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A PALYNOLOGICAL INVESTIGATION OF SOIL PROFILES DEVELOPED IN COVER SAND[1]

by

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[1] This publication is an abstract of a dissertation written in Dutch, entitled: Een palynologisch onderzoek van in dekzand ontwikkelde bodemprofielen. (Wageningen, 1962.)

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CHAPTER I

INTRODUCTION

It is not long ago in the Netherlands that the development of podsol profiles in sandy soils has been solely attributed to heath growth. This conception was apparently confirmed by palynological investigation of the "heath podsol profile" by BEYERINCK (1931, 1933a, b) and FLORSCHÜTZ (1941). It was also concluded from incidental data that a heath vegetation formerly occurred on podsolized soils (SCHRÖDER 1934, VERMEER-LOUMAN 1934, FLORSCHÜTZ 1941) and on a humous sand soil (POLAK 1936) found under peat of the Atlantic or still older periods.

After the second world war Dutch pedologists arrived at the view that a great deal of the podsol profiles must have developed under forest. In this connection an important part was attributed to the oak forest. However, this theory could not be proved by studying the relationship between the type of soil and vegetation, mainly because original vegetations are almost totally absent in the Netherlands.

It was found possible to gain a better insight into the problem by systematically applying of palynological investigation to soil profiles covered either by Holocene drift sand or peat. Alle the profiles investigated developed in cover sand. This is an eolic deposit mainly of Würm-Glacial age, constituting the top layer of the greater part of the Dutch Pleistocene. The profiles mainly belong to the normal podsol type, but certain other profile types were also analysed, e.g. highly gleyed profiles. They were so selected that the covering layers date from the Lateglacial and various Holocene periods. In this way an attempt was made to follow the development of the soil profile in connection with development of vegetation since the Lateglacial.

The analysis of buried profiles always has the great advantage that we know for certain they have not been disturbed by tillage. Nor can the vegetations from which the pollen and spores originate have been influenced by man, unless the covering soil layers are fairly young.

During the course of the study it became evident that as far as the pollen content of sand was concerned the palynological literature of the subject was inadequate for the correct interpretation of the pollen diagrams obtained. The investigation was therefore extended to include a study of the significance of sand diagrams in general. In particular attention was paid to the development of pollen profiles [1]) in sand soil.

The diagrams were zoned by correlation with the successive periods of the

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[1] By pollen profile is meant the vertical distribution of the pollen in the soil, as shown by the pollen diagram.

vegetational history since the Lateglacial, as shown in Table I (VAN DER HAMMEN 1953, VAN ZEIST 1955, ZAGWIJN 1956, POLAK 1959).

TABLE I. Division and vegetational history of the Lateglacial and Holocene

Period	Vegetation	Pollen spectra in peat diagrams
HOLOCENE	Subatlantic	
± Fagus-Carpinus period in the sand diagrams [1]	*Fagus* important and afterwards *Carpinus* also, continual disafforestation	Marked increase in *Fagus*, *Carpinus* reaches fairly high values, marked increase in non-arboreal pollen (NAP), especially *Cerealia*
	Subboreal	
	Fagus spreads, increasing influence of man	Increase in *Fagus*, small percentages of *Carpinus*, increase in NAP, agricultural weeds and *Cerealia* represented
HOLOCENE	Atlantic	
	Alder forest and mixed oak forest, finally *Fagus* immigrates and the influence of man begins (agriculture)	*Alnus* and the *Quercetum mixtum* reach high values, *Fagus* appears in the top part of the zone and occasionally *Cerealia*, hardly any *Pinus*, boundary with the Subboreal is formed by the decrease in *Ulmus*, and the boundary with the Boreal by the *Pinus-Alnus* crossing
	Boreal	
	Fir and birch forests, *Corylus* very important, warmth-loving trees become more important	*Pinus* usually dominant, *Corylus* and occasionally also *Betula* occur with high values, the *Quercetum mixtum* and *Alnus* show a slight increase
	Preboreal	
	Dense closed fir and birch forests, warmth-loving trees immigrate	NAP decreases rapidly, at first *Betula* very well represented, afterwards *Pinus* as well; *Corylus* appears and often *Ulmus* as well
LATEGLACIAL	Late Dryas-time	
	Park landscape with *Betula* and *Pinus*	Rapid increase in NAP, *Pinus* decreases
	Alleröd oscillation	
	Fairly dense forests, first *Betula*, afterwards *Pinus* and *Betula*	Rapid decrease in NAP, *Betula* chiefly present at first, afterwards a high percentage of *Pinus*
	Older Dryas-time	
	First tundra, afterwards parklandscape with *Betula*	High NAP values, *Betula* present

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[1] In the sand diagrams the boundary between Atlantic and Fagus-Carpinus period is located at the appearance of *Fagus* or *Carpinus* (cf. p. 12).

CHAPTER II

DESCRIPTION OF THE SOIL PROFILES

The 29 profiles investigated were found in groups in different parts of the Netherlands (see Fig. 1). Each profile series is named after its find place. They are arranged below in order of age.

Within each series the profiles were generally covered by peat or sand about the same time, but despite this their morphological features may show great divergencies. On the other hand, profiles of different dates may sometimes closely resemble each other.

For the description of the profile horizons the symbols in table II are used (Soil Survey Manual 1951, Schema voor Profielbeschrijving van de Stichting voor Bodemkartering). The various colours were determined according to the "Munsell soil color charts". In the diagrams use is made of the abbrevations of the colour descriptions (in Dutch, cf. the legend). The colours are shown

FIG. 1. Locations at which the profiles investigated were found

TABLE II. Explanation of the symbols for the profile horizons

Symbol		*Description*
A		eluviation horizon
(A)		weakly developed A
	A_1	the dark coloured top part with a high content of organic matter
	A_2	the light grey or white-coloured bottom part with maximum eluviation
	A_3	transition to B, but more closely resembling A than B
	AB	transition to B, equal resemblance to A and B
	AC	transition to C, equal resemblance to A and C, B absent
B		illuviation horizon
(B)		weakly developed B
	B_1	transition from A to B, but more closely resembling B than A
	B_2	the central part with maximum illuviation
	B_{2h}	B_2 with very great accumulation of organic matter
	B_3	transition to C, but more closely resembling B than C
	BC	transition to C, equal resemblance to B and C
C		little or no change in the parent material
G		grey gley horizon highly reduced by ground water, containing bivalent iron compounds
	GC	C-horizon with fairly marked gley effect
	g	slight gley effect, rust-coloured trivalent iron compounds mostly present
I		top of a double podsol profile
II		bottom of a double podsol profile
d		different grain-size distribution of the sand
u		unconformable layer, for instance a stone or peat layer
an		layer deposited by man

by the profiles under dry conditions. For practical reasons separate descriptions are used in the text.

The colours of the illuviation horizons have been divided into three groups according to their hue and are termed "faintly reddish brown" (hue 10 YR), "fairly intense reddish brown" (hue 7.5 YR) and "intense reddish brown" (hue 5 YR) by the author. The darkness of the brown B may often vary considerably in a horizontal direction, but in general its hue is constant. The intense reddish brown B horizons are restricted to the dry podsol type.

The A_2 horizons always show a 10 YR hue. Two groups have been distinguished, viz. a grey (value 5 or 5.5) and a white one (value higher than 5.5, usually 6.5). Each of these two groups is divided into a sub-group having a hue somewhat shifted to 7.5 YR. According to the Munsell color charts the more intense reddish tinge could only be accounted for by giving it a greater "chroma", viz. 1.5 instead of 1. Within the grey group this tinge is usually related to a relatively great lightness (value 5.5). In the text the grey colour with the greater chroma has been described as violet grey, the white colour being termed pinkish white in the corresponding case.

Grey and violet grey A_2 horizons are common in soils which podzolized during dry soil conditions. Several pedologists will attribute a grey A_2 to the effect of heath growth and a violet grey one to soil formation under forest. White and pinkish white A_2 horizons indicate wet conditions during podsolization, the pinkish white colour being by far the most common.

UDDELERMEER

By way of exception, Uddelermeer I is not a profile developed in sand which has been analysed by the author. It represents a thick, sub-aquatic organic deposit, consisting of layers of dy and gyttja and covering the sandy bottom of the small "Uddelermeer" lake. It was investigated by POLAK (1959). It will hereinafter be termed a dy profile.

Parts of the various diagrams of this deposit obtained by POLAK are reproduced here as they are a good subject for comparison with the diagrams of the podsol profiles found near the shore of the lake. In this way it might be possible to show whether pollen spectra in sand show certain divergencies from dy spectra owing to the influence of local vegetation, of selective corrosion or some other factor.

Uddelermeer II is situated 40 m east of the lake under an earth wall which was built from the 7th to the 10th century A.D. Its A_2 horizon has a grey colour, the B is fairly intense reddish, dark brown. Besides humus, the latter horizon contains some iron, as was shown when igniting the sand. Below the B_2 horizon dark brown fibres occur. The profile developed during relatively dry soil conditions.

Uddelermeer III is situated not far from Uddelermeer II under a remnant of the vast heath moor which covered the area before it was reclaimed in modern times. Profile III differs from profile II in that the eluviation and the illuviation horizon developed to a greater depth, the latter also being very highly indurated.

In both profiles fairly large pebbles are found in the BC horizon. They form part of a horizontal thin stone layer which approaches the slightly declining soil surface at some distance from the two profiles.

STAPHORST

The dry podsol profiles Staphorst I and II were found under a thin peat layer which in turn was covered by a thick layer of humous sandy mould. The latter is a product of human activity dating from after the 12th century A.D.

The A_2 horizon of Staphorst I is grey in the upper part and violet grey below. The B horizon is very compact and fairly peaty. Its colour is fairly intense reddish, dark brown. In the C, dark brown fibres are found. The covering peat layer is here 12 cm thick and undamaged.

Staphorst II is a double podsol profile. The upper eluviation horizon is much the same as the corresponding layer of the former profile. The subjacent illuviation horizon is thin and fairly faded. The lowest A_2 horizon is slightly violet grey. Like the lowest B horizon it stretches over a relatively great depth. Above this profile the peat layer is very thin and torn.

Profiles of the type Staphorst II are found scattered over the normal podsol type in the region. A similar occurrence of double podsol profiles was described by TAMM (1950) in Sweden. Here they are found under forest.

Special attention was paid to a system of burrows at a depth from 20 to 45 cm below sand surface in profile II (cf. fig. 4 on p. 52). In one burrow a specimen of the genus *Halictus* was found. 1) Apparently this digger-bee had been at work here. It may have brought pollen into the soil for the feeding of its larvae.

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[1] The determination was made by Dr. J. B. M. VAN DINTHER, Laboratorium voor Entomologie, Wageningen.

EPE

Epe I is a dry podsol profile with an A_2 horizon resembling the A_2 of Staphorst I and a B horizon, which is indurated and intense reddish brown. In the C, dark brown fibres are present. Iron could not be identified in any horizon when the sand was ignited. The profile is overlaid by a very thin peat layer which is covered in turn by a thick layer of Holocene drift sand.

As to the colours of the successive horizons and the presence of dark brown fibres in the C, the profiles Epe II and III resemble profile Epe I.

The fairly dry podsol profile Epe II is found under a fairly thick peat layer in a little fen, some hundreds of yards from the former profile. The upper 6 cm of the profile, though apparently forming part of the eluviation horizon, is to be considered as Holocene drift-sand. The original soil surface immediately below could be identified on account of its relatively slight pollen content and high content of charcoal particles. Apparently the forest which once covered this old soil surface was destroyed by fire. The burnt layer could be related to the thin uppermost layer of the podsol profile I, showing similar features. As the drift-sand layers of the two profiles are connected, it is evident that the peat layer at profile I is somewhat older than the drift-sand layer at profile II.

In the B horizon two highly indurated fibres are present. Under and above these fibres the B is less indurated. The upper part of this horizon contains an organic substance of a caseated kind. [1]) Iron is present in the lower part of the B at some distance below the fibres and in the C horizon.

The dry podsol profile Epe III is situated on the fairly steep margin of the little fen. Owing to its different topographic situation it developed to a much greater depth than Epe II. The upper 7 cm of the profile is also to be considered as Holocene drift-sand. Caseated material is absent in the top of the B, which is moderately indurated and contains one very hard fibre. This fibre, and the deeper part of the B and the C horizon, contain much iron.

As to the iron content of the successive layers, however, we can hardly compare the profiles; since they are situated partly within the range of the ground water, iron may be a secondary feature.

PEEL, SERIES H

Peel I, II and III are found at the top and Peel IV at the flank of a narrow sand ridge. The distance between the successive profiles is about 25 m. The ridge consists of Pleistocene cover sand to a depth of at least 1.30 m. It is covered with peat of Subboreal age. In the neighbourhood of the ridge soil topography is very level. Here, loamy sand is mostly found at some depth below normal cover sand.

Peel I, II and III all belong to the dry podsol type. In the sequence mentioned they must have developed with slightly increasing moistness. This is inferred from the increasing depth of soil formation. Apart from this the profiles are very similar. Their A_2 horizon is violet grey throughout its depth. The B,

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[1] Caseated matter is commonly found in the B horizon of podsol profiles in a relatively low situation. In an unreclaimed area these profiles are usually covered by a vegetation of *Erica tetralix* and *Molinia coerulea*. The term "caseated" refers to a field-pedological characteristic, the chemical composition being left out of consideration.

which is indurated and not caseated, is an intense reddish brown. Dark brown fibres are found below the B.

Under periodically wet soil conditions Peel IV developed to much greater depth than the former profiles. Its A_2 is pinkish white and the B a fairly intense reddish brown. The latter looks intensely flamed. It is not of the indurated or caseated type.

NOORDOOSTPOLDER

The two podsol profiles Noordoostpolder I and II developed under periodically very wet soil conditions. They were found on a very steep slope on the edge of a deep gully in Pleistocene cover sand, under *Carex* peat of Subboreal date. These profiles are 1.50 m apart. Owing to the high water table, the deeper sand layers could not be sampled, but the missing samples were taken later when it had sunk (Noordoostpolder III).

The eluviation horizon extends over a very great depth. The bleached sand has a pinkish white appearance. The B, which is a fairly intense reddish brown, has a flame-like appearance. It contains caseated material. Noordoostpolder I mainly differs from Noordoostpolder II in having a very deep A_1 horizon.

DELFZIJL

Owing to the existance of two deep pits near Delfzijl which were made for the construction of sluices we were able to sample soil profiles at a depth of about 7 m below sea level. They were found under peat of Atlantic date, consisting of remnants of reed, sedges, alder and birch. In one pit (A), several stems of oak were found on the sand which itself contained partly decayed oak and alder roots. In the other pit (B) very many stumps of fir and large quantities of fir-cones bore witness of a former forest. One find of poplar wood should also be mentioned. Only roots of alder were encountered in the sand of this pit.

Here and there the cover sand is very loamy, but the profiles analysed are not of a loamy type.

In pit A only one profile (I) was investigated because of the sand had a very uneven surface. In pit B, which had a level sand surface, four profiles (II, III, IV, V) were sampled at distances apart of several tenths of metres. In the said succession the profiles in pit B show features indicating increasing moistness during podsolation.

Delfzijl I is a fairly wet podsol profile with a pinkish white A_2 and a faintly reddish brown B horizon. The latter is not indurated and contains caseated matter in its upper part.

Delfzijl II is a fairly dry podsol profile with a grey A_2 and a fairly intense reddish brown B horizon. The B is slightly indurated and not caseated.

Delfzijl III has a deeper solum than Delfzijl II. Its A_2 horizon is fairly white at a certain depth, without a pinkish tinge. The B differs from that of the former profile by its slight content of caseated matter and by showing root holes filled up with bleached sand.

The A_2 horizon of the wet podsol profile Delfzijl IV is coloured pinkish white, the B faintly reddish brown. The latter has a flame-like appearance and is rather faded. It contains many root holes with bleached sand. Caseated material is absent. The illuviation horizon developed to a great depth as is rather common for podsol profiles which arose under wet conditions. In the neighbourhood of these profiles loamy sand is found at several points, where a very thin A_2 is encountered.

Delfzijl V is a very wet gley podzol profile (LAATSCH 1957, p. 248) having a gley horizon under an eluviation horizon. The A_2 is not so white as the corresponding horizon of the wet podsol profiles described above. In the yellowish green G horizon rusty coloured spots formed after exposure to the air.

In all four profiles in pit B a non-stratified sand layer was perceptible over a well-stratified sandy subsoil and separated from it by a more or less gradual transition zone. The upper layer reaches different depths, viz. 40 cm, 40 cm, 20 cm and 16 cm in or beneath the solum of the respective profiles (cf. fig. 5 and 6 on p. 53 and 54). The phenomenon was only clearly visible after a monolith was made by pouring strongly adhering lac along the vertical profile wall. Monoliths of this kind were also obtained from the Velzen series but not from the others.

The origin of the non-stratified upper sand layer is mainly due to mixing activities (FRANZ 1952, HOEKSEMA 1953) of the soil fauna during the Holocene after the deposition of the well-stratified sand during the Pleistocene. In the profiles investigated the topography of the bottom of the non-stratified layer did not, in fact, indicate a fairly deep effect of solifluction during the Glacial period. The mixing of soil material, known as homogenization (HOEKSEMA 1953), must be regarded as the earlier soil formation, this being was succeeded by podsolization when the biological activity receded. The latter process usually started as a result of a rising of the water table during the Holocene.

APPINGEDAM

Like Delfzijl V, the Appingedam profile is a gley podsol profile. It was found at nearly the same depth below the sea level under *Phragmites-Carex* peat of Atlantic date. 35 cm below the sand surface a highly impermeable layer of boulder clay was found.

FLEVOLAND

In the newly-reclaimed polder of Oostelijk Flevoland fossil stumps of a former fir forest covered a great area of *Carex* peat in which scattered areas of Pleistocene cover sand occurred. Under the peat, the sand was usually found at a depth of less than 50 cm. Peat growth started during the Atlantic. Originally the tree stumps must have been enclosed in the peat, which was afterwards abraded to the level of the ancient forest floor or slightly below.

Flevoland I is a wet podsol profile. Locally the peat is 46 cm thick. The sandy subsoil is very level in the vicinity. An A_2 horizon is lacking. The B developed fairly deeply. It has a flame-like appearance and is rather faded. It is faintly reddish brown. Caseated material is not found in it.

Flevoland II is present on a fairly steep but very short slope of the sandy subsoil. It is covered with 10 cm of peat. The well-developed A_2 horizon has a pinkish white colour. The upper 4 cm are stratified probably as a consequence of sedimentation caused by surface water flowing down periodically. The B horizon is very shallow, it has a faded appearance and is not caseated.

Flevoland III was found under an undisturbed peat layer of only 5 mm thick below a fir root, on a level sand plateau. It has the same features as Flevoland I and apparently developed under equally wet conditions.

VELZEN [1])

The Velzen profiles were found 16 m below the sea level in a pit which had been made for the construction of a tunnel. [2]) The Pleistocene cover sand, at the top of which they developed, is overlaid by the so-called Dutch lower peat. This peat began to grow during the transition from the Boreal to the Atlantic. Immediately above the profiles investigated it consists of remnants of sedges, for the rest also of reed, alder and birch. The profiles are several tenths of metres apart.

Velzen I is a wet humous gley profile with a fairly dark grey AC under the A_1 horizon. It is rich in ferrous iron compounds.

Velzen II is a fairly dry and shallow podsol profile with a grey A_2 and a pale, faintly reddish brown B horizon.

Velzen III closely resembles Velzen II, but the B is coloured somewhat paler.

Velzen IV is an intergrade between a podsol and a humic gley profile. A bleached A_2 horizon is missing. The B developed weakly and to some extent it has the nature of a C. The profile is only weakly gleyed. It is situated at the bottom of a little gully in the cover sand, in the middle of rather dry podsol profiles. 32 cm below the bottom of the gully there is a thin loamy layer and somewhat deeper still a thin peat layer. On top of the profile a few cm of sand seem to have been removed by human activity.

Homogenization (cf. p. 9) took place up to about 40 cm below te sand surface of profiles Velzen II and III and up to 35 cm depth in profile Velzen I. At Velzen IV stratification of sand is absent from the sand surface as low down as the loamy layer.

PEEL, SERIES L

The profiles of this series all developed in the very level cover sand area in the neighbourhood of the sand ridge on which the profiles Peel I, II, III and IV were found. The sand has been covered by gyttja and by peat since the Lateglacial. The distances between Peel V and VI, and between Peel VI and VII are both 150 m.

The wet podsol profile Peel V was overgrown by *Carex* peat during the transition period between the Boreal and the Atlantic. Its A_2 horizon has a

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[1] The investigation of Velzen I, II and III has been published before (HAVINGA 1957). The profiles are discussed again here because more information has been gained on the significance of the diagrams.

[2] A detailed study of the soil profiles in the tunnel pit has been made by PONS (1959).

pinkish tinge but is not so white as the A_2 horizon of the various other wet podsol profiles investigated. The B has a pale, flame-like appearance and has a faintly reddish brown hue. From 23 to 26 cm and below 33 cm soil material consists of loamy sand. Some pebbles were found both in the sand and the loamy sand.

Peel VI podsolized very weakly. The solum developed in sand with a very high content of gyttja-like organic matter. The overlying pure gyttja sedimented since the Preboreal. This soil formation was classified as an old low heather profile by VAN NISPEN TOT PANNERDEN (1952).

Peel VII occurs under gyttja of Lateglacial age. Since no soil formation could be observed as an effect of vegetation, there cannot be said to be a soil profile in the pedo-genetic sense. The greyish sand contains many scattered peaty elements.

CHAPTER III

DESCRIPTION OF THE POLLEN DIAGRAMS

Pollen preparations of sand were made by means of the acetolysis and hydrofluoric acid method (FAEGRI and IVERSEN 1950, p. 62-63).

The arboreal and non-arboreal species which may have grown in the vicinity of the profiles investigated have not been omitted from the arboreal pollen sum (Σ AP = 100%) or non-arboreal pollen sum (Σ NAP), as is usual with peat diagrams. The fact is that the diagrams of the soil profiles must primarily reflect the local vegetations, under which soil formation took place. On the other hand, pollen analysis of peat is usually made in order to study the development of regional vegetation.

High values for *Ericaceae* nearly always entirely consist of *Calluna*. For this reason *Calluna* percentages are not separately quoted unless only very few *Ericaceae* pollen grains were found. Non-arboreal pollen species are represented in the diagrams when they consist of 4% or more. Lower percentages are included in the supplementary table XI. In the Noordoostpolder, Delfzijl, Appingedam and Velzen series, non-arboreal species are mostly not separately distinguished.

In the following the descriptions of the various zones of the sand parts of the diagrams are placed in quotation marks so as to stress the relative value of zoning sand diagrams as is usual in peat diagrams, since it has been found that in several cases the composition of successive sand spectra is not a sound basis for a division of the diagram into zones according to the various periods of vegetational history. The same is true, in fact, of some of the peat spectra in certain diagrams of the profiles investigated.

The border between the Atlantic and Subboreal zone is placed by modern palynologists at the first slight fall of the *Ulmus* curve. Such a subtle distinction is only applicable, however, provided very statistically reliable data are available. This is the case, for example, when many pollen grains have been counted in samples from an organic sub-aquatic lake deposit. Zonation of sand diagrams will usually be less reliable owing to the influence of local vegetation, selected pollen corrosion in mineral soil, and other possible pedological factors. Moreover, pollen is scarce in the deeper sand layers so that here, one has to be content with a fairly small number of pollen grains per spectrum. In the older literature a more distinct change in pollen composition was often used as a criterion for the beginning of the Subboreal, viz. the appearance of *Fagus*. This appearance falls relatively high in the relating diagrams, in consequence of the fact that former investigators contented themselves with a fairly small number of pollen grains counted per spectrum. Thus a sporadic occurrence was generally overlooked. The present writer applies the mentioned phenomenon again when zoning sand diagrams, but the period after the appearance of *Fagus* is now called the Fagus-Carpinus period. In this connection it should be noted that in several diagrams (Peel I, II, III, Epe III) the zone begins with the curve for *Carpinus* instead of *Fagus*. In peat diagrams this irregularity is very unusual.

The depths mentioned in the following descriptions indicate distance from the original soil surface, which now is found under Holocene drift sand or under peat. The + sign is added to indicate height above this surface (o-level).

UDDELERMEER

I. This diagram is made up of parts of the diagrams I and III obtained by POLAK (1959)[1], from the sub-aquatic sediment in the Uddelermeer lake. According to this research worker the following zones are to be distinguished: Boreal zone 465 cm, Atlantic zone 445–415 cm, Subboreal zone 395–225 cm, Subatlantic zone above 225 cm.

If we zone this diagram in the same way as our sand diagrams, the border between the Atlantic and Fagus-Carpinus zone is put between 295 and 275 cm.

II. "Boreal" zone 70 cm, "Atlantic" zone 63–39 cm, "Fagus-Carpinus" zone above 39 cm. Unlike diagram I, *Secale* is not represented in the top spectrum.

III. Since this diagram is much the same as diagram II it is not reproduced here. It only differs from the former in having *Secale* represented in the top spectrum and having no "Boreal" zone.

STAPHORST

I. "Boreal-Atlantic transition" zone 40–32 cm, "Atlantic" zone 25–2.5 cm, Fagus-Carpinus zone (in peat) 0–+11 cm.

II. "Atlantic" zone 40–10 cm, "Fagus-Carpinus" zone, with the recent species *Fagopyrum* already represented, 7.5–2.5 cm. In the thin and torn peat layer and in the mould layer, spectra indicating the same period are found at +0.5 cm and +4.5 cm respectively.

EPE

I. "Atlantic" zone 8.5–5 cm, Fagus-Carpinus zone (in peat) +0.5 cm.

II. "Boreal-Atlantic transition" zone 34 cm, "Atlantic" zone 26-3 cm,

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[1] The writer is greatly indebted to Dr. B. POLAK for kind permission to reproduce the diagrams.

"Fagus-Carpinus" zone (partly in drift sand) 0.5–+5 cm, Fagus-Carpinus zone, with *Secale* and *Fagopyrum* already represented (in peat) +10–+25.5 cm.

III. "Boreal" ("Preboreal"?) zone 72 cm, "Boreal-Atlantic transition" zone 59–40 cm, "Atlantic" zone 31–21 cm, "Fagus-Carpinus" zone with *Secale* represented above 4 cm (partly in drift sand) 11–+7.5 cm.

PEEL, SERIES H

I. "Boreal" zone 42 cm, "Boreal-Atlantic transition" zone 37–30 cm, "Atlantic" zone 25–10 cm, "Fagus-Carpinus" zone 5–0 cm, Fagus-Carpinus zone (in peat) +11–+21 cm.

II. "Atlantic" zone 45–15 cm, "Fagus-Carpinus" zone 10–5 cm, Fagus-Carpinus zone (in peat) +0.5 cm. At 45 cm an inferred spectrum, lacking *Tilia*, has been drawn. This spectrum shows the position of *Alnus* with respect to *Pinus*. In agreement with the "Atlantic" character *Alnus* appears to be the dominating of the two species.

III. "Atlantic" zone 58–30 cm, "Fagus-Carpinus" zone 25–0 cm.

IV. "Preboreal" zone 71 cm, "Boreal" zone 63–43 cm, "Boreal-Atlantic transition" zone 38 cm, "Atlantic" zone 33–9 cm, "Fagus-Carpinus" zone 4 cm, Fagus-Carpinus zone (in peat) +1 cm.

NOORDOOSTPOLDER

I. "Atlantic" zone 66–54 cm, "Fagus-Carpinus" zone 46–2 cm, Fagus-Carpinus zone, *Carpinus* not yet represented (in peat) +1–+9 cm.

II and III. "Atlantic" zone 115–40 cm, "Fagus-Carpinus" zone, *Carpinus* not yet represented 30–0 cm.

DELFZIJL

I. "Boreal" zone 29–24 cm, "Atlantic" zone 21–0.5 cm, Atlantic zone (in peat) +2–+12 cm.

II. "Boreal" zone 27–3 cm, "Boreal-Atlantic transition" zone 1 cm, Atlantic zone (in peat) 0–+15 cm.

III. "Boreal" zone 38–9? cm, "Atlantic" zone 7(?)–0 cm, Atlantic zone (in peat) +2–+14 cm.

IV. "Boreal" zone 18–3 cm, Atlantic zone (in peat) +1–+7 cm.

V. "Atlantic" zone 23–1 cm, Atlantic zone (in peat) +1–+10 cm.

APPINGEDAM

"Atlantic" zone 15–1.5 cm, Atlantic zone (in peat) +1–+15 cm.

FLEVOLAND

I. "Boreal" zone 18–2 cm, Atlantic zone (in peat) +2–+46 cm.

II. "Boreal" zone 45–10 cm, "Boreal-Atlantic transition" zone 7.5 cm, "Atlantic" zone 5–2 cm, Atlantic zone (in peat) +2–+9 cm.

III. "Boreal" zone 30–1.5 cm, "Boreal-Atlantic transition" zone 0.7 cm, Atlantic zone (in peat) +0.5 cm.

VELZEN

I. "Boreal" zone 14.5–9,5 cm, "Atlantic" zone 4.5 cm, Atlantic zone (in peat) +1–+4 cm. The diagram probably represents only the upper part of the pollen profile. Below 14.5 cm the sand has not been analysed.

II. "Boreal" zone 35–11 cm, "Boreal-Atlantic transition" zone 8.5 cm, "Atlantic" zone (partly in peat) 6–+1 cm, Boreal-Atlantic transition zone (in peat) +2–+3 cm. [1]

III. "Boreal" zone 41–31.5 cm, "Boreal-Atlantic transition" zone 26.5–18.5 cm, "Atlantic" zone 13.5–0.6 cm, Boreal-Atlantic transition zone (in peat +0.8 cm. [1]

IV. "Preboreal" zone 37.5–28 cm, "Boreal" zone 23–3 cm.

PEEL, SERIES L

Where the pollen profiles of this series are coupled with great masses of *Algae*, they must have developed when the area was submerged. Hence the arboreal pollen must originate from regional tree growth. For this reason the relative zones have been indicated without using quotation marks.

V. Eemian zone 42–35 cm, Preboreal zone 31 cm, Eemian zone 25 cm, "Preboreal" zone 15–9 cm, "Boreal-Atlantic transition" ("Boreal"?) zone 6–1 cm, Boreal-Atlantic transition zone (in peat) +1 cm, Atlantic zone (in peat) +3–+5 cm. [2]

The Eemian spectrum in the loamy sand at 25 cm, is separated from the Eemian zone in the loamy sand below 33 cm by a Preboreal spectrum in normal sand. This is a good evidence that the soil material was washed away and resedimented.

VI. Eemian zone 28–17 cm, Lateglacial zone 12–2 cm, Preboreal zone (partly in gyttja) 1–+5 cm, Boreal zone (in peaty gyttja and peat) +7–+11 cm. [2]

VII. Eemian zone 33–21 cm, Würm-Glacial (older than Alleröd) zone 15–5 cm, Older Dryas-time zone 0 cm, Alleröd zone (in gyttja) +2–+6 cm, Late Dryas-time zone (in gyttja) +10–+22 cm, Preboreal zone (in gyttja) + 26 cm, Boreal zone (in peat) +29–+33 cm, Atlantic zone (in peat) +36 cm.

