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VEGETATIONAL AND CLIMATIC DEVELOPMENTS DURING THE LATE GLACIAL AND THE EARLY HOLOCENE AND AEOLIAN SEDIMENTATION AS RECORDED IN THE UTERINGSVEEN (DRENTE, THE NETHERLANDS)

P. CLEVERINGA[1], W. DE GANS[1],
E. KOLSTRUP[2] & F.P. PARIS[1]

ABSTRACT

Cleveringa, P., W. de Gans, E. Kolstrup & F.P. Paris (1977). Vegetational and climatic developments during the Late Glacial and the early Holocene and aeolian sedimentation as recorded in the Uteringsveen (Drente, The Netherlands). Geol. Mijnbouw, 56, p. 234-242.

A lithological and palynological investigation has been made of the Late Glacial and early Holocene filling of a pingo remnant in Drente (The Netherlands). It was found that the deposition of aeolian sands, although of varying nature, was uninterrupted from the beginning of the Late Glacial until the end of the Boreal. From the pollen records a vegetational development was reconstructed and its dependance on temperatures, moisture conditions, and soil development is discussed. It was concluded that the mean July temperatures were at least 10° C – possibly 13° C – in the Bølling, probably 12° – 13° C in the Earlier Dryas, around 14° C at the beginning of the Allerød, and at least 12° C in the Late Dryas time.

INTRODUCTION

The Drente Plateau is situated in the north-eastern part of The Netherlands (Fig. 1). The morphology of this area is characterized by a large number of circular or oval closed depressions called *"dobben"* by the local inhabitants. Some of these *"dobben"* are probably remnants of pingos filled in with gyttja during the Late Glacial of the Tubantian (Weichselian), and at a later date (at the beginning of the Holocene) with peat (M a a r l e v e l d & v a n d e n T o o r n, 1955; d e G a n s, 1976). The gyttja deposition was sometimes discontinuous as is shown by the presence of thin layers of aeolian sand. In order to investigate the relationship between the vegetational development and the aeolian sedimentation during the Late Glacial and the beginning of the Holocene, one of these remnants of pingos, viz. the Uteringsveen, was chosen because it contains well-developed intercalations of aeolian sand in the gyttja. The geological sequence in the Uteringsveen seemed also very suitable to establish the termination of the aeolian sand sedimentation, on which question little information is available in The Netherlands, as well as in the neighbour countries.

The gyttja and peat of two cores were analyzed as to pollen content, organic material, and aeolian sediment (inorganic material). In order to study the differences in sedimentation of sand and pollen within the *"dobbe"* a core was taken close to the edge and another one from the centre of the depression.

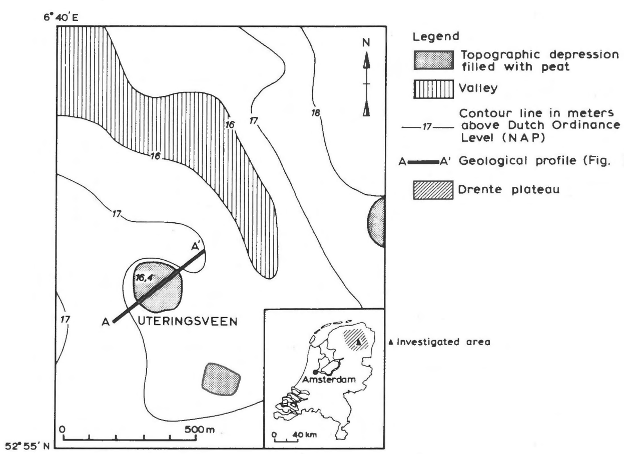

Fig. 1
Location of the investigated area.

[1] Instituut voor Aardwetenschappen der V.U., de Boelelaan 1085, Amsterdam.

[2] Hugo de Vries Lab., afd. Palynologie, Sarphatistraat 121, Amsterdam.

GEOLOGY OF THE DRENTE PLATEAU

During the Saalian glaciation the Drente area was covered by an ice-mass which deposited several metres of till upon the sands of the Peelo and Eindhoven Formations (D o p p e r t *et al*., 1975) (Table I). During the Eemian interglacial and the Early Tubantian the top of this till became weathered. This weathered layer is found as an unsorted mixture of sand and gravel called "keizand". The keizand and the till both belong to the Drente Formation (t e r W e e, 1966). During the Upper Pleniglacial of the Tubantian, the Late Glacial, and probably the early Holocene, aeolian sands were deposited on top of the keizand (t e r W e e, 1966). These sands conceal the older relief. Because of the relief of the aeolian sands it is impossible to distinguish between aeolian depressions, pingo-remnants and other types of depressions without borings.

In figure 2 a geological profile of the Uteringsveen is given. A keizand rampart and upturned and dislocated till are clearly visible; furthermore, it is evident that the gyttja sedimentation started in the Late Glacial time and the Uteringsveen is therefore thought to be a pingo-remnant (d e G a n s, 1976).

FIELD AND LABORATORY METHODS

The two sections in the Uteringsveen were sampled by means of a tube borer (ϕ 50 mm). The section near the edge of the dobbe is constructed from two complementary cores close to one another.

