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ON THE LATEGLACIAL AND POSTGLACIAL VEGETATION OF SOUTH LIMBURG (NETHERLANDS)

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CHAPTER I

INTRODUCTION

The history of the vegetation found in the southern part of the province of Limburg was up to now practically unknown. This is partly due to the scarcity of peat sediments which makes this region unattractive to palynologists. Compared with other parts of the Netherlands South Limburg shows in its soil as well as in its climate a particular character. The soil in the area investigated by us consists of limestone and of loess. For that reason and also on account of its somewhat different climate its vegetation presently differs conspicuously from that found in the other parts of the Netherlands. This suggests that the history of its vegetation will be different too.

It is not for the first time that peat deposits in South Limburg were made an object of palynological investigation.. BELDEROK and HENDRIKS described in 1953 the stratigraphy and palynology of a bog, situated near Sittard, i.e. on the northern border of South Limburg. Furthermore provisional investigations of peat samples obtained from some bogs were made between 1950–1957 at the "Botanical Museum and Herbarium", Utrecht. We mention samples of a bog in the valley of the "Rode Beek" between Schinveld and Gangelt, from a small bog on the heath at Brunssum, from peat deposits in the region of Voerendaal and from a small bog in the neighbourhood of Schinnen. It was clear already from the pollen diagrams obtained from these peat deposits, that the history of the vegetation of this part must have been different from that which could be established so far for other parts of the Netherlands. For instance the pollen diagram of a bog near Voerendaal shows very high percentages of *Tilia*, percentages that are not reached in any of the diagrams that have so far been obtained from deposits in the Netherlands.

For these reasons, in 1957 the investigation of peat deposits in South Limburg was started on a larger scale. With the exception of the bog near Schinnen, the already mentioned bogs were included in this investigation. Moreover the adjacent parts of Belgium and of Germany were also taken into consideration. As these regions show in geological and geographical respect the same character as South Limburg, it seemed desirable to include them too in the investigation.

GENERAL REMARKS WITH REGARD TO THE AREA INVESTIGATED BY US

Compared with the rest of the Netherlands South Limburg is a very hilly country. The average altitude is 150–200 m above sea level and in the most south eastern part of the region a row of hills reach altitudes of 270 m above sea level. In this respect South Limburg forms a transition between the Ardennes in the south and the low lying plains of the lower Rhine. The number of streams is not large. For that reason South Limburg gives us the impression of a rather extensive plateau, which is divided by the streams in a number of smaller ones. The most important differences in altitude are found along the borders of the plateaus. The landscape upon the plateaus is not hilly at all, but only slightly undulating. All the streams found in the region are tributaries of the river Maas, which flows through the western part of South Limburg. In South Limburg five streambasins are present, the most important of which are those of the Geul and the Geleen. Less important are those of the Worm, the Voer and the Rode Beek. Only the basins of the Geleen and of the Rode Beek are situated entirely on Dutch territory. The Voer is an entirely Belgian stream and the Geul rises in Belgium, but the lower course and part of the middle course of this stream are situated on Dutch territory. The Worm, finally, is almost completely a German stream. A part of it however, forms a portion of the eastern frontier of the Netherlands.

CHAPTER II

GEOLOGICAL STRUCTURE

The surface soil in the Netherlands consist for the greater part of sediments of holocene and pleistocene age. Only in the most eastern and southern parts of the country older sediments reach the surface.

As has been pointed out in the introduction, these soil conditions are partly responsible for the particular character of the flora of to day. Some aspects of the geology, in so far as they are of importance for the distribution and origin of the bogs and for the present vegetation, have to come up for discussion. However, it would take too much time to treat the geological structure of South Limburg in detail. For the comprehensive survey of its geology we refer to the handbooks dealing with the subject (FABER, 1942, 1948; PANNEKOEK, 1956).

SEDIMENTS OF PRE-TERTIARY AGE

The most important sediments in South Limburg consist of limestone deposited during the upper Senonian. These sediments reach the surface in many places, chiefly along the slopes of the valleys. However, these limestone sediments do not occur all over the region. Map 1 (p. 7–8) shows, in a simplified form, a map of South Limburg, drawn by VAN RUMMELEN and reproduced in JONGMANS, KRUL and VOS (1941); on this map all quaternary sediments are omitted. It shows that the limestone sediments are confined to the southern part of the region and to the adjacent part of Belgium. The limestone deposits are bordered in the north by a fault, known as the fault of Kunrade. The villages Locht, Kunrade and Klimmen are situated on this very fault. North of the fault of Kunrade the limestone disappears beneath tertiary sediments. To the south the area in which the limestone sediments reach the surface is bordered by a fault roughly running along the line Aachen–Verviers. South of this fault sediments of Devonian and Cambrian age reach the surface.

Between the two faults the limestone does not form a closed cover. In the first place they have disappeared because of the eroding action of the rivers. This is observed chiefly in the valley of the Berwinne and in the upper part of the valley of the Geul, where older sediments reach the surface. Secondly because the original stratification has been disturbed by a number of smaller faults.

The sediments which preceded the upper Senonian ones consist of clay and sand from the Hervien and Aachenien (lower Senonian and of schists and sandstones from the Carboniferous). The Aachenien is a coast sediment deposited at a time when the sea did not yet cover South Limburg so completely as it did during the upper Senonian.

The Hervien the socalled "greensand of Vaals", is a sediment which was formed after a transgression of the sea. Between Aachenien and Hervien we find therefore a basis conglomerate. The Hervien consists of clay and sand layers which show a green colour owing to the presence of a ferro compound. Permian, Triassic and Jurassic are lacking in South Limburg. Sediments from these periods have been removed completely by erosion.

It depends on the intensity of the erosion which of the earlier mentioned sediments reach the surface. If we ascend the slopes of the valley of the upper Geul, we meet successively Carboniferous, Aachenien, Hervien and Senonian. The Gulp has incised itself less deeply; only the Hervien reaches the surface here.

Sediments of tertiary age

In contrast to the region south of the fault of Kunrade the borders of the geological formations in the northern part of South Limburg are determined completely by the presence of faults. The most important ones are the Feldbiss, the Sandgewandt and the fault of Heerlerheide. On account of the faults the geological map of this region has the aspect of a patchwork quilt. All the sediments reaching the surface here are of tertiary or quaternary age.

Oligocene. Oligocene sediments are almost completely lacking in the southern part of South Limburg. Only locally the erosion has left some rests of them on the plateaus. These sediments are covered here by sediments belonging to the upper terrace and by loess. In the northernmost portion of the southern part of South Limburg these sediments are sometimes exposed, for instance on the heigher parts of the Ubaghsberg and along the slopes of the lower Geul. We wish to draw special attention to a definite stratum of the lower Oligocene, the *Cerithien clay*, the name of which refers to the presence of *Cerithium plicatum*. The Cerithian clay is of importance because a number of little brooks owe their existence to this impermeable layer. Middle-Oligocene clay is present as well.

Miocene. South of the fault of Kunrade sediments dating from the Miocene are lacking. However in the northern part of South Limburg they are well developed. They consist of very fine granular sands, in which brown-coal layers are present. The Miocene sediments reach the surface on the heath of Brunssum i.e. between Heerlen and Brunssum. The north-east border of the area in which Miocene is exposed is the Feldbiss, a NW-SE running fault. North of this fault the Miocene disappears under Pliocene and Quaternary sediments. The south-west border of the Miocene is formed by the fault of Heerlerheide. However, even south of this fault a thin cover of Miocene sands may locally be present.

Pliocene. Pliocene sediments are almost entirely restricted to the most north-eastern part of South Limburg. Everywhere else these sediments have been removed almost completely. Only on the already mentioned Ubaghsberg the erosion has left some rests of them. The Pliocene is represented here by a terrestrial sediment, deposited by the Rhine, and consisting of coarse sands alternating with layers of gravel and clay.

Sediments of quaternary age

During the Pleistocene the size of the streams varied considerably. Periods with a strong erosion alternated with periods, in which sand was deposited. In this way terraces arose. Roughly speaking we distinguish in South Limburg in the valley of the Maas three terraces: viz. the upper, the middle and the lower terrace. In each terrace a number of steps may be present (Zonneveld, 1955).

The upper terrace is widespread. It covers almost everywhere the older sediments, except in the most north-eastern and in the south-eastern parts of South Limburg and on the complex of the Ubaghsberg. In these three regions the younger sediments have not yet been removed by erosion at the time in which the upper terrace was formed. In later periods the Maas did not reach these parts. The upper terrace consists mostly of coarse gravel, sometimes of sand and rarely of clay. The material was derived from the Ardennes. Only in the eastern parts of South Limburg Rhine gravel occurs. The lime content of these sediments is very low. They may reach a considerable thickness, but usually it is about 10 meter.

In the period, following that in which the upper terrace was formed, the rivers incised themselves to a depth of about 60 meter; along the slopes of these old river beds older sediments are now exposed. After this time a new period of sedimentation set in. Important parts of the valleys were filled up with the sediments of this so-called "middle terrace", which consist of the same material as those of the upper terrace. In the next period the middle terrace in its turn was incised, and when the erosion slowed down, the lower terrace was deposited. The lower terrace is only a few meters thick. The rivers incised themselves to a depth which lies below the base of the upper terrace. Therefore we do not find sediments belonging to the terraces at the bottom of the valleys. A map showing the position of the terrace sediments has been given by Van Rummelen (1942a).

Loess. The loess, a finely granular, permeable, yellow-brown sediment covers the older sediments with the exception of those which form the lower terrace. It may reach a considerable thickness (up to 18 m). Loess is in this part of Europe not restricted to South Limburg; it is present in Germany, in Belgium and in the northern parts of France as well.

According to several authors (Druif, 1927; Van Doormaal, 1945; Vink, 1949) loess is an aeolian sediment, originating from the moraines in the north. The air-borne character of the loess finds its expression in its finely granular texture; it is a typical dust sediment (Dechering, 1936). Moreover the loess has no resemblance at all to underlying sediments. Van Rummelen (1925, 1942) supposes that the loess is a weathering product not of the moraines, but of the limestone.

Weathering products of limestone are doubtless present in South Limburg. A fairly coarse product is the "Kleveneerd", a clay soil which is displaced over a short distance only. The kleveneerd occurs mainly on slopes where the loess disappeared. A coarser product which does not undergo any horizontal displacement at all is the "flinteluvium". According to Van Rummelen the finest weathering product of the limestone is the loess, which has been displaced over a greater distance than the kleveneerd. From a botanical point of view it is not necessary to pay much attention because the kleveneerd deposits usually do not exceed 60 cm in thickness. Owing to the high lime content of the kleveneerd the vegetation on it bears a strong resemblance to the vegetation found on pure limestone. Nature and distribution of the kleveneerd has been studied by BRETELER (1951).

The loess did not stay in the places where it had been deposited. During the lateglacial and postglacial periods a strong displacement took place. First, there was a displacement of the soil under the glacial and lateglacial conditions prevailing at the end of the Pleistocene, at which time the frozen soil slid down along the slopes (solifluction); in this way the loess was mixed with other deposits. This came to an end in the earlier part of the Holocene, for then the soil was covered by dense forest, so that there can have been no displacement of any importance. A second displacement took place in the later part of the holocene in which man began to play an important rôle. Man began to clear the forest and this resulted in a strong displacement of the soil. The displaced soil has generally been described under the name colluvial soil.

According to VAN NISPEN TOT PANNERDEN (PANNEKOEK, 1956) a complete loess sediment consists of three strata. At the base of the sediment we find a stratum which proves to be deficient in lime. The second stratum consists of strongly displaced material; it often contains layers of sand, boulders and shells of tertiary age. In the uppermost stratum which is usually thicker than the two others, we distinguish a layer containing lime ("erdmergel") and a layer from which the lime has been removed. This uppermost layer *i.e.* the layer which is deficient in lime, has a brown colour. It has apparently not been leached very strongly up to now (DOORMAAL, 1945), since the highest percentage of colloids occurs here. For this reason the top soil is the most fertile stratum of the loess deposit (EDELMAN, 1950).

The loess deposit is almost never complete. By solifluction and erosion a part of the sediment disappeared. In case of a strong erosion the "erdmergel" or even material of the terraces are exposed. Especially the borders of the plateaus show such a strong erosion.

Near the Dutch-Belgian frontier and outside the region of the terraces of the Maas the loess deposit often proves to be interrupted. Here areas covered with loess are alternating with areas without loess. The flat areas still have a top soil of loess; the slopes, on the other hand, have a top soil of loam intermingled with flints: the "flinteluvium". This soil must be regarded as a weathering product of rocks dating from the Senonian. A second region where loess is lacking is the region north of Heerlen. Here Miocene and Pliocene sand reach the surface.

Colluvial soils. According to DECHERING (1936) the loamy soils at the bottom of the valleys consist for the greater part of transported loess.

CHAPTER III

PEAT DEPOSITS

One of the most important factors in the development of peat is a sufficient supply of water. For this reason we will begin with some remarks in the water balance of the region.

In the limestone area in the southern part of South Limburg the number of brooks is, as a rule, small. On account of the good drainage in the limestone and in the loess, the rain water does not flow off along the surface. The limestone and loess are very permeable (JONGMANS, KRUL and VOS, 1941) and on account of this there is in these soils an important flow of groundwater. Moreover the floes of limestone are connected with each other. For that reason, the distance over which water can be transported is fairly large. On account of the great permeability of the limestone, almost all valleys in the southern part of South Limburg are dry. Nevertheless, a number of brooks are present. The latter owe their existence to the presence of an impermeable layer. The most important ones are the clay belonging to the Hervien and the Cerithien clay of the Oligocene. These layers, therefore, are of importance for the origin of springs.

The Hervien is the impermeable layer which is responsible for the existence of the Gulp, the Voer, the Eyserbeek, the Berwinne and many of the small tributary brooks of the upper Geul. The geological map shows that in their upper course these brooks have incised their bed in clay belonging to the Hervien.

The Cerithien clay is responsible for the streams arising north of the Geul between Valkenburg and the Maas (KLEIN, 1913). The northern side valleys of the Geul that are found east of Valkenburg and the southern side valleys of the Geul are dry, because in these parts no impermeable layers occur. Therefore the Geul may be regarded as a true limestone river.

The Geleen belongs to an other type of river, because it has several tributary brooks. KLEIN (1913) explained the difference between Geul and Geleen by the presence of tertiary clay north of the fault of Kunrade. The groundwater in the limestone which flows to the north, would be dammed up by the tertiary clay. Only a part passes; the latter surplus appears in the form of springs at the surface. We refer to the work of JONGMANS and VAN RUMMELEN (1935) for a survey of the impermeable layers found in South Limburg.

Our considerations on the natural drainage system in South Limburg indicate that in the southern part of this region, the conditions for the formation of peat must be regarded as extremely unfavourable. The formation of peat is not dependent upon the rainfall alone, but upon the evaporation and the structure of the soil as well. As the evaporation and the rainfall certainly are not unfavourable, the differences in the structure of the soil are in South Limburg the most important factor in the development of peat. On account of the great porosity of the soil, the ground water in the southern part of this region is found at a great depth. For this reason the soil is dry, warm and well aerated; the organic material in it is destroyed completely by the activity of aerobic bacteria. Hence that bogs are lacking here.

However, north and south of the southern part of South Limburg other conditions prevail. Here too the level of the phreatic surface is deep, but as has been mentioned before, here impermeable layers are present, and these layers supply the surplus of water that is necessary for the development of peat. The water surplus prevents the activity of aerobic bacteria, and results in the long run a shortage of oxygen (LUNDEGARDTH, 1957). However, if we consult the geological map, we find that the number of bogs is very small. The geological map

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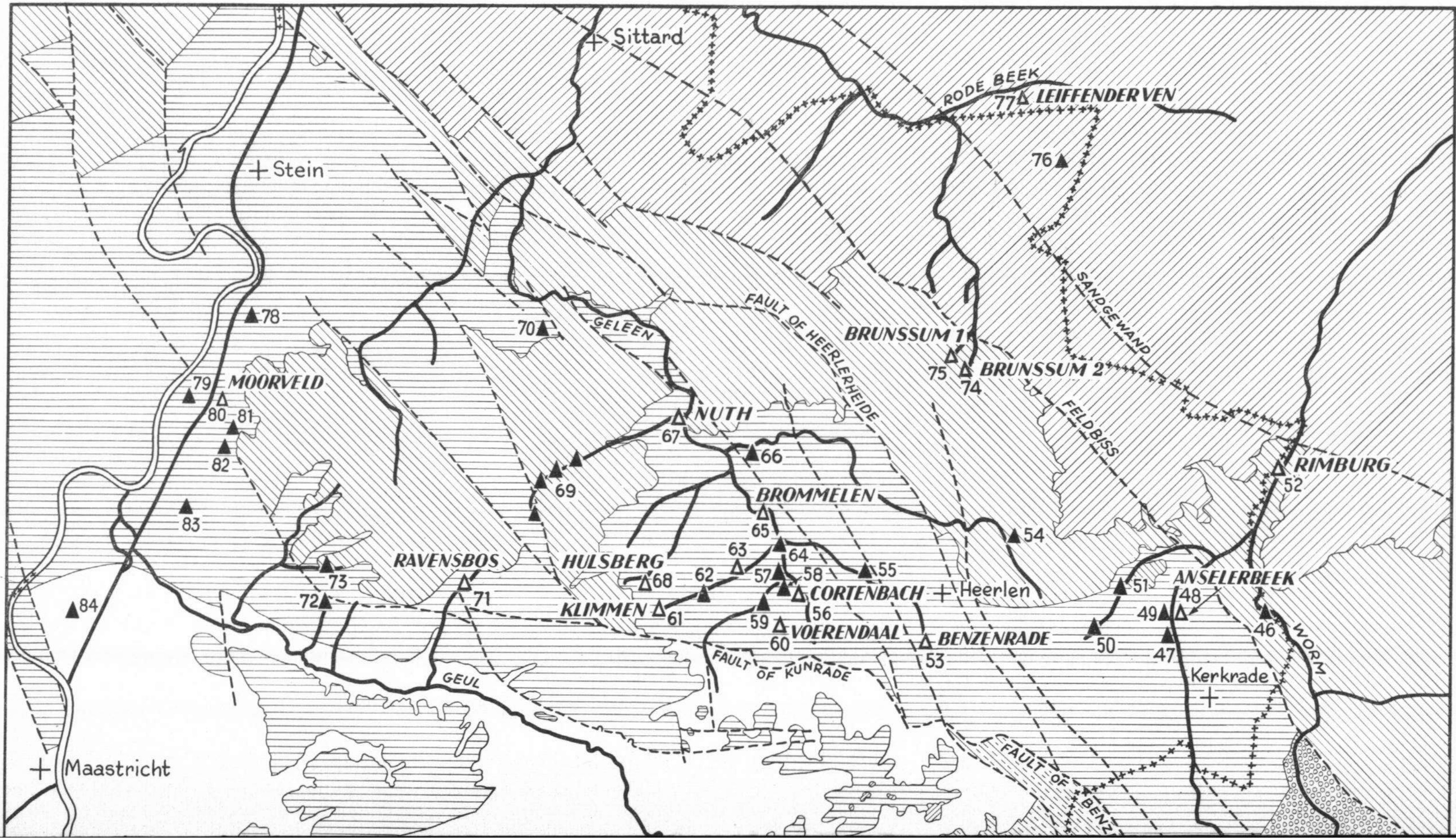
Map 1. Geological map of the underground of South Limburg and adjacent regions. Quaternary sediments have been omitted. Simplified from the map given by F. H. van Rummelen (JONGMANS, KRUL and VOS, 1941). △: peat present. ▲: localities with stagnating water and springs without peat.


Sittard
Stein
Maastricht
Heerlen
Kerkrade
RODE BEEK
77 LEIFFENDERVEN
76
SANDGEWAND
FAULT OF HEERLERHEIDE
BRUNSSUM 1
BRUNSSUM 2
75
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FELDBISS
RIMBURG
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GELEEN
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VOERENDAAL
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BENZENRADE
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FAULT OF KUNRADE
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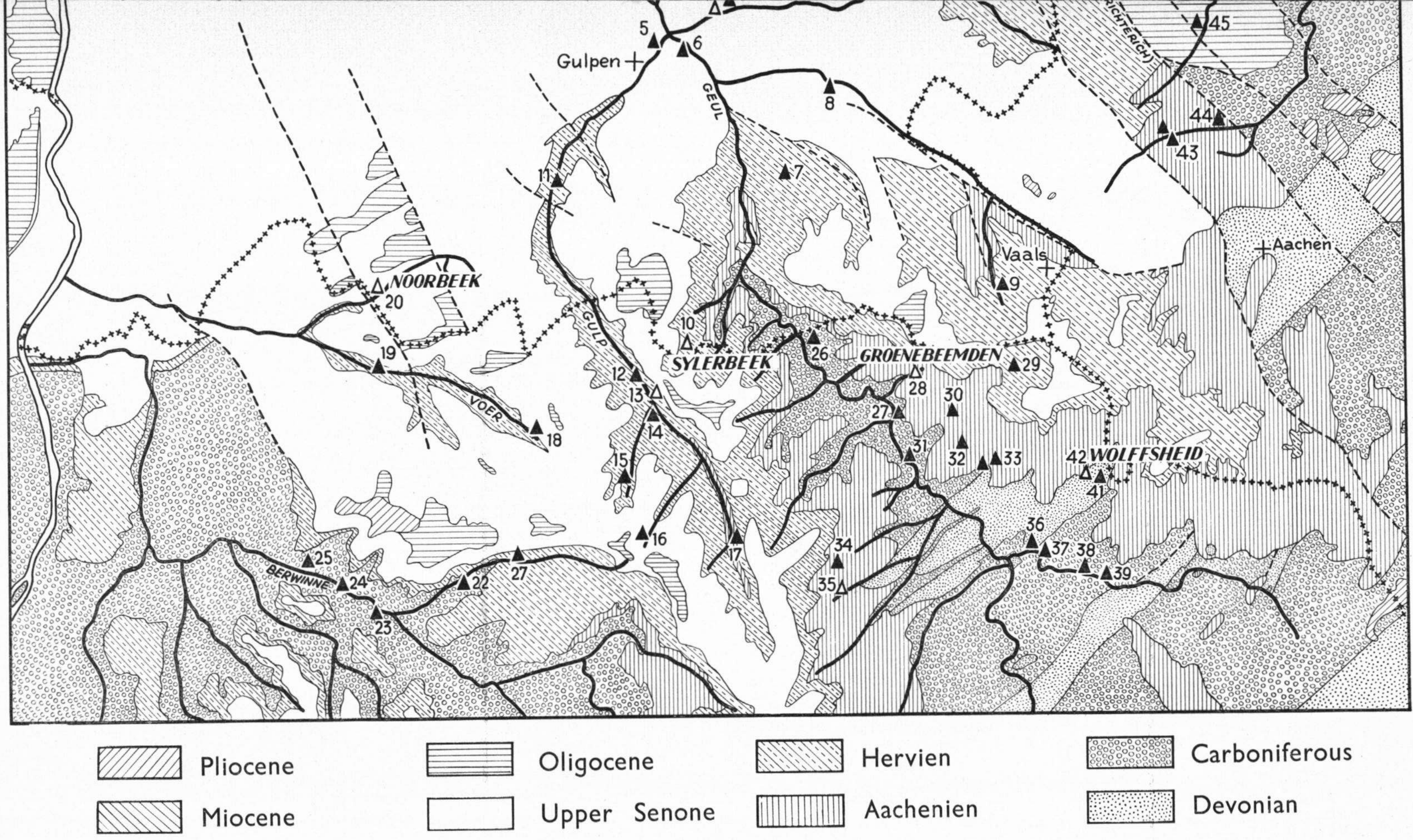

Gulpen
GEUL
GULP
VOER
NOORBEEK
SYLERBEEK
GROENEBEEMDEN
WOLFFSHEID
BERWINNE
Vaals
Aachen
Pliocene
Miocene
Oligocene
Upper Senone
Hervien
Aachenien
Carboniferous
Devonian

shows three sites where fen peat has developed. These sites are: 1) Leiffenderven, in the north-eastern part of South Limburg, 2) the spring area of the Rode Beek, 3) the area round Voerendaal. We supposed that these localities would not be the only ones. Indeed we found north of the fault of Kunrade several places where peat is present. The size of these bogs is mostly very small. For that reason they are not marked on the geological map. As a result of the dryness of the soil on the plateaus, bogs are lacking here completely. They are restricted to the valleys. The origin of the bogs is mostly topogenic; they may arise, for instance, in the spring areas of the valleys, or in branches of rivers, that have been cut off from the present bed. This position at a low level is from a palynological point of view a disadvantage, for on this account the development of peat did not proceed undisturbed; often the peat became mixed with sand or clay, deposited by brooks; sometimes the development of the peat ceased temporarily; and in case of a very strong erosion, parts of the peat deposit were swept away. For that reason some pollen diagrams may show gaps. In this respect, the conditions for a palynological investigation are in the bogs of South Limburg much less favourable than in an extensive raised bog.

At this time practically all bogs are overgrown with *Alnus*, with the exception of a small number of bogs, where *Alnus* has been cleared, and which have now been converted into meadows. For this reason the tracing of bogs means an investigation of the *Alnus* bushes in the valleys.

We saw already, that peat deposits are lacking south of the fault of Kunrade. It was originally our plan to trace bogs as near as possible to the limestone area. This ideal had to be given up. Almost all the bogs prove to be situated north and north east of the limestone area. A second region with peat deposits is present in the basin of the upper Geul. However, the region of the upper Geul is not by far so important as the region north of the fault of Kunrade.

A survey will follow now of all the sites investigated for the presence of peat; in this survey sites with and without peat are included. In the survey South Limburg has been devided into four parts: the limestone district, the loess district, the valley of the Maas and the valleys of the Berwinne and of the upper Geul. In each district the sites are arranged valley after valley. The numbers in the survey refer to the map on which all the quaternary sediments have been omitted (Map 1).

LIMESTONE DISTRICT

EYSERBEEK

1. Springs of the eastern slope of the valley, small *Alnus* wood between Broek and Prickart . . . clay
2. Forest near Bulkensmolen . . . . clay
3. Springs south of the forest of Eys . . . . clay
4. *Alnus* bush along the Eyserbeek, south of the railway embarkment . . . . 40 cm peat, not included

GEUL

5. *Alnus* bush on the west side of the Gulp . . . . clay

6. *Alnus* bush opposite the "Oude Geul" . . . . . clay
7. Spring south of Mechelen . . . . clay

Sinselbeek

8. Marshy meadows east of Wahlwiller . . . . . clay

Zieversbeek

9. Spring of the brook; *Alnus* bush . . . . clay

Sijlerbeek

10. Spring of the brook; *Alnus* bush . . . . peaty clay

Gulp

11. Marshy meadow near the castle of Karsveld . . clay
12. Marsh south of the castle of Teuven . . . . . clay
13. *Alnus* bush north of the railway Visé-Moresnet . clay, peat, not investigated
14. *Alnus bush*, mouth of the brook of Remersdael . clay
15. Spring of the brook of Remersdael . . . . . . lime, loam
16. Spring of the brook of Mabroek . . . . clay
17. *Alnus* bush north of Gulpen . . . . clay

Voer

18. *Alnus* bush south of Krindael . . . . clay
19. Marshy places around the castle of Ottegroeven clay
20. *Alnus* bush, south-west of Noorbeek . . . . . . peaty clay: Noorbeek

BERWINNE AND UPPER GEUL

Berwinne

21. Marshy meadow west of Neer-Aubel . . . . . clay
22. Spring near Kreft . . . . clay
23. *Alnus* bush east of Herwière . . . . clay
24. *Alnus* bush on the east side of the Berwinne . . clay
25. *Alnus* bush south-east of Têchereux . . . . . . clay

Upper Geul

26. Marshy meadow near Sippenaken . . . . . . clay
27. Flat area east of Plombières . . . . clay
28. Spring near Groenebeemden, *Alnus* bush . . 80 cm peat: Groenebeemden
29. *Alnus* bush near Bosselaar . . . . sand
30. *Alnus* bush south-west of Gemmenich . . . . . clay
31. Marshy meadow east of Op de Geul, east side of the Geul . . . . clay
32. Marshy meadow east of Eiksken . . . . clay
33. *Alnus* bush near Boschhuizen . . . . clay
34. Marshy meadow near the castle of Broich . . . clay
35. Marshy places around the castle of Streversdorp 20 cm peat, not investigated
36. *Alnus* bush near Nieuw Moresnet. . . . . . . clay
37. Marshy places along the road Nieuw Moresnet-Hergenrath . . . . clay
38. Marshy meadow with springs between Hergenrath and Astenet. . . . . clay
39. *Alnus* bush along the Geul. . . . . clay
40, 41. Marshy meadows south of the road Nieuw Moresnet-Aachen . . . . clay
42. Spring north of Wolffsheid; *Alnus* bush . . . . 100 cm peat: Wolffsheid

LOESS REGION NORTH OF THE FAULT OF KUNRADE

Worm

43, 44. Marshy meadows east and west of the road Heerlen-Aachen, upper Worm . . . . clay

45. *Alnus* bush in the valley of the Anselerbeek south of Banck	clay
46. Meadow in the valley of the Worm near Haanrade	clay
47. Marshy meadow in the valley of the Anselerbeek, north of the castle of Oud-Ehrenstein. . . .	clay
48. *Alnus* bush in the valley of the Anselerbeek. . .	100 cm peat: Anselerbeek
49. Marshy meadows west of Anselerbeek.	clay
50. Sheets of water near Streithagen	coal, dust
51. *Alnus* bush west of Hopel	clay
52. Meadow in the valley of the Worm near Rimburg	140 cm peat: Rimburg

GELEEN

53. Spring of the Geleen near Benzenrade	60 cm peat: Benzenrade
54. Marshy meadow near the ruin of Schaesberg .	clay
55. Wood near Eykendermolen	clay, loess
56. *Alnus* bush near the castle of Cortenbach . . .	100 cm peat: Cortenbach
57. *Alnus* bush near Puttendermolen	clay
58. *Alnus* bush north of the railway station of Voerendaal	clay
59. Marshy meadow near the castle of Puth. . . .	clay
60. Meadow east of the castle of Haaren	80 cm peat: Voerendaal
61. Springs of the Retersbeek; *Alnus* bush	30 cm peat: Klimmen
62. Meadow in the valley of the Retersbeek near Nieuw-Hof	clay
63. *Alnus* bush near Retersbeek	10 cm peat, not investigated
64. *Alnus* bush near the castle of Rivieren	clay
65. *Alnus* bush near Brommelen in the valley of the Geleen	300 cm peat: Brommelen
66. Meadow opposite the castle of Hoensbroek . .	clay
67. *Alnus* bush near Nuth.	280 cm peat: Nuth
68. Spring of the Hulsberg brook near Hulsberg, *Alnus* bush	60 cm peat: Hulsberg
69. *Alnus* bushes along the Platsbeek	clay
70. Marshy meadow and *Alnus* bushes near Spaubeek	clay
71. Spring in the Ravensbos, *Alnus* bush	60 cm peat: Ravensbos
72. *Alnus* bushes near Raar	clay
73. Marshy places near Waterval	clay

RODE BEEK

74. Springs of the Rode Beek	90 cm sand: Brunssum 2, 3
75. idem	80 cm peat: Brunssum 1
76. *Alnus* bush near Vosbroek	clay
77. Meadow in the valley of the Rode Beek between Gangelt and Schinveld	300 cm peat: Leiffenderven

VALLEY OF THE MAAS

78. *Alnus* bush near Terhagen	clay
79. Meadow near Huis Geulle	clay
80. *Alnus* bush near Moorveld at the watermill . .	20 cm peat: Moorveld
81, 82, 83. *Alnus* bushes in the Armenbos and Bunderbos	clay
84. Marshy meadow near Borgharen	clay

In addition to these sites we visited part of Belgium situated to the north-west of South Limburg. Loess is lacking here, and the region is therefore scarcely inhabited. For the greater part it is occupied by heath and pine woods. No peat of any importance has been found.

A glance on the map 1 (p. 7–8), on which the quaternary sediments have been omitted, shows that many bogs are concentrated in the valley of the Geleen, especially in the triangle Ravensbos-Heerlen-Nuth. In this very triangle sediments of Oligocene age are present at a slight depth below the surface. The impermeable clay of this layer is perhaps responsible for the fact that here more bogs are occurring than elsewhere. Bogs which probably owe their existence to this layer are Ravensbos, Hulsberg, Klimmen, Nuth, Brommelen, Voerendaal, Cortenbach, and Benzenrade.

CHAPTER IV

PRESENT ASPECT OF THE VEGETATION

There are doubtless many factors which may exercise an influence on the vegetation, but we will confine our attention here to climate, soil and human interference.

Climate

The climate in South Limburg is atlantic though with some continental and submontane features. The submontane character of the climate appears clearly in the annual precipitation.

According to figures, compiled by DE LEEUW (1935), the annual precipitation in South Limburg increases from west to east simultaneously with the increase in altitude in that direction. In the western and nothern parts the main annual precipitation is about 650 mm. In the most south-eastern part it increases to 900 mm. The continental feature of the climate is of secondary importance only. We find it especially in the lower western and northern parts of the region. These parts have a maximum rainfall in July and belong to that region of the european continent in which summer rains prevail. In the other parts of South Limburg the precipitation is distributed more or less evenly over the year.

Soil

From a plantgeographical point of view the area investigated here belongs to the atlantic province of the Euro-Siberian North American region. In our area moreover plantgeographical districts may be distinguished (VAN SOEST, 1934):

1. the cretaceous district south of the fault of Kunrade. It comprises all the localities where limestone reaches the surface. We refer to the map given by DIEMONT and VAN DER VEN (1953). Owing to local particularities of the climate as well as on account of the character of the soil a number of thermo- and neutrophytes are present. These two groupes of plants represent the central-european feature in the vegetation. Many thermo- and neutrophytes find on the warm and dry slopes suitable growth conditions.
2. the loess district, north of the fault of Kunrade. The loess district too possesses some thermo- and neutrophytes but here their number is smaller than it is in the cretaceous district.

FOREST ASSOCIATIONS

Owing to the particular character of the soil, in South Limburg forest associations are present that are almost completely absent in the other parts of the Netherlands. However on account of the rich soil, a large part of the forests have been destroyed by man. Especially in medieval times, but even earlier, large tracts have been cleared. The only places where at present woods occur are 1) the less rich soils; 2) those slopes which are too steep to be used for agricultural purposes. Among the remaining forest the following types are represented: (Jongmans and Diemont, 1942; Diemont, 1944; Van Leeuwen and Doing Kraft, 1955, 1959).

Forest on rich soil.

1. *Associations belonging to the Carpinion*

At the foot of the slopes we often find a deposit of loessoid loam. In case this layer is well drained, *i.e.* when it is not too thick and when it covers limestone or sand, the wood belongs to the *Querceto-Carpinetum fraxinetosum* (*typicum*). Among the trees in this wood we may mention *Quercus*, *Acer*, *Carpinus* and *Fraxinus*. In South Limburg a number of variants of this subassociation are present (Van Leeuwen and Doing Kraft, 1955). A second type is the *Querceto-Carpinetum loniceretosum* (*stellarietosum*), occurring on slightly leached loess loam (Westhoff, 1951).

On account of the slightly leached soil, acidophilous species occur in this type of forest: *Betula verrucosa*, *Oxalis acetosella*, *Maianthemum bifolium*, and others. According to Diemont (1955), in earlier times these types of woods will have occurred on the plateaus too. A third type of wood is confined to the cretaceous district: the *Querceto-Carpinetum orchidetosum*. We find this type of forest on places where limestone reaches the surface. Usually limestone reaches the surface in the middle part of the slopes, where it is covered, however, by a thin layer of loess or "kleveneerd". It is especially in this type of wood, that we find the neutro- and thermophytes (*Clematis* and several orchids). Usually it is less dense than the *Querceto-Carpinetum fraxinetosum* and *loniceretosum*.

When forests of this type are felled, a *Mesobrometum* takes its place; this association has to be considered therefore as a regressive stage of the *Querceto-Carpinetum orchidetosum*. If mowing or grazing by cattle ceases, a forest of the original type returns (Diemont and Van der Ven, 1953; Schwickerath, 1944).

A fourth and fifth type of forests are the *Querceto-Carpinetum saniculetosum* and the *Querceto-Carpinetum melicetosum*, the former belonging to the group of rich associations of which the *Querceto-Carpinetum fraxinetosum* is an other example, the latter to the group of less rich associations, which is represented also by the *Querceto-Carpinetum loniceretosum*. In both types of wood *Fagus* may occur. The associations of the *Carpinion* occur on soils older than the Holocene but usually not on sandy soils. Nowadays in South Limburg the forest associations of the *Carpinion* are present on the lower and middle part of the slopes (Van Leeuwen and Doing Kraft, 1955), and usually along the slopes a zonation of the associations mentioned before is to be found (Barkman, 1948). The *Querceto-Carpinetum loniceretosum* is present on the higher parts of the slopes; below this zone we find the *Querceto-Carpinetum* *orchidetosum*, whereas the wood at the foot of the slopes has the character of the *Querceto-Carpinetum fraxinetosum*.

On account of the high content of nutrients in the soil, a B-zone is almost completely lacking in the stratification. Only the stratification in the soil of the *Querceto-Carpinetum loniceretosum* may show a B-zone (*stellarietosum:* JESWIET and DE LEEUW, 1933; WESTHOFF, 1951). Under the influence of man the woods belonging to the *Querceto-Carpinetum* have often been changed into shrub vegetations (*Prunetalia*). The *Querceto-Carpinetum* may be degraded into the *Carpino-Prunetum* (*Rubion subatlanticum*) or into the *Pruneto-Ligustretum* (*Berberidion vulgaris*). The *Pruneto-Ligustretum typicum* is connected with the *Querceto-Carpinetum fraxinetosum;* the *Pruneto-Ligustretum orchidetosum* with the *Querceto-Carpinetum orchidetosum.* As mentioned before, in case of a complete destruction the latter association is replaced by the *Mesobrometum.*

2. *Associations belonging to the Alno-Ulmion*

The associations belonging to the Alno-Ulmion are present on Holocene, more or less wet and mineral soils, which do not show distinct stratification (see p. 55). In South Limburg these types of wood are found at the bottom of the valleys. According to VAN LEEUWEN and DOING KRAFT (1959), proceeding from the *Querceto-Carpinetum fraxinetosum* zone towards the brook we find successively associations belonging to the *Ulmion*, the *Alnion incanae* and to the *Salicion.*

On account of the high measure to which the soil which supports the *Salicion* has been brought in culture, in South Limburg, only fragments of the *Salicetum triandrae-viminalis* and of the *Saliceto-Populetum* are still present. The *Salicion* represents the initial phase in the succession, which starts on the sediments deposited by the brooks. The soil on which these types of woods occur, are characterized by the high frequency of the yearly inundations. In case of less frequent inundations the succession leads to associations belonging to the *Alnion incanae* (cf. the *Querceto-Carpinetum filipenduletosum* p.p. and the *Alnion glutinosae* p.p.

In the *Alnion incanae* a beginning development of peat may be present. The *Alnion incanae* comprises the following associations: in the first place the forest found near the springs with fast running water which contains a high content of oxygen; this is the *Cariceto remotae-Fraxinetum* a forest on minerogenous soil, in which *Fraxinus* usually is dominant, though sometimes together with *Alnus glutinosa.* A second representative of the *Alnion incanae* is the *Pruneto-Fraxinetum* (cf. *Querceto-Carpinetum filipenduletosum* p.p.) which occurs on alluvial soils along the brooks. The *Pruneto-Fraxinetum* is a forest of *Fraxinus*, mixed with *Quercus robur*, *Alnus glutinosa* and *Corylus avellana; Carpinus* may be present too (transition to the *Carpinion*), just as *Salix.* The association is bordered towards the brook by the *Cariceto remotae-Fraxinetum.* The latter forms a fairly broad zone along the brooks. At the surface of the soil a thin layer of peat may be present here. The areas, in which this type of wood occurred have been turned almost completely into hayfields. The *Macrophorbieto-Alnetum* (cf. *Querceto-Carpinetum filipenduletosum* p.p. and *Alnion glutinosae* p.p.) occurs in the same sites as the *Pruneto-Fraxinetum*, but it shows a stronger relationship to the *Alnion glutinosae*. In this type of forest *Alnus* is dominant; it occurs together with *Fraxinus*, *Quercus* and a little *Salix*. *Fraxinus* may become dominant where the soil is better drained. The *Macrophorbieto-Alnetum* is present in sites with a high phreatic surface (at a depth of 1–4 dm), provided that the groundwater does not run. The peat layer is on the average somewhat thicker than it is in the *Pruneto-Fraxinetum* (3 dm) (MAAS 1959).

Associations belonging to the *Ulmion* and represented in South Limburg are the *Fraxino-Ulmetum*, a forest on young calcareous sediments, and the *Stachyeto-Quercetum* (cf. *Querceto-Carpinetum stachyetosum*). In this type of forest especially *Quercus* and *Fraxinus* occur mixed to some extent with *Alnus* and *Ulmus*. The association resembles the *Carpinion* by the occasional occurrence of *Carpinus*. The soil may show a beginning of a zonation.

The associations of the *Alno-Ulmion* may degrade into associations belonging to the *Prunetalia* in the same way as the associations of the *Carpinion*. Associations belonging to the *Prunetalia* but derived from the *Alno-Ulmion* are the *Sambuco-Prunetum* (*Rubion subatlanticum*) on neutral to slightly acid soil, and the *Sambuco-Ligustretum* (*Berberidion*) derived from the *Fraxino-Ulmetum*.

According to VAN LEEUWEN and DOING KRAFT (1955) the succession from the *Salicion* and from the *Alnion incanae* runs along two ways. A first possibility is the succession to the *Alnion glutinosae*. On low sites the water stagnates, and an accumulation of peat starts (see page 57). A second possibility is the succession over the *Ulmion* in the direction of the *Carpinion*. The inundations become less frequent by the increase in thickness of the sediments deposited by the river. In case of a complete cessation of the inundations, out of the *Ulmion* a *Carpinion* may arise. At this stage of the succession the maturing of the soil starts (see page 55).

3. *Associations belonging to the Alnion glutinosae*

These types of forest occur on soils with a high phreatic level (at an average depth of ca 30 cm). The water usually stagnates. We distinguish the following associations and subassociations: the *Cariceto elongatae-Alnetum typicum* and the *Cariceto elongatae-Alnetum cardaminetosum amarae*, the latter subassociation occurring in the spring areas of the brooks. In case a thick layer of peat has developed in a site which became gradually less marshy, the forest is the *Thelypterideto-Alnetum* (to-day absent in South Limburg). Finally we have to mention the *Betuleto-Salicetum* (see page 17).

In the associations of the *Alno-Ulmion* and the *Alnion glutinosae* the stratification of the soil often shows a gley horizont. Usually the reaction of the soil is neutral. The upper layer of the *Stachyeto-Quercetum* (*Querceto-Carpinetum stachyetosum:* WESTHOFF and MELTZER, 1942) may show an acid reaction, but by the rise of the phreatic surface in winter a sufficient supply of nutrients is safe-guarded.

Forest on poor soil

A number of sites in South Limburg have a soil which shows an acid reaction. They are:

1. The sand of the terraces found along the borders of the plateaus, in places where the loess has been removed;
2. The "flinteluvium" found in the southern parts of the area; especially between Vijlen and Vaals a great forest complex is still present.
3. Rests of tertiary deposits spared by the erosion (Ubaghsberg).
4. The part north of Heerlen, where sands of the Miocene and Pliocene age reach the surface.

The soil in the first three sites supports an association of the *Violeto-Quercion:* the *Querceto-sessiliflorae.* This type of forest shows in the undergrowth submontane elements, *viz. Luzula luzuloides* and *Luzula silvatica.* Among the trees *Quercus petraea* and *Betula* are dominant. From the shrub layer we mention *Frangula alnus, Sarothamnus scoparius, Rubus spec., Corylus avellana* and *Sorbus aucuparia.* Among the herbs several acidophilous species occur; e.g. *Maianthemum bifolium, Teucrium scorodonia, Convallaria majalis* and *Pteridium aquilinum.*

The largest stretch of land with an acid soil reaction, is the part north of Heerlen. The leading association found in this part is the *Querceto-Betuletum* (*Vaccinio-Quercion*). In this association *Quercus petraea* is replaced by *Quercus robur.* The soil is in this wood type usually more or less leached out. A B-zone is always present. A third forest type present in the part north of Heerlen is the *Betuleto-Salicetum* (*Alnion glutinosae*), an association on very wet, sandy and minerogenous soils.

These types of wood are as a rule highly influenced by man who planted several exotic trees (e.g. *Robinia pseudoacacia* and *Quercus americana*) and *Pinus silvestris.* Where the wood has been felled the soil is occupied by species belonging to the *Calluneto-Genistetum.* Typically acidophilous representatives of this association are *e.g. Calluna vulgaris, Genista anglica, Sarothamnus scoparius* and *Rumex acetosella.*

The poor soils in South Limburg are usually recognizable from afar by the presence of *Pinus, Sarothamnus* and *Calluna.* If we inspect a forest map of the region, the soil conditions are clearly revealed in the distribution of the trees, especially of *Pinus.* Examples of differences in the vegetation found on different soil types has been given by VAN RUMMELEN (1936).

We mentioned already the influence of human interference. Indeed, especially in South Limburg man strongly influenced the character of the forest. As we have seen already the forest which once covered the soil has been cleared, and artificial monocultures have taken its place. The associations of the *Alno-Ulmion* and the *Alnion glutinosae* have usually been transformed into hayfields; the associations of the

Carpinion into orchards and the associations of the *Quercion* into fields, on which cereals and other crops are grown.

The present woods which for one reason or another were spared did not remain uninfluenced by man. Especially when the forest has been thinned out the light requiring species obtain a better chance in the struggle for life. This is one of the reasons which make it unlikely that the present woods show a fully natural aspect. To contribute to the solution of this problem is one of the aims of the present work.

CHAPTER V

MATERIALS AND METHODS

Field work

At present no bogs are into exploitation. Therefore it is not possible to take samples from perpendicular walls of peat. All the samples have been collected by means of a Dachnowsky sonde in the modification developed at Utrecht (Eshuis, 1946). The bored cylinders of peat (20 cm in length) were preserved in glass culture-tubes. This method in preserving peat samples has the advantage that the peat practically does not dessicate.

Laboratory work

Each cylinder was divided longitudinally into two halves. One half was used for the stratigraphic work, the other half for the palynological investigation.

1. Stratigraphic work

The stratigraphic work has been carried out in order to obtain a better insight in the character of the vegetation of the bogs themselves. For this purpose an investigation has been made of the macroscopically recognizable rests in the peat; including, for instance, fruits, leaves, wood, etc. This work has been carried out in three stages:
a. by direct inspection of the peat;
b. by making a suspension of the peat in water; in such a suspension seeds come to the surface and can be removed by means of a brush;
c. by sieving of the peat and investigating separatily the components of the latter.

2. Palynological investigation

In a number of instances it was necessary to take samples from the halved peat cylinder in parts that were very close to each other. Therefore in the halved peat cylinder narrow grooves were cut, which were covered with strips of paper mentioning the depth to which they responded. In this manner it was easy to take a sample between two known spectra, when the investigation of such a sample seemed desirable.

The samples were treated according to the acetolytic method of Erdtman (1934, 1936, 1943). The prescription, given in Eshuis (1946) has been followed, except that the samples were neither bleached or stained. Sand could usually be removed by allowing it to settle. This method is only effective in case of coarse sand. Fine sand was removed by means of HF. The unused part of the suspension was kept in small tubes of glass for later control. For preservation some phenol was added.

a. Tree pollen sum (ΣAP)

The tree pollen sum comprises the pollen grains of *Alnus*, *Corylus*, *Betula*, *Pinus*, *Picea*, *Abies*, *Salix*, *Fraxinus*, *Quercus*, *Ulmus*, *Tilia*, *Fagus* and *Carpinus*. In a large number of samples about 500 AP (arboreal pollen grains) were counted. However, on account of the small number of pollen grains that were present in many samples, it was not always possible to count 500 AP. Especially when the ΣAP is low, the curves pertaining to trees that are but poorly represented have to be accepted with some reserve. In a few cases the number of pollen grains in the samples was so large that it was possible to count 1000 AP. Further considerations concerning the counting of pollen grains will follow in chapter VI.

b. Diagrams

Each diagram has been divided into a number of subdiagrams, each on another scale. The first subdiagram comprises the curves obtained for *Alnus*, *Betula*, *Salix*, *Pinus* and the *Quercetum mixtum*. The second subdiagram gives separate curves for the trees belonging to the *Quercetum mixtum* (*Tilia*, *Ulmus*, *Quercus*, *Fraxinus*, *Acer*), *Fagus* and *Carpinus*. *Fagus* and *Carpinus* have been removed from the first subdiagram, where they usually have been placed, in order to avoid an unsurveyable course of the curves in the first subdiagram (VAN ZEIST, 1955).