The gyttja part of diagram Peel VII closely resembles a certain part of diagram Helenaveen (XII), obtained by VAN DER HAMMEN (1953). The latter represents the pollen content of a gyttja profile, situated about 6 km s.s.e. of Peel VII.

It may be concluded from the spectra 1 cm below 0-level in diagram VI and 26 cm above 0-level in diagram VII that the Preboreal started with *Betula* dominance in the Peel region. This is contrary to the opinion of VAN DER HAMMEN (1953) who stated that in the southern Netherlands *Pinus* dominance was probably normal at the beginning of the Preboreal.

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[1] The peculiar, aberrent zonation will be explained below (cf. p. 30). Some of the diagrams of the lower peat in the Velzen tunnel pit obtained by DOPPERT (1957) show features somewhat resembling the Velzen II and III diagrams. Just above the sand surface the *Pinus* and *Alnus* curves bend towards each other, tending to make a second intersection above another *Pinus-Alnus* intersection. However, they do not join again as in the above-mentioned Velzen diagrams.

A second point of intersection would probably have been found, had the analyses been made at shorter vertical intervals.

[2] A hiatus between Eemian (Riss-Würm Interglacial) and Holocene or Lateglacial was also shown by ESHUIS (1946)in the Peel area.

CHAPTER IV

THE DEVELOPMENT OF A POLLEN PROFILE IN A SAND SOIL

1. INTRODUCTION

Since micro-fossils have been found in eolic sand sediments (BEYERINCK 1931), the question as to how pollen arrives into a sand soil has been studied by palynologists. The right answer to this question is of primary importance for the explanation of pollen diagrams in sand. Hitherto there have been various theories on this question. According to several research workers (BEYERINCK 1931, 1933a, JONAS 1935, BENRATH and JONAS 1937, FLORSCHÜTZ 1941, and DE PLANQUE 1950) who were struck by the resemblance of sand to peat diagrams, pollen profiles in sand usually developed as a result of simultaneous sedimentation of pollen and sand. However, it was also stressed (WASSINK 1934) that such a resemblance is no evidence for this process to have taken place. In the opinion of DEWERS (1935), MOTHES, ARNOLDT and REDMANN (1937), SELLE (1940), FIRBAS, LOSERT and BROIHAN (1939), DIMBLEBY (1957), GODWIN (1958) and MUNAUT (1959), downwash of pollen into a soil is generally the cause. In addition to these two theories, others found in the literature start from a combination of the following processes: sedimentation and infiltration (ENGMANN 1937, FLORSCHÜTZ and MENENDEZ AMOR 1959); infiltration of pollen and colluviation of soil owing to erosion and accumulation of sub-soil material on to soil surface in consequence of earthworm activity (WELTEN 1958); infiltration of pollen and mixing of soil by biological activity (ERDTMAN 1943, TRAUTMANN 1952); infiltration of pollen into the soil, homogenization of the pollen containing soil, and possibly simultaneous sedimentation of pollen and sand (HAVINGA 1957).

It is obviously possible to assume that all these processes may have played a more or less important part in the development of pollen profiles in sand. However, it is very difficult to prove exactly which process or processes resulted in a particular pollen profile. The fact is that only the result can be observed but not the processes themselves. Now a sand diagram often makes it possible to explain the presence of pollen in the sand in different ways. Moreover for a proper interpretation it is not sufficient to know only the processes which were active but also the effect of each.

In the following paragraphs an attempt will be made to solve these problems. Most of the conclusions were drawn by comparing the diagrams of individual series. A study of the vertical distribution of absolute pollen frequencies has also thrown light on the matter. We shall deal with this first.

2. THE VERTICAL DISTRIBUTION OF ABSOLUTE POLLEN FREQUENCY [1])

Profiles II, IV, and V of the Delfzijl series were selected for the investigation into distribution of pollen frequency. These three profiles have been

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[1] The absolute pollen frequency (APF) in sand was determined as follows: 1 g of sand is boiled with KOH-10%. Minerals, coarse organic matter and humus colloids are removed by decanting, filtering, centrifuging, and boiling with HF. The remaining pollen suspension is measured in cm^3 after adding several drops of glycerine. The suspension is shaken, and 1 cm^3 remo-

within reach of atmospheric pollen during the same Holocene periods, as they were covered by peat at the same time.

The APF data in the respective diagrams show that in the fairly dry podsol profile II pollen and spores occur in much greater quantities than in the wet podsol profile IV and the very wet gley podsol profile V. For instance, APF is 180,000 in diagram II at 10 cm depth, 1250 in diagram IV at 8 cm and 4500 in diagram V at 6 cm. The APF values are even highest in diagram II if they are computed by eliminating the effect of *Filicinae* spores on APF, though these spores represent by far the highest percentages in this diagram. It may be concluded from the foregoing that the pollen and spores cannot have been deposited simultaneously with the cover sand. Had this process happened the highest APF values would be expected in the diagrams IV and V owing to the fact that conservation of pollen and spores is favoured by the wetness of the soil. For instance, glacial pollen is only found in glacial cover sand when it was wet for the entire period during and following its deposition (cf. p. 19). Another phenomenon at variance with the sedimentation theory is that the pollen profiles IV and V developed to a less depth than pollen profile II. These phenomena can only be explained by assuming that pollen and spores infiltrated the sand after its deposition.

In the lower part of the pollen profiles pollen concentrations are very small. It must be assumed that accidental supply or removal of even minute quantities of pollen at these depths must have had a very great relative effect. Yet the differences between the very small APF values found in diagram IV from 8 to 18 cm may be explained, as it was proved that a relation exists between small pollen concentration and humus content as far as the small values are found in the A_2 horizon of the relative podsol profile. At depths of 13 and 15.5 cm in the A_2, where APF is minute (5 and 30 respectively), no humus could be identified by chemical analysis. Boiling sand from these depths with KOH did not even change the colour of the clear KOH solution. At a depth of 8 cm in the A_2, where APF is much greater (1250), humus content was found to be 0.06%. In the AB horizon, at 18 cm, a higher APF is also found. This horizon is obviously rich in humus. Pollen was apparently washed out to a very great extent in the A_2 horizon of this wet podsol profile.

In the higher parts of the various profiles, where there is a much greater pollen content, vertical distribution of pollen frequency is very regular. This is shown by the graphs in Fig. 2 in which the APF values of profile II, and of profile V to 11 cm, are plotted logarithmically against the depth. In both graphs the points are almost in a straight line. 1) This means that the pollen concentration decreases in a downward direction in accordance with a geometrical series. If the values of log. APF are adjusted to the numbers of centimetres representing the respective depths, the following regressive equations are obtained:

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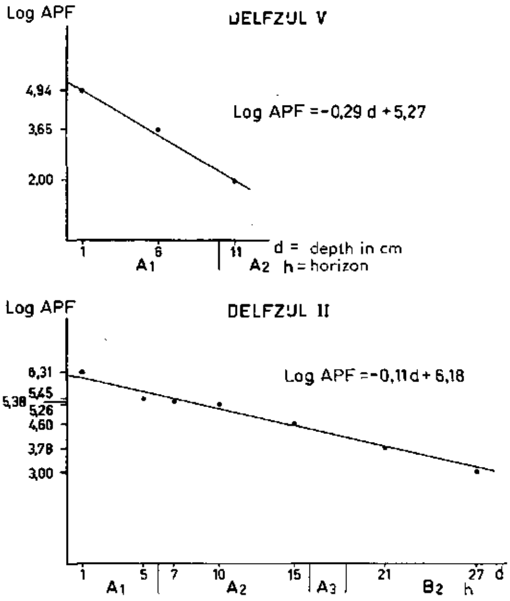
ved from it with a pipette and placed on a microscopic slide, inside a little wall previously made by means of a glue tube. After the water has evaporated, the glue wall is eliminated, and a drop of glycerine placed on to the pollen grains adhering to the slide. To determine the APF all pollen grains must then be counted and the number obtained multiplied by the number of cm^3 of the pollen suspension.

[1] A similar relation between APF and depth below sand surface can also be shown for the APF data of DIMBLEBY (1957, p. 21), especially for those of the Crowthorne profile.

FIG. 2
Graph showing the distribution of pollen frequency in the profiles Delfzijl V and Delfzijl II



for pollen profile Delfzijl II: $\log APF = -0.11d + 6.18$,
for pollen profile Delfzijl V: $\log APF = -0.29d + 5.27$.

It follows from these two equations that at profile II the pollen concentration ($10^{6.18}$) at the sand surface roughly has the same magnitude as at profile V ($10^{5.27}$). The pollen concentration decreases much sooner at Delfzijl V than at Delfzijl II.

It is noticeable that the great differences in the *Filicinae* percentages in diagram Delfzijl II have no effect on the trend of the log. APF curve. This curve does not even show any response between 5 and 15 cm, yet over this distance the *Filicinae* percentages increase enormously below (from 1% to 4050%).

It is tempting to draw conclusions from the foregoing as to possible changes in the composition of vegetation. It follows from the regular trend of the curve that the high fern percentages cannot have resulted, for example, from an accidental extra supply of spores to the soil. Such an enrichment might have been caused by partly filled fern sporangia washing down via the holes of decayed roots. Hence we are forced to assume that the change in the *Filicinae* curve is solely related to a change in composition of the normal pollen rain. If this is true the vegetation from which the pollen and the spores originate must also have changed, the proportion of ferns in this vegetation decreasing substantially some time before peat growth started.

For the present, however, no general validity should be attached to such conclusions drawn from vertical distribution of pollen and spore concentrations. A proper insight will only be gained by a more general study of pollen frequency in sandy soil.

In addition to the APF determinations discussed above similar analyses were made from the pollen store in the top sand layers of the Epe profiles, above, in and below the thin burnt sand layer with charcoal. It was found that the burnt layer contained very little pollen at Epe I, much more at Epe II, and a great deal at Epe III (cf. the diagrams). The concentration of charcoal increases in the inverse direction, viz. from Epe III to Epe I. It may be concluded from these phenomena that at Epe I peat growth cut off the original sand surface from pollen rain very soon after the forest was destroyed by fire. At Epe II peat growth started later so that here pollen was able to infiltrate a fairly long time after the forest fire, during which period sand-drift took place. At Epe III pollen infiltration was not arrested. This profile was only covered by a little drift sand.

3. THE DIFFERENT METHODS BY WHICH POLLEN ENTERS SAND SOILS

a. *Simultaneous sedimentation of pollen and sand*

Several research workers (cf. p. 15) investigating pollen in sand soils started from the point of view that there was a more or less regular drift and resedimentation of a small amount of sand throughout the Holocene. In the previous paragraph it was shown, however, that sedimentation was of no importance for the development of the pollen profiles of the Delfzijl, pit B series. In certain regions of the cover sand landscape, some sand was in fact deposited in the manner described. This is evident from the fact that in this landscape organic sediments are found which caught a certain amount of sand during their formation. Thus, VAN ZINDEREN BAKKER (1948) mentions the occurrence of sand in peat layers of Preboreal, Boreal and Atlantic date in the Veluwe. POLAK (1959) found a small amount of sand in every sample she analysed of the sub-aquatic organic sediment in the little lake, the Uddelermeer, in the same area. The sediment was formed from the Lateglacial to the Subatlantic period.

In order to obtain a good idea of the quantity of sand which was deposited in the Uddelermeer and its neighbourhood we analysed the sand content of a number of samples of the organic sediment. They were taken from depths corresponding to the Atlantic and Subboreal zone of POLAK's pollendiagram. These periods are also shown in our sand diagram Uddelermeer II. From the data obtained it was calculated that the amount of sand deposited during these two periods would correspond to a layer of cover sand 4.5 cm thick. Sedimentation from the air might even be less because the sand found could be partly supplied by flowing water. The total length of the Atlantic and the Subboreal zone in the sand diagram is 63 cm. Evidently most of the deep pollen profile Uddelermeer II resulted from other processes than sedimentation.

The slight significance of sedimentation also agrees well with the fact that near the podsol profiles investigated the horizontal layer of pebbles is situated only 6 cm below the soil surface.

The diagrams of the Peel H series show the following differences which cannot be explained if we start from the sedimentation theory. In profile I the lowest spectrum of the "Atlantic" zone with a very high *Tilia* percentage is found 20 cm below the sand surface, in the AB horizon. In profile III, an "Atlantic" spectrum with much *Tilia* is only found at a far greater depth, viz. 58 cm, in the BC.

The very deep pollen profiles of the Noordoostpolder series developed under a dense oak forest, in a wet sand soil. It is evident that in this case sedimentation of sand from the air cannot have had any effect. The pollen must have infiltrated the forest floor.

The very thin sand layer which may have been deposited upon the Pleistocene cover sand soil during the Holocene cannot usually be distinguished. Owing to soil formation it obtained the same appearance as the original A_1 of the soil profile. Part of pollen which was deposited at the same time as this sand may also have infiltrated the underlying sand.

The sedimentation process described is to be clearly distinguished from the deposition of cover sand during the Pleistocene and possibly the very first beginning of the Holocene period. The latter process gave rise to the cover sand landscape.

In most cover sand soils pollen from the sedimentation period is entirely absent. Evidently soil conditions were very unfavourable for pollen preservation at that time. This is probably connected with the fact that soil formation was then either very slight or failing.

In the profiles Velzen IV and Peel V, VI and VII, pollen from the sedimentation period was in fact found. The relative pollen spectra show that this pollen dates partly from the Würm-Glacial (Peel VI, VII) and the Preboreal (Peel V, Velzen IV) and for the rest from the Eemian (Peel V, VI, VII). Besides pollen, these spectra show great quantities of algae. Evidently sedimentation of pollen and sand occurred in a pool or lake. Morphological features of the various profiles indicate that they were under wet conditions during the Holocene. Peel VII was even so wet that a soil profile in pedogenetic sense did not develop at all. In the wet soils, conditions were very good for the preservation of pollen and algae.

The upper part of the diagrams Velzen IV and Peel V consists of spectra without algae. The sand in which these spectra are found was deposited when the water table had already sunk into the soil.

It was evident from the microscopic pollen preparations of the four profiles that pollen content (APF) did not decrease in a downward direction in the sand with algae (cf. p. 16). To save time, however, exact determinations were not made.

During the Holocene, sand drift of a local kind was a fairly common phenomenon in the cover sand landscape. Consequently the relief changed considerably here and there. Where a thick layer of sand was blown upward, another even complete podsol profile was able to develop over the one covered. Secondary pollen is mainly found in the resedimented sand layers. This originates from the blown-out podsolized soil in the neighbourhood. When a soil is blown out pollen from different depths becomes mixed. Now the pollen content of the upper part of a podsol profile generally containing the youngest pollen spectra is far higher than the pollen content below, where old spectra may often occur. Consequently the composition of secondary pollen can hardly be affected by pollen which is relatively old. It will have a composition resembling spectra of a relatively late date.

It will be evident from the foregoing that the diagram of a pollen profile in blown sand is usually a continuation of the diagram of the pollen profile in the covered sand. This is shown, for instance, by diagrams II and III of the

Epe series. It was also shown by a diagram of a very thick layer of Holocene drift sand covering a brown podsolic profile in fluvio-glacial sand (HAVINGA, in print).

b. *Sedimentation of pollen simultaneously with accumulation of sand on to soil surface, due to biological activity*

In a well-homogenized soil a good deal of soil material is brought on to the soil surface by the rich soil fauna. But this process is unable to influence the composition of the pollen profile because sedimenting pollen is not stored in the accumulating sand but intermingled with the entire soil profile (cf. below, p. 22). In a podsolized soil, however, the rather scarce burrowing fauna will mainly bring material from the subsoil to the top of the soil profile, soil mixing being of no importance. In this case, therefore, we must assume that younger spectra are added to the top of the pollen profile. KEILHACK (1899) has shown that the accumulation may sometimes be fairly important. But similar arguments used when discussing sedimentation of pollen and sand during the Holocene, prove that the process cannot have much effect on the profiles analysed.

c. *Eluviation of sand and pollen*

This process sometimes occurred before sedimentation of eolic sand during the Pleistocene had finished, and consequently before a soil profile in the pedo-genetic sense developed. In this way the hiatus in the Peel L diagrams (cf. p. 14) may be explained.

The podsol profile Flevoland II, which is situated on a short gradient in a very wet sand area, was covered with very thin sand layers by water floating on the surface of the soil after completion of soil formation. This is shown by the remarkably stratified appearance of the upper 4 cm of the A horizon. The pollen stock therein may either be of secondary origin or air-borne. This phenomenon is only found by way of exception.

d. *Downwash of pollen*

When we compare diagram Staphorst II with Staphorst I, we must conclude that pollen of *Fagus, Carpinus* and cultivation plants was washed down into the sand of profile Staphorst II via the cracks in the overlying thin peat layer. Most of this pollen did not arrive below a depth of 5 cm. The process may have lasted for not more than 700 years since the former peat moor was not reclaimed before ± 1250 A.D.

A similar indirect demonstration of downwash is found in the Epe series. At Epe III, pollen of *Fagus, Carpinus* and *Cerealia* infiltrated 9 to 11 cm below the original sand surface. At Epe I and II such pollen is absent from the upper layer of the podsol profile. Here the sand surface was covered by peat before or rather soon after these species of pollen formed part of the pollen rain. Quantitative pollen distribution in the burnt sand layer with charcoal was shown to be influenced by the same causes (cf. p. 18).

Downwash must have occurred at Staphorst II via the pores between the sand grains, since root holes are not present in the sand underlying the peat layer. In soils under a living vegetation, pollen may be transported to a certain extent through the holes of decayed roots and burrows of soil animals. It is a fairly common phenomenon for ancient root holes in the B horizon to be filled up with bleached sand of the A_2 (cf. the Delfzijl III and IV profiles). In such holes pollen obviously has the same composition as in the A_2 horizon.

Though downwash may be a fairly important factor for development of pollen profiles, there are still many phenomena which cannot be explained in this way. They are as follows in the profiles investigated.

In profile I of the series Peel H, pollen spectra occur in the indurated B horizon which indicate the "Boreal-Atlantic transition" period, but in the neighbouring Profile II, pollen spectra in this horizon indicate the "part of the Atlantic" in which *Tilia* spread enormously in the surrounding area.

In each of the series Staphorst, Delfzijl pit B and Flevoland, there is no relation between depth of the pollen profile and depth of podsol B horizon, although there is good agreement between the diagrams of the various profiles within each series.

A great deal of pollen is often found below a B horizon even when this is indurated (Peel I, II, III), although it cannot have penetrated the impermeable layer.

Vertical quantitative pollen distribution is not influenced by the presence of the B horizon, as is shown in the pollen frequency graph of Delfzijl II in Fig. 2 on p. 17. If downwash had been very important during and after podsolization, a relative increase in pollen content might be expected either in the B or just above it.

Many diagrams have their bottom closed by spectra reflecting a later period of the Holocene. In such cases pollen from earlier periods had evidently been destroyed. Now if we assume that this destruction occurred after downwash of pollen, difficulties arise when interpreting differences which often exist between the bottoms of various diagrams of a series. Thus in diagram Epe II, the lowest spectrum reflects the "Boreal-Atlantic transition" period. In diagram Epe III a spectrum of similar composition is found at 40 cm, but below it spectra occur which indicate an older part of the same period and at the bottom even a "Boreal" spectrum. The lowest part of the Peel II and III diagrams is formed by "Atlantic" spectra, but in the Peel I and IV diagrams, corresponding spectra are underlain by still older spectra going back as far as the "Boreal" period. How can we explain, as before, that "Boreal" pollen was preserved at Epe III near the fen, but not at Epe II below the fen? In the latter profile soil was wettest during and after soil formation and moreover, it was cut off from the atmosphere by peat growth. Why are "Boreal" spectra absent from the fairly dry Peel II and III profiles but present in the Peel I and IV profiles, which are respectively the driest and wettest of the series? Apparently pollen destruction cannot be caused by direct chemical oxidation only, as in that case one might expect the older pollen to have been preserved in the Epe II instead of the Epe III profile and to be present in the Peel II and III profiles just like in the Peel I profile.

All these phenomena are a good indication that the pollen profiles were mainly formed before the podsolization phase of soil formation, viz. before downwash became the dominant process. During the preceding homogenization phase, there was an intense mixing of soil material from different depths, thus counteracting any differentiation of soil into an eluviation and illuviation horizon. As a result of this process the pollen in soil was also mixed, and pollen continually raining on the soil surface became thoroughly mixed (see below, p. 22).

Downwash can only have a considerable effect on the composition of a pollen profile after the homogeneous forest soil begins to degrade. During the period in which the illuviation horizon of the podsol forms but has not yet grown impermeable, some pollen may wash down as deep as this horizon. But it must be considered that pollen is not usually transported by this process over long distances. This is shown, for instance, by the diagrams of the series Staphorst and Epe (cf. p. 20). The presence of an impermeable B horizon cannot, of course, prevent pollen from infiltrating into the A horizon. Thus in many cases the spectra which arose in the upper part of this horizon were no doubt considerably affected in this way.

In the gley podsol profiles Appingedam and Delfzijl V and also the very wet podsol profile Delfzijl IV, the soil must have been very wet from a very early stage. Consequently biological activity in the soil must have soon ceased and soil mixing can only have lasted for a very short time. Apparently, the relative pollen profiles mainly developed as a result of downwash, the leached sand of the A_2 being easily percolated by the pollen.

e. *Pollen distribution as a result of homogenization*

In the preceding paragraph phenomena were discussed which would appear to indicate that homogenization was most important factor in the development of most pollen profiles.

A more direct argument in favour of this theory is that in the Delfzijl II, III, IV and Velzen II, III profiles a relationship was found to exist between the length of the pollen profile and depth above which the original stratification of the eolian cover sand entirely disappeared (cf. p. 9 and 10). A similar observation was made by DEWERS (1935) who investigated pollen in soils which developed in stratified dune sand.

The composition and depth of pollen profiles in soils subject to homogenization, and the manner in which they developed could well form the subject of a special study. In addition, research might be made into the changes to which those pollen profiles are subject when there is a change in the composition of the pollen rain or the soil degrades to a podsol.

Though such investigations could not be made, some insight was gained into the problems. This is based on the following considerations.

It is a well-known fact that earthworms are the most important factor involved in soil mixing (SCHEFFER and SCHACHTSCHABEL 1960). Moreover these creatures bring much organic matter from the litter into the soil. For example, HOEKSEMA et al. (1956, p. 117) once observed that a single earthworm (*Lumbricus* spec.) had drawn 160 birch leaves into the mouth of its burrow. At the same time, of course, much pollen which had previously rained on the soil was entrained with the leaves. Finally this pollen must have formed part of the excrementa, the content of the pollen grains being digested but not the pollen wall (DIMBLEBY 1957). Now earthworms plaster their burrows with their excrement and consequently pollen will be brought into the soil at every depth inside the space of the burrows. RAY (1959) has shown by experiment that earthworms quickly carry pollen through the soil.

In addition to earthworms there are many other animals, for instance various Arthropodes, which burrow the soil more or less deeply and may cause a similar effect.

As a consequence of sedimenting pollen being brought into the soil the pollen profile is continuously rejuvenated. Owing to the mixing process, however, it keeps a homogeneous composition throughout its depth at the same time.

It might be expected that this rejuvenation would not have a very great effect because the spectra are still partly composed of the older pollen brought into the soil during the older periods. When, for example, pollen found its way into a soil during the Atlantic, it was mixed up with the pollen store of Boreal date. Consequently one might expect the resultant mixed pollen spectra to have a composition like spectra of the Boreal-Atlantic transition period. In fact, however, there is often no trace of Boreal pollen flora in sand diagrams, even when the sand had already been cut off from the pollen rain by peat growth during the last phase of the Atlantic or the beginning of the Subboreal (cf. the diagrams Peel II, III, Noordoostpolder II, III).

Of course it should not be assumed that there was no supply of pollen to the soil during the Boreal. We are therefore obliged to assume that the older pollen disappeared as a result of corrosion.

It is a well-known fact that pollen corrosion is very common in sand soil. It is shown, for instance, by the poor state in which pollen in sand is usually preserved. It is also indicated by the fact that pollen frequency in sand under peat is independent of the period during which peat growth started (cf. for example the APF-data of the Epe and the Delfzijl series). The main problem, however, is by what causes and during which phase of soil formation pollen was mainly destroyed.

It was mentioned on p. 21 that the differences between the bottom spectra of the various diagrams of a few profile series exclude the possibility that corrosion was caused by direct chemical oxidation. This conclusion agrees very well with the results of pollen corrosion experiments conducted by KIRCHHEIMER (1935). This research worker found that pollen suspended in water was easily affected by microbes. In the absence of these organisms there was no corrosion.

Now a podsolized sand soil is relatively sterile (LOUB 1956, 1960). The amount of micro-organisms and the number of species may be as small as in a peat moor (LOUB 1956). On the other hand micro flora are abundant in a homogeneous forest soil. This means that pollen destruction in a soil now podsolized must have chiefly occurred during the homogenization phase of soil formation. The rejuvenation of the pollen profile was then greatly favoured by this process. During the following podsolization phase pollen not yet destroyed, was preserved to a certain extent. If we start from these fundamental ideas the following outline explanation may be given as to how pollen profiles of varying composition arise.

When a forest soil was in a well-homogenized state during a certain period of the Holocene, all spectra of the pollen diagram from this soil represented that period. During the following period the spectra all came into line with the new period provided there was no decrease in homogenization depth. If, however, this happened at the time, the pollen profile differentiated into two zones, the upper in which rejuvenation was in progress, the lower having the pollen spectra fixed (cf. Fig. 3). A continuous rise in the interface resulted in the fixed lower part „growing" proportionally, increasingly younger spectra being added on top of it. In the end, the pollen profile became fixed throughout its length. However, fixation was not absolute as the upper spectra could

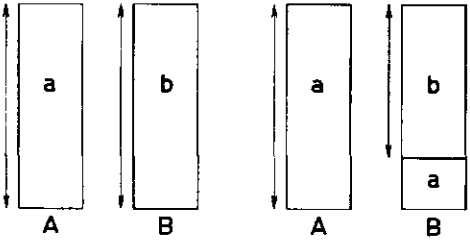


Fig. 3. Change of a pollen profile under the influence of homogenization

↕ Homogenization depth

a. Pollen composition representative of period A.

b. Pollen composition respresentative of period B.

On left: the homogenization depth is the same during period B as during the preceding period A.

On right: the homogenization depth is less during period B than during period A.

still be rejuvenated to a certain extent as a result of downwash of pollen.

When during the fixation of the pollen profile there was a repeated shift in the composition of the pollen rain, it became composed of many varying spectra. This was generally the case when fixation went on for several periods of the Holocene. These periods may be found in the various zones of the diagrams (e.g. Peel IV). In some cases, however, violent fluctuations of pollen curves are no indication that the pollen was deposited over a long period. This is shown, for instance, by the Velzen II and III diagrams (cf. p. 30).

From the diagram type with shifting pollen curves another type with parallel curves may be distinguished. The latter developed either as a result of a very rapid decrease in biological activity in the soil, or as a result of a very marked influence of local vegetation. This vegetation may have retained its composition during several periods of the Holocene (cf. the diagrams Noordoostpolder I, II, III).

Occasionally a relatively protracted "Boreal-Atlantic transition" zone is present (Staphorst I, Peel I). Most probably it is the result of an incomplete rejuvenation of the pollen profile over the relative depth during the Atlantic. Thus the spectra by no means indicate the transition period in question but are actually mixed spectra.

If this theory is applied to the interpretation of the diagrams there are no further serious difficulties. For instance, the different composition of the bottom spectra of Epe III compared with Epe II, and of Peel I and IV compared with Peel II and III (cf. p. 21) are easely explained by assuming differentation of pollen profile to have first begun at Epe III, and Peel I and IV (viz. during the Boreal). At the same time, however, it must be assumed that the different behaviour may occur even when soil conditions vary only slightly, as otherwise it could not have been found in the Peel series.

f. *Arbitrary over-representation*

Pollen of some plant species occasionally finds its way into sand soils as a result of "accidental" causes, so that its presence cannot be explained. In the present study this phenomenon is termed arbitrary over-representation. It is not restricted to sand soil, however, for sometimes it is also exhibited by peat diagrams having incidental high percentages for some plant species. For instance, the sharp peak of the curve for the herbs at 4 cm above sand surface level in diagram Delfzijl II is due to the presence of a single pollen species, which was not identified more accurately.

In one case, however, the cause of an arbitrary over-representation in sand is obvious, viz. at Staphorst II. In the dry podsol profile the marsh plant *Valeriana* is represented by a relatively large amount of pollen. Now this pollen is just found within the area at which the burrows of the digger-bee *Halictus* were found, so that we can be fairly certain that the pollen of this very good bee-plant (ZANDER 1937) was brought into the soil by the insect.

A digger-bee was also found at Uddelermeer III. It is a known fact that several species of the genus *Halictus* prefer *Compositae* with a yellowish flower. [1]) Perhaps the inexplicably high values for *Liguliflorae* (*Taraxacum* type) which are rather common in sand diagrams may partly be explained in this way.

Arbitrary over-representation of *Liguliflorae* (*Taraxacum* type) is found in the Uddelermeer, Epe, Peel H series and at Velzen II, III; of *Succisa* in the Peel H series, of *Salix* at Peel III and Velzen I, II. That the presence of *Liguliflorae* in sand diagrams may be caused by "accidental" factors, is clearly shown by the extremely high *Liguliflorae* percentages in the "Atlantic" zone of diagram Uddelermeer II. Only one *Liguliflorae* grain was found in samples of Atlantic date of the organic sediment in the nearby Uddelermeer lake among the several thousands of pollen grains counted by POLAK (1959). In the Subboreal zone of the sand diagram *Liguliflorae* are practically absent. In the organic sediment of corresponding age, however, no less than 14 pollen grains were found. In the Peel H series the "accidental" character is evident from the fact that high *Liguliflorae* percentages are present in a different diagram zone in Peel I than in Peel II, III and IV. An analysis of a second sample from the same depth proved that the high *Salix* percentage 9.5 cm below the sand surface in diagram Velzen I cannot reflect the real share of the tree in vegetation. In the new sample no *Salix* pollen was found at all.

It will be shown in chapter V, p. 32 that *Calluna* may also be subject to arbitrary over-representation. This may even be the case when high *Calluna* percentages are found over a fairly great depth (Velzen II, III).

Diagrams with incidental high values for these species are occasionally met with in the literature. For instance, high *Compositae, Succisa* and *Salix* percentages are mentioned in sand diagrams by JONAS (1938), high *Compositae* and *Valeriana* percentages in peat diagrams by BROUWER (1947) and WERTH and KLEMM (1936) respectively.

4. SELECTIVE CORROSION

Hitherto little attention has been paid to the selective corrosion of pollen. Admittedly several investigators (SMITH 1920, ERDTMAN 1921, 1931, RUDOLPH 1929, WASMUND 1931, LÜDI 1932, HESMER 1933, SCHUBERT 1933, PFAFFENBERG and HASSENKAMP 1934, FIRBAS, LOSERT and BROIHAN 1939,

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[1] Communication by Dr. J. B. M. VAN DINTHER, Laboratorium voor Entomologie, Wageningen.

SELLE 1940, LEMÉE 1946) came to the conclusion that selective corrosion may play a certain part, but their statements are usually not very well founded. The most important conclusions were that the pollen of *Tilia, Pinus* and *Corylus* was probably more highly resistant than that of other tree species. On analysing pollen content of peat in an area of *Populus* forests, ERDTMAN (1931 b) found that *Populus* pollen was easily destroyed. OBERDORFER (1937) and BORSE (1939) showed that *Carpinus* pollen vanishes very soon after its sedimentation.

