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History of Vegetation and Agriculture

at Hassing Huse Mose, Thy, Northwest Denmark, since the Ice Age

by SVEND TH. ANDERSEN

INTRODUCTION

Thy is the westernmost part of North Jutland, which is delimited from the Jutland mainland by the Limfjord (Fig. 1). Large areas in the west and north of Thy are covered by wind-blown sands. The central and eastern parts consist mainly of sandy and clayey tills, which rise to 94 m altitude, and Holocene deposits (Pedersen 1989, Fig. 2).

The western Limfjord area was densely inhabited from the time of the Ertebølle Culture (S.H. Andersen 1990) and up through prehistoric and historic times. There are scattered graves and finds from the Early and Middle Neolithic Funnel Beaker Cultures in Thy (Kristensen 1989, Davidsen 1985, Kristiansen 1988) and numerous finds from the Middle Neolithic Single Grave Culture and the Late Neolithic (Glob 1945, Vandkilde 1990). The concentration of Bronze Age finds and graves is one of the densest in Denmark (Baudou 1985, Kristiansen 1985), and there are numerous settlements, graves and finds from the Iron Age (Hedeager 1985, Fonnesbech-Sandberg 1985, Hvass 1985). Dense new settlements appeared again in the Medieval Period (Baudou 1985). Natural woodlands had disappeared from Thy by the last century (Ødum 1968), due to the intensive agriculture.

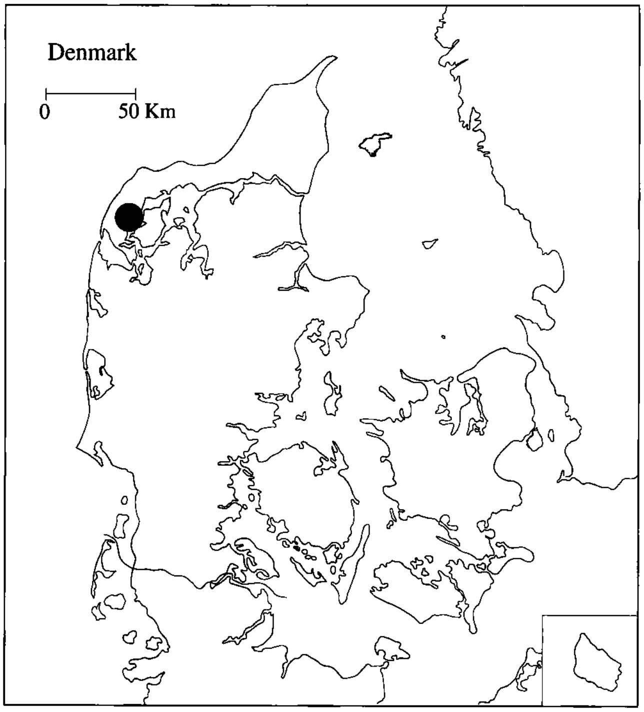

Fig. 1. Map of Denmark with the location of Hassing Huse Mose.

The sand drift in western Thy began already in the Middle Neolithic (Liversage 1987), but the extensive dune areas were not created till after the early 13th century (Hansen 1957). The dune sands were stabilized by planting of marram grass since the late 18th century, and extensive pine plantations were established since about 1885. Small private plantations have appeared in Thy since about 1900.

The climate in Thy is oceanic (15.8° in July, 0.3° in January, Lysgaard 1969). Wind directions are equally distributed in the spring and predominantly westerly in the summer. The average wind velocity is higher than at inland localities (5.9 and 3.6-5.0 m sec^{-1} in the spring, 4.8 and 3.0-4.4 m sec^{-1} in the summer, Frydendal 1971).

Due to the intensive settlement history, it was decided to establish a radiocarbon-dated regional pollen diagram from Thy. 10 localities were examined by B. Odgaard and P. Friis Møller 1985. Of these, only one contained deep non-calcareous deposits suitable for radiocarbon dating: a small swamp named Hassing Huse Mose near Bedsted. Two cores for pollen analysis and radiocarbon dating were extracted 1987 by B. Odgaard and P. Friis Møller. 1991 a core was extracted from the nearby Ove Sø by B. Odgaard and P. Rasmussen. A radiocarbon-dated pollen diagram from Hassing Huse Mose was published by Andersen and Rasmussen (1993). This pollen diagram comprises four mid-Holocene elm declines. The size of a reservoir effect on

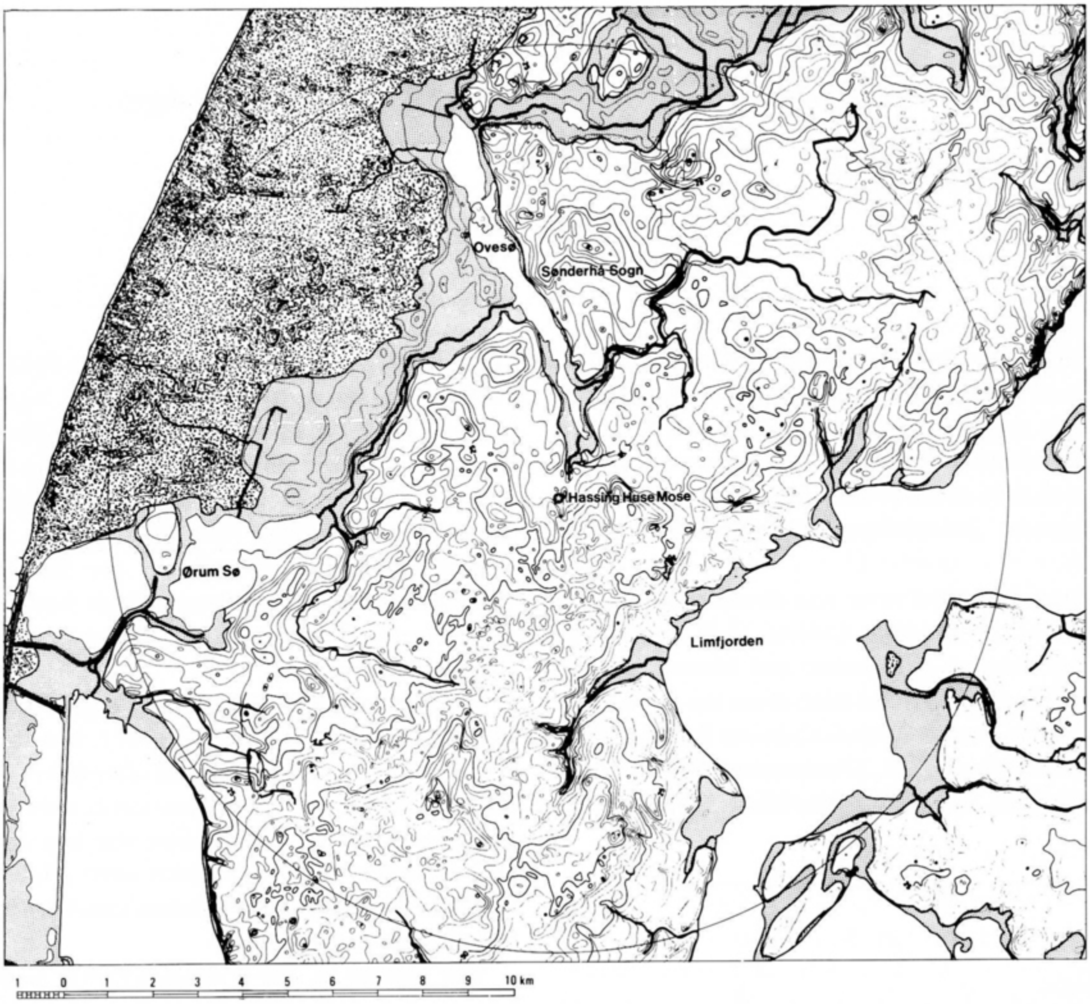

Fig. 2. Map of surface contours in central Thy around Hassing Huse Mose. Coarse dots: Sand dunes. Shaded: Holocene freshwater and marine deposits. The radius of the circle is 10 km. Base map from Danmark 1:100.000. Geodætisk Institut 1982. Reproduced by permission of Kort- og Matrikelstyrelsen no. A.404/85.

the age-determinations of gyttja samples and precise datings were obtained by comparing dates for consecutive samples with the atmospheric calibration curve (wiggle dating), and by dating of the humus and alkali-insoluble fractions of two samples, separately.

THE SITE

Hassing Huse Mose is located in central Thy (56°49'N, 8°27'E, Fig. 1). It is oval in shape and about 250 x 150 m in size (3.1 ha, Fig. 3). The surface is at 10 m altitude, and the maximum depth of the Holocene deposit is 8.3 m. The site is surrounded by low hills up to 21 m altitude; the sides of the basin are rather steep, and there is no surficial inlet or outlet. The Holocene deposit is 3 m swamp peat above 5 m gyttja. Most of the swamp peat was dug away for fuel industry during World War II, except for two narrow walls, which extend from the west shore to the center of the basin. They had been used for support of narrow-gauged rail tracks. The pits are now water-filled up to near the surface of the peat walls. The area around the site is cultivated intensively.

Cores were extracted at two points on the southern peat wall, series 1 at 96 m, and series 2 at 17 m from the shore. Series 1 is near the centre of the basin.

METHODS

Coring and sampling

Consecutive cores were extracted from the swamp peat in series 1 with a Russian-type sampler (Aaby and Digerfeldt 1986), 50 cm long and 6.3 cm wide. Three additional cores were obtained with a piston corer of Livingstone type (Aaby and Digerfeldt 1986), 1.3 m long and 10 cm in diameter. The deepest of these cores contained the lowermost part of the swamp peat and the top part of the underlying gyttja. Other cores from the gyttja in series 1 and in series 2 were extracted by the piston corer. Depth levels of the gyttja cores from series 1 deeper that 3.54 m were adjusted by subtraction of 0.16 m (Andersen and Rasmussen 1993). Samples were taken for microfossil analysis (0.5 cm thick) and radiocarbon dating (2 cm slices).

Ash content

Ash content (% dry weight) was determined by combustion at 550°C.

Pollen and charcoal analysis

The samples were treated for pollen analysis by boiling in 10 % KOH, sieving (peat samples), treatment with HF overnight and acetolysis. The residues were mounted in silicone oil. The numbers of pollen grains and charcoal particles larger than 0.01 mm were counted at 200 or 500 x magnification. English plant names and their equivalents in latin are listed in Table 6.

The diameter of the pore *annulus* was measured on pollen grains of the grass family. Average size (largest and smallest diameter) was measured on grains with annulus diameter larger than 6 μm, and surface-sculpture (scabrate or verrucate) was determined with phase-contrast equipment.

The pollen analyses were performed by H. Krog, B. Stavngaard and S.T. Andersen.

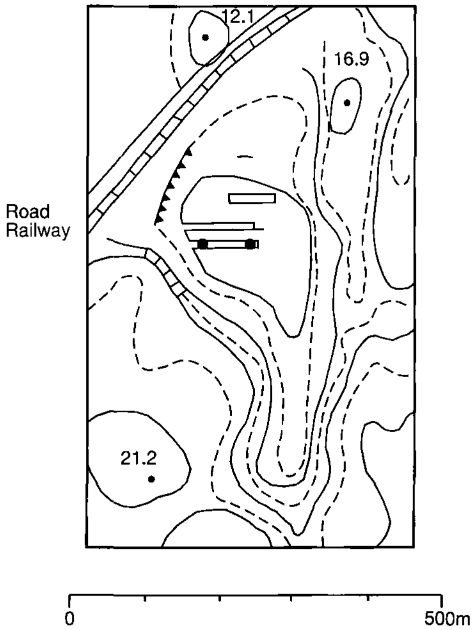

Fig. 3. Topographic map of Hassing Huse Mose and its surroundings. The sections in Hassing Huse Mose are indicated by black circles. Detail of Denmark 1:25.000, Sheet 1116 IV SØ (1964). Reproduced by permission of Kort og Matrikelstyrelsen no. A.404/85.

Pollen diagrams

The pollen taxa were grouped in seven categories: Trees, non-tree plants from forest and coppice, wild grasses, plants from open-ground habitats, taxa of ambiguous significance, wet-ground plants and aquatics. Hazel and yew were considered trees. Heather was included in the wet-ground plants because of massive occurrence in the swamp peat.