The Quercetum mixtum

The curve of the *Quercetum mixtum* has been maintained in spite of the fact that the *Quercetum mixtum* is not a well-defined vegetation unit. The maintenance of the curve of the *Quercetum mixtum* in the first subdiagram has an important advantage. Usually one of the components of the *Quercetum mixtum* is more important than the other ones and in this way it remains possible to compare this component with the other trees of which curves are included in the first subdiagram.

Corylus

Following BERTSCH (1942), FAEGRI and IVERSEN (1950), JONKER (1952), and VAN ZEIST (1955), *Corylus* was included in the ΣAP. Therefore *Corylus* has been considered as a forest tree. It is not difficult to compare these diagrams with diagrams which do not include Corylus in the ΣAP.

Alnus

As has been stated in an earlier paper (JANSSEN, 1959), *Alnus* disturbs in South Limburg diagrams the normal course of the curves. Alnus belongs to the vegetation of the bog itself, and not to the forest on the surrounding slopes. Therefore, following FRIES (1958) and TRAUTMANN (1957), in some diagrams *Alnus* was removed from the tree pollen sum. The new percentages have been calculated for the trees only. As usual the percentages for the herbs refer to a tree pollen sum including *Alnus*. It was not always possible to remove *Alnus* from the tree pollen sum. Only in five diagrams the number of the tree pollen grains was so high that after the removal of *Alnus* the remaining pollen sum is high enough to calculate reliable percentages. These five diagrams are: Rimburg, Leiffenderven, Nuth, Wolffsheid, and Anselerbeek. The course of the tree pollen curves calculated when *Alnus* is not included in the tree pollen sum is shown in the seventh subdiagram.

Salix

Salix which may belong to the vegetation of the bog as well has been left in the tree pollen sum. In our diagrams *Salix* shows but very low percentages, and does not influence the curves of the other trees.

Subdiagrams 1 and 2 are of the composite type. Sometimes, however, tree pollen grains (usually components of the Quercetum mixtum) occur in a low percentage. In that case these curves have been drawn separatily. In the second subdiagram we find the curves of shrubs which are not included in the tree pollen sum (*Myrica*, *Frangula*). In the third subdiagram the curves have been drawn separately. It comprises the curves of the cereals and of the wild Poaceae and Cyperaceae. As border line between the cereals and wild Poaceae we have assumed a diameter of 40 μ (FAEGRI, 1944). In the fourth, fifth and sixth subdiagrams the curves have mostly been drawn separatily. Sometimes however the percentages in these subdiagrams reach such a high value that one or more subdiagrams of the composite type have been intercalated. The curve of the Rosaceae includes pollen of the *Comarum* type. Excluded are *Sanguisorba* and *Filipendula*. No distinction was possible between *Sparganium* and *Typha angustifolia*. These pollen grains have been mentioned under the name *Typha angustifolia*. The tree pollen sum of each spectrum has been given in the first subdiagram. In addition the zonation of FIRBAS (1949) has been shown on the left side of the first subdiagram.

CHAPTER VI

THE BOGS

In this chapter a description of the bogs will be given. Several aspects will come up for discussion, viz. dates with regard to the vegetation as it is now, the composition of the peat and the palynological results.

To explain the course of the curves in the pollen diagrams we placed ourselves on an ecological and sociological standpoint. It is certainly not possible to distinguish exactly vegetational units in the pollen diagrams. The pollen grains found in the samples are derived from several types of vegetation found in the vicinity of the sites where we collected our material. Thus, what the pollen diagram shows us, is the joint effect of the plant succession taking place in different types of vegetation. At first sight an attempt to separate plant associations in the pollen diagrams seems a dangerous enterprise. Still, such a separation is possible to some extent, if we include in our considerations the results of the stratigraphic analysis, which gives us an impression of the vegetation on the bog, and if we take into account the demands which plants put on soil conditions. Of course, only the requirements of plants of the present time are known, but it is unlikely that earlier in the holocene period the reaction of plants to the environment differed from the present one.

A second indication for the character of the vegetation of the bog is sometimes found in the course of the curves obtained for the herbs. It is a fortunate circumstance that we are now able to distinguish several kinds of herbaceous pollen grains. The pollen grains of the herbs are often a valuable supplement to the stratigraphic analysis. In this manner it is often possible to exclude plants which certainly formed no part of the vegetation of the bog. In the present chapter we want to discuss first the succession in the vegetation of the bogs. The course of the curves of the vegetation in the surrounding part has been mentioned, without any explanation, only in relation to the zonation of the pollen diagrams.

The zonation in the pollen diagrams, proposed by FIRBAS (1949) for central Europe, has been applied, because it appeared to the best one for South Limburg. For reasons explained later, we want to avoid the zonation used by BLYTT (1876) and by SERNANDER (1910). Later on we will discuss the other zonations which have been accepted in north-western Europe.

In the present paper we placed the transitions between the zones, where the following changes took place:

transition III/IV:	decrease in the number of the pollen grains of herbaceous plants; final amelioration of the climate;
transition IV/V:	first rise of *Corylus* (FIRBAS, 1949);
transition V/VI, VII:	intersection of the *Pinus* curve with that of *Alnus*;

transition VII/VIII: According to Jessen (1934, 1938), Iversen (1941), and Waterbolk (1954) this transition must be placed where there is a fall in the curves of *Ulmus* and *Tilia*, and where neolithic agriculture beginns; this point is recognizable by the appearance of cereals and of Plantago lanceolata; these points correspond with an increase of *Fagus*;

transition VIII/IX: second increase of *Fagus* and decrease of *Corylus* (Persch, 1950; Hummel, 1949); in the Danish diagrams Jessen (1934, 1938) and Iversen (1941) place the transition at the level where *Fagus* shows its first increase; it is obvious that their transition corresponds to that in the other parts of Western Europe; it depends only upon the type of soil and the migration of *Fagus*.

Abbreviations in the present paper:

L.F.	: Leiffenderven	Vo.	: Voerendaal
N.	: Nuth	Co.	: Cortenbach
BRO.	: Brommelen	Br.	: Brunssum
Ri.	: Rimburg	(F)	: Firbas
A.	: Anselerbeek	(O.S.)	: Overbeck, Schneider
B.	: Benzenrade	(J, I)	: Jessen, Iversen
Ra.	: Ravensbos	A.P.	: Tree pollen
Gr.	: Groenebeemden	N.A.P.	: Non-tree pollen
W.	: Wolffsheid		

Map 2 shows the position of the bogs in relation to the geological nature of the soil at the surface.

Benzenrade (Diagram 12)

Description of the site

The bog of Benzenrade is situated in the spring area of the Geleen. The stream arises south of Heerlen, and just between the cretaceous district and the loess district. It receives water from two sources near Benzenrade. At the eastern source a layer of about 50 cm peat has developed. The bog is small in extent.

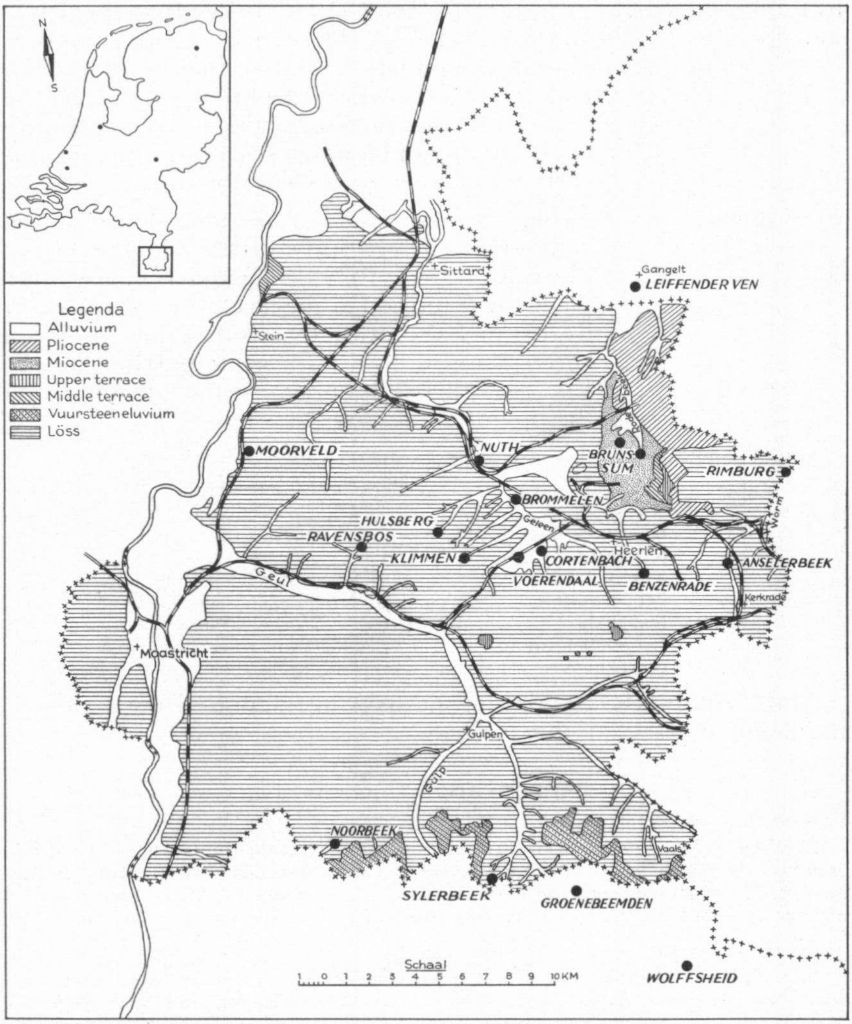
Present aspect of the vegetation

The vegetation that is now found in the vicinity of the source, is an *Alnus* bush with *Alnus glutinosa, Rubus spec., Caltha palustris, Ranunculus ficaria, Paris quadrifolia, Stachys sylvatica, Filipendula ulmaria, Carex spec., Melandrium rubrum, Urtica dioica.* Typical for the vegetation near a spring are *Adoxa moschatellina* and *Primula elatior.* The present vegetation of the bog is probably either a *Macrophorbieto-Alnetum* or a *Pruneto-Fraxinetum.* On the margin of the bog we find *Corylus avellana.* In the neighbourhood of Benzenrade almost all the woods have been cleared.

Stratigraphic results

The organic material consists for the greater part of roots of *Carex*, some leaves of *Phragmites* and fragments of *Alnus glutinosa* wood. The peat is mixed with a high percentage of loam (average 70 %).
fruits: 1–20 cm: *Crepis paludosa* (1×), *Carex flacca* (1×);
20–40 cm: *Crepis paludosa* (1×).

In the lower part of the peat a fragment of an *Equisetum* stem was found.



Map 2. Geological map of the superficial soil and distribution of the investigated bogs (F. H. van Rummelen in JONGMANS, KRUL and VOS, 1941).

PALYNOLOGICAL RESULS

The number of pollen grains found in the peat is small. Therefore it was not possible to count many pollen grains. The bog started its growth in zone xa. The lower part of the diagram (zone xa: 47.5–41 cm) shows high percentages of *Quercus*. In zone xb: (41–0 cm) *Quercus* decreases and *Pinus* increases, apparently on account of the presence of plantation of pine. The behaviour of *Pteridium* (present in the lower part of the diagram only) demonstrates that the rests of

Quercus woods which surrounded the bog, were felled. In the upper part of the diagram *Fraxinus* shows a peak.

The diagram shows clearly that the bog was surrounded by fields. We find a high percentage of cereals and a large number of pollen grains belonging to other herbs. We draw attention to the fact that the curves of *Rumex acetosella* and *Plantago lanceolata*, both herbs growing outside the bog, show a tendency to decrease.

In the vegetation of the bog itself a remarkable succession is visible:

47.5–41 cm: Pollen grains of *Filipendula ulmaria* and of *Crepis paludosa* and spores of *Equisetum* are especially abundant; the maximum of *Equisetum* coincides with the finding of a stem of this plant;

41 –20 cm: *Filipendula* disappears and *Crepis paludosa* increases strongly, later on the Poaceae as well. This indicates that the succession runs in the direction of the *Sphagno-Alnion.*

20 – 0 cm: Decrease of *Crepis* and *Equisetum* and a temporary increase of *Lythrum* and *Epilobium* (probably *Epilobium hirsutum*), indicating that the succession now turns into an opposite direction viz. to the *Macrophorbieto-Alnetum* or that the *Alnus* wood was cleared.

According to MÖRZER BRUINS and WESTHOFF (1951) and to VAN DIJK (1955) in case of a clearing of the *Alnus* wood its place is taken by the *Valerianeto-Filipenduletum*, in which *Crepis paludosa*, *Valeriana officinalis*, *Stachys palustris* and *Phragmites communis* are abundant. Indeed *Alnus* decreases from 41 cm upwards. At this level *Pinus* rises probably on account of an intensified long distance transport.

The rise of *Fraxinus* may be due to the above mentioned succession from the *Alnion glutinosae* to associations of the *Alnion incanae*, in which *Fraxinus* is present.

Ravensbos (Diagram 16)

DESCRIPTION OF THE SITE

The small bog of Ravensbos is situated in the spring area of a brook north-west of Valkenburg. As we saw in chapter II, we find along the northern slopes of the Geul an impermeable layer of Oligocene clay, the Cerithien clay (KLEIN, 1914). On account of the stagnation of water above this layer the conditions were favourable to the development of peat. The spring area of the brook which arises in the Ravensbos was a sheet of water which gradually contracted, but in the centre of the area open water is still present. The outer zone of this sheet of water has been filled up completely with organic material. Here we find several brooklets running down towards the open water.

PRESENT ASPECT OF THE VEGETATION

The vegetation along the margin of the area is an *Alnus* bush with *Alnus glutinosa*, and *Frangula alnus*. Undergrowth: *Chrysoplenium oppositifolium*, *Primula elatior* (both plants of springs), *Fragaria vesca*, *Rubus spec.*, *Cirsium palustre*, *Luzula campestris*, *Ranunculus repens*, *Glechoma hederacea*, *Nasturtium officinale*, *Poa nemoralis*, *Galium palustre*, *Crepis paludosa*, *Dryopteris thelypteris*, *Sium latifolium* and several species of

Carex. According to MAAS (1959) we find in the spring area the *Macrophorbieto-Alnetum*, the *Cariceto remotae-Fraxinetum* and the *Pruneto-Fraxinetum*. The dominance of *Alnus*, combined with the occurrence of *Crepis*, makes it probable that we are dealing here with the *Macrophorbieto-Alnetum cardaminetosum*. The occurrence of *Frangula alnus* and that of *Dryopteris thelypteris* indicate a tendency to develop in the direction of the *Alnion glutinosae*. The bog is surrounded by woods in which *Quercus robur* is the dominant tree. The woods moreover contain young trees of *Fagus* and *Acer*, and in some places *Pinus* and *Abies* have been planted.

STRATIGRAPHIC RESULTS

The peat is composed of rests of *Alnus* and *Carex*. In the lower part up to 60 cm depth we find mainly wood of *Alnus*, in the upper part mainly roots of *Carex*. Between 40–60 cm a seed of *Luzula* was found.

PALYNOLOGICAL RESULTS

The peat contains a small number of pollen grains. From 60–22.5 cm (zone xa) *Quercus* is the dominant tree, from 22.3–5 cm (zone xb) *Pinus* and *Abies* increase on account of the cultivation of these trees. In zone xb *Quercus* decreases, and *Fraxinus* shows a slight increase. The subdiagram, in which the herbs are shown, indicates that the bog was surrounded by forest. *Plantago lanceolata*, *Rumex acetosella* and *Centaurea cyanus*, typical indicators of agriculture, are present but do not reach high precentages. The only curves which show high values, are those of the Asteraceae (*Crepis*) and Brassicaceae, plants which are supposed to belong to the vegetation of the bog itself.

Groenebeemden (Diagram 10)

DESCRIPTION OF THE SITE AND PRESENT ASPECT OF ITS VEGETATION

Near Groenebeemden, a hamlet situated on Belgian territory, west of Gemmenich, arises a tributary of the Geul: the Waschbach. The small spring area of the Waschbach supports an *Alnus* bush with an undergrowth of *Filipendula ulmaria*, *Equisetum*, *Ranunculus repens* and *Carex spec.* The number of plants is too small to allocate the vegetation of the bog to a definite association. Probably we are dealing with the *Macrophorbieto-Alnetum*. The direct surroundings of the bog have completely been brought in cultivation, but half a km to the north an extensive forest area is found on the acid soil of the flinteluvium.

STRATIGRAPHIC RESULTS

The peat has a thickness of 80 cm and is an *Alnus-Carex* peat, with, in a small amount, rests of Bryophyta.

Between 20–22.5 cm and 55–58 cm a layer of sand was deposited.

Seeds and fruits: 20 –40 cm: *Carex acutiformis* (1 ×);
40 –60 cm: *Senecio spec.* (1 ×), *Vicia tetrasperma* (1 ×);
60 –72.5 cm: *Carex panicea* (1 ×);
72.5–80 cm: *Polygonum amphibium* (1 ×).

PALYNOLOGICAL RESULTS

On account of the considerable percentage of sand and clay that is present in the peat, it was not possible to count a large number of pollen grains. The peat appears to consist entirely of zone x. The lower part of the diagram starts with a decreasing *Fagus* and an increasing *Quercus* percentage. *Quercus* reaches its maximum (45 %) at a depth of 60 cm. The transition from zone xa to zone xb lies at a depth of 45 cm. In zone xb *Pinus* increases, *Quercus* decreases, and *Abies* and *Fraxinus* make their appearance. *Alnus* must have been present in the bog itself. This is clearly demonstrated at the beginning of zone xb. The curve of *Alnus* reaches a maximum at the level where the decrease of *Quercus* and the increase of *Pinus* are interrupted. That a large number of herbs reach high percentages (especially *Artemisia*, *Rumex acetosella*, *Plantago lanceolata* and the cereals), shows that the surroundings of the bog have been brought in culture. To the flora of the bog itself we must ascribe the maxima of *Equisetum* and of *Dryopteris thelypteris* in the lower part of the diagram. These maxima go together with the presence of *Thalictrum*, *Valeriana*, *Menyanthes*, *Filipendula* and *Typha*, indicating that the environment must have been wetter than it is nowadays. The decrease of *Dryopteris thelypteris*, the disappearance of *Valeriana* and *Thalictrum* and the appearance of *Fraxinus* in the upper part of the diagram is perhaps an expression of a succession from the *Alnion glutinosae* to the *Alno-Ulmion* (*Macrophorbieto-Alnetum*).

Wolffsheid (Diagram 14)

Description of the site

The small bog of Wolffsheid is situated near the hamlet of this name, halfway Moresnet-Aachen, north of the road between these two places. According to a geological map of Wunstorf (1911), the bog is situated outside the loess district. From the lower part to the upper part of the slopes we find successively Aachenien, Hervien and "Flinteluvium". Only in the north-western direction a small area covered with loess is present.

Present aspect of the vegetation

The spring area is probably a *Macrophorbieto-Alnetum* with an undergrowth of *Filipendula ulmaria*, *Rubus spec.*, *Sorbus aucuparia*, *Equisetum spec.*, *Carex spec.*, *Sium latifolium*, *Ranunculus repens*, *Nasturtium officinale*, and *Epilobium parviflorum*. Along the margin of the bog many specimens of *Knautzia arvensis* were present. With the exception of the valley along the border of which the bog is situated, the bog is surrounded by woods in which *Quercus robur* is the leading tree. We find moreover in these woods *Pinus* (cultivated) and *Fagus*.

Stratigraphic results

The peat consists for the greater part of *Carex* roots and of *Alnus* wood.

0–12 cm: brown peat. Seed of *Solanum dulcamara* (2×), fruit of *Carex panicea* (1×);
12–20 cm: black humus mixed with sand;
20–34 cm: brown peat mixed with clay; a seed of *Solanum dulcamara* (1×) and a fruit of *Carex silvatica* (1×);
34–40 cm: dark brown, rough peat;
40–60 cm: black rough peat; fruits: *Rubus* (1×), *Carex acutiformis* (1×);
60–80 cm: peat black-grey, homogeneous;
80– cm: clay.

Palynological results

In the diagram *Alnus* shows the highest percentages. The diagram comprises zone IX and zone X. With the exception of the spectra found at a depth of 40, 45, 50 and 55 cm, it was possible to count so many tree pollen grains that *Alnus* could be excluded from the tree pollen sum. If *Alnus* is left out of consideration, *Fagus* shows the highest percentages in the lower part of the diagram. At a depth of 45 cm we find the transition from zone IX to zone X. At this level the curve of the decreasing *Fagus* intersects the curve of the increasing *Quercus*. *Corylus*, *Calluna* and the Asteraceae tubuliflorae are increasing as well. *Pteridium* increases very fast and reaches a high peak. Meanwhile the cereals too are increasing. As we shall see these phenomena indicate that the wood was felled. At the same time the number of pollen grains in the samples decreases strongly. At a depth of 40 cm the wood was partly regenerated. The spectrum of 40 cm shows once more a maximum of *Fagus*, together with a minimum of *Corylus*, *Calluna*, *Pteridium* and the Asteraceae tubuliflorae. Above 40 cm the wood was felled once more. *Fagus* continues to decrease, but remains still fairly high in the upper part of the diagram. These relatively high percentages of *Fagus* in the uppermost spectra are probably due to the fact that *Fagus* has remained abundant in the surrounding woods. According to SCHWICKERATH (1933, 1944), we find the *Fagetum calcareum* in the neighbourhood (Klauserwald).

At a depth of 30 cm we find the transition from zone xa to zone xb. *Pinus* increases strongly on account of the presence of pine plantations. However, it should be noted that the increase of *Pinus* started much earlier, viz. at the depth where the clearance of the woods began. It is not necessary to assume that the increase of *Pinus* from the depth of 60 cm upwards is due to cultivation of the pine. The mere clearance of the forests may be responsible for the fact that *Pinus* is overrepresented, because this pollen may be transported over long distances.

Moorveld

Moorveld a small bog near Hulsen, east of the watermill and along the railroad Maastricht-Sittard, contains a very small number of pollen grains. Therefore, it was not possible to draw a pollen diagram. All the samples taken from the 25 cm thick peat deposit show a high percentage of *Pinus*. The dominance of *Pinus* makes it probable that the peat has developed in zone xb. Indeed, *Pinus* is a much planted tree in the surroundings of the bog. The composition of the vegetation of the bog comprises *Alnus glutinosa*, *Quercus robur*, *Fraxinus excelsior*, *Geranium robertianum*, *Filipendula ulmaria*, *Epilobium vulgaris*, *Brachypodium sylvaticum*, *Viola riviniana*, *Rubus spec.* and *Carex spec.* (*Cariceto remotae-Fraxinetum* or *Pruneto-Fraxinetum:* MAAS, 1959).

Noorbeek

Along the small stream running to the river Voer we find south of Noorbeek marshy places supporting *Alnus* bushes with an undergrowth of *Primula elatior*, *Caltha palustris*, *Phragmites communis*, *Galium aparine*, *Asperula odorata* and *Rubus spec.* According to MAAS (1959) the *Pruneto-Fraxinetum* and the *Macrophorbieto-Alnetum* are present here. On account of the dominance of *Alnus* the latter association is the most probable one. From the 80 cm packet only the uppermost 20 cm is more or less peaty. The peat contains a very small number of pollen grains (especially of

Pinus). Therefore, no pollen diagram has been drawn. The major portion of the uppermost part consists of clay. Three fruits of Poaceae and one fruit of *Ranunculus repens* were found.

Sijlerbeek

The spring area of the Sijlerbeek, a tributary of the Geul in the south-eastern part of South Limburg, supports a fragment of an *Alnus* bush with *Cardamine pratensis*, *Primula elatior*, *Caltha palustris*, *Peucedanum palustre*, *Mentha aquatica* and *Rubus*, *Carex* and *Juncus spp*. The 30 cm thick sample is very clayy. It contains a small number of pollen grains and a fruit of *Carex panicea*. Roots of *Carex* proved to be abundant. No diagram has been drawn.

Klimmen

The bog of Klimmen is situated near the village of Klimmen at the northern border of the loess district. Here we find the spring of the Retersbeek, a tributary of the Geleen. The present day vegetation of the bog comprises *Salix* spec., *Alnus glutinosa*, *Caltha palustris*, *Primula elatior*, *Cardamine pratensis* and several species of *Carex*. The sample taken from the uppermost part of the packet of 50 cm did not contain much pollen. Among the grains found in the samples *Pinus* is dominant. On account of this small number of pollen grains no diagram has been drawn. Only the uppermost part of the packet consists of peat. Fruits of *Carex inflata* and *Carex panicea* have been found; furthermore leaves of *Phragmites*, roots of *Carex* and a fragment of an *Equisetum* stem.

Hulsberg

DESCRIPTION OF THE SITE AND PRESENT ASPECT OF THE VEGETATION

North-east of Hulsberg we find the spring area of the "Hulsbergerbeek", a southern tributary of the Geleen. Only the bog supports a wood. The surroundings have been cleared completely and brought under cultivation. The vegetation is a very rich one. Along the margin of the bog we find especially *Salix* and *Quercus robur*. The bog itself contains *Alnus glutinosa*, *Ribes nigrum*, *Sambucus racemosa*, *Caltha palustris*, *Primula elatior*, *Adoxa moschatellina*, *Ranunculus acer*, *Anemone nemorosa*, *Oxalis acetosella*, *Phragmites communis*, *Filipendula ulmaria* and several species of *Carex*. According to data given by MAAS (1959), the presence of *Sambucus racemosa* points to the *Cariceto remotae-Fraxinetum*. However on account of the nature of the soil it is more probable that the vegetation of the bog belongs to the *Macrophorbieto-Alnetum*.

STRATIGRAPHIC RESULTS

The 60 cm thick sample contains *Alnus* wood and *Carex* roots. One fruit of *Ranunculus* was found.

PALYNOLOGICAL RESULTS

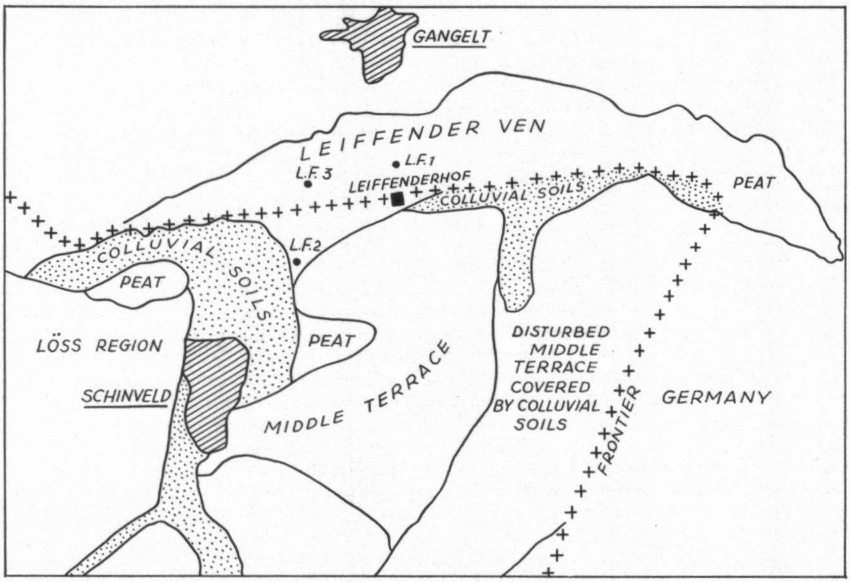
Only the uppermost half of the packet contains enough pollen grains to compose a pollen diagram, even though the tree pollen sum is not high.

The diagram (not published) shows high percentages of *Pinus* and *Quercus*, alternating with each other. The diagram comprises only zone xb: *Fagus* low, *Tilia* and *Ulmus* low, and *Pinus* high. The fact that the bog is a small forest island in the midst of fields, finds its expression in the high percentages of the cereals and of other herbs. It is remarkable that the cereals, Cyperaceae, and the other Poaceae show a strong decrease in the upper part of the diagram. We do not know how to explain this phenomenon.

Leiffenderven (Diagram 3 and 4)

DESCRIPTION OF THE SITE

Leiffenderven, the only bog in South Limburg of a fairly large size, is situated in the valley of the "Rode Beek", and forms a natural frontier between the Netherlands and Germany. The valley of the "Rode Beek" has been filled up almost completely with peat. Hence the for South Limburg unusual size of the bog. The bog ows its development to the presence of Pliocene clay in the underground at the bottom of the valley (FABER, 1942). The bog is not situated in the region with a cover of loess, although the loess district is not far away. According to the geological map of the Netherlands (TESCH, 1946), it is found at a distance of about 2 km, near the village of Schinveld. Both north and south of the valley of the "Rode Beek" loess is lacking. South of the valley the soil consists of colluvial sediments deposited by the stream and of sediments belonging to the Middle Terrace, the latter partly disturbed and covered with a thin layer of colluvial sediments (map 3).



Map 3. Geological map of the region round Leiffenderven. From *Tesch, 1946:* geological map of the Netherlands 60/4.

According to the geological map of EBERT, KAISER and FUCHS (1937) we find north of the valley (on German territory) from south to north successively colluvial sediments deposited by the brooks, Lower Terrace (sand), Middle Terrace (sand), and on the plateau sediments of the Upper Terrace (gravel).

PRESENT ASPECT OF THE VEGETATION

In the vicinity many woods have been cleared, especially north of the valley. The woods in the north are mostly pine plantations. South of the valley more wood have been preserved. Owing to the rather poor character of the soil these woods belong to the *Quercetum-Betuletum*. In the undergrowth of the wood *Pteridium aquilinum* is very abundant. However, plantations of *Pinus* and of other coniferous trees occur here as well.

The soil of the bog has completely been taken into cultivation. On account of bad drainage, the bog has the aspect of a wet meadow in which many weeds occur. In an ungrazed part of the bog, we find apart from the Poaceae, (especially *Holcus lanatus*), *Filipendula ulmaria, Lotus uliginosus, Achillea ptarmica, Cirsium arvense, Juncus* *effusus, Polygonum lapathifolium, Plantago lanceolata, Medicago lupulina,* and some pioneers of a woody vegetation (*Salix, Betula* and *Quercus robur*). Several of the above mentioned herbs indicate that the soil is rich in nutrients, probably on account of dunging.

However, not long ago the vegetation of the bog must have had a quite different character (see the discussion of zone VIII of the Leiffenderven).

The packet discussed in the present paper is not the first one bored in the Leiffenderven area. In 1953 already two packets have been investigated. The results however, were somewhat unfortunate. In the first packet (L.F.1), bored exactly north of the farm "Leiffenderhof", zone V, IX and X were lacking. The second packet (L.F.2) taken on the margin of the bog, between Leiffenderhof and Schinveld, was even more incomplete as zone IV, V, IX and X were lacking. Therefore, a renewed investigation has been started as a part of the present work. This third packet (L.F.3) was bored half a km west of the locality where the first packet was bored. As the first two packets do not show more details than the third one, only the analysis of the latter is published in the present paper. Map 3 shows the localities mentioned above, whereas Fig. 1 gives an impression of the relations existing between the stratigraphic zones in the three profiles.

Stratigraphic results

0– 5 cm: brown *Sphagnum cuspidatum* peat; fruits: *Trichophorum caespitosum* (3×);
5– 20 cm: brown *Eriophorum-Sphagnum cuspidatum-Scheuchzeria* peat; a small number of *Carex* roots; fruits and seeds: Brassicaceae (2×), *Trichophorum caespitosum* (3×);
20– 30 cm: *Eriophorum-Sp. cusp.-Scheuchzeria-Carex* peat; peat coarse;
30– 40 cm: *Carex-Eriophorum* peat;
40– 50 cm: *Eriophorum-Sp. cusp.-Scheuchzeria* peat; peat black, coarse;
50– 60 cm: *Eriophorum-Sp. cusp.* peat;
60– 70 cm: *Eriophorum-Carex-Sp. cusp.* peat; fruit of *Carex panicea* (1×);
70– 80 cm: *Sp. cusp.-Eriophorum-Scheuchzeria* peat; seed: *Eleocharis palustris* (1×), fruits of *Carex inflata* (1×) and *Carex pallescens* (2×); peat black coarse;
80– 85 cm: *Sp. cusp.-Scheuchzeria-Eriophorum* peat; peat coarse;
85–120 cm: *Alnus* peat, brown-black with wood of *Alnus* and roots of *Carex;* seed: *Myosotis palustris* (1×);
120–132 cm: black *Alnus* peat without wood;
132–160 cm: *Carex-Eriophorum* peat; peat black, coarse;
160–205 cm: *Phragmites-Eriophorum* peat; highest concentration of *Phragmites* and *Eriophorum* between 170–190 cm; Fern sporangia between 170–180 cm and 185–195 cm; between 198–205 cm some *Scheuchzeria;* seed: cf. *Scirpus lacustris* (1×);
205–226 cm: clay;
226–260 cm: sandy *Carex* peat;
260–281 cm: sandy gyttja; less sand than in the preceding zone;
281–287 cm: sand;
287–296 cm: very sandy *Carex-Hypnaceae* peat;
296–300 cm: peat very sandy, less *Carex;*
300– cm: gravel.

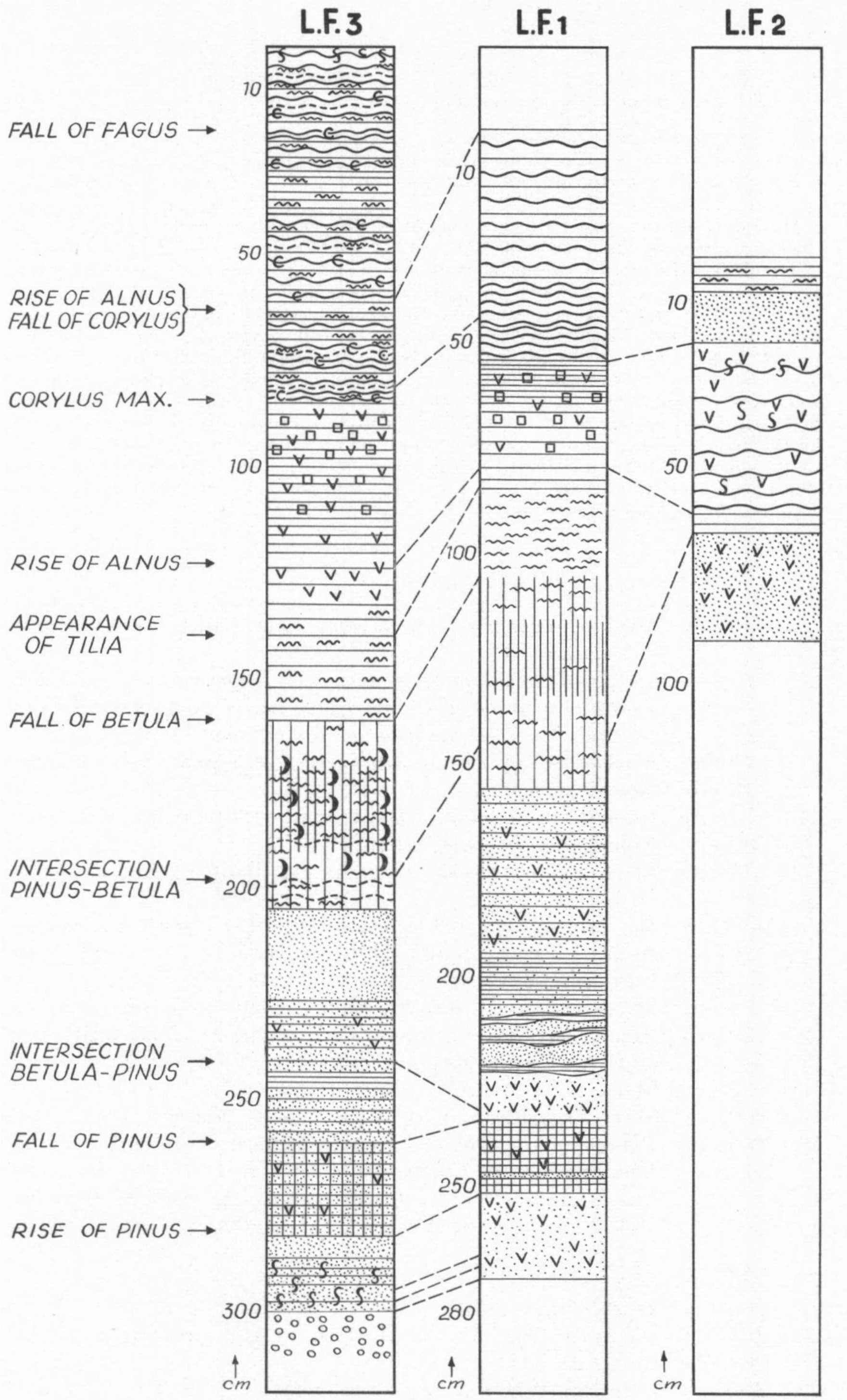


Fig. 1. Comparison between three borings made at Leiffenderven; the interrupted lines connect corresponding levels in the pollen diagrams.

Palynological results

Zones I, II and III, which belong to the late glacial time, will be discussed in chapter VII.

Zone IV (197.5–159 cm)

Zone IV is characterized by the dominance of *Pinus*, whereas *Salix* is present in very low percentages (2 %). The curve of *Betula* is rather irregular (percentages varying between 33 % and 4 %). We wish to draw attention to the fact that the curve of the Poaceae reaches high percentages. The occurrence of high percentages of the Poaceae agrees with the character of the peat, which is a *Phragmites-Eriophorum* peat. As is proved by the presence of leaves of *Phragmites* and *Eriophorum* we suppose therefore that the pollen grains of the Poaceae are from *Phragmites*. Moreover, fluctuations in the curve of the Poaceae and of *Betula* alternate with those in the curve of *Dryopteris thelypteris*. At the levels which show high percentages of *Betula* and of the Poaceae, the curve of *Dryopteris* shows a minimum. This phenomenon expresses perhaps a variation in the vegetation of the bog itself. Though no fragments of *Betula* were found, it is quite well possible that *Betula* (*Betula pubescens*?) was represented in the vegetation of the bog itself. We refer to Straka (1952), who found the same correlation. The alternation between *Dryopteris* and the Poaceae is more or less recognizable in the peat stratigraphy too. Between 180–187.5 cm i.e. in the zone where stems of *Phragmites* were very abundant, no fern sporangia were found.

In the upper part of the zone the first thermophilous tree, *Corylus*, makes its appearance, and somewhat later it is joined by *Quercus* and *Ulmus*.

Zone V (159–138 cm)

At the beginning of zone V *Corylus* shows its first increase. At the same level *Betula* decreases to zero, whereas the first pollen grains of *Alnus* make their appearance. It is difficult to recognize the transition to zone VI. The diagram shows two intersections between the curves of *Alnus* and *Pinus*. Between the intersections *Corylus* reaches a maximum. The question of the transition from zone V to zone VI, will be discussed in chapter VII. In the upper part of zone V *Tilia* makes its appearance.

Zone VI *and zone* VII (138–85 cm)

In zone VI and zone VII *Alnus* reaches a high maximum, and *Pinus* decreases to zero. Of the *Quercetum mixtum Quercus* is here the most important component. In the beginning of zone VI the percentages of *Ulmus* and *Tilia* are equal. However at a depth of 120 cm, where *Alnus* reaches its maximum, and *Quercus* begins to expand, *Tilia* is more important than *Ulmus*. *Fraxinus* and *Frangula* are now present in low percentages. It is noteworthy that in zone VII *Fagus* makes its appearance and that *Quercus* subsequently decreases and that *Betula* increases.

The local vegetation still contains *Dryopteris thelypteris*. According to VAN DIJK (1955) *Dryopteris thelypteris* is a differential species of an association of the *Irido-Alnion*. One association, the *Cariceto elongatae-Alnetum* (*Alnetum glutinosae s.s.*, MEYER DREES, 1936) which occurs on a minerogenous soil, does not contain *Dryopteris thelypteris*. This association is abundant in the eastern parts of the Netherlands. The second association, the *Thelypterideto-Alnetum* in which *Dryopteris thelypteris* is present, occurs on peaty soil. According to BODEUX (1955), the peat in a real *Alnus* forest must have a thickness of at least 1 cm. This condition was fulfilled here. Therefore we have to regard the local vegetation of Leiffenderven in zone VI and zone VII as a *Thelypterideto-Alnetum*.

Zone VIII (85–62.5 cm)

At the beginning of zone VIII the influence of man becomes strongly marked. *Plantago lanceolata*, Chenopodiaceae, *Rumex*, *Artemisia*, Poaceae and Ericaceae are expanding.

The vegetation of the bog changes conspicuously. Plants growing on a soil showing a neutral or alkaline reaction decrease or disappear (*Dryopteris thelypteris* and *Alnus*). Plants indicating a soil with an acid reaction taking their place Ericaceae, *Sphagnum*, *Myrica*, *Andromeda* and *Betula*).

VAN DIJK (1955) distinguishes in this succession three stages:

1. rise of *Alnus* and *Myrica;*
2. disappearance of *Alnus;* rise of *Frangula alnus* and of *Betula pubescens* (*Saliceto-Franguletum*);
3. disappearance of *Frangula alnus*.

The second stage, the transition from *Irido-Alnion* to *Sphagno-Alnion*, is recognizable in our diagram. Just before the disturbance we find in the diagram the highest values of *Frangula* and the first rise of *Betula*. From here on the composition of the peat does not show any important change. It appears from the stratigraphic analysis that the local succession does not result in a raised bog. The main components of the bog in this period and in the following ones are *Sphagnum cuspidatum*, *Scheuchzeria* and *Carices*, a typical combination for the *Scheuchzerietalia palustris* NORDH., 1936. The local vegetation will probably have been one of the associations of the *Rhynchosporion albae* W. KOCH, 1926. According to OBERDORFER (1957) we find in the *Rhynchosporion* especially several *Carices*, *Eriophorum*, *Andromeda polifolia*, *Vaccinium oxycoccus*, *Sphagnum cuspidatum*, and *Scheuchzeria* i.e. exactly the same species as occur in this peat according to the stratigraphic analysis as well as to the pollen diagram. We are not dealing here with the *Sphagnion fusci* BR. BL. 1920, because in the Sphagnion other Sphagna occur (*Sp. magellanicum*, *Sp. rubellum*, *Sp. papillosum* and *Sp. molluscum*). As *Calluna* does not occur in the *Rhynchosporion*, we must assume that *Calluna*, which reaches high percentages in the diagram, occurred in the area outside the bog. In the diagram we find an indication for this assumption in the fact that *Corylus* (certainly not part of the vegetation of the bog itself) and *Calluna* reach their maximum at the same depth. The rise of *Calluna* is probably due to human interference with the vegetation (see page 72). The occurrence of *Calluna* is quite well possible because the region round Leiffenderven is not covered by loess but by sediments belonging to the terraces.

The supposition that the local vegetation had the character of the *Rhynchosporion*, is supported by the observations of BECKER (1874) and of SCHWICKERATH (1930, 1933) made before the disturbance of the bog by man. According to Becker extensive heath areas were present in the surroundings of the bog, and this is in agreement with our assumption that *Calluna* occurred there. Among the species growing in the bog BECKER mentioned *Myrica gale*, *Narthecium ossifragum*, *Rhynchospora alba*, *Rhynchospora fusca* and *Andromeda polifolia*. According to SCHWICKERATH (1933) the vegetation of Leiffenderven was the *Caricetum limosae*, which is one of the associations of the *Rhynchosporion*. The species mentioned by DE WEVER (1911, 1912, 1913, 1914, 1917, 1918) also point to the *Rhynchosporion* but moreover to associations of the *Caricion davallinae* (*Tofieldietalia*) which indicate a more calcareous habitat (*Cladium mariscus*, *Carex pulicaria*, *Carex dioica*, *Gymnadenia conopea*, and *Triglochin palustris*). The *Nanocyperion* occurred probably in the local vegetation as well. BECKER and SCHWICKERATH mentioned *Cyperus flavescens*, *Cyperus fuscus*, *Cicendia filiformis*, *Centunculus minimus*, *Radiola linoides*, *Juncus tenagea* and *Moenchia erecta*, a combination of plants typical for the *Cicendieetum filiformis*.

Both *Rhynchosporion* and *Cicendieetum filiformis* are plant communities occurring in depressions or in the lag of a raised bog. Usual it is a transitional stage ("Zwischenmoor", *Scheuchzeria* peat) in the succession between a "Flachmoor" and a "Hochmoor" (raised bog) which usually lasts but a short time. At Leiffenderven the succession stagnated at the stage of the "Zwischenmoor", though invaders of the *Sphagnion* were already present (SCHWICKERATH, 1933). This is due perhaps to the small size of the bog and to the presence of the Rode Beek, which supplies mineral nutrients. Indeed, about 80 years ago the number of depressions was considerable (BECKER, 1874). The described succession, which does not lead to a real raised bog is known from the Eiffel (HUMMEL, 1949: Dürre Maar) and from the Eggegebirge (TRAUTMANN, 1957). According to HUMMEL the succession to a raised bog stagnates in case of a sufficient supply of soligenous water, as under these circumstances the bog remains mesotrophic. According to BUCHWALD (1951a), the succession stagnates in the continental climate, as a consequence of the decreased precipitation, at the level of the *Rhynchosporion*.

It is difficult to say whether the change in the local vegetation at the transition from zone VII to zone VIII was influenced by man. It is possible that man diverted the course of the Rode Beek with the result that the supply of nutrients and of oxygen stagnated. By that a succession in the direction of a raised bog would have set in. Another possibility is, that the Rode Beek changed its course spontaneously. Such a diversion is quite conceivable if we take into account the dynamic character of the area round Leiffenderven. The changed situation might have resulted in a more favourable condition for occupancy. However, without the intervention of man, a succession to a raised bog may also have taken place. Usually, when the thickness of the layer of incompletely decomposed material increases, the supply of suitable nutrients and oxygen in the upper part decreases and the succession of the vegetation will proceed in the direction of a raised bog. According to BUCHWALD (1951a), the succession to a "Zwischenmoor" is possible when the phreatic surface falls and when at the same time supply of nutrients becomes insufficient. The structure of the upper layer of peat is changed (the peat is pulverized) and the Ph decreases. TRAUTMANN (1957) takes into account a natural drainage of the bog by means of brooks which dig their bed deeper in the soil, by which the phreatic surface falls. A decreasing precipitation may have the same result. At Leiffenderven either a decreasing precipitation or an insufficient supply of nutrients or both these factors may be responsible for the change which the vegetation of the bog underwent at the transition from zone VII to zone VIII.

At present the *Rhynchosporion* has disappeared completely in the Leiffenderven area due to a, failed, attempt of exploitation (SLOFF, 1931) and of bringing it into cultivation.

In the lower part of zone VIII the vegetation outside the bog must have undergone most important changes. *Tilia* disappears and for a short time *Pteridium* is present and *Corylus*, the Poaceae and the Ericaceae show a maximum. However, after this shock a new equilibrium is established. The percentages of the Poaceae and of *Corylus* are much higher than they were previously. It is noteworthy that the *Fagus* curve does not show any influence of the human occupation. Since its first appearance in zone VII *Fagus* continually increases. Later on we will return to this question. Soon after the beginning of zone VIII *Carpinus* made its appearance for the first time. Zone VIII ends at a depth of 62.5 cm where *Corylus* decreases and *Fagus* shows its second increase.

It is difficult to distinguish the zones IX and X established by OVERBECK and SCHNEIDER (1938). If we want to divide our zone VIII, we may assume that the short *Corylus* maximum at a depth of 82.5 cm corresponds to the C4 of Overbeck and Schneider i.e. to zone IX and if we do this, the remaining part of zone VIII must be regarded as zone X (O.S.).

Zone IX (62.5–20 cm)

In the vegetation of the bog itself we do not find any clear indication of a change. Just as in zone VIII *Sphagnum* and *Eriophorum* remain important components of the vegetation, and the vegetation of the bog therefore remains a community which must be regarded as belonging to the *Rhynchosporion*. It is noteworthy that *Sphagnum* shows a distinct minimum between 57.5–40 cm and that *Betula* reaches a maximum at the same level. *Betula* obviously obtained a change of expanding during the time at which *Sphagnum* was less abundant. This phenomenon might perhaps be regarded as indicating an alternation between the *Rhynchosporion* and the *Betulion pubescentis*.

Apart from the presence of *Alnus*, zone IX is characterized by the dominance of *Fagus*. In the lower part of the zone the percentages of the herbs are decreasing strongly. Pollen grains of the cereals too are less abundant than in zone VIII. These phenomena point to a regeneration of the woods. However, we have to stress the fact that the composition of the woods is different now from what it was in zone VI and zone VII. *Alnus* increases but does not reach such a high percentage as in zone VI and zone VII. *Tilia* has disappeared almost completely. The curve of *Ulmus* is more regular but shows very low percentages. The more important trees are now *Fagus* and *Carpinus*. *Fagus* shows two maxima, one (F 1) at a depth of 60 cm and a second one (F 2) at a depth of 30 cm. It is possible that the F 1 is opurious because the minimum of *Fagus* at a depth of about 45 cm coincides with the already mentioned maximum of *Betula*, a tree which belongs to the vegetation of the bog itself. If we remove *Betula* from the tree pollen sum, the *Fagus* minimum disappears and *Fagus* continues to increase up to the maximum found at a depth of 30 cm. *Carpinus* reaches its highest percentages at this level.