It is usually assumed that selective corrosion of pollen has a greater effect in sand than in peat. However, some research workers (FLORSCHÜTZ 1941, KEIT and MOTHES 1943, TRAUTMANN 1952) don't share this opinion.

a. *The investigation of the Uddelermeer profiles*

Although in the diagram of the podsol profile Uddelermeer II, the same zones may be seen as in the diagram of the sub-aquatic organic sediment Uddelermeer I, some remarkable differences exist between the two diagrams. Thus *Alnus* is dominant in diagram II, the *Quercetum mixtum* mostly coming third, after *Corylus*. In diagram I, however, the *Quercetum mixtum* is dominant. This is a consequence of *Quercus* being very well represented. Another striking difference is that the *Calluna* percentages are slight in diagram I but high in the other.

It can be inferred from the dy diagram that the sand soil in the environment of the lake was covered with a fairly dense forest. This means that local tree growth must have greatly affected pollen rain at the site of the podsol profile analysed. On the dry sand soil *Quercus* may have grown fairly well and one cannot imagine that a forest mainly consisting of *Alnus* could have grown on it, as suggested by the diagram of the podsol profile. The only possible interpretation of this discrepancy is that since the beginning of the Atlantic period, pollen raining upon the sand soil was, in fact, mainly derived from *Quercus*, but that after its sedimentation the *Quercus* pollen was destroyed to a much larger extent than the pollen from the other tree species represented.

In order to ascertain whether one or more other pollen species might also have behaved otherwise in sand than in dy we may again compare the sand and dy spectra, after neutralizing the various effect of *Quercus* on the composition of the two kinds of spectra. In table III this is done by placing the *Quercus* percentage in each sand spectrum on a level with that in the dy spectrum with which the first is compared. At the same time the values for the remaining pollen species are deduced proportionally, so Σ AP keeps its value of 100%.

The table shows that when the sand and dy spectra are compared they resemble each other fairly well. Yet some obvious differences may be observed which must have a systematic cause.

Unlike the dy diagram, *Fraxinus* is entirely absent and *Salix* almost entirely absent from the sand diagram. The absence of *Fraxinus* pollen in the sand is probably due to the fact that this pollen is very susceptible to corrosion. Even in peat it is hardly preserved. The absence of *Salix* pollen is explained in a quite different way; it must be related to the fact that *Salix* is pollinated by insects, so that its pollen is not broadcast in great masses. The incidental high percentages for the tree in some sand diagrams are a good indication that the pollen can be well preserved in a sand soil. The occurrence of *Salix*

TABLE III. Comparison of the deduced sand spectra of diagram Uddelermeer II with the dy spectra of diagram Uddelermeer I. In each case the *Quercus* percentage in the sand spectrum is equated to that in the dy spectrum

Depth in cm	Spectrum	Percentages															
		Abies	Alnus	Betula	Carpinus	Corylus	Fagus	Picea	Pinus	Salix	Acer	Fraxinus	Quercus	Tilia	Ulmus	Quercetum mixtum	Ericaceae
1	sand	–	58	1	1	6	1	–	3	–	–	–	27	2	1	30	300
190	dy	–	35	11	1	14	4	–	2	2	–	3	27	–	1	31	30
9	sand	–	36	13	+	12	–	–	3	+	–	–	30	5	1	36	145
205	dy	–	35	11	+	13	4	–	3	1	–	2	30	+	1	33	20
19	sand	–	35	10	1	17	–	–	3	–	–	–	25	8	1	34	134
225	dy	–	38	8	+	14	6	–	4	1	+	2	25	1	1	29	20
29	sand	–	30	11	–	20	1	1	3	–	+	–	28	5	1	34	240
275	dy	–	30	10	–	22	+	–	5	1	+	2	28	1	+	31	5
39	sand	–	25	9	–	17	–	–	7	–	–	–	33	8	1	42	128
305	dy	–	27	12	–	20	–	–	4	+	+	2	33	1	+	36	5
49	sand	–	23	7	–	8	–	–	14	–	–	–	36	11	1	48	124
355	dy	–	29	11	–	18	–	–	3	+	–	2	36	1	+	39	5
56	sand	–	20	12	–	15	–	1	13	–	–	–	32	6	1	39	67
395	dy	–	28	11	–	18	–	–	5	1	–	1	32	2	2	37	5
63	sand	1	23	16	–	16	–	3	13	–	–	–	26	1	1	28	40
445	dy	–	27	12	–	20	–	–	7	1	–	2	26	2	3	33	2
70	sand	–	19	9	–	14	–	3	37	–	–	–	10	2	6	18	63
465	dy	–	5	12	–	20	–	–	40	1	–	–	10	–	2	12	2

in the dy diagram is readily understood when it is considered that the tree must have grown on the actual shore of the lake.

Compared with the dy diagram *Tilia* shows a distinct but not great over-representation in the sand diagram. A local occurrence of this tree, as well as relatively great resistance to pollen corrosion may be the cause. The relatively high percentages for *Pinus* at 49, 56 and 63 cm and for *Alnus* at 70 cm in diagram II indicate the presence of mixed spectra at these depths (cf. p. 24). The over-representation of *Alnus* at 1 cm is not readily interpreted. The fairly great under-representation of *Fagus* in the same diagram possibly originates from selective corrosion of the relative pollen.

Starting from the principle of selective corrosion of *Quercus* pollen, the relatively high *Calluna* percentages in the sand diagram may be partly interpreted. The destruction of most of the *Quercus* pollen caused a great recession of Σ AP. Consequently the relative share of Σ NAP must have increased considerably, and with it the percentage of *Calluna*. That this cannot be the only cause, however, can be seen from the fact that the deduced sand spectra still have higher *Ericaceae* percentages than the dy spectra. The latter phenomenon has no doubt been caused by local influence of the *Calluna* undergrowth in the oak forest. It can be estimated what would have been the *Ericaceae* percentages if the oak forest spectra had not been influenced by selective corrosion. To this end we have best deduced these spectra in such a way that the *Quercus* percentage is 80. This value is in good agreement with the average for the tree in surface samples from oak forests, as calculated from data by JONASSEN (1950, p. 21, 31). The deduced spectra (at depths of 9 and 29 cm) reproduced in table IV show percentages for Σ NAP and *Ericaceae* no longer too great for pollen spectra reflecting a forest (cf. p. 31).

TABLE IV. Two deduced sand spectra of diagram Uddelermeer II in which the *Quercus* percentage is equated to 80

Spectrum	Percentages													
	Alnus	Betula	Carpinus	Corylus	Fagus	Picea	Pinus	Salix	Quercus	Tilia	Ulmus	Quercetum mixtum	Σ NAP	Ericaceae
9 cm	11	2	+	4	–	–	1	+	80	2	+	82	45	40
29 cm	8	3	–	5	+	+	1	–	80	2	+	82	73	70

The Noordoostpolder diagrams show that sand spectra with more than 70% *Quercus* may, in fact, occur. In the fairly wet soil which probably podsolized fairly rapidly, conditions for preservation of the delicate *Quercus* pollen were much better than in the dry soil near the Uddelermeer. A great deal of *Quercus* pollen has also been found in the fairly wet podsol profile Delfzijl I.

b. *Oxidation experiments*

It has not yet been ascertained exactly how pollen corrosion occurs. KIRCHHEIMER (1935) proved by experiments that the pollen wall is corroded rapidly by microbes. Pollen in aquatic suspension without microbes is not affected at all. It was proved by ZETSCHE (in KIRCHHEIMER 1935) in a similar way that *Lycopodium* spores are more resistant than *Corylus* pollen.

According to DIMBLEBY (1957) pollen grains in the excrementa of earthworms and honey-bees have an unchanged exine. This author stated that pollen is destroyed rapidly in soils with a pH > 5.

In order to obtain some idea as to whether various pollen species may show differences as to the durability of the exine, chemical oxidation tests were performed with mixed suspensions of *Alnus, Quercus* and *Tilia* pollen (cf. table V).

The table shows that pollen is strongly oxidized by potassium permanga-

Table V. Oxidation of pollen of *Alnus* (*A*), *Quercus* (*Q*) and *Tilia* (*T*) by potassium permanganate

	Mutual ratios of the quantities of pollen grains before and after oxidation	Numbers of pollen grains counted	Visual evaluation of corrosion
	A : Q : T		
before oxidation	29: 51: 20	500	no corrosion
after oxidation by			
0,01 n $KMnO_4$, pH 5,6	2: ½:97½	500	very marked corrosion
	4: 0: 96	500	very marked corrosion
0,02 n $KMnO_4$, pH 5,6	1: ½:98½	500	very marked corrosion
	½: 0:99½	500	very marked corrosion
0,05 n $KMnO_4$, pH 5,6	0: 0:100	7	extremely marked corrosion
	0: 0:100	100	extremely marked corrosion
0,04 n $KMnO_4$, pH 1	17: 6: 77	200	very marked corrosion
	3: 2: 95	200	very marked corrosion
0,04 n $KMnO_4$, pH 13	14:55½:30½	200	fairly slight corrosion
	19: 58: 23	200	fairly slight corrosion

nate at pH 5.6 even if it has a concentration of only 0.01 n. Oxidation is also very strong in a highly acidic milieu (pH 1), but at a very high pH (13), pollen is not greatly affected.

In an acid milieu, in the sequence *Tilia, Alnus, Quercus,* pollen is more susceptible to oxidation. The resistance of *Tilia* pollen greatly exceeds that of the two other pollen species. At pH 13, however, the *Alnus* pollen is least resistant. It should be borne in mind that the latter conclusion is based on two experiments only.

The results of the experiments in an acid milieu are in agreement with the conclusions of the Uddelermeer investigation; at any rate, it cannot be said that there are any contradictory results.

CHAPTER V

RELATION BETWEEN SAND SPECTRUM AND VEGETATION

It is fairly obvious that pollen spectra in a sub-aquatic sand deposit must be interpreted in the same way as dy spectra. They are not discussed below.

Sand spectra of a non-sub-aquatic type, however, must be interpreted rather like the spectra of surface samples taken in a forest or in the open. This follows from the fact that the pollen analysed is in both cases derived from a soil which formed the location for the vegetation.

1. LOCAL INFLUENCE

According to JONASSEN (1950) a surface spectrum from a forest reflects its composition within a circle having a radius of only a few hundred metres. Similar statements have been made by BORSE (1939) and SCAMONI (1950).

Several diagrams of the profiles investigated, show that sand spectra were also greatly influenced by local vegetation. Thus the Noordoostpolder and Peel H diagrams show much higher percentages for *Quercus* and *Tilia* respectively than would be the case if regional tree growth had been reflected only. In the diagrams Velzen II and III the aberrant zoning must indicate local tree growth. Spectra occur with *Alnus dominance* below peat spectra representing the Boreal-Atlantic transition period, and above the lowest of the two crossings of the *Alnus* and *Pinus* curves. These spectra can only have arisen from local growth of *Alnus* during the end of the pinerich Boreal. This vegetation then developed in consequence of a rising ground water table preceding the peat growth.

In many cases local influence can only be seen after two or more diagrams of a series have been compared. For instance, the diagrams of the podsol profiles II, III, IV of the Delfzijl series are preponderantly composed of spectra with much *Pinus*. They have an appearance of normal Boreal spectra not differing from Boreal peat spectra. In the diagram of the gley podsol profile V of this series, however, spectra are present in which *Alnus* dominates. This aspect resembles normal Atlantic spectra. Nevertheless, the various diagrams must al reflect the same – Boreal (cf. p. 35) – period, as the respective profiles were covered by peat at the same time. Evidently the different pollen floras only indicate variations in local vegetation; in fact these could even be expected to judge from the varying soil profiles.

The varying behaviour of *Corylus* in the sand diagrams of the Velzen series is possibly also connected with soil conditions. Very high percentages for this shrub are found in diagrams II and III of the fairly dry profiles and only low ones in diagrams I and IV of the wet gley profiles.

Diagram Velzen IV differs noticeably from the other Velzen diagrams owing to the quite different trend of the *Alnus* and *Pinus* curves. This must be attributed, however, to a direct influence of soil conditions on the descent of pollen in various Holocene periods (cf. chapter VI, 2).

When a certain tree species is represented incidentally with a high percentage in a sand diagram, there is a good chance of arbitrary over-representation. This has been proved for *Salix* in diagram Velzen I (cf. p. 25). In such a case all the other tree species represented have proportionately receded percentages in the spectra in question.[1]) Occasionally only a few of the other species show a transitory decrease, in which case we must conclude that there was a temporary change in local tree growth. A good example of this is found in diagrams Delfzijl III and IV. The *Tilia* and *Betula* curves in these diagrams show a peak at different depths, whereas the *Betula* and/or *Pinus* curves recede at the same time. The *Alnus* and *Corylus* curves show no response. Apparently, the first was unable to do so because the pollen of

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[1] In the spectra with incidentally high *Salix* values of the Velzen I, II and Peel III diagrams, the trend of the curves for the other tree species is not affected because *Salix* is kept out of Σ AP

Alnus originated from regional forest vegetation only, this tree forming no part of the *Pinus* forest at the site of the podsol profiles analysed.

Apart from the AP section, the various diagrams of a series may also show differences in the NAP section, indicating a varying composition of local vegetation. Thus the high *Filicinae* percentages in diagrams Delfzijl II, III and IV reflect a dense and fairly extensive undergrowth of ferns in a fir forest (cf. p. 33), whereas diagram Delfzijl V shows that the ferns were practically absent under the alders on the very wet gley podsol soil. The *Ericaceae* are represented in most spectra of the podsol diagrams, albeit with very low values; in the gley podsol diagram they are almost entirely absent. In the Velzen series the *Ericaceae,* herbs and *Filicinae* are represented with high or fairly high percentages in the podsol profile diagrams, whereas very low percentages are found in the gley profile diagrams I and IV.

2. THE SIGNIFICATION OF A HIGH Σ NAP: Σ AP RATIO

Several research workers have ascertained the degree to which the Σ NAP: Σ AP ratio of a spectrum of a surface sample may increase before it will reflect an open vegetation and consequently regional tree growth. According to JONASSEN (1950, p. 50) Σ NAP is usually less than 50% in surface spectra from a forest. The percentage will only be somewhat higher in the most open form of birch or fir forest. (FIRBAS 1934, p. 137) stated that the quantity of non-arboreal pollen is usually less than the quantity of arboreal pollen in a forest. In fir forests with much undergrowth of *Ericaceae,* one may find as much as 100% pollen from the shrub calculated at the amount of tree pollen. Occasionally, this value may even be considerably exceeded (FIRBAS 1937). AARIO (1944), who analysed surface samples at the tree line near and in the arctic and alpine area, obtained data similar to that of JONASSEN and FIRBAS. When in the first case Σ NAP approached 100%, the spectrum already represented the tundra.

Like spectra from surface samples with a low Σ NAP: Σ AP ratio, this type of sand spectra will reflect local forest vegetation. As regards sand spectra with a high ratio, however, there are several possibilities, and it may often be a rather complicated matter or even impossible to discover whether an open vegetation is reflected or not.

In some cases it is very evident that the pollen cannot have originated from such a vegetation, viz. when the high Σ NAP values result from a marked arbitrary over-representation of *Liguliflorae* or *Succisa.*

It is not so easy to interprete high *Calluna* percentages. Frequently they arose as a result of selective destruction of *Quercus* pollen. This possibility must always be taken into account when analysing pollen from soil profiles which developed under fairly dry conditions. On such profiles, there may quite easily have existed an oak forest with an undergrowth of *Calluna.* Moreover, dry soil conditions favour the corrosion of *Quercus* pollen.

In this way we may (partly) interprete the high *Ericaceae* percentages in the diagrams Uddelermeer II (already discussed before), Staphorst I, II, Epe I, II, III and Peel I, II, III. A combination of high *Ericaceae* percentages and low *Quercus* percentages is also found in the diagram of the fairly wet podsol profile Peel IV. In the wet podsol profiles Delfzijl I and Noordoostpolder I, II, III which have also been present under an oak forest (with and without

Calluna undergrowth respectively), the pollen composition is not affected by selective corrosion as is shown by the *Quercus* percentages. The interpretation of the high *Ericaceae* percentages in the Peel diagrams is borne out by the fact that no such high percentages are present in the spectra with much *Tilia*. Unlike the *Quercus* pollen, the pollen of *Tilia* was not subject to severe corrosion.

Obviously one should take into account the effect of selective corrosion of *Quercus* pollen only, when evaluating post-Boreal spectra. *Quercus* was not well represented in the flora before the Atlantic.

High *Ericaceae (Calluna)* values may also (partly) result from arbitrary over-representation. In some cases it is shown by the presence of numerous lumps of *Calluna* pollen in the microscopic preparation (Delfzijl I at 13 cm). In the Velzen series it is essential to assume this, when explaining the phenomenon that in diagram Velzen II high *Ericaceae* percentages are present below the lowest *Pinus-Alnus* intersection but in diagram Velzen III on a level with that intersection and above. It would be absurd to suppose that heather extended to the surroundings of profile Velzen III after a local *Alnus* vegetation had spread there. This is the more unlikely because an inverse development of heath vegetation might be read from diagram Velzen II. The very irregular fluctuations of the *Ericaceae* curves in the diagrams Staphorst I, II, Epe II and Peel I, III probably (partly) result from the same factor.

It is likely that high *Calluna* percentages often arose from a combination of the two factors of selective corrosion of *Quercus* pollen and arbitrary over-representation.

Ericaceae curves may probably also show fluctuations, which are partly due to changes in vegetation. Thus a temporary decline of the oak forest may have considerably promoted the growth or the flowering of *Calluna*.

When high *Ericaceae* percentages occur over a long distance in a sand diagram, the possibility should still not be overlooked that an open heath vegetation may actually have been present. The latter is always the case when the pollen dates from the recent period, when heath moors had extended enormously. A good example of this is found in the drift sand part of diagram Epe III, in which *Secale* is already represented.

3. POST-BOREAL SPECTRA WITH HIGH ERICACEAE PERCENTAGES

In accordance with the above it may be maintained that post-Boreal sand spectra with high *Ericaceae* percentages (> 100%) usually reflect regional tree growth. It does not matter how those values arose, viz. either owing to an open heath vegetation in the neighbourhood of the profiles investigated or in consequence of selective corrosion of the *Quercus* pollen from local oak forest.

Sand spectra with high Σ NAP values no doubt give a poorer reflection of regional tree growth than peat spectra, since their pollen must also have been subject to selective corrosion.

The regional nature of the AP section of post-Boreal sand spectra with high *Calluna* percentages, is in most cases easily recognized from the behaviour of *Alnus*. As a rule this tree is represented by very high percentages in these spectra, as in post-Boreal peat spectra of a regional type. If arbitrary over-representation were the only reason for the high *Calluna* percentages, the sand spectra would show a great influence of local tree growth and consequently *Quercus* dominating in the AP-section instead of *Alnus*.

On a dry soil, a great amount of *Calluna* pollen and much *Alnus* pollen from local alder growth could only have been deposited near the fringe of an alder forest on wet soil. The relative amount of *Alnus* pollen that finds its way into the first-mentioned soil may also have increased considerably when the water table rose, as in this case *Alnus* may have spread on it as well. This would explain the high *Alnus* percentages in the sand spectra with very high proportion of *Ericaceae* in the diagrams of the fairly dry podsol profiles Velzen II and III, which are of Boreal age. However, it is only by way of exception that this kind of interpretation should be employed.

4. BOREAL SAND SPECTRA WITH HIGH Σ NAP PERCENTAGES

Sand spectra from the Boreal period which are greatly influenced by local forest vegetation usually have the same composition as spectra reflecting a regional vegetation of that period, since both kinds of spectra may show high values for *Pinus, Corylus* and *Betula*. As a result the AP section of Boreal sand spectra with a high Σ NAP: Σ AP ratio does not indicate whether or not they are influenced by local tree growth. To ascertain this it is best to analyse more than one profile in a small area. If it is then found that the tree pollen composition varies from place to place, it may be concluded that the soil was covered with forest. Thus the high Σ NAP values could not denote an open vegetation, but probably result from arbitrary over-representation. Below it will be shown that higt Σ NAP values may also arise in case of fern undergrowth in a forest, the ferns producing enormous quantities of spores.

Boreal sand spectra with high Σ NAP values occur in the diagrams Velzen II and III, below the lowest *Pinus-Alnus* intersection. Their tree pollen composition corresponds to that of Boreal spectra reflecting regional vegetation. However, the differences between the *Pinus-Corylus* ratios in the twc diagrams show that local growth of shrubs and trees is reflected. In the part of the two diagrams between the two *Pinus-Alnus* intersections, the influence of local growth of alder is revealed by high *Alnus* percentages, as a result of which the spectra even lose their Boreal aspect. In fact, in this case the NAP sections of the diagrams also show that the high Σ NAP values could not denote an open vegetation, the latter being mainly caused by *Liguliflorae* and *Ericaceae* in over-representation (cf. p. 25 and 32).

In the Delfzijl series in the diagrams II, III and IV a high Σ NAP: Σ AP ratio is present as a consequence of *Filicinae* being very well represented. The differences between the AP sections of these diagrams, though fairly slight, must be due to variations in the composition of a local fir forest.

Here a more direct indication of the existence of a fir forest on the site of the profiles analysed was found in the presence of vegetable remains.

The question now arises as to whether high *Filicinae* percentages result from arbitrary over-representation or from a great production of spores of an undergrowth of ferns. Spectra from surface samples with high *Filicinae* percentages are seldom referred to in the literature. Thus FIRBAS (1934, p. 133) says he found 200% *Filicinae* and 20% *Ericaceae* pollen in an open birch forest with *Aspidium dilatatum* and *Myrtillus*.

In order to gain a better insight into the significance of high *Filicinae* percentages, some surface samples were analysed from forests with a luxurious undergrowth of ferns and from a treeless vegetation partly composed of ferns, near the North Sea coast (cf. table VI).

TABLE VI. Surface spectra of various vegetations of which ferns form part

Vegetation	No.	Percentages														ΣAP
		Alnus	Betula	Carpinus	Corylus	Pinus	Salix	Fraxinus	Quercus	ΣNAP	Ericaceae	Cyp. + Gram.	Kruiden	Filicinae		
oak and birch forest with *Dryopteris austriaca*	1	1	94	–	2	1	–	–	2	115	–	5	3	107		150
	2	6	30	1	1	1	–	–	61	176	–	10	6	160		150
oak forest with *Polypodium vulgare*	3	5	8	–	1	13	–	1	72	52	1	15	4	32		150
fir and birch forest with *Pteridium aquilinum*	4	1	42	1	1	49	–	–	6	39	2	9	8	20		150
open vegetation of *Polypodium vulgare*, *Calluna vulgaris*, grasses	5	12	17	–	4	38	4	–	25	3380	80	700	100	2500		25
	6	11	20	–	5	36	–	–	28	3530	1480	600	100	1350		25

It can be seen from the table that both the fern and tree species have a great influence on the *Filicinae* percentages in the forest spectra. The two values for *Filicinae* 107% and 160% are derived from two different parts of a dense oak-birch forest in which mainly birch and oak are found. According to POHL (1937) *Quercus* produces less pollen than *Betula*.

These two high values are evidence that high *Filicinae* percentages need not reflect an open vegetation composed of ferns. It may be assumed that in a somewhat less dense forest than that investigated, even greater relative quantities of spores may be found. If, for example, the relative amount was only doubled it would already agree with the *Filicinae* percentages in the diagrams Delfzijl III and IV.

But this does not explain the extremely high *Filicinae* percentages in diagram Delfzijl II. A percentage which surpasses 1000 is only reached under the extreme conditions near the treeless sea coast. Apparently this means that we must partly attribute the enormous percentages to arbitrary over-representation (however, cf. also p. 17).

It might also be thought that selective corrosion of tree pollen is an important factor explaining the high Filicinae percentages. Of course *Quercus* pollen is not to be considered in the case of Boreal spectra, but *Populus* might be a possibility. However, no good indication for this assumption was given by the wood remains found, only one piece of this tree being encountered.

5. MIXED SPECTRA

It was assumed in the foregoing that each spectrum of a sand diagram corresponds to a certain stage in vegetation development. In chapter IV, p. 24 it was shown, however, that pollen of two successive vegetations may be represented together by a mixed spectrum. It is impossible to tell from the composition of spectra between two diagram zones, whether they are to be taken as mixed spectra or as a representation of a vegetation of a transition period. More certainty can probably be obtained about this when the diagram of a soil profile is compared with a diagram of a nearby organic sediment.

CHAPTER VI

THE SIGNIFICANCE OF SAND SPECTRA WITH REGARD TO DATING POSSIBILITIES

1. DATING OF SAND LAYERS

Pollen spectra can only be used for dating sand layers, when it can be assumed that the pollen and sand were deposited together. This is the case with most of the spectra of the Peel L diagrams in which many algae are present, showing that the material was deposited under water.

Holocene drift-sand may also contain pollen by which its age can be determined. This is particularly true of drift sand layers which were never within reach of soil-forming processes. Although a great or even preponderant part of the pollen in such sand was secondarily transported, from a blown-out soil elsewhere, this cannot be a serious objection. It was shown in chapter IV, p. 19 that this secondary pollen usually indicates a relatively late age as its composition is hardly influenced by older pollen derived from greater depths of the blown-out soil.

It should be remembered, however, that dating may be endangered when the drift sand spectra are greatly influenced by local vegetation, either on the site of the blown-out soil or in the vicinity of the profile investigated.

If the pollen penetrated after deposition of the sand, as is common with pollen in cover sand soils, the spectra only give an idea of the age of the pollen; not of the sand layers containing it.

Owing to its local nature, it may be difficult or impossible to place a sand spectrum in a certain period of the Holocene. In this respect, sand spectra are similar to spectra of surface samples which in many cases are also unrepresentative of regional tree growth. For instance, a pollen spectrum obtained from a surface sample in a fir forest was found to have almost the same composition as "Boreal" sand spectra in the Flevoland III and Delfzijl IV diagrams (cf. table VII). These sand spectra were found below peat layers of Atlantic date.

When the above is taken into account it is easy to understand why the diagrams of the different profile types of the Delfzijl, pit B series appear to indicate different Holocene periods. Either the "Boreal" zone in the podsol profiles II, III, IV reflects a local fir forest during the Atlantic, or the "Atlantic" zone in the gley podsol profile V reflects a local alder forest during the Boreal. The later theory is obviously the more likely one. Even during the Boreal fir cannot have grown on the very wet gley podsol profile. The alder, which already formed part of the flora at the time, found a good site there.

TABLE VII. Comparison of a recent surface spectrum of a fir forest with two "Boreal" sand spectra

Spectrum	Percentages						
	Alnus	Betula	Carpinus	Corylus	Fagus	Pinus	Quercetum mixtum
surface spectrum	3	7	0	1	0	83	6
Flevoland III, 30 cm	0	8	0	2	0	90	0
Delfzijl IV, 10,5 cm	4	11	0	4	0	77	4

If we have only one sand diagram, it may sometimes be rather difficult to determine whether or not the trend of tree curves shows local influence. An example for this is found in the Appingedam diagram. If zoning is applied to this diagram in the usual way an Atlantic date will be attributed to the sand spectra showing a high proportion of *Alnus*. For a correct interpretation, however, attention should be paid to the fact that the pollen concerned is derived from a very wet gley podsol profile. This means that local alder growth most probably gave rise to the high *Alnus* percentages. If we start from this point of view the composition of the spectra becomes clearer as regards the other tree species. The dominance of *Pinus* over *Quercetum mixtum* can then be interpreted as indicating the Boreal period. It is, in fact, very unlikely that during the Atlantic *Pinus* was more frequent than *Quercus* and *Tilia* in the vicinity of the profile.

Occasionally one spectrum or part of the spectra of a sand diagram are so influenced by local forest that their composition seemingly contrasts with their real age. This is shown by the two "Boreal" sandspectra with high values for *Quercetum mixtum* in the Delfzijl III and IV diagrams and by the aberrant composition of the upper part of the Velzen II and III diagrams (cf. p. 30).

It is conceivable that only one pollen diagram is available of a sand soil in which the composition of the successive spectra does not differ from that in a normal (peat) diagram reflecting regional tree growth. In such a case one has to rely on the Σ NAP: Σ AP ratio in order to judge whether or not the tree pollen curves were influenced by local vegetation. It was explained in chapter V what possibilities or difficulties are afforded by the use of this ratio.

2. DATING OF THE COMMENCEMENT OF PEAT GROWTH

In order to determine the period at which peat growth started dates are commonly used which may be read from the uppermost sand spectrum and the lowermost peat spectrum in a diagram. It will be shown below that this method may be a source of error if pedological aspects are not taken into consideration at the same time. Hitherto palynologists have paid no attention to this question.

During a certain period preceding the beginning of peat growth it will depend on hydrological soil condition, whether or not sedimenting pollen is able to penetrate into the soil. Its chance of doing so decreases with increasing soil wetness. This is apparently the reason why pollen diagrams of different soil profiles under the same layer of peat occasionally have their upper side closed by spectra indicating different Holocene periods. A clear example of this is seen in the Flevoland series. In the diagrams of the very poorly drained podsol profiles I and III, Boreal spectra with *Pinus* dominance are found near the underside of the section representing the Atlantic peat. It is only in profile II, where drainage was better, that *Alnus* pollen was able to penetrate into the sand after completion of the sedimentation and infiltration of pollen mainly derived from *Pinus*. The sand part of this diagram shows an "Atlantic" zone 7 cm long above the "Boreal" zone. It is possible, however, that the "Atlantic" zone partly developed as a result of superficial sedimentation of sand by running water (cf. p. 10) simultaneously with sedimentation of pollen.

When the position of the sand surface is traced by reference to the guide level formed by the fir stumps on the peat it can only be concluded that incipient peat growth first occurred in profile I and last in profile III. The latter profile is situated about 46 cm nearer guide level than profile I. This means that it was not covered by peat until the 46 cm thick layer at Flevoland I had been formed during the Atlantic. During this entire period a carr forest must have existed on the very wet soil and no pollen was able to infiltrate. If, however, the diagram is interpreted in the usual way it is unjustly concluded that in Flevoland III peat growth started as early as the Boreal-Atlantic transition period.

A similar explanation may be given as to why, unlike the other profiles of the Velzen series, sand spectra with a high proportion of *Alnus,* dating from the later part of the Boreal, are lacking in profile Velzen IV. If we note the peculiar situation of profile IV, viz. in a little gully with impermeable layers at some depth, it will be clear that at this site the soil must have been extremely wet from a fairly early date, thus preventing infiltration of *Alnus* pollen. However, we are not sure that in the very thin top layer of the profile now missing, younger spectra have also been absent.

It may be difficult to determine the date of incipient peat growth if the peat spectra directly above the sand surface have been influenced by local tree growth on the sand soil. This may have occurred when trees did not die immediately after incipience of the peat growth. The phenomenon is clearly demonstrated in diagram Velzen II by the "Atlantic" peat spectrum 1 cm below the spectra at 2 and 3 cm representing the Boreal-Atlantic transition period. If, for instance, the peat had been analysed at intervals of 5 cm or more above the spectrum at 1 cm (cf. DOPPERT 1957), it is certain that only peat spectra of "Atlantic composition" would have been found and the conclusion made that peat growth did not start before the Atlantic.

