LATE-GLACIAL FLORA AND PERIGLACIAL PHENOMENA IN THE NETHERLANDS

BY

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Phot. 1.
Mekelermeer (Prov. of Drente). The black line indicates the spot where the boring took place.

Phot. 2.
Bergvennen, Lattrop (Prov. of Overijssel).
Flowering *Lobelia* on the foreground.

In quella parte del libro della mia memoria, dinanzi alla quale poco si potrebbe leggere, si truova una rubrica, la quale dice: *Incipit vita nova.*
In jenem Abschnitt des Buches meiner Erinnerung, vor dem nur wenig Lesenswertes aufgezeichnet ist, findet sich eine Ueberschrift, die da lautet: *Incipit vita nova.*
DANTE ALIGHIERI, Vita Nuova.

PREFACE.

When looking back over the years I devoted to this work I cannot but arrive at the conclusion that this period has been a very happy one in many respects. There were many persons who helped me and several of them have become my friends.

In the very first place it was Prof. Dr. F. FLORSCHÜTZ who aided me in so many ways, that accomplishment of this study without him would have been wellnigh impossible. From the beginning he assisted me with his extensive knowledge of the literature and of the peat-deposits in the Netherlands, his constructive criticism and not last of all with his unfailing enthousiasm. The great number of excursions I was allowed to make in his company shall always be amongst my best memories. We also made many excursions together with Prof. Dr. I. M. VAN DER VLERK, without the help of whom it would have been extremely difficult to reach various remote spots. His advice and his ideas on the division of the Pleistocene have been extremely valuable to me. I also have the best memories of my collaboration with Ir. H. D. M. BURCK and Dr. C. C. W. J. HIJSZELER. While my first interest in the scenery of Twente was awakened by my older friend, Mr. J. B. BERNINK, it was with my friend and fellow-student Drs. HENK ZWART that I first visited the brook-valleys near Ootmarsum, now about five years ago. Also the collaboration and the discussions with my friend Drs. H. WOLF NELSON have ever been a great support. Of the numerous other persons who helped me, by discussions or in any other way, I would like to cite Mr. G. C. MAARLEVELD, various other collaborators of the "Stichting voor Bodemkartering" at Wageningen, of the Geological Survey at Haarlem, Dr. L. M. J. U. VAN STRAATEN at Groningen, Drs. A. J. WIGGERS and Mr. W. ZAGWIJN. Drs. W. MEYER was kind enough to determine some fossil mosses for me, while Drs. J. BARKMAN checked determinations of mosses made by myself.

The drawings were made by Miss COR ROEST. Important help was given by Miss METTY VICARI, Miss BEP HAGEMAN and Miss NEL VAN MOURIK, who sacrificed much of their free time in order to type the manuscript or to register the pollen-finds. The translation was made by Miss M. E. DRIESEN. Photograph 9 was taken at the pollenanalytical laboratory of the Danish Geological Survey. Photographs 11 to 20 inclusive were taken at our request by Mr. W. H. DINGELDEIN at Denekamp, photographs 35 and 36 by Mr. MASTENBROEK, while photographs 39 to 42 inclusive were made by Drs. H. W. NELSON. All other photographs were taken by ourselves.

The size frequency distribution analyses were undertaken, through the intermediary of Drs. P. Bruin, by the "Bodemkundig Instituut T.N.O." at Groningen. Important financial support was given to me by the "Stichting Molengraaff-fonds", enabling me to attend the Botanical Congress in Stockholm in 1950 and to make the excursion to northern Lapland annexed to it. I am very grateful to the leader of this excursion, Prof. Dr. G. Einar du Rietz and also to Dr. Olof Hedberg, for their clear explanations in the field and for their friendship.

Dr. A. Cailleux enabled Mr. Nelson and myself to enjoy the hospitality of his laboratory in Paris during a week, in order to introduce us in his working-methods. Dr. Sigurd Hansen of the Danish Geological Survey enabled me to do fieldwork with him in North-West Jutland during a month, which gave me an opportunity of getting a better insight into the differences between the old and the young moraine-region. That month near the Bovbjerg Klint has made a great impression on me in more than one respect.

Dr. Johs. Iversen, of the Danish Geological Survey is undoubtedly one of those whose support was indispensable for this study. He twice gave me the opportunity to spend a few weeks in the laboratory of D.G.U., to become familiar with his research-methods. The help and hospitality of him who has become a real friend shall not lightly be forgotten. The weeks I spent at Charlottenlund, in the time lilac and laburnum were flowering, shall be amongst the happiest of my life.

INTRODUCTION.

In the East of Holland, in the Province of Overijssel, there is a region that, from the point of view of landscape, is one of the most beautiful and the most interesting we know in this country: Twente. Already in glancing through this publication it will be clear that this region played an important part in our research. Apart from the fact that our personal predilection for Twente undoubtedly was of some influence, this choice was equally directed by the geological wealth of that region coupled to the fact that here, as a consequence of numerous recent excavations, the deposits were excellently exposed. Of course, our research equally extended over other provinces but, whereas there a stress was laid on pollenanalytical research, geological research was less intensive than — for the reasons explained above — in Twente. Finally the research carried out near Usselo together with that carried out in S.W. Noord-Brabant, yielded together the solution for the dating of part of the coversands.

Aim of the research.

1. To obtain by means of pollenanalytical surveys, carried out over the whole country, more precise information concerning the vegetation and the development of vegetation during the Late-glacial.
2. To throw some new light, by means of field and laboratory research, on the problem of the periglacial actions: the formation of coversands, kryoturbation and the formation of erosion valleys.
3. To arrive at a synthesis of geological, climatological and botanical information by means of palaeobotanical as well as field-geological research, and so to also obtain dating of the various young periglacial deposits.

Working-method.

a. Pollenanalytical research.

Part of the material was collected in exposures in pits and accidental excavations, part of it was obtained by borings with the "Dachnovski-auger", while still other samples originate from deeper borings.

In the laboratory the samples were treated as below (compare Faegri and Iversen (1950)):

1. Boil the sample with KOH, remove coarse particles by mechanical means; centrifuge.
(2. If the sample is rich in lime, remove by acid; centrifuge.)
3. If the sample contains clay, boil it 3 to 4 minutes with 30—40 % HF. Chalk also disappears in this manner. Centrifuge (Pyrex-glass!). (If necessary, pour warm HCl 10 % over it afterwards. Centrifuge).
4. Dehydrate with glacial acetic acid. Centrifuge.

5. Treat with a fresh mixture of 9 parts anhydric acetic acid and one part H_2SO_4 conc. Heat in a waterbath to the boiling point. Centrifuge.
6. Wash with water. Centrifuge.

After this the contents of the centrifuge-tube, together with a few drops of water, is poured into a watchglass and is dried therein until most of the water has disappeared (do not let dry completely!) and a few drops of glycerine are then added.

We did not apply coloring. Since we counted all preparations with an enlargement of 430, coloring in our opinion has no advantage, since then there is no danger to overlook smaller grains. Even the more sensitive grains, like those of *Juniperus*, can be very well recognized without coloring. After the counting the preparations were sealed with a sealing-wax. All slides are kept in the collection of the "Rijksmuseum van Geologie en Mineralogie" at Leyden.

In those cases where we came across lake deposits, we generally counted about 400—600 pollen-grains of those species that are included in the pollensum.

In other cases, where we had to do with peat or with deposits having undergone a strong local influence, we stopped at 250—300 grains, as in these cases the counting of more grains was of no use to our object. In a few cases, that is to say in the case of some samples of the cold period preceding the Late-glacial, it was impossible to count within a reasonable period of time such an amount of grains, and we had to be content with about 150. In all cases the amount of grains counted is mentioned separately in the description of the diagrams.

For the determination of the pollen-grains and spores we used our collection of preparations of recent pollen and spores. If a determination could not be given accurately, the find was not mentioned (exception: cf. *Selaginella helvetica*). For our diagrams we always used the method of presentation proposed by Iversen (1947). The advantages offered by this mode of presentation for the Late-glacial can be supposed to be known sufficiently. Anemophile plants, represented only by a few grains in a diagram (e. g. *Sanguisorba minor*), and not belonging to those species of which nearly always a curve can be drawn, have not been included in the total. Naturally this has no influence whatsoever on the development of the curves in the diagram.

Juniperus, actually belonging to the trees and shrubs, was not included in the total either. Since *Juniperus*-pollen is not easily recognisable and is readily impaired, we thought better not to include it, with a view to comparability with diagrams of others in which *Juniperus* is not mentioned on the one hand and, on the other hand, with a view to comparability with some of our own diagrams in which *Juniperus* could not be counted because of a slight damage to the material. We made a difference between standard diagrams in which a larger number of pollen-grains were counted and dating diagrams in which a smaller amount of grains was counted. The former were mainly intended for botanical aims, the latter more for geological ones. An important aid in documentation of finds in the pollenanalytical field is micro-photography. Since the camara at our disposal was not entirely up to the standards required for good micro-photographs of pollen-grains, we are unable to publish an important number of such photographs. Dr. Iversen was kind enough to take a few photographs for us in the pollenanalytical laboratory of the Danish Geological Servey (phot. 9).

b. Other Palaeobotanical research.

The mosses were partly determined by us and then checked by Mr. J. BARKMAN and partly they were determined for us by Mr. W. MEYER.

Further we determined charcoal and, very provisionally, seeds as well. The research material was obtained by first drying the peat, the gyttja or the clay and then rinse it on a sieve.

c. Field-research.

Here we made use of both natural and artificial exposures, and we used an auger, with which sand samples could be taken up to a depth of about two meters. Furthermore, the morphology of the landscape played an important part. Searching for exposures we succesfully used air-photographs.

In Twente especially we had the opportunity to carry out a rather longdrawn field-research in combination with geological mapping.

d. Research of size-frequency distribution and the method of CAILLEUX.

We did not have the opportunity to seriously inquire into the size-frequency distribution of the various coversands as this would have meant a too comprehensive task. We therefore had to content ourselves with a somewhat restricted number of analyses, permitting only preliminary conclusions.

It was for the same reason that we were unable to analyse all our sands according to the method of CAILLEUX; we could only examine provisionally a few samples.

Doubtless an extensive size-frequency-, CAILLEUX- and sediment-petrological research will result into a large quantity of new information.

Research on recent surface-samples.

FIRBAS (1935) and AARIO (1940) published important results of research on recent surface-samples. Some of the most important results were: higher percentages of herbs in regions poor in trees or entirely treeless, predominance of *Pinus* and the presence of thermophiles in tundra-spectra.

During an excursion (organised by the International Botanical Congress, Stockholm, 1950) to Swedish-Lapland under the direction of Prof. Dr. G. EINAR DU RIETZ, we have been able to take a certain number of surface-samples in the neighbourhood of Lake Torneträsk, in Torne Lappmark.

The greater number of these samples contained too little pollen in order to make a spectrum. Three samples, however, provided us with a sufficient amount of pollen and we shall give the spectra in diagram No. XX (top: IVERSEN-diagram; bottom: treepollen-diagram).

Sample 1 was taken in the Middle Alpine belt, on a marshy spot with a vegetation of *Sphagnum, Salix spp.* etc., on the slope of Nissontjårro.

Sample 2 was taken in a large open area in the Subalpine Birch-forestbelt, from a rich fen, with a vegetation of *Carex* spp., *Eriophorum, Betula nana* etc., and surrounded by *Salix lapponum-* and *Salix glauca*-shrub; Katterjåkk, at an altitude of about 520 m.

Sample 3 was taken in the Subarctic Birch-forest with scattered groops of pines, from a rich fen; Abisko-valley (altitude about 400 m).

Below a table is shown with the complete analyses of these samples.

	Salix	*Betula*	*Pinus*	*Picea*	*Gramineae*	*Cyperaceae*	*Empetrum*	*Ericaceae*	*Juniperus*	*Tubuliflorae*	*Selaginella selaginoides*	*Sphagnum*	*Dryopteris*	*Lycopodium*			Total
3	1	58	21	×	2	3	12.5	2.5	2	1	—	×	×	1.5	*Alnus*	×	210
2	1	25	14	×	2.5	56	1	—	0.6	1	0.3	0.6	×	1.5	*Rosaceae*	×	340
1	×	5.5	10	×	2.5	81	0.3	—	1.4	—	—	×	×	×	*Cruciferae*	×	300

In placing these three spectra, from high to low, on top of each other and taking as a basis for calculation the tree-pollen and pollen of anemophile herbs and *Ericales* on the one hand, and the tree-pollen alone, on the other hand, 2 diagrams are then obtained. The Iversen diagram gives in one graph a reasonably clear picture of the sequence of the various vegetations. The tree-pollen diagram (without herb curves) naturally gives an exact picture of the tree-pollen deposit (together with the herb curves of course one gets a picture of the vegetation too in this case).

The *Pinus*-percentage is highest in the tree-pollen diagram, in sample 1, taken far beyond the tree-line, and lowest in sample 3, taken in a region where *Pinus* is actually found.

Of course, in Lapland, differences in height are of importance but the horizontal distances also are rather important (sample 2 lies at a distance of nearly twenty km of the Abisko-valley, where *Pinus* is found (sample 3)).

The rather high percentage of *Empetrum*-pollen in sample 3 that must have been caused by the *Empetrum* from the *Empetrum-Vaccinium* undergrowth in the neighbouring wood, is interesting. As a consequence, the N.T.P.-percentage increased therefore with 12.5 percent.

The *Juniperus*-pollen was extremely well preserved, partly having still all gemmae.

In making comparisons with Late-glacial diagrams, the fact will of course have to be taken into consideration that surface-samples usually originate from marshy vegetations, whereas the greater part of our Late-glacial spectra are derived from lake-deposits. The former are, of course, rather more locally influenced; in sample 2 for instance, the *Cyperaceae* are certainly over-represented because of the local *Cyperaceae*-growth. However, this distorts the picture less than one might have expected.

We might summarize the conclusions to be drawn from these samples from Lapland as follows (cf. the Iversen-diagram):

1. A percentage of about 20 % *Pinus* may be caused by the presence of relatively few pines in the birch-forests.
2. A percentage of about 15 % *Pinus* in a "Park landscape"-spectrum

need not indicate the presence of pine on that spot. In the case in question (sample 2) the pine grows at a distance of about 20 km.

3. The *Salix*-percentages are — certainly in samples 1 and 2 — lower than might be expected in view of the vegetation. Apparently the small arctic-alpine willows especially, also scatter few pollen (in accordance with sample 1).
4. When vegetation becomes treeless, *Pinus* is dominating in the tree-pollen spectrum. (Was established already some time ago by FIRBAS (1935) and AARIO (1940).)
5. In case of dense forest, the presence of a large number of wind-flowering plants in the undergrowth (i. c. *Empetrum*), may cause a rather strong increase of the non-tree-pollen percentage.
6. Although *Juniperus* is a common shrub in Lapland, its pollen-percentages are rather low.

We shall come back to the significance these conclusions can have when interpreting Late-glacial diagrams.

IVERSEN (1947) examined recent gyttja-samples from Greenland. He compared the spectra so obtained with the recent vegetation. He then found that *Alnus viridis* and *Betula nana* were over-represented and that *Salix, Gramineae, Cyperaceae* and *Ericaceae* were under-represented, whereas the pollen-percentage of *Empetrum hermaphroditum* coincided with the part taken by this plant in the recent vegetation.

Secondary pollen and long-distance transport.

From time to time pollen-grains of thermophile trees are found in Late-glacial deposits, but then in very low percentages only, generally not more than 1 or 2 in 400 grains. This percentage may, as an exception, be somewhat higher such as in the sediments rich in clay down on the bottom of the Mekelermeer (diagram I).

These grains, in those cases, are generally accompanied by "Tertiary" and "Interglacial" pollen-grains and "Hystrix" (a problematical fossil), so that it is highly probable that these grains are of a secondary character. IVERSEN (1939) devoted a publication to secondary pollen. A correlation method, such as used by him, cannot be considered for our diagrams. Furthermore, the amount of secondary pollen is nearly always so low that it does not visibly influence the curves of the graphs. A somewhat more extensive consideration of secondary pollen in Dutch Late-glacial sediments has been given previously (VAN DER HAMMEN, 1949).

In finding a few pollen-grains of thermophile trees, occurring in a sediment rich in clay and giving a typical Late-glacial spectrum, together with a few grains of e. g. *Sequoia* and *Pterocarya*, we feel that their secondary character has been sufficiently proved.

We also are of the opinion that most of the "interstadial indications" appearing at the bottom of some of the older diagrams, were caused by secondary pollen.

The question is, in what way this secondary pollen, apparently simultaneously with the minerogene material, found its way into the Late-glacial deposits. Since aeolian influence played a very important part in that period and the minerogene material therefore has to be seen as an equivalent of coversand, of "loamy" coversand or of loess (see Chapter VII), this pollen too must have been carried there by the wind, together with the minerogene material. The question as to the origin of the secondary pollen is therefore actually identical with that concerning the origin of the loess or of the "loamy" driftsand. Possibly boulder-clay was an important source, since boulder-clay itself contains a large amount of secondary pollen, absorbed by the land-ice from older deposits. But in the end this problem might possibly be solved only by means of sediment-petrological research.

Another possibility of explaining the presence of pollen-grains of thermophile trees, is transport over a long distance. The presence of grains, carried along in this manner, in recent tundra-spectra is generally known. If at the same time "Tertiary" pollen is present, no accurate conclusion can be drawn, however, concerning the presence of pollen transported in such a way into sediments. We do however believe that it is very possible that pollen-grains of e. g. *Corylus* and *Ulmus*, sporadically found in Late Dryas-deposits (where generally no "Tertiary" pollen is found), may have got there by transport over a long distance.

Pollen-grains of *Alnus* need not indicate a secondary influence as they may originate from e. g. *Alnus viridis* or *Alnus incana*, but their coinciding with undoubtful secondary pollen may, in some cases, make a secondary origin likely. The pollen of *Pinus* forms generally, as IVERSEN was able to prove, one of the most important components of the secondary pollen and it is precisely this we cannot, in Holland, abstract by a precise method. Fortunately however, the quantity of undoubtful secondary pollen is so small that also the influence of secondary *Pinus*-pollen on the curves of the graph can be nothing but negligible. In mentioning the recent surface samples, we already mentioned the predominance of *Pinus*-pollen in treeless arctical regions, caused by transport over long distances.

In summarising we therefore can say that the possible presence of a large amount of secondary pollen is indeed a difficult problem for the pollen-analyst, since it impairs the accuracy of his conclusions, but knowing this difficulty he will, in most cases, still be able to date the material accurately.

Literature.

The basis of our knowledge of the flora of the Dutch Late-glacial and the earlier "Würm-glacial" was formed by FLORSCHÜTZ (i. a. 1927, 1939, 1941). Since then articles by WATERBOLK (1948) and by us (VAN DER HAMMEN, 1949) on the subject of Allerød-oscillation in Holland were published. We also were able to prove the Bølling-oscillation in Holland.

Finally, DE PLANQUE (1950) published an Allerød-diagram from the Province of Friesland.

As far as the literature on periglacial phenomena in Holland is concerned, this is too extensive to be discussed here. For this subject we therefore refer to the geological part of this work.

The division of the Last Glaciation.

When trying, by means of existing literature, to obtain a more or less definite division of the Weichsel-glacial, one cannot but come to the conclusion that such a division cannot be really made. All geological divisions of the Weichsel-glacial, made up till now, are based on the interpretation of moraines, whose location very often is far from certain, and about which opinions are strongly divided in many cases.

Often for instance, one cannot exactly say whether a terminal-moraine represents a stage of retreat only (formed during a standstill of the ice during its general retreat from the uttermost moraines), or whether it was formed during a new advance of the ice after this had first retreated much further.

This means therefore, that one cannot, on the ground of end-moraines only, deduct that a certain number of interstadia have existed. Furthermore, older end-moraines may have been overridden and therefore may have escaped perception forever. How for instance could one determine how many stadia and interstadia there have been during the expansion of the land-ice up to the moraines of the "Brandenburg-stadial"?

The conclusion to be drawn from all this cannot be but, that the division of the Würm-glacial into: Brandenburg-stadial, Aurignac-interstadial, Frankfort-Posen-stadial, Masurian-interstadial and Pomeranian-stadial is uncertain in parts and cannot be accepted without criticism and be applied to deposits outside the glacier-covered area.

It is interesting to note in this context that GROSS (1937), who carried out a pollen-analytical examination of the Masurian-interstadial deposits, arrived at the conclusion that these deposits were Late-glacial and that the Masurian-interstadial probably did not exist at all. WOLDSTEDT (1950) also, is sceptical as to the Masurian interstadial. Only the Aurignac-interstadial is nearly generally accepted; it tallies with a generally occurring weathered zone in the loess.

VAN DER VLERK and FLORSCHÜTZ (1950) already pointed out the difficulty of basing a division of the Pleistocene on geomorphological data only. They therefore proposed a division of the pleistocene on a palaeontological basis, a division they carried out for Holland. If a division of the Last Glaciation (the Tubantian of VAN DER VLERK and FLORSCHÜTZ) is to be carried out on a palaeontological basis, pollen-analysis will in the first place have to be considered. As long as the existence of an interstadial has not been proved by pollen-analysis and, possibly by other palaeobotanical and palaeozoological research, its existance remains doubtful. There are, however, a few other data indicating that there must have been only one extensive interstadial, the Aurignac-interstadial, since in most cases, only one clear weathered zone is to be found in the loess of Germany.

Also SOERGEL (1938) believes, on the ground of his "Vereisungskurve", that there has been only one extensive interstadial. The warmth-maximum of a second interstadial is, in his curve, very low.

GAMS (1937) then is of the opinion that this interstadial tallies with the zones l and m (the topmost "temperate flora" from the Eemian-diagrams of JESSEN (JESSEN and MILTHERS, 1928). Zone k would then represent the first stadial phase of the Weichsel-glacial, with a "sub-arctic" vegetation. The latter authors were of the opinion that this phase was a strong climatological oscillation in the Eemian.

GAMS bases his opinion on the fact that the diagrams covering this stadial and interstadial phase, are situated outside the uttermost moraines of the last glacial period and that in the diagrams, originating from places inside these moraines, that series does not occur.

In Holland, the same interstadial (Aurignacian) would then have been established by FLORSCHÜTZ near Hengelo (Sluisput) and by VAN SOMEREN near Zwolle (Zwarte Water) (VAN DER VLERK and FLORSCHÜTZ, 1950), in the first case separated by largely one meter of sand, containing remains of "cold" animals, from the Eemian. (Principal components: *Quercetum mixtum, Corylus, Alnus, Pinus, Betula* and *Picea.*)

This interstadial, situated close upon the Eemian, is the only one that has been pollenanalytically established in a certain number of places in Europe up till now. We are calling it for the time being by the local name of Salland-interstadial, and the preceding stadial phase by the local name of Zwolle-stadial.

The only clear indication, in our opinion, of a second interstadial was found by FLORSCHÜTZ, also near Hengelo on a stratigraphically higher level than the former (VAN DER VLERK and FLORSCHÜTZ, 1950). (This supposed second-interstadial layer was found between sediments with a Dryas-flora. Its content of Cyperaceae-pollen was small compared with that of the adjacent layers.) The principal spectra-components are: *Pinus, Betula, Picea, Alnus, Corylus.*

Since this is in our opinion the only clear pollenanalytical indication of a second interstadial (unfortunately based exclusively on the analysis of sediments with a strong minerogene character, so that the influence of secondary pollen cannot entirely be excluded) that was ever found, its general acceptance will have to be postponed untill more pollenanalytical data on the subject are available. (The diagram published by FLORSCHÜTZ (1947) of a presumably second-interstadial loess-layer near Nijmegen seems less convincing us.) For the time being it will be well to reckon with the existence of one extensive interstadium in any case.

Another difficulty is, where to let the Late-glacial begin. This limit will have to be defined also in the first place with the help of palaeontological data, after which one can further try to obtain correlation with the stadia of retreat of the land-ice. We shall come back to this subject in one of the following chapters.

For the period between the Salland-interstadial and the beginning of the Late-glacial in which "Hoch-glaziale Verhältnisse" must have prevailed (see Chapter I), we want to introduce the name "Pleni-glacial". This period might possibly have been interrupted by still a second interstadial, the Hengelo-interstadial (with sub-arctic vegetation?). As opposed to the "Hochglazial" of GAMS (1937), the limits of the "Pleni-glacial" are based on palaeontological data exclusively. Our provisional division is as follows:

Holocene.

Tubantian { Late-glacial.
Pleni-glacial.
Salland-interstadial.
Zwolle-stadial. }

Eemian.

This division, therefore, has the advantage of being based on palaeontogical data found in several places and that the deposits on top of the Salland-interstadial need not be inserted in a system of stadial phases and interstadials that have not or not yet been generally accepted from a palaeontological point of view (see more on this in Chapter I).

As far as the division of the Late-glacial is concerned, we followed the zone-division of JESSEN and MILTHERS (1901) and of IVERSEN (1947), introduced in Holland previously (VAN DER HAMMEN, 1949).

Pollenanalytical limits.

In defining limits on a pollenanalytilal basis, we have to wonder in how far these limits, from a geological point of view, are also synchronical. While in Holland e. g. sub-arctic forests, during a general deterioration of the climate at a certain time, were transformed into a sub-arctic parklandscape, the same deterioration of climate in Jutland resulted into transformation of the then prevailing sub-arctic parklandscape into tundra.

It is clear that in this case the time of deterioration of climate is synchronical, in both cases characterized by an increase of the non-tree pollen, although the diagrams do not show entirely the same picture. Synchronical limits therefore will have to be drawn on the basis of changes in the mutual relations of plants or groups of plants present already before the occurrence of the change in climate. On the other hand it will never be possible to establish synchronical limits over a larger area on the basis of the first appearance of a species that was not present before in that area.

For in this case the limit need not coincide with the time of climatological change, for now the immigration-time is doing to play a role, and therefore, a shorter or longer period may have lapsed between change in climate and immigration of the species. Therefore the limit e. g. Late-glacial—Post-glacial (therefore also the limit Pleistocene-Holocene) may not, in our opinion, be established where the first thermophiles (*Corylus, Ulmus,* etc.) appear, since this limit will certainly not be synchronical over a larger area. For these thermophiles will have needed, after final amelioration of climate, a certain time to migrate from Southern-Europe to Northern-Europe and consequently the limit Pleistocene-Holocene in Holland would therefore not be synchronical with that of Denmark for instance, where the thermophiles must have arrived later.

It is therefore better, in case at least a synchronical geological-climatological and not a biological limit is desired, to establish the limit at the first clear signs of definite amelioration in climate, at the end of the Late Dryas-time. At that moment namely, the change can be established on the basis of an alteration in the relation of plants already present previously. In that manner a limit is obtained that can be followed at any rate over a great part of Europe.

All this has, of course, an approximate value only, since there might be certain circumstances slowing down also alteration in the relation between plants already present, but in any case the chance of making mistakes is much smaller.

If a certain change in climate takes place very gradually, the establishment of approximately synchronical limits may become extremely difficult. Fortunately, however, most of the changes in climate during the Late-glacial seem to have taken place relatively quickly; they are shown at any rate as rather clear boundaries in the diagrams.

In connection with the above it has been always a problem where to establish the bottom-limit of the Late-glacial. For here the first appearance of large birch trees is unsuitable, since in this case the immigration-factor does not allow for synchronical limits; in addition the pollen-grains of large birch trees cannot be distinguished from those of *Betula nana* with certainty. It will therefore be necessary to find other means in order to establish this limit, the first clear amelioration of climate, on palaeontological grounds. We shall discuss this further in Chapter II.

If, however, we wish to establish a division on a palaeontological-climatological basis, and therefore not on a geomorphological one, we first shall have to give another definition for the conception Late-glacial.

It can in that case not read:

The Late-glacial is the period beginning with the retreat of the land-ice from the inner baltic moraines and ending with its retreat from the great Middle-Swedish terminal-moraines. But our definition would read: the Late-glacial is that period at the end of the Tubantian that, after the preceding cold, begins at the first signs of improvement of the climate and ends where the final amelioration of the climate begins.

Once these limits of the Late-glacial, on a palaeontological basis, shall have been defined, it can be endevoured later to correlate them with the phases of retreat of the land-ice.

We call this new Late-glacial Upper Tubantian, the Pleni-glacial Middle Tubantian and the Salland-interstadial + Zwolle-stadial-phase Lower Tubantian.

Principles and definitions.

It would appear usefull to name once more separately the principles on which we based ourselves and to state our definitions of a few notions we shall use frequently furtheron. We started from the principles, proposed by VAN DER VLERK and FLORSCHÜTZ (1950) for the division of the Pleistocene: a division on a palaeontological basis and the use of local names whenever correlation with other regions is not yet quite certain.

Furthermore we are of the opinion that geological-climatological limits, established by means of pollen-analytical data, have to be determined on the basis of changes in the relations of vegetation components that were already present previous to the change in climate, and not on the basis of the first appearance of new components.

The Salland-interstadial is that interstadial, that was found close upon the Eemian and that, most probably, tallies with zones l and m of the "Skaerumhede-series" from Danish Eemian diagrams and, possibly, also with the great or Aurignacian interstadial.

(Principal components: Quercetum mixtum, *Alnus, Corylus, Pinus, Betula, Picea.*)

The Pleni-glacial (Middle Tubantian) is the cold period situated between the Salland-interstadial and the Late-glacial (possibly interrupted by a subarctic interstadial).

The Late-glacial (Upper Tubantian) is that period at the end of the Tubantian that, after the preceding cold (of the end of the Pleni-glacial), begins at the first signs of an amelioration of climate and ends where the final amelioration of climate begins.

PALAEOBOTANICAL PART.

CHAPTER I.

FLORA AND CLIMATE DURING THE PLENI-GLACIAL (Middle Tubantian).

The flora and the climate during the Zwolle-stadial was, in Holland, sub-arctic (see the diagram of Zwolle-Zwartewater in VAN DER VLERK and FLORSCHÜTZ, 1950), whereas the Salland-interstadial itself knew a "temperate flora". This knowledge is of great importance, since now we can per definitionem include all deposits above the Eemian, and providing extreme cold pollen-spectra, in the Pleni-glacial (see Introduction). For the Late-glacial begins, also per definitionem, there where the first signs of an amelioration in climate appear at the end of the Pleni-glacial. (A possible sub-arctic interstadial in the Pleni-glacial cannot trouble us here, since the continuation of the Late-glacial shows a very characteristical development in vegetation that cannot be confounded with others. Furthermore, above such an interstadial extreme "cold" spectra should follow once more.)

The Pleni-glacial material we worked on, results for the greater part from borings and was also collected in pits. The boring-samples of diagrams XVIII and XIX were collected untouched during deeper borings carried out especially for the purpose of palaeobotanical and sedimentological research by the Dutch Geological Survey. The samples of diagram XVII were collected during a deeper boring, carried out with a view to the supply of drinking water, and they were put at our disposal by the "Rijks Instituut voor Drinkwatervoorziening".

Review of the diagrams.

For names of places of the diagrams see the Table, Fig. 1. All the material was very poor in pollen, so that it was impossible to count a larger number of grains within a reasonable period of time.

Diagram XV, Apeldoorn (Province of Gelderland).

Pollensum: 200.

Research has been carried out on 3 small "peat"-layers at a depth of respectively 460—465 cm, 370—390 cm and 270—290 cm below the surface. These small layers were exposed during diggings carried out for the construction of an installation for water-purification, slightly North of Apeldoorn. The material consisted of fine vegetal detritus mixed with loam, in some places more resembling peat, and also containing macroscopical remains of *Betula nana, Cyperaceae* and *Hypnaceae*.

Whereas nearly all spectra show a very cold picture, this seems not to be the case with spectra 7 and 9, since the birch is here more or less strongly represented. However on the spot where these samples were taken, leaves and twigs of *Betula nana* were found in considerable quantities. Since also all the *Betula*-pollen in these samples was of the *Betula nana* type (as to the possibility of determination of this pollen see Chapter III), and the

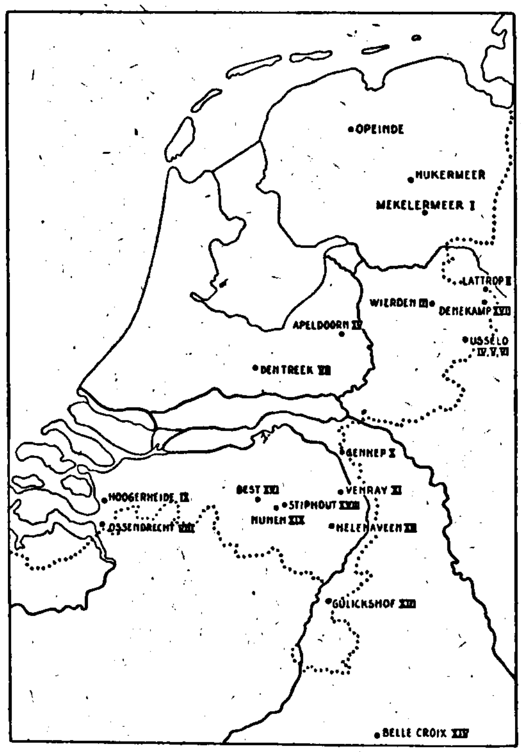


Fig. 1.

more so as in sample 7 the pollen-grains in the preparation were still assembled in large clusters, we certainly are confronted here with the influence of a local vegetation of *Betula nana*. As far as this is concerned therefore, the diagram presents an entirely erroneous picture. The same argument might of course be advanced in the case of *Cyperaceae* in the other spectra, but our experience taught us (Late-glacial *Cyperaceae*-peat is always easy to recognise; see also the spectra of the recent samples from Lapland) that a local *Cyperaceae*-vegetation in a forrested, or partly forrested region can raise the herb-percentage but can never let it dominate completely. Also the low *Artemisia*-percentages (we shall revert to this fact later on), the whole picture given by the diagram and the geological circumstances (see the Geological Part), show that we certainly have to place this material in the Pleni-glacial. *Plantago* is fairly well represented and also *Helianthemum* is occurring (see also diagram XVI, Best). In sample 6 a grain of *Sanguisorba officinalis* was found (see Chapter III). The high percentages of *Selaginella* in the bottom layer (up to 100 %!) are interesting. The macro-botanical content of this "tundra-peat" is discussed below.

Diagram XVI, Best (Province of Noord-Brabant).

Pollensum: 200.

The material for this diagram was collected in 1947 in an exposure intended for barracks on the Best Heath, and put at our disposal by Prof. FLORSCHÜTZ and Prof. VAN DER VLERK. The complete profile visible in this pit was as follows (depths in meters below the surface):

0.00—2.40	fine sand.
2.40—2.95	gray loam (loess). (From 2.65—2.75 also a slightly humus containing thin layer of loam).
2.95—3.05	loam, strongly mixed with "detritus".
3.05—4.20	grey loam (loess).

The border-level between sand and loam was kryoturbate, as well as the loam layer containing "detritus" ("Wannenboden").

At 2.90 m the following skeleton parts of mammals were found:

a tusk of *Mammonteus primigenius.*

a tooth and part of a tibia of *Coelodonta antiquitatis.*

(Determination Prof. Dr I. M. VAN DER VLERK.)

Apparently the material of the undermost five samples was deposited in a small lake in a loess region; especially sample 2, in the layer containing a comparatively large quantity of detritus, shows high percentages of *Myriophyllum* and *Batrachium.* The deposit of loess continued uninterruptedly and mixed with the vegetal detritus that was deposited in the lake simultaneously. Probably, the lake was nearly completely filled during the deposit of the topmost samples (6, 7 and 8) and was covered with loess in which no pollen of waterplants are found any more. Also the absence of *Pediastrum* in the topmost samples is an indication hereof.

Part A of the diagram shows clearly that the material must have been deposited in a completely treeless landscape. Percentages of herb-pollen are between about 90 and 95 %! Amongst the herbs, the *Cyperaceae* dominate strongly, then follow the *Gramineae.* The *Ericales*-percentage is rather low. *Artemisia* is represented, in the bottom sample by as much as 6 %. It is highly probable that this plant was indeed occurring in this region, perhaps especially on sheltered spots. Represented are also, by rather low percentages in general: *Plantago, Helianthemum, Caryophyllaceae, Cruciferae, Selaginella selaginoides, Sphagnum* and *Equisetum.*

The Tubantian age of this deposit appears from the find of skeleton parts of *Coelodonta antiquitatis* according to VAN DER VLERK, characteristical for the Tubantian in Holland (VAN DER VLERK and FLORSCHÜTZ, 1950). This type of loess-deposits is quite frequent in other parts (in fairly thick layers) of Noord-Brabant as well, and, as a result of research still in course in the pollenanalytical and sedimentological fields, undertaken, by some scientists, it has also become probable that a large part of these deposits in any case belong to the Tubantian.

Diagram XVIII, boring Stiphout (Province of Noord-Brabant).

Pollensum: 200 (Sample 5: 350).

This diagram was made in connection with the research mentioned above and still being carried out. Here too, the deposit just as in Best, consists of loess with layers containing vegetal detritus. Near the spot where the boring was carried out, there was a loam pit, where the loess with the two topmost small layers containing detritus, locally "kryoturbate", was exposed (Phot. 3 and 4). These layers containing detritus (the loess itself was as good as sterile) gave a pollen-analytical picture that, except for the water-plants, entirely tallies with that of Best. Here too, a complete domination of herbaceous pollen in which the *Cyperaceae* play the predominant role.

As to the Tubantian age of this material we refer to what we mentioned on the subject in treating the Best-diagram.

Diagram XIX, boring Nunen (Province of Noord-Brabant).

Pollensum: 150.

This diagram also shows exactly the same picture as the two preceding ones. Here, at the depth of about 450 cm, there is a thin peat-layer inserted in the loess-containing detritus. In samples 3 and 4 the *Gramineae* are dominating. Here too, in sample 2, *Artemisia* is represented by a few percent (about 3 %), rendering it probable that this plant really occurred at the time of the deposit of this material. The percentage of secondary pollen (in sample 6 also *Tsuga*) is rather high in most of the samples. (In the small peat-layer, however, it is lacking nearly entirely). It should be taken into consideration that, in drawing a tree-pollen diagram in which this secondary pollen is included a completely erroneous picture will be obtained.

Diagram XVII, boring Denekamp (Province of Overijssel).

Pollensum: 200.

In this boring the (Saale-glacial) boulder-clay is situated at a depth of about 40 m. During borings for drinkwater-supply, as was the case here, the samples are generally taken as soon as new material is reached, therefore from the top of the layer in question. The peat-samples therefore, from the two thick bottom peat-layers will probably have been taken from the top of each of these layers. It is therefore not impossible that the bottom-spectrum dates from the top of the Eemian and the one above that, from the topmost part of the Salland-interstadial. However this cannot be said with certainty on the basis of those two spectra. These two relatively "warm" spectra do prove however, that the extremely "cold" spectra situated above them must be placed in the Pleni-glacial (Middle Tubantian). These spectra show again exactly the same picture as those of the diagrams mentioned above.

Diagram XXI (topmost spectrum) Almelo (Province of Overijssel).

Pollensum: 170.

This spectrum is made of a thin loam-layer mixed with vegetal detritus near Wierden (in the vicinity of Almelo) at a depth of about 5 m below the surface. In this layer a tooth of *Mammonteus primigenius* was found. In the same pit, dug for the construction of a canal, remains of a Dryas-flora with steppe-plants were found, by FLORSCHÜTZ, at a depth of 6 m.

This spectrum again tallies completely with the spectra of the diagrams discussed above. Here follow a few other data, not mentioned in diagram XXI.

Gramineae 9.5 %; *Cyperaceae* 79.5 %; *Artemisia* ×; *Selaginella sel.* ×; *Sphagnum* ×.

Phot. 3.
Humus containing layers in loess. Middle-Tubantian (Pleni-glacial). Loam-pit near Stiphout (Prov. of Noord-Brabant). Height of the profile about 2 m.

Phot. 4.
Humus containing layer (slightly "kryoturbate") in loess. Middle Tubantian (Pleni-glacial). Loam-pit near Stiphout (Prov. of Noord-Brabant).

Macrobotanical contents of the "Tundra-Peat".

Near Apeldoorn (Deventer brug) a number of samples were taken for macro-botanical research from three super-imposed peat-layers of the same age as those of diagram XV. This gave the following results:

Toplayer:

Selaginella selaginoides.
Selaginella cf. *helvetica.*
Carex sp. div.
Comarum palustre.
Cenococcum geophilum.
Calliergonella cuspidata.

Sand under the toplayer:

Carex sp. div.
Cenococcum geophilum.
Betula nana (leaves, twigs).
Drepanocladus cf. *revolvens.*
Campylium protensum.
Campylium stellatum.

Middle layer:

Caryophyllaceae,
(cf. *Stellaria* and *Silene*).
Comarum palustre.
Oenanthe.
Potamogeton sp.
Hippuris vulgaris.
Selaginella selaginoides.
S. helvetica.
Carex sp. div.
Campylium polyganum.
Drepanocladus fluitans.
D. revolvens.
D. lycopodioides.
Calliergon cordifolium.
C. sarmentosum.

Bottom layer:

Menyanthes trifoliata.
Comarum palustre.
Carex sp. div.
Drepanocladus intermedius.
D. cf. *lycopodioides.*
Calliergon giganteum.
Scorpidium scorpioides.

One might say with some reserve that the topmost layer indicates a slightly acid or neutral fen, the middle-layer a wet, circumneutral fen and the bottom-layer a neutral or slightly alkaline fen.

Also the peat-layers of diagram XV were examined as to their contents of mosses. This investigation brought to light the following species (determination Mr W. MEYER):

Aulacomnium palustre.
Brachythecium mildeanum cf. var. *udum.*

In the narrow moss-layer in the loess near Nunen, the following species were found (determination Mr W. MEYER) at a depth of about 4.5 m (Diagram XIX):

Calliergon richardsonii.
Drepanocladus cf. *revolvens.*
Drepanocladus vernicosus.

Concerning the species mentioned above, the following can be added.
Auacomnium palustre is to be found up to about 2500 m in the Alps and up to the regio alpina in Scandinavia; also in Greenland.

Calliergon richardsonii is (sub-)arctic-alpine. From North-Scandinavia down to Sleswick-Holstein. Is no longer found in Holland. Also in England only found as a sub-fossil.

Drepanocladus vernicosus occurs in the mountains up to over 2000 m.

Brachythecium mildeanum var. *udum* is an arctic-alpine variety. On sandy, wet places.

Campylium polyganum is to be found up to Siberia, Greenland and Spitzbergen. In Holland especially in wet dells in the dunes.

The Dryas-flora.

We mentioned already above that the Dryas-flora of Wierden was situated slightly below a thin layer that, according to the pollenanalytical dating, has to be placed in the Pleni-glacial. (We are mentioning already in passing that finds of a Dryas-flora from the Late-glacial are unknown in Holland.) The two Dryas-floras of Hengelo (VAN DER VLERK and FLORSCHÜTZ, 1950) are situated above the Salland-interstadial; they can neither be Late-glacial and will therefore have to be placed in the Pleni-glacial (Middle Tubantian). We think it possible, that all finds of a Dryas flora, made in Holland up till now, belong in the Pleni-glacial. The fossil Dryas-flora, according to FLORSCHÜTZ (i. a. VAN DER VLERK & FLORSCHÜTZ, 1950), often shows a mixed character (arctic-alpine-, sub-arctic-, pontic-pannonic-, and temperate species). The solution of the problem of this mixed flora has not yet been found. It is possible that secondary elements (originating from older deposits) occur in this fossil flora.

Vegetation and climate.

With the help of the data discussed above, one can try and form a picture of vegetation and climate during the Pleni-glacial.

In the first place we can establish that the landscape, during a great part of that period, must have been arctic and completely treeless. In the river plains and in the plains between the hill-ridges, there must have been a great number of *Hypnaceae-Cyperaceae* fens and small lakes in old river beds and gullies, formed by the snow-melting-water. In the formation of these fens the tjäle should certainly have played an important part. In-between there must have been rather large surfaces without any vegetation or only sparsely overgrown (in this context see also the Geological Part).

Leaves of Dryas and of small-leaved willows were frequently found in deposits from the Pleni-glacial, but then often washed together in small "basins" in snow-melting-water deposits. It would seem possible that the "dry" elements of the "Dryas-flora" may have grown essentially on the higher parts, in this case, on the hills (having often a richer soil) and that the small leaves, together with the snow-melting-water arrived in the deposits of the valley-plains. This could then explain the absence of Dryas-finds in the relatively flat region of the Province of Noord-Brabant. However, nothing definite can be stated on the subject.

During a great part of the Pleni-glacial (during which the analysed peat in Noord-Brabant, Twente and Apeldoorn was deposited) the vegetation must have been, apart from treeless, very poor, compared with that of the Late-glacial. We draw this conclusion on the ground of a comparison of the pollen contents of the deposits concerned.) However, investigations of the macro-fossils of the Dutch "Dryas-flora" yielded a considerable list of species or genera. But in our opinion one must not loose sight of the circumstance that macro-fossil- and micro-fossil floras are not well comparable. A typical plant, often represented by rather high pollen-percentages in the Late-glacial, *Artemisia*, does occur in the Pleni-glacial, but only with a relatively low percentage. These low percentages will probably have been caused by, in comparison with the Late-glacial, extremely cold climate, as most species of *Artemisia* make relatively high demands as to the climate

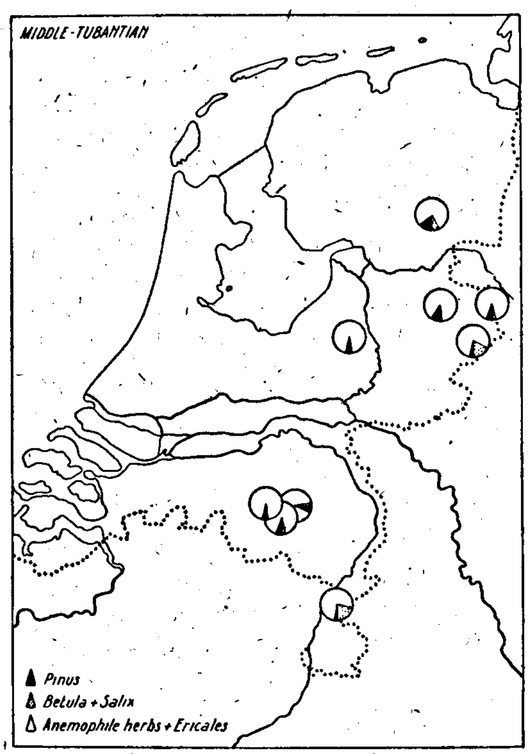


Fig. 2.