Zone X (20–0 cm)

At a depth of 20 cm, man interferes for the second time. *Plantago lanceolata*, *Rumex* and other indicators of agriculture return. *Fagus* and *Carpinus* show a steep fall, *Corylus* reaches a maximum together with the cereals and the Poaceae, and the *Quercus* curve rises. Again *Alnus* decreases, but now temporarily. After the first activity of man the *Alnus* curve rises, and soon reaches a higher summit than it does in zone IX. Some parts of the bog probably become more eutrophic on account of the human activity. An indication for the more eutrophic character of the bog is the occurrence of *Nymphaea* and *Lemna* in the pollen diagram. Moreover *Dryopteris thelypteris* increases again. Therefore, the higher percentages of *Alnus*, which prefer more eutrophic conditions, may be explained by an expansion of this tree in the bog itself.

On account of the clearing of the original forests, *Pinus* increases. However *Pinus* does not reach absolute dominance. When the upper part of the diagram is present, the diagram shows, as a rule, a *Pinus* dominancy. It looks therefore, as if the uppermost part of the peat deposit is lacking.

Brommelen (Diagram 5)

DESCRIPTION OF THE SITE

The bog of Brommelen is situated in the valley of the Geleen, north-west of Weustenrade. The peat has been deposited in an arm cut off from the stream. The top soil of the plateaus on both sides of the valley is loess and this loess covers sands belonging to the Middle Terrace. The soil in the valley itself consists of colluvial sediments. On account of the fertile character of the soil the woods in this region have been cleared completely. The only site which has not been cleared, is the bog itself. The area in which the peat has been deposited, is very small. The diameter of the bog does not exceed 250 m.

Present aspect of the vegetation

At present the vegetation of the bog is a fragment of an *Alnus* bush with many species of *Carex* and *Juncus*. At the margin of the bog where the soil is drier, we find *Arum maculatum*, *Primula elatior*, *Lamium maculatum*. *Populus* is the only tall tree in the region. It has been planted.

Stratigraphic results

0– 20 cm: brown black *Alnus* peat; seeds: *Lycopus europaeus* (4×);
20– 70 cm: black *Alnus* peat; between 40–60 cm one fruit of *Alnus;*
70– 80 cm: clay;
80–120 cm: black *Alnus* peat with much wood of *Alnus;* fruit of *Carex echinata* (1×); catkins of *Alnus* (2×);
120–140 cm: black *Alnus* peat with much wood of *Alnus;* fruits of Poaceae (2×), *Carex* (1×); some sporangia of ferns;
140–161 cm: idem, no seeds or fern sporangia;
161–170 cm: *Carex* peat; clayy; many roots of *Carex;* less wood of *Alnus;* fruits: *Alnus* (1×), *Carex* (1×), Poaceae (2×);
170–205 cm: *Carex* peat with a high clay content; wood of *Alnus* present (190 cm); seed of *Viola spec.* (1×);
205–220 cm: *Carex-Alnus* peat; *Alnus* wood at 219 cm;
220–240 cm: *Alnus* peat with some Bryophyta; *Alnus* wood at 225 cm;
240–260 cm: *Alnus* peat with some roots of *Carex;* from 240–242.5 cm and from 256–257.5 cm the peat contains a small percentage of sand;
260–280 cm: *Alnus* peat with very many rests of *Alnus* wood; at 270 cm a fragment of *Quercus* wood was found;
280–302 cm: *Alnus* peat, strongly decayed;
302– cm: clay.

Palynological results

Zone VI *and zone* VII (302.5–235 cm)

In zone VI and zone VII *Tilia* shows high percentages (average 40 %); *Quercus* is less important. According to Firbas (1949), it is possible to distinguish these two periods. The older one (up to 275 cm) does not contain pollen grains of *Fagus* (zone VI). In the younger part (zone VII) *Fagus* is already present, though the *Fagus* curve is often interrupted. The *Corylus* curve shows two maxima, one at a depth of 290 cm and a second one at a depth of 265 cm. The maxima in this curve coincide with minima in the *Tilia* curve. It is difficult to say whether the *Corylus* maxima correspond with the C2 and C3 established by Overbeck and Schneider (1938). Noteworthy is the presence of a small number of pollen grains of *Viscum*. At the end of the period the first signs of human activity are recognizable by an increase of the percentages of the herbs.

The curve of the cereals starts at a depth of 245 cm. All the pollen grains of the cereals belong to the *Triticum* type. At the same depth the Poaceae, *Rumex*, Asteraceae liguliflorae and Chenopodiaceae increase or make their appearance. *Tilia* decreases strongly after its last maximum, and *Quercus* increases. *Corylus* sinks to very low percentages.

Zone VIII (235–164,165 cm)

Zone VIII represents a time in which the influence of man on the vegetation must have been very marked. The period starts at the level where the *Quercus* curve intersects the *Tilia* curve. From this level on the herbs that have already been mentioned, and *Pteridium* are increasing strongly. Moreover the percentages of *Plantago lanceolata* and of *Artemisia*, herbs that were already present in zone VII, are increasing. From the beginning of zone VIII *Pinus* expands. The pollen of this tree soon reaches a higher percentage than that of any other tree. The rise of the Cyperaceae is connected with the stratigraphic change from *Alnus* peat to *Carex* peat.

The majority of the samples taken from the peat deposit in zone VIII contain but a small number of pollen grains, probably because of the increasing content of inorganic material. Between 205–170 cm we find a layer of clay and displaced loess containing such a small number of pollen grains that it was impossible to draw a diagram.

From the beginning of zone VIII up to a depth of 215 cm the *Fagus* curve do not show any influence of the human activity. Between 230–215 cm *Fagus* increases slowly. However, after a maximum at a depth of 215 cm we find a fall. This fall of *Fagus* is a temporary one. The first spectrum following the layer of displaced loess (170 cm) shows a percentage of *Fagus* (12 %) not reached in any of the previous periods.

With the exception of the spectra obtained at a depth of 170 cm and of 165 cm *Corylus* shows very low percentages. It is not possible to divide zone VIII.

Zone IX (164,165–80 cm)

The beginning of zone IX is characterized by a fall in the curves of *Pinus*, *Corylus* and *Quercus* and a rise in the curves of *Fagus* and *Alnus*. *Fagus* shows two maxima, one at a depth of 164 cm (F 1), where *Carpinus* is absent and a second one at a depth of 117.5 cm, where *Carpinus* is already present. In contrast to Leiffenderven we find in the lower part of the zone that the percentages of the herbs are still high, indicating the influence of man. However, the curves of the herbs show already a tendency to decrease. It is obvious that human influence decreased, and that the woods were partly regenerated. Human influence ends at a depth of 130 cm. *Fagus* expands, the pollen of *Plantago*, the Brassicaceae and *Rumex* disappear, and that of the Poaceae reach very low percentages. The curve of the Filicales which showed a continuous rise since the beginning of zone VIII, decreases strongly at the beginning of the *Fagus* time. At a depth of 80 cm we find the transition to zone X.

Zone x (80–0 cm)

Zone x is characterized by a renewed rise in the curves of the cereals (*Secale*), *Plantago lanceolata*, Poaceae, Chenopodiaceae, Asteraceae, Brassicaceae and *Rumex*. Moreover, *Centaurea cyanus* makes its appearance. *Fagus* decreases and is replaced by *Quercus*. The *Pinus* curve shows a slight rise. The Cyperaceae and the Filicales are expanding.

The upper part of the diagram (from 50 cm) shows a rise of *Pinus* on account of the planting of pine woods (zone xb). *Alnus*, which shows a high percentage in zone xa, decreases in the upper part of the diagram.

Ulmus and *Tilia* are present in low percentages but the curves of these trees are often interrupted.

Fraxinus was present already in zone vi and zone vii but the curve of this tree shows nowhere percentages of some importance. The diagram shows over all the periods a negligible percentage of Ericaceae and of *Sphagnum*.

Nuth (Diagram 7)

Description of the site

The small bog of Nuth is situated in the valley of the Geleen, at the mouth of the Platsbeek, near the village of Nuth. The particularities with regard to the soil mentioned for Brommelen, which is situated not far from Nuth, apply also to the surroundings of the bog of Nuth.

Present aspect of the vegetation

At present the vegetation is an *Alnus* bush. Shrubs and herbs under the trees are *Rosa canina, Rubus spec., Sorbus aucuparia, Corylus avellana, Anemone nemorosa, Primula elatior, Lamium maculatum, Melandrium rubrum, Cardamine amara, Stachys silvatica, Adoxa moschatellina* and several species of *Carex* and Poaceae.

According to dates given by Maas (1959), we are probably dealing here with the *Pruneto-Fraxinetum.*

Stratigraphic results

The deposit is over its whole depth an *Alnus* peat. It contains many rests of wood, mainly of *Alnus*. At two levels the peat is interrupted, viz. 72.5–82.5 cm: peat mixed with sand and 240–262.5 cm: clay.

Among the other rests we mention:

large fragm. of *Alnus* wood at:	90, 110, 127, 142, 190 and between 265–272.5 cm;
wood of *Viburnum* at:	160 cm;
fruits of *Alnus* at:	0–20 cm (1×), 40–60 cm (13×), 82.5–100 cm (2×), 100–120 cm (4×), 120–140 cm (6×), 200–220 cm (1×).
fruits of Poaceae at:	120–140 cm (2×);
catkins of *Alnus* at:	40–60 cm (2×), 120–140 cm (1×).

Leaves of Bryophyta have been found only between 180–220 cm.

Palynological results

The diagram of the bog clearly shows that in the vegetation of the bog *Alnus* was dominant. Amont the trees *Alnus* reaches in the diagram an average percentage of 80 %. The diagram in which *Alnus* was not included, was composed in an other way than it usually is. Usually the tree pollen-grains including *Alnus* were counted to a number of 500. However, on account of the high percentages of *Alnus*, the number of the remaining tree pollen-grains is too small to calculate significant percentages. Therefore, we counted tree pollen-grains, excluding *Alnus*, till a tree-pollen sum of 150 was reached. The percentages of the herbs were calculated in the usual way.

The disturbing influence which *Alnus* exercises on the curves of the other trees, has been discussed already in an earlier paper (Janssen, 1959). Anthers of *Alnus* have often been found (at 15, 45, 55, 60, 105, 135, 140, 145, and 275 cm). Besides *Alnus*, an important component of the vegetation of the bog itself is *Dryopteris thelypteris* whose presence indicates that the vegetation of the bog itself was an association of the *Alnion glutinosae* (*Thelypterideto-Alnetum*). A sporangium of this fern has been found at a depth of 65 cm. The diagram shows that *Alnus* and *Dryopteris* are alternating. At the depth where the *Alnus* curve shows a minimum, *Dryopteris* expands.

The greater part of the diagram comprises the time during which *Fagus* was the dominant tree in the surroundings of the bog. On the second place we find *Carpinus*. The *Carpinus* curve often intersects that of *Fagus*.

The diagram starts in the lower part of zone ix, showing high percentages of *Quercus* and *Corylus*. *Fagus* and *Carpinus* are present, but do not reach high percentages. At a depth of 225 cm the *Fagus* curve intersects the *Quercus* curve, and *Corylus* decreases. From this spectrum onwards to a depth of 22.5 cm *Fagus* and *Carpinus* remain the main components of the woods. The percentages of the herbs are very low during the *Fagus* time. In the lower part of zone ix cereals are present, but the curve is often interrupted. However, in the upper part of the zone they are always present, though man did not influence the composition of the vegetation. From a depth of 90 cm the N.A.P. increases slightly, however without a marked effect upon the curves of the trees. From a depth of 40 cm we find a second increase in the percentages of the herbs, especially of the Asteraceae and of *Filipendula*. At this level *Fagus* decreases, but it remains together with *Carpinus* the dominant tree in the forests. We find the transition from zone ix to zone x at a depth of 22.5 cm. From this level on the influence of man upon the vegetation becomes very marked. The percentages of the cereals, Poaceae and *Plantago lanceolata* are increasing. *Centaurea cyanus* is present now too. The percentage of *Fagus* and *Carpinus* decrease, those of *Quercus*, *Corylus* and *Fraxinus* increase. In the uppermost spectra *Quercus* and *Corylus* decrease, *Pinus* expands, and *Fraxinus* reaches the highest percentage among the trees. The rise of *Fraxinus* and the decrease of *Dryopteris thelypteris* probably reflects a succession from the *Thelypterideto-Alnetum* to the *Pruneto-Fraxinetum*.

The number of pollen grains of the Ericaceae found in the samples is small. *Sphagnum* is not present in the diagram. The percentages of *Tilia* and *Ulmus* are small. The curves of these trees are often interrupted.

Anselerbeek (Diagram 2)

Description of the site

The bog of Anselerbeek is situated in the valley of the Anselerbeek, north of the country seat "Oud-Ehrenstein". Along the slope (east side) of the valley Septarian clay, a sediment belonging to the middle Oliogocene, is present. On account of the presence of this impermeable layer we find several springs along the eastern slope of the valley. The bog of Anselerbeek lies in one of these spring areas. The top soil on the plateaus at both sides of the valley consists of loess which covers sand belonging to the Upper Terrace. The loess is completely under cultivation.

Present aspect of the vegetation

The eastern slopes of the valley are the only localities where woods are present. They consist for the greater part of deciduous trees, though conifers have been planted locally. The vegetation of the bog is a *Macrophorbieto-Alnetum* with *Filipendula ulmaria, Urtica dioica, Primula elatior, Ranunculus repens, Rubus spec.* and several species of the Poaceae.

Stratigraphic results

0– 20 cm: peat black; much wood of *Alnus* and many roots of *Carex;* a few leaves of *Sphagnum papillosum* and of *Eriophorum;* seeds and fruits: *Ranunculus repens* (1 ×), *Stachys silvatica* (1 ×), *Carex spec.* (2 ×), *Alnus* (1 ×);

20– 30 cm: peat black-brown; many roots of *Carex;* some gravel;

30– 40 cm: clay;

40– 60 cm: peat grey-brown, composed of wood of *Alnus* and roots of *Carex;* seeds and fruits: *Alnus glutinosa* (2 ×), *Rubus spec.* (1 ×), *Lycopus europaeus* (2 ×), *Trifolium pratense* (1 ×);

60– 80 cm: peat grey-brown; wood of *Alnus* and roots of *Carex;* a few leaf sheaths of *Phragmites;*

80– 90 cm: idem; seed: *Lycopus europaeus* (1 ×);

90–100 cm: idem; a fragment of an Equisetum stem and some leaves of Bryophyta.

Palynological results

When *Alnus* is left out of consideration, *Fagus* reaches in the lower part of the diagram the highest percentages. We have to stress the fact that indicators of human activity are present already in fairly high percentages. The curve of the cereals reaches a percentage of 10 %, whereas *Plantago lanceolata* is present, though its curve is interrupted. Pollen grains of *Rumex* and *Centaurea cyanus* and spores of *Pteridium* are often present in the samples as well.

From a depth of 80 cm the curves of *Fagus* and *Tilia* decrease and the *Quercus* curve increase slightly. *Pinus* moreover expands. *Pinus* reaches maximum percentages at depths of 65 and 75 cm. Meanwhile the content of clay in the peat increases. At a depth of 60 cm *Pinus* sinks to a low percentage, whereas *Quercus* increases now from 25 % to 56 %. It was not possible to bridge the great variations in percentages between 60 and 65 cm. A sample taken at a depth of 62.5 cm contained a very small number of pollen grains, probably on account of the high content of clay at this level. The important jump in the curves of *Quercus* and *Pinus* seems to indicate that between 60 and 65 cm either peat has been removed or that the development of peat stagnated. However, the other curves do not support this supposition.

Between 60 and 25 cm *Quercus* is the most important tree. Between 40 and 30 cm the peat is interrupted by a layer of clay which does not contain pollen grains. However, on both sides of the clay layer, the percentages of *Quercus* are high, whereas the course of the curves of the other trees makes it probably that not much peat has been lost. The *Fagus* curve, which decreases at first, reaches a new maximum at a depth of 30 cm. However, now the *Fagus* curve does not intersect the *Quercus* curve. The period after the *Fagus* dominance is usually characterized by an increasing human activity. The present diagram does not show this phenomenon very clearly. The only indication for an increasing activity of man is the course of the curves of *Plantago lanceolata* and *Pteridium*. As we saw already in the *Fagus* time, *Plantago lanceolata* is present but its curve is interrupted. In the *Quercus* time the curve of *Plantago lanceolata* is continuous, and its pollen reaches a higher percentage. The curve of *Pteridium* shows a peak at the beginning of the *Quercus* time.

On the other hand the curve of the cereals seems to indicate a decreasing activity of man, even if we calculate the percentages of the cereals on the base of a tree-pollen sum without *Alnus*.

There are two possibilities to explain these phenomena. In the first place it is possible that man influenced the vegetation already in zone IX. In that case no marked difference between zone IX and zone X would have been present. A second explanation is that the *Fagus* time in the present diagram does not represent zone IX, but that it represents a part of zone X. Such a development is quite possible. The bog of Anselerbeek is situated in the neighbourhood of the castle "Oud-Ehrenstein", and therefore it is possible that the *Fagus* woods have been maintained here much longer than elsewhere. In the present time *Fagus* is still fairly abundant in the area round the castle.

The upper part of the diagram belongs to zone Xb, the time of the pine plantations. In this zone *Fraxinus* reaches a somewhat higher percentage. *Tilia* disappears almost completely and *Quercus* decreases strongly.

In none of the periods *Ulmus* is of much importance. The same holds for *Sphagnum* and the Ericaceae. However, in the *Fagus* time the Ericaceae reach a higher percentage.

Rimburg (Diagram 6)

DESCRIPTION OF THE SITE AND PRESENT ASPECT OF THE VEGETATION

The bog of Rimburg is situated in an old bed of the river Worm on the Netherlands German frontier, south of the village of Rimburg. At present the bog has been brought into cultivation, i.e. it has been converted into a pasture. With the exception of some rests of woods on the upper parts of the surrounding slopes, the region round the bog has been cleared almost completely. The Upper Terrace on Dutch- and as well on German territory is covered with a layer of loess. (TESCH, 1946; EBRET, KAISER and FUCHS, 1937).

Stratigraphic results

0 – 20 cm:	black Bryophyta peat with some limonite; many roots are present, but not many roots of *Carex;* some fragments of the stem of *Equisetum;* fruit: *Glyceria maxima* (1×);
20 – 40 cm:	black *Alnus* peat; some leaves of *Sphagnum papillosum;* between 37.5–40 cm some fernsporangia;
40 – 60 cm:	black *Alnus* peat; in the lower part mixed with roots of *Carex;* much wood of *Alnus;* seeds: *Lychnis flos-cuculi* (1×);
60 – 70 cm:	*Carex* peat; wood not abundant; many roots of *Carex;* at 70 cm a fragment of *Alnus* wood;
70 – 82.5 cm:	*Carex* peat, the lower part more and more loamy; fruits of *Carex panicea* (6×); many chaffs of *Carex;*
82.5–100 cm:	*Carex-Alnus* peat with some leaves of Bryophyta and a stem of *Equisetum;* fruits: *Carex panicea* (2×);
100 –140 cm:	black *Alnus* peat, strongly decomposed;
140 cm:	clay.

Palynological results

Zone VII (140–97.5 cm)

The peat formation starts in zone VII. In the local vegetation *Alnus* is dominant. *Pinus* and *Corylus* are decreasing. The curve of the *Quercetum mixtum* increases on account of a rise of the *Tilia* curve up to 56 % (Σ A.P. without *Alnus*); *Betula* and *Salix* show very low percentages. The continuous *Fagus* curve starts at a depth of 110 cm.

Zone VIII (97.5–62.5 cm)

At the beginning of zone VIII the *Tilia* curve suddenly falls, the curve of *Quercus* and *Pinus* rise and *Fagus* shows its first increase. At the same level we note a very pronounced rise in the curve of the herbs, among which several indicators of civilisation are found, viz. *Plantago, Rumex, Artemisia*, etc. At a depth of 92.5 cm the curve of the cereals starts.

The rise in the curve of the Cyperaceae is due to a change in the local vegetation which finds its expression in the change from *Alnus* peat to *Carex* peat. At the beginning of the zone we also note a rise of *Equisetum* which belongs apparently to the vegetation of the bog itself.

From 82.5–77.5 cm we find a layer of loam, which contains a very small number of pollen grains. Just above the loam layer both the peat composition and the pollen diagram show another aspect. The *Alnus* curve decreases from 50 % to 20 %, whereas *Corylus* rises from 12 % to 28 % (tree-pollen sum without *Alnus*). *Pinus* reaches its highest values, *Tilia* disappears almost completely and the *Betula* curve begins to rise. The fall of *Alnus* agrees well with the change from *Alnus-Carex* peat to a pure *Carex* peat. The percentages found for the herbs remain high. At the top of the zone the curve of the Filicales rises. Rests of ferns, however, were not found.

Carpinus is present in zone VIII, but shows very low percentages. Its curve is not continuous.

Rather unexpected is the occurrence of pollen grains of *Helianthemum*, and *Hippophae* and that of a single spore of *Selaginella selaginoides*, as they are usually abundant in diagrams of the late-glacial. It may be that these pollen grains are not autochthonous, but that they were transported to the present site from late-glacial sediments. In this way it is also possible to explain the high percentages of *Pinus*. If we adopt such an explanation, at least a part of the pollen grains of *Artemisia*, the Chenopodiaceae, etc. may also be of foreign origin. On the other hand, the high percentages of *Pinus* may be the effect of a clearing of the forests. As we will see in chapter VII, this explanation is more plausible. Moreover it should be borne in mind that *Helianthemum* is to day an indigenous component of the vegetation of South Limburg, and that *Hippophae* although no longer present in this region occurs on calcareous soils in the dune- and wadden district. It therefore does not seem unreasonable to suppose that *Helianthemum* and *Hippophae* were part of the vegetation in zone VIII (compare page 72, 73). The occurrence of *Selaginella* in the diagram, however, remains inexplicable.

Zone IX (62.5 – 37.5 cm)

Zone IX is characterized by a local dominance of *Alnus*. Between 61 and 47.5 cm the percentages of *Alnus* are very high and depress the other curves strongly. The diagram including *Alnus* in the tree-pollen sum therefore does not show whether the fall of *Fagus* after its first maximum is spurious or real. The diagram obtained by excluding *Alnus* from the tree-pollen sum shows that the *Fagus* curve really has two maxima (F 1, F 2).

At the depths where *Fagus* reaches its lowest percentages *Quercus* intersects the *Fagus* curve, and *Corylus* shows a slight peak. The *Pinus* curve which decreased already in zone VIII, gradually falls to low percentages. The number of *Carpinus* pollen grains is very small. Only at the level of F 2 the somewhat higher value of 7 % has been found. *Betula* decreases gradually. The interrupted curves of *Tilia* and *Ulmus* remain low. The curves of the herbs, indicators of civilisation and of Cyperaceae sink to low percentages. Only between F 1 and F 2 the curves of the Cyperaceae and the Poaceae are slightly rising.

Compared with zone VIII *Equisetum* has in the vegetation of the bog itself been replaced by the Filicales. The occurrence of fern sporangia in the peat (37.5–40 cm) coincides with the high value of 367 % found for the spores.

Zone X (37.5–0 cm)

Alnus is once more the dominant tree in the vegetation of the bog. In the lower part of the zone (xa) *Fagus* shows a steep fall, whereas the *Quercus* curve rises. At first the curves of *Corylus* and *Betula* are both rising, but at the level where *Betula* reaches its maximum *Corylus* begins to decrease. Finally *Betula* falls, whereas *Corylus* reaches a new maximum of 31 %.

The herbs do not show any change compared with the preceding zone.

Between 22.5–20 cm the diagram shows a gap both stratigraphically and pollenanalytically. At this level *Pinus* suddenly rises on account of the decreasing percentages of *Quercus*. At a depth of 15 cm *Fagus* decreases for the second time. The other tree curves remain more or less constant.

During the *Pinus* time (zone xb), herbs as Cyperaceae, Poaceae, *Artemisia*, Chenopodiaceae, *Rumex* and Asteraceae are more important than they were previously. We noted the occurrence of pollen grains of *Polygonum persicaria* and *Centaurea cyanus*. In zone xb the *Alnus* peat has changed into a *Carex-Bryophyta* peat.

Cortenbach and Voerendaal

Description of the site

Near the village of Voerendaal, west of Heerlen, we find in the valley of the river Geleen an alluvial area which is unusually large for South Limburg. According to Klein (1914), in post-glacial times a lake must have been present here, which extended in a north-western direction. Klein suggests that the outlet of the lake was found near Nuth, where the valley of the Geleen narrows. In the course of the time the lake silted up and peat was formated. Klein mentioned already that near the castle of Haaren as well as near the castle of Cortenbach, the upper part of the sediment is peat, whereas its lower part is clay mixed with lime. In the clay Klein found *Helix hispida* and *Succinea fagotiana*.

We mentioned already in our introduction that a pollen diagram made from peat in this region (Van Eck, unpublished) shows a high percentage of *Tilia*.

In order to obtain more information with regard to the development of the vegetation, four borings were carried out in the region near Voerendaal. Voerendaal 1 and 2 have been taken within a distance of 10 m from each other in a meadow east of the castle of Haaren. Cortenbach 1 and 2 have been taken from localities north of the castle of Cortenbach where we find an abrupt fall in the soil surface.

Present aspect of the vegetation

The recent vegetation of Cortenbach comprises *Alnus glutinosa*, *Salix spec.*, *Carex spec.*, *Cirsium palustre*, *Sonchus oleraceus*, *Filipendula ulmaria*, and plantations of *Populus*.

Cortenbach 1 has been taken above the fall, Cortenbach 2 on the margin of a meadow at the south side of the fall. In all four samples the underground of the lime and peat sediments is Cerithian clay of Oligocene age (Jongmans, Krul and Vos, 1941).

Stratigraphic results

In agreement with Klein the upper part of the four samples was found to be peat, the lower part clay with a high content of lime. The peat stratigraphy has been investigated only at Cortenbach 2 and Voerendaal 1. Voerendaal 2 has much resemblance with Voerendaal 1, whereas Cortenbach 1 has been disturbed too much.

Voerendaal 1

0 – 50 cm:	clay;
50 – 80 cm:	*Alnus* peat; seed: *Stachys palustris* (1×);
80 – 97.5 cm:	gyttja with a small percentage of lime, wood of *Alnus* and clay; between 86–89 cm a layer of lime;
97.5–120 cm:	clay and lime; two fern sporangia.

Cortenbach 2

0 – 82.5 cm:	clay;
82.5– 87.5 cm:	*Alnus* peat; seeds and fruits: *Scirpus* (1 ×), *Carex spec.* (1 ×), *Thalictrum flavum* (1 ×); wood of *Alnus;*
87.5–120 cm:	*Alnus* peat with some lime; wood of *Alnus* and of *Salix;* fruit of *Eleocharis palustris* (1 ×), seed of *Lysimachia nummularia* (1 ×);
120 –180 cm:	alternating layers of lime and *Carex* peat;
180 –195 cm:	*Carex-Phragmites* peat; lime present; fruit: *Scirpus* (1 ×);
195 –208 cm:	*Phragmites-Carex;* less lime than in the preceding zone;
208 –220 cm:	lime with some *Carex* roots;
220 –232 cm:	lime with some bands of *Phragmites* peat;
232 –260 cm:	*Phragmites* peat with lime;
260 –280 cm:	*Phragmites* peat; lime absent;
280 –295 cm:	*Carex-Bryophyta* peat, strongly decomposed; lime present;
295 –300 cm:	clay and lime.

Palynological results

Voerendaal 1 (Diagram 9)

Zone v (120–97.5 cm)

The lower part of the diagram shows a dominance of *Pinus*. *Corylus*, *Quercus* and *Ulmus* are present but in low percentages. In the flora that must have belonged to the bog itself the Filicales reach high percentages.

Zone vii (97.5–57.5 cm)

At a depth of 97.5 cm, together with the change from lime to gyttja, *Alnus* rises very suddenly from 2.5 to 45 % and *Pinus* falls from 80 to 25 %. Somewhat higher in the diagram *Fagus* is present already. These phenomena seem to indicate that zone vi is lacking in the diagram.

Up to a depth of 82.5 cm the curves run fairly parallel. *Alnus* shows a value of about 45 %, *Pinus* 25 % and *Corylus* about 20 %. Compared with *Quercus*, *Tilia* forms an important part of the *Quercetum mixtum*. *Ulmus*, which reaches its maximum at 97.5 cm, decreases gradually.

The herbs show maximum values up to a depth of 72.5 cm. We have to draw attention to the presence of pollen grains of *Lemna* and *Typha* (*Sparganium*). Together with the character of the peat (gyttja), these pollen grains indicate that the area must have been a lake. This may perhaps be the explanation for the high percentages of *Pinus*. Usually *Pinus* manifests itself strongly in a woodless region (Aario, 1940). In agreement with the stratigraphical analysis of the peat composition, between 82.5–57.5 cm (*Alnus* peat), the *Alnus* curve rises strongly to a percentage of 90 %, whereas the other tree curves approach zero.

Quercus is now the main constituent of the *Quercetum mixtum*. *Tilia* and *Ulmus* disappeared. The curves of the herbs reach low percentages at this time.

Zone VIII (57.5–50 cm)

Zone VIII is characterized by features indicating the influence of man. The curve of the cereals (not *Secale*) starts. The percentages of *Quercus* and *Pinus* are rising, *Alnus* decreases again. The curves of the herbs show increasing percentages. *Fagus* shows its first increase. The peat is covered by a layer of loam and clay which does not contain pollen grains.

Voerendaal 2 (Diagram 11)

The diagram of Voerendaal 2 shows much resemblance to that of Voerendaal 1. It starts in zone IV: *Corylus* is present in low percentages, but *Quercus* and *Ulmus* not yet.

Zone V shows a *Corylus* maximum. *Ulmus* is the main constituent of the *Quercetum mixtum*.

Zone VII (82.5–55 cm): lower part gyttja with *Alnus* and *Pinus* both 40–50 % and many pollen grains of herbs. *Corylus*, however, is less important than it is at Voerendaal 1. The upper part of zone VII shows an increase of *Alnus* and a fall of *Pinus* and of the herbs. The uppermost spectrum (50 cm) represents the beginning of zone VIII.

Cortenbach 1

The results of Cortenbach 1 are the same as those of Voerendaal 2. The diagram starts in zone IV where *Corylus* has not yet made its appearance. A little above the level where *Corylus* comes in, the deposit is highly disturbed. In the disturbed zone the curves show very irregular fluctuations.

The upper four spectra give a more normal picture. They belong to zone X. As the diagram does not show any new aspect, it has not been published.

Cortenbach 2 (Diagram 8)

Zone IV (300–209 cm)

In the lower part of the zone *Betula* decreases and the *Pinus* curve rises. In the whole zone *Pinus* remains very high. At a depth of 235 cm the *Corylus* curve becomes continuous. The percentages of the herbs are low.

Zone V (209–120 cm)

Zone V starts at a depth where the *Corylus* curve rises, and *Quercus* and *Ulmus* make their appearance. *Corylus* reaches its highest values (65 %) at the base of the zone. During the *Corylus* maximum we find in agreement with the composition of the vegetation of the bog itself (*Carex-Phragmites* peat) a higher percentage for the Poaceae and for the Cyperaceae. In the lower part of the zone *Quercus* and *Ulmus* keep each other in balance, but *Ulmus* soon becomes the main component of the *Quercetum mixtum*. After the *Corylus* peak this tree decreases, and remains up to the end of the zone at a percentage of about 30 %.

Besides *Phragmites* and *Carex* during zone IV and zone V Filicales and *Equisetum* were present as well in the vegetation of the bog. (*Equisetum* sporangia at 270 cm and 300 cm, sporangia of the Filicales at 160, 208, and 280 cm). The occurrence of these sporangia coincides with high percentages of *Equisetum* and Filicales in the diagram.

Zone VII (120–82.5 cm)

Though the rise of *Alnus* is here more regular than it is at Voerendaal, we suppose that here too zone VI is absent. *Fagus* is present already in low percentages from the base of the zone. Here too it is possible to divide the zone in a lower part in which *Pinus* and *Corylus* show high percentages, and an upper part, where *Alnus* becomes dominant. Although there is no difference in the palynological results we know from the stratigraphic analysis, that the gyttja zone which was present at Voerendaal, is lacking here. Furthermore an important decrease in the curves of the herbs is lacking too during the *Alnus* dominance. Only the curves of the Brassicaceae and of the Asteraceae, which show a rise in the lower part of the zone, show a slight decline at the time of the *Alnus* dominance.

In agreement with the results obtained at Voerendaal is the fact that *Typha* (or *Sparganium*) reaches its highest percentages in the lower part of the zone. In the upper part of the zone *Ulmus* decreases and its curve intersects the *Quercus* curve.

We mentioned already that the gyttja zone of Voerendaal is not present at Cortenbach. The explanation is probably that Cortenbach is situated at the margin of the former lake, whereas Voerendaal is situated in the centre of the latter. From the low *Alnus* percentages in the lower part of the zone it appears that *Alnus* was not abundant. Moreover, the presence of herbs indicates that the vegetation was an open one. Probably the pollen grains of *Alnus* arose from a narrow *Alnus* zone (*Alnion incanae*) along the margin of the lake.

The fact that at Cortenbach the curves of the herbs scarcely decrease in the upper part of the zone (VIIb), may also be explained by the different position of the two sites. At the margin of the bog the vegetation must have been more open than it was in the centre (Voerendaal), where *Alnus* now begins to occur (*Thelypterideto-Alnetum*), depressing the curves of the herbs. The fact that the curves of the trees follow the same pattern both at Voerendaal and at Cortenbach, may find its explanation in the circumstance that the curves of the herbs reflect more closely the vegetation of the bog itself, whereas the curves of the trees give an impression of the vegetation in the Voerendaal area as a whole.

The difference between the margin and the centre of the bog appears in zone IV and zone V as well. At Voerendaal the sediment is lime without any recognizable rest of plants. At Cortenbach lime is present in zone IV and zone V, but it is often interrupted by zones of *Phragmites*-

and later on of *Magnocaricion* peat. This indicates a silting up of the lake starting from the margin. The lime may have been deposited in times in which the level of the lake was high, and the peat in times in which it was low.

We did not succeed in finding here the high *Tilia* percentages which were earlier found in the Voerendaal region.

Finally we have to draw attention to the presence of *Secale* in zone VII. The presence of these pollen grains might be an argument in favour of the supposition that this zone does not belong to zone VII but to zone X. However, in zone X usually *Tilia* and *Ulmus* show very low percentages. The percentages of these trees are too high to refer our zone to a much later time.

THE BOGS ON THE HEATH OF BRUNSSUM

The heath of Brunssum, situated north of Heerlen, is one of the regions where loess is absent. The top soil consists of sand of Miocene age. On account of the character of the soil the vegetation is a very poor one compared with that in the other parts of South Limburg. Therefore the history of the vegetation may possibly have been different from that elsewhere in South Limburg. The dominant trees on the heath are *Betula* and *Pinus*, the latter planted, occupying extensive areas along and on the heath of Brunssum. In the northern part of the heath we find an extensive area in which the heath has been destroyed by drifting sands. Man is probably responsible for the present sand drifts. In the northern parts many abandoned brown-coal pits are present. They are now filled with water.

In the valleys on the heath a number of marshes are present. According to VAN DER STIGHEL (1942) the rainwater stagnates by the presence of layers of brown-coal in the underground which gives rise to marshes.

Brunssum 1 (Diagram 13)

DESCRIPTION OF THE SITE

The bog of Brunssum 1 is situated in the north-western part of the heath of Brunssum. At the bottom of a little valley, which runs to the north, we find a marshy vegetation where locally peat has been deposited. Unfortunately we find on many places that the peat has been removed by man. Though the boring has been taken from a site which seems fairly undisturbed we have to take into account that a part of the deposit may have disappeared. To the north the valley is filled up by sand drifts.

PRESENT ASPECT OF THE VEGETATION

In the vegetation of the marshes *Betula* is the dominant tree. Moreover shrubs of *Alnus incana, Salix, Quercus robur* and *Frangula alnus* are present. The herbs are *Rumex acetosella, Corynephorus canescens, Carex spec., Erica tetralix, Epilobium angustifolium, Sonchus oleraceus, Tussilago farfara.* Outside the marshes we find mainly *Hieracium vulgaris, Calluna vulgaris, Betula and Pinus.*

STRATIGRAPHIC RESULTS

0– 5 cm: many roots, but not typically roots of *Carex;*
5– 8 cm: peat black by the presence of charcoal; many roots;
8–12 cm: *Sphagnum papillosum* peat mixed with a few *Eriophorum* leaves and roots (not *Carex*);
12–20 cm: *Sphagnum papillosum* peat, practically not decomposed;

20–40 cm: *Spagnum papillosum* peat, rough, brown; between 20–30 cm a few *Phragmites* leaves;

40–56 cm: *Sphagnum papillosum* peat mixed with a few Sphagna of the sections *Subsecunda*, *Cuspidata* and *Acutifolia;* peat rough, brown;

56–60 cm: *Sphagnum papillosum* peat mixed with a few *Sphagnum acutifolium* rests;

60–68 cm: Peat composed of *Sphagnum cuspidatum*, *Sp. acutifolium*, and *Sp. rubellum;* some roots of *Carex* and leaves of *Sphagnum molle;*

68–76 cm: Peat highly decomposed, black, mixed with sand; leaves of *Sphagnum cuspidatum* and roots of *Carex;* fruits of *Carex panicea* (2×).

Palynological results

In the lower part of the diagram *Corylus* is the most important tree. Up to a depth of 8 cm *Corylus* decreases and *Quercus* reaches the highest percentages. Meanwhile *Fagus* expands.

The *Tilia* curve shows fairly high percentages. The *Tilia* curve starts with a percentage of about 5 %..After a decline between 40–60 cm it intersects the *Fagus* curve. *Tilia* reaches a maximum of 15 % at a depth of 32.5 cm. After that the percentages of *Tilia* are decreasing.

Ulmus shows its highest percentages in the lower part of the diagram, after which the *Ulmus* curve sinks gradually. Above the *Tilia* maximum the *Ulmus* curve is often interrupted.

Alnus and *Betula* play a less important rôle in the vegetation than *Quercus* and *Corylus*. After a slight rise in the lower part of the diagram, the curves of *Alnus* and *Betula* remain fairly constant at a percentage of 15 %.

Many pollen grains of herbs have been found. In the first place we have to mention the high percentages of the cereals and of *Plantago lanceolata*, indicating that man was present already. Quite in agreement with the stratigraphic composition of the peat, is the presence of spores of *Sphagnum* and pollen grains of *Drosera*. However, several pollen grains have been found indicating that the soil on the heath was not so deficient in nutrients as it is now. They are: *Humulus lupulus*, which occurs irregularly, but reaches high percentages, *Utricularia*, *Convolvulus* and *Tilia*. These euthropic conditions may be explained by assuming either a higher level of the phreatic surface or the presence of loess. According to Druif (1927) loess has been deposited on the heath of Brunssum in the same way as in the loess region, but it was removed by erosion.

At a depth of 8–9 cm, where the stratigraphic composition of the peat suddenly undergoes a change, the development of the vegetation is interrupted. The percentages of *Fagus*, *Tilia* and *Quercus* go down, the percentages of *Betula* increase. The fairly high percentages of *Fagopyrum*, together with a charcoal zone in the peat, indicate that we are dealing with a "buckweat fire-culture". On account of the fire we find the following stages in the composition of the vegetation:

1. a sharp decrease of *Fagus*, *Quercus* and the cereals; increase of *Pinus* (long distance transport), *Betula* and *Corylus; Rumex acetosella* reaches a maximum of 240 %; increase of the Poaceae;
2. decrease of *Tilia* and *Rumex;* the Poaceae reach a maximum; proceeding increase of *Betula;*
3. decrease of the Poaceae; the Chenopodiaceae reach a maximum; fall of *Pinus* and *Corylus;*
4. *Betula* reaches a percentage of 94 %; the herbs and the other trees fall to zero.

The upper 10 cm of Brunssum 1 belong to recent times. According to LEHMANN (1940), *Fagopyrum* was introduced in Europe after 1400 A.D. The presence of *Fagopyrum* therefore is an indication that the peat in the upper part of the diagram has been built up in recent times. Still the most recent time is lacking at Br 1, as *Pinus* and *Calluna* remain low. The high percentage of *Betula* reminds already of the composition of the present day vegetation. It is not impossible that at a depth of 7.5 cm a part of the deposit is lacking.

Brunssum 2 (Diagram 15)

DESCRIPTION OF THE SITE AND PRESENT ASPECT OF THE VEGETATION

The bog of Brunssum 2 is situated in the spring area of the "Rode Beek". The present vegetation is a *Saliceto-Betuletum* with *Betula*, *Salix* and *Alnus*. The bog is surrounded by heath and (on the west side) by *Pinus* plantations.

STRATIGRAPHIC RESULTS

The boring of 100 cm consists for the greater part of sand which contains a larger or smaller content of humus. The organic material is almost completely decomposed. The only organic remains that have been left, consist of unknown roots and of some fragments of *Alnus*. No seeds were found.

PALYNOLOGICAL RESULTS

The tree curves in the diagram do not show much variation. The most important tree is *Corylus* (about 75 %), which tends to decrease towards the upper part of the diagram. Among the trees of the *Quercetum mixtum*, *Tilia* shows the highest percentages. In the lower part of the diagram *Ulmus* is more important than *Quercus;* in the middle part the percentages of *Ulmus* and *Quercus* are equal, whereas in the upper part of the diagram the *Quercus* curve rises and intersects the curve of *Tilia*. On account of the high percentage of sand these high percentages of *Tilia* may be ascribed to a differential destruction of the pollen grains.

The percentages of *Pinus*, *Alnus* and *Betula* are low. *Fagus* and *Carpinus* are present, but also in low percentages.

In the lower part of the diagram the number of pollen grains of herbs is small. However, above a depth of 45 cm the percentages of the cereals, Poaceae and *Rumex* increase. Successively the Poaceae and *Rumex* reach a considerable peak. Beginning with this level more grains of other herbs have been found.

Though no *Sphagnum* leaves have been found, spores of *Sphagnum* are fairly abundant in the samples.

Brunssum 3

The boring Brunssum 3 (56 cm) has been analysed pollenanalytically by Miss N. C. Rem in 1952. The results are almost the same as those obtained in Brunssum 2. Therefore it is not necessary to reproduce the diagram in the present paper. However some differences with the diagram of Brunssum 2 must be pointed out. viz.

1. The main constituent of the *Quercetum mixtum* is not *Tilia* but *Ulmus*. Ulmus reaches in the lower part of the diagram a percentage of 20 %. Only in the upper part of the diagram *Tilia* expands. However, the *Tilia* curve does not intersect that of *Ulmus*.
2. The peat is less strongly decomposed than that at Brunssum 2. It is not possible to date the diagrams of Brunssum 2 and Brunssum 3.

Brunssum 4 (diagram 1)

The diagram of Brunssum 4 which was made in 1953, show a pattern which differs considerably from the other diagrams of the heath of Brunssum. Therefore it seems worth to publish the diagram though many shortcomings adhere to it. The lower part of the diagram shows high percentages of *Corylus*, but then *Quercus* and *Tilia* begin to increase. In a *Sphagnum* zone *Tilia* reaches the very high percentage of 50 %. The uppermost spectrum shows high percentages of *Betula* and of the Ericaceae. The *Tilia* curve runs down sharply and intersects that of *Quercus*. *Pinus* is present but does not reach high percentages, which indicate that the most recent period is not represented in the diagram.

DISCUSSION OF THE VEGETATION OF THE BOGS

In only two of the bogs that were investigated by us the vegetation of the bog itself indicates an acid reaction of the soil; viz. at L.F. (Rhynchosporion during zone VIII, IX and X; (see page 32) and in the bogs on the heath of Brunssum. The vegetation of the other bogs remains eutrophic. It seems to us that this is not accidental. The bogs in which the soil is acid, are situated outside the loess district, whereas the other bogs are situated in the loess district. In the loess district the soil will receive continually a supply of nutrients and lime preventing a fall of the Ph.

Among the trees we have to mention the different behaviour of *Alnus* and *Betula*. In zone VIII, IX and X of L.F. and in the bogs of Brunssum *Alnus* does not belong to the vegetation of the bog itself, as *Betula* (*pubescens*) does.

The other bogs show a different situation: *Alnus* is highly local wheras *Betula* (probably *Betula pendula*) does not occur in the *Alnion glutinosae.* The pollen grains of *Betula* therefore must have arrived from outside the bog. This is clearly shown by the percentages of *Betula* shown in the diagrams. At L.F. and Br. the *Betula* pollen reach a fairly high percentage. In the other bogs the percentages of *Betula* as a rule do not exceed a few per cents.

We have to distinguish in our region three types of bogs. The first type comprises the bogs which have arisen by means of a silting up of a lake (L.F., Co and Vo). These bogs show the normal succession starting in euthrophic fresh water: *Phragmition-Magnocaricion-Alnion glutinosae* (WESTHOFF and MÖRZER BRUINS, 1951). The second type comprises the bogs in the spring areas of the brooks. The thickness of the peat is usually less than in the bogs of the first type. Moreover in these bogs the development of peat did not start before zone x (compare page 86). The present vegetation is always one of the associations of the *Alnion incanae.* A third type comprises the bogs which developed in an arm, cut off from a stream (BRO, Ri, Nuth). The present vegetation of the bog of Nuth too is an association belonging to the *Alnion incanae.* However, the thickness of the peat deposit exceeds that of the peat in the second type. Moreover, the development of the peat started before zone x.

The vegetation of the bogs of the second and of the third type probably had the character of an *Alnion incanae* vegetation. An indication in favour of this assumption is the content of minerogenous matter found in the peat. According to MAAS (1959) the content of minerogenous matter in the peat of the *Pruneto-Fraxinetum* is 50–85 % and in the *Macrophorbieto-Alnetum* 65–85 %. In agreement with the dates of Maas we find a high content of minerogenous matter in the bogs of the spring areas (B: 48–89 %, W: 43–79 %, Ra: 22–49 %, Gr: 51–86 %, A: 41–95 %). With the exception of Ri the soil in the bogs of the third type too have a high content of minerogenous matter (Nuth: 45–70 %, BRO: 29–66 %, Ri: 8–19 %). However, it seems desirable to draw attention to the fact that the former vegetation of these bogs must have shown a closer relationship to the *Alnion glutinosae* than it does nowadays. The rise of *Fraxinus* observed in the upper part of several diagrams may indicate a succession from the *Alnion glutinosae* to the *Alnion incanae.* At B we find in the upper part of the diagram a decrease of *Dryopteris thelypteris,* which may due to the same succession. A rise of *Fraxinus* and a decrease of *Dryopteris thelypteris* is visible in the upper part of the diagrams of Nuth and Gr too. An indication of a closer relationship with the *Alnion glutinosae* may be seen in the lower content of minerogenous matter found at BRO, Ri and Ra. For other explanation for the rise of *Fraxinus* we refer to page 86.

In contrast to the bogs of the third and second types the content of minerogenous matter in the peat of the bogs belonging to the first type is low (10–14 %). This indicates that the vegetation of these bogs must certainly be referred to the *Alnion glutinosae* (*Thelypterideto-Alnetum*).

Besides the *Macrophorbieto-Alnetum* and the *Pruneto-Fraxinetum* the *Cariceto elongatae-Alnetum* and the *Cariceto remotae-Alnetum* may occur in the spring areas as well. From a palynological point of view it is difficult to distinguish these four associations from each other, especially because we may expect that several types of *Alnus* vegetations are occurring in the neighbourhood at a short distance of each other. On the sites where running water is present and where we find a sufficient supply of oxygen, the *Cariceto remotae-Fraxinetum* is present; on the sites between the small water courses in the spring area the other associations occur. This situation is a very dynamic one on account of the frequent diversions in the course of the streams.

CHAPTER VII

DISCUSSION OF THE ZONES

In this chapter we will consider the development of the vegetation round the bogs in so far it can be reconstructed by the aid of the diagrams. First of all we will try to find out in how far these diagrams are similar to each other and then we will consider the points in which they differ.

For comparison with the development of the vegetation in adjacent regions we chiefly consulted the papers by FLORSCHÜTZ and VAN OYE, 1939 and by PERSCH, 1950 (Ardennes), by STRAKA, 1952 and by HUMMEL, 1949 (Eiffel), by ESHUIS, 1946 (Peel), and by VERHOEFF, 1957 (Central Limburg). For comparison with its development in the northern parts of the Netherlands the studies of WATERBOLK (1954) and VAN ZEIST (1955) were taken into consideration. In addition to these diagrams published by these authors special attention was paid to the diagrams given by MÜLLER (1953) and by STEINBERG (1944) who investigated loess regions in Central Europe.