CHAPTER VII

THE DEVELOPMENT OF VEGETATION IN THE VARIOUS PROFILES

The question as to during which phase of soil formation a certain vegetation occurred, has been answered by assuming that pollen cannot penetrate into an illuviation horizon which develops, after it has become fairly compact. Thus a pollen spectrum in or below the B_2 horizon of a given podsol profile will reflect a vegetation of a period at which soil was still in a well homogenized state (cf. p. 9) or only weakly podsolized. As regards a spectrum in the A horizon two possibilities exist. The relating vegetation may already have been present during the homogenization phase but also subsequently, when the podsol profile was already formed.

Our knowledge of the development of vegetation obtained by pollen analysis of sand soil is obviously rather inaccurate. A serious drawback is the fact that little or no pollen has been preserved of several plant species.

Table VIII gives a summary of the vegetations occurring in the investigated profiles during the successive phases of soil formation.

Some of the data provided by the pollen diagrams will be considered more closely.

The perpetual problem as to whether high *Corylus* percentages in Boreal spectra may reflect forest mainly composed of *Corylus* (FIRBAS 1949, p. 150) is answered in the affirmative by the Velzen II and III diagrams. Its *Corylus* percentages are very much higher than those in two surface spectra obtained by us from an oak forest with an extremely dense undergrowth of hazel. On the other hand they are very similar to the *Corylus* percentage of a surface spectrum of a vegetation of hazel with some oaks (JONASSEN 1950, p. 26). (Cf. table IX.)

In the earlier part of the Atlantic a linden forest occurred in the surroundings of the Peel H profile sand a forest partly composed of linden in the surroundings of profile Delfzijl I. Near profiles Delfzijl III and IV this tree was occasionally frequent as early as the Boreal. The loamy nature of the sand soil in the immediate vicinity of all these profiles probably favoured growth of linden (KÖIE 1951, IVERSEN 1958, JANSSEN 1960).

It is concluded from the diagrams of the dry podsol profiles which were not covered with peat or drift sand until after the Boreal or not covered at all, that the forest was generally composed of *Quercus* since the Atlantic. The proportion of *Betula* must have been a very minor one. This contradicts TÜXEN'S (1937) theory according to which the dry sand soils were originally overgrown by the *Querceto-Betuletum*. The pollen analytical data do not, however, permit of a conclusion which is more in line with this theory. If the spectra are so inferred that the *Quercus* values are 80% (cf. p. 28), then the *Alnus* values still average 10%. This is fairly high for a tree species which cannot have formed part of the plant communities on dry soils. Hence the admitted value for *Quercus* cannot be too high. The *Betula* percentages in the spectra inferred are, however, even less than 10%.

It can only be concluded from the composition of the herb pollen that the herbs represented formed some part of the vegetation in the vicinity of the profiles investigated. For instance, the pollen of *Potamogeton* and of *Typha*

TABLE VIII. Vegetation and soil formation in the profiles investigated during various Holocene periods

Period	Vegetation	Soil formation	District of occurrence
Preboreal	birch forest	homogeneous forest profile	Epe III
	fir and birch forest	homogeneous forest profile	Peel IV
Boreal	birch forest	homogeneous forest profile	Epe III
	birch and fir forest	wet podsol profile	Peel V
	birch and fir forest	homogeneous forest profile	Peel I
	fir forest	homogeneous forest profile	Peel IV
	fir forest	homogeneous forest profile	Uddelermeer II
	fir forest	homogeneous forest profile	Delfzijl I
	fir forest	intergrade between podsol and humous gley profile	Velzen IV
	fir forest	homogeneous forest profile, occasionally followed[1] by humous gley profile	Velzen I
	fir forest, fairly dense undergrowth of ferns	wet podsol profile, occasionally preceded[1] by homogeneous forest profile	Flevoland I, II, III
	fir and birch forest, dense fern cover	homogeneous forest profile, followed by fairly dry or fairly moist podsol profile	Delfzijl II, III
	fir forest, dense fern cover	wet podsol profile, occasionally preceded by homogeneous forest profile	Delfzijl IV
	open forest of hazel mixed with fir, dense cover heather, ferns, grasses and herbs	homogeneous forest profile, followed by fairly dry podsol profil	Velzen II, III
	alder forest	practically submerged, fairly dry podsol profile	Velzen II, III
	alder forest	humous gley profile	Velzen I
	alder forest	gley podsol profile	Delfzijl V
	alder forest	gley podsol profile	Appingedam
Atlantic	birch forest	fairly moist podsol profile, finally practically submerged	Delfzijl III
	birch forest	practically submerged wet podsol profile	Flevoland III
	alder forest	practically submerged wet podsol profile	Flevoland I, II
	linden-oak-birch forest	homogeneous forest profile, followed by fairly wet podsol profile	Delfzijl I
	linden forest (in the earlier Atlantic)	homogeneous forest profile	Peel I, II, III, IV
	oak forest (in the later Atlantic)	homogeneous forest profile, occasionally followed by dry podsol profile	Peel I, II, III

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[1] During the same Holocene period.

TABLE VIII. (continued)

Period	Vegetation	Soil formation	District of occurrence
Atlantic	oak forest (in the later Atlantic)	homogeneous forest profile, occasionally followed by fairly wet podsol profile	Peel IV
	oak forest	homogeneous forest profile	Uddelermeer II
	oak forest	homogeneous forest profile, followed by fairly dry or dry podsol profile	Epe II, III
	oak forest	homogeneous forest profile, occasionally followed by wet podsol profile	Noordoostpolder I, II, III
	very open oak forest, dense heather cover	homogeneous forest profile, followed by dry podsol profile	Staphorst I, II
Fagus-Carpinus period (Sub-boreal)	oak forest	homogeneous forest profile, occasionally followed by dry podsol profile	Uddelermeer II
	oak forest with/or heather cover	dry podsol profile	Epe III
	oak forest	dry podsol profile, occasionally preceded by homogeneous forest profile	Peel I, II, III
	oak forest	fairly wet podsol profile, occasionally preceded by homogeneous forest profile	Peel IV
	oak forest	wet podsol profile, occasionally preceded by homogeneous forest profile	Noordoostpolder I, II, III
(Sub-atlantic)	oak forest	dry podsol profile, occasionally preceded by homogeneous forest profile	Uddelermeer II
Historic time	heath moor	dry podsol profile	Uddelermeer III
	heath moor	dry podsol profile	Epe III

TABLE IX. Surface spectra of vegetations containing *Corylus*

No.	Vegetation	Percentages										
		Alnus	Betula	Carpinus	Corylus	Fagus	Pinus	Fraxinus	Quercus	Ulmus	Σ NAP	ΣAP
1.	oak forest with dense hazel undergrowth	1	11	0	14	1	9	0	64	0	85	100
2.	oak forest with dense hazel undergrowth	1	19	2	37	1	8	4	28	0	48	100
3.	hazel brushwood	1	7	0	60	+	28	0	3	1	17	384

in the drift-sand layer of the dry podsol profile Epe III, apparently originates from plant growth in the little fen on the border of which the profile was found.

CHAPTER VIII

SOME PEDOLOGICAL RESULTS

It can be seen from table VIII that during te Boreal, Atlantic and Fagus-Carpinus periods both homogeneous forest profiles and podsol profiles occurred under various vegetations. During each of these periods new podsol profiles arose as a result of degradation of homogeneous forest profiles.

To the best of the author's knowledge, homogeneous forest profiles have never been found under peat. This must be explained by the fact that when a homogeneous soil became very wet some time before peat growth started, it would begin to podsolize, whatever the kind of vegetation present or the Holocene period concerned.

When podsolizing set in over a certain area there may still have been considerable local variations in hydrological soil conditions. Now in a peat-covered area, the profiles developed in the sand below generally show different morphological features, indicating more or less wet soil conditions during their formation. This means that once a relatively dry podsol profile had come into existance, its morphological features did not change when subsequently the water table continued to rise. At any rate the visual aspect was not influenced considerably.

It is impossible to say whether in some cases podsolization started before the process was forced by the rising water table. It may be supposed that this happened, for instance, owing to calcium carbonate being gradually washed out of cover sand originally containing some of that compound, and the vegetation changing its composition at the same time.

An exact answer cannot be found unless one is able to find and analyse a series of podsol profiles successively covered by drift-sand deposited during the various Holocene periods. Soil conditions in those profiles should be such, that it would be out of the question for either a high water table or stagnant water to have ever occurred in the soil.

It is very probable that most of the Pleistocene cover sand landscape not covered by peat also podsolized as a result of hydrological soil conditions. This must be true as far as the lower areas are concerned. Thus a podsol profile now covered by heath may have developed under a fir forest during the Boreal. Of course, the morphological features of the Boreal "fir podsol profile" may have differed more or less from those of the recent "heath podsol profile".

In the literature contradictory opinions are found as to the extent to which the podsolizing process is influenced by various plant species. It is usually assumed, however, that the process is promoted by *Coniferae* (SCHEFFER and SCHACHTSCHABEL 1960, p. 285) and *Ericaceae*. Such a connection cannot be detected in the investigated profiles. If, indeed, the kind of vegetation in those profiles had some influence on the podsolizing process, apparently it must have been eclipsed by the influence of hydrological soil conditions. It is only the much greater development of profile Uddelermeer III compared with profile Uddelermeer II that is to be connected with changes in vegetation.

In this case, however, a heath moor developed where once an oak forest existed. Another possible factor is a difference in the duration of soil formation, profile III not being buried some 1000 years ago like profile II.

Several writers assume that the type of vegetation has some influence on certain profile characteristics not directly dependent on the intensity of podsolization. Thus a violet or pinkish tinged A_2 horizon is often considered to indicate that the podsol profile developed under forest and not under heath (SCHEYS, DUDAL and BAYENS 1954, CNOSSEN and HEYINK 1958). A grey A_2 horizon or a fairly reddish B horizon is said to be characteristic of a heath podsol profile. An illuviation horizon of a caseated kind probably indicates a vegetation of much *Erica tetralix* and *Molinia coerulea* (cf. p. 7).

In table X the podsol profiles investigated are arranged together with the vegetations under which they arose, according to the colour of the A_2, the hue of the B and the occurrence of caseated material in the B horizon. It is obvious that as far concerns the profiles investigated no clear connection exists between these characteristics and type of vegetation.

TABLE X. Some features of the podsol profiles investigated and the hydrological conditions and vegetations under which they developed

Colour A_2 horizon	Hydrological conditions during podsolization	Vegetation	Profile
grey	dry	heath moor, preceded by oak forest with heather undergrowth	Uddelermeer III
grey	dry	oak forest, heather undergrowth	Uddelermeer II
grey	fairly dry	fir and birch forest, dense fern cover	Delfzijl II
grey	fairly dry	open forest of hazel mixed with fir, dense cover of heather, ferns, grasses and herbs	Velzen II, III
grey above violet grey	dry	heath moor, preceded by oak forest with heather undergrowth	Epe III
grey above violet grey	dry	very open oak forest, dense heather cover	Staphorst I, II
grey above violet grey	dry	oak forest, heather undergrowth	Epe I
grey above violet grey	fairly dry	oak forest, heather undergrowth	Epe II
violet grey	dry	oak forest, heather undergrowth	Peel I, II, III
white	fairly moist	fir and birch forest, dense fern cover	Delfzijl III
pinkish white	fairly wet periodically	oak forest, heather undergrowth	Peel IV
pinkish white	fairly wet	linden-oak-birch forest	Delfzijl I
pinkish white	wet periodically	oak forest	Noordoostpolder I, II, III

TABLE X. (continued)

Colour A_2 horizon	Hydrological conditions during podsolization	Vegetation	Profile
pinkish white	wet	fir forest, dense fern cover	Delfzijl IV
pinkish white	wet	fir forest, fairly dense fern undergrowth	Flevoland II
Hue B horizon			
10YR	fairly dry	open forest of hazel mixed with fir, dense cover of heather, ferns, grasses and herbs	Velzen II, III
10YR	fairly wet	linden-oak-birch forest	Delfzijl I
10YR	wet	fir forest, dense fern growth	Delfzijl IV
10YR	wet	fir forest, fairly dense fern undergrowth	Flevoland I, II, III
10YR	wet	birch and fir forest	Peel V
7,5YR	dry	heath moor, preceded by oak forest with heather undergrowth	Uddelermeer III
7,5YR	dry	oak forest, heather undergrowth	Uddelermeer II
7,5YR	dry	very open oak forest, dense heather cover	Staphorst I, II
7,5YR	fairly dry	fir and birch forest, dense fern cover	Delfzijl II
7,5YR	fairly moist	fir and birch forest, dense fern cover	Delfzijl III
7,5YR	fairly wet periodically	oak forest, heather undergrowth	Peel IV
7,5YR	wet periodically	oak forest	Noordoostpolder I, II, III
5YR	dry	heath moor, preceded by oak forest with heather undergrowth	Epe III
5YR	dry	oak forest, heather undergrowth	Peel I, II, III
5YR	dry	oak forest, heather undergrowth	Epe I
5YR	fairly dry	oak forest, heather undergrowth	Epe II
Caseated B horizon			
present	fairly dry	oak forest, heather undergrowth	Epe II
present	fairly moist	fir and birch forest, dense fern cover	Delfzijl III
present	fairly wet	linden-oak-birch forest	Delfzijl I
present	wet periodically	oak forest	Noordoostpolder I, II

SUMMARY

The investigation was begun in order to gain an insight into the connection between development of vegetation and soil formation during the Holocene in the Pleistocene cover sand area.

Palynological investigation of sand was used by several research workers as far back as about 30 years, but it was never shown exactly how pollen profiles in sandy soils may develop and how a sand diagram should be interpreted. Consequently we were obliged to study also the general significance of sand diagrams.

For this purpose we analysed the pollen and spore content of several podsol profiles and some gley profiles covered by drift sand and peat layers of differing age. It was shown from the diagrams obtained that pollen may enter sandy soil and move in it as a result of the following processes:

1. Mixing of pollen in the soil as a result of biological activities.
2. Downwash of pollen sedimenting from the air.
3. Simultaneous sedimentation of pollen and sand.
4. Arbitrary over-representation.

Generally speaking the first process was most important for the development of pollen profiles. It was active during the presence of the homogeneous forest profile before soil degradation began. This degradation gradually intensified, resulting in the development of a podsol profile. In the meantime downwash of pollen became the main process. The composition of pollen spectra above the more or less compact illuviation horizon of a podsol profile is often considerably influenced in this way. Simultaneous sedimentation of pollen and sand was usually of minor importance. This rule does not apply to as regards the pollen profiles present in cover sand which were once deposited in a pool and have since then always been under very wet conditions. Arbitrary over-representation is due to unknown causes. It can be seen where one or more herb species in a sand diagram are too highly represented in proportion to their possible share in vegetation. Inexplicably high *Liguliflorae* percentages were frequently encountered. High *Calluna* and probably also high *Filicinae* percentages are sometimes partly attributable to factors not yet known.

Pollen composition in mineral soil may be greatly influenced by selective corrosion. Thus it was shown that *Quercus* pollen is very susceptible to corrosion in fairly dry sandy soil. Owing to the selective destruction of this pollen, spectra originating from an oak forest with *Calluna* undergrowth often assumed the character of pollen spectra reflecting an open heath vegetation. In the arboreal section of those spectra *Alnus* will dominate, as it does in post-Boreal peat spectra of a regional character. In wet sandy soil, however, *Quercus* pollen is well preserved.

Very frequently the arboreal section is greatly influenced by local tree growth. Consequently it is not always possible to determine accurately the age of pollen spectra in sand.

The chief general ecological and pedological results of the investigation are as follows:

During the Boreal period both fir and alder forests occurred, the latter locally, viz. where soil was very wet. During this period the hazel was not only pre-

sent as undergrowth but also formed groves of its own. During the Boreal, Atlantic and Fagus-Carpinus periods both homogeneous forest profiles and podsol profiles occurred under very different types of vegetation. During each of these periods new podsol profiles arose as a result of degradation of homogeneous forest profiles. In the profiles investigated no influence could be found of the composition of vegetation on the colours of the eluviation and illuviation horizon.

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PHOTOS, POLLEN DIAGRAMS AND TABLES

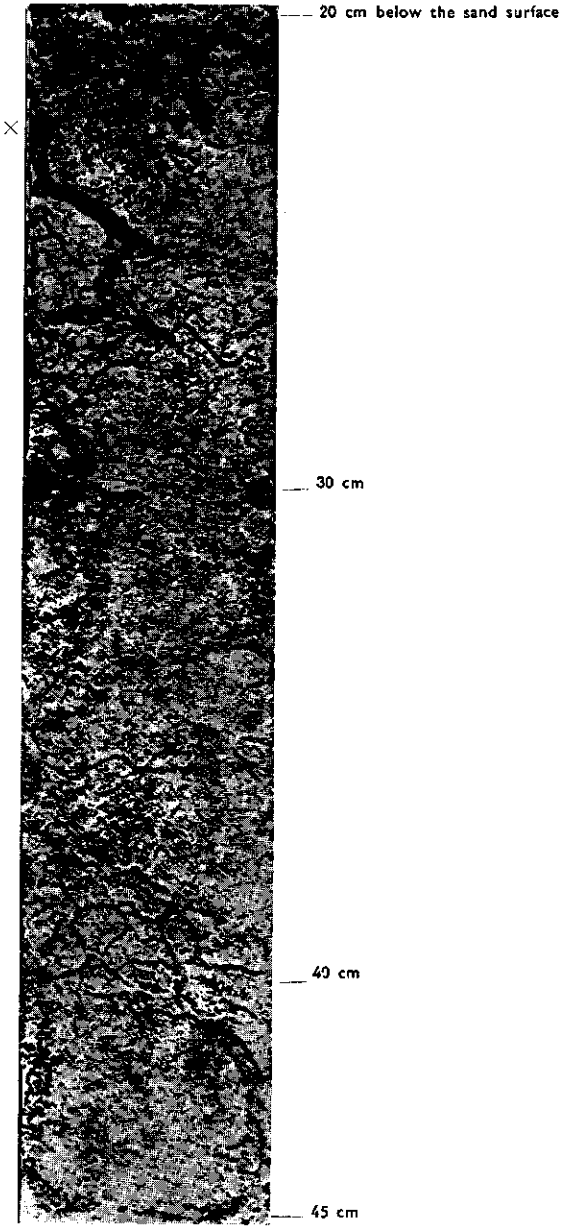


FIG. 4. Profile Staphorst II. System of *Halictus* burrows; the digger bee was found at ×

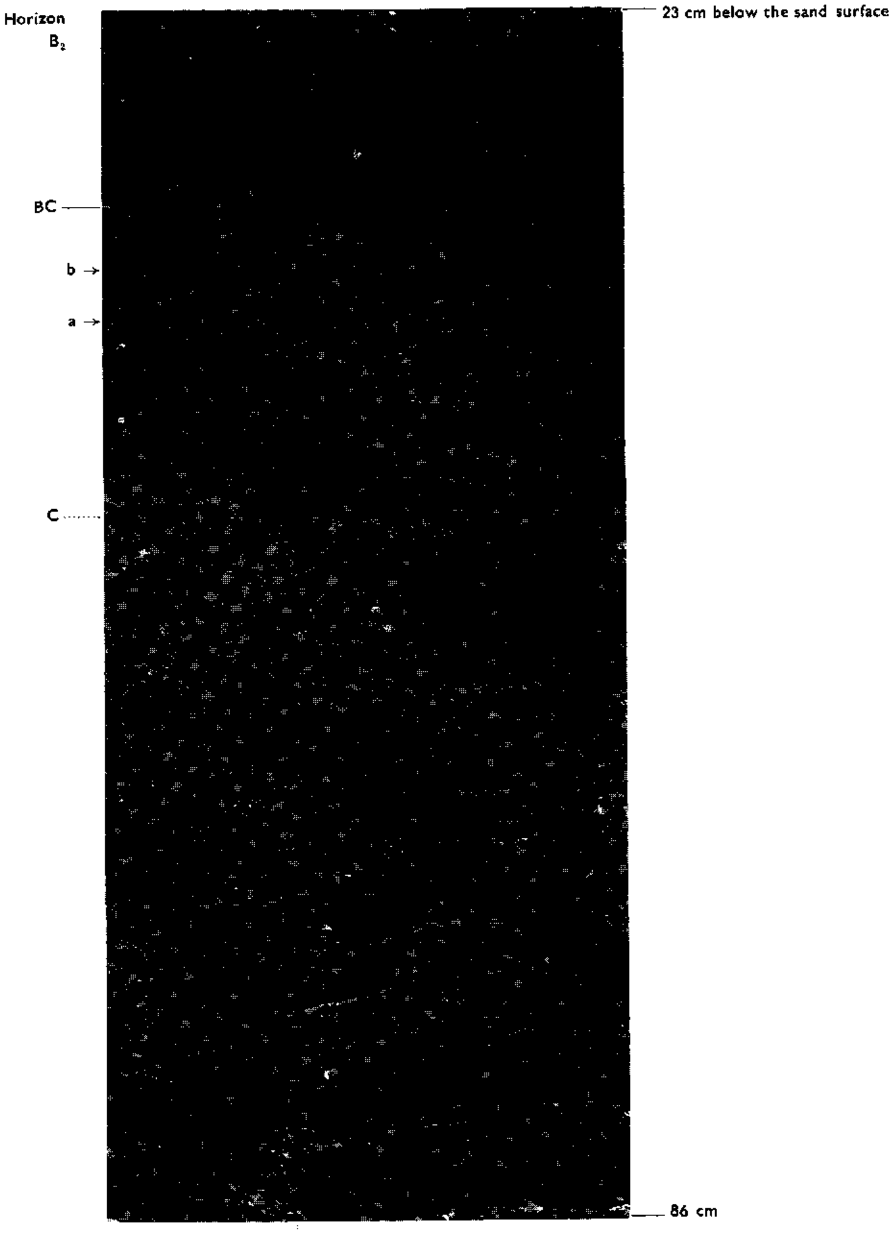


FIG. 5. Profile Delfzijl II

a. Level above which the original stratification of the cover sand has totally disappeared
b. Bottom of the pollen profile

—— Clear } transition between two profile horizons
······ Vague

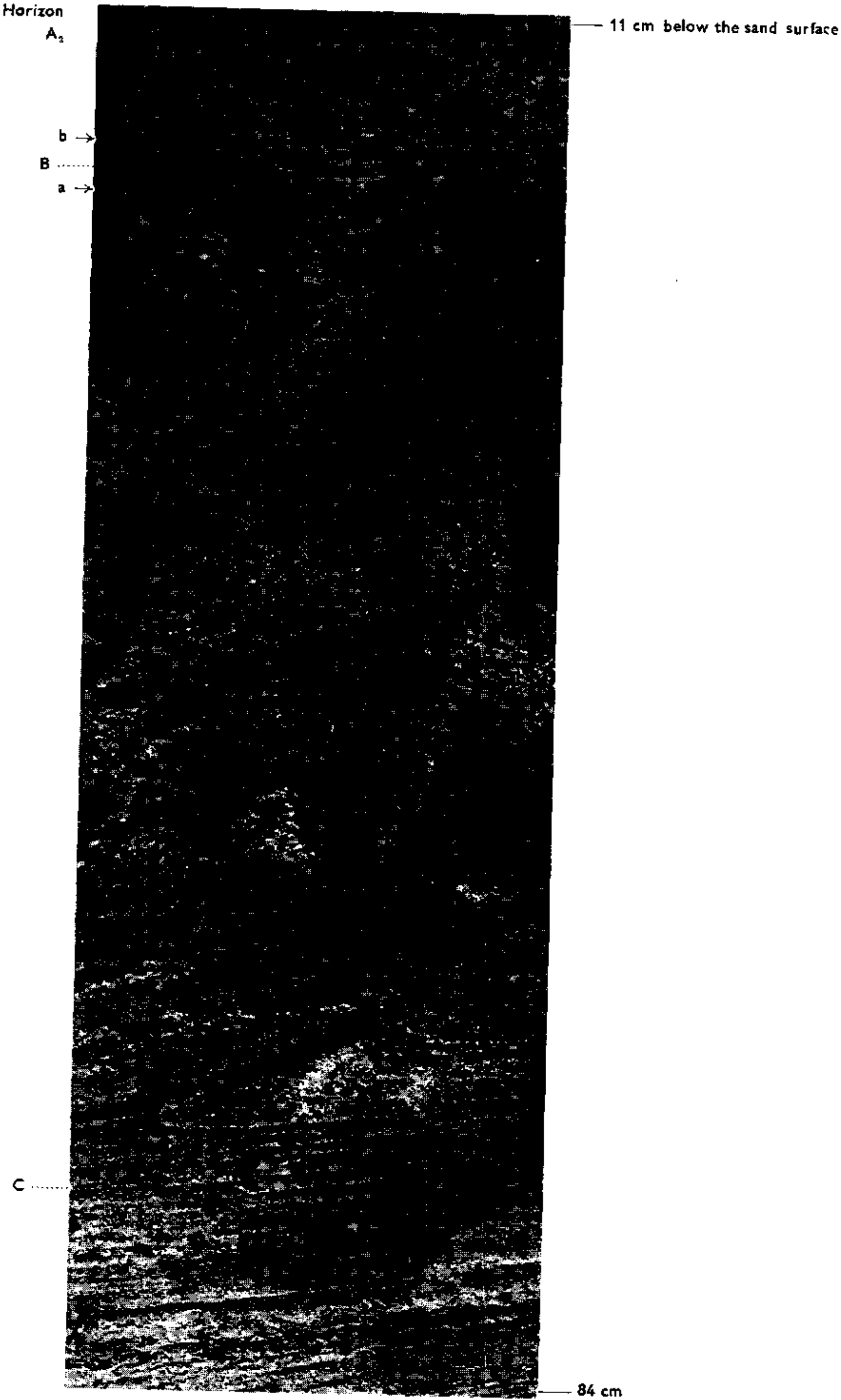
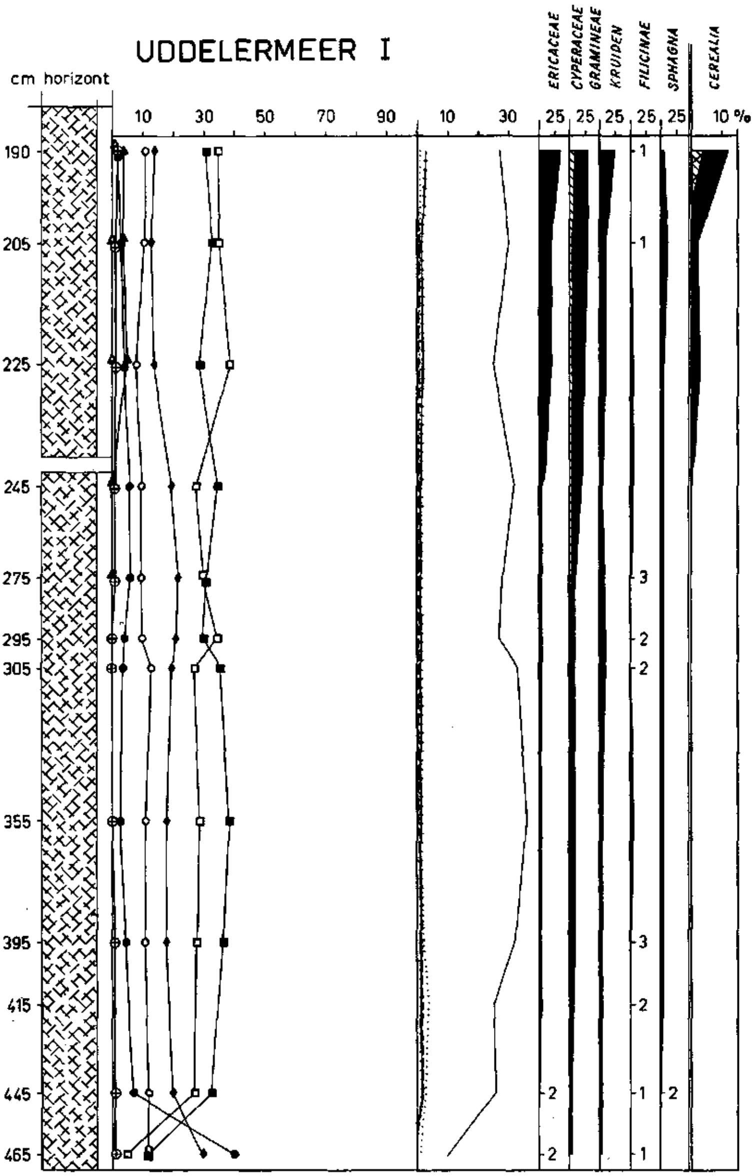
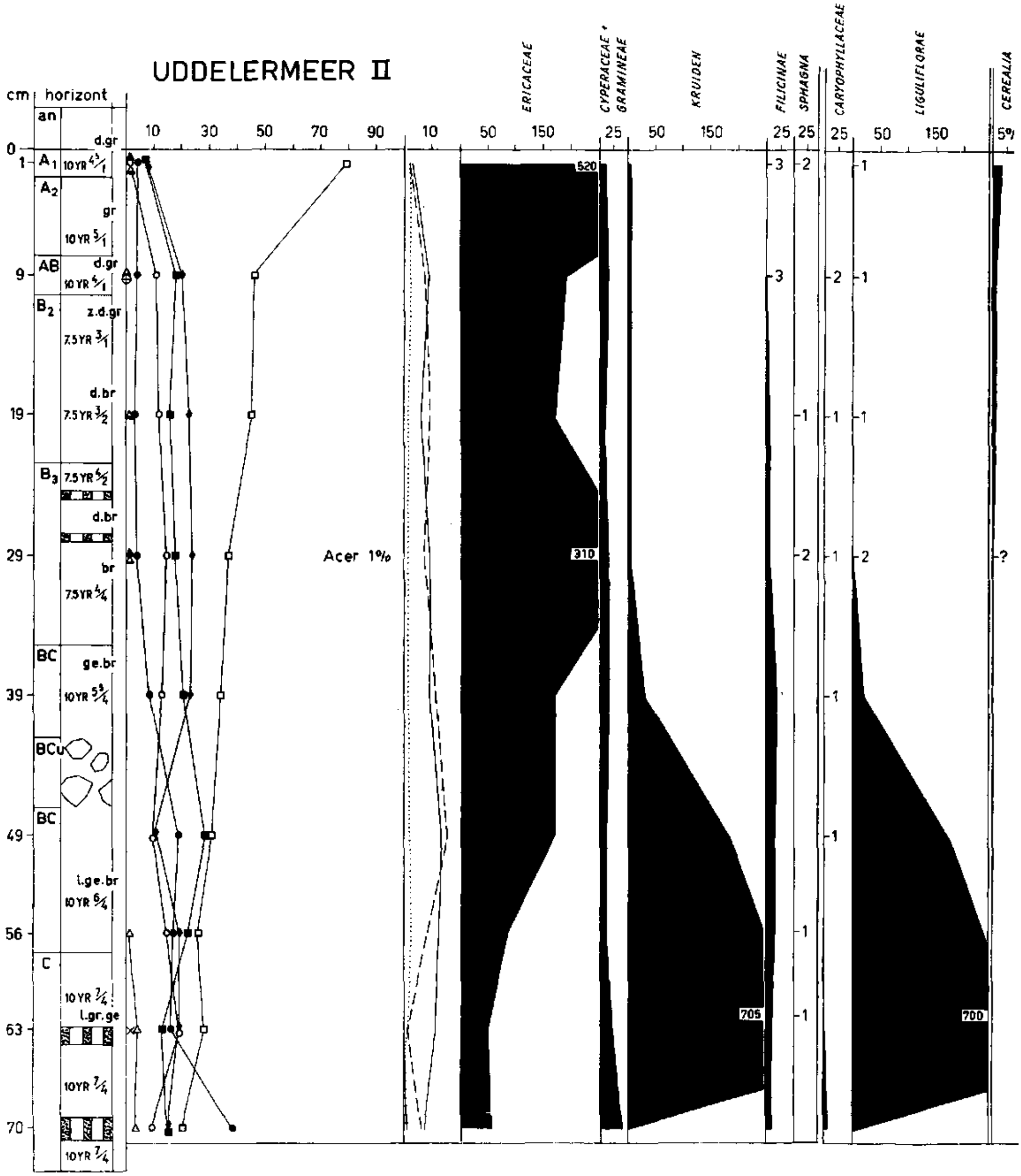
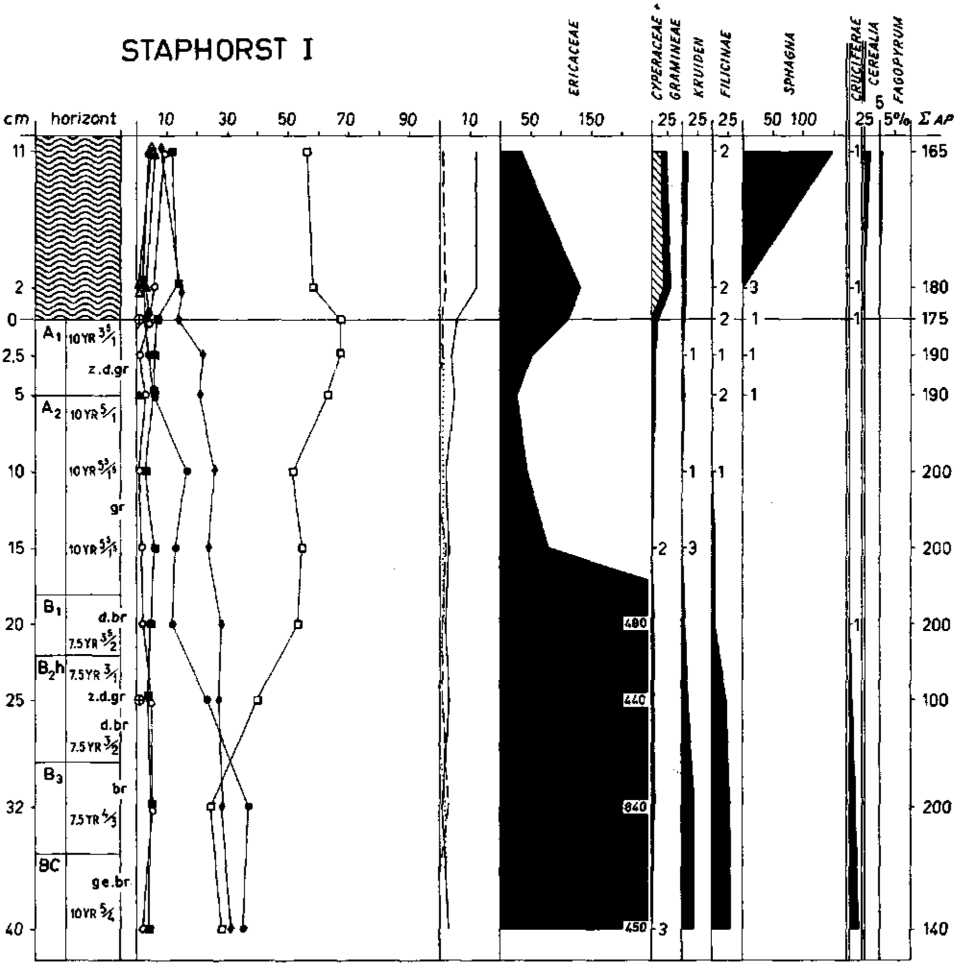


