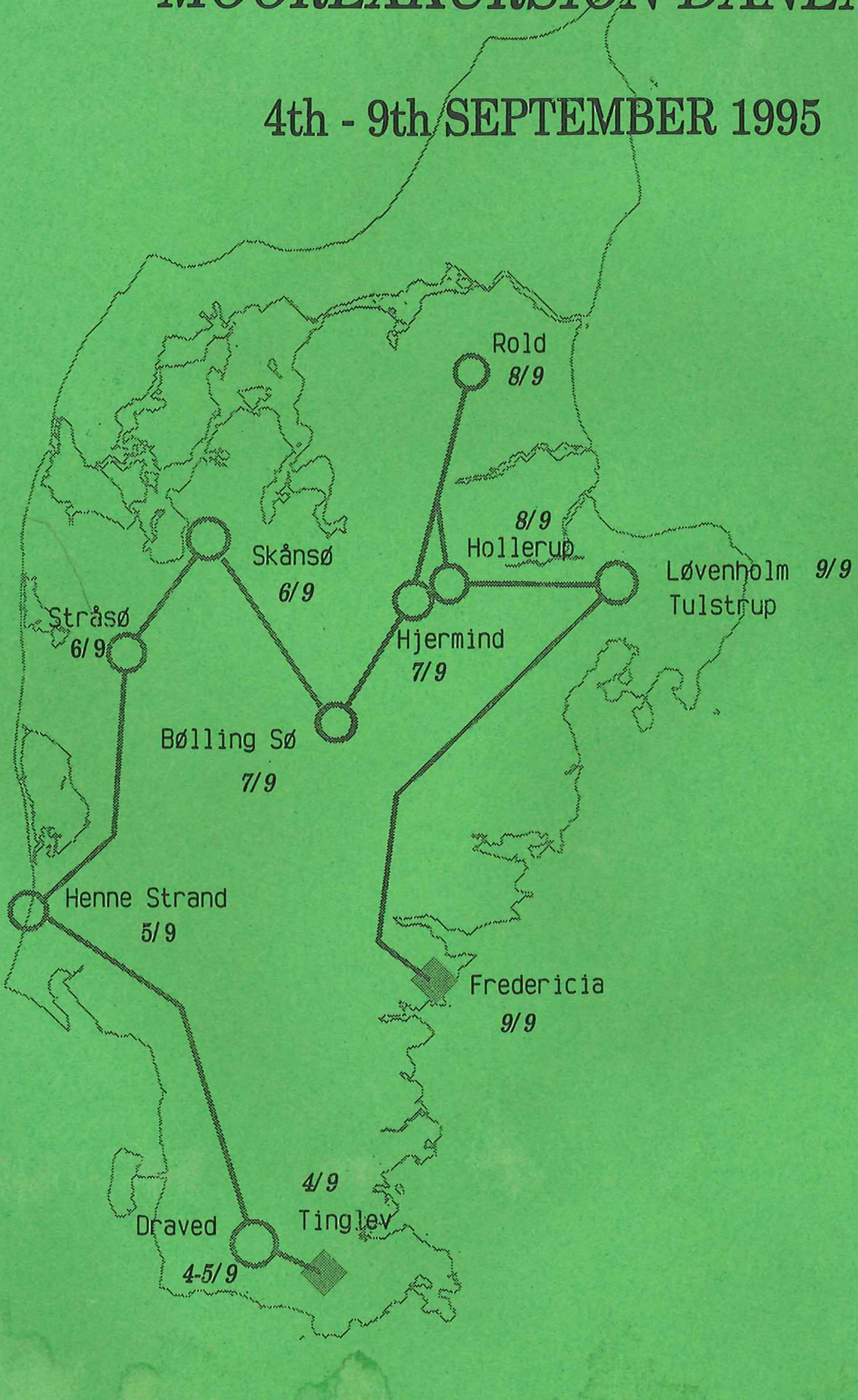
MOOREXKURSION DÄNEMARK

4th - 9th SEPTEMBER 1995



Willy Tinner

Guide to Danish excursion, September 1995.

By *Bent Aaby, Svend Th. Andersen, Kristian Dalsgaard, Peter Friis Møller and Bent Odgaard*

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INTRODUCTION TO THE PHYSICAL GEOGRAPHY AND VEGETATION OF DENMARK

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Geography

The peninsula of Jutland and 474 islands form a typical morainic archipelago with the rocky island of Bornholm detached to eastward. The total area is 43 080 km2 (excl. Greenland and the Faroe Islands). The Danish population, about 5 mill., is not very different in size from that of the other Scandinavian countries, but the population density is much higher.

The land border with Germany is 67 km in length, but the sea boundary, the total length of coast, is more than 7400 km. Thus the Danish territory is a much dissected land mass, and sea and land are intimately connected, as no place lies more than 52 km from the nearest coast.

It is not only its archipelago character which gives Denmark a distinctive stamp; relief features and soil also contrast with analogous features of the other Scandinavian countries, and finds its parallel in NW Germany and The Netherlands. The huge deposits of till which built up the Danish hilly and hummocky relief, as well as the vast outwash plains, are consequences of the fact that Denmark is an area of glacial accumulation.

The boulder content of the moraines is a guide to the origin of the ice flow and to the lands over which it passed. Many rocks, such as limestone, were plucked out and carried along, but as these rocks extend widely under Denmark and neighbouring countries they do not provide much information as a rule. More useful as indicator boulders are rocks whose outcrop is distant and more limited. The principal ones are the rhomb-porphyry of the Oslo region, the porphyry from Dalarna and the so-called Østersø (Baltic) quartz porphyry, the original area of which is the floor of the Baltic near the Åland Islands. These key-boulders make it clear that the ice-sheets advanced from the Scandinavian regions north of, as well as east of Denmark at various times.

Quaternary geology

The history of the formation of the Danish landscape during the Quaternary is mainly the history of glaciations, interglacial and interstadial periods and marine transgressions.

The pre-Quaternary surface, consisting mostly of Tertiary and Cretaceous deposits (Fig. 1), is in most places covered by thick Quaternary deposists, at places hundreds of metres thick. Traditionally, pre-Quaterny surfaces were thought to have little connection to the present surface morphology, but an increasing number of deep corings have lead to a realisation that this is not true. For example, the "tunnel valleys" of eastern Jutland have been shown not only to be depression in the present landscape, but also to be very deeply incised valleys in the pre-Quaternary surfaces. The pre-Quaternary deposits have a direct influence on plant distributions today since mesosoic calcareous outcrops - or drift material from these - largely determine the distribution of calciphilous plant taxa.

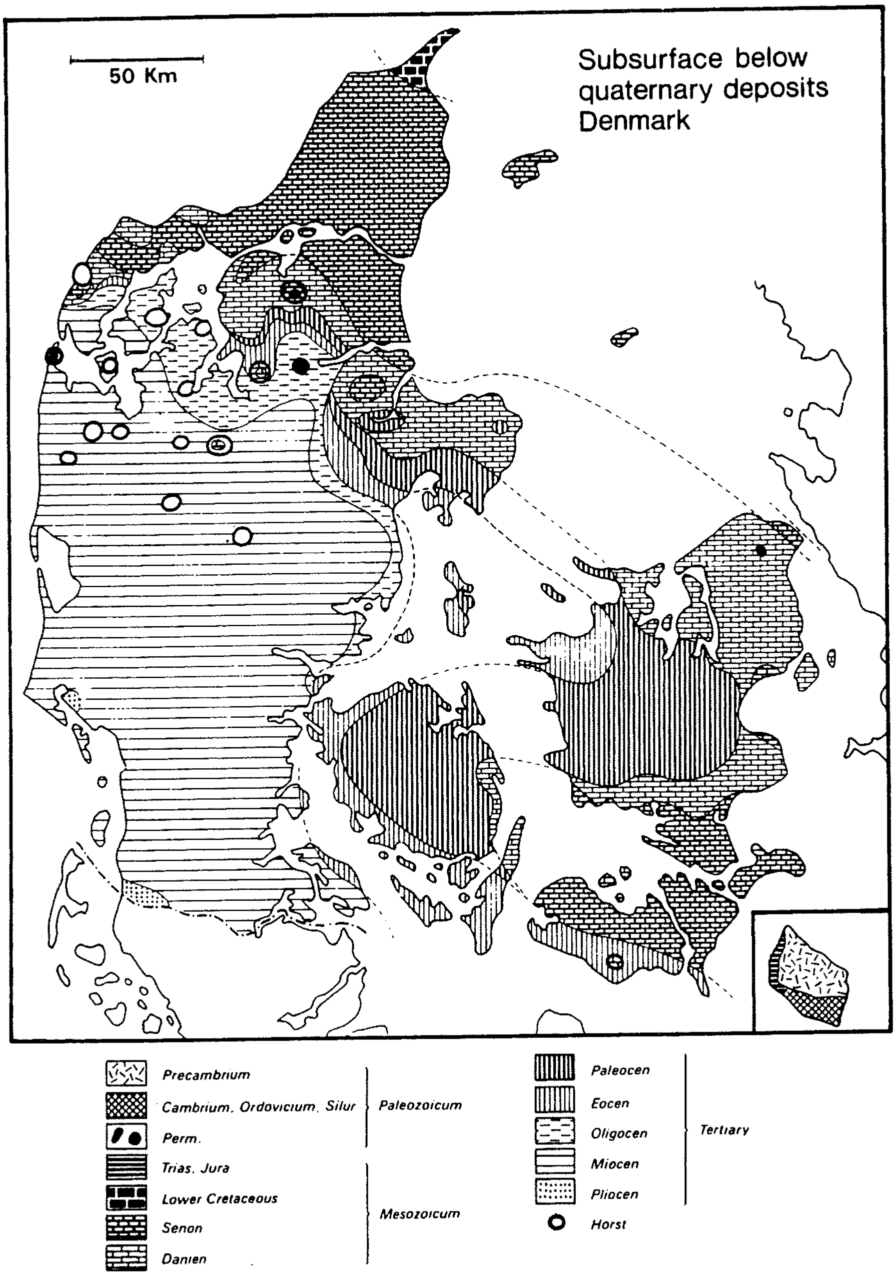
Three interglacial periods have been identified in Denmark: Harreskovian, Holsteinian and Eemian (Fig. 2). Deposits of these periods are mainly lacustrine but from the Holsteinian and Eemian also marine deposits are known. Pollen stratigraphies from the interglacial periods

reveal only few taxa that are not present naturally in the area today, most notably Picea, which was present in all three interglacials. Abies and Pterocarya were present during the Holsteinian, and Buxus during the Eemian. The interglacial periods can, however, be identified by typical pollen zonations.

The Saalian glaciation was the last one to cover the entire country. During the Eemian the sea transgressed a large part of Denmark (Fig. 3.). A large number of lacustrine and peat deposits are known from the Eemian, especially from western Jutland, where the deposits are often covered by only a shallow layer of solifluction or fluciglacial material, and the are basins still visible as shallow depressions in the present landscape. The pollen stratigraphy of the Eemian deposits has been divided into 7 typical zones: 1. Betula, 2. Betula-Pinus, 3. Quercus, 4. Quercus-Corylus, 5. Carpinus-Picea, 6. Picea and 7. Pinus. Basically the first half of the Eemian was dominated by deciduous trees, the last half by coniferous vegetation (Picea, Pinus). Macrofossil analysis documents the presence of wet-ground and water plants now extinct in the area: Brasenia schreberi, Aldrovanda vesiculosa, Dulichium arundinaceum, Trapa natans. Similarly a number of exotic animals were present: fallow deer (Dama dama), Bison priscus and probably also elephant and rhinoceros. Traces of interglacial Man have been reported (to be discussed at the Hollerup site).

The early Weichselian is characterised by a number of stadials and interstadials but it is a matter of current debate whether some of Denmark was glaciated for a shorter period already in the early Middle Weichselian. The main glaciation, however, reached the area in the late middle Weichselian, and formed the main stationary line in Jutland (Fig. 4). It is an unresolved debate whether this line represents the maximum extent of the Weichselian or not. Some evidence suggests intermittent glaciation of areas quite far from the main stationary line. During the Middle Weichselian western Jutland, outside the main stationary line, was highly altered by the formation of the large sandurs and by solifluction. By about 13,000 BP the ice sheet has melted and a part of the northern Jutland was covered by the arctic Younger Yoldia Sea. Due to isostatic uplift shore-lines of the Yoildia Sea are today found as high as 60 m above present sea level in norther Jutland. The terrestrial late glacial development is characterised by the well-known North Europan sequence of stadials and interstadials. In the Allerød period open Betula woodland extended over Denmark, which in the Younger Dryas period was replaced by arctic vegetation types. Periglacial phenomena like ice wedges, arctic soils, pingos and strong eolian activity are well known from the Younger Dryas period. The eolian sand from this period (cover sand) are deposited in shallow, very low hills rather than in dunes like the deposits from later eolian activity. At the end of the late glacial period large areas, which now are covered by sea, were terrestrial (Fig 4).

Following the dramatic increase of temperature in the early Holocene, sea level increased strongly. By 8000 BP the North Sea had come into existence with about its present configuration, and the English Channel was open for direct inflow from the warm Gulf Stream. During the Holocene the northern part of Jutland has witnessed an isostatic uplift (Fig. 5), which was, however, not quick enough to keep pace with the sea level rise. Shore lines from the mid Holocene Tapes (Litorina) transgression can therefore be found up to 13 meters above present sea level in northern Jutland (Fig. 5).



[redacted]. The pre-quaternary sediments (substratum) of Denmark. – Drawn after Sorgenfrei (1958).

Fig. 1

Stage	Substage	Chronozone	C-14 Years BP	blage zone
G. Flandrian	Gc. Late	Gc1. Subatlantic	2.500	IX
	Gb. Middle	Gb2. Subboreal	5.000	VIII
		Gb1. Atlantic	8.000	VI + VII
	Ga. Early	Ga2. Boreal	9.000	V
		Ga1. Preboreal	10.000	IV
F. Weichselian	Fc. Late	Fc4. Younger Dryas	11.000	LW 3
		Fc3. Allerød	11.800	LW 2
		Fc2. Older Dryas	12.000	LW 1c
		Fc1. Bølling	13.000	LW 1a+b
	Fb. Middle	Fb1. Hengelo	37.000	
			50.000	
	Fa. Early	Fa4. Brørup		EW2e-5
		Fa3. Upper Herning		EW2d
		Fa2. Rodebæk		EW2c
		Fa1. Lower Herning	(115.000)	EW1-2b
E. Eemian.	Ec. Late			E7 E6 E5
	Eb. Middle			E4 E3
	Ea. Early		(130.000)	E2 E1
D. Saalian				
C. Holsteinian				
B. Elsterian				
?				
A. Harreskovian				
?				

Fig. 2

The division of the Danish Quaternary used in the list. References: S. T. Andersen (1965, 1975, 1980), Houmark-Nielsen and Kolstrup (in press), Mangerud et al. (1974).

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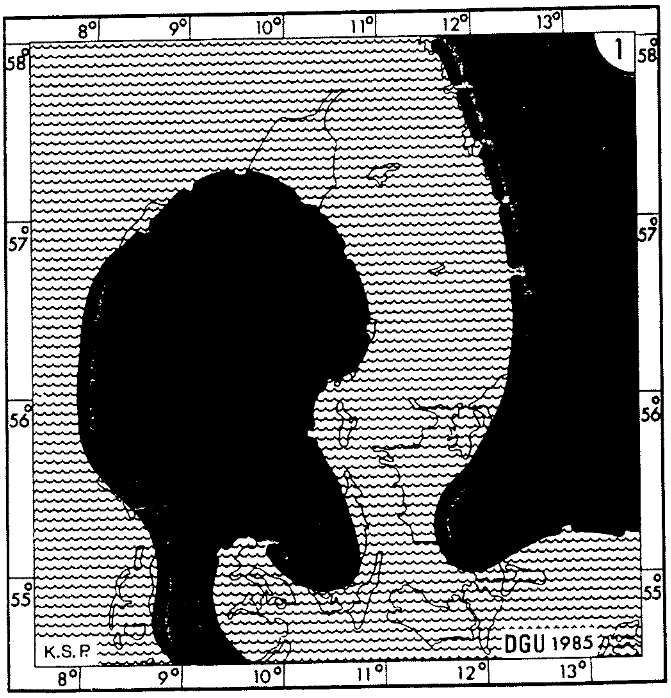
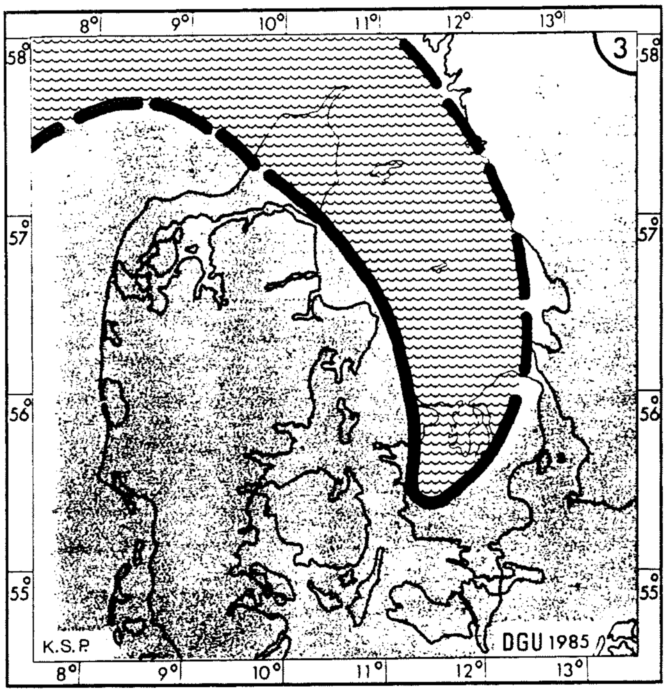
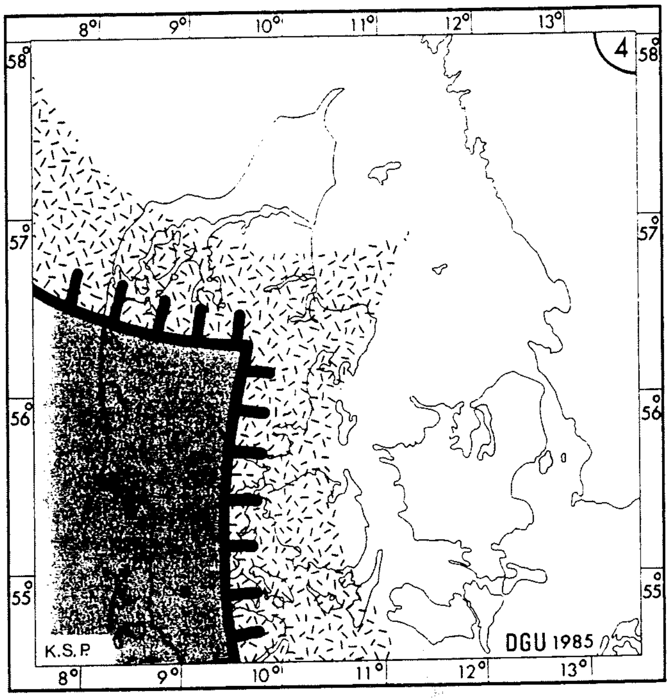


Fig. 3

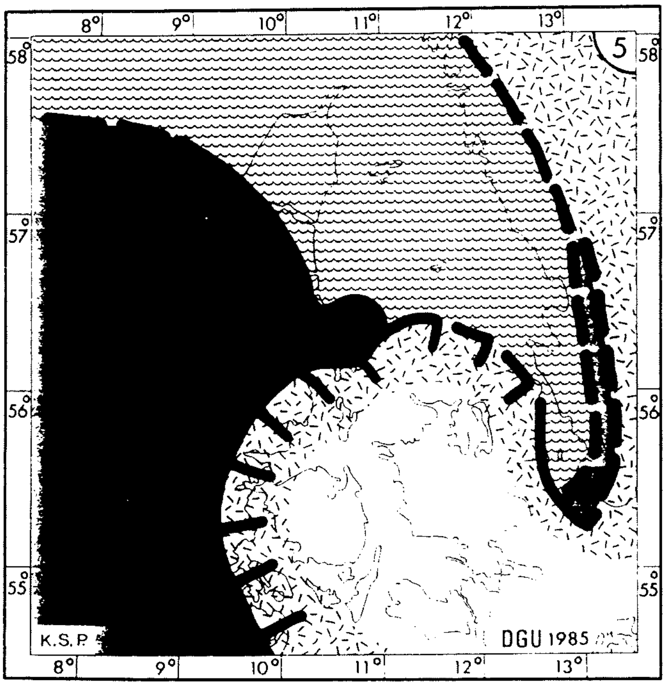
. Land-sea configuration in the Eemian. First scenario in the palaeogeographic suite of 6 for the Pleistocene part of the Late Quaternary.



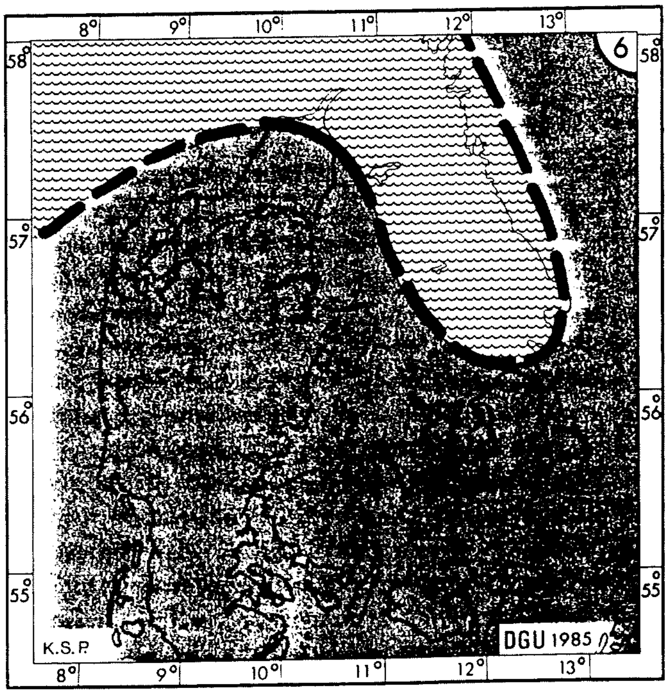
[redacted]. Land-sea configuration in the Middle Weichselian. Third scenario. 45,000 – 35,000 BP.



[redacted]. Land-sea-ice configuration in the Late Middle Weichselian. Fourth scenario. 22,000 – 16,000 BP.

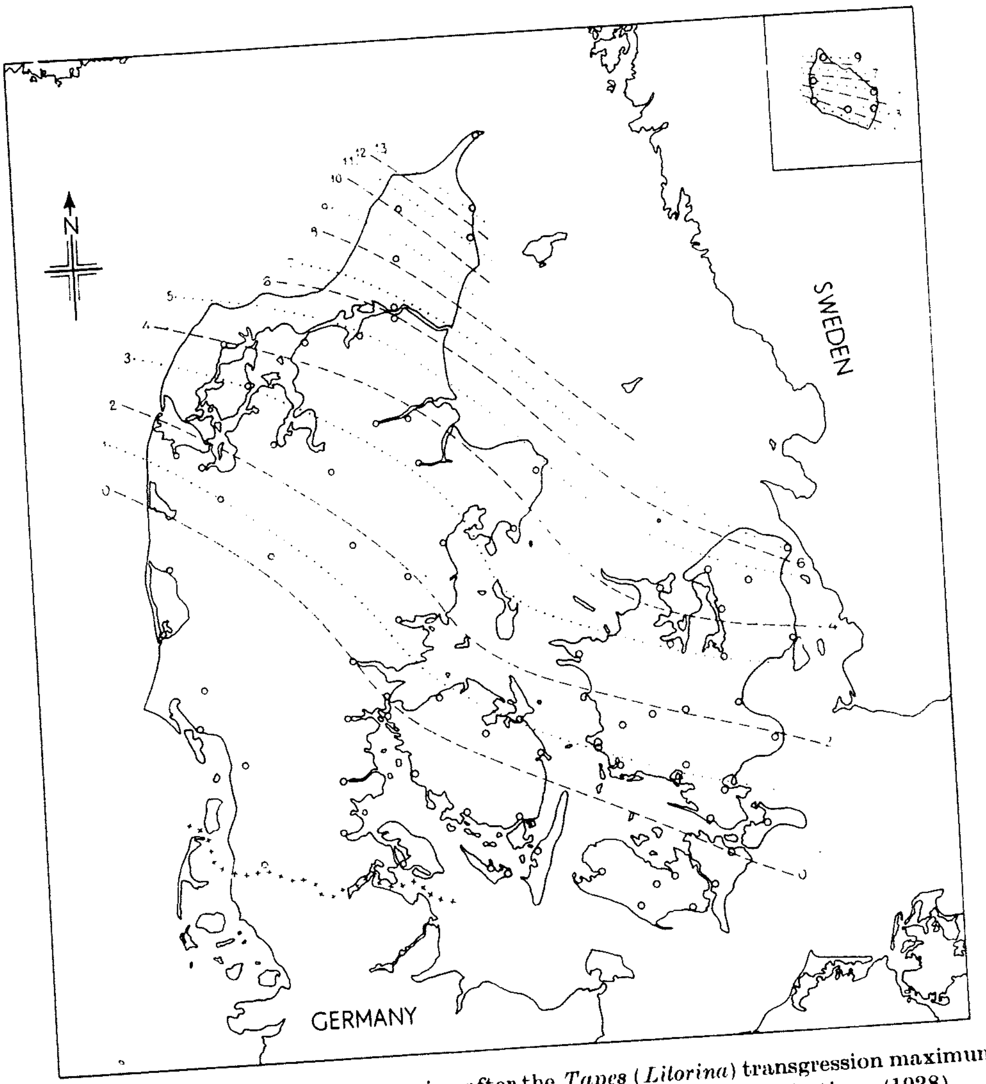


[redacted]. Land-sea-ice configuration in the Late Middle Weichselian. Fifth scenario. 16,000 – 13,000 BP.



[redacted]. Land-sea configuration in the Late Weichselian. Sixth scenario, around 11,000 BP.

Fig. 4



[redacted]. Isobases showing the regression after the *Tapes* (*Litorina*) transgression maximum in northeastern Denmark. Equidistances 1 m. From MADSEN and others (1928).

Fig. 5

The Danish landscapes

Glacial landscapes

The hill islands of West Jutland

In the Weichselian glaciation the ice extended to the central part of Jutland with a Main Stationary Line going S-N up to the town of Viborg and bending westward to the North Sea (Fig. 1). Thus West Jutland remained unglaciated during the Weichselian, when the landscape formed by Saalian till were subjected to a radical transformation. Many lakes disappeared as a result of sedimentation, drainage and infilling by organic matter, and the watercources reached their depth limits. Solifluction, erosin and other exogenic processes have transformed the original glacial landscape into the present-day 'old moraine' landscape, the oldest of all Danish landscapes. These old glacigenic landsapes are named 'hill islands' and they present in their gentle configuration a contrast to the pronounced relief of the 'young moraine' (Weichselian) landscapes in eastern Denmark.

A description of the hill islands is best put in the form of a negative count of their landscape elements. They lack tunnel valleys and marginal moraines; lakes, very hilly areas and undrained depressions are rare. Feature which make up the morphological character of Weichselian moraine landscapes. The size of the hill islands varies considerably, from 2 000 km2 to isolated hummocks with a surface of a few hundred m2. These 'islands' may rise out of the outwash plains with a slope so gradual that topographically their limits are vague; at other places erosion slopes make them rise sharply out of the plains. However, the presence of stones will tell if we are on till soils or not.

Outwash plains

Between the hill islands the enormous plane surfaces of the outwash plains seem to be quite flat, but in reality they are very faintly dipping sand and gravel cones with their apices along the Main Stationary Line (Fig. 1). The slope varies in the different parts of the plain; it is greatest near the apex and decreases outwards. In the middle of the plains the gradient is 1:700, in the outer parts it is 1:1000. These are the tremendous deposits of the meltwater rivers and extensive inland deltas formed beyond the ice margin in the Weichselian.

In many places the borderline between outwash plain and the Weichselian moraine landscape is formed by terminal till mounds, clearly delimited as higher ridges along the highest parts of the plain. However, the transition may be quite different. There is a reversal of these relief details in places where relatively large meltwater deposits were laid down, but the till deposits were thin. Here the outwash plain may lie at a higher level than the adjoining parts of the moraine landscape. The border consists of a slope, caused by slide of outwash sand after the supporting glacier - or dead ice - melted away. In many other localities the transition from the terminal moraine landscape to outwash plain is devoid of distinct relief characters.

The levelled surface of the outwash plains is dissected by valleys; because of the changes in drainage since the formation of the outwash plains, and as a consequence of the altered levels, they are often 'valleys within valleys', the younger valleys having cut down into the older ones. These have been other modifications of the original outwash plain surface. There are some examples of outwash plains with dead-ice relief near the Main Stationary Line. The originally flat surface of the plains is broken by more or less circular hollows, formed by subsidence when masses of dead ice melted. These hollows may be filled by lakes or bogs (e.g. Abkær Bog, Aaby 1988).

Young moraine landscapes

The eastern and northern part of Denmark belong to the Weichselian moraine landscapes with the highest point in Denmark, Yding Skovhøj, 173m a.s.l Surface forms capable of being described as original are rare, however. In our densely populated land Man has been perceptible in the transformation of the landscape by ploughing, drainage, digging and other physical changes of the landscape.

The young moraine landscapes have two different forms : hill country and flats.

The hilly country was formed in the marginal zone of the ice by the accumulation of till deposits. The largest ranges of hills were formed in places where the glaciers in their advance pushed large volumes of earlier deposited material together into ridges, which reflect the position of the ice margin. Parallel hill systems are found where the ice margin oscillated without overwhelming previously deposited marginal tills. The material is composed of grains of all sizes from clay particles to large boulders.. If stratified sand and clay are components of the marginal till deposits, they are highly transformed, dislocated and folded. Marginal tills of this type may occur as hills some hundreds of metres long, or sometimes as rows of hills which can be followed for kilometres. The material of these marginal tills is widely used industrially. Gravel pits are often dug and large quantities of road material are produced from the boulders.

The marginal hill has its longitudinal axis parallel to the ice margin, another type, the drumlin type has its longitudinal axis conforming to the movement-direction of the ice. The surface is smooth with a gradual fall on all sides. Often the drumlins are grouped and have the same longitudinal orientation, or they may lie in line. They vary in length from a few hundreds of metres to a kilometre, and some are even longer.

Another characteristic Danish moraine terrain is the hummocky moraine landscape with many small hills devoid of any particular longitudinal direction; they lie in unsystematic groups and the many undrained depressions are likewise irrigular in their placing. This remarkable till landscape was formed in conjunction with melting masses of dead ice, and the hummocky surface is a direct consequence of the irrigular accumulation of the till in the ice. Lumps of dead ice may have caused the hollows.

The moraine flats are essentially assotiated with the destibution of boulder clay, whereas the former mentioned hill landscapes may wary in character being gravelly, sandy or clayey. High-level flats, called moraine plateaux, occur at several places in eastern Jutland (e.g. between Horsens and Kolding, and around Fredericia). The original surface form the moraine plateau is often intersected by deep erosion gullies. In some cases the erosion phase is relatively young and the plateau is cut only here and there at the edge. In others the process is more advanced, the retrogressive erosion of the streams having disintegrated the plateau surface.

On account of their fertile soil and their levelled surface, the moraine flats are the most fertile farmlands in the country.

The meltwater deposits have left their mark in the glacigenic landscape other than in outwashed plains, although the latter are easily the most dominant form of deposition of glacifluvial meterial. They have also built up landscape forms as eskers, which are elongated hills occurring mainly in the Danish Islands. They usually lie at right angles to lines where the ice was stationary. The eskers often lie in flat landscapes and therefore are in marked contrast to there surroundings. Kames are also found and a modification occuring in Denmark is named hat-formed hill. The structure of its stratified sand and gravel reveals that it was formed by deposition in water, and in the case of eskers, their steep walls must be taken to be ice-contact slopes.

Valley landscapes

In Denmark, the valleys formed by normal fluvial erosion can be classified scematically according to their erosion phase. The older forms typically suggest 'valley within a valley'. They are polycyclic, i.e. the erosive forces changed during the modelling process because of variation in the position of the tetreating ice margin and erosion basis during the Holocene. These Holocene valleys, varying in size from small rain gullies with a V-shape profile to mature river valleys with flat bottoms some hundreds of metres wide, have carved up the higher parts of the young moraine landscapes, outwash plains and late-Weichselian plateaux in Northern Jutland without altering their main outlines.

Subglacial tunnel valleys, cut under the ice contrast sharply with the Holocene valleys. First of all the dimention vary. The large ones are almost 2 km wide. The longitudinal profile is uneven and the bottom floor consists of hollows with lake or mire depressions alternating with higher moraine thresholds.The easterly and lowest parts of these tunnel valleys are submerged and form the East Jutland fiords.The direction of the tunnel valleys is often determined by the surface-topography of the pre-Quaternary, as old valley structures normally are found below the present tunnel valleys.The surrounding glacial landscape often lies 100 m above the bottom of the tunnel valley, and very steep slopes, often covered by deciduous forest vegetation, lie along the valleys and fiord sides. Water erosion has grooved the slopes, but these gullies (secundary valleys) seldom extend back beyond one kilometres from tunnel valley. One the other hand the plateau is cut up a good deal in this belt, and in places the valleys are so close together that parts of the intervening surface are reduced to narrow remnants or have disappeared altogether, the valley sides then meet the ridges or 'false hills'.

Extra-marginal meltwater valleys formed by the large rivers of the melting period run along the ice margin or at right angles to it. At many places, there are extensive valley landscapes where the two valley systems cross, as in the Mossø, and Salten Langsø region in Jutland The river Gudenå runs through both meltwater valleys and tunnel valleys, which cause and explain the many changes of direction in its flow.

The large valley systems which in former times were extensive swamp regions, have long formed natural lasndscape borders. Present-day county, district and parish boundaries still follow the rivers in the broad valley bottoms which by regulation and drainage have been transformed into farmland and pastures.

Marine forlands

About 10% of Denmarks surface is built up by marine sedimentation. These forlands are low and flat, and are most frequent in the most northerly parts of Jutland, such as the Limfiord area. The late-Weichselian marine plateaux flats (Yoldia clay) are most extensive in Vensyssel in North Jutland. The surface is almost horizontal, especially on the more extensive ones. The late-Weichselian sea floor is now elevated due to isostatic movement, but uplift varies, having been greatest to the north, in Vensyssel, where the maximum is 35 m in relation to the present sea level. Holocene, elevated marine plains from the Littorina Sea is found in northen Jutland at at lower level than the Yoldia clay. In parts of these littorina plains, where drainage is inefficient because of the flat terrain and slight elevation above the sea level, the soil is swampy. The two largest raised bogs in Denmark (Store Vildmose and Lille Vildmose) are located on littorina plains which emerged from the sea about 2000 B.C.

Dune landscapes

In Denmark aeolian dunes cover no more than 1.6% of the total area. They are formed of beach sand, dried by the wind and blown inland. The most prominent coastal dunes are found along the westcoast of Jutland. There is a practically unbroken belt of dunes from Skagen in northernmost Jutland to the peninsula af Skallingen outside Esbjerg, continuing on the seaward side of the North Sea islands. There distribution is the result of the frequency of westerly winds and the great breadth of the North Sea shore in conjunction with the heavy transport of sand along the coast.

The so-called inland sands on the outwashed plains are inland dunes formed from the sand and gravel of the fluvial plains. Some of these dunes are of Late-Weichselian origin (coversands) other are of Holocene age. The younger dune formations are supposed to be initiated by human activity (cutting of turf from heathland and pasture), and dates from various time periods. During the Weichselian aeolian sand also accumulated on the hill islands in western Jutland and the very sandy topsoils found today at many sites may be due to mixing of eaolian sand with the Saalian till.

Climate

Denmark has a temperate coastal climate. It is determined by the position of the country in the west wind belt of the north temperate zone on the west side of Eurasia. That Denmark faces the North Sea, and is not open to the Atlantic is another vital factor. Thus, the country has not a typical maritime climate as e.g. the British Isles. On the other hand, the ameliorating influence of the Baltic Sea does not result in a continental climate as that of East Europe. Exceptionally, when winter ice closes the Baltic and it ceases to act as a thermal reservoir, masses of cold air from the east may spread over Denmark and cause an 'ice winter'. This occurs in about five winters per century. In the last of the three ice winters 1939-42, a temperature of -31°C was measured, the lowest ever recorded in Denmark. Conversely, summer high pressure systems over Scandinavia keep out the cool westerlies, and high temperatures are recorded. The highest air temperature measured under such conditions is 35.8°C, measured in central Jutland in 1911. However ice winters and heat waves are rare; more moderate temperatures are the general rule.

The annual mean temperature for the country is about 8°C. The yearly variation of air temperature (Fig. 2) shows that the coldest month is february and the warmest being july. The average mean temperature for these two month are -0.5°C and 16.5°C respectively. Although Denmark is small in extent there are typical regional climatic differences, above all between the coast and the interior owing to marine influences. The coldest month on the west coast has an average temperature of 0.5°C, but the interior of the island of Bornholm in the Baltic has less than -1°C. Summer temperatures also show that continentality increases towards the east. The temperature at the west coast is then 15°C whereas the southeast of the country has over 17°C. The length of the frost-free period also varies regionally. On an average the last night-frost on the west coast is on April 3rd, whereas inland in Jutland it is as late as May 19th. The first night-frost of autumn comes about September 28th in the interior of Jutland but not until November 27th in parts of Bornholm.

The annual precipitation varies between more than 800 mm (in southern Jutland) and about 450 mm recorded from a small island between Sealand and Funen (Fig. 3). The rain is mainly cyclonic. The precipitation diagram shows that rain falls all the year round, and that in this respect too, annual variations may be considerable (Fig. 4). Winter precipitation is relatively small, and the spring month are also dry. The wettest months are August and October.

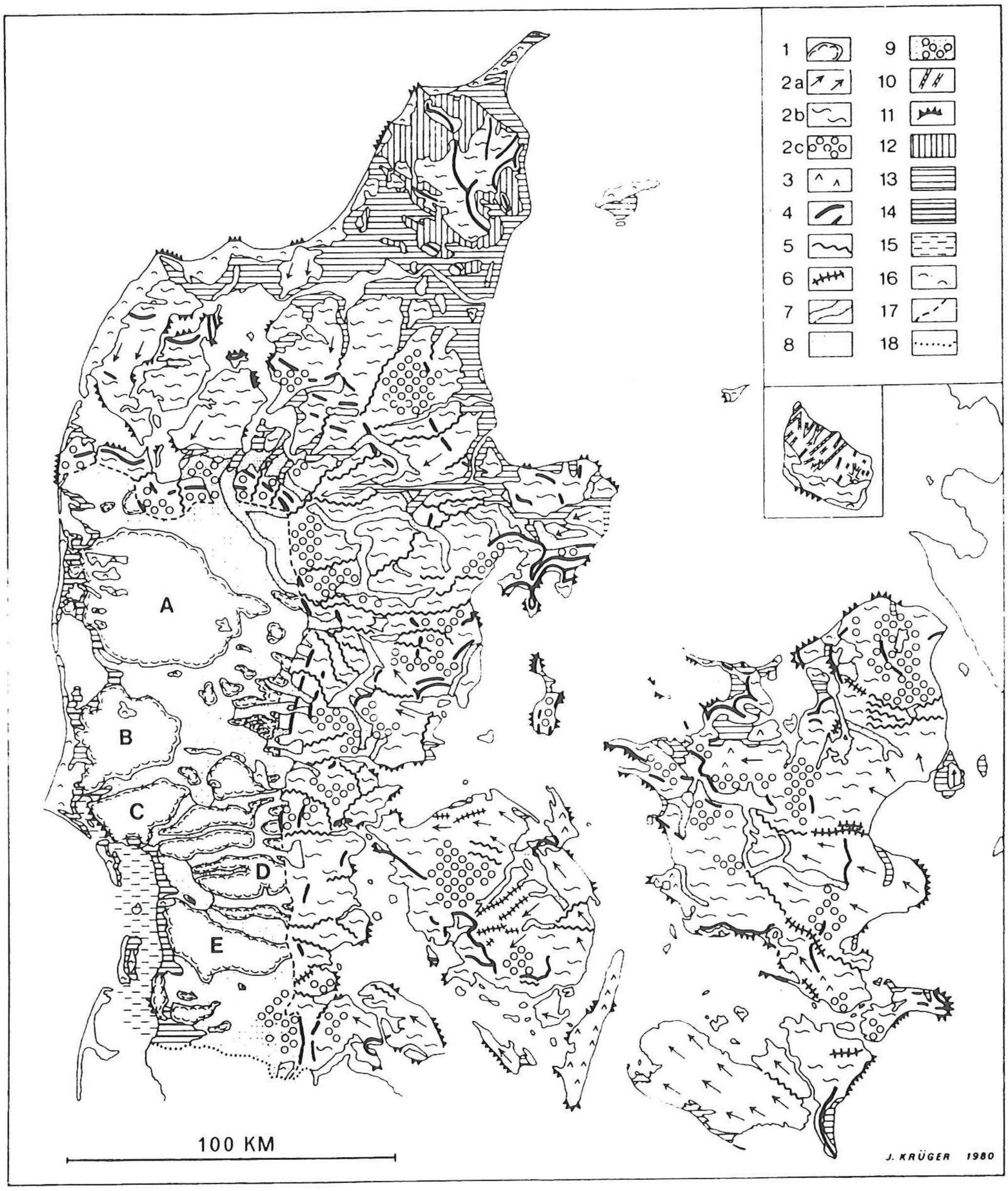


Fig. 1.

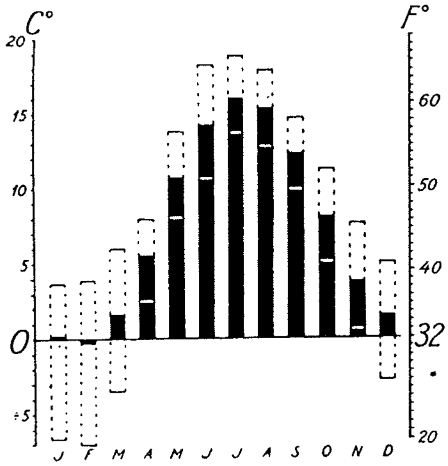
Geomorphological map of Denmark:

1. *Morainic landscape from the Saalian glaciation.*
2. *Morainic landscape from the Weichselian glaciation.*
   a. *Drumlinized ground moraine, mainly till plains.*
   b. *Undulating ground moraine.*
   c. *Hummocky moraine or fields of kames.*
3. *Field of dislocated kames, so-called 'hatshaped' hills.*
4. *Distinct ice-marginal hills.*
5. *Tunnel valley.*
6. *Esker.*
7. *Extramarginal meltwater valley or small outwash plain.*
8. *Extensive outwash plain.*
9. *Outwash plain with kettle holes.*
10. *Fissure-valley landscape.*
11. *High cliff.*
12. *Marine foreland of Late-glacial age (the Yoldia plateau).*
13. *Marine foreland built up since the Stone Age (the Litorina plains)*
14. *Salt marsh.*
15. *Tidal flat.*
16. *Dune landscape.*
17. *Main Stationary Line during the Weichselian glaciation.*
18. *The Danish-German border.*

Compilation based on maps by Geological Survey of Denmark, Axel Schou, Per Smed and Johannes Krüger.

The capital letters on the map indicate the main morainic landscapes from the Saalian glaciation: A. Skovbjerg, B. Varde, C. Esbjerg, D. Rødding, E. Toftlund.

Fig. 2.



Yearly variation of air temperature. Black column: mean monthly temperature. White column above: highest mean monthly temperature since 1874. White column beneath or white line through the black column: lowest mean monthly temperature since 1874.

Annual average precipitation 1931-60, mm.

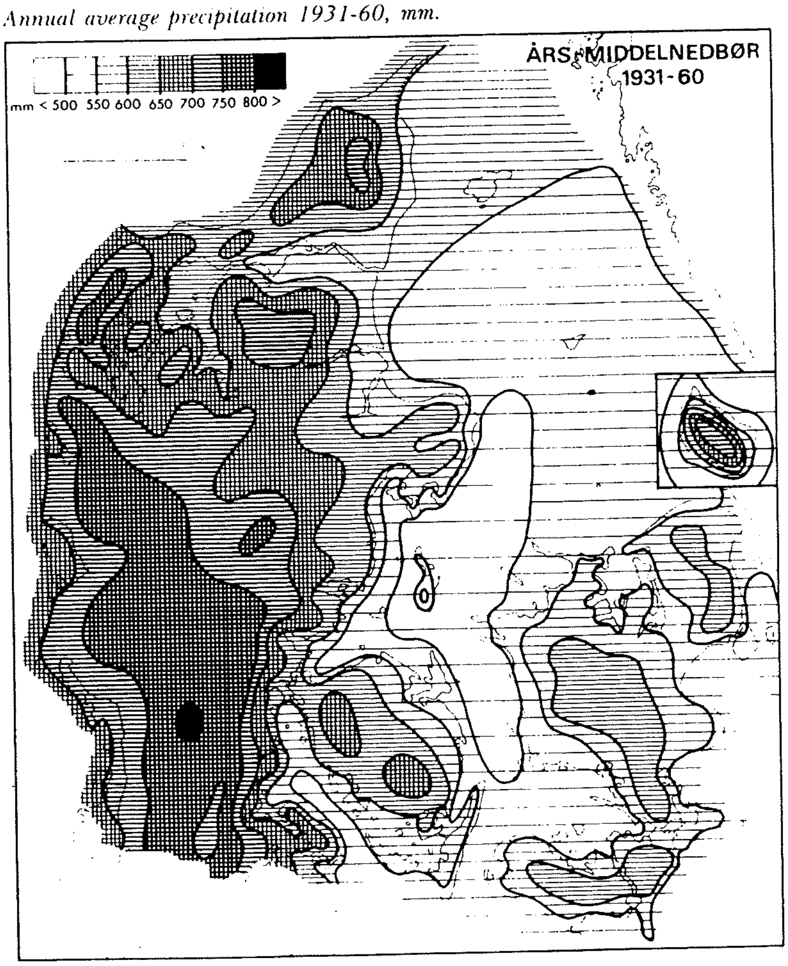
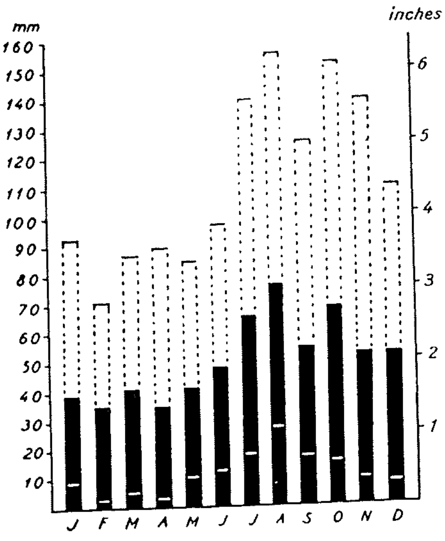


Fig. 3

Fig. 4.



Yearly variation of precipitation. Black column: mean monthly precipitation. White column: extreme monthly maximum precipitation value since 1874. White line: extreme minimum since 1874.

Plant geography

Phytogeographically Denmark belongs to the western, (sub)oceanic part of the nemoral deciduous forest zone. Denmark is close to the border of the boreo-nemoral zone, from which it is characterised by the absence of natural Picea. Especially in Jutland, the flora is rich in (sub)oceanic element which are sensitive to low winter temperatures like Erica tetralix, Narthecium ossifragum, Genista anglica, Ilex aquifolium, Luzula silvatica (Figs. 1 and 2).

Generally, however, the local plant distribution in Denmark is determined by soil variation and land use rather than by climate. Thus taxa showing a preference for nutrient rich soils (e.g. Fraxinus excelsior, Lactuca muralis, Figs. 3 and 4) are most frequent in the area glaciated during the Weichselian, while taxa on poor soils have their main distribution west and south of the Weichselian main stationary line (e.g. Genista pilosa, Fig. 5). Some, but not many, taxa have range limits passing through Denmark (e.g. Carpinus betulus, Acer campestre, Arum maculatum, Carex pendula, Rubus chamaemorus, Figs. 6-10).

Natural woodland types on a wide range of soil types, except the very moist and wet, are dominated by Fagus. Woodland with much Tilia is now very rare and Tilia cordata generally seems to have a limited success of regeneration in the area, and seeds are often barren. Fagus is widely distributed as a natural tree except in an area of western Jutland (Fig. 11). Its absence there has been widely discussed and the traditional explanation has been that of local climate and poor soils. Climatic gradients are, however, short in Denmark and Fagus grows well on poor soils in other parts of the country. In contrast, prehistoric and historic landuse seems to explain the local distribution of Fagus adequitely. Fagus expanded in Denmark in the late Iron Age, when a general woodland regeneration took place in eastern Denmark. Recent studies of vegetational history demonstrate that the areas where Fagus is today absent coincide with the sites where no Iron Age woodland regeneration took place.

Typical for western Jutland are the oak scrubs, which are dominated by low, crooked Quercus robur, often mixed with Q. petraea and hybrid forms. Important is also Populus tremula and Sorbus aucuparia while Fagus is absent. The presence of these scrubs have long played an important role in the discussion of the history of woodland and heathland in Jutland.

The heathland of Jutland is typical in having a mixture of northern (boreal) elements (e.g. Empetrum nigrum, Cornus suecica, Arnica montana, Vaccinium vitis-idaea) and southern elements (Genista species). The Danish Calluna-Empetrum heathland type is replaced in northern Germany by a Calluna-Genista type with very little, if any, Empetrum. The Jutland heaths lack the Erica cinerea of the extremely oceanic Europe.

Fig. 1.

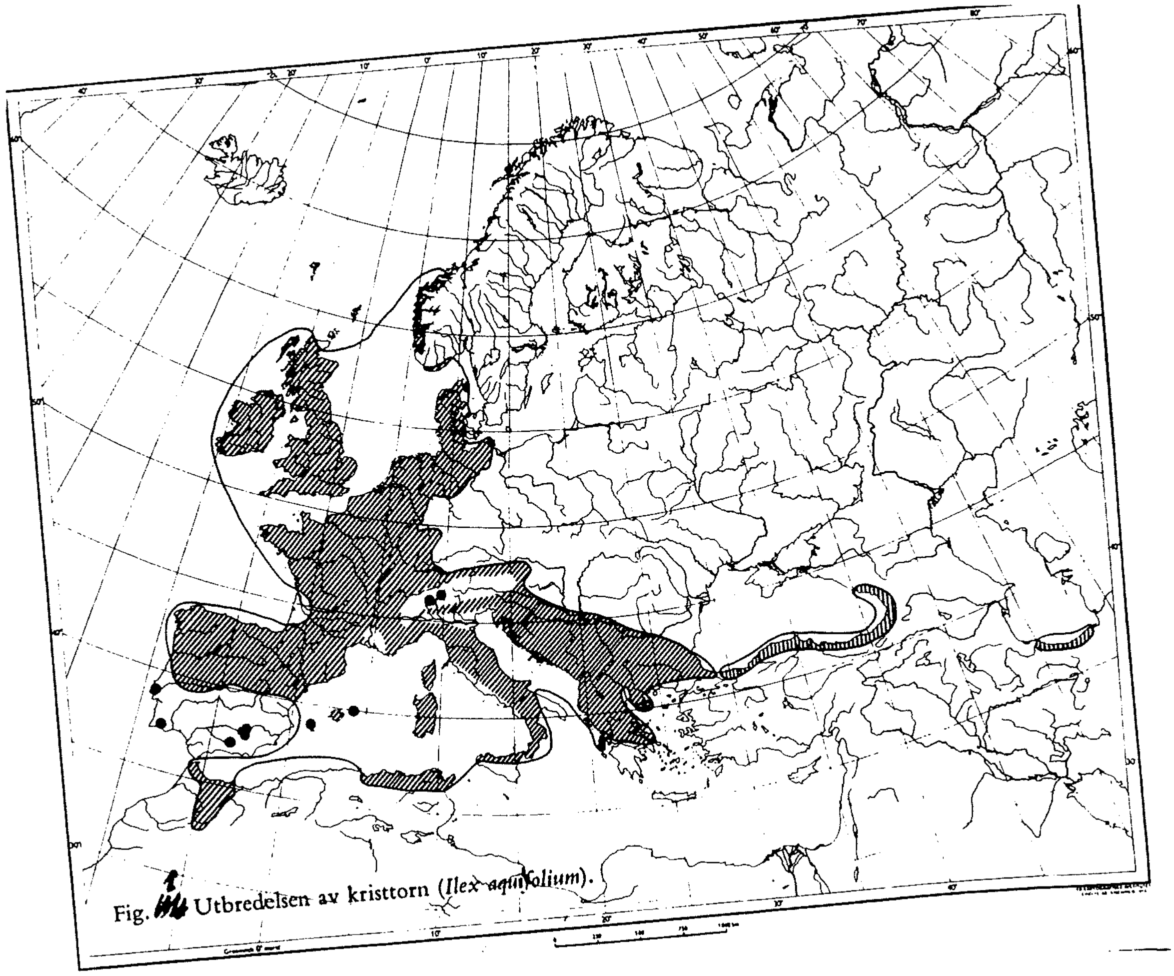


Fig. 1. Utbredelsen av kristtorn (Ilex aquifolium).

Fig. 2.