(some subspecies however occur in the arctic tundra). In some danish pollen-diagrams from Jutland, where the Allerød-oscillation is represented by a park-landscape, and the Older Dryas- and Late Dryas-time by a tundra, *Artemisia* also seems so react in the same way upon the climate, as it shows relatively high percentages in the Allerød-deposits. Of the other "Late-glacial plants", only *Helianthemum* is actually found fairly regularly and furthermore also *Plantago* sometimes, but the percentages are often low. *Juniperus* too, is nearly completely absent as well as *Salix*. As far as the latter is concerned, the small-leaved willows apparently disperse but a relatively low amount of pollen and here, possibly, their manner of growth plays an important part. This should also be compared with sample 1 of diagram XX (recent surface-samples from Lapland), where the *Salix*-percentage in the Middle Alpine Belt is also low; in other respects too, this spectrum has a striking resemblance to the spectra from the Pleni-glacial.

The low *Artemisia*-percentages might, of course, also have been caused by a, with regard to the Late-glacial, more oceanic climate. This however is extremely unlikely, on geological-geographical grounds.

Summarising, we can therefore say that, during a great part of the Pleni-glacial, an arctic climate must have prevailed, causing an entirely treeless and, in comparison with the Late-glacial, poor vegetation. The great aeolian movement of material is also making it very likely that vegetation was very scarce in large regions. It may be possible that there was a distinct difference between the flora on the slopes of the hills (realatively dry and rich; Dryas-flora) and that of the plains situated below (*Hypnaceae-Cyperaceae*-fens).

Fig. 2 is giving a pollenspectra-map for a great part of the Pleni-glacial.

CHAPTER II.

THE BOUNDARY PLENI-GLACIAL — LATE-GLACIAL.

It has already been expounded in the Introduction what principles guided us in framing a stratigraphy on palaeontological basis. In order to do so, a new definition of the notion Late-glacial was necessary. In this definition the beginning of the Late-glacial was determined: there, where after the immediately preceding cold of the Pleni-glacial, the first clear signs of an amelioration of the climate appear. It will therefore be necessary now to further define this boundary on the basis of pollenanalytical data. As also already set forth in the Introduction, in order to define such an, approximately synchronic, boundary over a larger region, only changes in the relations of already present vegetation-components may be used as a basis. Consequently, in the case of transition of an entirely tree-less arctic vegetation (*Betula nana* was present!) into a sub-arctic park-landscape, the immigration of the first large birches (therefore the passing of the tree-line) is unsuitable to function as a boundary. For, in various regions the period between the amelioration of the climate and the immigration may vary in length and consequently, such a limit is not synchronical either.

It will therefore be necessary to look in the diagrams for an indication for amelioration of the climate lying below the point of immigration of the first large birches. This we believe we have now found. To wit, in diagrams dating back far enough, a clear change in the course of the *Artemisia*-curve becomes apparent, somewhere below the Bølling-oscillation. Here this curve rises from the low values, shown at the bottom of the diagram, to values characteristically high for the Older Dryas-time. As appeared in the preceding Chapter, the *Artemisia*-curve is low in the Pleni-glacial diagrams and spectra, and may even drop to zero. There are, however, spectra with somewhat higher values e. g. in Diagram XIX 3 % and in Diagram XVI 6 %. These higher values, appearing incidentally, indicate that *Artemisia*, although mostly in small quantities, was actually represented in the vegetation. This presence, in our opinion, is sufficient to make the *Artemisia*-rise into a valuable limit. For although *Artemisia* could flourish very well in the cold of the Late-glacial (it even survives the cold between Bølling and Allerød without a loss in percentage), this genus, taken as a whole, is a relatively thermophile one, and the extreme cold of a great part of the Pleni-glacial was comparatively unfavourable to it.

From the above it follows that the *Artemisia*-rise permits us to establish approximately synchronical boundaries, and that this must be point where first amelioration of climate appears. The *Artemisia*-rise therefore provides us with the boundary Pleni-glacial—Late-glacial.

Now this has been establishhed, one can naturally try and find out whether this limit can be correlated in one way or another with the stages of retreat of the land-ice. In order to find this out, investigations should be made to see to what extent the *Artemisia*-rise is still apparent at the bottom of the Late-glacial diagrams, lying between the various moraines of the stages of retreat. Unfortunately however, we are unable at this moment, to state much on that subject. In the diagram of Bølling-Sø (IVERSEN, 1947), lying entirely on the outside of the zone of the extreme ice-fringe in Jutland, the *Artemisia*-rise is visible. A diagram of Akkerup Mose on Fyn (IVERSEN, 1947), however, starts at the bottom already with high *Artemisia*-percentages. As the diagram does not, however, continue completely down to the boulder-clay (the undermost part of the Older Dryas-loam was not analysed), we are unfortunately unable to draw precise conclusions from this fact. However, new data from Denmark and Northern Germany will probably throw more light on this matter in the future.

CHAPTER III.

VEGETATION AND CLIMATE DURING THE LATE-GLACIAL

(Upper Tubantian).

The Late-glacial zone system.

As already mentioned in the Introduction, the Late-glacial zone system, as it was established in Denmark by JESSEN (1935) and IVERSEN (1942), can also be applied to the dutch Late-glacial diagrams. It reads as follows:

	IV	Preboreal	
Late-glacial	III	Late Dryas-time	
	II	Allerød-oscillation	
	Ic	Earlier Dryas-time	Older Dryas-time
	Ib	Bølling-oscillation	
	Ia	Earliest Dryas-time	

It was IVERSEN (i. a. 1947), who subdivided Zone I into a, b, and c, when he found in his Diagram of Bølling-Sø, below the Allerød-oscillation, another smaller oscillation of climate, appearing in a higher percentage of tree-pollen and in a modification in sedimentation (less minerogene). Since doubts have been voiced from time to time as to the existance of a Late-glacial oscillation (or of immigration of large birches) already previous to the Allerød-oscillation, we shall advance in Chapter IV our arguments and proofs for the existence of the Bølling-oscillation in full.

We insist here once more on the fact that in Holland leaves of *Dryas*, or of other typical tundra-plants, have never been found in Late-glacial deposits; we therefore only use the names mentioned above in a purely stratigraphical sense.

As we exposed in Chapter II, the beginning of the Late-glacial lies at the *Artemisia*-rise.

This occurrence cannot be, in North-Western Europe in any case, but approximately synchronical. On the other hand, the bottom-limit of the Bølling-oscillation, appearing in the diagram in an increase of the tree-pollen, is not synchronical. The change in sedimentation does not have a synchronical limit either, as a lower minerogene component may also depend directly on presence or absence of trees (by which a smaller supply of minerogene material, in casu by the wind, will be caused). If therefore all limits of subdivisions of the Zones would also be based on climatological changes only, the bottom-limit of Zone Ib would have to be established at the *Artemisia*-rise. Zone Ia therefore would then be included in the Pleni-glacial and would no longer belong to the Late-glacial.

For practical reasons, however, and because the original division by IVERSEN is based on the increase of the *Betula*-pollen, we prefer to consider the zone between the *Artemisia*-rise and the immigration of the first large birches as belonging to Zone Ia.

Zone Ia, therefore, is Late-glacial and is the period interposed between the first amelioration of climate and the immigration of the first large birches. This diagram-zone might therefore not appear for instance in more southerly situated regions of Europe. It should therefore never be forgotten that although the bottom-limit of Zone Ia is synchronical, its top-limit is not.

Likewise, the top limit of Zone Ib is synchronical, but not its bottom limit. We find an analogy with Zone IV, as this apparently may not occur at all in more southerly regions, because of early immigration and expansion of thermophiles. Consequently the top-limit of the Late Dryas-time is therefore approximately synchronical here, but not the top-limit of the Preboreal.

In summarising we can therefore say that we are placing the total of Zone I in the Late-glacial and that we are maintaining also the subdivisions into Ia and Ib, on the ground of a practical zonation in the diagram.

In doing this however, it should never be forgotten that the bottom limit of Zone Ia, the top limit of Zone Ib and the top limit of Zone Ic are indeed approximately synchronical in various regions of Europe, but that this is not the case with the bottom limit of Zone Ib.

Likewise, the top limit of Zone III is approximately synchronical, but not always that of Zone IV.

Although this sometimes will yield practical difficulties, yet geological limits will exclusively have to be based on synchronical Zone-limits and consequently zone Ia + Ib will have to be considered as a whole.

List of pollenanalytically established Late-glacial species, genera, groups of genera or families.

In the case the name of a family is mentioned and also that of a genus or a group of genera of that family, this implies that other pollen-types of that family, that could not be determined up to the genus or that group, were also found.

Alisma
Alnus cf. *viridis*
Angelica type
cf. *Arctostaphylos*
Armeria vulgaris
Artemisia
Batrachium
Betula
Botrychium lunaria
Calluna vulgaris
Campanula
Caryophyllaceae
Centaurea cyanus
Chenopodiaceae
Cirsium
Comarum type
Compositae
Cornus
Cruciferae
Cyperaceae
(*Dryas* type)
Dryopteris felix-mas
Dryopteris linnaeana
Dryopteris thelypteris
Empetrum cf. *hermaphroditum*
Empetrum cf. *nigrum*
Epilobium angustifolium
Equisetum
Filipendula
Galium type
Gramineae
Helianthemum cf. *nummularium*
Helianthemum cf. *oelandicum*
Hippophaë
Hippuris vulgaris
Isoëtes

Jasione
Juniperus
Labiatae
Liguliflorae
Litorella
Lychnis type
Lycopodium selago
Lycopodium sp.
Lycopus type
Mentha type
Menyanthes
Myriophyllum alterniflorum type
Myriophyllum spicatum type
Nuphar
Nymphaea
Ophioglossum
Oxyria type
Parnassia
Pinus
(*Plantago* cf. *alpina*)
(*Plantago lanceolata*)
Plantago cf. *maritima*
Plantago cf. *media*
(*Plantago* cf. *montana*)
Potamogeton
Polygonum bistorta type
Populus
Potentilla type
Ranunculaceae
Rosaceae
Rubiaceae
Rubus chamaemorus
Rumex acetosa or *acetosella*
Salix
Sanguisorba minor
Sanguisorba officinalis
cf. *Saussurea*
cf. *Selaginella helvetica*
Selaginella selaginoides
Sparganium
Sphagnum
Stellaria type
Succisa
Thalictrum
Tubuliflorae
Typha angustifolia
Typha latifolia
Ubelliferae
Urtica dioeca
Utricularia
Vaccinium type
Valeriana

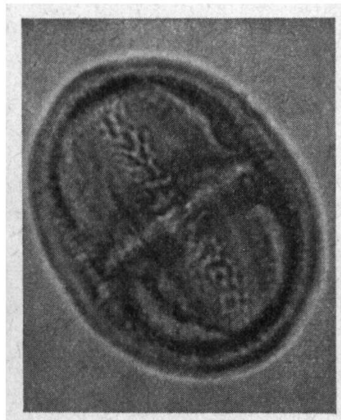
Remarks concerning a few of the plants established pollenanalytically.

We shall confine ourselves here to a few remarks only. Only in the case of finds of important pollen-grains, remarks concerning the morphology of the pollen have been added. As to the morphology of the pollen in general we are referring to the literature on this subject (i. a. ERDTMAN, 1943, and FAEGRI and IVERSEN, 1950).

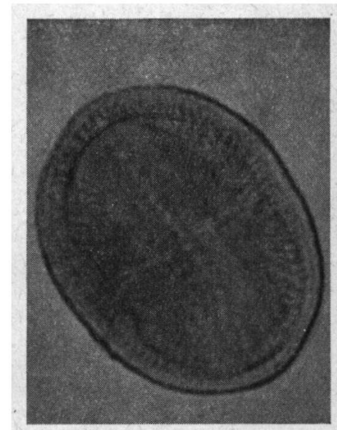
Betula. Unfortunately the pollen of *Betula nana* cannot be distinguished clearly from that of the large birches. A difference in size that can be statistically proven does however exist. But it is possible, without statistical research, to form an idea, on the basis of the difference in size and of the type of the grains found, whether there is an important influence of *Betula nana*-pollen or not. And this, in our opinion, is even very feasible when carrying on research on the development of a treeless region into e. g. a subarctic park-landscape. For we found that in all diagrams showing a completely developed Zone I, the samples below the Bølling-oscillation yielded nearly exclusively pollen of the *Betula nana* type, whereas only at the beginning of Zone Ib these are accompanied by larger pollen-grains as well (of large birches), and that the latter are disappearing again for the greater part in Zone Ic.

The local influence of *Betula nana* may, in a fen, be sometimes very important (compare diagram XV), whereas also, in a lake-deposit (on account of the shore-vegetation) its influence may sometimes still be rather important (compare the bottom of diagram XIII and the map with Pleni-glacial spectra, fig. 2).

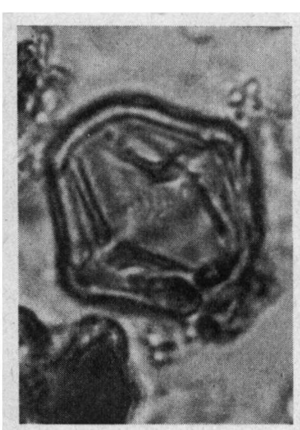
Phot. 5.



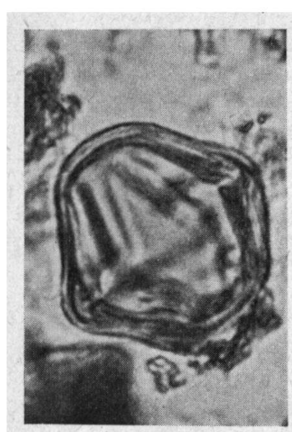
Phot. 6 a.



Phot. 6 b.



Phot. 7 a.



Phot. 7 b.

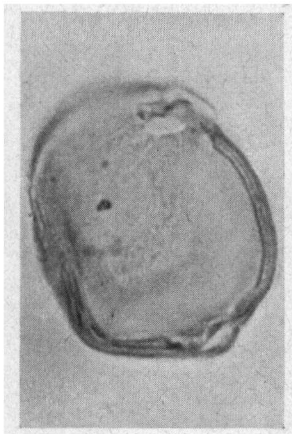
Phot. 8.

Phot. 5. *Centaurea cyanus.* Pollen-grain from the Preboreal. Belle Croix (Hautes Fagnes, Belgium). Enlargement about 1100 ×.

Phot. 6 a, b. *Centaurea cyanus.* Pollen-grain from the Allerød-oscillation. Wierden (Prov. of Overijssel). Enlargement 1000 ×.

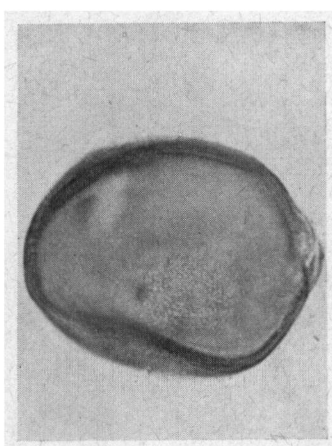
Phot. 7 a, b. *Sanguisorba officinalis,* Pollen-grain from the Older Dryas-time. Usselo (Prov. of Overijssel). Equatorial view. Enlargement 1000 ×.

Phot. 8. *Sanguisorba officinalis.* Pollen-grain from the Allerød-oscillation. Wierden (Prov. of Overijssel). Polar view. Enlargement 1000 ×.

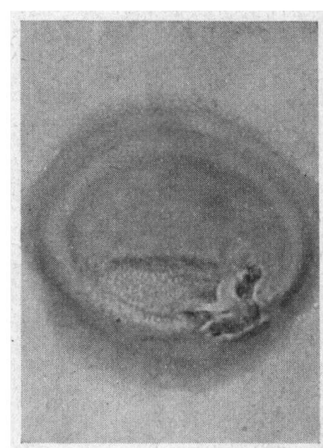


Phot. 9 a.

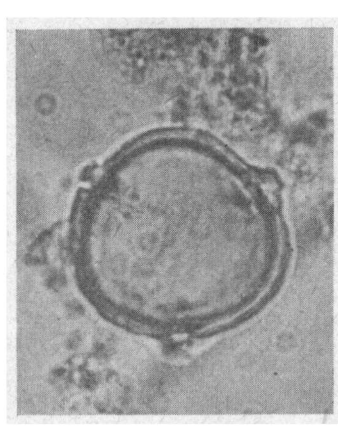
Phot. 9 b.



Phot. 9 c.



Phot. 9 d.



Phot. 10.

Phot. 9 a, b. *Sanguisorba minor.* Pollen-grain from the Older Dryas-time. Hijkermeer
c, d. (Drente). Enlargement 1000 ×. Photo D. G. U.

Phot. 10. *Sanguisorba minor.* Pollen-grain from the Older Dryas-time. Mekelermeer (Drente). Enlargement about 830 ×.

Plantago. Part of the grains were of the *Plantago maritima*-type, a few also of the *Plantago media*-type. On one occasion a grain of *Plantago lanceolata* was found in a lime-gyttja of Markelo (Province of Overijssel), dating from the Allerød-time (diagram not published here). Very frequently however, especially in the South, pollen-grains of other types were found. It now appeared that part of these grains resembled very closely those of *Plantago montana* (grains large; pores very indistinct, could not be counted; sculpture clear). A few others resembled very closely *Plantago alpina* (pores approximately 7—11, fairly large, clear and with a somewhat protruding annulus; sculpture clear). We might therefore have found here a few alpine elements in the Late-glacial flora, which, in that case, must have played a more or less important part in the South of the Netherlands.

Helianthemum. Most of the pollen-grains of *Helianthemum* found by us, tally with the grains found by IVERSEN in danish Late-glacial deposits and determined by him as *H.* cf. *oelandicum* (IVERSEN, 1940). Some of them do also closely resemble those of *H. nummularium.*

We also found a few grains (especially in the Pleni-glacial deposits) that were smaller and therefore more resembled those of *H. alpestris.*

Rumex. All curves for *Rumex* are based on the *acetosa-acetosella*-type. According to IVERSEN (oral information) those two species can be distinguished according to the relative length of the colpae (or according to the varying size of polar area index). *Rumex acetosa* has short furrows and *Rumex acetosella* long ones. The greater part of the grains found by us in Late-glacial deposits, seems to have relatively long furrows (therefore a relatively small polar area).

Empetrum. By far the greatest number of grains tally with those of *Empetrum nigrum.* Sometimes however, larger grains were also found tallying with those of *E. hermaphroditum.*

Calluna vulgaris. These grains were mainly found in samples from the end of the Allerød-time, and also in samples from the Late Dryas-time.

Sanguisorba minor. A first find has already been published (VAN DER HAMMEN, 1949). Since then we have made a fairly large amount of new finds, coming for the greater part from the Older Dryas-time and from the beginning of the Allerød-time (Phot. 9). As to further data, see VAN DER HAMMEN & IVERSEN, 1951.

Sanguisorba officinalis. This species was determined for us by Dr. IVERSEN with the help of a drawing we sent him. Later we were able, aided by recent material for comparison, to check all our finds.

S. officinalis was especially found in samples from the Older Dryas-time, but also regularly in samples from the Allerød- and Late Dryas-time (Phot. 7 and 8). As to further data, see VAN DER HAMMEN & IVERSEN, 1951.

Centaurea cyanus. We found two grains of the corn-flower in a sample from the Preboreal (Diagram XIV, Belle Croix) and one grain in a sample from the beginning of the Allerød-time (diagram III, Wierden). (Phot. 5 and 6).

IVERSEN (1947) mentioned for the first time the find of three *Centaurea cyanus*-grains in danish Late-glacial deposits.

It seems now to be certain, that *C. cyanus* belongs to the Late-glacial flora.

Polygonum bistorta type. P. viviparum also belongs to this type (HEDBERG, 1946).

Parnassia. Grains thereof were found by us fairly frequently in all Zones of the Late-glacial.

cf. *Selaginella helvetica.* A few micro-spores were found, resembling very closely those of *S. helvetica.* The occurrence of this plant in the dutch "Dryas-flora" has already been proved by the finding of macro-spores (VAN DER VLERK and FLORSCHÜTZ, 1950).

Description of the diagrams.

For the names of the places of the diagrams the map, fig. 1, should be consulted. Long descriptions have always been avoided and only the facts that seemed most important have been mentioned. For the rest the diagrams may speak for themselves. A summary of the results is given at the end of this chapter.

Diagram Hijkermeer (Province of Drente).

See for this diagram: VAN DER HAMMEN, 1949.

Diagram I, Mekelermeer (Province of Drente).

Pollensum: 400—600.

The profile was bored with the "Dachnovski-auger" in the extreme border of the marginal vegetation-zone of the lake (Phot. 1). On the bottom, an alternation of small layers of loam and of loamy sand was found that recalls the alternation of small layers of the Older driftsand (see Chapter VII).

In the undermost samples, a fairly large amount of secondary pollen was found (see bottom right of the diagram). Among the "Tertiary types" there are i. a.: *Sequoia*, *Pterocarya*, *Tsuga* and *Carya*. The diagram resembles closely that of the Hijkermeer (VAN DER HAMMEN, 1949).

The *Artemisia*-rise, although not very pronounced in this diagram, lies between samples 2 and 3. The Bølling-oscillation occurs, although not as clearly as in the Hijkermeer, and the boundary between Zone Ic and Zone II is not so clear as that in the Hijkermeer-diagram. Zone II starts with a *Betula*-time.

The *Empetrum*-curve again reaches very high values in Zone III, while the Preboreal starts with a *Betula-time*, without thermophile trees. It is not excluded that the pine was completely absent here during the Late Dryas-time. The low *Pinus*-values (10—15 %; see Introduction) might indicate this, as well as the fact that the Preboreal starts with a *Betula*-time. *Salix* and *Juniperus* are represented by relatively high percentages at the end of Zone Ib and at the beginning of Zone Ic.

Potamogeton: High values in Zone I. *Isoëtes:* high values in Zones II and IV. Undoubtedly, the fact whether the lake was eutrophic or not (connected with the supply of minerogene material) will play a part in these ratios. Whether the absence of *Isoëtes* in Zone III is caused by the fact that the water was eutrophic or by the climatological deterioration, is difficult to say. Possibly both factors played a role here.

A few grains of *Parnassia* were found in samples 2, 3, and 5. We are giving in this diagram a curve for *Populus* (see also diagram XII), showing somewhat higher values in the Preboreal.

Diagram II, Lattrop (Bergvennen) (Province of Overijssel) (Phot. 2).

Pollensum: 200—300 (sample 7, 13 and 14:400).

The profile was bored in a fen partially filled up with peat. The diagram begins in Zone Ib. The *Empetrum*-expansion begins already very early in Zone II, just as it appears from other diagrams from Twente (Diagrams IV, V and VI).

It is very likely that the high *Empetrum*-percentages in Zone II originate from the undergrowth of the pine-birch-forests (see Introduction). The Preboreal begins with pinewoods. In the first Preboreal spectrum the first grains of thermophile trees were also found already. (Q. M. 1 %; *Coryl.* 1 %; *Aln.* 1 %). The *Sphagnum*-percentages in Zones II and III are very high.

Diagram III, Wierden (Province of Overijssel).

Pollensum: 200—250.

The material was collected in an excavation for the construction of a canal (Phot. 41). For further information see Chapter VII. This diagram also begins with the Bølling-oscillation. Zone II shows a maximum of herbs in the middle. This is also the case in the diagram of Usselo and (less pronounced) in that of Lattrop. (For more information see the end of this chapter and Chapter IV).

The *Salix*-peak in sample 8 probably has to be attributed to local influences, as the material was deposited in a fossil brook-bed. Afterwards this brook-bed was filled up with peat, and was covered with sand during the Late Dryas-time. In making a second analysis of sample 4 from the beginning of the Allerød-time, we found a pollen-grain of *Centaurea cyanus* (Phot. 6). We have already, at the beginning of this chapter, given some information on this subject. We also found a pollen-grain of *Sanguisorba officinalis* during this same analysis.

Diagrams IV, V and VI, Usselo A, B and C (Province of Overijssel).

For the discussion of these diagrams see Chapter IV.

Diagram VII, den Treek (Province of Utrecht).

Pollensum: 200—350. Dating-diagram.

This diagram was made of a Late-glacial peat-layer (about 20 cm thick) covered by a few meters or coversand. The diagram shows clearly that this peat layer was deposited during the Allerød-time. It also appears that the covering over with sand started at the beginning of the Late Dryas-time. FLORSCHÜTZ (1939) published already previously a diagram of this same peat-layer, by which he established the Late-glacial age of this peat.

Diagram VIII, Ossendrecht (Province of Noord-Brabant).

Pollensum: 250—350. Dating-diagram.

This diagram was made of a thin layer of detritus, intercalated in coversand (Phot. 39). Sample-distance 2.5 cm. It is very clear here once more, that the covering with sand started during the Late Dryas-time. See further: NELSON & VAN DER HAMMEN, 1950.

Diagram IX, Hoogerheide (Province of Noord-Brabant).

Pollensum: 250—350. Dating-diagram.

Thin layer of detritus (about 10 cm) intercalated in coversand (Phot. 40).

Sample 6 originates from a thin layer containing humus (about 1 cm) in the coversand, about 60 cm above the detritus layer.

The high percentage of *Botrychium*-spores is striking.

See further: NELSON & VAN DER HAMMEN, 1950.

Diagram X, Gennep (Province of Limburg).

Pollensum: 350—450 (samples 10 and 11: 250).

This diagram begins with Zone III. Striking are the relatively low *Empetrum*-values. It is also striking that the first grains of thermophile trees already appear, when after the Late Dryas-time the percentage of herbs begins to diminish. When the herbs percentage has diminished until about 10 %, the *Corylus*-percentage has already risen to 7 %. There is no reason to assume here a hiatus in the deposit, or to think of pollution. Possibly the southerly situation plays a part here.

Diagram XI, Venray (Province of Limburg).

Pollensum: 200—350. Dating-diagram.

Peat-layer under largely 1 m of coversand. Also this sand-covered peat-layer was deposited in the Allerød-time. The deposition of sand starts at the beginning of the Late Dryas-time. Just as in Diagram X, the *Empetrum* values are low hére.

For the rest, the undermost spectra from the peat may have been influenced locally, since here and there pieces of wood of the birch appeared in them. This explains probably the low *Pinus*-values.

Diagram XII, Helenaveen (Province of Noord-Brabant).

Pollensum: 400—600.

This material, situated at the basis of the peat covering this region was bored with the aid of the "Dachnovsky-auger". ESHUIS (1946) published a diagram of a spot not far from the one we chose.

The undermost spectra just show the transition of Zone I into Zone II. The Allerød-time begins here with a birch-forest-phase with still relatively high *Artemisia*-values. The *Empetrum*-values in Zone III are relatively low. The expansion of the thermophile trees occurs very early here, just as in diagram X. Consequently, the Preboreal birch-pine-forest-time is actually lacking completely. We shall come back to this remarkable fact later on in this chapter. In this diagram we are also giving a curve for *Populus* that appears here mainly in the Allerød-time.

Just as in other diagrams, the *Sphagnum*-expansion begins in the top part of Zone II and continues in Zone III.

Diagram XIII, Gulickshof (near Susteren) (Province of Limburg).

Pollensum: 300—450.

East of Susteren there is a relatively large area with lime-gyttja, covered with a small layer of peat. From this lime-gyttja we collected a profile by means of the "Dachnovski-auger". FLORSCHÜTZ (1941) published a diagram of the same spot. This diagram, however, differs from ours through the presence of a relatively large amount of *Corylus* in all samples. We are unable to furnish a precise explanation for this difference. Below 290 cm a small loam-layer was found, containing no pollen at all.

The greatest surprise was the fact that this diagram showed a very clear Bølling-oscillation. Above the Bølling-oscillation the diagram shows (Zone Ic), notwithstanding the southerly situation, a high peak of herbs. After that follows a fairly gradual decrease of the pollen of herbs, so that it is difficult to establish the limit between Zone Ic and Zone II. This will have to be put somewhere between sample 18 and sample 26. In Diagram I (Mekelermeer) there was also a transition-zone between the high herbs peak of Zone Ic and the Allerød-time, although there the limit was still fairly clear.

The *Pinus*-percentage in Zone II is relatively low, in spite of the southerly situation. *Empetrum* is, just as in the other diagrams from the South-Eastern Netherlands, represented in Zone III by relatively low percentages only. Unfortunately, the peat lying on top of the lime-gyttja was much younger so that here we are unable to follow the developement of vegetation into the Preboreal. The topmost layer of the lime-gyttja, on the other hand, allows us to presume that the end of the Late Dryas-time was already drawing near.

Diagram XIV, Belle Croix (Hautes Fagnes, Belgium).

Pollensum: 500—700.

The material for this diagram was bored in one of the many "viviers" of the Hautes Fagnes Plateau, at an altitude of 550 m above sea lèvel. This great altitude does not allow to compare this diagram without comment with the Dutch diagrams, since e. g. the maxima of herbs are bound to be much higher than could be expected on the ground of the more southerly situation. The undermost samples containing higher percentages of herbs may still belong to Zone III. The *Empetrum*-percentage is very low (0,5 %). Zone III is followed by a relatively thick Preboreal zone, probably also caused by the great altitude, in which *Pinus* and *Betula* dominate alternatively. In sample 6 two pollen-grains of *Centaurea cyanus* were found (Phot. 5).

Macro-botanical contents of the Late-glacial deposits.

A cursory research into the macro-botanical fossils from the deposits near Usselo resulted in the following:

Early Dryas-time	Allerød-time	
Chara	*Chara*	Thin charcoal-layer.
Carex sp.	*Selaginella selaginoides*	
Scirpus sp.	*Pinus sylvestris* (cones, wood)	*Pinus* (charcoal)
Potamogeton sp.	*Betula* sp. (wood)	*Carex* sp.
	Carex sp.	*Scirpus* sp.
	Phragmites	*Potamogeton* sp.
	Menyanthes trifoliata	*Menyanthes trifoliata*
	Batrachium sp.	*Comarum palustre*
		Batrachium sp.
		Caryophyllaceae
		Empetrum cf. *nigrum*

Late Dryas-time
Selaginella selaginoides
Carex sp.
Potamogeton sp.
Hippuris vulgaris
Menyanthes trifoliata
Batrachium sp.
Empetrum cf. *nigrum*

Mr. W. MEYER determined a few mosses for us.

Near Usselo (profile B), *Scorpidium scorpioides* was found in the deposits from the Bølling-oscillation and the *Hypnaceae*-layer formed in the beginning of the Late Dryas-time, entirely consisted of *Campylium polyganum*.

Near Wierden (Diagram III) the following species were found in the deposits of the Allerød-time:

Calliergon giganteum
Scorpidium scorpioides
Campylium polyganum
Drepanocladus sp.

With some reserve one might say that these species indicate a neutral, or slightly alkaline fen. Especially *Campylium polyganum* is interesting. This species, occurring up to Siberia, Greenland and Spitzbergen, grows in Holland especially in wet dells in the dunes. In Usselo it apparently grew under comparable circumstances; an old brook-bed in which coversand was beginning to be deposited. The situation near Wierden (Diagram III) was also similar.

Vegetation and climate.

In Chapter I we already discussed the vegetation and the climate during a great part of the Pleni-glacial. In Fig. 2, a few pollen-spectra thereof have been given. In studying this map one should consider that the somewhat higher *Pinus* values may have been caused through the influence of secondary pollen and of long-distance-transport and the somewhat higher *Betula*-values appearing from time to time, through the influence of *Betula nana*-pollen. In Chapter II we then discussed the boundary Pleni-glacial—Late-glacial which we established at the *Artemisia*-rise.

Zone I, Older Dryas-time.

From a climatological point of view we can divide this Zone into two: I (a + b) anl Ic; if however we make a division according to vegetation, we can divide this Zone into three: Ia, Ib and Ic. It is hard to say whether the amelioration in climate starting at the *Artemisia*-rise, reached its maximum already very soon, or whether this maximum was reached only in the course of or near the end of Zone I (a + b).

As far as the proof for the existence of the Bølling-oscillation is concerned, we are referring to the discussion of Diagram IV (Usselo A) in Chapter IV. We only can add to this what we have said at the beginning of this chapter about the pollen of *Betula nana* and of large birches. During a certain period after the *Artemisia*-rise, the percentage of pollen of herbs is decreasing and birch-pollen increases up to a maximum of about 50 %. Fig. 3 gives a pollen-spectra-map for the maximum birch-expansion during the Bølling-oscillation. The pine remains very low in these spectra and was undoubtedly not present in the Netherlands during the Bølling-oscillation. At the beginning of Zone Ic (Earlier Dryas-time), the percentage of herbs suddenly increases strongly. Fig. 4 gives a pollen-spectra-map thereof. A remarkable phenomenon can be seen in the diagrams showing a completely developed Zone I. At the transition from Zone Ib into Zone Ic, the *Salix*-curve shows namely often a very striking peak; sometimes there appear signs of a second but less striking peak at the transition from Zone Ia into Zone Ib.

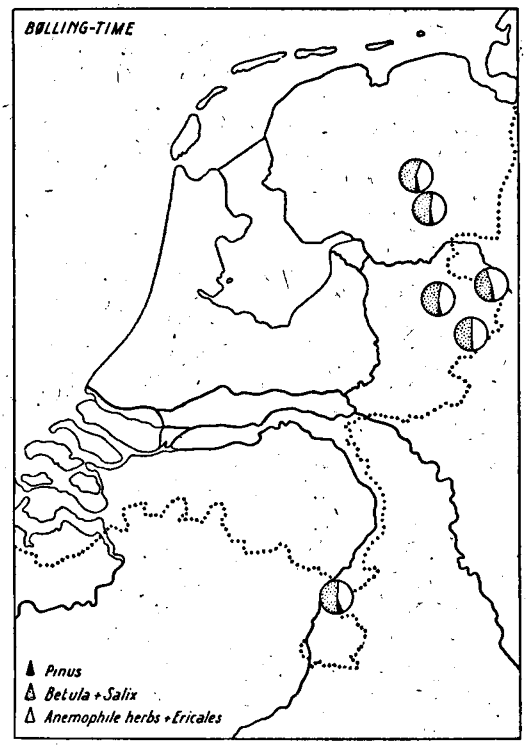


Fig. 3.

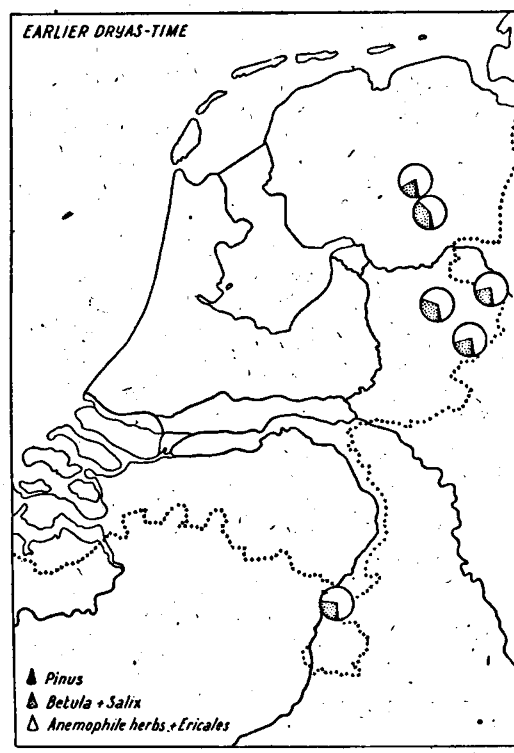


Fig. 4.

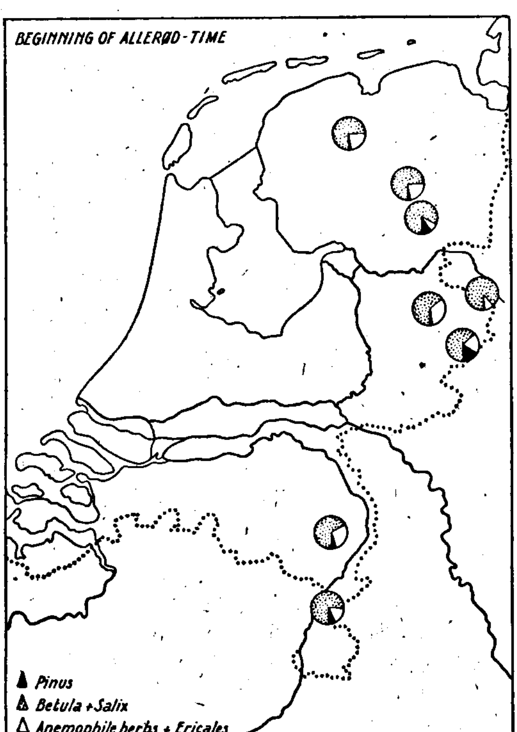


Fig. 5.

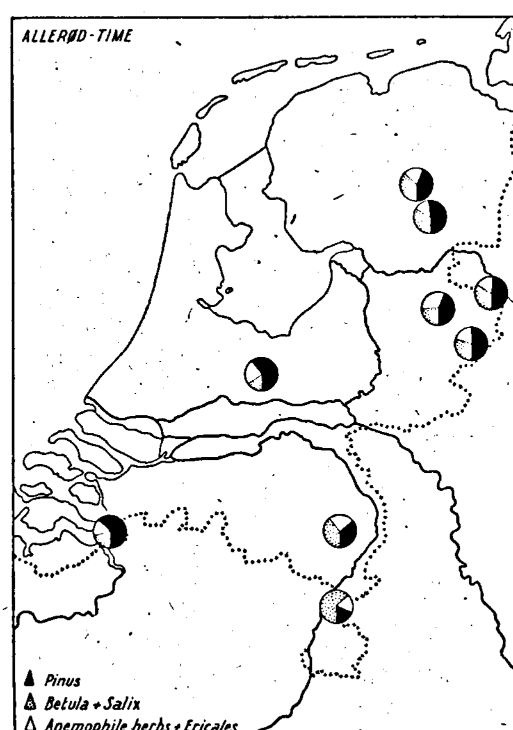


Fig. 6.

In a few cases the peak in the *Salix*-curve is accompanied by a peak in the *Juniperus*-curve. The peak in the *Salix*-curve occurs together with percentages of herbs lying between about 45—65 (the *Juniperus*-peaks also nearly always coincide with herbs percentages situated between these values). We believe to have found in this *Salix*-peak (sometimes also *Juniperus*-peak) an indication for the passing of the tree-line. For in Lapland e. g. the situation is such that the willow has its greatest expansion just about the tree-line and somewhat above it, while on drier spots *Juniperus* takes the place of *Salix* (DU RIETZ, 1950).

We think therefore, that we have found here a good auxiliary in order to establish the passing of the tree-line in the diagrams. It should however not be forgotten that exclusively lake-deposits, that have not been influenced locally can be used to this end. One of the most important conclusions to be drawn from the above is, that during the maximum expansion of the birch during the Bølling-oscillation the tree-line had already passed in the Netherlands and that therefore large birches must have actually occurred here at that time.

However, only this question remains: why the *Salix*-peak is less pronounced at the transition from Zone Ia into Zone Ib than at the transition from Zone Ib into Zone Ic. This now might perhaps be connected with the fact that the maximum of climatological amelioration possibly was reached early, at, or shortly after the *Artemisia*-rise and that the climate remained constant during the rest of Zone I (a + b). A region might have come into being then, in which growth of trees was possible but in which, due to the delaying immigration-factor the birch did not yet occur. At the immigration of the birch into that region a climatological tree-line would than in fact have been absent and therefore perhaps also a clear zone of optimal *Salix*-expansion. The same consideration might furthermore also be valid for the *Juniperus*-peak, sometimes appearing in the diagrams. As far as the high values of *Juniperus* (and also of *Salix*) are concerned the following might be added: as these plants spread relatively little pollen, or are at least under-represented in recent samples (see Introduction), they must have had sometimes an extremely important share in the vegetation during the Older Dryas-time.

During the Older Dryas-time the climate (in comparison with the Late Dryas-time) was relatively continental. Various plants, having their largest expansion in Zone I, indicate this. In the first place this is *Artemisia*. Fig. 9 is giving its maximum percentages for Zone I. The highest values are situated in the South and in the East of the Netherlands. During the Late Dryas-time the values are much lower (Fig. 10). We shall come back to this fact below. A similar expansion is shown by a few other plants as well, such as *Plantago*, *Helianthemum* and *Hippophaë*. We are citing as an example in Fig. 11, a map of the maximum *Plantago*-values in Zone I. Here again, the highest values are to be found in the South and the East. Fig. 12 gives the same for Zone III; in this case there are again much lower values except for the South-East.

Above we already mentioned the finds of *Sanguisorba minor*-grains. Fig. 13 gives a survey of these finds. This survey shows that all finds were made in Zone I and in the beginning of Zone II, whilst only one find occurred in Zone III and this is situated again in the South-East.

Summarising we can therefore say that some of these plants point to

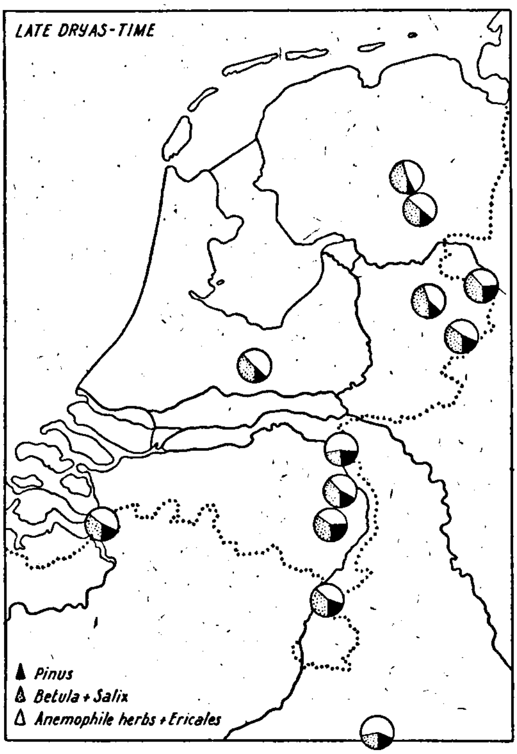


Fig. 7.

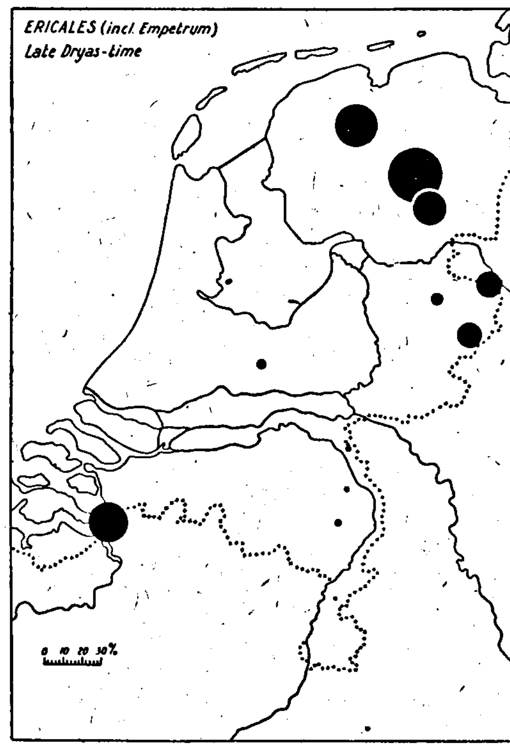


Fig. 8.

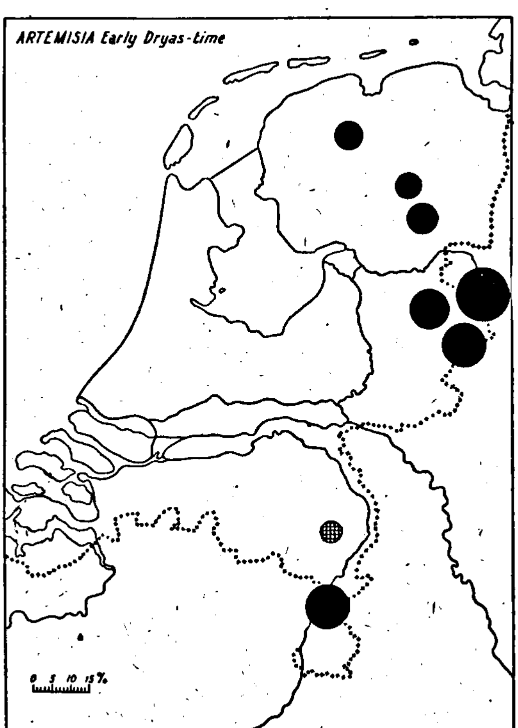


Fig. 9.

