Acta Bot. Neerl. 21(3), June 1972, p. 261–284

PALYNOLOGY OF A SECTION FROM THE RAISED PEAT BOG 'WIETMARSCHER MOOR', WITH SPECIAL REFERENCE TO FUNGAL REMAINS

B. VAN GEEL

Hugo de Vries-Laboratorium, Afdeling Palynologie, Universiteit van Amsterdam

SUMMARY

The results of an analysis of pollen, spores and other micro-fossils (or parts of such fossils) with a characteristic form, from a 195 cm high peat section are reported. It appeared that certain Fungi types are connected with more strongly humified layers, which were presumably formed under drier conditions. Other fungal types show a clear connection with the peat-forming vegetation. An attempt was made to identify the micro-fossils other than pollen grains, which in some cases proved to be possible. A more extensive study is required before more accurate identifications can be arrived at and the emanating interpretations can be substantiated.

Attention was paid to cyclic phenomena in the *Alnus* curve in the diagram. According to calculations with the help of ^{14}C datings, cycles of about 32 years occurred. Further analysis may lead to an answer to the question whether this is a matter of periodic or cyclic phenomena and may reveal the possible cause of the fluctuations.

By means of the pollen diagram information was obtained concerning the influence of prehistoric man on the vegetation from about 1700 B.C. to about 300 A.D. It appears that the influence is relatively important in the period between about 700 B.C. and 100 A.D. In this period agriculture on field complexes of the 'Celtic Field' type was probably carried out in the neighbourhood of the Wietmarscher Moor. By the beginning of the Christian era *Secale* pollen appears in the section for the first time. A decrease in population density is marked during the second century of the era. The reliable part of the diagram ends at the 10 cm level which corresponds to a date of about 300 A.D.

Through a further analysis of microscopic and macroscopic remains in peat bogs one may expect to gather novel data regarding various aspects of peat analysis discussed in this article.

INTRODUCTION

In this report a palynologic analysis is given of successive 1 cm samples of a 195 cm long section from a raised peat bog in Western Germany called 'Wietmarscher Moor' (for the location of the section Wietmarscher Moor III see *fig. 1*).

The samples were taken on October 17th, 1968, from a vertical peat wall, formed after peat digging. The upper two metres of peat were sampled by means of four metal 'gutters' each 50 cm long. In addition, four blocks of peat of 50 × 20 × 20 cm each were gathered from which later horizontal thin slices were cut for ^{14}C datings. The distance from the lower side of the section to the mineral subsoil (probably 'cover sand') is unknown.

By means of a microscopic analysis the samples were examined for the presence of pollen grains and spores of mosses and ferns, and also of other

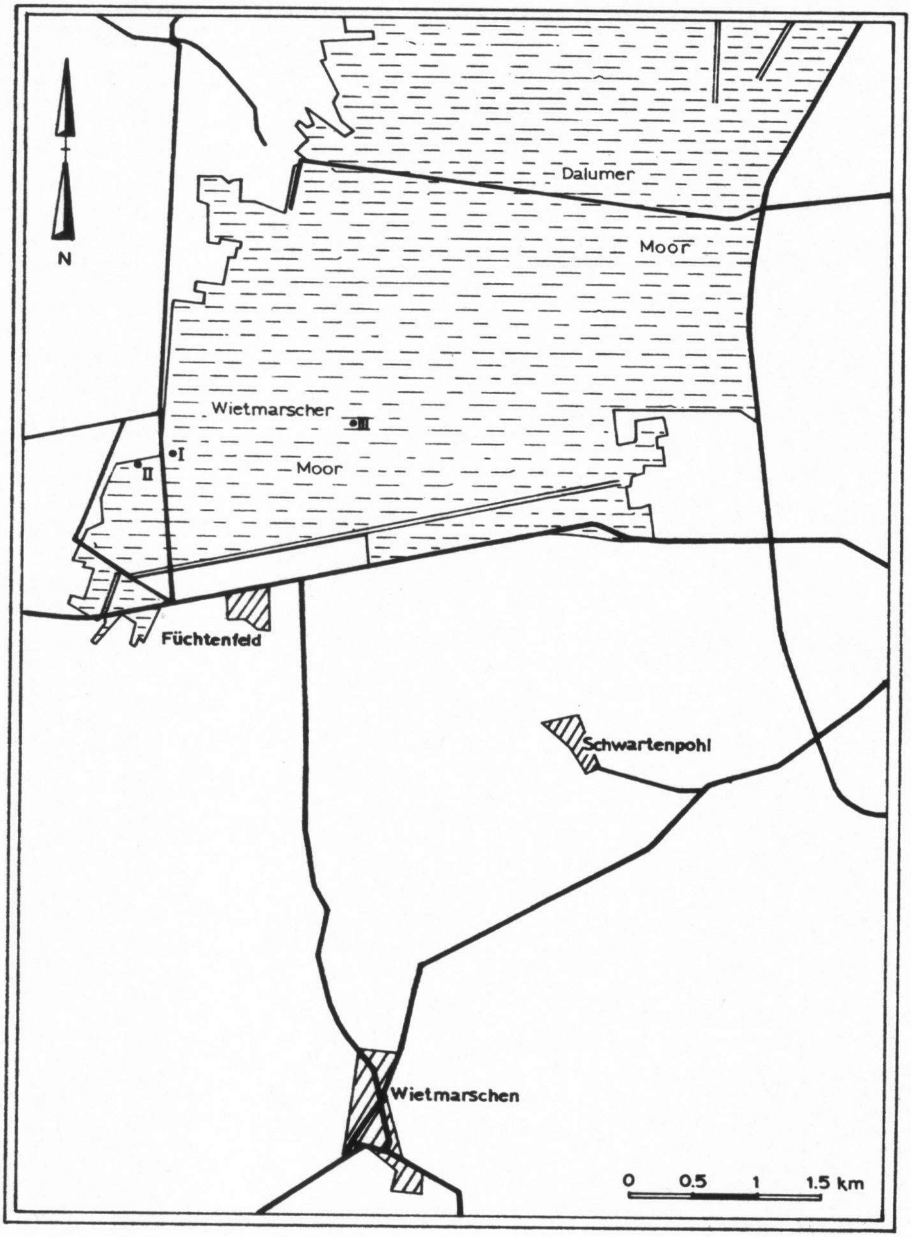


Fig. 1. Location of the section Wietmarscher Moor III.

micro-fossils with a characteristic form, such as spores and other fossilized remains of Fungi.

Furthermore the peat-forming vegetation was studied by means of an examination of the samples for the presence of macro-remains and of the degree of humification of plant remains recovered from the peat.

An impression was gained of the influence of prehistoric man on the vegetation in the Wietmarscher district at the time when the sampled 195 centimetres of peat were formed.

The analysis of the samples also revealed cyclic fluctuations of certain pollen curves, as previously recorded in other centimetre diagrams (WIJMSTRA *et al.* 1971).

The pollen total in most samples amounts to 300–400 A.P. grains (see *fig. 2*).

The following items are successively discussed:
1. Zonation and dating of the pollen diagram.
2. The influence of prehistoric man on the vegetation.
3. Cyclic fluctuations of some pollen curves.
4. Analysis of fungal remains.
5. Interpretation of the analysis of fungal remains.
6. Rhizopoda.
7. Peat-forming vegetation and humification.
8. Description of the strictly local peat development in the section.

2. RESULTS

2.1. Zonation and dating of the pollen diagram (see *fig. 2*, appendix 1)

The regional development of successive vegetation types in this district is well known as a result of pollen analysis of the Dutch part of the adjacent 'Bourtanger' peat bog (see, e.g., VAN ZEIST 1955, 1956, 1967).

Corylus shows a drop characteristic of the Subboreal-Subatlantic boundary, which may have set in already before the beginning of the section. After a maximum at 174 cm the curve falls off and at 143 cm *Corylus* for the first time attains a percentage lower than 10%. After another maximum at 137 cm the drop of the *Corylus* curve definitely ends at 104 cm.

Fagus shows a rise at 154 cm, which according to the ^{14}C dating GrN-6224 must have taken place at about 1000 B.C. (conventional ^{14}C age; see below).

Tilia pollen regularly occurs in low percentages in the lower part of the section, but especially after the 110 cm level the pollen of this tree becomes quite rare.

Striking are the relatively high percentages of *Fraxinus* in the interval between 66 and 57 cm.