Pollen percentages were based on the sum of land-plant pollen. Wild grass pollen was included in the land plants because the pollen frequencies follow the frequencies of open-ground plants. The ambiguous and the wet-ground plants had to be excluded, because the pollen from these plants found in the peat may derive from local vegetation. This procedure is not quite satisfactory, because ambiguous and wet-ground plants may also have occurred in land vegetation around the basin. The frequencies of algae (*Pediastrum* and *Botryococcus*) and charcoal particles were related to the land-plant pollen sum. *Algae* were not recorded at 2.95-3.68 m depth, because of massive occurrence, and charcoal was not recorded below 5.74 m depth. Tree pollen percentages corrected for differential pollen productivity were calculated separately (Andersen 1970, 1978). Depth levels from the two sections were correlated by pollen analysis and variations in ash content, and were converted into calendar years based on radiocarbon dates. The pollen diagrams were drawn using the computer program TILIA-GRAPH written by E.C. Grimm, by B.V. Odgaard. Pollen zone borders were determined with the computer program CONISS written by E.C. Grimm (1987). Frequencies for individual taxa within ambiguous, wet-ground plants and aquatics were not drawn.

The pollen sums varied between 500 and 800, in general. Lower pollen sums occurred in the late-glacial samples (300-500, below 8.56 m depth) and in the swamp peat (150-250, at 1.10-1.80 m depth). 2000-3000 pollen grains were counted in the pollen diagram published by Andersen and Rasmussen (1993, at 3.00-5.74 m depth).

Rarefaction analysis

The numbers of pollen taxa recorded in a sample increases with the number of counted pollen grains. Pollen taxon richness was therefore estimated using the computer program RAREPOLL developed by J.M. Line (Birks *et al.* 1986, Birks and Line 1992). The rarefaction program estimates the numbers of pollen taxa (E(T)), which would have been found in all the samples if their pollen sums had been equal to that of the smallest count, and 95% confidence intervals for the estimate. Taxon richness was estimated for the whole section based on the counts of land plant pollen (excluding ambiguous plants, wet ground plants and aquatics, lowest pollen sum 153), and for the gyttja samples separately (below 2.94 m depth). The ambiguous and the wet-ground plants were included in the counts for the gyttja samples. The lowest pollen sum was 484 (the two lowermost samples were excluded because of low pollen sums). A similar pollen sum was used for rarefaction analysis in Andersen and Rasmussen (1993, lowest count 2015 grains).

Pollen diversity and species diversity are generally correlated (Odgaard 1989, 1992a) and are sensitive to vegetation disturbance (discussion in Andersen and Rasmussen 1993).

Radiocarbon dating

Radiocarbon datings were performed at the C-14 Dating Laboratory of the National Museum and the Geological Survey of Denmark, using standard methods (Andersen and Rasmussen 1993). The datings were supervised by H. Tauber, K.L. Rasmussen and U. Rahbek. Coarse and fine fractions (>0.07 and <0.07 mm) were separated by wet sieving and were dated independently in peat samples. Alkali-soluble and -insoluble fractions were dated in one case and average dates were calculated (see below), the dates of gyttja samples are bulk datings. Two dates, at 5.01-5.11 m and 5.94-6.04 m depth, were based on the alkali-soluble humus fraction (Andersen and Rasmussen 1993). Dates at 3.82 and 4.42 m were obtained from Andersen and Rasmussen (1993).

The radiocarbon dates were calibrated into calendar years utilizing the CALIB ver 3.03 ^{14}C age calibration program (Stuiver and Reimer 1993), which is based on the atmospheric curves in Linick *et al* 1986, Kromer and Becker 1993, Pearson and Stuiver 1993, Pearson *et al* 1993 and Stuiver and Pearson 1993.

The calibrations were based on moving averages corresponding to the age span of each sample. Midpoints were calculated as the geometric average of the two outer bounds of the calibrated age ± 1 standard deviation in cases where more than one intercept was obtained by the calibration program (cf. Andersen and Rasmussen 1993). A reservoir effect of 120 years was assumed for the gyttja sample ages except for the two humus samples, which were assumed to be of terrestrial origin (Andersen and Rasmussen 1993).

A smoothed depth/age curve for series 1 and 2 in combination was calculated by B.V. Odgaard as a least square spline utilizing the SAS procedure TRANSREG transcribed by B.V. Odgaard. Two dates (at 1.70 m and 2.91 m) were rejected as they were far outside the 2 standard deviation boundaries. The five uppermost dates were used as fixed points. Dates for the following levels were estimated: 0.01 m, AD 1940 (beginning of peat digging), 0.06 m, AD 1900 (reforestation), 8.58 m, 9100 BC (juniper maximum, Fredskild 1979). The dates below 8.58 m were extrapolated assuming a constant deposition rate. The spline curve was used for conversion of depth to calendar years in the pollen diagrams.

RESULTS

Sediments

The sediments in series 1 and 2 are described in Table 1. Mineral content is indicated by figures for ash content in percentage of dry weight. 90% ash content may correspond approximately to 50% of the volume (An-

Series 1	
0.00-0.01 m	Litter
0.01-0.35 m	Decomposed swamp peat (*Turfa herbacea*$^{2\text{-}3}$). Colour reddish-brown. Many fresh rootlets. Ash content 20-50 %.
0.35-1.95 m	Decomposed swamp peat (*Turfa herbacea*$^{2\text{-}3}$). Colour reddish-brown. Ash content 10-20 %.
1.95-2.81 m	Somewhat decomposed swamp peat (*Turfa herbacea*^{2}). Colour reddish-brown. Ash content 10%.
2.81-2.94 m	Slightly decomposed swamp peat (*Turfa herbacea*^{1}). Colour reddish-brown. Ash content 10%. The lower limit was sharp, slightly oblique.
2.94-3.61 m	Fine-detritus gyttja. Colour yellow-brown. Ash content 20-30 %.
3.61-4.50 m	Fine-detritus gyttja. Colour reddish-brown. Ash content 20-35 %.
4.50-7.34 m	Fine-detritus gyttja. Colour reddish-brown. Ash content 15-30 %.
7.34-8.20 m	Fine-detritus gyttja. Colour reddish-brown. Ash content 20-50 %. The lower limit was sharp, some what uneven.
8.20-8.23 m	Clay-gyttja. Colour greenish-grey. Ash content 50- 90 %.
8.23-8.26 m	Clay. Colour greenish-grey. Ash content 95 %. Several small pebbles occurred.
Series 2	
3.40-4.05 m	Gyttja. Colour reddish-brown. Ash content 15-50 %.
4.05-4.23 m	Clay-gyttja. Colour greenish-brown. Ash content 20 -80 %.
4.23-4.55 m	Clay-gyttja. Colour greenish-grey. Ash content 90- 95 %.

Table 1. Description of sediments. The indices for *Turfa herbacea* indicate humification according to Troels-Smith (1955).

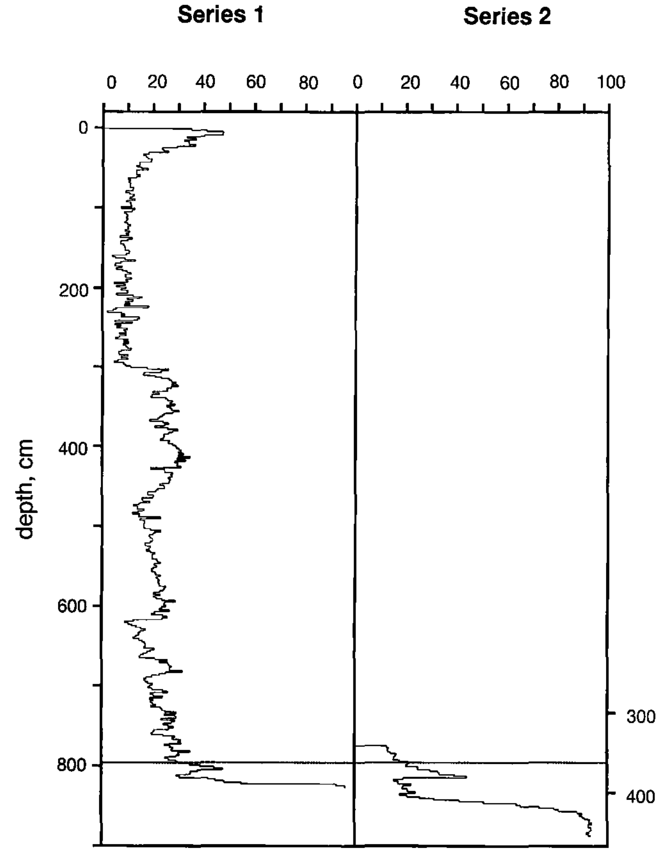

Fig. 4. Curves for ash content (percent of dry weight) in the two sample series from Hassing Huse Mose.

dersen 1984). The transition from gyttja to swamp peat at 2.94 m in series 1 marks the *Verlandung* of the former lake. The *Verlandung* was rather abrupt and was probably caused by a lowering of the water level. The decreased ash content above 8.23 m in series 1 and above 4.23 m in series 2 marks the beginning of the Holocene.

Variations in ash content are shown in detail in Fig. 4. The ash content is likely to be influenced by external factors such as soil and shore erosion and internal conditions such as productivity and decomposition of organic matter. Changes in ash content are, therefore, difficult to interpret.

The high ash content (above 90%) below 8.23 m in series 1 and 4.23 m in series 2 indicates high erosion and low organic productivity in the lake. The abrupt decrease in ash content above these levels (to 30 and 20%) is probably due to stabilization of the vegetation cover and an increase in organic productivity at the beginning of the Holocene. A temporary re-increase of ash content (to 48 and 45%) is evident in both series (at 8.02 and 3.80 m depth). The significance of this event is uncertain. The ash content decreases up through the gyttja series (to around 15%), with some irregularities, and increases again above 4.80 m depth (up to around 35%). Peaks of the ash content at these levels coincide with elm decline phases and may be due to increased erosion in connection with vegetational disturbance (Andersen and Rasmussen, 1993).

The ash content decreases abruptly at the transition to the swamp peat (at 2.94 m depth), and is low (around 10%) up through the peat. The ash content increases from 0.63 m depth up to 48% near the surface.

Correlation of section 1 and 2

The onset of sedimentation of organic matter in a small lake may vary considerably, as the oldest sediments may occur near the leeward side of the basin (Odgaard

	Depth ser. 1	Diff.	Depth ser. 2	Diff.	Diff. ser. 1-2
Hazel 70%	7.96 m		3.62 m		4.34 m
Ash content, peak	8.02 m	0.06 m	3.80 m	0.18 m	4.22 m
Ash content 90%	8.22 m	0.20 m	4.26 m	0.46 m	3.96 m

Table 2 Correlation of characteristic events in series 1 and series 2.

	Coarse fraction		Fine fraction	
	y B.P.	st.d.	y B.P.	st.d.
Insoluble	3450	125	3200	85
Soluble	3470	80	3220	80

Table 3. Radiocarbon dates for alkali-insoluble and -soluble fractions of a peat sample (0.97-1.93 m).

1993). Series 1 at the centre of Hassing Huse Mose was, therefore, supplemented with series 2 near the west margin.

The two sections were correlated by pollen analysis and by the variations in ash content. A decrease in herb pollen and a birch and a hazel maximum could be recognized in both series, and the ash curves are closely correlated (Fig. 4). Depth levels for characteristic events are compared in Table 2. The thickness of corresponding sediments are 2-3 times larger in section 2 than in section 1, and the difference in corresponding levels increases from 3.96 to 4.34 m. These differences indicate sediment focusing in the shallow leeward part of the basin in the early Holocene as found also by Odgaard (1993). Pollen spectra and radiocarbon dates from section 2 from level 3.62 m downward were used in the joined diagrams due to the higher time resolution. 4.34 m were added to these depth levels.

Radiocarbon dating of peat samples

Radiocarbon dates of peat samples may be younger than expected due to infiltration with humus and penetration of rootlets from above. Alkali-soluble and insoluble fractions were dated separately for one sample (Table 3), and coarse fractions (>0.07 mm) and fine fractions (<0.07 mm) were dated and compared (Table 4). The ages of the soluble and insoluble fractions in Table 3 are identical. Infiltrated humus, therefore, is unlikely to affect the datings. The age difference between coarse and fine fractions is very large (–400 and +1270 years) in two cases (0.15-0.21 m and 2.37-2.41 m). The former sample contained many modern rootlets (Table 1). The young date for the coarse fraction was therefore rejected, and only the fine-fraction date was accepted for this sample. The very old date for the coarse fraction in the other sample (5390 B.P.) must be due to an unknown error. This dating was also rejected, and only the fine-fraction date accepted. The difference between coarse and fine fractions is insignificant

	Depth	Coarse fraction			Fine fraction		Diff.	Weighted av.	
m	W,g	y B.P	st.d.	W,g	y B.P.	st.d.	y	y B.P.	st.d.
0.15-0.21	4.34	520[1]	80	27.32	960	65	–440	–	
0.23-0.27	3.85	1610	80	12.17	1340	70	+270	1400	70
0.37-0.51	4.35	1840	65	11.58	2050	75	–210	1990	70
0.51-0.65	4.90	2760	80	14.50	2770	75	-10	2770	75
0.97-1.03	12.23	3460	75	27.73	3210	60	+250	3300	65
1.27-1.31	9.27	3650	80	15.86	3600	80	+50	3620	80
2.33-2.37	6.50	3990	80	7.80	4030	75	–40	4010	75
2.37-2.41	8.18	5390[1]	70	9.01	4120	85	+1270	-	
2.57-2.61	7.24	4150	80	12.75	4140	85	+10	4140	85
2.89-2.93	9.85	4240	85	11.12	4030	85	+210	4130	85

[1] date rejected

Table 4. Radiocarbon dates for coarse fractions (>0.07 mm) and fine fractions (<0.07 mm) of peat samples, W = dry weight.

in four other samples, and the coarse fraction is older than the fine fraction in three samples and younger in one sample. It was concluded that penetration of younger rootlets from above affected only the topmost dating. Bulk samples dates were calculated for the other samples, making allowance for differences in weight of the two fractions.