Samples were taken from the cores at every 5 mm. To obtain an exact correlation between pollen data and sedimentological data each sample was split into two. One part of the samples was used for pollen studies; it was treated with KOH, and subsequently acetolysed according to E r d t - m a n (1933) and F a e g r i & I v e r s e n (1966). The results of the pollen analyses are represented in so-called Iversen diagrams (I v e r s e n, 1942). A pollen total of 300 has been used.

The other part of the samples was used to investigate the grain-size distribution and to establish the organic / inorganic-material ratio. For these analyses all samples were dried, weighed, and subsequently boiled in H_2O_2. After this treatment the inorganic material remains. The organic / inorganic ratio was established after weighing the dried residue. Afterwards the grain-size distribution of this residue- divided into three classes: $< 16\mu$, $16\text{-}50\mu$, $> 50\mu$, – was obtained

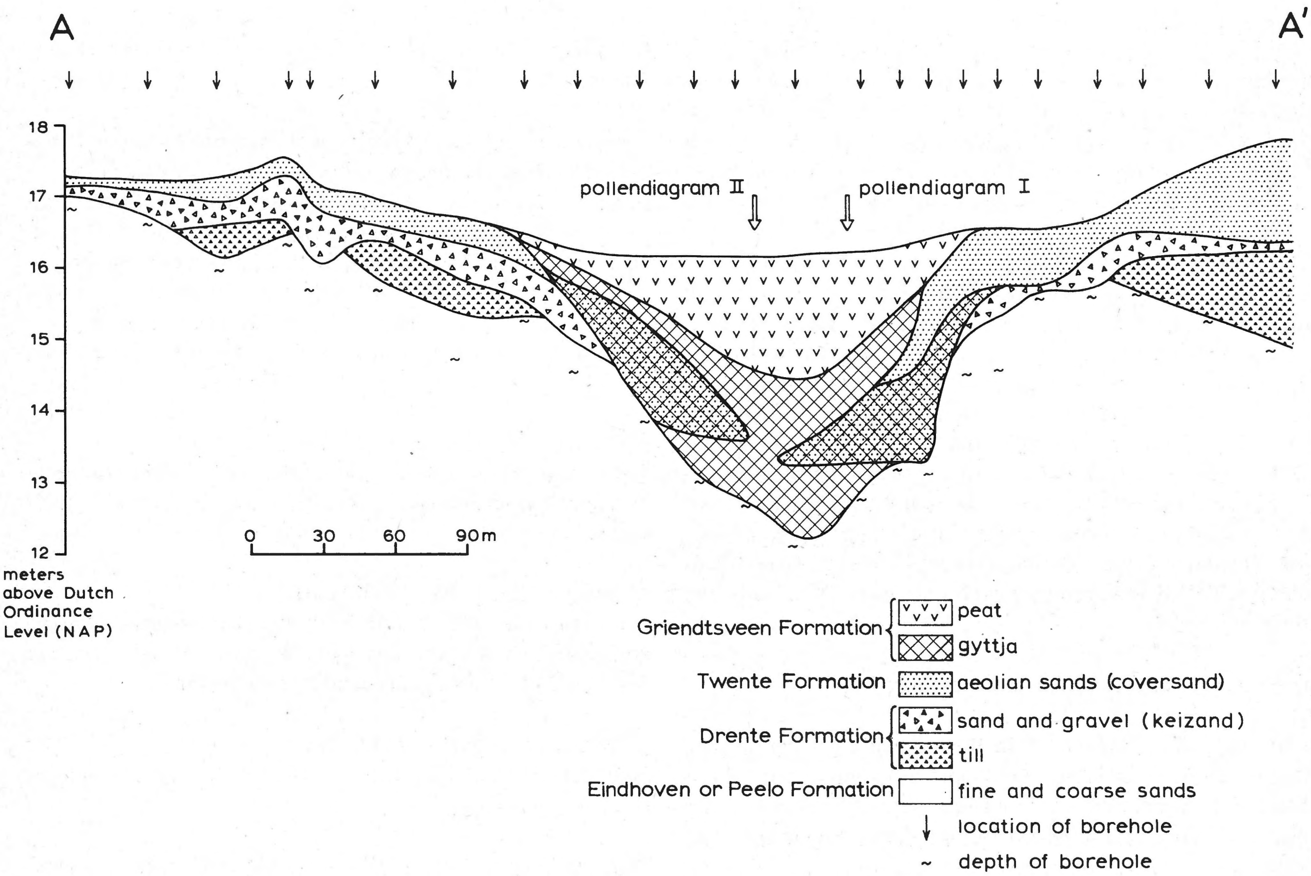

Fig. 2
Geological profile through the Uteringsveen.

HOLOCENE	Griendtsveen Formation	peat, gyttja
TUBANTIAN	Twente Formation	eolian sands / peat, gyttja
EEMIAN		
SAALIAN	Drente Formation Eindhoven Formation	keizand / till fine and coarse sands
HOLSTEINIAN		
ELSTERIAN	Peelo Formation	fine and coarse sands

Table I. Chronostratigraphic position of the lithologic units under investigation

by means of the Atterberg method (A t t e r b e r g, 1912) and fractional sieving.

