

A PALYNOLOGICAL INVESTIGATION OF THE MOERSHOOFD, HENGELO, AND DENEKAMP INTERSTADIALS IN THE NETHERLANDS

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ABSTRACT

Kolstrup, E. & T.A. Wijmstra (1977). A palynological investigation of the Moershoofd, Hengelo, and Denekamp Interstadials in The Netherlands. *Geol. Mijnbouw*, 56, p. 85-102.

A palynological study has been made of some organic deposits from The Netherlands dated between ca. 50,000 and 30,000 B.P. From the recent ecology and distribution of plants found as fossils in the Moershoofd Interstadial complex, the Hengelo Interstadial and the Denekamp Interstadial, it was concluded that the average July temperatures were 13°, 13-15° and 10°C, respectively. Furthermore a decrease of at least 5°C was found within a time span of 1,500 years during the Moershoofd Interstadial complex.

INTRODUCTION

Some years ago a project was started at the Palynological Department of the Hugo de Vries-Laboratory in Amsterdam to investigate the Middle Pleniglacial interstadials of the Tubantian (Weichselian). Incorporated in this study was the analysis of peat deposits near Voorthuizen and Bussloo (fig. 1). These layers were found in sand pits dug during the construction of highway E8. In addition a peat layer near Eerbeek and the peat deposit at the type locality of the Denekamp Interstadial near Laarhuis, were included in the study (fig. 1). The chronostratigraphic correlation of these peat layers with the Moershoofd, Hengelo, and Denekamp Interstadials (van der Hammen, 1971a,b) could be established by the radiocarbon dates shown in Table 1.

LABORATORY METHODS

All samples were prepared with KOH followed by acetolysis. Glycerine-gelatine was used as an embedding medium.

To obtain a good idea of the composition and development of the vegetation the sections were analyzed with 1 cm intervals between consecutive samples. In all the diagrams the percentages are calculated on the basis of the sum of A.P. (arboreal pollen) and dry N.A.P. (non-arboreal pollen), the

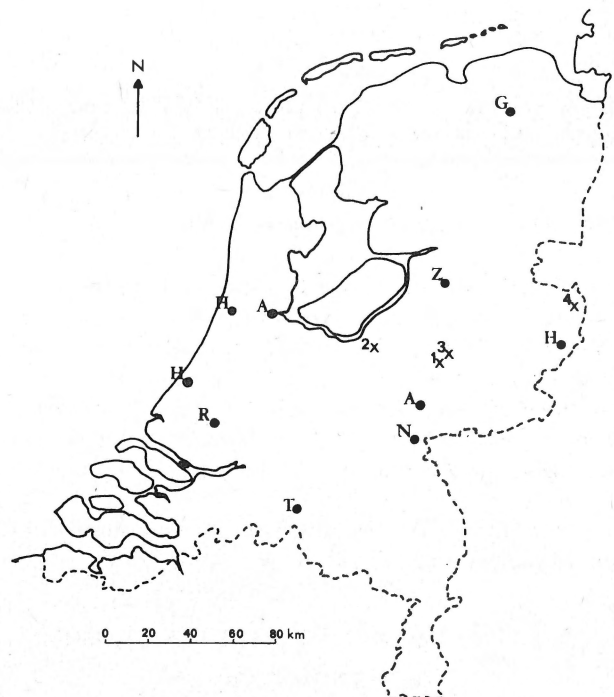


Fig. 1

Location of samples.

A. Town, 1 x Locality.

1 - Eerbeek: 52°09'00"N, 6°04'49"E

2 - Voorthuizen: 52°14'N, 5°37'E

3 - Bussloo: 52°12'18"N, 6°05'42"E

4 - Laarhuis: 52°19'N, 6°57'E

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Locality	Groningen laboratory number	Depth in metres	Date B.P.	Type of deposit	Interstadial
Eerbeek	GrN-7103	3.90	45,400 ⁺ 1,900 – 1,500	Loamy peat	
–	GrN-7104	5.15-5.17	49,700 ⁺ 4,400 – 2,800	Loamy peat	
–	GrN-7105	5.37-5.39	> 47,300 δ criterion		Moershoofd complex
			55,000 ⁺ 12,000 – 4,700	Loamy peat	
–	GrN-7106	5.47-5.49	51,000 ⁺ 5,400 – 3,200	Peaty loam	
–	GrN-7107	5.555-5.575	49,900 ⁺ 5,300 – 3,200	Peaty loam	
Voorthuizen	GrN-5923	7.40 ¹⁾	> 44,450	Loamy peat	Moershoofd complex
–	GrN-5940	5.30 ¹⁾	> 50.800 ²⁾	Peaty loam	
–	GrN-6821	4 ¹⁾	49,200 ± 600 ²⁾³⁾	Moss	
Bussloo	GrN-6768	2.26-2.27	31,500 ± 510 ⁴⁾	Loamy peat	
–	GrN-6619	2.40-2.42	36,850 ± 620	Peat – loamy peat	Hengelo
–	GrN-6618	2.58-2.60	38,420 ⁺ 1,400 – 1,190	Peat – loamy peat	
Laarhuis	GrN-4349	2.25-2.29	29,300 ± 300	Peat	
–	GrN-4348	2.51-2.55	30,100 ± 300	Peat	Denekamp

¹⁾ Depth above N.A.P. (Dutch Ordnance Level). ²⁾ No pollen diagram available. ³⁾ Enriched sample. ⁴⁾ Probably too young. Taken in uppermost part of peat layer. Humus infiltration in the layer above.

Table 1.
Annotated list of radiocarbon datings from the Middle Pleniglacial

water plants and spores thus being excluded. In some cases it is doubtful whether a pollen type belongs to the “dry” group or not (e.g. *Ranunculus*), and in such cases it has been included in the pollen sum.

In the Bussloo section measurements of the size of *Betula* pollen in some spectra have been carried out (fig. 3) and some spectra have also been studied in order to separate the *Salix* types.

In Voorthuizen the deposits have been investigated for their Coleoptera content by R. B. Angus (1975).

UNCERTAINTIES AS TO OUR INTERPRETATION OF THE DIAGRAMS

Before giving descriptions and interpretations of the pollen diagrams we must point out some difficulties encountered during interpretation.

A comparison of present arctic and subarctic vegetation types with their climatic environments on the one hand and

our diagrams on the other yielded useful information. Yet we have not found a single recent vegetation type which corresponds exactly to those found in the Pleniglacial diagrams.

When we try to compare reconstructed Middle Pleniglacial vegetation types with those of subarctic to arctic regions, we do not know to what extent the difference in latitude, i.e. the shorter day length and the higher culmination point of the sun in our area as compared to more northern latitudes, has an effect on plant life. Figure 12 in Blüthgen (1966) shows that the amount of energy received from the sun in June in most parts of Scandinavia is more or less equal to that found in The Netherlands. This similarity permits us to presume that the effect of day length and solar altitude is of minor importance when it comes to an interpretation of former mean temperatures. Previously Iversen (1973), and Brackmann-Jerosch (1919, cited in Florsschütz, 1949) had reached the same conclusion regarding aquatic vegetation.

One might also raise the question of whether lakes, in particular the shallower ones, became very cold during the