Sedimentation rates

The calibrated radiocarbon dates and three estimated dates were used for computation of the spline curve in Fig. 5. This curve is based on dates from section 2 below 8 m and from section 1 above 8 m depth. The sedimentation rate was low in section 2 at 8.14-8.60 m depth (1970 years/m) and increased at 7.96-8.14 m (870 years/m). The corresponding rates were lower at section 1 (4525 years/m and 2610 years/m) due to sediment focusing at section 2 nearer the west shore. The sedimentation rate increased at 8-3 m depth in section 1 (900 years/m). This figure is similar to the figure calculated for a shorter depth interval by Andersen and Rasmussen (1993, 970 years/m, 3.06-6.41 m). Small variations in sedimentation rate such as those found by Andersen and Rasmussen (1993) may occur. The sedimentation rate increased somewhat at 1.3-3.1 m (730 years/m) and decreased strongly above 1 m depth (5380 years/m at 0.06-0.58 m). This decrease in sedimentation rate (x7.4) is rather similar to the increase in ash content above 0.63 m (x5). Hence, the increase in ash content may be explained by increased decomposition of organic matter.

Wild-grass and cereal pollen

The identification of species in the grass family is difficult. Only one species, rye, can be identified with certainty because of its characteristic shape. Other species have identical or overlapping size ranges, which hamper the identification of individual pollen grains. Three main groups can be distinguished, wild grasses with small pollen and pore *annulus*, the barley group with large size and *annulus*, and scabrate sculpture, and the oat-wheat group with large grains and *annulus*, and verrucate sculpture. The barley group includes some wild grasses (Andersen 1979). Due to overlapping size ranges, these groups must be distinguished by size statistics (cf. Andersen 1988).

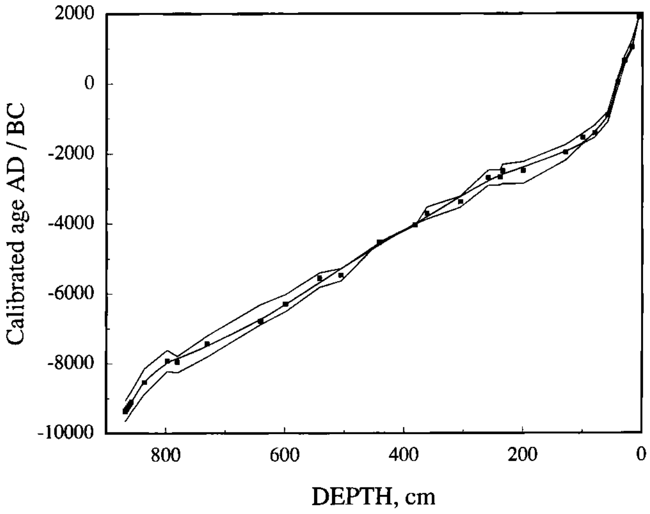

Fig. 5. Age determinations from Hassing Huse Mose used for calculation of a smoothed depth/age curve. The outer bounds for two standard deviations are indicated.

In Hassing Huse Mose, the pollen dimensions are likely to be nearly the same as the figures stated in Andersen (1979). However, the variations in pollen size (the average of the largest and the smallest diameters in each grain) were modified by the fact that nearly all grass pollen grains were more or less strongly crumpled. The average size of crumpled grains may be near that of inflated grains (Andersen 1979) or may have decreased. The *annulus* diameter, in contrast, is rarely modified. The identifications were therefore, based on *annulus* and size measurements, and observations of sculpture type, in combination.

The diameter of the pore *annulus* was smaller than 6.4 μm in 86% of the pollen grains from the grass family. These pollen grains almost certainly belong to wild grasses, as pollen grains with *annulus* smaller than 6.6 μm are very scarce in the cultivated species (Andersen 1979).

Scabrate pollen grains with *annulus* diameter 6.9 μm were mainly 15.0-32.8 μm in size (Fig. 6). Pollen grains of this size range are frequent in wild grasses. The pollen grains 33.4-43.7 μm in size were referred to barley-type, as pollen grains with similar *annulus* size (7.2 μm) are frequent in barley (size range ± 2 standard deviations 33.2-41.4 μm) and other species in the barley group. Scabrate grains with size range 27.6-44.9 μm predominate in grains with *annulus* diameter 8.1 μm, and grains with larger *annulus* (9.25-11.5 μm) vary 26.4-44.9

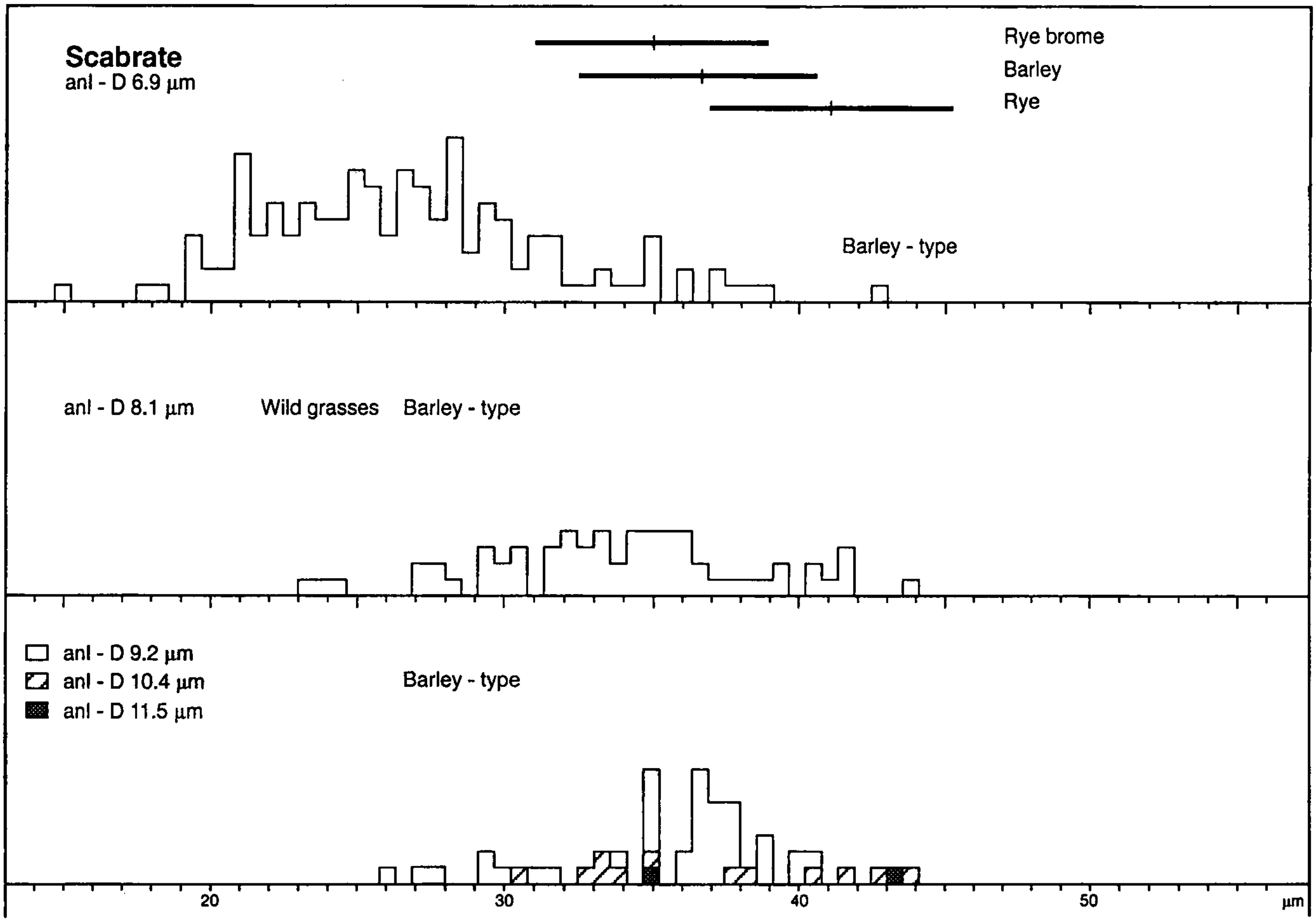

Fig. 6. Average diameters (largest + smallest diameter/2) of pollen grains from the grass family with scabrate sculpture, and *annulus* diameters 6.7-11.5 µm, from Hassing Huse Mose. Mean size (±2 standard deviations) for modern species are indicated.

µm in size. These pollen grains were also referred to the barley-type. Some of them are very small due to shrinking.

Rye-brome, which was cultivated in prehistoric time (Knörzer 1967, Jensen 1985), and the weed *Bromus hordeaceous,* have large pollen grains with somewhat smaller *annulus* than barley (7.64 and 7.55 µm). Pollen grains with *annulus* 7.2 µm predominate in these species, whereas grains with similar *annulus* (6.9 µm) are scarce in the barley-type pollen from Hassing Huse Mose (Fig. 7). The brome species were, therefore, scarce there, if present at all. Pollen of millet with a large *annulus* (8 µm) and small size could not be identified. The pollen grains of einkorn, the weed couch grass, the sea-shore species lyme grass and marram grass, and the aquatic float grass, are similar to those of barley. Pollen of einkorn and the sea-shore plants were probably scarce at Hassing Huse Mose. Couch grass may have occurred as a weed, and a few pollen grains typical of float grass were noticed. Some pollen grains of couch grass and float grass may therefore be included in the barley-type. The barley-type may also include crumpled pollen of rye. No inflated pollen grains of rye were seen.

The average *annulus* diameter of 129 grains of barley-type is 8.50 µm and is slightly larger than that of barley (8.23 µm). Pollen grains with *annulus* diameter 6.9 µm are scarcer than pollen of this size class in barley (7.2 µm, Fig. 7). The lower size limit for grains with a large *annulus* (9.2-11.5 µm) is 26.4 µm. These grains almost certainly belong to barley-type. Barley-type pollen with small *annulus* (6.9 µm) and size-range 26.4-32.2 µm may therefore have been missed, whereas pollen of rye and float grass with larger *annulus* diameter (8.93 and 9.55 µm) may be included in the barley-type pollen.

In conclusion, the barley-type pollen in Hassing Huse Mose is likely to derive mainly from barley, but a few pollen grains of rye-brome, couch grass, float grass and rye may have been included.

Verrucate pollen grains from Hassing Huse Mose with *annulus* diameter 6.9 and 8.1 μm and size ranges 17.3-38.5 μm (Fig. 8) fall within the variations of the pollen of wild grasses with verrucate sculpture. The largest of these species is meadow oat (*annulus* 7.55 μm, size range 29.6-41.7 μm). One pollen grain with *annulus* 8.1 μm and average size 44.9 μm was referred to oat-type. Pollen grains with *annulus* 9,6 μm are very scarce in meadow oat (Fig. 7). The verrucate grains with *annulus* 9.2 μm were therefore included in the oat-type. The size range is 24.2-50.6 μm. A few of these grains may belong to meadow oat or some other wild grass. The grains with *annulus* 10.4-12.7 μm belong to the oat-type. The size range is 33.4-49.5 μm, and is within the range of oat and wheat species.

The average *annulus* diameter of 50 pollen grains included in the oat-type is 9.96 μm, and slightly smaller than that of oat (10.72 μm). Grains with *annulus* diameter 9.2 μm are somewhat more frequent than grains with similar *annulus* in oat (9.6 μm, Fig. 7). Some wild grass pollen may, therefore, have been included. The average annulus diameter in bread wheat (11.88 μm) is larger than in the pollen grains referred to oat type and grains with *annulus* diameter 12.7 and 13.8 μm are considerably scarcer than in bread wheat. The pollen grains of oat-type are therefore likely to belong mainly to oat, and pollen grains of bread wheat and other wheat species with still larger *annulus* are very scarce.