THE POLLEN DIAGRAMS

In the following pages a description and an interpretation will be given of the two pollen diagrams from the Uteringsveen (diagrams U.V.I. and U.V.II; see enclosures 1 and 2).

To aid the interpretation of the vegetational and climatic development the birch pollen grains from the lower part of diagram U.V.II were measured from the top of a pore to the opposite face. The changes between small ($< 25\mu$) and large ($> 25\mu$) *Betula* pollen aren given in Fig. 3. From a comparison with the findings of R o b e r t s s o n (1973), B e r g l u n d & D i g e r f e l d t (1970), and F r e d s k i l d (1975) it is concluded that the *Betula* pollen smaller than 25μ predominantly represents *Betula nana* (dwarf birch), and that the pollen larger than 25μ represents (a) larger *Betula* species.

The temperature estimates for the different zones were found by means of a comparison of the recent ecology and distribution of plants (e.g. H u l t é n, 1971), found as fossils in the Uteringsveen according to the method described in K o l s t r u p & W i j m s t r a (1977), using both arborescent and herbaceous forms as indicators. Since no radiocarbon datings are available, the zonations are based on biostratigraphical correlations with other diagrams.

Finally, it should be mentioned that during our work two papers appeared concerning the ecologic importance of fungal remains and spores of algae (v a n G e e l, 1976a, b). In diagram U.V.II (enclosure 2) curves are given of some of the fungi and algae.

Diagram Uteringsveen I (Encl. I): description

Zone 0 (356 – 351 cm) – In this part of the diagram very low percentages of *Betula* and *Pinus*, and high percentages of *Salix* and Cyperaceae are found. The various herbs and water plants are poorly represented both as far as percentages and as the number of different types are concerned.

Zone I (350,5 – 326 cm) – This zone is characterized by rather high percentages of herbs and relative low values of *Pinus*. *Betula* has maximum values of 56%. A large number of plants show higher percentages than in zone 0 or appear for the first time at the transition from zone 0 to zone I. Newcomers forming continuous curves are *Juniperus, Artemisia, Galium, Rumex*, and in the lower part of the zone *Polygonum amphibium*.
Among the plants represented by somewhat higher percentages than in the preceding zone, the Rosaceae, the Compositae, the Ranunculaceae, and *Selaginella selaginoides* are the most conspicuous. Some herbs are only represented by single grains, e.g. *Hippophae* and *Sanguisorba*. Most water plants are relatively well represented. It should be mentioned that *Myriophyllum* in this zone consists of the *M. spicatum/verticillatum* type only.
This zone has been divided into subzones Ia + b, and Ic:

– Subzone Ia + b (350,5 – 331 cm)
In this subzone the percentages of *Betula* are higher while those of *Salix* and *Pinus* are low. The measurements of *Betula* pollen grains (Fig. 3) made for the U.V.II diagram suggested to us that we should tentatively subdivide this zone into an a- and a b-subzone also.

– Subzone Ic (330,5 – 326 cm)
Pollen of *Betula* occurs in low percentages while the Cyperaceae and Gramineae attain higher percentages than in the preceding subzone. *Botryococcus* and *Pediastrum* exhibit maxima.

Zone II (325,5 – 278,5 cm) – The transition to zone II has been placed at the incipient rise of the *Betula* curve (I v e r s e n, 1942). In general it can be said that zone II has high *Betula* percentages. The percentages of Cyperaceae, Gramineae, and most herbs are lower than in zone I. *Myriophyllum*, exclusively *M. Alterniflorum*, forms a continuous curve. The same holds for *Isoetes* except in the lower part.
Zone II has been subdivided into subzones IIa1, IIa2, and IIb.

– Subzone IIa1 (325,5 – 323,5 cm)
The *Betula* percentage is rapidly rising. Most herbs are rapidly decreasing in number. Scattered grains of *Urtica* are present.

– Subzone IIa2 (323 – 303,5 cm)
Pinus has low and *Betula* very high percentages. *Salix* is important in the lowermost part. *Sanguisorba* and *Urtica* are represented by single grains, and *Isoetes* appears.

– Subzone IIb (303 – 278,5 cm)
Pinus attains higher percentages, while the *Betula* percentages decrease somewhat.

Zone III (278 – 230,5 cm) – *Betula* is well represented and

attains values of about 50 %, except in the upper part of the zone, while the *Pinus* percentages generally remain below 10 %.
Empetrum, other Ericales, and *Artemisia* occur in relatively high percentages. Although the total percentage of the other herbs is rather low, many different pollen types are represented. The curves of the water plants all show very low values, only *Myriophyllum* attaining higher percentages in the upper part.

Zone IV (230 – 215 cm) – In this zone *Pinus* attains higher percentages. *Corylus* and *Populus* appear but are very poorly represented. The *Juniperus* and the *Filipendula* percentages are a little higher than in the preceding zone, while the percentages of *Empetrum* and *Artemisia* are lower. The water plants and some spore-plants become more frequent. The *Myriophyllum* pollen both in this zone and in zone V is almost exclusively *M. alterniflorum.* Zone IV is subdivided into three subzones:

– Subzone IVa (230 – 226,5 cm)
The *Pinus* curve has a small maximum and the Cyperaceae, *Empetrum*, and *Artemisia* curves show small minima.