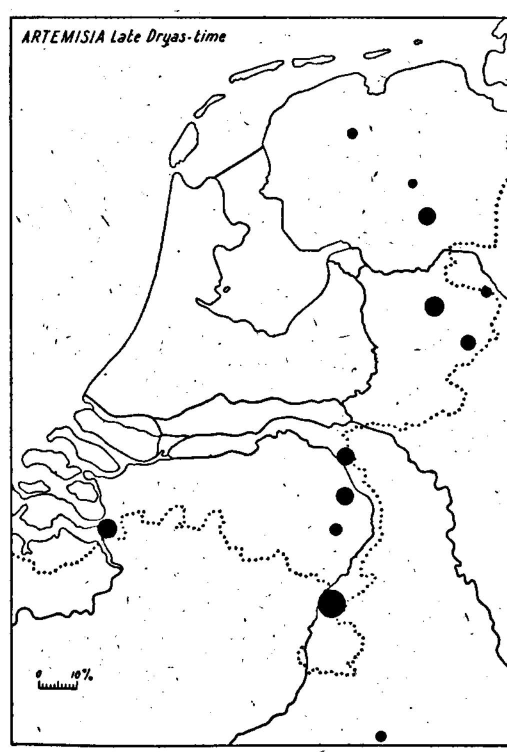


Fig. 10.

the same direction, that is to say, that the climate during the Older Dryas-time must have been relatively continental and that this continentality increased towards the East, but especially towards the South-East. In connection with some of these plants one might also say that the vegetation at that time must have had a more or less steppelike character.

Grains of *Sanguisorba officinalis* were especially found in Zone I, but also fairly frequently in Zones II and III. Fig. 14 gives a survey of their occurrence, showing clearly (viz. Fig. 13) that this plant shows much less preference for a given zone.

Zone II, Allerød-time.

The limit between Zones Ic and II is generally very clear, only exceptionally less so (diagram XIII). Zone II always begins with a birch-forest-time, while perhaps only in the East, the pine immigrated fairly early (Fig. 5).

The climate during this birch-time seems still to have been relatively continental. The *Artemisia*-percentage does indeed decrease, but this is caused by the greater density of the forests; the *Helianthemum*-curve often follows its normal course during that time and grains of *Sanguisorba minor* e. g. were also still found. (From that time dates also the find of a pollen-grain of *Centaurea cyanus*). This birch-time is followed up by a pine-forest-time or a pine-birch-forest-time (Fig. 6). At the highest *Pinus*-percentages is the vegetation-optimum. At about the same time the expansion of *Empetrum* and *Ericaceae* begins, whereas indications for the occurring of *Helianthemum* and suchlike plants are entirely lacking most of the time. It is in the middle of the Allerød-time therefore, that a clear turn of the climate takes place from relatively continental to relatively oceanic. It is hard to state with certainty whether the vegetation-optimum completely coincides with the climatological optimum or whether the immigration-factor has slowed down the vegetation-optimum. To the latter's advantage is the fact that even in the Late Dryas-time the climate must have been sufficiently favourable for the growth of pine and that therefore the conclusion seems to be very likely, that this must certainly have been the case during the birch-forest-time at the beginning of Zone II. The greatest care is therefore to be taken in correlating over larger distances the vegetation-optima in the Allerød-time. A better point for correlation is in that case, the beginning and especially the end of the Allerød-time because here, especially as far as this last point is concerned, immigration plays no role whatsoever. The turn: continental—oceanic neither furnishes us with indications as to the actual situation of the climatological optimum. For this turn is very possible a consequence of the fact that the sea level, due to the melting off of the ice, had risen to such an extent that the sea could exercise a perceptively stronger influence on the climate; even if we could indicate the time of the highest sea level, this point might still show a fairly important shifting with regard to the climatological optimum, as we know from interglacial sea level-rises (Brouwer, 1948). Fig. 6 shows that the *Pinus*-maxima are relatively low in the South-East of the Netherlands, this being indeed a fact that was not at all expected. Everything seems to indicate (see also Fig. 5), that in Holland the immigration of the pine took place from the East (and perhaps also via the relatively low regions of Northern France and Flanders in the South-West) but very likely not from the South-East. It is now the question what might be the cause thereof. It is certain that the climatological circumstances were not less favorable here for the

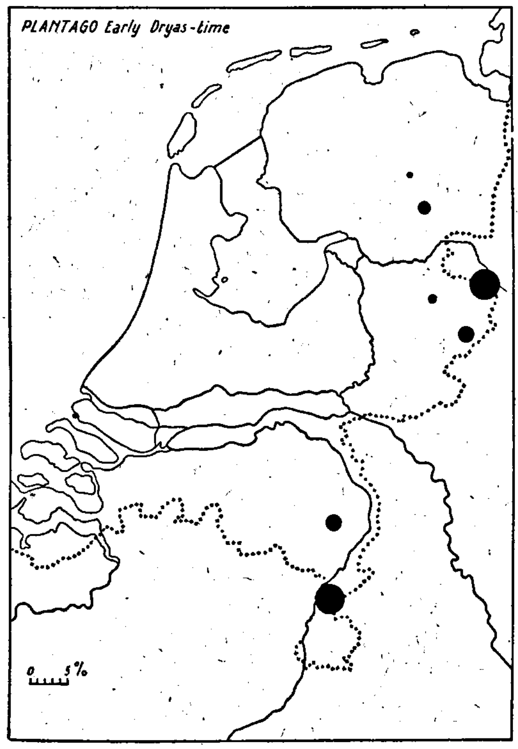


Fig. 11.

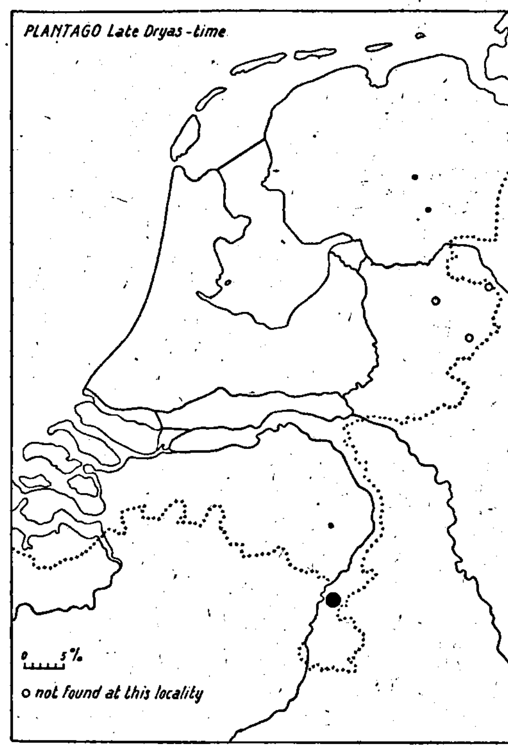


Fig. 12.

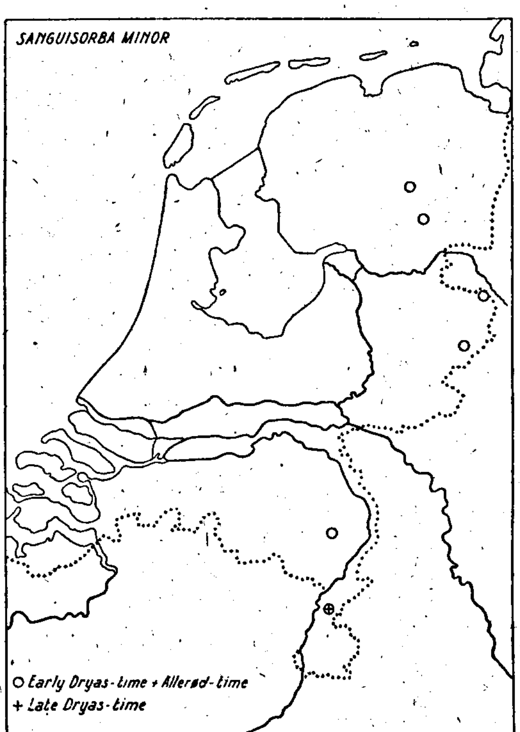


Fig. 13.

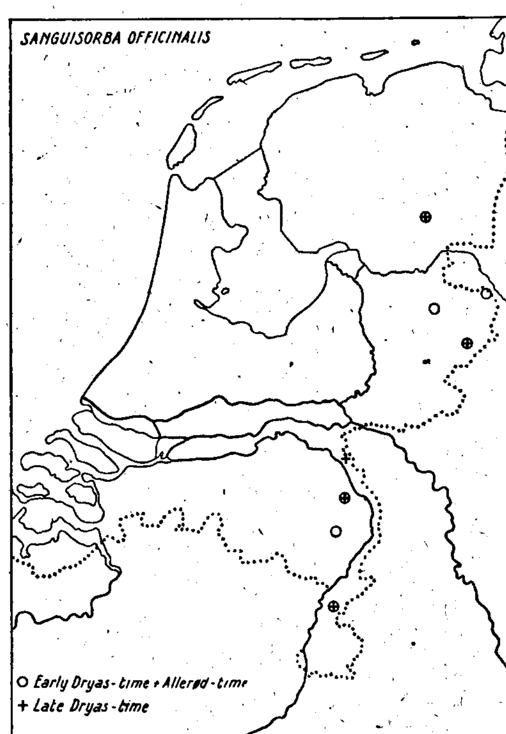


Fig. 14.

growth of the pine as the *Pinus*-maximum here is reached during the Late Dryas-time. It even appears from comparison between the maps (Fig. 6 and 7) that, while in Zone II the reverse was true, in Zone III the pine reaches higher values in the South-East than in the North. It seems therefore to be quite clear that we are here confronted with a delayed immigration of the pine. The cause thereof may be the fact of the presence, South and South-East of the region under consideration, of the Ardennes—Eifel massive, that by its greater height, can have formed an obstacle.

It is remarkable to note that the pine-forest-time of Zone II shows often a somewhat higher percentage of herbs than the birch-forest-time. Apart from the fact that here, especially in the pine-time, forest fires might have played a role (viz. Chapter IV), other factors as well (difference in density between pine and birch-forests, difference in pollen-production or in undergrowth) might have been the cause. In any case such a, generally fairly feeble, peak in the herbs-curve cannot lead to parallelisation with the colder middle parts in some Allerød-diagrams from Denmark (IVERSEN, 1947). For as opposed to these, it is highly probable that these feeble herbs-peaks coincide exactly with the optimum of the vegetation.

Zone III, Late Dryas-time.

At the beginning of Zone III the percentages of herbs are again increasing (Fig. 7). Generally the *Pinus*-percentages are also decreasing, except for the South-East (see above). In the diagrams from the North of the country, *Pinus* decreases so much that there is the possibility that the pine completely disappeared here locally (see for this matter what was said in the Introduction on recent surface-samples). Generally the highest non-tree-pollen values are reached in the top-part of Zone III. The forest-density must have decreased considerably in that time and the vegetation must have acquired the character of a park-landscape. In this park-landscape the pine must also have played a certain part next to the birch. In that period *Ericales* too (especially *Empetrum*) are strongly increasing. The maximum is generally reached in the topmost part of Zone III.

In the North and in the West, very high values are reached, but in the South-East the maxima are relatively very low (Fig. 8).

It has been presumed sometimes, that the *Ericales*-expansion in Late Dryas-time might be the consequence of impoverishment of the soil during the Allerød-time. This is very unlikely however, since, during the Late Dryas-time, important transport and deposit of minerogene material took place again (see Chapter VII), while at the same time nothing indicates a strong impoverishment of the fossil Allerød-soils (see Chapters IV and VII).

As we already pointed out above, we are of the opinion that the expansion of *Empetrum* indicates a more oceanic character of the climate. This is in harmony with the fact that the more continental South-East gave much lower values and also with the fact that Zone III provided much lower values for *Artemisia* than Zone I (compare Fig. 9 and 10) and that also other plants, such as *Helianthemum* and *Sanguisorba minor* (Fig. 13) are not or much less represented. Another fact, that can also point in the same direction, is that the *Sphagnum*-expansion begins at the top of Zone II and prolonges itself into Zone III. This might equally indicate a greater precipitation in that time. The turn in climate, continental—oceanic, occurs already in the middle of the Allerød-time and with it the beginning of the *Empetrum*-expansion.

It is clear that the very strong increase in Zone III must also be a consequence of the better chances this plant obtained due to partial disappearance of the forest.

On the other hand it should not be forgotten that *Empetrum* may also have had in important share in the forest-undergrowth and that consequently the non-tree-pollen percentage may have been increased out of proportion (see Introduction: recent surface-samples). It is not unlikely that sometimes also the relatively high N.T.P.-percentage in the topmost part of Zone II have been influenced by this as well.

Zone IV, Preboreal.

The beginning of the Preboreal lies at the beginning of the final amelioration of climate. It is here that we also establish the beginning of the Holocene. In Holland this limit is situated there where the park-landscape of the Late Dryas-time merges into pine-forest or birch-forest. In the diagrams this is shown in a generally rather steep decline of the N.T.P.-curve. This limit, therefore, generally is relatively clear and is therefore, in practice, very useful as boundary Pleistocene-Holocene. In the North, the Preboreal sets in with a birch-time, in the South with a pine-time. This very probably is connected with the fact whether the pine was or was not occurring there during the preceding Late Dryas-time. It namely appears that especially in the North, the *Pinus*-values in Zone III are relatively low. We therefore might deduct from the fact that the Preboreal sets in with a birch-time in certain regions, that during Late Dryas-time the pine did not occur there. The fact is striking that in the diagrams of the South (and the East?) thermophile trees are occurring very early, immediately at the beginning of the Preboreal. In the North however, they are preceded by a zone, although a narrow one, without (or nearly without) thermophile trees. The consequence of this is, that in the South Zone IV may in fact be nearly entirely lacking. It will however be necessary to analyse a larger amount of material of Preboreal age in order to acknowledge these facts finally.

CHAPTER IV.

DATING OF THE CULTURE OF USSELO.

Introduction.

During the summer of 1949 we had the occasion to study intensively the geological situation in the area of the pre-historical ("epipalaeolithical") atelier near Usselo. There at that time, as well in preceding years, excavations had taken place, all under the direction of Dr. C. C. W. J. HIJSZELER. It had been established that the artefacts were all found in a low sand-ridge, in the close vicinity of a sand-covered peat-layer. The "Late-glacial" age of this peat was already established by FLORSCHÜTZ (1941).

Archaeological finds in the peat, however, had never been made, so that an accurate dating of the culture of Usselo had not yet been possible. Since then more has become known concerning the development of the vegetation during the Late-glacial in the Netherlands and so the ground was prepared for a nearer pollen-analytical dating of the peat. Further study of the profile exposed in 1949, enabled moreover to date the culture-layer itself. These datings provided later on also the key to the solution of a few geological problems, not only in Twente, but also in other eastern and in northern parts of our country.

The layer containing the archaeological objects has a very typical habitus with wormlike bulges upwards and downwards, and furthermore produced smaller or larger lumps of *Pinus*-charcoal. Layers of the same kind have been found under analogous stratigraphical circumstances in many places in the eastern and northern provinces of the Netherlands. We shall come back to this in Chapter VII.

The geological research.

In this discussion of the geological results, the outcome of the pollen-analytical investigations to be considered later on, have already been used. The excavation-area in the "Usselerveen" is situated in a coversand region.

Profile A was exposed during the excavations. Fig. 15 gives a survey of this profile (height twice exaggerated in comparison with the horizontal scale). The sand-ridge in which the finds occurred is beginning due right. All these finds were made in a layer of sand, that was distinguished by both colour and shape (see above) from the underlying and the overlying sand. In the profile this layer is indicated by means of small black squares. It appears from the bearing of the layer that there was already a sand-ridge at the time of the habitation. This sand-ridge must have been situated along a cut-off branch of a brook in which lake-sediments were deposited.

Already during the habitation, a low degree of aeolian transportation of sand must have taken place; in the middle of the small lake lacustrine deposits from that time alternate with small sand-layers, while nearer to the

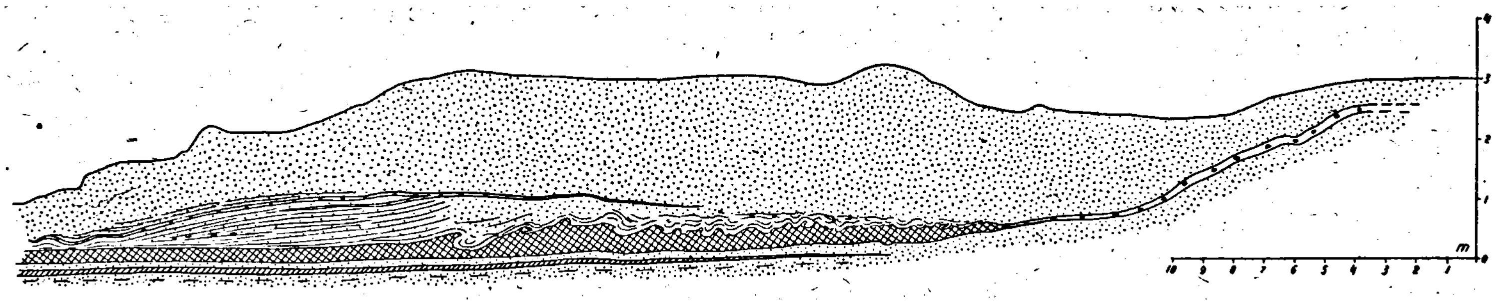


Fig. 15.
Profile Usselo A, general view. Explanation see text.

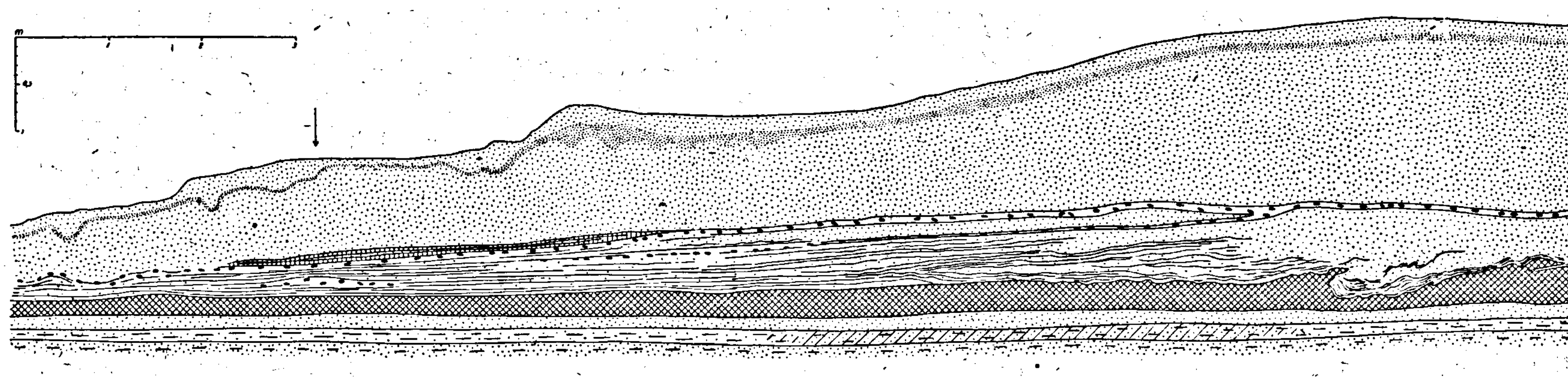


Fig. 16.
Profile Usselo A, detail of Fig. 15. Explanation see text.

beach hardly any deposits occurred at the beginning. The charcoal-layer can be followed from the beach, where it has its bearing close on top of the peat, up to where it divides itself into a number of small charcoal-layers. These small layers can again be followed in the small sand-layers between the organogene lake-deposits. Fig. 16 (horizontal and vertical scale are the same here) shows the lefthand part of profile A in greater detail, so that the bearing of some of the charcoal-layers can be followed more accurately. The compact layer of detritus-gyttja (double hatched in the profile) was deposited during the Allerød-time. An important part of the small layers of organogene material, situated on top of it, dates from the last part of the Allerød-time; only the topmost layers have been deposited in the beginning of the Late Dryas-time. Afterwards however, the small lake was completely filled with coversand so that the spot where it was once, was incorporated into the sand-ridge that was already previously present. Below the deposits from the Allerød-time, there are sediments containing a large amount of sand and loam, in which there is a clearly distinguishable layer containing much less sand and, in some places, a fairly large amount of organogene material. This layer was deposited during the Bølling-oscillation. From the profile-sketches it appears that here there can be no question of layer-disturbances. We shall come back, in Chapter V, on the kryoturbate phenomena that can be seen in the right-hand part of the profile.

In Fig. 34 a diagrammatic development of the situation of the excavation area during the Late-glacial was sketched on the basis of profiles. We shall come back to this in connection with the research on coversands (Chapter VII).

Profile B was already partially exposed in a sand-pit in the above mentioned sand-ridge at a distance of about 800 m from Profile A. Fig. 35 is giving a survey of the entire profile and Fig. 17 a detail of this profile. Fig. 17 shows a section through a small fossil brook-bed in which there are two organogene layers, separated by and covered with sand. The topmost peat-layer is forming, as it were, the continuation of the "charcoal-layer". Here, even large lumps of charcoal and partially burned pine-trunks are occurring in the peat. The bottom-layer in the "brook-bed" is formed by peat containing a large amount of sand and clay and it can be followed as a thinner layer, containing humus, in the rest of the profile. According to pollenanalytical dating, the bottom-layer was deposited during the Bølling-oscillation and the top-layer during the Allerød-time. Just as was the case in profile A, the deposits below, in between and on top consist of sand or of very sandy material. The sand at the bottom is furthermore containing a fair amount of "loam". We shall come back in Chapter VII to the importance of this profile for the dating of the coversands. Also as far as finds of the charcoal-layer in other regions of the Netherlands are concerned, as well as the stratigraphical position and its importance in general, we are referring to said chapter.

Pollenanalytical dating.

Diagram IV, Usselo A. (Province of Overijssel).

When profile A was exposed, a sample-series for pollenanalytical research was taken (spot indicated by an arrow in the profile-drawing, Fig. 16). In the above we already mentioned the fact that the culture-layer is here enclosed by the peat and is visible in small layers containing charcoal and sand.

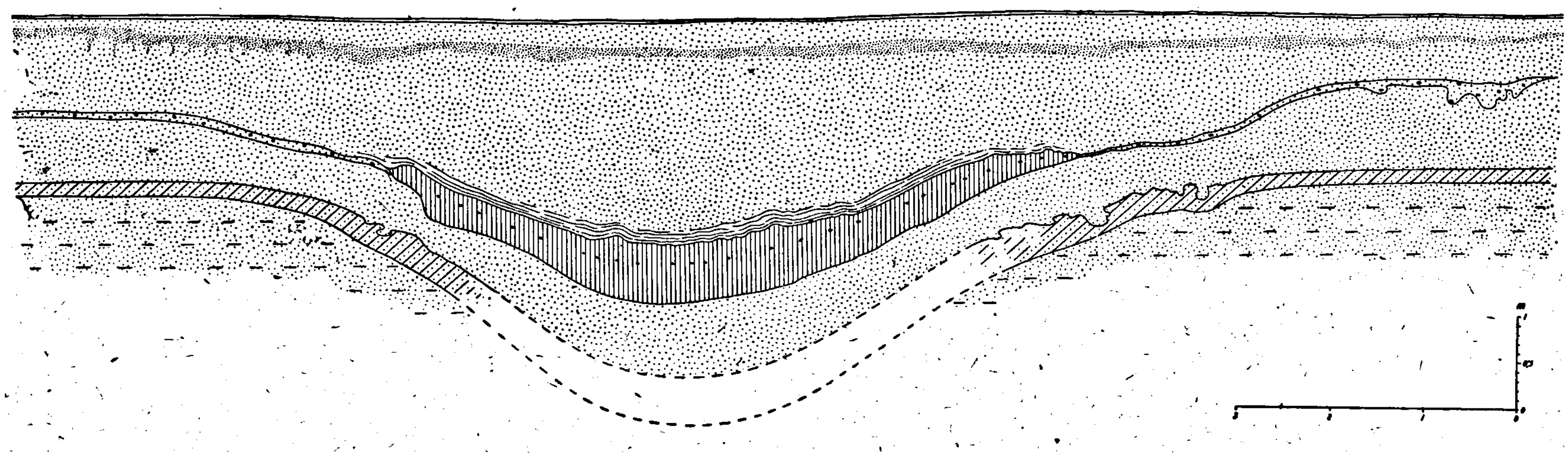


Fig. 17.
Profilo Usselo B. Explanation see text.

In the profile, sketched next to the diagram Usselo A, the undermost charcoal-layer, containing a high amount of little lumps of carbonised pinewood, was indicated separately. The sandy layer situated below it contained but a small quantity of scattered lumps of charcoal, whereas the layers situated below did not contain any charcoal at all. The peaty and sandy deposits on top of the thin charcoal-layer contained but a rather small amount of charcoal that was sometimes clearly concentrated in small layers and sometimes dispersed.

Pollensum: 350—500. The sample-distance varies from 2,5—5 cm.

The lithology can be read from the profile next to the diagram. Contemplating the great lines of the diagram, the following immediately catches the eye: samples 1 to 14 inclusive are yielding high herb-percentages, whereas *Pinus* is hardly entirely lacking. In the samples situated above *Pinus* appears in important percentages, whereas samples 15 to 30 inclusive contain relatively low herb-percentages and in samples 31 to 35 inclusive higher herb-percentages have again been found. If, at the same time, attention is given to the development of the curves for *Empetrum, Hippophaë* and *Helianthemum*, the latter two appearing essentially in the lower part of the diagram and the first one showing higher values in the top-part, we can establish without any doubt that in the diagram we are finding a reflexion of the vegetation during the Early Dryas-time, the Allerød-time and the Late Dryas-time (viz. Zones I, II and III). Also the change in sedimentation is tallying herewith. We shall now discuss these three zones consecutively.

In Zone I of the diagram a not unimportant change of climate is still visible. For the herb-percentage decreases to about 50 at first and then increases again considerably. The *Salix*-curve has its most important peak in sample 10, with a herb-percentage of 57. This development of curves in Zone I has also been established elsewhere in our country (see Chapter III), and the change in climate that caused this must be identical with the Bølling-oscillation. Sometimes it has been presumed that layer-disturbances were the cause of the fact that in some diagrams a temporary amelioration of climate before the Allerød-oscillation seemed to have to be established. However, since we were able to study the profile in an exposure where it appeared that the layers were not disturbed in such a way (Fig. 15 and 16), this argument is no longer valid. Furthermore there is another important argument, also applicable to the diagrams based on bored samples. If a layer-disturbance would really have occurred, it should be expected that the "Bølling-layer" would show the same pollenanalytical picture as the Allerød-layer. This however is not the case at all. The Bølling-layer is yielding typical Older Dryas-time spectra, in which the high *Artemisia*-values are the most striking factor. (Compare furthermore the curves for *Helianthemum, Hippophaë* and *Pinus*). Also the *Salix*-peak in exactly the same place as e. g. in the diagram of the Hijkermeer (VAN DER HAMMEN, 1949) is striking. We have already tried, in Chapter III, to explain this remarkable fact. The existence of the Bølling-oscillation as a separate climatological change has therefore been proved conclusively herewith. We further mention here the find of a few pollen-grains of *Parnassia* in samples 2 and 3.

In Zone II of the diagram the herb-percentages suddenly strongly decrease and *Pinus* is immediately playing an important role. In the top of this zone there is a remarkable herb-peak. It might be possible to put this parallel with a similar symptom in some danish Allerød-diagrams, that might possibly have been caused by a slight climatological change. Since, however, this peak in the diagram Usselo B coincided exactly with an important charcoal-layer, we presume that it might have been caused by a more or less local forest-fire and therefore cannot be used as a parallel of the peaks in the danish diagrams (see Chapter III). In the diagram Usselo A too, some small lumps of charcoal are already found at this level. In this context it is also important to note that in spectrum 25 there is precisely a top of the *Chenopodiaceae*-curve, which might indicate the presence of human dwellings, and that in sample 26 a pollen-grain of *Epilobium angustifolium* was found, a plant often growing in places where the forest is burned down or cut down (see also the discussion of the diagram Usselo B). The most important small charcoal-layer in diagram A is situated just on top of the herb-peak. The diagram shows, on top of this layer, a steep *Betula*-peak (sample 27), which even weighs down the percentage of herbs. Since in samples 28 and 29 the *Betula*-curve is again decreasing and *Pinus* recovers, it would seem likely that also in this strange development of the curves, the influence of a forest-fire might be distinguished: for in a burned-down-forest-area *Betula*, under the given circumstances uses to come back in the very first place, after which other trees, in casu the pine, are taking back their place only later. Here too there is again (in sample 28) a peak in the *Chenopodiaceae*-curve.

Is Zone III the herb-percentages are again increasing considerably, while also the expansion of *Empetrum*, that started already in Zone II, is continuing.

It is interesting to note the fairly regular occurrence of pollen-grains of *Sanguisorba officinalis*, here limited to Zone I and the find of a few grains of *Sanguisorba minor*. The *Juniperus*-peak at the beginning of the herb-peak in Zone II, perhaps being connected with the latter, is remarkable.

As the culture-layer could be followed in the profile, it could also be dated fairly accurately. During the (perhaps not uninterrupted) habitation of the sand-ridge a certain amount of aeolian transportation of sand from the ridge into the "lake" took place.. While, as a consequence, the peat-forming was stopped close to the beach, the organogene deposit in the middle continued resulting into an alternation of sand, partially containing charcoal, and of small layers of organic material. Some of these sandy layers formed, in the profile, the continuation of the culture-layer. On that basis we can establish now that habitation began towards the end of the Allerød-time and that it continued (possibly with interruptions) up to in the very first beginning of the Late Dryas-time.

Diagram V, Usselo B. (Province of Overijssel).

Samples taken in profile B (Fig. 17). Pollensum: 200—350.
Sample-distance 5 cm or 2,5 cm.

Two superimposed peat-layers in a fossil brook-bed, separated by and covered with sand. The bottom-layer was kryoturbate. Since these are peat-layers deposited in a narrow brook-bed, it could be expected that local influences might trouble the pollenanalytical picture. To a certain extent this is indeed the case; however, important conclusions can be drawn from the diagram, the more so as interpretation becomes more accurate after comparison with the diagram Usselo A. The diagram of the undermost peat-layer reflects the Bølling-oscillation, the uppermost peat-layer the Allerød-oscillation as well as the beginning of the Late Dryas-time. Between Bølling-time and Allerød-time a sand-layer is deposited which tallies with profile A, where the deposit from that time is also very sandy. The bottom-part of the uppermost peat-layer is strongly influenced by a local vegetation of *Salix* (wood probably of the willow was also found here). The course of the herb- and *Empetrum*-curves in the topmost part of the diagram shows however a very strong resemblance with the harmonizing part of diagram A. The herb-peak (sample 15) also present here, in Zone II, coincides with a very clear charcoal-layer. At this level we also found many partially carbonized trunks of pines, while also birch-trunks were found, as well as an important quantity of pine-apples (the latter partially also at a lower level). In sample 15 also a pollen-grain of *Epilobium angustifolium* was found (just as in diagram A, sample 26!). Somewhat higher up in the profile too, a certain amount of charcoal was found. The *Chenopodiaceae*-curve is again remarkable in this diagram. Without knowing diagram A, one might be inclined to establish the limit between Zones II and III between samples 17 and 18, but after comparison with this diagram, that has not suffered from such strong local influences, it seems preferable to establish the limit between samples 20 and 21.

Diagram VI, Usselo C. (Province of Overijssel).

Pollensum: 200—300. Sample-distance 5 cm and 2.5 cm.

The material for this diagram was already collected during a previous excavation in the "Usselerveen" by Dr. HIJSZELER and examined by us later. It was collected closer to the original beach of the lake than the material of diagram A. This might perhaps explain the somewhat deviating course of the *Pinus*-curve in Zone II. For the rest, the picture shown by this diagram tallies nearly completely with that of diagram A. It is interesting to note, that here Zone Ic (Earlier Dryas-time) is lacking (sand!). It therefore seems as if the Bølling-oscillation is absent. Such diagrams occur more often e. g. the diagram of DE PLANQUE (1950).

In sample 4 a grain of *Sanguisorba officinalis* was found.

Living-conditions of the Usselo-man.

As we can see from the above, man, who fashioned the flint-objects of Usselo, lived during the end of the Allerød-time and the very beginning of the Late Dryas-time. In that period there were, at first, nearly closed forests of pine and birch. In the undergrowth *Empetrum* was probably beginning to take a more or less important place. During the habitation-phase forest-fires occurred, very possibly more than once. We find a reflection of this in the pollen-diagrams, while also especially the charcoal and the half carbonized tree trunks point in that direction. On the "burned-down" spots, where in the beginning i. a. *Epilobium angustifolium* will have grown, *Betula* must have come back in the first place, after which the natural forest could recover itself. It is hard to decide whether the fires had a natural cause (lightning) or an unnatural one. In the latter case the cause may have been either intentional or unintentional. In any case, forest-fires must have occurred rather often and over larger regions since, also in many other places in the eastern and northern provinces, a fair amount of charcoal of *Pinus* was found in the "Usselo-layer". At any rate it seems likely that towards the end of the Allerød-time the possibility of originating and expansion of forest-fires had increased. In the first place, because the pine-forests must then have been much more extensive than at the beginning of that time.

Later, an increasing number of trees and amongst them possibly especially the pine must have died under the influence of the approaching cold of the Late Dryas-time. The landscape in the neighbourhood of the "Usselerveen" was generally flat and low with, as the only elevation, the sand-ridges not higher than a few meters. The low country was cut by shallow brook-valleys of relatively little depths. Undoubtedly there must have been a number of dead ends filled with water, in which, during the Allerød-time, organogene deposits were formed. Alongside one of these dead branches the sand-ridge, on which the Usselo-man had his ateliers was situated. He therefore must have had water at his disposal close at hand. *Chenopodiaceae*, occurring undoubtedly also in the natural vegetation, will have found in the neighbourhood of human habitations an extremely favorable site. Under the influence of habitation and possibly also under the influence of forest-fires, some deposition of dune-sand occurred locally. Deposition of coversand occurred to the East of the original ridge in the "Usselerveen". This and also the dip of the layers must lead to the conclusion that western winds must have prevailed in that time.

Man in that time must undoubtedly have found his food mainly in hunting. The find of a great number of *Empetrum*-seeds in the thin charcoal-layer of diagram A gives rise to the thought that also the berries of *Empetrum* (crowberry) may have been part of this food. Amongst the plants established pollenanalytically, also *Rumex* (sorrel) might perhaps taken into consideration as vegetable diet.

Since the Usselo-man also lived in the very first beginning of the Late Dryas-time, he encountered the beginning of the cold of this time. The sub-arctic pine-birch-forest changed then into a sub-arctic park-landscape in which *Empetrum* was fairly largely expanded.

Summarising it can be said that the Usselo-man lived in circumstances that in various respects underwent the influence of the transition from the Allerød-time to the Late Dryas-time.

GEOLOGICAL PART.

CHAPTER V.

SOLIFLUCTION AND KRYOTURBATION.

It is not our intention to give in this chapter a survey of the many forms of solifluction and kryoturbation and of their possible mode of origin. We shall only mention here a few facts concerning the dating of some structures as well as the consequences of that dating and we shall also describe a few forms that have not yet often been observed.

The hills in the eastern part of the Netherlands are often covered with a frequently structureless cover of boulders, gravel, sand and loam. These components may occur there in various ratios of mixture and the deposit is never sorted. On the geological map of the Kingdom this cover is often indicated as a "bottom-moraine" or as a residue thereof. In various exposures (Fig. 18) we were however able to establish that the boulder-clay is in

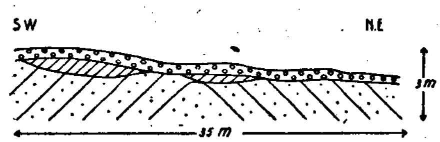


Fig. 18.
Exposure in the hill-ridge North of Ootmarsum (Prov. of Overijssel). Ice-pushed sand and gravel deposits, remains of the boulder-clay covering, and solifluction-cover.

reality only occurring as slight remains of erosion underneath this cover, while generally completely lacking in many other places. We therefore are undoubtedly confronted here with a solifluction-cover covering the hills, while of the originally present bottom-moraine, only small remainders are left. Also the name "bottom-moraine-residue" is not right here, since a considerable amount of older material must have been included in the solifluction-cover. It is possible that on the ice-pushed hill-ridges of Twente, containing a core of Tertiary, solifluction was stronger through the presence of loam at a certain depth below the surface, than e. g. in a sand-region such as the Veluwe.

With the aid of the pollen-diagrams discussed in chapters I and III it is now possible to date a few kryoturbate structures. It appears that in various places, such as the South-West of Noord-Brabant and near Usselo, peat or gyttja-layers from the Allerød-time (near Usselo also from the Bølling-oscillation) show the structure of a "Wannenboden". This is slightly visible in Phot. 39, also in Fig. 17 and, in slightly deviating forms, in Fig. 15.

Generally, soon above the peat or the gyttja, the coversand-layers are again in a horizontal position. The structures will therefore have originated here at the beginning of the Late Dryas-time and at the beginning of the Earlier Dryas-time, during the beginning of the deposit of the coversand from these periods (see Chapter VII). They therefore cannot have come here into being in the beginning of the Preboreal as a consequence of the omittance of the tjäle.

Since elsewhere the presumption is fairly generally accepted, that since the land-ice retreated from its extreme moraines there was no longer a "perenne tjäle" (permafrost), an assumption based on the absence of "Wannenboden" and frost-cracks inside the region of the outmost Weichsel-moraines (POSER, 1947 and 1948), the question rises now, in how far this conclusion tallies with the observations in the Netherlands.

It is a fact that in some "Late-glacial" deposits in Holland "Wannen" and "Taschenboden" have been found, a fact therefore that seems not to tally with the conclusions of POSER. We found however also that the coversands from the Upper Tubantian were lying undisturbed on the valley-slopes, from which follows that a strong action of solifluction can no more have taken place since the beginning of the deposition of these sands. Added to this there is the fact that large frost-cracks have never been found in deposits from the Upper Tubantian. We therefore have to come to the conclusion that it is not impossible that the kryoturbate phenomena found in the deposits from the Upper Tubantian must have originated either under the influence of an "annual" tjäle or entirely independently of the climate. Let it be a premise in considering this problem that in the cases observed, structures in peat or gyttja, covered by coversand, are always concerned and that it appears from the disposition of the layers that their formation must have taken place during the beginning of the deposition of the coversand. Here are also concerned deposits that fairly certainly were under water during the deposition of the driftsand, in small lakes or in the dead branches of brooks. This means therefore that the material was a kind of pulp, saturated with water and that therefore the circumstances were about the same as those of a soil on top of a tjäle, thawed in spring.

It has become clear, as a consequence of research of various kinds, that certain striking structures of schist and sandstones in older deposits, strongly resembling "Wannen", must have originated on the bottom of the sea as a consequence of the sinking of sand into clay, caused by unequal load on the clay by the specifically heavier sand (MACAR and ANTUN, 1950). EMERY (1950) explained interformational folding in "Pleistocene" strata of southern California to the sinking of a layer of beach sand into an underlying marsh deposit of sandy-silt, in the same way as described above. Certain sinkings of sand into peat or gyttja below water-level might therefore also be explained in that manner.

In order to try and prove the possibility of such a manner of origin we are making a series of experiments in the laboratory for experimental geology of the Rijksmuseum van Geologie en Mineralogie at Leiden. As these experiments are still being carried out we cannot yet give any information on this subject; in the case positive results might be reached, we hope to make these known later, in a separate publication. For the time being it will be necessary to reckon with the possibility of such a manner of origin of certain "kryoturbate structures". Especially structures of the kind as encountered near Usselo (Fig. 15 and 16) can enter into consideration for this explanation. Other structures, such as those encountered in the South-West of Noord-Brabant (Fig. 39), where the entire layer of organogene material is transformed into "Taschen", seem not to lend themselves so easily to the explanation indicated above, since here also the underlying sand is involved in the structure. It should therefore not be forgotten either that in the case of an "annual" tjäle, kryoturbate structures may certainly also have originated as a consequence of alternate freezing and thawing of the top-layer of the soil in spring. In any case "Wannen" and "Taschenboden" cannot definitely prove a "perenne tjäle" and, some "Wannen"-like structures cannot even furnish certain proof for the existence of an "annual" tjäle. In this respect it may be of interest that VAN LIERE & CROMMELIN (1949) found an example of very recent "kryoturbation" in the Netherlands, formed without frost-action.

In comparing the kryoturbate structures from the Middle Tubantian with those of the Upper Tubantian, it appears that the former are often much more complicated. Phot. 32 and 33 show such a fairly complicated structure of a loam layer (loess?) in the undermost part of the Older coversand near Apeldoorn, at a depth of about 3.5 m below the surface. On top of it there was undisturbed Older coversand, and also beneath it the coversand was as good as undisturbed, while at a depth of about 5.5 m there was the top-limit of the fluviatile material (see Chapter VII). Phot. 36 shows a heavily disturbed peat-layer from the Middle Tubantian near Apeldoorn. It even would seem here as if "intrusions" of peat into sand have occurred. Also near Apeldoorn, peat-layers of the same age were found whose top-limit was nearly level, and whose bottom-limit showed sinkings of peat into sand.

Apart from that, in the Middle Tubantian near Wierden, typical "Wannenboden" were also encountered.

Near Apeldoorn, in the deposits from the Middle Tubantian, a kryoturbate structure was found that seems to have been but little observed up till now. As far we know it was only described by VAN GALEN (1943). Immediately on top of the Older coversand there was here a layer of gravel and sand, for the greater part unsorted, that at its bottom contained often a large amount of loam. (Phot. 27; Fig. 19.) We consider this layer as solifluction-material that is only somewhat sorted by running snow-melting-water in a few places. The spot near Apeldoorn is the only one where we found solifluction-material on the Older coversand and the occurrence of this layer makes it very possible that a strong solifluction could occur there also during the deposit of the Older coversand. The coversand below this solifluction-layer is structureless up to about 1 m below the bottom-limit of the gravel; below this level the layer disposition is normally horizontal. In the structureless sand there are remarkable sinkings of loam with some gravel (Phot. 23, 24, 25 and 26). These sinkings originate at the limit-level of gravel and sand. From there they descend like a thin braid (sometimes vertically, sometimes at a slight tangent) and show at the end a droplike thickening. The thin braid appears to be, when further dug out, a sheet about 10 cm wide and about 1 cm thick. If the droplike thickening reaches down to the level where the sand is again undisturbed, it shows there a very clear horizontal flattening (Phot. 23 and 24). Undoubtedly this level will have to be considered as the top-limit of the tjäle in summer. In the layer on top of it, thawing in summer (and about 1 m deep), the sinkings of loam with gravel took place while, due to the movements in the sand oversaturated with water, all stratification disappeared. The sinkings could not go deeper than the top-limit of the frozen underground on which they could not but flatten out.

It is not simple to find a conclusive explanation for these remarkable structures but there is one observation that might indicate the direction in which this solution will have to be searched. In some places namely, these "drop-structures" merged into a system of small cracks filled with loam,

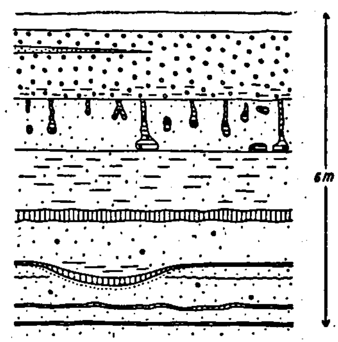


Fig. 19.
Profile in the Middle Tubantian (Pleni-glacial) deposits near Apeldoorn. Explanation see text.

that strongly reminded of a similar phenomenon near Wiene, discovered and described by FLORSCHÜTZ and VAN DER VLERK (1937). However we will have to desist of trying to explain this phenomenon any further.

Real large frost-cracks were also found exclusively in the Middle Tubantian. Such a frost-crack in horizontal and vertical section, and part of a system of frost-cracks is shown in Phot. 35. It is true that we also sometimes found small, filled-up cracks in deposits from the Upper Tubantian, but these belong to a quite different order of magnitude and are of a different structure than the ones mentioned in the first instance.

In summary it can therefore be said, that there must have been a perenne tjäle during the Middle Tubantian, a conclusion that can be drawn especially on the basis of the occurrence of real frost-cracks and of frost-cracks-systems, as well as on the basis of the occurrence of very violent kryoturbate structures.

During the Upper Tubantian (Late-glacial) there occurred perhaps no perenne tjäle, since the coversand from that time was found to be lying undisturbed on the valley-slopes of the erosion valleys, and as real frost-cracks are absent. The origin of certain kryoturbate structures in sediments of that time might then be explained by repeated freezing of the upper part of the thawed soil in spring (only "annual" tjäle), and possibly also partially entirely without the influence of frost, through the occurrence of sinking of material with higher specific gravity into material with lower specific gravity, as a consequence of unequal load.

The conclusions on the absence of a perenne tjäle, drawn on the fact of the absence of frost-cracks and "Wannen-boden" in the region formerly covered by the Weichsel-glaciation (i. a. POSER, 1947), do not agree with the finds in our country. For frost-cracks have been found in sediments (from the upper part of the Middle Tubantian) that must have been deposited when the Weichsel-ice had retired already from its outmost moraines.

CHAPTER VI.

THE FORMATION OF EROSION-VALLEYS.

Introduction.

Since GRIPP held his lecture entitled "Ueber eine morphologische Grenze im nordwestdeutschen Flachland und deren Bedeutung" in 1925, much has been written on the morphological action of the climate in periglacial regions. We therefore shall not give a survey of the literature here, but we shall only advance a few of the data therefrom which are of importance to us.

PASSARGE (1931) explains the origin of certain dry valleys (funnel-valleys) by the joined action of solifluction and snow-melting-water.