Andersen and Rasmussen (1993) mentioned two pollen grains of wheat-type (*annulus* diameters 10 μm) at 3.68 and 5.14 μm depth (3870 and 5370 BC).

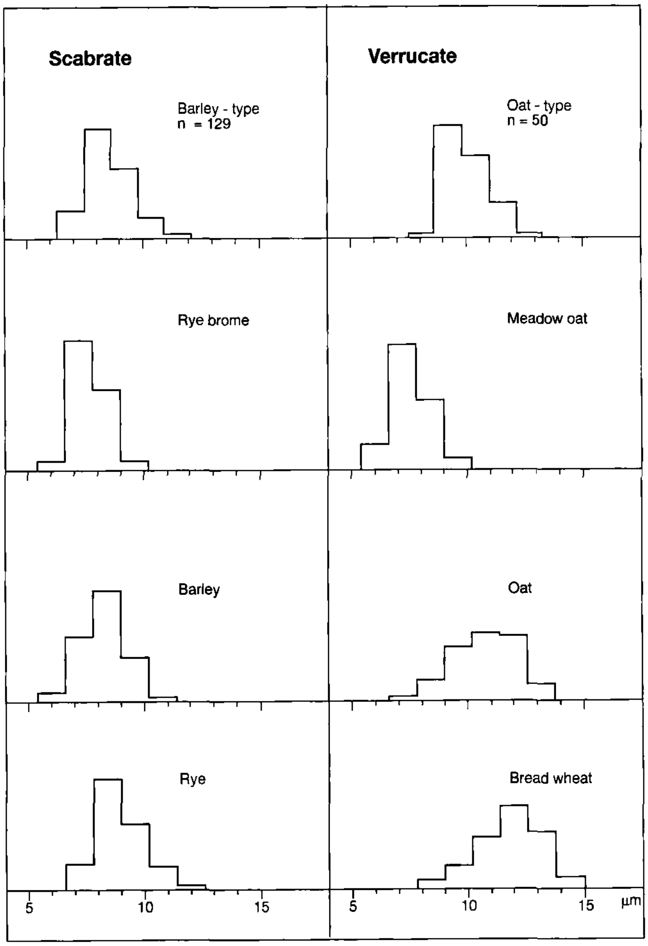

Fig. 7. Variations in *annulus* diameter in pollen grains determined to barley-type and oat-type and in modern species.

Vegetation history. Local vegetation

The pollen diagrams were divided into 13 pollen zones named by characteristic features. 8 zone borders were found by the CONISS program, the others by characteristic changes in the pollen diagram (alder/hazel-birch zones, hazel-birch/hazel zones, herbs 1/herbs 2 zones, herbs 2/herbs 3 zones). The oldest pollen zone is from the Weichselian (late-glacial). The other zones represent the Holocene up to the present day. The Holocene series began at 9080 B.C.

The pollen diagram Fig. 9 shows a survey of land plants, other plant groups, *algae* and charcoal dust. The correlation with cultural periods is shown.

The curves for ambiguous plants, wet-ground plants, aquatics and *algae* are strongly influenced by the change (at 3100 B.C.) from a lake with scarce local vegetation to a swamp with a high local pollen production. Ambiguous and wet-ground plants are frequent in the late-glacial and occur scatteredly up through the gyttja deposit. These plants were most likely members of dry-land or wet-ground vegetation around the lake. Aquatics are frequent in the birch-pine pollen zone and increase again in the uppermost part of the gyttja (white water-lily, pondweed, water crowfoot). Their decrease in the hazel-elm pollen zone was probably due to increased water depth. The increase in the alder pollen zone and again in the hazel pollen zone indicates

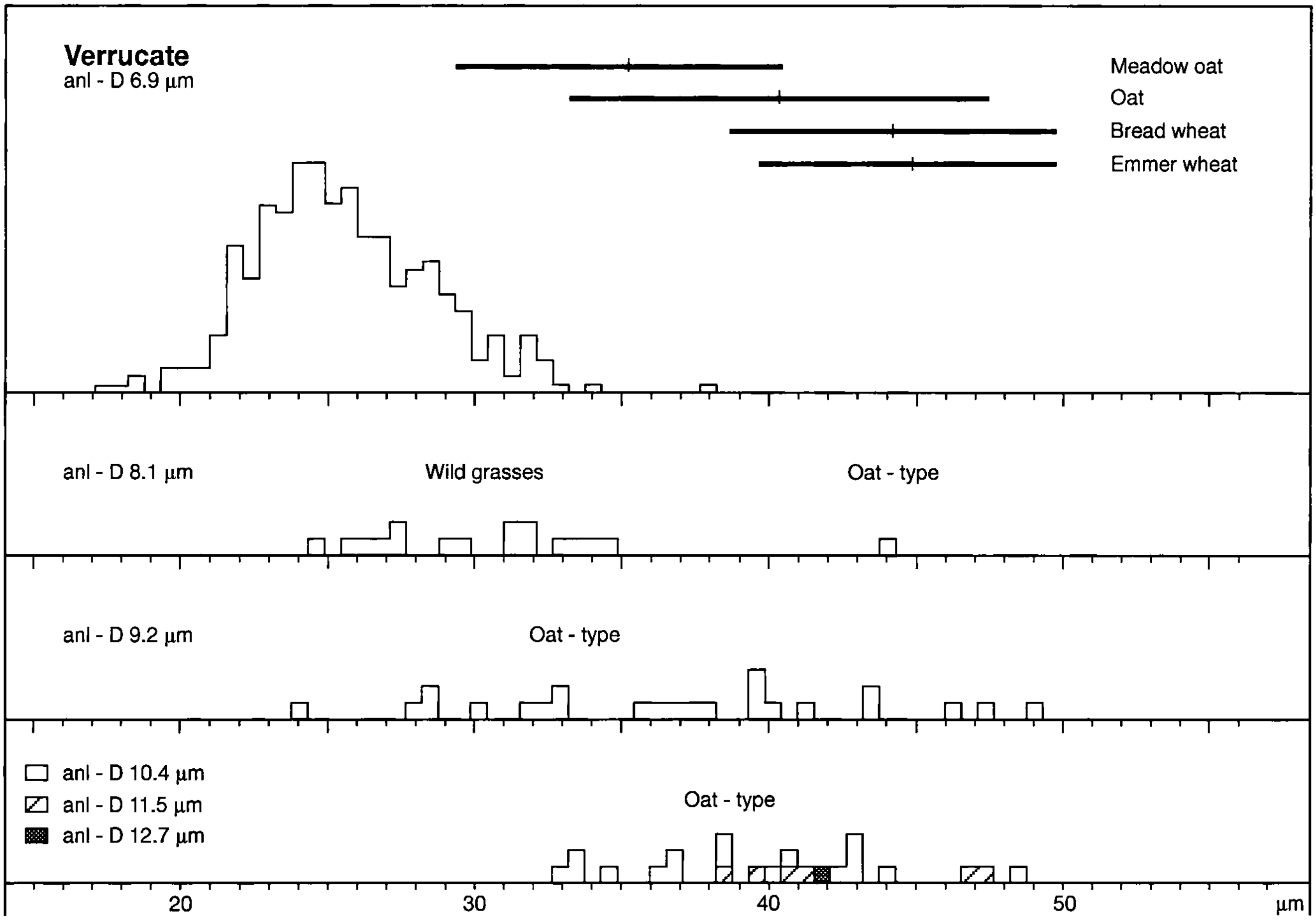

Fig. 8. Average diameters of pollen grains from the grass family with verrucate sculpture and *annulus* diameters 6.9-12.7 µm. Mean size and size ranges for modern species are indicated.

changes to lower water depth probably because of lowering of the water level, or infilling of the basin with sediment. The ash content is high at these levels (above 4.80 m depth, Fig. 4). Masses of algae (*Pediastrum*) occurred in the topmost part of the gyttja (not recorded).

Wet-ground plants (sedges, ferns and cat's tail) are particularly frequent in samples from the lowermost part of the swamp peat. Other local plants (bog myrtle, heather, bilberry, willow, meadow sweet, cinquefoil) are very frequent in the upper part of the swamp peat (above 0.46 m, 220 B.C.). Wet-ground heath vegetation apparently developed in the swamp, probably due to oligotrophication. Heather pollen was scarce (below 5%) up to that time. Aquatic plants (water violet, pondweed, water crowfoot, bladderwort) and *algae* re-appear in the upper part of the swamp peat (after 1100 B.C.) and indicate the presence of shallow pools with neutral or slightly acid water (species of water milfoil). The increase in aquatic plants coincides with the increase of organic matter and decrease in sedimentation rate (above 0.50 m depth) due to increased decomposition of organic matter.

Land vegetation development

Pollen curves for land plants are shown in Fig. 10 A-C and corrected tree pollen percentages in Fig. 11. The tree pollen percentages are likely to be strongly influenced by pollen transported over a long distance at times with a scarce tree cover.

1. Herb pollen zone, around 9075-9360 B.C. Tree pollen is scarce (about 40%). About one half of the tree pollen is pine pollen, which is likely to be transported from a far distance. Tree cover was therefore very scarce. A maximum for juniper at the top of the zone is characteristic of the transition from the Younger Dryas to the Holocene. Pollen from grasses and herbs such as mugwort, sheep's sorrel and the goosefoot family are frequent. Plants included in the wet-ground group (crowberry, sedges) were also common.

2. *Birch-pine pollen zone, around 8295-9075 B.C.* Tree pollen increases strongly (74 to 95%) indicating invasion by forest. Birch is dominant (73%) at first, pine increases to a maximum (25%) near the end of the zone, and aspen increases too. Hazel appears and increases to 25% near the end of the zone, and elm appears. Grasses and open-ground herbs decrease and oak fern is common, indicating stabilized forest. Some wet-ground plants (willow, meadow sweet) were common. Pollen of heather is scarce up through the gyttja series and indicates presence of a few acid-type sites.