– Subzone IVb (226 – 221 cm)
The *Pinus* curve has a small minimum and the *Empetrum* and *Artemisia* curves have small maxima.

– Subzone IVc (220,5 – 215 cm)
The pollen composition is similar to that in subzone IVa.

Zone V (214,5 – 166 cm) – In this zone the deciduous trees (*Corylus, Quercus, Ulmus*) have appeared. Zone V is divided into two subzones:

– Subzone Va (214,5 – 194 cm)
Ulmus and *Quercus* appear but occur in very low percentages in this zone. The *Corylus* curve varies between 0 and 19 %, and *Pinus* and *Betula* have varying but generally almost equal percentages around 35 %. A single pollen grain of *Hedera* is present. Most herbs occur in about the same percentages as in the preceding zone.

– Subzone Vb (193,5 – 166 cm)
Corylus, Quercus, and *Ulmus* show fairly constant values of 20 %, 2 %, and 3 %, respectively. *Pinus* is rather constant around 50 %, and *Betula* around 12 %. *Tilia* and *Fraxinus* are represented by single grains and *Hedera* is regularly encountered. The herbs are poorly represented both as far as the number of different types and the percentages are concerned. *Botryococcus* attains somewhat higher values than in the preceding subzone.

Diagram Uteringsveen II (Encl. II): description

Zone O (350,5 – 349 cm) – This zone is characterized by high percentages of Cyperaceae, up to 80 %. The percentages of A.P.-pollen and of algae are very low. Pollen of riparian and aquatic plants is nearly absent, only *Polygonum* and *Potamogeton* being represented. Among the fungi, type B (*Clasterosporium caricinum*) is well represented.

Zone I (348,5 – 320 cm) – The percentages of Cyperaceae are lower than in the preceding zone. *Betula, Salix, Juniperus*, and *Pediastrum* attain higher percentages. New arrivals represented by continuous curves in this zone are: *Artemisia, Thalictrum, Selaginella selaginoides*, and *Equisetum.*
Present in smaller amounts, but more frequent than in zone 0, are: *Helianthemum*, Chenopodiaceae, Compositae tubuliflorae, *Rumex, Filipendula*, Ranunculaceae, and Umbelliferae,
With regard to the proportion tree/non-tree pollen we can divide this zone into two: subzone Ia+b and subzone Ic with high and with low tree/non-tree pollen ratios, respectively.

– Subzone Ia+b (348,5 – 327,5 cm)
The transition from zone O to subzone Ia+b is marked by an important increase in the amount of many pollen types.
In subzone Ia+b the percentages of *Betula* pollen are fairly high, whereas those of *Salix* and *Pinus* are low. From the measurements of pollen grains of *Betula* (Fig. 3) a tentative subdivision of this subzone into a subzone Ia and a subzone Ib could be established. In subzone Ia (348,5 – 341,0 cm) *Betula nana* is dominant (about 80 %), whereas in subzone Ib (340,5 – 327,5 cm) only about 60 % *B. nana* pollen is present.

– Subzone Ic (327 – 320 cm)
The Cyperaceae attain higher percentages, whereas those of *Betula* are lower in the preceding subzone. *Artemisia, Thalictrum*, and *Equisetum* become less frequent. The curves of *Selaginella selaginoides* and Zygnemetaceae attain slightly higher percentages. A single grain of *Jasione* was found.

Zone II (319,5 – 283 cm) – In this zone *Betula* is dominant. Most herbs have lower percentages than in zone I. From figure 3 it can be seen that the small *Betula* pollen is replaced by a larger *Betula* pollen type. The marsh and water plants (*Filipendula, Thalictrum*, and *Potamogeton*) and the open-habitat plants (*Helianthemum*) are less frequent than in the preceeding zones. *Myriophyllum* (almost exclusively *M. alterniflorum*) forms a continuous curve.
The same holds for *Isoetes*, except in the lower part of the zone.
Zone II has been subdivided into subzones IIa1, IIa2, and IIb.

– Subzone IIa1 (319,5 – 315 cm)
Betula is rapidly rising, whereas most herbs are decreasing. Most aquatic plants and open-habitat plants of zone I are still present. Single grains of *Urtica, Typha angustifolia*, and *Nymphaea* were encountered.

– Subzone IIa2 (314,5 – 298 cm)
Herbs are represented by low and *Betula* by very high percentages. *Salix* attains percentages of up to 10 % in the lower parts. The riparian, aquatic, and open-habitat plants characteristic of zone I have decreased in number. Single grains of *Hydrocotyle, Polygonum amphibium* and *Stratiotes aloides* were found.

– Subzone IIb (297,5 – 283 cm)
The *Betula* pollen percentage has decreased while *Pinus* has become more important with average percentages of 25 %. The percentages of Gramineae and Cyperaceae are fairly constant. *Isoetes* is an important element.