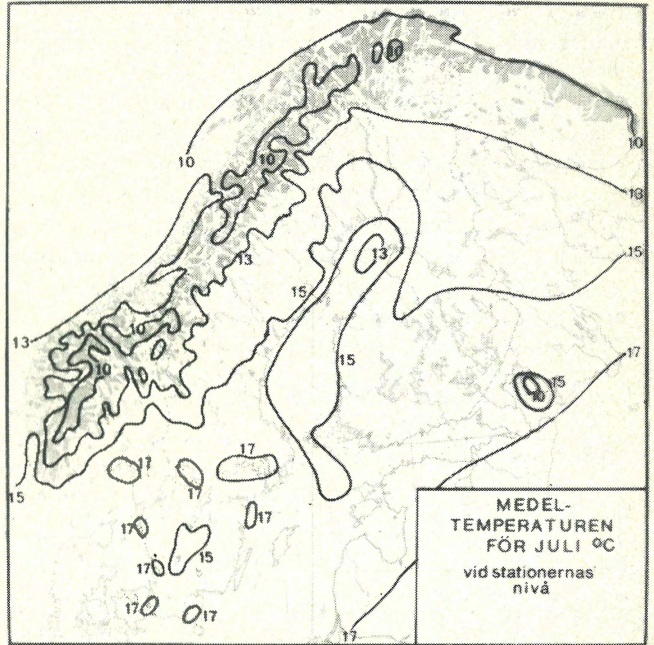
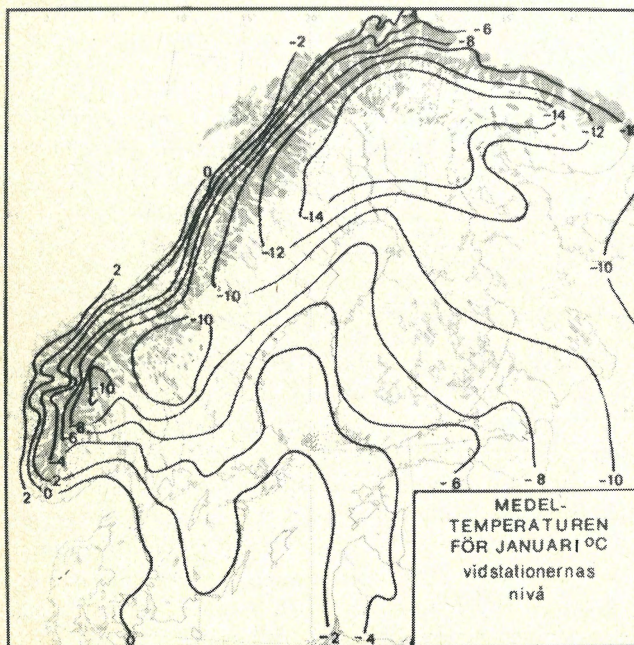
summer nights in The Netherlands. According to G.F.A. van Zuilen (Fysisch Geografisch en Bodemkundig Lab. in Amsterdam, personal communication) nowadays even shallow lakes, say less than 1 m deep, in The Netherlands remain fairly warm during the summer nights. We therefore think that during the warmer periods of the Pleniglacial lake temperatures cannot have dropped appreciably during the night either.

Another difficulty is that the summer seasons, i.e. the growth periods, during the Pleniglacial in The Netherlands may, at least in warmer intervals, have been longer than they are in higher latitudes to-day. This poses the following question: can plants now found in areas with a short summer and requiring a certain mean July temperature, of say 10°C, to complete their life cycle, possibly manage to complete their development during a summer with a lower mean July temperature, of say 8°C, provided the growing season is longer? Our impression obtained from the literature is that this is not the case. Plants adapted to shorter summers usually tend to have a shorter life cycle (see Sørensen, 1941). To check this conclusion all plants identified to the species level in the pollen diagrams have been investigated as far as the July temperatures and growing season is concerned by means of the maps in Hultén (1971) (see fig. 2). It was found that the ranges of most of our indicator plants (table 2) follow the July isotherms, but not the curves of the duration of the growing season. We therefore think that the duration of the growing season does not appreciably change the demands of these plants regarding the summer temperature.

A further problem is the scarcity of information concerning the autecology of the plants known from the Pleniglacial. Of necessity we were forced to apply the principle of actuality to our interpretations, even though we are aware that this renders the resulting conclusions less reliable.

INTERPRETATION METHODS

The traditional way to interpret this type of pollen diagram has been to compare the amount and composition of the arboreal pollen (A.P.) with the non-arboreal pollen group (N.A.P.). This method has proved to be insufficient for our pollen diagrams and we have therefore tried to identify as



many pollen types as possible to the species level.

In the Bussloo 1 diagram we tried to establish which *Salix* and *Betula* taxa were present in some of the spectra. In the spectra at 281 cm and 283 cm almost equal quantities of the *Salix herbacea* and *S. polaris* type on one hand and of the *S. glauca* type (Faegri & Iversen, 1966) on the other, were found, whereas in the spectrum at 275 cm only the *S. glauca* type was present (a total of 15-20 grains was counted in each slide). In the spectra at 259, 257, 256 and 234 cm, all *Betula* pollen grains seen in polar view were measured from the top of a pore to the opposite face. Thus in spectra 257, 256 and 234 two different size classes could be deduced (fig. 3). Comparing our results with the findings of Robertsson (1973) and of Berglund & Digerfeldt (1970), we think that the maximum around 21 μ represents *B. nana*, and the maximum around 25 μ indicates the presence of (a) different *Betula* type(s), probably *B. pubescens* and/or *B. tortuosa*.

From the method given in Ellenberg (1974) and

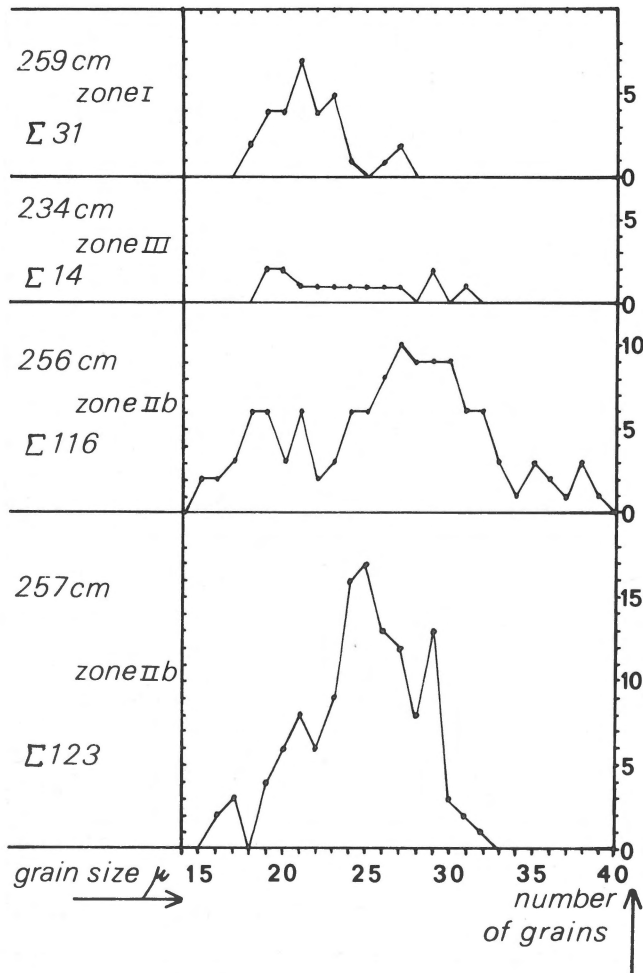


Fig. 3
Grain size measurements of *Betula* pollen in some pollen spectra. Total number of measured grains indicated. For further explanation see text. 259 cm, zone I, is from Bussloo section 2.

from the maps in fig. 2 we have tried to make a tentative reconstruction of the former environment, based on the pollen types which could be identified to the species level. The results are given in fig. 4 and table 2, respectively. Fig. 4 shows that the vegetation types consist of heliophilous species, with temperature requirements ranging from cold to warm. The continentality varies from oceanic to sub-continental. Both terrestrial and hydrophytic plants are represented. The acidity and the nitrogen content of the soil shows a fairly broad range, but generally speaking, the more terrestrial forms are found on acid soils poor in nitrogen, whereas the hydrophilous ones are found in a more basic environment. In table 2 the average July temperatures deduced from fig. 2 are given for some of the species. For *Selaginella selaginoides* a maximum July temperature is given. We have done this after some hesitation because its present southern extension might equally well be influenced by other ecological factors, e.g. soil conditions and shading.

INVENTARISATION OF THE POLLEN DIAGRAMS

As mentioned above, pollen have been sampled at four localities: Eerbeek, Voorthuizen, Bussloo and Laarhuis. The results of the analysis are reproduced in various pollen diagrams, which are described and interpreted below.

The following nine paragraphs deal with these sections, which are named respectively:

- Eerbeek section 1
- Eerbeek "coversand" sample
- Eerbeek section 2
- Voorthuizen lower organic layer
- Voorthuizen middle organic layer
- Voorthuizen upper organic layer
- Bussloo section 1
- Bussloo section 2
- Laarhuis section

In the chapters "Voorthuizen lower organic layer" and "Bussloo section 1" some general remarks are given on the Voorthuizen and the Bussloo localities respectively.

EERBEEK SECTION 1

Depositional environment

The peat layers at Eerbeek (see fig. 1) were found in an alluvial fan east of the Veluwe push moraine. From the lithological column (fig. 5) it can be seen that the lowermost part of the lower peat layer is cryoturbated and that the peat is interbedded in a deposit of alternating sand and loam of the older coversand type (van der Hammen *et al.*, 1967). In this deposit root layers occur locally (see below). We think that at that time the vegetation was underlain by permafrost prohibiting the escape of water, so that conditions were favourable for peat development.