In *fig. 3* the course of the curves of *Fagus*, *Carpinus*, *Betula*, and *Corylus* is shown next to a time-scale. This time-scale was constructed with the help of the ^{14}C datings, guided by the following suppositions:

a. The rate of peat deposition was more or less constant between the beginning of the section (at 200 cm) and the 156 cm level.

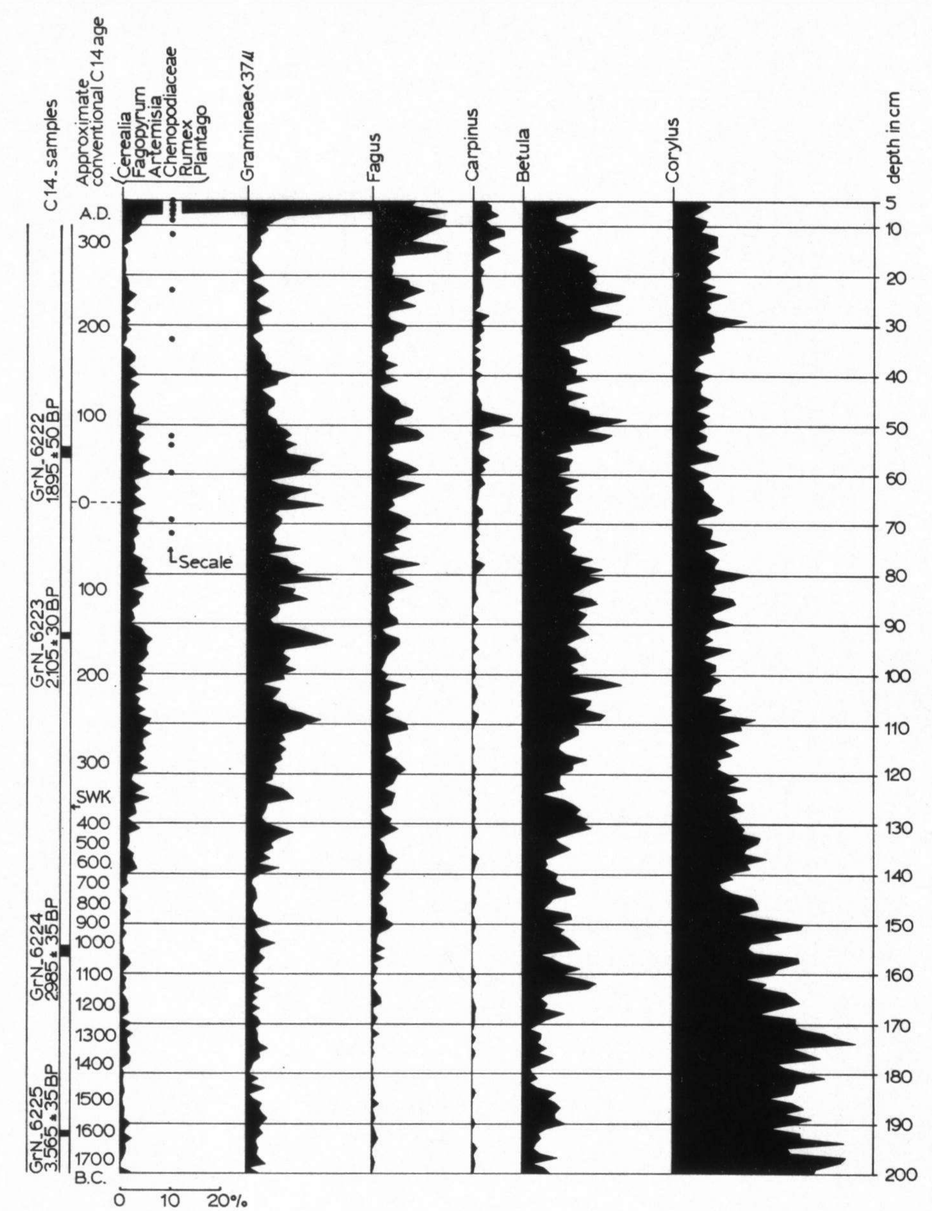


Fig. 3. Selection of a number of curves from the diagram Wietmarscher Moor III, placed next to a time-scale.

b. The peat accumulation was constant between the S.W.K. at 127 cm and the upper side of the section. For an explanation of the abbreviation S.W.K., see under 2.7.
c. The rate of accumulation of peat must have been low in the strongly humified peat between the 155 cm level and the S.W.K. at 127 cm; at any rate the resulting peat deposit was comparatively thin.

It goes without saying that the time-scale, because of the interpolation techniques, can only be used with some reserve. From the 45 cm level up to the 10 cm level of the section the rate of accumulation of peat was probably lower than estimated (presence of strongly humified peat). In that case the 10 cm level may be younger than the 300 A.D. age indicated in the time-scale.

No attempt was yet made to use the tree-ring calibration of the ^{14}C calendar for the conversion from ^{14}C chronology to A.D.-B.C. chronology, considering the still tentative nature of the conversion curve (see BAKKER *et al.* 1969).

Hence a time-scale (see *figs. 3, 5* and *6*) constructed with conventional ^{14}C datings was used. Considering the curve as given by BAKKER *et al.* (1969, fig. 9) of the relation between conventional ^{14}C age and tree-ring age, an obvious similarity of both curves from about 300 B.C. to 300 A.D. can be noticed. Since the decrease of the human influence discussed in this paper (see 2.2) and the cycli in the *Alnus* curve (see 2.3.) both occur within this period, it is hardly necessary in these cases to correct the conventional ^{14}C ages.

At the ^{14}C Laboratory of the Groningen State University four samples have been dated. These samples yielded the following results:

Laboratory number	sample number	depth level	age estimated
GrN – 6222	W.M. 1	55 + 56 cm	1.895 ± 50 B.P.
GrN – 6223	W.M. 2	92 – 93 cm	2.105 ± 30 B.P.
GrN – 6224	W.M. 3	155 + 156 cm	2.985 ± 35 B.P.
GrN – 6225	W.M. 4	192 cm	3.565 ± 35 B.P.

The position in the section and the thickness of the samples have been indicated in the diagram (*figs. 2, 3, 5*).

2.2. The influence of prehistoric man on the vegetation

From the course of the pollen curves of *Plantago lanceolata*, *P. major*, Gramineae, *Rumex*, *Artemisia*, Chenopodiaceae, and cultivated plants (Cerealia, *Fagopyrum*) an impression of the influence of prehistoric man on the vegetation, caused by agriculture and stock-raising, could be gained.

In the diagram (*figs. 2* and *3*) the varying influences of human activities on the vegetation in the Wietmarscher district can be traced from about 1700 B.C. till about 300 A.D.

Fig. 2 shows the course of the separate curves of the plants, whereas in *fig. 3* a curve was constructed from the sum of the percentages of the plants indicating human influence. In *fig. 3* the changes of the curves in time are shown by means of the time-scale (see above).

It appears that the influence of man on the vegetation during the Bronze Age was not as great as it was during the Iron Age. The intensification of agriculture in the Iron Age, judging by its manifestation in the pollen diagram, might be connected with the occurrence in the neighbourhood of field complexes of the 'Celtic Field' type. On the basis of ^{14}C datings, mainly of material gathered during an excavation at Vaassen (Gelderland), these field complexes are now best chronologically fitted in between circa 500 B.C. and circa 150 A.D. (oral communication by Brongers).

These field complexes may have been present on the river dunes along the rivers Vechte and Ems and also to the South of the Wietmarscher Moor. In any case they have been present at comparable sites in the Netherlands and just beyond the Dutch-German border in Germany (see *fig. 4*, prepared by Brongers). Brongers and Woltering surveyed them there with the help of aerial photographs, after which affirmation took place by field observation of the spotted sites.

In the Klokkenberg near Denekamp (VAN DER HAMMEN 1965, VAN DER HAMMEN & BAKKER 1971) in the central part of the 'es' (German: *Plaggenboden*) a basal layer was found. This layer could be dated with ^{14}C samples at somewhere between 500 B.C. and 0 A.D. and therefore represents possibly a 'Celtic Field'.

The higher Cerealia percentages between the 60 cm and 50 cm levels might point to a closer proximity of the fields to the peat bog during the first century of the Christian era.

By the beginning ot the Christian era *Secale* pollen appears in the section for the first time. According to VAN ZEIST (1968) the Romans probably introduced the cultivation of rye in the South of the Netherlands, because the oldest records for charred seeds of *Secale cereale* are found only in Roman sites. The pollen of *Secale*, present in this pollen diagram by the beginning of the Christian era, may indicate that rye was also grown outside the Roman-occupied territory.