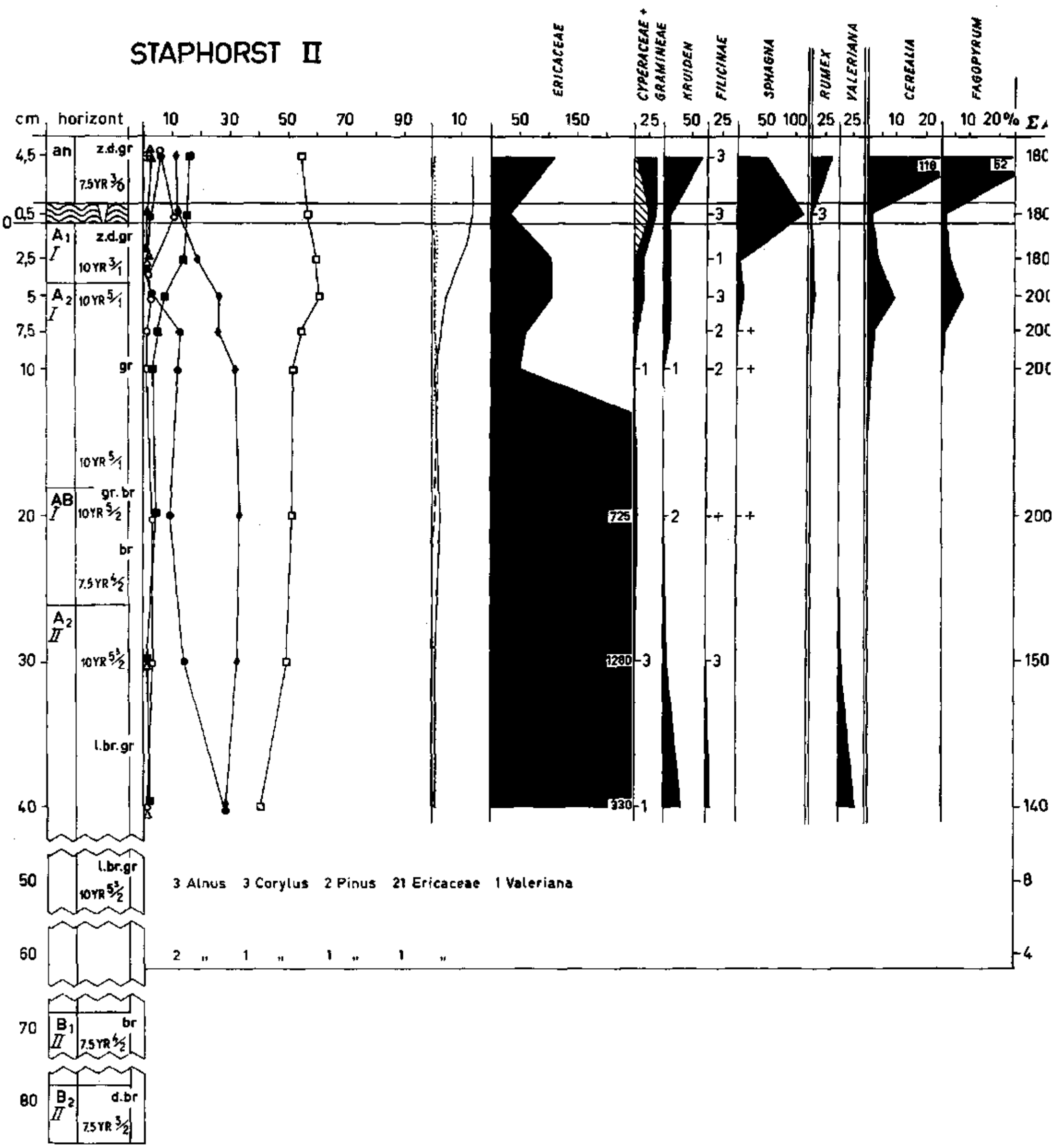
FIG. 6. Profile Delfzijl IV

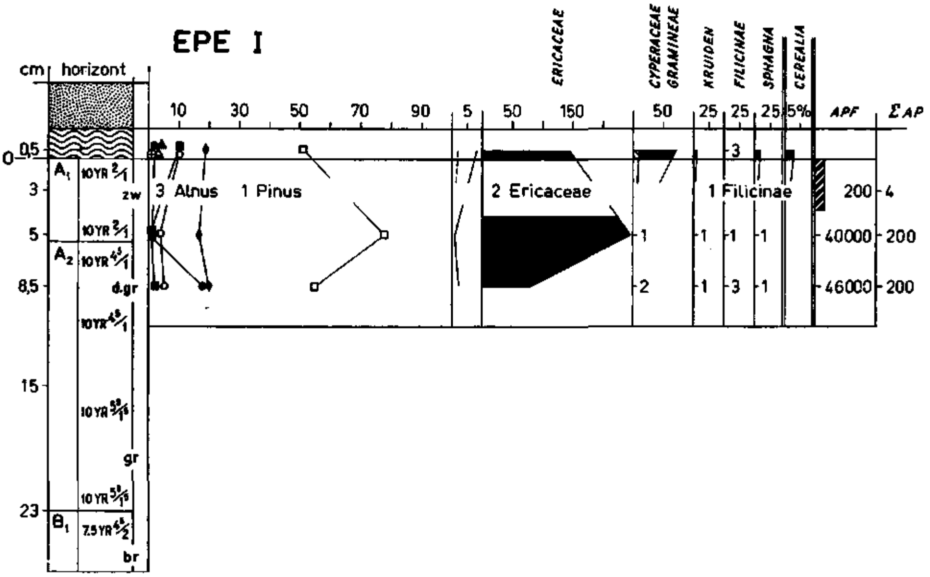
a
b
——
……
} cf. fig. 5

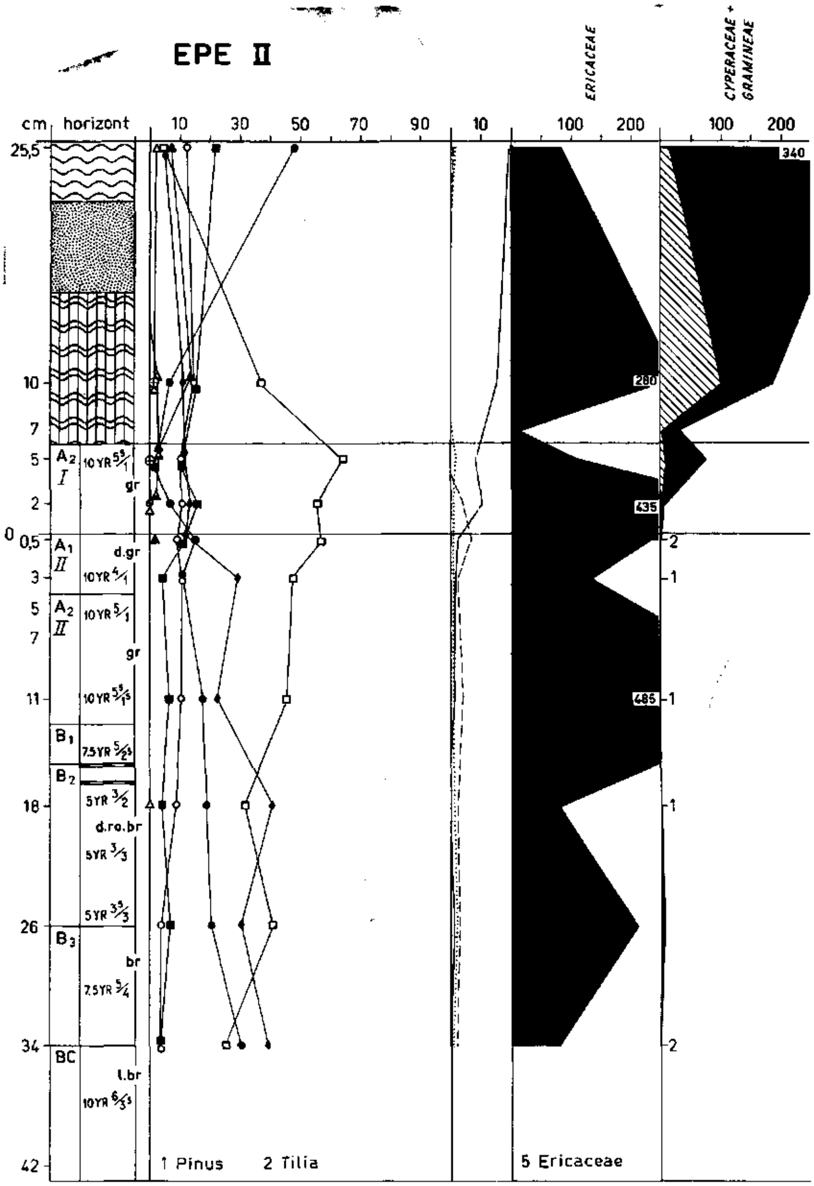

UDDELERMEER I
cm horizont
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
CEREALIA
10
30
50
70
90
10
30
25
25
25
25
25
10 %
190
205
225
245
275
295
305
355
395
415
445
465
1
1
3
2
2
3
2
1
1
2
2
2

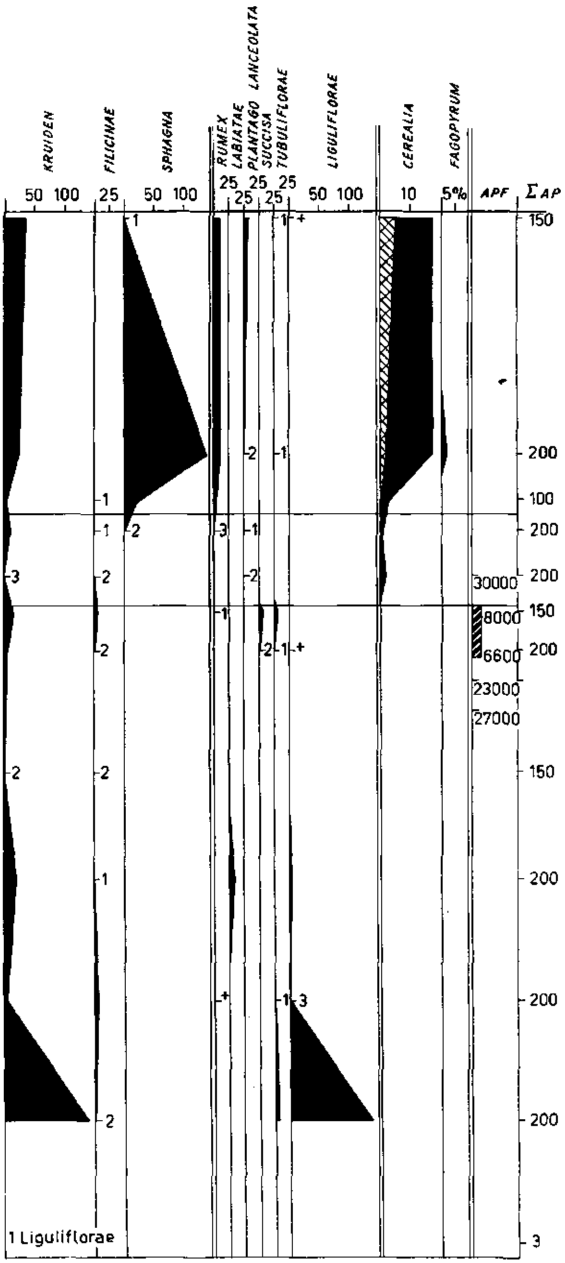

UDDELERMEER II
cm
horizont
an
A1
A2
AB
B2
B3
BC
BCu
BC
C
d.gr
10YR 4.5/1
gr
10YR 5/1
d.gr
10YR 4/1
z.d.gr
7.5YR 3/1
d.br
7.5YR 3/2
7.5YR 4/2
d.br
br
7.5YR 4/4
ge.br
10YR 5.5/4
l.ge.br
10YR 6/4
10YR 7/4
l.gr.ge
10YR 7/4
10YR 7/4
0
1
9
19
29
39
49
56
63
70
10
30
50
70
90
10
50
150
Acer 1%
ERICACEAE
520
310
CYPERACEAE + GRAMINEAE
25
KRUIDEN
50
150
705
FILICINAE
25
3
3
SPHAGNA
25
2
1
2
1
1
CARYOPHYLLACEAE
25
2
1
1
1
1
LIGULIFLORAE
50
150
1
1
1
2
700
CEREALIA
5%
?

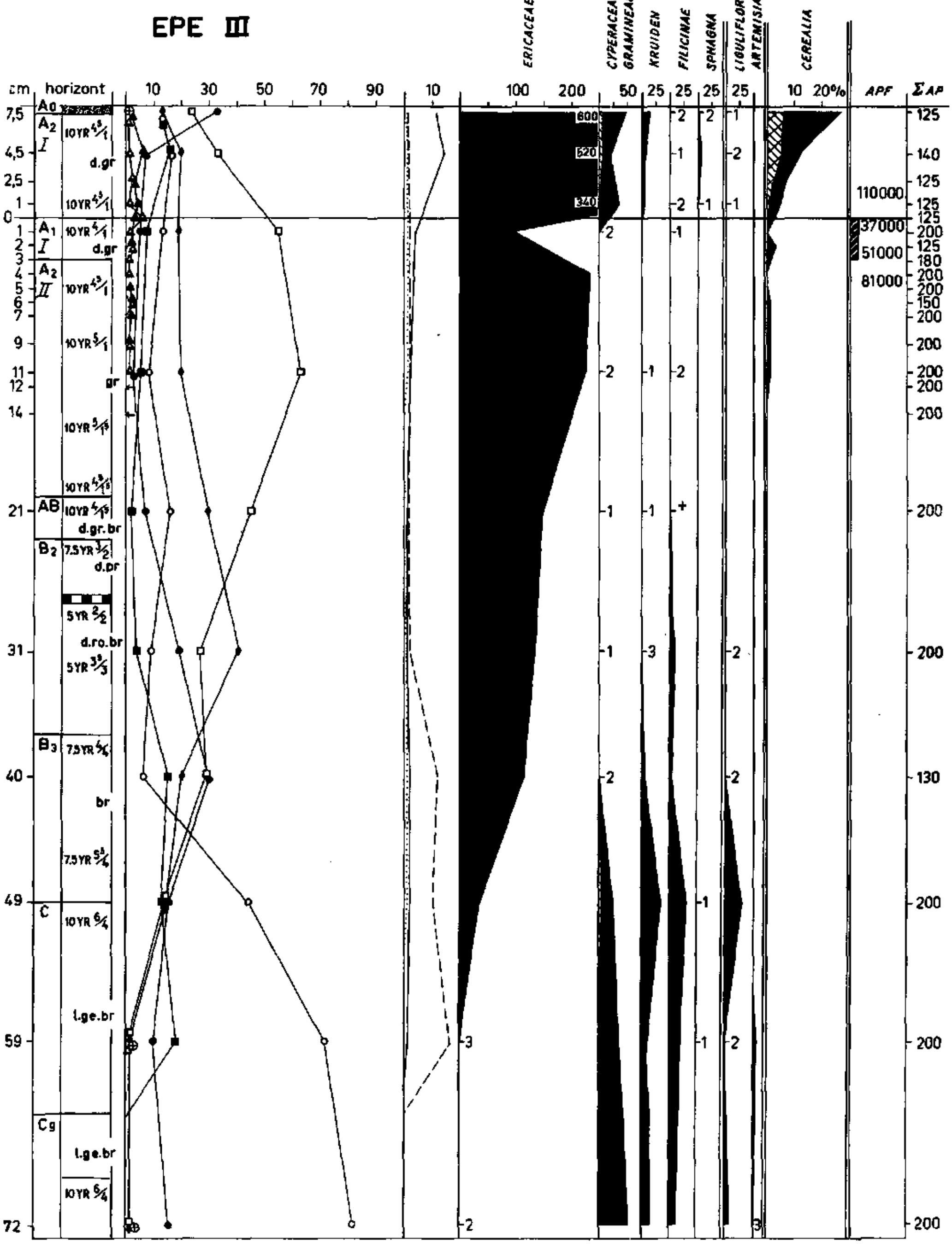

STAPHORST I
cm
horizont
10 30 50 70 90
10
50 150
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
CRUCIFERAE
CEREALIA
FAGOPYRUM
25 25 25
50 100
25 5 5%
Σ AP
11
2
0
2,5
5
10
15
20
25
32
40
A1 10YR 3.5/1
z.d.gr
A2 10YR 5/1
10YR 3.5/1.5
gr
10YR 5.5/1.5
B1 d.br
7.5YR 3.5/2
B2h 7.5YR 3/1
z.d.gr
d.br
7.5YR 3/2
B3 br
7.5YR 4/3
BC ge.br
10YR 5/4
480
440
840
450
165
180
175
190
190
200
200
200
100
200
140


STAPHORST II
cm
horizont
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
RUMEX
VALERIANA
CEREALIA
FAGOPYRUM
Σ
10 30 50 70 90 10 50 150 25 50 25 50 100 25 25 10 20 10 20%
4,5
0,5
0
2,5
5
7,5
10
20
30
40
50
60
70
80
an
z.d.gr
7.5YR 3/0
A1 I
z.d.gr
10YR 3/1
A2 I
10YR 5/1
gr
10YR 5/1
AB I
gr.br
10YR 5/2
br
7.5YR 4/2
A2 II
10YR 5.5/2
l.br.gr
l.br.gr
10YR 5.5/2
B1 II
br
7.5YR 4/2
B2 II
d.br
7.5YR 3/2
725
1280
330
118
52
180
180
180
200
200
200
200
150
140
8
4
3 Alnus 3 Corylus 2 Pinus 21 Ericaceae 1 Valeriana
2 " 1 " 1 " 1 "


EPE I
cm
horizont
0
0,5
3
5
8,5
15
23
A1
A2
B1
10YR 2/1
zw
10YR 2/1
10YR 4.5/1
d.gr
10YR 4.5/1
10YR 5.5/1.5
gr
10YR 5.5/1.5
7.5YR 4.5/2
br
10
30
50
70
90
5
50
150
50
25
25
25
5%
APF
ΣAP
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
CEREALIA
3 Alnus
1 Pinus
2 Ericaceae
1 Filicinae
3
1
1
1
1
2
1
3
1
200
4
40000
200
46000
200

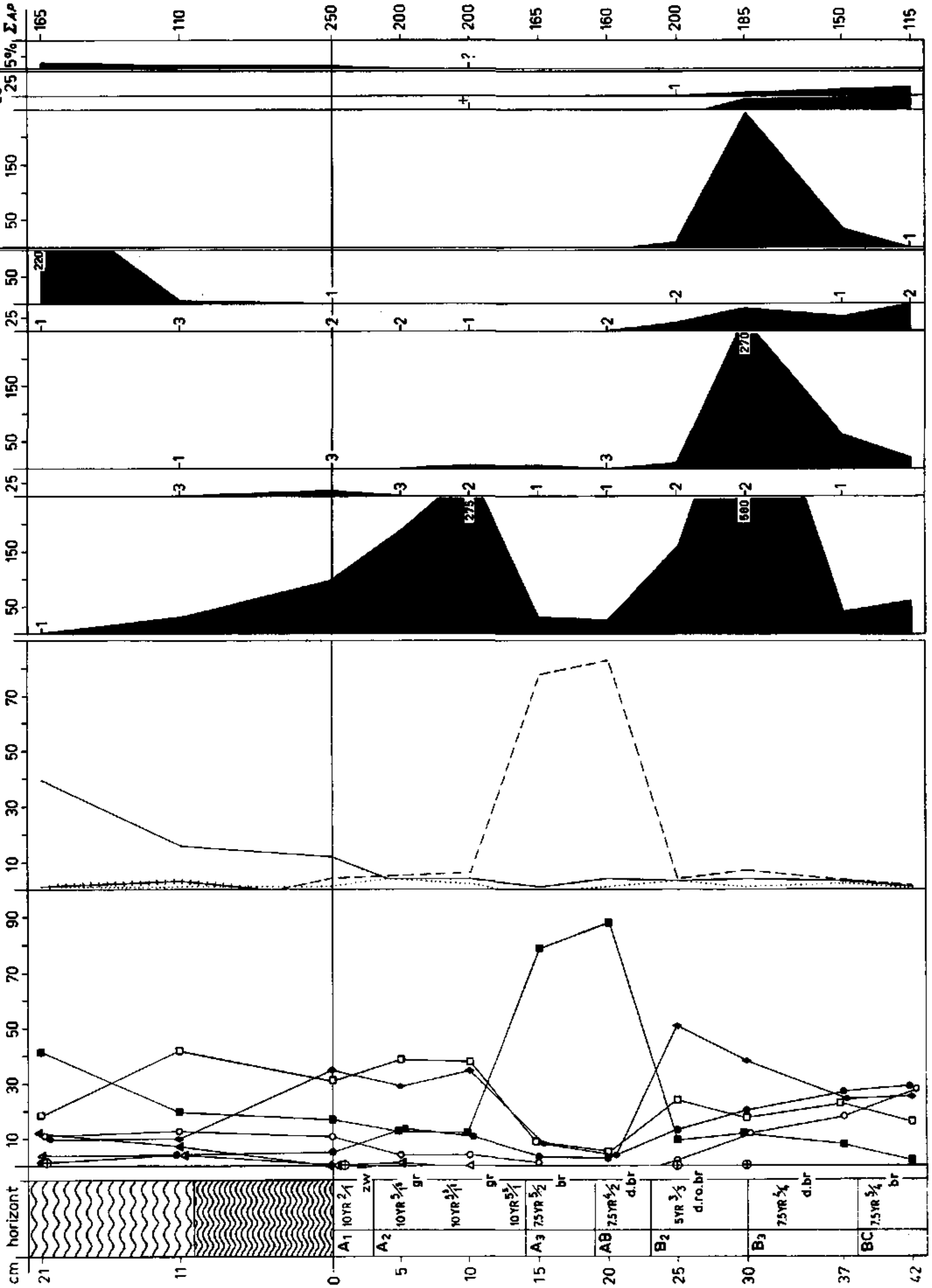

EPE II
cm
horizont
10 30 50 70 90
10
ERICACEAE
100 200
CYPERACEAE + GRAMINEAE
100 200
25,5
10
7
5
2
0
0,5
3
5
7
11
18
26
34
42
A2 I
10YR 5.5/1
gr
A1 II
d.gr
10YR 4/1
A2 II
10YR 5/1
gr
10YR 5.5/1.5
B1
7.5YR 5/2.5
B2
5YR 3/2
d.ro.br
5YR 3/3
5YR 3.5/3
B3
br
7.5YR 5/4
BC
l.br
10YR 6/3.5
280
435
485
340
2
1
1
1
2
1 Pinus
2 Tilia
5 Ericaceae


KRUIDEN
FILICINAE
SPHAGNA
RUMEX
LABIATAE
PLANTAGO LANCEOLATA
SUCCISA
TUBULIFLORAE
LIGULIFLORAE
CEREALIA
FAGOPYRUM
APF
ΣAP
50 100
25
50 100
25 25 25 25 25
50 100
10
5%
150
200
100
200
200
30000
150
8000
6600
200
23000
27000
150
200
200
200
3
1 Liguliflorae