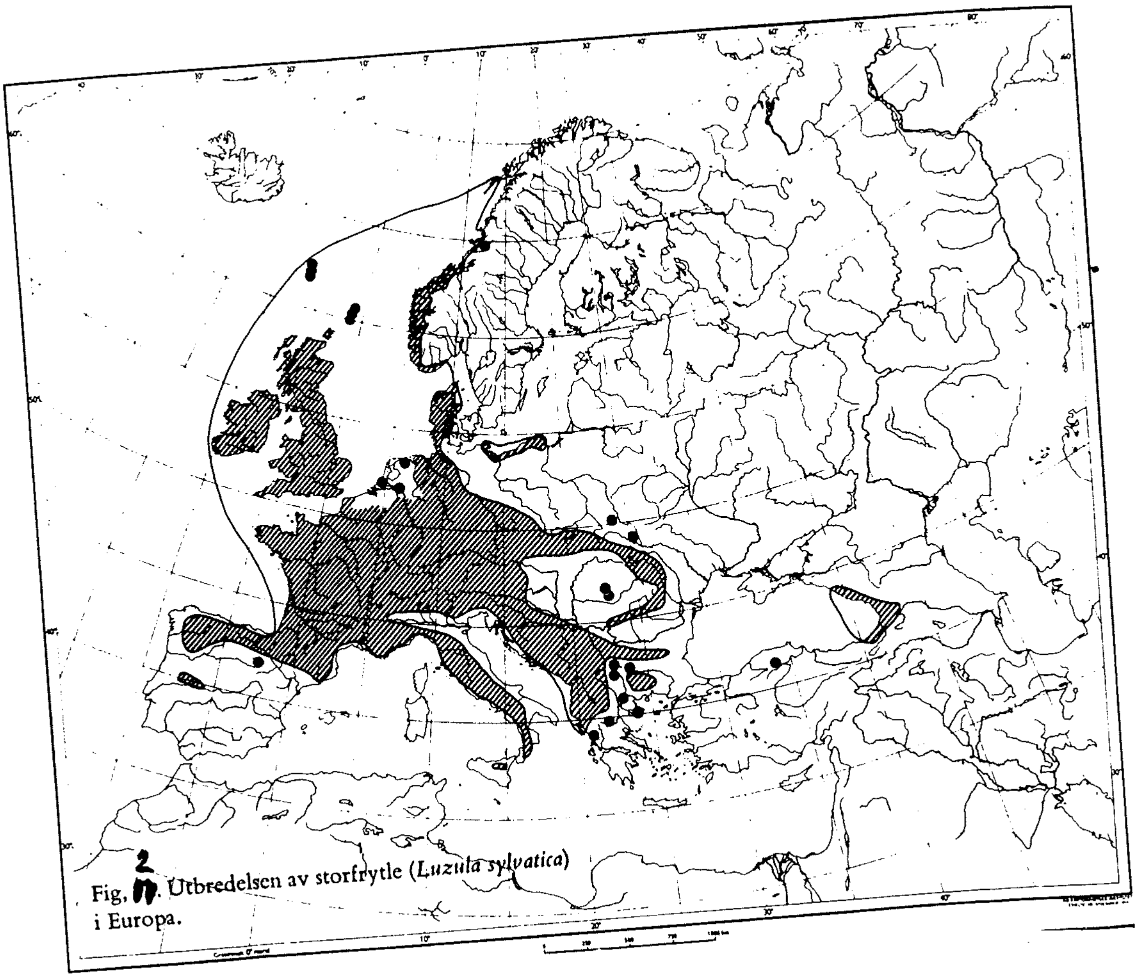
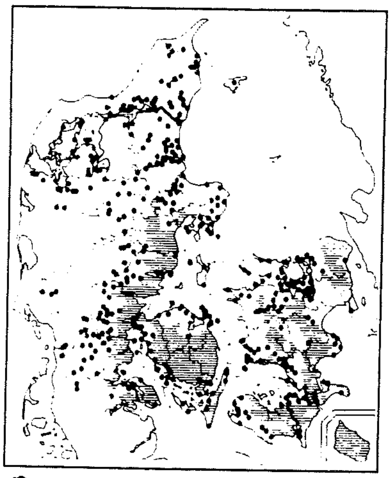
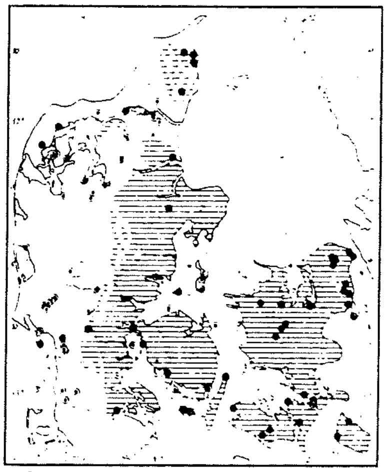


Fig. 2. Utbredelsen av storfrytle (Luzula sylvatica)
i Europa.



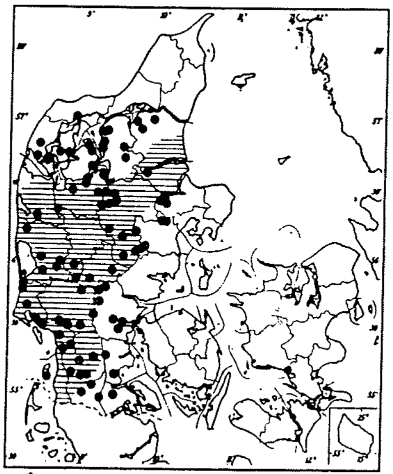
[redacted]. Fraxinus excelsior. SØ 1968.

Fig. 3.



[redacted]. Lactuca muralis. AP 1961.

Fig. 4.



[redacted]. Genista pilosa. KJ 1931.

Fig. 5.

Fig. [redacted]. *Carpinus betulus* L.
N f. linien antagelig alle plantet eller forvildet. (North of the line probably all cultivated or escaped).

Fig. 6.

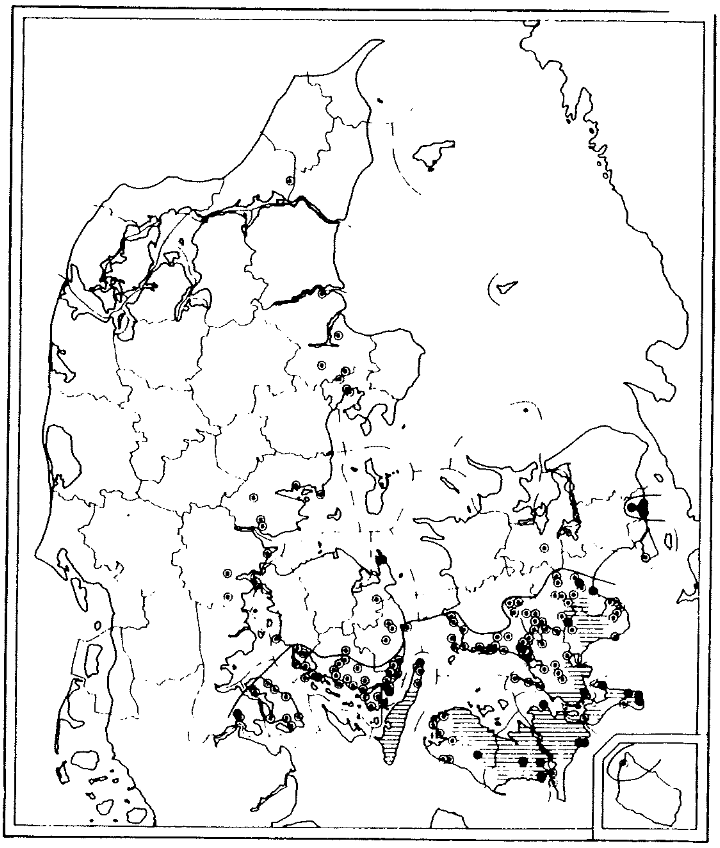


Fig. [redacted] *Acer campestre* L.
N f. linien og i d. 47 antagelig alle forvildet. (North of the line and in d. 47 probably all escaped).

Fig. 7.

Fig. 8.

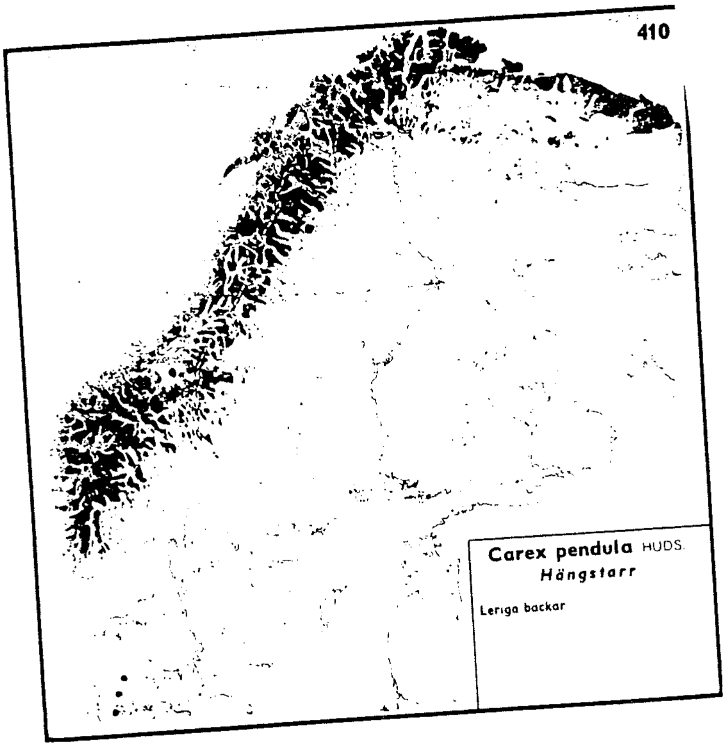


Fig. 9

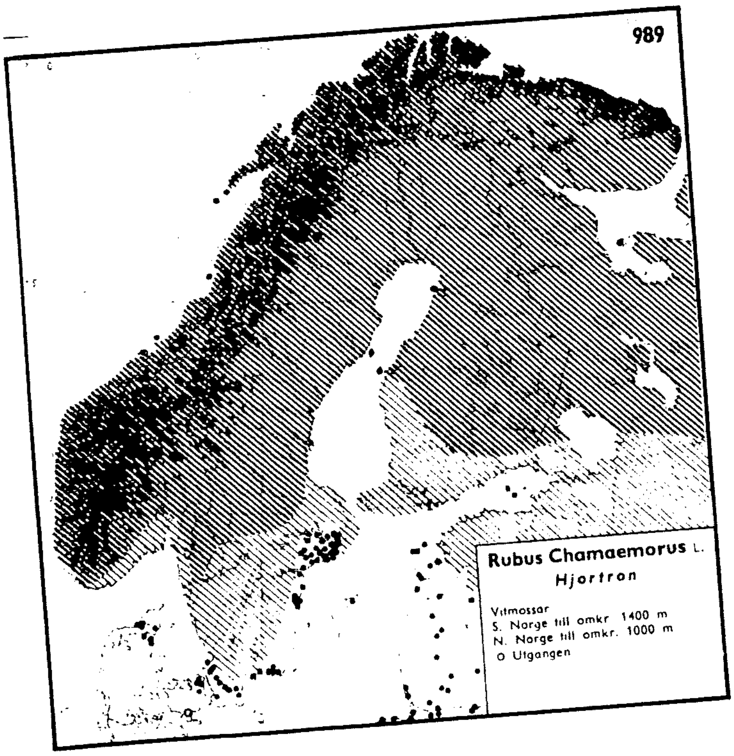


Fig. 10.

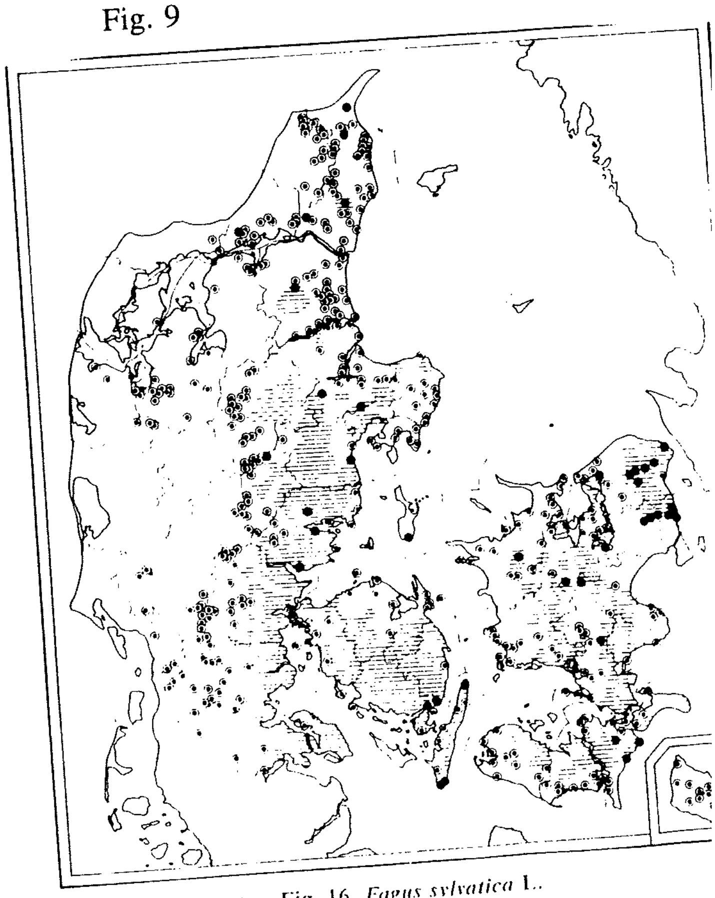


Fig. 11. Fig. 16. *Fagus sylvatica* L.

The map of Denmark

Denmark is an intensively cultivated country: 65-70% of the area is farmland, or used for horticultural purposes (Fig. 1). Shifting cultivation is by far the most common cultivation system as it occupy 52% of the Danish area. Town areas, roads and other trafic constructions and summerhouse areas cover 10-15%. About 13% of the country is forested and 9% is areas with a natural or semi-natural vegetation having no or only a sparse tree cover. These nine per cent of extensively used areas consist of lakes and rivers (~1%), salt marchers, salt meadows and other areas influenced by saline water (~1%), meadows (~1%), bogs and fens (~2%), heathlands and pastures (~2%) and dunes (~3%).

Modern changes of landscape and environment

The rural landscape

The structure of the rural landscape was formed following the legal redistribution of the land by the end of the 18th century. Before that time most farm buildings were concentrated in villages, a pattern which had remained for centuries. During the 19th century many farms were moved so they became surrounded by own prperties. Along with the intensification of farming, many new farms were established. This gradual filling up of the rural landscape came to an end during the first part of the 20th century. Since then only a few new farms have been added and today the number of farms has decreased due to specialization and formation of larger economic units.

The last decades of massive farm amalgation and technological advance have resulted in other significante and substantial changes. Hedges, stone and earth banks have been removed and the field pattern has changed towards larger units.

At the beginning of the 19th century more than two thirds of the population in Denmark were rural. Now less than 20% are living outside the urbanized areas, and only about 5% of the labor force work in agriculture. Up to the beginning of the 1950s more than half of the agricultural labour force were hired. Today about 85% of the farmwork is done by the farmers themselves and their families.

Drainage

Artificial drainage of lakes and mire areas is documented since early medieval times, and from the middle of the last century systematic drainage activities have been undertaken. Today (1980) about 50% of the farmland area have been drained, and more intensively on the Danish Islands (69%) than in Jutland (41%). Drainage constructions have been and are still subsidised by the state, and the activities were most intensive in the periods 1960-80 and 1940-70 (see Fig. 2).

Based on information obtained from geological and topographical mapping in the last century and historical documents it has been proved, that about 20-25% of the young moraine landscape was water-logged and covered by mires, wet meadows or lakes before drainage was undertaken. Today only about 2-3% of our country is water-logged. This development is documented from farmland areas as well as from forested areas.

Intensive and extended drainage has strongly influenced the vegetation and the flora and fauna of wetland areas, as well as the physionomy of our landscape which today have no parallel in the past. However, drainage is important for the farmers as it has given a growing season about 3 weeks longer than in the middle of the last century.

Fertilizers and manure

Supply of nutrients are important for the crop production. Manure was in former times the most commom source of vital nutrient-ion supply. Manure is still important, but especially since the 1950s artificial fertilizers have played an important rôle, and for nitrogen they are the most common source of nutrient (Fig. 3). In this century the total supply of N-nutrients have increased by a factor of 10 (from about 60,000 tons to about 560,000 tons). The intensive use of fertilizers have resulted in pollution of ground-water by nitrate. The main source is often claimed to be nitrate originating from manure. This probleme has increased in recent years because of the tendency to concentrate livestock on fewer farms, which leads to difficulties in the distribution of manure to sufficiently large areas and at the proper time of the year.

Air pollution by NHx

Ammonia emission from farmland originates mainly from livestock dung. In the atmosphere NH3 gradually change into ammonium (NH4+)-particles. Ammonia and ammonium (commonly named NHx) precipitate as dry- or wet deposition. Dry deposition of (NH4+) is most important close to the source, whereas wet deposition of (NH4+) dominates at longer distances from the source.

About 60,000tons nitrogene in the form of NHx is deposited on land with 75% originating from Danish sources. The mean immision is 21 kg N ha-1 yr-1, but varies between regions mainly from 15 to 30 kg N ha-1 yr-1 .(Fig. xx). This kind of air pollution contribute to eutrophication of the environment and especially heathlands, oligotrophic fens and raised bogs are threatened by the increased content of NHx originating from farmland.

The increased content of N-nutrients also influence the ecological conditions in marine areas; especially for the fiords and the shallow sea areas around Denmark as the immision of atmospheric NHx increases the algea production. This is of special importance in summer time when the run off from rivers is low. High primary algae production causes anarobic conditions at the sea floor which harm the flora and fauna at the bottom.

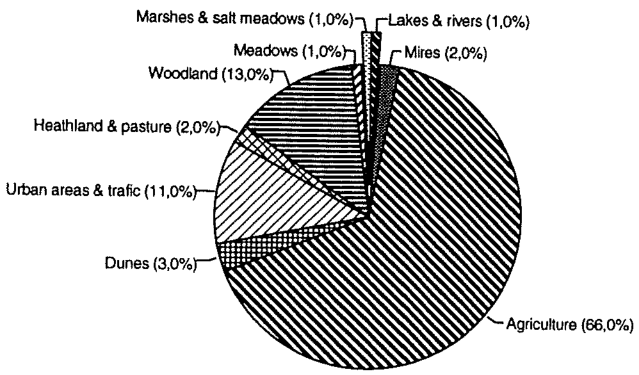


Fig. 1.

Drained agricultural area in total for the country (○), on the Danish Islands (□), and Jutland (▽).

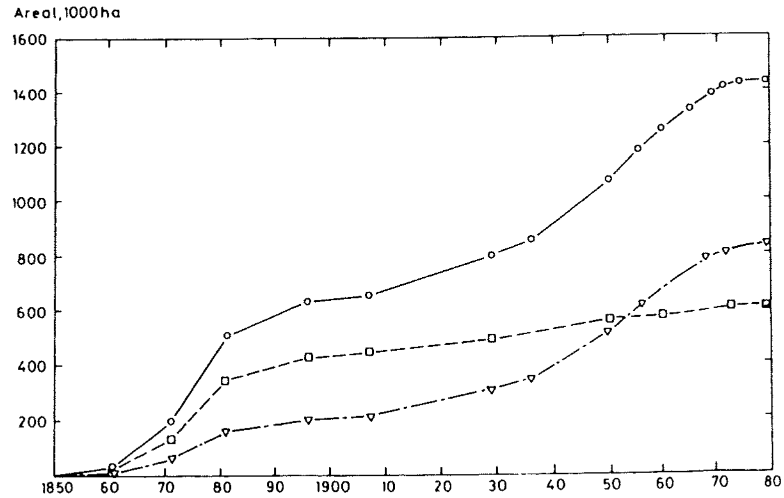


Fig. 2

Consumption of fertilizers and manure in this century, stated in tons of pure nutrient for nitrogen (N), phosphorous (P) and potassium (K), respectively. Notice that the registration method for nutrient content in manure was changed 1974/75.

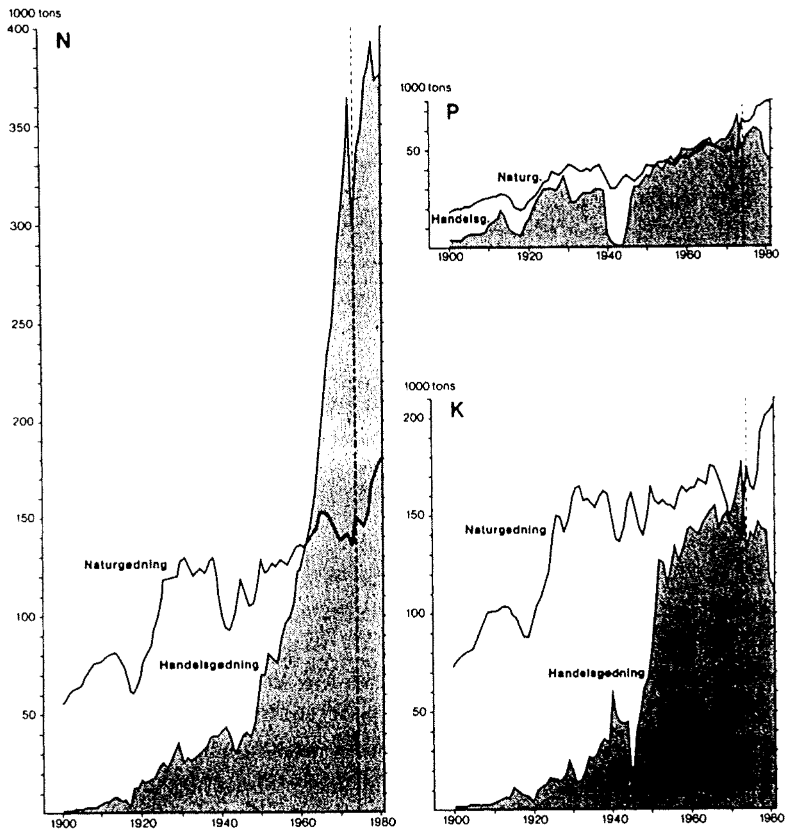


Fig. 3.

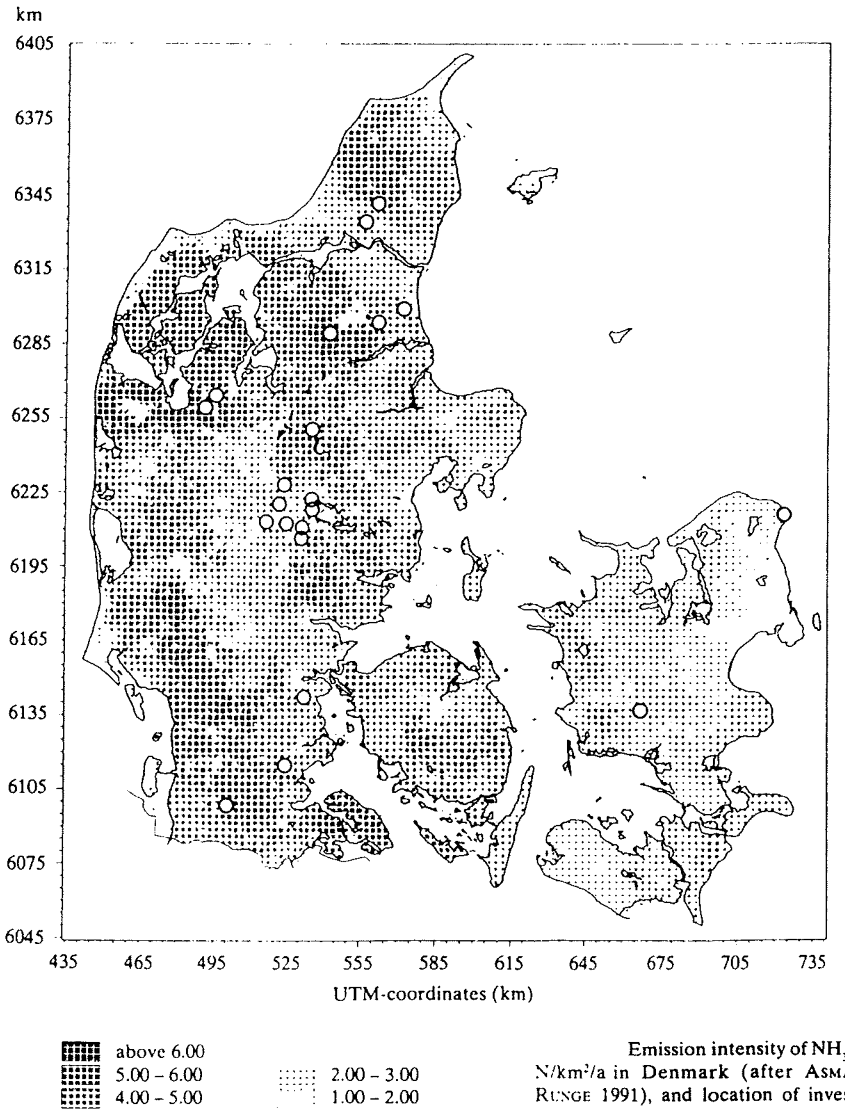


Fig. 4.

Emission intensity of NH_3-N tons N/km²/a in Denmark (after ASMAN and RUNGE 1991), and location of investigated bogs

Monday 4th September

1. stop: Draved Forest

Bent Aaby and *Peter Friis Møller*

Location nos 4.1 - 4.2
Vegetation type: Nemoral deciduous forest types
Matters for discussion: Modern vegetation and ecology, vegetation history, soil development

General description

Draved Forest is located 4 km south of Løgumkloster in the southwestern part of Jutland. The distance from the sea is 20 km. The forest is owned by the Danish state and the present area is 200 hectares.
Draved Forest is located on a lobe of a "hill island" consisting of clayish till from the Saale glaciation and partly surrounded by Weichselian sandur (outwash sands). The major parts of the sands was formerly covered with bogs and other wetlands, of which some more or less disturbed remnants are left. The major part of the surroundings is cultivated arable land. The soils in the forest include a complex of podzolic aeolian sands with thick layers of raw humus and gley-podzols.
Due to high groundwater level and the small scale topographical variation between dunes and slopes, the soil conditions and plant communities vary very much within few metres or even decimeters.

Draved Forest was for hundreds of years surrounded by bogs and peatlands. Although some cuttings was done, the general species composition remained unchanged. The humid lower parts of the forest was in despite of some of the high soil areas almost undisturbed until about 1800 (1783), where a part of the forest was cleared and cultivated and forest management with intensive drainage and plantings was invented.
The major part of the forest are still managed - a.o. with plantations of Picea, Abies, Fraxinus, Quercus robur and Q. borealis. A minor part - 35 ha in total is remnant of the natural forest and have been protected as research area in free succession since the 1950s, officially since 1963.
The natural forest in these parts consist of mixed stands of Tilia cordata, Alnus glutinosa, Betula pubescens and Quercus robur with singular Populus tremula and Malus silvestris. On high podzolic soil of Fagus, Betula pubescens and Quercus robur. Corylus avellana, Frangula alnus, Sorbus aucuparia and Ilex aquifolium occurs in the understorey.
The ages of the canopy trees are approx. 100-150 with a few trees of 200-250 year.
In general the regeneration of oak is very sparse within the stands.

Draved Forest have been research area since 1947, where Iversen initiated pollen analytical, pedological as well as forest ecological studies. An important purpose with the ecological studies was to receive a better basis for the interpretation of pollen diagrams (e.g. Andersen 1970). Later the study of natural forest dynamics, environmental monitoring and aspects of biodiversity became important too.
In the 1950s some archaeological experiments was carried out in a small part of the forest

(cutting with stoneaxes and experimental stoneage cultivating techniques).

The research stands are monitored with regular (5-10 (25) years intervals) measurement of tree diameters, classification of crown wealth and actual development tendency and measurements on regeneration and field vegetation, annual tree pollen production, daily precipitation and weekly groundwater-level.

Due to a national strategy for natural forests and untouched forests, the whole forest will be taken out of the forest management latest in 2000; coniferous plantations would be removed and the natural drainage system more or less restored or at least the artificial destroyed. The forest will by then become one of the most important research ares i Denmark in relation to unmanaged forest
dynamics.

Vegetation history

The vegetational history of Draved forest is well known from Johs. Iversens many and detailed pollen analytical investigations of terrestrial soil profiles and from other investigations. Podzol soil with a well developed raw humus layer is found on high ground in the forest area, often on aeolian sand covering Saalian till deposits (Fig. 1). The SE and low lying part of the forest is mostly covered with acid forest peat. Both the peat and the extended raw humus layers are suitable sources for pollen analytical investigations of the past.

The deep organic layers often goes back to the early Subboreal, although the chronology is difficult to determine in podzols, and they give the best opportunity to study retrogressive vegetational succession on leached soil.

The pollen analytical investigations have been concentrated to the western part of the forest close to a natural Tilia stand (Location no. xx) and to the eastern part (Location no. xx).

Forest part 386
Location no. 4.1
Vegetation: Mixed Tilia cordata-Quercus robur-Fagus sylvatica-Alnus glutinosa vegetation
Matters for discussion: Modern vegetation and ecology, vegetation history, soil development, modern pollen deposition

Diagrams from two sites will be discussed (see Iversen 1964)
Site 1. The profile is a gley-podzol with a 35 cm deep layer of raw humus (Fig. 2). The site is quite near the western edge of a dune area. Only a few metres to the west is found a rich mixed forest of Tilia cordata, Alnus glutinosa and Fagus sylvatica on mull gley. The pollen diagram thus covers both the raw humus forest with Quercus robur and Betula pubescens, and the fertile mull forest. The outstanding feature in the diagram is the fact that the forest composition is essential the same throughout, except that Fagus immigrates in the middle of the sequence and expands at the expense of Quercus. The Tilia curve is only slightly declining in the first stages of the raw humus formation. A 'Viking age landnam' is clearly marked in the series by a thin horizon with microscopic charcoal fragments. Pollen of Chamaenerium-type and Melampyrum also appear at that level, as does Calluna pollen from a neighbouring heath area. These pollen show close-by agricultural activity. The forest up to

this time has been rather dark and very little affected by man. Now is was opened up for cattle-grazing. However, the forest was not cleared, and nothing indicates that the composition of the mixed Tilia-Quercus-Fagus-Alnus forest has been seriously affected also after the human exploitation, and the pollen spectra just before the 'landnam' is almost identical with the sub-recent analysis. Thus, it appears that the forest composition on the gley soil has been surprisingly stable throughout the last 3-4000 years registered in the diagram. In this respect the stand in Draved seems to be unique, for nearly all other woods in Denmark seem to have been pasture-land to some degree or cultivated fields at one or more occasions in the past.

Site 2. It is located east of site 1 at a distance of only 60 m. The site lies in the central part of the dune area with deep raw humus layers. The pollen diagram shows the vegetational changes since the Subboreal (Fig. 3). The diagram is divided into two completely different parts. The curves of the lower part indicate a dense Quercus forest, those of the upper part a Calluna heath. The change takes place in a marked charcoal layer.

The lower part of the diagram shows the composition and regeneration of a natural Quercus forest on podzol mixed with Ilex, Malus (Pyrus) and Pteridium. Frangula alnus and Betula appears as pioneers. At 40 cm a layer of Quercus bark was demonstrated in the profile, indicating a fallen tree. In the pollen diagram there is a sharp decline of Quercus and a corresponding rise of Betula. A similar regeneration cycle is probably registered in the diagram at 60 cm.

The sudden change from Quercus-Fagus forest to Calluna heath is caused by man. This is also evident from the appearance of cereal pollen, Fagopyrum pollen and a sharp rise in the frequency of weeds. However there are no indication that the burned area has been ploughed, but the fact that the forest did not regenerate denotes cattle grazing. By analysing contiguous samples the details of the succession after the burning can be followed. First a distinct increase of Pteridium takes place, Chamaenerium-type pollen is also found. Next the grass pollen curve reaches a high value, while Calluna dominates in the following samples. The topmost pollen spectra show that Betula now has spread on the heath, and that Empetrum and Vaccinium have replaced Calluna. These changes illustrates forest regeneration on acid soil.

The two diagrams illuminate the local retrogressive forest development in an area with little (site 1) or a distinct human impact on the vegetation (site 2). The results from the two sites - lying only 60 m apart - also emphases that the pollen spectra reflect the local vegetation only, but in a delicate and detailed way which point out the ecological processes in detail and also denote the interaction between man and his environment.

Forest part 365
Location no. 4.2
Vegetation: Mixed deciduous forest
Matters for discussion: Vegetation history, soil development

The area is dominated by an old mixed Fagus sylvatica - Quercus robur vegetation (Fig. 4). The topography is rather smooth and rises gradually from south to north. Saalian till is exposed in the southern part of the area with mull soils. The northern part has a thin cover of aeolian sand above the till and podzols have developed. Betula verrucose, Frangula alnus, Ilex aquifolium and Molinia coerulea are found on deep raw humus, whereas Sorbus aucuparia, Corylus avellana, Alnus glutinosa and Deschampsia caespitosus are present on mull soils. The canopy is rather dense (tree cover about 80%) and the ground flora is scarce.

A small research area has been selected for detailed analysis of the local vegetation history and its relation to soil development and human activity (Aaby 1983). Two profiles lying only seven metres apart were investigated to illustrate also short-distance similarities and dissimilarities in soil development and pollen representation. Sediment accumulation curves were constructed on the basis of historical information on changes in forest composition dating back to the Subboreal and the middle ages respectively (Fig. 5).

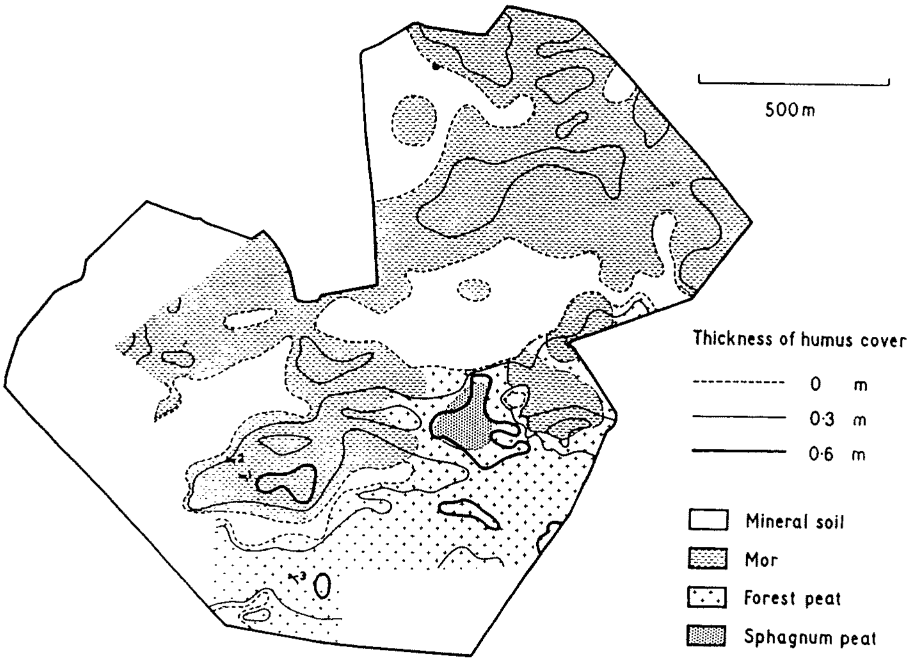
A primeval Tilia forest dominated the area until late Subboreal, when human interference is first detected in one of the diagrams. The human disturbance - probably leaf-hay gathering by shredding - did not substantially change the forest composition. It was practised until about 1650 when the mixed Tilia vegetation was felled and succeeded by a Quercus-Fagus-Betula vegetation which has dominated the area since. Thus, changes in the use of the forest was the faith of the Tilia forest. Viscum album was present in the area until eradication of its host. The presence of Viscum in the 16-17th centuries indicates that this species tolerates lower summer temperatures than earlier supposed.

Two types of pollen deterioration, corrosion and thinning were distinguished. The conclusion being that the pollen spectra are only slightly influenced by pollen deterioration, and differential destruction does not seem to be an important source of error in pollen analysis from the arthopod humus stage and the raw humus stage. Pollen destruction was important only in the lumbricid humus stage, and both types of pollen destruction are involved.

The investigation has demonstrated a close relationship between soil development, forest composition and human activity (Fig. 6). Anthropogenic disturbance and a changing forest composition accelerate soil development, which is also depending on lithology and topography. The development of a podzol was completed within a period of only 300 years in one of the sections, while it took more than 2000 years to reach the same state of maturity at the other site, only 7 m away.

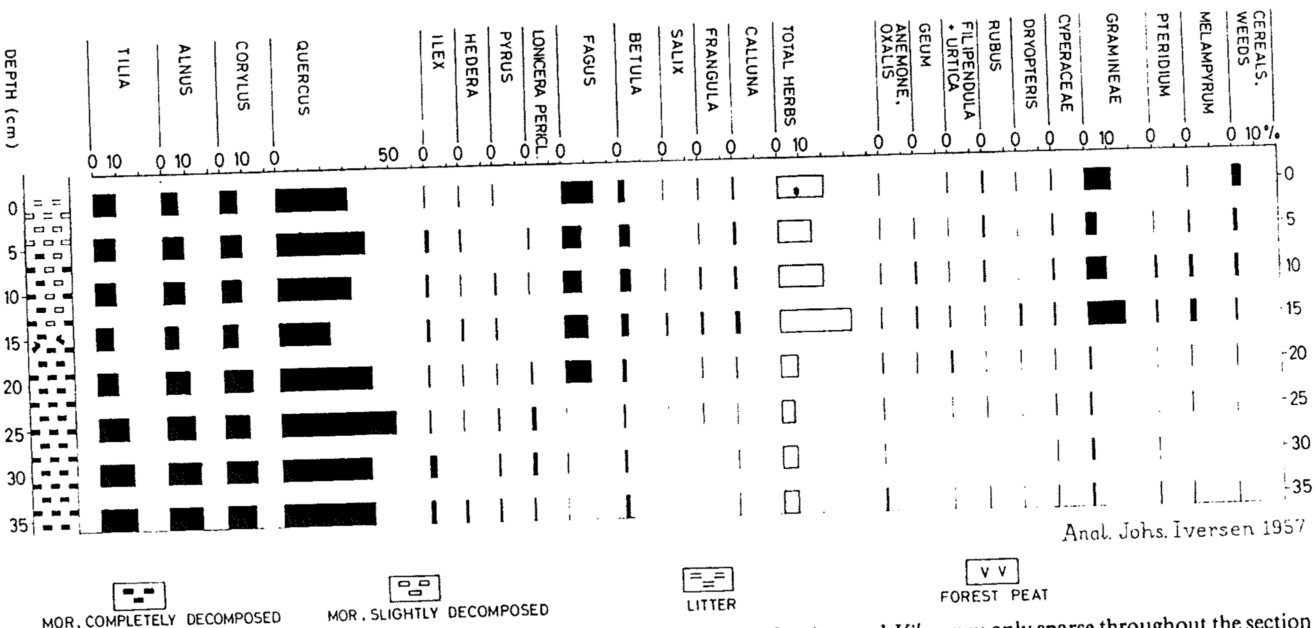
Night at:

Løgumkloster Vandrerhjem, Vænget 28, DK-6240 Løgumkloster,
tlf. +45 74 74 36 18



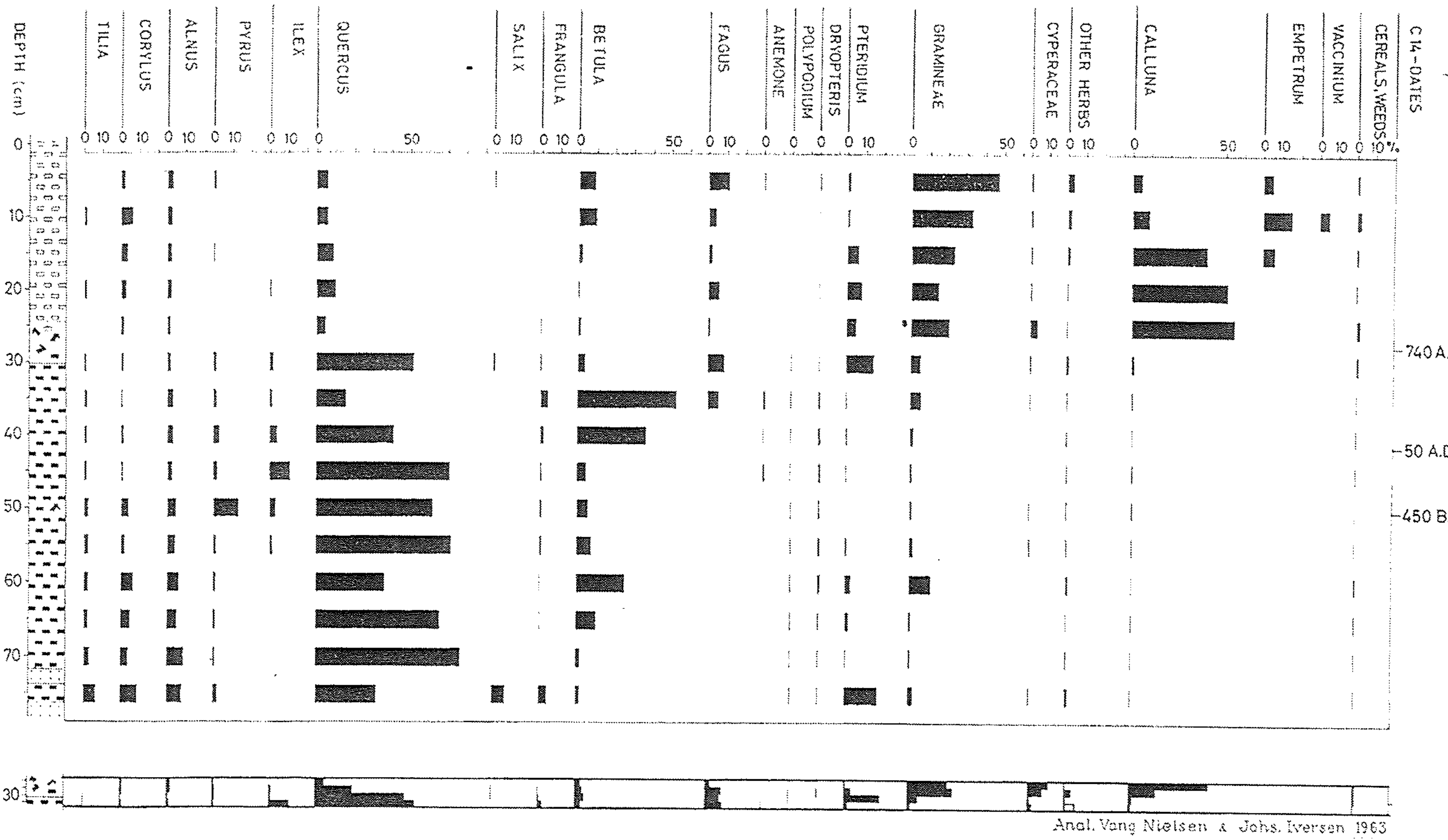
Humus types in the Draved Forest. Depth of mor and peat layer, if present. (Geological survey of Denmark, Inger Brandt & Johs. Iversen.)

Fig. 1



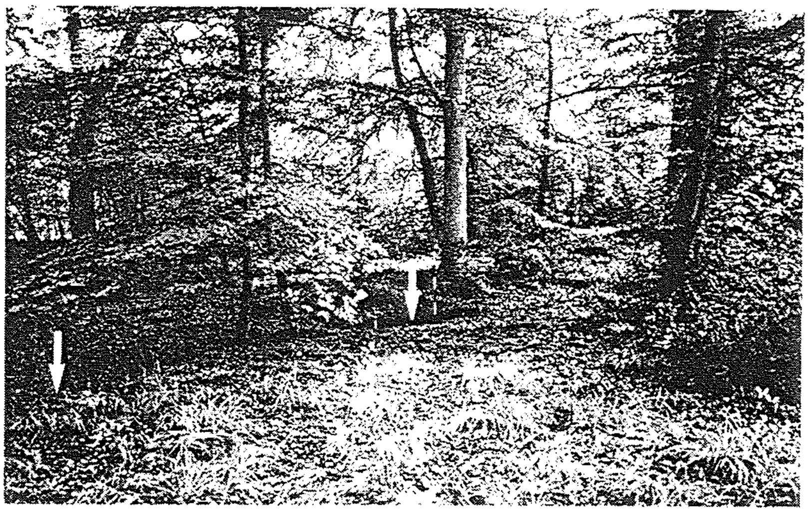
Mor-profile 1, in Draved Forest: pollen diagram. Pollen of *Pinus*, *Ulmus*, *Fraxinus* and *Viburnum* only sparse throughout the section; that of *Populus*, *Potentilla* cf. *erecta* and *Rumex* type *acetosella* only in and after the 'landnam' horizon at 15 cm. *Viscum* in the two samples, and one grain 5 cm below the surface. *Trientalis* and *Acer* only in the bottom sample.

Fig.2



Mor-profile 1 in Draved Forest: pollen diagram. Beneath: diagram section covering four contiguous samples (28–31 cm below the surfac of deposit), each 1 cm thick, showing the succession after the local 'landnam' burning (A.D. 740 ± 100). Pollen of *Pinus*, *Ulmus*, *Fraxinus*, *Populus*, *Heder Lonicera periclymenum*, *Filipendula* and *Melampyrum* only sparse throughout the section; *Carpinus* (long-distance transport) only in the upper half. A fe grains of *Viscum* (45 cm) and *Succisa* (73 cm). 'Weeds' include *Plantago lanceolata*, *Rumex* type *acetosella* and *Trifolium repens*; the latter two are onl demonstrated in and after the 'landnam'. Grains of Chenopods and *Artemisia* are not included in the weeds as they may have come from the salt-marshe

Fig. 3

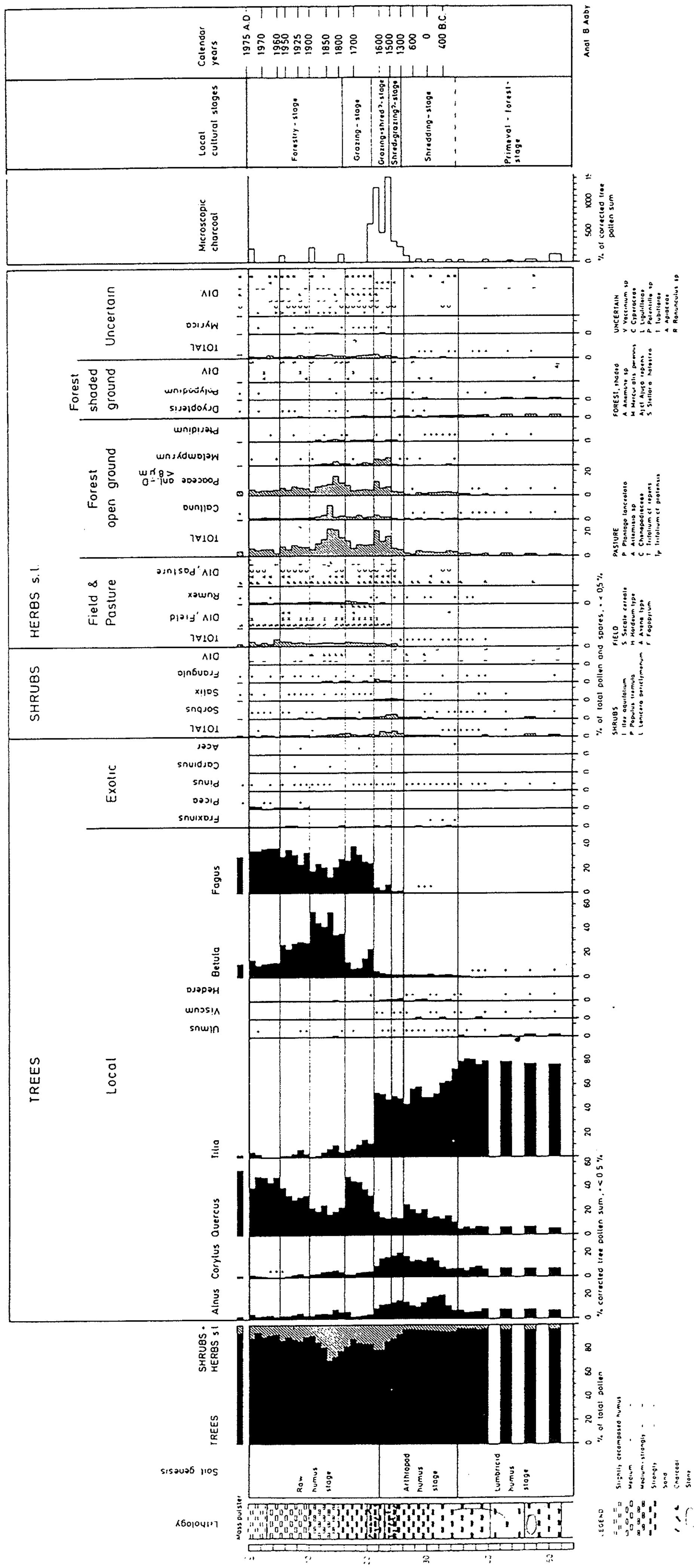


365:2 365:1

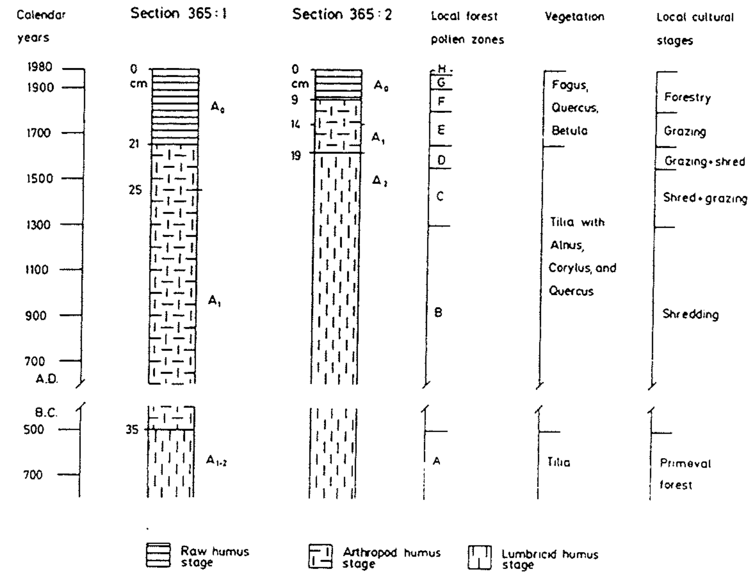
The investigation area in Draved Forest, part 365, seen from the east and the location of sections 365:1 and 365:2.

Fig. 4.

Fig. 5.



Percentage pollen diagram from section 365:1.



Schematic illustration of soil development at section 365:1 and 365:2 in relation to vegetation and human activity. The figure shows that the soil development at the two sites was similar but out of phase from Late Subboreal to about AD 1850. The arthropod humus stage lasted for about 2000 years at section 365:1 and only about 200 years at the other site.

Fig. 6.

Tuesday 5th September

1. stop: Draved bog

Bent Aaby

Location no. 5.1
Vegetation: Raised bog with natural vegetation
Matters for discussion: Present vegetation, peat stratigraphy, climatic changes, and pollution

The bog has an area of 500 ha and is located west of Draved forest (Fig. 1). Peat exploitation has taken place over centuries in the marginal parts of the bog and when peat cutting was intensified in the first part of this century, even the more central areas were damaged. Only 3.5 ha remain in natural state around the so-called 'Russian field', where an attempt at cultivation was carried out during the First World War.

The present vegetation

The undisturbed bog surface is rather flat with a hummock-hollow structure (Fig. 2). The mosaic structure disappears 10-40 m from the former peat excavation areas and is replaced by a uniform vegetation dominated by Calluna vulgaris and Eriophorum vaginatum. The surface slopes in this peripheral part due to artificial drainage from the neighbouring exploitation area. Scattered Betula pubescens trees are seen on the bog expanse.

Ten vegetation associations are distinguished. A Rhynchospora alba-Sphagnum cuspitatum soc. is present in the deepest part of the hollows. Rhynchospora alba- Sphagnum cuspitatum with Sphagnum tenellum is found mainly in the marginal part of the hollows. A Calluna vulgaris- Sphagnum tenellum soc. represents the regressive upper hollow stage. An Oxycoccus quadripetalus-Sphagnum magellanicum soc. occurs only on few places, often located on the NE side of the hummocks. Calluna vulgaris-Sphagnum magellanicum soc. is found at similar places on the hummocks and often with Sphagnum rubellum. The Calluna vulgaris-Eriophorum vaginatum soc. is the most important hummock community.Calluna vulgaris-Eriophorum with Empetrum soc., the Calluna vulgaris-Leucobryum soc., and the Calluna vulgaris-Sphagnum molle soc. are found on the driest places on the hummocks. The vegetation was described 30 years ago (Hansen 1966). Since then distinct quantitative and qualitative changes in vegetation composition has taken place, as demonstrated from the results of the bog monitoring programme (see below).

Geology and peat stratigraphy

The bog lies on the northeasternmost part of an 'hill island'. During the late Weichselian aeolian sand was blown in from the surrounding sandur plains. In the central part of the bog area is found a gyttja layer, about 1 m deep, above the sand (Fig. 3). It shows that a lake covered a large depression in the sand surface in Younger Dryas and Preboreal time. The lake was overgrown by an oligotrophic fen vegetation, and later trees dominated part of the mire. Since late Atlantic an ombrotrophic Sphagnum vegetation has dominated the area. The peat stratigraphy and its relation to the local environment and the climate has been studied (Aaby and Tauber 1975, Aaby and Jacobsen 1979).

Profile 1959. A large section has been cut in the central part of the bog close to the undisturbed segment. Macroscopic remains, pollen and rhizopods were analysed and the degree of humification were determined in the 2.5 m deep section. Based on 59 calibrated carbon-14 dates, accumulation rates during the last 6500 years of 0.16 to 0.80 mm yr-1 were found (Figs 4 and 5). A clear relation between humification degree and humidity (based on evidences from macroremains and rhizopods) at the time of formation was demonstrated, while the relation between measured growth rate and degree of humification changed with depth. These variations in growth rates are thought to be mostly a result of autocompaction.

Macrofossil analysis and peat stratigraphy indicate that a rather uniform Sphagnum imbricatum sociation ('Sphagnum lawn') had dominated the bog expanse for centuries until the middle ages. A few tussocks of Sphagnum imbricatum was found in 1966, but they have not been found in recent years. This fate of Sphagnum imbricatum seen in Denmark and in most Northeuropean countries is an enigma which has often been debated.

The extinction of the Sphagnum imbricatum on Draved bog is closely related to the formation of hummock-hollow surface pattern. Radiocarbon dates from one of the investigated places show that the surface was levelled around 1000 A.D. Three hundred years later the topography was more pronounced with vertical differences at about 10 cm, and when the Sphagnum imbricatum disappeared in the hollow area just after 1500 A.D. the difference had reached about 15 cm. At that time Sphagnum cuspidatum and Sphagnum tenellum was able to compete with Sphagnum imbricatum at low lying areas as a change in climate caused increased wetness on the bog plane. The ecological conditions were still favourable for Sphagnum imbricatum on the drier places between the hollows. The bog surface relief continued to increase with time and accordingly the hummocks became drier. About 200 years later, around 1700A.D. the investigated hummock area was too dry for Sphagnum imbricatum to compete with the Calluna vulgaris-Eriophorum vaginatum sociation which occupied the area and has dominated since that time. In another profile Sphagnum imbricatum disappeared from the emerging hollow area around 1300 A.D. and from the hummocks around 1600 A.D. Thus, the eradication of this Sphagnum species as a common species has lasted for more than 400 years on Draved bog..

The disappearance of Sphagnum imbricatum has been explained by increased dryness, autogenic bog processes, changes in trophic status, and climatically induced excessive wetness. The explanation for Draved bog seems to be a combined climatic-ecological effect which did not allow the species to grow in the wet hollows or in the dry hummocks. Sphagnum imbricatum may have persisted in the transitional zone between the hummocks and the hollows. This area, however, seem to have been too restricted for the survival of the species.