3. *Hazel-elm pollen zone, around 6975-8295 B.C.* Tree pol-

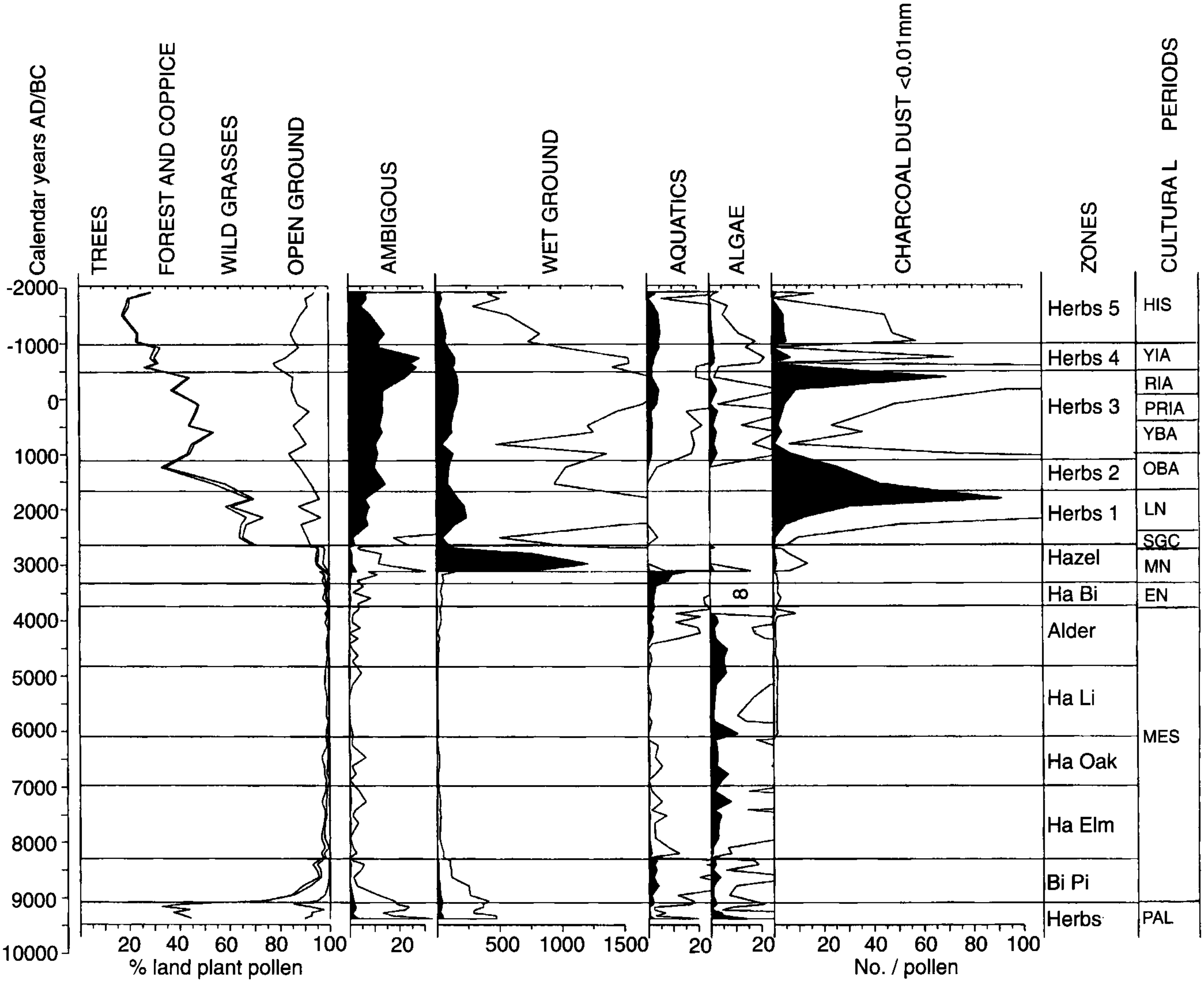

Fig. 9. Hassing Huse Mose. Percentages for plant groups included in the land plants (survey diagram), plant groups excluded from the land plants (black silhouettes, white silhouettes x10), for algae, and the frequencies of charcoal dust particles larger than 0,01 mm, (charcoal dust was not recorded in samples older than 6000 B.C.). Cultural periods are indicated (from Hvass and Storgaard 1993). HIS, Historic time, YIA, Late Iron Age, RIA, Roman Iron Age, PRIA, Pre-Roman Iron Age, YBA, Late Bronze Age, OBA, Early Bronze Age, LN, Late Neolithic, SGC, Single Grave Culture, MN, Middle Neolithic Funnel Beaker Culture, EN, Early Neolithic Funnel Beaker Culture, MES, Mesolithic, PAL, Palaeolithic.

len is frequent (96-98%) indicating a dense tree cover. Birch and pine decrease (to 15 and 5%). Hazel increases at the lower zone border (to 75%) and then decreases in the upper part of the zone (to 58%). Elm increases strongly from the middle part of the zone (to 12%, 22% corrected), and oak and alder pollen appear. Rowan and guelder rose are present, and so are grasses, mugwort, sheep's sorrel and the goosefoot family.

4. Hazel-oak pollen zone, around 6090-6975 B.C. Tree pollen is very frequent (97-99%). Oak increases (to 14%) and alder increases at the lower zone border (to 24%). Elm increases slightly (to 16%, 26% corrected) and lime is present. Hazel decreases continually (53 to 48%), and birch and pine decrease to low frequencies (4 and 1%). Hence, the tree communities became richer in species at the cost of hazel, birch and pine. Grasses, mugwort and sheep's sorrel are represented.

5. Hazel-lime pollen zone, around 4830-6090 B.C. Tree pollen is very high (98-100%). Lime increases abruptly at the lower zone border (to 12%, 47% corrected) and remains high throughout the zone. Hazel decreases (to 29%, 13% corrected), elm decreases somewhat (12%, 15% corrected), and alder is about 30% (20% corrected). The appearance of bracken and polypody indicate presence of an acid humus layer. Ivy and mistletoe are present, and so are a few pollen grains of grasses, mugwort and the goosefoot family. Andersen and Rasmussen (1993) recorded a pollen grain of wheat-type.

6. Alder pollen zone, around 3740-4830 B.C. Alder increases at the lower zone border and remains high throughout the zone (about 40%, 25% corrected) at the cost of hazel in particular (about 20%, 10% corrected). This increase in alder coincides with an increase of the aquatic plants (Fig. 9) and might reflect a lowering of the water level. An increase in ash (to 1%, 5 % corrected) could have the same cause. Lime remains high (10%, 40% corrected). The elm curve increases somewhat at the lower zone border (to 17%). The elm curve then decreases and re-increases twice. These two elm declines precede the classical elm decline at about 3800 B.C. They coincide with slight maxima for hazel. The elm declines were examined in detail by Andersen and Rasmussen (1993), who found, that the elm declines coincided with evidence of disturbance, probably by human activity. This disturbance is not clearly reflected in the present pollen diagram due to the lower pollen counts.

7. Hazel-birch pollen zone, around 3320-3740 B.C. Early Neolithic Funnel Beaker Culture. The lower zone border was placed at the classical elm decline, which began at 3790 B.C. The elm curve declines from 9 to 1% and then increases slightly, to 4%. The lime curve decreases slightly later than the elm curve (from 6 to 3%, 32 to 26 % corrected). The elm decline is followed by a maximum for birch (11%) and then an increase in hazel. Grasses, mugwort, sheep's sorrel, ribwort and barley-type are represented. This development was discussed by Andersen and Rasmussen (1993), who concluded that the features mentioned mark the transition to the Early Neolithic (with swidden cultivation of birch coppices and pasture, *cf.* Andersen 1992a). Disappearance of ivy may be due to human pursuance (Troels-Smith 1960).

8. Hazel pollen zone, around 2640-3320 B.C. Middle Neolithic Funnel Beaker Culture. The lower zone border was placed at a decrease in birch and elm and an increase in hazel. Tree pollen decreases somewhat in the zone (97 to 91%). Birch decreases (to 5%) and then increases near the end of the zone (to 20%), and elm decreases (to 1%). Hazel increases (to 51%, 47% corrected) alder decreases (to 15%, 10% corrected) and lime is low (around 5%, 15-30% corrected). Grasses, mugwort, sheep's sorrel and ribwort increase. Andersen and Rasmussen (1993) concluded that hazel coppices were used increasingly for swidden cultivation and pasture, a procedure which was typical of the Middle Neolithic Funnel Beaker Culture (Andersen 1992a). The *Verlandung* of the former lake took place in this pollen zone.

9. Herbs 1 pollen zone, around 1650-2640 B.C. Single Grave Culture and Late Neolithic. The lower zone border is distinguished by a sudden decrease of the tree pollen. The tree pollen decreased from 91 to 69% (22%) over only 30 years. This sudden deforestation marks a very radical change in land-use. The tree pollen percentages remain low up through the pollen zone (59-69%). The tree pollen curves also change radically. Hazel decreases strongly (51 to 5%, 47-5%, corrected), and birch and alder decrease in the upper part of the zone. There is a maximum for oak in the middle part, and pine and ash increase in the upper part. Local populations of hazel, birch and alder were probably cut away, and there was probably increased influence from more distant populations of pine and oak. Bracken and polypody indicate remains of woodlands or coppices. Grasses and open-ground herbs such as mugwort, sheep's sorrel, the goosefoot family and ribwort increase conspi-

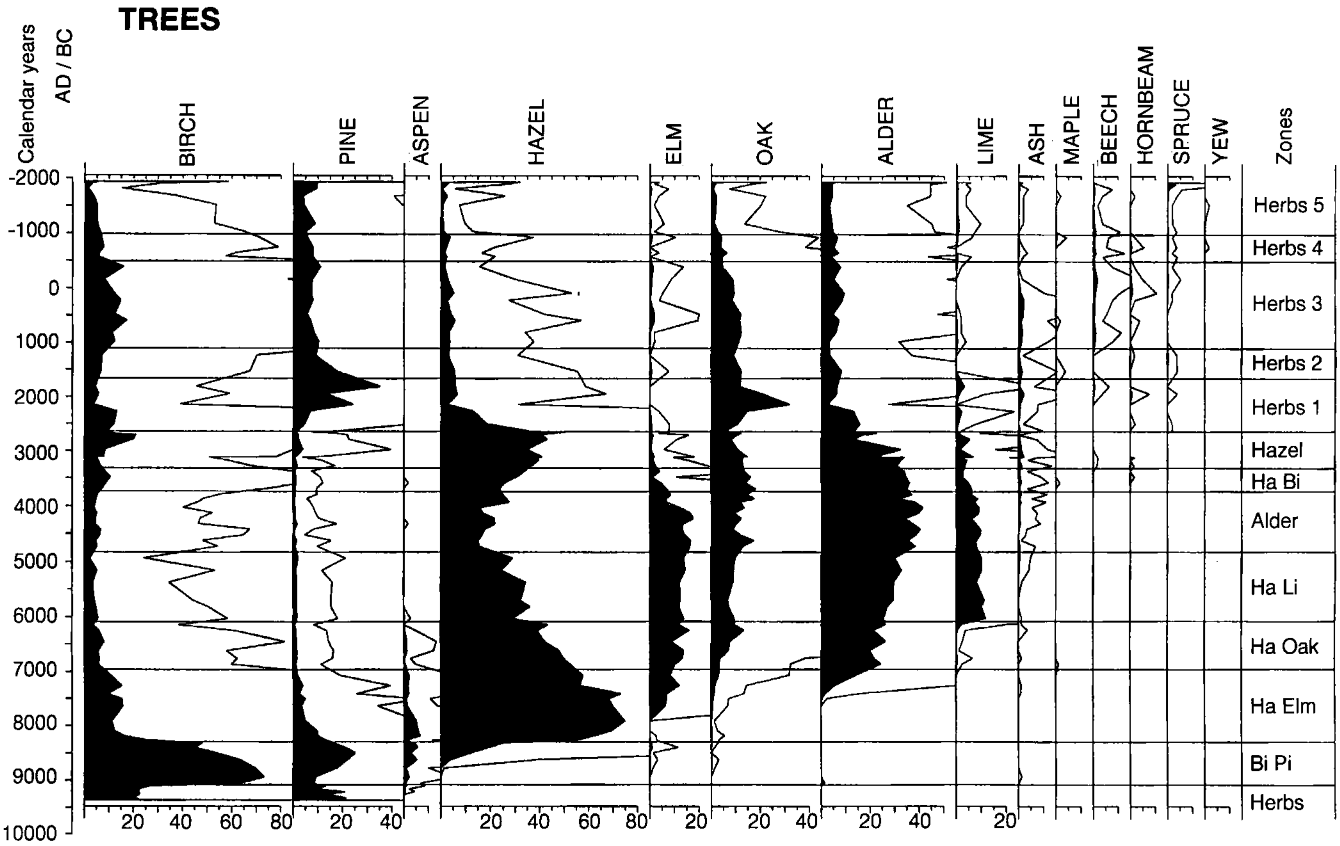

Fig. 10 A. Percentages for land plants in percent of the land plant total (black silhouettes, white silhouettes x10).

cuously, the number of open-ground plants increases, and barley-type pollen is common. The cleared areas apparently were used for pasture and field cultivation. A number of plants classified as ambiguous increase at this level (bedstraw-type, lingulate composites, milfoil-type, groundsel-type) and could have been part of the land vegetation. There is a very conspicuous maximum for charcoal dust in the upper part of the pollen zone (Fig. 9). It is difficult to say whether the charcoal derived from local or distant fires.

10. Herbs 2 pollen zone, around 1105-1650 B.C. Early Bronze Age. The lower zone border is placed at the beginning of a new decrease in tree pollen. The tree pollen decreases up through the pollen zone (69 to 33%). This decrease indicates renewed deforestation. All tree pollen curves are low. Birch increases somewhat in importance and pine and oak pollen is still important. Oak fern and bracken indicate presence of coppices. Grasses increase strongly (26 to 54%), plants from open ground increase somewhat (sheep's sorrel, goosefoot family, ribwort), and new species appear. Increased grazing pressure or field cultivation are indicated. The very high peak in grass pollen is not clearly reflected by the open-ground plants and might be due to overrepresentation of locally derived pollen.