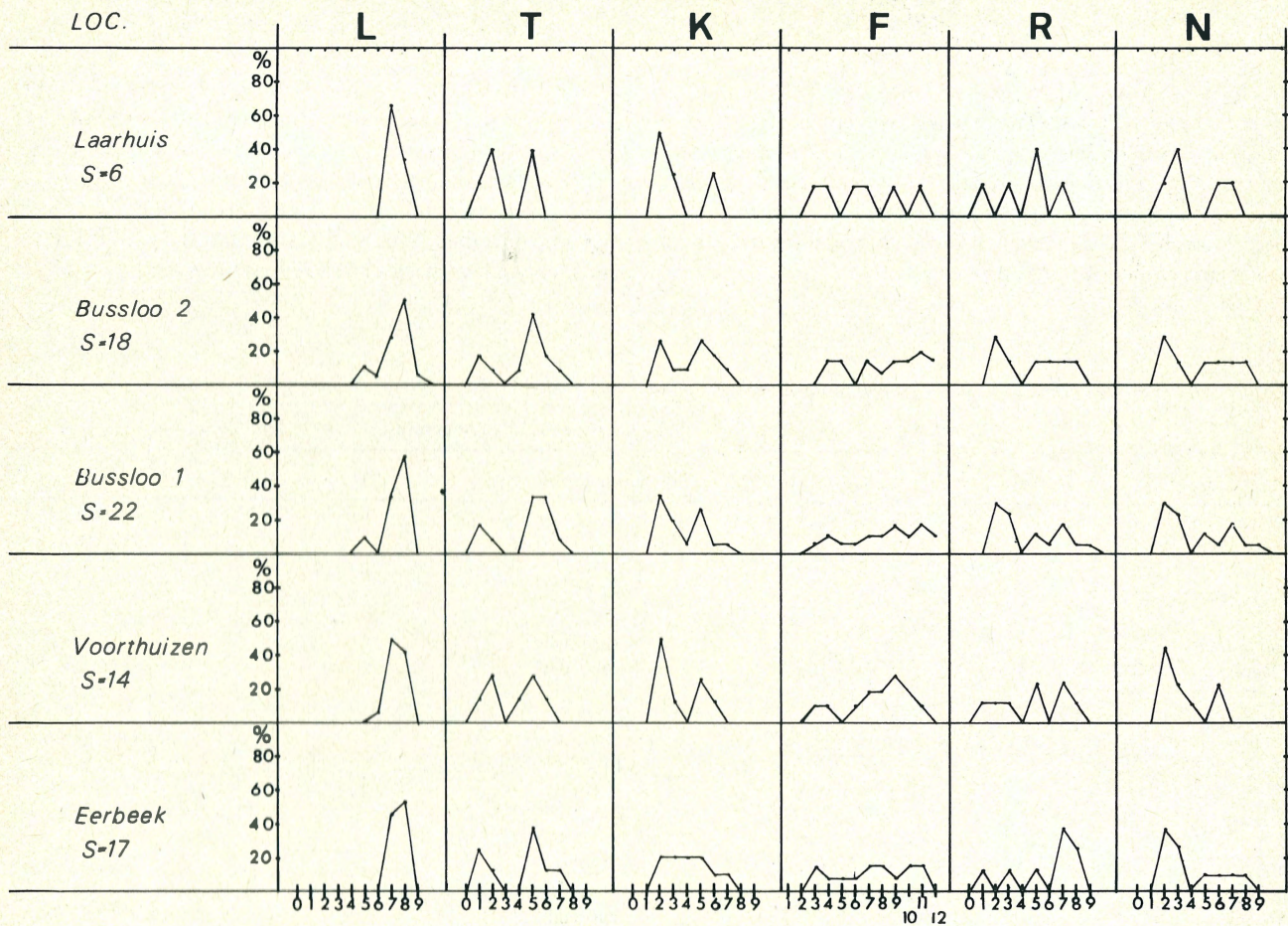


Fig. 4
Ecological requirements of some recent plants also found as fossils in the various interstadials. S-6 indicate the number of different plant types used for the investigation.

The following explanation of the letters L-N is taken from Ellenberg (1974).

L = "Light figure" (occurrence in relation to relative light intensity during summer time)

1 *full shadow* plant, often receiving less than 1%, rarely receiving more than 30% of full day light; 2 between 1 and 3; 3 *shadow* plant; 4 between 3 and 5; 5 *half shadow* plant, receiving more than 10%, but mostly less than 100%; 6 between 5 and 7; 7 *half light* plant; 8 between 7 and 9; 9 *full light* plant, rarely receiving less than 50%; 0 tree seedling in the undergrowth of forests

T = "Temperature figure" (Main distribution according to latitudinal zones and altitudinal belts)

1 only in *cold* (i.e. boreal, arctic or alpine) climate; 3 mostly in *cool* climate (e.g. montane to subalpine); 5 *intermediate*, i.e. concentrated in the submontane belt of Central Europe; 7 mostly in *warm* climate (more or less rare in northern Central Europe); 9 only in *very warm* climate (mediterranean)

K = "Continental figure" (main distribution according to the degree of continentality of the general climate with special emphasis on minimum and maximum temperature)

1 *euoceanic*, reaching Central Europe only in the extreme west; 2 *oceanic*; 3 between 2 and 4; 4 *suboceanic*, main area in whole Central Europe; 5 *intermediate*, from suboceanic to subcontinental; 6 *subcontinental*, main area in eastern Central Europe; 7 between 6 and 8; 8 *continental*, reaching only eastern parts of Central Europe; 9 *eucontinental*, scarcely reaching Central Europe

F = "Moisture figure" (occurrence in relation to soil moisture or water level)

1 in *extremely dry* soils, e.g. bare rocks; 3 in *dry* soils; 5 in *fresh* soils, i.e. under intermediate conditions; 7 in *moist* soils which do not dry out; 9 in *wet*, often not well aerated soils; 10 in *frequently inundated* soils; 11 *water* plant whose leaves mostly are in contact with the open atmosphere; 12 *underwater* plant, most wholly immersed in water

R = "Reaction figure" (occurrence in relation to soil reaction)

1 only in *very acid* soils; 3 mostly in *acid* soils; 5 mostly in *weakly acid* soils; 7 mostly in *neutral* soils, but also in acid and basic ones; 9 only in neutral or *basic* soils;

N = "Nitrogen figure" (occurrence in relation to the ammonia or nitrate supply)

1 only in soils *very poor* in mineral nitrogen; 3 mostly in *poor* soils; 5 mostly in *intermediate* soils; 7 mostly in soils *rich* in mineral nitrogen; 8 *nitrogen indicator*; 9 only in soils *very rich* in mineral nitrogen (indicating pollution, manure deposits or similars)

Description of the pollen diagram (enclosure 1) – In general it can be said that in this diagram the percentages of Cyperaceae are very high, whereas most other herbs are represented by very low percentages. Aquatic forms (*Pediastrum*, *Botryococcus*, *Batrachium*, and *Myriophyllum*) all show very low percentages. This diagram has been subdivided into 5 zones which are, from bottom to top:

Zone I 563-561 cm – A most characteristic feature of the lowermost zone is the relatively high percentage of *Salix* and the low percentages of Gramineae, *Potamogeton* and *Selaginella*. Furthermore, dicotyledonous herbs are poorly represented as far as both the number of types and the percentages are concerned. This is especially the case with the water plants, only a few species being represented at all.

Table 2.

Temperature requirements of plant species found in the Middle Pleniglacial interstadials.

Plant species	Average July temperatures			Jan. temp.		Comments	
	>10°C	>13°C!	>15°C	minimum	<17°C		>-8°C
<i>Armeria maritima</i>						+ ^x	^x Iversen (1973)
<i>Calystegia</i>			+	>10°C			
<i>Centaurea jacea</i>		+		occasionally below 10°C			} ^x Seldom above the timber limit. Iversen (1973)
<i>Filipendula</i> ^x	+			<10°C			
<i>Hydrocotyle</i>			+	>13°C			
<i>Jasione</i>		+		>13°C			
<i>Mercurialis</i>		+		ca. 13°C			
<i>Myrica</i>		+		occasionally below 10°C			} Almost exclusively these types in <i>Myrioph.</i> curve from Bussloo. If more than 5% in diagr. fairly common.
<i>Myriophyllum spicatum</i>	+			occasionally below 10°C			
<i>Myriophyllum verticillatum</i>		+		>10°C			
<i>Lobelia</i>	+			>10°C			
<i>Ranunculus</i> (<i>Batrachium</i>) <i>peltatus</i>		+		occasionally below 10°C			If more than 5% in diagr. → fairly common.
<i>Sanguisorba minor</i>		+		ca. 13°C			
<i>Sanguisorba officinalis</i>	+			>10°C			
<i>Selaginella selaginoides</i>						+ ^x	^x occasionally higher.
<i>Typha angustifolia</i>			+	>13°C			
<i>Typha latifolia</i>			+	ca. 12°C			
<i>Nymphaea</i>		+		>10°C			

Zone II 560-547 cm – The pine, birch, and willow are represented by almost equal values of about 1-3% throughout this zone. The percentages of Gramineae, *Potamogeton* and *Selaginella selaginoides* are relatively high, attaining maximum values of 22, 31 and 25%, respectively. The values of herbaceous dicots are generally somewhat higher, in this zone than they are in zone I; most conspicuous is the relatively high amount of Saxifragaceae, the *Parnassia* and *Saxifraga oppositifolia* types forming continuous curves in most of the zone. From the zone limit I-II the Rosaceae form a continuous curve to the top of the diagram. *Filipendula* is encountered for the first time in the zone. Among the water plants, *Pediastrum* forms a continuous curve with very low percentages at the limit I-II and upwards.