The development of the vegetation, especially in the later part of the post-glacial time (zones VI-X), will be considered from a phytosociological point of view.

Originally, e.g. by BLYTT (1876) and of by SERNANDER (1908) the history of the forests was regarded as a process which depended entirely on climatological changes. Indeed, it is commonly accepted that after the late-glacial time the climate ameliorated up to the zones VI and VII, and that in north-western Europe the temperature reached its post-glacial maximum in these zones (FIRBAS, 1949). In the later periods the climate certainly did not remain unchanged. According to IVERSEN (1944), the winter temperature fell at the transition between zone VII and zone VIII. Moreover, on account of the stratigraphy found in raised bogs and of certain variations observed in the pollen diagrams several authors arrived at the conclusion that the precipitation in the zones VIII, IX and X must have been variable (OVERBECK, 1952; WATERBOLK, 1954; VAN ZEIST, 1959). Even since medieval times the climate changed (FIRBAS, 1954). In our region it is, as we will see, very difficult to recognize with certainty an alteration of the climate. Although such a change is possible, its effect is often completely overshadowed by that of human interference. Moreover, it should be borne in mind that an alteration of the climate can only produce an effect, when a critical point is reached. It is quite conceivable that in South Limburg, where the soil (loess) is a very rich one, the effect of the climate on the vegetation may have been less pronounced than it was elsewhere. For that reason it seems advisable to consider the history of the forests in South Limburg more as a plant succession, in whose development the interference of man at times played an important part, than as a reflection of climatological alterations. As we will see, many particularities in the diagrams may be explained by reference to the factors mentioned above. It is doubtfull whether in our region any changes in the diagrams may actually be regarded as the result of fluctuations in the climate, although such fluctuations certainly will have been present.

The parts of the diagrams which we want to consider from a phytosociological point of view are those comprising the zones VI, VII, VIII, IX and X. Before zone VI many species had not yet arrived in the region and so the conditions for a competition between the trees were completely different from what they are at the present time. Moreover, before zone VI, the climate certainly was very different from what it is nowadays. For these reasons it is almost impossible to compare the vegetation of these lower zones with plant associations that are found at present in the same region and up to zone VI our findings will be considered only in the usual palynological way. However, from zone VI on a more satisfactory picture of the changes in the composition of the vegetation could be obtained by making use of experience gained in the field of phytosociology.

The conditions for a coördination of our palynological findings with the results of phytosociological studies, are extremely favourable in South Limburg. In contrast to the extensive raised bogs found in the other parts of the country, the bogs of South Limburg are for the greater part of a small size. Up to now the attention of palynological workers was drawn in the first place to the raised bogs, which certainly are more suitable for palynological investigation than the often disturbed small bogs found in our region. On the other hand, a disadvantage of extensive raised bogs, from the point of view of palynology, is that the herbaceous pollen was mostly derived from herbs growing in the bog itself, whereas the tree pollen was derived from the vegetation outside the bog. As the distance to the forests around a raised bog is large, the tree-pollen spectra in the diagram of such a bog reflect certain changes in the vegetation of the forest over a large area. The spectra obtained from a raised bog, therefore represent "*long distance spectra*". In such a case it is very difficult to recognize in the pollen diagram different types of vegetation in the forest. In a small bog the variations in the diagram must be due in a large part, to differences in the vegetation occurring at a short distance from the site where the samples were taken. Here it is easier, therefore, to distinguish in the pollen diagram the different types of vegetation by which the bog in the subsequent stages of its development was surrounded.

Our considerations are based in the main on those expounded in a paper by TÜXEN (1931). Tüxen is of opinion that in a valley roughly the following types of vegetation may be distinguished, viz.

(1) the vegetation of the bog;
(2) the vegetation on the colluvial soils along the streams (Auenwälder);
(3) the vegetation on the slopes of the valley and on the plateau above it.

Though certain ideas of Tüxen are untenable (especially those concerning the part played by *Fagus*), the main principle proved to be a sound one. Already in 1931 Tüxen pointed out that it would be desirable to investigate small bogs, though for other reasons than have been expounded here.

The zonation proposed by Tüxen is roughly recognizable in three vegetation units that are present in South Limburg. The vegetation on the slopes and on the plateaus, mentioned under (3), has to be referred to the *Carpinion* which occurs on soils which show a differentiation in layers. The vegetation of the bog (1) has the character either of the *Alnion glutinosae* or of one of those associations belonging to the *Alnion incanae* which indicate the presence of a peaty soil (*Macrophorbieto-Alnetum* or *Pruneto-Fraxinetum*). The vegetation on colluvial soils (2) must be referred to the *Alno-Ulmion* (*Ulmion*). The *Alno-Ulmion* established by OBERDORFER (1953) for the Euro-Siberian region, comprises associations which originally were referred to the *Alnion glutinosae* and to the *Carpinion*. The hygrophilous associations of the *Querceto-Carpinetum* distinguished by Tüxen in 1936, viz. the *Querceto-Carpinetum stachyetosum* and the *Querceto-Carpinetum filipenduletosum* have been removed from the *Carpinion* and are now placed in the *Alno-Ulmion* (cf. p. 15). The same applies to a part of the *Alnetum glutinosae*.

We find the associations of the *Alno-Ulmion* on colluvial, usually minerogenous soils, which are inundated periodically by the stream. A Gley horizont is always present. DOING KRAFT (1955) states that the soil of the *Alno-Ulmion* is rich, young and wet, not layered and not leached, the phreatic surface being too high. In case of a fall of the phreatic surface (BURRICHTER, 1953), the soil is separated in two layers and the vegetation very gradually changes in one or another association of the *Carpinion*, a succession which may take one to several centuries. According to I. S. ZONNEVELD (1958) after the sedimentation of the soil by the stream a physical maturation takes place during which the water content and the amount of organic matter decreases and the content of minerogenous matter increases. The various degrees of maturing are recognizable by the presence of definite associations. In the various stages of maturing in the Biesbos (western Netherlands) the vegetation was found to be respectively a *Scirpeto-Phragmietum*, a *Salicetum albae* or a *Cariceto remotae-Fraxinetum*. Especially

CLASS	QUERCETO – FAGETEA DECIDUOUS FORESTS, SOIL RICH														VACC.-QUERCETO PICEETEA DECIDUOUS-CONIFEROUS FORESTS SOIL POOR					ALNETEA-GLUT. BROOK-FORESTS			
ORDER	FAGETALIA FORESTS ON OLDER, PROFILED SOIL					POPULETALIA FORESTS ON YOUNG HOMOGENEOUS SOIL									QUERCETALIA ROB.-PETRAEAE								
ALLIANCE	CARPINION FORESTS OF THE HILLS					ALNO – ULMION									QUERCION ROB.-PETRAEAE				BETULION	ALNION GLUT.			
SUB-ALLIANCE						SALICION SOIL WET		ALNION INC. SOIL MOIST			ULMION SOIL HUMID				VIOLETO-QUERCION LESS POOR			VACC. QUERCION POOR		IRIDO-ALNION SOIL RICH			SPHAGNO-ALNION SOIL POOR
ASSOCIATION	QUERCETO-CARPINETUM					SALICETUM TRIANDR.-VIMIN.	SALICETO-POPULETUM	CARICETO REM.-FRAXINET.	PRUNETO-FRAXINETUM	MACROPHORBIETO-ALNETUM	FRAXINO-ULMETUM	ULMETUM SUBEROSAE	ANTHRISCO-FRAXINETUM	STACHYETO-QUERCETUM	CONVALLARIO-QUERCETUM	VIOLETO-QUERCETUM	QUERCETUM PETRAEAE	QUERCETO-BETULETUM	BETULETUM-PUBESCENTIS	CARICETO ELONGATAE-ALNETUM		THELYPTERIDETO-ALNETUM	SALICETO-FRANGULETUM
SUB-ASSOCIATION GROUP	BETULA less rich		FRAXINUS rich																				
SUB-ASSOCIATION	Q-C LONICERETOSUM	Q-C MELICETOSUM	Q-C FRAXINETOSUM	Q-C ORCHIDETOSUM	Q-C SANICULETOSUM															C.E-A TYPICUM	C.E-A CARDAMINET.		
ALNUS	–	–	–	–	–	–	–	**A**2	**A**2	**A**5	–	–	a	a	a+	a+	–	–	–	**A**5	**A**5	**A**5	a1
BETULA VERRUCOSA	a2	a2	–	–	–	–	–	–	–	–	+	+	+	+	A2	A2	A2	**A**3	a	–	–	–	a1
BETULA PUBESCENS	a2	a2	–	–	–	–	–	–	–	–	+	+	+	+	a3	a3	a3	A4	**A**5	–	–	–	**A**3
QUERCUS PETRAEA	A3	A3	a3	a3	a3	–	–	–	–	–	–	–	–	–	a1	a1	**A**3	a1	–	–	–	–	–
QUERCUS ROBUR	A4	A4	A3	A3	A3	–	–	**A**2	**A**3	–	**A**4	**A**3	**A**5	**A**5	**A**5	**A**5	**A**4	**A**5	–	a1	a1	a1	–
FAGUS	a1	A4	–	–	A4	–	–	–	–	–	–	–	–	a	a1	a1	**A**2	a1	–	–	–	–	–
CARPINUS	**A**3	**A**3	**A**2	**A**2	**A**2	–	–	–	a	–	–	–	–	a	–	a	a	–	–	–	–	–	–
CORYLUS	**A**3	**A**3	**A**4	**A**4	**A**4	–	–	**A**3	**A**3	**A**1	**A**2	**A**2	–	**A**2	a1	A2	A2	–	–	–	–	–	–
ULMUS GLABRA	–	–	–	–	a	–	–	–	–	–	–	–	–	a2	–	–	–	–	–	–	–	–	–
ULMUS CARPINIFOLIA	–	–	–	–	–	–	–	A+	a1	–	**A**3	**A**5	**A**3	**A**3	–	–	–	–	–	–	–	–	–
FRAXINUS	a1	a1	**A**3	**A**3	**A**3	–	–	**A**2	**A**3	**A**1	**A**$^3_4$	**A**2	**A**$^3_4$	**A**$^3_4$	a	a	a	–	–	–	–	–	–
TILIA CORDATA	–	–	a	a	–	–	–	–	–	–	a	a	a	a	–	–	–	–	–	–	–	–	–
SALIX	a	a	a	a	a	**A**5	**A**5	**A**3	**A**3	**A**3	a	a	a	a	a	a	a	a	**A**1	**A**3	**A**3	**A**3	**A**3

PRESENCE	DOMINANCE-ABUNDANCE	
A 30–100%	5 DOMINANT	, cover > 50%
	4 CODOMINANT	, cover 25-50%
A 10–30%	3 ABUNDANT	, cover 5-25%
	2 FREQUENT	, cover scanty, rather numerous
a 1–10%	1 SPARSE	, cover scanty, number small
	+ RARE	, cover scanty, very few

TABLE I

Presence and dominance-abundance of the trees in the wood associations occurring in the Netherlands.

in the later stages of maturation, when a balance has been reached between the supply and the demolition of organic matter, an indication of an A-1 zone on the soil packet is present already. According to I. S. Zonneveld the vegetation occurring at the stage where the demolition of organic matter remains behind the supply, and where therefore an accumulation of organic matter (peat) takes place, can be assigned to the *Alnion glutinosae.*

Before proceeding with detailed analysis of the zones, we will first of all consider for the trees separately in what kind of forest they occur. For the recently recognized associations of the *Alno-Ulmion* we consulted especially the work of Van Leeuwen and Doing Kraft (1955, 1959). Table 1 shows the presence and dominance-abundance in the different types of woods.

Alnus glutinosa

Present especially in the *Alnetalia glutinosae* occurring on poorly drained soils, but often present in the *Alno-Ulmion* as well (especially in the *Alnion incanae*). This is in agreement with the findings of several other authors (Jongmans and Diemont, 1942; Tüxen, 1937; Lohmeyer, 1951; and Burrichter, 1953), according to which *Alnus* occurs in the *Querceto-Carpinetum filipenduletosum* and sometimes in the *Querceto-Carpinetum stachyetosum* too, i.e. in associations belonging to the *Alno-Ulmion.* A low occurrence of *Alnus* is shown by some "wet" associations of the *Violeto-Quercion.* However, *Alnus* certainly does not reach dominance in these types of wood. In the *Carpinion,* as it is defined now, *Alnus* is absent.

Betula verrucosa

Betula verrucosa is abundant on more or less dry soils with an acid reaction (Oberdorfer, 1949), especially therefore in the *Quercion-roboris-petraeae.* It never occurs in the *Alnion glutinosae* or in the *Alno-Ulmion.* In the *Carpinion* it is present only in the less rich associations of the *Querceto-Carpinetum* (*Querceto-Carpinetum loniceretosum* and *Querceto-Carpinetum melicetosum*). This means that in the loess region of South Limburg the tree is practically absent. According to Oberdorffer (1949), the tree is the first pioneer in cleared parts of the *Quercion-roboris-petraeae.*

Betula pubescens

Betula pubescens is abundant especially in the *Quercion-roboris-petraeae,* the *Betulion pubescentis* and the *Sphagno-Alnion* and may be an important element in the vegetation outside the loess district (cf. p. 51). It is unfortunately not possible to separate the pollen grains of *Betula pubescens* from those of *Betula verrucosa.*

Pinus sylvestris

According to Oberdorfer (1949), this tree occurs on soils where deciduous trees are absent, but there is no relation between it and the nutrient content of the soil, for it thrives on poor soils as well as on rich ones, though in the latter habitats it can not compete with the deciduous trees (Rubner, 1925; Buchwald, 1951); in the *Alnion glutinosae* it is absent.

Quercus robur

Quercus robur is very well represented in the *Alnion incanae,* in the *Ulmion* and in the *Quercion-roboris-petraeae.* Less important is *Quercus robur* in the *Carpinion* and in the *Alnion glutinosae,* and it is lacking in the *Salicion.*

Quercus petraea

Quercus petraea occurs in the *Violeto-Quercion* (especially in the *Quercetum sessiliflorae*) and in the *Carpinion.* In the *Alnion glutinosae* and in the *Salicion* it is lacking. *Quercus petraea* occurs in the *Alnion incanae* and in the *Ulmion,* although it has here, in contrast to *Quercus robur* a limited share in the vegetation. It is not possible to distinguish the pollen grains of *Quercus robur* from those of *Quercus petraea.*

Fagus sylvatica

Fagus grows on more or less well drained soils. Therefore the tree is lacking in the *Alno-Ulmion* and in the *Alnion glutinosae*. This agrees with the fact that *Fagus* does not occur in the *Quercetum-Carpinetum filipenduletosum* and is scarce present in the *Querceto-Carpinetum stachyetosum* (TRAUTMANN, 1957; TÜXEN, 1937; JONGMANS and DIEMONT, 1942). In some subassociations of the *Carpinion*, *Fagus* may be present, but here it never reaches dominance. *Fagus* reaches its optimum in a humid climate.

Carpinus betulus

Carpinus is especially abundant in the *Carpinion*. It is lacking in the *Alnion glutionosae* and in the *Alno-Ulmion* with the exception of the *Stachyeto-Quercetum*, which among the associations of the *Alno-Ulmion* comes nearest to the *Carpinion*.

Corylus avellana

Corylus is present in the *Carpinion* and in the *Alno-Ulmion* (excl. the *Salicion*). It may be present in the *Violeto-Quercion* as well, but here it is less important than in the *Carpinion* and in the *Alno-Ulmion*. When forests on rich soil are felled, *Corylus* forms a regeneration stage (OBERDORFER, 1949; SCHWICKERATH, 1944).

Ulmus carpinifolia and *Ulmus glaber*

Ulmus carpinifolia occurs especially in the *Ulmion* (OBERDORFER, 1949; PASSARGE, 1953, 1956; LOHMEYER, 1951; VAN LEEUWEN and DOING KRAFT, 1955, 1959). It is lacking in the *Alnion glutinosae*. *Ulmus glaber* is present in the *Carpinion* in a low frequence. It is not possible to distinguish the pollen grains of the two species.

Fraxinus excelsior

Fraxinus excelsior has its optimum in the *Alno-Ulmion* (OBERDORFER, 1949, 1953; VAN LEEUWEN and DOING KRAFT, 1955, 1959). Moreover it may be abundant in the rich associations of the *Carpinion*. It is lacking in the *Alnion glutinosae* and in the *Salicion*.

Tilia platyphyllos

Tilia platyphyllos is abundant in the *Acereto-Tilietum* (LOHMEYER, 1953; OBERDORFER, 1957), an association which is referred by Oberdorfer to the *Quercetalia pubescentis*. According to Lohmeyer the association is a pioneer vegetation on steep and sunny slopes. This agrees with the subatlantic-mediterranean-montane distribution of the tree (ZEIDLER, 1953). It does not belong to the native flora of the Netherlands.

Tilia cordata

According to ZEIDLER (1953), *Tilia cordata* is a more continental tree than *Tilia platyphyllos* and it has a more northern distribution (RUBNER, 1953). Its continental character appears from its frequent occurrence in the loess region east of the Harz. According to PASSARGE (1953, 1956) *Tilia cordata* is present especially in the associations of the *Alno-Ulmion* (*Sambuceto-Alnetum*, *Carpino-Ulmetum*, *Fraxino-Ulmetum*). Though in western Europe *Tilia cordata* nowadays plays an inferior rôle in the vegetation, the tree is sometimes present in associations with *Alno-Ulmion* character, cf. LOHMEYER, 1951, Hannover (in the *Querceto-Carpinetum stachyetosum* and in the *Querceto-Carpinetum filipenduletosum*); LOHMEYER, 1957 (in the *Stellarieto-Alnetum glutinosae*); OBERDORFER, 1952, Kraichgau (in the *Querceto-Carpinetum circaeetosum* and the *Querceto-Carpinetum molinietosum*); OBERDORFER, 1957 (in the *Fraxino-Ulmetum*; MEYER DREES, 1936, Achterhoek (in the *Querceto-Carpinetum stachyetosum*). As the *Alno-Ulmion* is nowadays scarce in our part of South Limburg, *Tilia cordata* is here not found in the associations of the *Alno-Ulmion*. In the *Carpinion* (especially in the *Querceto-Carpinetum fraxinetosum*) *Tilia cordata* is present in a low frequency.

Salix

Salix fragilis, *S. triandra*, *S. viminalis* and *S. alba* are abundant in the *Salicion* and in the *Alnion incanae*, whereas *Salix cinerea* occurs especially in the *Alnion glutinosae*. *Salix caprea* occurs especially in the *Carpinion*. It is not always possible to distinguish the pollen grains of the different species of *Salix*.

Zone I, II and III (late-glacial)

The late-glacial is represented only in the diagram of L.F. We constructed the diagram in the way introduced by IVERSEN (1942), including a number of herbs in the pollen sum. Included are pollen grains which with some probability can be said to be derived from the vegetation outside the bog, viz. trees, Poaceae, *Empetrum*, *Juniperus*, Apiaceae, *Artemisia*, Asteraceae, Brassicaceae, Chenopodiaceae, *Helianthemum*, *Hippophae*, Lamiaceae, *Plantago maritima*, Rubiaceae, *Rumex*, *Sanguisorba*, *Thalictrum*, *Epilobium* and *Polygonum bistorta*. In contrast to the usual way in constructing the diagrams, Cyperaceae have been left out, because *Carex* roots are often present in the sandy layers of the borings. In this way the often high percentages of the Cyperaceae do not depress the percentages of the herbs which are present in a much lower number.

Following FIRBAS (1949) we distinguish a zone I (old Dryas time), a zone II (Alleröd time) and a zone III (young Dryas time). Moreover, it is possible to divide zone I into a zone Ia (oldest Dryas time), zone Ib (Bölling time), and a zone Ic (older Dryas time); (VAN DER HAMMEN, 1951). Zone Ic and zone III represent temporary deteriorations of the climate during the late-glacial.

The pleniglacial is apparently not present in our diagram because the *Artemisia* pollen reaches already in the lower part of the diagram a value of 2 %. According to VAN DER HAMMEN (1951) the transition between pleniglacial and late-glacial is characterized by a decrease of the very high percentages of the herbs with the exception of *Artemisia*, which shows an increase. For this reason we must refer the lowermost spectra to zone Ia. The Bölling time is characterized by a dominance of *Betula* and by a low percentage of the herbs, which indicates that the vegetation is here less open than it was in the preceding period. According to VAN DER HAMMEN (1951) the vegetation of the Bölling time had the character of a parc landscape in which *Betula* was present in scattered specimens. *Salix* which showed very high percentages in zone Ia decreases here to 6 %. *Pinus* shows a slightly higher percentage but the latter nevertheless remains low. It can therefore be doubted that *Pinus* was present in the Bölling time. That pollen grains of *Pinus* are present in the samples may be ascribed by long-distance transport. The temporary increase of *Betula* is a well-known feature of the Bölling time. We find it in the northern part of the Netherlands (VAN ZEIST, 1955; VAN DER HAMMEN, 1951) as well as in Denmark (IVERSEN, 1954).

In zone Ic the percentages of the tree pollen decrease again in favour of those of the herbs. Some shrubs and several herbs (*Juniperus*, *Rumex*, Cyperaceae, *Artemisia*, *Hippophae*, *Plantago*) reach their highest values, which indicates that the region once more was woodless. *Betula* and *Pinus* decrease and are replaced by *Salix*.

The Alleröd time is characterized by a dominance of *Pinus*, whereas *Betula* and *Salix* decrease strongly. The low percentages of the N.A.P. indicate that closed pine forests must have been present.

The high percentages of *Pinus* are in striking contrast to the situation found in the northern part of the Netherlands. According to VAN DER HAMMEN (1951) and VAN ZEIST (1955) in the northern part of the Netherlands, *Pinus* rises in the upper part of zone II, but *Betula* still remains an important factor in the vegetation. In our region the composition of the vegetation in the Alleröd time shows a closer resemblance to that of southern Germany than to that of north-western Europe. For that reason we may perhaps ascribe the high *Pinus* percentage to the geographic position of the region. We should, on the other hand, take into consideration, that diagrams from Susteren and from the Peel (VAN DER HAMMEN, 1951), a few km north of Leiffenderven, show the normal west-European pattern. It is quite well possible that the particular soil conditions in our region may have played a rôle as well. Indeed, the diagrams taken from bogs in other loess regions (STEINBERG, 1944; MÜLLER, 1953), show the same high *Pinus* value as those from South Limburg. We shall return to these soil conditions in our discussion of zone III. In agreement with several authors (VAN DER HAMMEN, 1951; FIRBAS, 1949; STEINBERG, 1944; VAN ZEIST, 1955) we found that the minerogenous content of the soil decreases strongly in zone II.

In zone III we observe the following changes. The N.A.P. rises, especially *Artemisia*, and *Juniperus* returns. In the lower part of the zone *Pinus* decreases, but this tree remains superior to *Betula*, which rises gradually. *Empetrum* makes its first appearance. The minerogenous content of the peat increases strongly. At a depth of 237.5 cm *Pinus* falls suddenly and *Salix* reaches temporarily high percentages. From 227.5–205 cm only pure sand is present, which still contains a number of late-glacial pollen grains (*Empetrum*, *Helianthemum*, *Sanguisorba minor* etc.), but in addition we find several pollen grains of thermophilous trees (*Alnus*, *Tilia*, *Ulmus*, *Corylus*). It is highly probable that these pollen grains have been transported from other regions. Therefore we omitted in the curves the part belonging to the layer between these two depths. In the diagram of L.F. 2 this part of the zone is undisturbed. It shows a domination of *Betula* and upwards a decrease of *Salix; Pinus* remains constant.

We draw the attention to the ratio *Empetrum: Artemisia*. In our diagram *Artemisia* is more important than *Empetrum*, which indicates that the character of the vegetation was more that of a steppe than that of a tundra (FIRBAS, 1948). In the recent tundras of Norway and Lapland *Empetrum* is very abundant (STRAKA, 1952). In zone III, according to FIRBAS (1950, 1951), *Artemisia* plays in continental regions a more important rôle than *Empetrum*, whereas the position is reversed in the more oceanic Western Europe.

The most oceanic part of Europe is Ireland, where *Empetrum* occurs already in zone I and in zone II (JESSEN, 1949; MITCHELL, 1951). In the Netherlands *Empetrum* occurs only in zone III. In zone I the climate was too continental to allow the development of a real tundra vegetation.

According to VAN DER HAMMEN (1951) in the northern part of the Netherlands the oceanic element (*Empetrum* and *Sphagnum*) is more strongly developed than in the south-eastern direction, where *Empetrum* shows lower percentages, and where *Artemisia* is somewhat higher than it is in the north. However, the contrast between zone Ic and zone III (climate continental-oceanic) is present in our diagram as well. *Artemesia, Plantago* and *Helianthemum* reach in zone Ic their highest percentages. The contrast between these two zones is here certainly less important than it is in the northern part of the Netherlands.

Besides the climate, the soil may play a rôle (FIRBAS, 1949a). According to STRAKA (1952), the dominance of either *Empetrum* or *Artemisia* in the north-west middle mountains depends upon the type of soil.

Indeed, *Empetrum* is a genus found in the *Nardo-Callunetae* and the *Querceto-Piceetae*, both vegetation types occurring on acid soils in an oceanic and montane climate, whereas *Artemisia* occurs in the *Rudereto-Secalinetae* and in the *Festuco-Brometae* on neutral to alkaline soils.

In the Eiffel we find in zone III, a high percentage of *Artemisia* which may be ascribed to the rich character of the soil. The same may apply to the loess region of South Limburg. In zone III the soil was certainly not leached. For that reason the percentages of *Empetrum* which is an indicator of leached soils (IVERSEN, 1954), remains low. In this way it is possible to explain the fact that in the northern part of the Netherlands *Sanguisorba minor* and *Helianthemum* are almost lacking in zone III, whereas in our diagram these two species (especially *Helianthemum*) are fairly abundant. We must admit that the bog of Leiffenderven is situated outside the loess region, but the distance from loess to bog is so short that a transport of pollen from the loess district is quite well conceivable. If this is so, the vegetation in the loess region in the period in which in zone III peat was deposited, would have to be regarded as a glacial steppe (FIRBAS, 1949a) or, according to the terminology of BÜDEL (1949), as a loess tundra. The superiority of *Artemisia* above *Empetrum* is visible in other diagrams from loess regions as well (STEINBERG, 1944; MÜLLER, 1953).

The soil is perhaps responsible for the high *Pinus* percentages as well. According to STRAKA (1952), in the Eiffel, a high percentage of *Pinus* in zone III must be explained by long distance transport from the lowlands along the upper Rhine where *Pinus* forests were present in zone III (FIRBAS, 1950). If we want to apply the explanation of Straka to Leiffenderven, it is difficult to see how at Susteren (VAN DER HAMMEN, 1951), scarcely 20 km to the north, *Pinus* could be low; to explain this we would have to assume that the long distance transport came to an end somewhere between Leiffenderven and Susteren. We do not want to accept this; it does not look very probable. The only other explanation would be that at Leiffenderven *Pinus* forests were present in the neighbourhood at the time the lower part of zone III was deposited.

The deterioration of the climate does not result immediately in a sharp fall of *Pinus;* still *Pinus* shows the highest percentages. Only a proceeding deterioration of the climate in the upper part of zone III results in a sharp decrease of *Pinus* and in its substitution by *Betula*.

Salix reaches a high percentage in three periods, viz. in zone Ia, in zone Ic and between the *Pinus* and *Betula* time in zone III. According to VAN DER HAMMEN (1951), a high *Salix* percentage would indicate that the forests are disappearing. This may be true for the *Salix* peaks in zone Ia and in zone Ic, but not for the *Salix* maximum in zone III at a depth of 235 cm, where the forests do not disappear but only change in composition. According to WELTEN (1950) a *Salix* percentage of more than 5 % indicates a well developed shrub vegetation and a transition to wood. The *Salix* maximum in zone III is perhaps due to a temporary increase of the degree of humidity. A slight indication in this direction are the high percentages reached by the Rosaceae (pollen of the *Comarum* type).

At the end of zone III the first indications of an ameliorating climate become noticeable. *Typha latifolia* makes its appearance (IVERSEN, 1954) and *Phragmites* is now the main peat producer (AVERDIECK, 1957). Sand grains disappear completely.

The suppositions given above may be supplemented by a few additional remarks. The behaviour of *Filipendula* is the same as in Denmark (IVERSEN, 1954) and in the northern part of the Netherlands (VAN ZEIST, 1955), viz. a decrease in zone III in contrast to the increase, shown by the other herbs. The work of VAN DER HAMMEN (1951) shows the decrease of *Filipendula* less clearly. Rebedded pollen grains are especially present in zone Ic and in zone III, where their presence is explainable by the more open character of the landscape during these periods. *Juniperus* is present in zone Ic and in zone III, just as in Denmark (IVERSEN, 1954) and in the northern part of the Netherlands (VAN ZEIST, 1955; VAN DER HAMMEN, 1951). Compared with other diagrams from the late-glacial the percentages of the Poaceae are low. We do not know how to explain this. Cyperaceae percentages are high in the zones Ia, Ic and III, just like the percentages of the other herbs.

Zone IV

For comparising the zones IV and V as shown in our diagrams with the corresponding part in the diagrams obtained from adjacent regions, we have only two diagrams at our disposal viz. Leiffenderven and Cortenbach 2. The number of diagrams is certainly not large, but it is worth to discuss them because they show noteworthy features.

The connection with the late-glacial is present only at L.F. Though we find at Cortenbach 2 at the bottom of the diagram a decrease of *Betula*, the percentages of the herbs are low, showing that the late-glacial is not represented.

The zone is characterized by an almost absolute dominance of *Pinus*. Often (Co) pollen grains of *Pinus* are the only tree pollen found in the samples. According to VAN DER HAMMEN (1951) a dominance of *Pinus* beginning on the lowermost part of zone IV is typical for the southern part of the Netherlands. Indeed, in the northern part the *Pinus* curve does not intersect the *Betula* one before the middle of zone IV, whereas in the Rheinpfalz (FIRBAS, 1935) and in the Eiffel (STRAKA, 1952) *Pinus* is dominant already from the beginning of zone IV. The same difference is visible between diagrams from the loess region east of the Harz (MÜLLER, 1953: *Pinus* dominant) and diagrams from the region to the north of it (FIRBAS, 1952: *Betula* dominant). Apart from the southern position, therefore, one of the reasons of the dominance of *Pinus* is the presence of loess, which permitted *Pinus* to reestablish itself already in the beginning of zone IV (compare also the discussion of zone II, p. 61).

Both at Co 2 and at L.F. *Corylus* appears, but this tree does not reach more than a few percents. In the upper part of the zone *Quercus* and *Ulmus* make their appearance.

The behaviour of *Betula* is somewhat irregular. At L.F. *Betula* is present in zone IV, wheras at Co it is lacking. ESHUIS (1946) already drew attention to this phenomenon which is noticable in the Peel too. Sometimes *Betula* shows a low percentage, sometimes it is dominant. The same holds for sites in the centre of the Netherlands (ESHUIS, 1946). In the Ardennes too *Betula* shows a variable percentage (FLORSCHÜTZ and VAN OYE, 1939). As we saw at L.F. there is some evidence that at least part of the pollen grains of *Betula* belong to the vegetation of the bog itself. The very high percentages of *Pinus* found at Cortenbach may be explained by the absence of *Betula* at this site which was situated at that time in a lake and in the strong overrepresentation of *Pinus* which accordingly arose. In other regions the irregular behaviour of *Betula* may be explained in the same way. Though there is a clear difference in the relation between *Betula* and *Pinus* in the northern and southern part of the Netherlands, it is not possible to decide in individual cases whether *Pinus* was of more or less importance without taking into account the presence or absence of *Betula* on the site where the sample was taken.

It is, on the other hand, possible that *Betula* occurred outside the sampling area too. The irregular behaviour of this tree may be explained by the fact that *Betula* is a typical pioneer tree. In the succession to the climax forest it may cover large areas. However, this *Betula* dominance usually is, from a palyonological point of view, a very short one (ca. 50 years). For that reason this explanation is less probable than the first mentioned one.

Thus the vegetation in zone IV must have consisted of *Pinus* forests mixed, especially in the valleys, with much *Betula*. *Corylus* had not yet a large share in the vegetation.

Zone V

In our two diagrams zone V is characterized by high percentages of *Pinus* and by the circumstance that *Corylus* plays a more important part in the vegetation than it did in zone IV. *Betula* decreases to a few percents; the components of the *Quercetum mixtum* show a rise.

In north-west Germany (OVERBECK and SCHNEIDER, 1938), in Denmark (JESSEN, 1938), in the Eiffel (STRAKA, 1952), and in the lower mountains of central Germany (STEINBERG, 1944; MÜLLER, 1953), zone v shows a high percentage of *Pinus* and an increase of *Corylus*, *Quercus* and *Ulmus*, whereas in the upper part of the zone *Tilia* and *Alnus* appear and *Corylus* reaches a maximum (C 1).

At L.F. and at Co 2 indications of a similar sequence in the appearance of the thermophilous trees are present. At Co 2 we find in the peat a zone with *Quercus* and *Ulmus*, but in which *Alnus* and *Tilia* are not yet present.

As the layer in which *Alnus* makes its first appearance, may be absent here, it is impossible to say whether *Alnus* and *Tilia* are already present in the upper part of zone v. At Co 2 the presence of the lower part of the zone too is uncertain. Here we find a very sudden rise of the *Corylus* percentage at the time at which *Quercus* and *Ulmus* make their appearance. As in many regions (at L.F. too) *Quercus* and *Ulmus* appear already in zone IV, i.e. before the rise of *Corylus*, it is possible that at Co 2 at this level too a gap in the peat deposit is present.

At L.F. we find an other complication. As we have seen two intersections are present between the curve of *Pinus* and that of *Alnus*. Between the two intersections *Corylus* reaches a maximum, but whether this *Corylus* maximum may be regarded as the C1, is doubtful. If we remove *Alnus* from the tree-pollen sum, this *Corylus* maximum disappears. Consequently, the transition between zone v and zone VI must be placed at the first intersection of *Pinus* and *Alnus*. However, if we accept this as the boundary line, it becomes very difficult to subdivide zone v. It is, moreover, dangerous to use *Alnus* for the demilitation of a zone, because the behaviour of this tree is highly influenced by local conditions.

JESSEN (1938) did not use the intersection between the curve of *Pinus* and that of *Alnus* as a criterium for the transition between zone v and zone VI, but the intersection between the curve of the *Quercetum mixtum* and that of *Pinus*. At L.F. we find the last mentioned intersection at a depth of 120 cm. If we accept the boundary line of Jessen, it is possible to divide zone v in the way proposed by Overbeck and Schneider. In the lower part (va) only *Quercus* and *Ulmus* are present. In the upper part (vb) *Tilia* makes its appearance, *Alnus* and *Quercus* increase, *Pinus* decreases and *Corylus* reaches a maximum. At the transition to zone VI the *Tilia* line intersects the *Ulmus* curve. *Alnus* and *Quercus* increase still further. However, in contrast to other regions, at L.F. *Alnus* is present already in zone va.

At Cortenbach 2 we find the first *Corylus* maximum in zone va, whereas the usual place of the C 1 is in zone vb. On account of the supposed gap in the peat it is not possible to say whether a maximum corresponding to the usual C 1 is present or not.

Ulmus reaches at Co 2 a much higher percentage than it does at L.F. At L.F. the percentages of *Ulmus* always remain smaller than that of *Quercus*. At Co 2, on the other hand, *Quercus* and *Ulmus* are represented for some time by the same percentage, but then *Ulmus* becomes the main constituent of the *Quercetum mixtum*. In many other regions in zone v an *Ulmus* dominance has been found (FLORSCHÜTZ and VAN OYE, 1939; HUMMEL, 1949; VAN ZEIST, 1955; MÜLLER, 1953; BEL-

DEROK and HENDRIKS, 1953; ESHUIS, 1946: Heitrakse Peel). It has often been supposed (JESSEN, 1949) that high percentages of *Ulmus* indicate an oceanic climate. MITCHELL (1951) drew attention to the fact that the behaviour of *Ulmus* is related to that of *Pinus* and *Corylus*. According to Mitchell we find in Europe in zone v from east to west a decreasing *Pinus* percentage and an increasing percentage of *Quercus* and *Ulmus*. In West Ireland, however, the percentage of *Pinus* rises once more. This finding in Western Ireland leds Mitchell to the assumption that a high percentage of *Ulmus* can not simply be a question of climate. Indeed, even in the centre of Europe (MÜLLER, 1953), it is difficult to explain the high percentages of *Ulmus* by an oceanic climate. As in Eastern Ireland high percentages of *Quercus* and of *Ulmus* in zone v are accompanied by low percentages of *Pinus*, Mitchell suggests that the rise of the *Quercetum mixtum* at the transition to zone VI is due to a fall of *Pinus* and that the latter is caused by an increase of *Alnus*. The same would hold for *Corylus*, which reaches its maximum during the time in which *Pinus* decreases.

At Co 2 too we find a rising percentage of the *Quercetum mixtum* accompanied by a decreasing percentage of *Pinus*. However, *Corylus* shows here a decrease, whereas *Alnus* is not yet present. Therefore, it seems to us that the solution of the question must be more complicated than Mitchell supposes.

According to JONASSEN (1950), in closed forests, the distance over which the pollen grains of *Corylus* are dispersed, is very small. Thus, a high percentage of *Corylus* in zone v must mean that the main part of the vegetation consisted of hazel groves, in which but a small number of larger trees were present. Jonassen supposes that *Corylus* mainly occurred in the wetter sites. In the drier sites *Pinus* and *Quercus* must have been present. This means that in the Voerendaal region *Corylus* must have occurred mainly along the margin of the lake. This is in agreement with the fact that we find along this margin the *Alno-Ulmion* in which *Corylus* certainly occurs. However, on account of the open character of the forests found on the plateaus, it is improbable that *Corylus* was completely absent on the latter. The occurrence of *Corylus* in the immediate vicinity of the lake, is confirmed by the presence of anthers, at L.F. (132.5 cm) as well as at Co 2 (140 cm). A second species along the margin of the lake was *Ulmus*, which is, as we have seen, especially abundant in the *Alno-Ulmion*. In consequence of this it is not necessary to assume either a decrease or an increase of *Pinus* on the drier sites. The hypothesis that in the Voerendaal region *Corylus* and *Ulmus* were inhabitants of the lake margin, is supported by the difference between Vo (centre of the lake) and Co (margin). At Vo *Pinus* shows a higher percentage and *Ulmus* and *Corylus* lower ones than they do at Co. As mentioned before, in the centre of the lake *Pinus* must be overrepresented on account of long-distance transport. An overrepresentation of *Pinus* in the centre of a lake has been shown by PENNINGTON (1949) too.

A second factor in the Voerendaal region which may have favoured an increase of the percentage of *Ulmus*, is the small distance by which this site is separated from the cretaceous district. In Ireland *Ulmus* is, according to MITCHELL (1951), common in zone V in case the soil contains lime, whereas in the opposite case *Quercus* is prominent. The same holds for recent vegetation types in the Netherlands. *Ulmus* is abundant especially in the *Ulmetum suberosae,* an association found on those dunes which contain lime in the soil, and in the *Fraxino-Ulmetum,* an association of river banks containing lime. *Ulmus* is rarely found in the *Carpinion,* and then only when the latter occurs on limestones.

The rather irregular behaviour of the *Corylus* curve is not unusual in the southern part of the Netherlands. According to ESHUIS (1946) the C 1 is often lacking, and when it is present, its position often varies.

We do not agree with ESHUIS (1946) and with VERHOEFF (1957) that in the southern part of the Netherlands the sequence in which the components of the *Quercetum mixtum* appear varies. That Eshuis and Verhoeff came to this conclusion, may be due to a comparatively low pollen sum in their samples and to a greater distance between their pollen spectra.

Zone VI and VII

Zone VI and zone VII are not only present at L.F., Vo and Co but also at Ri and BRO. In agreement with the findings of FIRBAS (1949), zone VI was found to be characterized by high percentages of the *Quercetum mixtum,* of *Corylus* and of *Alnus* and by the absence of *Fagus.* In zone VII *Fagus* is present in low percentages. The same behaviour of *Fagus* has been observed in the Eiffel (HUMMEL, 1949; STRAKA, 1952), in the Untereichsfeld (STEINBERG, 1944), in the Ardennes (PERSCH, 1950) and in the dry part of central Germany (HUMMEL, 1953). In the Peel the first part of the *Fagus* curve is irregular.

The appearance of *Fagus* at the transition between zone VI and zone VII is in contrast to what is found in the northern part of the Netherlands and in north-western Germany, where the first pollen grains of Fagus were not found before zone VIII (WATERBOLK, 1954). In Drenthe, according to VAN ZEIST (1955) *Fagus* is present already in zone VII. Farther to the north, viz. in East Holstein (AVERDIECK, 1957) *Fagus* was found to make its appearance also in zone VII. These discrepansies are without doubt partly due to the fact that in the older investigations the tree-pollen sum often was too low. That, for instance, in the region near Köln no *Fagus* pollen was found before zone VIII is probably to be ascribed to the low value of the tree-pollen sum. It is, on the other hand not impossible that in northern Germany actually differences were present between adjacent regions (East and West Holstein, AVERDIECK, 1957).

The most striking fact is that at Ri and BRO the percentages of *Tilia* are very high, but that at L.F. *Quercus* is the main component of the *Quercetum mixtum.* Except at Co 2, *Ulmus* remains everywhere low. The dominance of *Tilia* over *Ulmus* is according to WATERBOLK (1954) typical for the southern part of the Netherlands. Indeed, in the northern part of the Netherlands *Ulmus* is often a very prominent tree in the diagrams, although, of course, not so prominent as *Quercus*.

In many diagrams (Vogesen: OBERDORFER, 1936/1937; Eiffel, Ardennes and in the Untereichsfeld) there is in the behaviour of *Ulmus* and *Tilia* a difference between zone VI and zone VII. In zone VI *Ulmus* is more important than *Tilia*, whereas in zone VII the *Tilia* curve intersects the *Ulmus* curve, *Tilia* reaching a higher percentage. On account of the absence of zone VI at Ri, BRO, Co and Vo, it is impossible to say whether the same behaviour may have been present here. Anyhow, at L.F. *Tilia* is in zone VI as well as in zone VII superior to *Ulmus*. This is in agreement with the finding of VAN ZEIST (1959a).

The dominance of *Tilia* over *Quercus* may be explained in three different ways:

1) *By differential destruction*

The pollen grains of *Tilia* and of the Coniferae show a very high resistance against corrosion (FIRBAS, 1949). Indeed, we find at Vo temporarily a larger number of pollen grains of *Tilia* at the very depths where *Pinus* is high. A high percentage is often correlated with the presence of a high amount of sand in the peat, a factor which accelerates the decomposition of the peat (ESHUIS, 1946; SCHUBERT, 1933). However, except at BRO, sand is absent in our peat. Moreover, even at BRO there is no correlation between the narrow zones of sandy peat and the changes in the percentages of the *Tilia* pollen. Therefore it seems reasonable to reject a differential destruction of the peat as an explanation of the dominance of *Tilia* over *Quercus*.

2) *By differences in the fertility of the soil*

The high *Tilia* percentages may be due to the high degree of fertility shown by the soil in South Limburg. Indeed, we find at L.F., which is situated outside the loess district a replacement of *Tilia* by *Quercus*. According to KÖIE (1951) the silt content necessary for the occurrence of *Tilia* must be 16 %. However, it is difficult to compare L.F. with the other bogs because it is of a much larger size.

3) *By differences in the extent of the bog*

Our diagrams reveal a close correlation between *Alnus* and the components of the *Quercetum mixtum*. At the very depths where *Alnus* reaches high percentages, *Quercus* proves to be more important than either *Tilia* or *Ulmus* (L.F.: zone VI and zone VII; Vo and Co: upper part of zone VII). Reversely, at the very depths where *Alnus* is comparatively low *Tilia* and *Ulmus* are more important than *Quercus*. This correlation may be explained if we take into account the extent of the bog and the character of the vegetation of the bog itself. As we have seen already, *Tilia cordata* and *Ulmus* are abundant in the *Alno-Ulmion*, which occurs on colluvial and young soils. It is certainly not easy to distinguish the pollen grains of the different *Tilia* species, but when the intermediate grains are left out of consideration they may be divided into two groups, and then the larger group appears to belong to *Tilia cordata* (L.F., Ri, BRO). Though the amount pollen produced by *Tilia* is large (POHL, 1937; HYDE and WILLIAMS, 1945), the distance over which the pollen grains of this entomophilous tree are transported, is but small (REMPE, 1937). For this reason *Tilia* is highly underrepresented in the pollen diagrams. High percentages are reached only in case the distance between the site where *Tilia* trees were growing and the site where the pollen was collected, is but small. This condition would have been fulfilled when *Tilia* had been present on the colluvial soils in the valleys. We mentioned already that *Tilia cordata* may occur in the *Alno-Ulmion*, and this means, indeed a short distance between the atlantic *Tilia* forests and the site where the pollen was collected. However, it is not impossible that *Tilia platyphyllos* was present as well, especially on limestone in the cretaceous district. According to BARKMAN (1948) and to OBERDORFER (1957) the *Querceto-Carpinetum orchidetosum* is related to the *Quercion-pubescentis-petraeae* in which *Tilia platyphyllos* occurs (*Acereto-Tilietum*). Moreover, we find nowadays in South Limburg a fragment of the *Querceto-Lithospermetum* which must be referred to the *Berberidion*, and the latter occurs on the same soils as the *Quercion pubescentis*. The occurrence of *Tilia platyphyllos* on limestone is therefore not improbable. The larger distance in combination with the bad dispersal of the pollen grains of *Tilia platyphyllos* must be responsible for the fact that we do not find strong indications of the presence of this tree in the diagrams. In those bogs in the Eiffel that are situated outside the valleys pollen grains of *Tilia platyphyllos* are actually present (HUMMEL, 1949).

The situation found at L.F., at Ri and BRO and at Co and Vo differ strongly, At L.F. in the valley a wide area must have been covered by the *Thelypterideto-Alnetum* (see p. 32). The *Alno-Ulmion* zone, however, must have been narrow. As *Quercus robur* is a component of the *Thelypterideto-Alnetum* (VAN DIJK, 1955; BURRICHTER, 1953), at least a part of the pollen grains of *Quercus* may be of local origin and for this reason *Quercus* may show in the diagram higher percentages than either *Tilia* or *Ulmus*. Quite different is the situation at Ri and BRO. The area of the *Thelypterideto-Alnetum* must have been small (this follows from the small size of the bog and the low percentages of *Alnus*), whereas the greater part of the valley must have been occupied by the *Alno-Ulmion*. For this reason, *Tilia* is here superior to *Quercus*. In this respect the percentages of *Pinus* deserve our attention. At L.F. the low percentages of *Pinus* indicate that the forests must have been very dense. At Ri and BRO the percentages of *Pinus* are somewhat higher than they are at L.F. and indeed, the associations of the *Alno-Ulmion* are less dense than the *Thelypterideto-Alnetum* (WESTHOFF, 1956: Beekbergerwoud; VAN DIJK and WESTHOFF, 1955). In the Voerendaal region we find another complication. We mentioned already (p. 45) that in the lower part of zone VII the Voerendaal region must have been a lake, whereas in the upper part of the zone the site was occupied by a *Thelypterideto-Alnetum*. At Voerendaal, in the centre of the lake, we find in the lower part of zone VII pollen of *Tilia* and *Ulmus* which must have been imported from the margin of the lake. However, on account of the much larger distance between the sites where the trees grew and the sites where we collected our samples, the percentages are lower than at Ri and BRO. In the upper part of the zone the presence of the *Thelypterideto-Alnetum* prevents the pollen grains of *Tilia* and *Ulmus* to reach the centre of the lake. At Co we are on the margin of the lake and therefore in the neighbourhood of the *Alno-Ulmion*. Accordingly, in the lower part of the zone *Ulmus* becomes prominent. However, in the upper part of the zone, in which the lake was filled up and the *Thelypterideto-Alnetum* occupied the site, *Quercus*, which is a component of this association, becomes more important.

It is unknown to us why at Co 2 *Tilia* was replaced by *Ulmus*. From an ecological point of view the difference between the two trees is not important because *Tilia* as well as *Ulmus* occur in the *Alno-Ulmion*. We draw the attention to the fact that according to an earlier investigation of the Voerendaal region (MECHELINCK, not published) *Tilia* may show here an equally high percentage as at Ri and BRO.

In other regions we find the same correlation between the *Quercetum mixtum* and *Alnus*. In the Untereichsfeld (STEINBERG, 1944) in Germany, where small bogs situated in a loess region have been investigated, *Tilia* and *Ulmus* proved to be high, whereas *Alnus* showed low percentages. The diagrams of STRAKA (1952) from peat present in small craters in the Eiffel show a *Quercus* percentage between that of *Ulmus* and that of *Tilia*, and a low percentage of *Alnus*. Though HUMMEL (1949) who investigated similar craters in the Eiffel did not construct a *Quercus* curve, it is visible in her diagrams that *Quercus* is low in comparison to *Ulmus* and *Tilia*. The diagram published by VERHOEFF (1957) shows an intersection of *Quercus* with *Ulmus* and *Tilia* accompanied by an increase of *Alnus*. In our region the same relation is visible in the diagram constructed by BELDEROK and HENDRIKS (1953). Furthermore, the opinion of PFAFFENBERG (1952) that a high *Tilia* percentage is typical for a small bog, is in agreement with our own experience.

