. 400), and in Medieval to modern time (after A.D. 1100). In order to gain a fuller insight into the development of agricultural expansion and vegetational development, the Holmegård pollen diagram should be compared with a regional diagram from a more central settlement area, e.g. western Zealand.

Our knowledge as to the size of the area represented in regional pollen diagrams is imperfect. The vegetational development in the Præstø area (Mikkelsen 1949) has differed essentially in some periods. This site is about 20km away from the Holmegård Bog area; thus half this distance is possibly the outermost limit for the Holmegård area. Tentatively, the regional pollen diagram therefore reflects vegetation in an area between 80km^2 (radius 5km) and 300km^2 (radius 10km).

Although the regional pollen diagram obviously reflects cultural stages, the analyst is faced with the problem of describing the farmland in detail. Pollen grains of cereals, spurrey (*Spergula arvensis*) and cornflower (*Centaurea cyanus*) are indicators of cultivated fields, but these plants are sparsely represented in pollen diagrams the only exception being rye. Most of the herb pollen recorded originates from weeds with a high pollen producing capacity, such as wild grasses, wormwood (*Artemisia*), plantain (*Plantago lanceolata*), and sorrel (*Rumex acetosella*). These plants are often considered good indicators of pasture, used for grazing and hay collecting. However, they may also have occurred in the fields and on the banks which separated the fields. These weeds may therefore indicate fields as well as permanent pastures (Behre 1981).