POSER (1936) wrote an important article on valleys in West-Spitzbergen and Greenland. He based himself, in explaining the origin of these valleys (that he compared with dry valleys in Germany), on the gulleys formed by snow-melting-water on a tjäle and in which snow accumulations are formed. During the thaw, setting in suddenly, a strong erosion occurs during which the valley is enlarged. The solifluction has an influence on the shape of the valley. It is clear that also the climate (more or less precipitation) has an influence on the size and shape of the valleys created in such a manner. According to POSER, PASSARGE overstresses solifluction. The circuslike or recesslike beginning of some German dry valleys that is hardly comparable with "source-recesses", is explained by the erosion occurring when melting of a snow-accumulation takes place. Often a dishlike or flat basinlike beginning of the valley is observed. Dry valleys with wide, flat valley-bottoms are also found in dry regions, where, in the rainy season (e.g. in Chili), chiefly a quick discharge over the surface takes place, but these valleys never have this wide, dishlike or flat basinlike beginning. This beginning can therefore be a proof as well for the fact that many German dry valleys actually originated under periglacial circumstances. According to GRIPP (1939) the so called "Radialzertalung" is typical for the older moraine-regions: from the highest point in a region, valleys with a straight course and a regular fall point in all directions. In the younger moraine-region on the other hand, the valley-system has far from reached such "maturity": many depressions of the terrain have not yet been cut into at all and the watercourses present there are still completely depending on the relief formed by the land-ice. Such a "Radialzertalung" as in the first-mentioned case, will therefore not be able to come into being under the present circumstances of climate and vegetation in the last-mentioned region, certainly not in regions where the soil consists of porous sand. GRIPP also devotes consideration to the "Radialzertalung" in regions consisting of impermeable loam. This is of great importance with respect to the region examined by us in greater detail, where the subsoil is partially formed by tertiary loam. GRIPP states with reference to Germany amongst others the following: Starlike arranged dry valleys occur in regions that are porous down to below the present level of groundwater.

There is however as much of "Radialzertalung" in moraine-regions, dating from before the Weichsel-glacial, consisting of non-porous loam. The valleys are then strikingly wide and flat. They are neither dry by nature but through every valley runs a small brook. These brooks do not fit, as far as their size is concerned, the width of their valleys. In comparing these valleys with the valleys from the loam-regions of the moraines of the last glaciation, it appears that the latter have not yet been able to straighten their course and that therefore their course is still twisted, as opposed to the former. It is therefore highly probable that the valleys in the older moraine-regions with a loam-soil have originated periglacially during the last glaciation as well as in those with a sand-soil. Büdel (1944) gives amongst others a description of the dry valleys from the German "Mittelgebirge". They begin with flat, troughlike parts, where transport and supply by solifluction prevailed. After junction of some of such small valleys, the valley is obtaining steeper slopes and a flat bottom. Here transport by water prevailed.

We have made a detailed study of the erosion-valleys of north-eastern Twente, especially of those in the hill-ridge of Ootmarsum. We shall give the results hereof below, preceded by a brief survey of the geology of that region. At the end of this chapter we shall briefly mention what else there is known concerning erosion-valleys in the Netherlands.

Short survey of the geology of N. E. Twente.

The two most important morphological features in this region are (see Fig. 39 and 41):

1. The N.—S. course of the hill-ridge Enschede—Oldenzaal—Austiberg—Ootmarsum. The Ootmarsum-part of the hill-ridge is separated of the rest by a low region with an E.—W. course. The highest tops are formed in the Ootmarsum-region by the Kuiperberg, Hezeberg and Braamberg, up to a height of 76 m. Towards the North, the hill-ridge continues on German territory.
2. The valley of the Dinkel. This valley stretches away in N.—S. direction alongside the eastern border of said hill-ridge. The valley-bottom in the North (on Dutch territory) is about 20 m above ordnance datum of Amsterdam and slowly rises towards the South. On the West-side of the hill-ridge there is also a valley that, towards the West, is equally limited by hill-ridges or parts thereof.

In the beginning of the Tertiary, during the Eocene, nearly the whole region was situated below sea-level. During the Oligocene, the Miocene and the Pliocene the sea slowly retreated, so that Pliocene deposits do not occur in the Ootmarsum-region. In that region Eocene, Oligocene and Miocene deposits do however occur: mainly glauconite-containing clays and sands and "Septarian-clay". After the retreat of the sea valley-formation will have taken place and deposition of "Preglacial" sand and gravel (mainly of eastern origin). At the approach of the land-ice in the Drenthian (Saale-glaciation), deposition of fluvioglacial sand and gravel probably took place. The land-ice will, on arrival, first have taken possession of the valleys and so will have had a widening and deepening action, and thereupon, on greater supply of ice, will have exercised a sidelong pressure on the valley-sides; in that manner the

Tertiary and its younger fluviatile cover were pressed upwards, causing very intensive pushing-phenomena. Then the ice must have passed over the hills and must have deposited boulder clay (cover of bottom-moraine according to the geological map, in reality very poor and little erosion-remains thereof). After the disappearance of the land-ice from that region, sands were deposited that were generally taken to be fluvioglacial. We are however of the opinion that the possibility may not be excluded that these homogenous fine-grained sands between boulder-clay and Eemian are "coversands" from the last part of the Drenthian. The result of the CAILLEUX-method (strongly aeolian-fashioned, reworked marine sand) do in any case not oppose this. During the Eemian i. a. peat-layers were deposited in the Dinkel-valley and probably also in the other valleys. During the Pleni-glacial (Middle Tubantian), formation of coversands and of fluviatile sand and gravel took place (see Chapter VII). As a consequence of solifluction, "snow-drift", and snow-melting-water, the hills must have been leveled down to an important degree (see Chapter V). In the Late-glacial coversands were formed again (see Chapter VII). In the Holocene some sedimentation by brooks took place and in many places peat-formation occurred. Some formation of sand-dunes occurred in the Young-holocene time.

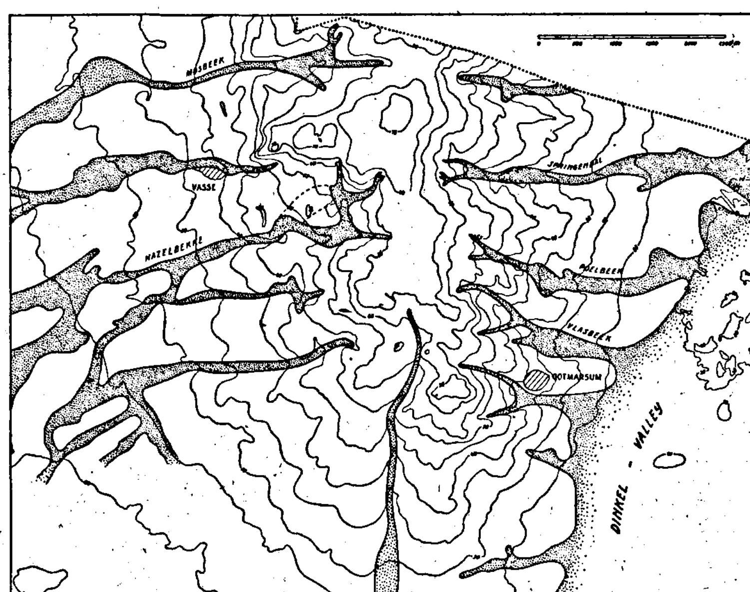


Fig. 20.
Map of the hill-ridge of Ootmarsum with the erosion-valleys. The width of the valleys in the upper course is somewhat exaggerated. Drawn with the aid of the topographical map of the Netherlands 1: 25.000, the Geological map 1: 50.000 and personal data.

The morphology of the erosion-valleys in N. E. Twente.

For a survey of the course of the valleys Fig. 20 should be consulted. It appears clearly from the contour-lines that the watershed has its course in the middle of the hill-ridge in a N.—S. direction. This watershed stretches for an important part over a fairly level plateau, forming the top of the ridge. It is clearly visible how the valleys stretch regularly in all directions from the ridge; so in principle there is here a starlike course of the valleys. The brooks East of the watershed are carrying their water towards the Dinkel, those to the West of it to the Regge. Most of the valleys are strikingly rectilinear. If sharp curves are still occurring, they have generally been caused by the presence of hard gravel-heads. The whole is forming a "mature" system of valleys. Fig. 21 shows a N.—S. section of the East flank

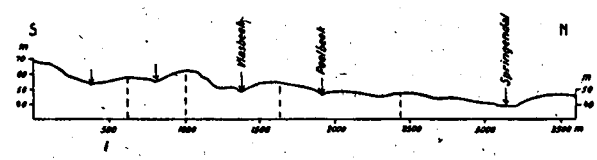


Fig. 21.
Cross section of the East flank of the hill-ridge of Ootmarsum.

of the hill-ridge. It can be clearly seen here how the surface of the ridge is leaning towards the valleys over a relatively large distance. On the air-photographs the valleys can often be seen excellently. The difference in color arises, because generally there are meadows in the valley, outside of it however, generally fields or woods. Where the valleys are approaching the plain, the picture becomes less clear.

We shall discuss some of the erosion-valleys in greater detail. They will be treated in the following order: the Springendal, the valley of the Mosbeek, the valley of the Hazelbekke, the valley of the Vlasbeek and other valleys.

The valley-sections have always been drawn vertically to the local valley-direction and with the face averted from the origin (Fig. 22, 23 and 24).

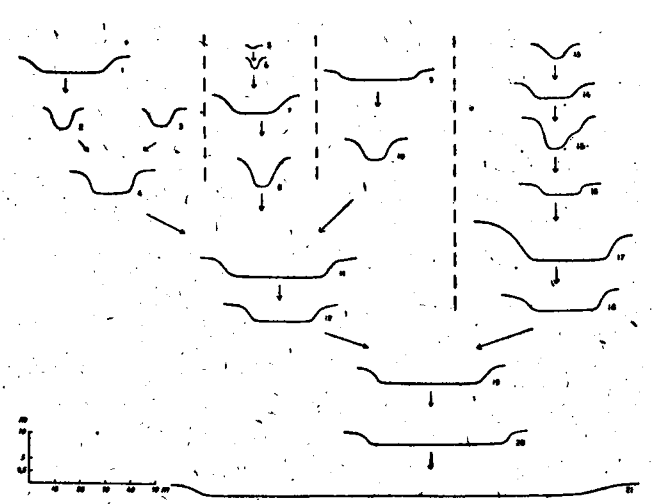


Fig. 22.
Cross sections of the Springendal (Ootmarsum).

The Springendal.

The Springendal, from a morphological as well as from a geological point of view, is one of the most important erosion-valleys in N.E. Twente. Alongside the valley strips of sand are occurring, indicated on the geological map of the Netherlands as fluvioglacial. In view however of the character

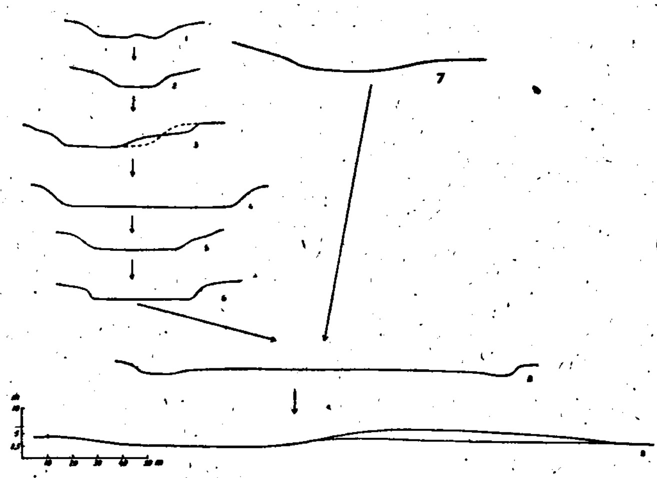


Fig. 23.
Cross sections of the valley of the Mosbeek (Vasse).

of these sands we believe to be in the presence of Younger coversand (see Chapter VII). This coversand is excellently exposed in a few places in the steep valley-side (Phot. 14). In one place we were able, by digging a profile,

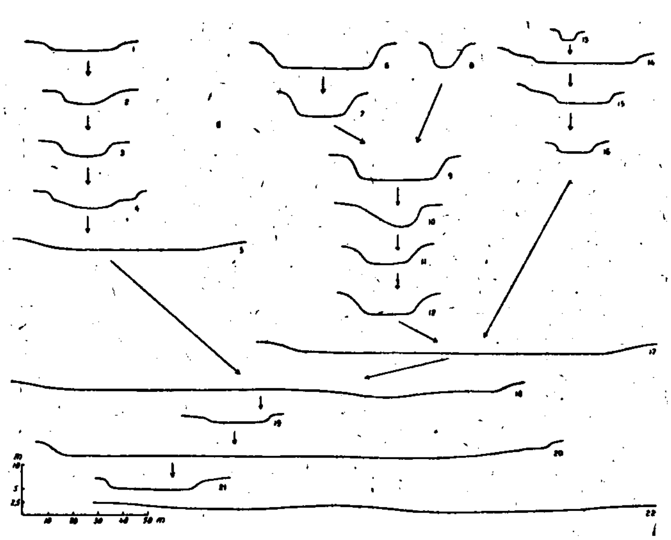


Fig. 24.
Cross sections of the valley of the Hazelbekke (Ootmarsum).

to ascertain that below this coversand there was a layer of unsorted gravel. We believe to be confronted here with the original solifluction-cover, such as we found it much better exposed in the valley of the Mosbeek. Outside these strips of coversand there generally is a solifluction-layer on the surface (see Chapter V), sometimes covered by a relatively thin stratum of coversand. The valley has for a great part cut into the coversand and, in the upper course, it is cutting also into older deposits, while the Tertiary is often to be found not far under the present valley-bottom.

The bottom of the valley is formed by peat, peaty sand, sandy peat or loamy sand. Below this there is a thicker or a thinner layer of gravel and of coarse sand, thick mainly in the upper course. From the morphological point of view the valley is striking because of its flat and relatively wide valley-bottom and the steep sides.

A section of the main valley is given in Fig. 26. The Tertiary is obliquely hatched, the Pleistocene sand and gravel-deposits dating from before the land-ice-covering are horizontally hatched (situation sketched, in reality much more complicated, irregular and ice-pushed), the solifluction-layer (on the valley-bottom possibly sorted), is indicated by small circles, the coversand is dotted and the Holocene covering of the valley-bottom is black.

In Fig. 25 a block-diagram of the Springendal is presented. We shall come back to this later on.

The upper course of the Springendal (Fig. 28) can be divided into a northern and a southern branch. the latter branches upstream into three valleys, indicated from South to North by the letters X, Y and Z, of which X again divides into two, indicated from South to North by X_1 and X_2. Valley X_1 begins with a flat, more or less circular basin, with a diameter of 20 m (Fig. 22^{1}), grown with an Alnetum (from here a small gulley, 6 m wide, leads upwards into the heath, Phot. 11). From this basin a small, deep, troughlike valley (Fig. 22^{2}) descends that soon joins X_2 (Fig. 22^{3}), having approximately the same shape, after which the valley shows already the typical form of flat valley-bottom with steep sides (Fig. 22^{4}) (Phot. 12).

Valley Y begins, just as valley X, with a flat wide part, from which, in this case, two small gulleys lead upwards into the heath (Fig. 22^{6}), having a flat throughlike beginning (Fig. 22^{5}). From the flat basin (Fig. 22^{7}), here too a steep and deep little valley descends downstream (Fig. 22^{8}).

Valley Z begins again with a beautiful, wide dishlike part, 30 m wide (Fig. 22^{9}), out of which comes the 7 m wide valley (Fig. 22^{10}).

Immediately after the merging of valleys Y and Z, the valley so formed merges with valley X. At this place the valley is wide (Fig. 22^{11}) and the flat valley-bottom consists of a fairly thick layer of gravel under a very thin peat-cover. Then, the valley continues, being slightly more narrow (Fig. 22^{12}) (Phot. 16).

The northern main branch begins again with a wide, more or less circular part with a diameter of 12 m (Fig. 22^{14}), from which a small dry valley leads upwards into the heath (Fig. 22^{13}). The valley is in the beginning still rather narrow and deep (Fig. 22^{15}), after which it takes the usual shape (Fig. 22^{16}). Then there is a part of the valley with a very high North-side and a less high South-side (Fig. 22^{17}), but soon afterwards both sides are again of the same height (Fig. 22^{18}). Just before the two main valleys merge, the northern valley shows a flat, half circular outward bend at the North-side. These outward bends of the valley-side occur more often in the Springendal, more or less clearly.

Immediately after the two valleys have joined (Phot. 13 and 15), there is in the northern valley-side, a very beautiful deep-cut circular "erosion-circus" (Fig. 32), from which a few insignificant flat gulleys are leading upwards. The diameter of this "circus" is over 60 m (the valley-diameter in this place is 40 m, Fig. 22^{19}) and the height of the side is 4—5 m. A remainder of the former valley-side stands, as an erosion-rest, in front of the entrance.

After the valley has narrowed to a width of 25 m, a small branch-valley, no longer very clear because of exploitation, enters the main valley from the South, after

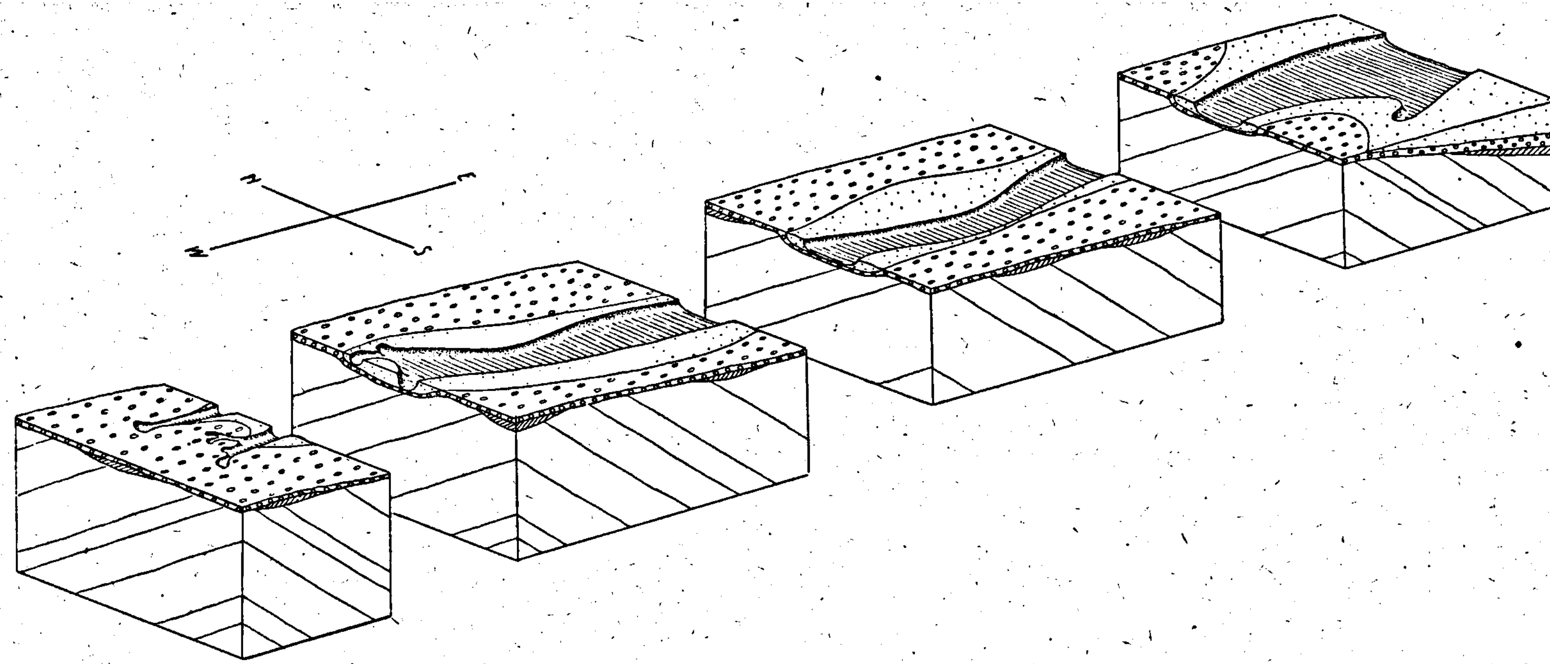


Fig. 25.
Block-diagram of the Springendal (Ootmarsum). Explanation see text. Hor. scale 1: 25.000; width of the valley slightly exaggerated; vertical scale strongly exaggerated. The holocene deposits in the valley have been omitted.

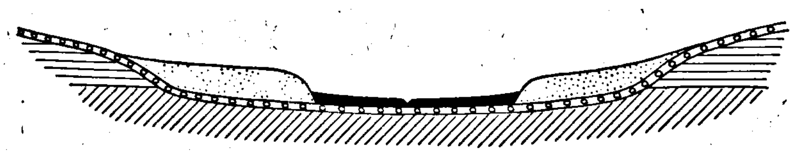


Fig. 26.
Cross section of the Springendal. Explanation see text.

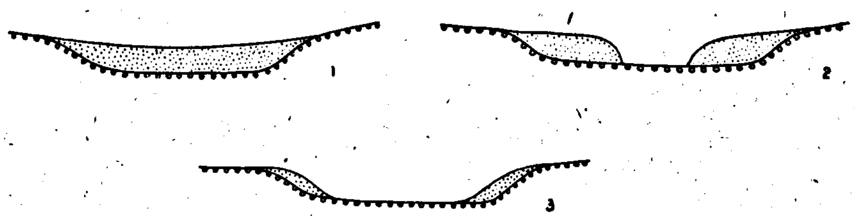


Fig. 27.
Cross sections of various types of erosion-valleys with a coversand covering.

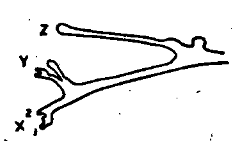


Fig. 28.
Sketch of the upper-course of the Springendal.

Fig. 29.
Beginning of the valley of the Hazelbekke near Braakhuizen (Ootmarsum).

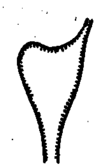


Fig. 30.
Beginning of a branch of the valley of the Hazelbekke (Ootmarsum).

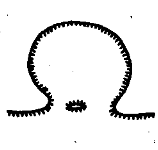


Fig. 32.
Part of the Springendal with a flat basinlike expansion.

Fig. 31.
Part of the valley-wall of the Springendal with half-circular expansion.

which the latter continues, slowly gaining in width. In one place an erosion-remainder of coversand was apparently left in the middle of the valley (Fig. 22^{20}). There again, there are half circular "erosion-circusses". In front of the "entrance" to one of those outward bends of the valley-side there is another erosion-remainder (Fig. 31). Apparently the valley sometimes widened by forming these "circusses", sometimes leaving erosion-remains. Furtheron the valley is about 150 m wide (Fig. 22^{21}), while the valley-sides are becoming gradually more level and less clear. There, where the valley crosses the road to Lage, but little is to be distinguished morphologically any more; the valley slowly merges into the Dinkel-valley.

The present water-drainage in the Springendal is effected by a relatively small brook. This has sometimes cut somewhat into the holocene cover of the valley-bottom. Sometimes this would seem also to have been done by man, in order to drain the marshy source-meadows in the upper course. Some source-water, therefore, seeps through the soil there, just as in the flat basinlike beginning of the valleys, due to the impermeable Tertiary occurring just below the valley-bottom. Erosion, however, does hardly occur any more, under the present circumstances, shown by the vegetation covering valley-bottom and valley-sides completely. We made a pollenanalytical examination of the peat covering the valley-bottom of the Springendal. It appeared that the peat-growth had started during the Atlanticum. This may lead to the conclusion that there in any case no or nearly no erosion took place from that time onward. We shall come back on the dating of this and of other valleys later on in this chapter.

The valley of the Mosbeek.

The valley of the Mosbeek is important, especially from a geological point of view. Morphologically much was lost unfortunately, due to more or less intensive cultivation. Often the shape of the valley is well preserved, apparently there where the Alnetum is still occurring. The valley possesses some very beautiful spots from the botanical point of view. There are two branch valleys, one coming from the North and one from the South (see Fig. 20). The coversands are again playing a part here.

The beginning of the valley is influenced by the lay-out of meadows; but one can still distinguish that it is flat and wide. From this, a morphologically clear valley develops (Fig. 23^{1} and 23^{2}) in which an Alnetum is developed and on the valley-sides of which there is a beautiful Ericetum.

There where, somewhat furtheron, the Alnetum ends, the valley-side is somewhat dug in and the valley is partially filled with the material so freed (Fig. 23^{3}; the dotted line indicates the possible original shape of the valley). While this unfortunately interfered with the shape of the valley, the exposure so originated offered us on the other hand an opportunity to prove our working hypothesis concerning the deposit of coversands in the erosion valleys, after this hypothesis had already become very likely.

It appeared that under a coversand-layer (bottom: fine, "loamy" sand, top: sand with strings of coarser grains) there was, on the valley-slope, a solifluction-cover consisting of boulders, gravel and sand (with on top a desert pavement), below which there was sand with gravel (Fig. 33). The coversands completely tallied with those we had found elsewhere in Twente and that we were able to date pollenanalytically also elsewhere. The age of the valley-coversands and the minimum age of the valleys could so be established. We shall come back to this in more detail later on.

A little past the spot where the valley is damaged, the Alnetum begins again. Here, the shape of the valley is again untouched (Fig. 23^{4}). Past the cross-road, the valley is again slightly more narrow (Fig. 23^{5}). Fig. 23^{6} is giving the section of the valley before it is joining the northern branch. This northern branch-valley is more or less flat, troughlike and assymmetrical (Fig. 23^{7}). Coversands occur at the western

Phot. 11.
Springendal, Ootmarsum (Prov. of Overijssel). The very first beginning of the erosion-valley in the heath. The slopes are grown with *Juniperus*. In the trees on the background there is a large flat "valley-basin". Viewed towards the East.

Phot. 12.
Springendal. The erosion-valley just beyond the flat "valley-basin". Viewed towards the East.

side of this valley. After joining up with the branch valley, the main valley shows on both sides small cuts with a little brook in each, the valley-bottom seems to be more or less convex (Fig. 23[8]); here,a beautiful Alnetum cardaminetosum has developped containing much *Chrysoplenium oppositifolium.* The valley coming from the South is wide and flat at the beginning. The valley is no more than a rather flat depression, the form of which is furthermore strongly influenced by cultivation, just as the upper course of the northern branch.

Finally it should be mentioned that the valley of the Mosbeek shows in its further course some accentuated widenings and narrowings and that the righthand bank of it, over a certain distance, is formed by a sand-ridge (Fig. 23[9]). This sand-ridge consists of the same coversands as those found on the valley-slope (see Chapter VII).

The valley of the Hazelbekke.

The valley of the Hazelbekke belongs, together with the Springendal, to the most important valleys of our territory from a geological and morphological point of view. Botanically also it is of importance and if it would be cultivated this would mean an irreparable loss of a very valuable natural monument. With the Hazelbekke valley the rather irregular course in the region of its origin, with branches towards various directions, is striking. We shall discuss lateron the course thereof as well as that of the irregular course of the continuation of all westward running brooks in the valley-plain West of the hill-ridge.

Here again, alongside the Hazelbekke valley, strips of coversands are occurring. In one case the coversand apparently filled a valley completely. Here, there is left but a flat depression of the site (indicated by stripes in Fig. 20) showing an upward bulge in the middle (Fig. 24[2]).

Three branches are forming the beginning of the valley (see Fig. 20), one with a N.-S. course (valley Z), one N. E.-S. W. (the valley near Braakhuizen, valley Y), and one E.-W. (valley X). Valley X has a beginning tending towards the "Springendal-type" (Fig. 24[1]). It is somewhat wider than the immediate continuation of the valley (Fig. 24[2]). A little further on the valley is grown with an Alnetum (Fig. 24[3]). Then it slowly widens (Fig. 24[4]). Just past the first cross-road it shows a width of about 70 m (Fig. 24[5]). The valley is grown here with a beautiful "source-forest" (Alnetum cardaminetosum).

Valley Y starts off with a wide valley-basin (Fig. 29 and 24[6] and Phot. 20) (from where a small valley leads upwards) continuing as a narrower valley (Fig. 24[7]) (with Alnetum card.). A small side-branch (Fig. 29) is narrow (Fig. 24[8]) and has no basin-like widening. After merging with this small side branch, there follows a wide valley (Fig. 24[9]), narrowing somewhat further on (Fig. 24[10] and 24[11]). On the site of Fig. 24[10] the valley is perhaps somewhat influenced by man (flat E-slope). We find the same picture on the spot where valley Y bends towards the West (from that point approximately Phot. 19 was taken). After this bend, where the Alnetum cardaminetosum begins again, the valley takes again the normal shape (Fig. 24[12]).

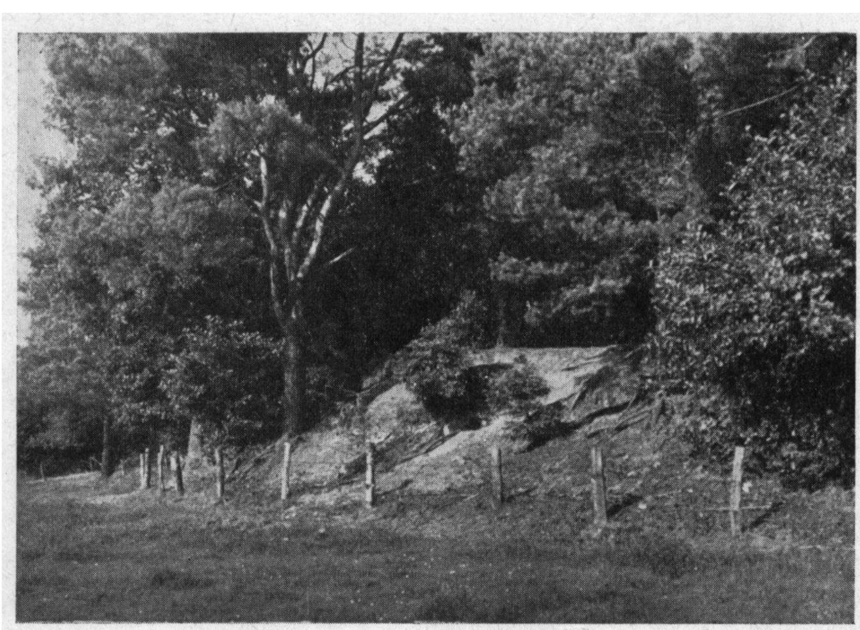
Valley Z takes its course entirely through fields. It starts with a small valley (Fig. 24[13]), entering into the wide beginning of the valley. This wide beginning (Fig. 30 and 24[14]) then soon narrows down to become the actual valley (Fig. 24[15] and 24[16]).

Valleys Y and Z join and become a wide flat valley (Fig. 24[17]), with a N.—S. course. After valley X joined in also, the continuation of the valley is directed E.—W.. At about this place, approximately 2.5 m of peat was bored in the valley. At the beginning the E.—W. directed valley is still very wide (Fig. 24[18]), afterwards however it is much more narrow (Fig. 24[19]), bending to the S. again and widening considerably just before crossing the main road Ootmarsum-Vasse (Fig. 24[20]; the valley-side has probably been influenced here by the construction of a water-mill). At the next — final — bend towards the West, the valley narrows again (Fig. 24[21]). After this the valley slowly widens and becomes less and less clear morphologically.

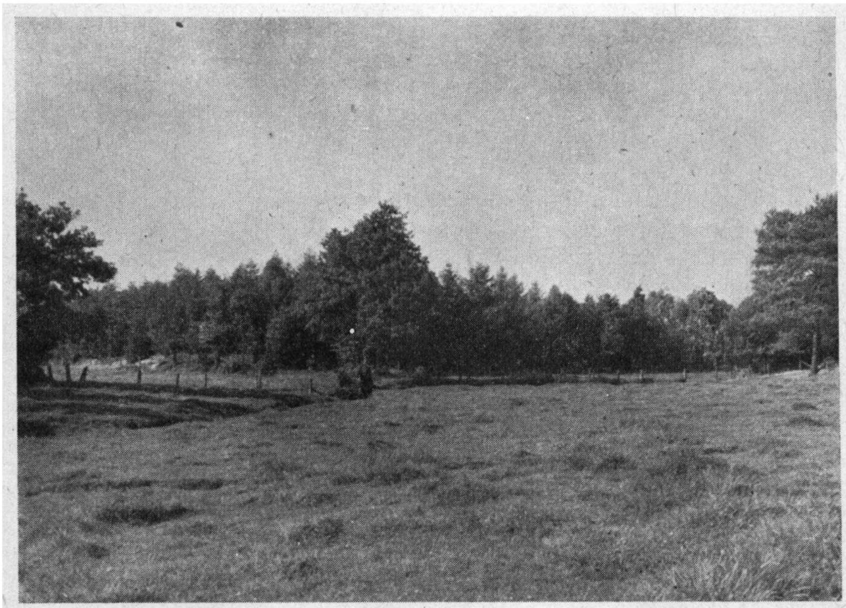
The flat depression with a coversand filling (Fig. 24[22]) seems to form a direct connection between valley Y (united with Z) and the continuation of valley X.

Probably the course of the valley of the Hazelbekke is locally influenced by relatively hard hills rich in gravel.

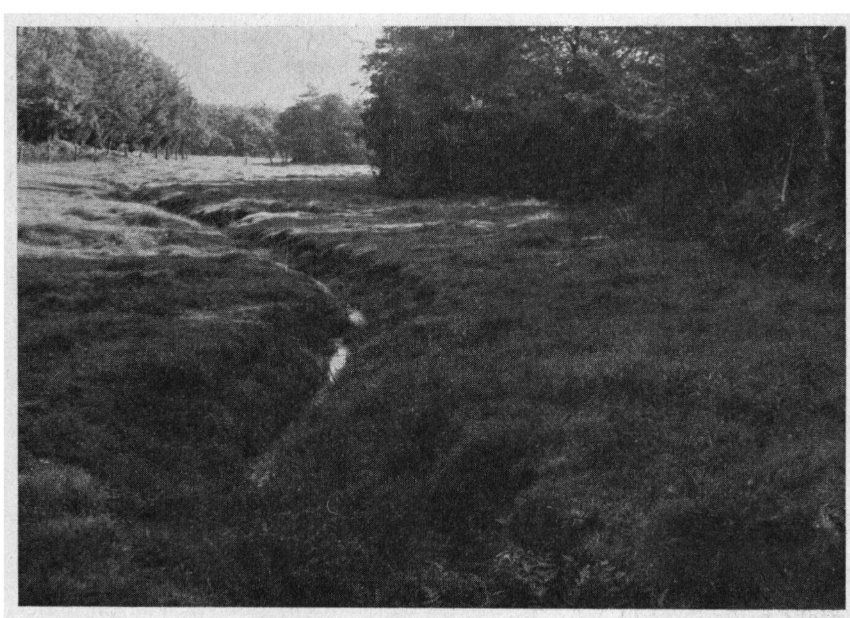
Phot. 13.
Springendal. Viewed towards the West from the steep slope of the valley, just beyond the meeting-point of the two main branches.



Phot. 14.
Springendal. The steep valley-slope, in which the Younger coversand (Upper Tubantian) is exposed. From this spot Phot. 13 was taken.



Phot. 15.
Springendal. Meeting-point of the two main branches.
Viewed towards the West.



Phot. 16.
Springendal. Southern branch. Viewed towards the East.
Recent brook incision.

The valley of the Vlasbeek.

On the northern as well as on the southern side of the Kersberg a valley is beginning, both joining on the eastern side of that hill (Fig. 20). Somewhat East of this meeting point they are joined by a third small valley, after which the valley suddenly widens considerably, continues into the Dinkel-valley and cannot be followed there very well any longer morphologically. The most northerly valley branch is deeply cut in at the beginning and is, next to the Springendal, one of the most striking erosion-valleys of Nutter. It can be seen beautifully from the main road from Oud-Ootmarsum to Vasse (Phot. 17 and 18). From this road it can also clearly be seen that the hills on both sides are sloping over a fairly large distance towards the valley, showing that the importance of the valley is greater than one might originally think, while standing in the valley.

The beginning of the valley is flat and dishlike but it has become unclear owing to agriculture. Next follows a flat, troughlike valley, the S. E.-side of which is steeper than the N. W.-side. After that the valley, when bending via East to S. E., becomes a deep valley with steep sides (about 6 m deep and 15—20 m wide), having a nearly pure U-form. The bend is possibly due to the harder gravel-containing hill due North of the valley. Furtheron the valley-sides are less high, but now the hill-slope on both sides of the valley becomes steeper than before. During borings executed in the valley it was established that the valley-filling amounts to more than 150 cm nearly everywhere: during a boring down to 2 m, the "autochthone" Tertiary was probably just reached in one place. Generally the bottom of the valley is consisting of a layer of modified Tertiary material mixed with sand and gravel. This fact was also established by us in a few other valleys. A small brook, a few decimeters wide, flows through the valley.

Little can be said here with certainty about the coversand-covering of the valley-sides, since in this region the valley borders on fields everywhere, where formerly dunging (and consequently raising) with heath-sods took place.

The southern branch valley can be seen extremely well from the road Ootmarsum-Vasse, looking towards the North—East. It catches the eye by its straight course. The beginning is wide but unfortunately the situation is strongly disturbed, since formerly "phosphorites" have been dug here. Very soon the valley becomes more narrow and its shape is flat and troughlike.

After the northern and southern valleys have joined, a brook flows on each side of it.

The third small branch valley is smaller than the two valleys discussed before. Its beginning is narrow and like a flat trough and, somewhat furtheron, it has rather steeper sides. The Eocene occurs here at about 110 cm below the valley-filling and the valley is grown in this place with an Alnetum. It then slowly becomes clearly asymmetrical, after which it joins the main valley. As the valley takes its course through cultivated country here, it is hard to say whether this asymmetry was caused by man or whether it is natural. After having received this branch, the main valley suddenly has become much wider and its bottom flat. Just North-East of Ootmarsum two small brooks clearly flow in it, in the South a small brook, a few decimeters wide, in the North one that is somewhat wider, about 1 m. The latter has somewhat cut in. The valley-bottom consists, below a thin peat-layer, of loamy sand whose base could not be reached with the hand-drill.

Other Valleys.

We are briefly mentioning a few valleys that will not be dealt with separately and amply.

The valley near Konink Hoek, lying only partially on Dutch territory, has a flat, troughlike shape and coversand is deposited on its slopes, forming a wide strip on each side of the valley.

Phot. 17.
Vlasbeek. Ootmarsum. Erosion valley, viewed towards the East.

Phot. 18.
Vlasbeek. Beginning of the erosion-valley. Viewed towards the West.
This photograph was taken from the same place as Phot. 17
(Nutterweg, Ootmarsum).

Also in the valley of the Poelbeek some coversand is deposited. The relief in the upper course is fairly sharp.

Two smaller valleys with a flat troughlike shape, South of Ootmarsum, seem to have been more or less dammed-off by the sand-ridge lying in the East.

The valley of Agelo, at the start having a N.—S. direction, is narrow over a large distance, then however, it suddenly widens considerably. This valley also seems to have been dammed-off by a sand-ridge, lying South of the hill-ridge of Ootmarsum. The present course of the valley at least shows, before having reached the ridge, a sharp bend towards the West.

The continuation of the valleys stretching westward is often very capricious in the plain. It would seem that the water had to find its way with difficulty. Valleys merge and separate again and show sidewise connections. As opposed to this, all eastward running brooks flow freely into the Dinkel-plain, where only here and there the "coversand-islands" arise. We shall come back in the following on this difference between the plain to the West and that to the East of the hill-ridge of Ootmarsum.

Dating and mode of origin of the erosion-valleys in North-East Twente.

After having given in the above a survey of the shapes of the valleys and of the data most important from a geological point of view, we shall now consider what conclusions can be drawn from this with a view to the dating and the mode of origin of the erosion-valleys.

In the first place the dating shall be treated. We shall endeavour to establish the minimum and maximum age of the valleys.

As has been slightly indicated in the above, the valley-bottom is very often covered by peat. This is in the first place already proof for the fact that today erosion no longer takes place there. The peat from the Springendal (sample taken in the northern valley, just before it joins the southern valley) was examined by us pollenanalytically, which enabled us to establish that the peat-forming began during the Atlanticum. Since that time therefore, erosion certainly no longer took place there. The complete covering by vegetation of all valleys equally indicates that at the present time no erosion or at least very little erosion takes place. Since erosion apparently did not take place or in any case only to a very slight extent during the Sub-boreal and the Sub-atlanticum, the period of increasing deforestation by man, it certainly will not have taken place in the preceding period of dense forests (Atlanticum, Boreal). The only possibility is that during the Holocene some source-erosion occurred, since water wells up in many places, especially at the beginning of the valleys. This is caused by the impermeable Tertiary clays and sandy clays lying very little below the valley bottom in these places.

We shall return to this possibility below. There is still another fact proving that during the Holocene little or no erosion took place (we have not taken into consideration here the sometimes visible narrow and shallow cuts of the brooks into the Holocene covering of the valley-bottom, Phot. 16).

We already mentioned this in passing, in discussing the valley of the Mosbeek and some other valleys. Many valleys or valley branches are lined by a strip of coversand. Sometimes, such as with the Springendal, this strip can be wide, with a more or less horizontal or faintly sloping surface. Sometimes also, the surface of the surrounding sands may slope a little more, and they then seem to be lying on the valley-slopes. Finally, the coversands can also occur in indepent strips, in shallow depressions of the hill-ridge. On the Geological map of the Netherlands these sands, in as much as they are indicated, have been mapped as being fluvioglacial. However, they tally completely with the coversand elsewhere in Twente (see Chapter VII) and for that reason we also considered them as such. In an exposure in the valley-side of the Mosbeek we found a possibility for (indirect) dating. The coversands, lying here on the slope of the valley-side (Fig. 33), were clearly

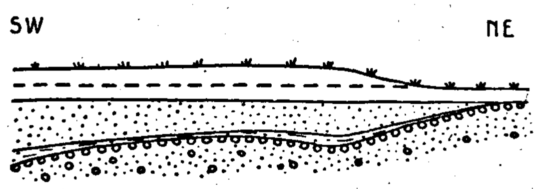


Fig. 33.
Profile in the valley-wall of the Mosbeek (Vasse).
Explanation see text.

differentiated into a bottom (thinner) layer of sand with small "loamy" strata and a top (thicker) layer of sand with small strips of coarser grains. Both types of coversand are occurring in exact analogy everywhere in the actual coversand-region in the plains surrounding the hill-ridge and the low sand-ridges lying there. We were able to date these sands (near Usselo) pollenanalytically and we found that the bottom-sands, with small loamy strata were deposited during the Pleni-glacial (Middle Tubantian) and the top-sands, with strings of coarser grains, during the Earlier Dryas-time and the Late Dryas-time (see Chapter VII). In the Springendal we exclusively found the coarser coversand. Since near the Mosbeek the bottom-coversand was only developed as a thin layer, it is highly probable that the deposit of coversand in the valleys began only during or at the beginning of the Late-glacial. The above leads to the conclusion that the erosion-valleys are older than the Late-glacial, since many of their valley-slopes are covered by the coversands from that time or are even completely or partially filled by it.

It is clear that the erosion could only start its work after the hill-ridge as such had appeared. The formation of the hill-ridge as an ice-pushed wall dates back to the Drenthian (Saale-glaciation) and in that time the hill-ridge must also have been covered by the ice. After the melting down of the ice, circumstances may have been favorable for erosion during a short period. However, looking at the region covered by land-ice during the last glaciation, such as Denmark or northern Germany, it appears that there, since the melting down of the ice, very little erosion has taken place. We therefore may also assume for the region covered by ice during the Drenthian, that as good as no erosion took place there during the period, still cold after the melting down of the ice. Also during the Eemian, with a climate strongly resembling that of the Holocene and with dense forests, only a small degree of erosion can have taken place.

Consequently, since the erosion-valleys, bearing witness of rather important erosive activity, must have come into being after the Eemian but before the Late-glacial, only the Middle Tubantian (Pleni-glacial) is left as sole possibility as to their period of origin (the climate during the Zwolle-stadial must have resembled that of the Late-glacial). This now entirely tallies with the fact that during the extreme cold that reigned during a great part of this period, together with a sparse vegetation, the erosive activity must have been important.

Naturally, the site of the erosion-valleys will already have been determined by primary depressions of the push-wall that will partially already have served as overground ways of drainage for the water after the disappearance of the ice. As we already mentioned in Chapter V, however, a very strong solifluction took place on the hill-ridges of Twente during the Pleni-glacial, that must have made to disappear most of the previously present relief-forms or in any case must have altered them very considerably. The actual shaping of the valleys therefore, should then have taken place during the Middle Tubantian.

We have therefore been able to establish that the valleys are "fossil" in principle, that they were shaped during the Tubantian and under periglacial circumstances. POSER (1936) and to some extent also BÜDEL (1944) explained the origin of such valleys in a manner that, in our opinion, is also applicable to our erosion-valleys. In spring a fairly sudden melting of the snow-masses, amassed during winter, will take place. The melting-water so freed will form gulleys that will however have to fight hard against solifluction. Only after the meeting of some of these gullies the quantity of water will have been sufficient to keep a valley open in the solifluction-masses thrusting forward. The beginnings of valleys where solifluction dominated, are shaped like a flat trough, whereas the main valleys, where water-transport dominated, show a wide, flat valley-bottom with more or less steep walls. A strong, sidelong erosion could take place here under the influence of the tjäle. The sides of both types of valley are, of course, covered with a layer of solifluction material. The following conditions are required therefore for the coming into existence of these valleys:

1. Large quantity of water freed within a short time.
2. Existence of a tjäle.
3. Possibly a poor vegetation permitting strong erosion.