EPE III

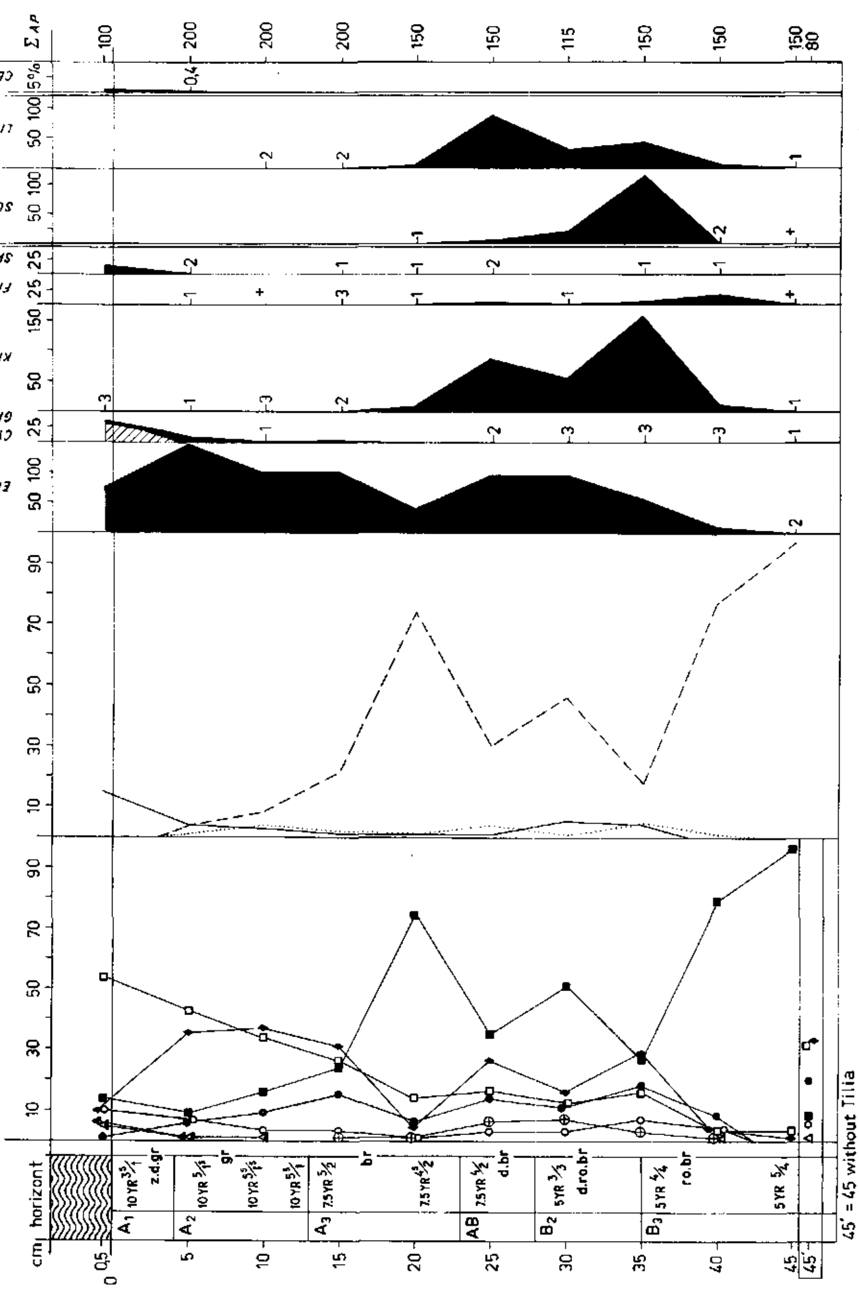
← no Fagus; no Carpinus

PEEL I

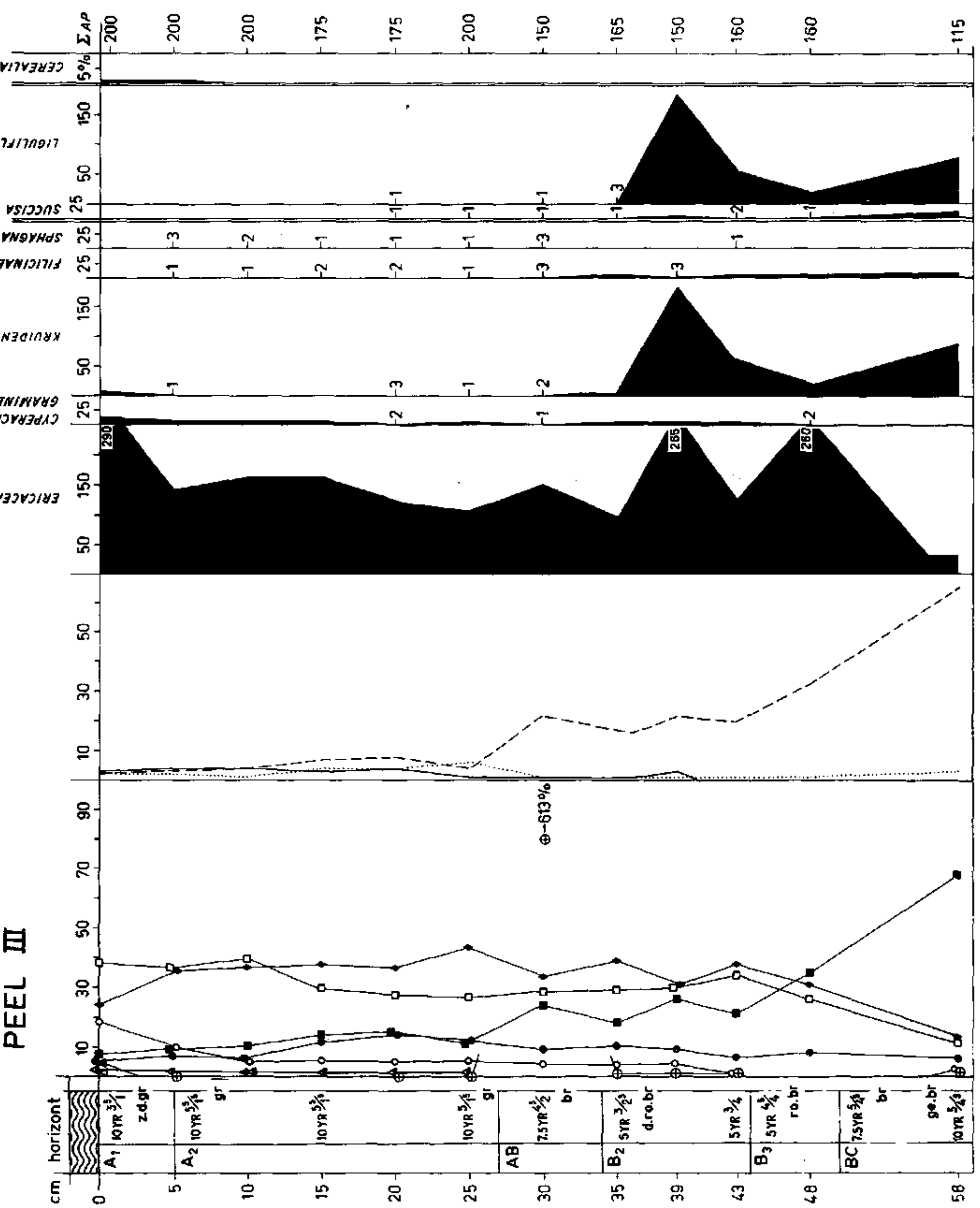


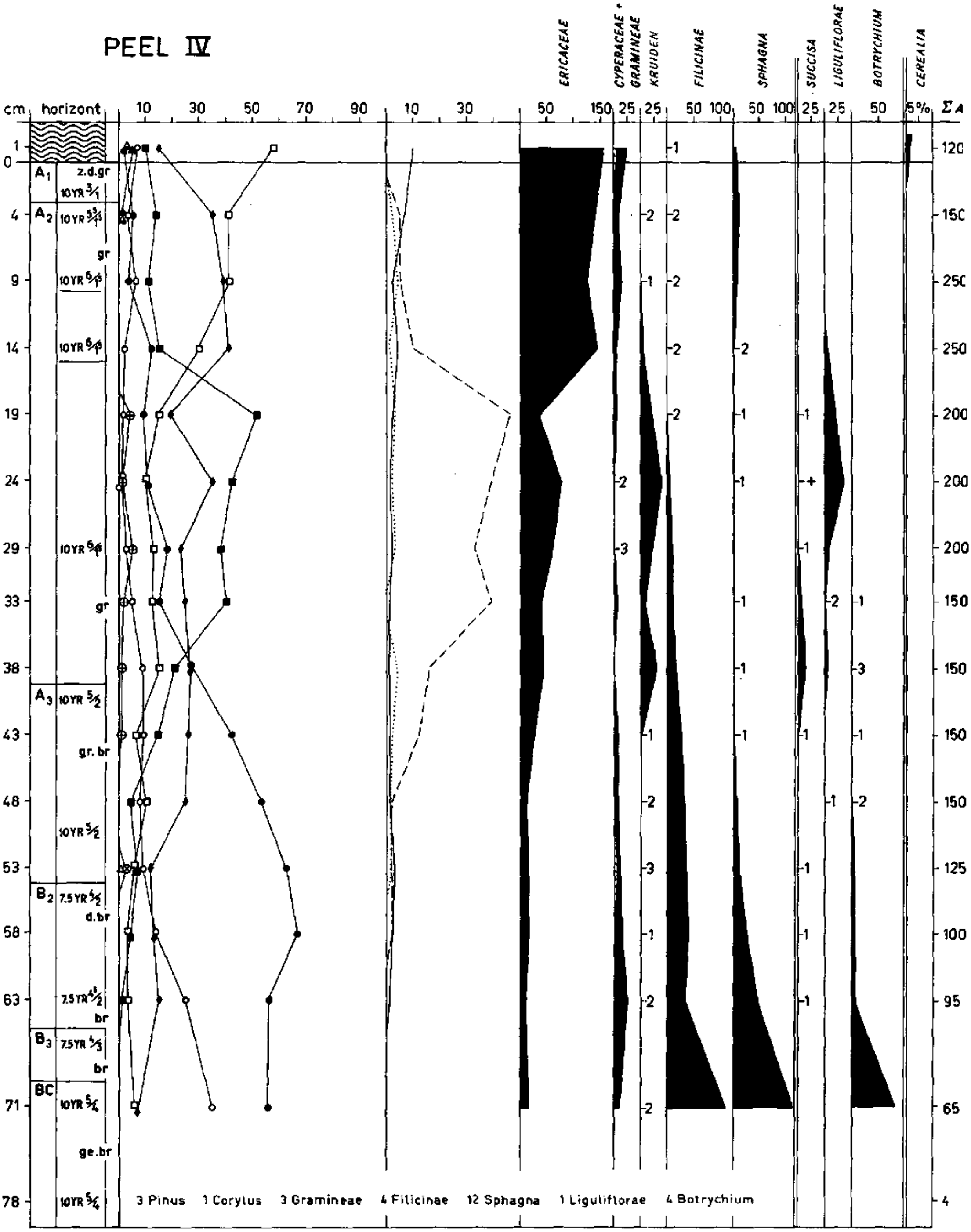
CEREALIA
BOTRYCHIUM
LIGULIFLORAE
SUCCISA
SPHAGNA
FILICINAE
KRUIDEN
GRAMINEAE
CYPERACEAE
ERICACEAE
5%
25
50
150
10
30
70
90
ΣAP
165
110
250
200
200
165
160
200
185
150
115
220
270
275
980
horizont
cm
21
11
0
5
10
15
20
25
30
37
42
A1
A2
A3
AB
B2
B3
BC
10YR 2/1
zw
10YR 5/1
gr
10YR 5/1
gr
10YR 5/1
7.5YR 5/2
br
7.5YR 4/2
d.br
5YR 3/3
d.ro.br
7.5YR 5/4
d.br
7.5YR 5/4
br

PEEL II



45' = 45 without Tilia

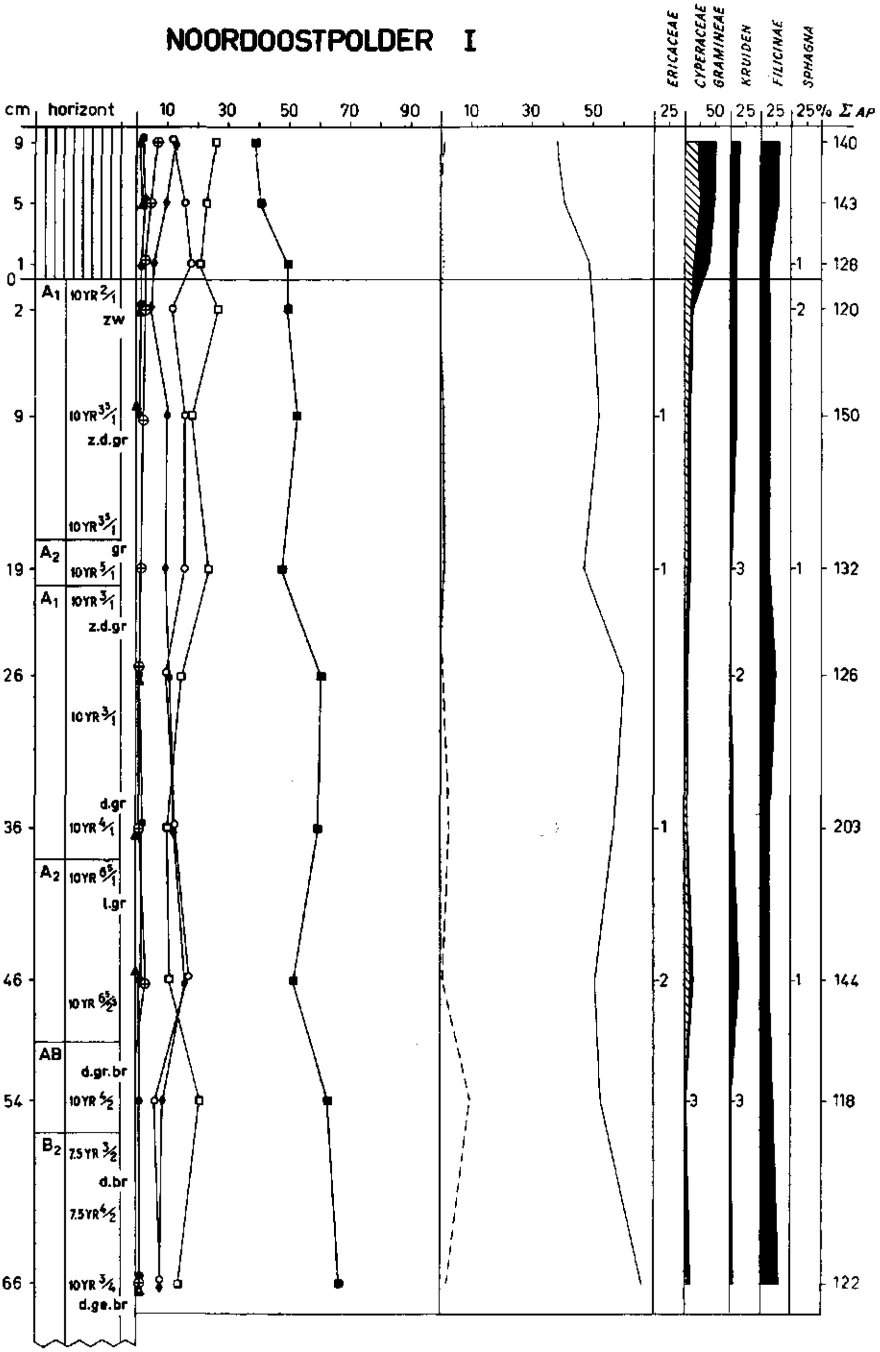

PEEL III
ΣAP
200
200
200
175
175
200
150
165
150
160
160
115
CEREALIA
5%
LIGULIFLORAE
150
50
SUCCISA
25
SPHAGNA
25
FILICINAE
25
KRUIDEN
150
50
CYPERACEAE + GRAMINEAE
25
ERICACEAE
290
265
260
150
50
50
30
10
90
70
50
30
10
⊕-61.3%
horizont
cm
A1
A2
AB
B2
B3
BC
10YR 3/1
z.d.gr
10YR 5/1
gr
10YR 5/1
10YR 5/1
gr
7.5YR 4/2
br
5YR 3/3
d.ro.br
5YR 3/4
5YR 4/4
ro.br
7.5YR 5/8
br
ge.br
10YR 5/8
0
5
10
15
20
25
30
35
39
43
48
58

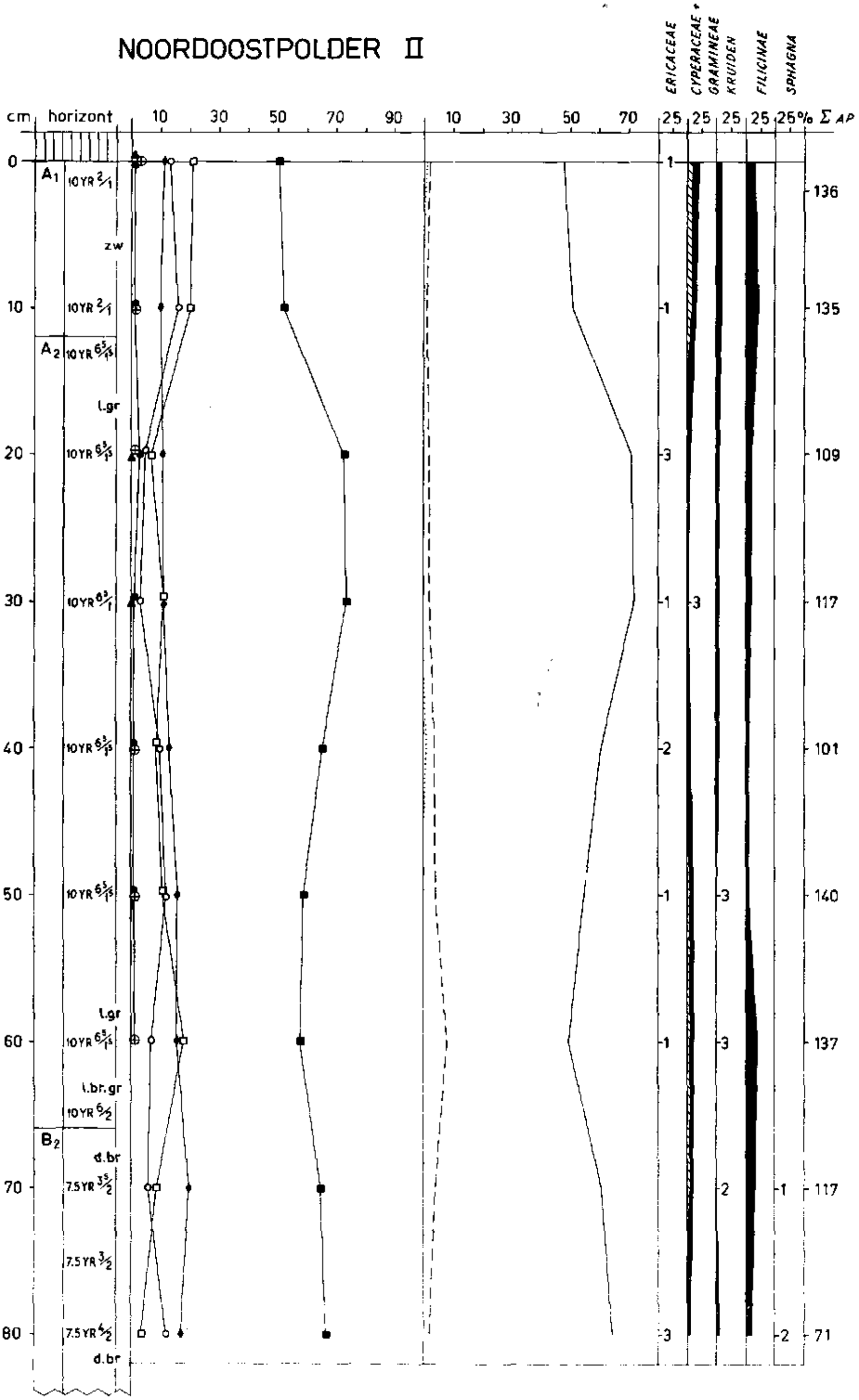


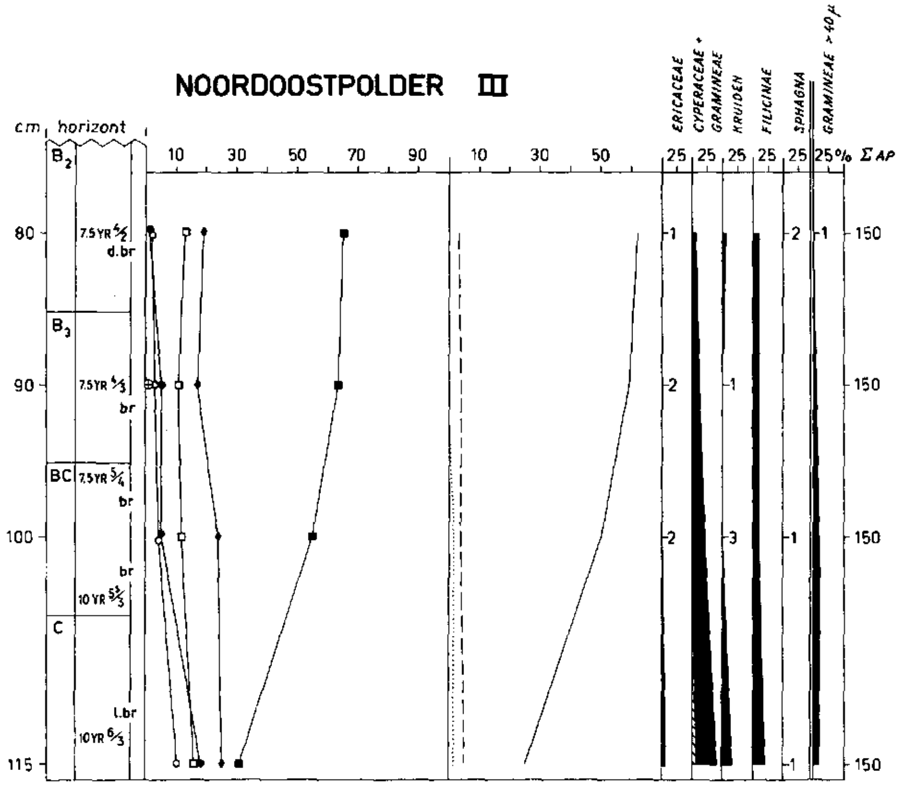
PEEL IV

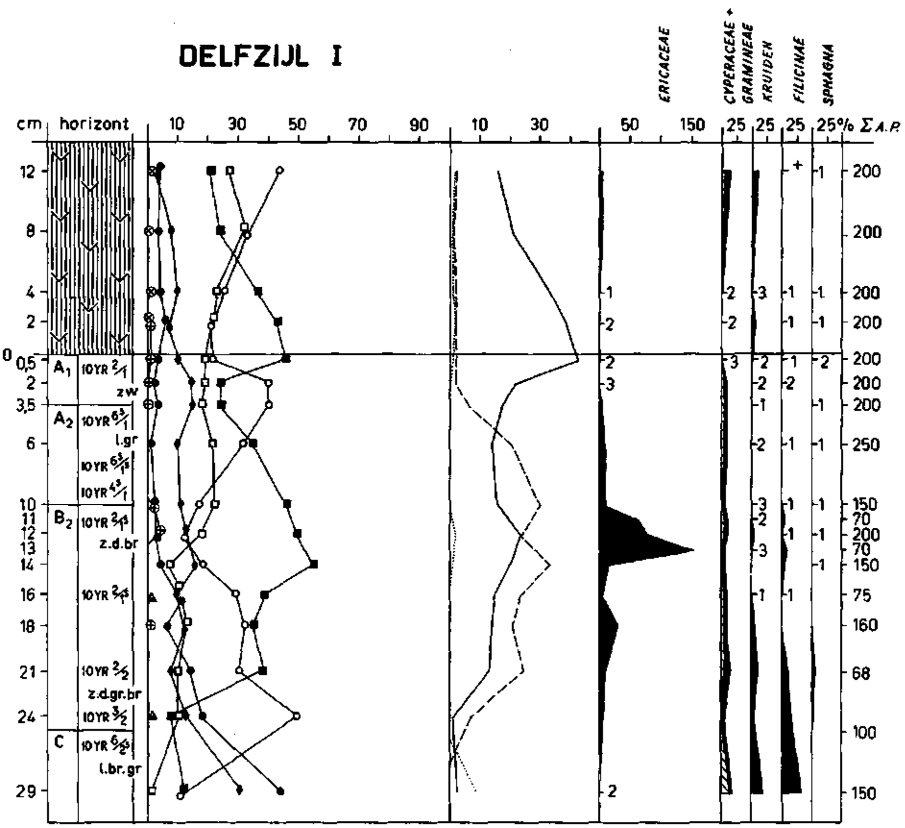
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
SUCCISA
LIGULIFLORAE
BOTRYCHIUM
CEREALIA
cm
horizont
10 30 50 70 90
10 30
50 150
25 25
50 100
50 100
25 25
50
5%
ΣA
1
0
4
9
14
19
24
29
33
38
43
48
53
58
63
71
78
A1 z.d.gr 10YR 3/1
A2 10YR 5.5/1.5
gr
10YR 6/1.5
10YR 6/1.5
10YR 6/1.5
gr
A3 10YR 5/2
gr.br
10YR 5/2
B2 7.5YR 4/2
d.br
7.5YR 4.5/2
br
B3 7.5YR 4/3
br
BC 10YR 5/4
ge.br
10YR 5/4
120
150
250
250
200
200
200
150
150
150
150
125
100
95
65
4
3 Pinus 1 Corylus 3 Gramineae 4 Filicinae 12 Sphagna 1 Liguliflorae 4 Botrychium

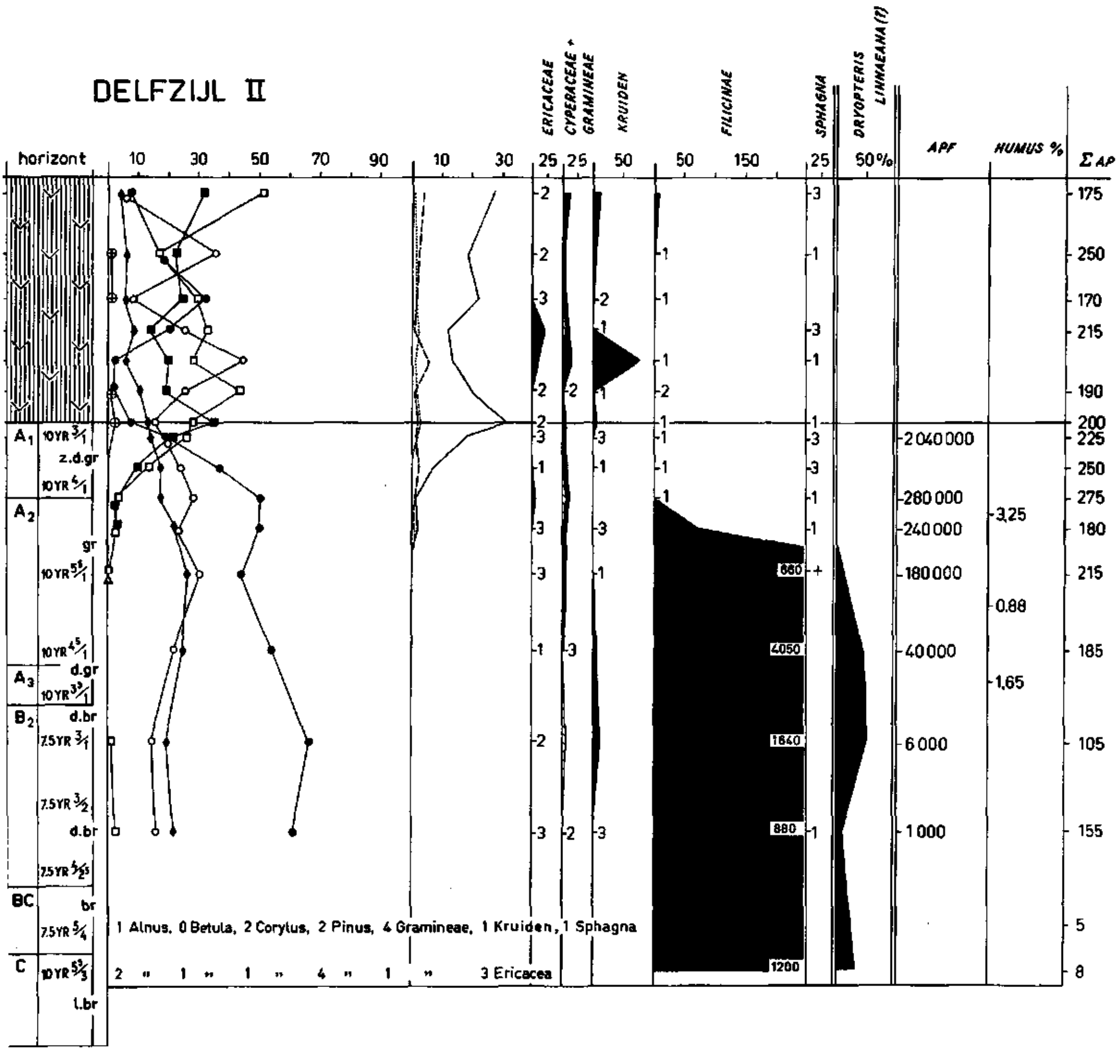
NOORDOOSTPOLDER I

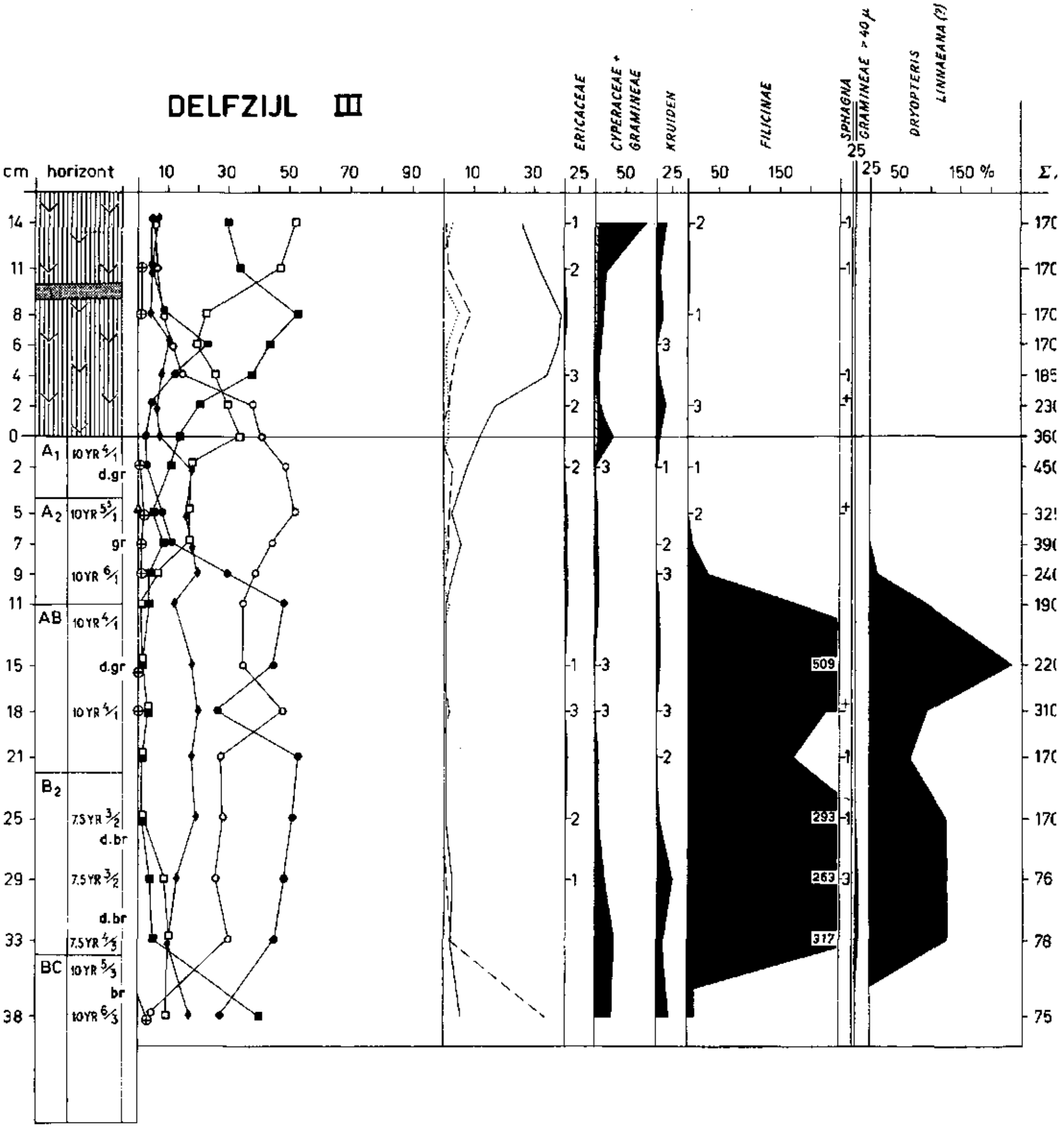


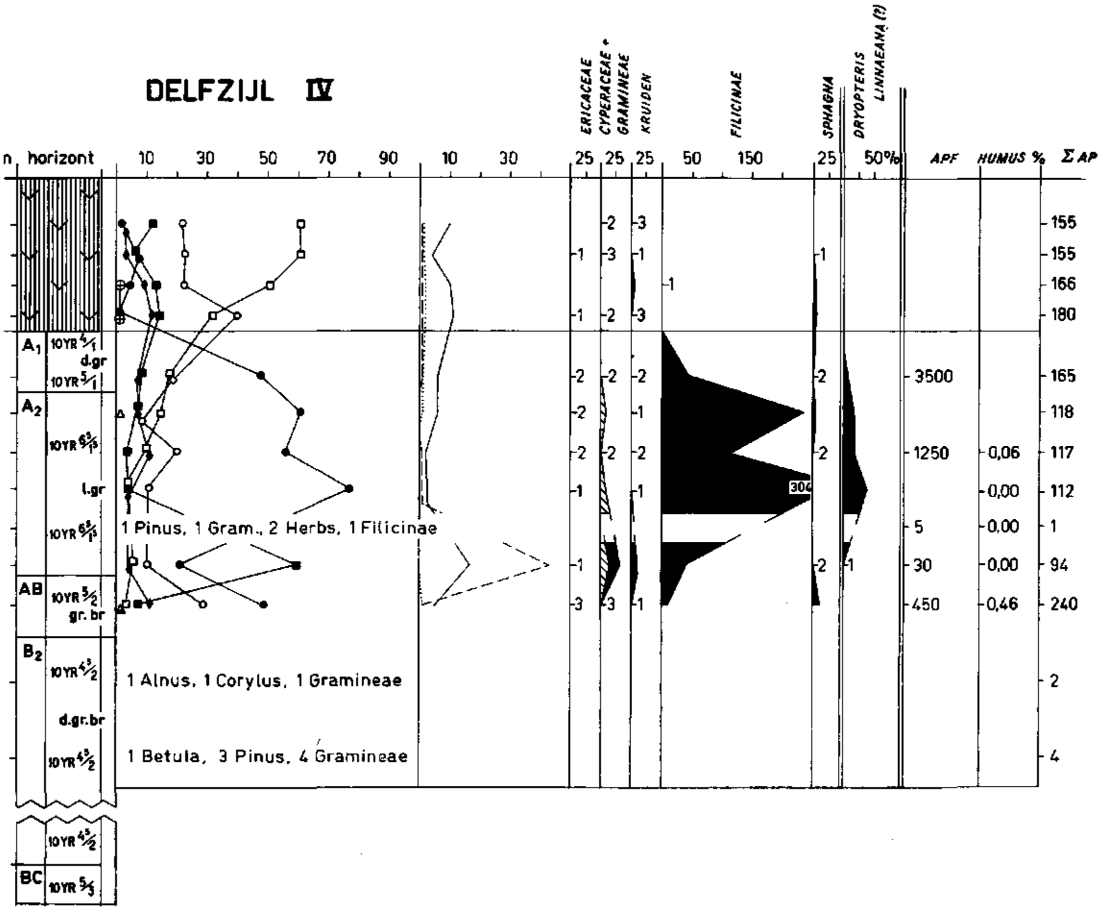

NOORDOOSTPOLDER II


NOORDOOSTPOLDER III
cm
horizont
B$_2$
B$_3$
BC
C
7.5YR 4/2
d.br
7.5YR 4/3
br
7.5YR 5/4
br
br
10YR 5/3
l.br
10YR 6/3
80
90
100
115
10
30
50
70
90
10
30
50
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
GRAMINEAE >40μ
25
25
25
25
25
25%
ΣAP
1
2
2
1
3
2
1
1
1
150
150
150
150