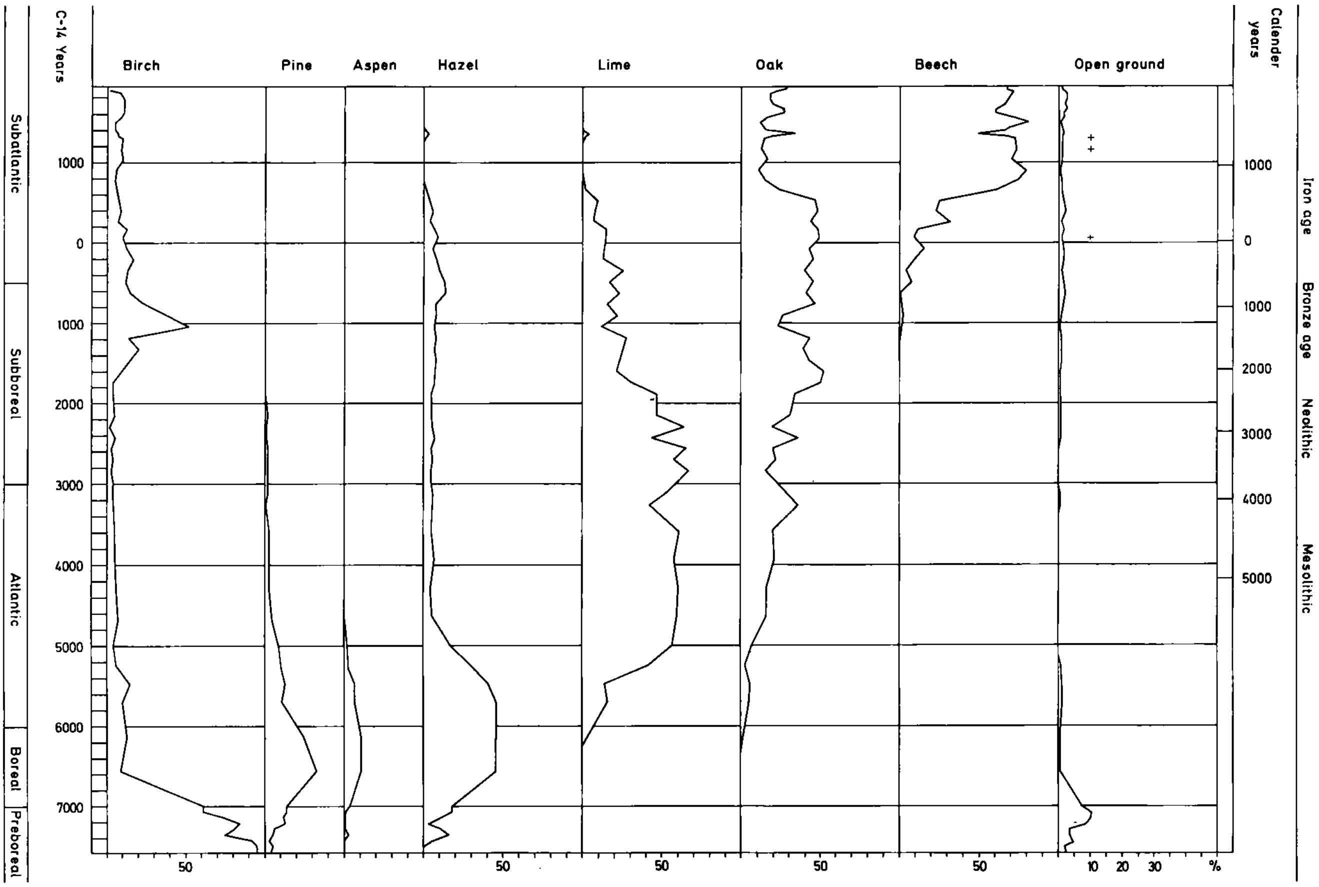

Fig. 4. Pollen diagram from small wet hollows in Eldrup Forest, Løvenholm, Djursland (from Andersen 1978). The diagram shows local forest development throughout the Holocene. The area was never cultivated, but the forest was exploited in the late Neolithic, Bronze Age and early Iron Age (felling of lime, see the text). Tree pollen frequencies were corrected according to Andersen (1970, 1980). Calendar years are calibrated according to Clark (1975).

POLLEN DIAGRAMS FROM SMALL HOLLOWS

As described previously, small wet hollows have proved to be extremely useful for the study of vegetational development on a narrow areal scale. Furthermore, it has turned out that small hollows with well-preserved deposits are numerous in Danish woodlands. In farmland, however, small hollows have often been disturbed by peat digging.

Eldrup Forest, Løvenholm

Small hollows were first investigated in the Løvenholm forests on Djursland (Eldrup Forest, Andersen 1973, 1978, Fig. 1). These woodlands are situated in a hilly area, which was marginal to dense settlements in prehistoric and historic time. The pollen diagrams, therefore, show the composition of the forest on upland soils and illustrate how uninhabited areas were exploited in the past. A pollen diagram which shows the vegetational development throughout the Holocene is shown in Fig. 4 (Andersen 1978).

Birch was dominant in Preboreal time, before 7000 radiocarbon years bc, and pine and hazel had just immigrated. There was a peak for open-land plants in the late Preboreal, indicating temporary opening-up of the tree canopy. Hazel then expanded and dominated the forest in Boreal and early Atlantic time (7000–5500 bc), with scattered birch, pine and aspen. Lime became dominant in Atlantic time, oak was scattered, and hazel was scarce. The lime-oak forest was dense, and open-land plants were extremely rare. A few peaks on the oak curve in late Atlantic and early Subboreal time may have been due to human activity (felling of lime trees).

In middle Subboreal time, around 3000 B.C. (in calendar years), lime decreased strongly, and oak expanded; birch also expanded, showing several peaks. Oak remained dominant for several millenia, during which beech immigrated, but remained scarce. These changes cannot have been due to natural causes, as oak and birch cannot compete successfully with lime in undisturbed forest. Hence, there can be no doubt that Man caused these changes in the forest. The pollen diagram thus reveals that Man felled lime in favour of oak, and that birch expanded temporarily due to clear-cuttings. Plants from open-land vegetation increased slightly, but remained scarce, indicating that open ground grazed by cattle cannot have occurred near the site. The pollen diagram does not show what the purpose of Man's activity was. The nearest possibility is swine husbandry, as pigs feed well on oak mast, and do not require extensive clearings.

Man apparently maintained oak woodland in Eldrup Forest for several millenia, from the late Neolithic till the middle of the Iron Age, around A.D. 400. This practice was then discontinued, and beech became a dominant tree until today. A few peaks for oak indicate intermittent human activity (the felling of beech trees) in Medieval and recent time.

The pollen diagram from the small hollow in Eldrup Forest thus shows that lime succeded birch and hazel forest, and became dominant on upland soils in Atlantic time. These marginal woodlands were inextensively exploited in Subboreal and early Subatlantic time, probably for swine husbandry. Beech forest prevailed from the middle Subatlantic till to-day.

Geel Forest, Zealand

In Geel Forest, a small wood north of Copenhagen, an extensive Iron Age field system was mapped by Viggo Nielsen (Nielsen 1970, Fig. 1). In order to investigate the impact of cultivation on a locally influenced pollen diagram, a small hollow situated within the field system was examined (Figs. 5–6).