These conditions must have been fullfilled in order to imagine the originating of these valley-shapes in a sand-region, permeable nowadays. As far as the occurrence of these valleys is concerned in regions with an impermeable layer at relatively little depth in the soil (as is the case in an important part of our territory), somewhat similar conditions as mentioned under 2 have been more or less fullfilled in that case under the present circumstances, but not so condition 1, neither condition 3. It is also important in judging this case, that in the impermeable boulder-clay-region of the young moraine-landscape, practically no source-erosion took place in Late-glacial and Holocene times (GRIPP, 1939). Apart from the dating of our valleys by means of the coversand and of other data, this argument also makes it clear that, in spite of the impermeable layer in the soil, the coming into existence of these valleys cannot possibly be explained by source-erosion under the present climatological circumstances. The presence of this layer can however furnish an explanation for a longer activity, even still into the Late-glacial, of some erosion without requiring a decision on the question whether or not a tjäle was still occurring at that time.

A very remarkable phenomenon is the sudden wide dish- or basinlike beginning of many of our valleys (especially beautifully preserved in the Springendal) and the erosion-circusses and semi-circusses present in some valleys. These shapes can be explained by snow-accumulations in the valleys in those places, causing a strong erosion when melting (POSER, 1936). It should be noted that the small valleys leading upwards from these basins are often dry valleys, sometimes with a *Sphagnum*-vegetation. The wide bifurcation-sites of the valleys strongly remind one of the wide beginning of the valley. They will therefore have to be considered as a valley-beginning from an earlier phase in the valley-formation.

Below the coversand-layer of the valley slopes there is, as far as we could find out, a solifluction-cover (Fig. 33).

Also on the bottom of these valleys there is a layer of coarse material (coarse sand, gravel and in the upper course also boulders) that should be taken to be the "fossil valley-bottom". That the valleys are much more important than one would think at first view, appears from the fact that the slope of the hills is often facing into the direction of the valley over a greater distance (see Fig. 21). As has been mentioned already before, the deposition of coversand in the valleys took place from the beginning of the Late-glacial; during that time therefore strong solifluction can have taken place no longer (the stratification of the coversand is undisturbed). In spite of the often fairly thick layer of coversand deposited in the valley, most of the valleys escaped complete filling up in their upper-course. This will have been due to the action of the snow-melting-water in spring that must have abounded in the Late Dryas-time that probably knew a more intensive precipitation.

There are however cases where apparently part of a valley was completely filled with coversand (Fig. 27[1]).

In other cases (e. g. the Springendal) a new valley was really formed in the old one (Fig. 27[2]). Fig. 25 is giving a block-diagram of this valley-type. The subsoil consists of deposits pushed by the ice, dating from before the ice-covering. The remains of the boulder-clay-cover have been obliquely hatched, the solifluction-cover is indicated by small circles (on the valley-bottom this material will generally be more or less sorted), and the coversand is dotted. The holocene deposits on the valley-bottom were omitted and the valley-bottom itself is hatched.

Finally there are cases in which one can only speak of a coversand-covering of the valley-sides (e. g. in the upper course of the Mosbeek; Fig. 27[3]. In the exposure in the Mosbeek-valley the layer "Older coversand" was very thin.

Apparently solifluction continued for a long time on the relatively steep valley slopes, while in the plain around the hills deposition of older coversand was already occurring (see Chapter VII). From the moment onwards that formation of coversand could also begin on the valley slopes, solifluction no longer occurred or in any case only very slightly. The behaviour of the valleys in the plain is noteworthy. In that respect there is a great difference between the Dinkel-valley and the valley West of the hill-ridge. The brooks in the North of the Dinkel-valley apparently found means to keep open complete plains with the aid of more or less North—South running Dinkel-branches; much of the younger coversand deposited here was apparently carried away by the water and only larger or smaller islands remained. As

Phot. 19.
Hazelbekke, Ootmarsum. Upper course of the erosion-valley near Braakhuizen, viewed uphill.

Phot. 20.
Flat "valley-basin" with which the valley of Phot. 19 begins. Hazelbekke, Ootmarsum.

opposed to this the brooks in the western plain had apparently a hard fight against the coversand, the course of the valleys is in any case very capricious, as if the course was checked again and again. Neither had the brooks here any help of a relatively larger river. Consequently, the younger coversand-cover remained untouched here for the greater part, although it is strongly cut through.

In summarising we can therefore now state the following:

The site of the erosion-valleys will already have been determined partially by differences in height already present and by slight erosion after the melting down of the Saale land-ice. The actual valleys were formed during the Middle Tubantian (Pleni-glacial) by eroding snow-melting-water, influenced by solifluction. The remarkable morphology of the valleys can be explained by a similar periglacial mode of origin. The original valley-slopes are covered by a solifluction-cover of stones, gravel and coarser sand, being a continuation of a similar layer covering the slopes of the valleys. The original valley-bottom is formed by a layer of equally coarse material, generally resting directly on the Tertiary (that is to say in the upper course).

During the Upper Tubantian (Late-glacial) coversand was deposited in the valleys. In most cases this did not lead to a complete filling: the coversand was carried away for a greater or smaller part.

During the Holocene very little or no erosion occurred, but deposition of some peat or of "brook-deposits".

The considerations set forth here concern, apart from the valleys around Ootmarsum that were examined in particular, all similar erosion-valleys in Twente such as the erosion-valleys of the hill-ridge Austiberg-Oldenzaal-Enschede, that were examined superficially.

Erosion-valleys elsewhere in Holland.

GRIPP (1938, 1939) published a map of the dry valleys near Arnhem ("Radialzertalung") and described them as valleys originated under the influence of periglacial actions during the "Würm-glacial" age.

MAARLEVELD (1949) described the dry valleys of the Veluwe. In this sand-region e.a. wide funnel-valleys are occurring.

EDELMAN and MAARLEVELD (1949) described also asymmetrical valleys of a sandr-plain in the S.W. of the Veluwe, that must have come into being, just as the former valleys, under periglacial circumstances.

MAARLEVELD (1950) published also an article in which he describes a funnel-valley with a debris-delta in front of its mouth.

CROMMELIN and MAARLEVELD (1949) finally, mention the occurrence of dry valleys in the ice-pushed ridge South of Nijmegen.

The fundamental difference between the valleys mentioned here and those described by us is, that the former are occurring all in permeable sand-regions, whereas the latter occur in a region where generally impermeable loam is to be found right below the surface. The deposit of coversand in the case of our valleys is also playing a not unimportant part.

CHAPTER VII.

THE FORMATION OF COVERSAND AND SNOW-MELTING-WATER DEPOSITS.

Introduction.

Since the research undertaken by FLORSCHÜTZ (1939) and by EDELMAN and CROMMELIN (1939), the great importance of peri-glacial aeolian deposits in our country has become increasingly clear.

After VAN BAREN (1910) had advocated the glacial character of some sand-ridges in eastern Overijssel, BURCK (1938) published a study in which he explained his theories concerning the "fluvioglacial" and the "glacial ridges" in that region, that had formed the basis for the already mapped formerly parts of the Geological Map of the Netherlands. The low sand-ridges occurring around many ice-pushed-walls and hills he explained as kames. This explanation, given at a time when but little was known as yet concerning the fundamental action of the periglacial climate during the Tubantian, is undoubtedly a very elegant one. In 1950 a preliminary announcement of the modified conceptions on the subject of the explanation of the sand-ridges was published (BURCK & VAN DER HAMMEN, 1950). Since then research was continued and as a consequence our insight was still somewhat improved and altered.

It is a noteworthy fact that in studying the coversands in our country, relatively little use was made of data concerning the action of the wind in present-day arctical and sub-arctical regions, although the "principle of actuality" should, according to LYELL, form one of the basic principles of geology. Undoubtedly the scarcity of literature in this field is playing an important part here.

An important publication on the action of wind in cold and moderate regions is that by SAMUELSSON (1926). We shall, in the course of this Chapter cite this repeatedly.

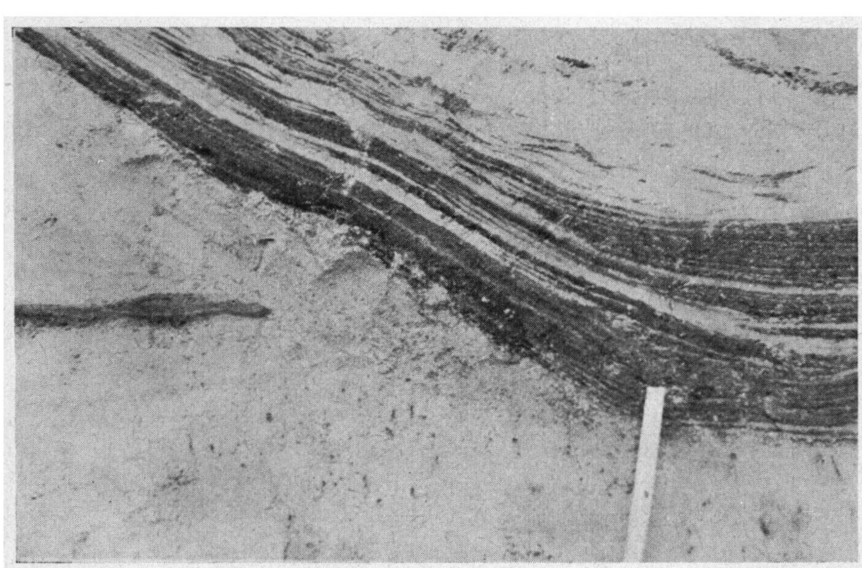
We would once more indicate here a principle on which we based ourselves. We are referring to the palaeontological basis of the division we established for the Tubantian. All classifications of coversands not resting on a palaeontological basis and for which a division into stadials and interstadials was established on other grounds, must be considered to be uncertain in our opinion.

The dating of the coversands.

When examining the coversands in Twente we were able to distinguish both in the region mapped as Lower terrace on the Geological Map and in the region mapped as fluvio-glacial (+ glacial ridges), two types of sand (Phot. 31).

On the surface there are generally relatively coarse sands with strings

Phot. 21.
Small peat layers and gully of snow-melting-water in Middle Tubantian (Pleni-glacial) deposits near Apeldoorn.



Phot. 22.
Snow-melting-water gully, detail of Phot. 21.

and small layers of coarser grains, or very fine gravel (Phot. 28). The thickness of this sand varies between a few decimeters and some meters.

Below them occur sands with a strikingly horizontal stratification and with an alternation of small layers of "loamy" sand with small layers, containing less fine material (Phot. 29, 30 and 34). Their total thickness generally could not be established, as the bottom-limit was not reached in most of the exposures. In a few deeper exposures (near Almelo and Wierden) it could be established that they can be fairly thick, in any case several meters.

In these sands two levels can be clearly distinguished:

1. The dividing-level between the two sand-types mentioned above. Sometimes this is developed as a somewhat thicker "loamy" layer, sometimes as a layer of a few decimeters, showing a gradual transition from one type to the other.
2. An about 10 or 15 cm thick layer of a lighter colouring with a very typical habitus, occurring at varying depths below the surface in the relatively coarse sands mentioned first. In this layer pieces of charcoal of the pine are always found. It generally shows striking "wormlike" appendices, pointing upward and downward (Phot. 37 and 38). Sometimes this layer may be unclear or entirely absent.

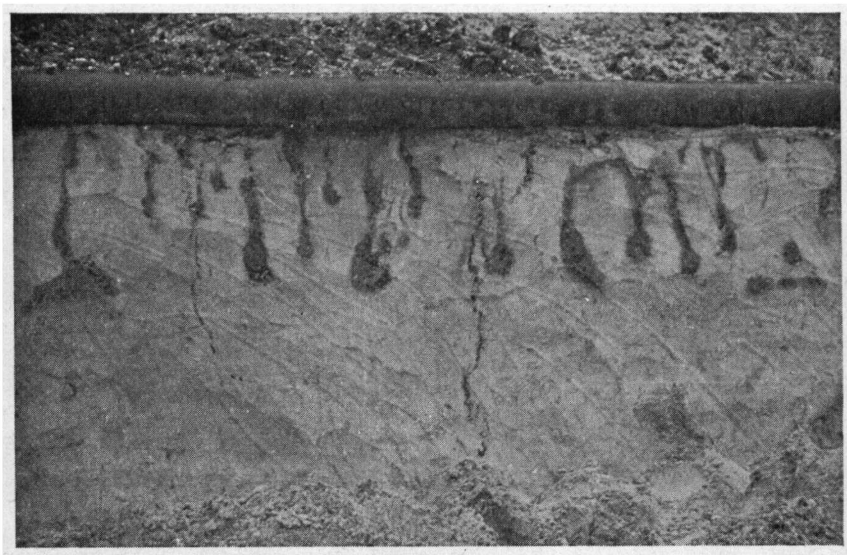
It became possible, due to a fortunate circumstance, to date both of these levels. Near Usselo namely, gyttja- or peat-insertions occurred in two places (Fig. 15, 16, 17, 34 f and 35). In Chapter IV the pollenanalytical dating of these insertions was treated in detail. It has been established consequently that the bottom-level tallies with the Bølling-oscillation and that the top one (the charcoal containing layer) represents the Allerød-time. In Fig. 35, the loamy coversand is indicated by dots and horizontal lines, the coarser coversand by dots exclusively and the Allerød-level by an interrupted line.

In the diagram Usselo B the *Artemisia*-rise is situated exactly in the dividing-layer between the "loamy" (Older) and the coarser (Younger) coversand. The above enables us to draw the following conclusions:

1. The Older coversand is older than Upper Tubantian and must have been formed in the Middle Tubantian (for further dating see below).
2. The sand between the Older coversand and the layer containing charcoal was formed in Earlier Dryas-time.
3. The sand on top of the charcoal-containing layer is younger than Allerød-time and must have been formed during Late Dryas-time. For further dating of this sand see below.

The diagrams of Wierden and of the Bergvennen (Lattrop) (see Chapter III) tally completely with these results as far as Twente is concerned. Here too, the zones similar to the ones mentioned above have a sandy (or loamy) development. As far as the Older coversand is concerned we can add that in Twente (near Wierden) the layers immediately below this sand could be dated as still being Middle Tubantian (see Chapter I), so that this coversand as a whole must have been deposited in the Middle Tubantian. This is in complete harmony with the fact that near Denekamp and Apeldoorn peat-layers of the same age occurred at the bottom of this coversand (see Chapter I).

Not only in Twente the charcoal containing layer has been found but



Phot. 23.
Kryoturbate structure of loam in sand. Middle Tubantian (Pleni-glacial). Apeldoorn. Height of the profile 3 m.

Phot. 24.
Detail of Phot. 23.

in many places in the eastern and northern Netherlands. It invariably occurs in sands having the same habitus as those described above and it always contains charcoal of the pine exclusively. Phot. 37 and 38 show the "Usselo-layer" in two places in the Province of Friesland. Furthermore it was also found in Drente and in Gelderland.

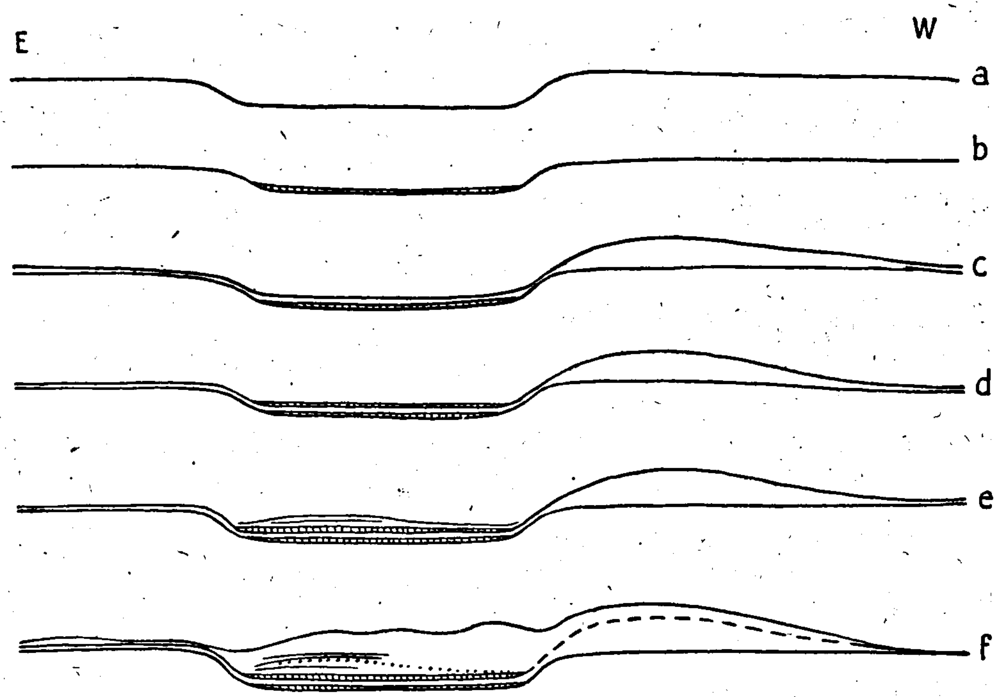


Fig. 34. Diagrammatic sections of the development of the coversand-ridge and the lake deposits in the excavation region of Usselo (Profile A) (Prov. of Overijssel).
a. End of the Middle Tubantian.
b. End Bølling-time.
c. End Earlier Dryas-time.
d. Allerød-time.
e. End Allerød-time (habitation phase).
f. End Late Dryas-time.

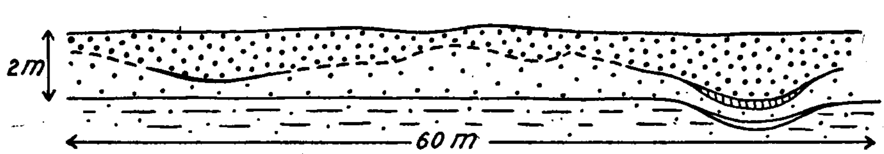


Fig. 35. Section through part of the coversand-ridge in the excavation region near Usselo (Profile B).

As appears from Fig. 36 and 37 the Bølling- and the Allerød-level may sometimes coincide. Peat or gyttja from the Allerød-time, intercalated between coversands was found not only in Twente but also i. a. in Utrecht (Den Treek), near Venray and in S.W. Noord-Brabant (Fig. 38, Phot. 39 and 40; see Chapter III). More often the sand situated below it contains more loam than that situated on top of it. However, the coversand from the Late Dryas-time may also have a "loamy" development, as is sometimes the case in S.W. Noord-Brabant. We shall come back to this further on in this chapter. Probably, the Earlier Dryas-coversand may often be absent outside the eastern Netherlands, so that Bølling-level and Allerød-level approximately coincide. In this respect a great amount of more specific work will still have to be done in the other provinces as well. In the South (Peel-region) important quantities of loess were deposited alongside with coversand during the Middle Tubantian (Chapter I; size frequency distribution-research by WIGGERS (oral information)).

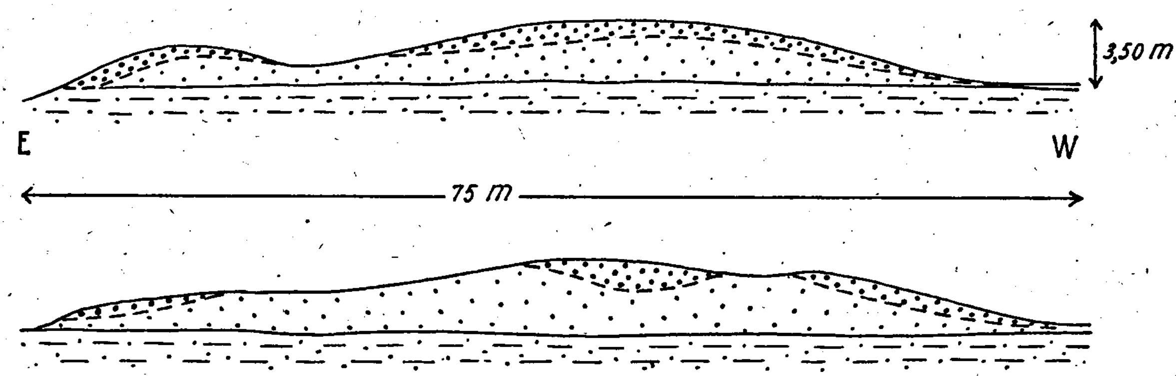


Fig. 36. Two profiles in the coversand-ridge near Wierden (Prov. of Overijssel).

In the above we stated that we consider the sand above the Allerød-level as Late Dryas-coversand. Since up till now it was generally presumed that the coversand on top of the "late-glacial" peat had originated in the beginning of the Preboreal, namely after disappearance of the tjäle (FLORSCHÜTZ, 1938, 1939), it would seem useful to state below the reasons for which we believe that this sand was deposited in Late Dryas-time.

1. From the foregoing it appeared that the formation of coversand always took place in relatively cold periods (Middle Tubantian, Earlier Dryas-time), and that a standstill in the coversand-formation occurred during the relatively warm periods (Bølling-time and Allerød-time).
2. A more or less gradual transition can be seen from the peat (or gyttja) of the Allerød-time to the sand lying on top of it. That is to say the peat is becoming more and more sandy towards the top, coinciding with the transition of Allerød-time into Late Dryas-time in the corresponding part of the pollen-diagram.

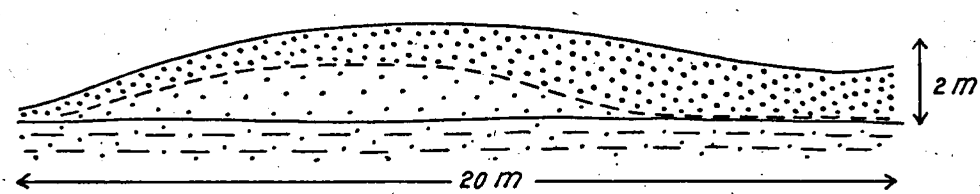


Fig. 37. Section through part of a coversand-ridge North of Weerselo (Prov. of Overijssel).

3. When examining a complete series of lake-deposits (see e.g. the diagram of the Hijkermeer and the Mekelermeer, Chapter III) it always appeared that the deposits from the Late Dryas-time contained a fair amount of sand, while on the other hand the deposits from the Allerød-time and the Preboreal-time were purely organogene and contained no sand at all. (FLORSCHÜTZ, 1938, also mentions that in the Soesterveen the peat from the Preboreal was as good as free from sand, as contrasted with the Late-glacial peat in that locality.)
4. Furthermore, small humus-containing layers yielding Late Dryas-spectra were encountered in the coversand on top of the Allerød-layer near Wierden and Hoogerheide.

While it is therefore highly probable, on the basis of the information under 1, that the topmost coversand was also deposited in a relatively cold period (in casu Late Dryas-time) it is clear, on the basis of 2, without

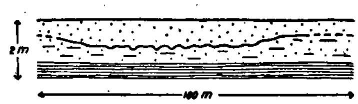


Fig. 38.
Diagrammatical profile of the coversand near Ossendrecht (South-West Noord-Brabant). Explanation see text.

further comment that the deposition started indeed at the beginning of the Late Dryas-time. 3 shows furthermore that the deposition of coversand must have stopped at the beginning of the Preboreal; while 4 finally, is furnishing yet another confirmation of the foregoing.

All this is completely in accordance with the fact that, at the present, the action of the wind is very strong in cold regions (SAMUELSSON, 1926).

If later on, during the Young-holocene, formation of sand-dunes took place, caused by deforestation by man, these are often separated from the Late Dryas-coversand by a podsol-profile and consequently easily recognisable by this alone.

Coversand-morphology.

It will have appeared from the above that the material formerly mapped on the geological map of Twente as fluvio-glacial, "kames" and "åsar" cannot be distinguished genetically from the material mapped as Lower terrace. Furthermore, all these deposits are of the same age: the topmost layers formed during the Upper Tubantian and those lying under them in the Middle Tubantian. It will also be explained in this chapter in what manner these sands must have been deposited. To start with we shall go into details of the morphology of the coversand-landscape especially of that in Twente.

In the landscape in the eastern Netherlands, especially in Twente, two unities can be distinguished: the hill-ridges and separate hills and the coversand-plains surrounding the former. The hill-ridges and separate hills have been formed by the pushing action of the land-ice during the Drenthian and they have been subjected to periglacial actions during the Tubantian. In Fig. 39 the hill-ridges are indicated by oblique hatching. The coversand-plains are partly corresponding with the valleys of small, more or less North—South flowing rivers (Dinkel, Regge), but partially, only more or less East—West running brooks flow through them. In Fig. 39 the cover-sand-plains have been left blank.

As already stated above, the same profile-type was found everywhere in the coversand-plains. On top there are always coversands deposited during

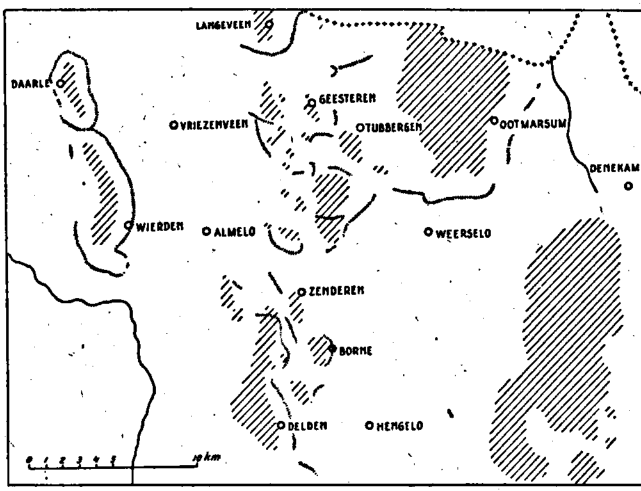
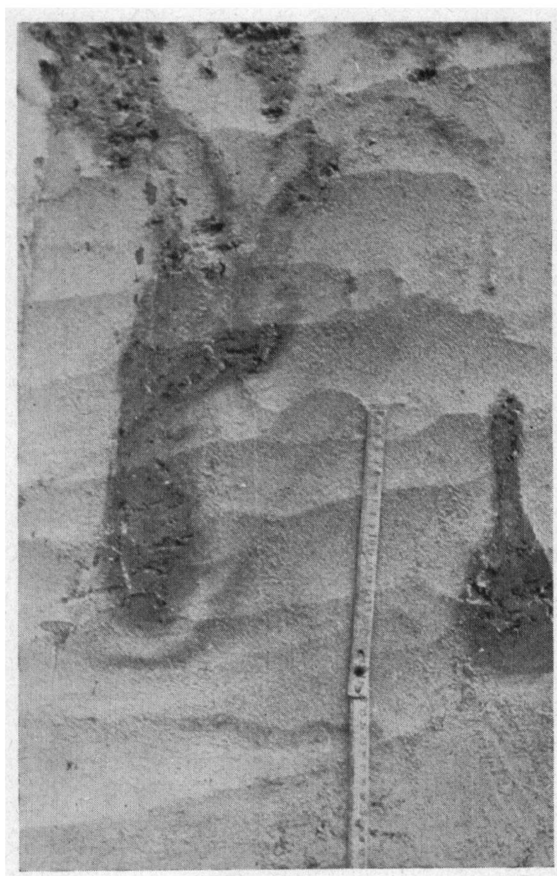


Fig. 39.
Map with ice-pushed-ridges, ice-pushed-hills and coversand-ridges (pseudo-kames and pseudo-åser) in East Overijssel. According to BURCK (1938).

the Upper Tubantian and containing small layers and strings of coarser grains, while below them there are coversands deposited during the Middle Tubantian with a noteworthy horizontal stratification as well as showing successive layers of more or less "loamy" sand.

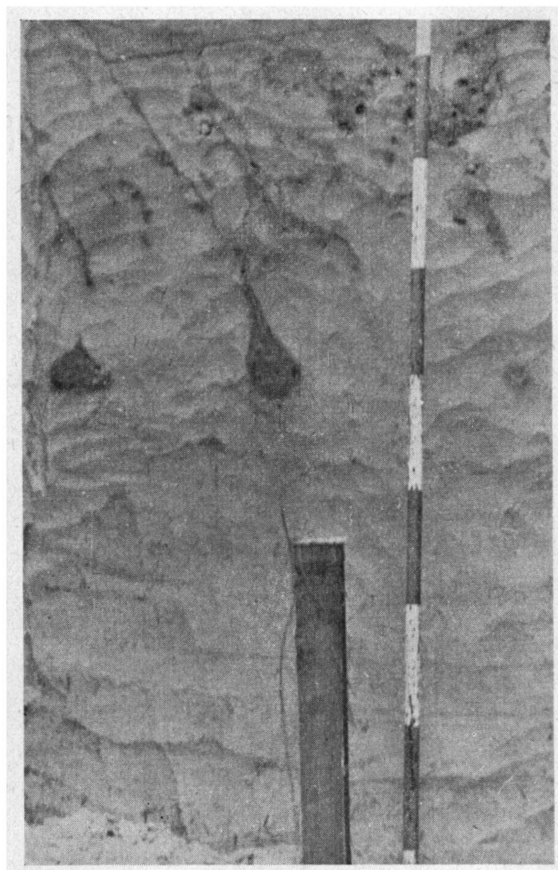
The coversand, in the plains not coinciding with the river-valleys, appears to be cut by more or less East—West directed shallow "brook-valleys"; the general slope of the ground is towards the West. The incisions are reaching the Older coversand through the Upper Tubantian coversand. Often low ridges are occurring alongside the valleys, thickenings of the Younger coversand. Due to the deposit of coversand, some valleys were apparently completely or partially filled during the Upper Tubantian. Such a filled brook-valley with a sand-ridge to its side was exposed near Usselo (Chapter IV).

As peat was occurring here below the sand, the valley could be dated as being older than Upper Tubantian. Likewise the valleys partially filled by coversand near Lattrop as well as a smaller brook-bed near Wierden (Phot. 41) could be dated as being at least of Upper Tubantian age (older than Bølling-oscillation) (Chapter III). It is therefore highly probable that the valleys date back to the topmost part of the Middle Tubantian, the more so since some of them are connected with or are forming the continuation of erosion-valleys from the Middle Tubantian (see Chapter VI). While therefore between the valleys from the Middle Tubantian, coversands were again deposited in the Upper Tubantian, most of the brooks were able to keep their valley open. However dead branches especially were filled up with aeolian sand. It is possible, of course, that part of the valleys was only formed during the Upper Tubantian. It even is very likely that in that time valleys were sometimes dammed off due to deposit of coversand and that, during spring-thaw, the snow-melting-water pursued an other passage.



Phot. 25.
Kryoturbate structure of loam in sand.
Middle Tubantian. Apeldoorn.

The sometimes rather complicated course of the valleys with sideways connections (see Fig. 20 due left), certainly makes one think of such a procedure (see Chapter VI). Fig. 34 gives a diagrammatic view of the development of a sand-ridge alongside a brook-valley near Usselo. The formation began during the Earlier Dryas-time and was completed in the Late Dryas-time. We see the same in Fig. 35, showing a profile through part of the same sand-ridge. The charcoal-containing layer is forming the dividing level between the Earlier Dryas- and the Late Dryas-coversand. It is remarkable that the surface of the Older coversand is lying nearly completely horizontally (parallel with its stratification), whereas the surface of the Earlier Dryas- and the Late Dryas-coversand is often fairly irregular. Apart from the sand-ridges following the valleys, there are also sand-ridges situated in a very striking manner. Namely these follow the contours of the hill-ridges at a certain distance. Some of these ridges have been indicated in Fig. 39. This noteworthy situation caused them to be described and mapped as



Phot. 26.
Kryoturbate structure of loam in sand.
Middle Tubantian. Apeldoorn.

"kames" (Burck, 1938). However, as we already stated (see above and Burck & van der Hammen, 1950), these ridges must be of the same age and must have originated in the same manner as the ones accompanying some valleys in the plains. It now appears, however, that the "pseudo-kames" as well as the latter ridges are lying on the boarder of lower and higher grounds. The lower ground is often formed, here too, by a fairly wide brook-valley. This valley or this depression therefore has a North—South direction, and this often forms a contrast with the direction of the valleys in the central part of the coversand-plains. Since, however, the general slope of the ground is East—West, the water from the valley with an East—West direction must have tried to find a passage at the East-side of the hill-ridges, a passage that could not be found in another way than giving a North—South direction to the discharge along the entire length of the hill-ridge. If therefore an explanation for the origin of the ridges alongside the valleys in the central part of the coversand-plains could be found, the remarkable situation of the "pseudo-kames" would have been explained as well. For in both cases the ridges are apparently depending on the boundary between lower and higher grounds and consequently the situation of these ridges depends on the situation of this boundary. Fig. 36 is showing two profiles through a "pseudo-kame" North of Wierden. Here again the very regular, horizontal surface of the Older coversand (dotted and striped) can be seen, as well as the much more irregular nature of the surface of the Earlier Dryas-coversand (charcoal-containing layer; interrupted stripe), and that of the Late Dryas-coversand. Fig. 37 too is showing a profile through part of a sand-ridge. This clearly shows that the Earlier Dryas-coversand may sometimes be lacking and that then the charcoal containing layer can therefore be resting immediately on the Middle Tubantian coversand.

Outside the ridges the Upper Tubantian coversand may have a rather flat stratification and may furthermore have but a thin development. Apart from in ridges, it may e. g. also be developed in shieldlike accumulations.

It appears that, apart from accumulation of sand also erosion by water in the brook-valleys (that will have been mainly snow melting-water in spring) will have played a certain part at the origin of the striking morphology of the coversand in the eastern Netherlands.

In the riverplains the coversand is often strongly cut in. As an example we shall take the Dinkel-plain. Not only the brooks coming from the West from the hill-ridge, but also the numerous more or less North—South running branches of the Dinkel cooperated in cutting strongly into the coversand here in a manner reminding one of a braided river system. In this way the remarkable landscape of "islands" and "valleys" came into being. The islands, composed for the greater part of Younger coversand, are being used as fields, the lower parts as meadows.

Fig. 40 shows an example of such a landscape in the neighbourhood of Lattrop. The valleys have been hatched horizontally, the "islands" covered by Younger coversand are white. Fig. 41 shows a section of the Dinkel-valley in which also the "islands" and "valleys" are included.

In the region reproduced in Fig. 40 a number of fens completely or partially filled up with peat or lake-deposits are shown in the East near the German frontier (indicated on the map by double hatching) (Phot. 2), appearing to form longdrawn sequences at closer examination. Between these fens there is Younger coversand with a fairly irregular surface. We are undoubtedly confronted here again with a system of valleys filled by coversand for the greater part during the Upper Tubantian. Pollenanalytical examination of the deposits in one of the fens (Chapter III; diagram Bergvennen, Lattrop) enabled us once more to establish that these valleys must be older than the Bølling-oscillation and that they consequently probably already existed during the youngest Middle Tubantian. We indicated a possible reconstruction of the course of these valleys in Fig. 40 by means of

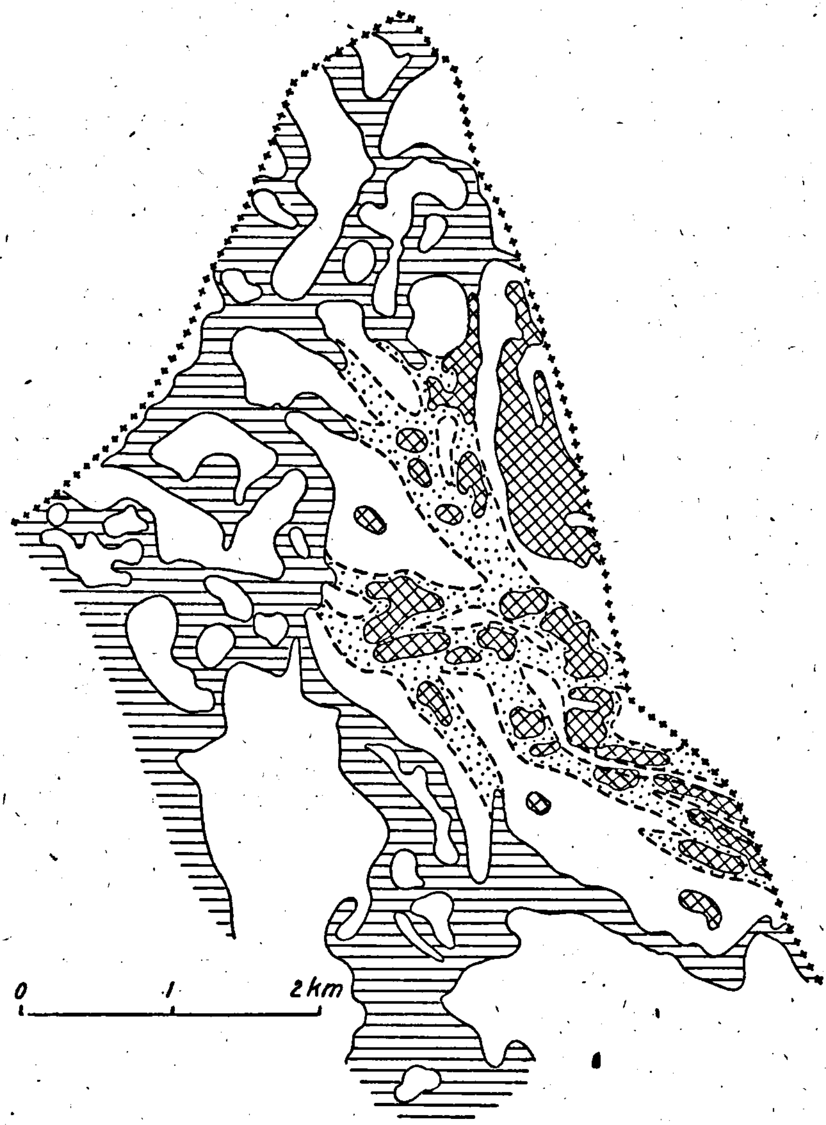


Fig. 40.
Map of Breklenkamp and the Bergvennen (Lattrop, Prov. of Overijssel) with a possible reconstruction of the "braided river-system" of the Dinkel partially filled up by coversand (dotted). Situation at the end of the Middle Tubantian. Explanation see text.

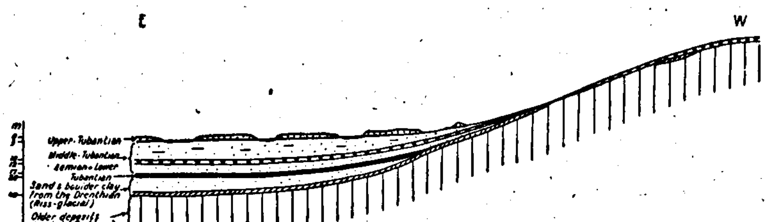


Fig. 41.
Diagrammatical profile through part of the Dinkel-valley and the hill-ridge of Ootmarsum.

dots. As they can be linked very normally with the valleys still present, the latter must for the greater part be of the same age as the former. Apparently certain valleys no longer served for the transport of water after the end of the Middle Tubantian and consequently organogene deposits could be formed there at some places, while the valleys also could be easily filled by coversand.

We might finally add that in exposures in the "islands" the charcoal containing layer from the Allerød-time was extremely well developed in some places, sometimes containing large lumps of charcoal of the pine.

We already mentioned in Chatper VI that also in the erosion-valleys on the hill-ridge of Ootmarsum deposition of coversand took place especially during the Upper-Tubantian (Fig. 25, 26, 27 and 33). Generally however, these valleys escaped complete filling up. On the other hand, little or no action of solifluction can apparently have taken place during the Upper Tubantian, for the coversand on the valley-side of the Mosbeek and on that in the Springendal was entirely undisturbed.

Mode of origin of the coversands.

In the first place the results of the size frequency distribution research will be discussed here. In Fig. 42 diagrams of the analyses have been shown according to the traditional method, while in Fig. 43 cumulative curves of the same analyses are given on arithmatic probability paper (according to Douglas and Brezensinska, 1941).

The following sands were analysed (the figures correspond with those in Fig. 42, 43 and 44):

1. Mosbeek, Ootmarsum. Younger coversand .... (U = 77)
2. Mosbeek, Ootmarsum. Older coversand .... (U = 102)
3. Springendal, Ootmarsum. Younger coversand .... (U = 58)
4. Manderveen (Prov. Overijssel). Younger coversand (probably Late Dryas-time) .... (U = 54)
5. Manderveen (Prov. Overijssel). Younger coversand (probably Earlier Dryas-time) .... (U = 70)
6. Apeldoorn, snow-melting-water deposit, below the undermost peat-layer of diagram XV .... (U = 45)
7. Apeldoorn. Older coversand, 1 m above the uppermost peat-layer of diagram XV .... (U = 77)
8. Siegerswoude (Prov. Friesland, Older coversand .... (U = 90)
9. Siegerswoude (Prov. Friesland), Younger coversand (Late Dryas-time) .... (U = 78)
10. Bergen op Zoom (Prov. N.-Brabant), Younger coversand ... (U = 72)
11. Wouw (prov. Noord-Brabant), Older coversand .... (U = 135)
12. Hoogerheide (Prov. N.-Brabant), Younger coversand .... (U = 111)
13. Wierden (prov. Overijssel), Younger coversand (Late Dryas-time) .... (U = 59)
14. Wierden, aeolian sand (Allerød-time) .... (U = 76)
15. Wierden, Younger coversand (Earlier Dryas-time) .... (U = 72)
16. Wierden, Younger coversand (Earlier Dryas-time) .... (U = 87)
17. Wierden, transiton Younger coversand to Older coversand... (U = 104)
18. Wierden, Older coversand (finer layer) .... (U = 113)
19. Wierden, Older coversand (coarser layer) .... (U = 76)

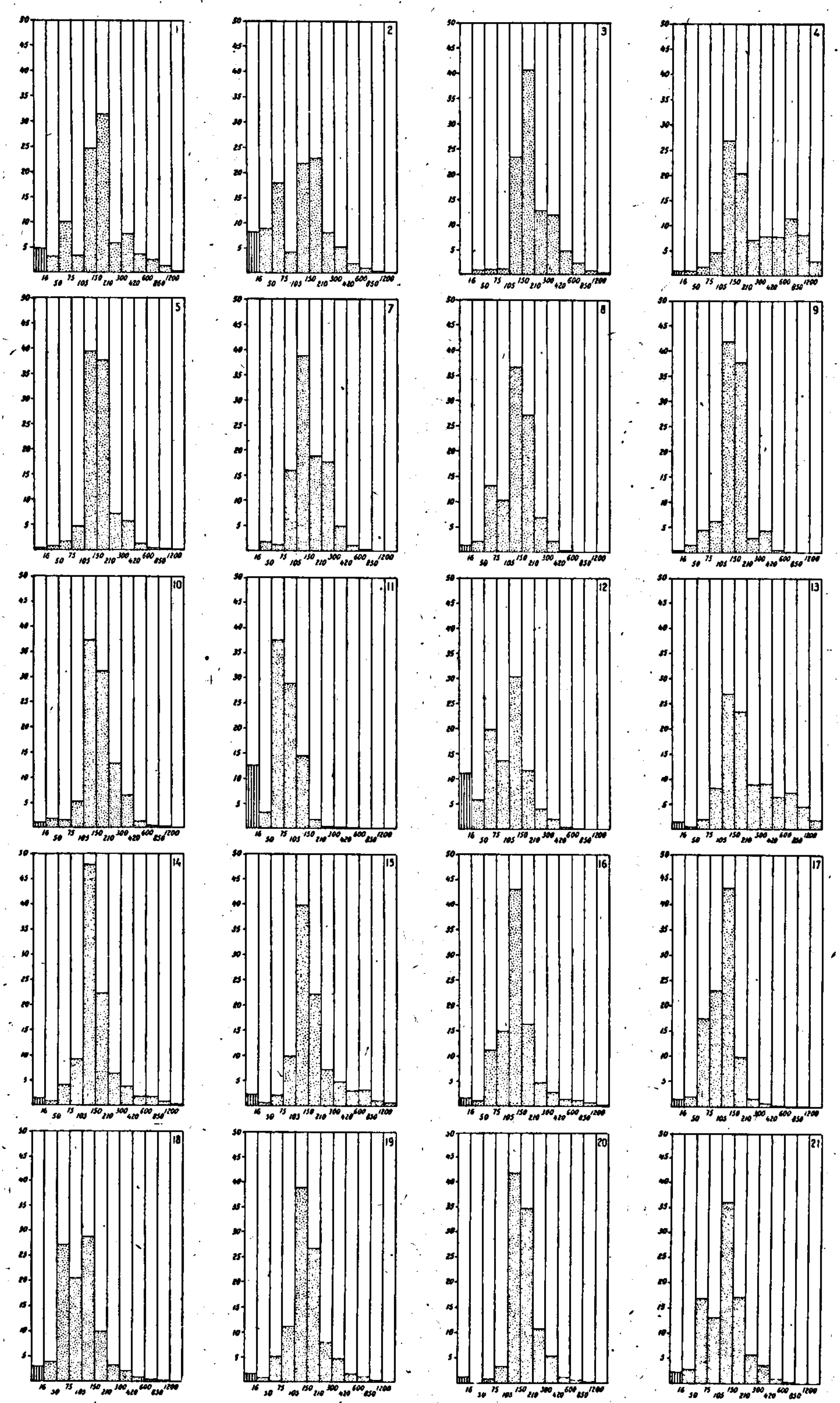


Fig. 42.
Size frequency distribution diagrams of Middle and Upper Tubantian sands.
Explanation see text.