The extension of the hollow- and hummock-area is influenced by the climatically determined water regime. Investigation of the stratigraphy in open peat profiles on the bog has shown that the centre of the hummocks are rather stable in time (Aaby 1976), and the hummocks transgress in stable and/or dry periods and regress when conditions become generally wetter (Fig. 5, 6). A theoretical section is shown (Fig. 6), and it can be demonstrated that some hummocks have existed at the same place for more than 2500 years. This result contradicts the theory of a hollow/hummock succession (Sernander' theory), and autonome succession between hollows and hummocks cannot have been responsible for the observed shifts in peat formation.

Palaeoclimatic changes

Past climatic changes are reflected in raised bogs as variations in the degree of decomposition (humification) of the peat. A trend towards accumulation of more light coloured peat indicates increasing humidity in the bog caused by the climate - either to a lower temperature or to higher precipitation. The opposite shift, from light to dark coloured peat, does not necessarily depend only on climatic parameters, because peat formed under stable climatic conditions will show the same trend. Shifts to darker peat formations are therefore ignored as indicators of climatic changes.

A number of large open sections in Danish raised bogs have been investigated to analyse past climatic shifts. Levels reflecting climatic changes have been dated using calibrated carbon-14 dates. From Draved bog a time/depth scale based on 55 dates has been used. In other cases one or two samples above and beneath levels in question have been dated. The dates seem to be systematically distributed in time (Fig. 7). Generally there is a time interval of around 260 years between the palæaeoclimatic shifts. The cyclisity in climatic changes has been proved statistically. Although raised bogs do reflect past climate, not every shift is indicated in the peat structure, because the rate of decay is rather slow. Raised bogs are therefore supposed to react as biological low-pass filters only reflecting general long term tendencies in climate, and the 260-year cycle seems to be the shortest periodicity revealed. The interpretation of changes in the degree of humification is supposed by historical evidence from the last millennium, and the youngest shifts are dated to about 1780, 1520, 1260 and 1000 A.D.

To demonstrate periodicity, a time span of generally more than 10 times the length of the individual periods concerned must be considered. In this investigation the time interval has been extended to about 5500 years, or more than 20 times the length of the period in question. The results suggest that a general trend toward decreasing mean temperatures and/or wetter conditions may begin in the early part of beginning of the next century in northwestern Europe. However much caution must be applied in proposing future climatic trends from these data as we do not know the nature of the past climatic changes and because we do not know the effect of the human impact on the atmosphere. Thus, pollution of the atmosphere may turn out to be a dominating factor in the future, perhaps resulting in climatic trends different from projected natural trends.

The monitoring programme for raised bogs

The drastic reduction in mire area due to exploitation etc. and an enhanced chemical loading of mires from air pollution has called for a systematic surveying of mire biotopes, and a special attention has been drawn to the oligotrophic mire types as the increased atmospheric deposition of nutrients may influence their natural vegetational dynamic and species composition. Therefore raised bogs are considered a most threatened biotope which now is being systematically monitored.

A 3-year monitoring programme was initiated in 1987 to obtain an actual status for areas on raised bogs which are still preserved in natural state. More than 30 areas are known, but for various reasons (often because of small areas with secondary lowering of the water table due to former peat excavation in adjacent areas) only 21 sites were included in the programme (Aaby 1987, 1989, 1990).

The programme included: General description of the bog; Description of the investigated area; Listing of plant species growing in the investigated area and their frequency estimated subjectively; Sampling of surface water and living Sphagnum from permanent stations; Measurements of pH in surface water at stations; Photo documentation at stations;

Detailed analysis of the vegetation (see Fig. 8). This is made in only 6 of the bogs for economic reasons; and finally investigation of bog stratigraphy.

Main results from Draved Mose

The botanical registration has shown that trees have spread into the investigation area on Draved Mose since 1961 and that Molinia coerulea, Deschampsia flexuosa and Senecio sylvatica probably also are among the new species on the bog. Narthecium ossifragum seems to be strongly favoured by the present growing conditions and forms dense and quickly expanding patches. Empetrum nigrum shows a similar expansion capacity; it was mentioned from only four places on Draved Mose in the early 60s (Hansen 1966) but today Empetrum is a common species in the same investigation area. Dead plants are rather frequent. Thus, the investigation area tends to be very labile at the moment.

Modern vegetational changes to Danish raised bogs

Knowledge of raised bog vegetation from earlier in this century (Fig. 9) and the present surveys have emphasized that distinct changes have taken place in recent years. From the many alterations in plant cover at least three main categories of changes can be distinguished.

1. Expansion of indigenous species. Narthecium ossifragum, Empetrum nigrum, and Betula pubescens seem to spread successfully.

2. Immigration of species. The monitoring programme has revealed that a number of species which formerly were confined to minerotrophic habitats are now present in natural raised bog vegetation in such numbers that they seem to be naturalized and able to reproduce under actual ombrotrophic conditions (see Fig. 10). The new species have immigrated from fens with a high water table as well as plant communities on dry soils. As a common feature, they all grow in oligotrophic habitats, and a few species are also found in mesotrophic habitats.

3. Recession (temporary?) of indigenous species. A distinct quantitative and qualitative decline in the lichen flora on raised bogs is shown. Dead plants were found on several bogs and especially Calluna vulgaris seems to have been weakened on many bogs. The high mortality is probably caused by extreme weather conditions in the winter 1985/86, when frost in the absence of snow cover and in combination with strong wind also damaged heather on many heathlands in Jutland. Calluna vulgaris also suffers from often severe attack by the heather beetle (Lochmaea suturalis) feeding on its foliage.

Reasons for the vegetational changes

Air humidity may have changed in recent years due to artificial lowering of water table in the intensively cultivated landscape surrounding the investigated bog areas. Contrary to earlier times only a few per cent of the landscape has a superficial water table today allowing a high water evaporation and transpiration rate. Lowering of the water table on the natural expanse of some bogs can also be the result of peat exploitation and other human disturbances in the adjacent bog area. However, the immigrating species come from wet as well as from dry oligotrophic habitats, which is not in favour of an explanation based solely on hydrological changes.

The non-indigenous herbaceous species have all migrated from plant communities with richer trophic conditions than formerly seen in the raised bog plant communities. This tends to indicate that increased atmospheric deposition of nutrients is important for the observed vegetational changes. Especially nitrogenous compounds may be of importance as deposition of ammonia (NH_3-N), ammonium (NH_4-N) and nitrate (NO_3-N) has increased drastically in recent decades, and these compounds have a direct nutritive value for plants, contrary to other nitrogenous compounds (NOx-N). Ammonia evaporation from livestock dung is high, and the NH3-N emission density in Denmark is the third largest in Europe. The importance of NH3 is stressed by the fact that most changes in the herbaceous vegetation are seen in areas which have a relatively high or a high emission of ammonia, whereas few vegetational changes are observed in areas with a low ammonia production (Fig. 11).

As most NHx-N originates from dung and other animal wastes, animal husbandry and especially cattle breeding is thought to improve the trophic conditions on raised bogs to such an extent that herbs and dwarf shrubs, formerly restricted to more nutrient-rich habitats than the raised bog, now find suitable growing conditions on some Danish raised bogs.

Increased annual deposition of nutrients may also have caused the expansion of some indigenous species. In addition to nutrients the atmosphere has also become richer in heavy metals, sodium, ozone and other chemical compounds which may have a toxic effect on some plant species. Especially lichens are known to be sensitive to air pollution.

While tentative explanations can be given for the observed alterations in the herbaceous vegetation, the question of tree growth on the bog expanse seems to be more complex as the frequency of trees and non-indigenous herbaceous plants shows no relationship. The present success of arboreal species may have a multicausal explanation which remains unsolved, although research is in progress.

Lead deposition at Draved bog and in Draved forest

Pollution of the environment with lead (Pb) has become the object of international concern during the last few decades and efforts have been devoted in recent years to acquire more knowledge of Pb distribution in various habitats, both at present and in the past.The chronology for the lead concentration profiles was established using the 210Pb dating method. The method was used only for dating the Pb concentration profiles. This partly overcomes the problem of metal mobility as stable Pb isotopes chemically and physically behave as 210Pb except for their 1-3% lower mass.

The sites

Monoliths of Sphagnum peat were collected from hollow sites at the raised bog. A raw humus profile was collected from Draved forest in a mixed Fagus-Quercus stand. Another peat/raw humus profile was taken from a Picea stand growing in an artificially drained raised bog area.

Results

The raised bog. The retention of Pb m-2 yr-1 was calculated for the last centuries in 1979 and 1986. The development in lead retention rate from the two investigations at the same site is very similar using the same analytical technique (Fig. 12). Thus only the 1986-results are mentioned. The Pb retention rate during the last century increases only slowly from 4µg Pb m-2y-1 in the period 1820-40 to 7µg Pb m-2y-1 at the end of 19'th century. The gradual increase continues and at 1955-60 the annual layers have more than doubled their Pb content compared to the values around 1900. A considerable increase is found after 1960 reaching a maximum of approx. 55µg Pb m-2y-1 in the period 1965-70. Almost identical retention rates were calculated for the following 5 year intervals followed by a distinctly lower value for the 1975-80 period, and the result for 1980-86 is 26µg Pb m-2y-1 or only half the maximum value obtained in the late 1960's.

The deciduous forest, profile 1975. The retention of Pb m-2y-1 in raw humus from the Fagus-

Quercus vegetation amounts to 10-15mg in the period 1850-1900 followed by a gradual increase in the two first decades of the 20th century (Fig. 14). The Pb retention at the 1930 level was calculated to 25mg m-2y-1 and since 1940 the Pb retention rate has accelerated reaching more than 55mg m-2y-1 in the 1955-60 period. The highest Pb retention, 65mg m-2y-1, was calculated for the surface layer from 1970-75. Thus, the Pb retention rate is about six times higher in levels from the 1970-75 period than in levels from the end of the last century.

The vegetation structure has been stable during the registration period.

The spruce forest, profile 1986. The Pb retention rate in layers from the end of the last century is approx. 5mg m-2y-1 (Fig. 13). However, the retention results for this period are rather uncertain as only one reliable 210Pb derived date at 19.5cm b.s. is available for constructing the lower part of the age-depth profile. The retention rate increases drastically after 1910 and remains almost stable at 20mg Pb m-2y-1 until 1950 when a new rise is recorded. Maximum Pb retention is 63mg m-2y-1 for the 1970-75 period and for the following 5 year period a 17% lower value was obtained. The retention rate falls by a further 17% in the surface layer representing the 1980-86 period. This modern rate of Pb retention, 43mg m-2y-1, is similar to the rates around 1950, but still 8 times higher than rates from the end of the last century.

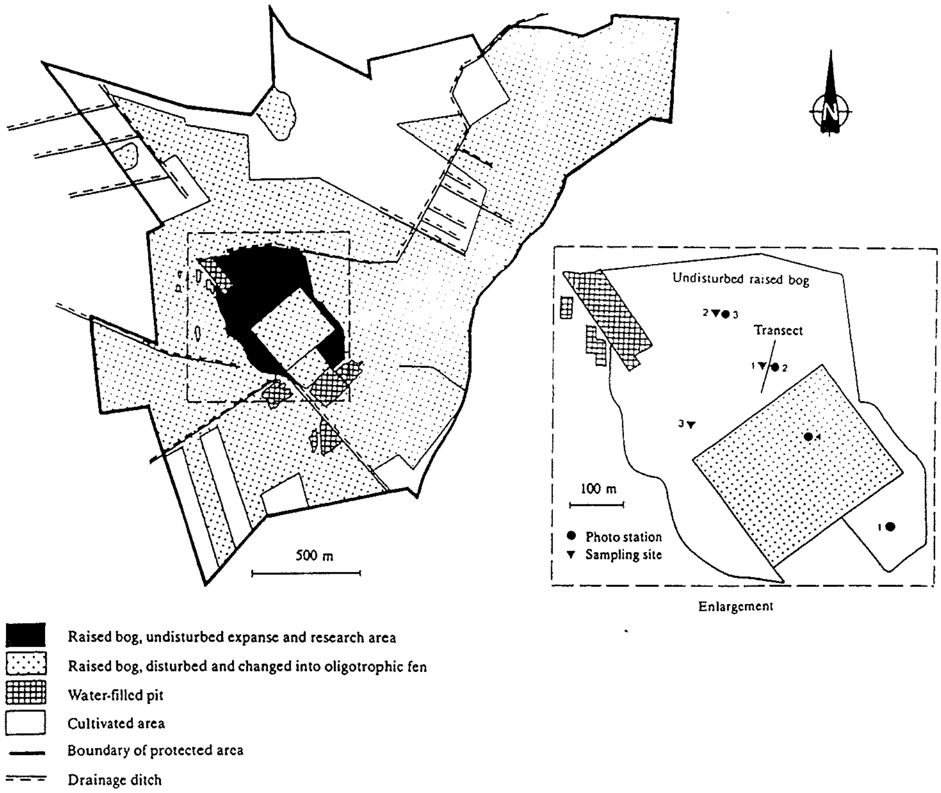
The vegetational structure has varied considerably at the sampling site during the long registration period, as two Picea stands have been established since bog reclamation approx. 1880. The distinct increase in annual Pb retention measured after 1910 may partly be due to filtering by trees. The felling of Picea abies in the early 1940's seems not to have had any influence on the Pb retention level as it remains stable at that time. About 10 years later much higher rates are measured coinciding with the emergence of the Picea sitchensis stand.

Comparison of lead retention rates

Raised bog sites. See above.

Forest sites. The lead retention rates from spruce forest profile-1986 were between 1.5% and 84.6% lower than the rates from deciduous forest profile-1975 for contemporary time intervals (Fig. 14). The greatest differences were calculated for the period 1840-1910, probably due primarily to differences in the vegetational structure at the sites. The Fagus-Quercus vegetation was rather dense between 1840-1900 and in the same period a treeless Sphagnum-Calluna vegetation (1840-80) or an open and low Picea abies stand was found at the other investigation site. Since 1960 almost identical retention rates have been obtained from contemporary periods from the two profiles. The data suggest 60-85% lower lead retention rates in levels representing a natural bog vegetation compared to contemporary levels from deciduous forest vegetation. It is also apparent that levels representing mature Picea stands have either similar, or up to 30% lower, lead retention rates than those found in the Fagus-Quercus forest. Normally spruce is suggested to have a higher lead deposition rate than deciduous stands. However, written sources describe the first generation of Picea after bog reclamation as being poorly developed and rather open in structure. The present spruce stand has also a rather open structure compared to well developed and dense Picea stands. The delicate constitution of Picea may have contributed to Pb retention rates similar to or slightly lower than those found in layers from the dense structured Fagus-Quercus forest.

Bog and forest profiles. The retention rates from spruce forest profile-1986 tend to be similar to rates obtained from contemporary time slices in bog profile-1986 in the periods 1840-80, 1880-1910 and 1940-50 when the forest investigation site was either an ombrotrophic mire or open forest/bog vegetation (Fig. 14). Prior to 1960, retention rates from the two forest sites, representing mature forest vegetation, were 50-250% higher than those from treeless vegetation in bog profile-1986. After 1960 the difference in retention rates between the forest profiles and the bog profile falls to 50% or less. This development probably has a multi-causal explanation. The lead retention rate excess at wooded sites compared to non-wooded sites is considered to be mainly a result of the different vegetational structure influencing the Pb deposition. However, other factors - such as changes in airborne particle size - are also of importance.



Part of Draved Mose with the preserved area in natural state (ruled are

Fig. 1.

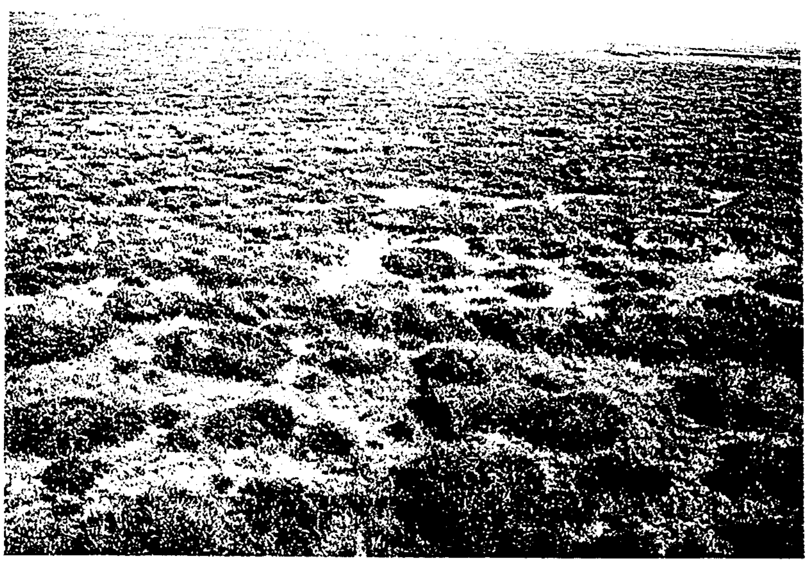
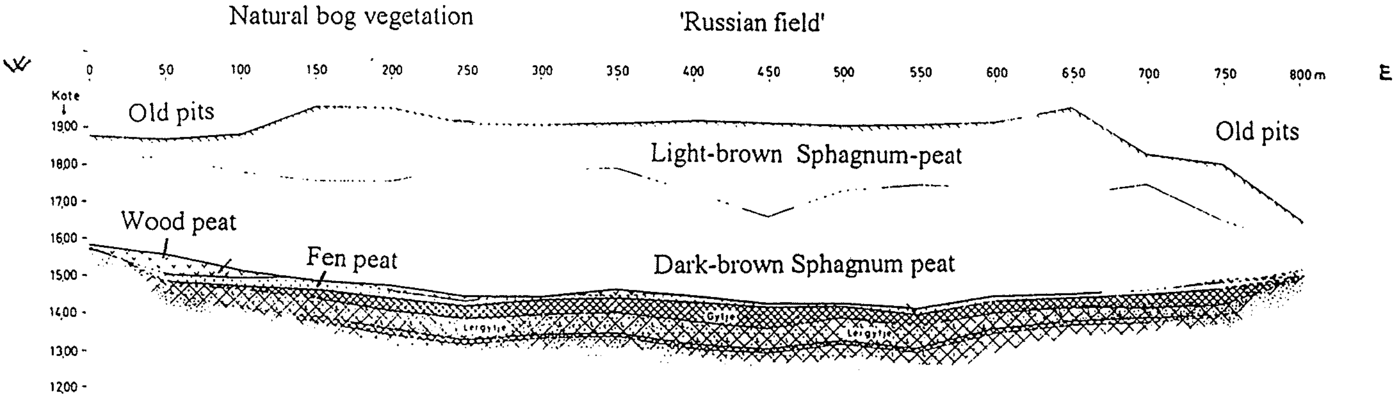


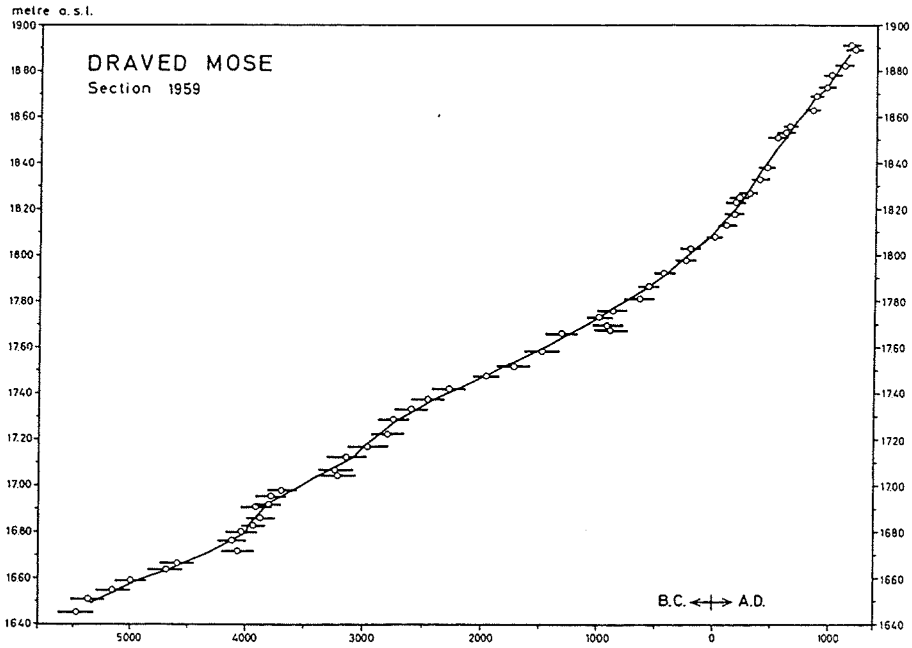
Fig. 2.

The raised bog expanse in Draved Mose as it looked in 1955 from an oberser-vation tower. The area is treeless and has a very distinct pattern of irregular hummocks and hollows (Photo by H. Krog).



Stratigraphy of the central part of Draved bog

Fig. 3.



Calibrated C-14 dates from section 1959 with statistical counting errors and error of calibration. The line indicates the rate of peat formation calculated on the basis of sliding means of 5 successive C-14 dates.

Fig. 4

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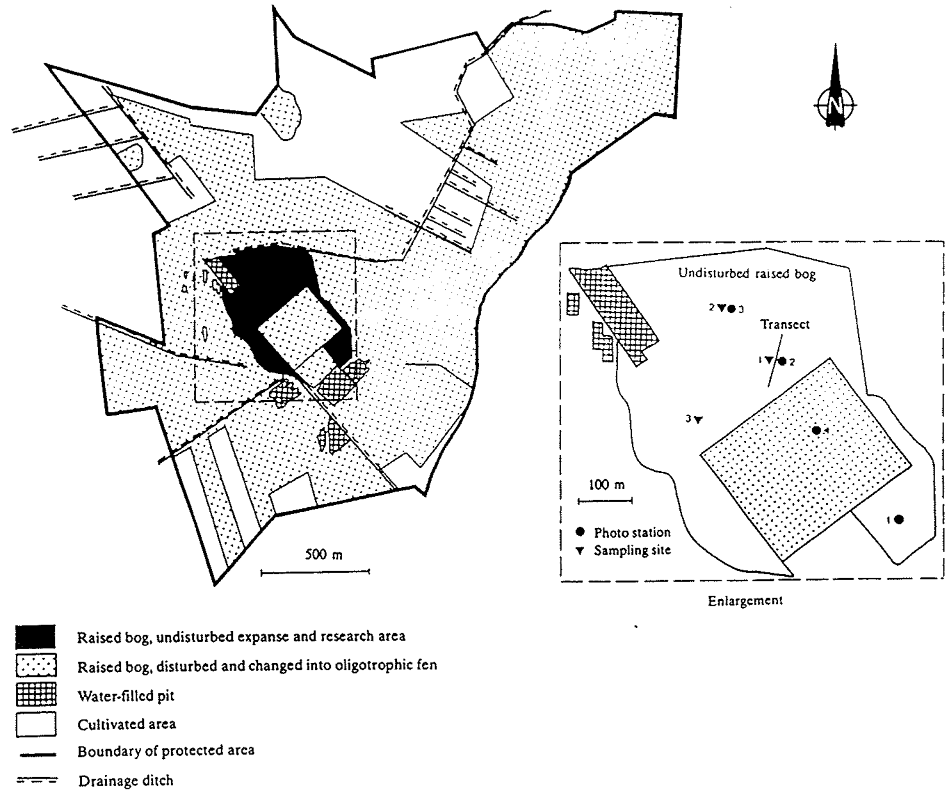

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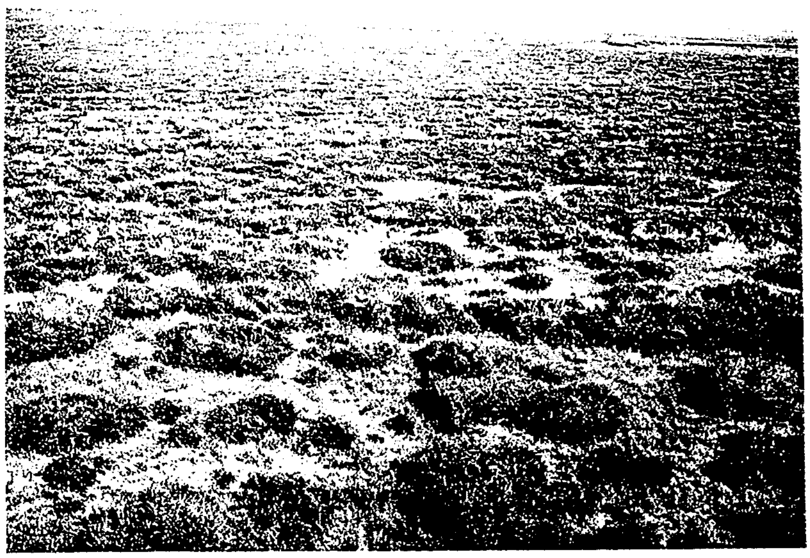

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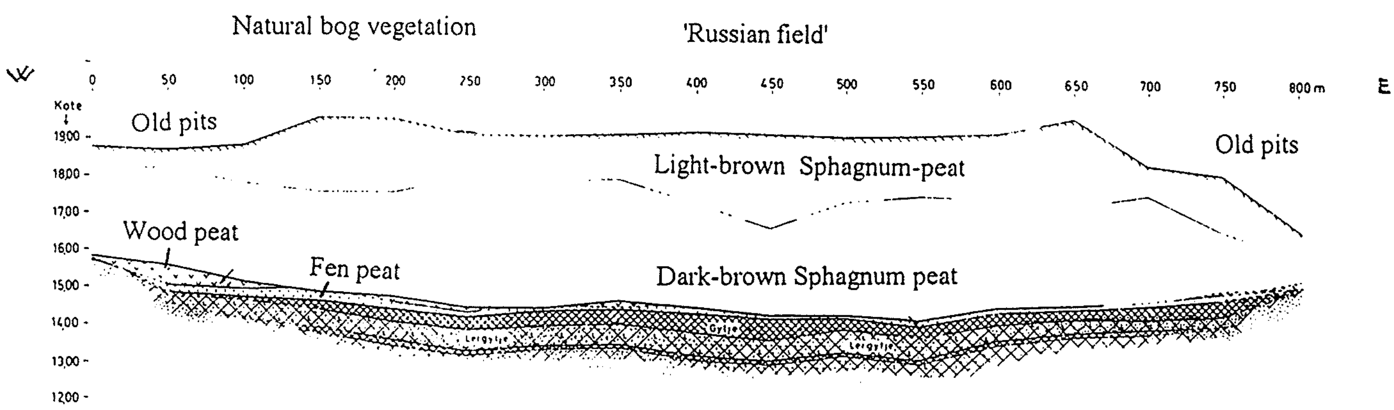

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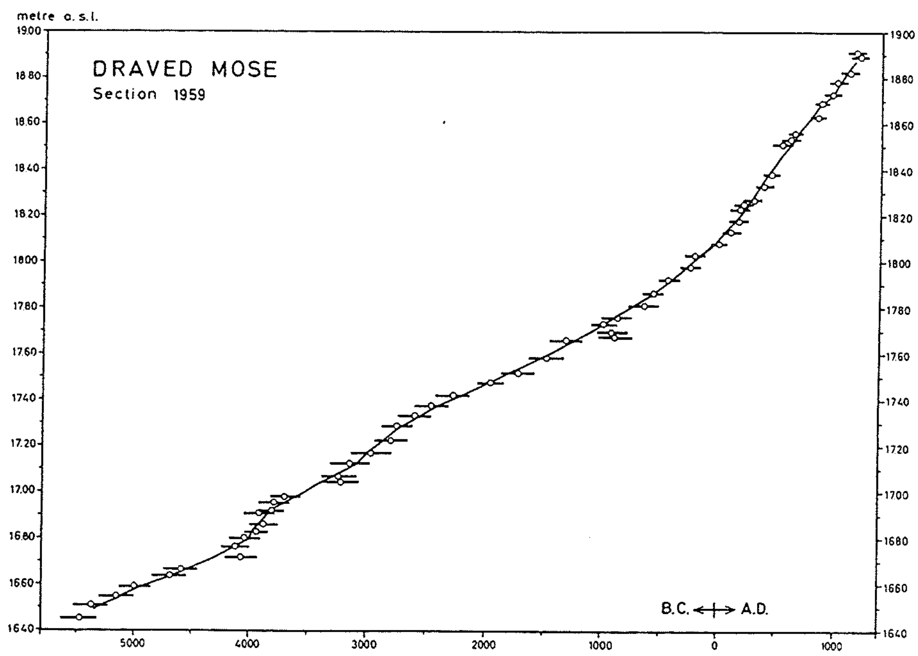

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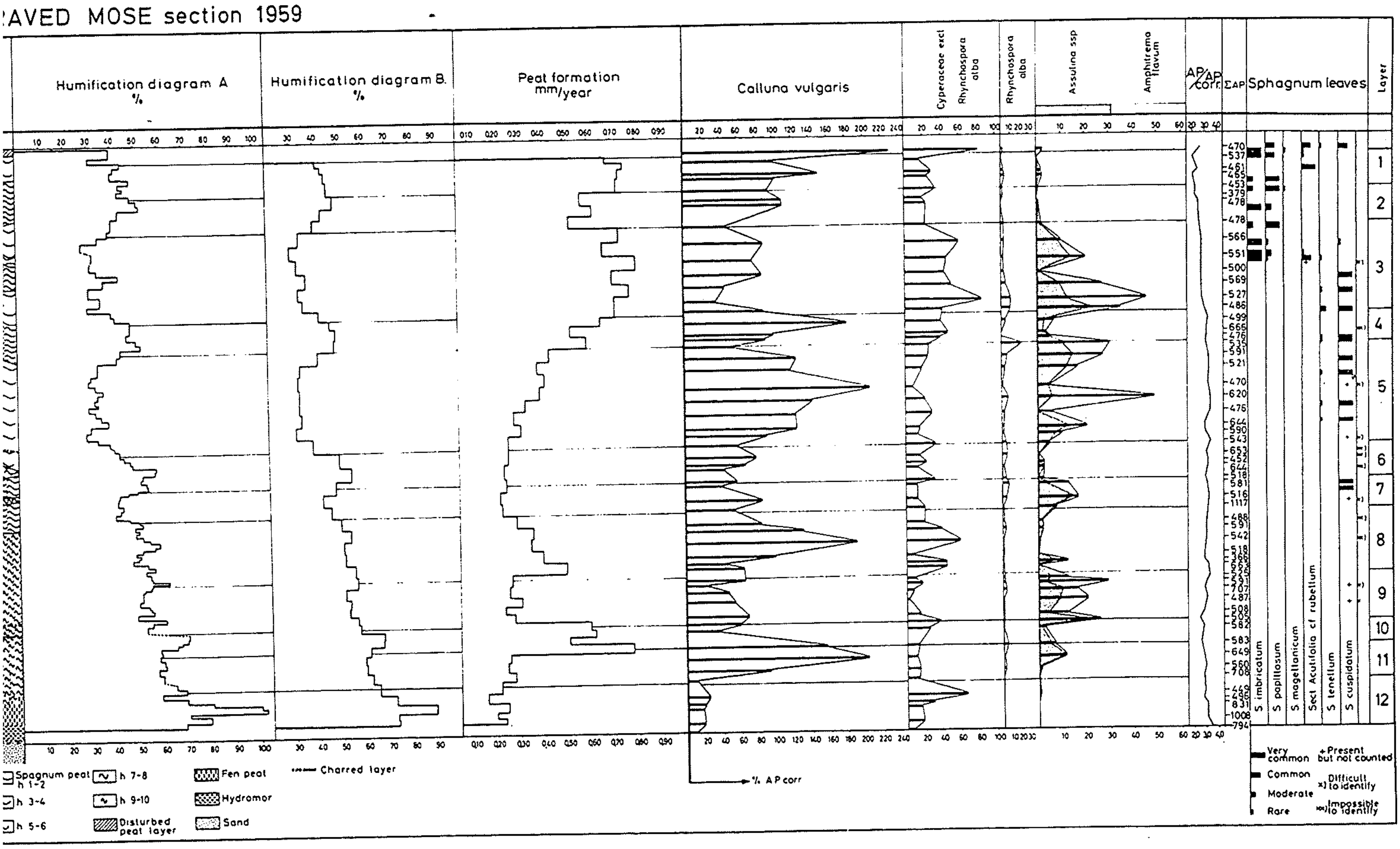
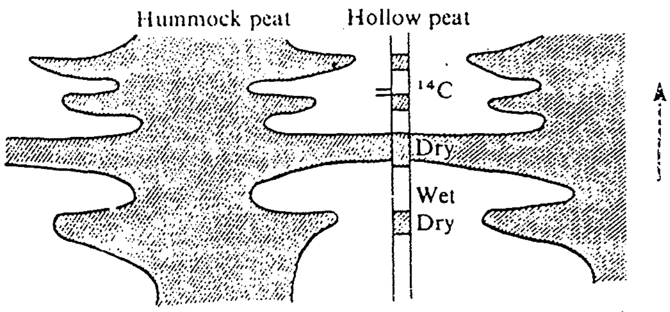


Fig 5.



Theoretical peat section showing that the hummock area increases in dry periods, and becomes smaller in wetter periods.

Fig. 6.

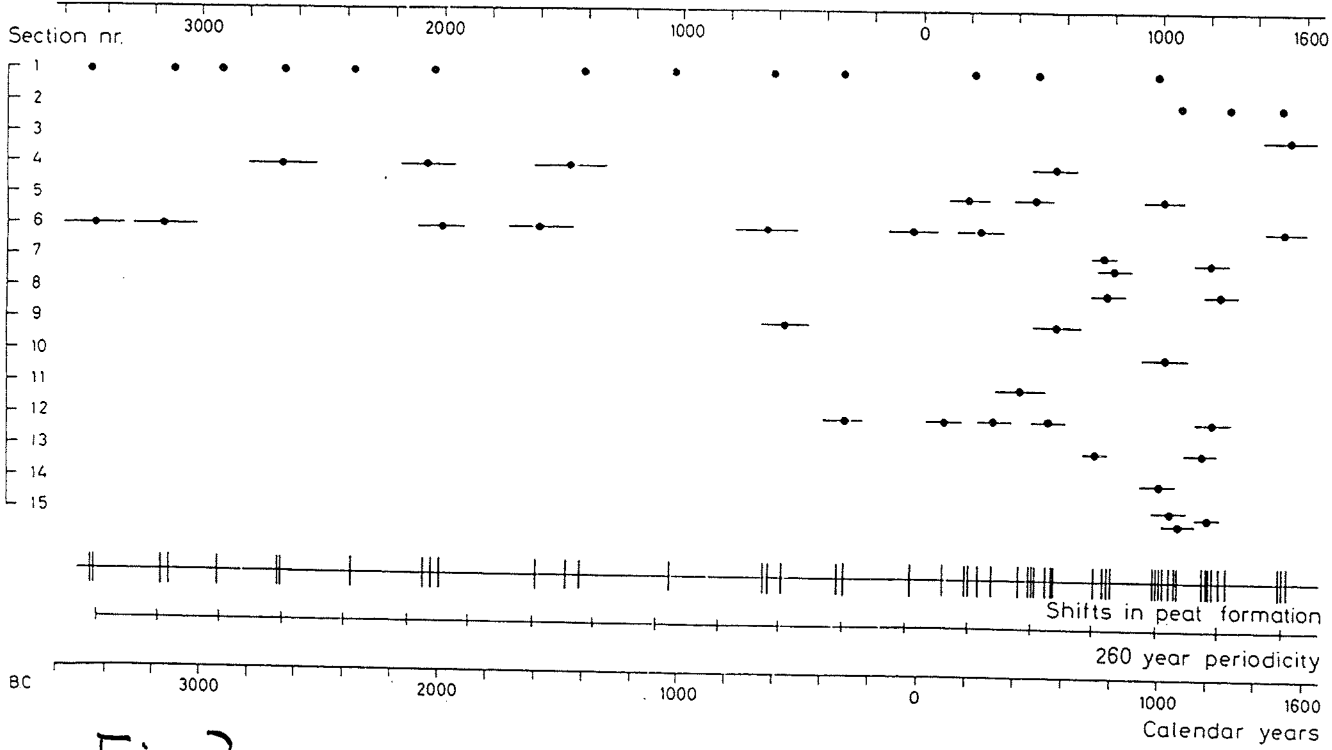


Fig. 7. Climatically induced shifts in peat formation from sections in Danish bogs.

Vegetation analysis along a 100 m transect with records of species within a 0.2 m² circle for every 0.5 m. Two hundred circles were analyzed.

Taxa	Frequency % (n=200)	Areal coverage, number of counts in category					Areal coverage, % of counts in category			
		+	1	2	3	Σ	+	1	2	3
Living plants										
Andromeda polifolia	62.5	118	7			125	94	6		
Betula pubescens	1.0		2			2		100		
Calluna vulgaris	15.0	15	11	3	1	30	50	37	10	3
Drosera rotundifolia	2.0	4				4	100			
Dryopteris carthusiana	8.5	13	4			17	76	24		
Empetrum nigrum	16.5	5	12	10	6	33	15	37	30	18
Erica tetralix	56.5	28	40	40	5	113	25	35	35	5
Eriophorum angustifolium	50.5	55	32	14		101	54	32	14	
Eriophorum vaginatum	81.0	12	25	69	56	162	7	15	43	35
Molinia caerulea	3.5	2	1	3	1	7	29	14	43	14
Narthecium ossifragum	2.5			1	4	5			20	80
Rhynchospora alba	12.5	13	10	2		25	52	40	8	
Senecio sylvaticus	0.5	1				1	100			
Scirpus cespitosus	1.0	2				2	100			
Vaccinium oxycoccos	62.0	82	31	11		124	66	25	9	
Aulacomnium palustre	1.0	2				2	100			
Dicranum undulatum	1.0	2				2	100			
Drepanocladus fluitans	1.5	2	1			3	67	33		
Hepatica sp.	19.5	22	14	3		39	56	25	19	
Hypnum cupressiforme/ericet.	22.0	15	23	5	1	44	34	52	11	3
Mylia anomala	1.5	3				3	100			
Odontoschisma sphagni	22.0	28	14	2		44	64	32	4	
Pleurozium schreberi	1.0	1	1			2	50	50		
Polytrichumstrictum	1.5	2	1			3	67	33		
Sphagnum cuspidatum	29.5	4	14	12	29	59	7	24	20	49
Sphagnum fallax	1.0		1	1		2		50	50	
Sphagnum magellanicum	8.5	1	9	6	1	17	6	53	35	6
Sphagnum molle	0.5		1			1		100		
Sphagnum papillosum	2.0		2	2		4		50	50	
Sphagnum rubellum	6.0	2	5	5		12	16	42	42	
Sphagnum tenellum	16.0	20	9	3		32	63	28	9	
Cladonia portentosa	28.0	25	23	8		56	45	41	14	
Cladonia fimbriata	4.0	8				8	100			
Hypogymnia physodes	0.5	1				1	100			
Algae sp.	4.5	5	4			9	56	44		
Dead plants										
Andromeda polifolia	1.0	2				2	100			
Calluna vulgaris	13.0	6	15	5		26	23	58	19	
Empetrum nigrum	0.5		1			1		100		
Erica tetralix	18.5	11	15	9	2	37	30	41	24	5
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Molinia caerulea	0.5		1			1		100		
Rhynchospora alba	2.5		3	2		5		60	40	
Vaccinium oxycoccos	1.0		2			2		100		

Fig. 8

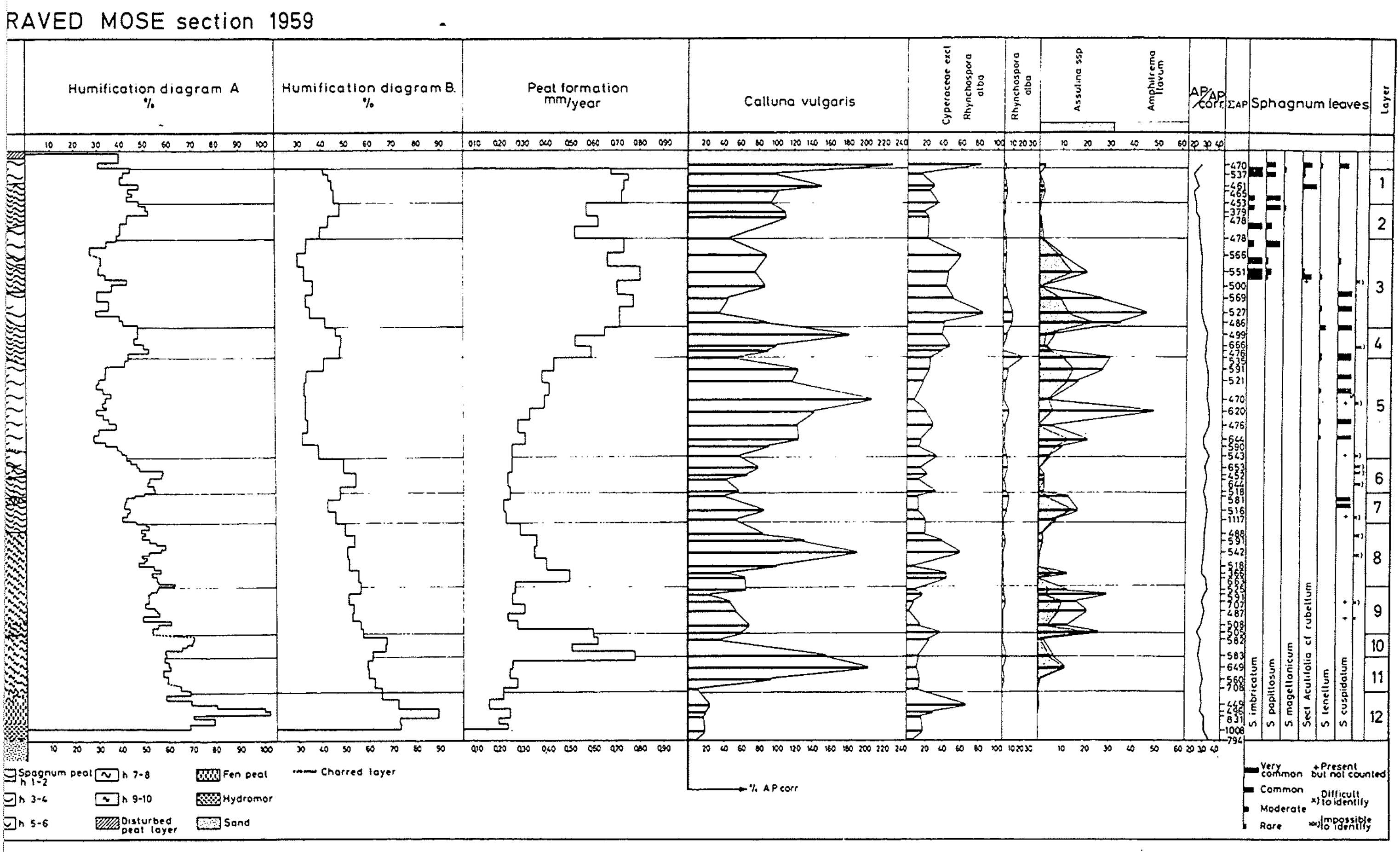
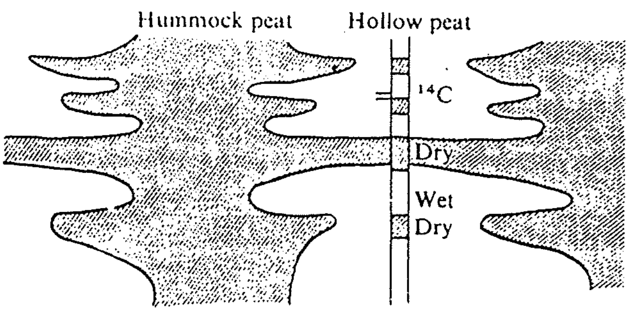


Fig 5.



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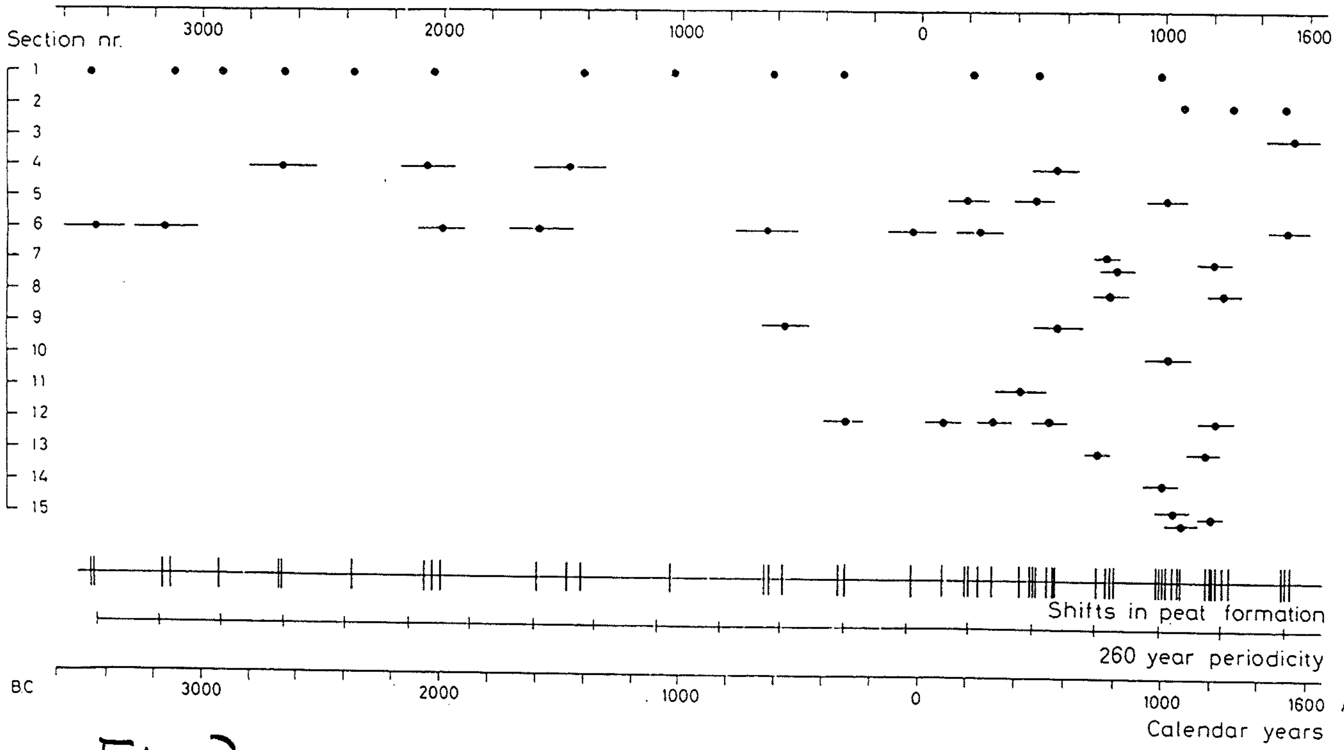

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Pleurozium schreberi	1.0	1	1			2	50	50		
Polytrichumstrictum	1.5	2	1			3	67	33		
Sphagnum cuspidatum	29.5	4	14	12	29	59	7	24	20	49
Sphagnum fallax	1.0		1	1		2		50	50	
Sphagnum magellanicum	8.5	1	9	6	1	17	6	53	35	6
Sphagnum molle	0.5		1			1		100		
Sphagnum papillosum	2.0		2	2		4		50	50	
Sphagnum rubellum	6.0	2	5	5		12	16	42	42	
Sphagnum tenellum	16.0	20	9	3		32	63	28	9	
Cladonia portentosa	28.0	25	23	8		56	45	41	14	
Cladonia fimbriata	4.0	8				8	100			
Hypogymnia physodes	0.5	1				1	100			
Algae sp.	4.5	5	4			9	56	44		
Dead plants										
Andromeda polifolia	1.0	2				2	100			
Calluna vulgaris	13.0	6	15	5		26	23	58	19	
Empetrum nigrum	0.5		1			1		100		
Erica tetralix	18.5	11	15	9	2	37	30	41	24	5
Eriophorum angustifolium	12.0	14	10			24	58	42		
Eriophorum vaginatum	20.5	2	26	13		41	5	63	32	
Molinia caerulea	0.5		1			1		100		
Rhynchospora alba	2.5		3	2		5		60	40	
Vaccinium oxycoccos	1.0		2			2		100		

Fig. 8

List of plant species considered to be indigenous to Danish raised bogs. Species in brackets are rare and occur partly in disturbed areas. *Pinus sylvestris* may be indigenous to the easternmost raised bogs in northern Sealand.

Flowering plants	**Mosses**
Andromeda polifolia	*Sphagnum cuspidatum*
Betula pubescens	*Sphagnum compactum*
Calluna vulgaris	*Sphagnum fallax*
Carex limosa	*Sphagnum fuscum*
Drosera intermedia	*Sphagnum imbricatum*
Drosera anglica	*Sphagnum magellanicum*
Drosera rotundifolia	*Sphagnum molle*
Empetrum nigrum	*Sphagnum capillifolium*
Erica tetralix	*Sphagnum papillosum*
Eriophorum angustifolium	*Sphagnum rubellum*
Eriophorum vaginatum	*Sphagnum tenellum*
Myrica gale	
Narthecium ossifragum	
Rhynchospora alba	
Rhynchospora fusca	
Rubus chamaemorus	
Scirpus cespitosus	
Vaccinium oxycoccos	
Vaccinium uliginosum	
(Agrostis canina)	
(Carex lasiocarpa)	
(Carex nigra)	
(Carex pauciflora)	
?Pinus sylvestris	

Fig. 9

List of non-indigenous plant species recently immigrated to Danish raised bogs. It is thought that they have become naturalized and are able to reproduce in some bogs. Species occurring in heavily disturbed areas (e.g. overgrown bog pits) and/or exclusively in hydrologically disturbed areas (e.g. drained areas near bog pits) are indicated with an asterisk (*). These species are thought not to reproduce.

Immigrants from wet habitats	**Immigrants from dry habitats**
Carex curta	*Epilobium angustifolium*
Carex nigra	*Deschampsia flexuosa*
Dryopteris carthusiana	*Picea* sp.
Molinia caerulea	*Pinus mugo*
Salix aurita	*Sorbus aucuparia*
Salix cinerea	*Vaccinium myrtillus*
Sphagnum fimbriatum	*Vaccinium vitis-idaea*
*Carex panicea**	*Frangula alnus**
*Carex rostrata**	*Galium saxatile**
	*Holcus lanatus**
	*Populus tremula**
	*Trientalis europaea**

Fig. 10.

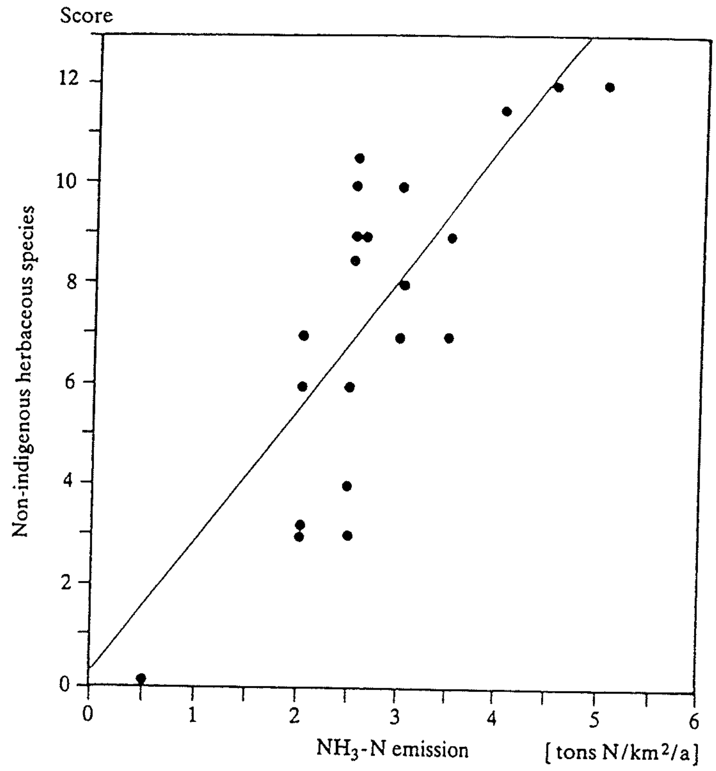
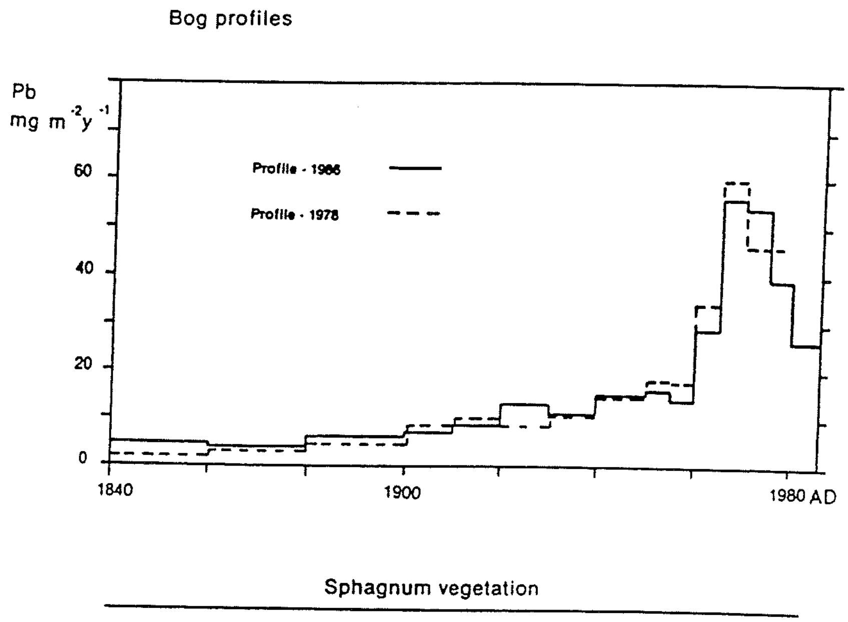


Fig 11.

Frequency (score) of non-indigenous herbaceous species compared with NH_3-N emission in the surroundings of the investigated raised bogs, and calculated regression line ($r = 0.77$, $DF = 19$;



Annual lead deposition on Draved bog.

Fig. 12.

List of plant species considered to be indigenous to Danish raised bogs. Species in brackets are rare and occur partly in disturbed areas. *Pinus sylvestris* may be indigenous to the easternmost raised bogs in northern Sealand.