The sediment in the hollow was just over 1m deep. The uppermost 30cm were very soft and contaminated; below, a clayey sediment with numerous stones occurred.

Fig. 6 shows a simplified pollen diagram and curves for ecological groups. The diagram indicates two periods with predominant open-land vegetation: one below 95cm in depth, and one at 55–80cm. Bracken (*Pteridium aquilinum*) predominated in the first period, and open-ground herbs and grasses in the second. Bracken is indicative of grazing; this fern is not eaten by cattle and sheep and often expands as a weed on pastures. Hence, it can be assumed that clearings with pasture occurred around the site during the first stage. Sorrel (*Rumex acetosella*), plantain (*Plantago lanceolata*), wormwood (*Artemisia*), grasses and other weeds were frequent in the second stage. These plants indicate that large open areas existed around the site for some time; they reflect the time when the field system around the site was in use. Pollen grains of annual weeds and cereals were scarce; perennial weeds with a large pollen production thus reflect the cultivation stage better than annual weeds and cereals do (see also Behre 1981).

The pollen diagram also shows that forest regenerated around the wet hollow in Geel Forest between the two periods with intensive cultural influence, and again after the abandonment of the fields. Woodland of lime, hazel, oak and beech regenerated after the first cultural stage, and beech forest expanded after the second stage (Fig. 6).

The age of the pollen diagram is not quite clear, due to difficulties in radiocarbon dating. The first cultural phase was probably neolithic, whereas the field systems belong to the early Iron Age (Nielsen 1970).

SOIL SECTIONS

Pollen diagrams from small wet hollows may elucidate local vegetational development for an extended time, in favourable cases the entire Holocene. Such sites are, however, not always available, and former soil conditions are not recorded directly. Pollen diagrams from undisturbed soil sections, on the other hand, may be found in areas where hollows are missing, and may reflect soil evolution.

Iversen (1958, 1964) found that pollen was excellently preserved in raw humus layers and he showed that pollen diagrams from such terrestrial deposits are useful for illuminating local vegetation history and former exploitation by humans. Pollen may also be preserved in acid mineral soils (with pH lower than 6). In brown earth (in Danish: *Muld*), pollen deposited on the surface is transported downwards and mixed with the mineral soil by burrowing earthworms. One can, there-

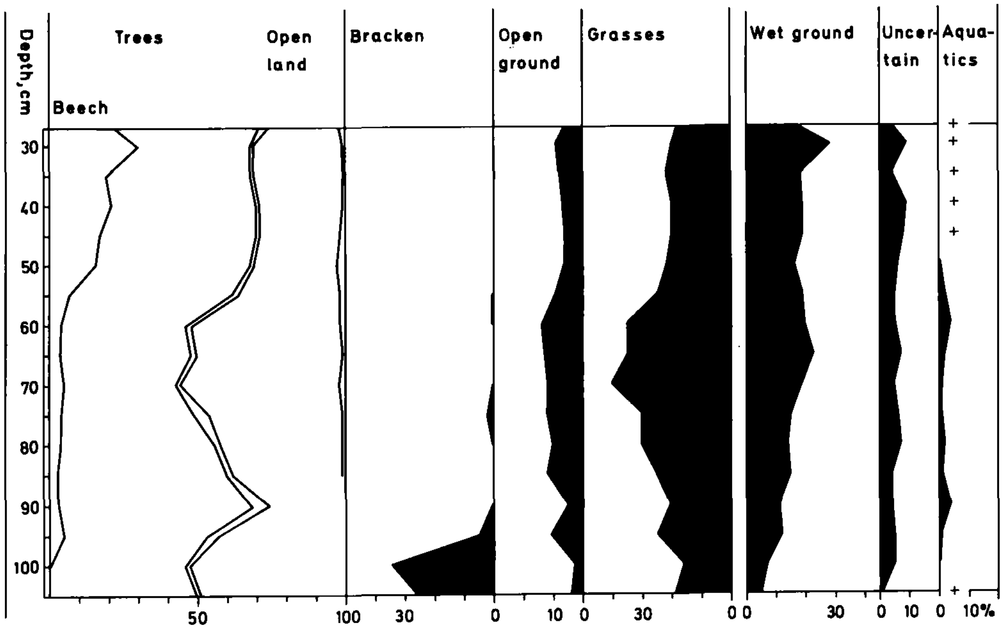

Fig. 5. Pollen diagram from a small hollow inside an Iron Age field system in Geel Forest, north of Copenhagen. The diagram shows the occurrence of trees and open land, and categories of herbaceous plants (bracken, open-ground plants, grasses, wet-ground plants, plants of uncertain significance, and aquatics); the three last-mentioned groups were not included in the pollen total). The diagram shows two periods of deforestation (below 95cm and at 55–80cm depth).