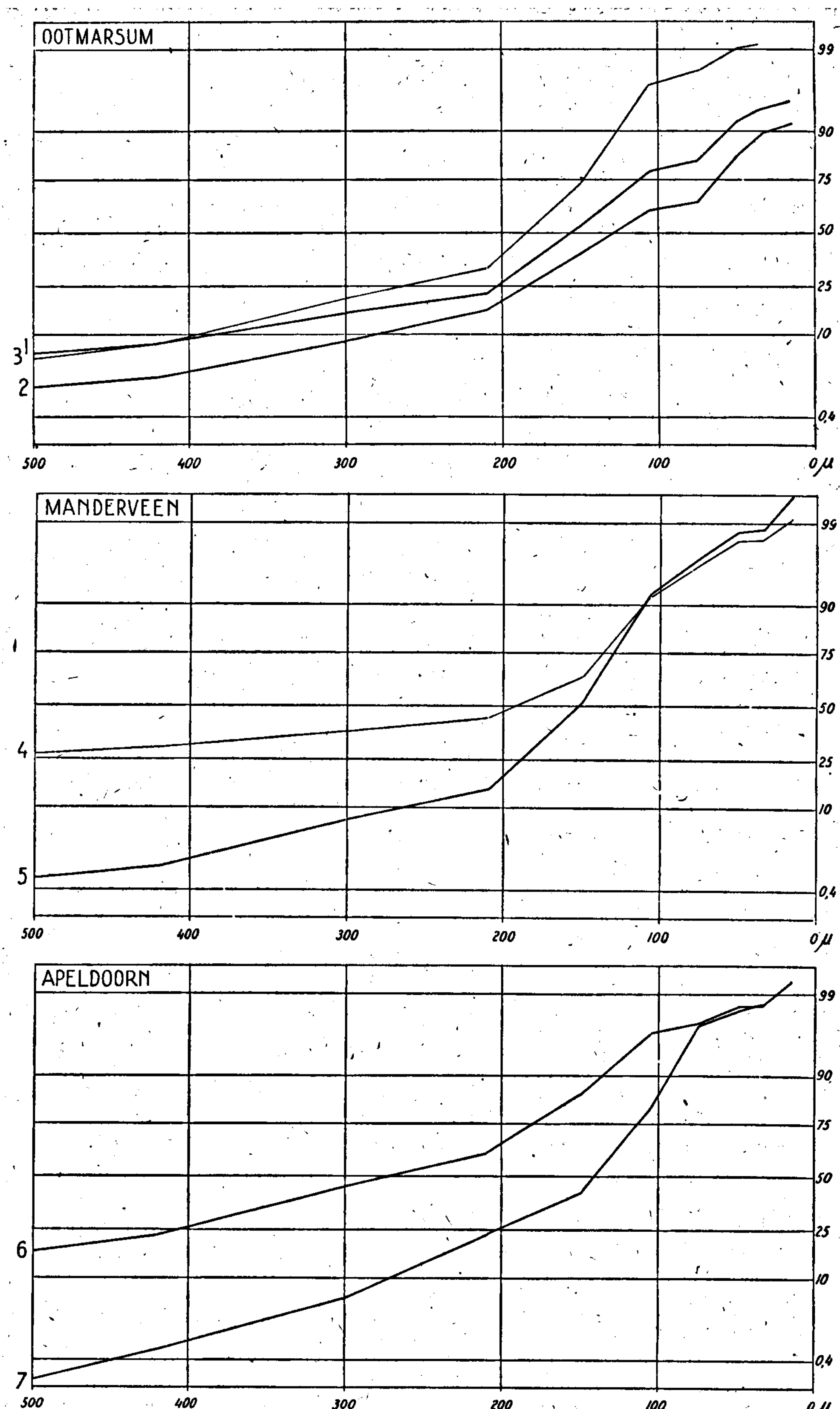


Fig. 43.
Size frequency distribution curves (cumulative) of Middle and Upper Tubantian sands, on arithmatic probability paper. Explanation see text.

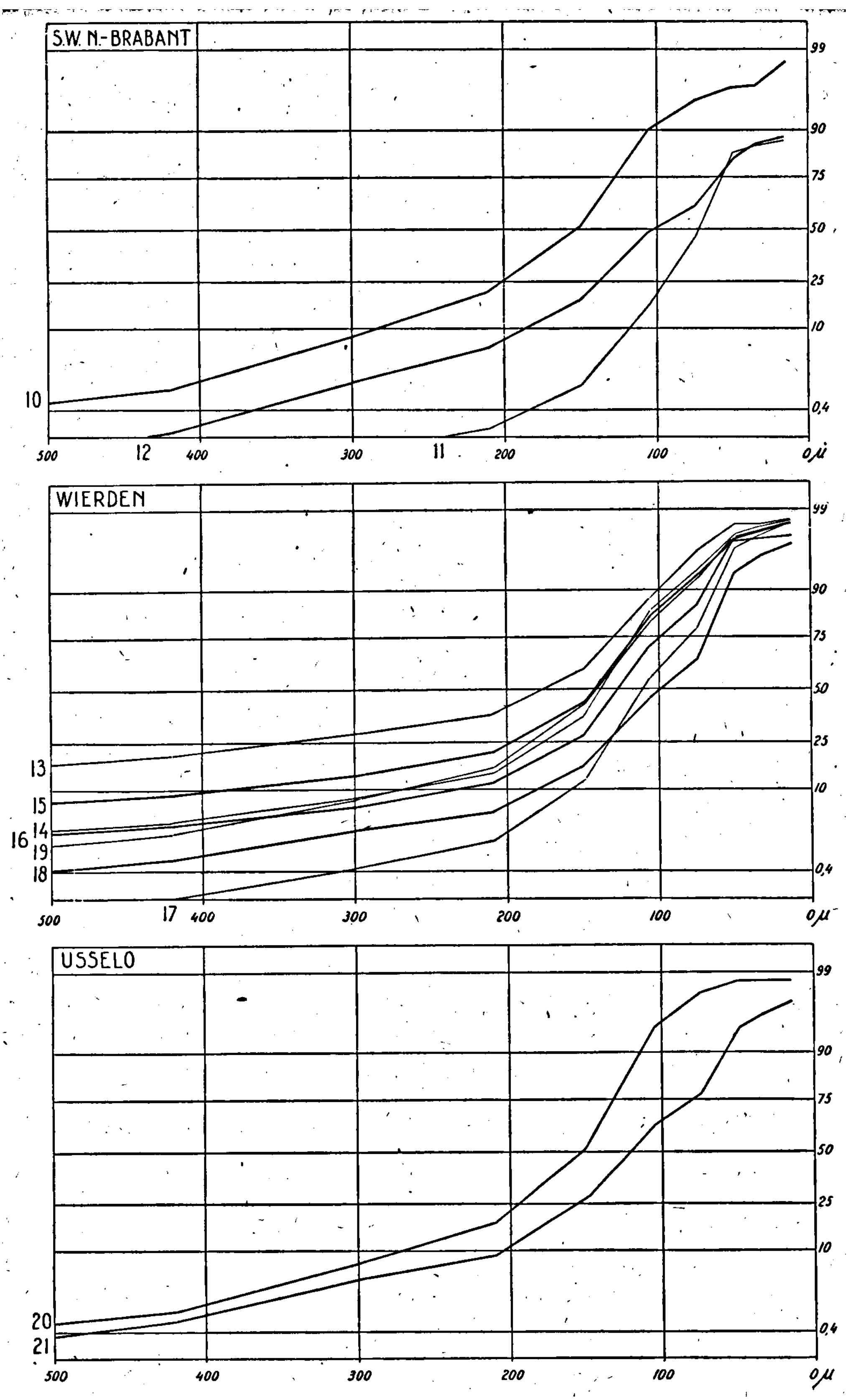
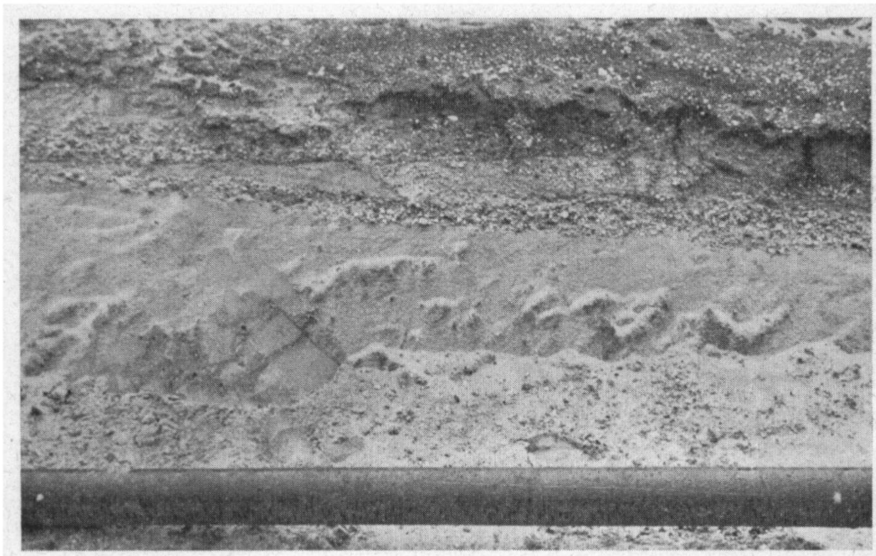
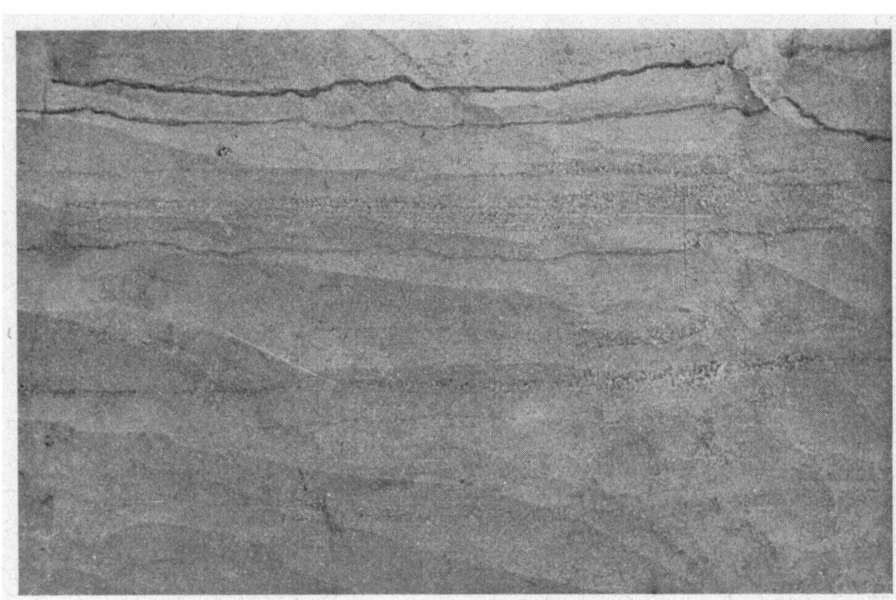


Fig. 44.
Size frequency distribution curves (cumulative) of Middle and Upper Tubantian sands, on arithmatic probability paper. Explanation see text.



Phot. 27.
Gravel layer situated above the level of the kryoturbate structures of Phot. 23—26 incl. Presumably Middle Tubantian. Apeldoorn. Height of the profile about 2 m.



Phot. 28.
Younger coversand. Upper Tubantian (Late-glacial). Coversand-ridge near Wierden (Prov. of Overijssel). Height 40 cm. Detail of Phot. 31.

20. Usselo (Prov. Overijssel), Younger coversand (Late Dryas-time) .... (U = 65)
21. Usselo, Older coversand .... (U = 97)

The cumulative curves generally show a "S-shape" (level part, steep part, level part), sometimes however they come nearer to a straight line. In general the M-figure of the Older coversand is lower than that of the Younger coversand; the latter is generally also coarser. The U-figure (see the above list) is higher for the Older coversand, which points in the same direction. It furthermore appears from Fig. 42 that the Older coversand often shows a double peaked curve, one in the 105—150 μ fraction and one in the 50—75 μ fraction. The Younger coversand sometimes shows a purely aeolian curve with a pronounced peak in the 105—150 μ fraction, but apart from that it generally shows fairly high percentages in the coarser fractions. Before endeavouring to draw any further conclusions we shall first discuss the various analyses separately.

1 and 2, coversands of the valley-slope of the Mosbeek. The former, judging by its habitus, was a Younger coversand, the latter an Older coversand. The cumulative curves are approaching a straight line. The Older coversand shows a very clear second peak in the 50—75 μ fraction, while also the loess-fraction is represented stronger than in the other analyses. The Younger coversand is coarser but is still showing a small second peak in the 50—75 μ fraction, while here the loess-fraction is hardly represented.

3 is a Younger coversand from the Springendal. The coarser fractions are fairly strongly represented here, while the fractions under 105 μ are nearly entirely lacking.

4 has a high percentage of the coarser fraction, while 5 is finer and has entirely the character of a dune-sand-curve.

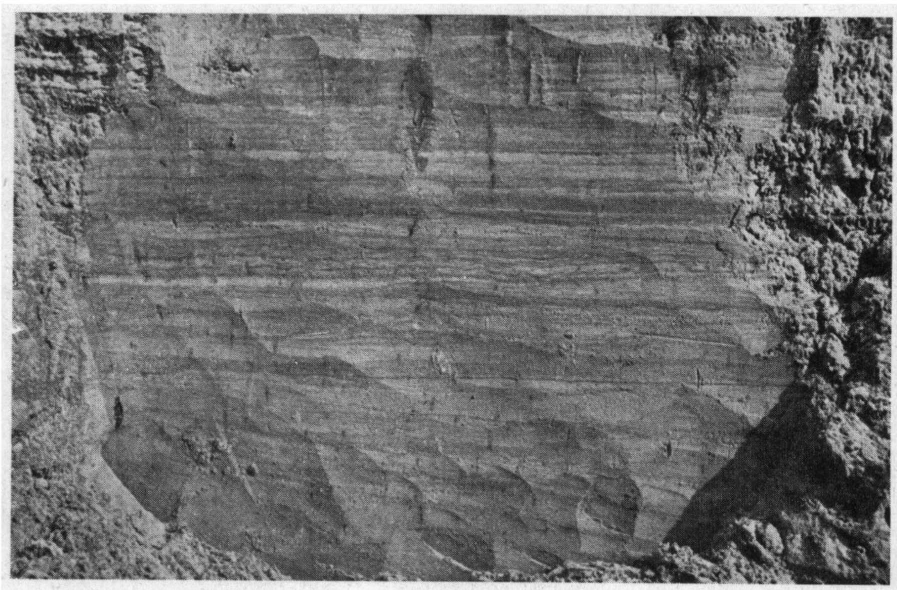
6 is a snow-melting-water deposit and consequently shows a completely different curve.

7 is a sample from the Older coversand. It does show a clear aeolian peak but it is coarser than the other Older coversands and does not show a second peak between 50 and 75 μ. This corresponds with the observation in the field that the Older coversand is slowly becoming coarser downwards. On the spot where the sample was taken, the "loamy" layers had already become very thin and were hardly perceptible any more.

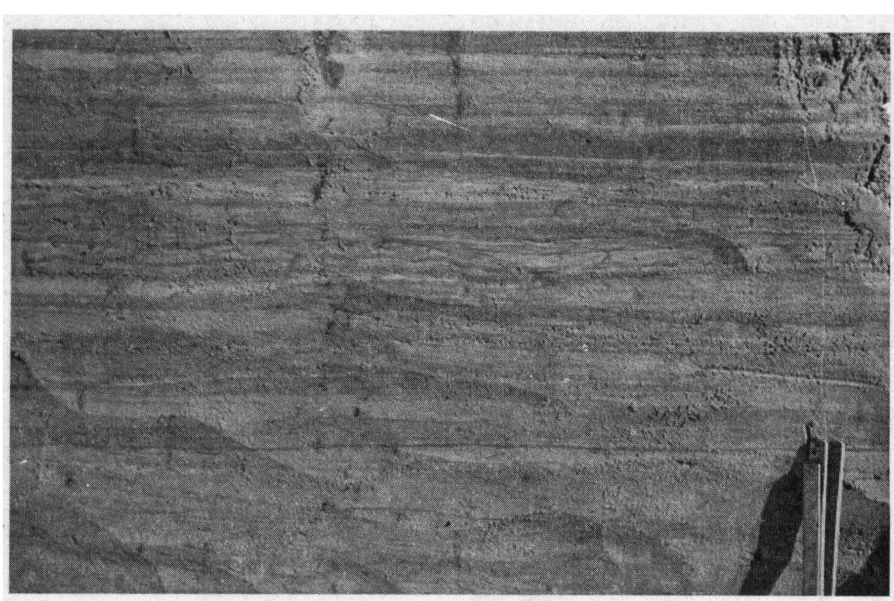
8, Older coversand from Friesland, again shows a small second peak in the 50—75 μ fraction, while the Younger coversand (9) of the same spot is again coarser.

10. Of the coversands from S.W. Noord-Brabant 10 is again showing an obvious aeolian peak. 11 (Older coversand) differs from all other sands as it shows one very clear peak in the 50—75 μ fraction; 12, a coversand from the Late Dryas-time, loamy at first sight, shows again a double-peaked diagram, one peak in the 50—75 μ, and one in the 105—150 μ, while the S-shape of the cumulative curve comes nearer to a straight line.

13 to 18 inclusive are a series of consecutive samples from the coversand-ridge near Wierden. The cumulative curves show a great resemblance. 13 again shows a strong representation of coarser fractions. 14 was taken in the charcoal containing layer from the Allerød-time, at a spot where it was fairly thick; it shows a very remarkable aeolian peak. 15 shows a similar diagram, but is somewhat richer in coarser fractions. In 16 the fractions 50—105 μ are somewhat stronger represented, in 17 again slightly stronger.



Phot. 29.
Older coversand. Middle Tubantian. Almelo (Prov. of Overijssel). Height 90 cm.



Phot. 30.
Older coversand. Detail of Phot. 29. Height 45 cm.

The Older coversand (18) shows again a second peak. While 18 is a sample from a "loamy" layer, 19 is a sample from a relatively coarse layer (the coarsest to be found there in the Older coversand). This last one appears again to have a normal aeolian character and to resemble 15 closely.

The samples of Usselo are showing again a coarser type with aeolian selection for the Younger coversand (20) and for the Older coversand (21) a finer more or less double-peaked type, the cumulative curve of which has a more level course.

In summarising the above it can therefore be stated that the Older coversand, originally described as sand with "loamy" layers, generally does hardly contain a loess-fraction and therefore cannot really be called "loamy". The "loamy" habitus must have been caused by the relatively strongly represented fraction 50—75 μ. One of the characteristics for coversand of this type seems to be the strong representation of this "fine-sand", causing a certain double-peakedness (105—150 μ and 50—75 μ) (2, 8, 18, and 21). Coarser layers in the Older coversand may lack this double-peakedness and show a character more like that of the Younger coversand (19). Further downwards the Older coversand becomes slowly coarse (7) and finally merges into snow-melting-water deposits (6).

We believe that we have to consider the loamy coversand (or at least a great part of it) from the southern and middle part of the Netherlands (with a peak in the 105—150 μ and a peak in the loess-fraction) as an equivalent (as far as both age and genetics are concerned) of the Older coversand in eastern Holland and elsewhere (S.W. Noord-Brabant, Friesland). In the Older coversand from eastern Holland and other places, part of the fine-sand fraction (50—75 μ) takes the place of the loess-fraction (16—50 μ). It should however always be taken into consideration that these are but preliminary conclusions that will have to be checked by a greater number of analyses.

The Younger coversand is generally considerably coarser than the Older coversand. This is especially striking in the case of that from the Late Dryas-time (4 and 13). There generally is a clear peak in the 105—150 μ fraction, sometimes however also in the 150—210 μ fraction. Also the samples from the pseudo-kame near Wierden show a clear selection. Occasionally also the 50—75 μ fraction in the Younger coversand may locally be presented stronger than usual (1) or it may exceptionally also take more the character of an Older coversand (12). We consider it extremely likely that the Younger coversand is an equivalent (as far as age and genetics are concerned) of the "coarser coversand" found on the surface in many places in the Netherlands, of the "pseudo-åsar" of the Veluwe (MAARLEVELD, 1951), of a great part of the so-called "river-dunes" and of the so-called "Boreal coversands" of Belgium.

Generalising somewhat we can now summarise the characteristics of the coversands as follows.

Older coversand (Middle Tubantian; Phot. 29 and 30):

Stratification strikingly horizontal, alternating small layers of somewhat finer and somewhat coarser material, does not show accumulation-forms such as ridges, dunes etc.; is generally finer (M-figure lower, U-figure higher) than the Younger coversand, shows less selection and shows two more or less definite peaks in the size frequency distribution diagrams, one in the 105—150 μ fraction and one in the fraction of 50—75 μ (or possibly 16—50 μ).

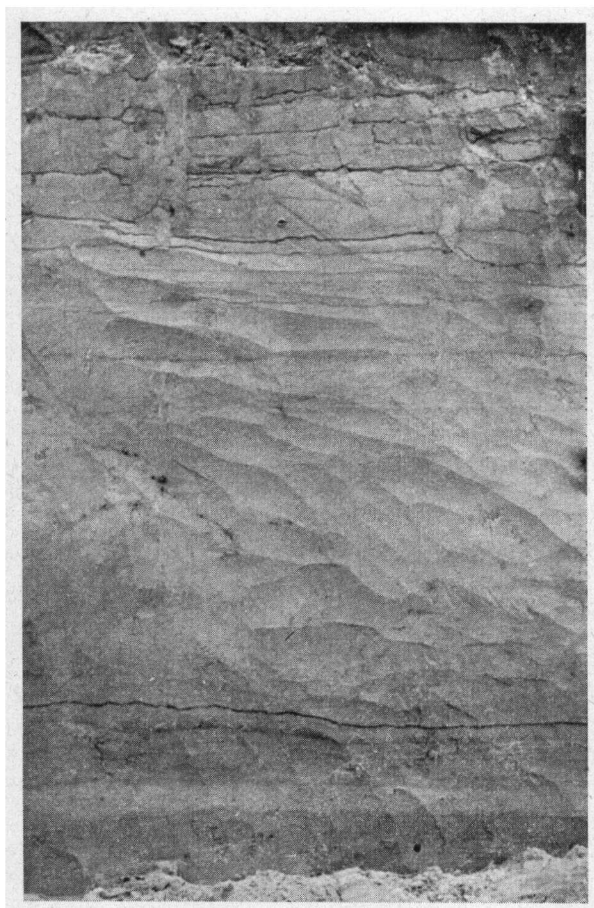
Younger coversand (Upper Tubantian; Phot. 28):

Often horizontal stratification with strings and small layers of coarser grains and sometimes some fine gravel, but sometimes also (in the ridges) showing somewhat criss-cross bedding; often shows accumulation-shapes such as ridges and flat "dunes"; is coarser (M-figure higher, U-figure lower) than the Older coversand, generally shows a clear peak in the 105—150 μ fraction and also often higher percentages in the coarser fraction following upon it (150—210 μ), while the fractions over 210 μ are relatively strongly represented and those under 105 μ generally very feebly.

In endeavouring, on the ground of these characteristics, to draw conclusions as to the genetics of the coversands one should take into consideration the fact that the climatic conditions during the deposition of the Older coversand, in the Middle Tubantian, were "arctic", while those during the deposition of the Younger coversand, in the Upper Tubantian, were "sub-arctic".

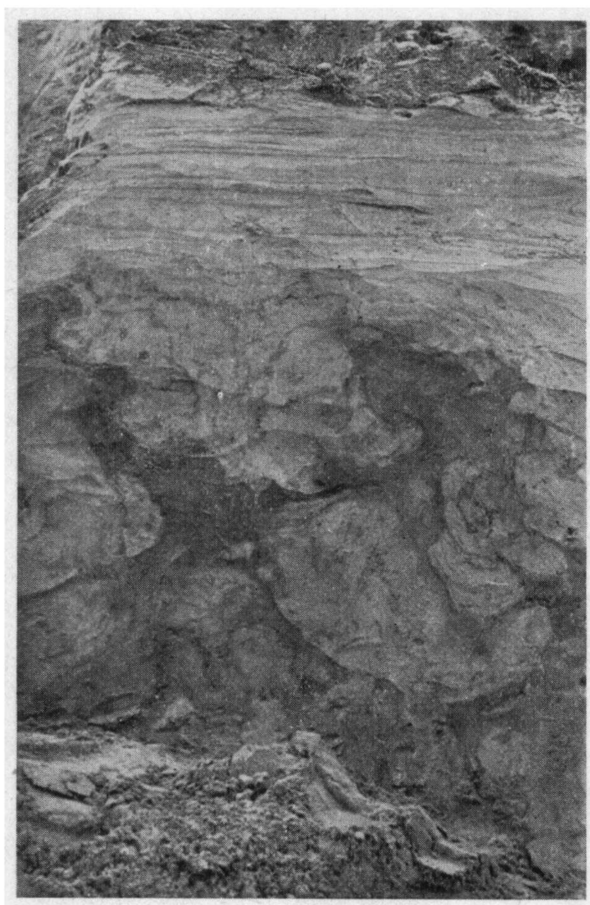
The Older coversand. Samuelsson (1926) mentions on the basis of his research in recent arctic and sub-arctic regions that in certain places and especially in those with a vegetation of brushwood, "drift"-material is occurring in alternate small layers. He furthermore supposes that snow is able to transport material that is at it were cemented to the snow-flakes and that consequently the whole has a lower specific weight than the sandgrains individually. Due to this, the transport capacity of a snow-storm would be much greater than that of the wind only. He found in a snow-profile alternately snow and small layers of minerogene material: fine dust and coarse grit that was apparently already partially mixed together. It is clear that aeolian transport by means of snow will be much less selective than transport by wind only. The double-peaked curves might therefore form an indication for the fact that the Older coversand originated in this manner, aeolian by the aid of snow. Furthermore it would not seem entirely impossible to us that the regular alternation of layers of coarser and finer material might possibly have been caused by a difference in the mode of deposition during summer and winter. As was already mentioned above, the coarser layers may apparently consist of better selected material. In any case the level stratification without the accumulation forms seems to correspond with the arctical conditions. The material may have been transported over relatively large distances and has been deposited as a cover. This is i. a. also advocated by the great homogeneousness of the Older coversand.

The Younger coversand. Samuelsson (1926) mentions that after a storm the snow is often covered by coarse grit (up to 10 mm), forming arched lines around the mountain peaks and around the hills. This proves that fairly coarse material also can be transported over relatively large distances, even if only at little height above the surface or gliding and "leaping" over the snow. Samuelsson also relates that at the edge of places free from vegetation a kind of small dams of relatively coarse material (fine gravel) may originate due to action by the wind. These dams are about 0.5 m high and follow the borderline of the spots free from vegetation at a certain distance. Generally speaking the Younger coversand is rather coarse and sometimes even contains some gravel (up to about 8 mm). In connection with the above and with the fact that it generally shows a clear aeolian selection it will be clear that the Younger coversand as a whole is an aeolian deposit notwithstanding the fact that sometimes a certain amount of fine gravel is occurring in it. As a whole it makes a more local impression than the Older coversand and this will no doubt have been influenced by the vegetation (sub-arctic, poor in trees or park landscape). Although the stratification can also be level, accumulation-shapes are very general, especially longdrawn flat ridges situated at the edge of brook-valleys but that can also occur independently. Also the "pseudo-kames" are situated on the border between a higher and a lower



Phot. 31.
Profile in the coversand-ridge near Wierden.
Younger and Older coversand. Height 2 m.

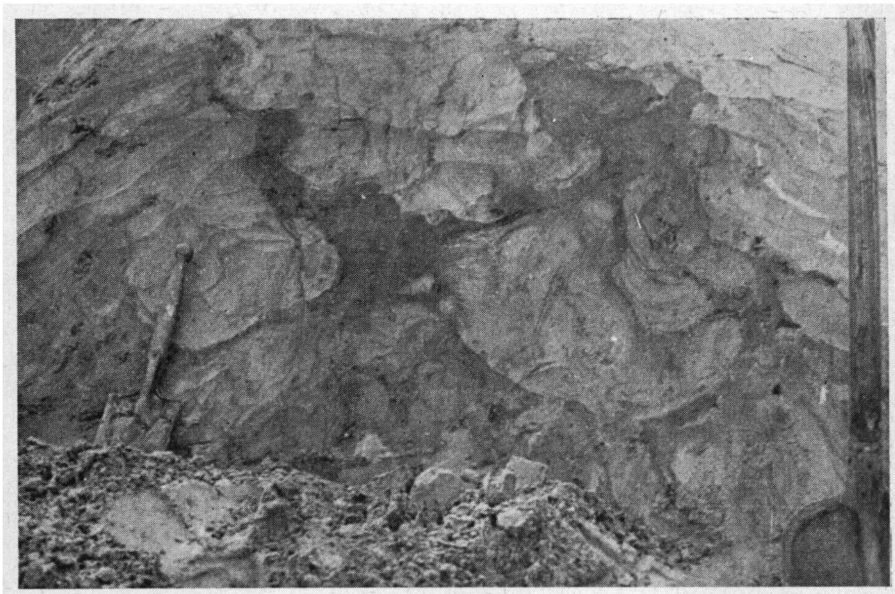
region. Especially the material in the pseudo-kames, following the relief of the hill-ridges at a certain distance, can be fairly coarse. Since these sand-ridges are furthermore situated at the western border of the brook-valleys or of the depressions, we believe it to be highly improbable that the material should have been blown out of the valleys. The coarser material, in the case of the pseudo-kames, will have rather come from the hill-ridges. Also the criss-cross bedding, if occurring, always indicates western winds. As far as the course of the ridges alongside the brook-valleys is concerned, we believe that here the cause must lie in the difference in vegetation (and we are especially thinking of trees) between the more protected valleys and the surrounding more exposed regions. As far as the coarseness of the material is concerned we would like to add the following. A supposition formerly advanced by us, stating that this coarseness might be caused by greater quantities of snow during the Younger Dryas-time, relatively rich in precipitation,



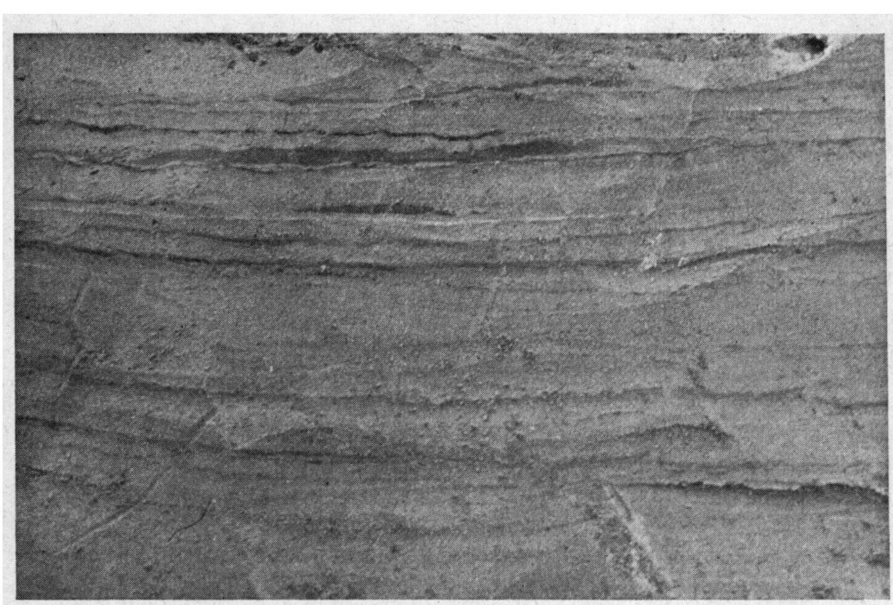
Phot. 32.
Undisturbed Older coversand on top of a strongly kryoturbate loam layer. Middle Tubantian. Almelo (Prov. of Overijssel). Height profile about 1.5 m.

(NELSON and VAN DER HAMMEN, 1950) does no longer seem very probable in some respects after the research discussed above was carried out.

SAMUELSSON mentions also the following that might be of importance for a possible partial explanation. When vegetation is locally lacking, the protecting cover against wind-erosion has disappeared. The wind then carries off the finer material leaving the coarser material behind. In the end a coarse-



Phot. 33.
Kryoturbate loam layer (see Phot. 32). Almelo. Height about 1 m.

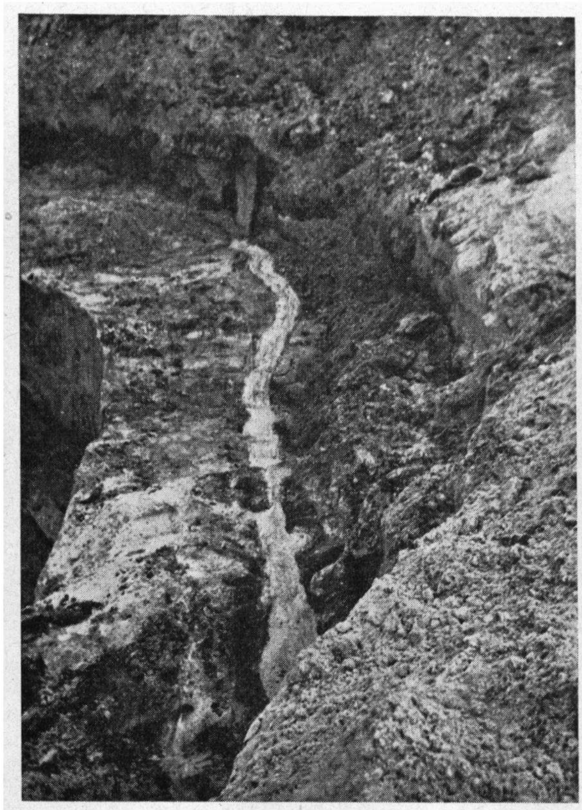


Phot. 34.
Older coversand with "loamy" layers (see Phot. 32). Almelo. Height about 50 cm.

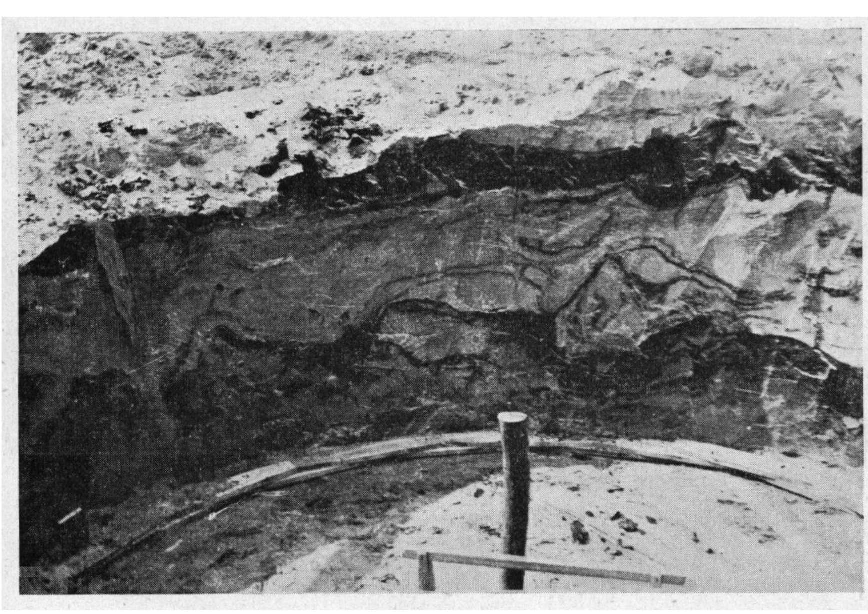
grained layer remains offering protection against further wind-erosion. It is not excluded that during the formation of the Younger coversand supply of material alternated with periods of blowing out. In that manner the strings and layers of coarser grains and fine gravel might be explained as being the levels of the blowing out. Of course the material must have had a certain amount of coarser material, but due to this blowing out of fine material and the remaining in place of coarser material there might be found an explanation for the remarkable size frequency distribution diagrams of types 4 and 13 (Fig. 42). However, also direct supply of coarse material can be considered amongst the possibilities, as is shown by the above.

Formation and dating of snow-melting-water deposits.

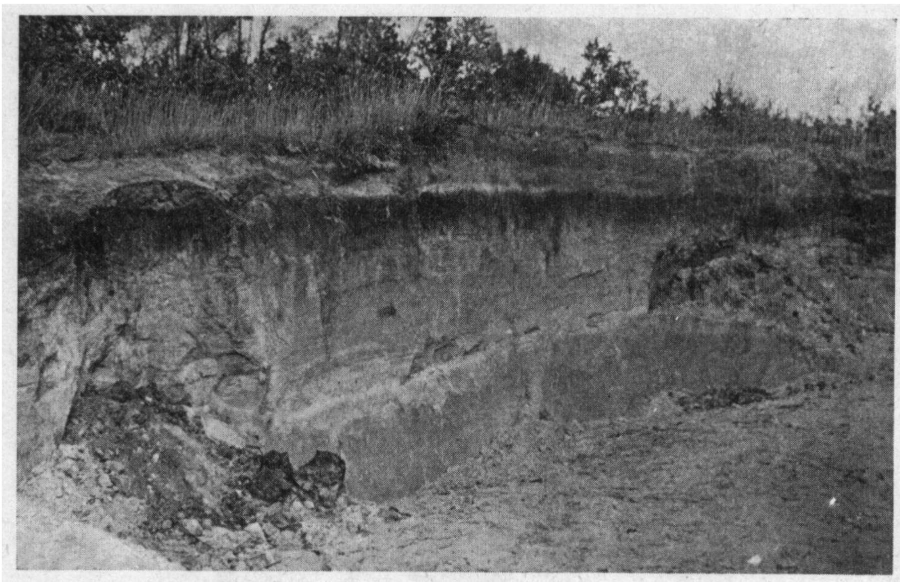
At a certain depth below the coversand from the Middle Tubantian there are generally coarser deposits containing some gravel. In deeper exposures, near Wierden and Almelo it could be established that this material is often showing a criss-cross bedding and that it must be for the greater part of fluviatile origin (Phot. 42). Near Apeldoorn a more or less gradual transition of the coarser material into the pure coversand could be seen. Near Wierden the toplimit of the coarser deposits was situated at about 3 m below the surface, North of Almelo at about 5.5 m and near Apeldoorn at about 4 m. A boring North of Denekamp (see Chapter I) showed it to lie at a depth of about 10 m. Whereas near Wierden there was a "desert-pavement" situated on the border of coarse material and the purely horizontally bedded coversand, the transition was again more gradual near Almelo. From the pollen-analytical point of view there was no difference between the peat-layers from the coarser fluviatle material and the Older coversand near Apeldoorn. Both deposits must have been formed during the Middle Tubantian. It also appeared from the analysis of a loamy layer from the top of the coarser material near Wierden that the deposition thereof, as well as that of the Older coversand, must have taken place during the Middle Tubantian. The vegetation during the deposition was in both cases treeless and arctic. Finally it is shown by the diagram of the Denekamp boring (see Chapter I) that there is no pollenanalytical difference between the peat-layer situated immediately at the basis of the coarser material and the peat-layers situated in the coversand above. All this material must have been deposited during the Middle Tubantian. In the coarser deposits near Apeldoorn a section of a flat gully, a few meters wide and partially filled by *Hypnaceae*-peat (Fig. 19) could be seen at a depth of about 4.5 m, during an excavation for the construction of a water purification installation. This gully is visible on Phot. 21, while a detail is shown in Fig. 22. It can be clearly seen there that this gully has cut into the underlying layers. Such gullies are occurring more often. We consider them to be the beds of snow-melting-water brooks that must have originated especially during spring thaw. We consider the typical fluviatile deposits mentioned above, such as they were excellently exposed especially near Wierden (Phot. 42), as deposits made by snow-melting-water. This material will for the greater part consist of transformed aeolian deposits; investigations according to the method of CAILLEUX showed that the grains were strongly aeolian-shaped, while grains being "emoussés luisants" were nearly completely lacking. The coarser material must originate from the hill-ridges, carried along by brooks having their source there. The snow-melting-



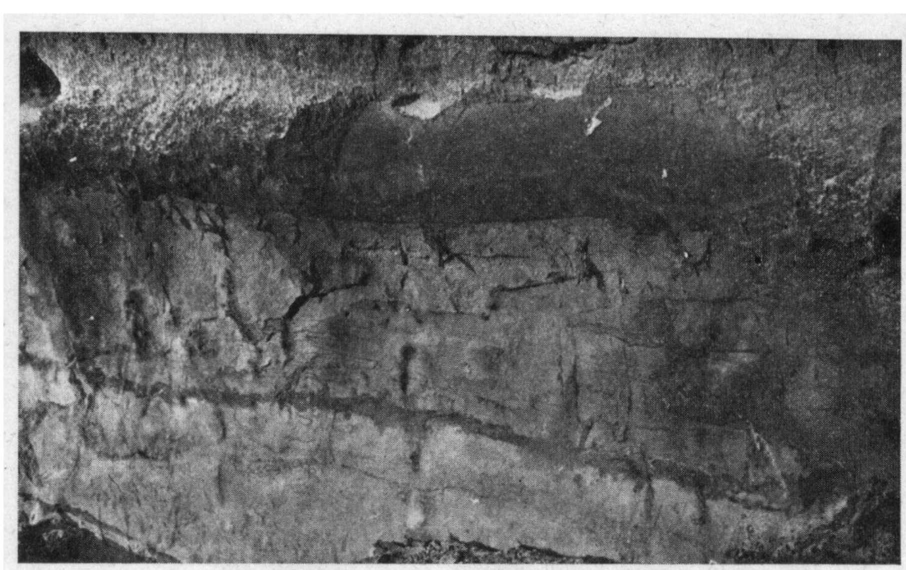
Phot. 35.
Frost-crack in Middle Tubantian (Pleni-glacial) deposits near Apeldoorn.
Width of the crack about 15 cm. Apeldoorn.



Phot. 36.
Middle Tubantian (Pleni-glacial) peat layers, highly kryoturbate.
Height of the profile largely 1—1.5 m. Apeldoorn.



Phot. 37.
"Usselo-layer" (the surface-layer during the Allerød-time) in coversand. Siegerswoude (Prov. of Friesland).



Phot. 38.
"Usselo-layer" in coversand. Wijnjeterp (Prov. of Friesland).

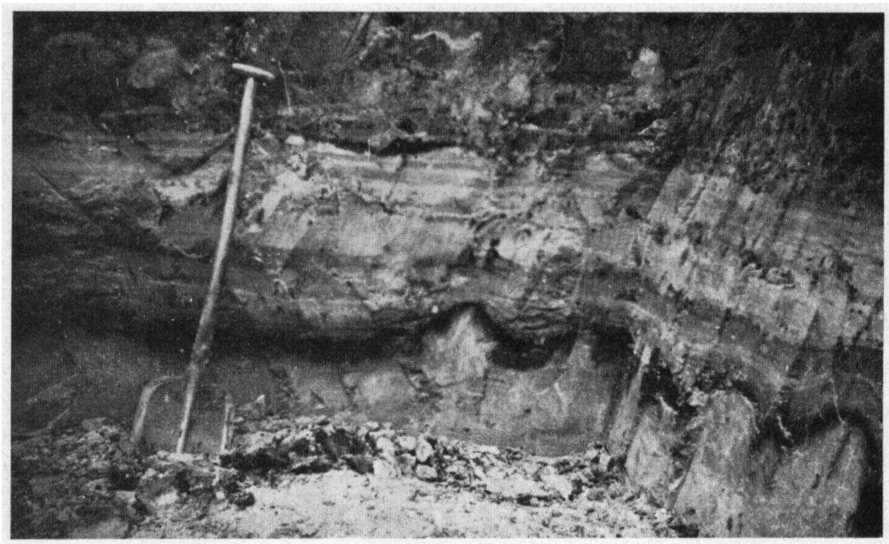
water deposits sometimes alternate, as far as we have been able to observe, with deposits of purely aeolian material. It appears not to be feasible to always make a distinction between them. All transitions are possible between snow-melting-water deposits with gravel, aeolian sand transported by snow-melting-water and typical coversand. Due to this it is not feasible to always indicate a sharp limit between the deposits. Fig. 43[6] is giving a curve of the size frequency distribution of a fluviatile, aeolian transformed sand with some gravel near Apeldoorn. It should also be mentioned that near Wierden there are small basins with organic material washed into them in the snow-melting-water deposits just as have been found elsewhere. In this material FLORSCHÜTZ found remains of a Dryas-flora with steppe plants (see Chapter I).

Undoubtedly often also normal fluviatile deposits must have been formed in the river valleys during the Middle Tubantian. However we do not have our own data on the subject and we will therefore not discuss it any further here. We only state the fact that PONS and SCHELLING (1951) are mentioning Late-glacial loamy river-deposits in the region of the great rivers and it is possible that the coarser deposits underneath the loam must be placed in the Middle Tubantian.

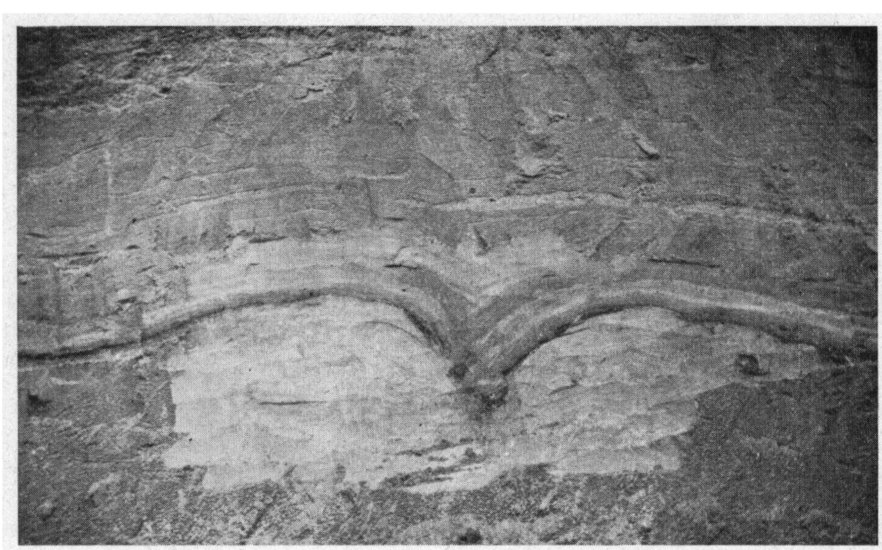
Outlines of the stratigraphy of the Tubantian.