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Calluna vulgaris	*Sphagnum fallax*
Carex limosa	*Sphagnum fuscum*
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Empetrum nigrum	*Sphagnum capillifolium*
Erica tetralix	*Sphagnum papillosum*
Eriophorum angustifolium	*Sphagnum rubellum*
Eriophorum vaginatum	*Sphagnum tenellum*
Myrica gale	
Narthecium ossifragum	
Rhynchospora alba	
Rhynchospora fusca	
Rubus chamaemorus	
Scirpus cespitosus	
Vaccinium oxycoccos	
Vaccinium uliginosum	
(Agrostis canina)	
(Carex lasiocarpa)	
(Carex nigra)	
(Carex pauciflora)	
?Pinus sylvestris	

Fig. 9

List of non-indigenous plant species recently immigrated to Danish raised bogs. It is thought that they have become naturalized and are able to reproduce in some bogs. Species occurring in heavily disturbed areas (e.g. overgrown bog pits) and/or exclusively in hydrologically disturbed areas (e.g. drained areas near bog pits) are indicated with an asterisk (*). These species are thought not to reproduce.

Immigrants from wet habitats	**Immigrants from dry habitats**
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Fig. 10.

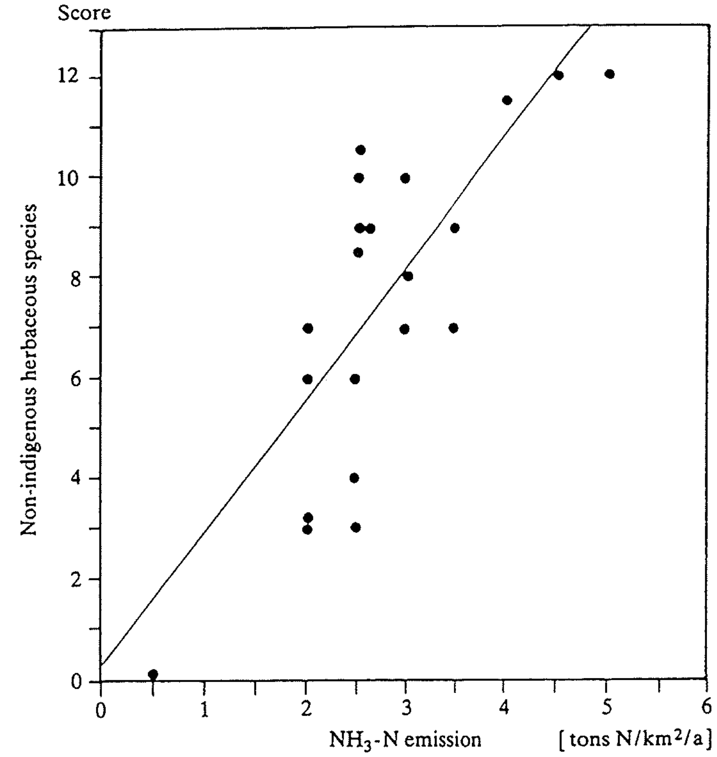
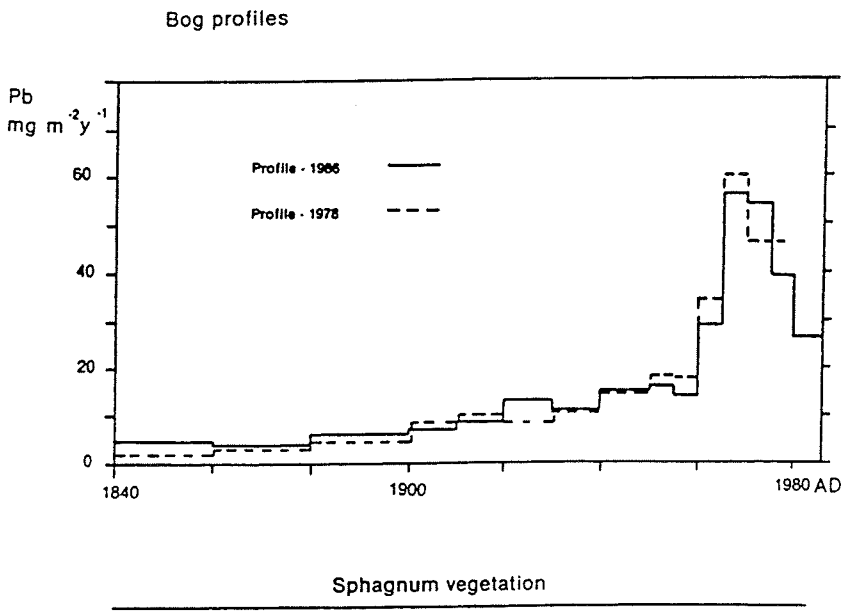


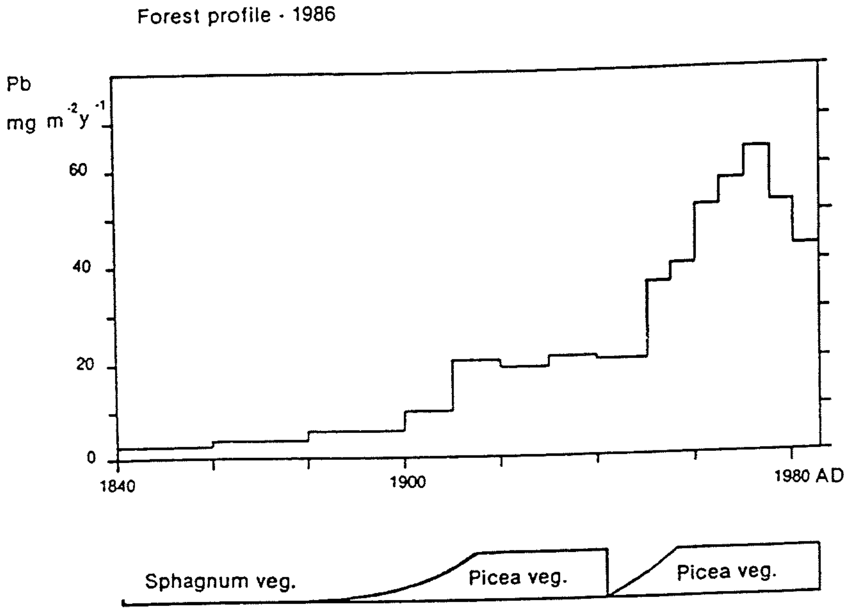
Fig 11.

Frequency (score) of non-indigenous herbaceous species compared with NH_3-N emission in the surroundings of the investigated raised bogs, and calculated regression line (r = 0.77, DF = 19;



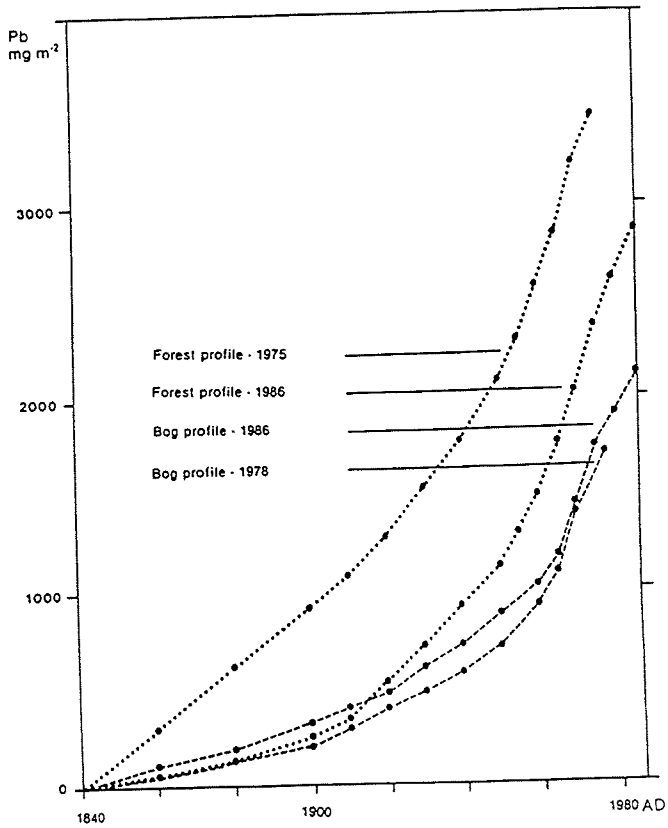
Annual lead deposition on Draved bog.

Fig. 12.



Annual lead deposition in a Picea plantation. The area is a former raised bog followed by two generations of Picea stands.

Fig. 13.



Cumulative curves for annual lead deposition since 1840 on raised bogs and in different forest vegetations in the Draved area.

Fig. 14.

2. stop: The dune landscape at Henne Strand

Bent Aaby

Location no. 5.2
Vegetation: Coastal dune and heath vegetation.
Matters for discussion: Present vegetation and succession of plant communities in relation to the physical environment.

Henne Strand is a popular recreation area with summerhouses. The recreation area is surrounded by natural dune vegetation, coastal heathland and plantations with remnants of coppice vegetation with Quercus, which has been the dominating tree in the few coppices found in this part of Jutland in former days. Both the dune area, the heathland and the oak coppices are protected.

A series of undisturbed coastal vegetation types are represented from the coastline over the dunes and into the heathland (Fig. 1). Main emphasize is given to the vegetation types, the geology and the environmental conditions which are typical for the Danish westcoast and unique on an European basis.

The dune landscape is part of the practically unbroken belt of dunes running along the westcoast of Jutland, but only at a few places they reach such size and hight as at Henne Strand. They are formed by heavy transport of sand from the sea. The open and flat sand beach has small and low embryo-dunes (Barkhan dunes). In plan they are crescentic with the horns pointing away from the wind. Generally it is the accumulation of sand around plant tussocks on the beach that initiate these dunes.

With the constant addition of sand the embryo-dunes merge and grow into continuous littoral dune formations running parallel to the shoreline. The westernmost exposed dunes have only a thin cover of vegetation, thus exposing the white aeolian sand. The vegetation cover becomes denser in the dune belt more far from the sea, where the supply of sand is smaller and the wind velocity has lowered. New plant communities are introduced and the 'white' littoral dunes are replaced by a succession of other types giving the mature dunes a 'green' or 'gray' colour.

When gales tear the dune vegetation to shreds, large masses of sand may move inland. Sand-flight disasters have formed waste large areas in former times. Nowadays migration of the dunes has been almost completely halted by planting of Ammophila arenaria.

Man and nature often cause many small blow-outs in the dunes which tend to combine into single large ones. The erosive force of the wind then is concentrated locally because some of the blow-out ravines will accommodate greater masses of air and make passage easier.

The embryo-dunes are the youngest dunes and may be only temporary formations. They often contain fragments of marine shells with a high Ca-content. The pH is about 7.5-7. The scattered pioneer vegetation consist of e.g. Honckenya peploides, Agropyron junceum, Cakile maritima, and Agrostis stolonifera.
The white dunes have a thin vegetation cover and the white quarts particles are often subjected to transport. The dunes at Henne are 20-25 m high as a maximum. The pH is about 7.0-6.5. The vegetation is dominated by Ammophila arenaria and Elymus arenarius. Common

species are: Agropyron junceum, Festuca rubra, Lathyrus maritimus, Carex arenaria, and Sonchus arvensis.
The green dunes have a continuous cover of vegetation and the accumulation of sand is low. The less extreme wind conditions far away from the coast allow the development of a stable and continuous vegetation cover. The soil is still rich in nutrients blown in from the sea, and the Ca-content is rather high too. The pH is about 7.0-6.5. Common species are: Festuca rubra, Ammophila arenaria, Poa pratensis, Rosa spinosissima, Hypochoeris radicata, Pimpinella saxifraga, Jasione montana, Taraxacum vulgare, Cerastium semidicandrum, Empetrum nigrum, Salix repens and Senecio vernalis. Shrubs of Hippophae rhamnoides and Crataegus oxyacantha are also part of the dune vegetation.
The gray dunes. Leaching of the soil is pronounced with increasing distance from the sea and pH has dropped to 6 or 5. The colour is grayey as lichens (mainly Cladonia-species) are frequent together with mosses (Tortula ruraliformis, Camptothecium lutescens). Phanerogames as Corynephorus canescens, Jasione montana, Hieracium umbellatum, H. pilosella, Erophila verna, Thymus serpyllum, Sedum acre, Anthoxantum odoratum, Vicia cracca, Deschampsia flexuosa, Empetrum nigrum and Calluna vulgaris are frequently seen.
The brown dunes (coastal heathland) are found further inland. Leaching is pronounced and pH in the top soil is about 5.0-4.2. The dunes are rather low, 2-10 m, and common plant species are: Calluna vulgaris, Empetrum nigrum, Deschampsia flexuosa, Carex arenaria, Carex pilosa, and Genista anglica. Erica tetralix, Molinia coerulea and Vaccinium uliginosum are prominente species in the wet and oligotrophic depressions together with Carex nigra, C. panicea and the rare Gentiana pneumonanthe.

Blow-outs and other types of wind erosion are often seen in all type of dunes which initiate new successions of vegetation types. Thus, the dune landscape has a complex pattern of vegetation types and plant communities determined by the distance to the sea, exposition, elevation and age.

Night at:

**Bork Havn Vandrerhjem, Langagervej 1, Bork Havn, DK-6893 Hemmet,
tlf +45 75 28 02 22**

HENNE STRAND

Dune type:	Embryo-	White-	Green-	Gray-	Brown-

pH:	7.5	7.0	6.0	5.5	5.0
$CaCO_3$ %:	0.8	0.4	0.2	0.1	<0.1
Org. matter %:	0.2	0.3	1.6	2.7	6.0

Agropyron junceum ————
Empetrum nigrum ————————————————
Calluna vulgaris ————————————
Deschampsia flexuosa ————————————

Fig. 1

Wednesday 6th September

1. stop: Stråsø inland dunes

Kristian Dalsgaard and Bent Odgaard

Location no. 6.1

The dune system at Stråsø cover a large area of several km^2, much of which is still vegetated by heathland, the rest mainly being covered by coniferous plantations. The history of the dune area is being investigated inside the Ulfborg project, which using a multidisciplinary approach aims at describing the development of the landscape and settlements with emphasis of the last millennium. Besides being the main coordinator of the Ulfborg project, Kristian Dalsgaard, geologist and pedologist, studies geomorphological and soil development in the Stråsø area.

The investigation concentrates on two subjects: 1) Old historical infield areas at the farmplace Stråsø, previously cultivated with plaggen technique and 2) dating of buried soils to achieve a chronology on the wind erosion and relate this to land-use as reflected by pollen analyses.

Only the second subject will be dealt with in this excursion. A section will be demonstrated trough a dune exposing 3 superimposed podzols. Intensive AMS ^{14}C-dating of various fractions of organic matter in the soils indicates that the timing of covering of each soil stage can be obtained from dating the base-extracted humus fractions of the top layers (Fig. 1, 2, 3). Similarly, the age of the same fraction in the illuviation horizons gives an estimate of the minimum age of the onset of the podzolization process. ^{14}C dates of acid extractions supply estimates of the movement of organic matter down through the profile.

Pollen assemblages from the soil section reflect that the vegetation at the time of burial was invariably a *Calluna*-heathland (Fig. 4). In addition, pollen assemblages in the deepest podzol suggest a development from a wooded landscape to a more and more open heathland landscape parallel to the soil development.

A core extracted from the lake Bos Sø, 8 km from Stråsø, revealed two metres over sediment covering the entire Holocene. Preliminary pollen analysis of the limnic sediment indicates a continuous deforestation and heathland expansion in the area since about 3000 BC (Fig. 5). Continuous loss-on-ignition measurements reveal a strong increase in inorganic matter in the last millennium BC (Fig. 5, 6) and a general correlation between *Calluna*-pollen and ignition residue (Fig. 7). Selected samples were dry sieved on $\sqrt[4]{2}$ scale and particle distributions were found to follow log-hyperbolic curves (Figs. 8, 9, 10). The mode of samples from Stråsø is smaller than typical windblown dune sand like sand from Stråsø (Fig. 9) and the limnic inorganic material is thought to represent short distance transported suspended materials. The amount of inorganic material in the Bos Sø core is, therefore, probably a continuous record of the eolian activity in the area.

Primilary datings on soils in the dune profile Stråsø.

A, acid extraction. F, fulvic acid. H, humic acid. R, residual by ^{14}C. ▲ by OLS

Fig. 1.

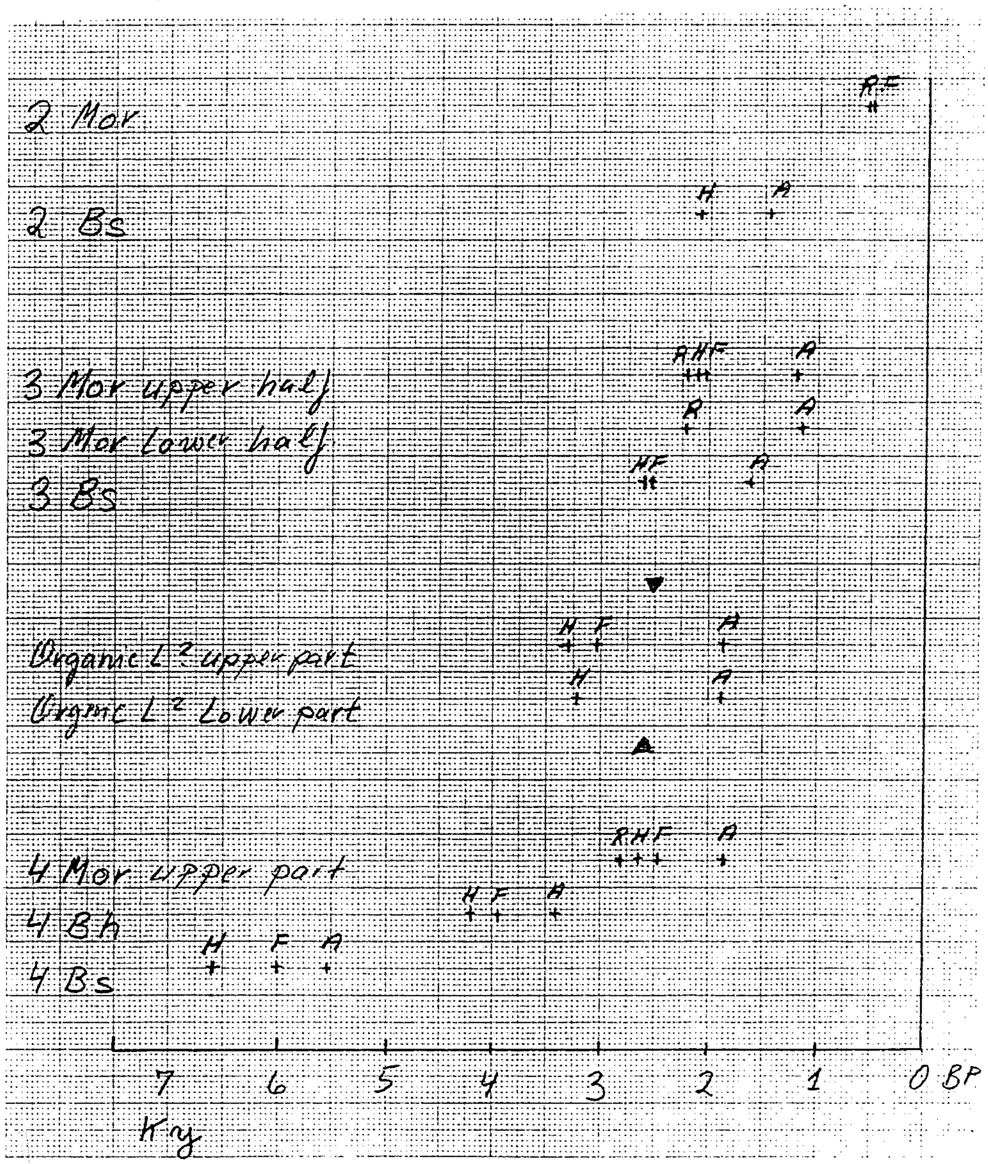
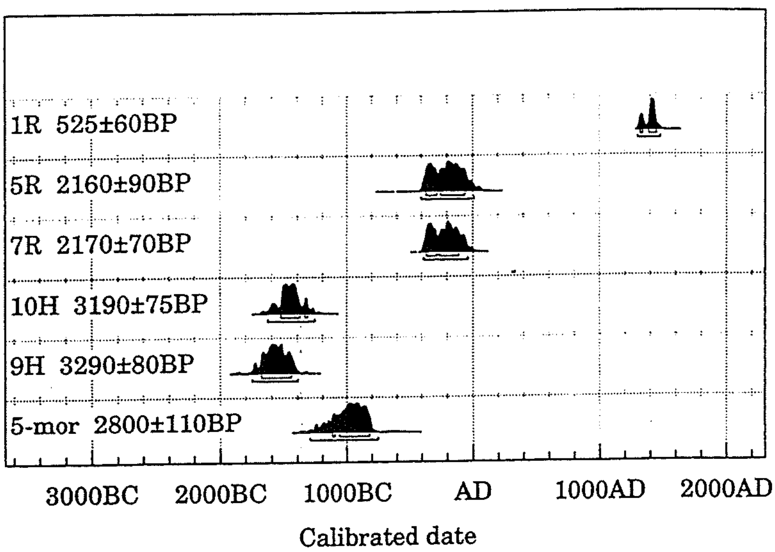


Fig. 2.

2. Mor
3. Mor upper half
3. Mor lower half
Org. layer lower
-11- upper
4. Mor



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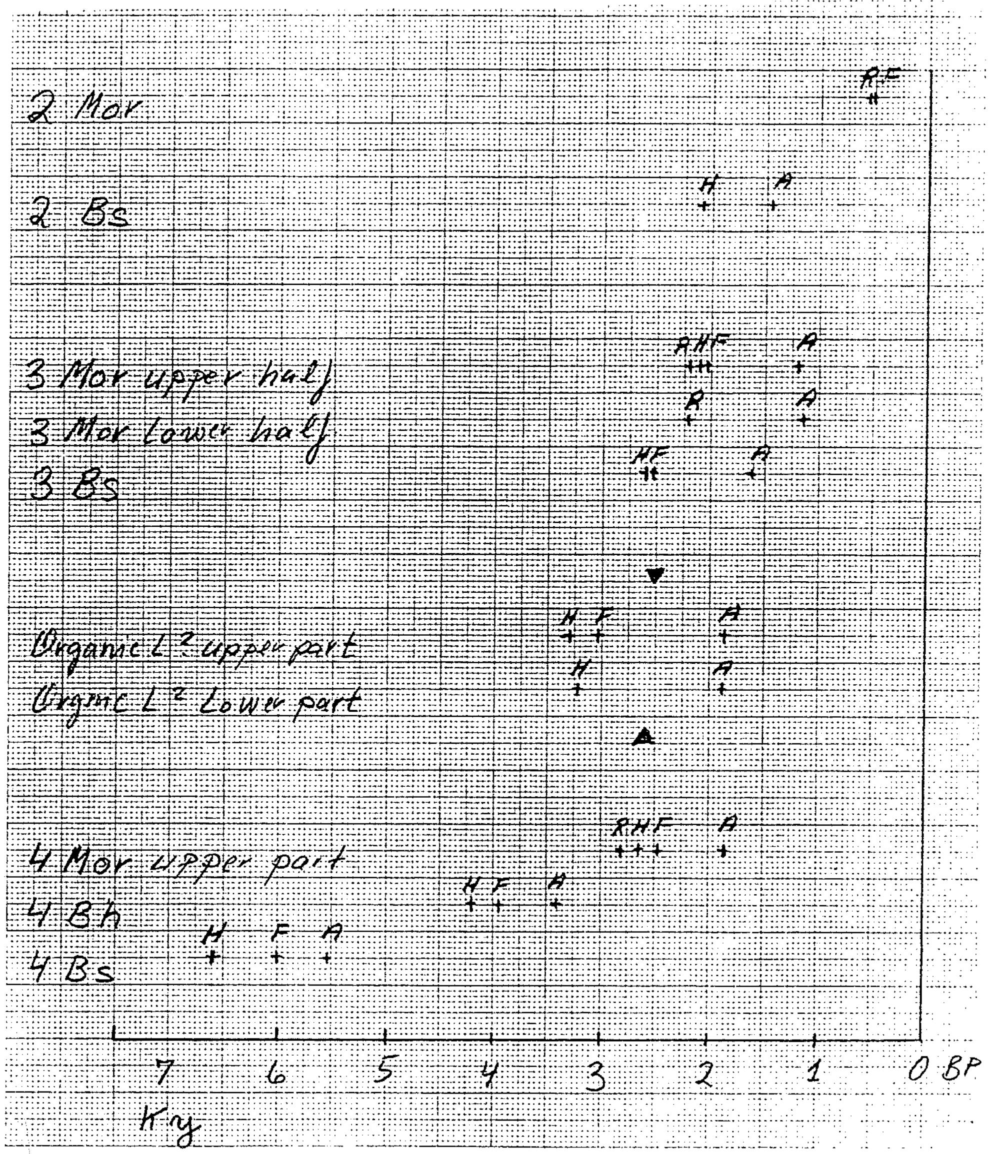

Fig. 1.

Fig. 2.

2. Mor
3. Mor upper half
3. Mor lower half
Org. layer lower
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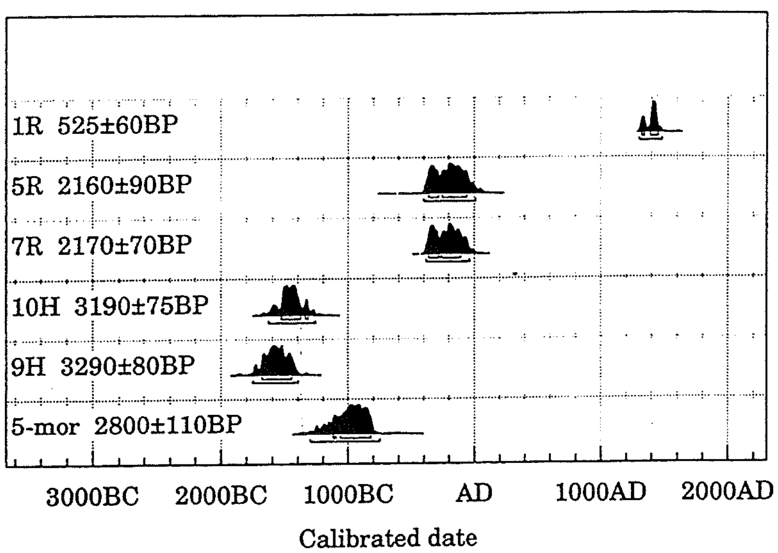
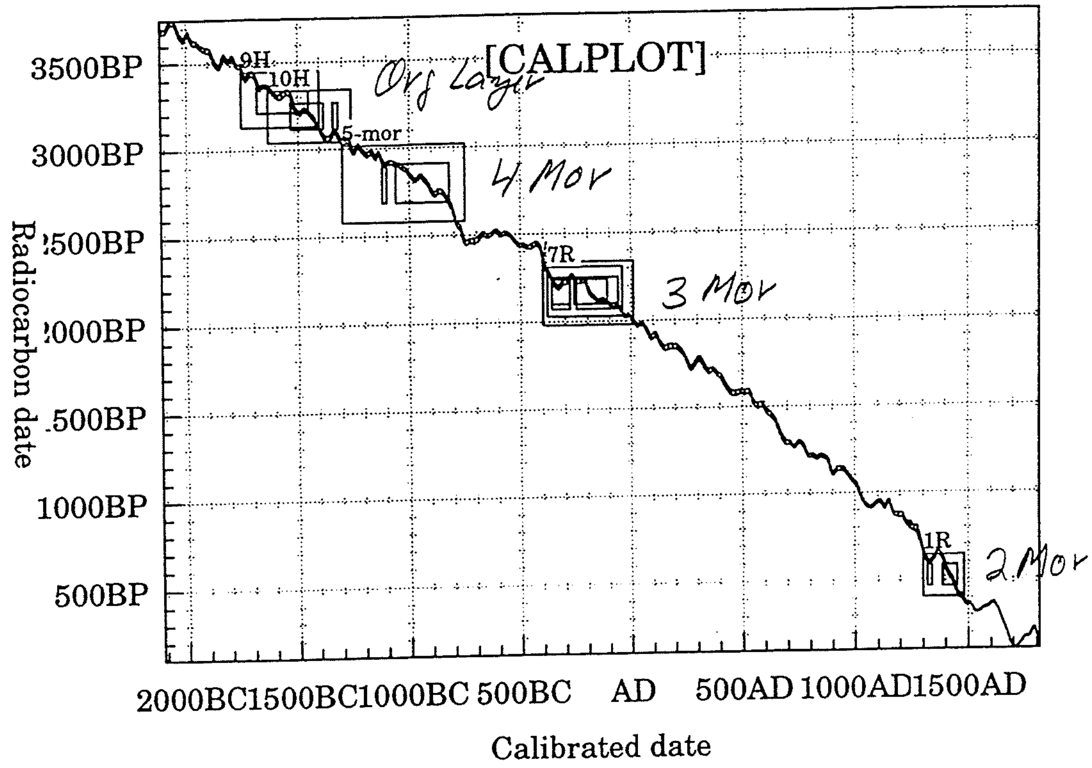
4. Mor

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Radiocarbon date
3500BP
3000BP
2500BP
2000BP
1500BP
1000BP
500BP
9H
10H
5-mor
7R
1R
Org Layer
4 Mor
3 Mor
2 Mor
2000BC 1500BC 1000BC 500BC AD 500AD 1000AD 1500AD
Calibrated date

Fig. 3.

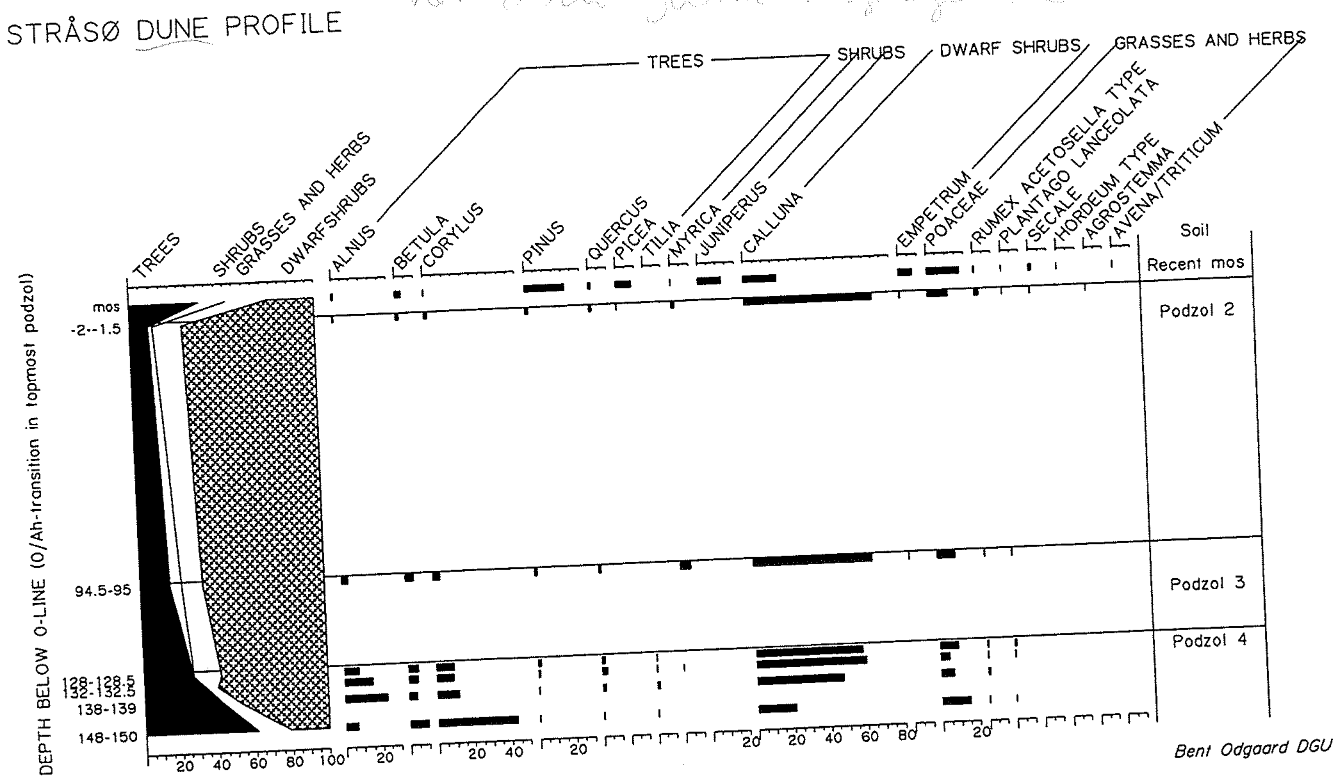

STRÅSØ DUNE PROFILE
TREES
SHRUBS
DWARF SHRUBS
GRASSES AND HERBS
TREES
SHRUBS
GRASSES AND HERBS
DWARFSHRUBS
ALNUS
BETULA
CORYLUS
PINUS
QUERCUS
PICEA
TILIA
MYRICA
JUNIPERUS
CALLUNA
EMPETRUM
POACEAE
RUMEX ACETOSELLA TYPE
PLANTAGO LANCEOLATA
SECALE
HORDEUM TYPE
AGROSTEMMA
AVENA/TRITICUM
Soil
Recent mos
Podzol 2
Podzol 3
Podzol 4
DEPTH BELOW O-LINE (O/Ah-transition in topmost podzol)
mos
-2--1.5
94.5-95
128-128.5
132-132.5
138-139
148-150
20 40 60 80 100
Bent Odgaard DGU

Fig. 4.

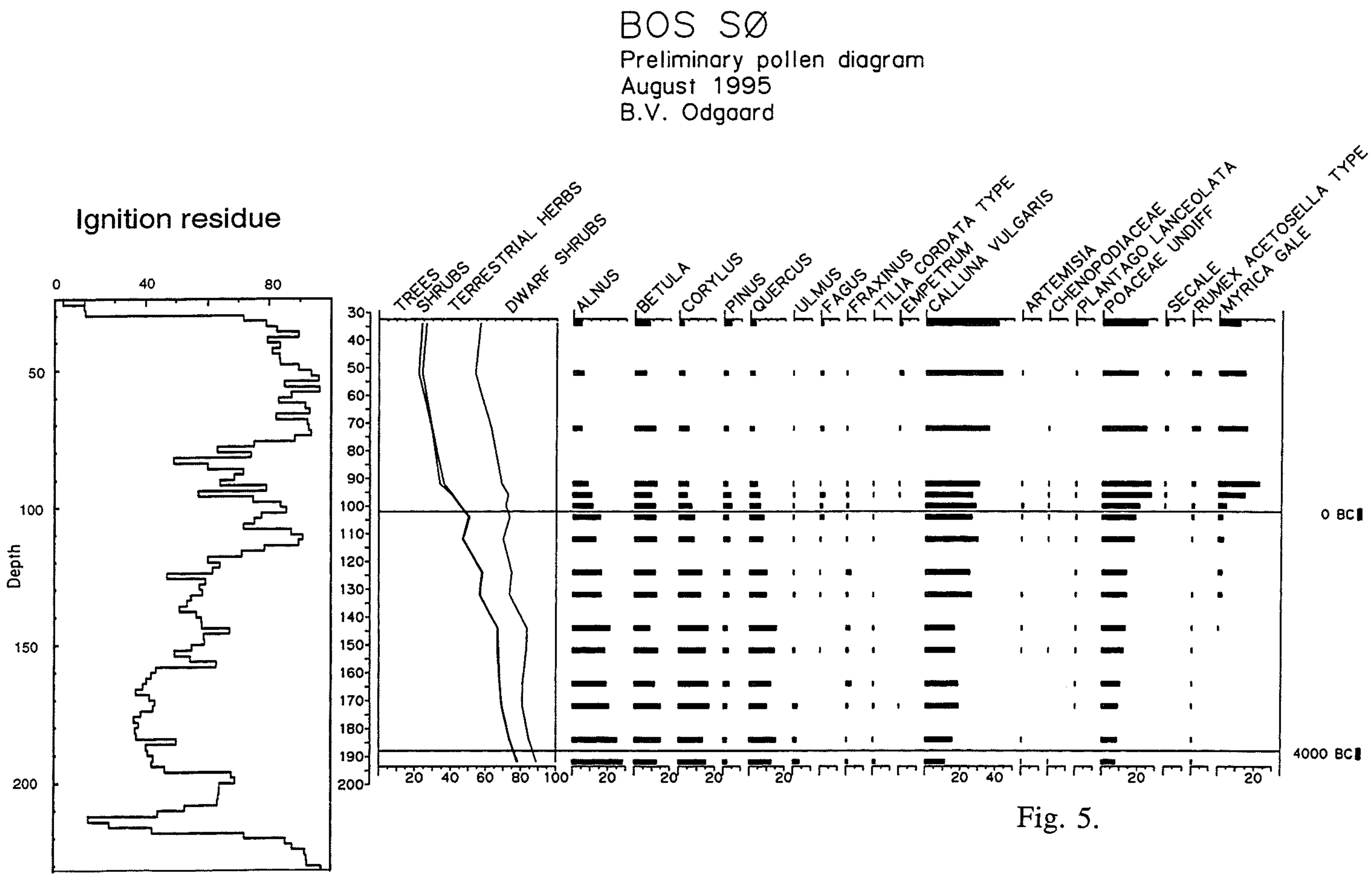


Fig. 5.

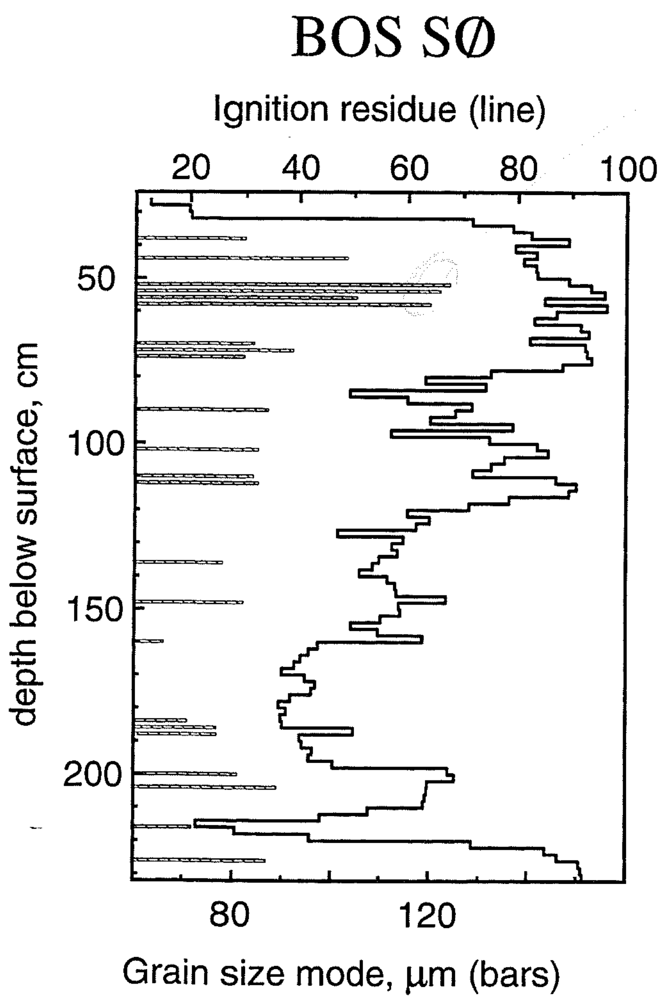
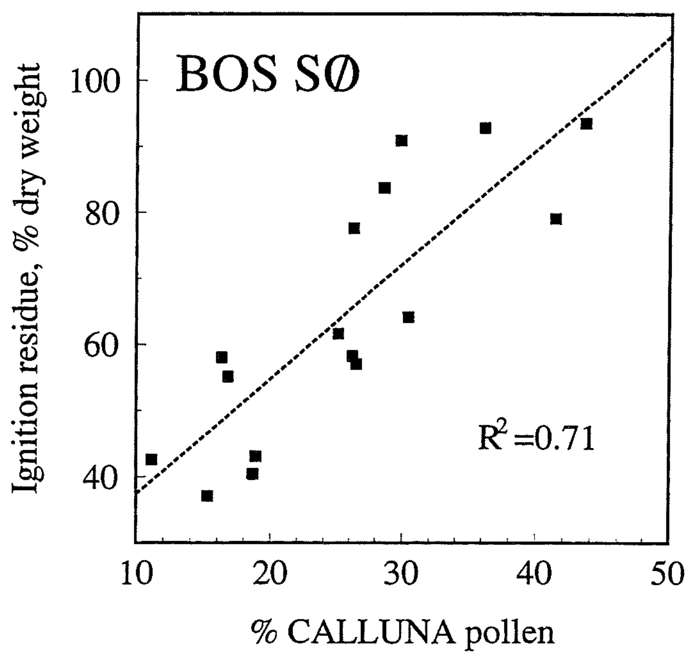


Fig. 6.

Fig. 7.



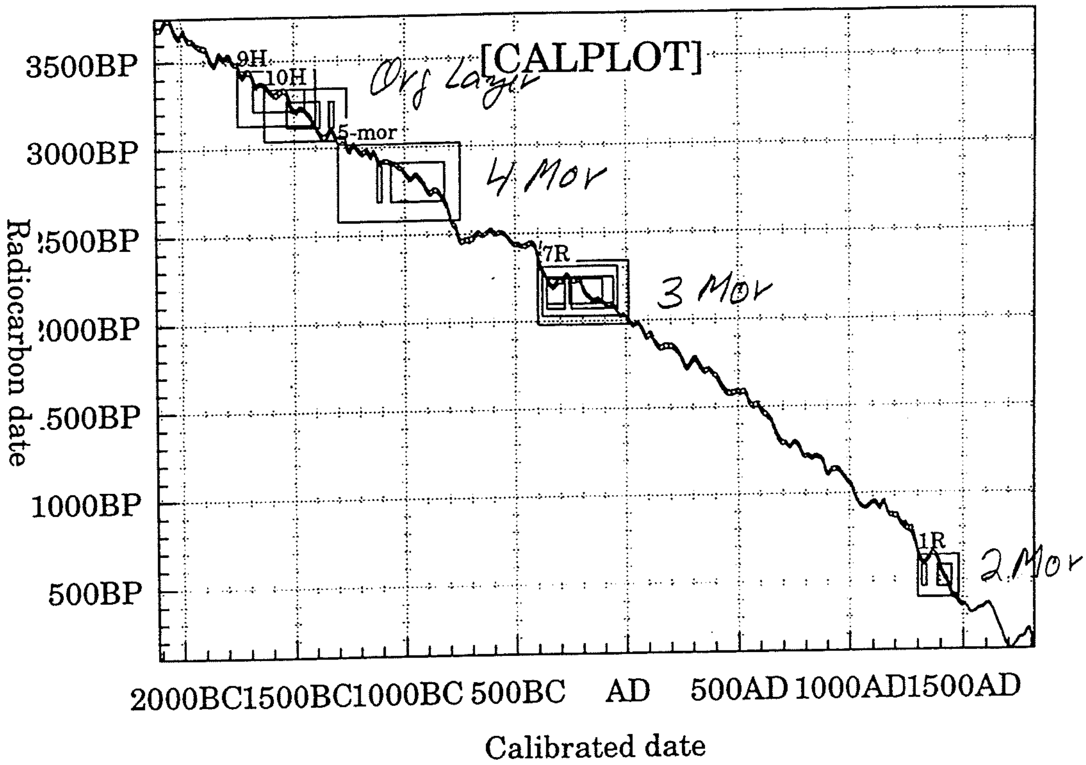
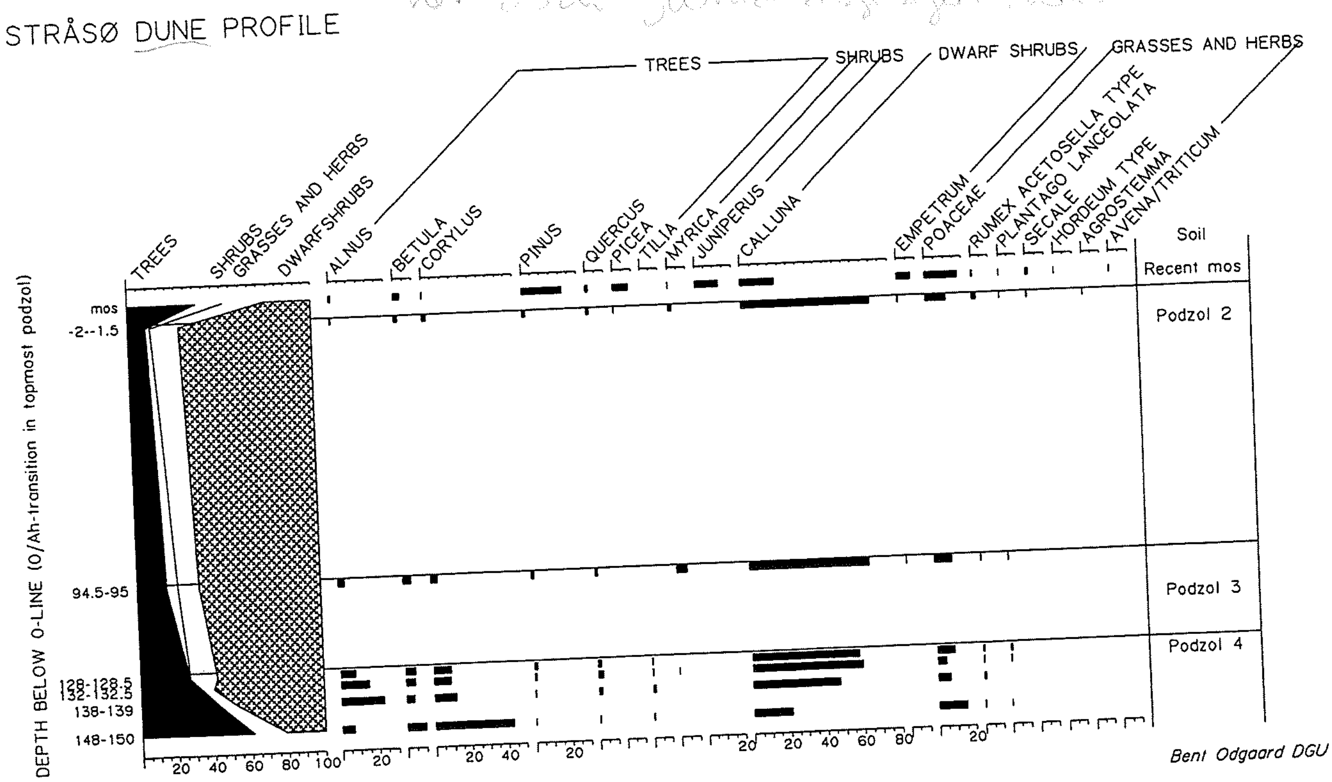

[CALPLOT]
9H
10H
5-mor
7R
1R
Org Lager
4 Mor
3 Mor
2 Mor
3500BP
3000BP
2500BP
2000BP
1500BP
1000BP
500BP
Radiocarbon date
2000BC 1500BC 1000BC 500BC AD 500AD 1000AD 1500AD
Calibrated date

Fig. 3.


STRÅSØ DUNE PROFILE
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Soil
Recent mos
Podzol 2
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DEPTH BELOW O-LINE (O/Ah-transition in topmost podzol)
mos
-2--1.5
94.5-95
128-128.5
132-132.5
138-139
148-150
20 40 60 80 100
Bent Odgaard DGU

Fig. 4.

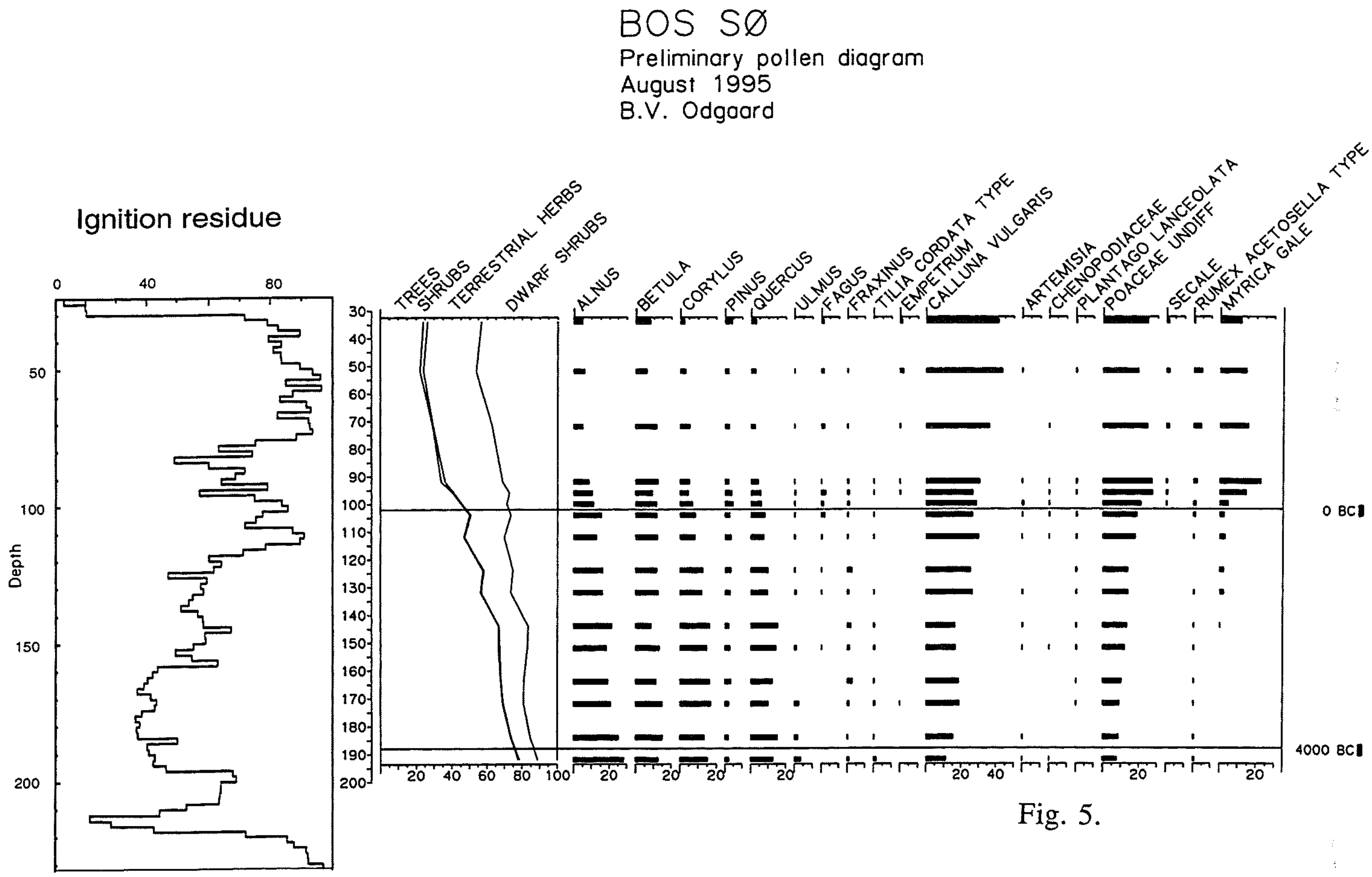


Fig. 5.

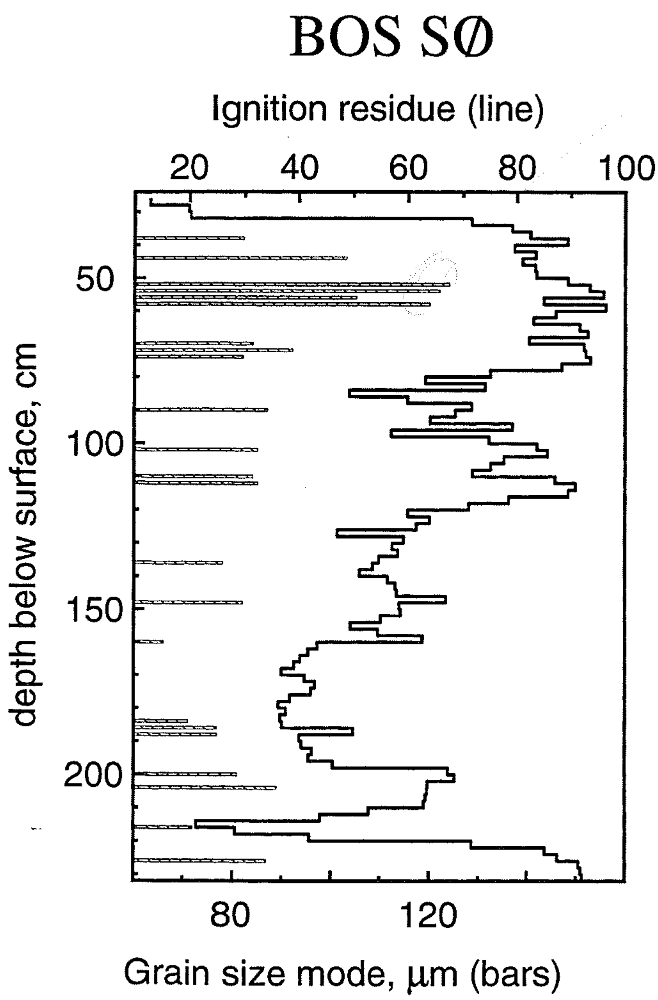
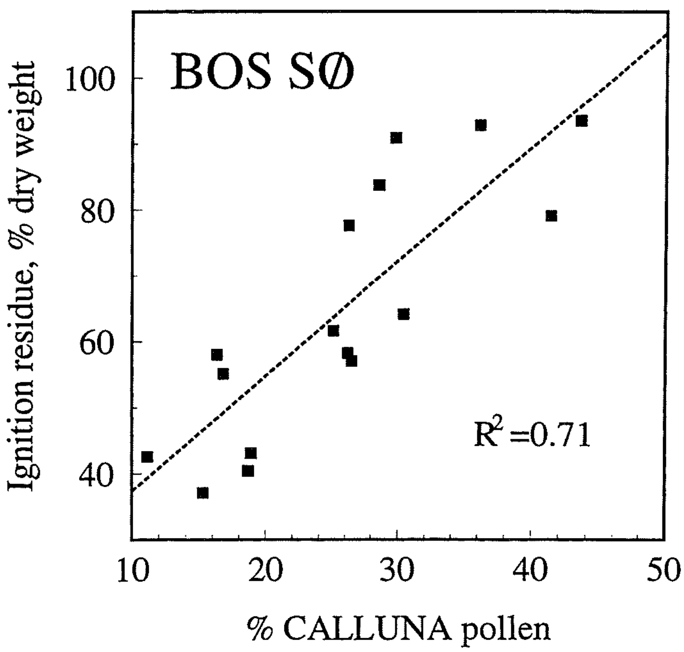


Fig. 6.

Fig. 7.