During the second century A.D. a fall of the curves of Cerealia, Gramineae, *Plantago*, *Rumex*, etc., is observed. The percentages of these plants remain low until about 300 A.D. (10 cm level), where the reliable part of the diagram ends (see under 2.7.). A similar reaction of a decrease in population density at the time of the beginning of the Christian era is marked in pollen diagrams from N.W. Germany and the Netherlands (KUBITZKI 1961; BURRICHTER 1969). Often the drop in population density is concomitant with an increase of the *Carpinus* percentages (KUBITZKI 1960). In places favourable for the development of the hornbeam, through having been abandoned by man, this tree could probably establish itself.

We see a similar short-term expansion of *Carpinus* in the diagram Wietmarscher Moor III during the decline of human interference with the vegetation around 100 A.D. The *Betula* percentages rise at about 100 A.D., but especially the third century seems to be characterized by high percentages of *Betula*. This tree probably found a good chance for development on poor soils.

Fig. 4. Map of the Dutch-German border district showing the soil distribution and the localised "Celtic Fields" (prepared by Brongers).

2.3. Cyclic fluctuations of some pollen curves

In the centimetre diagrams Wietmarscher Moor I and II (WIJMSTRA *et al.* 1971) certain cyclic fluctuations in the course of certain curves, which may be periodicities, are apparent. In the 'Lupendiagram Bergedorf' near Worpswede (SCHRÖDER 1930, 1931) where per sample 500–2000 pollen grains were counted, the *Alnus* curve in the raised bog part of the section shows fluctuations which are reminiscent of the fluctuations observed in certain stages of the diagrams W.M. I and W.M. II and in the diagram W.M. III. If indeed there is a question of periodicity, one may expect to find it in those parts of the section where the peat is not too strongly mixed and intermingled with roots of higher plants, such as Ericaceae and *Eriophorum*. It is possible that the 'periodicities' are connected with the unequal transgression of the peat bog as described by KOCH (1934a, b): During phases with a faster peat extension, *Alnus* would locally be ousted by the transgressing peat bog in the border zone, so that the curve of *Alnus* falls off, and the following rise of the *Alnus* percentage may be indicative of the return to more stable conditions. Wijmstra *et al.* mention other possible causes for the cyclic fluctuations in centimetre diagrams.

Between the two most recent ^{14}C datings, 1895 $\pm$ 50 B.P. (GrN - 6222) and 2105 $\pm$ 30 B.P. (GrN - 6223), respectively, 6½ periods in the *Alnus* curve (see *fig. 2*) can be distinguished, so that one such period must have lasted about 32 years. This calculation is based on a time difference of 210 years between the ^{14}C samples.

In the diagrams W.M. I and II we found a rate of sedimentation of about 1 centimetre peat in 20 years. Between the ^{14}C samples GrN - 6222 and GrN - 6223 in the section W.M. III the rate of sedimentation must have been of the order of 1 cm peat in about 6 years. Cycles of about 32 years found in the section W.M. III (with a sample thickness of 1 cm) cannot possibly be detected in peat with a rate of sedimentation of 1 cm in 20 years.

More calculations with the help of additional ^{14}C datings may provide the answer to the question whether it is a matter of periodicities or of cyclic fluctuations, and may indicate the possible causes of such intermittent changes.

2.4. Analysis of fungal remains

During the analysis of the section W.M. III certain remains of Fungi (including spores) with a characteristic form ('types') were counted and their frequency of occurrence was calculated as a percentage of a pollen total. Thus curves were obtained of organisms of which we very often do not even know the name, so that data concerning their ecology cannot be gleaned from the literature dealing with the ecology of recent species. Still, a number of interesting curves was obtained which proved to be of importance for the interpretation of the diagram (see under 2.8.).

Spores and other parts of Fungi (hyphae excluded) whose morphological features were not deemed sufficiently characteristic in form were included in a curve as 'Fungi diversi'. During the analysis it appeared that certain Fungi, which initially had been included in the 'Fungi diversi', had a characteristic form after all and were, therefore, counted as separate types. This is the reason why more curves appear higher in the section. The interrupted lines indicate in which part of the section the Fungi were included in the 'Fungi diversi'.

After their frequencies of occurrence in a certain part of the section had been calculated as percentages of a pollen total of 50 grains of tree pollen, some of the rarer types were more precisely recorded by calculating their frequencies as percentages of the A.P. total.

A screening of material not previously subjected to acetolysis did not yield remains of Fungi which had not already been recorded in acetolysed samples. The colour of the cell walls is hardly changed by acetolysis, so that the conclusion was drawn that fungal remains are quantitatively recovered from the acetolysed material.

About the possible use of Fungi in palynology GRAHAM (1962) remarked: "If the fossil Fungi are sufficiently diagnostic to allow precise identification, they can serve as index fossils and environmental indicators, placing one more group of organisms to the disposal of the stratigrapher and paleoecologist'.

Graham discussed the principles of palynology in relation to the possible use of fungal spores:

1. Fungi are notable for abundant spore production.
2. Pollen and spores are released into the atmosphere and fall, as pollen and spore rain, in approximate proportion to abundance.
3. Spores are susceptible to fossilization and suitable techniques are available for their recovery.
4. Morphological variation permits relatively precise identification.
5. Organisms are limited in ecological amplitude and their distribution patterns change with environmental variations. Environmental conditions can be deduced from the erstwhile presence of a given fauna and flora.

A closer study of fungal remains in West European peat bogs will ultimately provide cogent evidence of the occurrence inside or near the peat bog of (specific) host plants of Fungi represented in the diagrams. In this connection one must also think of the introduction of cultivated plants by man, in which way specific fungal parasites may have been imported, too. Conceivably there are species among the fungal remains (fossilized in peat) whose occurrence gives information about certain climatic factors, such as temperature and humidity, prevailing at the time of deposition of their spores in the bog.

We expect that remains of mycorrhizal Fungi will be present in connection with certain associated plants growing in the peat bog. Ericaceae, *Betula* and *Pinus* all have a mycorrhiza, and *Sphagnum* spores can only germinate in the presence of certain mycorrhizal Fungi (MÄGDEFRAU 1967). During a study of the structure of peat bogs in Bohemia, RUDOLPH (1917) found a connection between the increase of hyphae and the occurrence of mycorrhiza plants such as Ericales and *Pinus*.

Among the fungal remains present in peat we may also expect to find the remains of lichen Fungi. Lichens occur under dry conditions in raised peat bogs (on tops of tussocks).

2.5. Interpretation of the analysis of fungal remains

Although but little is known about the fungal organisms whose remains are recovered from peat, I believe to have found the reason why certain 'types' are represented in varying degrees of frequency and others may be absent.

Certain types encountered during the analysis of the section W.M. III show a clear connection with the peat-forming vegetation and the degree of humification of the peat (see under 2.8.).

My conclusions agree with those of HUIKARI (1956) who is of the opinion that higher percentages of fungal cells, as compared with the number of pollen grains, are indicative of moist conditions at the time of the peat deposition.