Zone III (282,5 – 229 cm) – The percentage of herbs has increased. The percentages of *Pinus* and *Betula* have decreased. Continuous curves of Ericales (predominantly *Empetrum*), *Selaginella selaginoides,* and *Sphagnum* are present. *Myriophyllum* and *Isoetes* disappear in this zone.
Zone III has been divided into two subzones: IIIa and IIIb.

– Subzone IIIa (282,5 – 261,5 cm)
Pinus has percentages around 10 % and *Betula* around 50 %.

– Subzone IIIb (261 – 229 cm)
Slightly higher *Pinus* and somewhat lower *Betula* percentages.

Zone IV (228 – 196,5 cm) – In this zone the tree pollen percentages has increased. For the first time *Corylus, Ulmus, Fraxinus, Tilia*, and *Populus* are represented in the pollen diagram. *Empetrum* attains lower percentages than in the preceding zone. *Selaginella selaginoides* spores are nearly absent. Pollen of riparian and aquatic plants (*Myriophyllum*, almost exclusively *M. alterniflorum, Equisetum, Sparganium* and *Isoetes*) becomes more frequent. The same holds for *Botryococcus.*
Zone IV has been divided into three subzones:

– Subzone IV a (228 – 225,5 cm)
Betula has a maximum and Cyperaceae and *Empetrum* have minima.

– Subzone IV b (225 – 222,5 cm)
Cyperaceae and *Empetrum* have maxima.

– Subzone IV c (222 – 211 cm)
The pollen composition is similar to that of Subzone IV a.

Zone V (210,5 – 177 cm) – The pollen percentages of Gramineae and Cyperaceae are decreasing and those of deciduous trees are increasing.

– Subzone V a (210,5 – 196,5 cm)
The curve of *Corylus* varies between 0 % and 15 %. A few pollen grains of *Quercus* and *Ulmus* are present. *Pinus* is increasing.

– Subzone V b (196 – 177 cm)
Corylus increases to 30 %. *Pinus* and *Betula* are represented by percentages averaging 30 %. A continuous curve of *Ulmus* is present.

Interpretation of the Uteringsveen diagrams

Upper Pleniglacial (zone 0) – In the lowermost zone (0) both pollen diagrams are indicative of a vegetation rich in Cyperaceae and Gramineae and poor in trees. In the section nearest to the shore of the former lake, (U.V.I.), more *Salix* pollen is found than in the section from the middle of the lake (U.V.II). We interpret this phenomenon as a result of local pollen dispersion of *Salix.*

Zone O is regarded as a pioneer stage in the vegetational development of the lake and its nearest vicinity but as only few plants have immigrated no conclusions can be made regarding temperature, water level, and other ecological factors.

– Bølling S.L. (subzone Ia+b)
The transition between zone 0 and zone I (viz. the transition from Pleniglacial to Late Glacial) has been placed where the *Artemisia* curve rises (v a n d e r H a m m e n, 1951).

Betula (nana) (Fig. 3), *Juniperus,* and many herbs began to appear and shot up in and around the depression which probably offered them more favourable conditions than did the surrounding coversand areas. During this period taller species of birches immigrated (Fig. 3), but they did not form dense stands as can be deduced from the fact that *Betula nana* remained well represented and pollen of many heliophytes also occur in high percentages.

Initially the environment was slightly basic (*Myriophyllum spicatum/ verticillatum, Selaginella selaginoides*), but became neutral upwards until the top of subzone Ic where *Selaginella selaginoides* and Zygnemataceae were present.

The presence of *Sanguisorba officinalis/minor, Polygonum amphibium, Myriophyllum spicatum/verticillatum, Filipendula*, and *Hydrocotyle*, suggest that the mean July temperature in this zone from the very beginning and probably even earlier (*Polygonum amphibium*: U.V.II, subzone 0) has been above 10° C. The presence of *Hydrocotyle* might even indicate a mean July temperature exceeding 13° C but although we do not exclude this possibility, we do not think it correct to give a temperature estimate based on only a single pollen grain.

This subzone is considered to represent the Bølling Interstadial s.l. (v a n d e r H a m m e n, 1971). The lower part Ia where *Betula nana* reigned almost supremely might correspond with the Earliest Dryas time and the upper part (Ib) might represent the Bølling Interstadial s.s. (v a n d e r H a m m e n, 1971).

– Earlier Dryas (subzone Ic)
In subzone Ic the Cyperaceae and the Gramineae percentages have increased at the cost of *Betula.* This phenomenon is

generally interpreted as a decrease in summer temperature. Van der Hammen *et al.* (1967) give a mean July temperature estimate below 10° C for this zone. In our diagrams, however, the presence of warmth requiring taxa, i.e. *Filipendula, Sanguisorba, Polygonum amphibium, Jasione*, and *Typha angustifolia* indicate a mean July temperature of 12 – 13° C.

In diagram U.V.II a maximum of Zygnemataceae is found in this zone. According to van Geel (1976b), Zygnemataceae are characteristic of lakes with a low, possibly fluctuating water level. The higher percentages of Gramineae in diagram U.V.I compared to the unchanged percentages of this family in diagramU.V.II might indicate that the riparian zone had become dryer. Also higher percentages of Cyperaceae and *Selaginella* (most pronounced in diagram U.V.II) and of *Botryococcus* and *Pediastrum*, may point to a lowering of the water level.