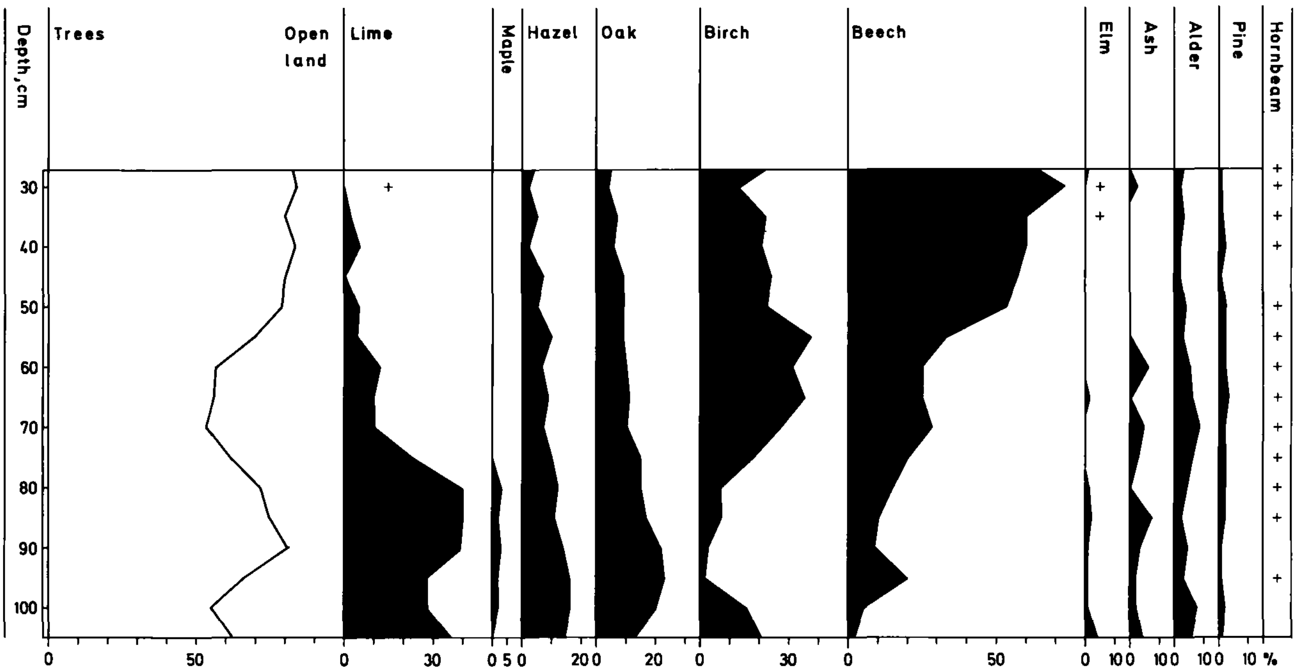

Fig. 6. Pollen diagram from Geel Forest showing the composition of the tree vegetation. The tree pollen frequencies were corrected according to Andersen (1970, 1980).