Zone III 546-534 cm – The percentages of the trees are all very low. The Gramineae also show low values never exceeding 10%. The Cyperaceae, on the other hand, attain rather constant, high values between 80% and 90%. Ericales, *Empetrum* and *Galium* form continuous curves in this zone, and the number of the other herbs attains its maximum, although the total percentage of herbaceous forms is only slightly higher than in zone II. Most water plants are present with very low values except *Potamogeton*, which has a maximum in the upper part of the zone.

Zone IV 533-523 cm – Somewhat higher percentages of *Betula*, Gramineae, *Artemisia*, and Rosaceae are found whereas the percentages of Cyperaceae are somewhat lower than they are in zones III and IV. The continuous curves of Ericales and *Galium* cease in the uppermost part. The curve of *Helianthemum* attains its highest values.

Zone V 522-510 cm – In zone V the values of *Pinus*, *Betula*, *Salix*, Gramineae and Cyperaceae are very similar to those found in zone III. Some Gentianaceae are found but the percentages of herbs are generally lower than in zone III as far as both the more terrestrial forms and the hydrophytes are concerned. Also the number of different types is lower in this zone than it is in zone III.

Interpretation

Most of the plants found in this deposit indicate a wet environment and were consequently part of a stand of vegetation in situ. Only *Artemisia*, Chenopodiaceae, *Empetrum*, most grasses and a few other plants must have occurred on drier sites in the vicinity. No trees were found except for a *Salix* scrub in zone I and possibly a few birches in zone IV. From the presence of *Filipendula*, *Sanguisorba officinalis*,

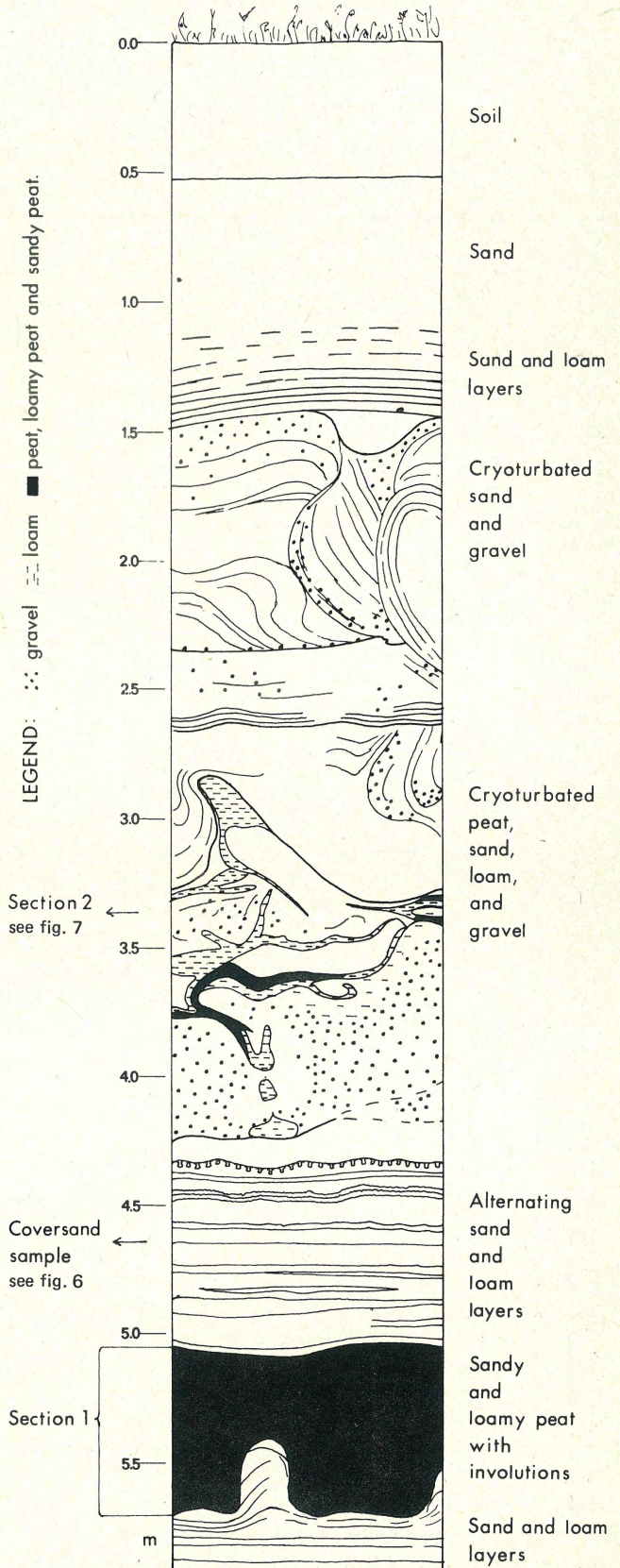


Fig. 5
Main profile locality Eerbeek. The position of section 1 is indicated. Section 2 and the coversand sample are found 10 m and 50 m west of this profile, respectively; only their stratigraphical positions are indicated in this figure (survey by E. Kolstrup).

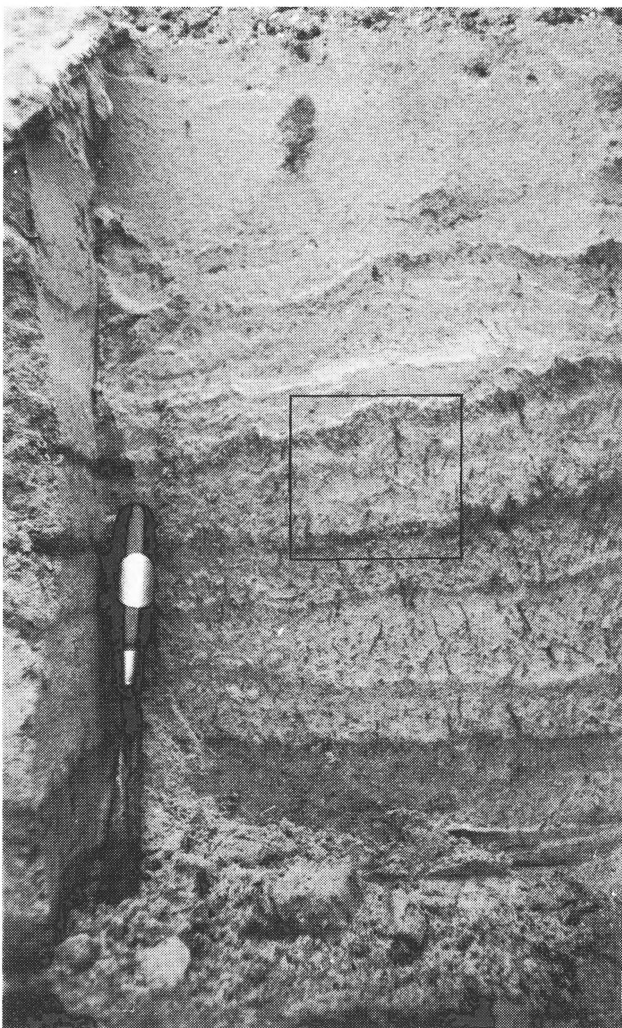


Fig. 6
Root horizons in horizontally laminated sand and loam layers. □ indicates location of sample. The visible part of the trowel is 30 cm long.