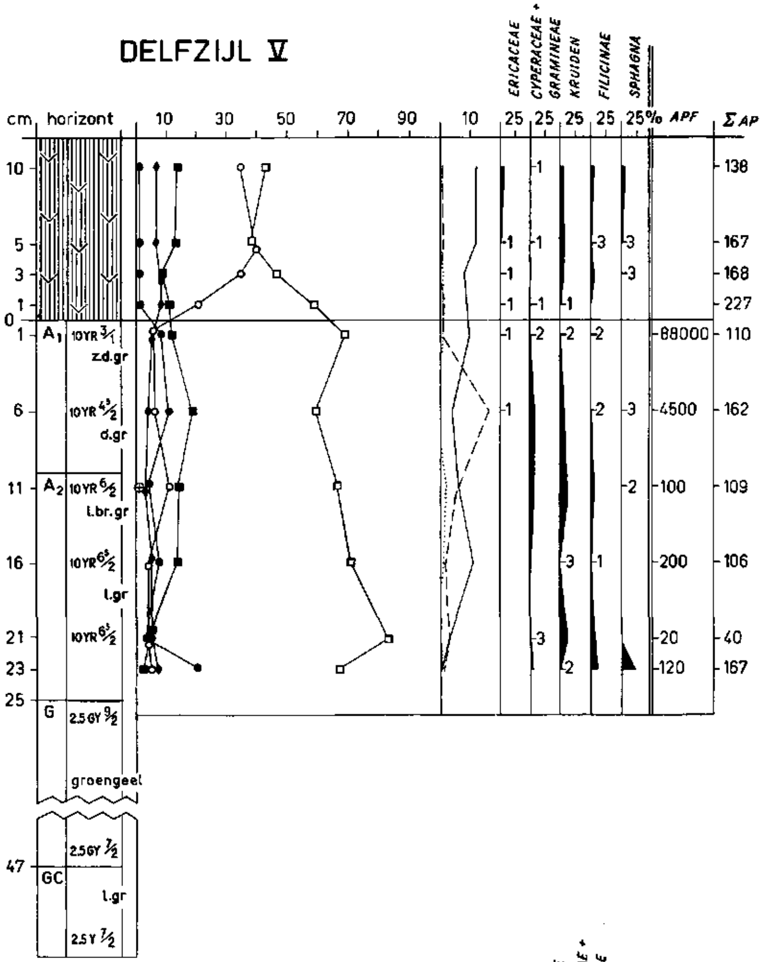

DELFZIJL I
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
cm
horizont
10
30
50
70
90
10
30
50
150
25
25
25
25%
ΣA.P.
12
8
4
2
0
0,5
2
3,5
6
10
11
12
13
14
16
18
21
24
29
A1
10YR 2/1
zw
A2
10YR 6³/1
l.gr
10YR 6³/1³
10YR 4³/1
B2
10YR 2/1³
z.d.br
10YR 2/1³
10YR 2/2
z.d.gr.br
10YR 3/2
C
10YR 6/2³
l.br.gr
200
200
200
200
200
200
200
250
150
70
200
70
150
75
160
68
100
150


DELFZIJL II
horizont
10 30 50 70 90
10 30
ERICACEAE 25
CYPERACEAE + GRAMINEAE 25
KRUIDEN 50
FILICINAE 50 150
SPHAGNA 25
DRYOPTERIS LINNAEANA (?) 50%
APF
HUMUS %
Σ AP
A1 10YR 3/1 z.d.gr 10YR 4/1
A2 gr 10YR 5.5/1 10YR 4.5/1 d.gr
A3 10YR 3.5/1
B2 d.br 7.5YR 3/1 7.5YR 3/2 d.br 7.5YR 5/2.5
BC br 7.5YR 5/4
C 10YR 5.5/3 l.br
1 Alnus, 0 Betula, 2 Corylus, 2 Pinus, 4 Gramineae, 1 Kruiden, 1 Sphagna
2 " 1 " 1 " 4 " 1 " 3 Ericacea
660 4050 1640 880 1200
2040000 280000 240000 180000 40000 6000 1000
3,25 0.88 1,65
175 250 170 215 190 200 225 250 275 180 215 185 105 155 5 8

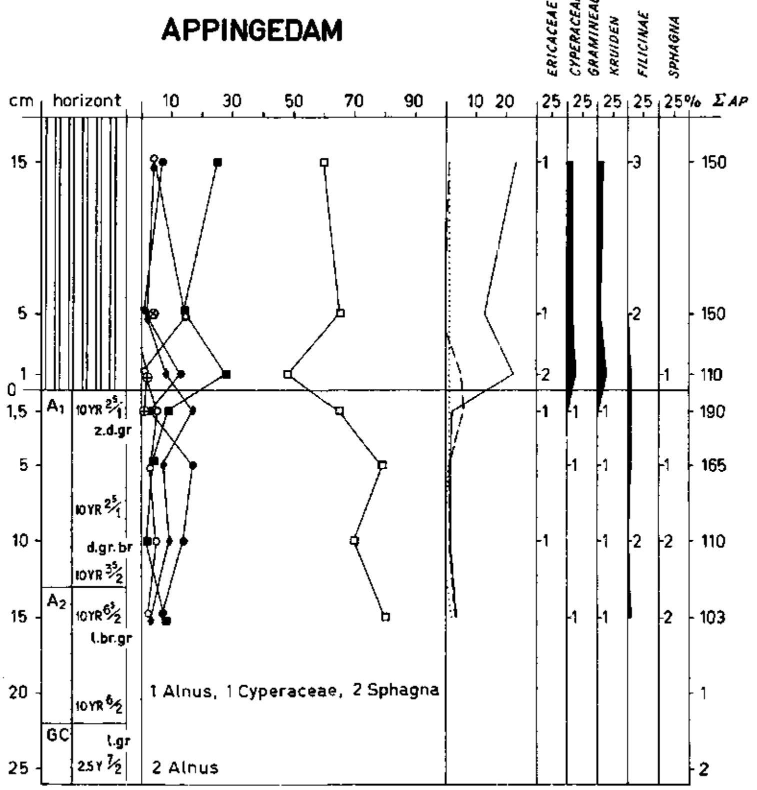

DELFZIJL III
cm
horizont
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA / GRAMINEAE > 40 μ
DRYOPTERIS LINNAEANA (?)
10 30 50 70 90
10 30
25 50 25 50 150 25 25 50 150 %
Σ
A1 10YR 4/1 d.gr
A2 10YR 5.5/1 gr
10YR 6/1
AB 10YR 4/1 d.gr
10YR 4/1
B2 7.5YR 3/2 d.br
7.5YR 3/2 d.br
7.5YR 4/3
BC 10YR 5/3 br
10YR 6/3
14 11 8 6 4 2 0 2 5 7 9 11 15 18 21 25 29 33 38
509
293
263
317

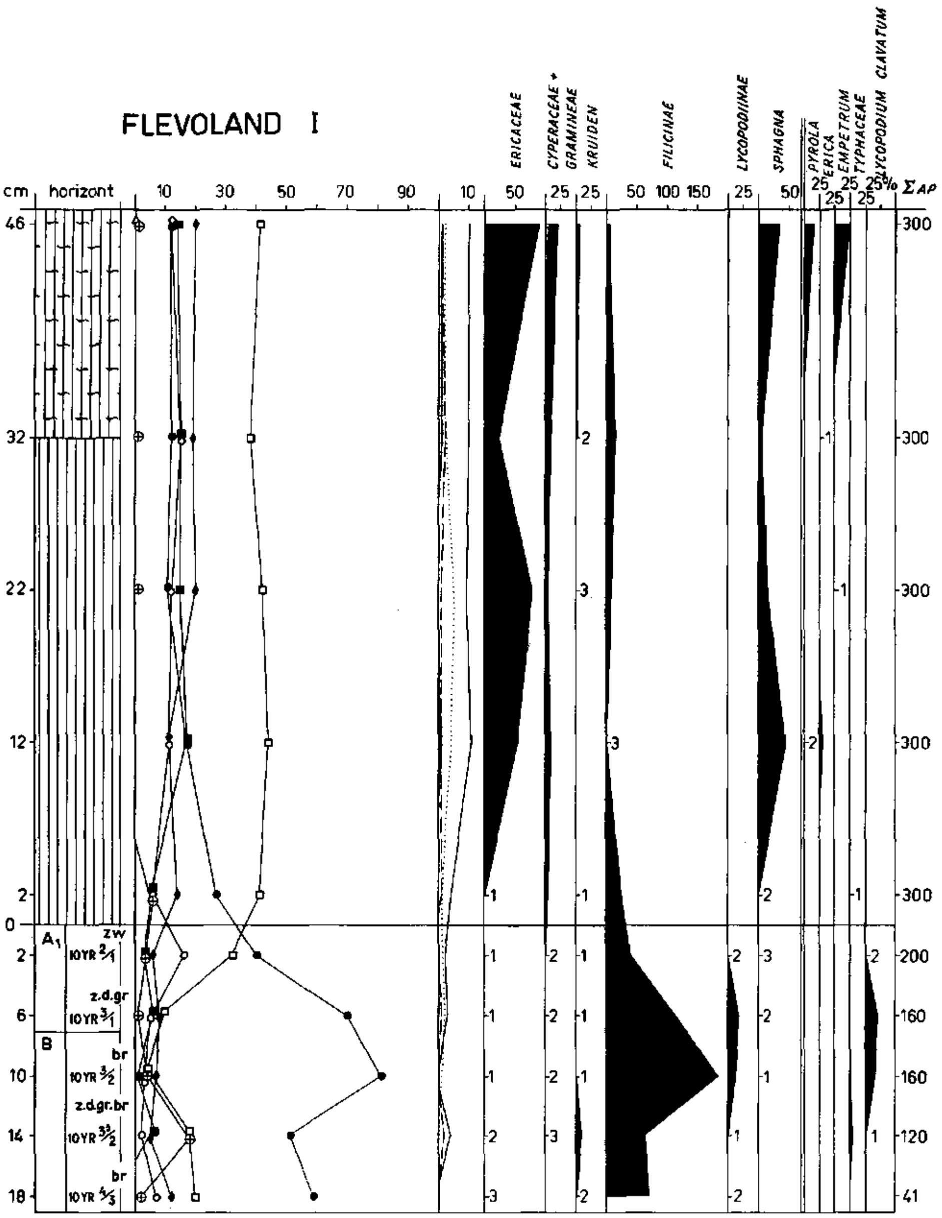

DELFZIJL IV
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
DRYOPTERIS LINNAEANA (?)
n
horizont
10 30 50 70 90
10 30
25 25 25 50 150 25 50%
APF
HUMUS %
Σ AP
A1
10YR 4/1
d.gr
10YR 5/1
A2
10YR 6.5/1.5
l.gr
10YR 6.5/1.5
AB
10YR 5/2
gr. br
B2
10YR 4.5/2
d.gr.br
10YR 4.5/2
10YR 4.5/2
BC
10YR 5/3
1 Pinus, 1 Gram., 2 Herbs, 1 Filicinae
1 Alnus, 1 Corylus, 1 Gramineae
1 Betula, 3 Pinus, 4 Gramineae
304
3500
1250
5
30
450
0,06
0,00
0,00
0,00
0,46
155
155
166
180
165
118
117
112
1
94
240
2
4

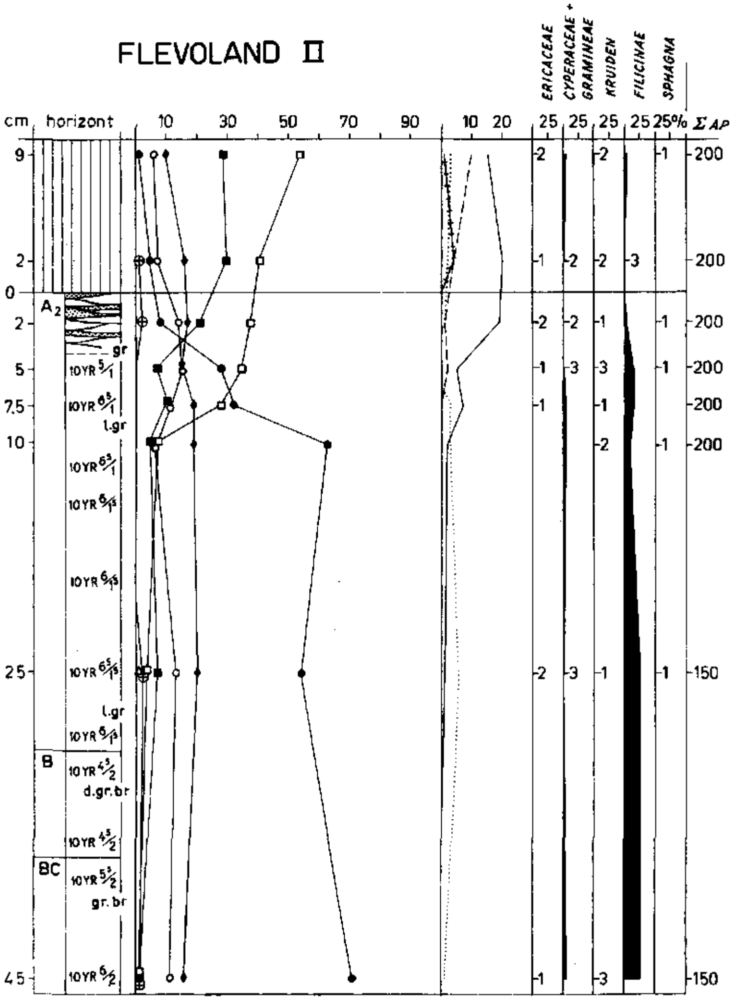
DELFZIJL V

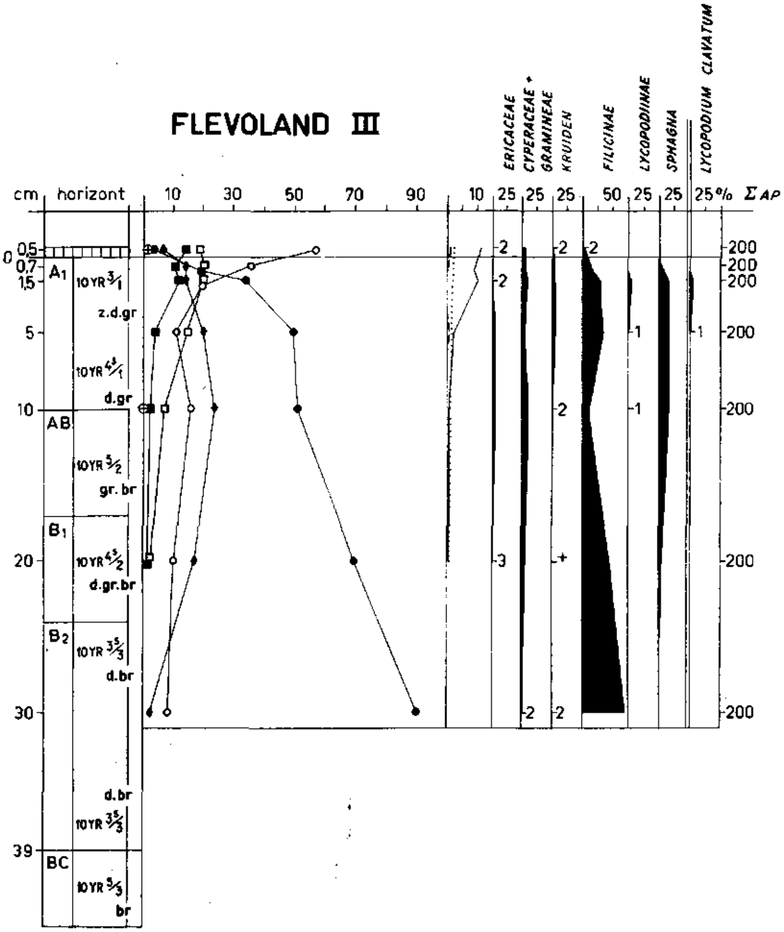


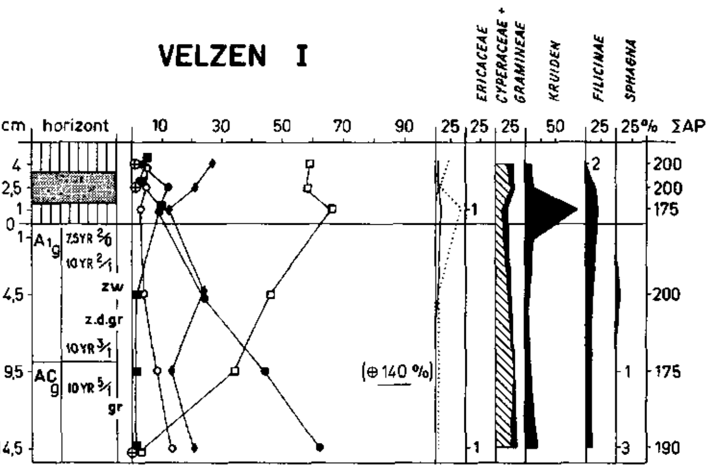
APPINGEDAM



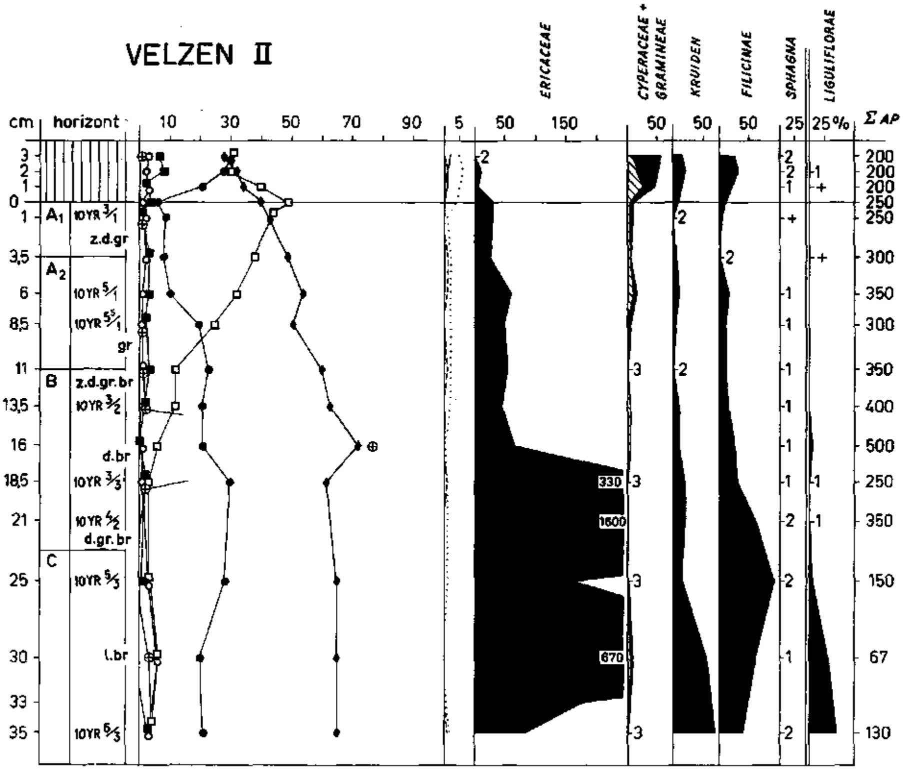

FLEVOLAND I
cm
horizont
10
30
50
70
90
10
50
25
25
50 100 150
25
50
25
25
25
25
25%
ΣAP
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
LYCOPODIINAE
SPHAGNA
PYROLA
ERICA
EMPETRUM
TYPHACEAE
LYCOPODIUM CLAVATUM
46
32
22
12
2
0
2
6
10
14
18
A1
B
zw
10YR 2/1
z.d.gr
10YR 3/1
br
10YR 3/2
z.d.gr.br
10YR 3/2
br
10YR 4/3
300
300
300
300
300
200
160
160
120
41


FLEVOLAND II
cm
horizont
10
30
50
70
90
10
20
25
25
25
25
25%
ΣAP
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
9
2
0
2
5
7,5
10
25
45
A2
gr
10YR 5/1
10YR 6.5/1
l.gr
10YR 6.5/1
10YR 6/1.5
10YR 6/1.5
10YR 6.5/1.5
l.gr
10YR 6/1.5
B
10YR 4.5/2
d.gr.br
10YR 4.5/2
BC
10YR 5.5/2
gr.br
10YR 6/2
200
200
200
200
200
200
150
150


FLEVOLAND III
cm
horizont
10
30
50
70
90
10
25
25
25
50
25
25
25%
ΣAP
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
LYCOPODIINAE
SPHAGNA
LYCOPODIUM CLAVATUM
0
0,5
0,7
1,5
5
10
20
30
39
A1
10YR 3/1
z.d.gr
10YR 4.5/1
d.gr
AB
10YR 5/2
gr. br
B1
10YR 4.5/2
d.gr.br
B2
10YR 3.5/3
d.br
d.br
10YR 3.5/3
BC
10YR 5/3
br
200
200
200
200
200
200
200
-2
-2
-3
-2
-2
-2
-+
-2
-2
-1
-1
-1