A higher percentage of *Pinus* accompanied by a low *Alnus* and a high *Tilia* percentage is shown in the work of NILLSON (1947). The results of MÜLLER (1953) in the dry region of central Germany are aberrant. MÜLLER found in lake sediments belonging to zone VII a higher percentage of *Pinus*, but *Quercus* proved to be superior to *Tilia* and *Ulmus*. The explanation evidently is that the lake of which Müller investigated the remains, was much larger than the areas in which in our region the bogs were formed. Moreover, the low precipitation in the dry region of central Germany, which is nowadays below 500 mm, may have played a rôle, for, according to FIRBAS (1928), ZEIDLER (1953), and KOCH (1944), *Tilia* (especially *Tilia platyphyllos*) requires a very humid climate. In the Hautes-Fagnes (PERSCH, 1950), on account of the large extent of the bog and perhaps also on account of the poor character of the soil, neither *Tilia* nor *Ulmus* exceeds *Quercus*, though the percentage of *Alnus* is low. According to FIRBAS (1952), in the young moraine region of Schleswig-Holstein too, high *Tilia* and *Ulmus* percentages have been found; *Alnus* is low in this region, but *Quercus* shows a higher percentage than either *Tilia* or *Ulmus*. It is difficult to explain the superiority that is shown here by *Quercus* but it may to a large extent be due to the large size of the bogs for such bogs generally give spectra indicating long distance.

It seems to us that in our region the size of the bog is the factor which more than another influences the percentages of the components of the *Quercetum mixtum* in the pollen diagrams. In case of a poor soil the latter certainly may be a limiting factor in the spreading of *Tilia* and *Ulmus*.

Except at Vo and Co *Pinus* is low already from the beginning of zone VI. As the pollen grains of *Pinus* may be transported over large distances, it is not possible to decide whether the *Pinus* pollen found in South Limburg in zone VI and in zone VII, was derived from the native vegetation. An indication that *Pinus* really may have been present is to be found in a study by BUTLER and HABEREY (1936), who detected *Pinus* wood in bandceramic settlements near Köln. At Co and Vo in zone VIIa, i.e. during the time that this area was a lake, *Pinus* shows in the diagrams high percentages, which must be due to overrepresentation (page 45). It may be that this overrepresentation too may be regarded as an indication that *Pinus* did not disappear completely during zone VI and zone VII.

The behaviour of *Corylus* is irregular. Like SCHUBERT (1933), we found but low percentages of *Corylus* in the alder peat. It should be realized that *Corylus* does not occur in the *Thelypterideto-Alnetum* (PFAFFENBERG, 1947; VAN DIJK, 1955; VAN LEEUWEN and DOING KRAFT, 1955, 1959). For this reason the percentages of *Corylus* found at L.F. and in the upper part of zone VII at Co and Vo, remain low. More important is *Corylus* at Ri, BRO and in the lower part of zone VII at Co and Vo. At Ri and BRO *Corylus* shows high percentages and this is comprehensible because the *Alno-Ulmion* in which *Corylus* occurs, must have been present in the neighbourhood of the small bog. At Vo and Co the pollen grains of *Corylus* are probably for the greater part derived from the *Alno-Ulmion* along the margin of the lake (see page 65).

It is not possible to distinguish the C 2 and C 3 of OVERBECK and SCHNEIDER (1938). This is probably due to the fact that the pollen grains of *Corylus* are derived from an area of limited extent.

According to the suppositions given above the vegetation at the time in which the peat of zone VI and zone VII were deposited must have been as follows (figure 3, 4, 5).

Vegetation of the bogs itself:	*Thelypterideto-Alnetum;*
Margin of the bog:	*Alno-Ulmion* with *Tilia cordata*, (*Ulmus*), *Alnus*, *Corylus* and *Quercus;*
Slopes and plateau:	*Quercus* and afterwards *Fagus;* locally on limestone perhaps *Tilia platyphyllos; Corylus.*

Zone VIII

Both at L.F., Ri and BRO zone VIII is characterized by a minimum of *Alnus*, a rise of *Corylus*, *Quercus*, *Pinus* and *Fagus*, and a fall of *Tilia*. Moreover, from the bottom to the top of the zone the N.A.P. increases strongly on account of the introduction of prehistoric agriculture.

Indicators of human occupation

1. *Cereals*

According to Hummel (1949), Butler (1938) and Waterbolk (1954), the anemophilous *Secale cereale* and *Avena sativa* are not yet present in the neolithic age nor in the bronze age. The other cultivated cereals are self-pollinating and the production of their pollen grains is very inferior to that of *Secale* (Müller, 1947: ratio 0.2–1.2 : 195). This implicates that the prehistoric *Triticum* and *Hordeum* species, if present in the diagram at all, must have occurred in very low percentages. In agreement with the findings of Hummel a.o., the pollen grains of the cereals never belong to the *Secale* type. However, in our samples other pollen grains have been found (especially at BRO) which show a strong resemblance to the cereal type of Firbas (1937), viz. grains provided with a large pore and a thick annulus. The size of these pollen grains exceeds 40μ.

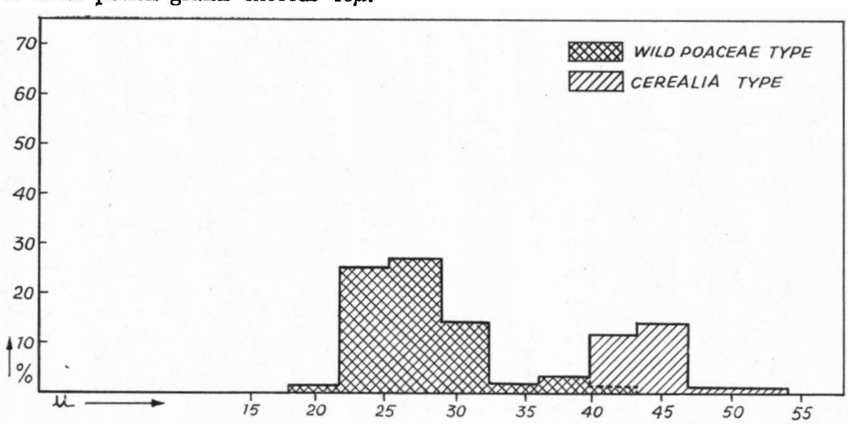


Fig. 2. Relation between size and pollen type of the Poaceae at Brommelen, 227 cm. Pollen sum = 250.

If we construct, according to the prescript of Firbas (1937), a curve showing the relation between size and percentage of the pollen grains belonging to the Poaceae (Fig. 2), it appears that there are two peaks. The curve, however, does not prove that the larger pollen type actually was derived from cultivated cereals; it only shows that we are dealing with at least two species, though more probably with two groups of species. According to Firbas (1937), the pollen of some wild Poaceae may show the same type as that of cereals. We find among this group halophytes, forest plants, hygrophytes and plants belonging to the *Bromion*. It is unlikely that in our region halophytic grasses would have occurred. The same may be said of forest grasses, because, as we will see, the area of the forests diminished strongly in this period. It is, on the other hand, not excluded that the pollen grains showing the same type as those of the cereals, may belong to hygrophytic grasses (*Glyceria fluitans*) or to grasses belonging to the *Bromion* (*Bromus erectus*).

2. *Artemisia*

Some species of *Artemisia* are found especially in the *Onopordietalia*, the communities occurring in ruderal sites. According to Iversen (1941), the pollen grains of *Artemisia* would be derived from *Artemisia vulgaris*, which only in recent times has been driven back by the introduction of deep ploughing. In South Limburg we have to take into account the occurrence of *Artemisia campestris*, a species present in the *Festuco-Brometae*, a class which comprises open communities occurring on warm and dry soils. It is not impossible that associations belonging to this class were present in South Limburg in zone VIII (cf. *Helianthemum:* page 72). Pollen grains of *Artemisia* are sometimes present in low percentages in zone VII too. According to WATERBOLK (1954), these pollen grains would be derived from *Artemisia campestris*, which would occur in open sites in the forests. However, since *Artemisia campestris* is a species belonging to the *Festuco-Brometae*, the presence of this species in a wooded region is improbable. Anyhow, the occurrence of pollen grains of some species of *Artemisia* already before zone VIII may indicate the presence of man in zone VII (compare also page 103).

3. *Rumex acetosella*

Rumex acetosella occurs especially in the *Corynephoretalia*. The species may reach dominance in abandoned fields (SISSINGH, 1950; SCHMITZ, 1952). According to SISSINGH (1950) it occurs mainly on abandoned fields occupied by the *Scleranthion* (*Secalinetalia*), less often on those occupied by associations belonging to the *Chenopodietalia*. At any rate *Rumex acetosella* may be regarded as an indicator of agriculture.

4. *Chenopodiaceae*

According to SISSINGH (1950) and BUCHWALD and LOSERT (1953) several representatives of the Chenopodiaceae occur in the weed associations that have been brought together in the *Chenopodietalia* and which accompanies the root-crop cultures. For this reason the occurrence of the pollen grains of the Chenopodiaceae indicates the cultivation of root-crops. At the same conclusion arrives STRAKA (1952).

5. *Plantago*

Plantago lanceolata is, according to IVERSEN (1941, 1949), the main indicator of human occupation. The plant occurs in the *Molinio-Arrhenatherae* (OBERDORFER, 1949, 1957), the (dunged) hay fields and meadows. Pollen grains of *Plantago major* have been found in a small number in zone VIII (see also page 85).

6. *Asteraceae*

According to STRAKA (1952), especially the Asteraceae liguliflorae are important indicators of human occupation. Indeed, we find these plants in the *Secalinetalia* (*Matricaria chamonilla* and *Anthemis arvensis*) and in the *Chenopodietalia* (*Chrysanthemum segetum*). In our diagrams, especially at BRO, the Asteraceae reach high percentages.

7. *Poaceae*

A high percentage of the Poaceae and a diagram which proves that the forests must have been more or less open, indicate the presence of man (FIRBAS, 1934). However, it is possible that the high percentages of the Poaceae found in the *Carex* peat at BRO and Ri are due to the presence of these plants in the bog itself. However, on account of the small size of these bogs, we suppose that at least part of the pollen grains of the Poaceae were derived from outside the bog. In the large bog of L.F. too, Poaceae may have been present, since in the communities occurring in this bog viz. the *Betulion* and the *Saliceto-Franguletum*, *Molinia* and other grasses are present. However, for the same reason as explained for *Calluna* (maxima of *Calluna*, of the Poaceae and of *Corylus* at the same time; cf. page 32) we suppose that the greater part of the pollen grains of the Poaceae were derived from outside the bog.

8. *Calluna*

Only at L.F. *Calluna* reaches high percentages. As we have seen already (page 32). *Calluna* was probably part of the vegetation outside the bog. In the loess district *Calluna* did not occur due to the rich character of the soil.

9. *Helianthemum*

Helianthemum, occurring in the diagrams of Ri and Co 2, is, according to STRAKA (1952), an indicator for dry mats on alkaline soils. The species is nowadays present in the *Mesobromion* (also in South Limburg) and in the *Xerobromion* (OBERDORFER, 1957). It is not impossible that, on account of the human activities, the *Mesobromion* was present already in zone VIII. A rise of *Helianthemum* after a clearing, has been reported by MIKKELSEN (1954). However, it may be that Mikkelsen was dealing with other species.

10. *Hippophae*

Pollen grains of *Hippophae* have been found in the samples of Ri. At present the species occurs especially in the *Hippophaeto-Salicetum* and in the *Hippophaeto-Ligustretum* (*Sambuco-Berberidion*), both associations found on calcareous sands in the dune- and wadden district in the Netherlands. It is improbable that *Hippophae* occurred in South Limburg in dune associations. The behaviour of *Hippophae* in South Limburg may have shown more resemblance with the occurrence of this plant in Central Europe. According to GAMS (1943), in a continental climate grazing of cattle may result in the development of an artificial steppe in which *Hippophae* is well represented. At present we find in South Limburg the *Sambuco-Ligustretum* (*Berberidion*), an association which is closely related to the dune associations in which *Hippophae* occurs, and *Hippophae* may have been present in this association. Thus we find in zone VIII the first indication of the presence of the *Prunetalia spinosae*, a group of associations whose development certainly is highly influenced by man. As mentioned. the *Mesobromion* may be present as well in zone VIII (cf. *Helianthemum*). For the relation between the *Mesobromion* and the *Prunetalia*, we refer to page 15.

11. *Brassicaceae*

According to TRAUTMANN (1957), the Brassicaceae too must be regarded as indicators of human occupation. At L.F., Co and Vo it is not probable that the Brassicaceae were constituents of the vegetation of the bog itself. At least in the *Thelypterideto-Alnetum* we do not find Brassicaceae (VAN DIJK, 1955). Brassicaceae, however, are present in the *Cariceto elongatae-Alnetum* and in some associations of the *Alnion incanae* (MAAS, 1959). As the local vegetation of the small bogs must be regarded as belonging to the *Alnion incanae* or shows at least some resemblance to this suballiance, the possibility that Brassicaceae may have belonged to the vegetation of the bog itself, can not be excluded.

12. *Polygonum persicaria*

Pollen grains of *Polygonum persicaria* have been found at Ri and BRO. This species indicates cultivation of root-crops (*Chenopodietalia*, cf. SISSINGH, 1950).

13. *Polygala*

Pollen grains of *Polygala* (*vulgaris*?) have been found at Ri. The species is abundant in the *Molinio-Arrhenaterae* (OBERDORFER, 1949).

THE BEHAVIOUR OF THE TREES

Originally, a fall of *Ulmus* and *Hedera* and a rise of *Fraxinus* at the transition between zone VII and zone VIII was ascribed by IVERSEN (1941) to a change in the climate. In 1944 Iversen arrived at the conclusion that the winter temperature, as indicated by the presence of *Ilex*, *Hedera* and *Viscum* had decreased with 2° to 3° C. According to FIRBAS (1949), the summer temperature decreased with 2° to 3° C as well. A short distance upwards in the diagrams of Iversen typical signs of the settling of man appear. Iversen described three stages in the development induced by man:

1. An increase of the N.A.P. including that of indicators of human occupation.

2. The percentages of the pollen grains indicating human occupation reach their maximum. The wood begins to regenerate, as is proved by a maximum of *Betula* followed by a maximum of *Corylus*.
3. The percentages of the pollen grains indicating human occupation decrease. Recovery of the type of forest that was present before the disturbance, though *Corylus* still remains high. In Denmark the ultimate clearing not followed by a regeneration of the forests, did not take place before the end of zone VIII.

In our diagrams the same phenomena are noticeable, though on another scale. The course of the curves is a smooth one, indicating that we are dealing with a series of settlements. As we will see, no complete regeneration of the forest did take place. For this reason the three stages of Iversen are not clearly distinguishable. The pioneer vegetation and the vegetation during the occupation itself are present at the same time.

Corylus and Betula

In all the diagrams constructed for our region the rise of *Corylus* is recognizable. *Betula* is less typical. We certainly find at L.F. a *Betula* maximum before the *Corylus* maximum, but we have to take into account that at L.F. *Betula* may have belonged to the vegetation of the bog itself. However, there is a possibility that part of the pollen grains of *Betula* (*Betula verrucosa*) is derived from a pioneer vegetation that developed after a clearing, because Leiffenderven is situated outside the loess district. At BRO *Betula* remains low, whereas at Ri it increases but only after the time at which *Corylus* reached its maximum values. The explanation probably is that the bogs of Ri and BRO are situated in the loess district. According to SCHWICKERATH (1944, 1954), *Corylus* is present on more or less alkaline soils in the degeneration stage ("Rückentwicklung") of the vegetation i.e. in woods belonging to the *Querceto-Carpinetum* or to the *Alno-Ulmion*. *Corylus* never is present in the woods or regions with an acid soil (*Quercion-roboris-petraeae*). In the latter kind of region *Betula* is a pioneer appearing after a clearing. According to KÖIE (1951), in Denmark for a good growth of *Corylus* the percentage of the silt fraction must be more than 16 %. Indeed, the silt percentage of the loess exceeds 16 % (JONGMANS, KRUL and VOS, 1941: silt percentage of the loess is 27 %).

The rise of *Betula* at Ri is perhaps due to a poverishment of the soil or to a proceeding denudation along the slopes, which exposes the sands belonging to the terraces.

It is quite well possible that at Ri sand was present on the slopes, because we find here a fairly high percentage of *Hippophae*, which according to OBERDORFER (1949) and GAMS (1943), is an indicator of sandy soils (cf. page 73).

Alnus

Special attention must be paid to *Alnus*. In several regions *Alnus* rises (Denmark: JESSEN, 1938; IVERSEN, 1941; Eiffel: HUMMEL, 1949;

STRAKA, 1952; Peel: ESHUIS, 1946; Ireland: JESSEN, 1949), or remains constant (northern Netherlands: VAN ZEIST, 1955; Hautes-Fagnes: PERSCH, 1950). According to MIKKELSEN (1954) the rise of *Alnus* is due to the fact that *Alnus* and *Betula* are now growing on the cleared areas where originally *Quercus* occurred. FIRBAS (1949) takes into account that the precipitation may have decreased or increased; a decrease may have taken place because *Alnus* now occurs on soils which previously were too wet. For the same reason *Quercus* may have decreased.

In contrast to the authors mentioned above we find in our diagrams a steep fall of the *Alnus* percentage at the beginning of zone VIII or somewhat later. At L.F. the fall of *Alnus* may easily be explained by the acidification of the soil induced by the local vegetation; this would have made it impossible for *Alnus* to maintain itself in the bog. On the other hand, it should be realized, that *Alnus* decreases at BRO, Ri and Vo as well, though no signs of an acidification are found here. The fall of *Alnus* at BRO and Ri is evidently related to the development of the vegetation of the bog from an *Alnetum* into one of the communities of the *Magnocaricion.*

According to VAN ZEIST (1960), who observed at Sittard (South Limburg) the same fall of *Alnus*, the *Carex* peat is the reflexion of a natural vegetation which arose by a deterioration of the climate at the transition between zone VII and zone VIII. This natural vegetation, a kind of grassland, might have been used by the domestic animals of prehistoric man for grazing.

It is also possible that the grasslands were the direct result of human activity. A slight indication for this assumption is present at BRO, where first indicators of human occupation appear and where later on the vegetation of the bog itself undergoes a change. A deterioration of the climate and human interference may also have acted simultaneously.

GODWIN (1949) too observed in his diagrams a fall of *Alnus*, but he is of opinion that this fall is too large to be ascribed entirely to the influence of man. This may be true in England, but in our region it is not impossible to explain the behaviour of *Alnus* as due to human influence. As mentioned before in South Limburg *Alnus* was restricted to the valleys (*Alnion glutinosae* and *Alnion incanae*), which are very vulnerable to human interference. Moreover, the extent of the bogs is small.

For that reason it can not have been difficult to clear the *Alneta*, even in prehistoric times. According to PFAFFENBERG (1952), who also investigated a small bog, grazing of cattle in an *Alnus* wood is sufficient to cause a decline of the *Alnus* percentage in the diagram.

A fall of the *Alnus* percentage in zone VIII is also present in the loess region of Köln (NIETSCH, 1940) and in Belgium (VANHOORNE, 1951; STOCKMANS and VANHOORNE, 1941).

However, as these authors do not draw the curves of the herbs, it is not possible to connect this fall with human activities. A fall of *Alnus* at the beginning of prehistoric agriculture, has been demonstrated by

STEINBERG (1944). In the Eiffel (STRAKA, 1952) *Alnus* shows a slight decrease in zone x (O.S.). However, indicators of human occupation appear already in zone IX (O.S.).

The difference with regions where *Alnus* rises is probably due to the fact that *Alnus* is confined to the bottom of the valleys and does not occur on the slopes.

Alnus probably suffered from selective felling in the valleys. In Ireland, where the *Alnus* percentage rises, *Alnus* does not only occur along the rivers, but in the woods as well (JESSEN, 1949); the same holds for the lower parts of the Netherlands.

The behaviour of *Alnus* strongly resembles the general fall of this tree in western Europe at the end of zone x (FIRBAS, 1949). The fact that already in zone VIII *Alnus* reacts heavily upon human influence, may be due on the one side to the vulnerable position of the stands, on the other side to the density of the human population. According to WATERBOLK (1954), the percentage reached by *Plantago lanceolata* in the neighbourhood of a settlement is about 3 %. The fact that at Ri *Plantago lanceolata* reaches 3 % and that at BRO the percentage sometimes is 7 %, indicates therefore that human influence is extremely high. This is in agreement with the fact that at BRO the percentages of the cereals are high compared with those in other regions. Furthermore we draw attention to the fact that at Ri the highest percentages reached by the indicators of civilisation coincide with a low *Alnus* percentage.

According to a calculation made by VAN ZEIST (1959a) on the base of the long-distance transport of *Pinus* pollen, near Sittard (South Limburg) about 2/3–3/4 of the forests in the neighbourhood must have been cleared.

A rise of *Alnus* in small bogs found in other regions (HUMMEL, 1949; STRAKA, 1952) need not be due to a possible occurrence of *Alnus* outside the valleys, but it may be caused by the circumstance that the influence of the human occupation was here lower than it was in South Limburg. Indeed, in the Eiffel the bogs are situated outside the valleys in stations which are less favourable for human occupation than the valleys itself. For that reason *Alnus* may here have taken part in the regeneration of the vegetation.

Especially when the diagram reflects the change in a vegetation which covered a large stretch of country, e.g. the changes which took place in the diagram from a raised bog, the chance that the percentage of *Alnus* pollen may show an increase will be greater, as this tree may have been part of the vegetation in the period of regeneration.

In chapter IX we will return to the question of the influence of human interference.

Quercus

We regard the rise of *Quercus* too as a result of human influence. In Denmark, during the period of land occupation *Quercus* decreased, but in the regeneration phase *Quercus* rose once more. The same pattern is visible at BRO. Moreover, on account of the fact that the landscape is now more open, the long-distance pollen transport from *Quercus* trees occurring in the woods on the plateaus is intensified. A rise of *Quercus* during zone VIII has been observed in many other regions (AVERDIECK, 1957; OVERBECK and SCHNEIDER, 1938; STRAKA, 1952; a.o.). According to FIRBAS (1949), already in prehistoric times the increase of *Qnercus* must have been favoured by man.

Pinus

An intensified long-distance transport plays a very important part in the case of *Pinus*. At BRO, Ri and Vo where the forests in the neighbourhood were cleared, *Pinus* therefore shows important percentages. An increase of *Pinus* on account of a decreasing density of the forests in the vicinity due to clearing, has been registered in many regions (HUMMEL, 1949; PFAFFENBERG, 1947). However, we have also take into account that this tree has enlarged its area. According to RUBNER (1925) and BUCHWALD (1951), *Pinus* grows on every type of soil, but in the competition with other trees it is always inferior on account of its extreme photophilous character and its bad reproduction.

Tilia and *Ulmus*

The behaviour of the curves of *Ulmus* and *Tilia* is interesting. We have seen already that originally the fall of *Ulmus* was ascribed to a change in the climate. FAEGRI (1944), however, is of opinion that the fall of *Ulmus* is due to the influence of man. According to Faegri, leaves of *Ulmus* were used as winter fodder for cattle. Recently VAN ZEIST (1959) discussed the behaviour of *Ulmus* in relation to *Fraxinus*, and came to the conclusion that in the Netherlands the fall of Ulmus can not be climatologically conditioned. Van Zeist and TROELS-SMITH (1955) adopt the opinion of Faegri that the fall of *Ulmus* is due to human activities, even when the influence of man is low.

The fall of *Tilia* has been ascribed by WATERBOLK (1954) to a decrease of the summer temperature. However, according to VAN ZEIST (1959), the fall of *Tilia* too must be due to human influence, as in the Netherlands both *Ulmus* and *Tilia* are decreasing at the transition between zone VII and zone VIII. If we accept the supposition of Van Zeist, we arrive at an interesting result. According to BÜKER (1939) and ELLENBERG (1937), settlements are established by preference in the area occupied by *Alno-Ulmion* associations. This preference is not restricted to recent times. SCHMITHÜSEN (1958) describes a neolithic settlement near Karlsruhe (Germany) which is situated at the margin of a valley. In South Limburg the bandceramic sites are found in similar sites (MODDERMAN, 1959). As we have mentioned already in our discussion of zone VII, *Tilia cordata* occurs especially in the *Alno-Ulmion*. In consequence of this, it is evident that in case of human activities especially *Tilia* must be affected. The decline of *Tilia*, therefore, may be due to human influence. In that case the steep fall of *Tilia* would indicate once more that the influence of man may be very strong. Indeed, above the layer of loam which is present at BRO and Ri *Tilia* falls to very low percentages. Its curve is interrupted now. A regeneration like that found in Denmark did not take place. Already before the transition between zone VIII and zone IX the continuity of the *Tilia* curve ceases.

The fall of *Tilia* (and of *Ulmus*) at the transition between zone VII and zone VIII is present throughout western Europe, but the fall is usually not steep. Often we find a continuous *Tilia* curve up to the beginning of zone IX (WATERBOLK, 1954; FIRBAS, 1949). This is doubtless partly due to the great extent of the investigated bogs whose pollen diagrams reflect the character of a vegetation covering a much larger stretch of country, so e.g. in the nothern Netherlands and north-western Germany. Therefore, when *Tilia* was spared in these areas, this would find its expression in the continuity of the curve. On the other hand, a less steep fall of *Tilia* may be present in small bogs as well (PFAFFENBERG, 1952; VAN OYE and FLORSCHÜTZ, 1946; NIETSCH, 1940; HUMMEL, 1949; STEINBERG, 1944; MIKKELSEN, 1954). Perhaps the explanation is that human influence was less strong here (low percentages of indicators of human occupation) or was lacking. In the Hautes-Fagnes (PERSCH, 1950) indicators of human occupation do not appear before zone IX, and for this reason the *Tilia* curve decreases but gradually up to this boundary line. In the diagrams constructed for the Peel no indicators of human occupation are present and this may be the reason why ESHUIS (1946) was unable to find the transition between zone VII and zone VIII.

In contrast to Drenthe (VAN ZEIST, 1959), where *Tilia* recovers after the first period of land occupation, in South Limburg a regeneration of *Tilia* is everywhere absent. Van Zeist discussed the possibility that there might be a relation between the degree of humidity (OVERBECK, 1952), and the extent to which the soil is leached on the one hand, and the behaviour of *Tilia* on the other. In our region the influence of man is so strong that it seems excluded that a climatological effect would become noticeable. Leaching of the soil is out of the question in the loess and the cretaceous district in South Limburg.

In the Eiffel, apart from a less strong human influence, another factor which may be responsible for a more gradual decrease of *Tilia* may be that we are dealing here with *Tilia platyphyllos* (cf. page 68). The slower fall of *Tilia platyphyllos*, therefore, may be due here to the increase of *Fagus*, which as mentioned, occurs outside the valleys, and as *Fagus* increases but slowly, *Tilia* too decreases slowly.

Fagus

We mentioned already that in the valleys a fairly large area must have been cleared. However, the behaviour of the *Fagus* curve shows that the clearings did not occur on such a large scale as was usual in medieval times. In our diagrams we observe together with the fall of *Tilia* a continuous increase of *Fagus*. The increase of *Fagus* is not spurious, i.e. it is not caused by the decrease of *Alnus*, for if we remove *Alnus* from the tree-pollen sum, the *Fagus* increase remains distinct As *Fagus* does not belong to the *Alno-Ulmion*, we suppose that the clearings did not extend to the upper part of the slopes and to the plateaus. We draw attention to the fact that at BRO, where we observed the strongest influence of man, *Fagus* shows a decrease just below the layer of loam. This slight fall of *Fagus* may perhaps be due to a somewhat more extensive clearing on the slopes. However, above the loamy layer *Fagus* starts with a higher percentage.

Carpinus

Carpinus is present already in zone VIII, but its curve is not yet continuous. Only at L.F. we find, in agreement with STRAKA (1952), a continuous *Carpinus* curve in the upper part of the zone. We will return to the question of *Carpinus* in our discussion of zone IX.

At Ri and BRO the peat in zone VIII is partly loamy. Moreover, we find in zone VIII a gap in the peat stratigraphy which is entirely filled by a layer of loam which does not contain pollen grains. Generally in a cleared area the erosion is intensified. It is, therefore, highly probable that this gap has something to do with the clearings. According to NATERMAN (1939) and HEMPEL (1956), in Germany the colluvial layers were deposited in medieval times. REICHELT (1953), however, comes to the conclusion that the possibility that colluvial layers have been deposited already in the bronze age, is not excluded. It is, of course, only in a bog possible to observe such an older layer of colluvial material. Outside the peat the layer must be present as well, but is not possible to distinguish it from the much younger layers deposited in the middle ages.

The presence of colluvial material from pre-medieval times is in agreement with the findings of STEINBERG (1944), who observed in zone VIII a higher content of minerogenous matter. In the region around Sittard VAN ZEIST (1959a) did not observe a gap in the peat stratigraphy. However, the result of two radiocarbon datings made in peat samples collected at Sittard shows that the presence of a gap is by no means excluded. At L.F. we do not find any trace of loam or clay in zone VIII, probably owing to the fact that this larger bog was not influenced by the erosion, taken place in the surrounding area. However, at L.F. 2 (margin of the bog) above zone VII a sand layer is present.

At Vo and Co the development of peat stops soon after the transition between zone VII and zone VIII; above this level a thick layer of loam is deposited.

We do not find in our diagrams indications for a decrease of the winter temperature (IVERSEN, 1944). In contrast to Denmark and Ireland (JESSEN, 1949), we find in the Netherlands (WATERBOLK, 1954; VAN ZEIST, 1955) and in Norway (FAEGRI, 1944) a fall of *Ulmus* at the time that *Plantago lanceolata* makes its appearance. The same holds for South Limburg, where *Tilia* falls at the rise of *Plantago lanceolata*. Moreover, pollen of *Hedera*, one of Iversens indicators of colder winters, has been found very scarcely in South Limburg. The number of pollen grains used for the tree-pollen sum was certainly too low to allow an exact registration of the behaviour of *Hedera*.

The general feature of zone VIII is therefore a strong influence of man on the *Alno-Ulmion*, by which *Alnus*, *Tilia* and *Ulmus* decrease, and *Corylus* and *Quercus* increase. Outside the valleys no clearing took place, except perhaps at BRO, where a slight fall of *Fagus* was observed which may be ascribed to a somewhat more extensive felling on the slopes.

Viscum which was present in zone VI and zone VII disappeared almost completely. This is perhaps an indication for a slight deterioration of the climate.

Zone IX

Zone IX is characterized by the dominance of *Fagus*, a decrease of *Corylus* and a rise of *Alnus*. In contrast to the preceding zone, the percentages of the herbs, including indicators of human occupation, are low. They often decrease to zero. Due to the strongly decreasing activity of man, the forest now regenerates, but its character has changed.

In our diagrams *Fagus* may show two peaks (F 1 and F 2). During the F 2 *Fagus* usually reaches its highest percentages. It is obvious that these percentages are no fully reliable measure for the frequency of the tree, as they are highly dependent upon the percentage reached by the pollen of the trees belonging to the vegetation of the bog itself. Therefore we have to consider the percentages of *Fagus* in relation to those of trees which occur on the same site. BUCHWALD and LOSERT (1953) and TRAUTMANN (1957), therefore judge the importance of *Fagus* in relation to that of *Quercus*, which in South Limburg too occurs together with *Fagus* on the upper part of the slopes and on the plateaus. During the F 1 and the F 2 *Fagus* shows a higher percentage than *Quercus* (Table 2).

TABLE 2

Ratio between the pollen of Fagus and of Quercus in zone IX and zone X

Zone	L.F.	BRO	Nuth	Ri	A
X	1.0:2.7	1.0:4.8	1.0:4.3	1.0:3.1	1.0:5.0
F 2	3.0:1.0	1.7:1.0	3.0:1.0	1.6:1.0	1.9:1.0
F 1–F 2	1.0:1.5	1.0:4.0	1.0:2.5	1.0:1.6	1.0:1.5
F 1	1.0:1.1	1.3:1.0	—	1.3:1.0	—

However, the real ratio *Fagus : Quercus* in the vegetation is not the same as that between the pollen percentages. According to POHL (1937), the pollen production of *Fagus* is less than that of *Quercus* (*Fagus : Quercus* = 1:1.56). Moreover, the rate at which the pollen grains of *Fagus* sink down is higher than it is with the *Quercus* pollen. The dispersal of the pollen grains of *Fagus*, therefore, is bad (LÜDI, 1947; FIRBAS, 1949). JONASSEN (1950) found that already within a few hundred meter from a *Fagus* wood the percentages of the *Fagus* pollen are decreasing strongly. According to STEINBERG (1944), the percentages of *Fagus* should be multiplied by a figure in the neighbourhood of 7. The forests on the upper part of the slopes, therefore, must have been real *Fagus* forests in which *Quercus* only played a minor rôle. The real ratio is still more in favour of *Fagus*, because at least part of the pollen grains of *Quercus* must have originated from the *Alno-Ulmion*, in which *Fagus* does not occur. According to TRAUTMANN (1957), the pollen grains of *Quercus* originated indeed from the *Querceto-Carpinetum filipenduletosum* (cf. *Pruneto-Fraxinetum*).

The diagrams always show a significant F 2. The F 1 is clearly recognizable only at Ri. At L.F. the decrease of *Fagus* after the F 1 may be caused by an increase of *Betula*, whereas at BRO the decrease of *Fagus* after the F 1 may be due to the rise of *Alnus*. Anyhow, the increase of *Quercus* indicates that between the F 1 and the F 2 the ratio *Fagus* : *Quercus* has been shifted in favour of *Quercus*. We will return to *Fagus* in chapter VIII.

In contrast to the upper parts of the slopes, where *Fagus* continued to increase, the decreasing activity of man was reflected much more clearly in the *Alno-Ulmion* zone and in the vegetation of the bog. At Ri, Nuth and BRO the vegetation of the bog was transformed again into an *Alnus* wood. *Alnus* reached in these bogs very high percentages (80 %). At L.F. too we find at the beginning of the zone a rise of *Alnus*, but here *Alnus* does not exceed 50 %. The difference may be explained by the fact that at L.F. *Alnus* was not a component of the vegetation of the bog itself, which was a *Rhynchosporion*. At L.F. *Alnus* occurred only in the narrow *Alno-Ulmion* (*Alnion incanae*) zone along the margin of the bog. As mentioned before, a rise of *Alnus* in the regeneration phase following a period in which the area was inhabited has been described already by IVERSEN (1941). The difference between Denmark and our region is that here *Alnus* does not regenerate before zone IX on account of the long lasting and stronger activity of man in zone VIII. A rise of *Alnus* after a period of occupation but below zone IX, is present near Köln (NIETSCH, 1940) and in the Eiffel (STRAKA, 1952).

Special attention must be paid to *Carpinus* and *Quercus*. *Carpinus* occurs especially in the *Carpinion*. Surface samples taken from regions where the *Querceto-Carpinetum* is abundant, indicate that *Carpinus* must be highly underrepresented in the pollen diagram (LÜDI, 1947; STRAKA, 1952; OBERDORFER, 1936–1937). These findings are in agreement with the fact that the upper spectra of our diagrams always show a very low percentage of *Carpinus*, although the *Querceto-Carpinetum* is well represented in South Limburg.

Several explanations have been given for this phenomenon.

1. According to BUCHWALD and LOSERT (1953) and JONASSEN (1950), the dispersal of pollen grains of *Carpinus* in a forest region is low.

2. Recent surface samples indicate that the percentage of *Carpinus* found outside the pollination time, is low (OBERDORFER, 1936–1937).

3. TRAUTMANN (1957) supposes that a low *Carpinus* percentage is related to a special character of the peat. In *Alnus* peat *Carpinus* pollen should decay more rapidly than in *Betula* peat. For South Limburg the supposition of Trautmann is improbable. The highest percentages of *Carpinus* are often found in *Alnus* peat (Nuth, BRO).

4. STRAKA (1952) suggests that the rôle of *Carpinus* in the *Querceto-Carpinetum* is overestimated.

FIRBAS (1951, 1954) draws attention to the fact that in many diagrams *Carpinus* reaches its highest percentages just before the forest is cleared (STEINBERG, 1944; PERSCH, 1950; HUMMEL, 1949; OVERBECK and SCHNEIDER, 1938; MÜLLER, 1953; MIKKELSEN, 1954). The diagrams of STRAKA (1952), show two *Carpinus* peaks just before the peaks of the cereals. The same phenomenon is present in South Limburg, where we find the maximum values of *Carpinus* just before the ultimate clearing of zone X. It looks therefore as if the increase of *Carpinus* is related to the activity of man. However, the *Carpinus* maximum is usually reached at a time at which human influence has diminished. An increasing activity of man in zone X usually results in a steep fall of the *Carpinus* curve. The influence of man has apparently a depressing effect upon *Carpinus*. FIRBAS (1954), therefore, supposes that the rise of *Carpinus* in zone IX is due to a possibly slow alteration of the climate. A change of the climate is certainly not excluded because according to FIRBAS (1954), an alteration of the climate actually took place between the 14th and the 17th century. A favourable effect of man upon *Carpinus* has been reported by MÜLLER (1947). Müller observed a rise of *Carpinus* which was accompanied by the presence of indicators of habitation. It seems to us that the contradiction between the findings of Müller and those of other investigators is due to differences in the measure in which man influenced the vegetation. We find a fall of *Carpinus* at the transition between zone IX and zone X, the time at which the large scale clearing of the forests began. On the other hand, in the diagram of Müller where *Carpinus* rises in the periods of habitation, the influence of man on the vegetation was but slight; *Plantago*, *Rumex*, *Artemisia* and Chenopodiaceae showing very low percentages; *Corylus*, *Alnus* and *Betula* do not show any relation with human occupation. It seems, therefore, probable that the increase of *Carpinus* is due to the presence of a people which for some reason scarcely influenced the composition of the vegetation. If we assume that in South Limburg a similar people was present in zone IX it is comprehensible that *Carpinus* increased. Indeed, we find in our region in zone IX a strongly decreasing activity of man, but the presence of cereals (now of the *Secale* type) indicates that man was certainly not absent. The strong decrease of the human activity appears from the very low percentages of the cereals. The curve of the cereals is often interrupted. We have to draw attention to the fact that at Anselerbeek, in contrast to the other diagrams, the cereals and the N.A.P. reach an unusual high percentage in the *Fagus* time and in conformity with this at Anselerbeek the percentages of *Carpinus* are low. The rise of *Carpinus* is in agreement with the view of the phytosociologists that when trees are cut down in a forest on rich soil, *Carpinus* rises on account of its faculty to regenerate from the stem stumps (BURRICHTER, 1953; HESMER, 1932; OBERDORFER, 1949). Moreover, recent phytosociological works indicates that the *Querceto-Carpinetum* itself is to some extent an anthropogenic community (DOING KRAFT and WESTHOFF, 1959).

As *Carpinus* is present especially in the *Carpinion*, we suggest that the latter must have been present between the *Fagus* zone and the *Alno-Ulmion* zone. The recent phytosociological view that in our region the *Querceto-Carpinetum* is no climatological climax but an association that is to a large extent dependent upon the presence of man (see chapter VIII), is in agreement with our findings, and it is therefore comprehensible that *Carpinus* will have reached its maximum just before the end of zone IX. It is not necessary to assume that the *Querceto-Carpinetum* remained confined to a zone along the slopes. Where man exercises his influence on the forests (and this applies to the *Fagus* forests on the plateaus too) a *Querceto-Carpinetum* may arise (DOING KRAFT and WESTHOFF, 1959). However, the presence of an anther of *Fagus* in zone IX at Nuth (140 cm) proves that *Fagus* was certainly not absent in the immediate vicinity of the bog.

We mentioned already that *Carpinus* appears in zone VIII. This means that in our region *Carpinus* was never withdrawn from the influence of man. In many regions (VAN ZEIST, 1955; STRAKA, 1952; HUMMEL, 1949; MÜLLER, 1953), the continuous part of the *Carpinus* curve starts in the upper part of zone VIII (zone X: O.S.). In our diagrams a *Carpinus* curve which is continuous in zone VIII is present only at L.F. This is perhaps due to the fact that at L.F. the human influence is less pronounced than at BRO and Ri. At BRO and Ri the strong activity of man (clearing of the *Alno-Ulmion* zone and possibly a clearing of the *Carpinion* zone as well) prevented the development of *Carpinus*. It is not impossible that a *Querceto-Carpinetum* was present even on the colluvial soils. We mentioned already that the *Querceto-Carpinetum* may arise from the *Alno-Ulmion* by a proceeding maturing of the soil in which a differentiation has been developed. The clearing of the *Alno-Ulmion* zone (*Tilia*) by man may result therefore in more favourable conditions for the establishment of *Carpinus*. The rise of *Quercus* in zone VIII may partly be due to the same cause. The relation *Carpinus*-man is clearly demonstrated in the Hautes-Fagnes (PERSCH, 1950; FLORSCHÜTZ and VAN OYE, 1939). In the Hautes-Fagnes we do not find any trace of man before the F 1. The curve of *Carpinus*, therefore, is not continuous before that horizon.

The final breakdown of *Carpinus* took place at the transition between zone IX and zone X. In zone X *Carpinus* falls on account of the substitution of the *Querceto-Carpinetum* by orchards and fields.

It appears from our considerations that between *Carpinus* and *Fagus* no correlation is present. The position of the *Carpinus* maxima varies from region to region. In regions where the F 2 is the last *Fagus* maximum before the increasing activity of man, *Carpinus* is high at the F 2 (Eiffel, South Limburg). The *Carpinus* maximum coincides on the other hand, with the F 3 in regions where man makes its appearance at a much later date (Hautes-Fagnes: PERSCH, 1950; Achterhoek: DANIELS, 1961).

In zone IX the *Tilia* curve remains low and interrupted. From what has been said in our discussion of *Carpinus*, it will be evident that the regeneration of *Tilia* may be prevented by the activity of man. Apart from climatological reasons, the decrease of the activity of man is therefore not sufficient for a recovery of *Tilia*. *Alnus* however, reacts momentarily. This may be explained by the fact that *Alnus* regenerates much more easily from stumps (IVERSEN, 1941). Moreover, apart from Leiffenderven the local vegetation in zone IX is again an *Alnus* forest which does not contain *Tilia*. Still at Anselerbeek we find during the *Fagus* time a continuous *Tilia* curve. As zone VIII, in which the influence of man is, as a rule clearly recognizable, is lacking here, we do not know whether we are dealing with a regeneration or with a possible absence of human interference in zone VIII. In the diagram given by STEINBERG (1944) *Tilia* is in zone IX represented by a higher percentage too.

Ulmus too does not regenerate easily from stumps and, therefore, *Ulmus* always shows very low percentages in our diagrams.

In agreement with the results obtained elsewhere in eastern Europe (FIRBAS, 1949), *Corylus* decreases strongly in zone IX. According to Firbas, the decrease of *Corylus* may be ascribed either to a proceeding degeneration of the soil or to a decrease of the precipitation. In South Limburg the former explanation is out of the question. In our diagrams (L.F., Nuth and BRO) later on *Corylus* often rises and this would not occur if the soil has been leached out. A change in the precipitation is quite well possible. Moreover, it seems to us that the decrease of *Corylus* is causally connected with the rise of *Fagus*. *Fagus* does not tolerate *Corylus* which has a high light requirement. In this way the fall of Corylus is indirectly connected with the decreasing activity of man. We find this relation to *Fagus* at A, Nuth and Ri, where *Corylus* shows a maximum between the F 1 and the F 2; when *Fagus* decreases, *Corylus* rises.

Zone X

Zone X is characterized by a renewed increase of human influence.

As indicators of the latter the same species were found in the samples as were present in zone VIII. We mention Chenopodiaceae (Ri, BRO, Nuth, Ra, W, Gr, A, L.F.), *Artemisia* (Ri, Gr, A, L.F.), *Rumex acetosella* (Ri, Gr, A), Asteraceae liguliflorae (Ri, L.F., BRO, Nuth, W, Gr, A), Poaceae (Ri, BRO, Nuth, Ra, W, Gr, A), Brassicaceae (BRO, Ra, W, B, Gr, A), *Polygonum persicaria* (Ri, L.F., BRO), *Helianthemum* (A, B), *Hippophae* (B, Ri), and *Polygala* (Gr, B).

The percentages of the cereals (*Secale* type) rise, and often reach high values (BRO, B, Gr, A, Ri, L.F.). *Plantago lanceolata* is present once more but its percentages are often (BRO, Nuth, Ri, L.F., Gr, Ra) lower than in zone VIII. This may indicate that at this stage agriculture becomes more important than stock raising.

In addition to these species we found a number of species which were not present in zone VIII:

1. *Centaurea cyanus*

   Pollen grains of *Centaurea cyanus* have been found at Gr, A, Ra, BRO, Nuth, Ri, L.F., B. According to SISSINGH (1950), this species indicates the presence of the *Secalinetalia*. Also in Denmark was observed that *Centaurea cyanus* does not occur before zone X (MIKKELSEN, 1954).

2. *Plantago major*
   At Gr, Nuth and B we found pollen grains of this species. *Plantago major* is a companion of man (OBERDORFER, 1949). The species is best represented in the *Plantaginetalia.*

3. *Polygonum aviculare* (A)
   Polygonum aviculare is abundant in several weed associations, especially in the *Plantaginetalia* (SISSINGH, 1950).

4. *Sanguisorba minor* (Gr, A)
   Sanguisorba minor is characteristic for the *Festuco-Brometae,* and occurs especially in the *Mesobrometum* (OBERDORFER, 1949). For that reason the occurrence of pollen grains of this species may indicate a clearing of the forests on the loess and the use of the cleared areas for grazing.

5. *Sanguisorba officinalis*
   According to OBERDORFER (1949), this species occurs in the *Molinietalia* (*Molinion* and *Calthion*), and the occurrence of pollen grains of this species at B and Ri therefore indicates the presence of hayfields.

6. *Ligustrum* (Gr)
   Ligustrum is abundant in the *Berberidion* (VAN LEEUWEN and DOING KRAFT, 1959) and its occurrence may indicate, therefore, a degradation of woods belonging to the *Carpinion* or to the *Alno-Ulmion.*

In comparison to zone VIII, the clearing took place on a much larger scale. *Fagus,* which occurred in zone IX, on the upper part of the slopes and on the plateaus, shows in the diagrams a steep fall, due to the transformation of the *Fagus* forests into arable land. Up to recent times the *Fagus* percentage remains low, except at Anselerbeek where a temporary *Fagus* maximum is present in zone x.

The rise of the N.A.P. indicates that the forests were cleared. According to FIRBAS (1934) and JONASSEN (1950), we find a clear distinction between bogs situated in a wood (low percentage of N.A.P.: Ra) and bogs situated in a cleared area (high percentage of N.A.P.: Gr, B, A, BRO).

Together with *Fagus, Carpinus* runs down owing to the large-scale transformation of the *Querceto-Carpinetum* into orchards and fields. In our diagrams *Fagus* and *Carpinus* are mainly replaced by *Quercus* and *Corylus.* Table 2 shows the changed relation between *Fagus* and *Quercus* (p. 80). In the lower part of zone x (zone xa) *Quercus* is the tree which reaches, at least if *Alnus* is left out of consideration, the highest percentages. The *Quercus* maximum is most pronounced in the small bogs, because here the distance between the *Quercus* zone and the bog is but small. The *Quercus* maximum is less clear at L.F., but if we remove *Alnus* from the tree-pollen sum the *Quercus* maximum becomes visible too. The relation between the quantity of *Quercus* in the diagram and the size of the bog was demonstrated earlier by PFAFFENBERG (1952) in north-western Germany.

The rise of *Quercus* and of the N.A.P. and the fall of *Fagus* is a generally observed phenomenon in western Europe (FIRBAS, 1949; STRAKA, 1952; HUMMEL, 1949; NIETSCH, 1940; etc.), though the fall of *Fagus* is not always a steep one. In the Eiffel (HUMMEL, 1949)

Fagus remains an important component of the vegetation (compare Wolffsheid). According to several authors (SELLE, 1941; HESMER, 1932), in zone x the increase of *Quercus* must have been favoured by human activity. We shall return to the question of *Fagus* and *Quercus* in chapter VIII.

As we have seen already, the recent view of the phytosociologists (chapter VIII: DOING KRAFT and WESTHOFF, 1959) is that the *Querceto-Carpinetum* is an association which owes its development to human interference. The activities of man lead to a transformation of the *Fagus* forest on the upper part of the slopes and on the plateaus into a *Querceto-Carpinetum*. As the *Alno-Ulmion* on colluvial soils disappeared almost completely, the pollen grains of *Quercus* must have found their origin in the *Querceto-Carpinetum*, which developed on older and more differentiated soils.