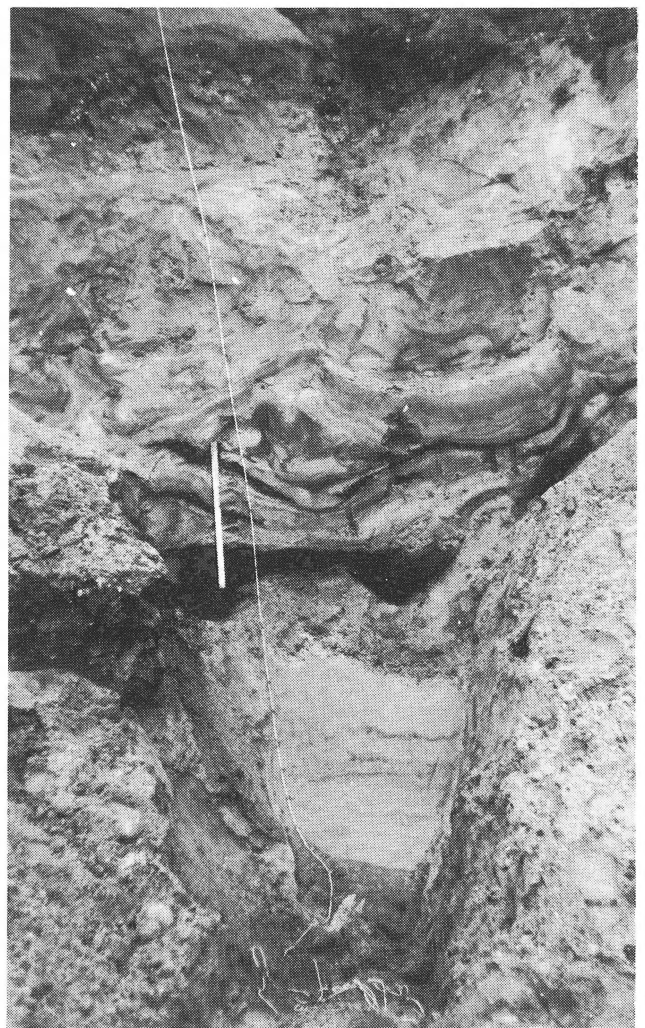


Fig. 7
Location of samples for Eerbeek diagram section 2. Sample is 50 cm high.

Cyperaceae curve has a maximum. From 3.80 to 3.51 m relatively high percentages of *Betula* and *Salix* are found and the Cyperaceae show a minimum. Between 3.51 and 3.46 m the percentages of *Betula* and *Salix* are again rather low, and the Cyperaceae attain values of about 80%. In the uppermost two centimetres of the diagram a small maximum is found in the *Betula* and *Salix* curves, the Gramineae values reach a minimum and the Cyperaceae a maximum in this part of the diagram. The water plants are represented in the whole diagram by very low percentages.

Interpretation — The pollen records indicate a moist environment. The presence of *Filipendula*, *Sanguisorba officinalis*, *Armeria* and *Selaginella selaginoides* suggest that the July temperature was slightly above 10°C. This deposit has been radiocarbon dated at 45,400 B.P. and also belongs to the Moershoofd Interstadial complex.

VOORTHUIZEN LOWER ORGANIC LAYER

The Voorthuizen locality

In the sandpit near Voorthuizen a series of sediments was exposed during the summer of 1969. Two profiles were studied in detail (see fig. 8), from which samples were collected for sedimentological analysis, ¹⁴C dating, pollen analysis, and a study of the erstwhile Coleoptera fauna (Angus, 1975). Fig. 8 shows that 3 layers of organic material are present, one between 750 — 640 cm, one between 620 — 515 cm, and one between 420 — 400 cm (all situated above N.A.P.). The pollen analysis of this section was done by M. Touber-Sieswerda.

The peat layers at Voorthuizen are found intercalated in sediments deposited in a dry aeolean environment (G.H.J.

Depth in cm	<i>Acer</i>	<i>Alnus</i>	<i>Corylus</i>	<i>Quercus</i>	<i>Pinus haploxylon</i> type	Other pre-Quaternary types
344						
345						
346						
347						
348						
349			1			
350						
351						
352						
367	1	1				
368						
379	2	1			1	1
380		2				
381	1			2		
382	1					
383						
384		1				
385		1				
386	1		1			
387		1				
388		1				

Table 4. Pollen grains found in Eerbeek section 2, not included in the pollen diagram (encl. 2).

Ruegg, Dutch Geological Survey, unpublished sedimentological report nr. 3).

Description of the lowermost organic layer (L.L.)

The lowermost organic layer consists of moss fragments of *Scorpidium turgescens* (T. Jens) Loeske = *Calliargon turgescens* (T. Jens) Kindb. A single pollen spectrum from this layer showed the following results: 1.2% *Pinus*, 2.3% *Betula*, 0.4% *Salix*, 16.3% Gramineae, 60.5% Cyperaceae, 12.8% *Artemisia*, 0.8% *Galium*, 2.7% *Thalictrum*, 0.4% *Sagina*, 0.4% Rosaceae, 0.4% Saxifragaceae, 1.2% *Helianthemum*, 0.4% Cruciferae and 0.8% *Ranunculus* (of a pollen total of 258 grains).

Interpretation

From these data a vegetation type dominated by arctic Bryophyta (Dickson, 1973) with some Cyperaceae, Gramineae and other herbs, but without trees can be deduced. No Coleoptera were found in this layer (Angus, 1975).

From a comparison with present tundra vegetations (Walter, 1968, 1974; Fredskild, 1973; Dickson,

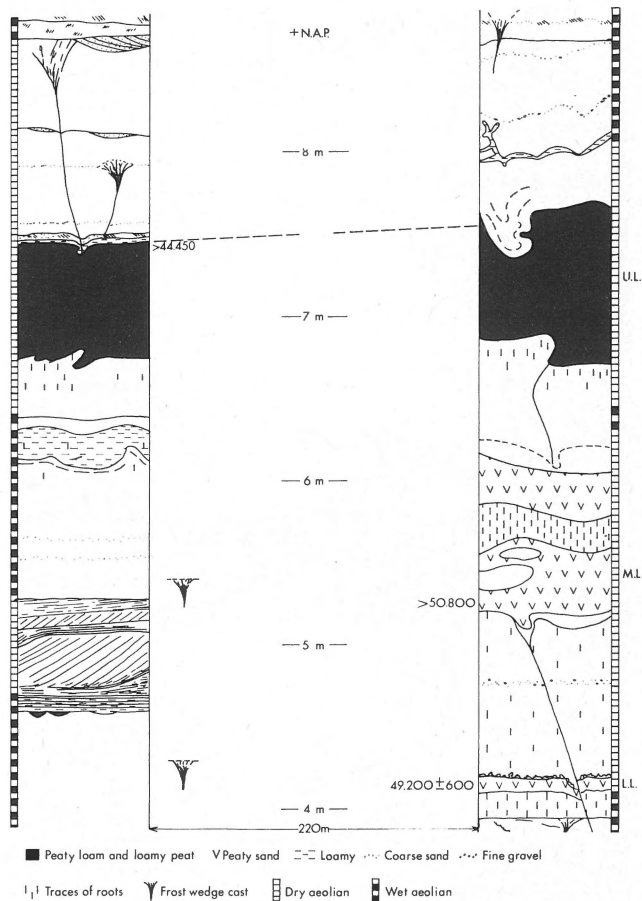


Fig. 8 Middle part of two sections from Voorthuizen. Radiocarbon dates are indicated. Depths are in metres above N.A.P. (Dutch ordnance level) (Survey by G.H.J. Ruegg).

1975) the impression was gained that our pollen data represent a vegetation type not unlike those found in areas where the mean July temperature is below 8°C but not below 2°C (Reiger, 1974). Judging from the type of vegetation it is the opinion of the authors that the July temperature has been between 5° and 8°C.

This layer has been radiocarbon dated at 49,200 years B.P. (see table 1) and belongs to the Moershoofd Interstadial complex.

VOORTHUIZEN MIDDLE ORGANIC LAYER (M.L.)

Description

The middle organic layer is very poor in pollen and no diagram has been made. However, two pollen spectra situated 15 cm and 35 cm above the base of the peat layer, respectively, were investigated. In the 15 cm spectrum 6 *Pinus*, 4 *Betula*, 2 *Salix*, 12 Gramineae, 33 Cyperaceae, 7 *Artemisia*, 1

Caryophyllaceae, 1 Rosaceae, 1 *Ephedra*, 2 *Sphagnum*, 1 *Selaginella*, 10 *Botryococcus* and 1 *Pediastrum* were found (Σ 67). At 35 cm, 10 *Pinus*, 3 *Alnus*, 1 large and 5 small *Betula* pollen grains, 1 *Salix*, 12 Gramineae, 11 Cyperaceae, 4 *Artemisia*, 4 *Thalictrum*, 1 Ranunculaceae, 1 *Compositae liguliflorae*, 1 Caryophyllaceae, 1 *Sphagnum* and 1 *Botryococcus* were present (Σ 54). Furthermore some Coleoptera were found in this layer (Angus, 1975).