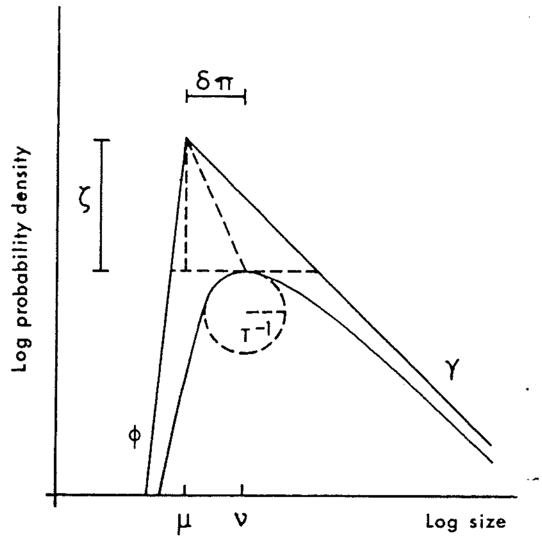


Figure [redacted]. The geometrical interpretation of the parameters of the hyperbolic distribution.

Fig. 8.

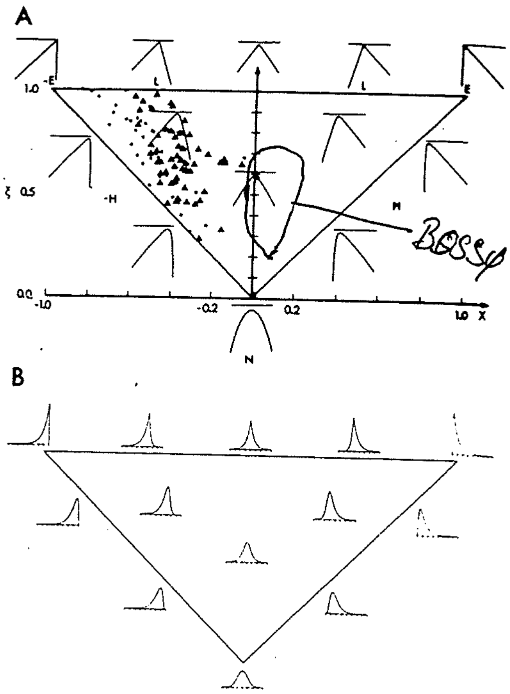
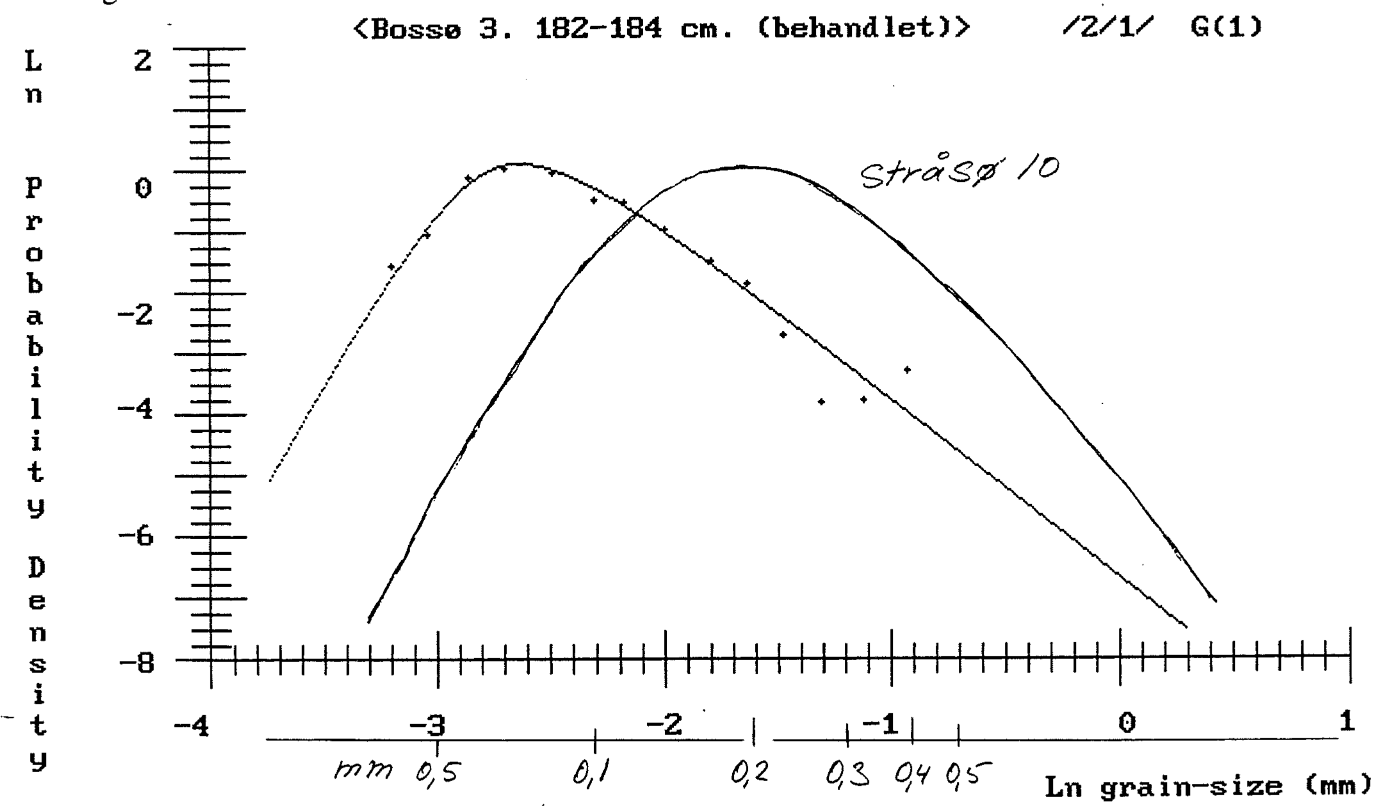


Figure [redacted]. The hyperbolic shape triangle. The letters at the boundaries indicate limit distributions: N, normal; L, Laplace; E, exponential; H^+ and H^-, positive and negative hyperbolic (for details, see text). (A) Log probability functions corresponding to selected (χ, ξ) values. (B) Representative probability functions corresponding to (A).

Fig. 9.

Fig. 10.



2. stop: Vind Hede

Bent Odgaard

Location no. 6.2

Just before the cultivation of the Jutland heathlands accelerated in this century the Danish archaeologist Gudmund Hatt managed to document a large number of celtic field systems which were preserved as low ridges in the heaths. Some of these systems still exist in preserved heath areas, one of them at Vind Hede (Fig. 1). Neighbouring the heath is an oak scrub of typical West Jutish type with low crooked oaks and aspen. Historical and pollen analytical evidence show that these scrubs have been heavily exploited by cutting and grazing, which has changed the original mixed deciduous woodland into one dominated by oak (Fig. 2). The heavy exploitation has also caused a soil degradation so that many scrubs now show thick humus layers on top of heavy podzols. On some soils, however, the process seems to be reversible, and oak invading heahtland will induce a de-podzolization (Fig. 3)

The heaths of western Jutland were also heavily exploited by the traditional land-use in the area. The main uses were for grazing - especially winter grazing, cutting of sods for fuel and manuring ("Plaggenwirtschaft") and cutting of heather for fodder. This traditional use was the basis of the maintenance of the heathlands through millennia. If heaths are left undisturbed a characteristic succession of plant communities takes place (Fig. 4).

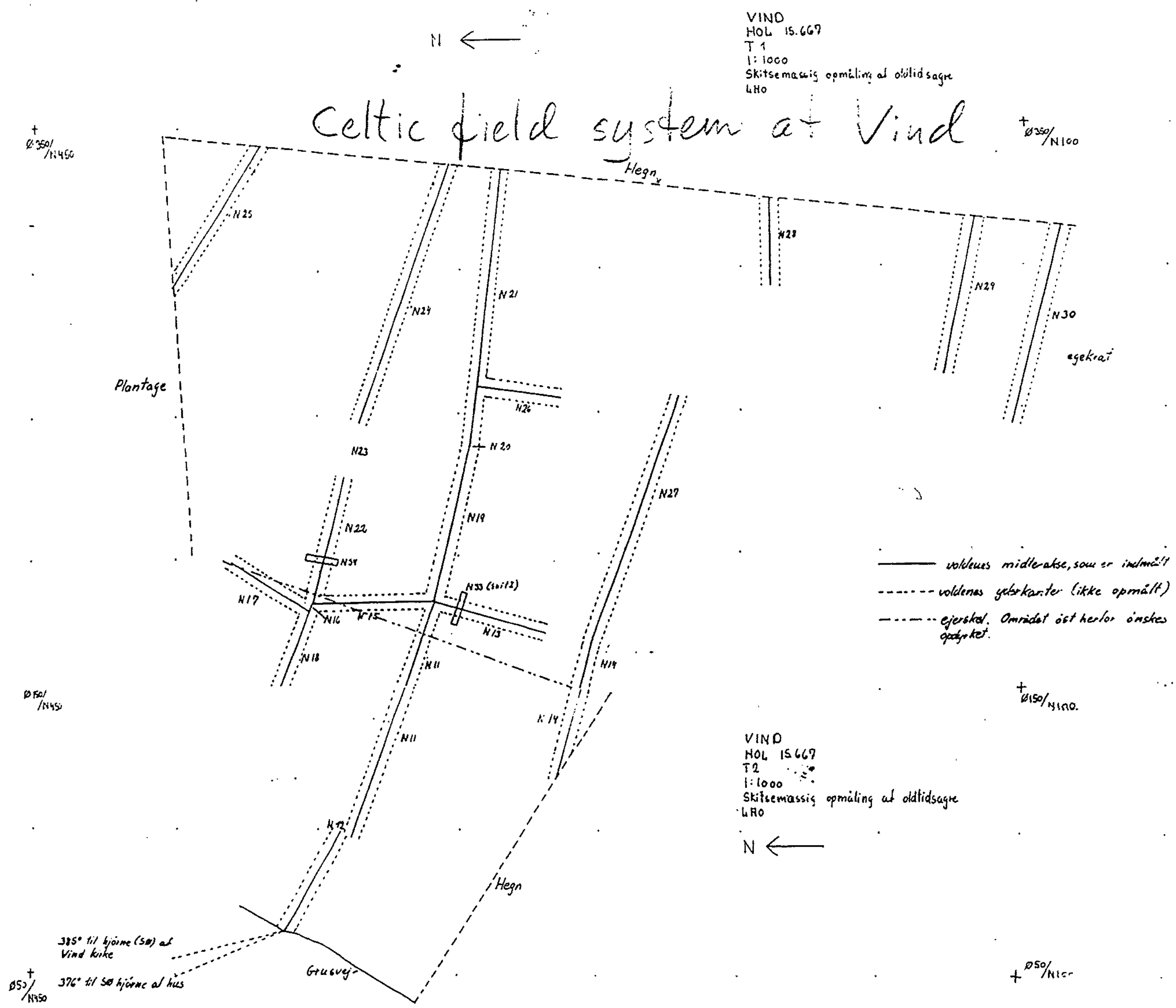
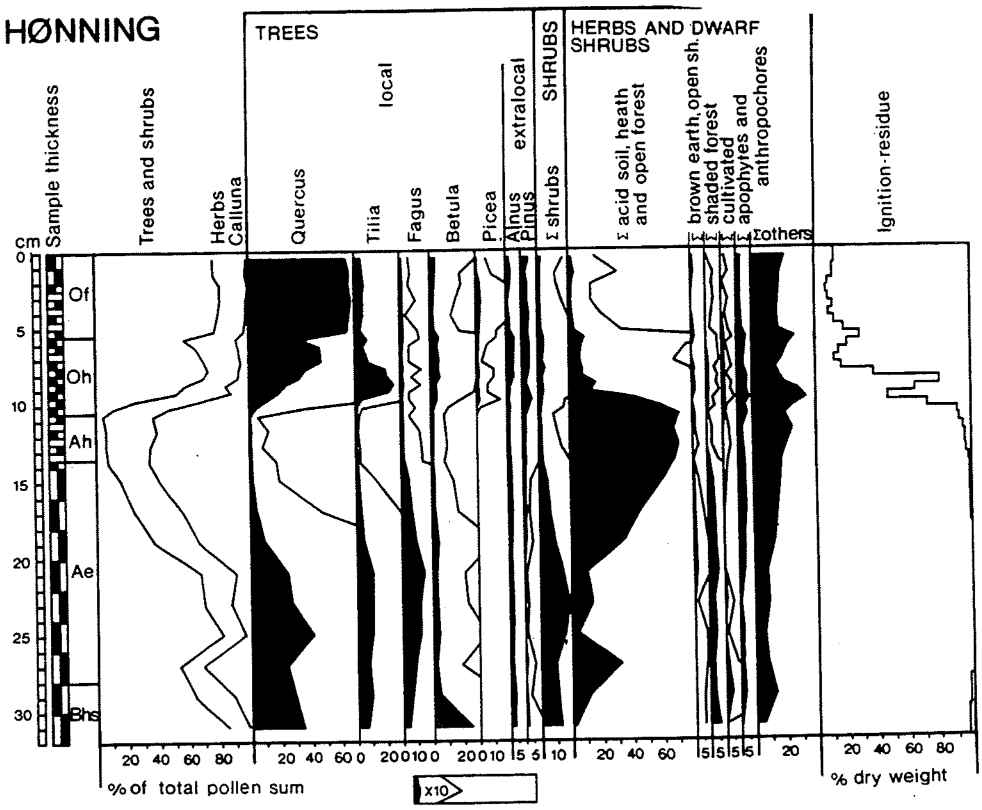
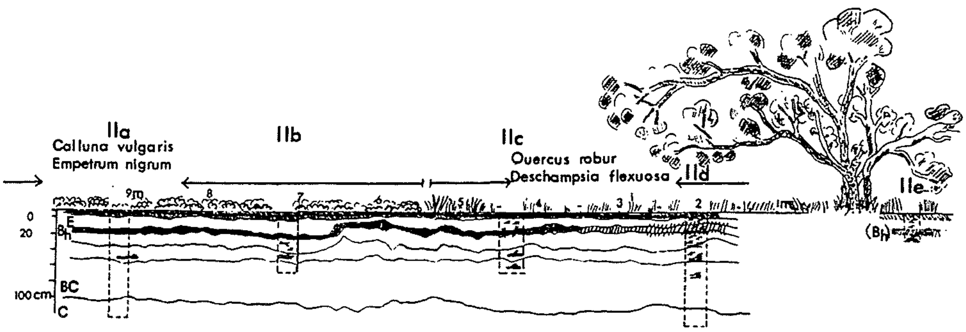


Fig. 1.



Pollen diagram from a recent soil section in the Hønning oak-scrub. The diagram shows a survey diagram, untransformed curves for trees, sum curves for shrubs and ecological groups and ignition-residue values.

Fig. 2.



Cross-section diagram of site II to show locations of the four soil profiles within the trench and the one profile beyond the oak that were described and sampled. Horizons are illustrated schematically.

Fig. 3.

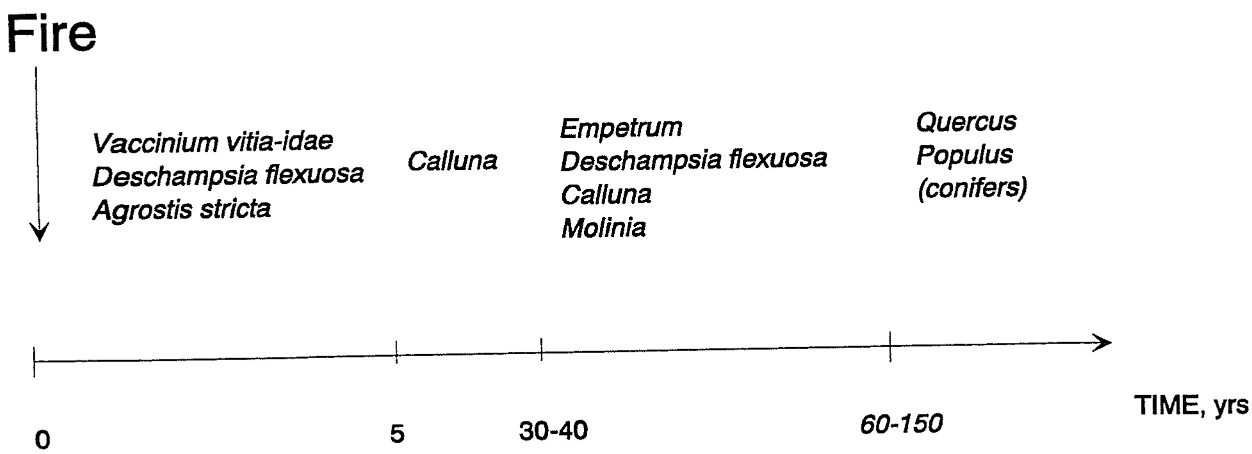


Fig. 4.

3. stop: Lake Skånsø

Bent Odgaard

Location no. 6.3

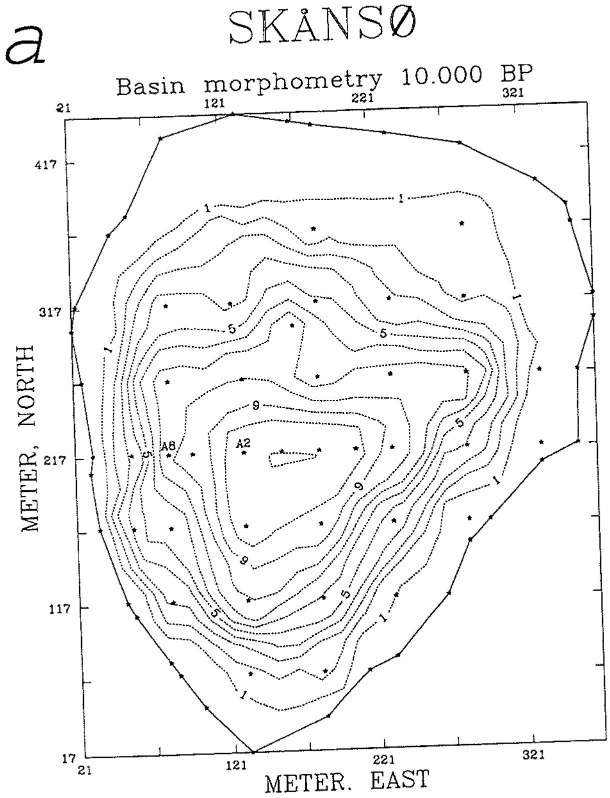
Skånsø is situated on a fluvioglacial plane, formed during the ablation of the Weichselian ice. Sand and silt carried by meltwater from the south buried blocks of ice which later melted and left numerous "dead ice" depressions in the sandur. Skånsø occupies one of these depressions. Although small, Skånsø shows a sedimentation pattern strongly influenced by wind-induced currents (Fig 1). Early Holocene sediments are only found in the western part of the lake along the sheltered shore. Later sediments are deposited obliquely and the area of sedimentation has gradually expanded (Fig. 2). The dominant direction of strong winds (> 10 m s^{-1}) is WNW and the eastern part of the lake is accordingly the most exposed area (Fig 3). Plots of the ratio observed:"expected" Holocene sediment versus the fetch demonstrate the effect of strong winds on the sediment thickness when the fetch exceeds about 150-200 metres (Figs. 4 and 5). Estimates of whole-lake sedimentation indicate very low terrestrial erosion rates until 4000 BC (calendar years) and an increase to more than ten times higher erosion rates later in the Holocene (Fig. 6).

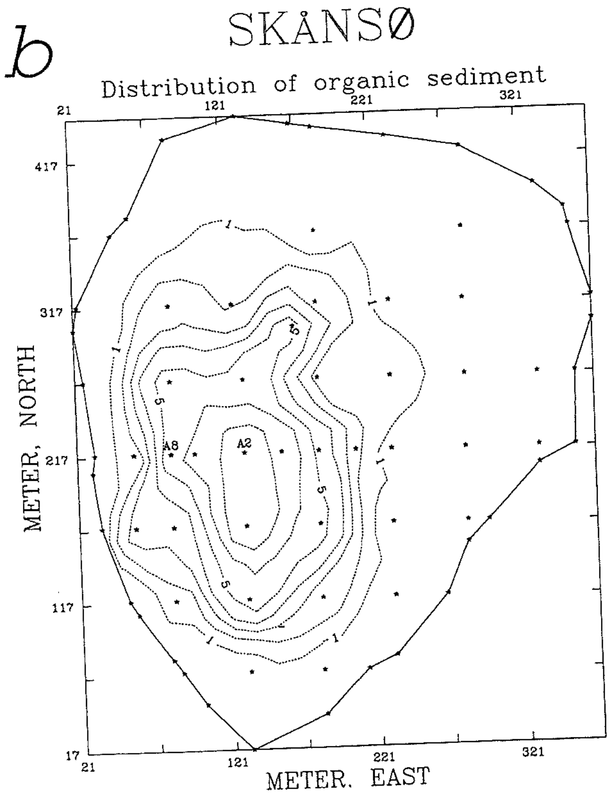
The pollen and spore results suggest that Skånsø has been oligo-mesotrophic throughout its history and some of the plants occurring here today have a very long continuity: 10,000 yrs for Lepidotis inudatum, Gentiana pneumonanthe, Littorella uniflora and Isoëtes lacustris (Fig 7). Pollen and macrofossil analysis document the use of the lake for retting of Cannabis sativa and Linum usitatissimum. During the time of this use (ca. AD 500 - 1800) the lake showed intermittent blooming of the Cyanobacteria Gloetrichia echinulata and periods with much Pediastrum (Fig. 8). This sheet-forming, colonial algae has a peculiar life history in that it survives by resting cells in the sediment surface during most of the year. In spring - early summer formation of colonies are initiated and phosphorus are taken up from the sediment in excess amounts of the consumption and stored internally. The colonies will eventually flow to the surface where they will increase in size and number until the internal phosphorus pool is depleted. Ordination of indicators of erosion and the palynological data suggest that increased nutrient loading caused a change of the lake vegetation (Fig. 9 and 10). After retting activities were discontinued the lake returned to its previous stage.

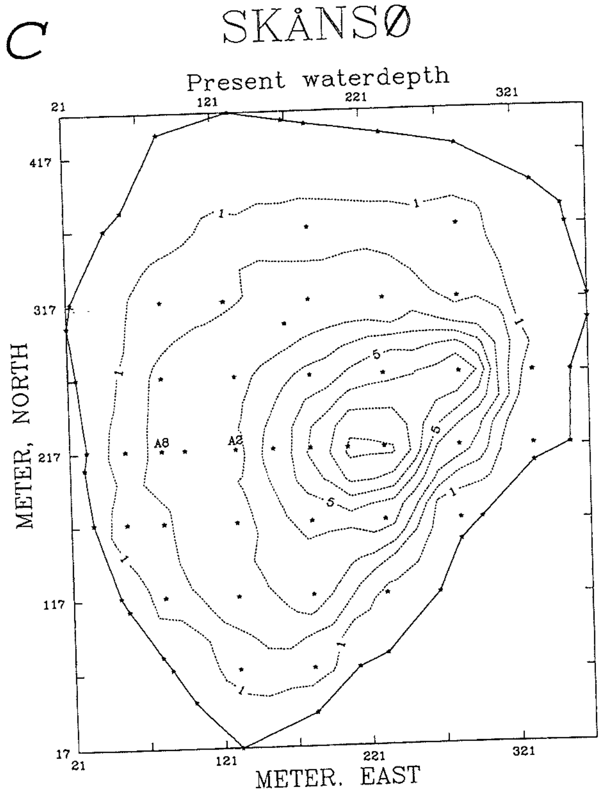
Skånsø is one of three lakes in western Jutland which has been studied to investigate the vegetational history in the area, especially the development of the heathland. During the woodland expansion of the early Holocene indications are found at Skånsø of a short recession which can be correlated with the Rammelbeek phase of The Netherlands and probably also the period of low water level documented by many studies in southern Sweden (Fig 11). After this short period a characteristic woodland succession took place. The initial open woodland of Betula and Pinus was replaced by Corylus at 8000 BC (calendar yrs), and by 7000 BC a mixed woodland of Tilia, Betula, Corylus, Ulmus and Alnus has developed. This vegetation was rather open due to the poor soils and had much more Betula than contemporary woodland on better soils. Shortly after 4000 BC agricultural activities are detected in the area but major deforestations did not take place in western Jutland until about 3000 BC, when heathland expanded at some sites. The exact timing of heathland expansions differs strongly between sites (Fig 12) and investigations of microscopic charred particles suggest a strong correlation between vegetational burning and heath expansions (Figs. 13 and 14). The results indicate that heathlands were maintained in young Calluna-dominated stages as a winter grazing resource.

Night at:

Viborg Vandrerhjem, Vinkelvej 36, DK-8800 Viborg, tlf: +45 86 67 17 81







[redacted]. Contours of (a) basin morphometry of Skånsø 10000 ^{14}C years BP, (b) distribution of Holocene gyttja, and (c) present morphometry. Coring points and the location of the main cores A2 and A8 are marked. The equidistance of contour lines is one meter.

Fig. 1.

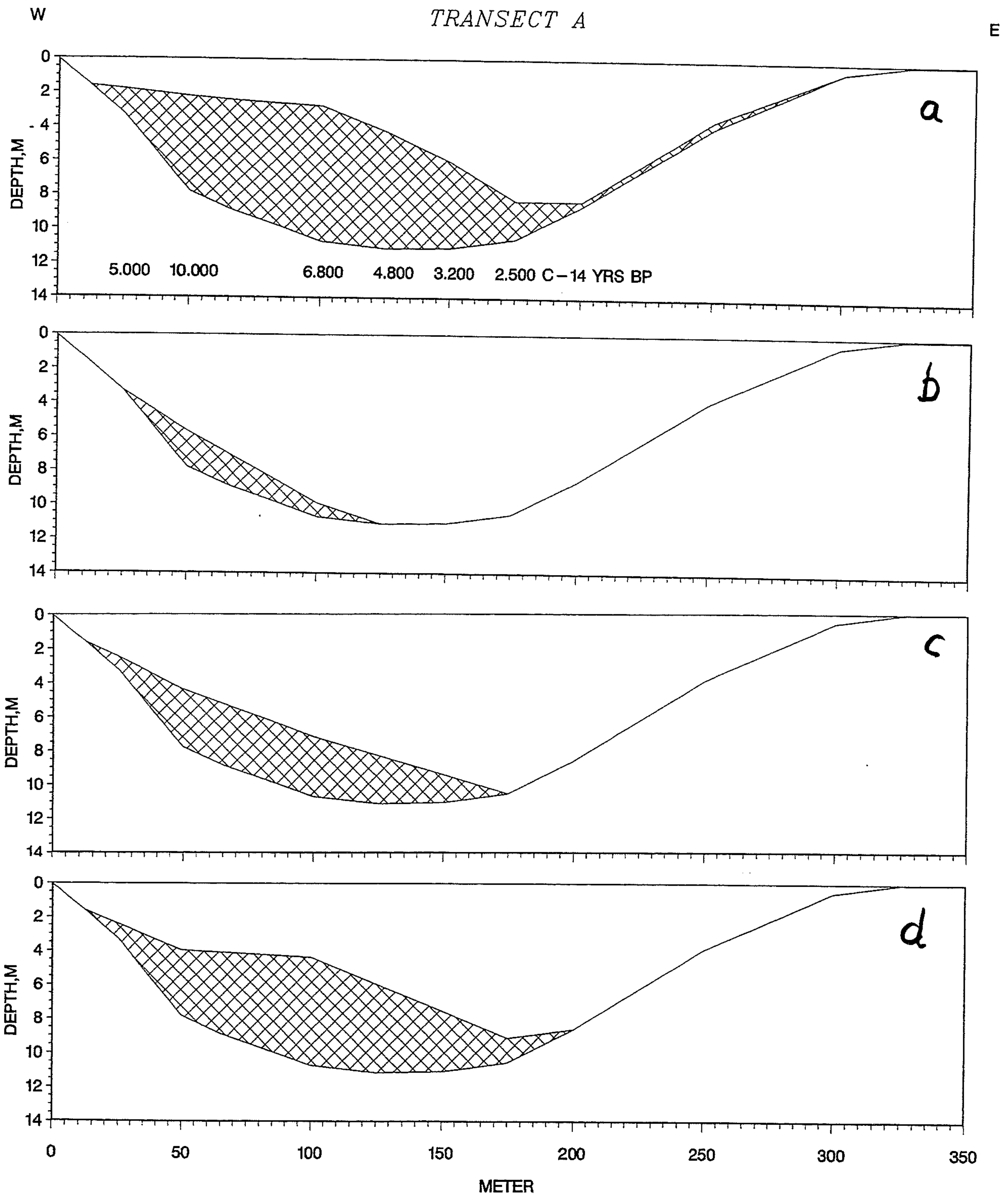


Fig. 2. West-East section of Skånsø at transect A showing (a) the total Holocene gyttja (cross-hatched) and datings for the onset of gyttja sedimentation, as well as gyttja distribution at (b) 5000 BP, (c) 2500 BP and (d) 1200 BP.

Fig. 2.

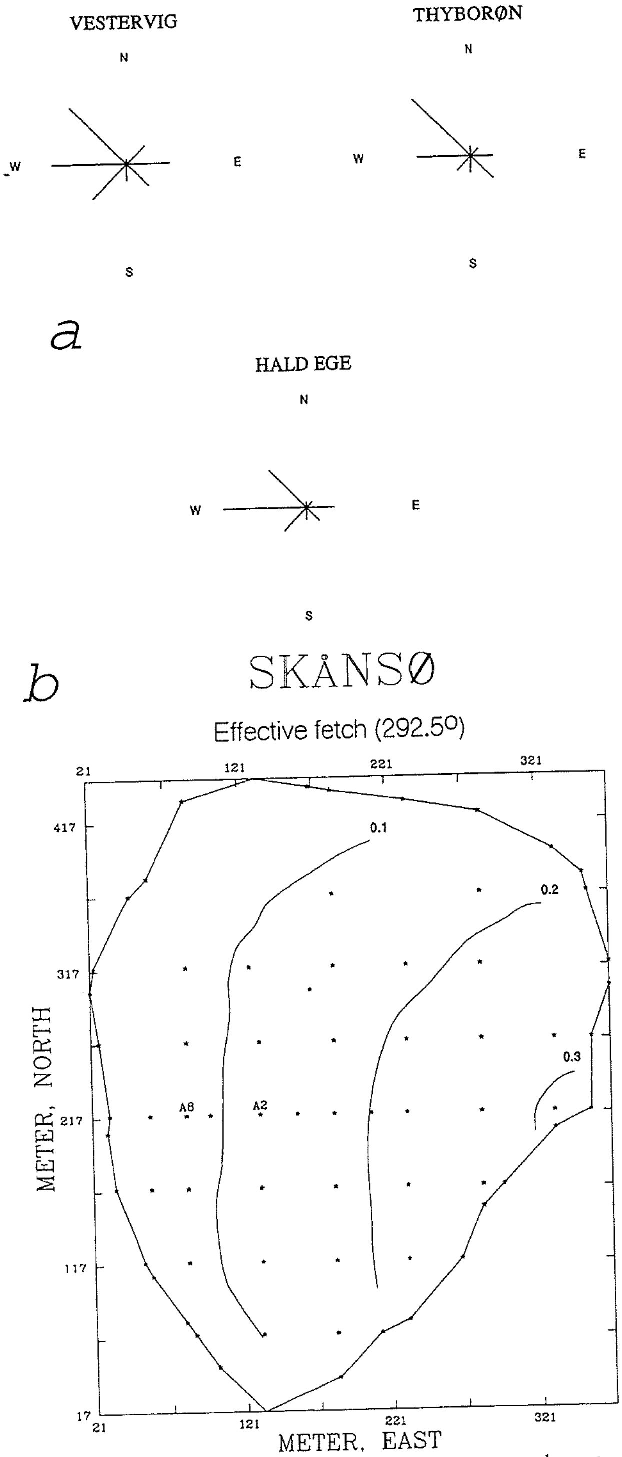


Fig. 3.

Fig. 4.

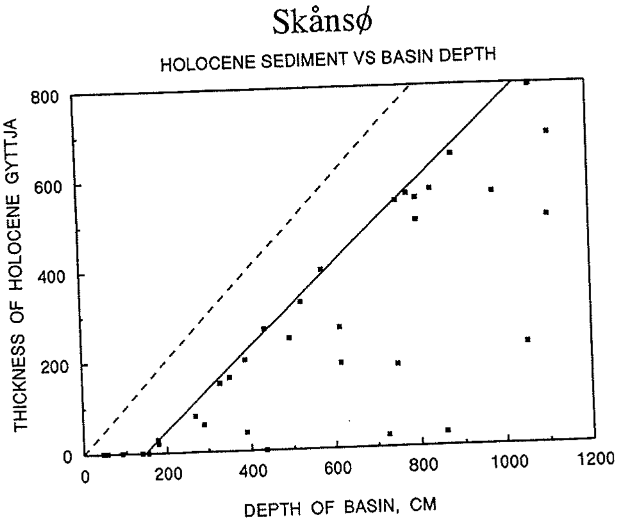


Fig. 3. (a) Wind-roses for windspeeds ≥ 10.8 m s^{-1} in the months March, April, September, October, November and December from three climatic stations close to Skånsø (data from Frydendahl, 1971). (b) Isolines for effective fetch (in km) in Skånsø in westnorthwestern direction (292.5°).

Fig. 4. The thickness of Holocene organic sediment in Skånsø plotted against basin depth at 10000 BP. Lines indicating y = x (dashed) and maximum estimate of sediment thickness (solid) are shown.

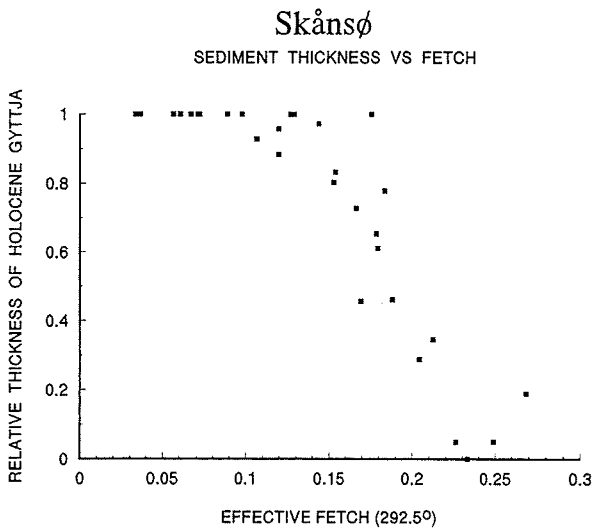


Fig. 5. Ratio of observed sediment thickness to maximum estimated thickness plotted against effective fetch of each coring point.

Fig. 5.

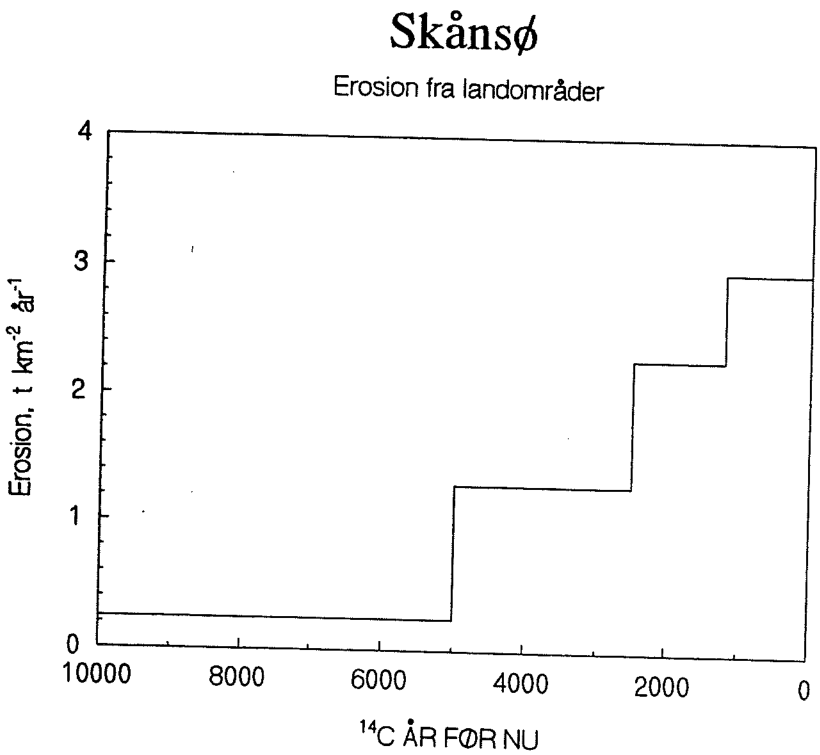
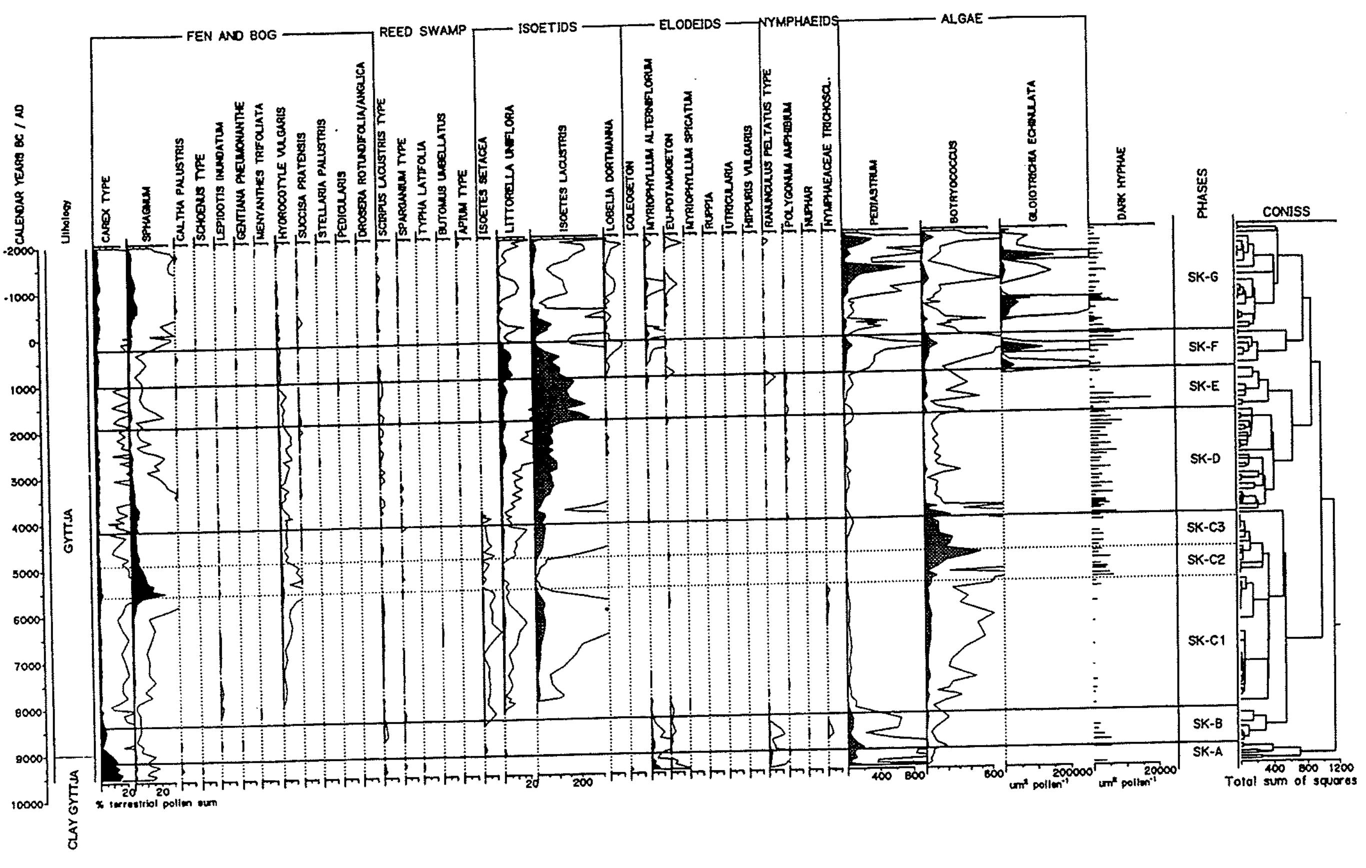


Fig. 6.



Relative (percentage) pollen diagram of wet ground pollen types from Skånsø plotted on a time-scale of calendar years. Percentages are shown as silhouettes, values exaggerated 10 times as lines. Note the change of scale.

Fig. 7.

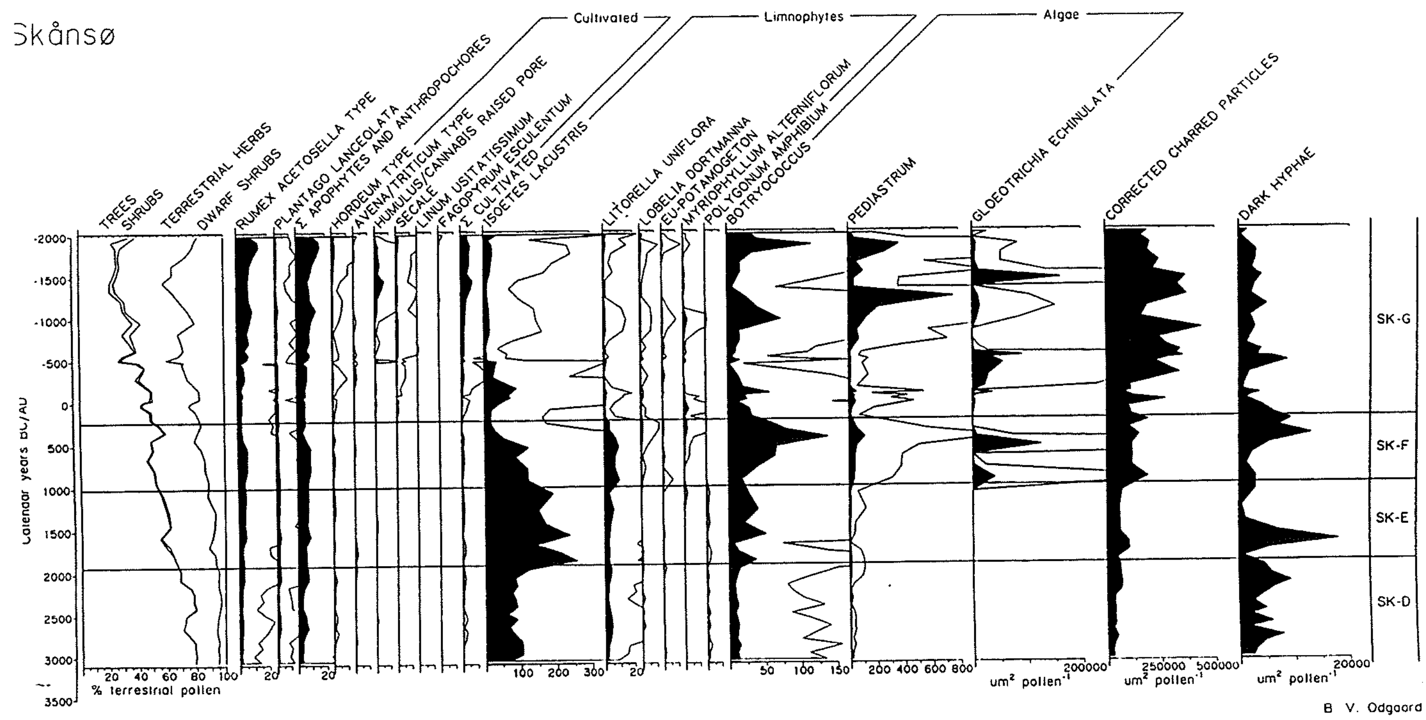


Fig. 8.

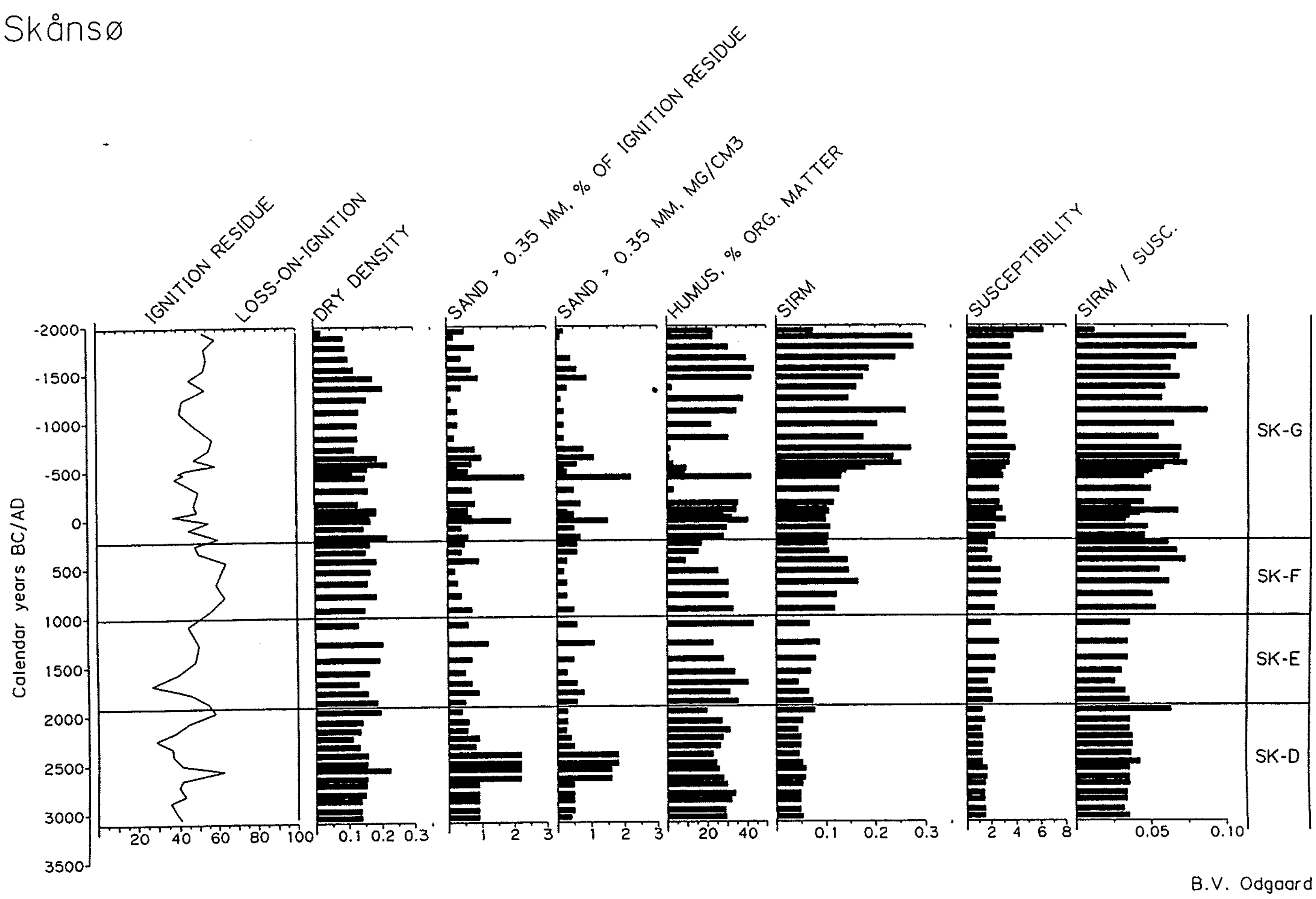
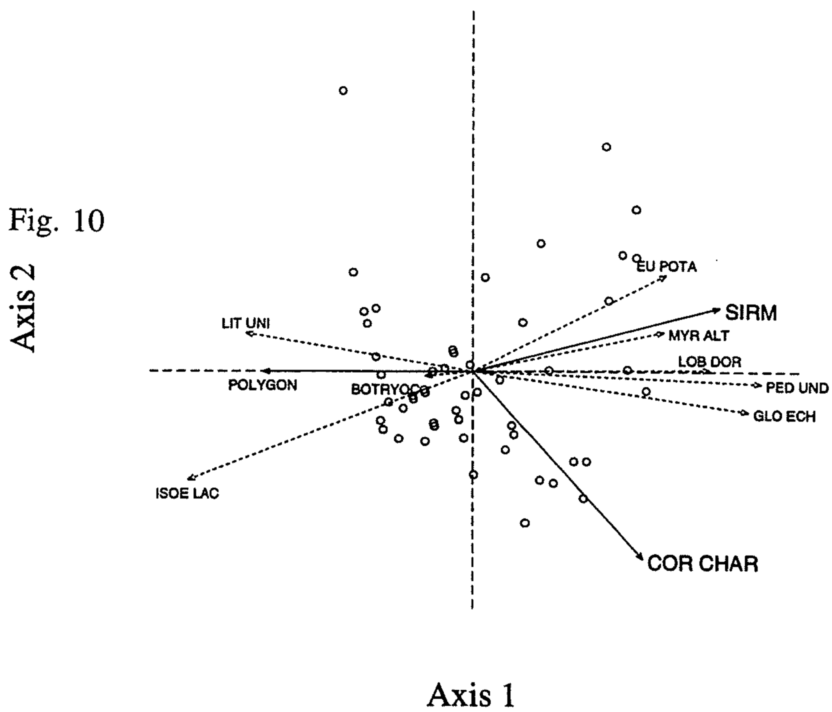

Skånsø
IGNITION RESIDUE
LOSS-ON-IGNITION
DRY DENSITY
SAND > 0.35 MM, % OF IGNITION RESIDUE
SAND > 0.35 MM, MG/CM3
HUMUS, % ORG. MATTER
SIRM
SUSCEPTIBILITY
SIRM / SUSC.
Calendar years BC/AD
SK-G
SK-F
SK-E
SK-D
B.V. Odgaard

Fig. 9.

Fig. 10


Axis 2
EU POTA
SIRM
MYR ALT
LOB DOR
PED UND
GLO ECH
LIT UNI
POLYGON
BOTRYOCO
ISOE LAC
COR CHAR
Axis 1

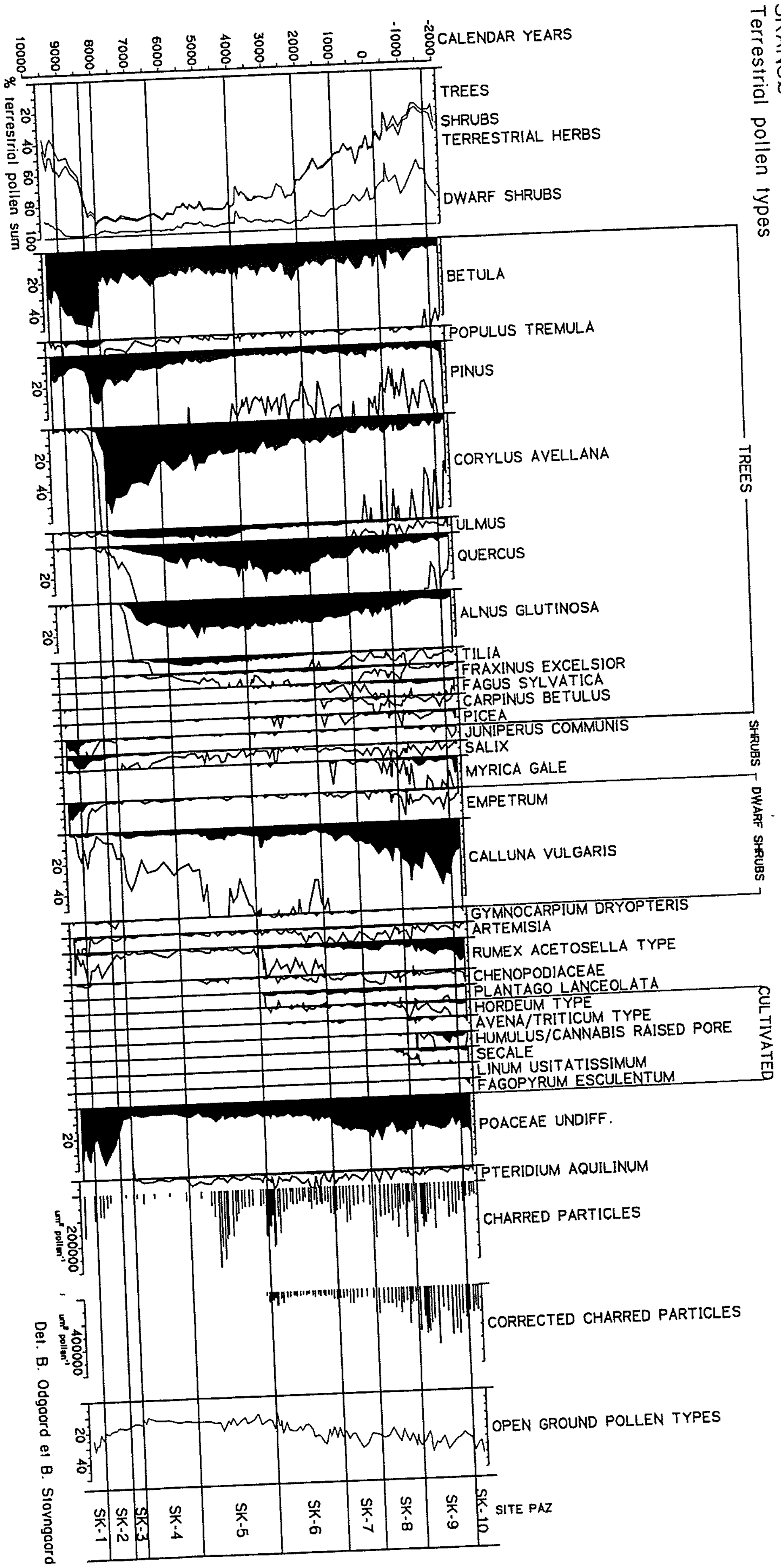
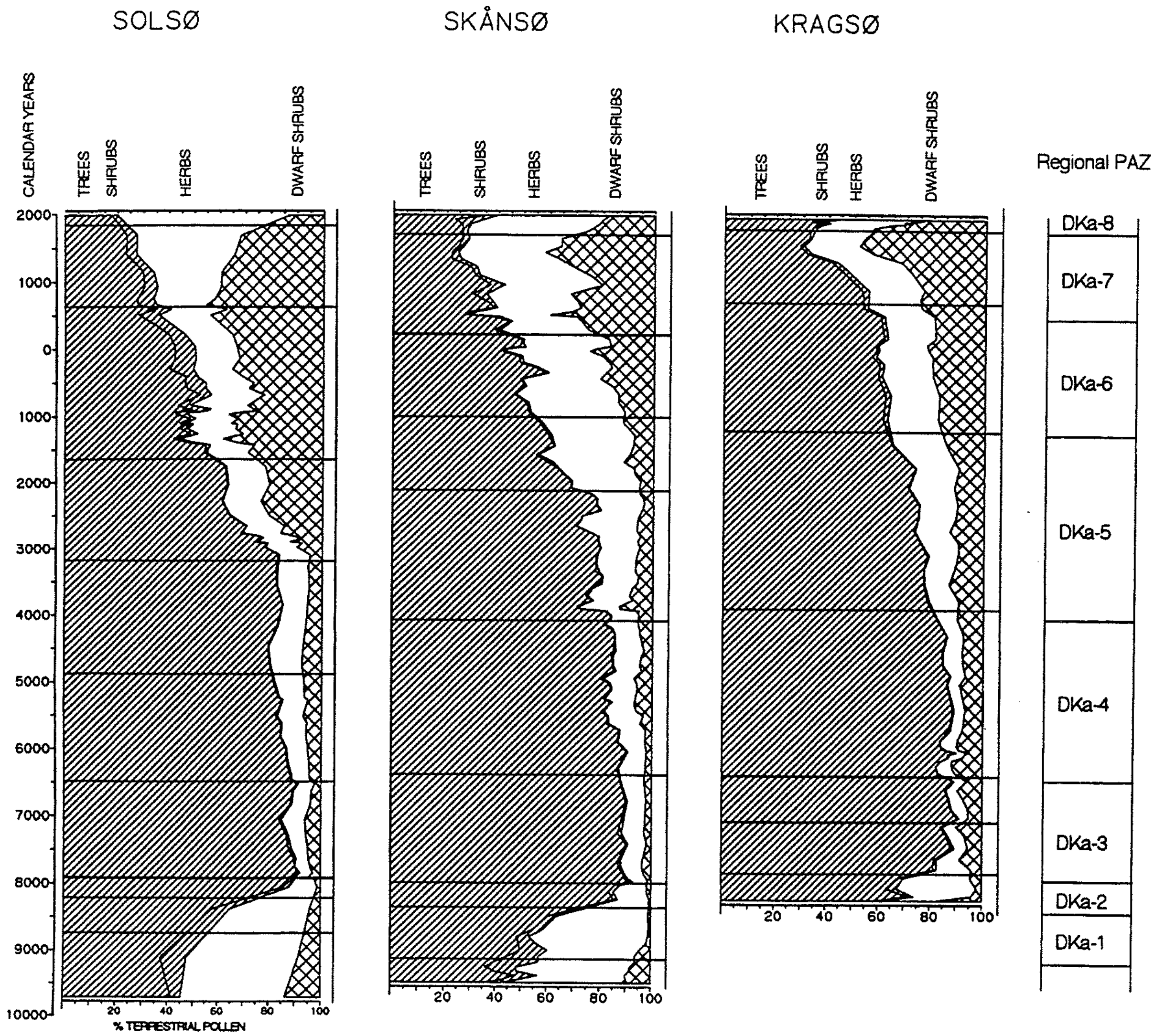

SKÅNSØ
Terrestrial pollen types
CALENDAR YEARS
TREES
SHRUBS
TERRESTRIAL HERBS
DWARF SHRUBS
% terrestrial pollen sum
BETULA
POPULUS TREMULA
PINUS
CORYLUS AVELLANA
ULMUS
QUERCUS
ALNUS GLUTINOSA
TILIA
FRAXINUS EXCELSIOR
FAGUS SYLVATICA
CARPINUS BETULUS
PICEA
JUNIPERUS COMMUNIS
SALIX
MYRICA GALE
EMPETRUM
CALLUNA VULGARIS
GYMNOCARPIUM DRYOPTERIS
ARTEMISIA
RUMEX ACETOSELLA TYPE
CHENOPODIACEAE
PLANTAGO LANCEOLATA
HORDEUM TYPE
AVENA/TRITICUM TYPE
HUMULUS/CANNABIS RAISED PORE
SECALE
LINUM USITATISSIMUM
FAGOPYRUM ESCULENTUM
CULTIVATED
POACEAE UNDIFF.
PTERIDIUM AQUILINUM
CHARRED PARTICLES
CORRECTED CHARRED PARTICLES
OPEN GROUND POLLEN TYPES
SITE PAZ
SK-1
SK-2
SK-3
SK-4
SK-5
SK-6
SK-7
SK-8
SK-9
SK-10
Det. B. Odgaard et B. Stavngaard

Fig. 11.