Here too the increase of human activity resulted in a stronger erosion and the latter lead to the deposition of colluvial soils in the valleys. At Gr and A we find layers of loam both in zone xa and in zone xb; at BRO a loam layer is present just above the F 2 and at Nuth sand layers are present in zone x; however the latter were present already in zone IX.

In the upper part of zone x (zone xb) the *Pinus* percentage rises on account of the cultivation of this tree. We often find just before or in the *Pinus* time a rise of *Fraxinus*. Especially at Nuth *Fraxinus* reaches a fairly high percentage. *Fraxinus* occurs especially in the *Ulmion* and the *Alnion incanae* and it is therefore quite natural that *Fraxinus* is present in the diagrams. However, it is difficult to find an explanation for the fact that the rise of *Fraxinus* is confined to recent times. It is possible that the renewed deposition of colluvial sediments in the valleys give rise to woods of the *Alnion incanae* and *Ulmion* type i.e. to woods in which *Fraximus* occurs. It is also possible that it is due to the fact that the vegetation of the bogs themselves changed into an *Alnion incanae* (see p. 52).

An indication that in zone IX more water is retained than in zone x may be seen in the fact that the bogs in the spring areas have come into existence after the *Fagus* period, and this may be due to the large-scale clearing of the forests; after such a clearing the soil is no longer able to retain the surplus of the precipitation.

The behaviour of *Alnus* in zone x is different in the diagrams. At Ri and Nuth *Alnus* remains the same as it was in zone IX. Other diagrams show a decrease of *Alnus*, but the latter does not start at the same time. At BRO, Gr and B the decrease did not take place before zone xb, whereas the diagrams of W, A and Ra show a gradual decrease of *Alnus* from the beginning of zone x. At L.F. *Alnus* decreases strongly in the lower part of zone xa, but afterwards it rises again, and reaches a higher percentage than it had in zone IX. As mentioned already in our discussion of zone VIII, a decrease of *Alnus* may be ascribed to the clearing of the *Alno-Ulmion*. The fact that the decrease did not always occur, or that it occurred later, is difficult to understand. It may be that the attention of the population was turned in the first place towards the forests on the plateaus and that it left the *Alnus* woods in the valleys intact (compare the low percentage of *Plantago lanceolata*). At L.F. the increase of *Alnus* after a fall may be ascribed to a change of the dystrophic bog into a more euthropic habitat.

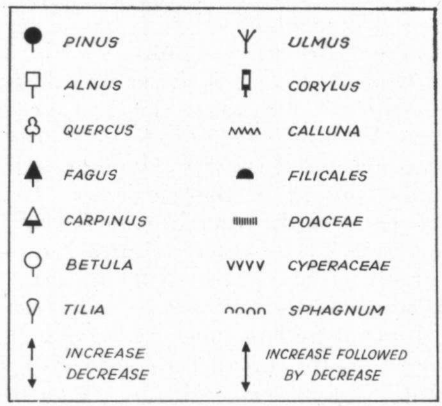
Due to the strong influence of man the three stages of Iversen (see p. 73) are scarcely recognizable. Only at Ri we find above the F2 a *Betula* maximum followed by a *Corylus* maximum. It is only at Ri that *Betula* reacts upon the human influence (compare also the behaviour of *Betula* in zone VIII). In some of the diagrams (Nuth, L.F. and Ri), a distinct *Corylus* maximum is present, in other diagrams it is but low (BRO). At Wolffsheid *Corylus* reaches fairly high percentages, but here the curve is irregular.

A decrease of *Corylus* after its maximum such as is found in South Limburg (L.F., BRO, Nuth) as well as in other parts of western Europe (TRAUTMANN, 1957; STRAKA, 1952; OVERBECK and GRIEZ, 1954) is ascribed by FIRBAS (1952, 1954) to a gradual degeneration of the soil. In consequence of this *Corylus* would reach high percentages only during the first period of the clearings. An indicator of the degeneration of the soil is the increase of *Betula*, which is usually observed after the *Corylus* maximum. In South Limburg, however, the rise of *Betula* is scarcely present. Moreover, in some diagrams (Ri and W) the *Corylus* maximum is not followed by a decrease. For this reason we are of opinion that in the loess and cretaceous district a degeneration of the soil need not be taken into account. Indeed, in recent times, the local soil still is a very rich one. According to OVERBECK and GRIEZ (1954), the absence of a *Corylus* maximum or the presence of a decrease following the maximum must be ascribed to a deterioration of the climate between 1450–1850 A.D. Indeed, we have some indications that in medieval times the climate was "better" than it is nowadays (FIRBAS, 1954: the upper limit of the forest in the "Riesengebirge" has receded since the middle ages; OVERBECK and GRIEZ, 1954: *Ulmus* in the middle ages somewhat higher; MULLER, 1947: bad vine years after the middle ages). A third explanation has been given by TRAUTMANN (1957). Trautmann takes into account that *Corylus* occurs mainly in the hygrophilous *Querceto-Carpinetum* i.e. in a part of the *Alno-Ulmion*. Trautmann, therefore supposes that the rise of *Corylus* is due to the fact that the *Alno-Ulmion* was thinned out. Later on *Corylus* decreased on account of the complete clearing of the *Alno-Ulmion*. It seems to us that the latter explanation is applied to a large measure to South Limburg. At BRO, where we find the strongest influence of man, a *Corylus* maximum is scarcely present, whereas at L.F. where the N.A.P. is lower than at BRO, a marked *Corylus* maximum is found. The same applies to our small bogs; viz. a strong influence of man is accompanied by a low percentage of *Corylus*. That *Corylus* shows at Wolffsheid a higher percentage may be due to the fact that the surrounding region even now supports an extensive wood including the *Alno-Ulmion*.

The same holds for the *Carpinion*. In case of a thinning out of this type of wood too *Corylus* rises.

TRAUTMANN (1957) explained the earlier decrease of *Carpinus* by assuming a selective felling of this tree. By the felling of the shade tree *Carpinus* shrubs (*Corylus*) and herbs in the wood would profit.

Figure 3, 4 and 5 show a rough survey of the development of the vegetation at L.F., Ri, BRO and at Co and Vo, according to our suppositions with regard to the distribution of the trees. As the geographical situation at BRO and Ri is the same, only one figure has been drawn; slight differences between Ri and BRO have been neglected. Zone xb and the zones before zone VII have not been included.



Legend to Figs 3, 4 and 5

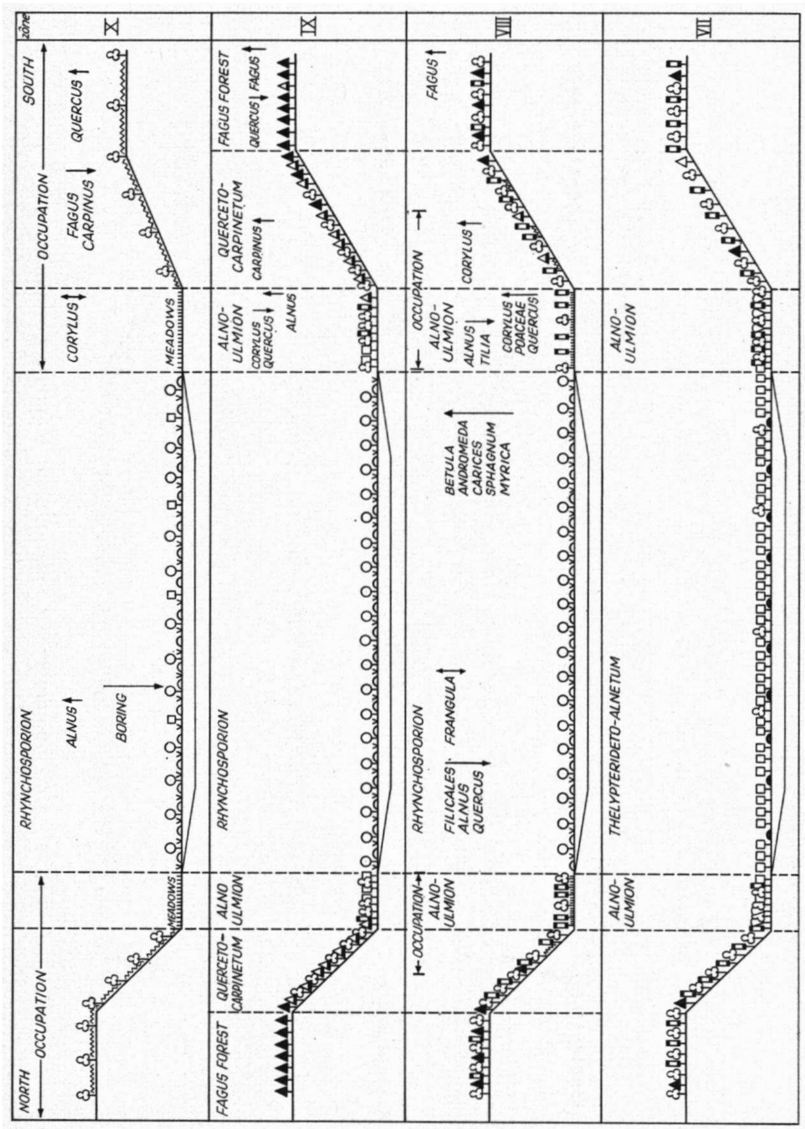


Fig. 3. Development of the vegetation at Leiffenderven.

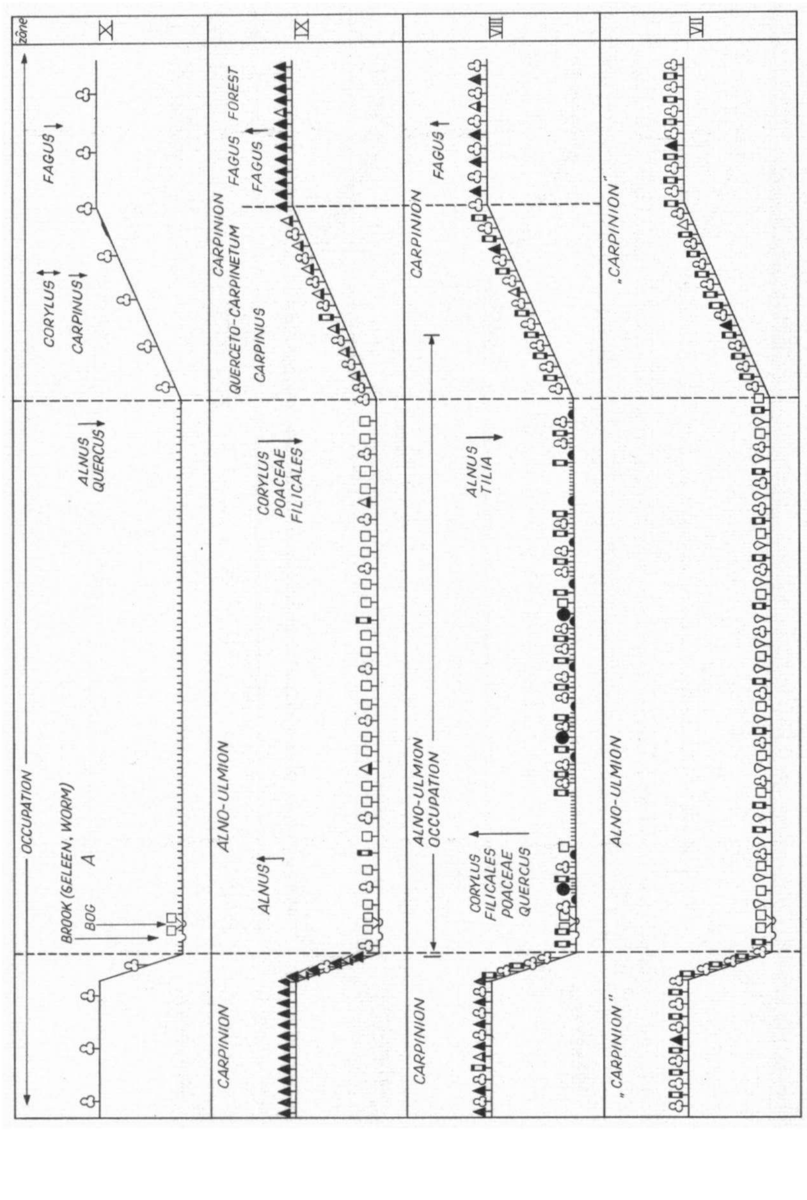


Fig. 4. Development of the vegetation at Rimburg-Brommelen.

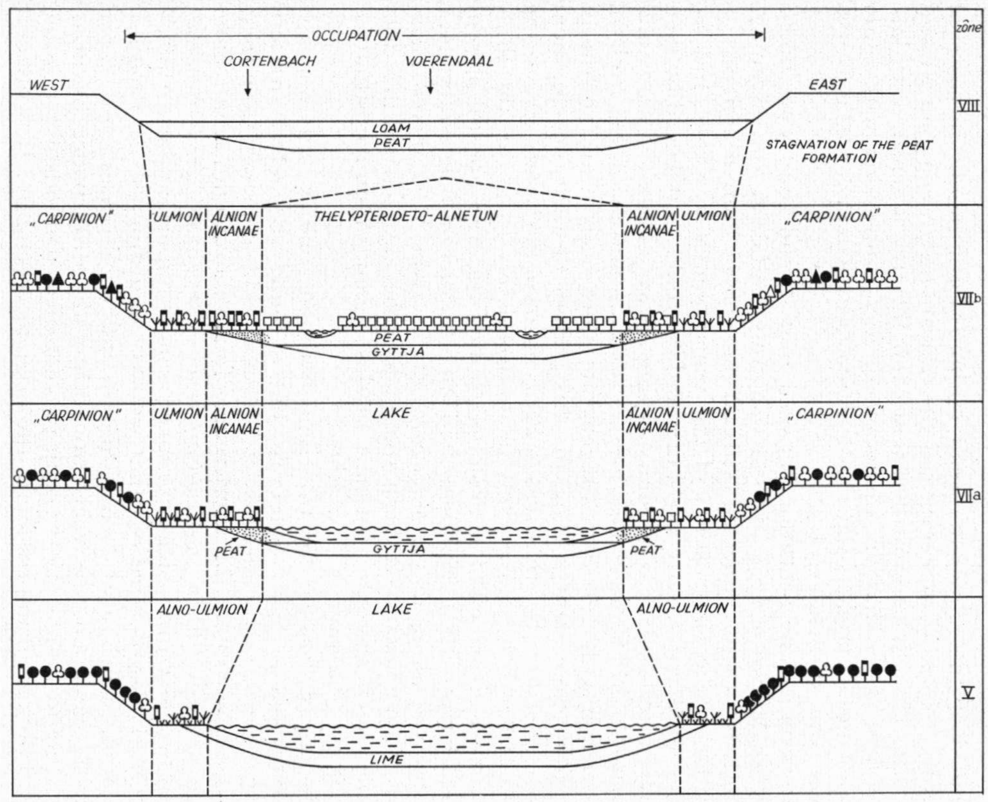


Fig. 5. Development of the vegetation at Cortenbach-Voerendaal.

CHAPTER VIII

DISCUSSION OF SOME INDIVIDUAL CONSTITUENTS OF THE VEGETATION

Fagus

Our diagrams show, in broad outline, a continuous increase of *Fagus* since its first appearance at the transition between zone VI and zone VII. Though its growth is slow, and the tree is sensitive to late night frost, *Fagus* has an advantage in the competition with other trees owing to the fact that it is a shade tree (RUBNER, 1925; DOING KRAFT and WESTHOFF, 1959).

However, at the transition between zone IX and zone X we find a final breakdown of *Fagus*. In our diagrams the fall in the percentage of *Fagus* is closely connected with an increase of human activities as reflected in the composition of the vegetation as a whole. Indeed, *Fagus* is unable to survive wood fires and is strongly influenced by such human interference as regular cutting down (DOING KRAFT and WESTHOFF, 1959). In such cases *Fagus* can not maintain itself in competition with trees which regenerate more easily from the stumps and need more light during the first stages of their development (*Quercus*, *Corylus*). For that reason *Fagus* is now a fairly rare tree in the woods of South Limburg. Only in the woods occurring on the flint-eluvium which are less often exploited, some *Fagus* trees are still present (DOING KRAFT, 1955), but near the Dutch frontier on Belgian territory we observed along the upper course of the river Voer mixed *Fagus* woods, which may have been spared here because agriculture does not play such an important part in this region. A similar situation reflects the diagram of Wolffsheid.

The fall of *Fagus* at the transition between zone IX and zone X is not restricted to South Limburg, but is found throughout western Europe. Several palynologists (cf. HESMER, 1932) conclude from these findings that without the interference of man the vegetation in regions where we now find a *Querceto-Carpinetum* or even a *Querceto-Betuletum* would be a forest in which *Fagus* plays a more important part. Already in 1931, TÜXEN pointed out that we have to distinguish 1) a natural vegetation which arises when human influence ceases, and 2) an original vegetation, the vegetation before the disturbance by man. According to FIRBAS (1954), with palynological methods it is possible only to obtain an impression of the original vegetation. It is difficult to arrive at a conclusion with regard to the natural vegetation because since a long time the woods have been influenced by man.

In South Limburg man must have been present from zone VIII on, and in consequence of this only the forests in zone VI and in zone VII are original ones in the sense of Tüxen. However, we may draw attention to the fact that the *Fagus* forests in zone IX arose at a time at which the influence of man was strongly decreasing, so that these forests may have a more or less undisturbed character. However, according to FIRBAS (1954), we have to take into account two factors which may have influenced this original vegetation found in zone IX, so that the latter, indeed, differs from the natural vegetation in the present time. These factors are:

1. *An irreversible degeneration of the soil.* The clearing of a forest on poor soil may result in a degeneration of the latter with the result that *Fagus* becomes inferior in the competition with other trees. In the loess and cretaceous district of South Limburg such a degeneration of the soil is improbable (compare the discussion of the fluctuations shown by *Betula* and *Corylus* in zone X: p. 87). According to KÖIE (1951), there is a relation between the behaviour of *Fagus* and the silt content of the soil (particles less than 0.02 mm). If the silt content is less than 8 %, *Fagus* is absent; between a content of 14–20 % *Fagus* reaches dominance in the forest when other factors (man, precipitation) are favourable. At a silt content of more than 20 % *Fagus* is always dominant. According to JONGMANS, KRUL and VOS (1941), the silt content of the loess in South Limburg is 27 %. DE VRIES (1948) too reported a high percentage of silt (20–30 %). It does not seem probable therefore that the recent scarcity of *Fagus* would be due to a degeneration of the soil. Perhaps an exception must be made for L.F. and Br, where the recent occurrence of *Betula verrucosa* and *Calluna* is an indication that the soil has been leached out.

2. *Alteration of the climate.* We have seen already (p. 87) that the climate has probably changed since zone IX. However, it seems to us that comparatively small changes in the climate can not be expected to exercise an appreciable influence so long as the soil does not act as a limiting factor, and that the precipitation moreover must have been sufficient for the growth of *Fagus.*

From these considerations it appears that *Fagus* must have been more important in the natural vegetation of South Limburg than it now is in the *Querceto-Carpinetum,* which is the community to which the remaining woods belong. Outside our region *Fagus* is now certainly not absent in the associations of the *Carpinion.* It may occur in the *Querceto-Carpinetum typicum* (BURRICHTER, 1953), in the *Querceto-Carpinetum asperuletosum* (BARKMAN, 1948; LOHMEYER, 1951, 1953; BURRICHTER, 1953), in the *Querceto-Carpinetum festucetosum sylvaticae* (LOHMEYER, 1951), in the *Querceto-Carpinetum luzuletosum* (LOHMEYER, 1953), in the *Querceto-Carpinetum saniculetosum* and the *Querceto-Carpinetum melicetosum* (VAN LEEUWEN and DOING KRAFT, 1955; DOING KRAFT and WESTHOFF, 1959). However, in none of these subassociations of the *Carpinion Fagus* ever reaches absolute dominance.

In the lowlands of western Europe pure *Fagus* woods (*Fagetum calcareum:* SCHWICKERATH, 1944) occur now especially on soils containing more than 0.05 % lime (MARKGRAF, 1932). It was already known that under influence of man the *Fagetum calcareum* may degrade into a

Querceto-Carpinetum primuletosum (Diemont, 1938; Schwickerath, 1944; Burrichter, 1953; Doing Kraft and Westhoff, 1959).

According to Tüxen (1933), the *Querceto-Carpinetum* would be the climax association, whereas the *Fagetum* would only be a transitional stage leading irrevocably to the *Querceto-Carpinetum*, and the dominance of *Fagus* was ascribed by Tüxen (1932) to the influence of man. The influence of man would result in a reduction of the area occupied by the *Quercus* woods and for this reason in the pollen diagrams the percentages of the other trees would rise. Secondly Tüxen pointed out that the raised bogs enlarged their area especially in regions where the forests do not contain *Fagus*. According to Tüxen, it is therefore desirable to investigate small bogs. As we have seen already, on account of such an investigation we arrived at the conclusion that *Fagus* must have been the dominant tree in a period in which the influence of man was less pronounced and in a region where raised bogs are lacking. This conclusion is in strong contrast with that of Pfaffenberg (1952) who investigated small bogs in a region where the *Querceto-Betuletum* is now the main association. The diagrams of Pfaffenberg show that from the beginning of zone VI *Quercus* and *Betula* played an important part in the vegetation. In zone IX *Fagus* reached a higher percentage, but *Fagus* never intersects the *Quercus* curve. It seems to us that the discrepansies in the results of the various investigators must be due to the character of the soil, which in the area investigated by Pfaffenberg certainly is less rich than it is in South Limburg.

An exception in our region is the diagram of Br 1. This diagram must belong for the greater part to zone IX, though *Fagus* never intersects the *Quercus* curve. It is probable that the pollen grains of *Fagus* were derived for the greater part from trees which occurred on the heath itself. Still it is possible that a part of the pollen grains of *Fagus* were derived from the loess region, which is 4 km removed from the site where we collected our samples. According to Firbas (1949) a percentage of a few per cents may be due to long-distance transport. Certainly the distance to the loess region is not a "long distance" (more than 10 km) but it seems to us that the percentage of 13 % *Fagus*, which has been found at Br 1, may not be ascribed completely to a transport of pollen grains from the loess region, because the distance over which the pollen grains of *Fagus* can be transported, is but short. Therefore we do not agree with the supposition of Zeidler (1957) that 20–30 % *Fagus* in the diagram may be due to a transport of pollen grains from trees growing at a distance of 5–8 km.

A presence of *Fagus* on the heath of Brunssum is quite well possible, because some indications make it probable that the soil was not always so deficient in nutrients as it is now (see p. 49). However, the lower *Fagus* percentages and the higher percentages of *Betula* and *Calluna* show that during zone IX the soil had a less fertile character than it has in the loess district. In contrast with our findings in the loess district, those on the heath of Brunssum are in agreement with those of Pfaffenberg (1952).

The fact that *Fagus* was a constituent of the forests in a region which now supports a *Querceto-Betuletum* (in a wider sense), is in agreement with the opinion of DOING KRAFT and WESTHOFF (1959) according to which *Fagus* may occur even in the *Querceto-Betuletum* (*Fageto-Quercetum*). In the loess district the forests in zone IX were, in contrast to those on the heath of Brunssum, pure *Fagus* forests. According to the opinion of phytosociologists, *Fagus* would become once more the dominant tree if man was no longer present (DOING KRAFT and WESTHOFF, 1959). At least in our region, the *Querceto-Carpinetum* must be considered as an association which owes its development to the presence of man. On better soils it is only under the influence of man that *Quercus* and *Corylus* can oust *Fagus*. On more degradated soils *Fagus* is replaced by *Quercus* and *Betula*.

This result is in agreement with the observations made by several other authors (BURRICHTER, 1953; LOHMEYER, 1951, 1953; DOING KRAFT and WESTHOFF, 1959; VAN DEN BERGHEN, 1957) according to which *Fagus* is the strongest rival in the competition with other trees. In the mountains with their high precipitation *Fagus* regenerates even on siliceous soils as soon as the human influence ceases, and this must be due to the optimal climate (*Luzulo-Fagion:* NOIRFALISE, 1956; VAN DEN BERGHEN, 1957; DOING KRAFT and WESTHOFF, 1959). Therefore, it must be ascribed to the strong human influence that we find in South Limburg not the *Fagetum* but instead of that the *Querceto-Carpinetum*.

An additional argument in favour of this assumption is found in the work of SEIBERT (1955). According to Seibert, the exploited woods (Niederwald) of Westphalia (Germany) would contain three groups of species which occur also in three corresponding types of *Fagus* woods.

As mentioned before (p. 83), we assumed that in zone IX the *Querceto-Carpinetum* zone was found on the slopes below the *Fagus* belt. A somewhat similar situation is not uncommon in western Europe where we find in the lowlands usually a zonation along the slopes of the hills (DIEMONT, 1938; JAHN, 1952; BURRICHTER, 1953), the lower part of the slopes supporting a *Querceto-Carpinetum*, the upper part a *Fagus* wood. It is not impossible that this zonation is not due to climatological differences only, but that it is partly due to the influence of man. On the upper part of the slopes a *Fagus* wood may be present, because here the human influence is slighter. An interesting situation is present on loess soil in Westphalia (BURRICHTER, 1953), where we find below the *Fagus* belt a *Querceto-Carpinetum dryopteridetosum*. The lower part of this *Querceto-Carpinetum* has been described by Burrichter as a *Quercus* variant, the upper part as a *Fagus* variant. This continuous transition from a *Querceto-Carpinetum* to a *Fagetum* is the situation we may expect in places where human influence gradually decreases towards the upper part of the slopes. In Limburg such a zonation is not present, because here human influence is very strong all over the slopes.

Our considerations hold only for western Europe. If we compare our findings with those obtained in the dry area of Central Germany, there appears to be a difference. In the dry area of Central Germany we are in the neighbourhood of the eastern boundary line of the area of distribution of *Fagus* (lower precipitation, continental climate). Though here too the soil is loess, the ratio *Fagus* to *Quercus* is in zone IX 2:3 (Müller, 1953), indicating that the soil conditions though very favourable, are not sufficient to neutralize the adverse influence of the continental climate. It is therefore possible that here the *Querceto-Carpinetum* is a climax association (Doing Kraft and Westhoff, 1959). Notwithstanding this *Fagus* was in the dry area of Central Germany in zone IX more important than it is nowadays, and at least a part of the *Querceto-Carpinetum* may owe its development to human interference.

In contrast to South Limburg in the dry area of Central Germany extensive *Fagus* woods are still present. *Fagus* occurs here only in the centre of the woods whereas the outer margin of the woods consists of *Corylus, Tilia, Quercus* and *Carpinus*. According to Passarge (1953), the retreat of *Fagus* towards the centre of the forest is not due to felling alone but also to the more continental climate of the surrounding fields (late night frosts). Indeed, it is a well-known fact that the "mesoclimate" becomes more arid in case of a clearing (Lundegardth, 1957).

According to Passarge, the great expansion of *Fagus* in zone IX would be due more to the humidity of the "mesoclimate" than to the humidity of the "macroclimate". However, it is improbable that in the more oceanic South Limburg the clearings of the woodland would have resulted in a change of the "mesoclimate", in such a way that the resulting climate would not tolerate the existence of *Fagus*. However, it is possible that the precipitation is now higher than it was at the beginning of zone X.

That *Fagus* pollen is better represented in zone IX than that of *Quercus* is in the lowlands of western Europe often found in those parts where the soil has not been leached out to a large extent. Sometimes the ratio is in agreement with the potential composition of the natural vegetation (Buchwald and Losert, 1953).

In the Netherlands we find an other region in which *Fagus* is superior to *Quercus* in zone IX viz. the eastern part of the country (Ten Houten, 1935; Daniels, 1961). According to Meyer Drees (1936), *Fagus* was especially abundant in the subcentreuropean district (Van Soest, 1934) where now some of the species are still present by which outside the Netherlands *Fagus* is accompanied. Our findings show that South Limburg constitutes a second region where *Fagus* predominated over *Quercus*. This result is in agreement with a forest map of zone IX drawn by Straka (1957).

It is in agreement with our suppositions that *Fagus* never reaches dominance in the diagrams of the region of poor cover sands in the higher eastern parts of the Netherlands, e.g. in Drenthe and in the Veluwe.

In our diagram *Fagus* is not superior to *Quercus* from the beginning to the end of zone IX. We mentioned already that at least two *Fagus* peaks are recognizable. These two *Fagus* peaks are recognizable in the diagrams of STRAKA (1952), HUMMEL (1949) and of STEINBERG (1944) too. In the Peel (ESHUIS, 1946) at least an indication of two *Fagus* peaks is recognizable. Some diagrams (PERSCH, 1950; DANIELS, 1961; OVERBECK and SCHNEIDER, 1938), on the other hand, show four *Fagus* peaks. In these diagrams the presence of a F 3 and a F 4 is correlated with a late (after the F 3) appearance of man (PERSCH, 1950; DANIELS, 1961). In the diagram of Overbeck and Schneider the curve of the cereals starts after the F2 but the gradual decrease of *Carpinus* indicates that the influence of man is low (cf. p. 83). We suppose therefore that in South Limburg and in the Eiffel the absence of the F 3 and of the F 4 is due to the strong influence exercised by man.

It is difficult to explain why the increase of *Fagus* is not continuous. Several reasons may come up for discussion.

1. *Influence of man*

The depression between the two *Fagus* peaks may be due to an increasing activity of man. Indeed, several diagrams (STEINBERG, 1944; HUMMEL, 1949; MIKKELSEN, 1949) show after the F 1 an increase of the percentages of those pollen grains which are derived from plants indicating human occupation. In South Limburg such an increase is not recognizable.

2. *Shifting of the phreatic surface*

Diagrams from the eastern Netherlands (DANIELS, 1961), Westphalia (BUDDE and RUNGE, 1940) and north-west Germany OVERBECK and SCHNEIDER, 1938) show a negative correlation between *Fagus* and *Alnus*. Usually diagrams constructed for bogs in a hilly landscape do not show this correlation, because a rise of the phreatic surface in the bog does not influence the *Fagus* forests on the slopes and on the plateaus. However, it is not impossible that *Fagus* reacts upon an alteration of the humidity whereas *Alnus* does not react to it.

3. *Alterations of the humidity*

In the northern Netherlands (VAN ZEIST, 1959) and in north-west Germany (OVERBECK, 1952) a correlation has been established between *Fagus* and the composition of the vegetation of the raised bogs. Moreover, in raised bogs a correlation exists between *Fagus* and the recurrency surfaces (MIKKELSEN, 1949) which may be regarded as indicators of changes in the humidity. According to these authors the expansion of *Fagus* took place in a series of jumps due to an increase of the humidity. VAN ZEIST (1959) distinguishes three stages in the expansion of *Fagus:*

first expansion : *Fagus* increases at the end of zone IX (O.S.) from 0.3–1 % in the northern Netherlands; this increase is accompanied by a change of the peat to *Sphagnum cuspidatum* peat;
second expansion : after the C 4, the appearance of *Sphagnum imbricatum;*
third expansion : *Fagus* reaches its highest values; formation of fresh *Sphagnum* peat in full swing.

According to MIKKELSEN (1949) on fertile soil the expansion of *Fagus* is not interrupted. In South Limburg the three stages in the expansion of *Fagus* are present, though no correlation whatever with the character of the peat is present. Only at L.F. we find at the transition between zone VII and zone VIII a change to *Sphagnum cuspidatum* peat. The second expansion is present just below the F 1. The third expansion gives rise to the F 2. We will return to this question in chapter X, where we want to discuss a possible synchronism in the behaviour of *Fagus.*

4. *Succession*

According to DOING KRAFT and WESTHOFF (1959), the equilibrium between the different tree species in a natural forest is not maintained during a period of unlimited length. In a *Fagus* forest *Fagus* may decrease because the condition of the trees deteriorates; the crown becomes less dense with the result that trees needing more light (*Quercus* and *Corylus*) expand. Indeed, this is the development occurring between the F 1 and the F 2. It is possible that the existence of the *Fagus* peaks may be explained in this way.

Carpinus

Carpinus makes its first appearance in zone VIII. In zone IX it expands, and here it reaches its highest values during the F 2. In zone X it decreases strongly. For possible explanations of the behaviour of *Carpinus* we refer to our discussion of zone IX.

Quercus

The first pollen grains of *Quercus* are present in zone V. In zone VI the percentage increases. In zone VI and zone VII the percentage of *Quercus* depends upon the size of the bog. In the two periods in which the region was inhabited (zone VIII and zone X) *Quercus* reaches its highest percentages. Due to the strong regeneration from stumps *Quercus* is able to reach dominance in zone X, viz. as soon as *Fagus* diminishes. Moreover, the development of *Quercus* was favoured by man more than *Fagus* because the leaves of *Quercus* were used as cattle fodder (BUCHWALD and LOSERT, 1953), whereas its bark (SEIBERT, 1955) and wood (PFAFFENBERG, 1952) were used too. In zone IX the percentages of *Quercus* are low. We have put forward arguments in favour of an origin of pollen grains of *Quercus* found in zone IX from an *Alno-Ulmion* and the *Carpinion* in the vicinity (page 83).

Corylus

Corylus makes its first appearance in zone IV. In zone V the percentages of *Corylus* are increasing. In this zone the *Corylus* curve shows a low peak. According to SCHMITZ (1955), the four *Corylus* peaks that are distinct in diagrams from north-western Germany and from the northern part of the Netherlands, are due to changes in the climate.

In South Limburg the C 2 and the C 3 are not distinct, whereas the *Corylus* peak in zone VIII (C 4?) is closely connected with human influence.

Only at L.F. we observe a real *Corylus* peak in zone VIII. At BRO the *Corylus* increase in zone VIII is small and at Ri the peak is absent. It remains possible that at BRO the C 4 actually was present, but that it is not visible because at the time it might be expected, then a gap in the peat stratigraphy is present.

In our diagrams a third *Corylus* peak is present in zone X; this peak too is due to the human influence. At present too *Corylus* is very abundant in the woods of South Limburg. Therefore it seems that in South Limburg the fluctuations in the *Corylus* curve probably do not reflect alterations in the climate. The C 1 is the only one which may be due to such an alteration. However, we know too little with regard to the reaction between vegetation and climate in zone V, but for the moment a climatological explanation for the fact that *Corylus*, which has been present already for a long time, increases in this zone is the only one we can give.

Tilia and Ulmus

Both *Tilia* and *Ulmus* make their appearance in zone V, *Ulmus* already in the lower part of the zone, *Tilia* not before the upper part. We have put forward some arguments (discussion of zones VI, VII and VIII) in favour of the assumption that *Ulmus* and *Tilia* belonged to some association of the *Alno-Ulmion*. In zone VI and in zone VII *Tilia* is often the main component of the *Quercetum mixtum*. Except at Co 2 *Ulmus* remains low. The fall of *Tilia* in zone VIII has been ascribed to human interference (see our discussion of zone VIII). In zone IX and in zone X on account of the strong influence of man no recovery of *Tilia* or *Ulmus* could take place. The same behaviour is present all over western Europe, but in several regions a degeneration of the soil, may be responsible, partly or entirely, for the low *Tilia* and *Ulmus* percentages. An exception to this rule is the loess region of the dry area of Central Germany, where *Ulmus* and *Tilia* reach their highest development. The composition of the forests in this region resemble that of the vegetation found in zone VI and in zone VII.

According to PASSARGE (1953), the *Tilia* and *Ulmus* woods can not be regarded as relics from the forests found in zone VI and in zone VII, because in the diagrams of this region (MÜLLER, 1953) at the transition between zone VII and zone VIII too a fall of *Ulmus* and of *Tilia* and a rise of *Fagus* is visible. Passarge therefore describes the recent *Quercetum mixtum* as a second *Quercetum mixtum* optimum. The opinion of Passarge is supported by the fact that the transition from *Fagus* forest to *Quercetum mixtum* is no direct one. About 200 years ago in the dry area of Central Germany *Corylus* and *Quercus* were very abundant owing to the excessive exploitation of the woods. *Ulmus* and *Tilia* returned in the last 200 years because nowadays the woods are protected against unjudicious exploitation.

If we apply the supposition of Passarge to South Limburg, we must remark that in the last mentioned region we are dealing now with the *Quercus-Corylus* phase. That *Tilia* and *Ulmus* did not recover, may be due to the high degree of cultivation of the region. Indeed, the small woods in the loess region are in a very early stage of development (DOING KRAFT, 1955). According to dates from Blink (JONGMANS, KRUL and VOS, 1941) we find in South Limburg 731 ha pine plantations, 180 ha deciduous woods, and 1469 ha coppice growth (especially along the slopes). These dates clearly demonstrate that the woods in our region are in an initial stage. It is not possible to say whether in South Limburg *Tilia* and *Ulmus* will return if the human influence diminishes as they did in the dry area of Central Germany. This may depend upon the speed of the *Fagus* regeneration which in the dry area of Central Germany may be less than it is in South Limburg. Anyhow the nature of the soil certainly can not be regarded as a hindrance to a recovery of *Tilia* and *Ulmus*.

Betula

In the loess district the part of *Betula* (*verrucosa*) in the post glacial time is a minor one. Only at Ri we find somewhat higher percentages, probably due to a local occurrence of terrace sands at the surface (see our discussion of zone VIII).

In the regions outside the loess district the percentages of *Betula* are higher (Br, L.F.). However, we have to take into account that at least a part of the pollen grains of *Betula* is produced by *Betula pubescens* which was present on the site itself.

Alnus

Alnus makes its appearance in the upper part of zone V. In our region *Alnus* is a component of the vegetation of the bogs itself (*Alnion glutinosae* and *Alnion incanae*) which are restricted to the valleys. The limiting size of the area of *Alnus* in a hilly region is clearly shown in the diagrams of PERSCH (1950), HUMMEL (1949) and STRAKA (1952) which refer to bogs outside the valleys. In these diagrams *Alnus* shows a very low percentage. In our region the presence of *Alnus* at the site of the boring is demonstrated by the fact that anthers and wood were often found in the samples, especially at Nuth. In our region a fall of *Alnus* is distinct in the two periods in which the region was inhabited; it is probably due to a selective felling of this tree. In the *Fagus* time a regeneration of *Alnus* took place.

Salix

Though *Salix* is abundant in the *Alnion incanae* and in the *Alnion glutinosae* (table 1), the tree always shows very low pollen percentages in the post glacial time. This is not unexpected as *Salix* is an entomophilous tree whose pollen grains are produced in a small number and are transported over a short distance only (HYDE and WILLIAMS, 1944; FIRBAS, 1949; FAEGRI and IVERSEN, 1950).

Pinus

The highest percentages of *Pinus* were found in zone IV and in zone V. In zone VI and in zone VII *Pinus* decreased to low percentages.

In zone VIII we observe an increase of the *Pinus* percentage, probably on account of a long-distance transport, which was facilitated by the clearing of the forests in the immediate vicinity of the bog. The same is distinct in recent surface samples. In a forest *Pinus* appears to be low, whereas in open country it shows a much higher percentage (AARIO, 1940; JONASSEN, 1950). In zone Xa *Pinus* usually does not rise, though the ultimate clearing of the forest begins already at the transition between zone IX and zone X. It is not impossible that in zone IX *Pinus* disappeared completely, whereas in zone VI and zone VII it only underwent a strong decrease (cf. page 70). In zone Xb a rise of *Pinus* is distinct; this is due to the presence of pine plantations.

Fraxinus

It is not possible to recognize in our diagrams the first appearance of *Fraxinus*. At L.F. *Fraxinus* is almost entirely absent, whereas at BRO and Ri it is present already from the end of zone VI.

Though *Fraxinus* is a component of the *Alno-Ulmion* we do not observe a fall of its percentages at the transition between zone VII and zone VIII. According to VAN ZEIST (1959) a rise of *Fraxinus* at this level must be ascribed to the fact that when a forest is felled *Fraxinus* flowers much sooner than the other trees. It may be that this is the explanation for the constancy with which *Fraxinus* is present. The highest percentages of *Fraxinus* have been found in zone Xb (cf. p. 86).

Myrica

Myrica is present only at L.F., where the shrub is a component of the vegetation of the bog itself. Though an identification of the pollen grains of *Myrica* is quite well possible, a range is present in which confusion with *Corylus* is not excluded. For this reason the percentages of *Myrica* and *Corylus* found at L.F. in zone VIII, IX and X must be regarded as approximate only. In the other diagrams a presence of *Myrica* may on ecological grounds be regarded as improbable.

Ericaceae

A higher percentage of the Ericaceae have been found only outside the loess district (L.F., W, Br). In the loess district they are present only in a few per cents. According to KÖIE (1951), *Calluna* and *Vaccinium myrtillus* occur only on soils with a low percentage of silt. As mentioned before, in the loess district this percentage is too high (cf. p. 93). Hence the absence of pollen grains of these plants in the diagrams of this district.

Picea and Abies

Picea and *Abies* are not native in the Netherlands (FIRBAS, 1949). The small percentage of pollen grains found in our samples is certainly due to long-distance transport from the mountains in Central Europe. At BRO *Abies* is present from zone VIII on, which demonstrates the intensification of the long-distance transport.

In zone Xb the percentages of *Abies* show a slight increase, probably due to recent planting of the tree (A, B, Gr, Ra).

Populus

As stated also by STRAKA (1952), FAEGRI and IVERSEN (1950) and FIRBAS (1949) the identification of pollen grains of *Populus* is very difficult, especially when the samples are not stained. This difficult identification applies also in a large extent to our bogs, where the preservation of the pollen grains usually is less good than in raised bogs. *Populus* was certainly present, but on account of the uncertain identifications, it was not possible to draw a curve.

CHAPTER IX

RELATIONS TO THE HISTORY OF HUMAN OCCUPATION

According to VAN ZEIST (1959), it is possible to distinguish two kinds of peoples:

1. Peoples, who practised agriculture, and whose presence is recognizable by a low percentage of *Plantago lanceolata* in the diagram. The influence which these men exercised upon the vegetation, was not great, because their cattle remained in the settlements (TROELS-SMITH, 1955).
2. Peoples, who practised stock raising, and whose presence is recognizable by a high percentage of N.A.P. in the diagram. By these people a much greater part of the forest was cleared.

In South Limburg the people which introduced the bandceramic culture pertained to the first kind. According to TACKENBERG (1953), these Danubiens were agriculturists. Recent radiocarbon datings suggest that the bandceramic culture was present in South Limburg about 4000 B.C. (WATERBOLK, 1959), viz. in zone VI and in zone VII.

Indeed, VAN ZEIST (1959) found in these zones a small percentage of *Plantago lanceolata* and one pollen grain of a cereal. In our diagrams a low percentage of *Plantago lanceolata* and of *Artemisia* is sometimes present in zone VI and zone VII, but it is doubtful whether those pollen grains may be regarded as indicators of the agriculture of the band-ceramic people, as the settlements of this people, that up to now could be traced, are restricted to the north-western part of South Limburg (MODDERMAN, 1959), whereas our bogs are situated mainly in the eastern and north-eastern part of the region. Moreover, some specimens of the species which commonly are found near human settlements (*Artemisia, Plantago lanceolata* and Chenopodiaceae), may occur on limestone and on unstable soils (FRIES, 1951).

The people of which traces are found in zone VIII, belonged to the second type of Van Zeist. It exercised a stronger influence upon the vegetation. Cultures which come into consideration, are the western neolithic culture and the culture of the beaker people. The western neolithic culture seems to be of little importance in South Limburg (BECKERS and BECKERS, 1940). According to TACKENBERG (1953), the beaker people were herdsman and to them cattle and sheep were more important than swine. The grazing of the cattle prevented a regeneration of the forest.

As we shall see, the transition between zone VII and zone VIII must be dated at about 1700 B.C., a dating which is in good agreement with the supposed start of the late-neolithic culture at 1750 B.C. (PESCHECK, 1950). We dated the transition between zone VIII and zone IX at about the beginning of our era. That means that the deviations from an undisturbed development that are recognizable in our diagrams, are due to human activities extending through the late-neolithic-, the bronze-, the iron-, and the Roman ages without any interruption. Indeed, BECKERS and BECKERS (1940) conclude from their archeological findings (character of the burial monuments) that up to the Roman period South Limburg was continuously inhabited. It seems that at the arrival of the Romans a collapse took place by the extirpation of the tribe of the Eburones, the original population of our region (BECKERS and BECKERS, 1940). DE LAET and GLASBERGEN (1959) too mentioned that the most completely continuous occupation has been found in the region occupied by the Eburones. The diagrams of STRAKA (1952) point in the same direction; in the Eiffel in zone IX and in zone X (O.S.) too pollen grains of the cereals are always present.

At our discussion of zone VIII we mentioned already that the civilisation must have reached a fairly high level and that a fairly large area must have been cleared and kept free from tree growth. Though in South Limburg traces of occupation from the late-neolithical-, bronze-, and the iron ages in the form of settlements are rare, BECKERS and BECKERS (1940) come to the conclusion that South Limburg must have been populated fairly densely, because the utensils of the pre-Roman population are widespread in the region. The clearings were nevertheless less extensive than in medieval times. According to DARBY (1956), in the bronze- and iron ages no further clearings took place, but the area that was occupied already, was used more intensively. At the arrival of the Romans large stretches of wood were still present. This is visible in our diagrams too. We supposed that in zone VIII the clearings were restricted to the valleys (cf. p. 78).

It is difficult to say which culture comes into consideration. In the first place the number of excavated sites is small. On one hand South Limburg has been investigated very incompletely up to now (MODDERMAN, oral information), on the other hand it is possible that the dwellings, in contrast to those of the bandceramic people, were built on the surface of the earth and not partly subterraneous (BECKERS and BECKERS, 1940). Secondly, South Limburg is situated at a crossing of several of the cultures which flourished in western Europe. We only mention the presence at Geilenkirchen and Aachen of burial monuments belonging to the Rhenan beaker culture and to the Halstatt-D culture (NIESSEN, 1950).

Rests of Roman buildings are very abundant in South Limburg. In the Roman period sheep breeding still was the most important means of subsistence (CLARK, 1952).

The regeneration of the forests in zone IX indicates a decreasing activity of man in the post-Roman period. According to BOISSONNADE (1927), in the Rhine land (Germany) the population decreased to 1/2 or 2/3. The result was that about 800 A.D. forests had returned all over Europe (DARBY, 1956). The regeneration of the forests is visible in the region east of Aachen (SCHWICKERATH, 1954) and in the Untereichsfeld (STEINBERG, 1944) as well. It is not before 1000 A.D. that large-scale clearings start with the result that the *Fagus* forest disappeared. Since then the soil, which once supported forests supports fields and orchards.

CHAPTER X

ZONATION AND DATING

As a result of their investigations the palynologists have been established several zonations. In western Europe some of these zonations proved to be more generally distributed. The oldest one is the zonation proposed by BLYTT (1876) and accepted by SERNANDER (1908), which is based upon an alternation of rainy and dry periods in the post-glacial time. After that of Blytt and Sernander, the most important zonations are those proposed by JESSEN (1934, 1938) and by IVERSEN (1941) for Denmark, by OVERBECK and SCHNEIDER (1938) for north-west Germany, and by FIRBAS (1949) for central Europe. In order to be valid for a region of some extent, e.g. for western Europe, a zonation must obviously be based upon synchronous conditions. Unfortunately, it is difficult to find in the diagrams for South Limburg features which are comparable with those found in the diagrams for other regions. As mentioned before the shape of many curves is in the zones VIII, IX and X influenced either by man, or by local conditions. It is especially due to the irregular behaviour of the *Corylus* curve that a correlation with the zonation of Overbeck and Schneider meets with difficulties. For that reason it is not possible to apply the zonation of these authors to South Limburg. As mentioned before, the curves of *Quercus*, *Alnus* and *Carpinus* too are highly influenced by man, and can therefore not be used as criteria for the demilitation of the zones. Only the behaviour of *Fagus* up to zone X is more or less independent of the influence of man. Therefore, a correlation with the zonations found in other regions is only possible by means of the *Fagus* curve. A second difficulty is that our small bogs mainly registrate the development of the vegetation in the immediate neighbourhood of the bog. It is possible therefore that a change in the vegetation which arose under the influence of man, did not find its expression in the diagram as long as the clearings did not extend to the immediate vicinity of the bog.

It is not difficult to apply the zonations proposed for other parts of western Europe to the part of the diagrams preceding zone VIII, because up to this period the influence of man is of no great importance. We do not know how to explain the changes in the percentages and the appearance of new elements in another way than by assuming changes in the climate, and so the zones IV, V and VI, VII may be said to correspond to the pre-boreal, the boreal and the atlantic time of Blytt and Sernander.