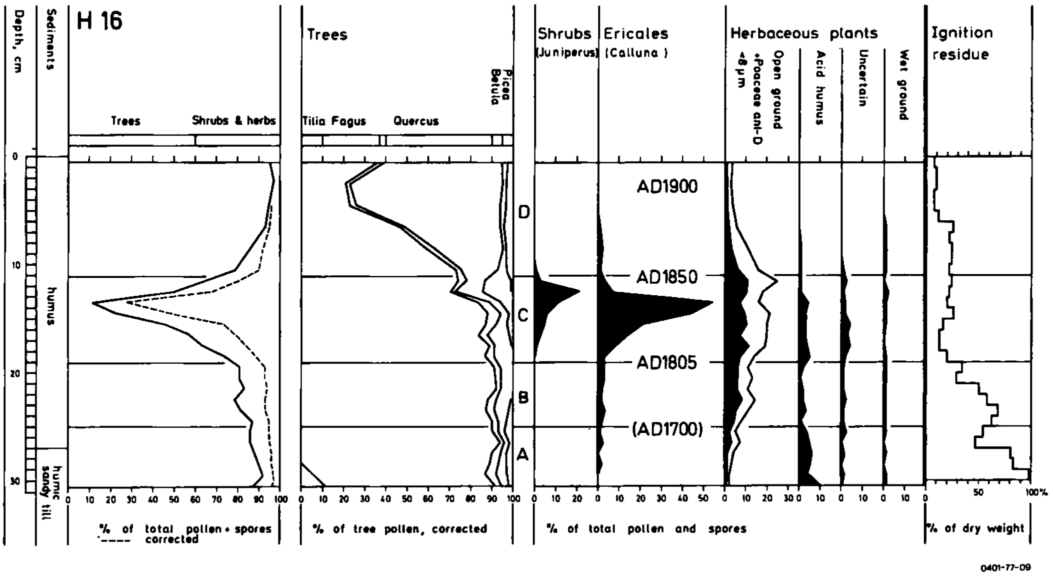

Fig. 7. Pollen diagram from a raw humus layer in Eldrup Forest, Løvenholm. The diagram shows the occurrence of trees and non-tree plants, corrected tree pollen frequencies, and categories of non-tree plants. A grazing stage about 1700–1800 and regeneration of forest are recorded. From Andersen 1979.

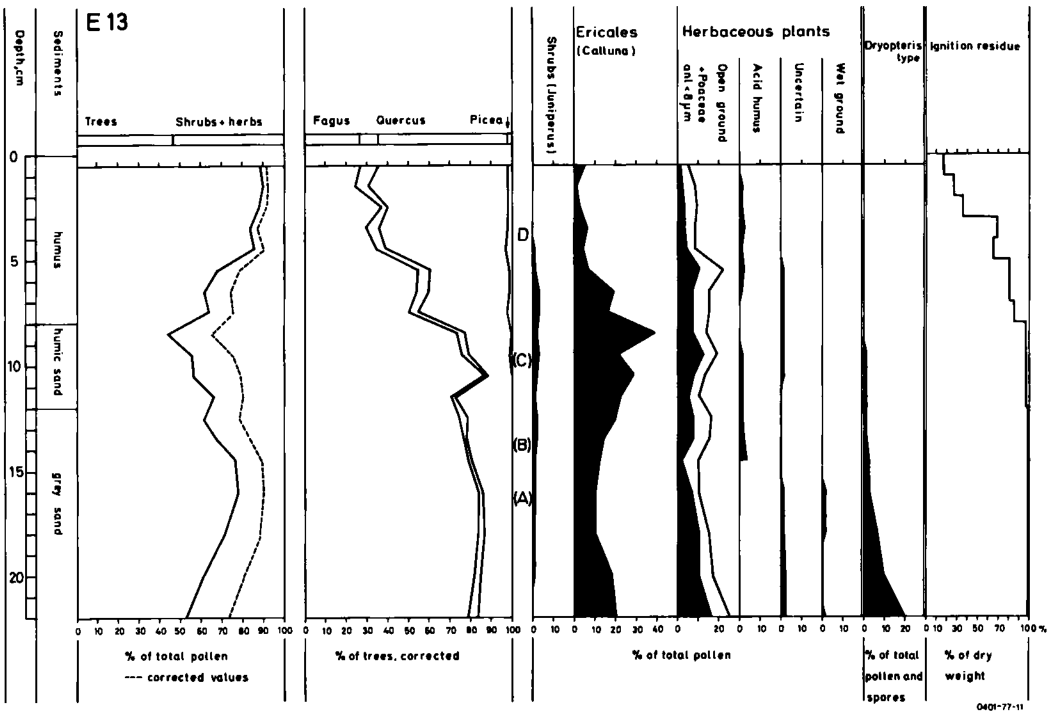

Fig. 8. Pollen diagram from podzol with a shallow raw humus layer near the section shown in Fig. 7. The pollen curves in the layers are similar to those in Fig. 7 but are smoothed due to mixing during the burial by soil fauna. From Andersen 1979.

fore, find pollen from former acid brown earth stages buried in soils, which have later developed into podzols.

Fig. 7 shows a pollen diagram from a raw humus layer in Eldrup Forest at Løvenholm (from Andersen 1979). The vegetation was originally beech forest, which was grazed in the 18th century. Cattle grazing was abandoned after the passing of the Forest Protection Law (*Skovforordningen*) of 1805; heather and juniper invaded the former glades, which, somewhat later, changed into oak forest.