Interpretation

The pollen assemblage points to a rather open vegetation type, but as compared to the moss layer, more *Betula* and *Salix* pollen is present and this might indicate that a shrub tundra was found in the vicinity. In comparison with the present-day extension of the tundra and shrub tundra zones and their climatic environments, we tentatively suggest a mean July temperature of about 8°C or may be a little higher, but certainly below 10°C for this zone. This conclusion is in excellent agreement with Angus' tentative estimate for this zone (Angus, 1975).

This layer has been radiocarbon dated at >50,800 years B.P. (table 1) and is thought to belong to the Moershoofd Interstadial complex.

VOORTHUIZEN UPPER ORGANIC LAYER (U.L.)

Description of the diagram

Every cm of the upper peat layer has been palynologically investigated (enclosure 3).

The diagram (encl. 3) exhibits rather low A.P./N.A.P. values, the A.P. (i.e. *Pinus*, *Betula*, *Salix*) making up about 24% of the sum. The dry herbs (N.A.P.) are dominated by Cyperaceae and, to a lesser extent, by Gramineae. Water plants are present in most of the diagram. Most numerous are *Batrachium*, *Tetrahedron*, *Pediastrum*, and *Botryococcus*. *Equisetum* forms an almost continuous curve never exceeding 5%.

Zone I 99-91 cm – This zone is characterized by high Cyperaceae values (67–85%), relatively low Gramineae values (8–21%), a *Betula* maximum (at 93–94 cm) of 19%, and very few other terrestrial herbs.

Zone II 90–28 cm – In this zone the Cyperaceae show a fluctuating, gradual decrease (from about 80% to about 50%), followed by a gradual rise (up to 65–70%). The Gramineae values increase gradually (from about 15 to about 30%) the curve being superposed by minor fluctuations. In this part of the diagram the number of various herbs attains a maximum. Many of the herbs are found almost continuously throughout this zone (viz. *Artemisia*, *Compositae*, *Plantago*, *Umbelliferae*, Caryophyllaceae, *Helianthemum*, Rosaceae, *Filipendula* and *Thalictrum*). Others are only found in parts

of the zone (viz. Chenopodiaceae, Cruciferae, *Empetrum*, *Epilobium* and Ranunculaceae) while yet others are only represented by a single grain or by very few (viz. *Polemonium*, *Geranium*, *Valerianella* type, *Gentianella*, *Parnassia*, *Montia*, *Armeria*, *Rhinanthus*, *Galium*, Papilionaceae, Labiatae, Scrophulariaceae and Dipsacaceae).

The water plants obtain high percentages: *Batrachium* generally 10–15%, *Tetrahedron* fluctuating, attaining maxima of more than 200%, *Botryococcus* also fluctuating but to a lesser extent, percentages between 1% and 45%, and *Pediastrum* strongly fluctuating, with maximum values of more than 500%. *Myriophyllum* is present but always in percentages under 3%. A few grains of *Menyanthes* were found.

Zone II has been divided in 3 subzones: IIa (90–68 cm), IIb (68–45 cm) and IIc (44–38 cm):

– Subzone IIa 90–68 cm

The Cyperaceae, *Betula* and *Batrachium* curves are rather irregular. The Cyperaceae curve always attains minima where the *Betula*, *Batrachium* and, to a lesser extent, the Gramineae curves have maxima and *vice versa*. The number of more occasionally found pollen grains is rather low.

– Subzone IIb 68–45 cm

Maximum values of herbs other than Gramineae and Cyperaceae. In the upper part a decrease of *Tetrahedron*.

– Subzone IIc 44–38 cm

Gramineae exhibit a maximum and Cyperaceae a minimum; low percentages of *Tetrahedron*.

Zone III 27–1 cm – In this zone the percentages of Gramineae have become lower, and those of Cyperaceae higher, than in the preceding zone. Some herbs disappear, for example Umbelliferae, *Epilobium* and *Filipendula*, while others (Chenopodiaceae, Cruciferae) are better represented than in the preceding zone. *Polygonum viviparum*, *Geranium* and *Centaurea jacea* are represented by single grains. The low percentages of most water plants are striking. Only *Pediastrum* obtains a fairly high percentage.

This zone is subdivided into a zone IIIa (27–11 cm) and a zone IIIb (10–1 cm):

– Subzone IIIa 27–11 cm

Very low *Betula* and *Salix* values.

– Subzone IIIb 10–1 cm

Betula again attains somewhat higher percentages. *Salix* and *Artemisia* obtain maximum values in this part of the diagram.

Interpretation

The pollen rain represented in our diagram is dominated by plants growing in moist sites and, therefore, gives a very local impression of the vegetation cover which is devoid of tall trees, with the possible exception of *Salix* in the upper part of the diagram (2 cm level). From the plant association we conclude that the local environment had the character of a moist depression in zones I and III and of a shallow lake in zone II, with a gradual transition to more elevated dry areas.

In the open water *Batrachium*, *Myriophyllum*, *Pediastrum* and *Botryococcus* were the dominant plants, in the driest places *Artemisia*, Chenopodiaceae, *Helianthemum*, *Empetrum* and probably most of the Gramineae were dominant, while most of the other plant groups might be found in the transitional area. From the presence of *Batrachium*, *Armeria*, *Centaurea jacea*, *Filipendula* and *Selaginella selaginoides* (see table 2) a mean July temperature slightly above 10°C and probably below 17°C, and an average January temperature above -8°C have been deduced.

This peat deposit is dated at >44,450 years B.P. and it is thought to belong to the Moershoofd Interstadial complex.

BUSSLOO SECTION 1

Depositional environment at Bussloo

The peat deposits at Bussloo were found in an abandoned river bed and are shown in fig. 9. At the bottom of the section is a sand deposit. In the western part of the profile a loamy peat layer (Bussloo section 1) was found. This peat layer is cryoturbated in its lower part and overlain by sandy loam, sand, peat (small upper diagram in Bussloo section 1), sand, gravel and, in the uppermost part, arable soil.

In the depression (fig. 9) a peat layer, Bussloo section 2, is found, overlain by a large-scale cross-bedded sand deposit, interpreted as a dune. In this dune dark brown humus bands were found crossing the original structures and extending downwards into the peat layer.

Description of the Bussloo section 1 diagram

This diagram (encl. 4) can be divided in 3 zones: I (289–269 cm), II (269–249 cm) and III (249–222 cm); zones I and II have been further subdivided in an a- and a b-zone.

Zone I 289–269 cm – In this zone very low *Pinus* and *Betula* values are found; Gramineae are rather poorly represented (ca. 15%), Cyperaceae abundantly (ca. 70%), Ericaceae and *Artemisia* poorly. *Parnassia* forms an almost continuous curve. Very few pollen grains or spores of *Filipendula*, *Batrachium*, *Myriophyllum* and *Selaginella* were recorded. *Pediastrum* and *Botryococcus* are represented by low values and *Potamogeton* is found continuously.

– Subzone Ia 289–275 cm

Salix percentages are low. A single grain of *Populus* (278 cm); *Plantago* and *Thalictrum* are rather abundant, 3.2% and 6%, respectively. Almost equal quantities of *Salix glauca* type and of the *S. herbacea*, *S. polaris* types (Faegri & Iversen, 1966).

– Subzone Ib 275–269 cm

The *Salix* curve attains a maximum coinciding with a *Plantago*, *Thalictrum* and *Helianthemum* minimum. A single grain of *Jasione* and a few grains of *Filipendula* are found. The *Salix* pollen in this zone consists exclusively of the *S. glauca* type (Faegri & Iversen, 1966). At the transition to zone II, the *Betula* percentages become higher than those of *Salix* and remain so in the rest of the diagram. The curves of *Batrachium*, *Myriophyllum* (both *M. spicatum* and *M. verticillatum* being present) and *Pediastrum* rise suddenly, *Artemisia*, *Plantago*, *Thalictrum*, and *Helianthemum* more gradually so, whereas *Parnassia* disappears.

Zone II 269–249 cm – The *Betula* percentages are higher and the *Salix* percentages lower than they are in zone I. There are two maxima in the grain size distribution of *Betula* (see fig. 3). The Gramineae show a maximum and the Cyperaceae a minimum. Most herbs attain higher percentages than they do in the preceding zone, in particular the Ericaceae, *Artemisia* and *Helianthemum*. High percentages of *Batrachium* and *Myriophyllum* (both *M. spicatum* and *M. verticillatum* present), attaining maxima of 65% and 60%, respectively. Also *Botryococcus* and *Pediastrum* attain high percentages.

– Subzone IIa 289–259 cm

Very low *Salix* percentages. Rise of *Batrachium* and *Myriophyllum*. A single grain of *Armeria* and *Hydrocotyle* and a few grains of *Filipendula* were found. The boundary between IIa and IIb is marked by the incipient fall of *Myriophyllum* and *Batrachium*.