SOLSØ
SKÅNSØ
KRAGSØ
CALENDAR YEARS
TREES
SHRUBS
HERBS
DWARF SHRUBS
Regional PAZ
DKa-8
DKa-7
DKa-6
DKa-5
DKa-4
DKa-3
DKa-2
DKa-1
2000
1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
20
40
60
80
100
% TERRESTRIAL POLLEN

Fig. 12.

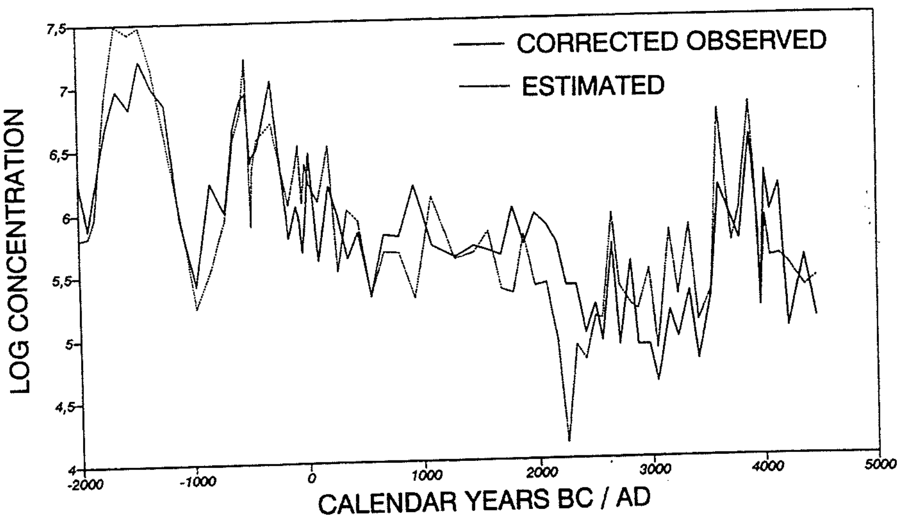


Fig. [redacted] Corrected observed and estimated log concentration of charred particles at Skånsø plotted against age.

Fig. 13.

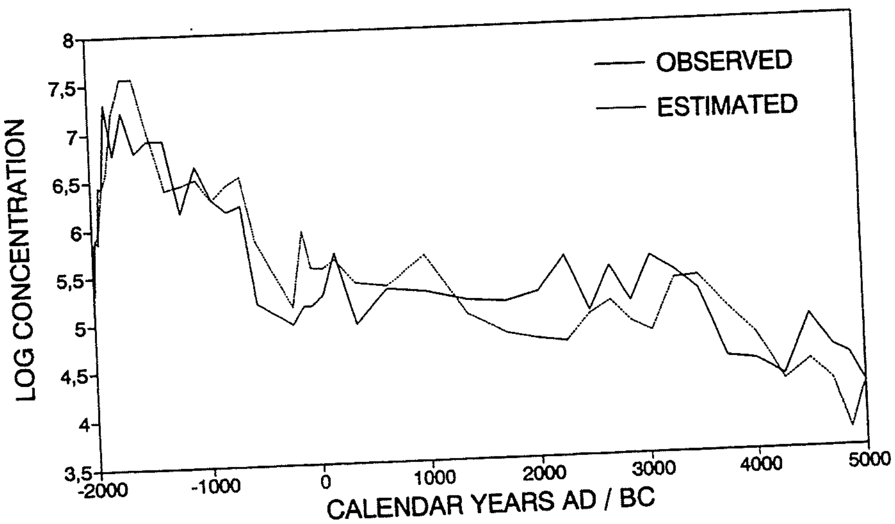


Fig. [redacted] Observed and estimated log concentration of charred particles at Kragsø plotted against age.

Fig. 14.

Thursday 7th September

1. stop: Bølling Sø

Bent Odgaard

Location no. 7.1

Because of the history of Quaternary research in Europe a number of interstadial type sections are located in Denmark: Brørup, Bølling and Allerød. Bølling Sø is situated just west of the main stationary line of the Weichselian ice. It was originally a shallow lake but was drained for agricultural purposes in this century. Plans for reflooding the area are well ahead.

The Bølling interstadial was first mentioned by Iversen (under the name "Bølling oscillation") in a Danish account on a the late-glacial pollen stratigraphy of another site: Nørre Lyngby. The basis of supposing an older late-glacial interstadial than the Allerød was that Iversen found the Allerød to consist of three periods defined by two separate maxima in tree-birch pollen, but at Bølling he found three clear tree-birch maxima (Fig. 2). Also stratigraphy came into consideration, since Iversen found clay to be characteristic of the pre-Allerød layers. At Bølling, however, Iversen discovered a sandy diatomite layer sandwiched between clay layers below characteristic Allerød gyttja-layers, and it was this diatomite with its peak in tree-Betula that Iversen named "Bølling oscillation".

A new coring was performed in 1960 in Bølling Sø, and material from this core analysed by Harald Krog. Finally, Hartmut Usinger (Kiel) in the early 1980s recored the site and made fresh pollen countings (Fig. 5). Based on an extremely thorough investigation on a number of late-glacial sites in Schleswig-Holstein (northern Germany) Usinger established a detailed common biostratigraphy based on pollen and spores but also on macrofossils (Fig. 4). This stratigraphy he then compared to results from neighbouring areas and concluded *i.a.* that all known Swedish late glacial sites lacked Bølling layers, and indeed that the "Bølling-oscillation" layer at the type locality probably belong to the early Allerød!

The basis of this conclusion concerning the Bølling site was the following considerations:

1) The Allerød biozone consists not only of two maxima of tree-birch but of several maxima, which are seen in detailed diagrams from northern Germany (Fig. 3) and indeed also from Denmark (Fig. 1).

2) The detailed results of Usinger demonstrates that although macrofossil evidence shows Betula pubescens to be present in the Bølling interstadial in Schleswig-Holstein Bølling interstadial Betula assemblages in northern Germany are dominated by Betula nana pollen type .

3) The "Bølling-oscillation" at Bølling has a substantial part of tree-Betula in the Betula pollen assemblages and cannot, hence, be correlated with the northern German Bølling period.

4) Ussinger correlates a peak in Juniperus in the beginning of the "Bølling oscillation" at the

Bølling site with the first Juniperus peak in the beginning of the Allerød in the northern German stratigraphy.

5) Pollen concentrations in the "Bølling oscillation" at the Bølling site are at the same level as concentrations in the later "Allerød" layers. By contrast, pollen concentrations in northern German Allerød layers exceed concentrations in the preceding Bølling layers by several orders of magnitude.

Arguments against the interpretation by Usinger include the Hippophaë and later Helianthemum peak in the "Bølling-oscillation" at the Bølling site, which may be correlated with the Bølling pollen zone Hippophaë-B.nana of Schleswig-Holstein.

Are Bølling interstadial layers lacking from the sequence at Bølling ????

During the excursion a coring through the late-glacial layers at Bølling will be attempted.

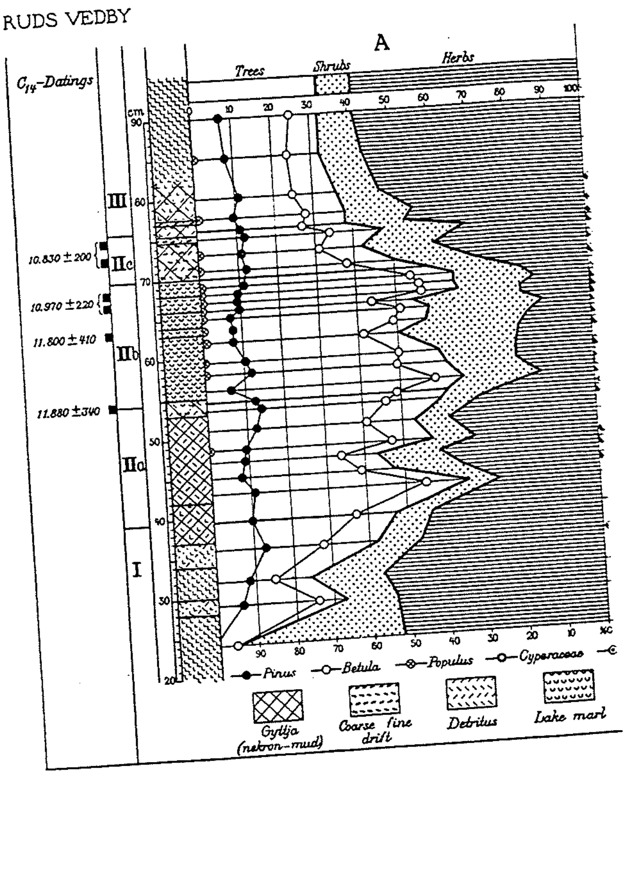


Fig. 1

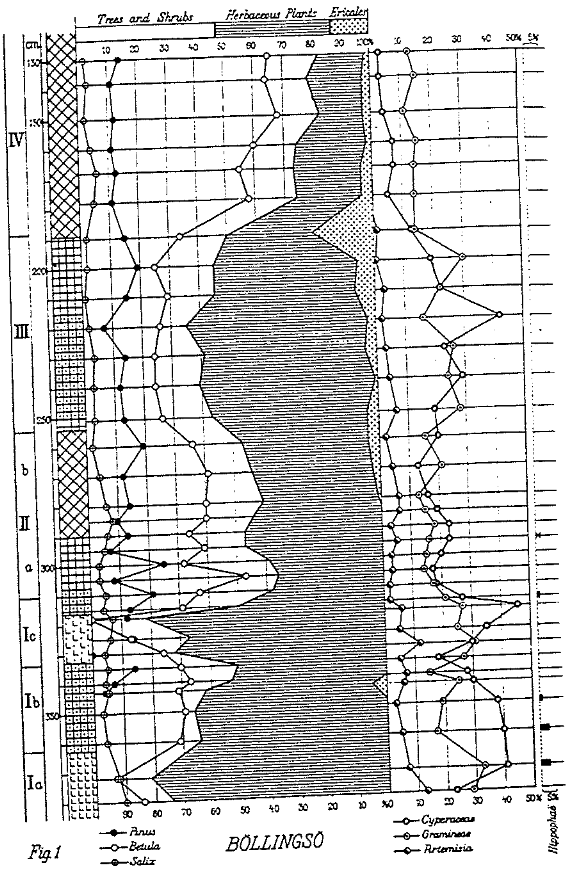


Fig. 2.

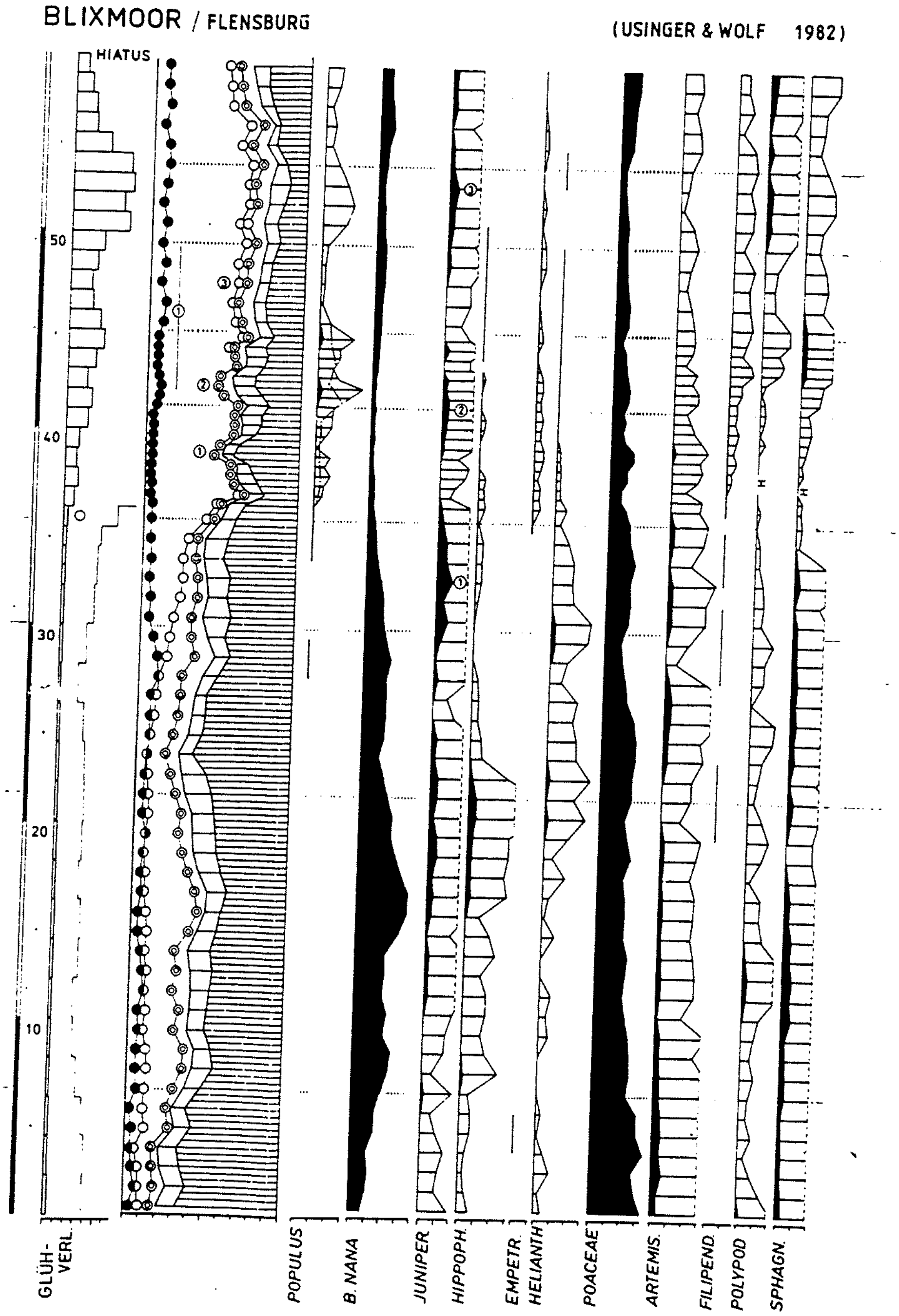

BLIXMOOR / FLENSBURG
(USINGER & WOLF 1982)
HIATUS
50
40
30
20
10
GLÜH-VERL.
POPULUS
B. NANA
JUNIPER.
HIPPOPH.
EMPETR.
HELIANTH
POACEAE
ARTEMIS.
FILIPEND.
POLYPOD
SPHAGN.

Fig. 3.

Bølling site with the first Juniperus peak in the beginning of the Allerød in the northern German stratigraphy.

5) Pollen concentrations in the "Bølling oscillation" at the Bølling site are at the same level as concentrations in the later "Allerød" layers. By contrast, pollen concentrations in northern German Allerød layers exceed concentrations in the preceding Bølling layers by several orders of magnitude.

Arguments against the interpretation by Usinger include the Hippophaë and later Helianthemum peak in the "Bølling-oscillation" at the Bølling site, which may be correlated with the Bølling pollen zone Hippophaë-B.nana of Schleswig-Holstein.

Are Bølling interstadial layers lacking from the sequence at Bølling ????

During the excursion a coring through the late-glacial layers at Bølling will be attempted.

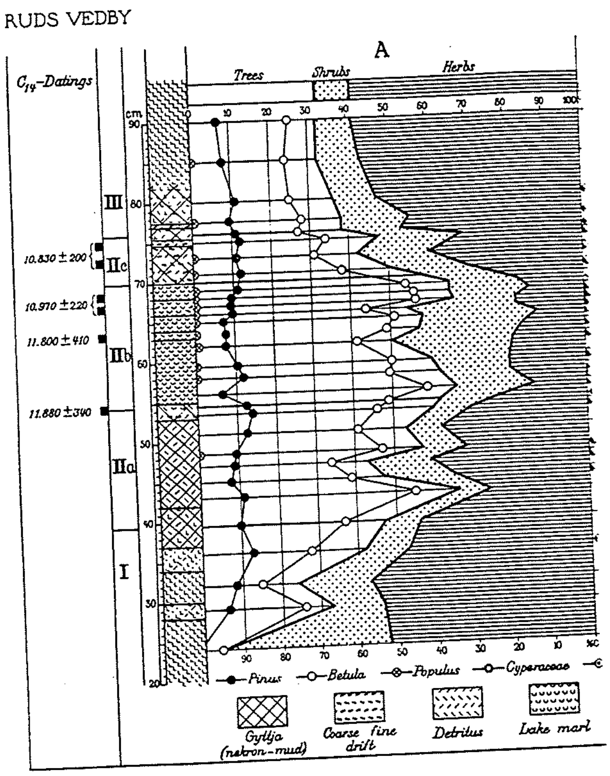


Fig. 1

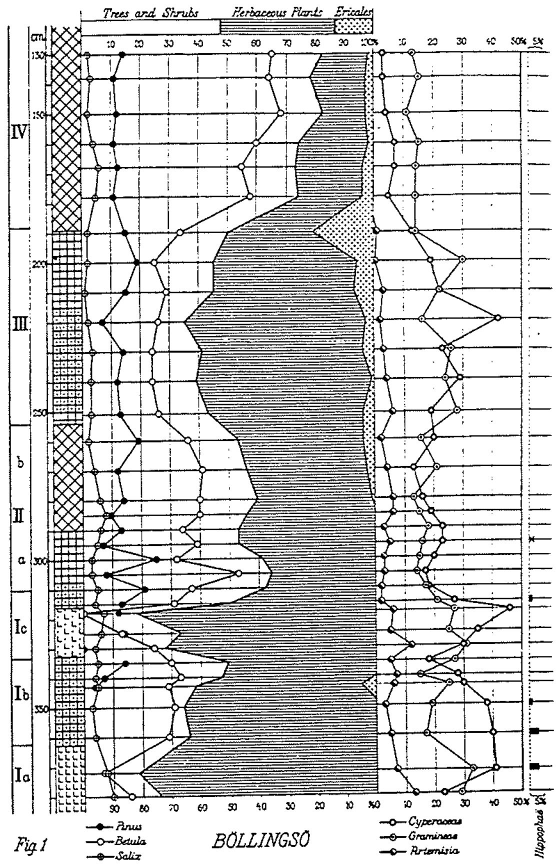


Fig. 2.

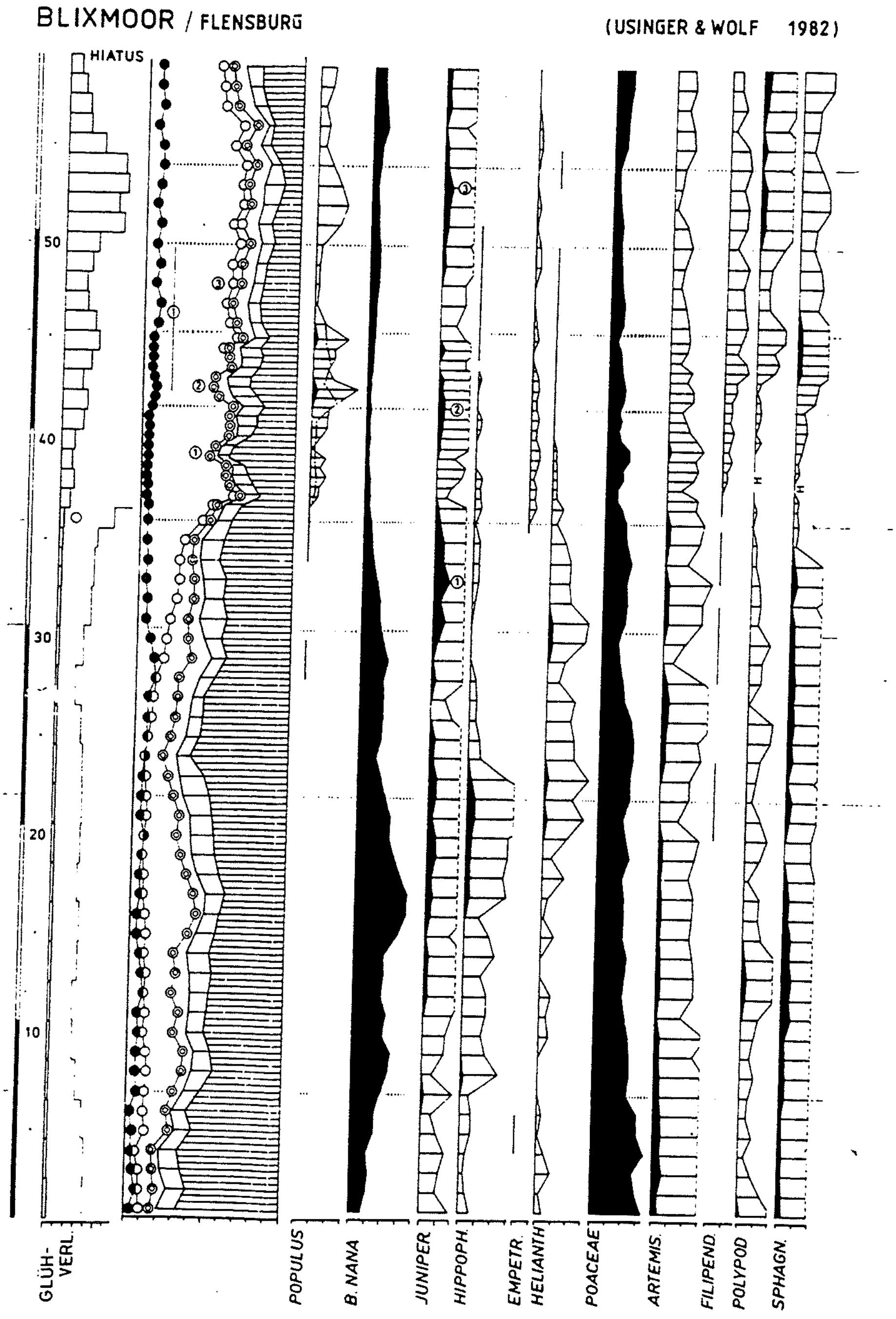

BLIXMOOR / FLENSBURG
(USINGER & WOLF 1982)
HIATUS
50
40
30
20
10
GLÜH-VERL.
POPULUS
B. NANA
JUNIPER.
HIPPOPH.
EMPETR.
HELIANTH.
POACEAE
ARTEMIS.
FILIPEND.
POLYPOD.
SPHAGN.

Fig. 3.

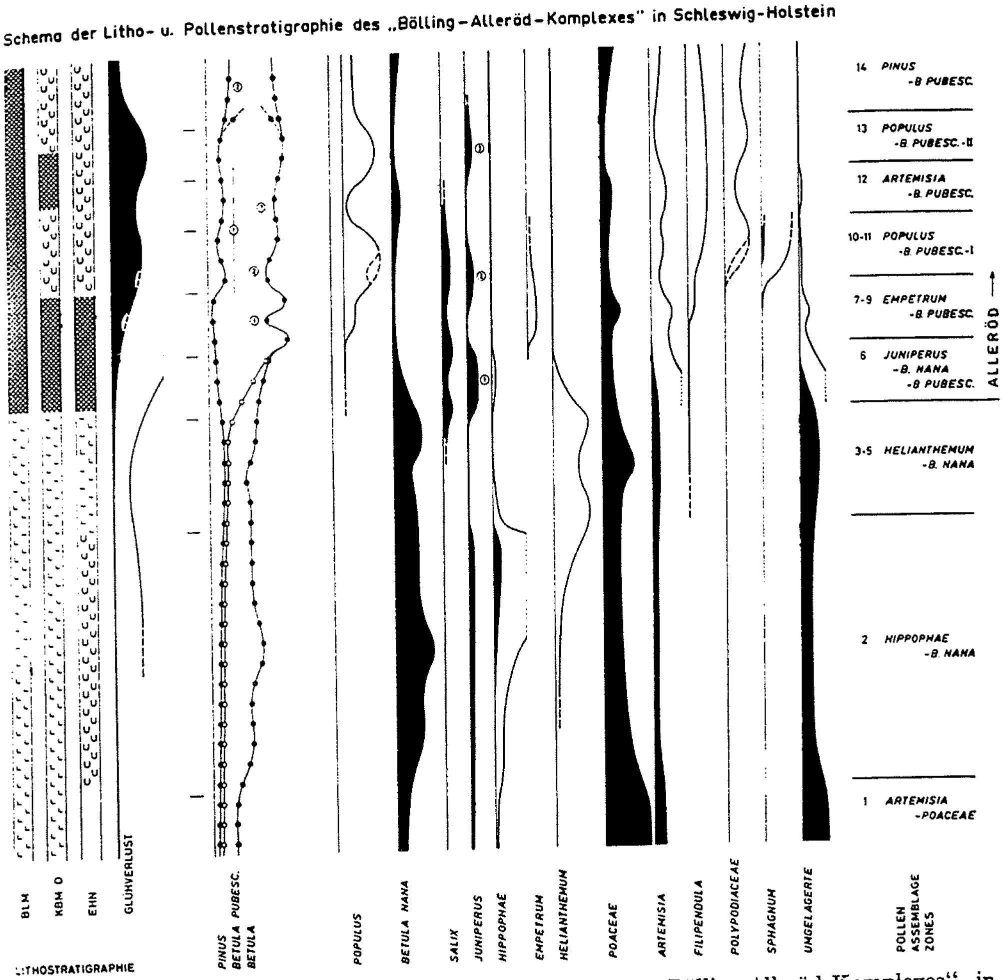


Abb. 2b. Schema der Litho- und Pollenstratigraphie des „Bölling-Alleröd-Komplexes" in Schleswig-Holstein (vgl. Abschn. 7. bzw. 6. und 8.). Sediment-Symbole nach TROELS-SMITH (1955). BLM: Entwicklung im Blixmoor; KBM D: Entwicklung in tieferen Bereichen des Kubitzbergmoores; EHN: Entwicklung in der Eichholz-Niederung.

Fig. 4.

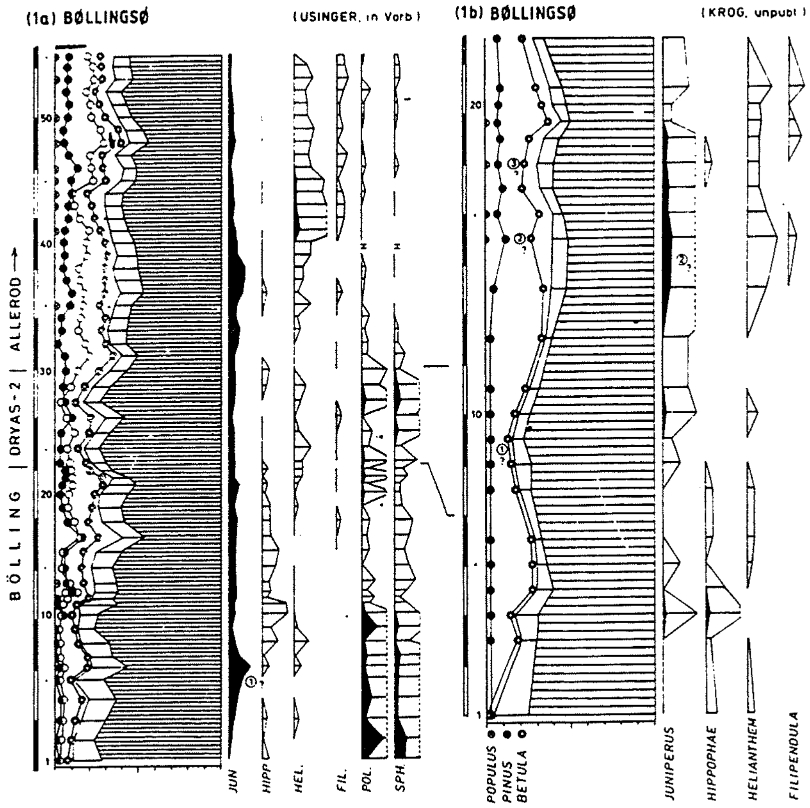


Fig.5.

2. stop: Hjermind fen

Bent Aaby

Location no. 7.2
Vegetation: Fen with Sphagnum and Calluna-Erica-Narthecium vegetation
Matters for discussion: Modern vegetation, vegetation history, paludification and mire expansion

Hjermind fen is located in a secondary erosion valley on the northern side of the broad valley of the river Gudenå in central Jutland (Fig. 1). The surrounding Weichselian moraine landscape has a gently undulating surface and the rather fertile soil is mainly used for agricultural purposes. Forests are found mainly in less fertile areas with sandy till or on the steep slopes of the river valleys.

A small brook is running through the secondary valley with a natural/seminatural alder-carr with Alnus glutinosa, Corylus avellana, and Fraxinus excelsior in the valley bottom. The western slope is covered with old managed Fagus-Quercus wood or Picea plantations, whereas the eastern slope has coppices with a Quercus-Betula vegetation, Fagus woods or planted Pinus and Picea stands. The soil is rather acid and oligotrophic mull and raw humus dominate. A small soligenous fen has developed on the eastern slope. Today it is surrounded by a Pinus sylvestris stand with trees of varying age. The oldest ones are planted about 100 years ago. The mire itself is small in size, only about 100x30 metres with the longest direction parallel to the direction of the valley. The surface of the mire is gently sloping (~4%) with scattered Pinus sylvestris on the otherwise treeless mire surface.

The fen vegetation is dominated by an Empetrum nigrum-Molinia coerulea sociation in the up-hill marginal area (Fig. xx). It changes to a Calluna-Erica-Narthecium sociation which is followed by a Sphagnum fallax-Sphagnum subnitens sociation on the wettest places. Further down-slope follows a more or less dense tree cover of Pinus sylvestris and Betula pubescens. The ground flora is rather scarce with Pleurozium schreberi and Vaccinium myrtillus. This forest area is not peat producing today.

The surface peat layer on the fen is weakly decomposed. It is only 15-30 cm deep and rests on more decomposed peat, 2-15 cm deep, in the upper part and on hydromor in the lower part of the fen area (Fig. 2). The total thickness of the organic deposits is 20-30 cm or less in the upper part and increases to about 50 cm in the lowermost fen area. Peat deposits are also present in the forested area further down-slope and the stratigraphy and thickness (30-50 cm) are similar to those of the 'living' fen except that a raw humus (mor) layer is found on the top. Part of the hydromor layer has an olive-brown colour originating from the exceptional high content of pollen grains.

Vegetation history

Pollen analytical investigations were carried out in 1994-95 and research is still in progress. The main results are discussed below, with only a preliminary chronology as radiocarbon dates are still not available. They will be based on AMS datings of pollen grains. The main profile is 50 cm deep and sampled from the lowermost area on the fen - only 2 m from the present margin of the mire. It illuminates the vegetational development on the valley slope since the Preboreal, probably in an unbroken sequence (Figs 3 and 4).

Preboreal pollen spectra. The slope was dominated by a herbaceous vegetation, mainly with grasses. Only a scattered tree and shrub vegetation was present dominated by Betula and

Fig. 4.

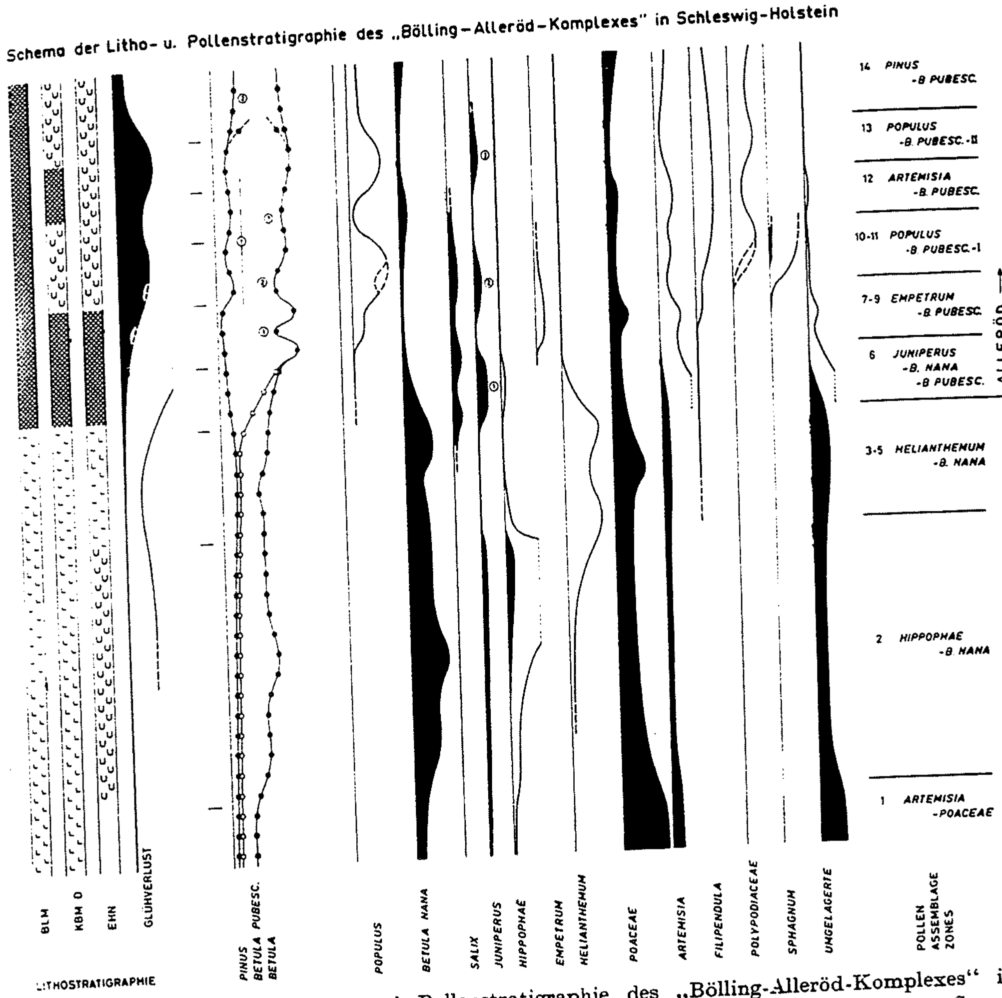
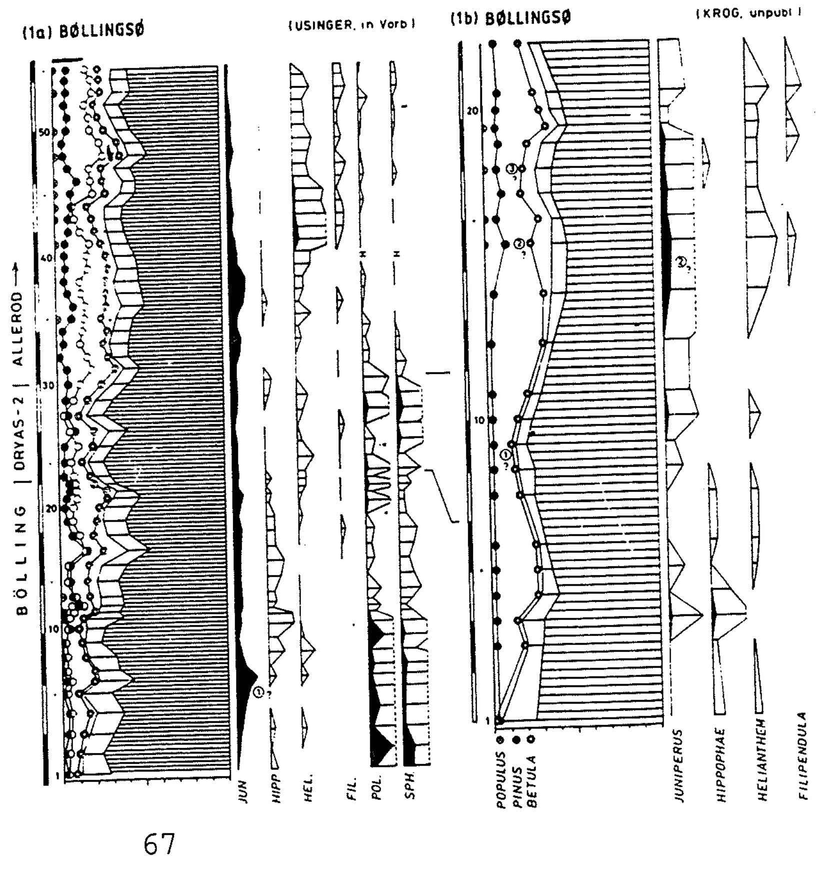


Abb. 2b. Schema der Litho- und Pollenstratigraphie des „Bölling-Alleröd-Komplexes" in Schleswig-Holstein (vgl. Abschn. 7. bzw. 6. und 8.). Sediment-Symbole nach TROELS-SMITH (1955). BLM: Entwicklung im Blixmoor; KBM D: Entwicklung in tieferen Bereichen des Kubitzbergmoores; EHN: Entwicklung in der Eichholz-Niederung.

Fig.5.



2. stop: Hjermind fen

Bent Aaby

Location no. 7.2
Vegetation: Fen with Sphagnum and Calluna-Erica-Narthecium vegetation
Matters for discussion: Modern vegetation, vegetation history, paludification and mire expansion

Hjermind fen is located in a secondary erosion valley on the northern side of the broad valley of the river Gudenå in central Jutland (Fig. 1). The surrounding Weichselian moraine landscape has a gently undulating surface and the rather fertile soil is mainly used for agricultural purposes. Forests are found mainly in less fertile areas with sandy till or on the steep slopes of the river valleys.

A small brook is running through the secondary valley with a natural/seminatural alder-carr with Alnus glutinosa, Corylus avellana, and Fraxinus excelsior in the valley bottom. The western slope is covered with old managed Fagus-Quercus wood or Picea plantations, whereas the eastern slope has coppices with a Quercus-Betula vegetation, Fagus woods or planted Pinus and Picea stands. The soil is rather acid and oligotrophic mull and raw humus dominate. A small soligenous fen has developed on the eastern slope. Today it is surrounded by a Pinus sylvestris stand with trees of varying age. The oldest ones are planted about 100 years ago. The mire itself is small in size, only about 100x30 metres with the longest direction parallel to the direction of the valley. The surface of the mire is gently sloping (~4%) with scattered Pinus sylvestris on the otherwise treeless mire surface.

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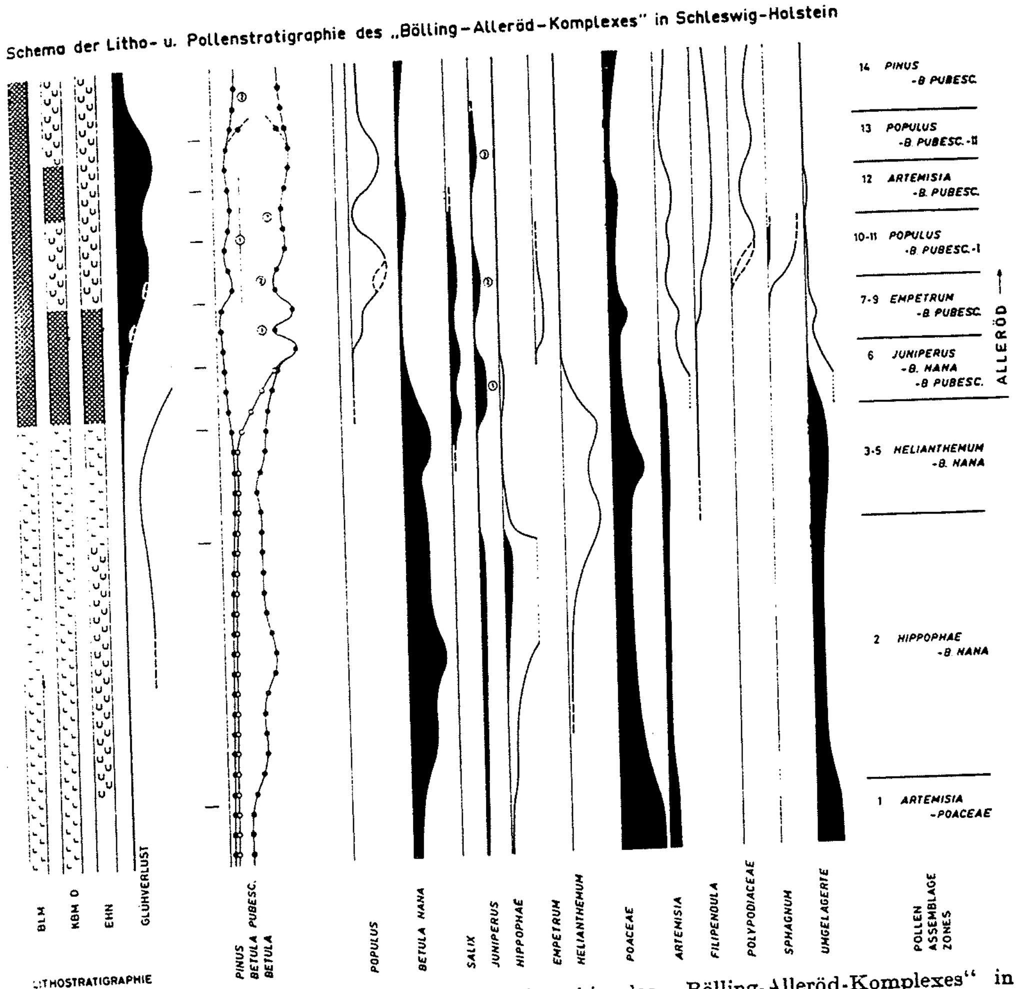

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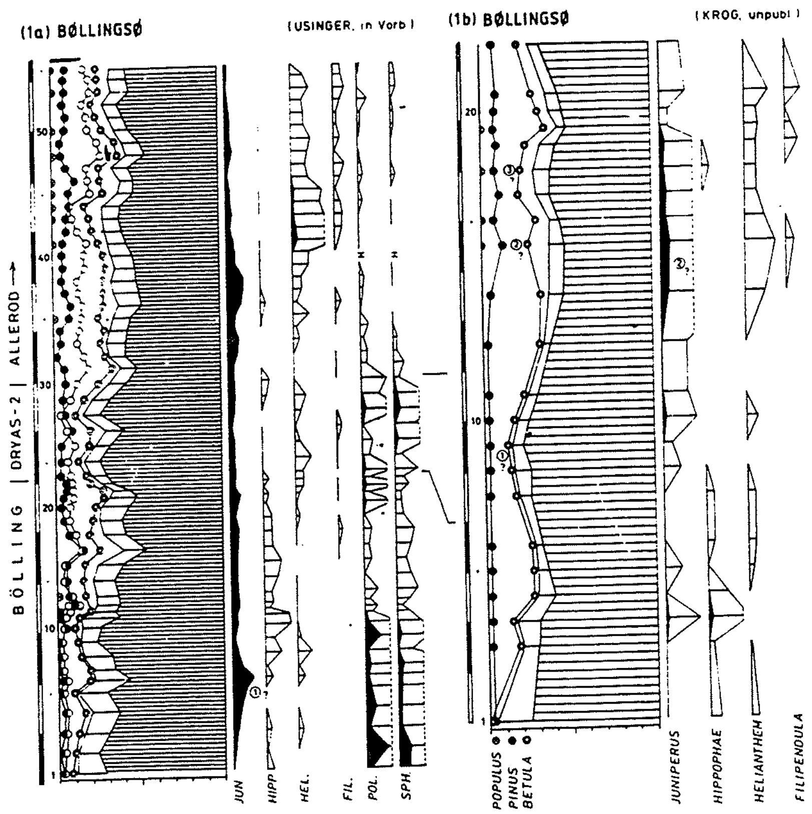

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Pinus.
Boreal-Atlantic-Subboreal pollen spectra. Trees successfully expanded in the area at the time of Corylus immigration. However the forest vegetation was rather open, allowing a rich ground flora to flower. Now species growing on wet ground were prominente as well as grasses. In regional diagrams the Boreal pollen spectra are often recognized by high Corylus values. This characteristic feature is not seen in the diagram from Hjermind, which shows the development of the local tree vegetation. Here Corylus was common but did not dominate. The soil was unstable and sand has washed into the sediment. Plantago lanceolata was part of the heliophilos ground flora. Later the soil stabilized and the forest cover became denser and was dominated by Tilia, Alnus and Corylus. Pinus and Betula was less frequent and Quercus, Ulmus and Fraxinus were not growing in the area or they were rare species. The ground flora was sparse.
No Ulmus-decline is seen and the forest composition remained stable except for the extinction of Pinus and decreasing importance of Betula. Reversal variations in the pollen frequency of Tilia and Alnus probably reflect hydrological changes. This explanation is supported by information on pollen preservation.
Late Subboreal-early Subatlantic pollen spectra. A sudden change in the pollen composition is seen in the diagram at 30 cm reflecting a disappearance of the forest vegetation, probably as a result of intensive grazing as burning was not used to clear the area according to the low content of charcoal in the sediment. Part of the former forested area now changed into an open fen area. The ecological conditions immediately were favourable for Narthecium ossifragum and other oligotrophic fen species. The forest clearance is supposed to have taken place in the Roman Iron Age (0-400 A.D.), as Secale cereale is present at low percentages. The tree pollen spectra from the first clearance period reflect the regional composition of the forest vegetation, dominated by Fagus and Quercus.
Middle and late Subatlantic pollen spectra. The tree vegetation on the slope regenerated with the same species as found in the area before the human interference. Grazing, coppicing and some burning was practised in the area during the following centuries. A new clearance phase is recognized at 21 cm, which probably occurred in early medieval times. The area became more open but the human interference did not course substantial changes in the tree vegetation. Selective felling of Tilia is demonstrated later in historical times, favouring Fagus and Quercus. However Tilia recovered and expanded again. The tree vegetation was erased probably in the 17th or 18th century and the slope changed into pasture for some time. Historical maps from the later part of the 18th century also show that the area was grass- and heathland at that time. After the legal redistribution of land around !800 A.D. the area became private owned and plantations with Picea were established by the end of the last century.

The pollen concentration change distinctly in the profile with a maximum of 30 mill. cm-3 in the hydromor. This type of sediment has only very few brown coloured hypha fragments and the pollen grains are rather well preserved. The accumulation rate is probably only about 1cm in 1000 years at the levels with the highest concentration of pollen. The thickness of the samples for pollen analysis is only 0.2 cm in these levels to compensate for the low accumulation rate.

Night at:

Rebild Vandrerhjem, Rebildvej 23, Rebild, DK-9520 Skørping,
tlf: +45 98 39 13 40

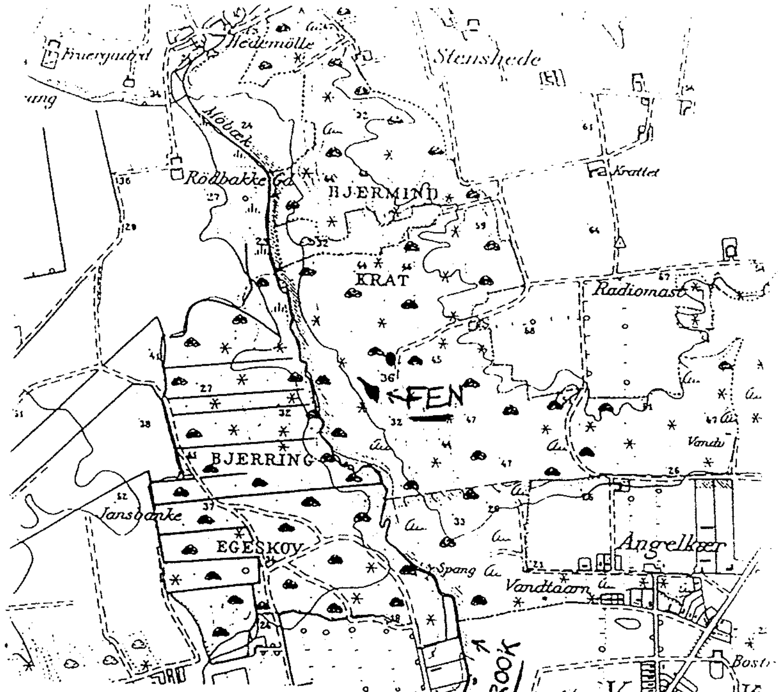
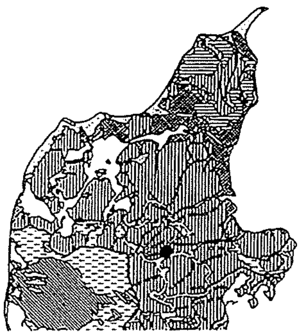
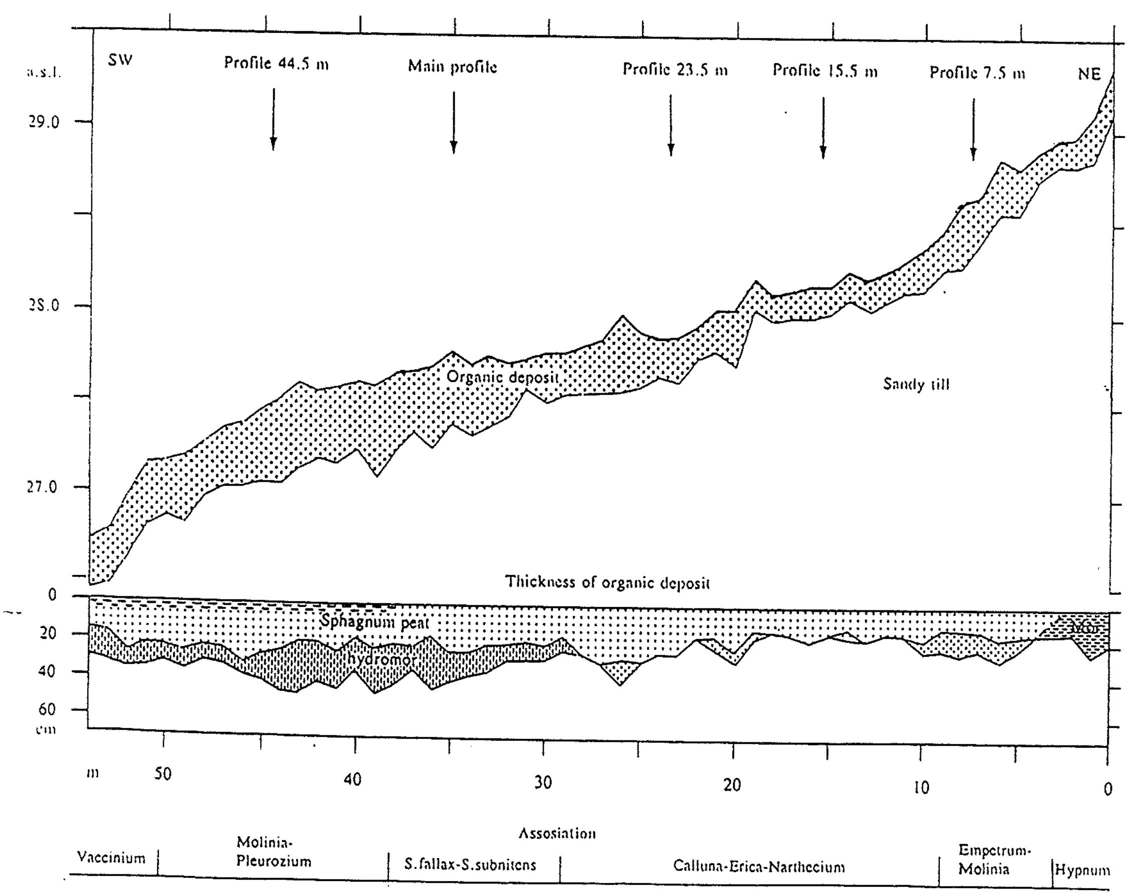


Fig. 1.

Fig. 2.