A similar development was traced in pollen diagrams from podzols with thin humus layers and in a brown earth from the same forest. In these sections, however, the pollen curves were smoothed out, because the pollen assemblages, which were originally deposited on the soil surface, became mixed vertically during the transportation into the soil by the soil fauna. Pollen diagrams from the podzols thus reflect the vegetational development in the brown earth stage, which preceded the podzolization, however, in a modified way, because of the mixing activity of the earthworms (Fig. 8).

Undisturbed humus layers and soils which record local vegetational development may still be found in forests, where the soil has not been ploughed. Outside the forests, in arable land and in heaths, undisturbed soils may be preserved beneath prehistoric monuments, and may reflect natural vegetation and the exploitation by Man prior to the erection of the monument.

THE HISTORY OF THE HEATH IN WEST JUTLAND

Until the end of the 19th century, vast areas of western Jutland were covered by heaths dominated by heather (*Calluna*) but devoid of trees, except for scattered small copses of crooked oaks. Today most of the heaths have been converted into arable land, but the oak-copses still exist.

The origin of this strangely attractive vegetation – heathland and oak-copses – has been discussed for almost two centuries. Contributions to the debate have come from widely different branches of science and the conclusions arrived at were equally divergent. Jonassen (1950) conclusively showed by several pollen diagrams that the 19th century heathland was once covered by forest. He imagined that prehistoric fields in western Jutland could only be cultivated for a short period due to infertility of the soil. Heather would then conquer the abandoned fields and the heathland expansion observed in the pollen diagrams was a reflection of this process. Jonassen thought that the heath expansion took place in the Subatlantic period. In his opinion, the vast heathland was the result of extensive agriculture combined with a climate unfavourable for trees in Subatlantic time.

Since the time of Jonassen's work pollen analysis has been strongly refined. Furthermore, accurate methods of dating non-calcareous organic deposits are available and our knowledge about heathland ecology is more complete. On this background the Geobotanical Department has initiated an investigation of the vegetational history of western Jutland, of which some preliminary results – a regional and a local pollen diagram – are presented here.

Lake Solsø (Fig. 1) was chosen as a site for a regional pollen diagram. Lake deposits are preferable to raised bog deposits in this connection, since pollen from local heather growing on the bog surface may obscure the regional heathland development in pollen diagrams from bogs. As Lake Solsø was oligotrophic, the sediments are suitable for radiocarbon dating. The lake is situated in a depression in sandy till from the Saalian (second-last) glaciation. Until an artificial lowering of the water table in the beginning of the 20th century it was probably about 200m in diameter. Groups of megalithic tombs and other burial mounds are indicated near Solsø on the map in Brøndsted (1966), but H. Rostholm, Herning Museum, has not been able to relocate the megalithic monuments in the present landscape. Until the end of the 19th century the area was almost totally covered by heath. The nearest oak-copses are about 4km away.

Fig. 9 shows a pollen diagram from Lake Solsø covering the entire Holocene. The open birch forest that established itself in the Preboreal, was soon invaded by pine. Later hazel arrived and became the most common tree in the Boreal and early Atlantic periods. Elm arrived during the Boreal and oak, alder, lime and ash during the early Atlantic. By the middle of the Atlantic, stable vegetation of these trees had developed. This early Holocene forest development in western Jutland resembles the development in eastern Denmark, but the less fertile soil induced a more open forest type where heather was able to grow and flower on the forest