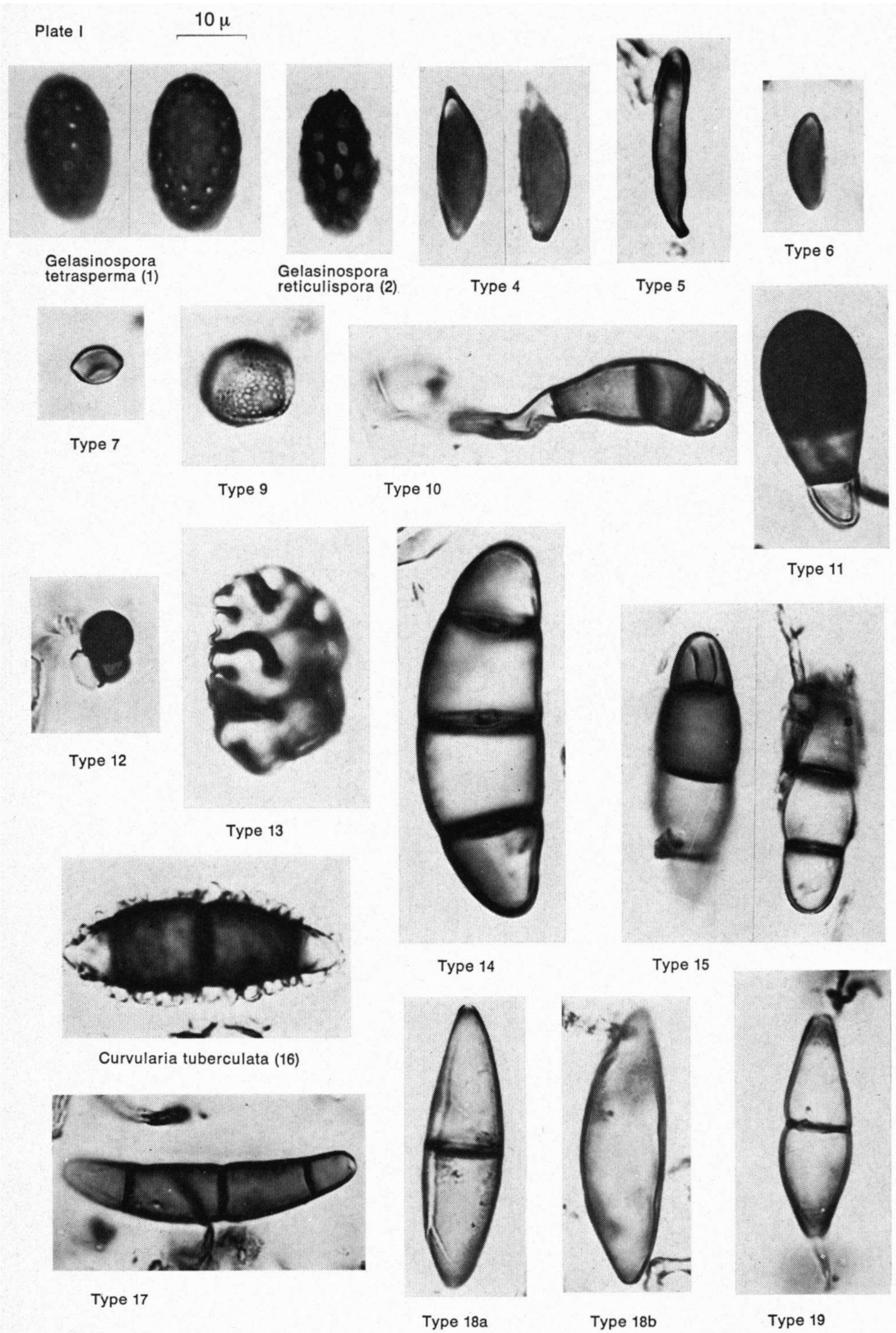
AARTOLAHTI (1965), following HUIKARI (1956), used fungal cells in an analysis of the development of raised peat bogs, as an expedient for the determination of the local moist conditions at the time of deposition of the peat. Aartolahti calculated the frequencies of fungal cells as percentages of 100 A.P. grains. Apart from the fungal cells method for the determination of the local moist conditions he also used the pollen curves of plants growing on peat and the identification of the *Sphagna* in the deposit. By means of these three methods supplementing each other, it is possible to get an idea of the changes in moisture conditions at the place where the samples were taken.

During the present investigation the peat was not examined for hyphae, however (barring perhaps the types 23, 24 and 25), but only for spores and other fossilized fungal remains with a characteristic morphology. It appeared that the various types often have a characteristic curve in the diagram: among the fungal remains there are a number of types which are apparently connected with the local moisture conditions at the time of the peat deposition; other types seem to show a relation with other phenomena (see under 2.8.).

As regards the form and measurements of the various types distinguished, the reader is referred to the photos (see *plates I, II, III* and *IV*). Of the types A, B and C there are no photos available; these types will be briefly described here. In *table I* the putative origin of the various types is indicated, and also the type of peat in which the various types were encountered.

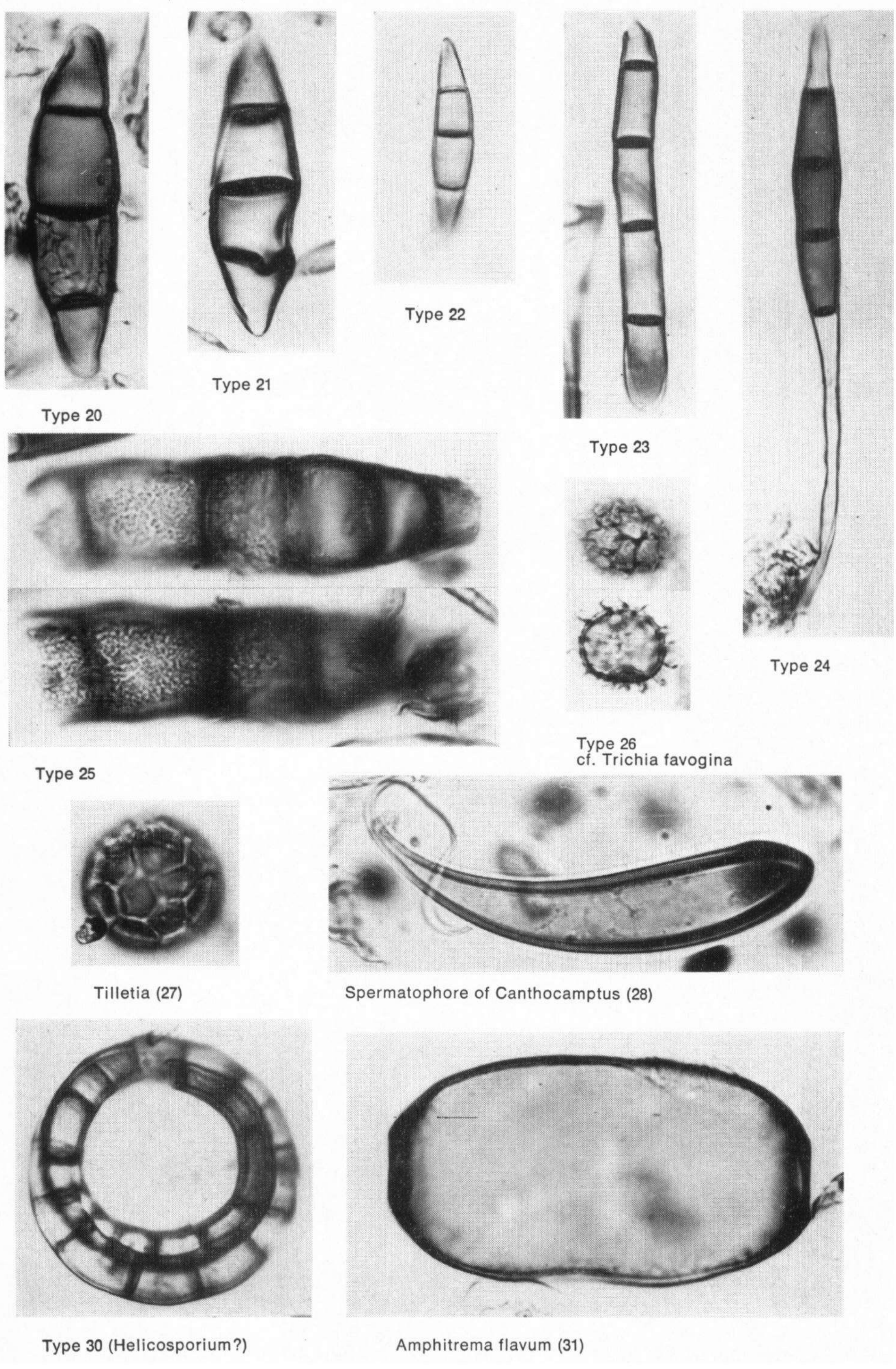
Some of the types distinguished could be identified, but it goes without saying that the taxonomy of the Fungi requires the aid of a trained mycologist.

Plate I, type 1:	Ascospores of *Gelasinospora tetrasperma* (see MOREAU 1953).
Plate I, type 2:	Ascospores of *Gelasinospora reticulispora*.
Plate IV, type 8:	cf. *Microthyrium*, ascocarp (see GODWIN & ANDREW 1951; ALVIN 1971).
Plate I, type 10:	Mr. G. J. BOLLEN (Wageningen; priv. comm.) suggests that these remains represent the conidia of *Trichocladium opacum*, a saprophyte.
Plate I, type 13:	Probably haustoria as they occur on parasitic Fungi.
Plate I, type 16:	Conidia of *Curvularia tuberculata* (see KAMAT & RAO 1970). This type has a very characteristic shape and only occurs in the samples between the levels 112 cm and 109 cm and between 98 cm and 95 cm.



Plates I, II, III and IV: Photos of micro-fossil types distinguished in the diagram Wietmarscher Moor III.