Hjermind Krat



Pinus.
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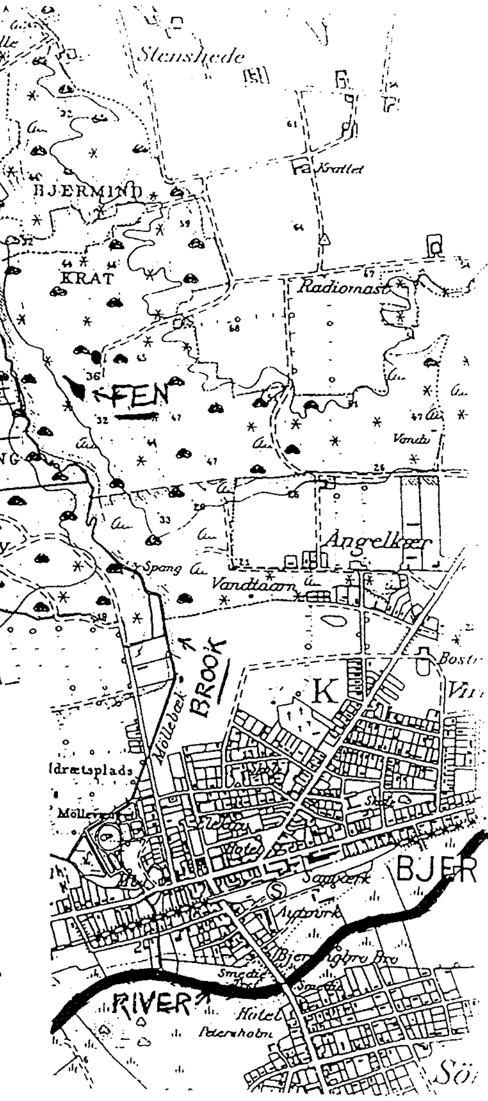
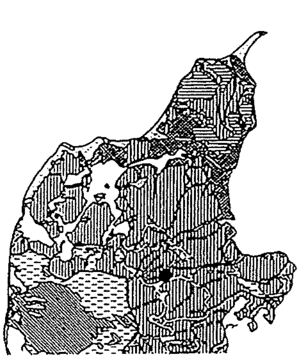
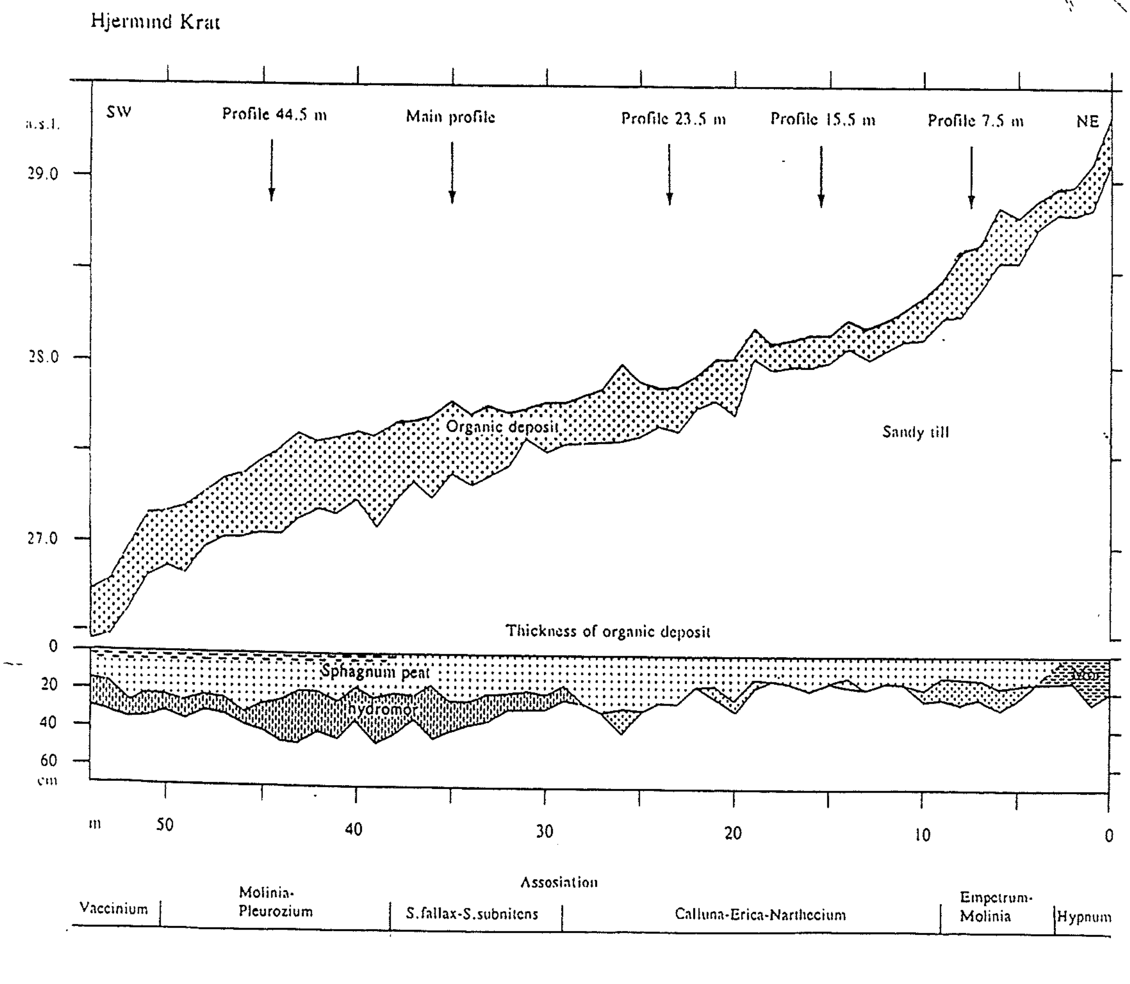
Fig. 1.



Stenshede
Rödbakke
BJERMIND
KRAT
Radiomast
FEN
BJERRING
EGESKOV
Angelkær
Vandtaarn
BROOK
K
Idrætsplads
BJER
RIVER

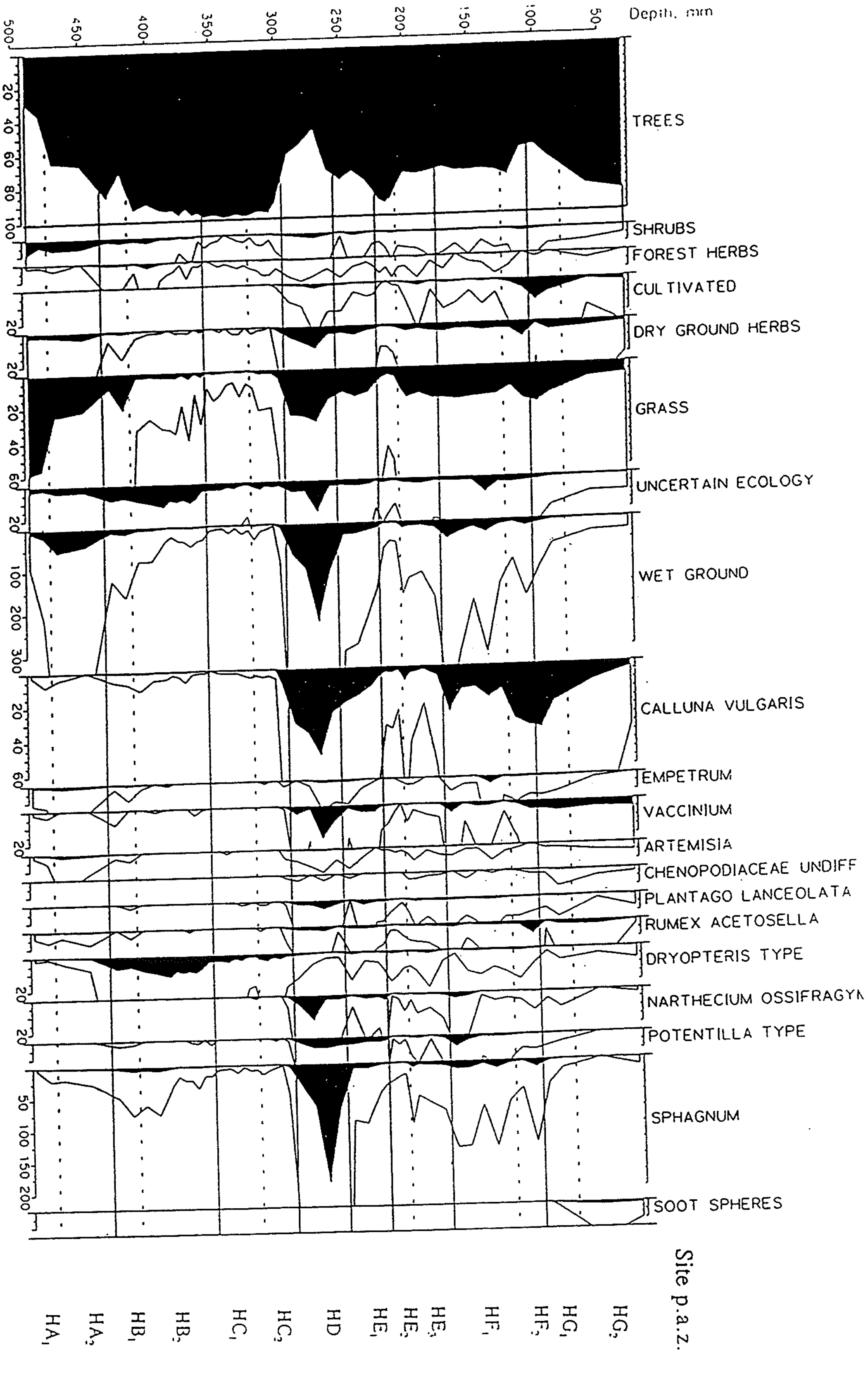
Fig. 2.

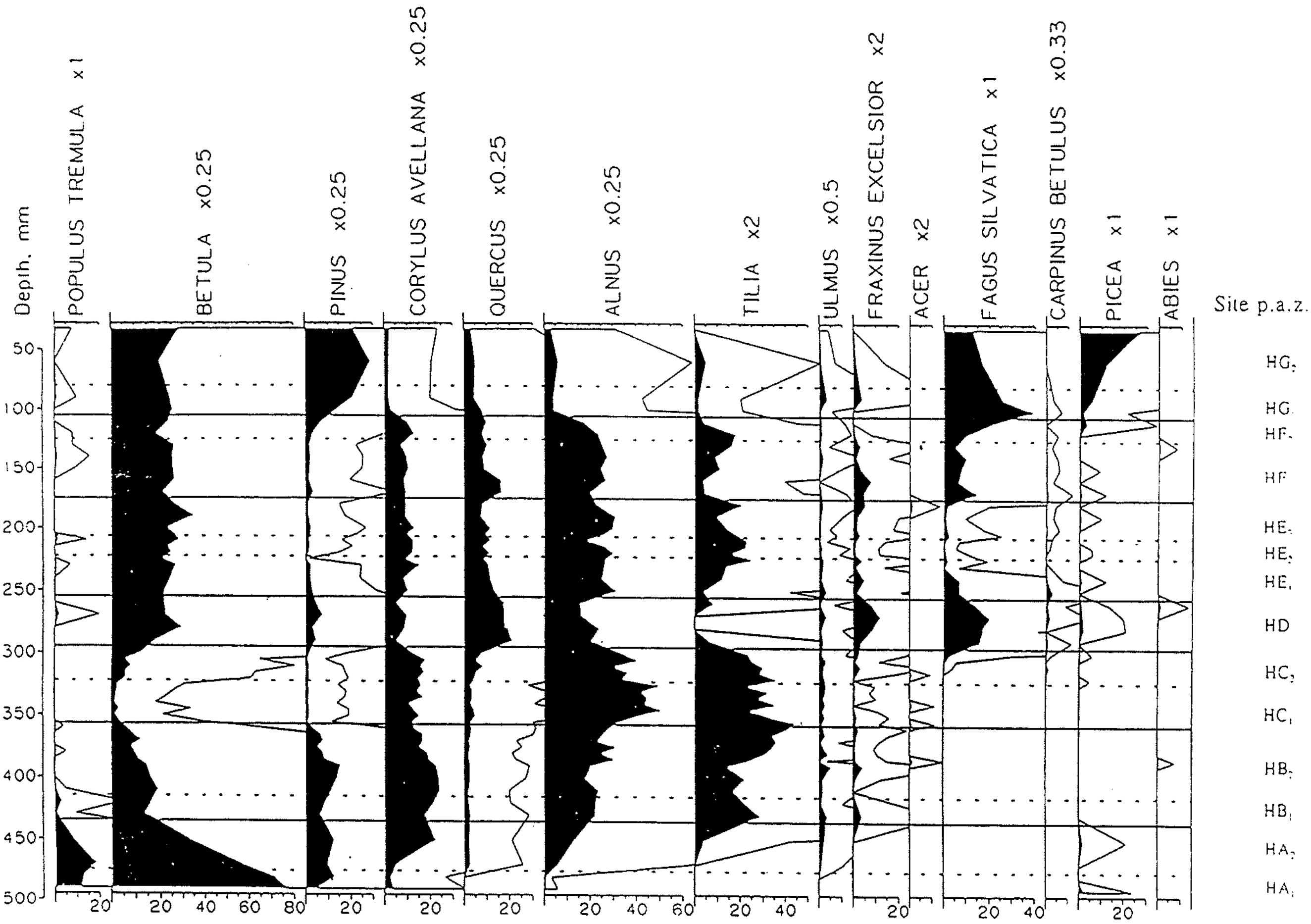




Hjermind Krat
a.s.l.
SW
Profile 44.5 m
Main profile
Profile 23.5 m
Profile 15.5 m
Profile 7.5 m
NE
29.0
28.0
27.0
Organic deposit
Sandy till
Thickness of organic deposit
Sphagnum peat
hydromor
0
20
40
60
cm
m
50
40
30
20
10
0
Assosiation
Vaccinium
Molinia-Pleurozium
S.fallax-S.subnitens
Calluna-Erica-Narthecium
Empetrum-Molinia
Hypnum

Fig. 3.


Depth, mm
500
450
400
350
300
250
200
150
100
50
TREES
SHRUBS
FOREST HERBS
CULTIVATED
DRY GROUND HERBS
GRASS
UNCERTAIN ECOLOGY
WET GROUND
CALLUNA VULGARIS
EMPETRUM
VACCINIUM
ARTEMISIA
CHENOPODIACEAE UNDIFF
PLANTAGO LANCEOLATA
RUMEX ACETOSELLA
DRYOPTERIS TYPE
NARTHECIUM OSSIFRAGUM
POTENTILLA TYPE
SPHAGNUM
SOOT SPHERES
Site p.a.z.
HA₁
HA₂
HB₁
HB₂
HC₁
HC₂
HD
HE₁
HE₂
HE₃
HF₁
HF₂
HG₁
HG₂



Depth. mm
POPULUS TREMULA x1
BETULA x0.25
PINUS x0.25
CORYLUS AVELLANA x0.25
QUERCUS x0.25
ALNUS x0.25
TILIA x2
ULMUS x0.5
FRAXINUS EXCELSIOR x2
ACER x2
FAGUS SILVATICA x1
CARPINUS BETULUS x0.33
PICEA x1
ABIES x1
Site p.a.z.
50
100
150
200
250
300
350
400
450
500
20
20 40 60 80
20
20
20
20 40 60
20 40
20
20 40
20

Fig. 4.

Friday 8th September

Rold Skov and Store Økssø

1. stop: Troldeskov in Rold Skov

Bent Odgaard

Location no. 8.1

AD 1800 was the point of time when Denmark has the smallest amount of woodland preserved: only about 4 % woodland coverage. The distribution of woodland at that time was very uneven (Fig. 1) and Rold Skov was one of the major large woods preserved. Canonical ordination on pollen samples from AD 1800, land-use data from contemporary maps and topographical data indicate a strong correlation between the percentage of tree pollen, the distribution of woodland in AD 1800 and strong relief (Fig. 2). These results suggest that woodland was preserved mainly in areas of varied topography where arable farming was very difficult. Until the forest preservation act of 1805 was passed - probably one of the first preservations laws in the world - woodlands were heavily exploited by grazing, cutting and by letting pigs eating the mast. Parts of Rold Skov still show signs of this heavy exploitation, notably the so-called Troldeskov ("Troll Wood"), consisting of old, crooked, winding, multi-stemmed *Fagus* trees.

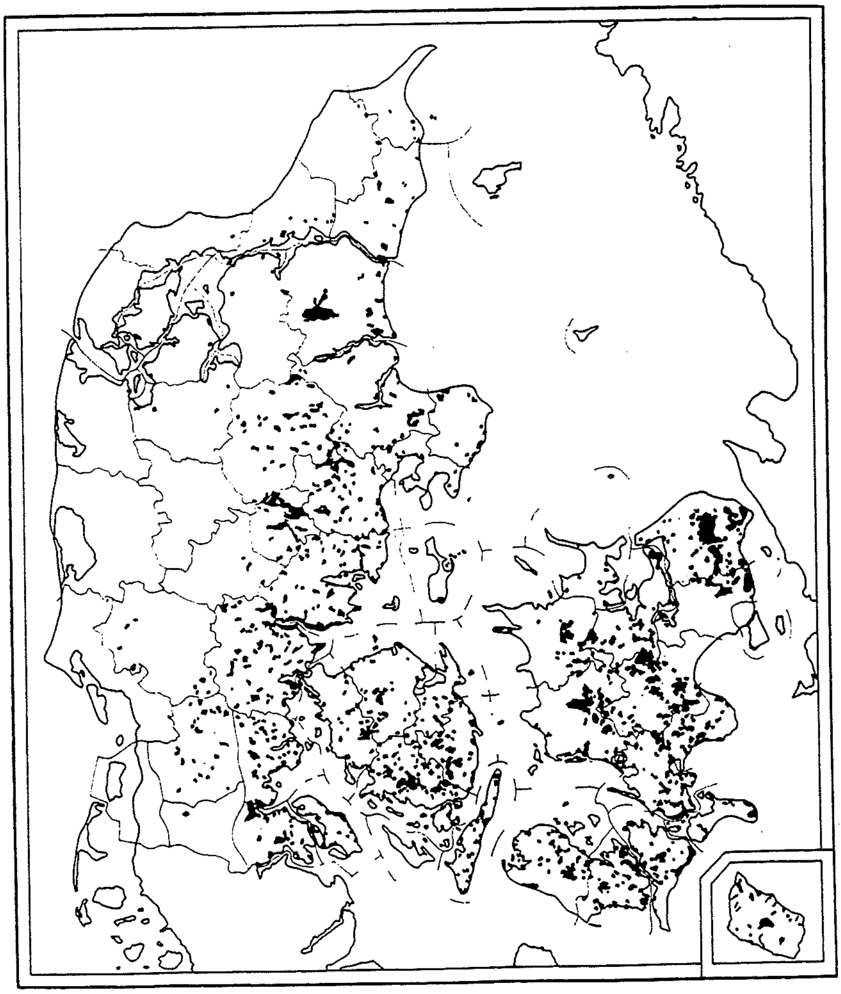
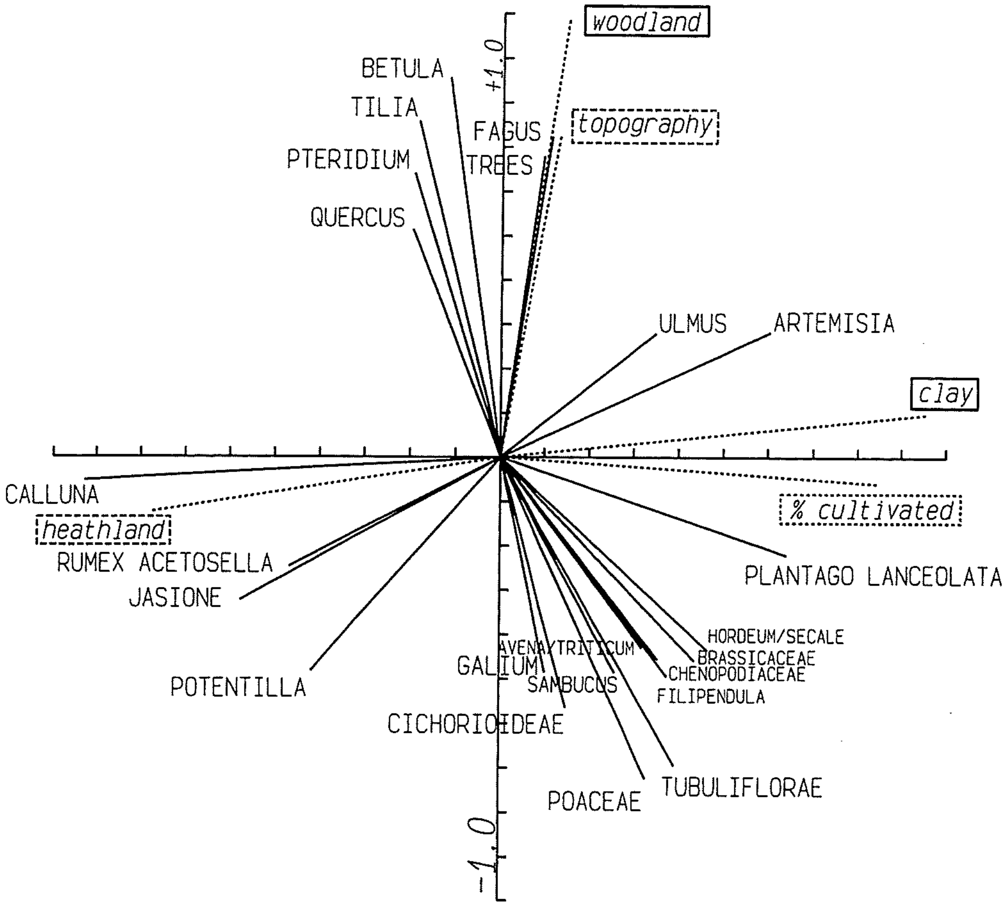


Fig. 1.
Woodland distribution at AD 1800

AD 1800



woodland
topography
BETULA
TILIA
PTERIDIUM
QUERCUS
FAGUS
TREES
+1.0
ULMUS
ARTEMISIA
clay
CALLUNA
heathland
RUMEX ACETOSELLA
JASIONE
POTENTILLA
% cultivated
PLANTAGO LANCEOLATA
HORDEUM/SECALE
BRASSICACEAE
CHENOPODIACEAE
FILIPENDULA
AVENA/TRITICUM
GALIUM
SAMBUCUS
CICHORIOIDEAE
POACEAE
TUBULIFLORAE
-1.0

Fig. 2.

2. stop: Store Økssø

Bent Odgaard

Location no. 8.2

A preliminary pollen diagram from the lake Store Økssø in Rold Skov (Fig. 1) shows some deforestation in the 3rd millennium BC but the overall picture from this site is the continuous dominance of woodland in the area until today. *Fagus* arrived to the area in the last millennium BC, showed intermittent maxima but surprisingly did not expand properly until Medieval time.

In a study of long-term floristic diversity dynamics Store Økssø was chosen as one of two sites. The other site chosen was lake Navn Sø, some 25 km west of Store Økssø, which is situated in an area richer in archaeological finds which was completely deforested in prehistoric time (Fig. 2). This paired site approach of lakes in similar geological settings but witnessing different intensity of human impact enables an assessment of the role of anthropogenic disturbance for the long-term development of floristic richness.

Pollen diversity is used as measurement of floristic richness in this investigation. In an earlier investigation a unimodal relationship between disturbance (in this case vegetational burning) and palynological richness was indicated (Fig. 3). The preliminary results of the present study supports these results in that pollen diversity - and therefore probably also floristic diversity - was highest in the area with strongest anthropogenic disturbance (Fig. 4).

The relationship between palynological and floristic richness, however, needs further quantification, and for this purpose a new project has just been initiated. Flora inventories are being made around lakes along a gradient from forest lakes to lakes in completely open agricultural settings. The floristic diversity results are related to palynological richness in surface pollen samples from the lakes with the aim to build a model between the two. It is hoped that this model can then be used to estimate floristic richness from fossil pollen assemblages.

STORE ØKSSØ
Preliminary pollen diagram

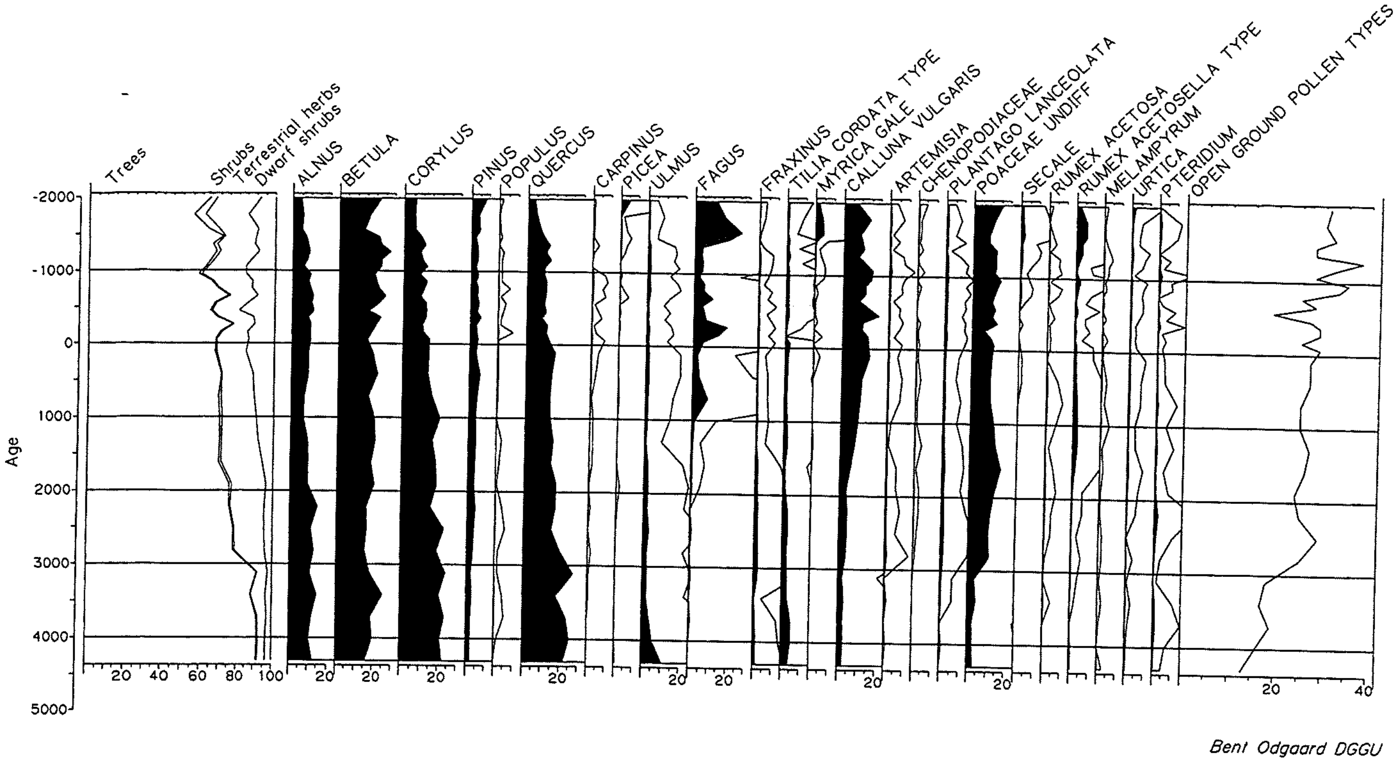


Fig. 1.

NAVNSØ
Preliminary diagram

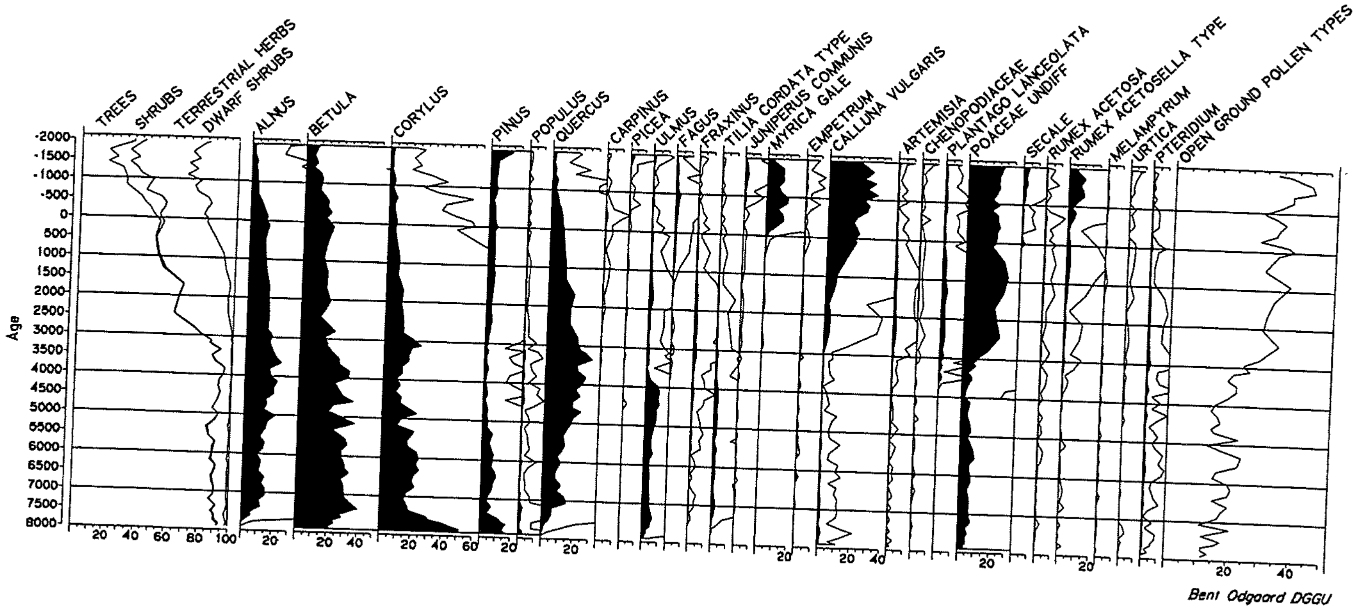


Fig. 2.

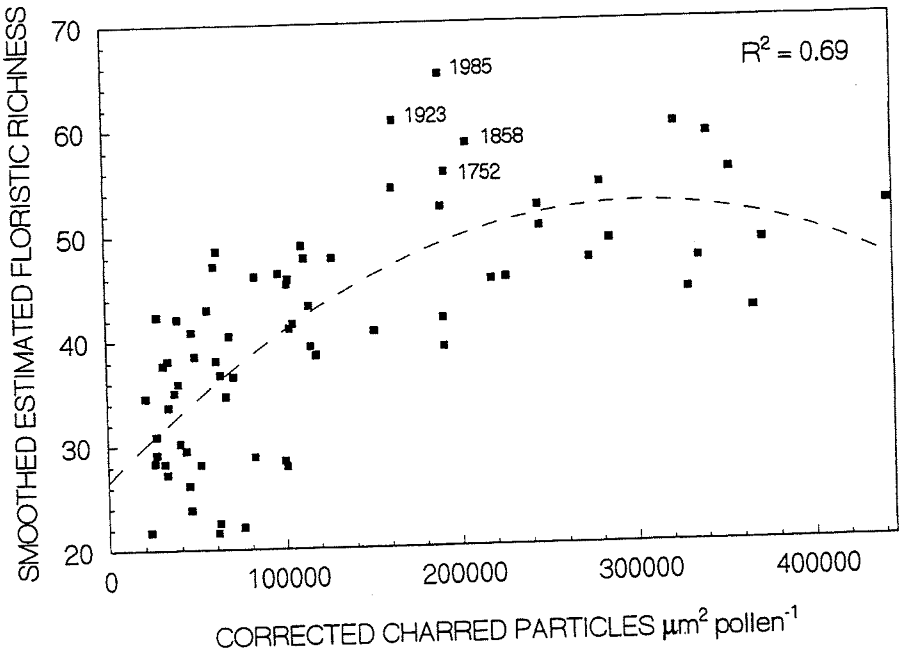


Fig. [redacted]. Smoothed estimated floristic richness since 4000 BC from Skånsø plotted against charred particles corrected for assumed differential focusing. The 2. degree polynomial plotted gives a better fit than 1. and 3. order polynomials. The most recent four samples are labelled by their age in calendar years.

Fig. 3

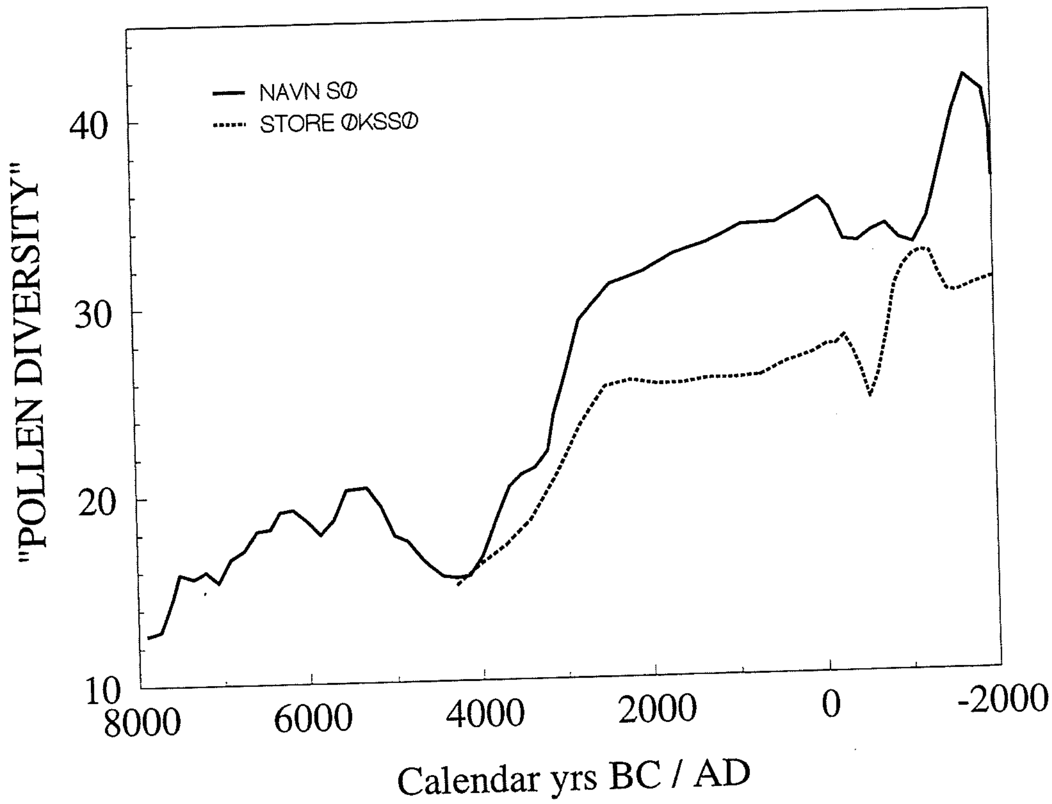


Fig. 4.

3. stop: Langemose in Rold Skov

Bent Aaby

Location no. 8.3
Vegetation: Oligotrophic fen vegetation (lagg) and raised bog vegetation.
Matter for discussion: Present vegetation, peat stratigraphy and bog dynamics.

Langemose is located in the eastern part of the extended Rold forest complex. Sandy till deposits and fluvioglacial deposits dominate the hilly landscape. The bog and the surrounding forest areas are private property and it has been legally protected since 1986 together with the adjacent forest areas.

Topography and vegetation

Langemose is a 24 ha complex of various mire types located in an irregular valley system (Fig. 1) surrounded by spruce plantations and old naturally regenerated *Fagus* stands which earlier was coppiced. The mire remains almost in natural state.

Three nuclei of ombrotrophic vegetation, 15 ha in total, are surrounded by oligotrophic fen vegetation, forming well developed lagg areas, which are undisturbed by man in most areas. The lagg is 3 - 6 m wide and a few *Juniperus, Pinus sylvestris, Frangula alnus* and *Betula pubescens* are found in the *Molinia caerulea* dominated fen vegetation.

The raised bog areas have a slightly domed surface with a gradual transition to the lagg. Thus, a sloping bog margin with trees is missing and the open bog expanse is dominated by a uniform *Eriophorum vaginatum - Calluna vulgaris - Erica tetralix* vegetation. The surface is relatively dry and *Sphagnum* species are of minor importance except at a few places. Hollow pattern has not been developed and *Sphagnum cuspidatum* is a rare species in the few depressions.

Corings have revealed that almost 4 m of peat deposit is present in the central part of the northwestern bog expanse (Fig. 2). A rising water table in the Atlantic resulted in the paludification of the valley bottom and a *Betula - Alnus* carr became established. Shortly afterwards it changed into an oligotrophic fen vegetation which passed into a raised bog vegetation. The lowermost 2 m of ombrotrophic peat is strongly decomposed and dominated by *Sphagnum, Eriophorum vaginatum, Erica tetralix* and *Calluna vulgaris*. The following 1 m of peat is moderately decomposed with *Sphagnum* and *Eriophorum vaginatum*. The peat 0.7 - 0.1 m below surface is weakly decomposed and dominated by *Sphagnum*. The uppermost 10 cm is strongly decomposed with a species composition similar to the present vegetation. The stratigraphy and peat composition visualize that the bog vegetation has changed considerably in modern times, and also the actual dry conditions have originated recently.

The mire is included in the monitoring programme for raised bogs.

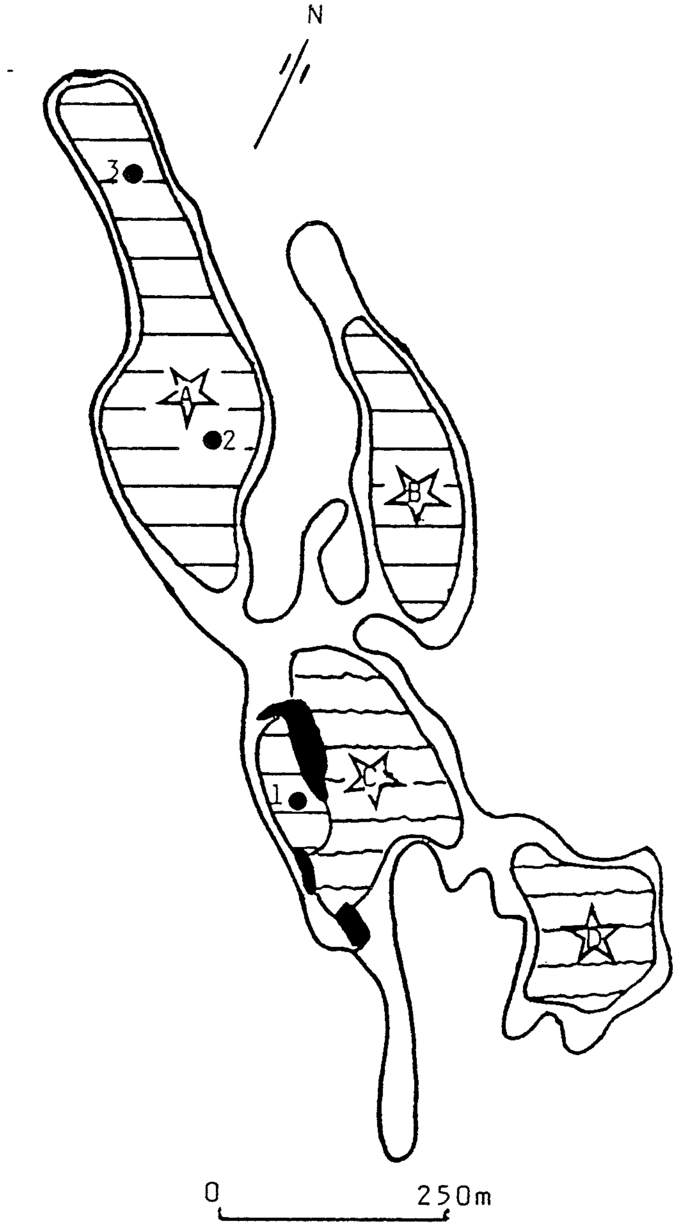


Fig. 1.

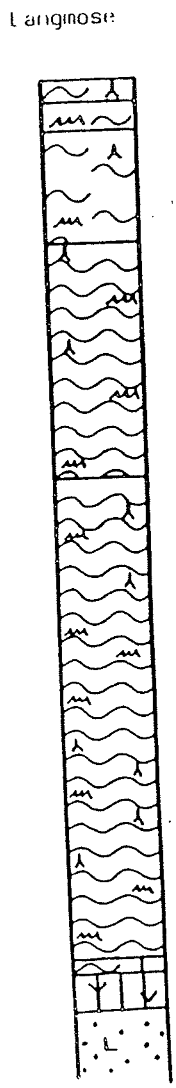


Fig. 2.

4. stop: Hollerup

Svend Th. Andersen

Location no. 8.4

Profile through lacustrine sediments of interglacial (Eemian) and early glacial (Weichselian) age.

Chronostratigraphy
Three interglacials are known from Denmark: The Harreskovian, the Holsteinian and the Eemian (Fig. 1). The Eemian is the youngest and is placed between the Saalian and the Weichselian glacials.

Lithology
The interglacial lake sediments are lake marl, calcareous gyttja and diatom gyttja. Above is clay-gyttja and stratified sand from the early Weichselian.

The sediments were deposited in a lake basin formed in the Saalian glacial landscape. Its extension is not known exactly but may have been over 400 m in diameter. The maximum depth of the lake sediments is 8,5 m. The lake sediments were originally exposed in an erosional side valley to the main Gudenå valley. The diatom gyttja was exploited in large pits around 1900-1960 (Fig. 2). Samples for pollen analysis were collected 1961 from a section in the diatom pit and by coring.

Vegetation history
The Eemian vegetational sequence begins with a *Betula* maximum and decreasing herb pollen values and ends with strongly increasing herb pollen (Fig. 3). 7 pollen zones were distinguished (Andersen 1965). E1, *Betula*-herbs. E2, *Betula-Pinus-Ulmus*. E3, *Quercus-Pinus-Betula*. E4, *Corylus-Quercus-Alnus-Taxus*. E5, Carpinus-*Picea-Alnus*. E6, *Pinus-Picea-Alnus-Betula*. E7, *Pinus*. The earliest Weichselian pollen zone has dominant non-tree vegetation and absence of trees.

Taxus, Ilex, Pteridium and others (*Hedera, Buxus*) indicate a warm climate throughout zones E3-E6. Increased values for *Betula, Pinus* and non-tree pollen indicate increased vegetational openness through zones E5-E7.

Andersen (1966) divided the interglacial vegetational sequence into three phases (Fig. 4), I, with dominant light-plants (protocratic), II, with dominant brown-earth plants (mesocratic), and III, with dominant acid-humus and light-plants (oligocratic and telocratic). The protocratic and mesocratic phases reflect immigration and establishment of increasingly dense vegetation on fertile brown-earth soils (Fig. 5). These phases are reflected by the deposition of lime-rich sediments in the lake (Fig. 4). The oligocratic and telocratic phases reflect increasing leaching and podsolization. The deposition of lime decreased and the sediment changed to non-calcareous diatom gyttja.

The change to the deposits of Weichselian age is reflected by a strong increase in insoluble silicates and quartz particles (Fig. 4) followed by deposition of the stratified sand.

The presence of man was testified by finds of marrow-split bones of fallow deer (*Dama dama*, Møhl-Hansen 1955).

Fig. 1. Chronostratigraphic division of the Quaternary in Denmark (Mangerud et al. 1974).

Fig. 2. Section in the pit at Hollerup (1961). 1, calcareous gyttja. 2, diatom gyttja. 3, clay-gyttja. 4, stratified sand. 5, till (Andersen 1967).

Fig. 3. Pollen diagram from Hollerup (Andersen 1965).

Fig. 4. Cumulative pollen curves (A, light-requiring plants. B, acid-humus plants. C, brown-earth plants) and curves for sediment components and *Pediastrum* (Andersen 1966).

Fig. 5. Glacial-interglacial cycle of environmental change (Andersen 1994).

Night at:

Randers Vandrerhjem, Gethersvej 1, 8900 Randers,
tlf: +45 86 42 50 44

Epoch	Age	
Series	Stage	
Holocene	Flandrian	+
Pleistocene	Weichselian	+
	Eemian	+
	Saalian s.l.	+
	Holsteinian	+
	Elsterian 'Interglacial III' 'Glacial B'	+ +
	'Interglacial II'= Harreskovian	+
	'Glacial A'	+
	'Interglacial I'= Osterholzian	
	Menapian Several stages in the Netherlands and North Germany	
Pliocene Miocene Oligocene Eocene Paleocene		

Fig. 1

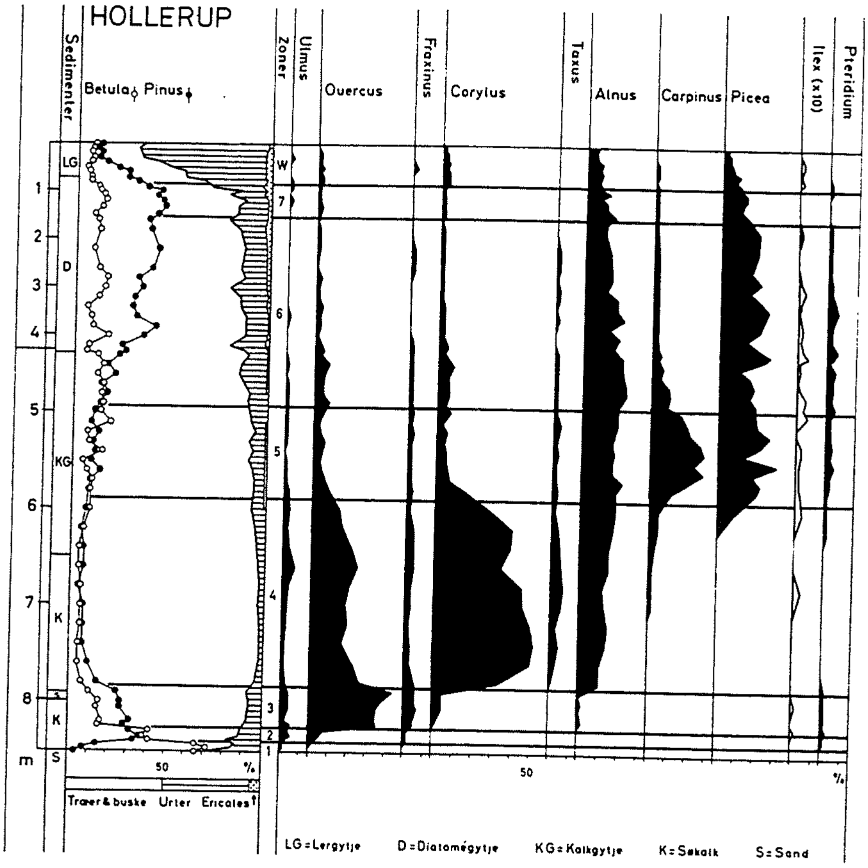


Fig. 3

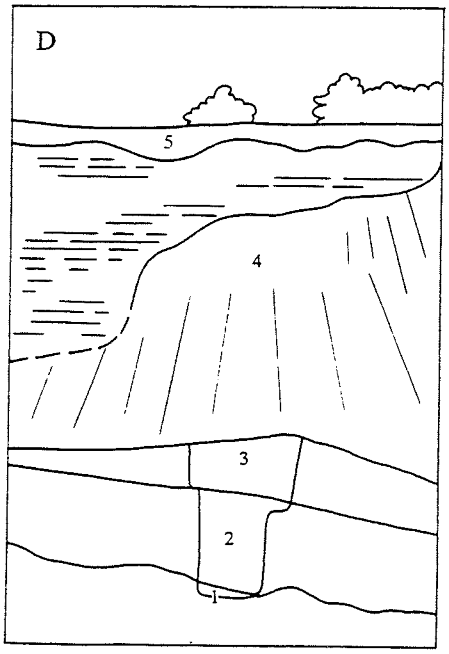


Fig. 2

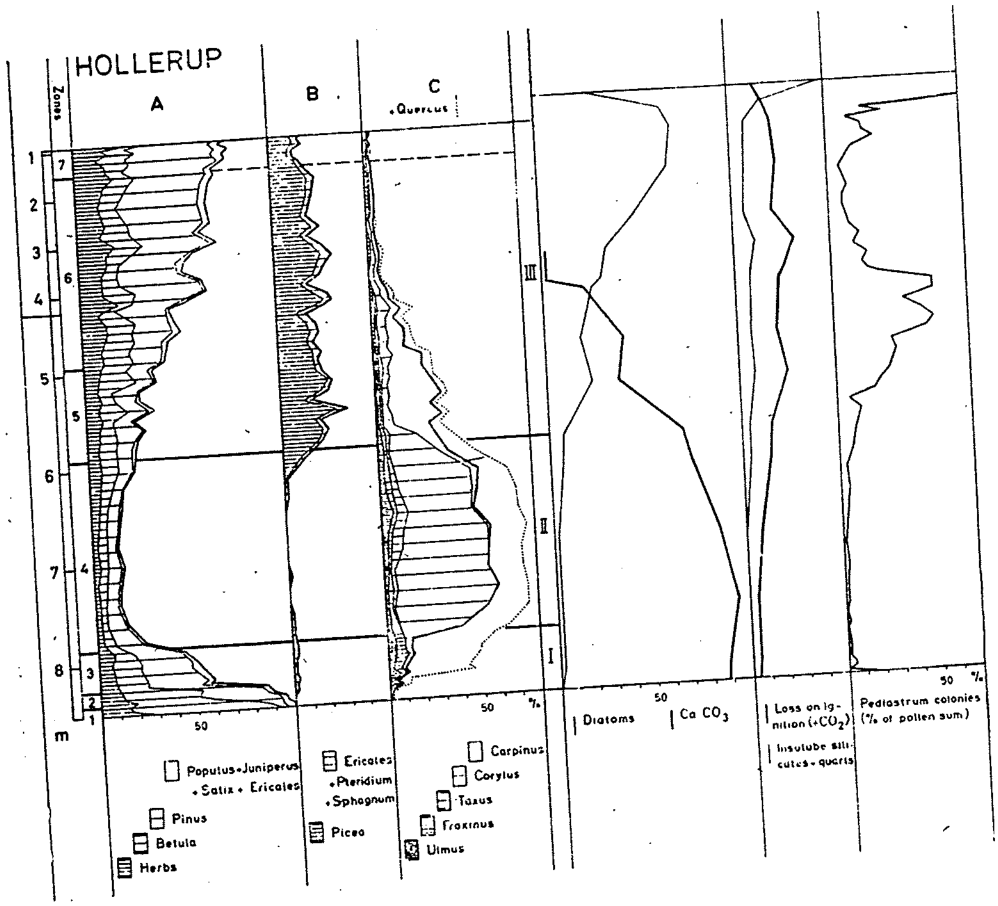

HOLLERUP
Zones
A
B
C
Quercus
m
50
%
I
II
III
Populus+Juniperus+Salix+Ericales
Pinus
Betula
Herbs
Ericales+Pteridium+Sphagnum
Picea
Carpinus
Corylus
Taxus
Fraxinus
Ulmus
Diatoms
Ca CO3
Loss on ignition (+CO2)
Insoluble silicates+quarts
Pedlastrum colonies (% of pollen sum)

Fig. 4

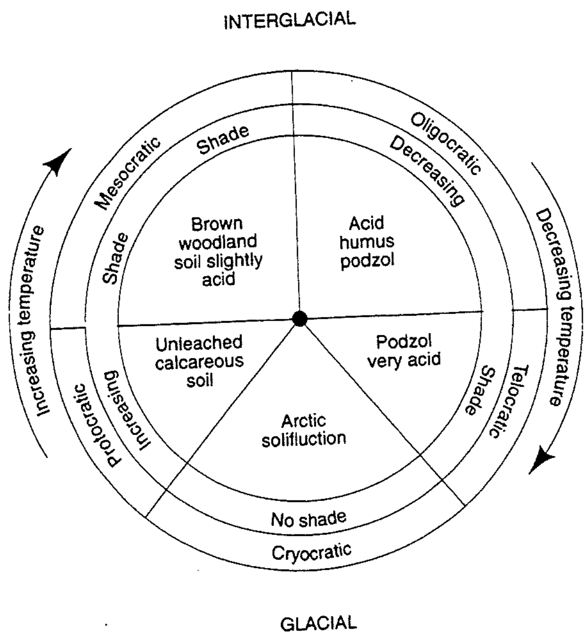

INTERGLACIAL
Increasing temperature
Mesocratic
Shade
Shade
Oligocratic
Decreasing
Decreasing temperature
Brown woodland soil slightly acid
Acid humus podzol
Unleached calcareous soil
Podzol very acid
Arctic solifluction
Protocratic
Increasing
Telocratic
Shade
No shade
Cryocratic
GLACIAL

Fig. 5

Saturday 9th September

Eldrup Forest Reserve.

Svend Th. Andersen

Location no. 9.1

Relic woodland with *Fagus sylvatica* and *Quercus petraea*

Location and substrate

The Eldrup Forest Reserve is situated in Løvenholm Forest in northern Djursland. The Løvenholm Forest consists of a number of original beech woodlands, which are united by spruce plantations (Fig. 1). The beech woodlands themselves are mostly converted to spruce plantations.

The Eldrup Forest Reserve is situated on a morainal ridge. The substrate is sandy till, which in some places is covered by meltwater sand up to 1 m deep. The soil is podzol with a humus layer up to 25 cm deep and a leached horizon. The depth of the leached layer increases from 4 cm at 40 % silt and clay to 30 cm at 3 % silt and clay (Fig. 2). Brown-earth occurs in a few patches. There are 2 hollows with peat and one small pond with clay-gyttja.

Present vegetation

Stands of *Fagus sylvatica* and stands of *Quercus petraea* form a mosaic pattern (Fig. 3).

Quercus petraea occurs mainly in western and central Jutland mostly in stands mixed with *Quercus robur*. The species is common in woodlands on northern Djursland. *Quercus robur* is absent in the Løvenholm Forest, and *Quercus petraea* occurs there in pure stands. The species is distinguished here from *Q. robur* by its long petioles (Fig. 4).

Pollen analysis and dendrochronology indicate that *Fagus* was dominant in the Reserve around 1700-1800 and that the patches of *Quercus petraea* arose 1805-1820 in glades, which had up to that time been grazed by cattle. The present tree distribution pattern therefore reflects land-use in Eldrup Forest around 200 years ago.

Quercus petraea is undoubtedly of old status in Eldrup Forest. Its present stands are being invaded by *Fagus*. Future studies may reveal how *Quercus petraea* survives in the beech forest.

Deshcampsia flexuosa, Melampyrum pratense, Pteridium aquilinum, Luzula pilosa, Qxalis acetosella and *Vaccinium myrtillus* dominate the ground flora.