11. Herbs 3 pollen zone, around A.D. 485-1105 B.C. Late Bronze Age, Pre-Roman and Roman Iron Age. The lower zone border is placed at an increase in tree pollen (33 to 44%). This increase is mainly due to a decrease in grass pollen, and is not clearly reflected by the curve for open-ground plants. The trees decrease slightly up through the pollen zone. Birch and oak are important, and ash increases (up to 28%, corrected). There is now a continuous curve for beech pollen (up to 1%). Mugwort, the goosefoot family and ribwort are frequent. Pollen of oat-type is present. Barley-type and sheep's sorrel increase (especially from around 500 B.C.), and knotgrass is common. These features indicate continued grazing and increased importance of cereal growing particularly in the Iron Age. Oat was introduced in

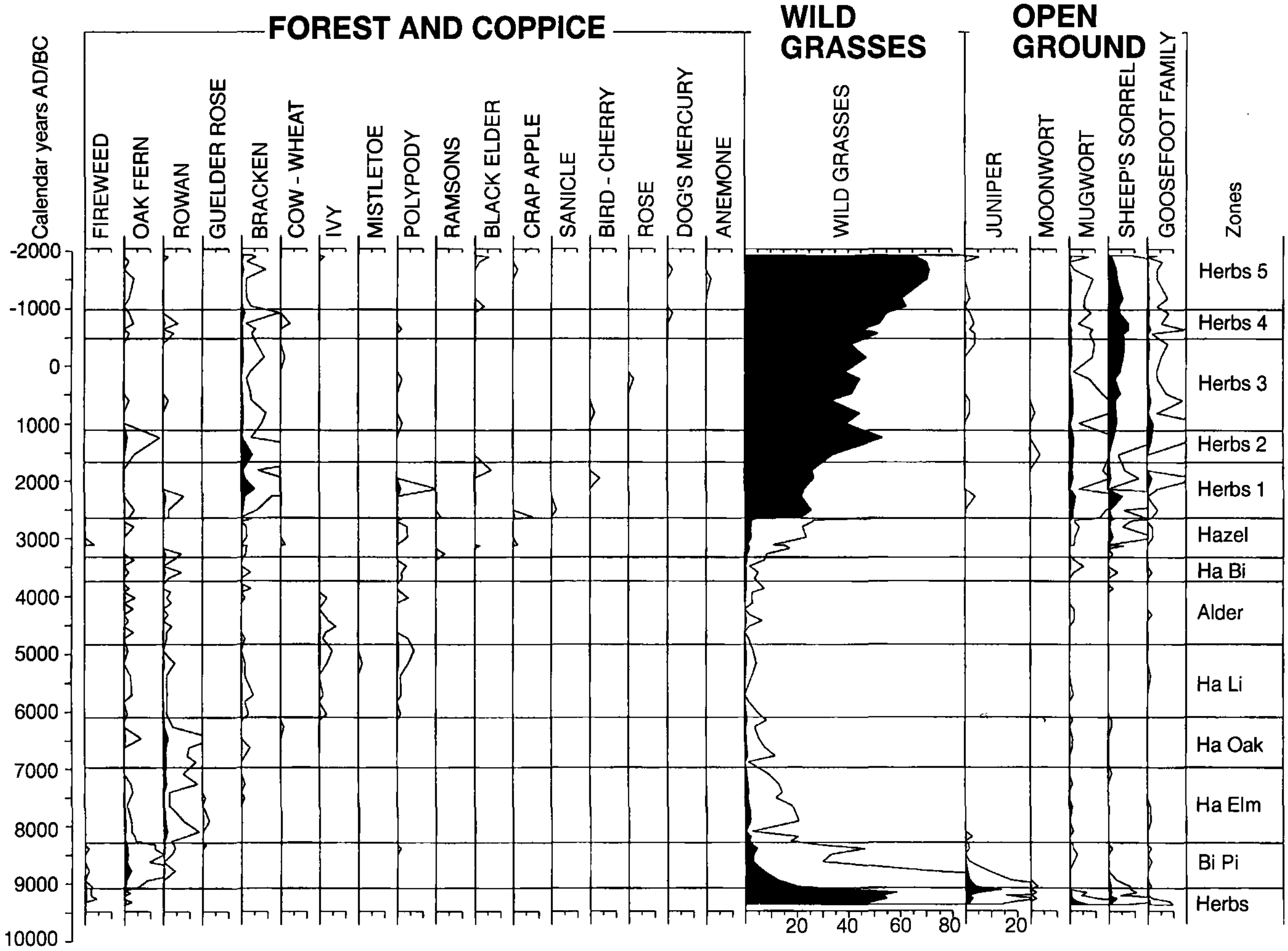

Fig. 10 B. Percentages for land plants in percent of the land plant total (black silhouettes, white silhouettes x10).

the Late Bronze Age (Jensen 1985, Rowley-Conwy 1984). A maximum for charcoal dust in the uppermost part of the zone is difficult to explain.

12. Herbs 4 pollen zone, around A.D. 485-985. Late Iron Age. The lower zone border coincides with a marked decrease in tree pollen (44 to 26%). Renewed forest clearance is indicated. All the tree species decrease in importance, birch and oak in particular. The grasses and sheep's sorrel increase, and there are many new additions to the flora of open-ground plants. Hence increased agricultural activity is indicated.

13. Herbs 5 pollen zone, around A.D 985-1940. Historical time. Trees decrease at the lower zone border (31 to 23%) and decrease further between A.D. 1185 and 1520 (24 to 17%), the trees increase again after A.D. 1815 (20 to 29%). No woodlands were present in Thy in the 19th century (Ødum 1986). The tree pollen present must therefore have derived mainly by far distance transportation. Increased frequencies of pollen of lime (up to 22% corrected) probably reflect planting around villages and manors. Establishment of plantations in the late 19th and the 20th century is reflected by the increase in the tree pollen, first pine, and then spruce and birch. Mountain pine was planted extensively in the sand dune areas in western Thy from around 1885 and spruce in the 20th century. The grasses increase conspicuously (55-71%). Barley-type and oat-type pollen is frequent, and sheep's sorrel decreases somewhat. This decrease may be due to improved methods to suppress weeds (the wheel plow). Grazing and cultivation of barley and oat were important, whereas cultivation of rye cannot be demonstrated. Increase in rye is usually fol-

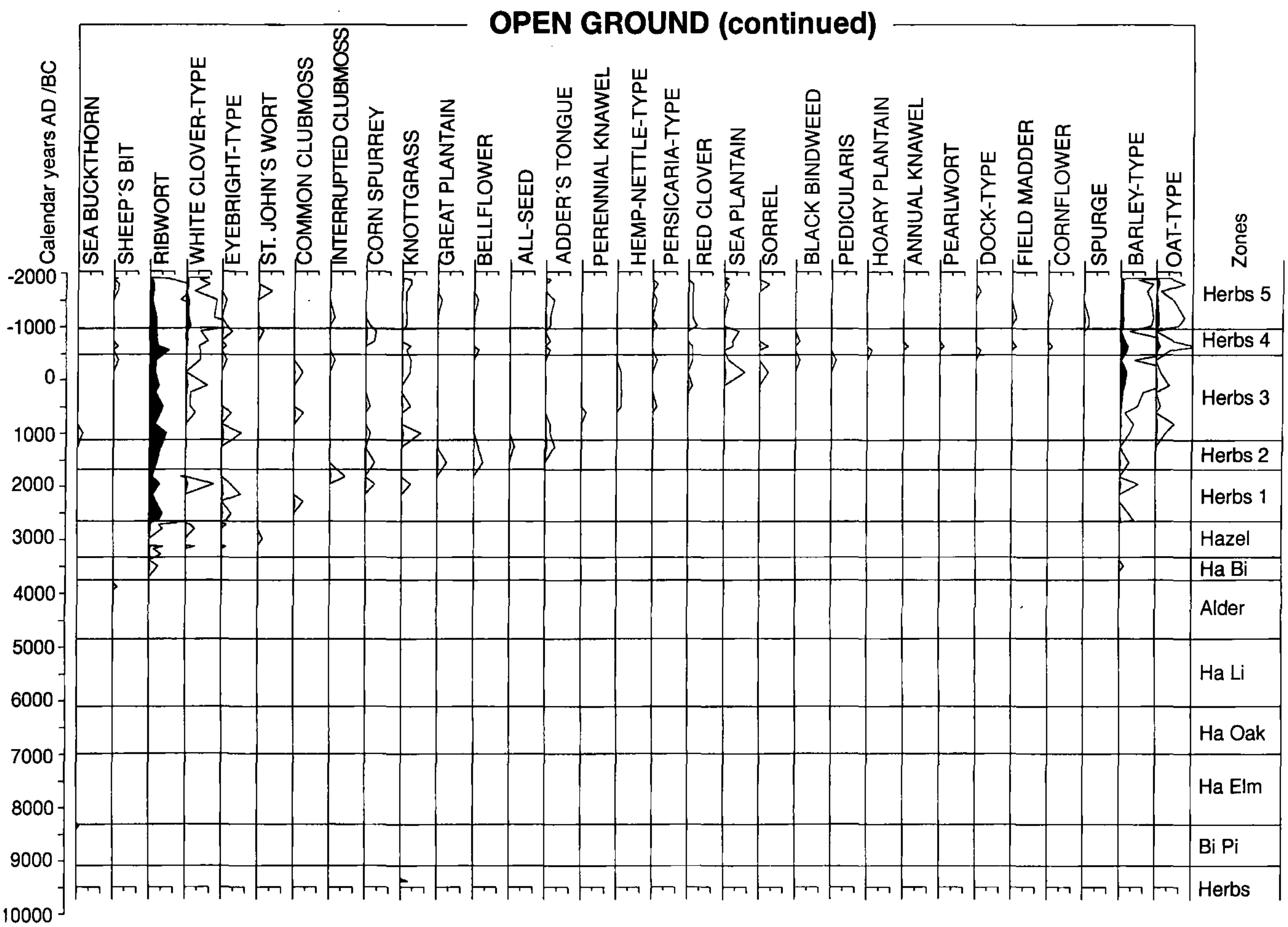

Fig. 10 C. Percentages for land plants in percent of the land plant total (black silhouettes, white silhouettes x10).

lowed by an increase in barley-type pollen, due to inclusion of crumpled rye pollen (Odgaard 1989). The absence of an increase in barley-type pollen at Hassing Huse Mose therefore indicates that rye was not cultivated extensively. The invasion by sand dunes in western Thy is not clearly reflected in the pollen diagram.

Landscape diversity

There are two curves for taxon richness, which were calculated by the rarefaction analysis. The first curve (Fig. 12), calculated for the gyttja series alone, includes the ambiguous plants and the wet-ground plants in order to estimate the whole land-plant flora. The curve is rather irregular due to a large variance. The taxon richness is around 17 in the lowermost herb pollen zone, it decreases in the birch pine pollen zone to around 15, and is around 13 in the hazel-elm to alder pollen zones. This general decrease in taxon richness reflects increasingly stable vegetation in the early pollen zones (protocratic and mesocratic phases, Birks and Line 1992). There is a peak for taxon richness in the hazel-birch pollen zone (22 taxa) just after the elm decline indicating vegetational disturbance. The vegetation stabilizes again, and taxon richness then increases to 22 taxa in the hazel pollen zone. Vegetational disturbance in the Early and the Middle Neolithic is evident.

A more detailed curve for taxon richness based on larger pollen counts (>2015) was shown by Andersen and Rasmussen (1993). This curve showed increased taxon richness during the two pre-Neolithic elm declines, and in the hazel-birch and hazel pollen zones.