Plate II



Type 20

Type 21

Type 22

Type 23

Type 24

Type 25

Type 26
cf. Trichia favogina

Tilletia (27)

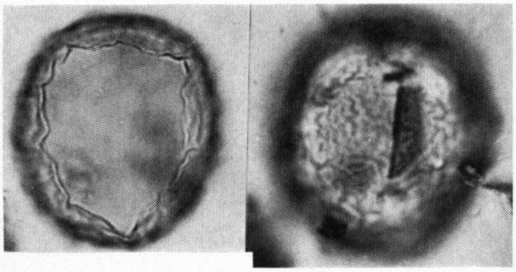
Spermatophore of Canthocamptus (28)

Type 30 (Helicosporium?)

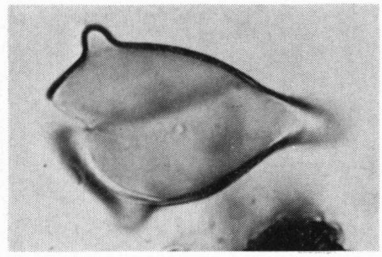
Amphitrema flavum (31)

Plate III

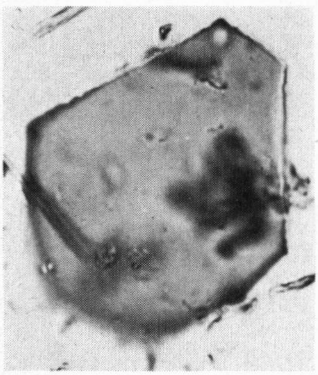
10 µ



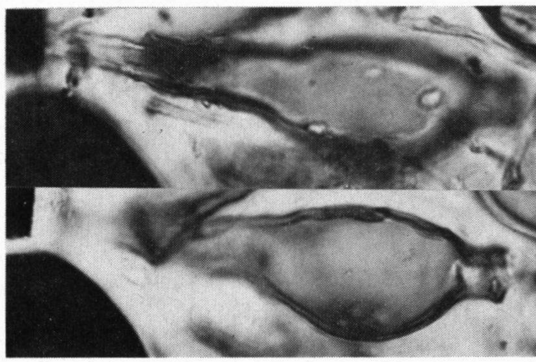
Type 33



Type 34

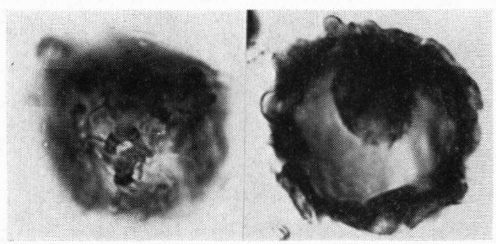


Type 35

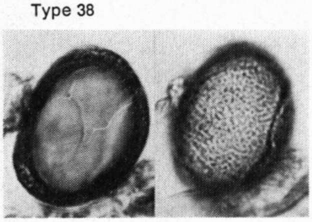


Type 36

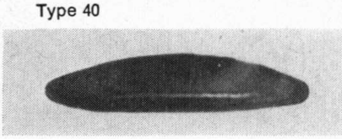
Type 38



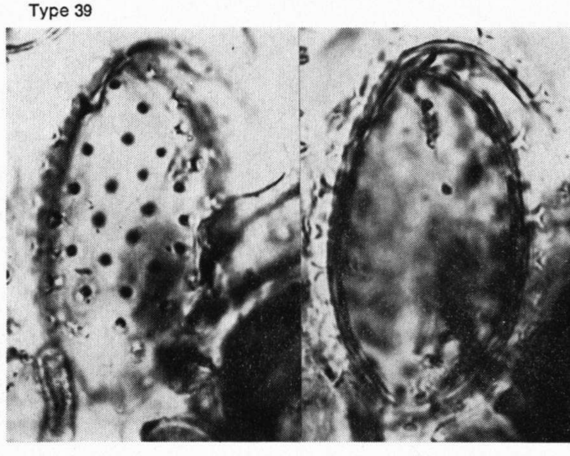
Type 39



Type 40



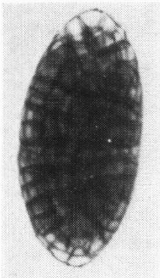
Type 44



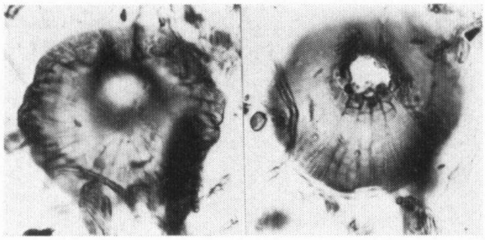
Hystricosphaeridae (41)

Plate IV

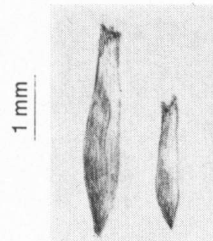
25 µ



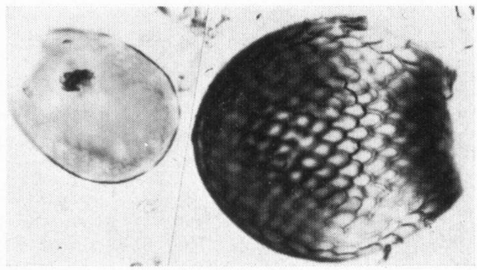
Type 3



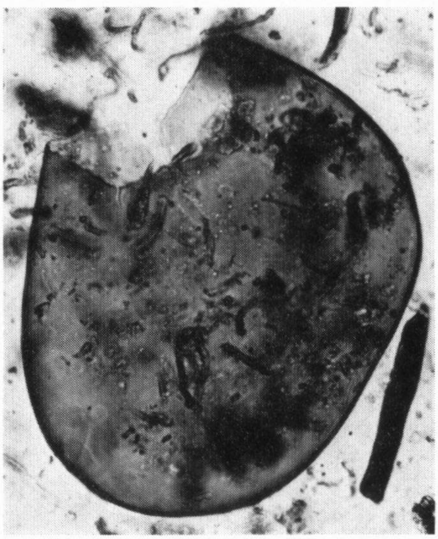
cf. Microthyrium, ascocarp (8)



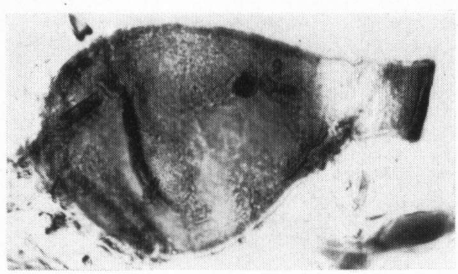
Type D



Assulina (32)

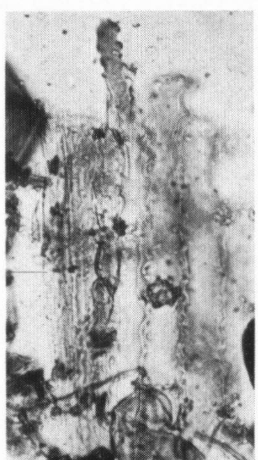


Type 29

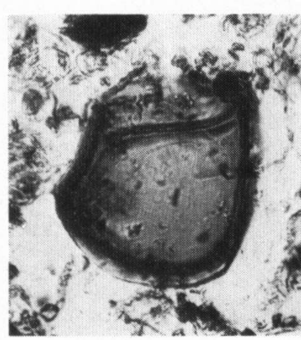


Callidina angusticollis (37)

Epidermis cf. Eriophorum (42)



Epidermis Monocot. (43)



Type 45

Table 1. Table with suppositions concerning the origin of the distinguished "types" and the connection of these micro-organisms with certain types of peat.