Holocene forest succession

The Holocene forest succession was studied in a peat hollow and in the pond (Fig. 5). Apart from small clearances in Medieval and recent time, the forest was never cleared away by man. The dominant trees were (1) *Betula* , (2) *Pinus, Corylus, Populus*, (3) *Tilia* with some *Quercus*, (4) *Quercus* with some *Tilia* and *Betula*, and (5) *Fagus* with some *Quercus* and *Betula. Tilia* was replaced by *Quercus* and *Betula* from around 3000 BC, and there are slight traces of human activities. The purpose of clearing *Tilia* was probably promotion of pig pannage. Burning is reflected by peaks on the *Betula* curve. *Quercus, Tilia* and *Betula* were replaced by *Fagus* around AD 500 due to a decline in human activity. Slight peaks on the

Quercus and *Betula* curves indicate clearances in Medieval and recent time. These clearances are reflected more strongly in soil sections elsewhere in the area, where pasture and cereal growing are indicated.

Recent vegetation changes in soil sections

Three soil sections are compared in Fig. 6, one from raw humus (H16), one from podzol (E13), and one from brown earth (W14). The raw-humus diagram shows a well differentiated pollen sequence. From around AD 1700 a clearance with herb vegetation appeared in formerly dense *Fagus* woodland, and there are indications of grazing. Grazing was abandoned 1805. Peaks for *Calluna* and *Juniperus* indicate cessation of grazing pressure. Seedlings of *Quercus* were established 1805-1820 according to dendrochronology. The young *Quercus* trees formed a closed canopy and began flowering around 1850, and the clearance was occupied by the *Quercus* stand, which we see to-day.

The podzol pollen diagram (E13) reflects the same vegetational sequence. Here, however, the pollen grains were transported into the soil by soil fauna, and the pollen curves became smoothed due to bioturbation. These features are only slightly recognizable in the brown earth (W14). Here the pollen curves are strongly smoothed due to intensive earth-worm activity.

Fig. 1. Original woodlands around Løvenholm. The Eldrup Forest Reserve is marked by hatching (Andersen 1984).

Fig. 2 Depth of leaching (A-horizon) in relation to clay and silt content of the A-horizon (Andersen 1984).

Fig. 3. Trees in the Eldrup Forest Reserve. Filled dots, *Fagus sylvatica*. Open dots, *Quercus petraea*. Sites for pollen diagrams are indicated (Andersen 1984).

Fig. 4. Length of leaf petioles in *Quercus robur* (Draved Forest) and *Q. petraea* (Eldrup Forest, Andersen 1984).

Fig. 5. Vegetation sequence in Eldrup Forest. *Betula*, birk, *Pinus*, fyr. *Populus*, asp. *Corylus*, hassel. *Tilia*, lind. *Quercus*, eg. *Fagus*, bøg. Open land, åbent land (Andersen 1984).

Fig. 6. Pollen diagrams from 3 soil sections. H16, raw humus, E13, podzol. W14, brown earth (Andersen 1979).

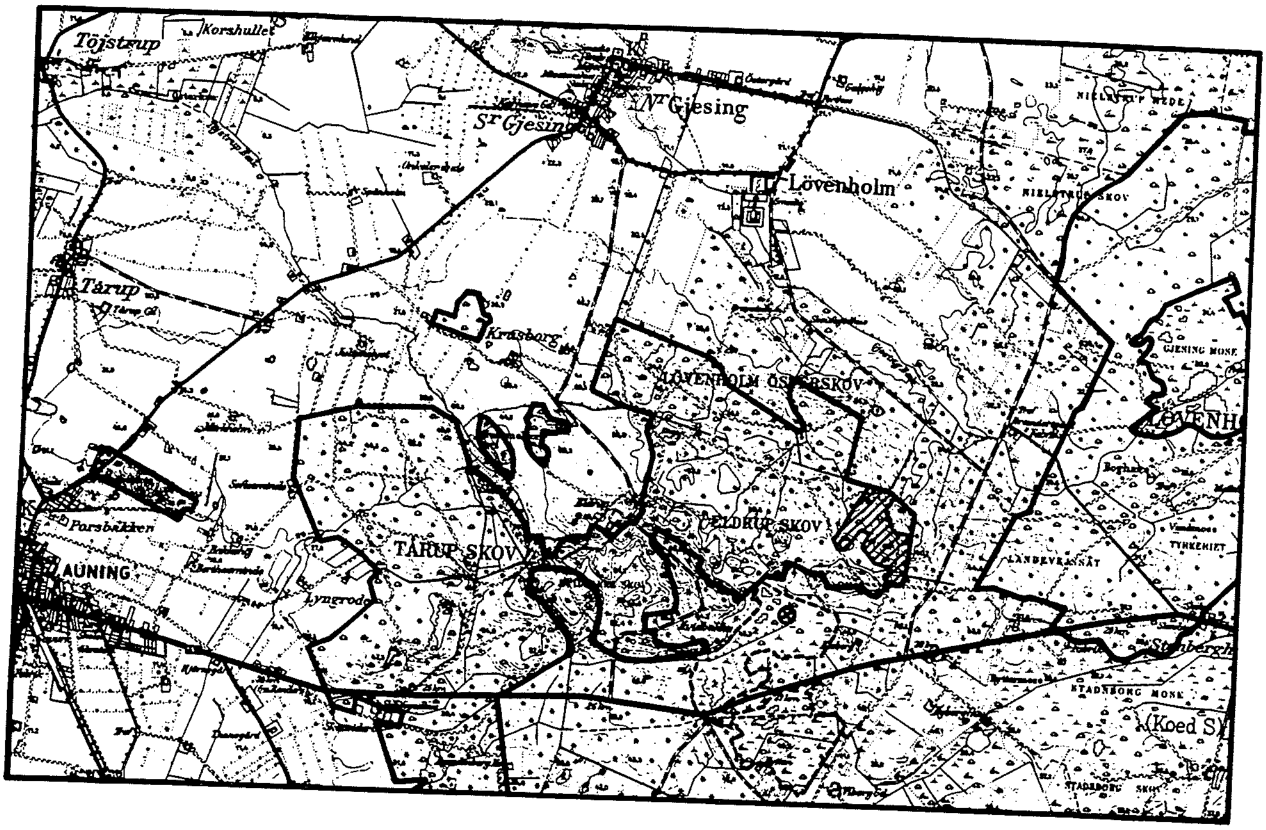

Töjstrup
Korshullet
Nr Gjesing
Sr Gjesing
Lövenholm
Tårup
Krasborg
TÅRUP SKOV
AUNING
Parsbakken
Lyngrode

Fig. 1

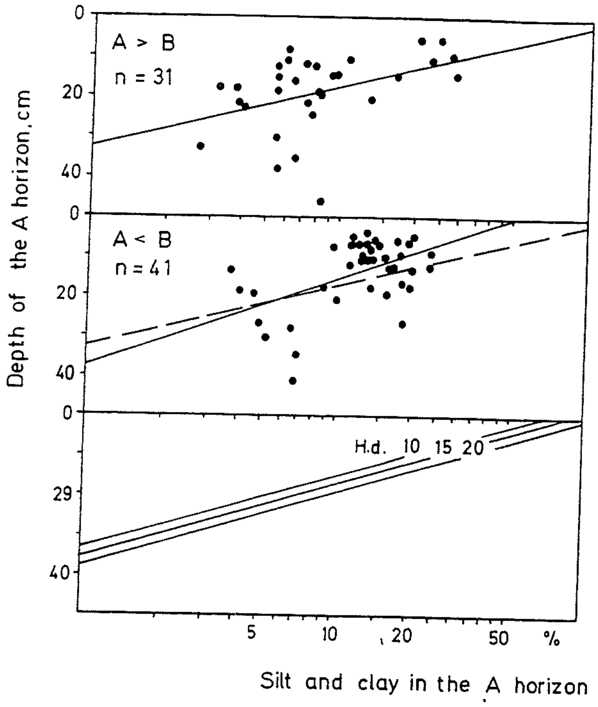

A > B
n = 31
A < B
n = 41
H.d. 10 15 20
0
20
40
29
5
10
20
50
%
Depth of the A horizon, cm
Silt and clay in the A horizon

Fig. 2

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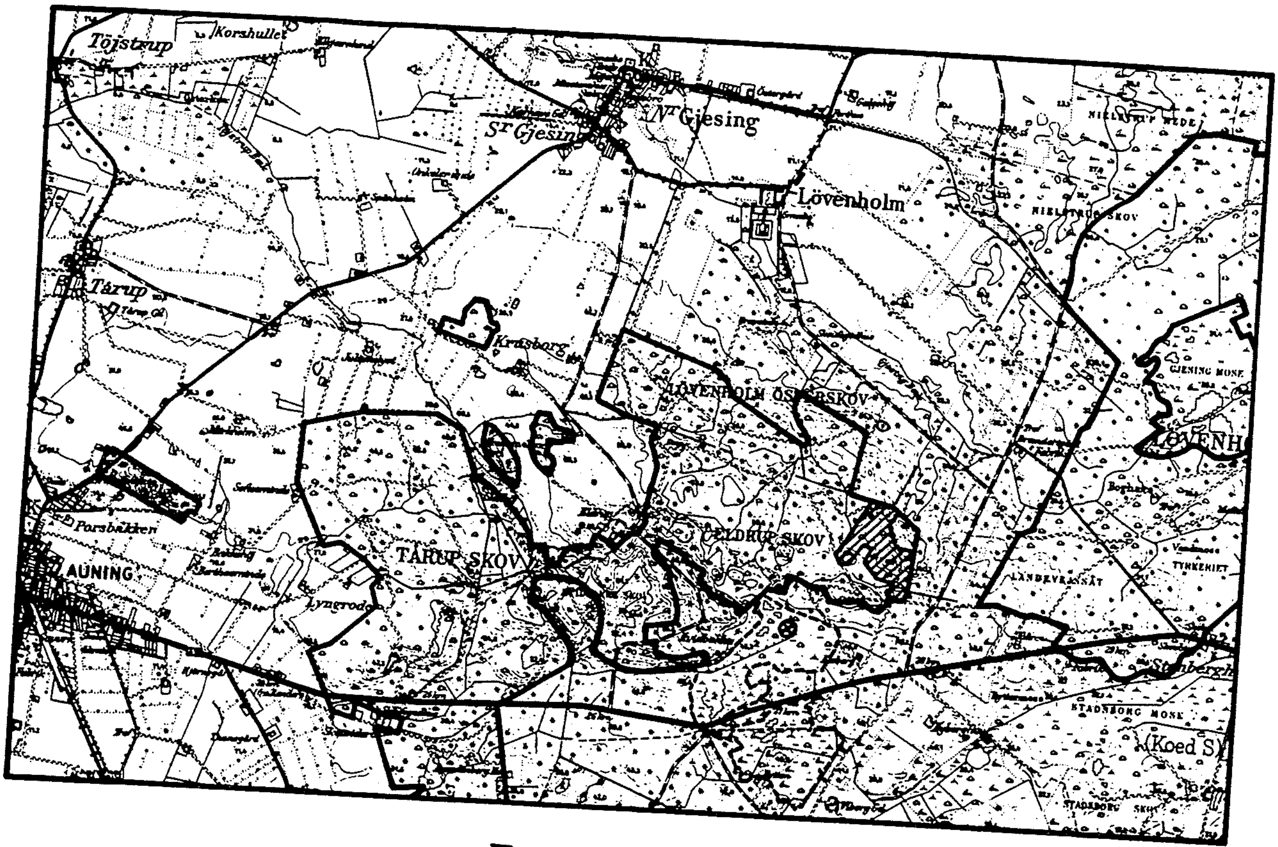

Töjstrup
Korshullet
Nr Gjesing
Sr Gjesing
Lövenholm
Tårup
Krasborg
Porsbakken
AUNING
TÅRUP SKOV

Fig. 1

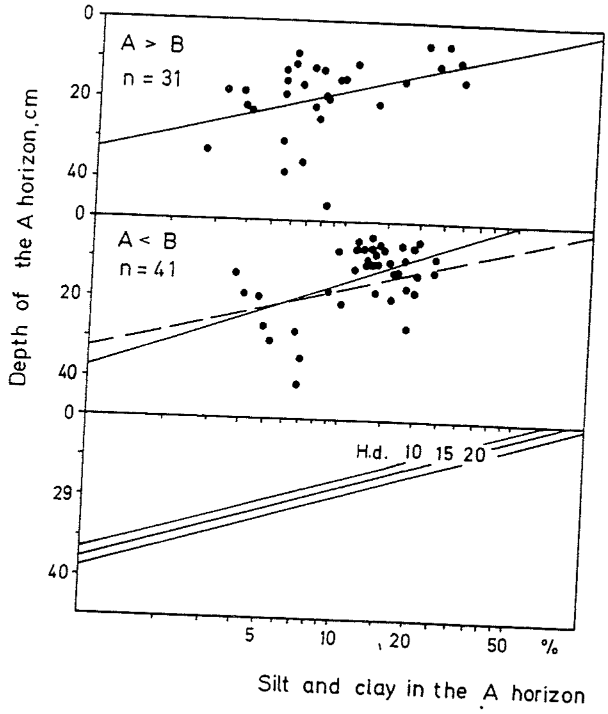

A > B
n = 31
A < B
n = 41
H.d. 10 15 20
0
20
40
29
5
10
20
50
%
Depth of the A horizon, cm
Silt and clay in the A horizon

Fig. 2

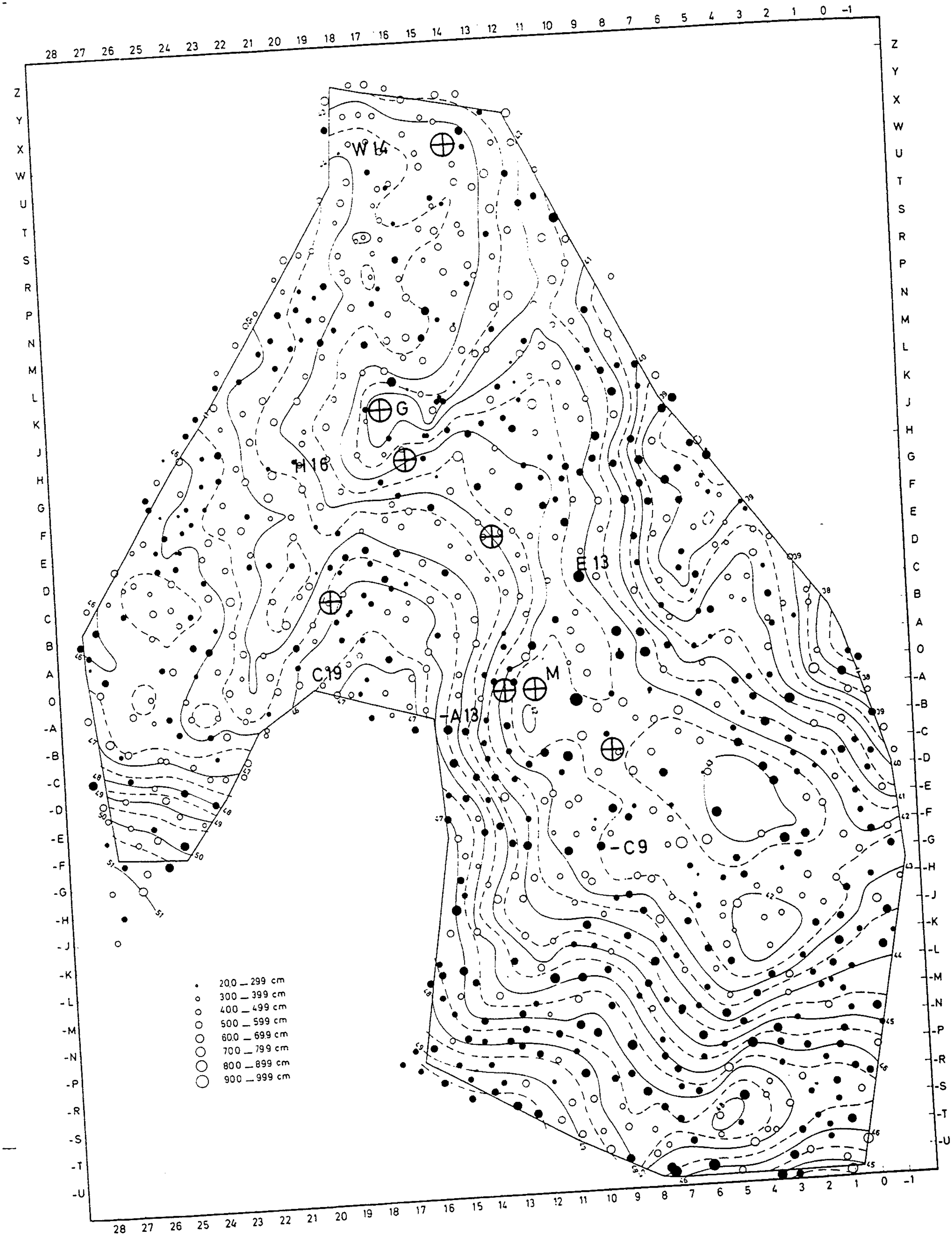

W14
G
H16
E13
M
C19
-A13
-C9
200 _ 299 cm
300 _ 399 cm
400 _ 499 cm
500 _ 599 cm
600 _ 699 cm
700 _ 799 cm
800 _ 899 cm
900 _ 999 cm

Fig. 3

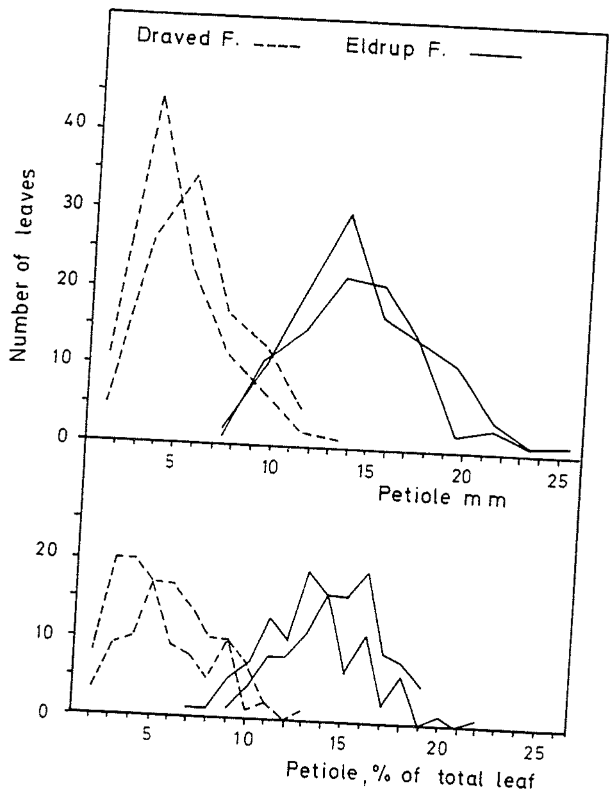

Draved F.
Eldrup F.
Number of leaves
40
30
20
10
0
5
10
15
20
25
Petiole mm
20
10
0
5
10
15
20
25
Petiole, % of total leaf

Fig. 4

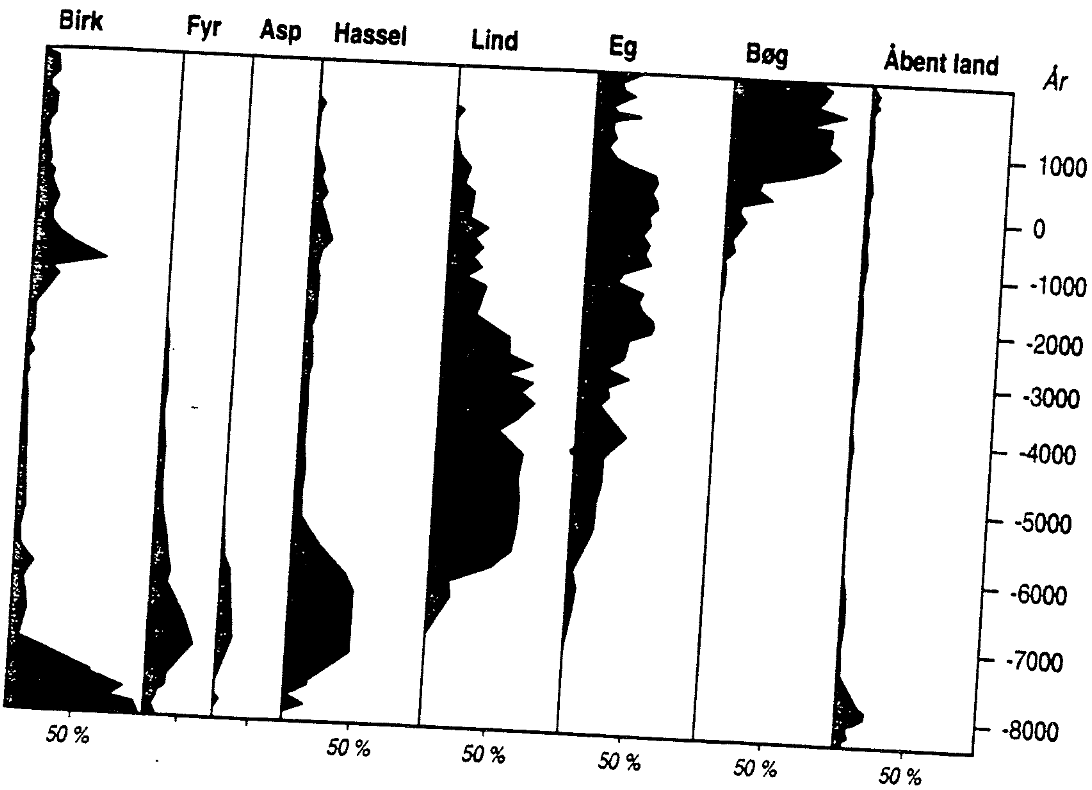

Birk
Fyr
Asp
Hassel
Lind
Eg
Bøg
Åbent land
År
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
50 %
50 %
50 %
50 %
50 %
50 %

Fig. 5

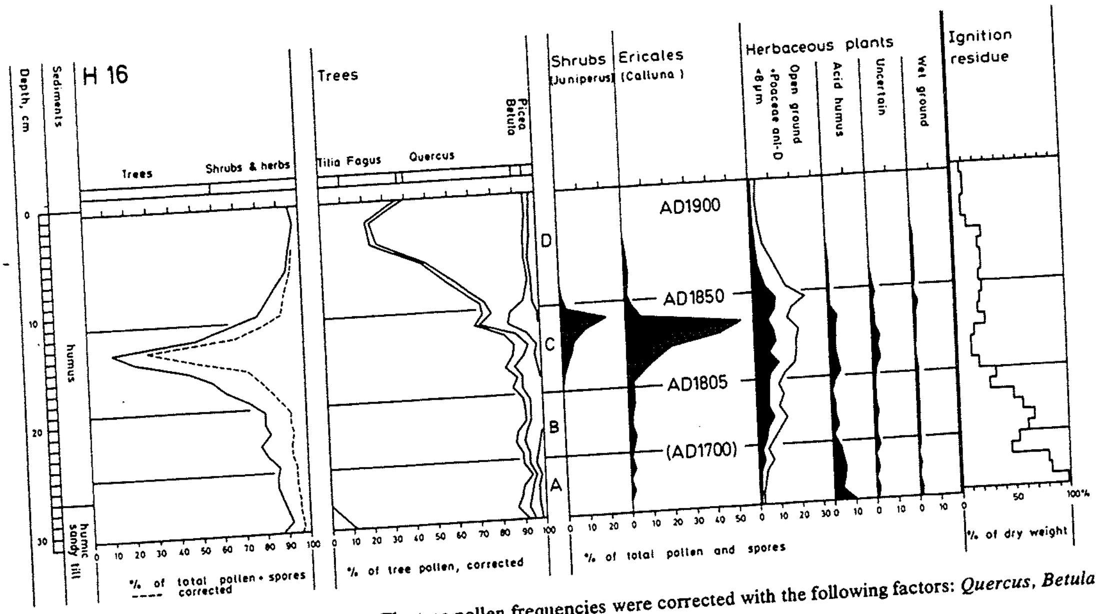
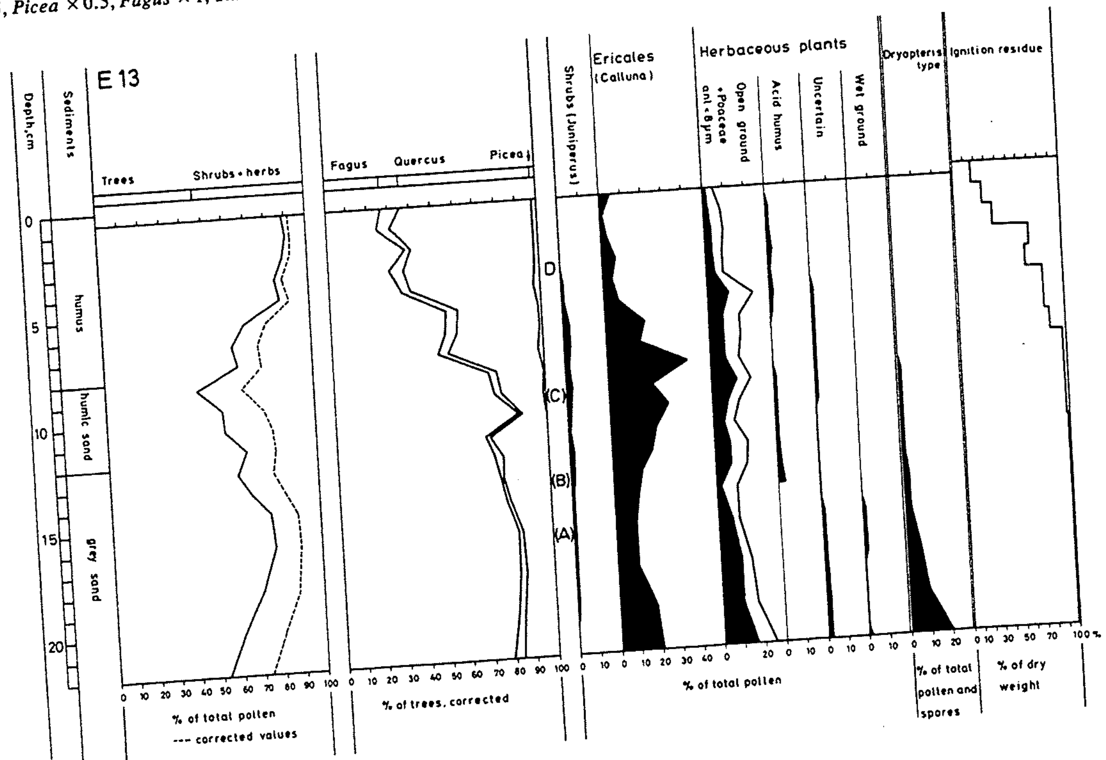


Fig. 9. Pollen diagram from section H16. The tree pollen frequencies were corrected with the following factors: *Quercus, Betula* × 0.25, *Picea* × 0.5, *Fagus* × 1, *Tilia* × 2 (Andersen 1970).



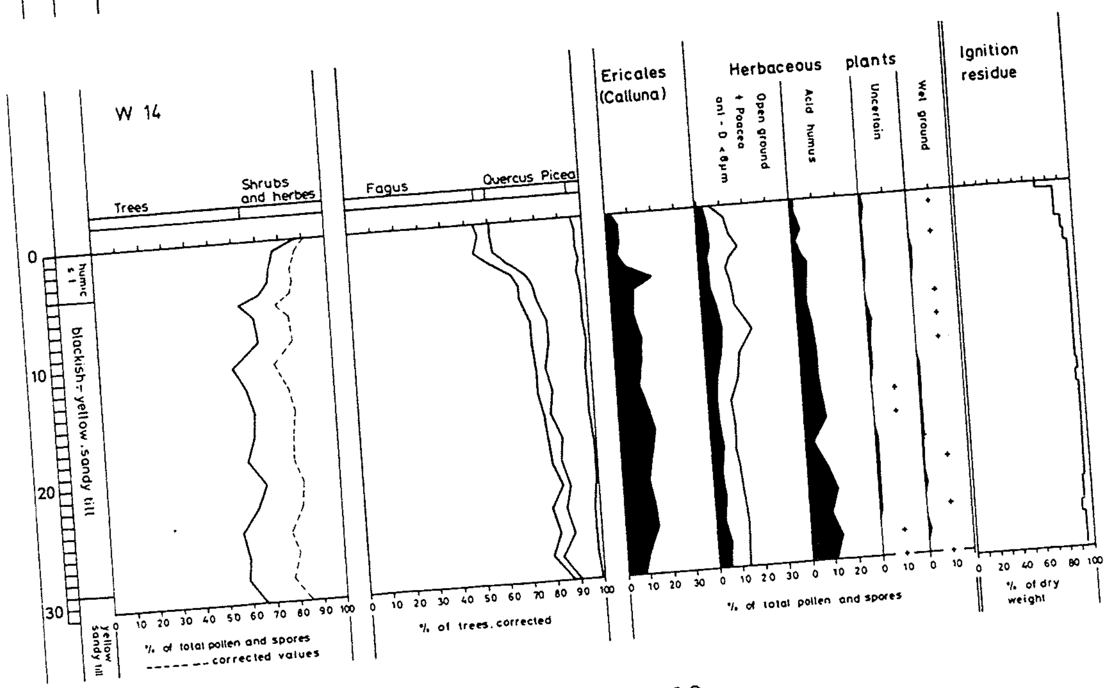


Fig. 6

Tustrup Megalith Field.

Svend Th. Andersen

Location no. 9.2

Land use in megalith time according to pollen analyses from soil horizons in grave mounds.

Location

The Tustrup Megalith Field is situated in northern Djursland. There are 2 dolmens, a passage grave and a cult house from the Middle Neolithic Funnel Beaker Culture (MN I a, 3300-3200 BC, Fig. 1).

Vegetation succession at Tustrup

Pollen analyses were worked out for soil sections beneath the mounds of the passage grave and one dolmen. Beneath the passage grave mound there was a podzol with a thin humic layer (1 cm, Ao), 5 cm bleached sand (A) and 8 cm reddish brown sand (B, Fig. 2). Beneath the mound of the dolmen there was a brown earth, 9 cm deep.

Pollen grains occurred to 15 cm depth at the passage grave. The pollen curves (Fig. 3) were smoothed during the burial similar to the pollen curves in the podzol section from Eldrup Forest (section E13, Fig. 6), but a vegetational succession can still be recognized.

Phase 1. Trees (birch) were replaced by grazed herb vegetation with high plantain. Deformation of the birch pollen indicates that the birch coppice had been burnt prior to the grazing stage. *Phase 2.* Birch coppice regenerated, and was burned and grazed again. *Phase 3.* Birch coppice regenerated just before the building of the mound.

Pollen was present only in the topmost samples of the brown earth at the dolmen. A birch coppice was burned and replaced by pasture vegetation with plantain (Fig. 3).

The pollen diagrams from the Tustrup megaliths indicate the use of a long-fallow swidden rotation system, where coppice was burned and grazed, and then re-established and burned again
(Fig. 4).

Land use in megalith time

Megalith graves are very common in Denmark. 44 pollen spectra from passage graves and dolmens from the Middle Neolithic Period Ia are shown in Fig. 5. The dots indicate pollen frequencies for original woodland (lime dominant), secondary coppice woods (hazel, birch, alder) and open land (herbs). The distribution of the pollen spectra indicate a highly varied landscape with relic lime woodlands, coppice and coppice replaced by herb vegetation. Tree pollen deformed by burning of trees on the ground is frequent in 66 % of the pollen spectra. This indicates that swidden rotation based on burning of coppices was used everywhere in the megalith landscape.

The pollen frequencies of herbs indicate the land use of the swidden areas (Fig. 6). Woodland herbs belonged to the fallow coppices. Sites with grasses, cereal pollen and weeds indicate sites with arable cultivation following the burning of coppices, and sites with ribwort plantain indicate pastures. Sites with pasture predominate. The burnt swidden areas were thus used for cereal cultivation for a short time, and then for prolonged.

Fig 1. Danish Neolithic chronology. The dolmens and the passage grave at Tustrup belong to the

Middle Neolithic Period Ia (3300-3200 BC, Nielsen 1993).

Fig. 2. Soil horizon beneath the mound of the passage grave. The Ao and A horizons are indicated by arrows.

Fig. 3. Pollen diagrams from the soil horizons beneath the mounds of the dolmen and the passage grave (Andersen, in print).

Fig. 4. Reconstructed swidden rotation cycle as practised by the megalith people (MNIa, Andersen, in print).

Fig. 5. Landscape variation around megalithic graves in Denmark according to pollen spectra from soils. Each dot represents a pollen spectrum (Andersen, in print).

Fig. 6. Land use around the megalithic graves based on pollen spectra with percentages of the total herb pollen (Andersen, in print).

Night at:

The train to Bern or wherever you are heading. The bus will take you to Fredericia train station.

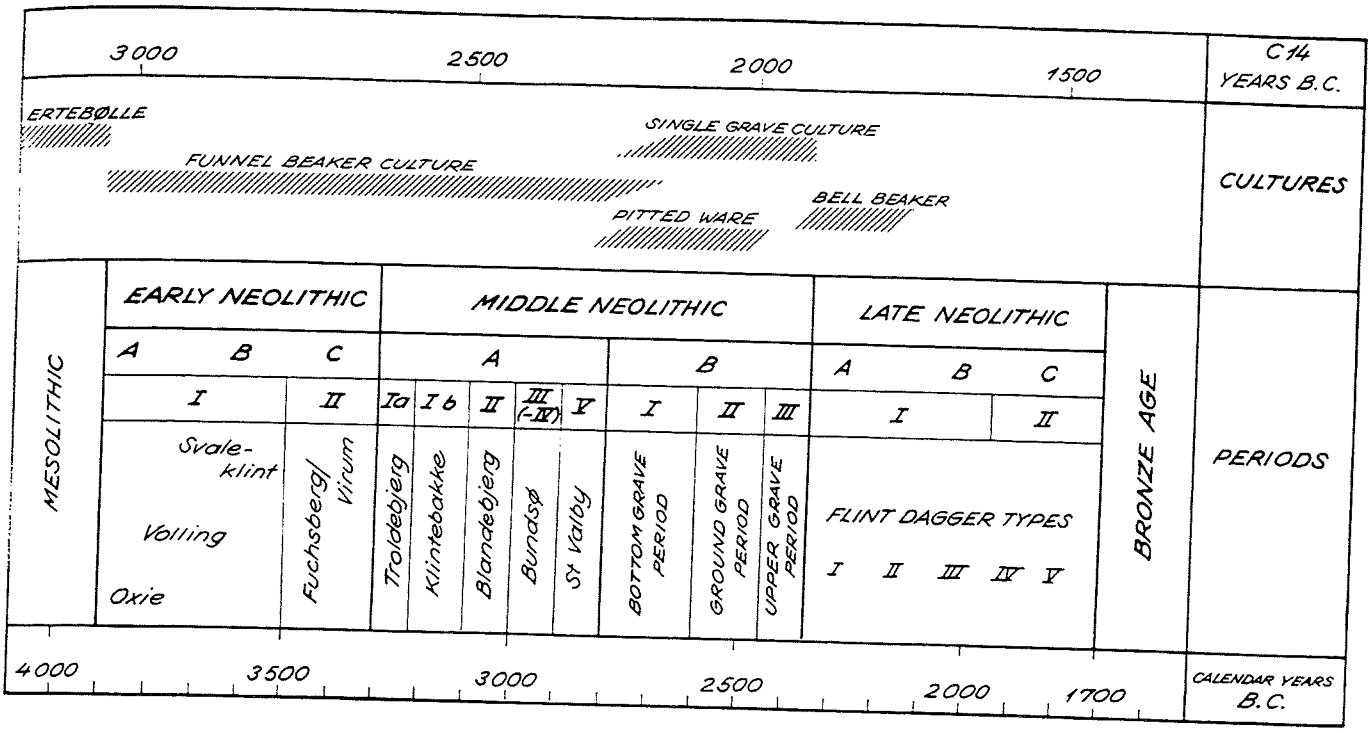

3000
2500
2000
1500
C14 YEARS B.C.
ERTEBØLLE
FUNNEL BEAKER CULTURE
SINGLE GRAVE CULTURE
PITTED WARE
BELL BEAKER
CULTURES
MESOLITHIC
EARLY NEOLITHIC
A B C
I II
Svaleklint
Volling
Oxie
Fuchsberg/Virum
MIDDLE NEOLITHIC
A
Ia Ib II III (-IV) V
Troldebjerg
Klintebakke
Blandebjerg
Bundsø
St Valby
B
I II III
BOTTOM GRAVE PERIOD
GROUND GRAVE PERIOD
UPPER GRAVE PERIOD
LATE NEOLITHIC
A B C
I II
FLINT DAGGER TYPES
I II III IV V
BRONZE AGE
PERIODS
4000
3500
3000
2500
2000
1700
CALENDAR YEARS B.C.

Fig. 1

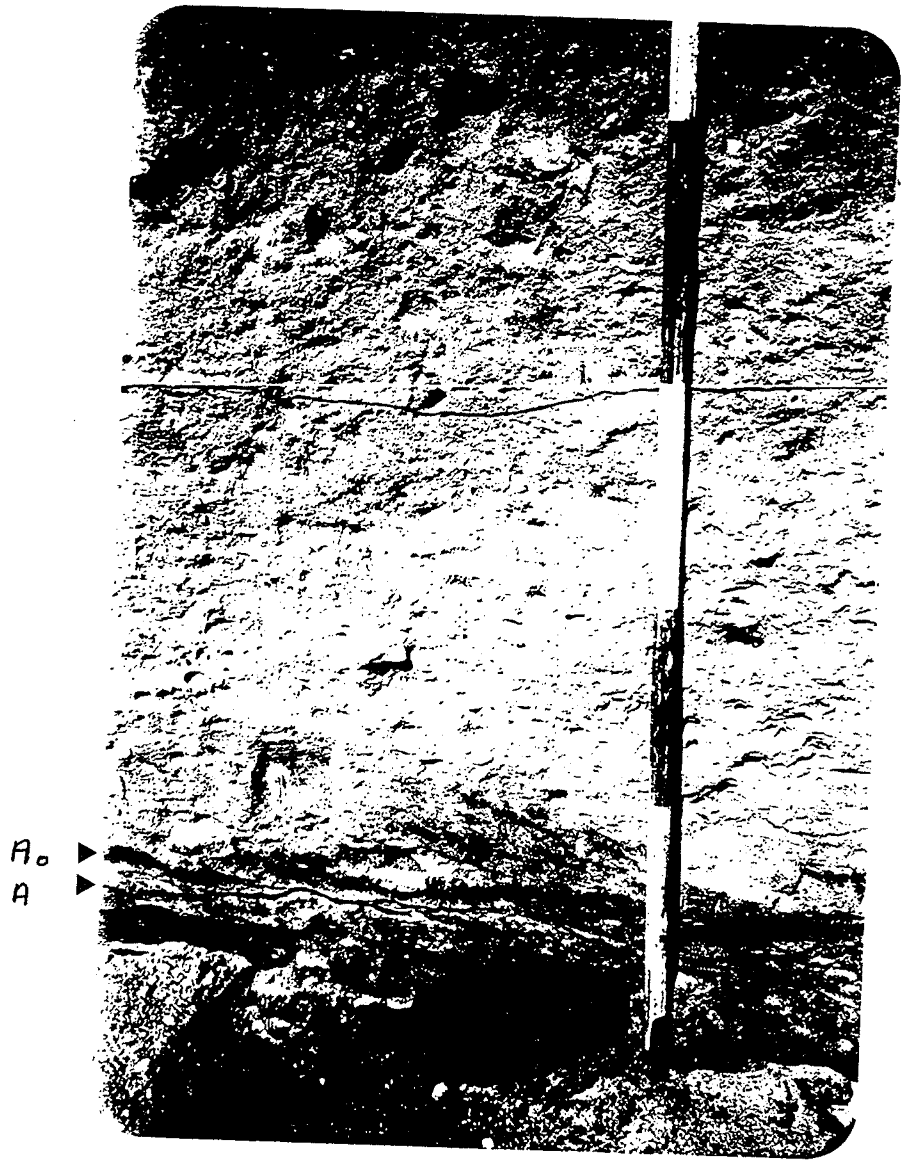

A₀
A

Fig. 2

Middle Neolithic Period Ia (3300-3200 BC, Nielsen 1993).

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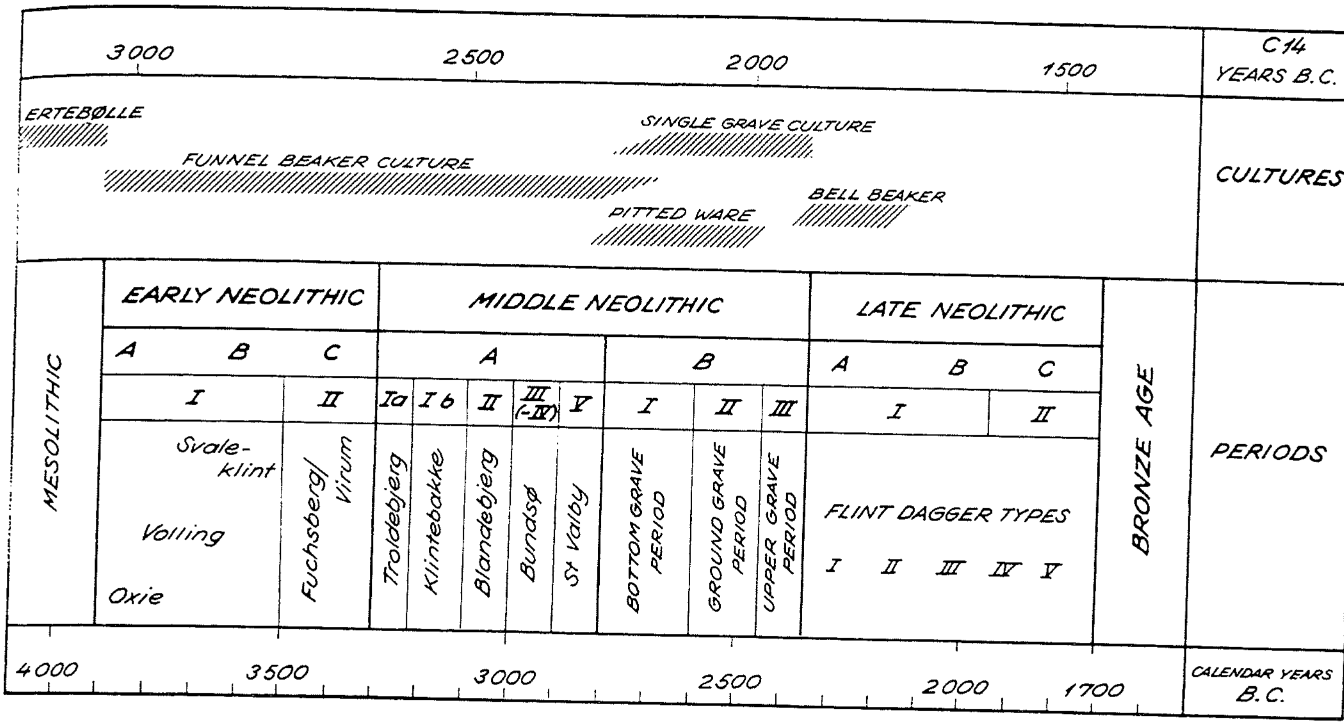
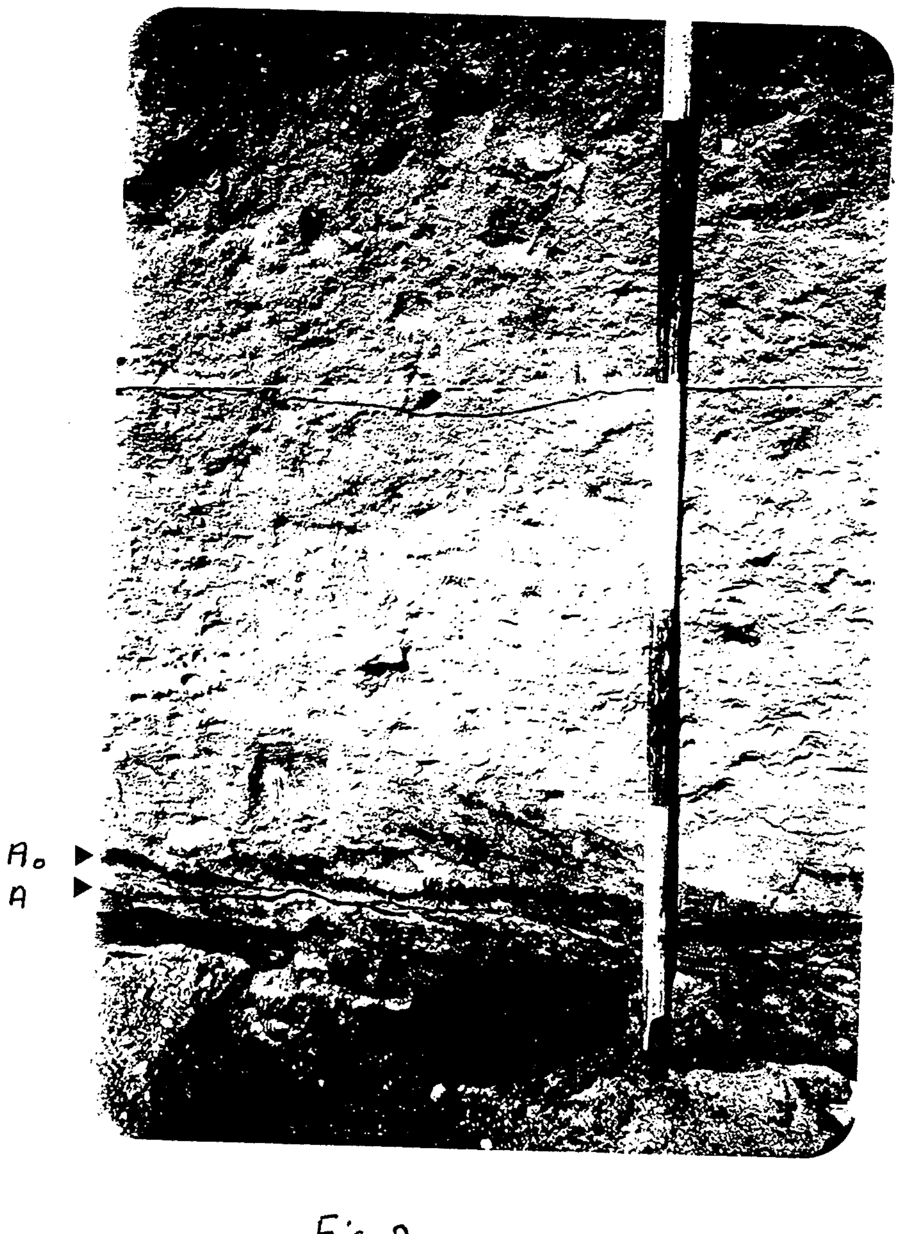


3000
2500
2000
1500
C14 YEARS B.C.
ERTEBØLLE
SINGLE GRAVE CULTURE
FUNNEL BEAKER CULTURE
BELL BEAKER
PITTED WARE
CULTURES
MESOLITHIC
EARLY NEOLITHIC
MIDDLE NEOLITHIC
LATE NEOLITHIC
BRONZE AGE
PERIODS
A B C
A B
A B C
I II
Ia Ib II III (-IV) V
I II III
I II
Svale-klint
Volling
Oxie
Fuchsberg/Virum
Troldebjerg
Klintebakke
Blandebjerg
Bundsø
St Valby
BOTTOM GRAVE PERIOD
GROUND GRAVE PERIOD
UPPER GRAVE PERIOD
FLINT DAGGER TYPES
I II III IV V
4000
3500
3000
2500
2000
1700
CALENDAR YEARS B.C.

Fig. 1



A0
A

Fig. 2

TUSTRUP MEGALITHS
Soil pollen analyses

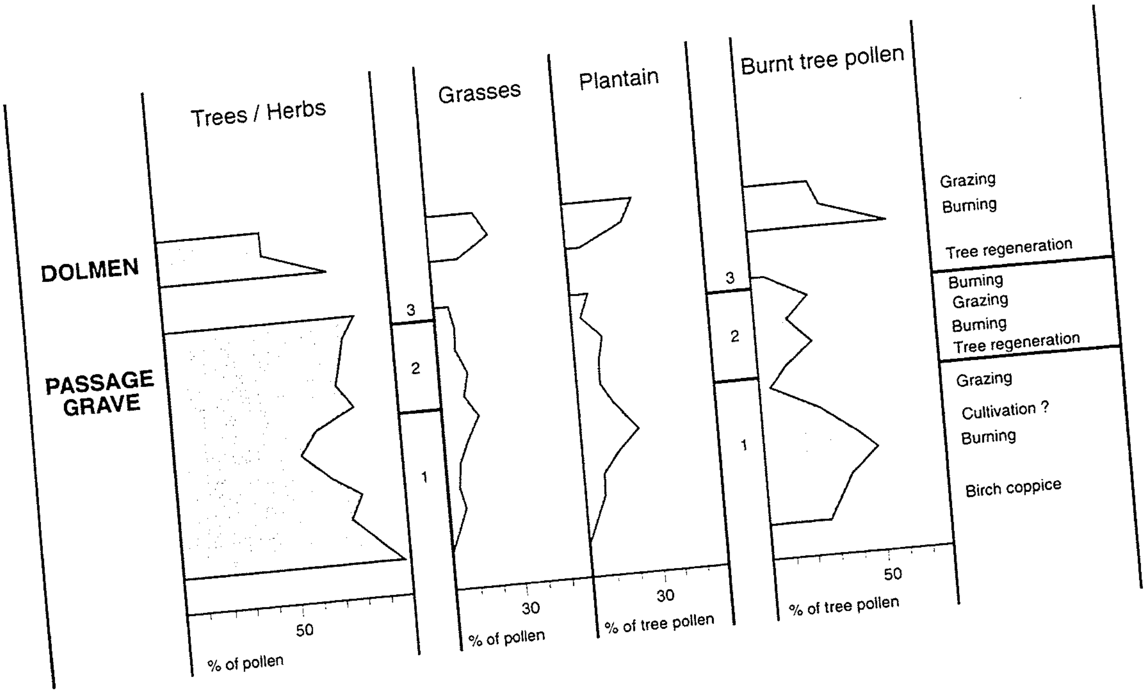


Fig. 3

MEGALITH SWIDDEN ROTATION

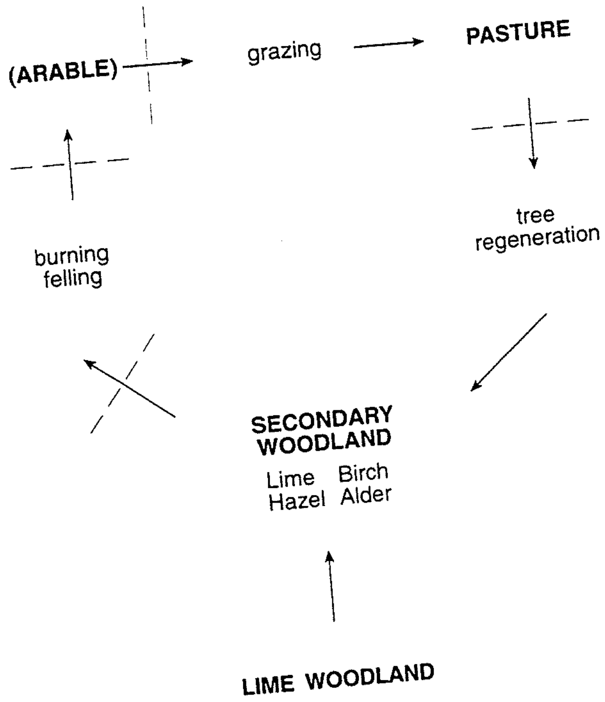


Fig. 4

MEGALITH LANDSCAPE

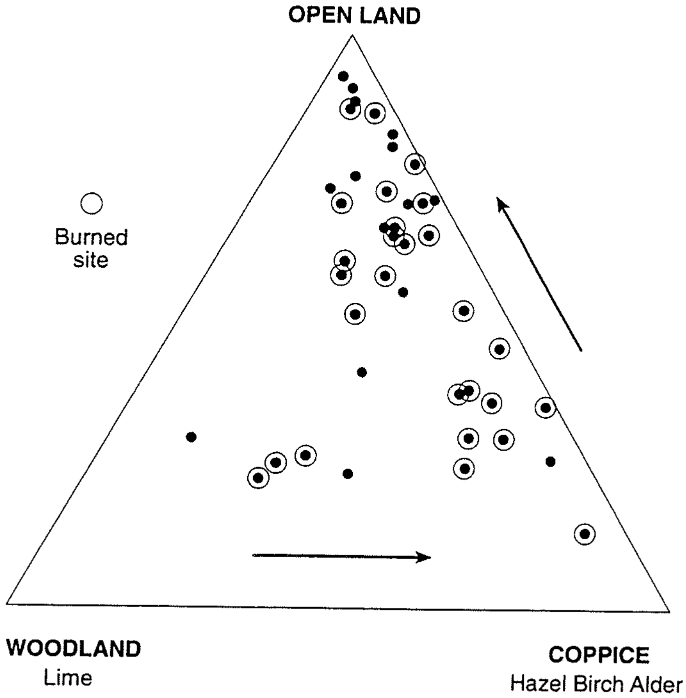


Fig. 5

MEGALITH LAND USE

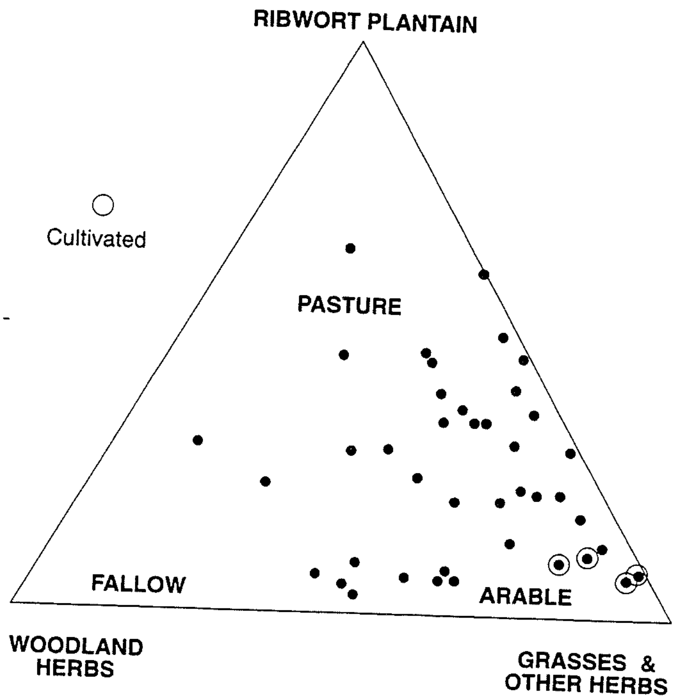


Fig. 6