Although we have indications for a lower water level in the Uteringsveen, no indications can be found for an important decrease in the precipitation during this period. Thus the decreased percentages of birch cannot be explained by extreme drought, but it cannot be explained by low summer

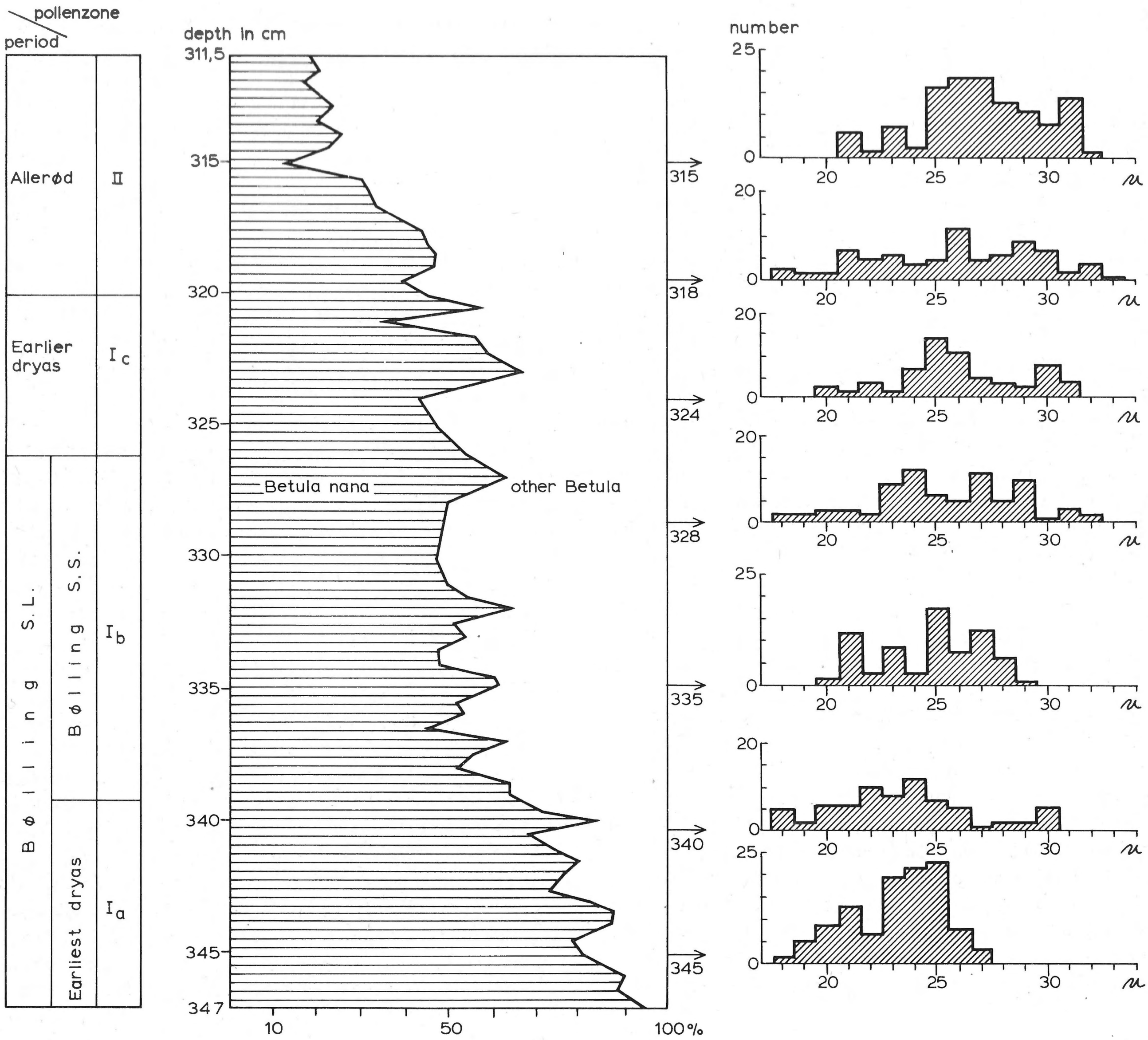

Fig. 3
Grain-size distribution of the Betula pollen from the lower part of enclosure II.

temperatures either. The reason for the low *Betula* percentages in this zone might be very cold winters, or dominance of the local vegetation in consequence of the lowered water level.

Because of the above mentioned evidence we think that the lower water level in the Uteringsveen might be caused by an increased evaporation due to higher summer temperatures. Another explanation is that the dobbe at that time was drained by the brooklet situated nearby (Fig. 1).

As no striking change in the composition of the sediments is found in this zone compared to the previous one it is concluded that the sedimentation has not changed appreciably (thus no excessive sedimentation of aeolian sands).

Allerφd (zone II) – The transition from the earlier Dryas to the Allerφd is placed by the incipient rise of the *Betula* curve.