As already explained in the Introduction, we made a division of the Tubantian on palaeontological-climatological grounds into Lower, Middle and Upper Tubantian. This division was also carried through in the preceding Chapters.

The Lower Tubantian comprises the stadial situated immediately above the Eemian and moreover the Zwolle-interstadial. This stadial + interstadial could already clearly be established twice by FLORSCHÜTZ & VAN SOMEREN and FLORSCHÜTZ & VAN DER VLERK (VAN DER VLERK and FLORSCHÜTZ, 1950). It is very likely that by means of further pollenanalytical and stratigraphical examination of boring samples, the Lower Tubantian can be established in various places. A few boring samples provisionally examined by us may perhaps already point in that direction. It might e. g. be quite possible that the topmost of the two undermost peat-layers of the Denekamp boring (see Chapter I) was deposited during the Zwolle-stadial and the loam layer, lying between these two peat-layers, in the preceding stadial. During a boring in the valley of the IJssel near Oene (municipality of Epe) peat was found from 11.75—15.00 m, grey clay from 11.20—11.75 m and from 10.50—11.20 m slightly humus containing clay. While a sample from the peat-layer resulted into a typical interglacial pollen-spectrum (Eemian), an analysis of the humus-containing clay yielded the spectrum pictured in diagram XXI. Here too a more-extensive examination might perhaps confirm that the grey clay + the humus-containing clay are belonging to the Lower Tubantian. Finally, a layer of humus-containing sand is occurring near Daarle (north of Wierden just inside the coversand-ridge) at a depth of 5.90—8 m, above the boulder-clay and below sand and loam-deposits which are very probably formed during the Middle Tubantian. A pollen-spectrum thereof is also reproduced in Diagram XXI. Although this spectrum closely resembles that of Oene we dare not, without further examination, utter even an assumption concerning its age since the whole lapse of time between the end of the Drenthian and the beginning of the Middle Tubantian may be eligible. The deposits situated



Phot. 39.
Allerød-layer in coversand. Ossendrecht (Prov. of Noord-Brabant).



Phot. 40.
Allerød-layer in coversand. Hoogerheide (Prov. of Noord-Brabant).

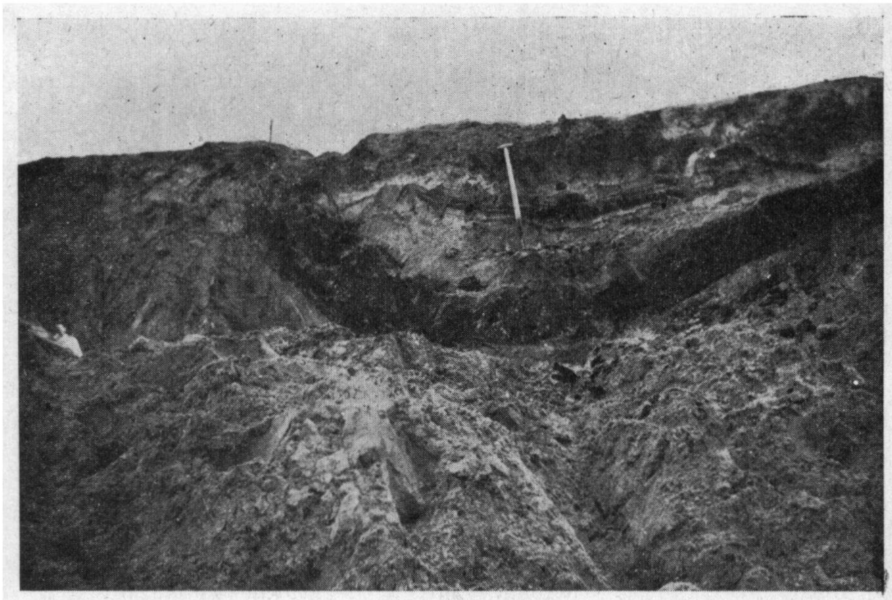
above the Eemian + Lower Tubantian, in so far as they produce very "cold" pollen-spectra (with low *Artemisia*-values) belong to the Middle Tubantian. Since the Zwolle-stadial was subarctic (and did not show very cold spectra), even if deposits from the Lower Tubantian cannot be recognized in a given case or if they are absent, we may place all deposits with very cold spectra, situated above the Eemian, with certainty in the Middle Tubantian. The deposits from the Middle Tubantian in the eastern Netherlands are consisting (exclusive the normal river-deposits) for a great part of coversands and coversands transformed by snow-melting-water. Below them there are often fluviatile deposits of sand and gravel that must have been deposited by running snow-melting-water, partially originating from the hill-ridges. From these hill-ridges the brooks transported material, supplied by solifluction in the upper course, towards the plain. In our opinion these deposits have probably been formed during the maximum cold of the last glaciation. In the Dinkel-valley (and perhaps also elsewhere) finer sediments are again lying underneath these coarser deposits. Possibly the Middle Tubantian includes another subarctic interstadial (the Hengelo interstadial). VAN DER VLERK & FLORSCHÜTZ (1950) mention it two times, near Hengelo and near Groesbeek. However, its components need in our view nearer affirmation. The Middle Tubantian was a period of strong periglacial actions. Especially during the deposition of its coarse sediments the action of solifluction and snow-melting-water must have been very strong. During the Middle Tubantian, after the formation of the coarser material, also the Older coversand was deposited. In the S.E. of Holland, especially in the Province of Noord-Brabant, only very little coarse material was apparently deposited. The sediments are generally finer here and probably consist for the gretaer part of coversands and loess.

We take the Upper Tubantian (including the greater part of the former "Late-glacial") to have begun at the first signs of an amelioration of the climate after the extreme cold of the Middle Tubantian: the rise of the *Artemisia*-curve. Both Bølling-oscillation and Allerød-oscillation are important stratigraphical levels. In the Earlier Dryas-time and in the Late Dryas-time sedimentation of coversand took place, that is often coarser than the coversand of the Middle Tubantian. As opposed to the coversand from the Middle Tubantian, the coversand from the Upper Tubantian shows various types of accumulation-forms amongst which especially the low longdrawn sand-ridges are noteworthy.

In Fig. 41 a diagrammatic section is drawn of the Dinkel-valley showing how the deposits from the Tubantian have developed there.

Below we are giving a table presenting a survey of the vegetation-development and of the most important periglacial actions during the Tubantian.

We have endeavoured in the foregoing to make a division on a palaeontological-climatological basis, independent of glacial morphology. We fully realise that part of our conclusions in the geological field (namely those concerning the stratigraphy of the Middle Tubantian) were drawn in consequence of research carried out in a fairly restricted region and that they sometimes may give the impression of having been over generalised. Only by means of extensive research carried out over the whole country and based on palaeontological dating, it will in the end be possible to establish whether these conclusions do indeed have such a general character.



Phot. 41.
Peat from Allerød-time in a fossil "brook bed", covered by Younger coversand. Wierden (Overijssel).

Photo 42.
Snow-melting-water deposits from the Middle Tubantian; about 5 m below the surface. Wierden (Overijssel).

			Vegetation			Sedimentation: Eastern part of the Netherlands	Sedimentation: N. Brabant	Rivers: Dinkel-valley	Rivers: Rhine & Meuse (PONS & SCHELLING, 1951)	Erosion-valleys	Solifluction and Kryoturbation	Culture-periods		Tentative correlation with glacial morphology
Holocene		Preboreal	Pine forest or Birch-pine forest			Final halt of Coversand-formation						Klosterlund	Lingby	Fini-Glacial
T U B A N T I A N	Upper-Tubantian / Late-Glacial	Late Dryas-time III	Park-landscape with Birches and Pines		rel. high Empetrum %	Younger Coversand		Beds locally filled up with Coversand	Deposition of river-loam and formation of „River-dunes"	Partly filling with Coversand	„Wannen-Boden"	Ahrensburg		W e i c h s e l - G l a c i a t i o n: Salpausselka st. / Goti-Glacial
		Allerød-oscillation II	Pine-Birch forest / Birch-forest	rel. oceanic / rel. continental		Standstill of Coversand-formation („Usselo-layer," form. of peat and detr. gyttja)						Usselo / Bromme	Wehlen	
		Older Dryas-time: Earlier Dryas-time Ic	Treeless landscape (or with few Birches)	Tree-line	rel. high % of „Steppe-elements", especially of Artemisia	Younger Coversand	?	Beds locally filled up with Coversand		Partly filling with Coversand	„Wannen-Boden"			
		Older Dryas-time: Bølling-time Ib	Park-landscape with Birches (no Pines)	Tree-line		Standstill of older Coversand formation						Hamburg II		
		Older Dryas-time: Earliest Dryas-time Ia	Treeless vegetation	Artemisia rise		Strong decrease of Coversand formation				Some deposition of Coversand on some valley-slopes?		Hamburg I		
	Middle-Tubantian / Pleni-Glacial	(Possibly interrupted by the „Hengelo-interstadial")	Treeless „Arctic" vegetation (at least during a great part of this time) Dryas-flora (with steppe-elements)			Older Coversand	Coversand and Loess	Forming of braided river system and of fluviatile deposits		Forming of erosion-valleys	Perenne tjäle large frost-cracks and frost-crack-systems, „Würge-Boden" etc. Strong action of solifluction			Dani-Glacial
						Coarse snow-meltingwater deposits and Coversand								Pomeranian stadial etc
						Coversand								
	Lower Tubantian	Salland interstadial	„Temperate Flora"			No Coversand formation						Aurignac ?		First inter-stadial
		Zwolle stadial	„Subarctic Flora"			Coversand ?								First stadial
Eemian														Saale-Weichsel interglacial

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A = *main diagram*

B = *separate curves of plants included in the pollensum*

C = *separate curves of plants not included in the pollensum*

Trees and shrubs (not including Juniperus) — *Anemophile herbs* — *Ericales (including Empetrum)*

- *Salix*
- *Betula*
- *Pinus*
- *Corylus (included in the pollensum)*
- *Alnus*
- *Quercetum mixtum (Quercus, Ulmus, Tilia, Fraxinus)*
- .... *Ulmus*

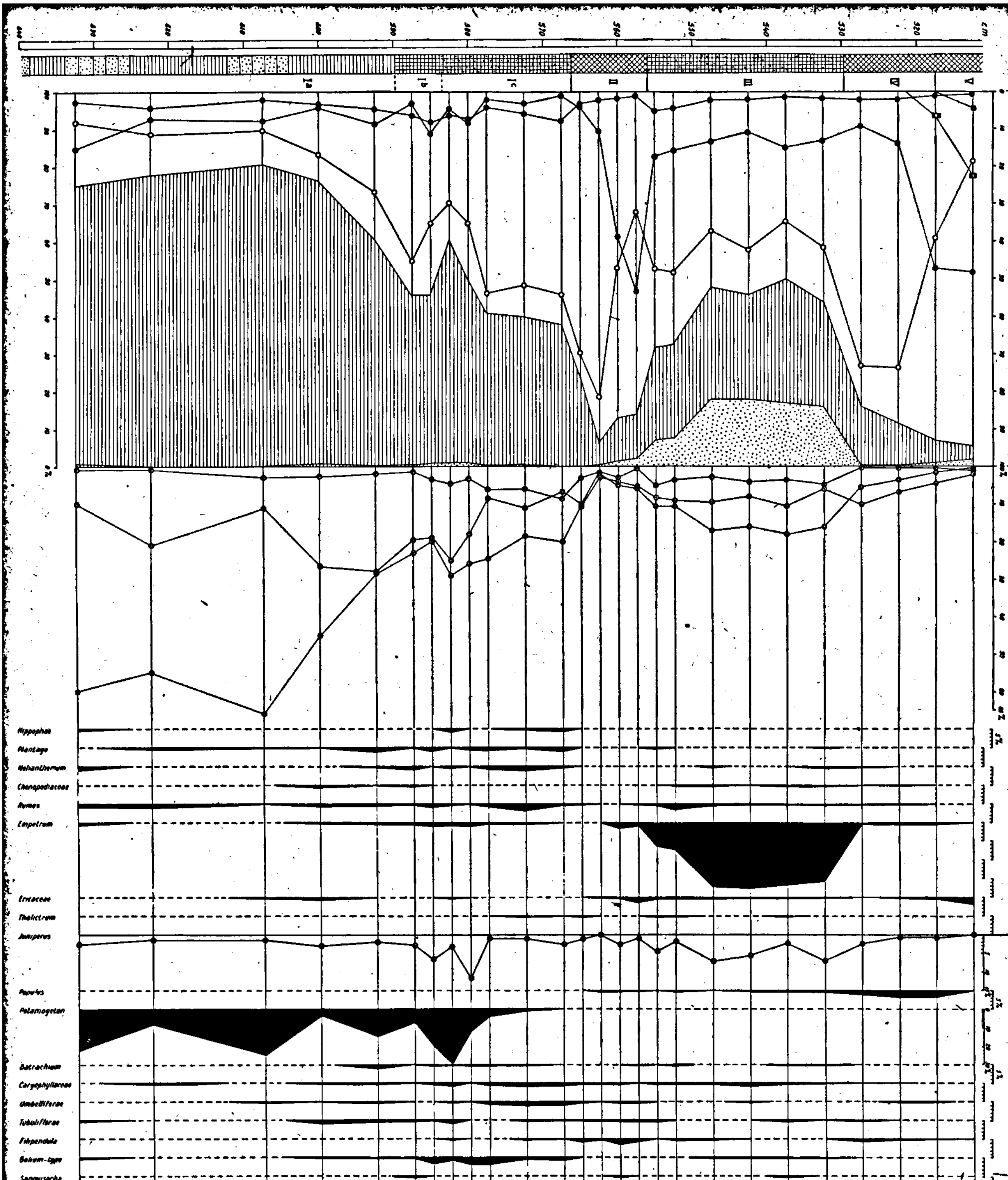
- *Cyperaceae*
- *Gramineae*
- *Artemisia*
- *Juniperus*

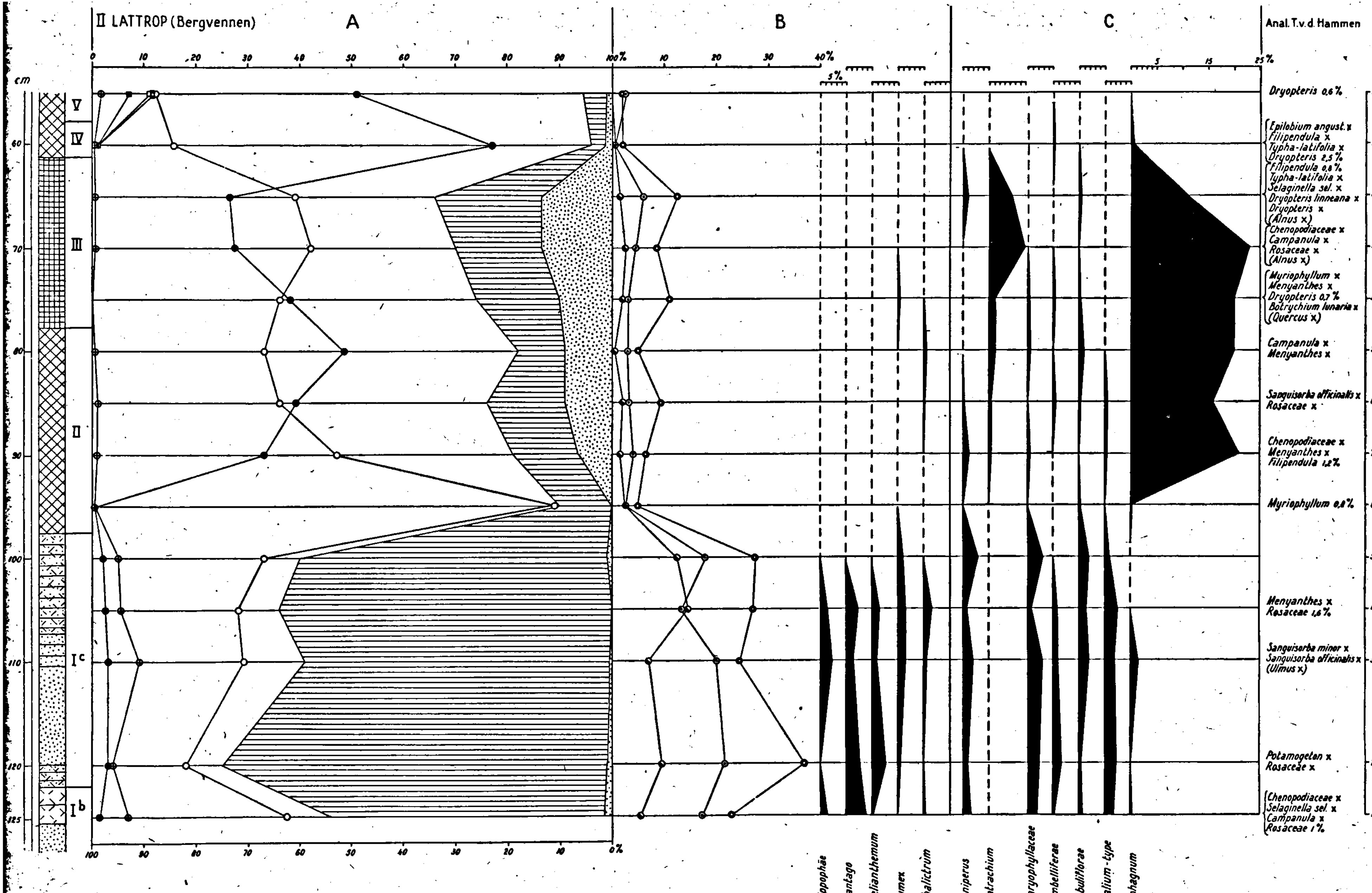
- *detritus gyttja (or dy)*
- *clay-gyttja*
- *lime-gyttja*
- *peat*
- *Hypnaceae-peat*
- *detritus*
- *loam or loess*
- *sand*
- *charcoal*
- *sand with plant-remains*

The depth is given in centimeters (diagr. XVII in meters) below the surface

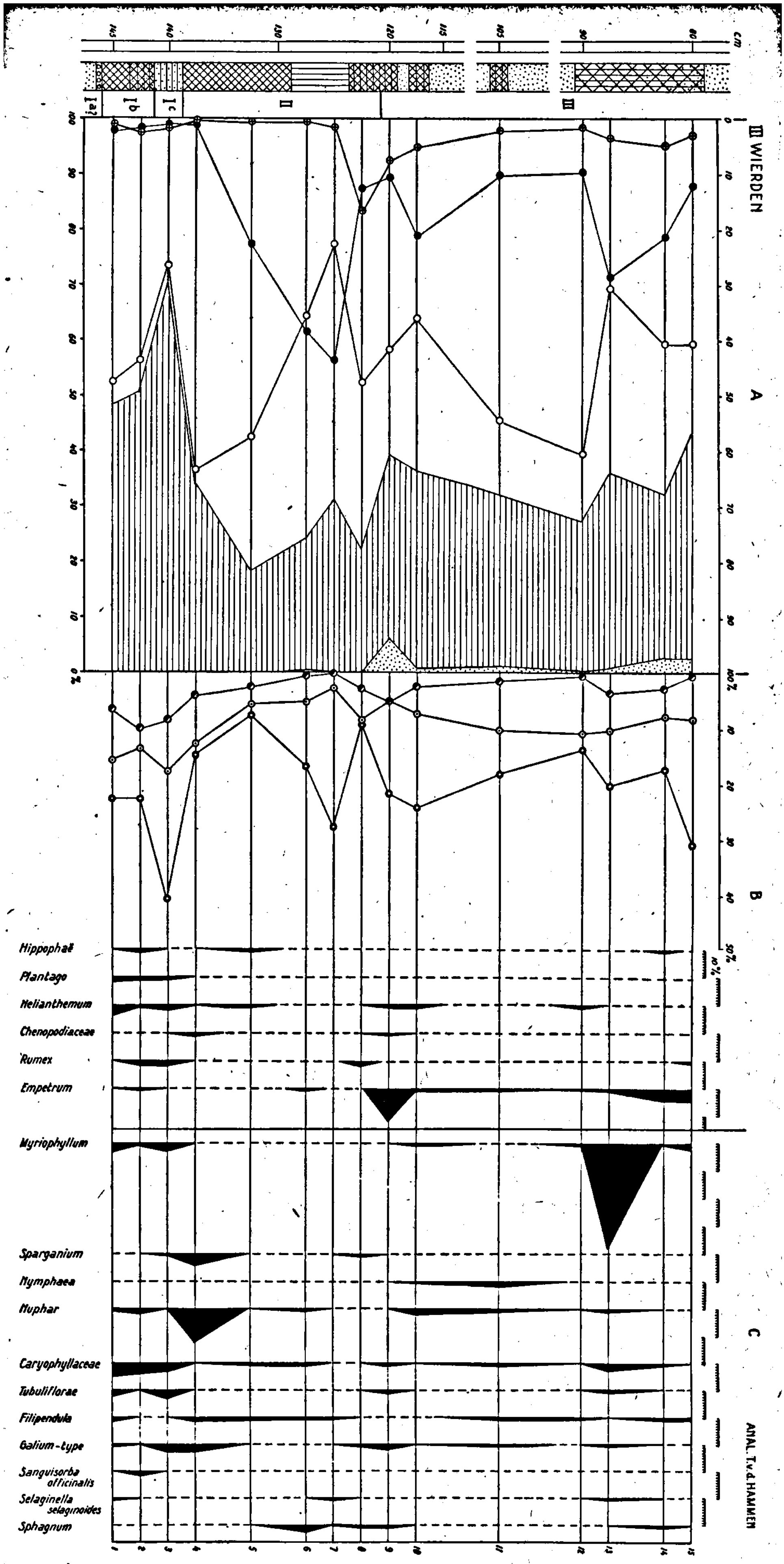
× behind a plant-name = one grain was found in this sample

LEGEND FOR ALL DIAGRAMS

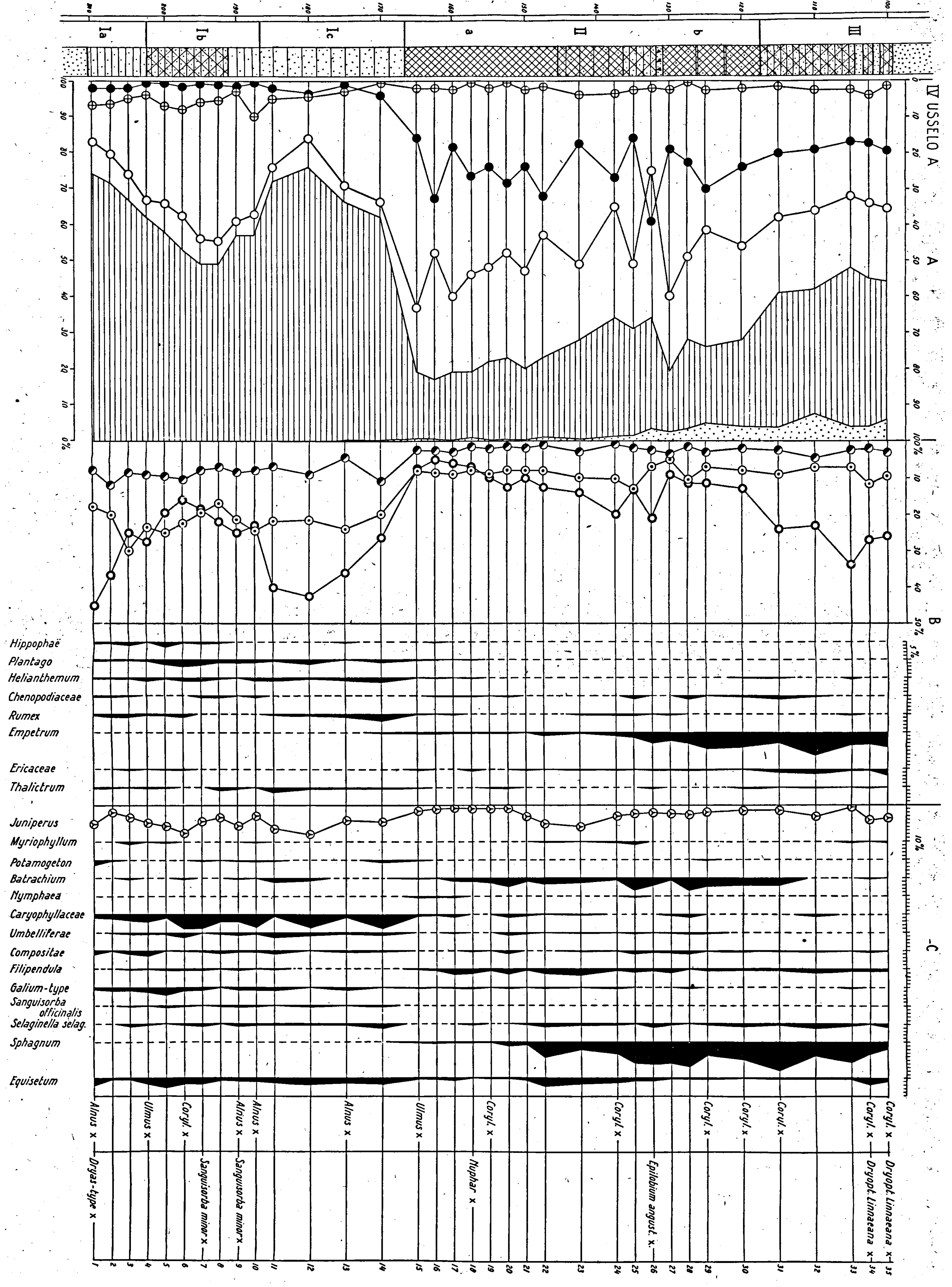

Hippophaë
Plantago
Helianthemum
Chenopodiaceae
Rumex
Empetrum
Ericaceae
Thalictrum
Juniperus
Populus
Potamogeton
Batrachium
Caryophyllaceae
Umbelliferae
Tubuliflorae
Filipendula
Galium-type
Sanguisorba officinalis
Selaginella selaginoides
cf. Selaginella helvetica
Sphagnum
Equisetum
Isoëtes
Corylus
Quercus
Ulmus
Alnus
Carpinus
Picea / Abies
„Tertiair" pollen
„Hystrix"



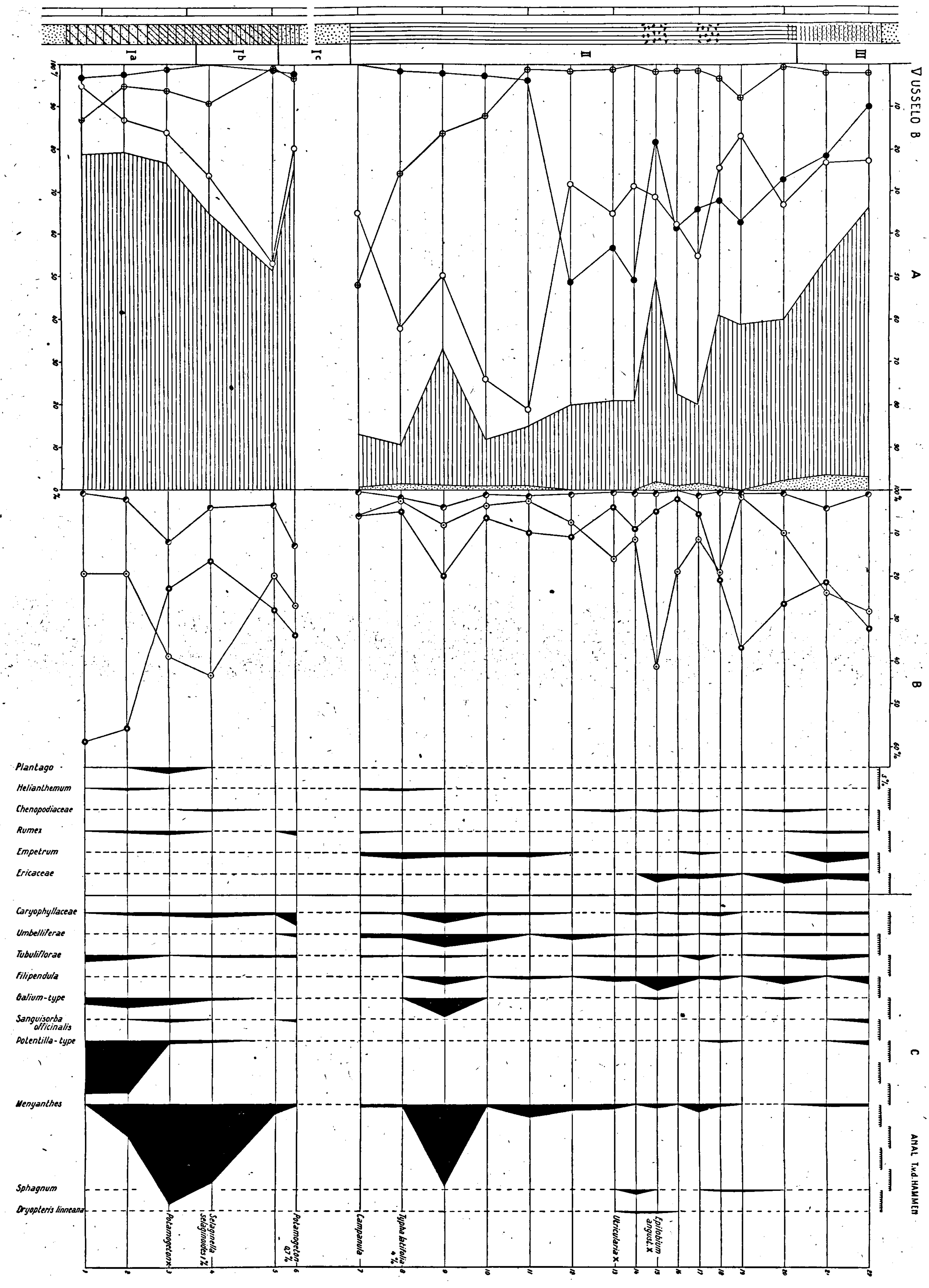
II LATTROP (Bergvennen)
A
B
C
Anal. T.v.d. Hammen
cm
V
IV
III
II
Ic
Ib
Dryopteris 0,6 %
Epilobium angust. x
Filipendula x
Typha-latifolia x
Dryopteris 2,5 %
Filipendula 0,8 %
Typha-latifolia x
Selaginella sel. x
Dryopteris linneana x
Dryopteris x
(Alnus x)
Chenopodiaceae x
Campanula x
Rosaceae x
(Alnus x)
Myriophyllum x
Menyanthes x
Dryopteris 0,7 %
Botrychium lunaria x
(Quercus x)
Campanula x
Menyanthes x
Sanguisorba officinalis x
Rosaceae x
Chenopodiaceae x
Menyanthes x
Filipendula 1,2 %
Myriophyllum 0,8 %
Menyanthes x
Rosaceae 1,6 %
Sanguisorba minor x
Sanguisorba officinalis x
(Ulmus x)
Potamogeton x
Rosaceae x
Chenopodiaceae x
Selaginella sel. x
Campanula x
Rosaceae 1 %
Hippophäe
Plantago
Helianthemum
Rumex
Thalictrum
Juniperus
Batrachium
Caryophyllaceae
Umbelliferae
Tubuliflorae
Galium-type
Sphagnum

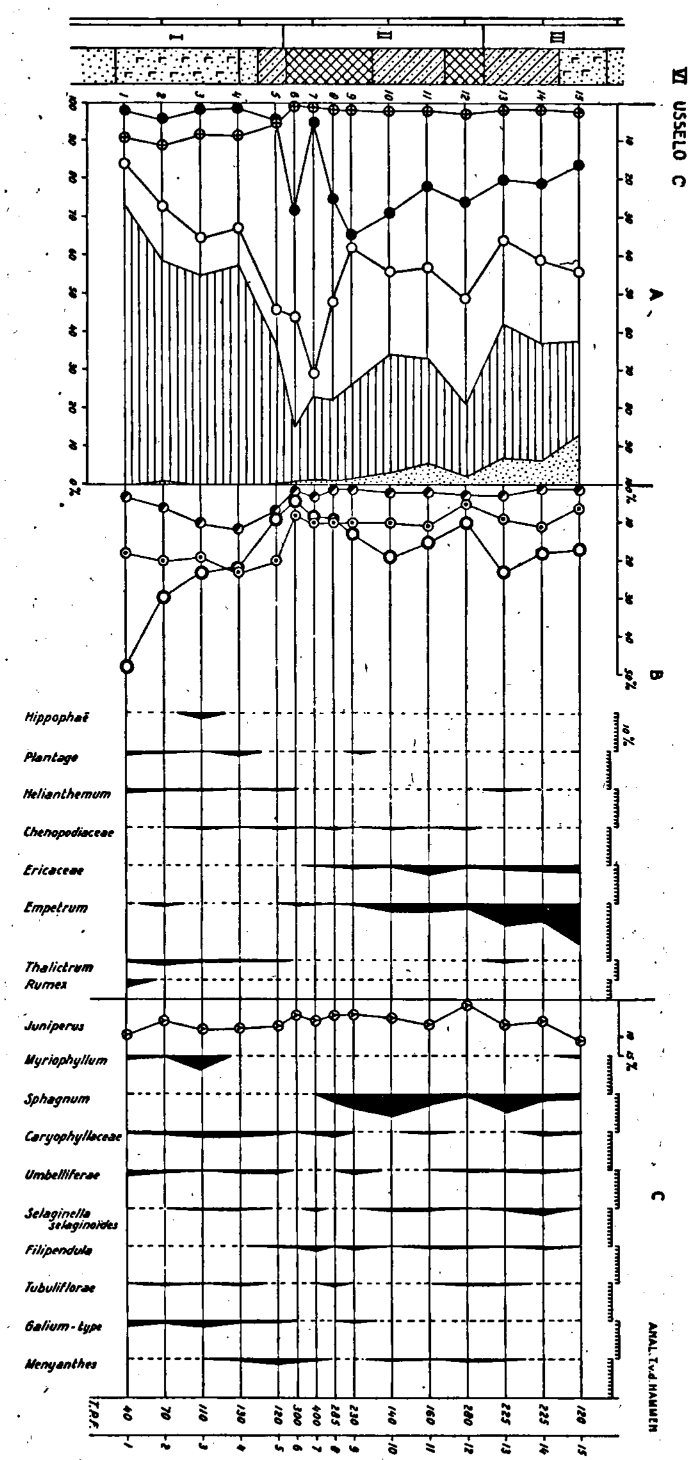


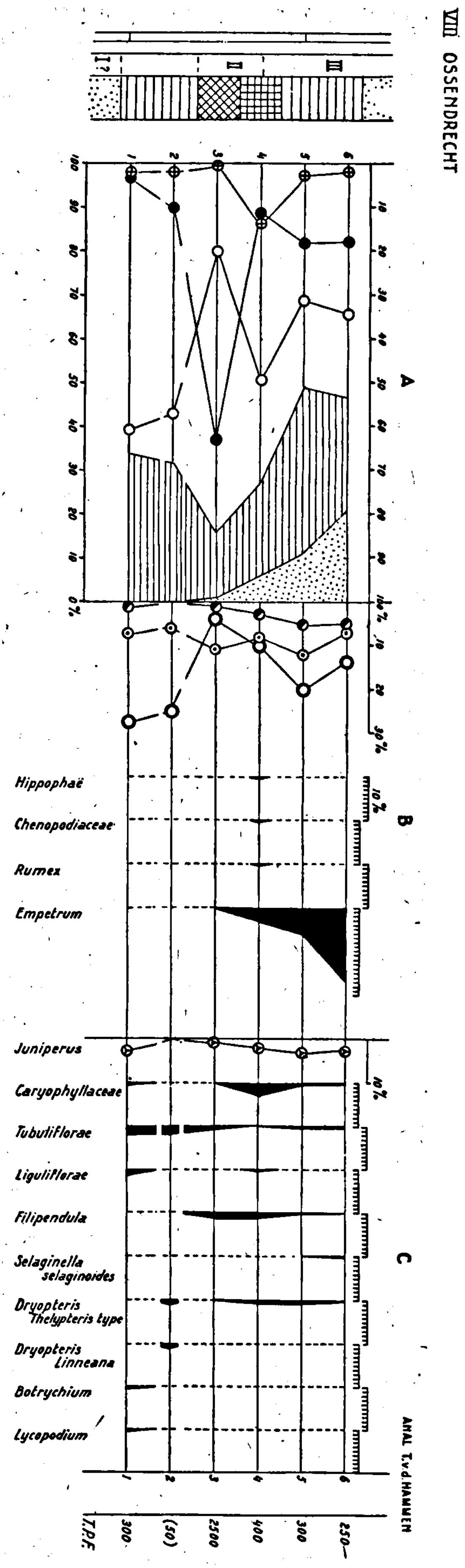
III WIERDEN
A
B
C
Hippophaë
Plantago
Helianthemum
Chenopodiaceae
Rumex
Empetrum
Myriophyllum
Sparganium
Nymphaea
Nuphar
Caryophyllaceae
Tubuliflorae
Filipendula
Galium-type
Sanguisorba officinalis
Selaginella selaginoides
Sphagnum
ANAL. T.v.d.HAMMEN

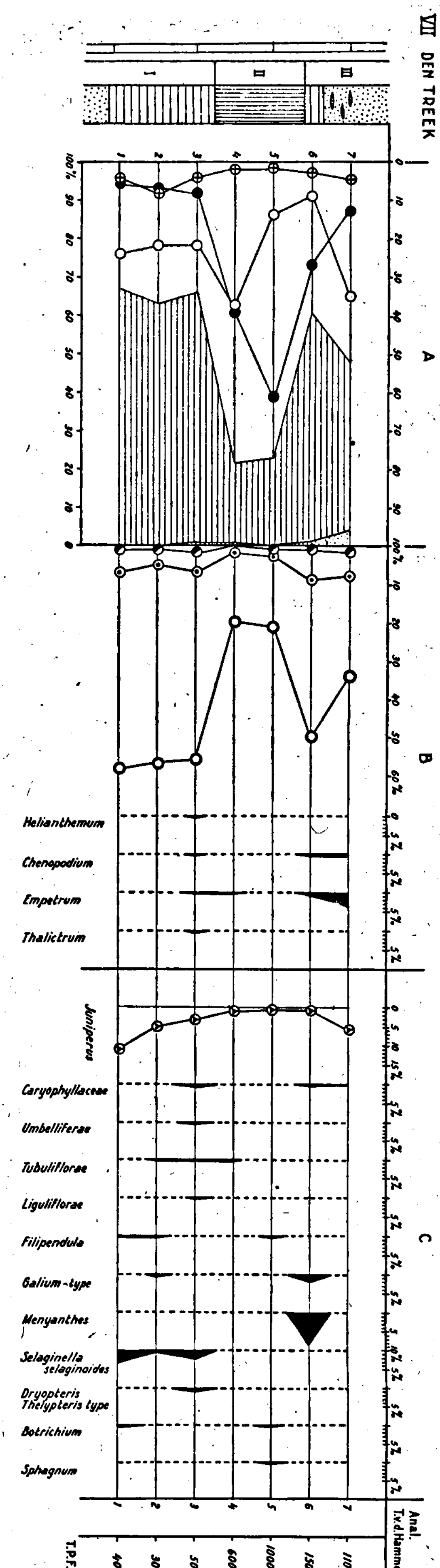


IV USSELO A
Ia
Ib
Ic
a
II
b
III
A
B
C
Hippophaë
Plantago
Helianthemum
Chenopodiaceae
Rumex
Empetrum
Ericaceae
Thalictrum
Juniperus
Myriophyllum
Potamogeton
Batrachium
Nymphaea
Caryophyllaceae
Umbelliferae
Compositae
Filipendula
Galium-type
Sanguisorba officinalis
Selaginella selag.
Sphagnum
Equisetum
Alnus x
Ulmus x
Coryl. x
Dryas-type x
Sanguisorba minor x
Nuphar x
Epilobium angust. x
Dryopt. Linnaeana x

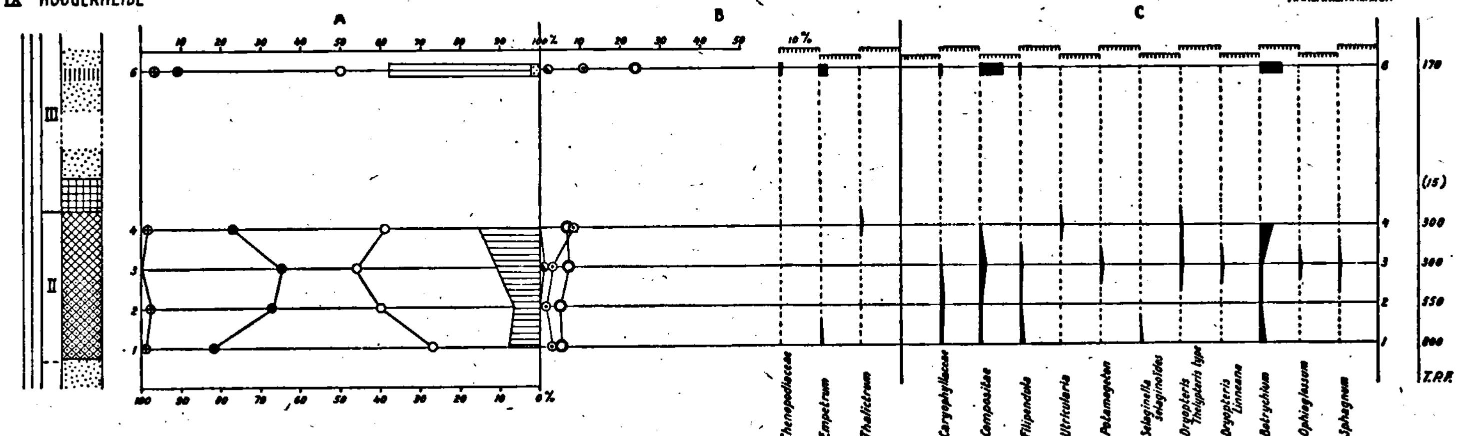

VUSSELO B
Ia
Ib
Ic
II
III
A
B
C
Plantago
Helianthemum
Chenopodiaceae
Rumex
Empetrum
Ericaceae
Caryophyllaceae
Umbelliferae
Tubuliflorae
Filipendula
Galium-type
Sanguisorba officinalis
Potentilla-type
Menyanthes
Sphagnum
Dryopteris linneana
Potamogeton x
Selaginella selaginoides 1%
Potamogeton 0.7%
Campanula
Typha latifolia + %
Utricularia x
Epilobium angust. x
ANAL. T. v. d. HAMMEN

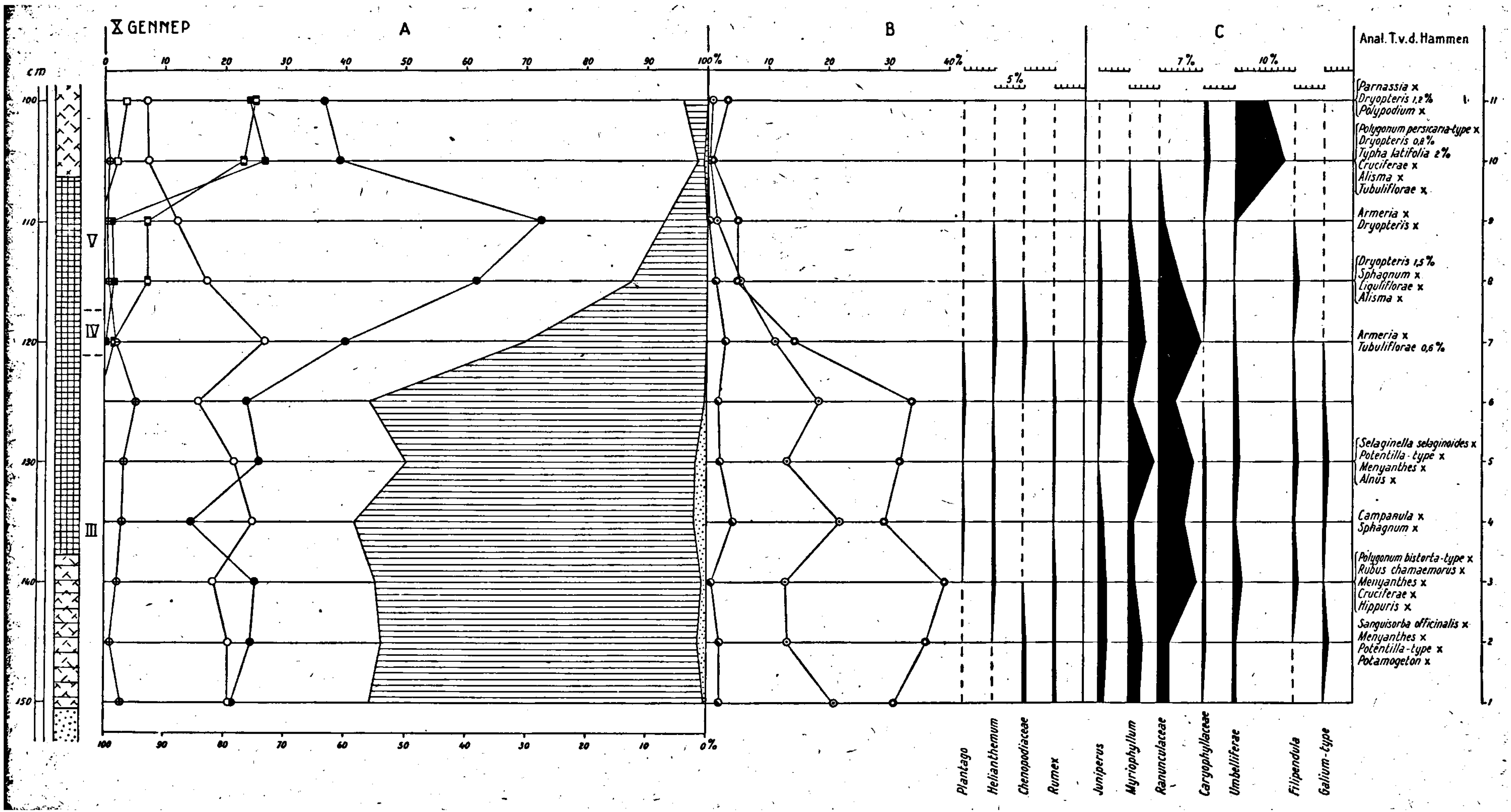

VI USSELO C
I
II
III
A
B
C
Hippophaë
Plantago
Helianthemum
Chenopodiaceae
Ericaceae
Empetrum
Thalictrum
Rumex
Juniperus
Myriophyllum
Sphagnum
Caryophyllaceae
Umbelliferae
Selaginella selaginoides
Filipendula
Tubuliflorae
Galium-type
Menyanthes
T.B.F.
ANAL. T. v. d. HAMMEN