The whole land plant flora could not be included in the taxon-richness estimate for the whole pollen series

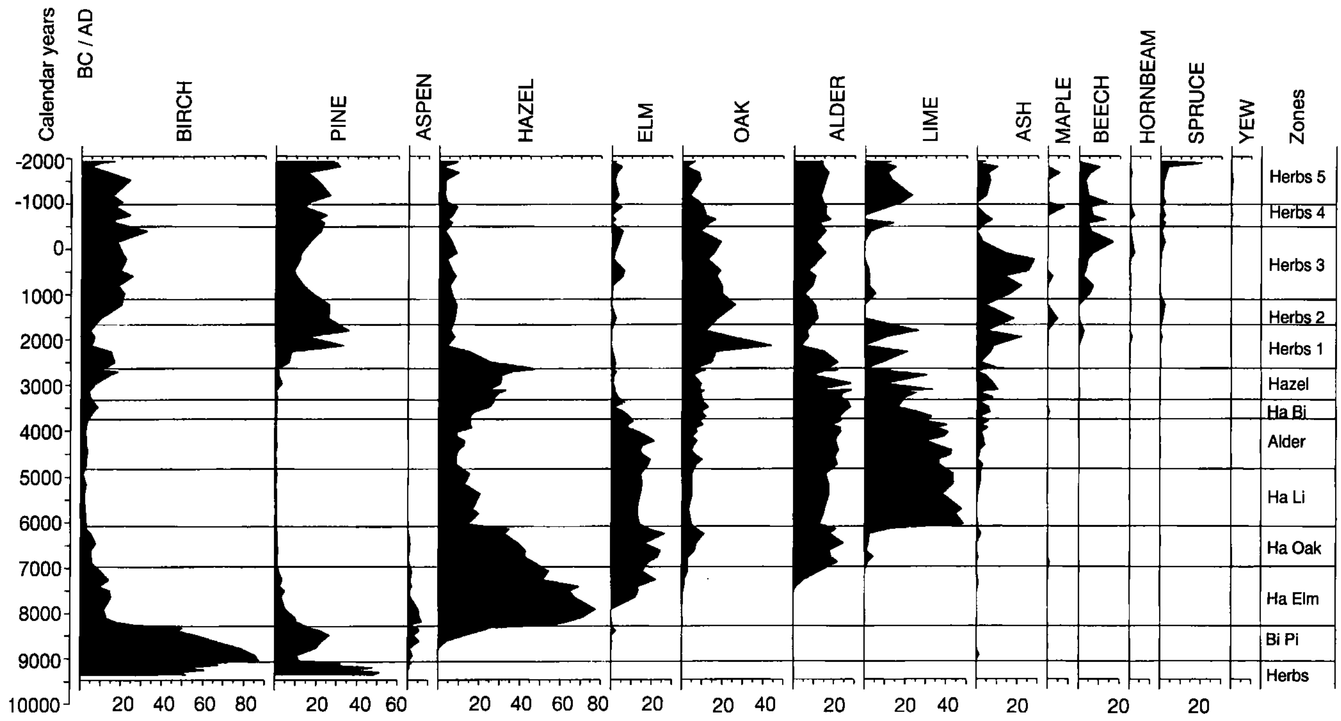

Fig. 11. Tree pollen percentages (percent of tree pollen) after correction for pollen productivity (Andersen 1970, 1980). Correction factors, birch, pine, aspen, hazel, oak, alder, yew, x0.25, hornbeam, x0.33, elm, spruce, x0.5, beech, x1.0, lime, ash, maple, x2.0.

in Fig. 13 because of uncertainties in the distinction of land plants from plants present in the swamp vegetation. The statistical uncertainty is large because of low pollen counts in a part of the swamp peat (lowest count 153 grains). The curve is too low in the earliest pollen zones because some land plants were missed. The taxon richness is fairly constant up through the hazel-elm to the alder pollen zones (around 8 taxa). The curve rises distinctively from the Early Neolithic hazel-birch pollen zone upwards and reaches a peak (19 taxa) in the herbs 4 pollen zone (Late Iron Age). The richness in taxa reflects increasing disturbance of vegetation and creation of diverse habitats caused by increasing land clearance and agricultural activity (*Homo sapiens* phase, Birks and Line 1992). Interestingly, the taxon richness decreases in the herbs 5 pollen zone (Historical period, around 17 taxa). This could reflect decreased vegetation diversity and creation of more uniform habitats at a time when human landscape exploitation was at a maximum (intermediate disturbance hypothesis, see Birks and Line 1992). Peglar (1993) showed a similar decrease in taxon richness at Diss Mere in East Anglia in post-Medieval time. In modern time, 20th century, the taxon richness decreases again (to 14 taxa), probably reflecting the uniformity of the modern agricultural landscape.

DISCUSSION

The pollen diagram from Hassing Huse Mose is unique in Denmark. It shows natural vegetational development on young till-soil of Weichselian age in northwestern Denmark, far from comparable pollen diagrams, and it illustrates an unusually strong and continuous deforestation upwards from the Neolithic, which in Denmark is matched only by pollen diagrams from the West Jutland heath areas.

Natural vegetation succession

The first 5000 years of the vegetational succession at Hassing Huse Mose were not, or only weakly, influenced by man. Features of the late-glacial vegetation (herbs pollen zone), abundant herbs, presence of crowfoot, juniper maximum, are typical of Danish pollen dia-

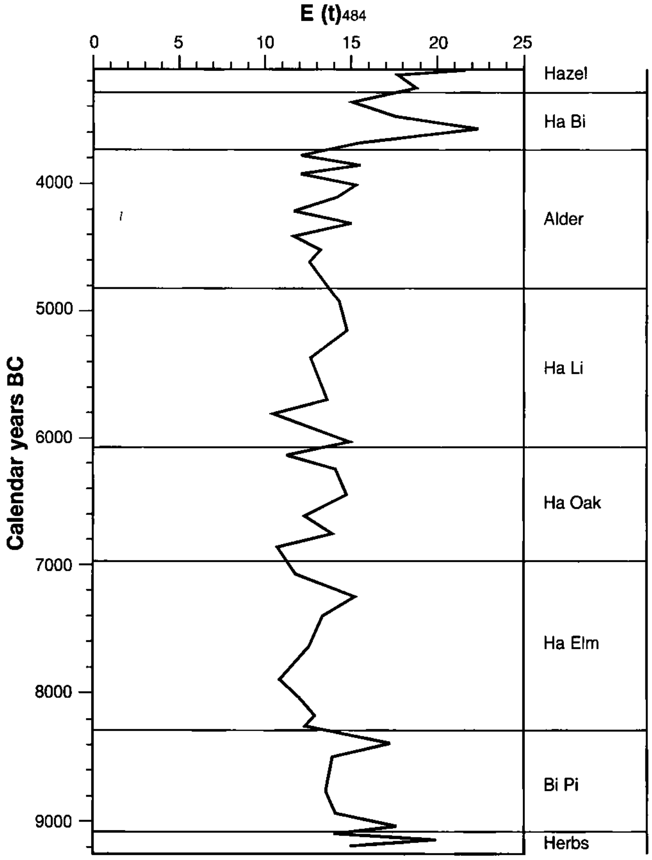

Fig. 12. Pollen taxon richness (E(T)) estimated by rarefaction analysis of pollen counts from gyttja samples in Hassing Huse Mose. Pollen from aquatic plants were excluded. Standard pollen count 484.

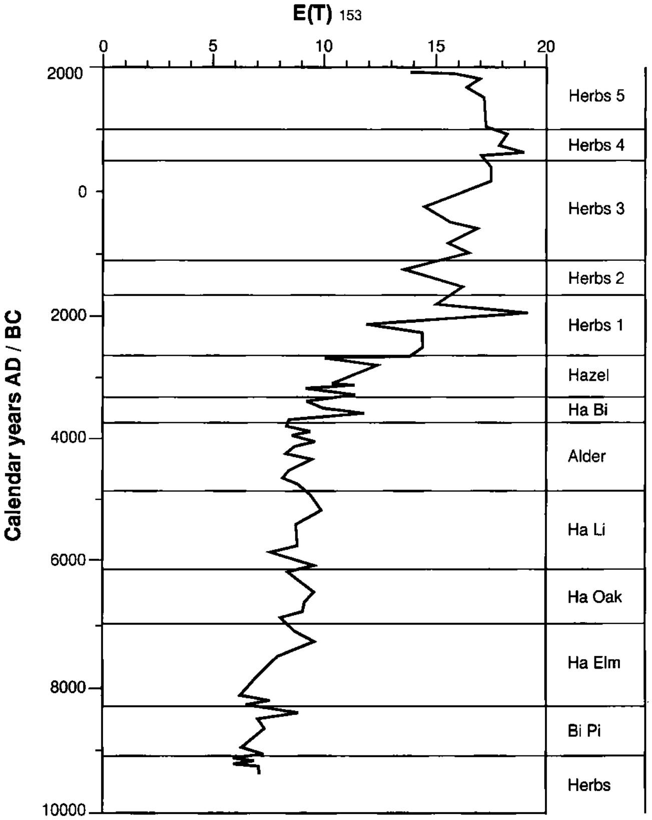

Fig. 13. Pollen taxon richness for all pollen counts from Hassing Huse Mose. Ambiguous plants, wet-ground plants and aquatics were excluded. Standard pollen count 153.

grams from the end of the Younger Dryas and the transition to the Holocene.

The early Holocene tree succession with subsequent maxima for birch, pine, aspen, hazel, elm, oak and lime is similar to that in other pollen diagrams from Denmark. A delay in the immigration of the trees to Thy might be expected. The time of immigration is difficult to assess from pollen diagrams. The first appearance of pollen grains (the rational limit) depends somewhat on the numbers of pollen counted, and the pollen may be derived by far distance transport. An expansion phase (the empirical limit), which reflects massive immigration may also be difficult to define in all cases. Table 5 shows calculated ages for the expansion of tree species at Hassing Huse Mose compared with dates for similar events at other localities in Denmark. Sites with published radiocarbon dated pollen diagrams from the early Holocene are scarce (4 localities). The nearest are Solsø, 80 km to the south, and Fuglsø Mose, 140 km southeast of Hassing Huse Mose. The ages obtained are rather uncertain, partly due to uncertainty in determining exact levels, partly due to difficulties in assessing ages precisely. Therefore, age ranges are shown in Table

Tree	HHM	Other localities
Lime	6100	6600-7000
Oak	6900	6600-7700
Alder	7300	7000-7900
Elm	7900	7200-7900
Hazel	8300	8300-8400
Pine	8900	8300-9500

Table 5. Calculated ages for the expansion of trees at Hassing Huse Mose, and the range for dates at other localities in Denmark (data from Aaby 1986, 1988, Aaby and Andersen 1986, Andersen et al. 1983, Fredskild 1979, Krog 1973, ages in calendar years B.C.).

5. It appears, that nearly all tree expansion ages from Hassing Huse Mose fall within the ages that could be expected from other sites in Denmark, with one exception, the expansion of lime, which seems to be somewhat younger than the ages obtained elsewhere.

Increasing vegetational stabilization and decreasing floristic diversity is indicated from the late-glacial herb pollen zone, through the early Holocene birch-pine zone to the hazel-elm zone. The decrease of the open-ground herbs and grasses in the birch-pine zone and the formation of a humus layer as indicated by the presence of oak fern are typical of the end of the protocratic and the transition to the mesocratic phase (Birks 1986, Birks and Line 1992).

Hazel, elm and alder expanded rapidly at intervals of 400-600 years. The quick expansion of these trees indicates that they did not meet with serious competition. Hazel was dominant for a short time, 350 years, at the cost of birch and pine. Elm expanded at the cost of hazel, presumably on moist and fertile soils, and alder then invaded the wet soils, at the cost of hazel and birch. Oak appeared together with alder but expanded at a slower rate. The invasion of lime was considerably delayed, around 1400 years later than alder. Lime expanded very rapidly and met little resistance from the other trees. It invaded sites with hazel in particular, and remained very frequent (30-40% corrected) for more than 1000 years. Pollen spectra from small hollows and soils indicate lime dominance and presence of hazel and oak on dry ground, whereas elm and alder were restricted to moist and wet sites, probably mixed with oak and hazel (Andersen 1978, 1984, 1991, Aaby 1983). The increase of alder, at around 4800 B.C., was probably of local significance, connected with a lower water level. Ash, which played a minor role, increased somewhat at the same time. The two first elm declines fell in the alder pollen zone.

Very high tree pollen frequencies, and low diversity, in the hazel-elm to alder pollen zones indicate dense and stable forest cover (mesocratic phase, Birks 1986, Birks and Line 1992). An acid humus layer developed (oak fern, bracken, polypody). Grasses were scarce and pollen from open-ground vegetation (mugwort, sheep's sorrel, goosefoot family) is very scattered. A single pollen grain of wheat-type may be due to far-distance transportation. The stronger winds in this part of Denmark had no effect on the tree density.

Culturally influenced vegetation

The first indications of human disturbance were found during the two elm declines in the alder pollen zone examined in detail by Andersen and Rasmussen (1993) and dated at 4520 and 4130 B.C. The specific pursuance of elm was explained by a preference for moist and fertile sites possibly combined with attacks by elm disease.

Anthropogenic influence is clearly reflected from the hazel-birch zone onwards (*Homo sapiens* phase, Birks 1986, Birks and Line 1992). The landscape was opened up only slightly during the Early and Middle Neolithic Funnel Beaker Cultures (hazel-birch and hazel pollen zones). Extensive deforestation began with the land clearances of the Single Grave Culture (2600 B.C.) and proceeded stepwise with new clearances in the Early Bronze Age (1650 B.C.), the Younger Iron Age (A.D. 500), and the Medieval (A.D. 1000) until complete deforestation was accomplished in the 17th to 19th centuries. This development was reversed by the establishment of plantations in the late 19th and in the 20th centuries.

The tree communities were changed drastically during the Early and Middle Neolithic (2600-3800 B.C.). Elm nearly disappeared, lime was strongly reduced, and was replaced by hazel and to some extent by birch, oak and alder. Maintenance of birch coppices and, later, hazel coppices is reflected (*cf.* Andersen 1992a).