Types	Remains of								Presence						Fotos	No curve in diagram
						epidermis. cells										
	Fungi	Rhizopoda	Rotatoria	Histrichosphaeridae	Copepoda	Eriophorum	Other Monocot.	Unknown	Especially in highly humified peat	Fresh peat	Cuspidatum. Rhynchospora peat	Eriophorum peat	Monocot. peat in general	No clear relation with peatforming vegetation or humification.		
1	•								•						•	
2	•								(•)						•	
3	•								(•)						•	
4	•								•						•	
5	•								•						•	
6	•								•						•	
7	•								•			•			•	
8	•											(•)			•	
9								•			•				•	
10	•								•						•	
11	•											•			•	
12	•								•						•	
13	•													•	•	
14	•													•	•	
15	•													•	•	
16	•													•	•	
17	•													•	•	
18	•											•			•	
19	•													•	•	
20	•													•	•	
21	•													•	•	
22	•											•			•	
23	•													•	•	
24	•													•	•	
25	•													•	•	
26	•													•	•	
27	•													•	•	
28					•									•	•	
29								•						•	•	
30	•													•	•	
31		•								•					•	
32		•												•	•	
33								•							•	
34								•							•	•
35								•						•	•	
36								•							•	•
37			•											•	•	
38								•						•	•	
39								•						•	•	
40								•						•	•	
41				•										•	•	
42						•						•			•	
43							•						•		•	
44	•													•	•	
45						(•)						(•)			•	
A	•													•		
B	•															
C								•	•							
D								•								

Plate II, type 22:	Ascospore of *Leptosphaeria* (G. J. Bollen, priv. comm.)
Plate II, type 26:	According to GRAHAM (1971) this spore type resembles *Trichia favogina* (Myxomyceta). Only four spores of this type were found in the whole section.
Plate II, type 27:	Conidia of *Helotium schimperi* (= *Tilletia sphagni*) (see FAEGRI & IVERSEN 1966).
Plate II, type 28:	Spermatophore of *Canthocamptus* (Copepoda) (See HESMER 1929).
Plate II, type 30:	Conidia of *Helicosporium* (see STEINECKE 1927).
Plate II, type 31:	*Amphitrema flavum* (Rhizopoda).
Plate IV, type 32:	*Assulina muscorum* + *A. seminulum* (Rhizopoda).
Plate IV, type 37:	*Callidina angusticollis* (= *Habrotrocha angusticollis*). According to Steinecke this organism, belonging to the Rotatoria, occurs in pools in peat bogs.
Plate III, type 40:	Probably an unknown pollen grain.
Plate III, type 41:	Hystricosphaeridae (?)
Plate IV, type 45:	The occurrence of these striate cells in *Eriophorum* layers suggests that they originate from *Eriophorum* plants.
type A:	Dark globules with a wall resembling those of other Fungi. Diameter circa 25 µ.
type B:	Irregularly formed groups of fungal cells which often occur in the section between the 60 cm and 50 cm level. This type especially occurs in the cells of plant remains as reported by FRÜH & SCHRÖTER (1904, Table III, fig. 2).
type C:	Black massive globules (diam. 0.2–0.35 mm) occurring in strongly humified peat.
Plate IV, type D:	(see sketch) This type occurs in peat containing remains of Monocotyledoneae.

2.6. Rhizopoda

Apart from other micro-fossils, the Rhizopoda still present in the samples after acetolysis were counted and included in the diagram: *Amphitrema flavum* (*plate II*, type 31) and *Assulina* (*plate IV*, type 32).

The Rhizopoda analysis is very incomplete, however, as acetolysis, necessary to obtain satisfactory pollen slides, completely destroys the remains of a number of species originally present in the samples. Untreated material shows the presence of *Arcella* and of *Amphitrema wrightianum* (see *fig. 2*). Also other Rhizopoda were recorded, but no complete survey of the Rhizopoda was made.

2.7. Peat-forming vegetation and humification

Every centimetre of the section W.M. III was examined with regard to its degree of humification, and the remains of *Sphagnum* leaves and of leaves and seeds of higher plants were recorded. An average of 4 g of peat per sample was examined.

A survey of the results is given in the column to the left of the diagram (*fig. 2*). The data are also shown separately in the last part of the diagram. An attempt was made to indicate the humification of the peat in a scale of five stages from more decayed to less decayed. One must, however, bear in mind that it is difficult to determine the degree of humification objectively. In one sample one sometimes finds plant remains in different stages of humification. Layers with many remains of Monocotyledoneae are mostly indicated as rather strongly or strongly humified, because samples from layers containing remains of

Monocotyledoneae may more or less pronouncedly resemble strongly decomposed *Sphagnum* peat, but if *Sphagnum* leaves happen to occur in such layers, they may be only moderately or hardly decomposed and, accordingly, indicate that layers rich in Monocotyledons are sometimes erroneously indicated as 'strongly decayed'. In this connection one must also bear in mind that roots of Monocotyledoneae may have penetrated older layers with a relatively low degree of humification. The presence of identifiable leaves of different *Sphagnum* species was also recorded. Advanced humification may render all *Sphagnum* remains unrecognizable, however, so that they no longer provide ecological pointers.

The section W.M. III is no exception to the rule that in W. European peat deposits an older (more humified) and a younger (less humified) *Sphagnum* peat can be discerned. The limit between these two was called '*Grenzhorizont*' by C. A. Weber. As pointed out by SCHRÖDER (1930, 1931), this '*Grenzhorizont*' is not synchronous throughout the area, so that he preferred to call it simply '*Kontakt des älteren mit dem jüngeren Moostorf*'. To-day the current term is S.W.K. = *Schwarz-/Weisstorfkontakt* (= zone of contact between dark and light peat).

The moderately to strongly humified older *Sphagnum* peat in the section W.M. III from the 200 cm level up to the 161 cm level consists of *Sphagnum* cf. *rubellum* in which in the 191–185 cm and 166–162 cm intervals *Sphagnum cuspidatum* layers are developed. The peat in the 161–127 cm interval is for the greater part strongly humified. The S.W.K. lies at the 127 cm level.

According to KOCH (1934a, b, c) in almost all bogs of the Mittelems district a '*Vorlauftorf*', rich in *Rhynchospora* remains, forms the contact between older *Sphagnum* peat and younger peat (*Sphagna* of the section *Cymbifolia*).

In the section W.M. III a similar situation is present. The *cuspidatum* layers between 156 and 151 cm and between 148 and 144 cm contain seeds of *Rhynchospora alba*, whereas *Sphagnum imbricatum* (section Cymbifolia) is regularly found from 151 cm upwards, but an additional tussock vegetation must have developed over the *cuspidatum* layer in the 148–144 cm interval: the strongly humified peat between 144 and 127 cm contains a relatively large amount of *Erica* and Monocotyledoneae remains and few (recognizable) *Sphagnum* remains. Only at the 127 cm level do we find an S.W.K. The peat above the S.W.K. is mainly built up of *S. imbricatum* in which also layers containing many remains of Monocotyledoneae are present.

The palynological data (such as the presence of *Fagopyrum* pollen) and ^{14}C datings indicate that a layer of peat above the 10 cm level has disappeared. This must be ascribed to the practice of buckwheat cultivation by burning off the peat surface. Hence the strongly humified sandy peat which forms the 9–5 cm interval cannot be expected to yield reliable palynological data.

2.8. Description of the strictly local peat development in the section

A description of the development of the peat is given here in view of:

1. The local plant growth (pollen, spores, and macroscopic remains of *Sphagna*, Ericaceae and Monocotyledoneae, among which *Eriophorum*).
2. The degree of humification.
3. The course of the curves of certain Fungi types which seem to be correlated with the progress of the local peat deposition.
4. The presence and the frequency of occurrence of *Amphitrema flavum* and *Amphitrema wrightianum*, which are ecological indicators of peat growth under rather moist to very wet conditions.

The moderately to strongly humified peat from the 200 cm level up to about the 142 cm level seems to have grown under wet conditions, judging from the presence of *Amphitrema flavum* and *Sphagnum cuspidatum* layers with *Amphitrema wrightianum*. The presence of macroscopic remains of *Erica tetralix* and *Calluna vulgaris* indicates that these plants must have grown locally in the peat, but they possibly only flowered on rare occasions, because the Ericaceae pollen percentages remain low, and lumps of Ericaceae pollen were not encountered. Very striking is the conformity between the pollen curve of the Ericaceae and the curve of fungal type 12 (*plate I*) whereas the curve of *Amphitrema flavum* shows a reverse trend.

From about the 142 cm level up to the 127 cm level the strongly humified peat contains only a few specimens of *Amphitrema flavum* whereas the locally growing Ericaceae must have flowered abundantly, judging from the high representation of their pollen grains and by the occurrence of lumps of Ericaceae pollen. There is again a conformity between the curves of the Ericaceae and the Fungi type 12, but also the Fungi types 1, 4 + 5 + 6 (*plate I*) and more particularly type 10 (*plate I*), attain relatively high percentages in this peat layer which, as it seems, was formed under drier conditions.

From the 127 cm level (S.W.K.) up to the 122 cm level peat deposition progressed under wetter conditions. *Amphitrema flavum* occurs again in somewhat higher percentages, whereas the Ericaceae curve falls off to lower percentages, as do the curves of the Fungi types 10, 12 and 4 + 5 + 6.