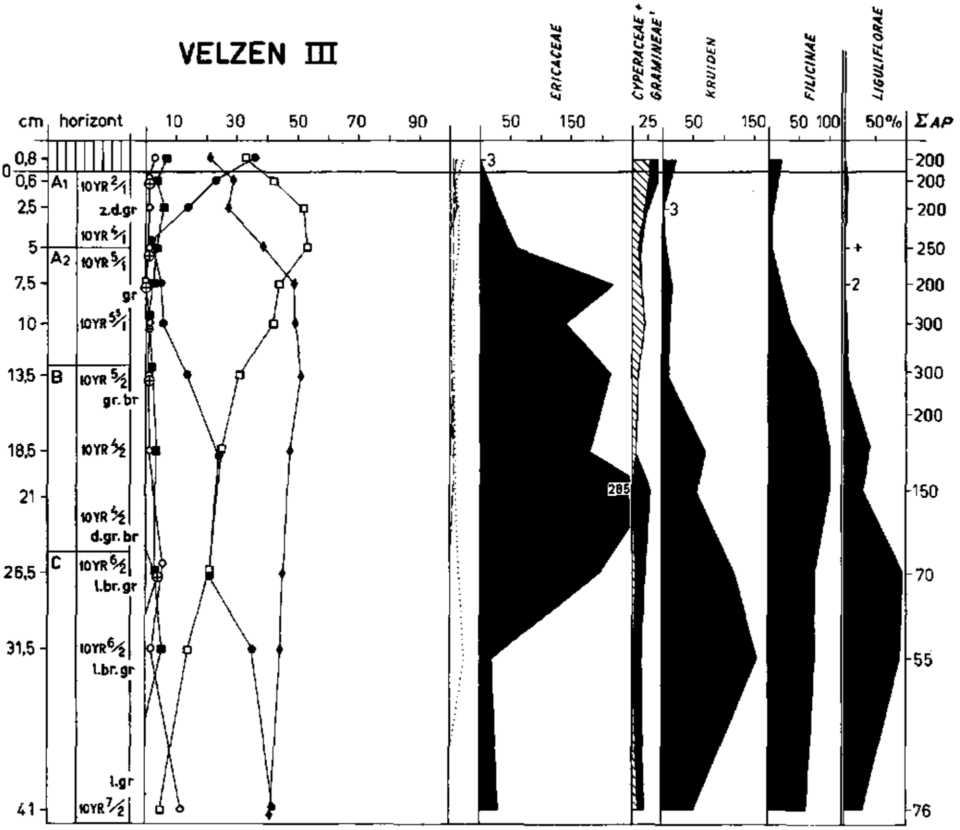


VELZEN I

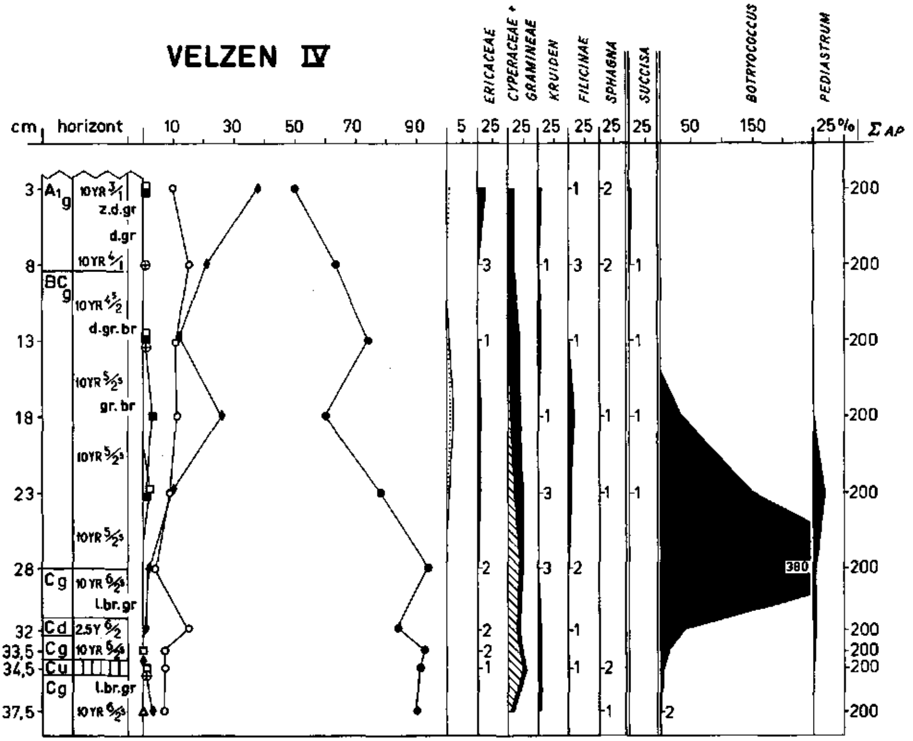


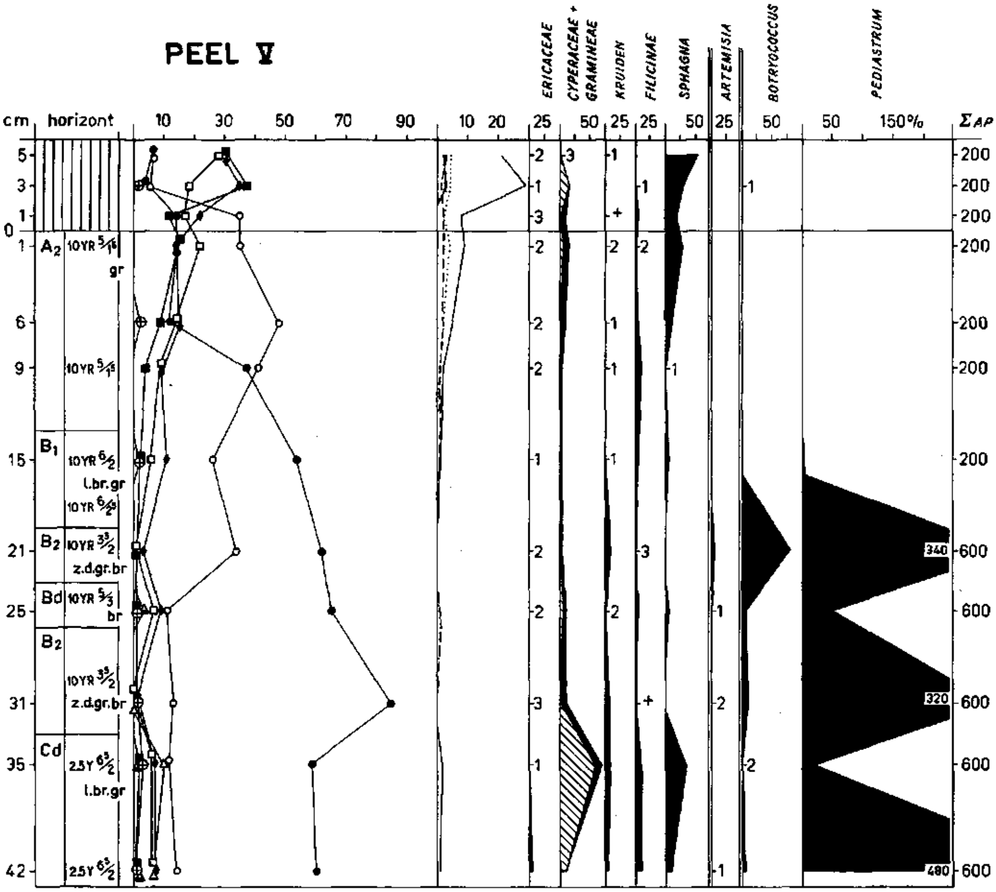
VELZEN II

VELZEN III



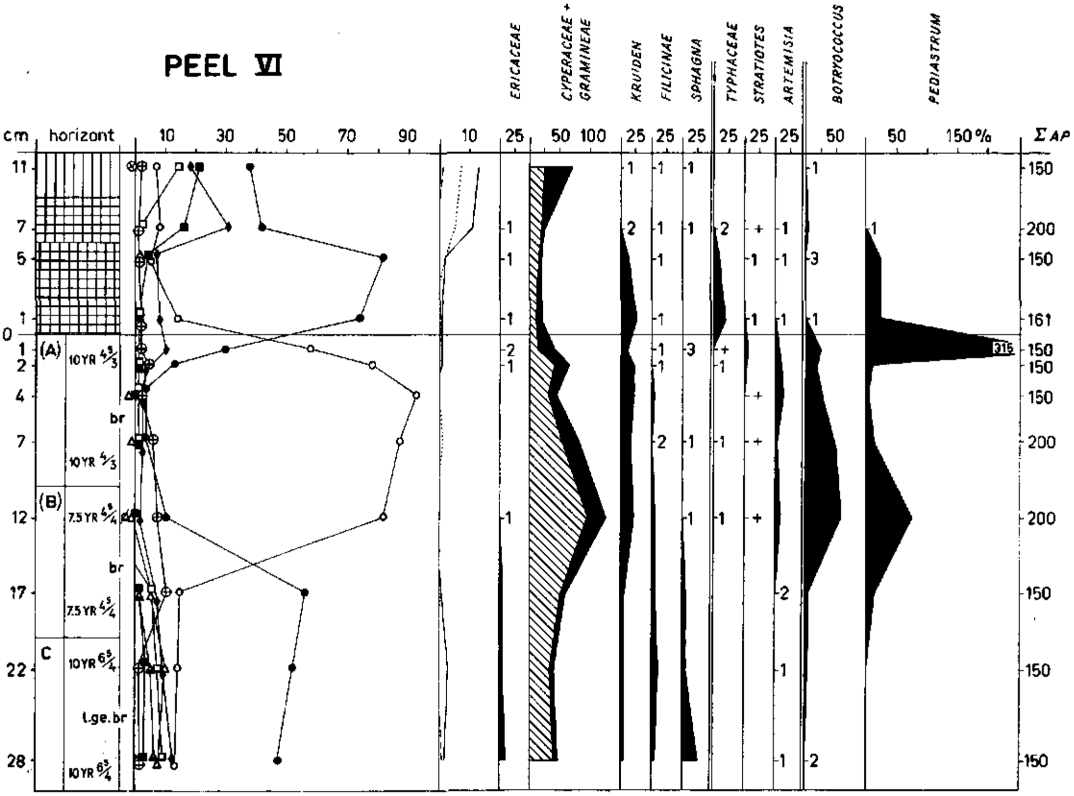
VELZEN IV

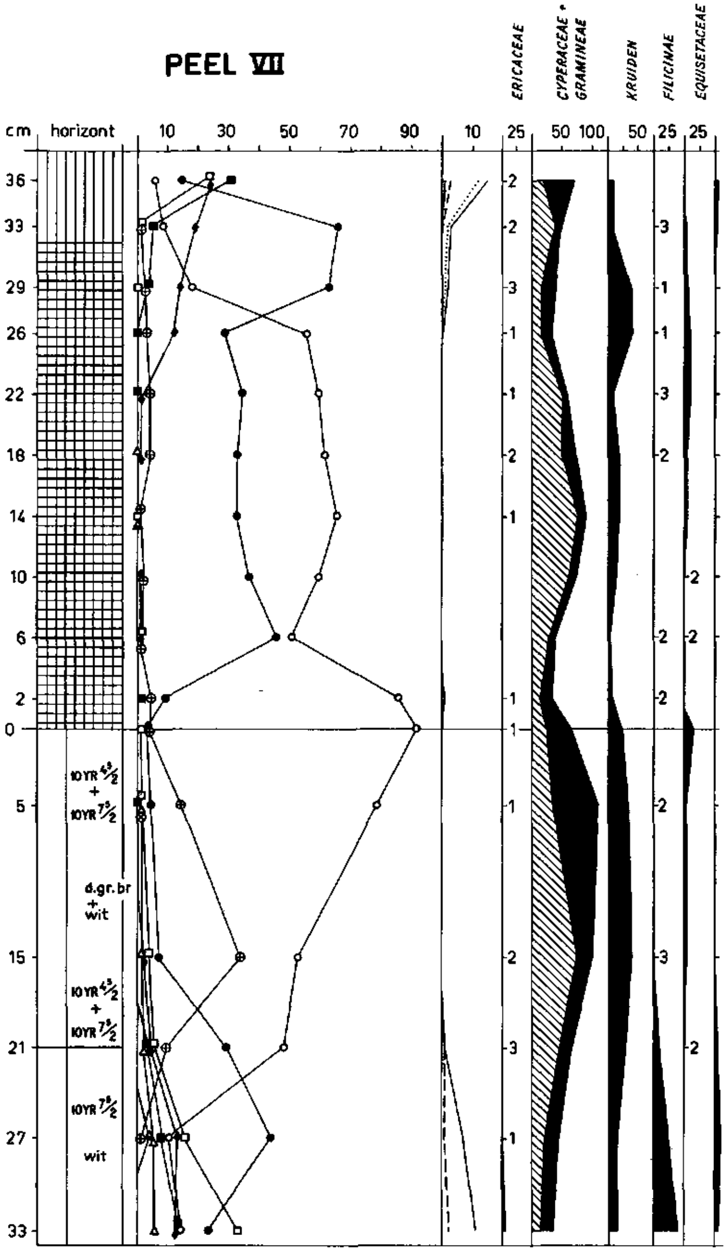




PEEL V

cm
horizont
10 30 50 70 90
10 20
25 50 25 25 50 25 50 50 150%
ΣAP
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
ARTEMISIA
BOTRYOCOCCUS
PEDIASTRUM
5
3
1
0
1
6
9
15
21
25
31
35
42
A2
10YR 5/1.5
gr
10YR 5/1.5
B1
10YR 6/2
l.br.gr
10YR 6/2.5
B2
10YR 3.5/2
z.d.gr.br
Bd
10YR 5/3
br
B2
10YR 3.5/2
z.d.gr.br
Cd
2.5Y 6.5/2
l.br.gr
2.5Y 6.5/2
340
320
480
200
600


PEEL VI
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
SPHAGNA
TYPHACEAE
STRATIOTES
ARTEMISIA
BOTRYOCOCCUS
PEDIASTRUM
cm
horizont
10 30 50 70 90
10
25
50 100
150 %
Σ AP
11
7
5
1
0
1
2
4
7
12
17
22
28
(A)
10YR 4⁵/3
br
10YR 4/3
(B)
7.5YR 4⁵/4
br
7.5YR 4⁵/4
C
10YR 6⁵/4
l.ge.br
10YR 6⁵/4
315
150
200
150
161
150
150
150
200
200
150
150
150


PEEL VII
ERICACEAE
CYPERACEAE + GRAMINEAE
KRUIDEN
FILICINAE
EQUISETACEAE
cm
horizont
10
30
50
70
90
10
25
50
100
50
25
25
36
33
29
26
22
18
14
10
6
2
0
5
15
21
27
33
10YR 4/2 + 10YR 7/2
d.gr.br + wit
10YR 4/2 + 10YR 7/2
10YR 7/2
wit
-2
-2
-3
-1
-1
-2
-1
-1
-1
-1
-2
-3
-1
-3
-1
-1
-3
-2
-2
-2
-2
-3
-2
-2
-2

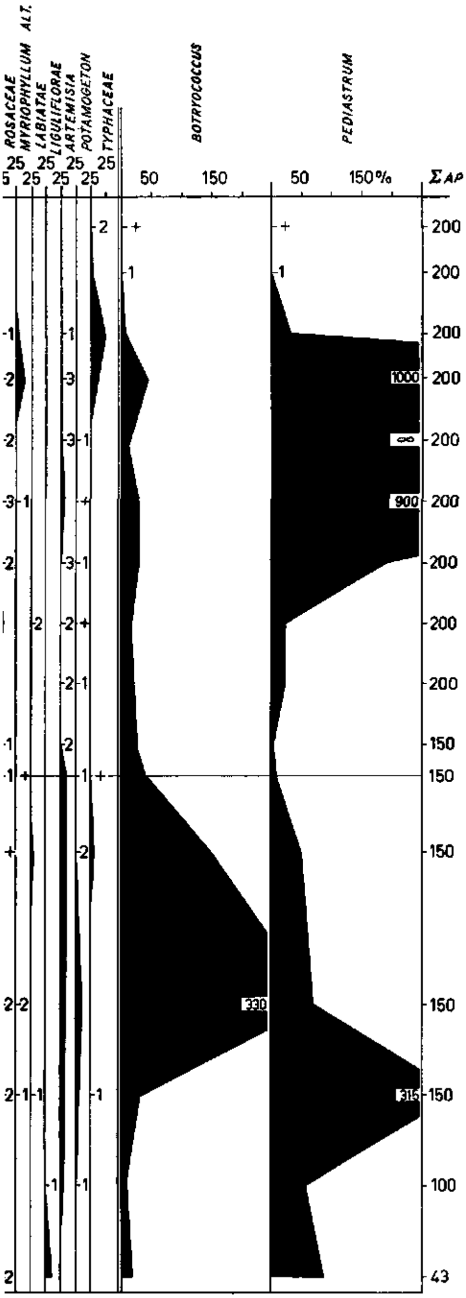

ROSACEAE
MYRIOPHYLLUM ALT.
LABIATAE
LIGULIFLORAE
ARTEMISIA
POTAMOGETON
TYPHACEAE
BOTRYOCOCCUS
PEDIASTRUM
5
25
25
25
25
25
25
25
50
150
50
150%
ΣAP
200
200
200
200
200
200
200
200
200
150
150
150
150
150
100
43
1000
∞
900
330
315

TABLE XI. Plantspecies which are not calculated in the pollen diagrams on account of low frequency

UDDELERMEER II

cm	Chenopodiaceae	Euphorbia	Ranunculaceae	Cruciferae	Hypericum	Rosaceae	Scrophulariaceae	Labiatae	Plantago lanceolata	Lonicera	Dipsacaceae	Succisa	Tubuliflorae	Artemisia	Pteridium	Polypodium	Lycopodium	Varia	
0																			
1	–	–	–	–	–	–	–	1	1	–	–	–	1	–	1	–	–	1	%
9	–	–	–	–	–	–	–	–	1	–	1	–	–	–	–	1	–	1	,,
19	+	–	+	–	–	1	+	–	1	–	–	1	1	–	–	–	–	–	,,
29	–	1	–	–	–	–	–	–	–	–	1	–	1	–	–	–	–	1	,,
39	–	–	–	+	1	1	1	+	1	–	–	1	+	–	1	–	–	+	,,
49	–	–	–	–	–	–	–	–	1	1	–	2	1	1	1	1	–	1	,,
56	–	–	–	–	–	–	1	–	–	2	–	–	1	–	1	–	–	–	,,
63	–	–	–	–	–	–	–	–	–	3	–	1	1	–	–	3	1	1	,,
70	–	–	–	2	–	+	–	–	–	–	–	–	–	–	2	2	2	2	,,

STAPHORST I

cm	*Juniperus*	Urticaceae	Polygonum	Chenopodiaceae	Caryophyllaceae	Ranunculaceae	Umbelliferae	Scrophulariaceae	Labiatae	Plantago lanceolata	Plantago maritima	Tubuliflorae	Liguliflorae	Centaurea cyanus	Potamogeton	Typhaceae	Lycopodium clavatum	Varia	
11	–	–	–	–	–	–	–	–	–	–	–	1	–	1	1	–	–	0	%
2	–	–	–	–	1	–	1	–	–	1	–	–	–	–	1	–	–	1	,,
	–	+	–	+	–	2	+	–	+	2	+	1	1	–	–	–	–	–	,,
0																			
2,5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	,,
5	–	–	–	1	1	–	–	–	1	1	–	–	–	–	–	–	–	1	,,
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	,,
15	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	,,
20	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	2	,,
25	–	–	–	–	–	–	–	–	4	–	1	–	–	–	–	–	–	–	,,
32	–	–	1	–	–	–	–	1	1	–	–	–	1	–	–	–	–	2	,,
42	1	–	–	–	–	1	–	1	–	–	–	–	–	–	–	–	1	3	,,

Staphorst II

cm	Myrica	Urticaceae	Chenopodiaceae	Caryophyllaceae	Ranunculaceae	Cruciferae	Hypericum	Rosaceae	Papillionaceae	Umbelliferae	Lysimachia	Scrophularia	Labiatae	Plantago maritima	Rubiaceae	Liguliflorae	Artemisia	Centaurea cyanus	Polypodium	Varia	
4,5	2	–	1	1	2	3	–	1	1	–	2	+	3	–	1	1	–	3	–	10	%
0,5	–	–	1	–	–	2	1	–	–	–	–	–	–	1	–	–	1	–	1	2	,,
0																					
2,5	–	–	–	–	–	1	–	–	–	–	–	–	–	1	–	1	–	1	–	4	,,
5	–	–	1	–	1	1	–	–	–	1	–	–	2	–	–	–	–	–	–	3	,,
7,5	–	–	–	–	1	1	–	–	1	–	–	–	1	–	–	–	–	–	–	3	,,
10	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	,,
20	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,,
30	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,,
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	,,

Epe I

cm	Chenopodiaceae	Umbelliferae	Plantago lanceolata	Tubuliflorae	Artemisia	Varia	
0,5	1	1	1	1	1	+	%
0							
3	–	–	–	–	–	–	,,
5	–	–	–	–	–	1	,,
8,5	–	–	–	–	–	1	,,

Epe II

cm	Chenopodiaceae	Caryophyllaceae	Ranunculaceae	Cruciferae	Papillionaceae	Onagraceae	Umbelliferae	Plantago major	Rubiaceae	Dipsacaceae	Artemisia	Centaurea cyanus	Potamogeton	Typhaceae	Pteridium	Polypodium	Lycopodium	Varia	
25,5	–	1	–	2	3	1	1	1	1	–	–	3	–	–	–	–	–	2	%
10	1	–	2	3	3	–	–	–	–	–	1	1	+	–	–	–	–	2	,,
5	1	–	1	–	–	–	1	–	–	–	–	–	–	1	–	–	–	1	,,
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	,,
0																			
0,5	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	,,
3	–	–	–	–	–	–	–	–	–	+	–	–	–	–	+	+	–	+	,,
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	2	,,
18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,,
26	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	,,
34	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	,,

EPE III

cm	Rumex	Chenopodiaceae	Ranunculaceae	Cruciferae	Rosaceae	Onagraceae	Umbelliferae	Convolvulus	Scrophulariaceae	Labiatae	Plantago lanceolata	Succisa	Tubuliflorae	Potamogeton	Typhaceae	Pteridium	Polypodium	Lycopodium	Varia	
7,5	–	1	2	–	–	1	1	1	–	–	3	–	–	–	3	–	–	–	2	%
4,5	–	1	–	–	–	–	–	–	–	–	1	–	–	1	1	–	–	–	1	,,
1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	2	,,
0																				
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,,
11	–	–	–	–	–	–	–	–	–	–	+	–	1	–	–	–	1	–	+	,,
21	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	,,
31	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	,,
40	–	–	–	1	–	–	–	–	–	1	–	–	2	–	–	–	–	–	1	,,
49	1	–	–	1	–	–	–	–	1	1	–	1	1	–	–	–	1	–	1	,,
59	–	–	–	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	,,
72	–	–	–	2	–	–	–	–	1	–	–	–	1	–	–	–	1	1	1	,,

PEEL I

cm	Caryophyllaceae	Ranunculaceae	Cruciferae	Rosaceae	Scrophularia	Labiatae	Plantago lanceolata	Tubuliflorae	Pteridium	Lycopodium clavatum	Varia	
21	–	–	–	–	–	–	–	–	–	–	–	%
11	–	–	–	–	–	–	1	–	–	–	–	,,
	–	–	–	–	1	–	1	–	1	–	1	,,
0												
5	–	–	–	–	–	–	–	–	–	–	–	,,
10	–	+	–	1	–	–	–	+	–	–	2	,,
15	–	–	2	2	–	–	–	–	–	–	1	,,
20	–	–	–	1	–	–	–	–	–	1	2	,,
25	–	1	–	–	–	1	–	–	–	1	–	,,
30	2	–	–	–	–	–	–	1	–	1	3	,,
37	1	–	–	–	–	–	–	–	–	–	2	,,
42	1	–	–	–	–	–	–	–	–	–	1	,,

PEEL II

cm	Rumex	Caryophyllaceae	Ranunculaceae	Cruciferae	Rosaceae	Umbelliferae	Labiatae	Plantago lanceolata	Botrychium	Lycopodium clavatum	Varia	
0,5	2	–	–	–	–	–	–	1	–	–	–	%
0												
5	–	–	–	–	–	–	–	+	–	–	–	,,
10	–	–	–	–	–	–	–	–	–	–	–	,,
15	–	–	–	–	–	–	1	–	–	1	–	,,
20	–	–	–	–	–	–	–	–	–	–	–	,,
25	–	–	–	–	–	–	–	–	–	1	–	,,
30	–	1	1	1	–	–	–	–	–	–	1	,,
35	–	1	–	–	1	1	–	–	1	–	–	,,
40	–	–	1	–	–	–	1	–	4	1	–	,,
45	–	–	–	–	+	–	–	–	+	+	–	,,

PEEL III

cm	Chenopodiaceae	Caryophyllaceae	Ranunculaceae	Cruciferae	Plantago lanceolata	Tubuliflorae	Botrychium	Polypodium	Lycopodium clavatum	Varia	
	1	–	–	–	2	–	–	–	–	1	%
0											
5	–	–	–	–	–	–	–	–	–	1	,,
10	–	–	–	–	–	–	–	–	–	–	,,
15	–	–	–	–	–	–	–	–	–	–	,,
20	–	1	–	–	–	–	–	–	–	+	,,
25	–	–	–	–	–	–	–	–	–	–	,,
30	–	–	–	–	–	–	–	–	–	+	,,
35	–	–	–	–	–	1	–	1	–	–	,,
39	–	1	1	–	–	–	–	–	–	1	,,
43	–	1	–	1	–	–	–	–	1	–	,,
48	–	1	–	–	–	–	–	–	–	–	,,
58	–	1	–	–	–	–	3	–	–	–	,,

PEEL IV

cm	Gramineae > 40µ	Chenopodiaceae	Caryophyllaceae	Ranunculaceae	Cruciferae	Onagraceae	Tubuliflorae	Polypodium	Pteridium	Lycopodium clavatum	Varia	
1	2	–	–	–	–	–	–	–	–	–	–	%
0												
4	–	1	–	–	1	–	–	–	–	–	–	”
9	–	–	–	–	–	–	–	–	–	–	1	”
14	–	–	–	–	–	–	–	–	–	1	+	”
19	–	–	–	–	1	–	–	–	–	1	1	”
24	–	–	1	1	1	–	+	–	–	1	2	”
29	–	1	3	–	–	–	–	–	–	–	1	”
33	–	–	1	–	–	–	–	–	–	–	–	”
38	–	–	1	–	1	–	–	–	–	1	–	”
43	1	–	–	–	–	–	–	–	–	–	–	”
48	–	–	1	–	–	–	–	–	1	–	–	”
53	1	–	–	–	–	–	–	–	–	–	2	”
58	1	–	–	–	–	–	–	2	–	1	–	”
63	–	–	–	–	–	1	–	2	–	3	1	”
71	–	–	1	–	–	–	–	2	–	–	–	”

FLEVOLAND I

cm	Myrica	Andromeda	Rumex	Chenopodiaceae	Cruciferae	Umbelliferae	Plantago major	Tubuliflorae	Potamogeton	Pteridium	Dryopteris linneana (?)	Varia	
46	2	1	–	2	–	1	–	1	1	1	–	–	%
32	–	–	–	+	–	–	–	–	2	1	1	–	”
22	–	–	–	2	–	–	–	1	–	1	1	–	”
12	–	–	–	–	–	–	–	–	–	2	–	–	”
2	–	–	–	–	–	–	–	–	–	–	–	–	”
0													
2	–	–	–	–	1	–	–	–	–	–	1	–	%
6	–	–	–	–	–	–	–	–	–	–	–	1	”
10	–	–	–	–	–	–	–	1	–	–	–	1	”
14	–	–	1	–	–	–	1	1	–	–	–	1	”
18	–	–	–	–	–	–	–	–	–	–	–	2	”

FLEVOLAND II

cm	Calluna	Erica	Gramineae > 40µ	Caryophyllaceae	Rosaceae	Umbelliferae	Scrophulariaceae	Tubuliflorae	Typhaceae	Pteridium	Dryopteris linneana (?)	Varia	
9	1	1	–	–	–	–	–	–	2	1	1	–	%
2	1	–	–	–	–	–	2	–	–	–	–	–	,,
0													
2	2	–	1	–	–	1	–	–	–	–	–	–	,,
5	–	1	–	–	–	–	+	1	1	–	1	+	,,
7,5	1	–	–	–	1	1	–	–	–	1	–	+	,,
10	–	–	–	–	–	–	–	1	1	–	–	–	,,
25	–	2	–	–	–	–	–	–	–	1	–	1	,,
45	1	–	–	1	–	–	–	2	–	–	–	–	,,

FLEVOLAND III

cm	Calluna	Erica	Thalictrum	Rosaceae	Scrophulariaceae	Labiatae	Rubiaceae	Valeriana	Tubuliflorae	Typhaceae	Pteridium	Dryopteris linneana (?)	Selaginella	Varia	
0,5	2	–	–	–	1	–	–	–	–	–	–	+	–	–	%
0															
0,7	–	–	1	–	1	–	1	+	+	–	–	–	–	2	,,
1,5	2	–	–	–	–	1	–	–	1	1	–	–	–	2	,,
5	5	–	–	1	–	–	–	–	3	–	–	–	1	1	,,
10	6	–	–	–	1	–	–	–	–	–	–	–	1	1	,,
20	2	1	–	–	–	–	–	–	–	–	1	1	–	+	,,
30	–	–	–	–	–	–	–	–	1	–	–	–	–	1	,,

VELZEN IV

cm	Erica	Cruciferae	Rosaceae	Filipendula	Papillionaceae	Myriophyllum	Umbelliferae	Labiatae	Plantago major	Plantago media	Valeriana	Succisa	Tubuliflorae	Liguliflorae	Artemisia	Potamogeton	Botrychium	Polypodium	Selaginella	Varia	
3	–	–	–	–	–	–	–	–	–	–	–	3	–	–	1	–	–	–	–	1	%
8	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	+	,,
13	–	1	1	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	1	,,
18	–	–	+	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	,,
23	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	1	–	–	1	,,
28	–	–	1	–	–	–	–	–	–	–	–	+	–	1	1	–	–	–	1	–	,,
32	1	–	–	–	–	1	–	–	–	–	1	–	1	–	1	–	–	–	–	1	,,
33,5	–	1	1	–	–	–	–	1	–	–	–	–	–	–	1	1	–	–	–	–	,,
34.5	–	–	–	1	1	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	,,
37,5	–	1	–	–	–	–	–	–	1	1	–	–	–	–	2	–	–	–	–	–	,,

PEEL V

cm	Calluna	Erica	Empetrum	Gramineae > 40μ	Chenopodiaceae	Caryophyllaceae	Ranunculaceae	Thalictrum	Cruciferae	Rosaceae	Umbelliferae	Scrophulariaceae	Labiatae	Menyanthes	Dipsacaceae	Tubuliflorae	Liguliflorae	Potamogeton	Stratiotes	Typhaceae	Pteridium	Polypodium	Equisetum	Selaginella selaginoides	Varia	
5	2	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	%
3	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	,,
1	3	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	,,
0																										
1	2	–	–	+	–	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	+	,,
6	2	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,,
9	2	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	+	,,
15	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	,,
21	1	1	–	–	–	–	1	–	–	–	+	–	1	–	–	+	–	–	–	–	–	–	–	–	–	,,
25	2	–	–	+	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	,,
31	1	–	1	–	–	–	+	+	–	1	–	1	+	+	–	–	–	–	–	–	–	–	–	–	–	,,
35	1	–	–	+	–	+	–	–	1	1	1	–	–	–	–	–	+	+	1	1	–	–	1	+	1	,,
42	4	+	–	+	+	–	–	–	–	1	–	1	–	–	1	–	–	–	–	–	–	+	–	+	–	,,

PEEL VI

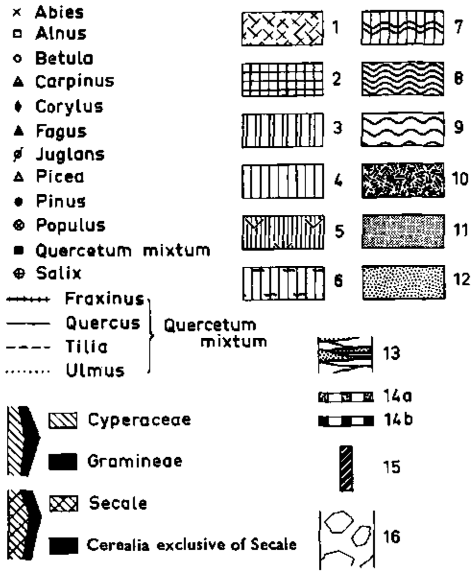
cm	Calluna	Erica	Empetrum	Gramineae > 40μ	Rumex	Polygonum convolvulus	Chenopodiaceae	Caryophyllaceae	Ranunculaceae	Thalictrum	Nuphar	Cruciferae	Helianthemum	Saxifraga oppositifolia	Rosaceae	Filipendula	Papillionaceae	Onagraceae	Myriophyllum	Myriophyllum alterniflorum	Umbelliferae	Scrophulariaceae	Labiatae	Plantago lanceolata	Plantago major	Plantago media	Menyanthes	Rubiaceae	Valeriana	Succisa	Tubuliflorae	Liguliflorae	Alismataceae	Potamogeton	Typha latifolia	Botrychium	Pteridium	Equisetum	Selaginella selaginoides	Lycopodium clavatum	Varia	
11	+	–	–	7	–	–	–	–	–	–	–	+	–	–	–	+	–	–	–	–	+	+	1	–	–	–	–	–	–	–	+	–	–	+	1	–	+	–	–	–	+	%
7	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	+	+	+	–	–	–	–	+	–	1	–	–	–	–	–	–	+	–	–	–	+	,,
5	–	–	–	–	–	–	–	–	–	–	–	+	–	–	+	–	–	–	–	–	1	+	–	–	–	–	–	–	–	–	–	+	1	–	1	–	–	–	–	–	–	,,
1	–	–	–	–	–	–	–	–	+	+	–	–	–	–	+	–	1	–	–	–	+	–	–	–	–	–	–	–	–	–	+	–	+	+	1	–	–	–	–	–	–	,,
0																																										
1	–	+	+	–	–	–	–	–	+	+	–	–	–	–	+	–	–	–	+	–	+	+	+	–	–	–	+	–	–	–	+	–	–	+	–	–	–	+	–	–	–	,,
2	+	+	–	–	–	+	–	–	1	1	–	+	–	–	+	+	+	–	–	–	1	1	–	–	–	–	+	–	–	–	2	1	–	–	–	–	–	–	–	–	2	,,
4	–	–	+	1	1	–	+	1	+	1	+	1	+	–	1	–	–	–	+	+	1	1	+	–	–	–	1	–	+	–	+	–	–	–	–	–	–	+	+	+	+	,,
7	+	–	–	–	–	–	–	–	+	1	–	–	+	–	1	+	–	1	+	+	1	+	–	2	–	–	1	+	+	+	+	+	–	1	+	1	+	+	–	+	2	,,
12	+	+	–	1	+	–	–	–	–	+	–	+	+	+	+	–	–	–	+	–	2	–	1	–	+	–	–	+	+	–	+	–	–	–	–	+	–	+	–	–	2	,,
17	5	–	–	+	–	–	+	–	1	–	–	+	–	–	1	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	,,
22	3	–	–	–	–	–	+	+	–	–	–	–	+	–	+	–	–	–	–	–	+	–	1	–	–	+	–	–	–	–	+	–	–	–	–	–	–	–	–	+	1	,,
28	8	–	–	–	–	–	–	–	–	–	–	+	1	–	1	–	–	–	–	–	–	1	2	–	–	–	–	–	–	–	+	–	–	+	+	+	–	+	–	–	1	,,

Peel VII

cm	Juniperus	Myrica	Vaccinium	Calluna	Erica	Empetrum	Gramineae > 40μ	Rumex	Rumex (Oxyria-type)	Chenopodiaceae	Caryophyllaceae	Euphorbia	Ranunculaceae	Nuphar	Papaveraceae	Cruciferae	Helianthemum	Hypericum	Saxifraga	Filipendula	Sanguisorba officinalis	Hippophaë	Lythraceae	Onagraceae	Myriophyllum	Umbelliferae	Hottonia	Scrophulariaceae	Scrophularia	Plantago major	Plantago media	Menyanthes	Rubiaceae	Valeriana	Tubuliflorae	Sagittaria	Stratiotes	Polypodium	Selaginella	Lycopodium clavatum	Varia	
36	–	–	–	2	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1	–	1	1	–	–	–	1	–	–	–	–	–	–	–	1	%
33	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1	,,
29	–	+	–	2	1	–	1	–	–	–	1	–	3	–	–	–	–	–	–	1	–	–	–	–	–	–	–	2	–	–	–	–	1	–	+	–	–	–	–	–	1	,,
26	–	–	–	1	–	–	1	1	–	–	+	–	2	–	+	1	–	–	–	1	–	–	–	–	+	+	–	2	–	–	–	1	–	–	–	1	–	–	–	–	1	,,
22	–	–	+	1	–	–	2	–	–	–	–	–	1	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	1	–	–	–	–	–	–	,,
18	1	–	–	1	1	–	1	1	–	–	–	–	1	–	–	+	1	–	–	–	1	–	–	–	1	+	–	1	–	–	–	1	+	1	–	–	1	–	–	–	–	,,
14	1	–	+	1	–	–	–	1	1	1	–	–	–	–	–	1	–	–	–	1	–	–	–	–	–	2	–	–	–	–	–	1	–	1	–	–	–	–	–	–	4	,,
10	1	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	2	–	–	–	–	–	1	1	,,
6	1	–	–	1	–	–	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	1	,,
2	1	–	–	–	–	–	1	–	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	,,
	1	–	–	1	–	–	1	1	–	–	–	–	–	1	–	–	1	?	–	–	1	–	–	1	–	1	–	–	–	1	–	1	1	–	–	–	–	–	1	–	–	,,
0																																										
5	–	–	–	–	–	–	2	–	–	–	–	1	–	–	1	+	–	–	–	–	–	+	–	–	1	2	–	1	–	–	–	1	1	–	2	–	–	–	–	–	1	,,
15	–	–	+	2	1	–	1	1	–	–	+	–	–	–	–	2	1	–	–	–	–	–	–	–	–	1	1	1	–	3	1	–	–	1	–	–	–	–	1	–	1	,,
21	1	–	–	3	–	–	–	–	–	–	–	–	3	1	–	2	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	1	1	–	–	–	–	3	,,
27	–	–	–	2	–	1	–	–	–	1	–	1	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	4	,,
33	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	2	–	–	–	,,

LIST OF POLLEN DIAGRAMS AND TABLES

LEGEND



+ less than 0,5% Kruiden = Herbs Horizont = Horizon

1. dy
2. gyttja
3. *Phragmites-Carex* peat
4. *Carex* peat
5. *Carex-Phragmites* carr peat
6. *Carex-Eriophorum* peat
7. *Carex-Sphagnum* peat
8. old *Sphagnum* peat
9. young *Sphagnum* peat
10. raw humus
11. clay
12. sand
13. washed-up dark grey and light grey sand layers (at Flevoland II)

14a. dark brown fibre (at Uddelermeer II)
14b. dark brown endurated fibre (at Epe II and III)
15. sand with charcoal (at Epe I, II and III)
16. layer of pebbles (at Uddelermeer II)

A_1, A_2, B_2, etc.: symbols for the profile horizons, see table II, p. 5
10 YR 3/1, etc.: indication of colour according to the "Munsell soil color charts"

Abbreviations (in Dutch) of the colour names
zw – black
gr – grey l.gr – light grey d.gr – dark grey z.d.gr – very dark grey
l.br.gr – light brownish grey
br – brown l.br – pale brown d.br – dark brown z.d.br. – very dark brown
gr.br – greyish brown d.gr.br – dark greyish brown z.d.gr.br – very dark greyish brown
ro.br – reddish brown d.ro.br – dark reddish brown
ge.br – yellowish brown l.ge.br – light yellowish brown d.ge.br – dark yellowish brown
l.gr.ge – very pale brown groengeel – greenish yellow
wit – white

LEGEND