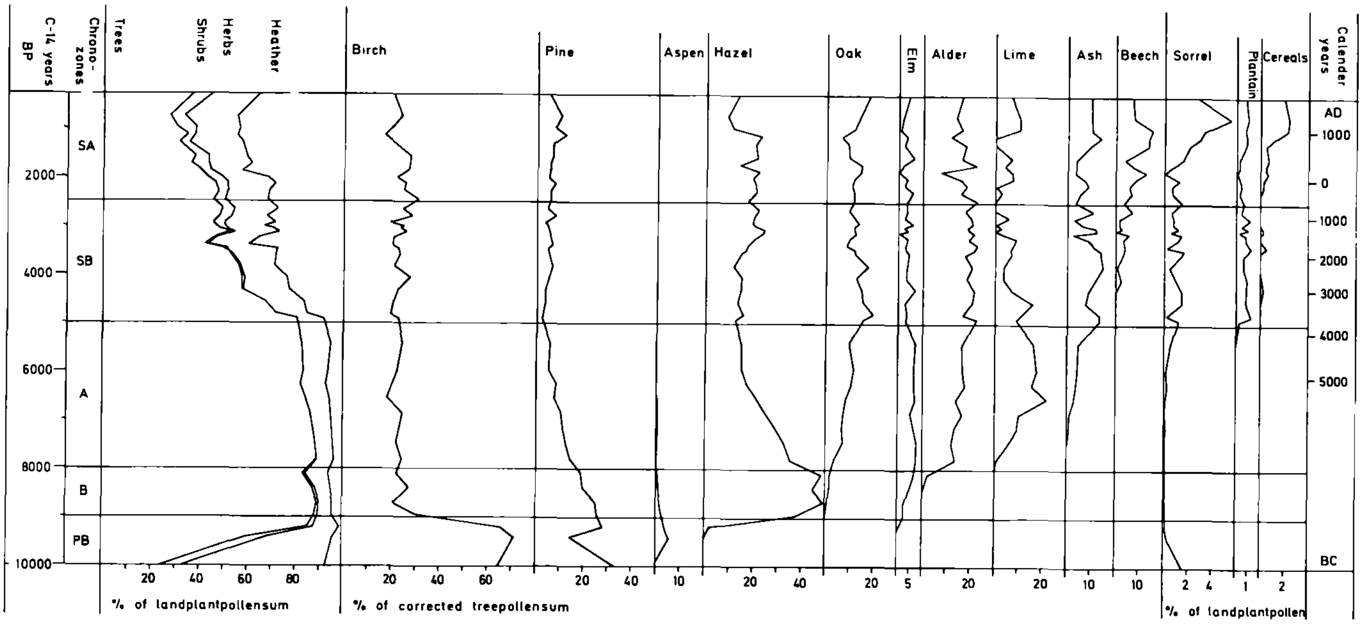

Fig. 9. Holocene pollen diagram from Lake Solsø including a survey diagram, a corrected tree pollen diagram (correction factors according to Andersen 1970, 1980) and separate curves for three components of the herb curve of the survey diagram (note different scales). The chronology of the the diagram is based on C-14 datings, and the convertion of C-14 years to calendar years is according to Clark (1975).

floor. Furthermore, the demanding trees, elm and lime, were less frequent in Western Jutland than in eastern Denmark, while birch was more common.

In the early Subboreal, the vegetation changed dramatically. The first pollen grains of plantain (*Plantago lanceolata*) document the introduction of farming, and heathland expanded at the expense of the forest. In the middle of the Subboreal, the heathland expansion stopped and an equilibrium was reached. Thus the pollen diagram reflects essentially unchanged vegetation from this time until the Birth of Christ. During this interval of about 2000 years (2000 B.C.–0) large areas were covered by young *Calluna*-heaths, whereas others bore forest, which differed from the Atlantic forest by, *i.a.*, the sparseness of lime. Grassland may also have been present, but fields were scarce.

Shortly after the Birth of Christ a new heath expansion started and continued nearly until today. Increasing frequencies of rye (included in the cereal curve) and sorrel (*Rumex acetosella*) reflect more intensive agriculture from the beginning of the present millenium.

Purely natural heaths can only exist in very rough climates like today on the Faroe Islands; there is no indication that the Danish climate was that severe at any time during the Subboreal and Subatlantic periods. Heather expands on abandoned sandy fields, but if the heath is not rejuvenated by new cultivation, or nursed by grazing or burning, it will after a few decades turn into grass- crowberry (*Empetrum*) heath and eventually be invaded by shrubs and trees. The prehistoric heaths must therefore have been nursed by Man, but with which method and for what purpose?

Ample charcoal dust throughout the deposits of the heathland period in Lake Solsø indicates frequent burning of the heathland. This is in accordance with the almost total absence of juniper-pollen in the pollen diagram. This wind-pollinated shrub can be effectively spread by sheep and is today almost exclusively found on pastures and grazed heaths. However, juniper does not tolerate burning; frequent heath fires would therefore have impeded the introduction of juniper to the area.

The pollen diagram from Lake Solsø shows that heathland expanded already in early Subboreal time and persisted in the area until quite recently. The regional diagram also gives indications of the prehistoric use of the heaths, but local pollen diagrams from buried soil sections may get us closer to an answer to our question.