From the 122 cm level up to the 113 cm level the peat is somewhat more humified and especially the fungal types 10 and 12 attain relatively high percentages. The Ericaceae percentages are also high in this interval. The percentages of *Amphitrema flavum* are rather low. It is likely that peat growth took place under somewhat drier conditions than in the layer between the 127 cm and 122 cm levels.

From the 113 cm level up to about the 105 cm level a phase follows during which peat growth took place under wetter conditions: The peat is only slightly humified and *Amphitrema flavum* attains somewhat higher percentages again, whereas the types 10 and 12 are represented by lower percentages.

In this part of the diagram the curves of these types of Fungi do not show conformity with the Ericaceae pollen curves any more, the Ericaceae percentages remaining high. This phenomenon is tentatively explained by supposing that the occurrence of the Fungi types 10 and 12 is associated with the degree of humification (and with the Ericaceae pollen curve as far as the latter shows a connection with the degree of humification). A singular phenomenon in the peat layer between the 113 cm and the 105 cm levels is the high percentage of *Sphagnum* spores.

From the 105 cm level up to the 96 cm level the peat is moderately to strongly humified. Ericaceae occurred locally and flowered (pollen in lumps). Type 12 and type 10 attain high percentages again. This part of the section is relatively rich in *Eriophorum* remains.

The explosive development of Fungi type 18 (*plate I*), the high percentages of type 4 + 5 + 6, and the presence of type 7 (*plate I*) are most probably associated with the presence of *Eriophorum* remains, more particularly so because they also attain high values in the *Eriophorum* layers present in higher parts of the section.

The peat between the 96 cm and 91 cm levels is but little humified. The Ericaceae curve reaches relatively low percentages and the presence of *Amphitrema flavum* is also indicative of somewhat wetter conditions. The types 10, 12, 4 + 5 + 6 and also type 18 are represented by relatively low percentages.

From the 91 cm level up to the 85 cm level the peat is moderately to strongly humified. Ericaceae grew and flowered *in situ*. The types 10 and 12 attain relatively high percentages. This peat layer contains a fairly large number of *Eriophorum* remains concomitant with high percentages of the types 18 and 4 + 5 + 6.

From the 85 cm level up to about the 72 cm level the peat is but little to rather strongly humified, whereas the Ericaceae percentages and also the percentages of the types 10 and 12 fall off.

From the 72 cm level up to about the 67 cm level the peat is strongly humified. The Ericaceae percentages are relatively high again, and the curves of the types 10 and 12 show maxima.

From the 67 cm level up to the 56 cm level the only slightly humified peat grew under relatively wet conditions, judging from the presence of *Amphitrema flavum*. The percentages of the Ericaceae and also of type 10 and type 12 are relatively low.

From the 56 cm level up to the 50 cm level *Amphitrema flavum* is almost entirely lacking. The Ericaceae percentages are fairly high and so are the percentages of type 10 and type 12.

From the 50 cm level up to the 45 cm level the Ericaceae percentages are somewhat lower again and the percentages of *Amphitrema flavum* are relatively high. Type 12 attains very low percentages. In this part of the section the peat must have grown under relatively wet conditions.

From about the 44 cm level up to about the 16 cm level a peat layer is present which is for the greater part built up of *Eriophorum* remains. In this layer especially type 18 and type 11 (*plate I*) occur, but also the types 1, 10, 7 and 22 (*plate II*) are frequently encountered.

The peat from the 16 cm level up to the 10 cm level is moderately humified and contains relatively few Fungi.

Fig. 5 shows a selection of the data from the diagram W.M. III which are

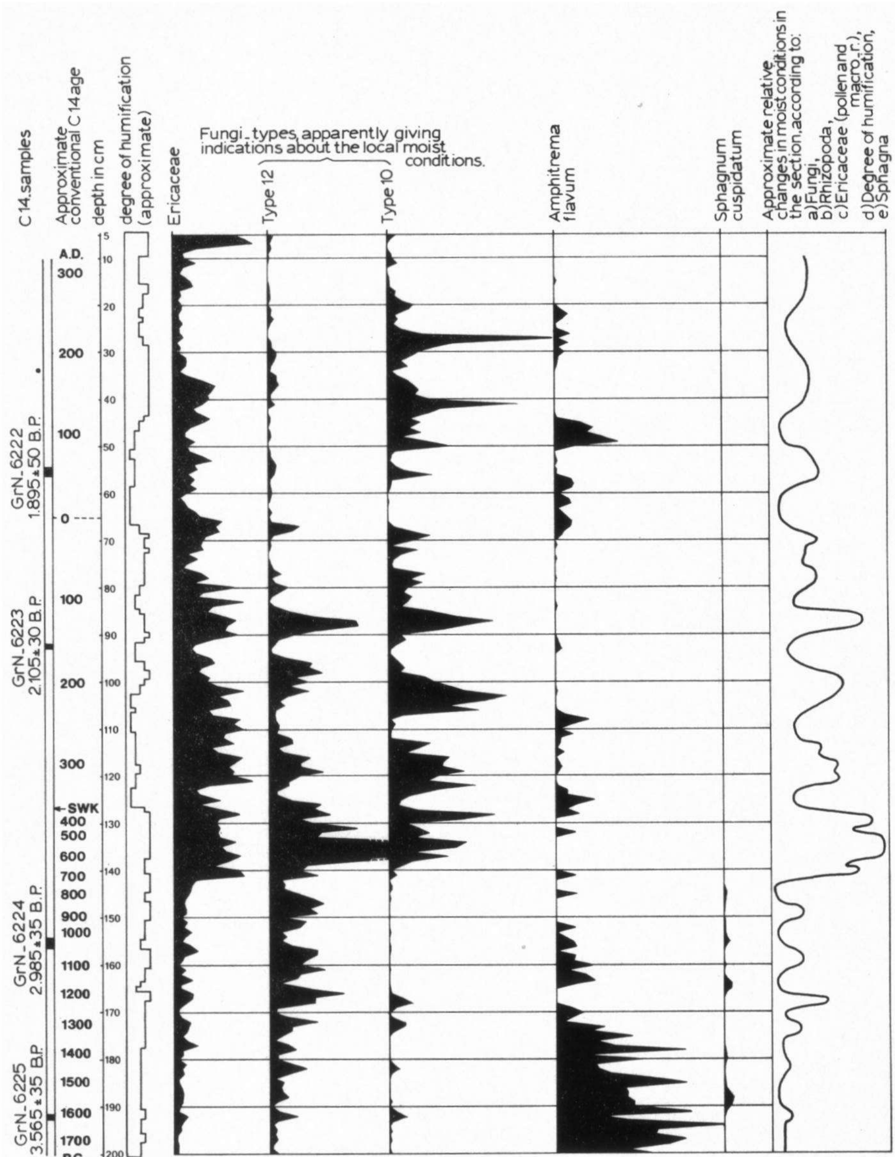


Fig. 5. Selection of data from the diagram Wietmarscher Moor III, apparently giving indications about the local moisture conditions.

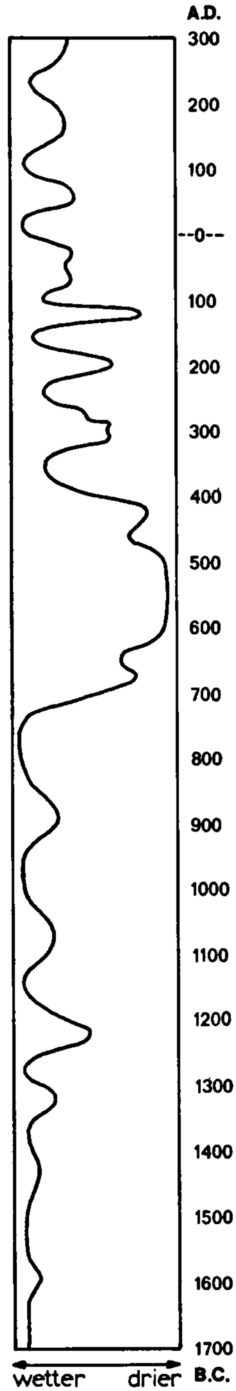


Fig. 6. Approximate relative changes in moisture conditions in the section on a linear timescale (approximate conventional ^{14}C age).

apparently indicative of the local prevalence of moist conditions. In this figure a curve shows the approximate relative changes in moist conditions in the section as deduced from the indications derived from the occurrence and the representation of Fungi, Rhizopoda, and Ericaceae (pollen and macroscopic remains), the degree of humification, and from the predominance of certain species of *Sphagnum*. *Fig. 6* shows the approximate relative changes in moist conditions in the section on a linear time-scale (approximate conventional ^{14}C age; see above).