The tree pollen frequencies were influenced increasingly by tree pollen transported from a far distance after the land clearance by the Single Grave people (2600 B.C.). The stepwise decrease of the tree pollen frequencies indicates that tree populations were present and available for clearance. Nearly all the tree pollen present at the time of complete deforestation (20%, 19th century) was transported from a far distance, except, maybe, for pollen derived from trees planted around villages and manors (lime, elm?) or a few wet habitats (alder, ash). It is difficult to say which tree pollen was derived from local populations at earlier times. The corrected tree pollen curves (Fig. 11) indicate that first hazel and then alder and birch populations were felled during the Single Grave and Late Neolithic expansion (herbs 1 pollen zone), lime at the Early Bronze Age expansion (herbs 2 pollen zone), and birch and oak in the Late Iron Age and Medieval Period (herbs 4 and 5 pollen zones). Birch, oak and ash were probably present in the Bronze Age and the Older Iron Age (herbs 2 and 3 pollen zones). Pollen spectra from soils beneath barrows from the Early Bronze Age (Andersen 1990, unpublished) indicate that tree vegetation of lime, hazel, birch and alder had been felled and the cleared areas used for cereal growing and then pasture prior to the building of the barrows. The frequency of pine increased strongly at the first land clearance (herbs 1 pollen zone) and remained high up to the present (Fig. 11). There is little doubt that this pollen was transported from a far distance.

Plants from forest and coppices were present from the Early Neolithic (hazel-birch zone) up to present time. Oak fern, bracken and polypody indicate acid humus layers, and several shrubs were probably connected with woodland remains or coppices (rowan, black elder, crap apple, bird cherry, rose).

The wild grasses began to expand in the Early Neolithic (hazel-birch pollen zone) and increased strongly during the intensive land clearance phases. The grasses were probably common in all extensively used habitats, and in fields and pastures. Their flowering was probably reduced in intensively grazed pastures (Andersen 1992a). Conspicuously increased taxon richness indicates increased landscape diversity in the Early and Middle Neolithic (Hazel-birch and hazel pollen zones), but the frequencies of open-ground plants were rather low. Mugwort, sheep's sorrel and the goosefoot family were present since the late-glacial. Ribwort, white clover-type and barley-type are new additions to the flora. The frequencies and numbers of open-ground plants increased continuously from the introduction of the Single-Grave Culture. They probably reflect vegetation on a variety of cleared habitats, such as pastures, fields, fallow land, meadows, roadsides and wasteland, but it is difficult to distinguish these habitats because most of these plants are likely to have occurred in several plant communities (Behre 1981).

Barley-type pollen is common from the time of the Single-Grave Culture, and oat-type from the Late Bronze Age (1000 B.C.). Their importance increases in the Pre-Roman Iron Age (500 B.C.) indicating increased emphasis on cereal growing. Sheep's sorrel was probably associated with the cultivated fields and fallow land together with other plants of weed-type (corn spurrey, knotgrass, perennial knawel, persicaria-type, black bindweed, annual knawel, pearlwort, field madder, cornflower).

Ribwort was common from 2600 B.C. Ribwort is common on various open habitats (Behre 1981), but survives grazing better than most other plants (Andersen 1992a), and its pollen may be extremely common in prehistoric soils indicating intensive grazing (Andersen 1990, 1992a). The continuous occurrence of ribwort pollen at Hassing Huse Mose, therefore, indicates that grazing was important in Thy since the time of the Single Grave Culture. The flora of pastures with high frequencies of ribwort is poor, probably because the herbs were prevented from flowering (Andersen 1992a). A few plants may have been associated with pastures (moonwort, eyebright-type, St. John's wort, adder's tongue). White clover-type is represented from the Neolithic onwards and increases together with red clover in the Iron Age. The clovers may have been promoted by fertilization of the pastures.

As heather was scarce (below 5%) before its expansion in the swamp, heath vegetation was scarce up to that time (200 B.C.). Development of heath since then cannot be proved.

Land-use and cultural history

The changes in land-use around Hassing Huse Mose as reflected in the pollen diagrams is intimately connected with the cultural history in Thy.

The scattered finds and graves from the Early and Middle Neolithic Funnel Beaker Cultures are reflected by evidence of the presence of pastures and open areas, and intensive coppice management.

Large areas were cleared from woodland and were used for pasture and cereal growing during the time of the Single Grave Culture and in the Late Neolithic. The start of these events (2600 B.C.) is slightly later than the introduction of the Single Grave Culture (2800 B.C.) and coincides with the Ground Grave Period (around 2600 B.C., Malmroos and Tauber 1977, Tauber 1986). Finds of Ground Grave-type are particularly frequent in Thy (Glob 1945). Hence, the main Single-Grave occupation of Thy probably took place in the Ground Grave Period. The Late Neolithic is also richly represented by finds (Vandkilde 1990).

Woodlands were cleared again in the Early Bronze Age marking new cultural expansion (from 1650 B.C.). Early Bronze Age graves and finds are particularly rich in Thy, maybe with a slight recession in the Late Bronze Age (maps in Baudou 1985). A recession in the Late

Bronze Age may also be indicated in the pollen diagram.

The pollen diagram indicates new land clearance in the Late Iron Age (from 500 B.C.), Medieval time (from A.D. 1000), and 16th century. Many new settlements appeared in Medieval time (Baudou 1985).

The pollen diagram from Hassing Huse Mose thus reflects increasingly intensive settlements and land-use in Thy from Early Neolithic time till today. There was a radical change from the coppice management of the Funnel Beaker Culture to the creating of large treeless areas from the Single Grave Culture onwards. The emphasis was on stock-breeding, but cereal growing increased in importance from the Early Iron Age. Woodlands were of decreasing importance. The natural forest was changed into secondary woodlands and coppices already in the Neolithic. The hazel coppices were cleared at the introduction of the Single Grave Culture, and only birch and oak coppices, and probably alder and ash on wet ground, remained. It appears that woodlands were cleared away whenever new land was needed, until complete deforestation was achieved. Woodlands were, therefore, of secondary importance in the agricultural economy. The need for woodland products must have been covered by import.

Complete deforestation similar to that in Thy is in Denmark only recorded in pollen diagrams from Lake Solsø and Lake Skånsø in the West Jutland heath areas (Odgaard 1989, 1992b). Deforestation began at Lake Solsø at around 2800 B.C. and at Lake Skånsø at around 2000 B.C. and was completed (around 20% tree pollen) within the last millennium. These sites are situated in areas with poor soils, and heath was prominent, whereas heather was scarce at Hassing Huse Mose, at least up to 200 B.C. Tree pollen was dominant in pollen diagrams from east Denmark up to the forest clearances in Medieval time (pollen diagrams in Mikkelsen 1949, Aaby 1986a, 1988) and woodlands still occurred in the 19th century in contrast to West Jutland and the western Limfjord area (Ødum 1968). The Weichselian till areas were therefore exploited more intensively in Thy than in eastern Denmark. It is difficult to explain these differences in agricultural exploitation. Up to the last century breeding and export of stock was very important in the western Limfjord area, and the peasants there were richer and more independent than in other parts of Denmark (Damgaard 1989). Barley and oat were grown for fodder, whereas bread corn (rye) was imported from the heath areas. Trade with agricultural products may therefore have been an ancient tradition in Thy.

Humification curves from Danish raised bogs (Aaby 1988, in Andersen 1992b) indicate a dry climate in the Early and Middle Neolithic (3000-4000 B.C.) and increases in humidity at around 2800 B.C., 1700 B.C., 0 A.D./B.C., A.D. 600 and A.D. 1600. These increases in moisture coincide with agricultural expansion in Thy (Andersen 1992b). The increasing agricultural exploitation in Thy could, therefore, be a response to increased moisture and availability of sites suitable for grazing or cultivation. The crop of grass and cereals in Denmark depends highly on the availability of moisture, and drought is fatal on light soils even in the moist climate of today (Aslyng 1986). The availability of sites suitable for pasture or cultivation may, therefore, have presented a limit for agricultural expansion. The increases in land-use intensity in Thy in the Single Grave Culture, the Early Bronze Age, the Late Iron Age and Medieval-recent time could be responses to increased production possibilities combined with a high pressure for products. An increase in tree pollen in the Late Bronze Age might be a response to drier climate (from 1000 B.C. to around 0 A.D./B.C.), which could have restricted agricultural exploitation of the lightest soils (Andersen 1992b).

The sediment series from Hassing Huse Mose have provided a radiocarbon chronology. However, the quality of the pollen spectra from the swamp peat is not quite satisfactory and some uncertain points are left unanswered. The pollen counts are very low in a part of the section, the contribution of pine pollen is difficult to interpret and it is difficult to distinguish the contribution of pollen from local swamp vegetation in the pollen spectra. The gyttja series from Ove Sø, which was mentioned in the introduction, is difficult to date by the radiocarbon method due to reservoir effects, but can be dated by cross-correlation with Hassing Huse Mose. A pollen diagram from Ove Sø is in preparation. This diagram will improve and clarify the results obtained in Hassing Huse Mose.

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Adder's tongue	*Ophioglossum vulgatum*
Alder	*Alnus glutinosa*
All-seed	*Radiola linoides*
Anemone	*Anemone*
Annual knawel	*Scleranthus annuus*
Ash	*Fraxinus excelsior*
Aspen	*Populus tremula*
Barley	*Hordeum vulgare*
Bedstraw	*Galium*
Beech	*Fagus sylvatica*
Bellflower	*Campanula*
Bilberry	*Vaccinium*
Birch	*Betula*
Bird cherry	*Prunus avium*
Black bindweed	*Polygonum convolvolus*
Black elder	*Sambucus nigra*
Bladderwort	*Utricularia*
Bog myrtle	*Myrica gale*
Bracken	*Pteridium aquilinum*
Bread wheat	*Triticum aestivum*
Cat's tail	*Typha latifolia*
Cinquefoil	*Potentilla*
Common clubmoss	*Lycopodium clavatum*
Cornflower	*Centaurea cyanus*
Corn spurrey	*Spergula arvensis*
Couch grass	*Elymus repens*
Cow wheat	*Melampyrum*
Crap apple	*Malus sylvestris*
Crowberry	*Empetrum nigrum*
Dog's mercury	*Mercurialis perennis*
Dock	*Rumex crispus*
Elm	*Ulmus*
Einkorn	*Triticum monococcum*
Eyebright	*Euphrasia*
Field madder	*Sherardia arvensis*
Fireweed	*Epilobium angustifolium*
Float grass	*Glyceria fluitans*
Goosefoot family	*Chenopodiaceae*
Great plantain	*Plantago major*
Groundsel	*Senecio*
Guelder rose	*Viburnum opulus*
Hazel	*Corylus avellana*
Heather	*Calluna vulgaris*
Hemp nettle	*Galeopsis*
Hoary plantain	*Plantago media*
Hornbeam	*Carpinus betulus*
Interrupted clubmoss	*Lycopodium annotinum*
Ivy	*Hedera helix*
Juniper	*Juniperus communis*
Knotgrass	*Polygonum aviculare*
Lime	*Tilia cordata*
Lyme grass	*Leymus arenarius*
Maple	*Acer*
Marram grass	*Ammophila arenaria*
Meadow oat	*Avenula pratensis*
Meadow sweet	*Filipendula*
Millet	*Panicum miliaceum*
Milfoil	*Achillea*
Mistletoe	*Viscum album*
Moonwort	*Botrychium*
Mountain pine	*Pinus mugo*
Mugwort	*Artemisia*
Oak	*Quercus*
Oak fern	*Gymnocarpium dryopteris*
Oat	*Avena sativa*
Pearlwort	*Sagina*
Perennial knawel	*Scleranthus perennis*
Persicaria	*Polygonum persicaria*
Pine	*Pinus sylvestris*
Polypody	*Polypodium vulgare*
Pondweed	*Potamogeton*
Ramsons	*Allium ursinum*
Red clover	*Trifolium pratense*
Ribwort	*Plantago lanceolata*
Rose	*Rosa*
Rowan	*Sorbus aucuparia*
Rye	*Secale cereale*
Rye brome	*Bromus secalinus*
Sanicle	*Sanicula europaea*
Sea buckthorn	*Hippophae rhamnoides*
Sea plantain	*Plantago maritima*
Sedge	*Carex*
Sheep's bit	*Jasione montana*
Sheep's sorrel	*Rumex acetosella*
Sorrel	*Rumex acetosa*
Spruce	*Picea abies*
Spurge	*Euphorbia*
St. John's wort	*Hypericum*
Water crowfoot	*Batrachium*
Water milfoil	*Myriophyllum*
Water violet	*Hottonia palustris*
Wheat	*Triticum*
White clover	*Trifolium repens*
White water lily	*Nymphaea alba*
Willow	*Salix*
Yew	*Taxus baccata*

Table 6. List of English plant names and their equivalents in latin (from Clapham *et al* 1956. Species names in latin follow *Flora Europaea*).

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