Subzone IIa1 is a transitional zone between zone I and II. The increase in tall species of birch and the decrease of most herbs can only be interpreted as a sudden change of the vegetational environment from a rather open vegetation to a more closed woodland in which the heliophilous herbs are suppressed (Iversen, 1973). This situation remains fairly stable for some time (subzone IIa2). Locally however, willows are found in the lower part of this subzone.

From the diagrams it is evident that there is a clustering of more thermophilous taxa, such as taller species of *Betula, Nymphaea alba, Typha latifolia, Stratoites aloides, Hydrocotyle, Filipendula, Sanguisorba, Urtica (dioica), Myriophyllum*, and *Polygonum amphibium* in zone IIa. Therefore it is concluded that the average July temperature was high, probably around 14° C, at the beginning of zone II.

In subsone IIb *Pinus* appears but it did not become an equally or even more important tree component than *Betula*. The most demanding herb taxa have disappeared and only the large birches, *Sanguisorba, Myriophyllum*, and *Polygonum amphibium* remained.

From the composition of the water plants present in our diagrams, it is concluded that the water level in the lake has been low during the Allerφd time.

For the lower part of zone II *Myriophyllum alterniflorum* indicates a slightly acid environment. Later on *Isoetes, Sphagnum* and the continuous curve of *Myriophyllum* point to a further acidification of the water in the lake. Also the ground in the surrounding areas became more acid in the upper part of the Allerφd (*Pinus* and *Empetrum* are found) and a soil development had probably taken place.

The disappearance of most of the temperature indicators found in the lowermost part of the Allerφd is either a result of this soil development, or it is caused by a decrease in summer temperature. Therefore no precise temperature estimates can be made for the upper part of the Allerφd.

Late Dryas (zone III) – In the following zone the percentages of pine have again become lower. *Betula* was still the most important plant, but the Ericales, especially *Empetrum*, became important also.

The presence of *Empetrum* (and possibly also *Sphagnum*) indicates a fairly high precipitation. Therefore it might be expected that the water level should become higher. The near absence of water plants and algae is therefore surprising. It is possible that the reason for this absence is the fast accumulation of sands into the lake but is also possible that the dobbe was drained by the brooklet.

Although large *Betula, Filipendula, Sanguisorba* (only *S. officinalis* is found in this zone), *Jasione, Urtica, Myriophyllum*, and *Polygonum amphibium* are present it is difficult to state the mean July temperature precisely as waterplants are relatively scarce in this zone. Casparie & van Zeist (1960) found *Nymphaea* and *Typha latifolia* in this zone, however, and these plants, together with the temperature indicators from the Uteringsveen, strongly suggest that the mean July temperature was not below 12° C. This temperature is somewhat higher than 10° C, as previously suggested (van der Hammen *et al.*, 1967) but it is in good agreement with the findings of Mania & Stechemesser (1969).

Preboreal (zone IV) – In the upper part of the Late Dryas time the pine immigrated into the area again and is found throughout zone IV together with *Betula* and small stands of *Populus* and *Juniperus*. As a result of the larger stands of trees in the area around the depression many herbs are suppressed. Only more umbraticolous plants such as *Fillipendula*, or plants attached to an environment less favourable for the above-mentioned trees or shrubs, could manage to survive at least temporarily (e.g. *Empetrum*).

Although no change is found in the depositional rate of aeolian sands in the Preboreal compared to the Late Dryas time a fairly high number of water plants have appeared. The reason for this may be that the temperature has increased, but it is also possible that the water level in the lake had become somewhat higher because the drainage has been impeded by accumulation of aeolian sands at the eastern side of the dobbe (Fig. 2). The presence of *Myriophyllum (alterniflorum), Isoetes*, and a few grains of *Typha latifolia* suggest that the water was slightly acid.

In zone IV three small, rather insignificant phases have been distinguished. It is evident that there are some differences between the two diagrams in this part. As no correlation can be made on the basis of the *Pinus* and *Betula* curves, we have made the subzonation by means of the Cyperaceae, *Empetrum, Artemisia, Sparganium*, and *Isoetes* curves.

During the lowest subzone *Pinus* (diagram U.V.I) and *Betula* (diagram U.V.II) spread at the expense of Cyperaceae, *Empetrum*, and *Artemisia*. During the second subzone *Pinus* and *Betula*, respectively, appear in smaller percentages, while *Populus, Empetrum*, and *Artemisia* spread; and in the third subzone the vegetation is very similar to that found in the lowermost one.

Zone IV is thought to represent the Preboreal period, and the small oscillations represented by subzones IVa and IVb should consequently represent the Friesland and the Rammelbeek phases (Behre, 1966; van der Hammen, 1971). The Rammelbeek phase is generally considered to be the result of a small decrease in temperature (Behre, 1966; Iversen, 1973).

If we compare our two diagrams which are situated within a distance of 50 metres from one another it appears that the Rammelbeek oscillation in diagram U.V.I is reflected in the slightly lower percentages of *Pinus*, while in diagram U.V.II it is reflected in the slightly lower *Betula* percentages. This difference makes us believe that the change in floral composition predominantly reflects a change in the stands of vegetation in situ (or growing at least close to the lake).