It remains to be seen to what extent the given description of the strictly local peat development at the sampling site is representative of the conditions prevailing in the entire raised bog and indicative of climatic fluctuations responsible for the changes in the composition of the peat deposits.

Some Fungi types seem to be connected with the local prevalence of moist conditions during the peat deposition, whereas other types are apparently associated with peat-forming plants.

The use of the curves of these apparently locally occurring types for correlations of diagrams is probably not permissible, owing to the local variation in peat structure and in degree of humification, even within one peat bog (see CASPARIE 1969).

Aartolahti came to the conclusion that the changes of the local moist conditions in the Finnish peat bogs which he examined find also an expression in the fluctuation of the representation of fungal cells. These changes in the local edaphic conditions are not determined by the climate, but by the natural development of the peat bogs. If the climatic changes are at all reflected in the representation of fungal cells, the drainage conditions and the degree of trophy in the peat (in spite of the growth) would remain unchanged, but this is of rare occurrence (AARTOLAHTI 1965).

CASPARIE (1969) reviewed the opinions of various authors about the role the climate plays with regard to the changes in the rate of humification in peat bogs.

ACKNOWLEDGEMENTS

The author thanks Dr. T. van der Hammen for his help during the preparation of this paper.

He would like to express his gratitude to Drs. J. A. Brongers of the State Service for Archeological Investigations at Amersfoort for the information supplied about 'Celtic Fields'.

He thanks Drs. W. A. Casparie of the Biological Archeological Institute at Groningen for the information concerning macro-remains.

He is indebted to Dr. W. G. Mook of the Radiocarbon Laboratory of the State University at Groningen for the ^{14}C datings.

The author owes many thanks to Mr. H. J. Koerts Meijer for preparing the drawings and to Miss M. van Uitert and Prof. A. D. J. Meeuse for translating and revising the English text.

REFERENCES

AARTOLAHTI, T. (1965): Oberflächenformen von Hochmooren und ihre Entwicklung in Südwest-Häme und Nord-Satakunda. *Fennia* **93**: 1–268 + Beil. I–IV.

ALVIN, K. L. (1971): The study of fossil epiphyllous fungi by scanning electron microscopy.

In: V. H. HEYWOOD (ed.), *Scanning Electron Microscopy*. The Systematics Association. Special Volume No. 4.

BAKKER, J. A., J. C. VOGEL & T. WIŚLAŃSKI (1969): TRB and other C-14 dates from Poland. *Helinium* **9**: 3–27.

BRONGERS, J. A.: Airphotography and 'Celtic Fields' in the Netherlands. (To be published in: '*Nederlandse Oudheden*'.

BURRICHTER, E. (1969): Das Zwillbrocker Venn, Westmünsterland, in moor- und vegetationskundlicher Sicht. Mit einem Beitrag zur Wald- und Siedlungsgeschichte seiner Umgebung. *Abhdl. Landesmus. Naturk. Münster* **31**: 1–60.

CASPARIE, W. A. (1969): Bult- und Schlenkenbildung in Hochmoortorf. (Zur Frage des Moorwachtstums-Mechanismus). *Vegetatio* **19**: 146–180.

FAEGRI, K. & J. IVERSEN (1966): *Textbook of Pollenanalysis*. Munksgaard, Copenhagen.

FRÜH, J. (1885): Kritische Beiträge zur Kenntnis des Torfes. *Jahrb. Geol. Reichsanstalt* **35** 677–726.

— & C. SCHRÖTER (1904): *Die Moore der Schweiz*. Bern.

GODWIN, H. & R. ANDREW (1951): A fungal fruit body common in postglacial peat deposits. *New Phytol.* **50**: 179–183.

GRAHAM, A. (1962): The role of Fungal spores in palynology. *J. Paleont.* **36**: 60–68.

— (1971): The role of Myxomyceta spores in palynology (With a brief note on the morphology of certain algal zygospores). *Rev. Palaeobot. Palynol.* **11**: 89–99.

HAMMEN, T. VAN DER (1965): De Klokkenberg bij Denekamp. *Tijdschr. Kon. Ned. Aard. Gen.* **82**: 123–136.

— & J. A. BAKKER (1971): Former vegetation, landscape and man in the Dinkel Valley. In: T. van der Hammen & T. A. Wijmstra (editors), *The Upper Quaternary of the Dinkel Valley. Med. Rijks Geol. Dienst. N.S.* **22**: 55–213.

HESMER, H. (1929): Mikrofossilien in Torfen. *Palaeont. Z.* **11**: 245–257.

HUIKARI, O. (1956): Primäärisen soistumisen osuudesta Suomen soiden synnyssa. (Referat: Untersuchungen über den Anteil der primären Versumpfung an der Entstehung der finnischen Moore). *Comm. Inst. Forest. Fenn.* **42**: 5.

KAMAT, M. N. & V. G. RAO (1970): The Genus Curvularia Boedijn from India. *Nova Hedwigia* **18** H. 2–4.

KOCH, H. (1934a): Ein Profil aus dem Bourtanger Moor als Beispiel zur Moor- und Waldgeschichte an der Mittelems. *Ber. dtsch. bot. Ges.* **52**: 101–109.

— (1934b): Mooruntersuchungen im Emsland und im Hümmling. *Int. Rev. Hydrobiol.* **31**: 109–156.

— (1934c): Untersuchungen zur Geschichte des Waldes an der Mittelems. *Bot. Jahrb.* **66**: 567–598.

KUBITZKI, K. (1960): Moorkundliche und pollenanalytische Untersuchungen am Hochmoor 'Esterweger Dose'. *Schr. naturw. Ver. Schleswig – Holstein* **30**: 12–28.

— (1961): Zur Synchronisierung der nordwesteuropäischen Pollendiagramme (mit Beiträgen zur Waldgeschichte Nordwestdeutschlands). *Flora* **150**: 43–72.

MÄGDEFRAU, K. (1967): Bryophyta. In: *Lehrbuch der Botanik*. 29. Auflage. Gustav Fischer Verlag. Stuttgart.

MOREAU, C. (1953): Les genres Sordaria et Pleurage. *Encycl. Mycol.* **25**: 1–330.

RUDOLPH, K. (1917): Untersuchungen über den Aufbau böhmischer Moore. Aufbau und Entwicklungsgeschichte südböhmischer Hochmoore. *Abh. K. K. Zool.-Botan. Ges. Wien* **9**: H. 4: 1–116.

SCHRÖDER, D. (1930): Pollenanalytische Untersuchungen in den Worpsweder Mooren. Ein Beitrag zur postglazialen Wald- und Klimaentwicklung Nordwestdeutschlands, insbesondere zur Grenzhorizontfrage. *Abh. Nat. Ver. Bremen* **28**: 13–30.

— (1931): Zur Moorenentwicklung Nordwestdeutschlands. *Abh. Nat. Ver. Bremen* (Sonderheft) **28**: 97–104.

STEINECKE, F. (1927): Leitformen und Leitfossielen des Zehlaubruches. *Bot. Arch. Königsb.* **19**: 327–344.

TOLONEN, K. (1966): Stratigraphic and rhizopod analyses on an old raised bog, Varrassuo, in Hollola, South Finland. *Ann. Bot. Fenn.* **3**: 147–166.

WIJMSTRA, T. A., A. SMIT, T. VAN DER HAMMEN & B. VAN GEEL (1971): Vegetational succession, fungi spores and short-term cycles in pollen diagrams from the Wietmarscher Moor. *Acta Bot. Neerl.* **20**: 401–410.

ZEIST, W. VAN (1955): Pollen analytical investigations in the northern Netherlands, with special reference to archaeology. *Acta Bot. Neerl.* **4**: 1–81.

— (1956): Die palynologische Bearbeitung des Münzfundes von Bargercompascuum. *Palaeohistoria* **5**: 93–99.

— (1967): Archaeology and palynology in the Netherlands. *Rev. Palaeobot. Palynol.* **4**: 45–65.

— (1968): Prehistoric and early historic food plants in the Netherlands. *Palaeohistoria* **14**: 42–173.

Appendix 1. Acta Botanica Neerlandica, Vol. 21 (3) 1972
Art. B. van Geel, Palynology of the 'Wietmarscher Moor'

Fig. 2. Diagram of the section Wietmarscher Moor III.