From zone VIII there is less agreement. As mentioned before we place the transition between zone VII and zone VIII at the level where *Tilia* begins to fall, *Fagus* shows its first increase, and pollen grains indicating human occupation make their first appearance. According to WATERBOLK (1954) in the northern part of the Netherlands and in Denmark, the fall of *Tilia* is accompanied by a fall of *Ulmus*. Now, recent radiocarbon datings suggest that the fall of *Ulmus*, though caused by human interference, must have taken place at the same time throughout an area of considerable extent, and must be dated at about 3000 B.C. (VAN ZEIST, 1959). PERSCH (1950), however, dated the transition between zone VII and zone VIII (*Fagus* represented by more than 5 %) at about 1700 B.C. If we assume that the first increase of *Fagus* found in our diagrams is synchronous with the first increase of *Fagus* found in the northern part of the Netherlands, we arrive at the same conclusion as Persch. In the northern Netherlands we find the first increase of *Fagus* at the transition between the neolithic to the bronze ages (in zone IX: O.S.); and in the diagrams of this part of the country it is synchronous with the occurrence of *Sphagnum cuspidatum* peat. Indeed, we find *Sphagnum cuspidatum* at L.F. at the transition between zone VII and zone VIII. However, it is not permitted to use *Sphagnum cuspidatum* as a boundary line between these two zones, as at L.F. its occurrence is not necessarily due to an increase of the precipitation alone. The behaviour of *Fagus* is an indication that in our diagrams the transition between zone VII and zone VIII must be placed at a later date than the fall of *Ulmus* in the northern part of the Netherlands. This result is in agreement with an archaeological dating (PFAFFENBERG, 1947: first increase of *Fagus* at about 2000 B.C.) and with a radiocarbon dating of the transition between zone VIII and zone IX (O.S.) (OVERBECK, ALETSEE, AVERDIECK, 1957: 1500 B.C.) in north-western Germany. Thus, if we place the beginning of the clearings between 2000–1500 B.C., this is in agreement with the opinion of NARR (1956) that in the Rhine land the clearings did not take place before the bronze age.

Jessen and Iversen placed the transition between their zones VII and VIII between the mesolithic and neolithic age. In this part of the diagrams, therefore, we can not accept the zonation of Jessen and Iversen. For South Limburg we must return thus to a subboreal time in the sense of Blytt and Sernander and exclude the neolithic age.

For that reason we do not find in South Limburg reasons to include zone VIIIb (O.S.) in the zone VIII of Firbas, as was proposed by WATERBOLK (1954) on account of the simultaneous appearance of *Plantago lanceolata* in the northern part of the Netherlands and in north-western Germany. It remains possible that human influence was present already in zone VIIIb (O.S.), but in our diagrams we do not find indications of such an influence. When we are right, the fall of *Tilia* in South Limburg can not be synchroneous with the fall of *Ulmus* in other regions. In the northern part of the Netherlands we find that the fall of *Ulmus* is accompanied by a low percentage of *Plantago lanceolata.* In our diagrams *Plantago lanceolata* soon reaches high values which indicate that here another type of agriculture must have been present (herdsman). It is therefore understandable that the transition between zone VII and zone VIII must be placed later. Our transition between zone VII and zone VIII may be synchronous with the increase of *Plantago lanceolata* in the northern part of the Netherlands (VAN ZEIST, 1955a: 2230 B.C.).

According to PERSCH (1950) the F 1 must be dated at about the beginning of our era. Just below that level we placed the transition between zone VIII and zone IX. This transition has been correlated with the zonation of Overbeck and Schneider by WATERBOLK (1954) and by VAN ZEIST (1955) in different ways. According to Waterbolk zone X (O.S.) belongs to the lower part of zone IX of Firbas. According to Van Zeist zone X (O.S.) belongs to the upper part of zone VIII of Firbas. It seems to us that the latter correlation is applicable to South Limburg. PERSCH (1950) as well as GROHNE (1956) suggest that the F 1 must be dated at the beginning of our era. Moreover, OVERBECK, MÜNNICH, ALETSEE and AVERDIECK (1957) dated the transition between zone X and zone XI (O.S.) at 125 B.C. It appears therefore that zone VIII of Firbas comprises zone X of Overbeck and Schneider. This dating is in agreement with our archeological dates. The dating of WATERBOLK (1954) of the transition between zone X and zone XI (O.S.) at 400 A.D. seems to be too late.

In our diagrams the transition between zone IX and zone X (O.S.) is not distinct. In zone X (O.S.) *Corylus* usually decreases and *Fagus* shows its second increase. Indeed *Fagus* increases during the course of our zone VIII, but it is not possible to determine where the increase starts. *Corylus* does not decrease markedly before the F 1, probably due to the increase of the influence of man. It remains possible that in our diagrams zone X (O.S.) is lacking on account of an interruption of the peat formation (WATERBOLK, 1954). For our region it is therefore better to apply the zonation of Firbas, who, in contrast to Overbeck and Schneider, left zone VIII undivided.

Both in the zonation of Blytt and Sernander and in that of Jessen and Iversen the transition between zone VIII and zone IX (subboreal time/subatlantic time) has been placed at the transition between zone IX and zone X of Overbeck and Schneider, a transition which is not distinct in our diagrams. For this reason these zonations are not applicable in our region.

The transition between zone IX and zone X, i.e. the beginning of the ultimate clearing of the forests, is found at the same time everywhere in western Europe. PERSCH (1950) dated the F 2 at 700 A.D. which is in good agreement with the archaeological proved fact that the ultimate clearings started at 1000 A.D. The dating of FIRBAS (1949): 800 A.D., is in agreement with the conclusion of Persch.

In our region the transition between zone Xa and zone Xb must be dated at about 1850 A.D., the time at which the planting of the pine woods began.

SUMMARY

The present study deals with the late-glacial and post-glacial development of the vegetation in the loess region of South Limburg (Netherlands). In the late-glacial time the continental element in the vegetation (*Artemisia*) is very pronounced, probably due to the particular soil conditions in South Limburg. The zonation of FIRBAS (1949) has been applied to the South Limburg diagrams.

Zone I: Tundra, a temporary amelioration of the climate (Bölling time) can be observed.

Zone II: Closed pine forests present (Alleröd time).

Zone III: In the lower part of the zone *Pinus* dominant, afterwards *Betula*.

Zone IV: Decrease of the percentages of the herbs; *Pinus* dominant in the vegetation; first appearance of *Corylus*.

Zone V: *Pinus* and *Corylus* dominant; in the lower part of the zone *Ulmus* and *Quercus* present, in the upper part also *Alnus* and *Tilia*.

The development of the vegetation in the following periods of the Holocene has been interpreted with the aid of dates from the field of plant sociology. Along a valley the vegetation of the bogs itself (usually *Alnion glutinosae* or *Alnion incanae*), the vegetation on the colluvial soils (*Ulmion*) and the vegetation along the slopes and on the plateaus (*Carpinion*) were distinguished. The changes in the vegetation of these vegetation units have been followed (Fig. 3, 4 and 5). The course of the curves in the pollen diagrams has been explained by taking into account the natural succession, human influence, soil conditions, and size of the investigated bogs.

Zone VI and zone VII: In the *Alno-Ulmion Tilia cordata* dominant. In zone VII first appearance of *Fagus* outside the valleys.

Zone VIII: Strong influence of man in the valleys by which *Tilia* and *Alnus* decrease and *Quercus* and *Corylus* increase. Outside the valleys less influence of man resulting in a proceeding increase of *Fagus*.

Zone IX: Regeneration of the forests in the valleys (exc. *Tilia* and *Ulmus*): *Alnus* increases, *Corylus* decreases. Outside the valleys *Fagus* dominant. Between the *Fagus* belt and the *Alno-Ulmion* belt probably a *Querceto-Carpinetum* present.

Zone X: Large-scale clearance of the forests. Outside the valleys *Fagus* and *Carpinus* decrease and *Corylus* and *Quercus* increase. In the valleys transformation of the *Alno-Ulmion* into grassland. In the upper part of the zone increase of *Pinus* due to planting.

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REFERENCES

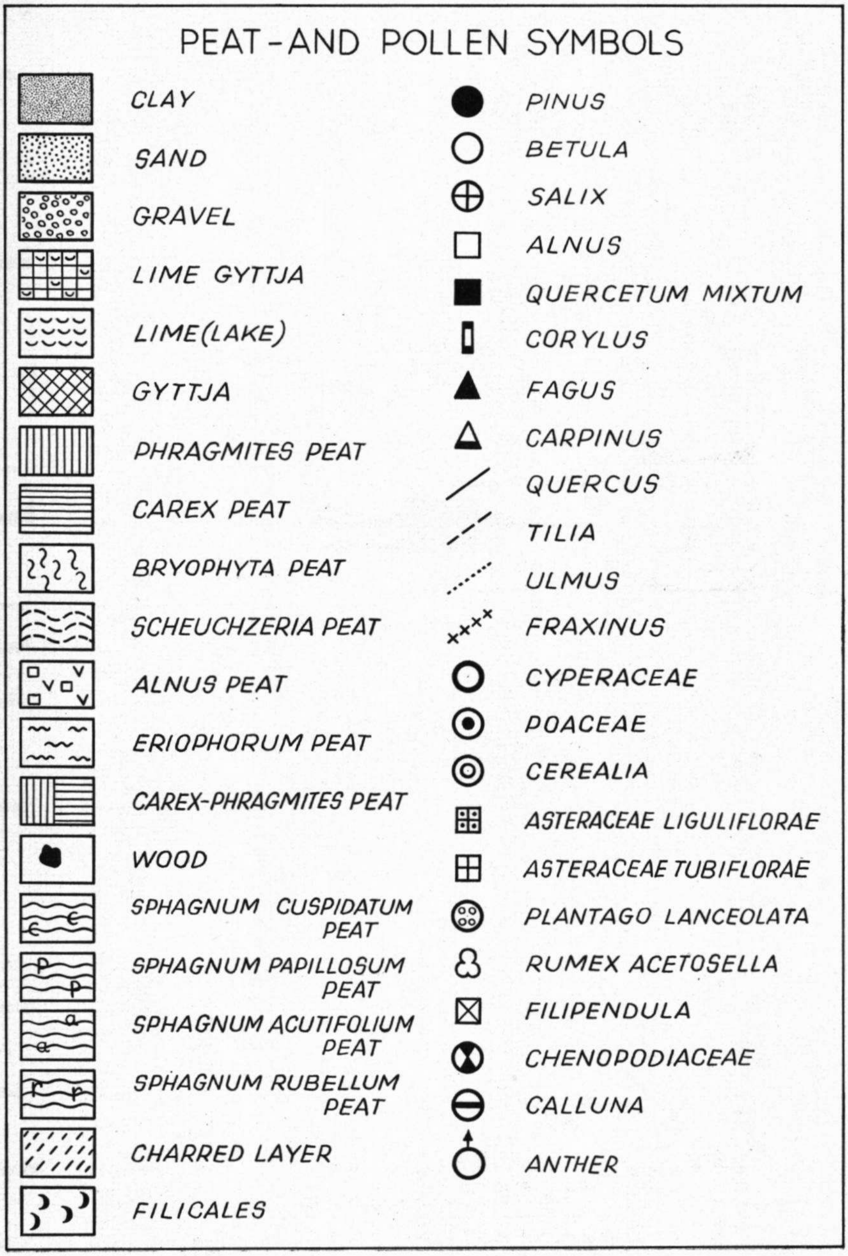
Aario, L., 1940. Annales academiae Scientiarum Fennicae. Serie A. Tome 54. Nr 8.
Averdieck, F. R., 1957. Nova Acta Leopoldina **19**. Nr 130. 152 pp.
Barkman, J. J., 1948. Publicaties van het natuurhistorisch Genootschap in Limburg **1**. Nr 1: 5–25.
Becker, G., 1874. Verhandlungen des naturhistorischen Vereins der Preusischen Rheinlande und Westfalens. **31**: 137–158.
Beckers, H. J. and G. F. A. Beckers, 1940. Voorgeschiedenis van Zuid Limburg.
Belderok, B. and J. Hendriks, 1953. Natuurhistorisch Maandblad **42**: 64–66.
Bertsch, K., 1942. Lehrbuch der Pollenanalyse. Stuttgart. 195 pp.
Blytt, A., 1876. Essay on the immigration of the norwegian flora during alternating rainy and dry periods. Christiania. 89 pp.
Bodeux, A., 1955. Mitteilungen der Floristische-soziologische Arbeitsgemeinschaft **N.F. 5**: 114–137.
Boissonnade, P., 1927. Life and work in medieval Europe. New York.
Breteler, H. G. M., 1958. Boor en spade **9**: 62.
Buchwald, K., 1951. Angewandte Pflanzensoziologie **1**. 72 pp.
———, 1951a. Angewandte Pflanzensoziologie **2**. 46 pp.
———, and H. Losert, 1953. Mitteilungen der Floristische-soziologische Arbeitsgemeinschaft. **N.F. 4**: 124–146.
Budde, H. and F. Runge, 1940. Abhandlungen aus dem Landesmuseum für Naturkunde der Provinz Westfalen. **11**: 1–28.
Büdel, J., 1944. Geologische Rundschau. Heft **7-8**: 482–519.
Büker, R., 1939. Abhandlungen aus dem Landesmuseum für Naturkunde der Provinz Westfalen. **10**. Heft 1.
Burrichter, E., 1953. Abh. aus dem Landesmuseum f. Naturkunde der Provinz Westfalen **15**. Heft 3. 91 pp.
Butler, W., 1938. Der Donauländische und Westische Kulturkreis der jüngeren Steinzeit. Handbuch der Urgeschichte Deutschlands **2**. Berlin und Leipzig.
———, and W. Haberey, 1936. Die Bandkeramische Ansiedlung bei Köln-Lindenthal. Römische Germanische Forschungen **11**.
Clark, J. G. D., 1952. Prehistoric Europe: The economic base: 91–108. London.
Daniels, A. G. H., 1961. In press.
Darby, H. C., 1956. The clearing of the woodland in Europe. In: Thomas, W. L., Mans rôle in changing the face of the earth: 183–216.
Dechering, F., 1936. Versl. van landbouwk. onderz. Rijkslandbouwproefstation Groningen Nr 42 (6). A. 36 pp.
Diemont, W. H., 1938. Mitt. der Florist.-soziol. Arbeitsg. in Nierdersachsen **4**. 182 pp.
———, 1944. Natuurh. Maandblad **33**. Nr 5: 33–35.
———, 1955. Natuur en landschap **9**: 1–15.
———, and A. J. M. H. van der Ven, 1953. Publ. van het Natuurh. Genootschap in Limburg. Reeks 6.
Dijk, J. van, 1955. In: Kortenhoef, een veldbiologische studie van een Hollands verlandingsgebied. Amsterdam: 60–67.
———, and V. Westhoff, 1955. Natuur en landschap **9**. Nr 2: 33–58.
Doing Kraft, H., 1955. De levende Natuur **58**: 93–99, 117–123.

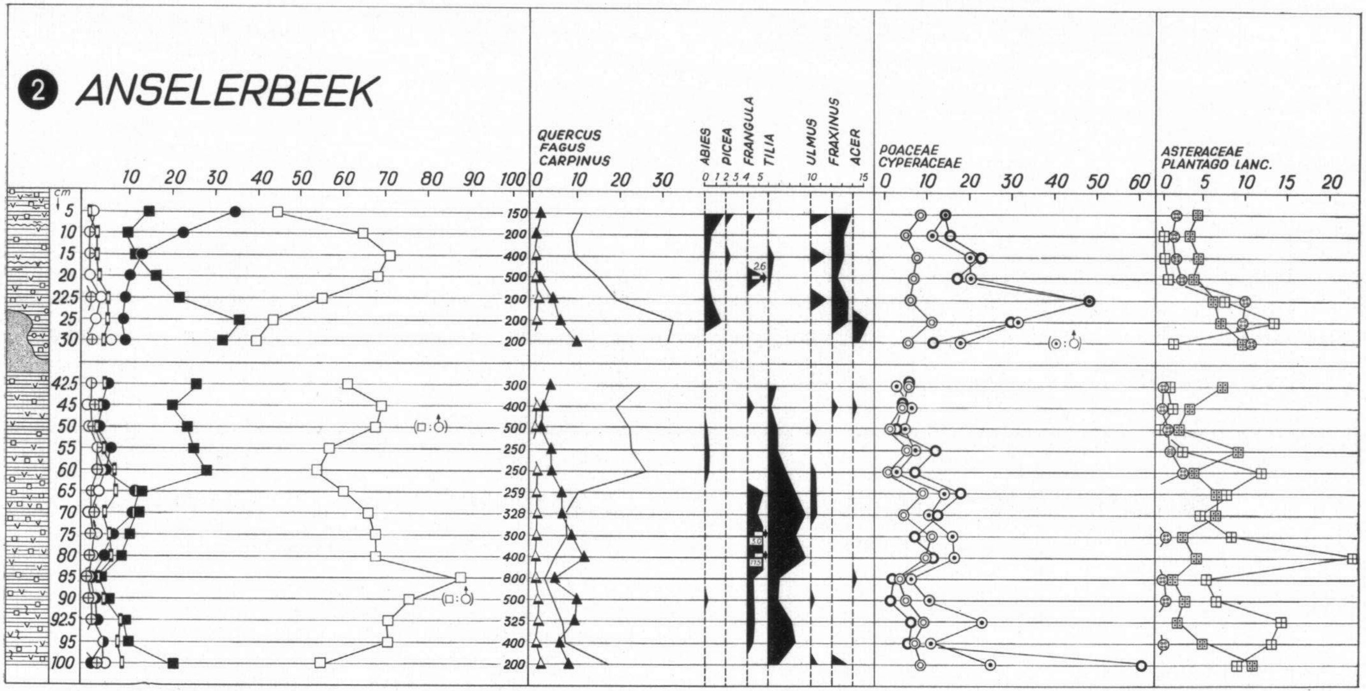
DOING KRAFT, H. and V. WESTHOFF, 1959. Jaarboek Ned. Dendr. Vereniging **21** (1956, 57, 58): 226–254.
DOORMAAL, J. C. A., 1945. Onderzoekingen betreffende de loess gronden van Zuid Limburg. Diss. Wageningen. 94 pp.
DRUIF, J. H., 1927. Over het ontstaan van de Limburgse loess in verband met haar mineralogische samenstelling. Diss. Utrecht. 330 pp.
EBERT, A., E. KAISER and A. FUCHS, 1937. Geologische Karte von Preussen und benachbarten deutschen Ländern. Preuss. Geol. Landesanstalt. Berlin. Blatt Geilenkirchen und Gangelt.
ELLENBERG, H., 1937. Mitt. der Florist.-soziol. Arb. gem. in Niedersachsen. Heft **3**: 204–235.
ERDTMAN, G., 1934. Svensk Bot. Tidskrift **28**: 345–358.
———, 1936. Ber. über das Geob. Forsch. inst. Rübel für 1935: 38–46.
———, 1943. An introduction to pollenanalysis. Waltham Mass. U.S.A. 239 pp.
ESHUIS, H. J., 1946. Palynologisch en stratigrafisch onderzoek van de Peelvenen. Diss. Utrecht. 143 pp.
FABER, F. J., 1942. Nederlandse Landschappen. Gorinchem. 400 pp.
———, 1948. Geologie van Nederland. Gorinchem. 448 pp.
FAEGRI, K., 1944. Geol. Föreningens i Stockholm Förhandlingar **66**: 449–463.
———, and J. IVERSEN, 1950. Textbook of modern pollen analysis. Copenhagen. 168 pp.
FIRBAS, F., 1928. Lotos **96**: 115–172.
———, 1934. Planta **22**: 109–146.
———, 1935. Beih. zum Bot. Centralblatt **52B**: 119–157.
———, 1937. Zeitschrift für Botanik **31**: 447–479.
———, 1948. Biol. Centralblatt **67**: 17–22.
———, 1949. Spät- und Nacheiszeitliche Waldgeschichte Mitteleuropas nördlich der Alpen: Bd **1**: Algemeine Waldgeschichte. Jena. 480 pp.
———, 1949a. Fortschritte der Botanik **12**: 86–130.
———, 1950. The new Phytol. **49**: 163–173.
———, 1951. Erdkunde **5**: 6–15.
———, 1952. Spät- und Nacheiszeitliche Waldgeschichte Mitteleuropas nördlich der Alpen Bd **2**: Waldgeschichte der einzelnen Landschaften. Jena. 256 pp.
———, 1954. Forstwiss. Centralblatt **73**: 1–8.
FLORSCHÜTZ, F. and EUG. L. VAN OYE, 1939. Biol. jaarboek **1-25**: 227.
FRIES, M., 1951. Acta Phytog. Suecica **29**. 216 pp.
———, 1958. Acta Phytog. Suecica **39**. 63 pp.
GAMS, H., 1943. Beih. Bot. Centralblatt **62B**: 68–96.
GODWIN, H., 1949. Phil. Transact. of the Royal Soc. of London **B. 223**: 275–287.
GROHNE, U., 1956. Natur und Volk **86**: 225–233.
HAMMEN, TH. VAN DER, 1951. Late-glacial flora and periglacial phenomena in the Netherlands. Diss. Leiden. 183 pp.
HEMPEL, L., 1956. Eiszeitalter und Gegenwart **17**: 35–42.
HESMER, H., 1932. Zeitschrift f. Forst- und Jagdwesen **64**: 557–607.
HOUTEN, J. G. TEN, 1935. Rec. Trav. Bot. Neerl. **32**: 430–437.
HUMMEL, H., 1949. Planta **37**: 451–497.
HYDE, H. A. and D. A. WILLIAMS, 1944. The new Phytol. **43**: 49–61.
——— and ———, 1945. Nature **155**: 457.
IVERSEN, J., 1941. Danmarks Geol. Unders. R 11, Nr 66.
———, 1942. Medd. fra Dansk Geol. För. **10/2**: 130–151.
———, 1944. Geol. För. i Stockholms Förhandlingar **66**: 463–483.
———, 1949. Danmarks Geol. Unders. R 4, Bd 3, Nr 6.
———, 1954. Danmarks Geol. Unders. R 11, Nr 80: 87–120.
JAHN, S., 1952. Angewandte Pfalanzensoziologie **5**. 77 pp.
JANSSEN, C. R., 1959. Acta Bot. Neerl. **8**: 55–58.
JESSEN, K., 1934. Acta Archeol. **5**: 185–214.
———, 1938. Quartair **1**: 124–139.
———, 1949. Proc. of the Royal Ac. **52B**: 85–290.
JESWIET, W. and W. C. DE LEEUW, 1933. Ned. Kruidk. Archief **43**: 309–333.

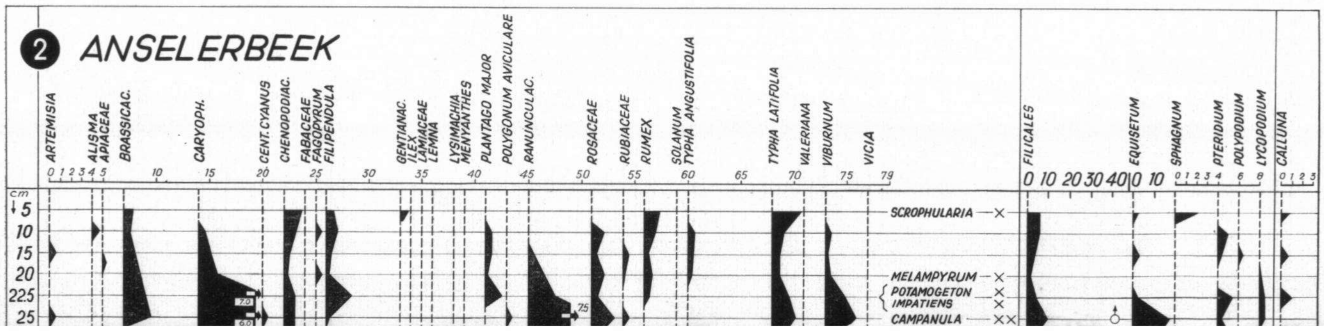
JONASSEN, H., 1950. Dansk Bot. Arkiv **13**: Nr 7.
JONGMANS, W. J. and W. H. DIEMONT, 1942. Jaarverslag 1940/1941 Geol. Bureau Mijngebied: 57–72.
———, W. J. F. M. KRUL and J. J. H. VOS, 1941. Waterwinning in Zuid Limburg. Rapport Waterleiding Mij.
———, and F. H. VAN RUMMELEN, 1935. Water **9** and **10**: 1–9.
JONKER, F. P., 1952. Taxon. **1** (6): 89–91.
KLEIN, W. C., 1911. Ber. über die Versamml. des Niederrheinischen Geol. Vereins: 24.
———, 1913. Hand. van het Ned. Nat.- en Geneesk. Congres. Delft.
———, 1914. Verh. van het Geol. Mijnb. Genootschap voor Nederland en koloniën. Geol. Serie **2**: 1–112.
KOCH, W., 1944. Schweiz. Zeitschrift f. Forstwesen **95**: 266–276, 299–304.
KÖIE, M., 1951. Dansk Bot. Arkiv **14**. 164 pp. Nr 5.
LAET, S. J. DE and W. GLASBERGEN, 1959. De voorgeschiedenis der lage landen. Groningen.
LEEUW, W. C. DE, 1935. The Netherlands as an environment for plant life. Leiden.
LEEUWEN, CHR. VAN, 1955. Beplantingen op vegetatiekundige grondslag en Nederlandse bosassociaties. Rapport Afd. Nat. bescherming en landschap Staatsbosbeheer.
———, and H. DOING KRAFT, 1959. Landschap en beplanting in Nederland. Veenman en Zonen, Wageningen 88 pp.
LEHMANN, H., 1940. Forsch. zur deutschen Landesk. **35**. Leipzig.
LOHMEYER, W., 1951. Angewandte Pflanzensoziologie **3**. 72 pp.
———, 1953. Mitt. der Flor.-soziol. Arbeitsg. N.F. **4**: 59–76.
———, 1957. Mitt. der Flor.-soziol. Arbeitsg. N.F. **6/7**: 247–257.
LÜDI, W., 1947. Ber. über das Geob. Forschungsinstitut Rübel Zürich für 1946: 82–92.
LUNDEGÅRDTH, H., 1957. Klima und Boden. Jena. 584 pp.
MAAS, F. M., 1959. Bronnen, bronbeken en bronbossen van Nederland in het bijzonder die van de Veluwezoom. Diss. Wageningen. 166 pp.
MARKGRAF, FR., 1932. Veröff. des Geob. Inst. Rübel, Zürich. Heft **8**: 15–62.
MEYER DREES, E., 1936. De bosvegetatie van de Achterhoek en enkele aangrenzende gebieden. Diss. Wageningen. 171 pp.
MIKKELSEN, V. M., 1949. Dansk. Bot. Arkiv **13**, Nr 5.
———, 1954. Danmarks Geol. Unders. R 11, Nr 80: 210–229.
MITCHELL, G. F., 1951. Proc. of the Royal Irish Ac. **53B**: 111–206.
MODDERMAN, P. J. R., 1959. Antiquity and survival **2**, Nr 5–6: 57–74.
MÖRZER BRUINS, M. F. and V. WESTHOFF, 1951. The Netherlands as an environment for insect life. Amsterdam.
MÜLLER, I., 1947. Planta **35**: 70–87.
MÜLLER, H., 1953. Nova Acta Leopoldina N.F. **16**, Nr 10. 67 pp.
NARR, K. J., 1956. In Thomas, W. L.: Mans rôle in changing the face of the earth: 134–147.
NATERMANN, E., 1939. Abh. des Naturwiss. Vereins zu Bremen **31/2**: 326–334.
NIESSEN, J., 1950. Geschichtlicher Handatlas der deutschen Länder am Rhein.
NIETSCH, H., 1940. Zeitschrift der deutschen Geol. Gesellschaft **92**: 351–364.
NILSSON, T., 1947. Medd. fra Dansk. Geol. Förening **11/2**: 201–218.
NOIRFALISE, A., 1956. Bull. de l'institute agronomique et des stations de recherche de Cembloux **24/2**: 208–239.
OBERDORFER, E., 1936/1937. Zeitschrift f. Botanik **30**: 513–573.
———, 1949. Pflanzensoziologische Excusionsflora für Südwest Deutschland und die angrenzenden Gebiete. Stuttgart. 411 pp.
———, 1952. Beitr. zur Naturk. Forschung in Südwestdeutschland **11**: 12–37.
———, 1953. Beitr. zur Naturk. Forschung in Südwestdeutschland **12/1**.
———, 1957. Süddeutsche Pflanzengesellschaften. Pflanzensoziologie **10**. 564 pp.
OVERBECK, F., 1952. Niedersächsisches Amt f. Landesplanung und Statistik **A 1/41**. 63 pp.
OVERBECK, F. and I. GRIEZ, 1954. Flora **141**: 51–100.
OVERBECK, F., K. O. MÜNNICH, L. ALETSEE and F. R. AVERDIECK, 1957. Flora **145**: 37–72.
OVERBECK, F. and S. SCHEIDER, 1938. Zeitschrift f. Bot. **33**: 1–54.

OYE, EUG. L. VAN, and F. FLORSCHÜTZ, 1946. Biol. Jaarboek **13**: 307–315.
PANNEKOEK, A. J., 1956. Geologische geschiedenis van Nederland. Den Haag.
PASSARGE, H., 1953. Archiv für Forstwesen **2**: 1–59, 182–208, 340–383, 532–551.
———, 1956. Archiv für Forstwesen **5**: 339–358.
PENNINGTON, W., 1949. Phil. Transact. of the Royal Soc. of London. Serie B. Vol. **233**: 137–175.
PERSCH, F., 1950. Decheniana **104**: 81.
PFAFFENBERG, K., 1947. Jahresber. der Naturhist. Gesellschaft zu Hannover **94-98**: 69–83.
———, 1952. Mitt. der Flor.-soziol. Arbeitsg. N.F. **3**: 27–43.
POHL, F., 1937. Beih. zum Bot. Centralblatt **56 A**: 365–470.
REICHELT, G., 1953. Petermanns Geogr. Mitt. **97**: 245–261.
REMPE, H., 1937. Planta **27**: 93–147.
RUBNER, K., 1925. Die pflanzengeographischen Grundlagen des Waldbaus. Aufl. 2.
———, 1953. idem, Aufl. 4. Radebeul und Berlin.
RUMMELEN, F. H. VAN, 1925. Natura **6**: 189.
———, 1936. Neerl. Kruidk. Archief **46**: 430–442.
———, 1942. Med. bij het jaarverslag over 1940 en 1941. Geol. Bureau voor het mijngebied: 73–83.
———, 1942a. idem: 85.
SCHMITHÜSEN, J., 1958. Angewandte Pflanzensoziologie **15**: 165–168.
SCHMITZ, H., 1952. Archeologia **2/3-4**: 15–22.
———, 1955. Eiszeitalter und Gegenwart **6**: 52–59.
SCHUBERT, E., 1933. Mitt. der Provinzialstelle f. Naturdenkmalpflege. Heft 4. Hannover.
SCHWICKERATH, M., 1930. Die Natur am Niederrhein **6**: 14–19.
———, 1933. Aachener Beitr. zur Heimatkunde **13**. 135 pp.
———, 1944. Das Hohe Venn und seine Randgebiete. Jena. Pflanzensoziologie **6**. 287 pp.
———, 1954. Die Landschaft und Ihre Wandlung auf geobotanischer und geographischer Grundlage entwickelt und erläutert im Bereich des Messtischblattes Stolberg. Aachen. 118 pp.
SEIBERT, P., 1955. Allg. Forst- und Jagdzeitung **126** 1–11.
SELLE, W., 1941. Zeitschrift f. Forst- und Jagdwesen **73/3**: 65–108.
SERNANDER, R., 1908. Geol. För. i Stockholm Förhandlingar **30**: 465–473.
SISSINGH, G., 1950. Onkruidassociaties in Nederland. Diss. Wageningen. 224 pp.
SLOFF, J. G., 1931. Nederl. Kruidk. Archief **1**: 41–62.
SOEST, J. L. VAN, 1934. Natuurwet. Tijdschrift **16/2-5**: 163–164.
STEINBERG, K., 1944. Hercynia **3**: 529–587.
STIGCHEL, J. W. B. V. D., 1942. Langs het spoor der eeuwen. Amsterdam. 130 pp.
STOCKMANS, F. and R. VANHOORNE, 1954. Instit. royal des Sc. Nat. de Belgique. Mémoire 130.
STRAKA, H., 1952. Arbeiten zur Rheinischen Landeskunde. Heft **1**. 116 pp.
———, 1957. Pollenanalyse und Vegetationsgeschichte. Die neue Brehm Bücherei. Heft **202**. Wittenberg.
TACKENBERG, K., 1953. in Valjavec, F., Historia mundi **2**: 11–66.
TESCH, P., 1946. Geologische kaart van Nederland. Schaal 1:50.000, uitgave: Geol. Stichting.
TRAUTMANN, W., 1957. Mitt. der Flor.-soziol. Arbeitsg. N.F. **6/7**: 276–296.
TROELS-SMITH, J., 1955. in Guyan, W. U. Das Pfahlbauproblem: Monographien zur Ur- und Frühgeschichte der Schweiz **11**: 11–57.
TÜXEN, R., 1931. Nachr. aus Niedersachsens Urgeschichte Nr 5: 59–106.
———, 1932. Forstarchiv **8**: 27–32.
———, 1933. Neerl. Kruidk. Archief. **43**: 293–309.
———, 1937. Mitt. der Flor.-soziol. Arbeitsg. in Niedersachsen. Heft **3**: 1–171.
VANDEN BERGHEN, C., 1957. Bull. de la Société Royale de Bot. de Belg. **89**: 15–20.
VANHOORNE, R., 1951. Bull. de l'institut royal des Sc. nat. de Belgique. Tome **27**. Nr 20.
VERHOEFF, K., 1957. Acta Bot. Neerl. **6**: 583–593.
VINK, A. P. A., 1949. Bijdrage tot de kennis van loess en dekzanden in het bijzonder van de zuidoostelijke Veluwe. Diss. Wageningen.

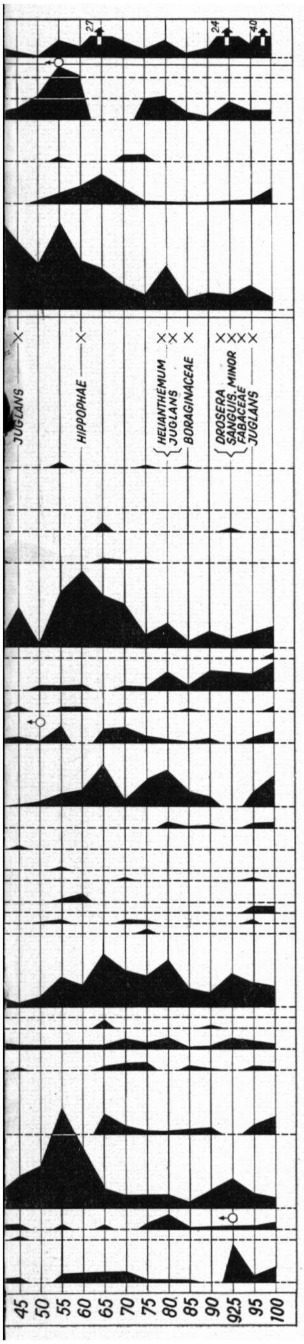
VRIES, O. DE, 1948. Tijdschrift van het Koninkl. Nederl. Aardr. Genootschap. Reeks **2/65**: 317–326.
WATERBOLK, H. T., 1954. De praehistorische mens en zijn milieu. Diss. Groningen. 153 pp.
———, 1959. Antiquity and survival **2** Nr 5–6: 12–56.
WELTEN, M., 1950. Ber. über das Geobot. Forschungsinst. Rübel, Zürich, für 1949: 48–56.
WESTHOFF, V., 1956. Gedenkboek „Vijftig jaar natuurbescherming in Nederland": 151–186.
———, and J. MELTZER, 1942. Inleiding tot de plantensociologie. 's Graveland.
WEVER, A. DE, 1911. Jaarb. Natuurhist. Genootschap in Zuid Limburg **1**: 29–41.
———, 1912. Idem **2**: 123–160.
———, 1913. Idem **3**: 43–115.
———, 1914. Idem **4**: 9–103.
———, 1917. Idem **7**: 1–52.
———, 1918. Idem **8**: 1–47.
WUNSTORF, W., 1911. Geol. Exkursionskarte für die Umgegend von Aachen. Königl. Pr. Landesanstalt. Berlin.
ZEIDLER, H., 1953. Mitt. der Flor.-soziolog. Arbeitsg. N.F. **4**: 88–109.
———, 1957. Idem N.F. **6/7**: 264–275.
ZEIST, W. VAN, 1955. Acta Bot. Neerl. **4**: 1–80.
———, 1955a. Palaeohistoria **4**: 113–118.
———, 1959. Acta Bot. Neerl. **8**: 156–185.
———, 1959a. Palaeohistoria **6/7**: 19–24.
ZONNEVELD, I. S., 1958. Angewandte Pflanzensoziologie **15**: 102–115.
ZONNEVELD, J. I. S., 1955. Tijdschrift van het koninkl. aardrijksk. Genootschap **72**: 329–343.

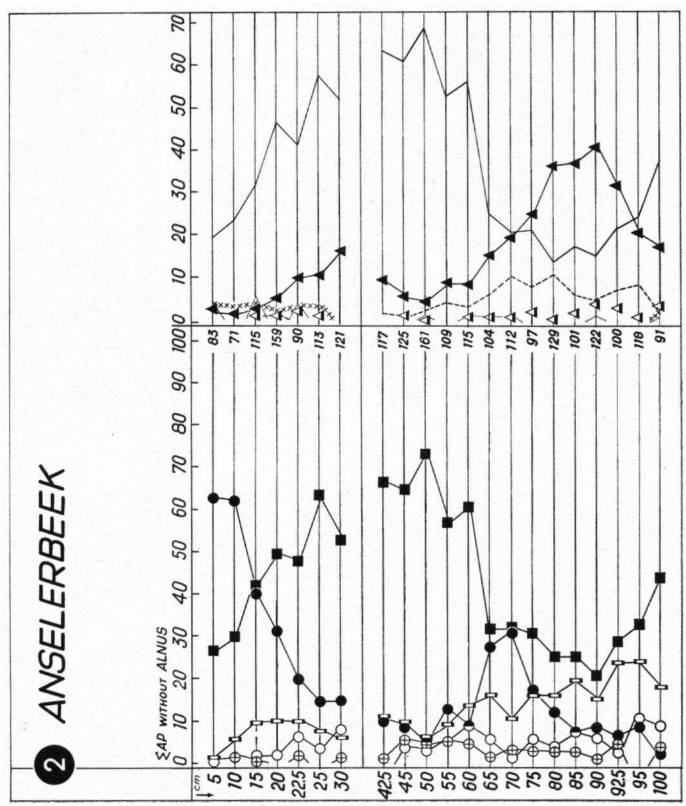

PEAT-AND POLLEN SYMBOLS
CLAY
SAND
GRAVEL
LIME GYTTJA
LIME(LAKE)
GYTTJA
PHRAGMITES PEAT
CAREX PEAT
BRYOPHYTA PEAT
SCHEUCHZERIA PEAT
ALNUS PEAT
ERIOPHORUM PEAT
CAREX-PHRAGMITES PEAT
WOOD
SPHAGNUM CUSPIDATUM PEAT
SPHAGNUM PAPILLOSUM PEAT
SPHAGNUM ACUTIFOLIUM PEAT
SPHAGNUM RUBELLUM PEAT
CHARRED LAYER
FILICALES
PINUS
BETULA
SALIX
ALNUS
QUERCETUM MIXTUM
CORYLUS
FAGUS
CARPINUS
QUERCUS
TILIA
ULMUS
FRAXINUS
CYPERACEAE
POACEAE
CEREALIA
ASTERACEAE LIGULIFLORAE
ASTERACEAE TUBIFLORAE
PLANTAGO LANCEOLATA
RUMEX ACETOSELLA
FILIPENDULA
CHENOPODIACEAE
CALLUNA
ANTHER

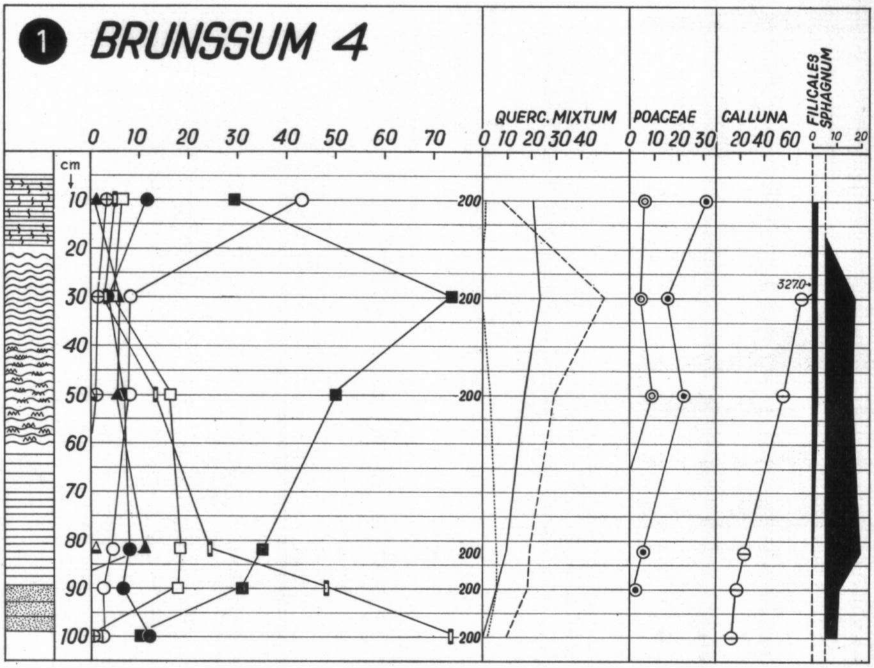

2 ANSELERBEEK
QUERCUS
FAGUS
CARPINUS
ABIES
PICEA
FRANGULA
TILIA
ULMUS
FRAXINUS
ACER
POACEAE
CYPERACEAE
ASTERACEAE
PLANTAGO LANC.
cm
150
200
400
500
200
200
200
300
400
500
250
250
259
328
300
400
800
500
325
400
200


2 ANSELERBEEK
ARTEMISIA
ALISMA
APIACEAE
BRASSICAC.
CARYOPH.
CENT. CYANUS
CHENOPODIAC.
FABACEAE
FAGOPYRUM
FILIPENDULA
GENTIANAC.
ILEX
LAMIACEAE
LEMNA
LYSIMACHIA
MENYANTHES
PLANTAGO MAJOR
POLYGONUM AVICULARE
RANUNCULAC.
ROSACEAE
RUBIACEAE
RUMEX
SOLANUM
TYPHA ANGUSTIFOLIA
TYPHA LATIFOLIA
VALERIANA
VIBURNUM
VICIA
SCROPHULARIA
MELAMPYRUM
POTAMOGETON
IMPATIENS
CAMPANULA
FILICALES
EQUISETUM
SPHAGNUM
PTERIDIUM
POLYPODIUM
LYCOPODIUM
CALLUNA
cm

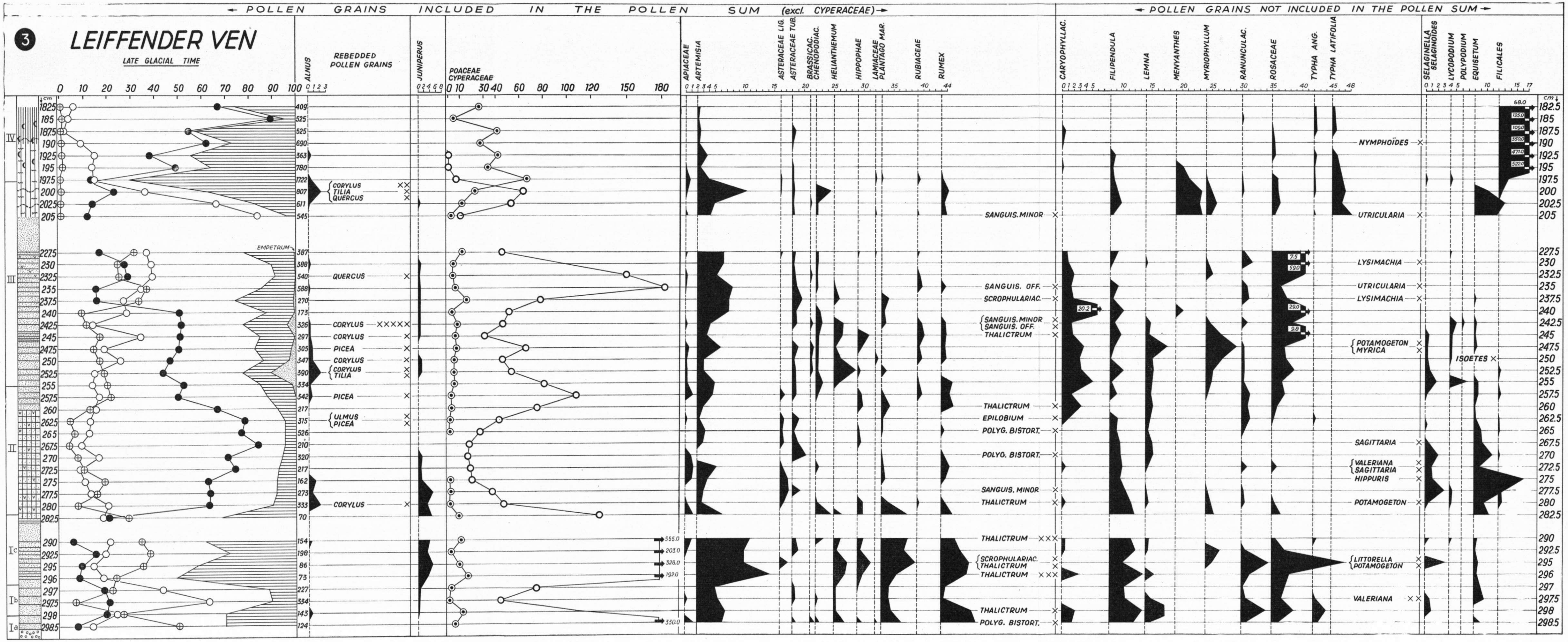
For diagram I (BRUNSSUM 4) please turn over