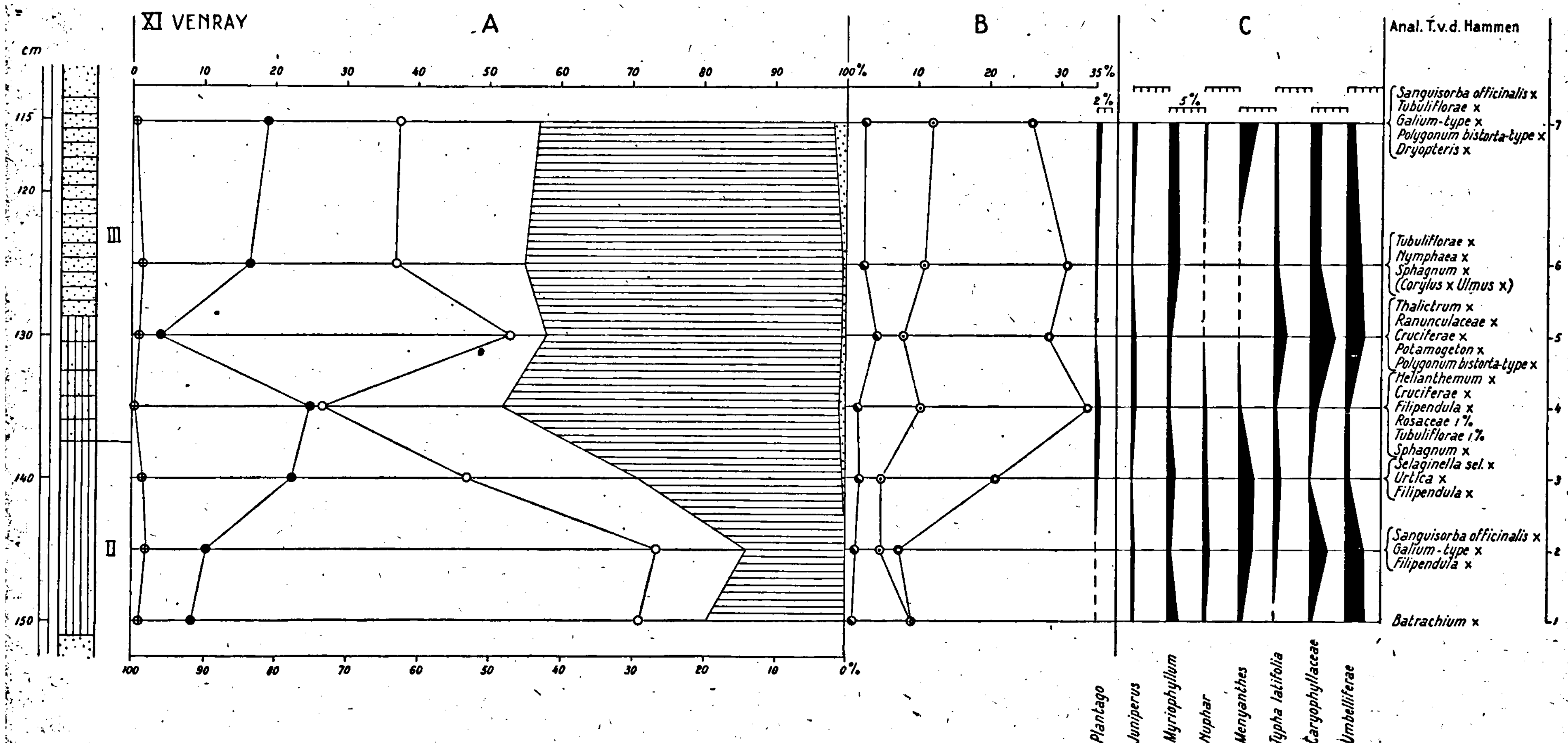

VIII OSSENDRECHT
I?
II
III
A
B
C
Hippophaë
Chenopodiaceae
Rumex
Empetrum
Juniperus
Caryophyllaceae
Tubuliflorae
Liguliflorae
Filipendula
Selaginella selaginoides
Dryopteris Thelypteris type
Dryopteris Linneana
Botrychium
Lycopodium
ANAL. T.v.d.HAMMEN
T.P.F.
300
(50)
2500
400
300
250

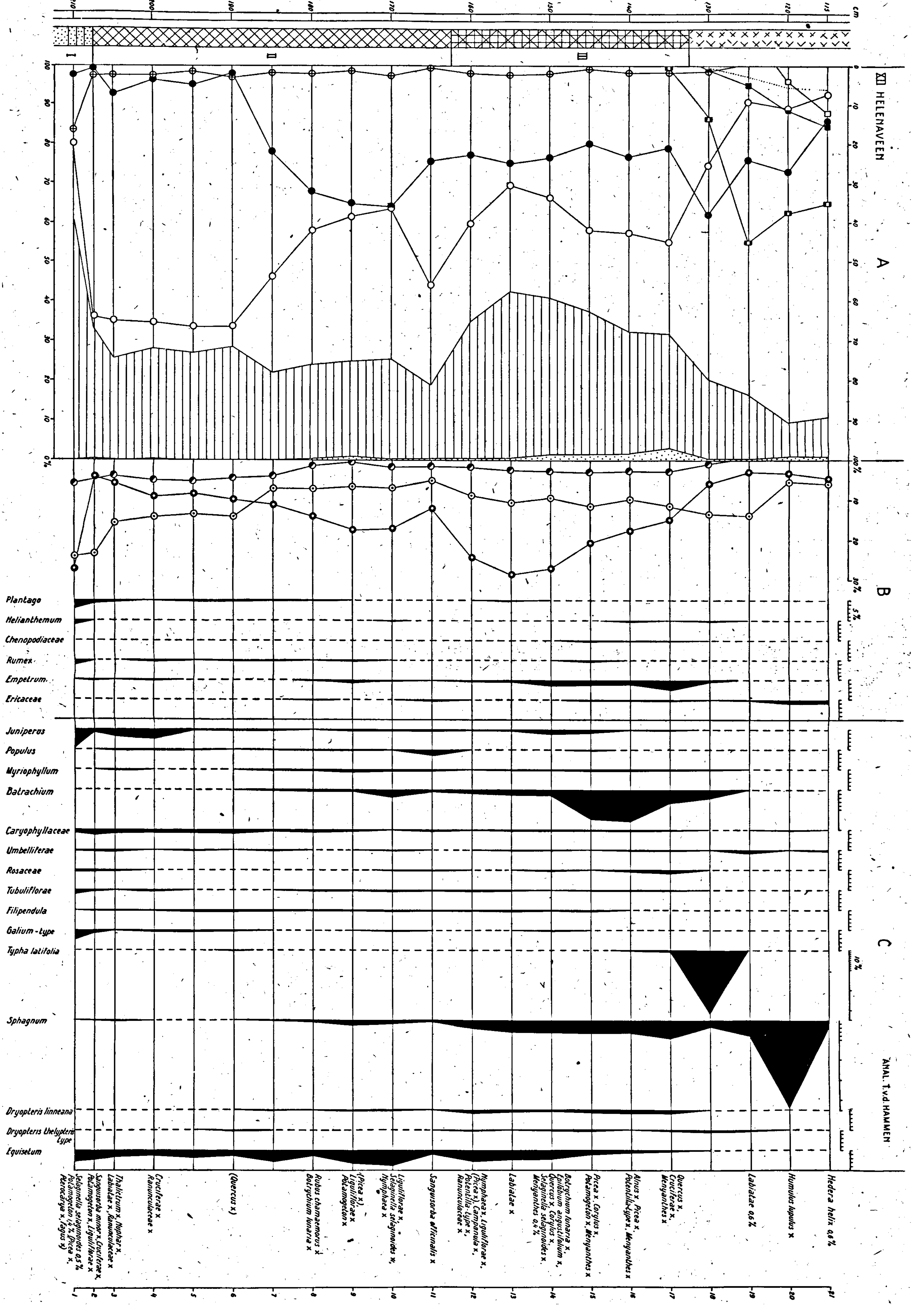

VII DEN TREEK
I
II
III
A
B
C
Helianthemum
Chenopodium
Empetrum
Thalictrum
Juniperus
Caryophyllaceae
Umbelliferae
Tubuliflorae
Liguliflorae
Filipendula
Galium-type
Menyanthes
Selaginella selaginoides
Dryopteris Thelypteris type
Botrichium
Sphagnum
Anal. T.v.d.Hammen
T.P.F.
40
30
50
600
1000
150
110

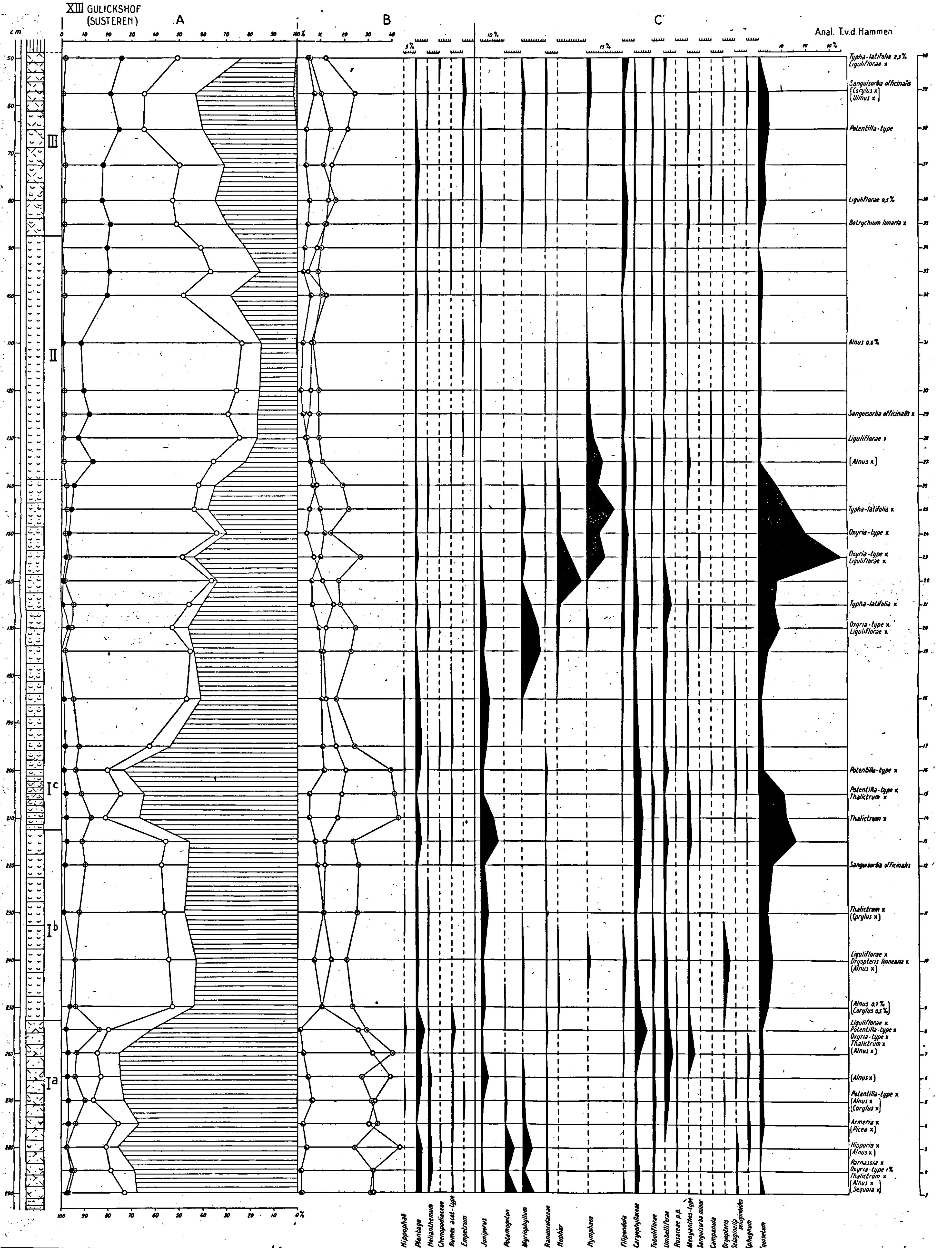
IX HOOGERHEIDE

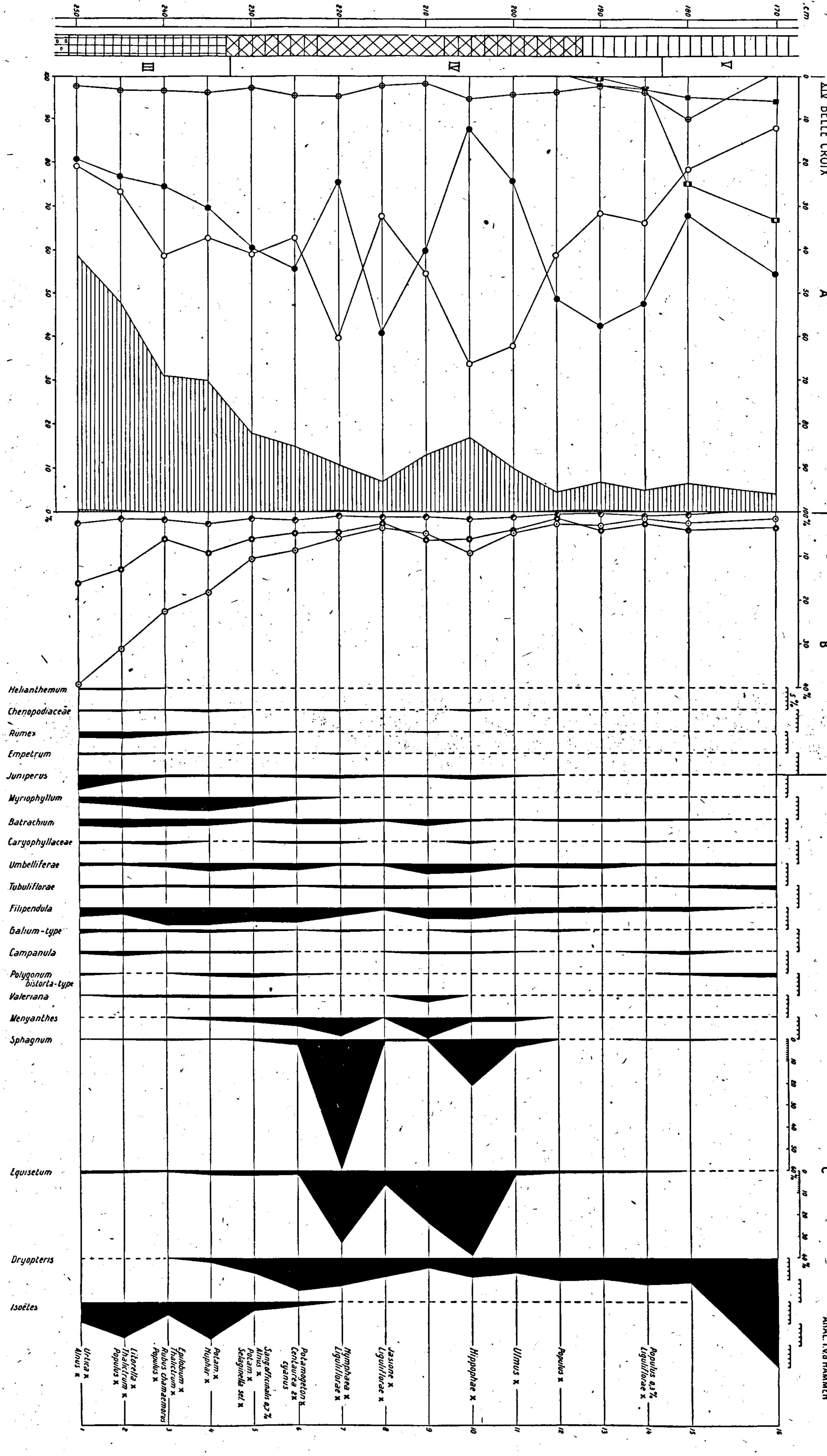


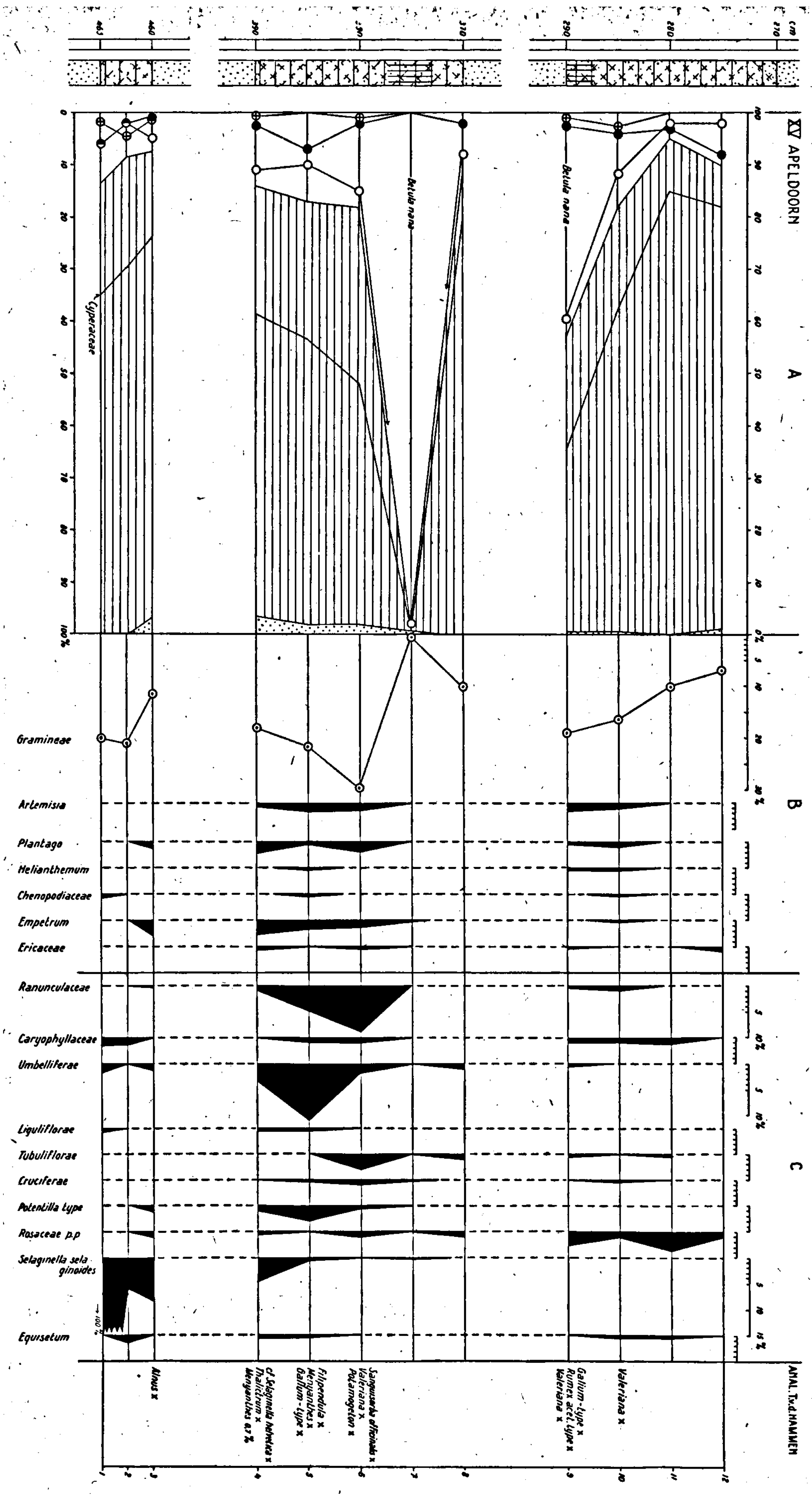

X GENNEP
A
B
C
Anal. T.v.d. Hammen
cm
V
IV
III
Plantago
Helianthemum
Chenopodiaceae
Rumex
Juniperus
Myriophyllum
Ranunculaceae
Caryophyllaceae
Umbelliferae
Filipendula
Galium-type
Parnassia x
Dryopteris 1,2 %
Polypodium x
Polygonum persicaria-type x
Dryopteris 0,8 %
Typha latifolia 2 %
Cruciferae x
Alisma x
Tubuliflorae x
Armeria x
Dryopteris x
Dryopteris 1,5 %
Sphagnum x
Liguliflorae x
Alisma x
Armeria x
Tubuliflorae 0,6 %
Selaginella selaginoides x
Potentilla-type x
Menyanthes x
Alnus x
Campanula x
Sphagnum x
Polygonum bistorta-type x
Rubus chamaemorus x
Menyanthes x
Cruciferae x
Hippuris x
Sanguisorba officinalis x
Menyanthes x
Potentilla-type x
Potamogeton x


XI VENRAY
A
B
C
Anal. T.v.d. Hammen
cm
115
120
130
140
150
III
II
0
10
20
30
40
50
60
70
80
90
100 %
35 %
2 %
5 %
Plantago
Juniperus
Myriophyllum
Nuphar
Menyanthes
Typha latifolia
Caryophyllaceae
Umbelliferae
Sanguisorba officinalis x
Tubuliflorae x
Galium-type x
Polygonum bistorta-type x
Dryopteris x
Tubuliflorae x
Nymphaea x
Sphagnum x
(Corylus x Ulmus x)
Thalictrum x
Ranunculaceae x
Cruciferae x
Potamogeton x
Polygonum bistorta-type x
Helianthemum x
Cruciferae x
Filipendula x
Rosaceae 1 %
Tubuliflorae 1 %
Sphagnum x
Selaginella sel. x
Urtica x
Filipendula x
Sanguisorba officinalis x
Galium-type x
Filipendula x
Batrachium x
1
2
3
4
5
6
7

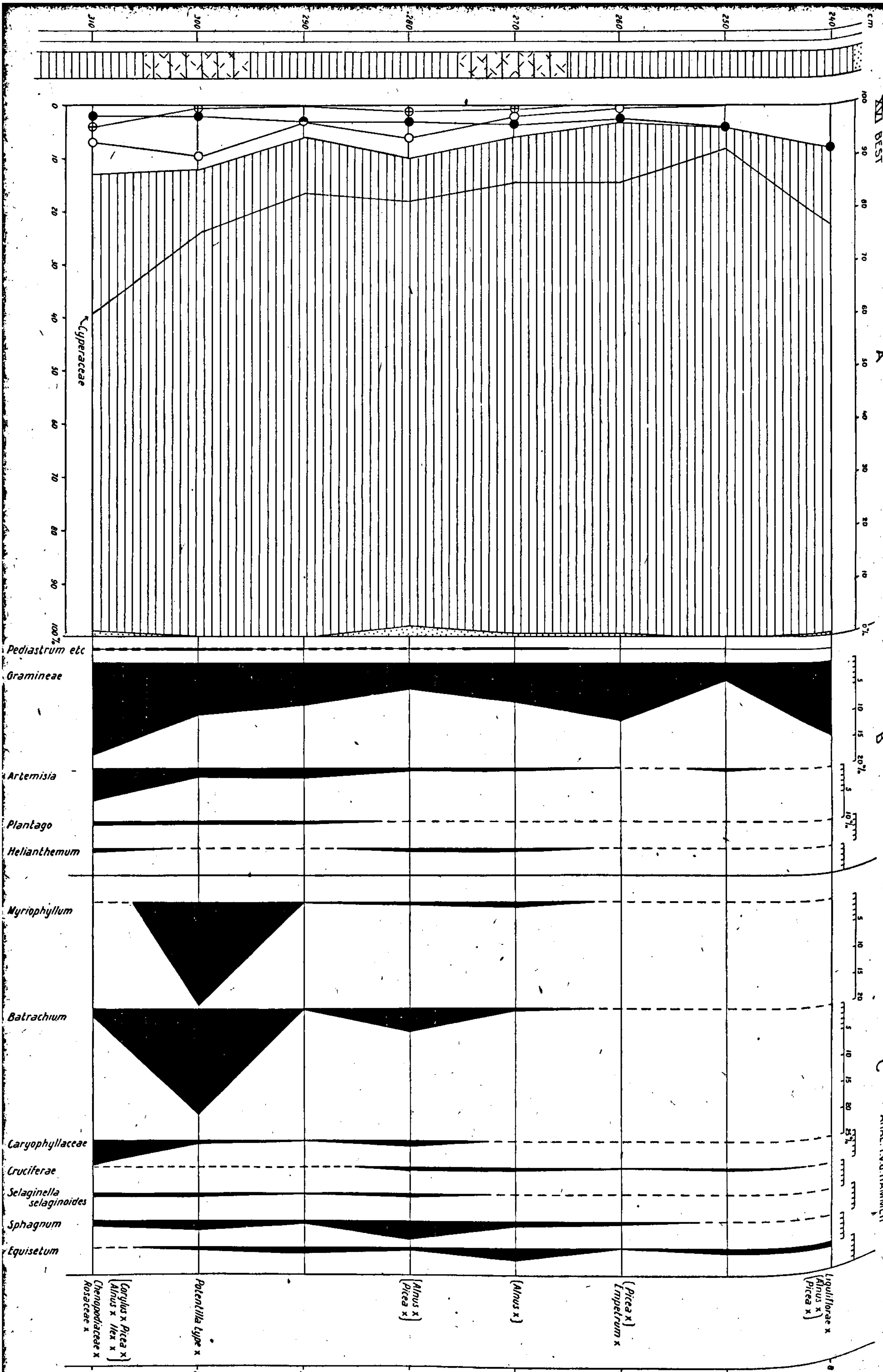

XII HELENAVEEN
A
B
C
ANAL. T.v.d. HAMMEN
Plantago
Helianthemum
Chenopodiaceae
Rumex
Empetrum
Ericaceae
Juniperus
Populus
Myriophyllum
Batrachium
Caryophyllaceae
Umbelliferae
Rosaceae
Tubuliflorae
Filipendula
Galium-type
Typha latifolia
Sphagnum
Dryopteris linneana
Dryopteris thelypteris type
Equisetum


XIII GULICKSHOF (SUSTEREN)
A
B
C
Anal. T.v.d.Hammen
cm
III
II
Ic
Ib
Ia
Typha-latifolia 2,3%
Liguliflorae x
Sanguisorba officinalis
(Corylus x)
(Ulmus x)
Potentilla-type
Liguliflorae 0,5%
Botrychium lunaria x
Alnus 0,6%
Sanguisorba officinalis x
Liguliflorae x
(Alnus x)
Typha-latifolia x
Oxyria-type x
Oxyria-type x
Liguliflorae x
Typha-latifolia x
Oxyria-type x
Liguliflorae x
Potentilla-type x
Potentilla-type x
Thalictrum x
Thalictrum x
Sanguisorba officinalis
Thalictrum x
(Corylus x)
Liguliflorae x
Dryopteris linneana x
(Alnus x)
(Alnus 0,7%
Corylus 0,5%)
Liguliflorae x
Potentilla-type x
Oxyria-type x
Thalictrum x
(Alnus x)
(Alnus x)
Potentilla-type x
(Alnus x
Corylus x)
Armeria x
(Picea x)
Hippuris x
(Alnus x)
Parnassia x
Oxyria-type 1%
Thalictrum x
(Alnus x
Sequoia x)
Hippophaë
Plantago
Helianthemum
Chenopodiaceae
Rumex acet.-type
Empetrum
Juniperus
Potamogeton
Myriophyllum
Ranunculaceae
Nuphar
Nymphaea
Filipendula
Caryophyllaceae
Tubuliflorae
Umbelliferae
Rosaceae p.p.
Menyanthes-type
Sanguisorba minor
Campanula
Dryopteris
Selaginella selaginoides
Sphagnum
Equisetum

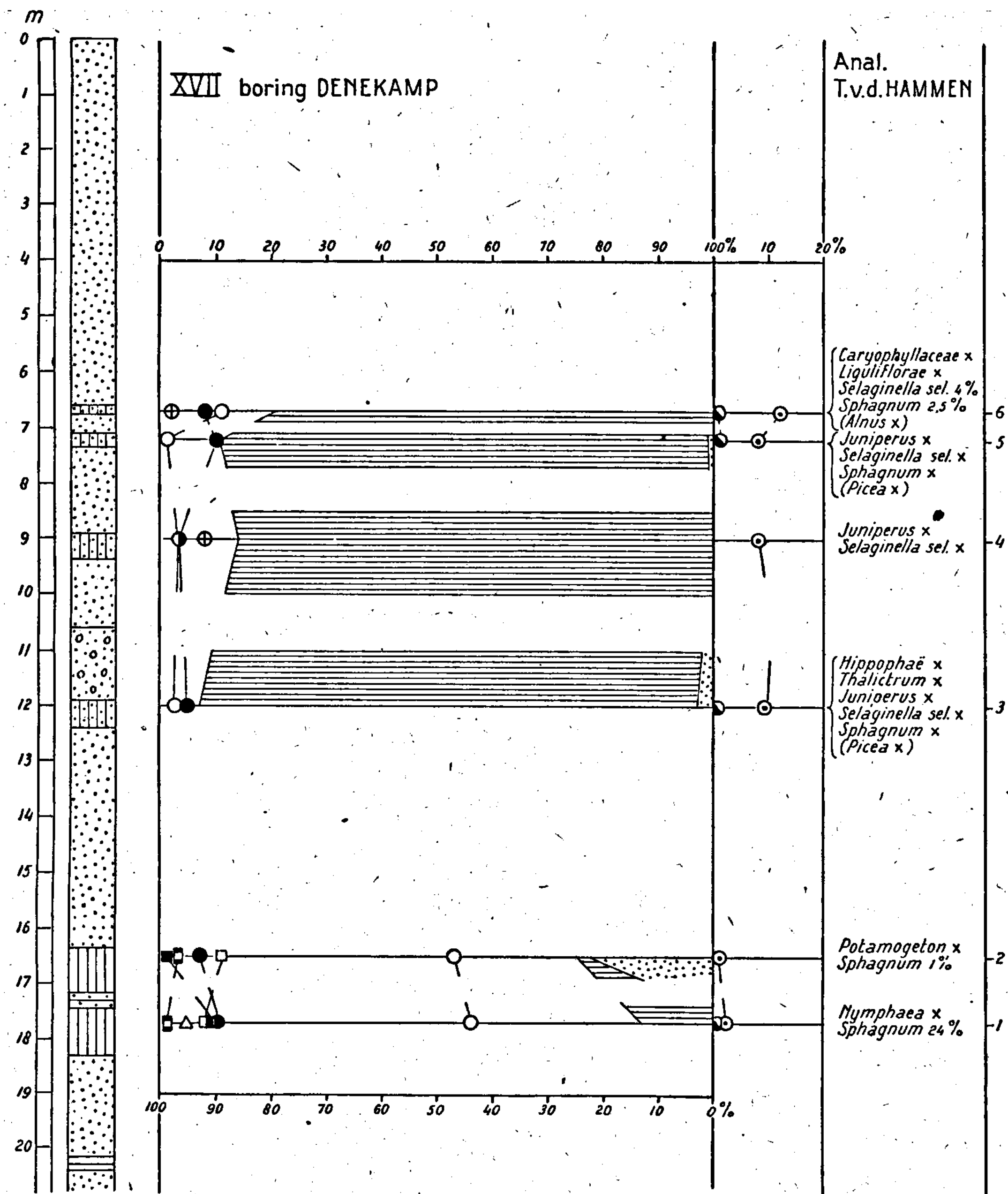

XIV BELLE CROIX
III
IV
V
cm
250
240
230
220
210
200
190
180
170
A
B
C
Helianthemum
Chenopodiaceae
Rumex
Empetrum
Juniperus
Myriophyllum
Batrachium
Caryophyllaceae
Umbelliferae
Tubuliflorae
Filipendula
Galium-type
Campanula
Polygonum bistorta-type
Valeriana
Menyanthes
Sphagnum
Equisetum
Dryopteris
Isoëtes
Urtica x
Alnus x
Litorella x
Thalictrum x
Populus x
Epilobium x
Thalictrum x
Rubus chamaemorus
Populus x
Potam. x
Nuphar x
Potam. x
Selaginella sel. x
Sang. officinalis 0.7 %
Alnus x
Potam. x
Potamogeton x
Centaurea 2 x
cyanus
Nymphaea x
Liguliflorae x
Jasione x
Liguliflorae x
Hippophae x
Ulmus x
Populus x
Populus 0.3 %
Liguliflorae x
ANAL. T.v.d HAMMEN

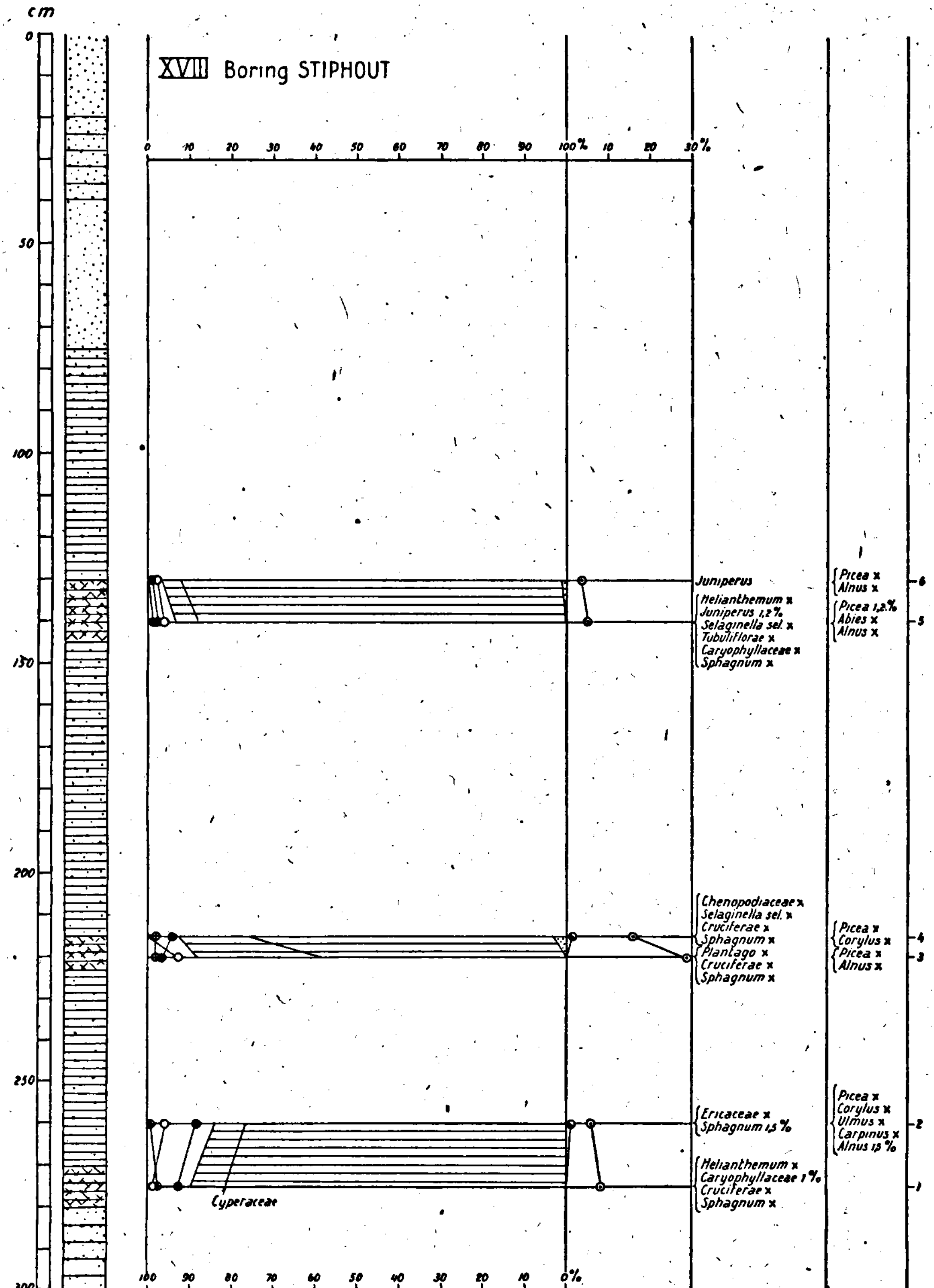


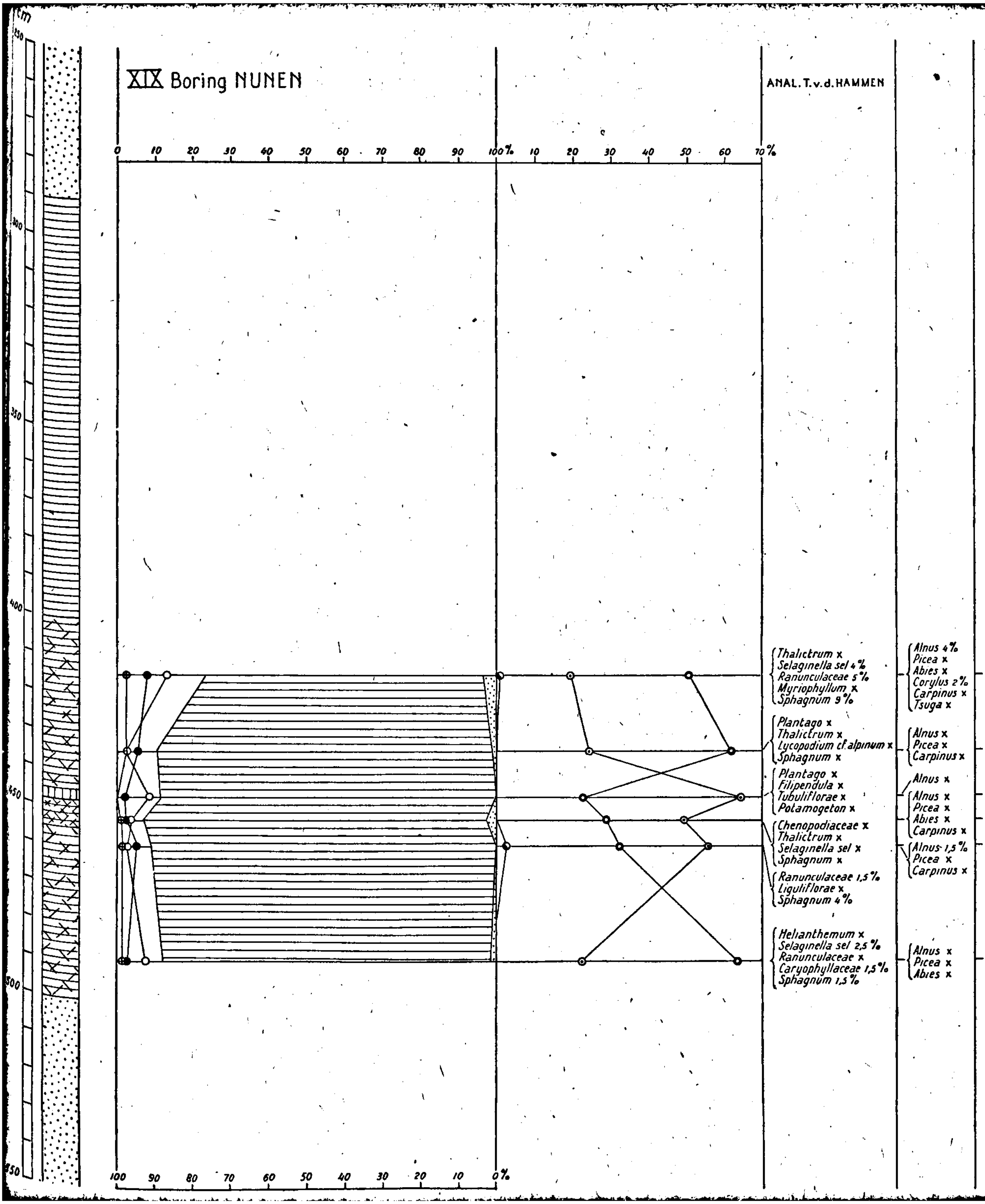
XV APELDOORN
A
B
C
Cyperaceae
Betula nana
Gramineae
Artemisia
Plantago
Helianthemum
Chenopodiaceae
Empetrum
Ericaceae
Ranunculaceae
Caryophyllaceae
Umbelliferae
Liguliflorae
Tubuliflorae
Cruciferae
Potentilla type
Rosaceae p.p
Selaginella selaginoides
Equisetum
Alnus x
cf. Selaginella helvetica x
Thalictrum x
Menyanthes 0.7%
Filipendula x
Menyanthes x
Galium-type x
Sanguisorba officinalis x
Valeriana x
Potamogeton x
Galium-type x
Rumex acet. type x
Valeriana x
Valeriana x
ANAL. T. v. d. HAMMEN



XVI BEST
A
B
C
Cyperaceae
Pediastrum etc
Gramineae
Artemisia
Plantago
Helianthemum
Myriophyllum
Batrachium
Caryophyllaceae
Cruciferae
Selaginella selaginoides
Sphagnum
Equisetum
ANAL. T. v.d. HAMMEN
Chenopodiaceae x
Rosaceae x
[Corylus x Picea x]
[Alnus x Ilex x]
Potentilla type x
[Alnus x]
[Picea x]
[Alnus x]
[Picea x]
Empetrum x
Liguliflorae x
[Alnus x]
[Picea x]
cm
310
300
290
280
270
260
250
240


XVII boring DENEKAMP
Anal.
T.v.d. HAMMEN
m
0 10 20 30 40 50 60 70 80 90 100% 10 20%
100 90 80 70 60 50 40 30 20 10 0%
Caryophyllaceae ×
Liguliflorae ×
Selaginella sel. 4%
Sphagnum 2,5%
(Alnus ×)
6
Juniperus ×
Selaginella sel. ×
Sphagnum ×
(Picea ×)
5
Juniperus ×
Selaginella sel. ×
4
Hippophaë ×
Thalictrum ×
Juniperus ×
Selaginella sel. ×
Sphagnum ×
(Picea ×)
3
Potamogeton ×
Sphagnum 1%
2
Nymphaea ×
Sphagnum 24%
1


cm
0
50
100
150
200
250
300
XVIII Boring STIPHOUT
0 10 20 30 40 50 60 70 80 90 100 % 10 20 30 %
Juniperus
Helianthemum x
Juniperus 1,2 %
Selaginella sel. x
Tubuliflorae x
Caryophyllaceae x
Sphagnum x
Picea x
Alnus x
Picea 1,2 %
Abies x
Alnus x
Chenopodiaceae x
Selaginella sel. x
Cruciferae x
Sphagnum x
Plantago x
Cruciferae x
Sphagnum x
Picea x
Corylus x
Picea x
Alnus x
Ericaceae x
Sphagnum 1,5 %
Helianthemum x
Caryophyllaceae 1 %
Cruciferae x
Sphagnum x
Picea x
Corylus x
Ulmus x
Carpinus x
Alnus 1,5 %
Cyperaceae
6
5
4
3
2
1
100 90 80 70 60 50 40 30 20 10 0 %


XIX Boring NUNEN
ANAL. T. v. d. HAMMEN
cm
250
300
350
400
450
500
550
0 10 20 30 40 50 60 70 80 90 100 %
10 20 30 40 50 60 70 %
100 90 80 70 60 50 40 30 20 10 0 %
Thalictrum x
Selaginella sel 4 %
Ranunculaceae 5 %
Myriophyllum x
Sphagnum 9 %
Plantago x
Thalictrum x
Lycopodium cf. alpinum x
Sphagnum x
Plantago x
Filipendula x
Tubuliflorae x
Potamogeton x
Chenopodiaceae x
Thalictrum x
Selaginella sel x
Sphagnum x
Ranunculaceae 1,5 %
Liguliflorae x
Sphagnum 4 %
Helianthemum x
Selaginella sel 2,5 %
Ranunculaceae x
Caryophyllaceae 1,5 %
Sphagnum 1,5 %
Alnus 4 %
Picea x
Abies x
Corylus 2 %
Carpinus x
Tsuga x
Alnus x
Picea x
Carpinus x
Alnus x
Alnus x
Picea x
Abies x
Carpinus x
Alnus 1,5 %
Picea x
Carpinus x
Alnus x
Picea x
Abies x
6
5
4
3
2
1

Recent surface samples from Northern Lapland