It is, in our opinion, very difficult to ascertain whether a small change in the floral composition, as happened during the Rammelbeek phase, is a result of a fall in temperature if none of the indicator plants disappeared and no new indicator plants appeared in the area. A vegetational change, such as found in the Preboreal, might equally well reflect a change in moisture conditions. For this discussion see also Bohncke & Dee (in prep.)

Boreal (zone V) – The transition from zone IV (Preboreal) to zone V (Boreal) has caused some difficulties because the two diagrams differ considerably in the upper parts. We have chosen to follow the criteria mentioned by Behre (1966) for a definition of the transition, even though the high *Pinus* percentages and the immigration of *Quercus* and *Ulmus* is only reflected in diagram U.V.I. The rise in the *Corylus* curve is found in both diagrams, however, and thanks to this curve it has been possible to correlate the two Uteringsveen diagrams.

From the composition of pollen in diagram U.V.I. it can be deduced that a vegetation type dominated by *Pinus* and *Betula* with some *Corylus, Juniperus,* and *Populus* was present. In the upper part of subzone Va this changed into a somewhat more open forest with almost exclusively *Pinus* and *Betula*. In the upper part of the Boreal period (subzone Vb) most herbs have disappeared and a fairly closed, mixed forest with *Corylus* and *Pinus* as the dominant trees is found.

The species of trees present in the Boreal time, combined with the presence of *Hedera*, indicate that the temperature has become higher also during the winters (Iversen, 1973). The decrease of *Corylus* and the almost disappearance of the few *Quercus* and *Ulmus* that were present (subzone Va, upper part) is probably caused by a temporary climatic deterioration.

Possible explanations of the differences between the pollen diagrams U.V.I and U.V.II

From the two pollen diagrams for the Uteringsveen it is clear that although they represent the same vegetational development and almost the same environment, there are significant differences between them. We think this is worth mentioning, because the composition of a pollen diagram seems to be dependent on the size of the erstwhile bog or lake from which the sample has been taken, and also on the location of the sampling site within the bog. Therefore, some tentative, general explanations will be given why some pollen types are better represented in one of the diagrams than in the other. We think there are four principal reasons for the discrepancies:

1. Some plants are poor pollen dispersers: this holds especially for entomophiles such as *Salix* (note zone 0, I, and IIa), but also for some wind-pollinated taxa. *Populus* pollen seems to drop almost directly on the ground (compare zone III, upper part, IV, and V).

2. Some pollen types can float on water: this is, for instance, the case with *Pinus* pollen. Persons familiar with lakes in areas where conifers abound, know that during the flowering season there is a yellow belt of pollen concentrated along the water. We think that the reason why U.V.II (zone V) contains less *Pinus* pollen than U.V.I. is that the *Pinus* pollen had been swept away from the centre of the lake by the action of wind.

3. The pollen of some plants is caught and held back by the vegetation belt along the shore: this is the case with the pollen of most herbs growing outside the bog but it may also apply to shrubs forming the undergrowth below taller trees. We think that, for instance, the difference in the *Quercus* and *Ulmus* curves in zone V may be explained in this way.

4. The proximity of the edge of the water: some plants are characteristic of the riparian zone, and changes in the water level are best reflected by these plants. Also, the pollen sedimentation in situ may be higher than in the central part of the lake. Illustrative examples are the *Equisetum* curve in zones III, IV, and V and the *Selaginella selaginoides* curve in subzone Ib and Ic.

THE LITHOLOGY AND ITS RELATIONSHIP TO THE VEGETATIONAL DEVELOPMENT

In contrast to the pollen sedimentation the deposition of aeolian sand does not show any conspicuous differences between the sections I and II. During the Bølling and the Early Dryas time there was a slow, rather constant accumulation of organic material in the Uteringsveen (enclosures I and II). The composition of the inorganic material, most of it being below 50 μ, indicates a sandloess deposit for this time (Woldstedt & Duphorn, 1974). From the floristic composition and the large amount of inorganic sediment (about 80%) it is concluded that barren areas must have been present in the vegetation cover at this time.

During the Allerød the accumulation of organic material increased but the major part of the sediment is still inorganic.

Thus the vegetation cover had become more closed but it is probable that a protecting humus layer had not yet become sufficiently developed. The composition of the inorganic material changed as the content of fines (< 50 μ) decreased.

In the Late Dryas time and during most of the Preboreal the organic component decreased to a minimum, generally below 5% by weight. The inorganic material consists predominantly of sand (> 50 μ). The reason for this change is not well understood, but it might be the presence of a more open vegetation cover, possibly associated with a more windy climate.

From the later part of the Preboreal and onwards the organic content gradually increased, which is indicative of still closer stands of vegetation followed by a decrease in aeolian activity. The sand deposition (and erosion) did not cease until the end of the Boreal or the beginning of the Atlantic (see also Koster, in prep.) when a well developed soil was present, and the vegetation cover became completely closed (Cleveringa & de Gans, in prep.).

From the fact that the aeolian sediments are found in deposits from the Bølling, the Allerød, and the beginning of the Holocene it is evident that aeolian activity took place not only during the dryer and colder intervals, but also, although to a lesser extent, during moister and warmer periods with an incomplete vegetation cover.

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