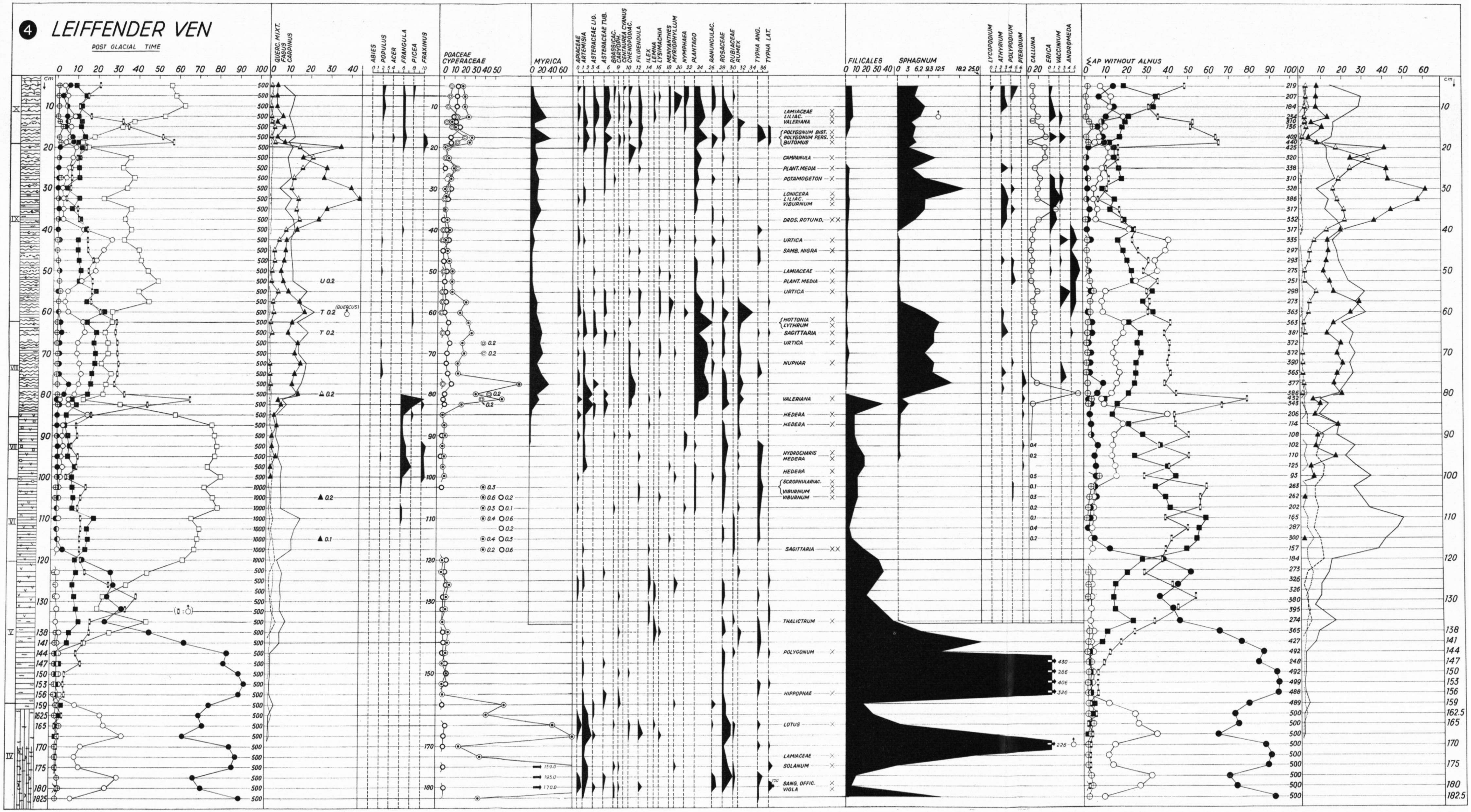




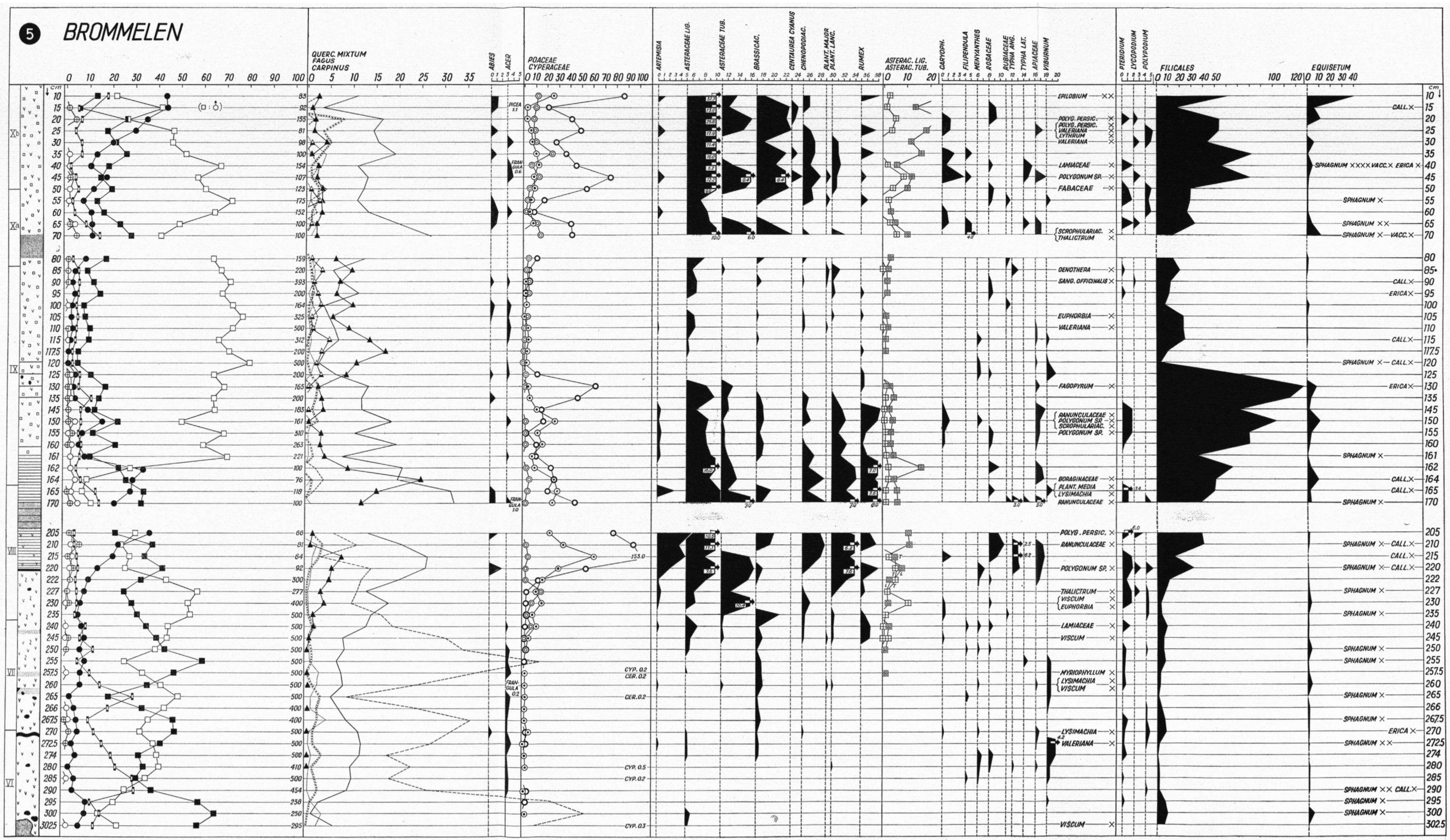
1 BRUNSSUM 4
0 10 20 30 40 50 60 70
QUERC. MIXTUM
0 10 20 30 40
POACEAE
0 10 20 30
CALLUNA
20 40 60
FILICALES
SPHAGNUM
0 10 20
cm
10
20
30
40
50
60
70
80
90
100
200
200
200
200
200
200
327.0

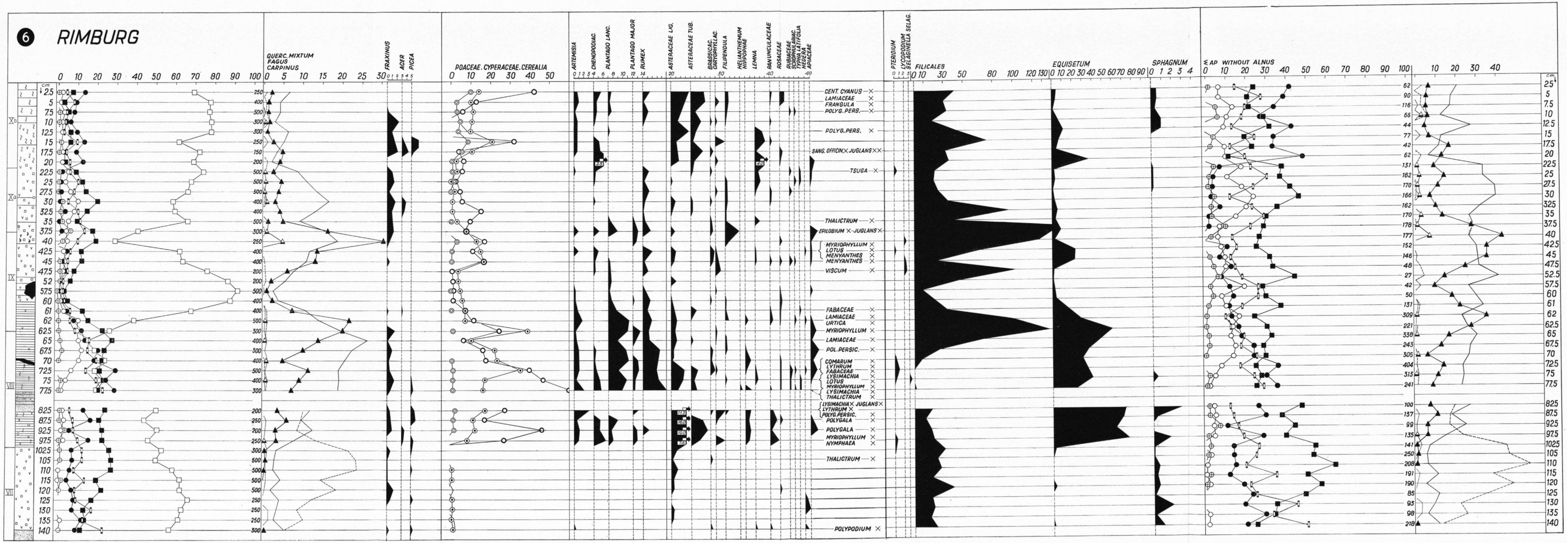


3
LEIFFENDER VEN
LATE GLACIAL TIME
← POLLEN GRAINS INCLUDED IN THE POLLEN SUM (excl. CYPERACEAE) →
← POLLEN GRAINS NOT INCLUDED IN THE POLLEN SUM →
ALNUS
REBEDDED POLLEN GRAINS
JUNIPERUS
POACEAE
CYPERACEAE
APIACEAE
ARTEMISIA
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICAC.
CHENOPODIAC.
HELIANTHEMUM
HIPPOPHAE
LAMIACEAE
PLANTAGO MAR.
RUBIACEAE
RUMEX
CARYOPHYLLAC.
FILIPENDULA
LEMNA
MENYANTHES
MYRIOPHYLLUM
RANUNCULAC.
ROSACEAE
TYPHA ANG.
TYPHA LATIFOLIA
SELAGINELLA SELAGINOIDES
LYCOPODIUM
POLYPODIUM
EQUISETUM
FILICALES
EMPETRUM
CORYLUS
TILIA
QUERCUS
PICEA
ULMUS
SANGUIS. MINOR
SANGUIS. OFF.
SCROPHULARIAC.
THALICTRUM
EPILOBIUM
POLYG. BISTORT.
NYMPHOÏDES
UTRICULARIA
LYSIMACHIA
POTAMOGETON
MYRICA
ISOETES
SAGITTARIA
VALERIANA
HIPPURIS
LITTORELLA
IV
III
II
Ic
Ib
Ia

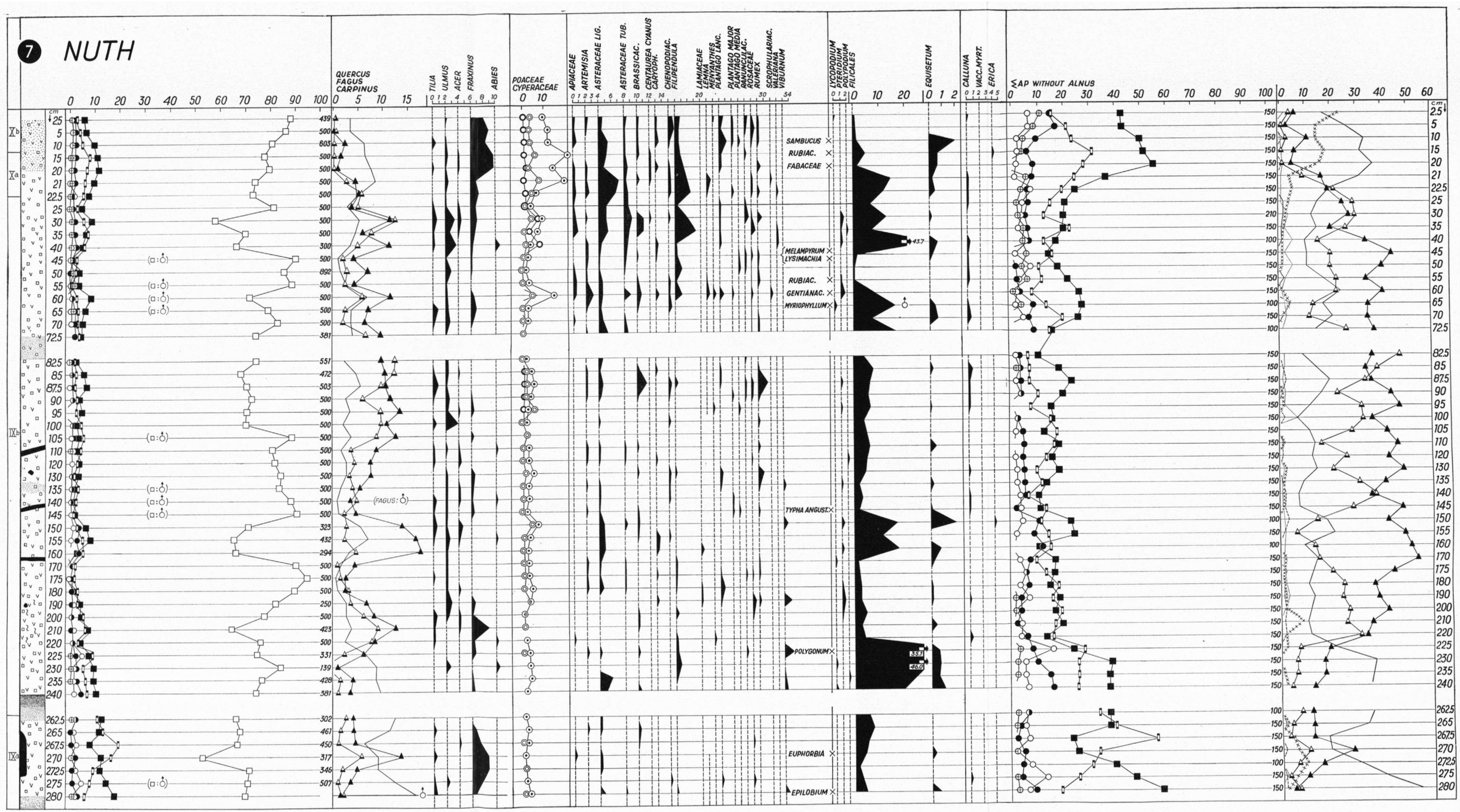


4 LEIFFENDER VEN
POST GLACIAL TIME
QUERC. MIXT.
FAGUS
CARPINUS
ABIES
POPULUS
ACER
FRANGULA
PICEA
FRAXINUS
POACEAE
CYPERACEAE
MYRICA
APIACEAE
ARTEMISIA
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICAC.
CARYOPH.
CENTAUREA CYANUS
CHENOPODIAC.
FILIPENDULA
ILEX
LEMNA
LYSIMACHIA
MENYANTHES
MYRIOPHYLLUM
NYMPHAEA
PLANTAGO
RANUNCULAC.
ROSACEAE
RUBIACEAE
RUMEX
TYPHA ANG.
TYPHA LAT.
FILICALES
SPHAGNUM
LYCOPODIUM
ATHYRIUM
POLYPODIUM
PTERIDIUM
CALLUNA
ERICA
VACCINIUM
ANDROMEDA
ΣAP WITHOUT ALNUS
LAMIACEAE
LILIAC.
VALERIANA
POLYGONUM BIST.
POLYGONUM PERS.
BUTOMUS
CAMPANULA
PLANT. MEDIA
POTAMOGETON
LONICERA
LILIAC.
VIBURNUM
DROS. ROTUND.
URTICA
SAMB. NIGRA
LAMIACEAE
PLANT. MEDIA
URTICA
HOTTONIA
LYTHRUM
SAGITTARIA
URTICA
NUPHAR
VALERIANA
HEDERA
HEDERA
HYDROCHARIS
HEDERA
HEDERA
SCROPHULARIAC.
VIBURNUM
VIBURNUM
SAGITTARIA
THALICTRUM
POLYGONUM
HIPPOPHAE
LOTUS
LAMIACEAE
SOLANUM
SANG. OFFIC.
VIOLA
(QUERCUS)
X
IX
VIII
VII
VI
V
IV
cm

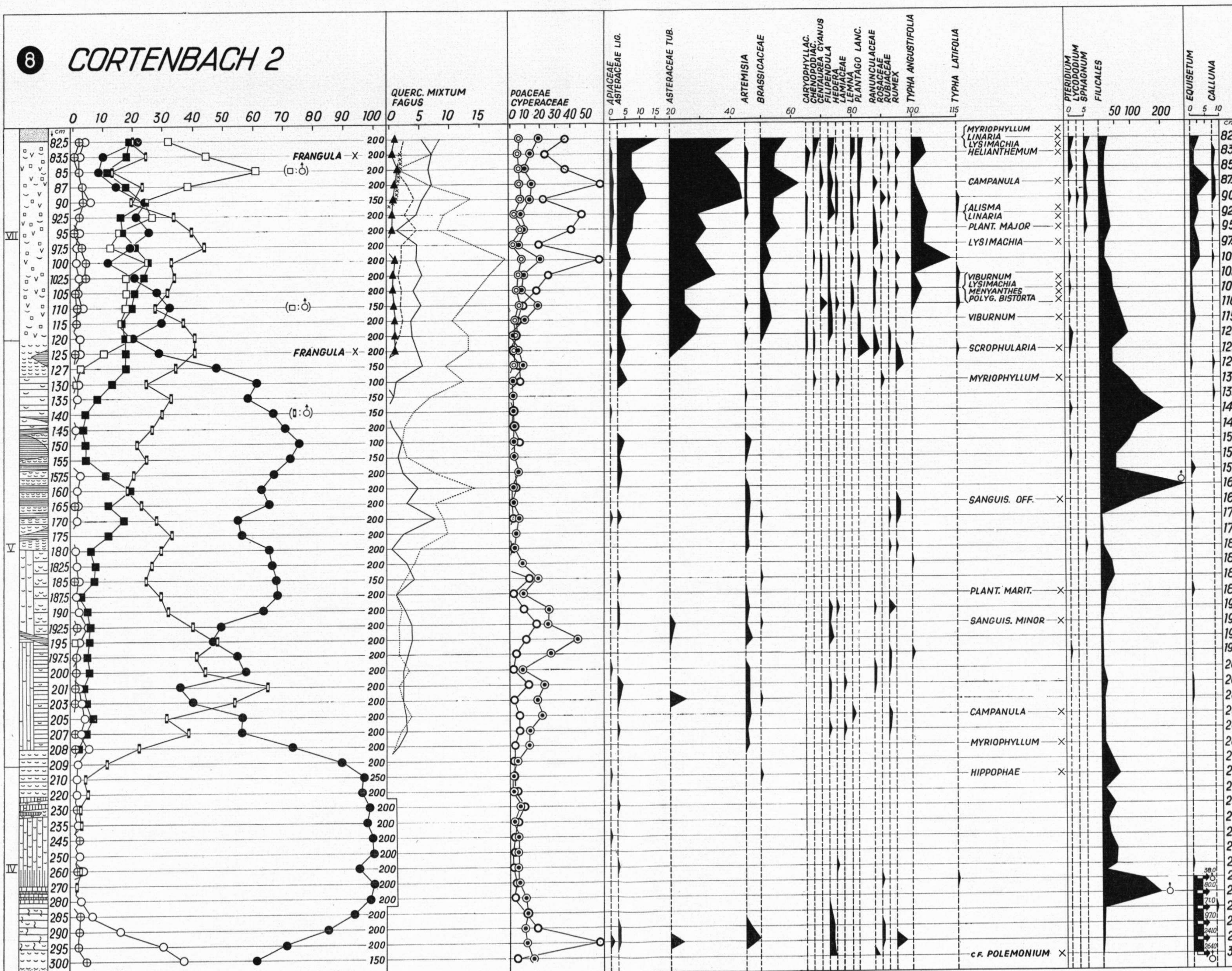

5
BROMMELEN
QUERC. MIXTUM
FAGUS
CARPINUS
ABIES
ACER
POACEAE
CYPERACEAE
ARTEMISIA
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICAC.
CENTAUREA CYANUS
CHENOPODIAC.
PLANT. MAJOR
PLANT. LANC.
RUMEX
ASTERAC. LIG.
ASTERAC. TUB.
CARYOPH.
FILIPENDULA
MENYANTHES
ROSACEAE
RUBIACEAE
TYPHA ANG.
TYPHA LAT.
APIACEAE
VIBURNUM
PTERIDIUM
LYCOPODIUM
POLYPODIUM
FILICALES
EQUISETUM
PICEA
FRANGULA
EPILOBIUM
POLYG. PERSIC.
VALERIANA
LYTHRUM
LAMIACEAE
POLYGONUM SP.
FABACEAE
SCROPHULARIAC.
THALICTRUM
OENOTHERA
SANG. OFFICINALIS
EUPHORBIA
FAGOPYRUM
RANUNCULACEAE
BORAGINACEAE
PLANT. MEDIA
LYSIMACHIA
VISCUM
MYRIOPHYLLUM
SPHAGNUM
CALL.
ERICA
VACC.
CYP. 0.2
CER. 0.2
CYP. 0.5
CYP. 0.3
cm

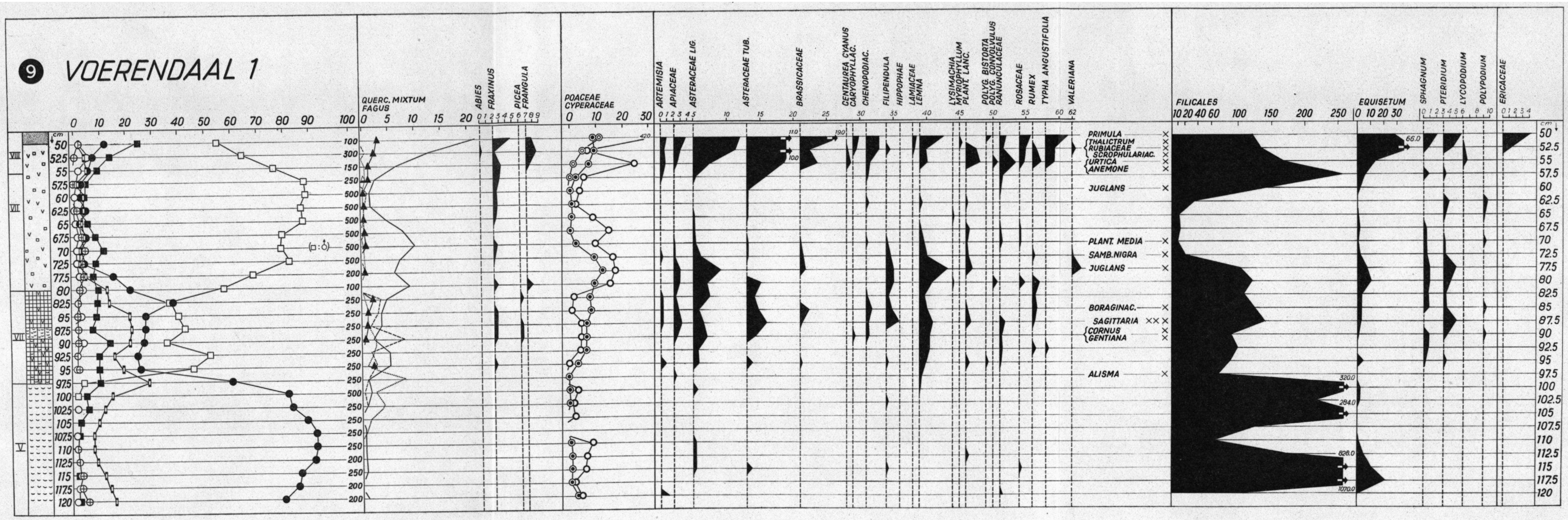


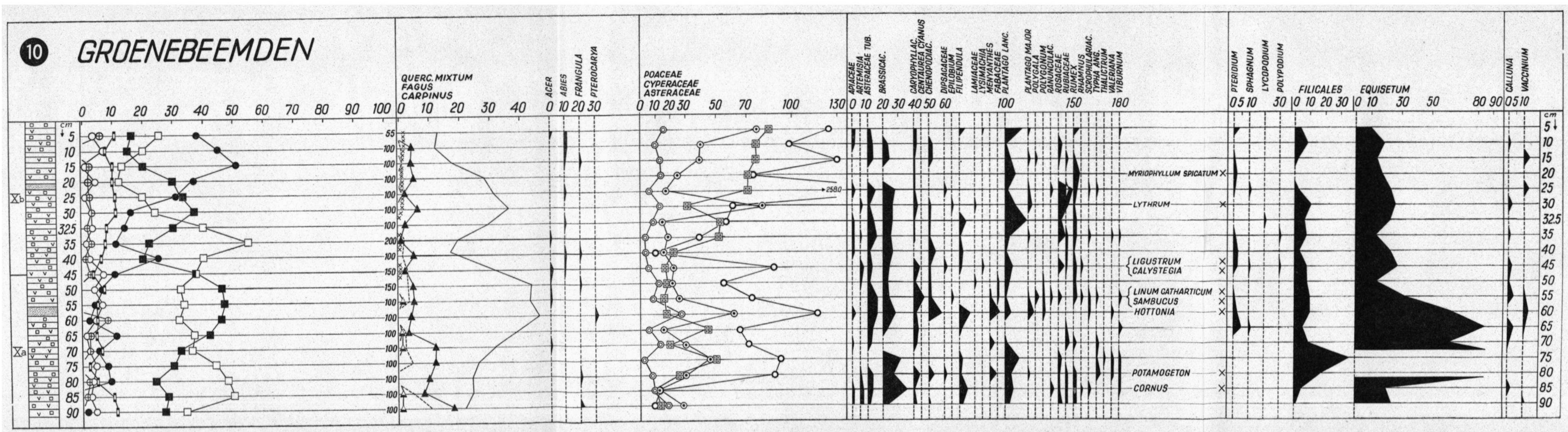
6 RIMBURG
QUERC. MIXTUM
FAGUS
CARPINUS
FRAXINUS
ACER
PICEA
POACEAE. CYPERACEAE. CEREALIA
ARTEMISIA
CHENOPODIAC.
PLANTAGO LANC.
PLANTAGO MAJOR
RUMEX
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICAC.
CARYOPHYLLAC.
FILIPENDULA
HELIANTHEMUM
HIPPOPHAE
LEMNA
RANUNCULACEAE
ROSACEAE
RUBIACEAE
SCROPHULARIAC.
TYPHA LATIFOLIA
HEDERA
APIACEAE
PTERIDIUM
LYCOPODIUM
SELAGINELLA SELAG.
FILICALES
EQUISETUM
SPHAGNUM
Σ AP WITHOUT ALNUS
CENT. CYANUS
LAMIACEAE
FRANGULA
POLYG. PERS.
SANG. OFFICIN.
JUGLANS
TSUGA
THALICTRUM
EPILOBIUM
MYRIOPHYLLUM
LOTUS
MENYANTHES
VISCUM
FABACEAE
URTICA
POL. PERSIC.
COMARUM
LYTHRUM
LYSIMACHIA
POLYGALA
NYMPHAEA
POLYPODIUM
cm

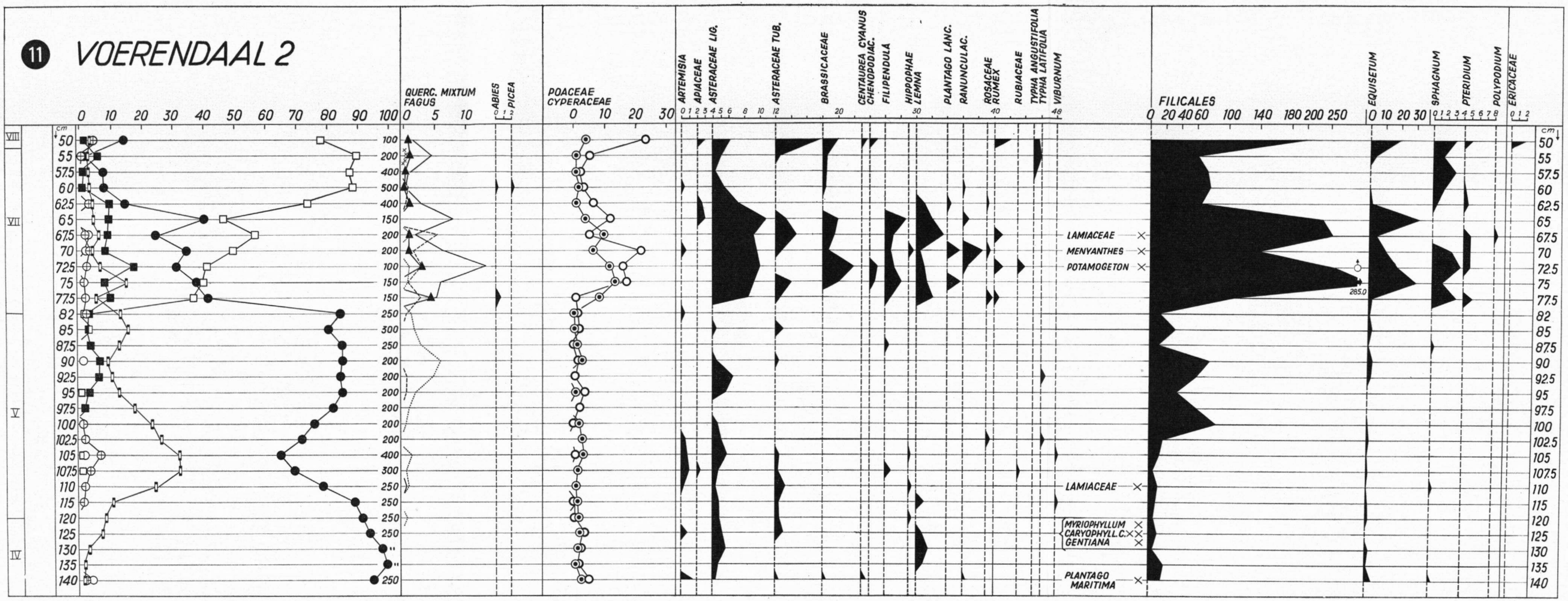


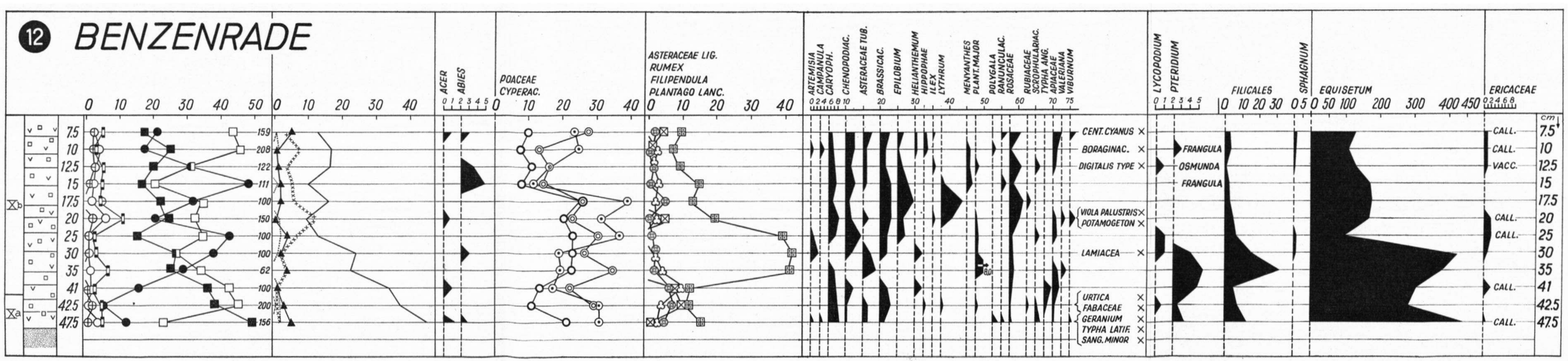
7 NUTH
QUERCUS
FAGUS
CARPINUS
TILIA
ULMUS
ACER
FRAXINUS
ABIES
POACEAE
CYPERACEAE
APIACEAE
ARTEMISIA
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICAC.
CENTAUREA CYANUS
CARYOPH.
CHENOPODIAC.
FILIPENDULA
LAMIACEAE
LEMNA
MENYANTHES
PLANTAGO LANC.
PLANTAGO MAJOR
PLANTAGO MEDIA
RANUNCULAC.
ROSACEAE
RUMEX
SCROPHULARIAC.
VALERIANA
VIBURNUM
LYCOPODIUM
PTERIDIUM
POLYPODIUM
FILICALES
EQUISETUM
CALLUNA
VACC.MYRT.
ERICA
ΣAP WITHOUT ALNUS
SAMBUCUS
RUBIAC.
FABACEAE
MELAMPYRUM
LYSIMACHIA
GENTIANAC.
MYRIOPHYLLUM
TYPHA ANGUST.
POLYGONUM
EUPHORBIA
EPILOBIUM
(FAGUS: ♂)
Xb
Xa
IXb
IXa
cm

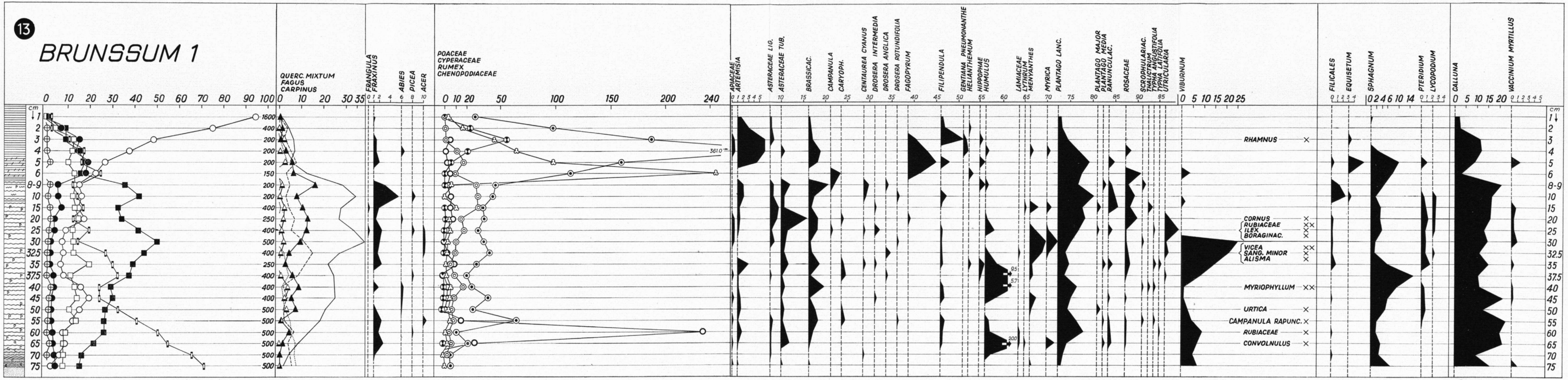

8 CORTENBACH 2
QUERC. MIXTUM
FAGUS
POACEAE
CYPERACEAE
APIACEAE
ASTERACEAE LIG.
ASTERACEAE TUB.
ARTEMISIA
BRASSICACEAE
CARYOPHYLLAC.
CHENOPODIAC.
CENTAUREA CYANUS
FILIPENDULA
HEDERA
LAMIACEAE
LEMNA
PLANTAGO LANC.
RANUNCULACEAE
ROSACEAE
RUBIACEAE
RUMEX
TYPHA ANGUSTIFOLIA
TYPHA LATIFOLIA
PTERIDIUM
LYCOPODIUM
SPHAGNUM
FILICALES
EQUISETUM
CALLUNA
FRANGULA
MYRIOPHYLLUM
LINARIA
LYSIMACHIA
HELIANTHEMUM
CAMPANULA
ALISMA
PLANT. MAJOR
VIBURNUM
MENYANTHES
POLYG. BISTORTA
SCROPHULARIA
SANGUIS. OFF.
PLANT. MARIT.
SANGUIS. MINOR
HIPPOPHAE
cf. POLEMONIUM
VII
V
IV
cm

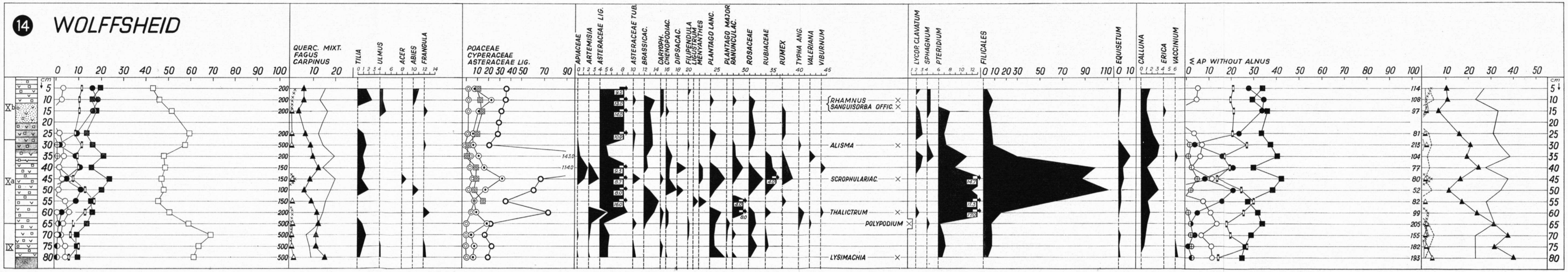

9
VOERENDAAL 1
QUERC. MIXTUM
FAGUS
ABIES
FRAXINUS
PICEA
FRANGULA
POACEAE
CYPERACEAE
ARTEMISIA
APIACEAE
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICACEAE
CENTAUREA CYANUS
CARYOPHYLLAC.
CHENOPODIAC.
FILIPENDULA
HIPPOPHAE
LAMIACEAE
LEMNA
LYSIMACHIA
MYRIOPHYLLUM
PLANT. LANC.
POLYG. BISTORTA
POLYG. CONVOLVULUS
RANUNCULACEAE
ROSACEAE
RUMEX
TYPHA ANGUSTIFOLIA
VALERIANA
FILICALES
EQUISETUM
SPHAGNUM
PTERIDIUM
LYCOPODIUM
POLYPODIUM
ERICACEAE
PRIMULA
THALICTRUM
RUBIACEAE
SCROPHULARIAC.
URTICA
ANEMONE
JUGLANS
PLANT. MEDIA
SAMB. NIGRA
JUGLANS
BORAGINAC.
SAGITTARIA
CORNUS
GENTIANA
ALISMA
VIII
VII
VI
V

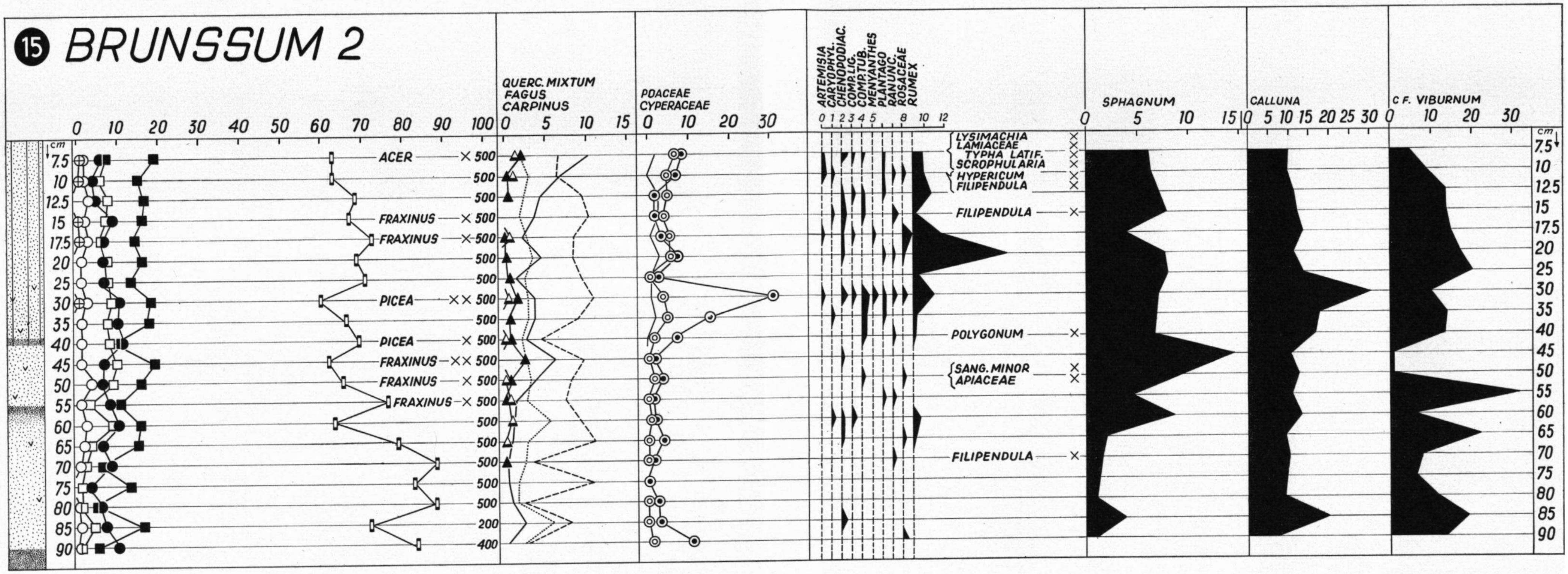

10
GROENEBEEMDEN
QUERC. MIXTUM
FAGUS
CARPINUS
ACER
ABIES
FRANGULA
PTEROCARYA
POACEAE
CYPERACEAE
ASTERACEAE
APIACEAE
ARTEMISIA
ASTERACEAE TUB.
BRASSICAC.
CARYOPHYLLAC.
CENTAUREA CYANUS
CHENOPODIAC.
DIPSACACEAE
EPILOBIUM
FILIPENDULA
LAMIACEAE
LYSIMACHIA
MENYANTHES
FABACEAE
PLANTAGO LANC.
PLANTAGO MAJOR
POLYGALA
POLYGONUM
RANUNCULAC.
ROSACEAE
RUBIACEAE
RUMEX
SANGUISORBA
SCROPHULARIAC.
TYPHA ANG.
THALICTRUM
VALERIANA
VIBURNUM
PTERIDIUM
SPHAGNUM
LYCOPODIUM
POLYPODIUM
FILICALES
EQUISETUM
CALLUNA
VACCINIUM
MYRIOPHYLLUM SPICATUM
LYTHRUM
LIGUSTRUM
CALYSTEGIA
LINUM CATHARTICUM
SAMBUCUS
HOTTONIA
POTAMOGETON
CORNUS
Xb
Xa

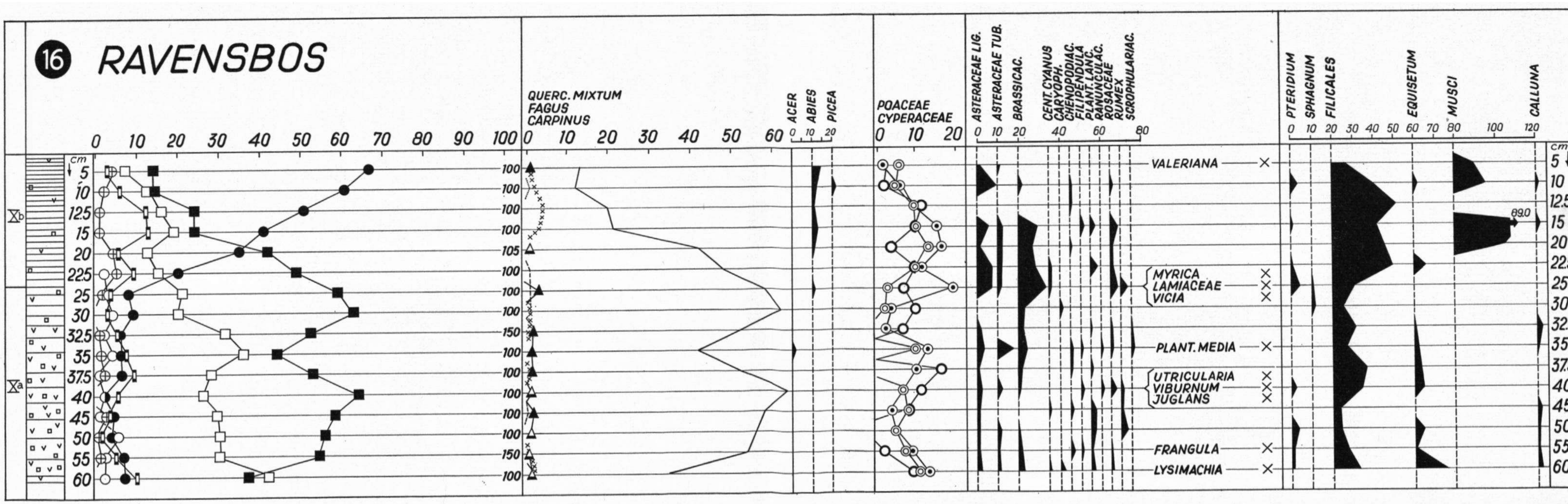

11 VOERENDAAL 2
QUERC. MIXTUM
FAGUS
ABIES
PICEA
POACEAE
CYPERACEAE
ARTEMISIA
APIACEAE
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICACEAE
CENTAUREA CYANUS
CHENOPODIAC.
FILIPENDULA
HIPPOPHAE
LEMNA
PLANTAGO LANC.
RANUNCULAC.
ROSACEAE
RUMEX
RUBIACEAE
TYPHA ANGUSTIFOLIA
TYPHA LATIFOLIA
VIBURNUM
FILICALES
EQUISETUM
SPHAGNUM
PTERIDIUM
POLYPODIUM
ERICACEAE
LAMIACEAE
MENYANTHES
POTAMOGETON
MYRIOPHYLLUM
CARYOPHYLL.C.
GENTIANA
PLANTAGO MARITIMA
285.0
cm
VIII
VII
V
IV


12 BENZENRADE
ACER
ABIES
POACEAE
CYPERAC.
ASTERACEAE LIG.
RUMEX
FILIPENDULA
PLANTAGO LANC.
ARTEMISIA
CAMPANULA
CARYOPH.
CHENOPODIAC.
ASTERACEAE TUB.
BRASSICAC.
EPILOBIUM
HELIANTHEMUM
HIPPOPHAE
ILEX
LYTHRUM
MENYANTHES
PLANT. MAJOR
POLYGALA
RANUNCULAC.
ROSACEAE
RUBIACEAE
SCROPHULARIAC.
TYPHA ANG.
APIACEAE
VALERIANA
VIBURNUM
CENT. CYANUS
BORAGINAC.
DIGITALIS TYPE
VIOLA PALUSTRIS
POTAMOGETON
LAMIACEA
URTICA
FABACEAE
GERANIUM
TYPHA LATIF.
SANG. MINOR
LYCOPODIUM
PTERIDIUM
FRANGULA
OSMUNDA
FILICALES
SPHAGNUM
EQUISETUM
ERICACEAE
CALL.
VACC.
cm
Xb
Xa


13
BRUNSSUM 1
QUERC. MIXTUM
FAGUS
CARPINUS
FRANGULA
FRAXINUS
ABIES
PICEA
ACER
POACEAE
CYPERACEAE
RUMEX
CHENOPODIACEAE
APIACEAE
ARTEMISIA
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICAC.
CAMPANULA
CARYOPH.
CENTAUREA CYANUS
DROSERA INTERMEDIA
DROSERA ANGLICA
DROSERA ROTUNDIFOLIA
FAGOPYRUM
FILIPENDULA
GENTIANA PNEUMONANTHE
HELIANTHEMUM
HIPPOPHAE
HUMULUS
LAMIACEAE
LYTHRUM
MENYANTHES
MYRICA
PLANTAGO LANC.
PLANTAGO MAJOR
PLANTAGO MEDIA
RANUNCULAC.
ROSACEAE
SCROPHULARIAC.
THALICTRUM
TYPHA ANGUSTIFOLIA
TYPHA LATIFOLIA
UTRICULARIA
VIBURNUM
RHAMNUS
CORNUS
RUBIACEAE
ILEX
BORAGINAC.
VICEA
SANG. MINOR
ALISMA
MYRIOPHYLLUM
URTICA
CAMPANULA RAPUNC.
RUBIACEAE
CONVOLNULUS
FILICALES
EQUISETUM
SPHAGNUM
PTERIDIUM
LYCOPODIUM
CALLUNA
VACCINIUM MYRTILLUS
cm
361.0


14
WOLFFSHEID
QUERC. MIXT.
FAGUS
CARPINUS
TILIA
ULMUS
ACER
ABIES
FRANGULA
POACEAE
CYPERACEAE
ASTERACEAE LIG.
APIACEAE
ARTEMISIA
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICAC.
CARYOPH.
CHENOPODIAC.
DIPSACAC.
FILIPENDULA
LIGUSTRUM
MENYANTHES
PLANTAGO LANC.
PLANTAGO MAJOR
RANUNCULAC.
ROSACEAE
RUBIACEAE
RUMEX
TYPHA ANG.
VALERIANA
VIBURNUM
RHAMNUS
SANGUISORBA OFFIC.
ALISMA
SCROPHULARIAC.
THALICTRUM
POLYPODIUM
LYSIMACHIA
LYCOP. CLAVATUM
SPHAGNUM
PTERIDIUM
FILICALES
EQUISETUM
CALLUNA
ERICA
VACCINIUM
Σ AP WITHOUT ALNUS
cm
143.0
114.0


15 BRUNSSUM 2
QUERC. MIXTUM
FAGUS
CARPINUS
POACEAE
CYPERACEAE
ARTEMISIA
CARYOPHYL.
CHENOPODIAC.
COMP. LIG.
COMP. TUB.
MENYANTHES
PLANTAGO
RANUNC.
ROSACEAE
RUMEX
SPHAGNUM
CALLUNA
cf. VIBURNUM
ACER
FRAXINUS
PICEA
LYSIMACHIA
LAMIACEAE
TYPHA LATIF.
SCROPHULARIA
HYPERICUM
FILIPENDULA
POLYGONUM
SANG. MINOR
APIACEAE
cm


16 RAVENSBOS
QUERC. MIXTUM
FAGUS
CARPINUS
ACER
ABIES
PICEA
POACEAE
CYPERACEAE
ASTERACEAE LIG.
ASTERACEAE TUB.
BRASSICAC.
CENT. CYANUS
CARYOPH.
CHENOPODIAC.
FILIPENDULA
PLANT. LANC.
RANUNCULAC.
ROSACEAE
RUMEX
SCROPHULARIAC.
PTERIDIUM
SPHAGNUM
FILICALES
EQUISETUM
MUSCI
CALLUNA
VALERIANA
MYRICA
LAMIACEAE
VICIA
PLANT. MEDIA
UTRICULARIA
VIBURNUM
JUGLANS
FRANGULA
LYSIMACHIA
Xb
Xa
cm