– Subzone IIb 259–249 cm

Maximum and gradual fall of the *Betula* curve. Decrease of *Myriophyllum* and *Batrachium*. Representation of Caryophyllaceae relatively high. A single pollen of *Jasione*. At the transition from zone II to zone III *Salix* attains almost the same values as *Betula*.

Zone III 249–222 cm – *Betula* and *Salix* are almost equally represented in this zone. Furthermore Ericaceae, *Artemisia*, Compositae and *Sphagnum* are gradually increasing, while *Batrachium* is gradually decreasing. A small peak of *Typha*

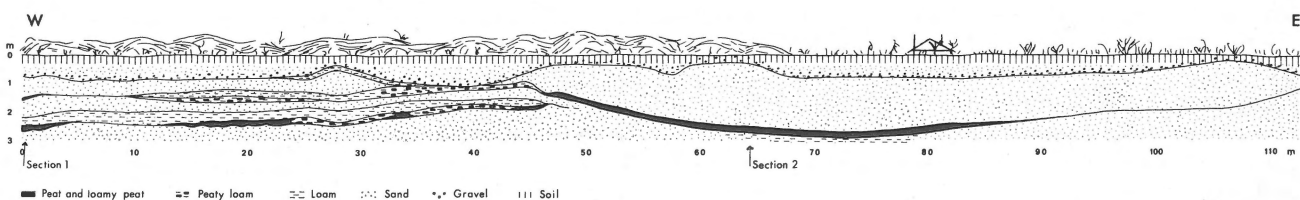


Fig. 9
Sketch of locality Bussloo with the location of sections 1 and 2 indicated (survey by E. Kolstrup).

latifolia, a few grains of *Typha angustifolia* and *Filipendula*, plus a single grain of *Populus*, *Calystegia* and *Hydrocotyle* are present.

Upper small diagram encl. 4

In the upper small diagram the *Betula* percentages are higher than those of *Salix*. Water plants are scarce. Single grains of *Sanguisorba officinalis* and *Mercurialis* are found.

Interpretation

As is the case in the Eerbeek and Voorthuizen diagrams, the Bussloo diagrams also reflect a stand of vegetation *in situ*. In the diagram Bussloo section 1 (encl. 4), however, a certain vegetational development can be seen. S p e t z m a n (1959) has found that in the flood plains in Alaska, when a river has abandoned a certain area, successional stages can be found as riparian vegetation moves in from the surroundings. Stages closely matching his first two phases are found in subzones Ia and Ib. At first a pioneer stage with herbs is found (subzone Ia), and thereafter a tall-shrub stage with tall willows has developed (subzone Ib). In Bussloo this stage is followed by a wetter local environment (with open water), with a few tall birches in the surroundings.

From the presence of *Filipendula*, *Calystegia*, *Jasione*, *Myrica*, *Hydrocotyle* and the water plants *Batrachium*, *Myriophyllum spicatum* and *M. verticillatum*, *Nymphaea*, *Typha angustifolia* and *T. latifolia* an average July temperature exceeding 13°C is evident (table 2), and it is probable that the July mean has even been about 15°C at times. From the presence of *Armeria* a winter temperature above -8°C can be deduced.

The radiocarbon dating of 39,420 years B.P. (table 1) places this peat deposit in the Hengelo Interstadial.

In the small upper diagram in this enclosure (4) *Sanguisorba officinalis* and *Mercurialis* are found, indicating a July mean temperature of about 13°C. The deposit represented in this small diagram is probably of the same age as the deposit in Bussloo section 2, but no substantiating evidence for this conclusion could be found.

BUSSLOO SECTION 2

Description

In this diagram (encl. 5) most of the pollen types occur in almost constant percentages throughout the diagram. It has, however, been possible to subdivide the diagram into two zones.

Zone I 282–245 cm — The relatively high *Betula* and low *Salix* and *Pinus* percentages, together with the low herb percentages and relatively high water plant percentages, constitute the characteristic features of zone I. Among the

herbs, only *Plantago* occurs in high percentages (3%). The percentages of Ericaceae, *Artemisia* and *Thalictrum* increase slightly in the upper part. Single grains were found of *Filipendula*, *Sanguisorba officinalis*, *Saxifraga nivalis*, *Gentiana nivalis*, *Myrica*, *Nymphaea*, *Typha angustifolia* and *Selaginella*.

The transition to zone II is marked by a fall in the curves of *Betula*, *Plantago* and most of the water plants (e.g. of *Botryococcus* and *Pediastrum*), while the curves of *Salix*, *Pinus* and some herbs (e.g. of Ericaceae, *Artemisia*, Caryophyllaceae and *Thalictrum*) are rising.

Zone II 245–224 cm — This zone contains almost equal percentages of *Betula*, *Salix* and *Pinus*, all of them usually being lower than 5%. Most herbs attain higher values than they do in the underlying zone. Only *Plantago* and *Parnassia* have lower percentages; the latter actually disappears in the upper part. The percentages of e.g. *Botryococcus* and *Pediastrum* are lower. Low percentages of *Filipendula* and single grains of *Sanguisorba officinalis*, *Typha angustifolia*, and *Typha latifolia* are found.

Interpretation

The presence of *Filipendula*, *Sanguisorba officinalis*, *Nymphaea*, *Typha angustifolia*, and *T. latifolia*, in combination with the low percentages of *Batrachium* and *Myriophyllum*, suggest that the average July temperature has been below that found in section 1 and we think it has been about 13°C.

Two radiocarbon datings are available from this peat layer. One is 36,850 years B.P., the other 31,500 years B.P. We think that the latter is probably too low because of humus infiltration from above and that the whole peat layer belongs to the Hengelo Interstadial.

LAARHUIS SECTION

At Laarhuis (near Denekamp) the type section of the Denekamp Interstadial (v a n d e r H a m m e n, 1971b) is situated. The depositional environment of this site is given in W i j m s t r a & S c h a l k e (1971) and a preliminary pollen diagram and the radiocarbon datings of the peat layer are given in v a n d e r H a m m e n (1971b).

Description of the diagram (encl. 6)

The present diagram can be divided into 5 pollen zones, viz., the zones L1–L5.

Zone L1 — The percentages of Cyperaceae are generally high. At samples 85 and 81, maxima in the curve for birch are found coinciding with lower percentages of sedges. The curve for *Salix* shows a gradual increase to 2% in this zone. A few grains of *Polygonum amphibium* and *Gentiana nivalis* occur.

Zone L2 — Noteworthy throughout this zone is the corres-

Depth in cm	<i>Abies</i>	<i>Acer</i>	<i>Alnus</i>	<i>Carpinus</i>	<i>Castanea</i>	<i>Corylus</i>	<i>Ilex</i>	<i>Picea</i>	<i>Populus</i>	<i>Quercus</i>	<i>Tilia</i>	<i>Ulmus</i>	<i>Carya</i>	<i>Classopollis</i> type	<i>Gardeniasporites</i> spec.	<i>Pinus haploxyton</i> type	Other older <i>Pinus</i> types	<i>Pterocarya</i> type	<i>Triopollinites</i> type	Other pre-Quaternary types
222			1		1	2		1							2	2			2	
223			7		1	2		4								2	3			
224		1	7	1		6		1		6				1		6				
225			7			6														
226			9	1		4		1		1						3				> 5
227	1	2	9	1		4		6		1				5		5				> 5
228			2			2		2								2				
229			6			4				2						1			1	
230			12			2		1												
231		1	7			6				1	1					1			2	3
232			4			1		4								1				4
233			6			2		2						1		1			1	
234			4			2		2												
235			2																	
236			5			3		1												
237			6			8														> 20
238			8			2		3								2				
239						3		3		1						1				
240			5			1		1					1							2
241			4			2							1							
242						2		1												> 20
243			1			3		1				1				1	1	1		
244			3	1		3			1	1						2			1	
245			4																	1
246			2			3		1		2				2					1	
247		1	1			2														> 10
248			7	1		3	1	1		1				2					1	
249			6			1		1		2				2						
250		1	2			1						1							2	
251			2			3		1		2										
252			1																1	
253						2								1					1	
254			3			1														
255			1							1		1								
256			1			3													1	
257			1			1						2							1	4
258			1			2													1	
259			1			1								1						1
260			2			3						1								
261																			1	
262			1			1														8
263																				1
264				1		2														
265			1			1														
266			1			1														
267						1														
268														2						
269												1								
270																				
271																				
272																				+
273																				
274			1																	
275								1												
276			1			1		1												

Table 5. Pollen grains found in Bussloo section 1, not included in the pollen diagram (encl. 4).