Fig. 10 shows a pollen diagram from a podzol preserved beneath a burial mound at Skarrild (Fig. 1). The mound was excavated by H. Rostholm and the oldest grave has been radiocarbon dated to 2550 B.C. (calendar years, Rostholm 1982).

The lowest pollen spectrum, at 15cm, reflects the vegetation in the brown earth stage. The site at that time was covered by alder-birch forest with occasional lime trees, and ground vegetation of grasses and herbs like devil's-bit (*Succisa*). The precise age of this vegetational stage is not known; it probably persisted until a few centuries – or perhaps decades – before the erection of the mound. The topmost pollen spectrum reflects the vegetation at the site – now a podzol – just prior to the making of the mound. The vegetation had changed to heath totally dominated by heather, but alder-birch forest was still present in the vicinity. Due to earthworm activity in the brown earth stage, the pollen spectra between the lower and the uppermost samples are mixtures of spectra from the forest and the heath stages.

The only logical explanation to this local vegetational change is that the forest was destroyed by Man and replaced by heath. Furthermore, vast amounts of microscopic charcoal in the topsoil show that the heath was maintained by burning. This is a perfect parallel to the forest clearence followed by heather expansion, which was demonstrated in a raw-humus pollen diagram from Draved, southern Jutland, by Iversen (1969). At this site the clearence took place in the Viking Age, but the heath in Draved was also nursed by burning.

The diagram from Draved (Iversen 1969) and the present one from Skarrild clearly do not support the view of Jonassen (1950) that the reason for the prehistoric heath expansion was heather invasion on abandoned fields. Pollen grains of cereals are absent from the soil section at Skarrild, and neither of the sites has ever been tilled.

The results presented here are few and limited geographically. Nevertheless, they do suggest the following answer to the question how and why the prehistoric heaths were maintained. *Calluna*-heaths were not primarily the accidental result of extensive short-time agriculture followed by abandonment; they were deliberately produced and maintained by prehistoric Man. The heather was nursed by regular burnings, probably with the object of producing grazing and fodder – both amply provided by young heather – for cattle and sheep.

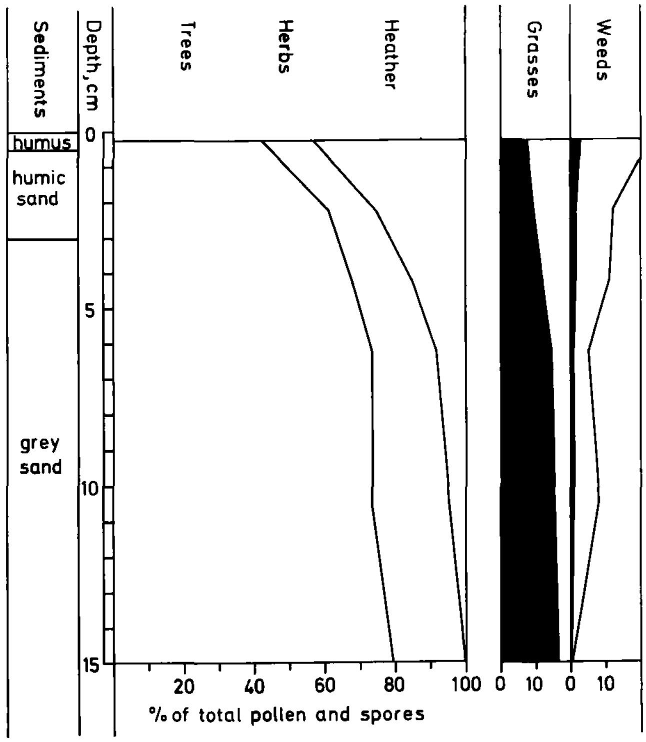

Fig. 10. Pollen diagram from a podzol located beneath a Single Grave mound at Skarrild. A survey diagram and separate curves for components of the herb curve are shown. The weed curve includes sorrel (*Rumex acetosella*), plantain (*Plantago lanceolata*), sheep's bit (*Jasione montana*) and wormwood (*Artemisia*).

CONCLUSION

Although the primary aim of the geobotanical studies at the Geological Survey of Denmark is to describe and understand vegetation in the past, the results presented here in a brief form give instances how these studies provide information about the vegetation and landscapes where Man lived in prehistoric and historic time. It is shown how human interference with nature and the vegetation in various ways can be traced on varying areal scales. Thus, the history of the vegetation is also the history of Man's changing environment and his interference with it, and is, therefore, not without interest for the archaeologist and the historian.

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