Depth in cm	<i>Abies</i>	<i>Acer</i>	<i>Alnus</i>	<i>Carpinus</i>	<i>Castanea</i>	<i>Corylus</i>	<i>Ilex</i>	<i>Picea</i>	<i>Populus</i>	<i>Quercus</i>	<i>Tilia</i>	<i>Ulmus</i>	<i>Carya</i>	<i>Classopollis</i> type	<i>Gardeniasporites</i> spec.	<i>Pinus haploxylo</i> n type	Other older <i>Pinus</i> types	<i>Pterocarya</i> type	<i>Tritopollinites</i> type	Other pre-Quaternary types	
277			1			1															+
278						1			1												
279																					
280			1																		
281						1															
282																			1		
283			1																		
284			3			1															
285			4																		
286						3															
287		1	2										3								
288	1					2		1								1					22
289			1										4		1			1			+

Table 5
Pollen grains found in Bussloo section 1 not included in diagram, continued

pondence of maxima in the grass curve with minima in the sedge-curves. *Artemisia*, Chenopodiaceae and *Thalictrum* show continuous curves. Between samples 71 and 74 a maximum of *Pediastrum* and lower Cyperaceae percentages are found. Some grains of *Polygonum viviparum*, *Armeria maritima* and *Valeriana* were present.

Zone L3 – The percentages of *Batrachium* are high. Also some seeds of this plant were found. Single finds of *Campylopusium*, *Epilobium* and Plumbaginaceae.

Zone L4 – Constant percentages of grasses. The percentages of sedges are diminished to 68%. Further characteristics are the high percentages of *Pediastrum* and the rise in the *Betula* curve. In sample 54 a few grains of *Polygonum viviparum* are found.

Zone L5 – In this zone *Salix* and *Betula* attain higher values, while the Gramineae percentages decrease.

Interpretation

From the plant taxa present in this site, e.g. *Batrachium* and *Armeria maritima*, a July temperature around 10°C and a January temperature of –8°C or higher can be deduced.

DISCUSSION AND FINAL CONCLUSIONS

As the radiocarbon datings of the Moershoofd Interstadial extend to the limit of the ¹⁴C-dating method, they are generally given with some diffidence or remain infinite (see table 1). It is, therefore, difficult to indicate precisely the

chronostratigraphic correlation between the Eerbeek and the Voorthuizen sections. From the radiocarbon dates and the pollen analytical results it seems plausible that the Voorthuizen diagram and the diagram section 2 Eerbeek are of approximately the same age if not overlapping, i.e. the age of both is probably between 46,000 B.P. and 45,000 B.P. Eerbeek section 1 is thought to fall approximately between 51,000 and 50,000 B.P., while the moss sample and the middle peat layer at Voorthuizen (fig. 8) are placed at about 49,000 B.P., and between 49,000 and 46,000 B.P., respectively.

From the ecological evidence found in the various interstadial peat layers it can be concluded that during the Middle Pleniglacial the average July temperature has periodically exceeded 10°C. The results are summarized in fig. 10. From this figure it appears that the Moershoofd Interstadial started with a fairly high July temperature, ca. 13°C, which decreased rapidly to 5°–8°C, slowly rising again to a little above 10°C.

During the older part of the Hengelo Interstadial, ca. 38,500 B.P., the July temperature was above 13°C, and possibly reached 15°C for some time. The peat sedimentation was interrupted and around 37,000 B.P. and later it took place under July temperature conditions of about 13°C.

The July temperature during the Denekamp Interstadial in the type locality Laarhuis near Denekamp averaged about 10°C.

An attempt to check the interpretations of our data with those from other areas has not been very successful because there is a lack of adequately dated pollen diagrams from the time span in question. However, we found no contradiction to our interpretation either in other pollen diagrams (Zagwijn, 1961, 1974; Teunissen & Teunissen-van

Depth in cm	<i>Acer</i>	<i>Alnus</i>	<i>Carpinus</i>	<i>Castanea type</i>	<i>Corylus</i>	<i>Fraxinus</i>	<i>Ilex</i>	<i>Picea</i>	<i>Quercus</i>	<i>Taxus</i>	<i>Tilia</i>	<i>Ulmus</i>	<i>Classopollis</i>	<i>Engelhardia</i>	<i>Gardeniasporites spec.</i>	<i>Pinus haploxylo type</i>	<i>Other older Pinus types</i>	<i>Triopollenites spec.</i>	<i>Other pre-Quaternary types</i>
224		3					1						4						
225		7																	5
226		4			1			1			1		2						
227		5	1		1								1			1			1
228	1	5							1				1					2	
229	1	2			1														
230		1					1		1	1		1							3
231		2			1			2	1									1	1
232	1	1	1		4			1				1	1						1
233	1	1	1		2								2					1	2
234		3					2						1					1	
235		5							1										1
236		3	1		1														1
237		3							1				1		1	1			1
238	1	2																	
239		1			1								1						
240		2			1														2
241		6											1			1			
242		2																	
243		1						1	1										
244		1	1					1								1		1	
245		6																	2
246		1			1								1						
247		3			1														
248		1																	
249									2										
250		1																	
251																			
252		1			2													1	
253		1							1										
254					1				1									1	1
255																			
256		1																	
257		1																	
258																			
259		1																	
260		1			1														
261		1							1										
262																			
263				1														1	
264		1																	
265		1																	
266		1																	
267		1																	
268		1				1			1										
269		1																	
270																			
271																			
272		1							1										
273		1																	
274																			
275														1					
276		2						1										1	
277		1																	
278		1							1										
279		2																	
280																			
281																			
282		1							1										1

Table 6. Pollen grains found in Bussloo section 2, not included in the pollen diagram (encl. 5).

YEARS B. P.	Average July temp.		
	5	10	15°C
25 000			
30 000)	
35 000)	
40 000)	
45 000))	
50 000))	
55 000			

Fig. 10
Estimated average July temperatures for the Moershoofd Interstadial complex and the Hengelo and Denekamp Interstadials.

Oorschot, 1974; Woillard, 1975; Korpela, 1969) or in facts from other fields of study e.g. deep sea cores (Shackleton, 1974; Emiliani & Shackleton, 1974; Ruddiman & McIntyre, 1976) and the Greenland ice core (Dansgaard *et al.*, 1971).

A point not satisfactorily explained by our interpretation is the near absence of large trees. The lack of more or less abundant tree growth is at variance with a postulated mean July temperature exceeding 10°C. However, for reasons explained above we feel that our temperature estimates are fairly reliable, so that we are inclined to attribute the incongruous scarcity of larger trees to some other cause such as (a) unfavourable soil conditions, (b) a slow migration rate of arborescent taxa, (c) drought, and (d) the prohibitive action of wind.

a) Although it is probable that the soil was still only poorly developed, this factor alone would not have prevented an extensive growth of *Pinus* and *Betula*.

b) The migration rate of the trees was certainly of importance, but it is not at all easy to estimate the precise influence of this factor, since we do not know for what distance the diaspores of the trees had to travel at that time. It is likely, however, that the barrier action of steppe-like areas in northern France delayed the migration.

c) Extreme drought cannot have been the sole cause of the absence of trees either, because the pollen spectra of the Dutch interstadials do not reflect a steppe vegetation (the representation of *Artemisia* and *Chenopodiaceae* is far too low). It is much more likely that the climate was fairly moist,

because *Empetrum* and *Sphagnum* were usually present, and also because of the fact that the local pools never dried up completely (see also fig. 4). From the presence of *Gentiana nivalis* and *Saxifraga nivalis* it can be deduced that snow falls (i.e. winter precipitation) occurred in periods.

d) It has been stated already that small numbers of poplars and large birches grew in The Netherlands during part of the Hengelo Interstadial, but surprisingly enough they never formed extensive stands (the *Betula* pollen percentages remain below 12%). We think that the most obvious explanation is that the climate was too windy. We do not only think in terms of severe storms, but also of constant winds blowing too strongly for the trees to thrive (for a discussion see, e.g., Green, 1974). This conclusion is supported by the fact that most of the taxonomically identified plants have rosettes, form cushions, are creepers, or have a woody stem. These life forms are not only found in the Hengelo Interstadial but in the Moershoofd Interstadial as well, and it is therefore possible that the absence of trees during the Moershoofd Interstadial can also be partly ascribed to the presence of too windy a climate. To sum up: The reason for an absence of trees during the Moershoofd Interstadial may have been twofold: 1) Migration problems after a very cold period (van der Hammen *et al.*, 1967) and 2) excessive wind action. During the Hengelo Interstadial the wind may have been the predominant limiting factor, while during the Denekamp Interstadial the temperature played a major role in limiting tree-growth.

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