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PALAEOHYDROLOGY OF THE TEMPERATE ZONE

PROCEEDINGS OF WORKING SESSION OF COMMISSION ON HOLOCENE-INQUA (EUROSIBERIAN SUBCOMMISSION)
HAILUOTO — OULANKA — KEVO, 28. 8.—6. 9. 1978

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Abstract

The flat, sandy landscape of northern Flanders provided excellent conditions for organic sedimentation soon after the end of the Pleniglacial. Topographically, this sedimentation took place in relatively deep abandoned riverbeds and in more shallow depressions left by periglacial morphogenesis. Due to aeolian activity, many of the latter were quickly covered by blown sand. From a climatic standpoint, it seems apparent that the relatively, cold, moist climate allowed the groundwater to reach its highest level since the Pleniglacial, so that organic sequences were able to rise to the level of the surrounding land.

The results of extensive pollen analyses are presented here, illustrated by a number of diagrams. The general course of vegetational development agrees with that elaborated since the initial work of Iversen and Van der Hammen. Making allowance for the more southerly latitude of the country, the following points need to be stressed:

— The onset of Lategiacial vegetational development does not go back any further than in more northerly regions.

— Immigration of thermophilous plants and expansion of the forest seems to have taken place somewhat faster.

— Vegetational development during the first half of the Lategiacial was markedly influenced by morphological and edaphic events.

Key words: aquatic plants, aeolian activity, ground water level

Although palynological investigations in Sandy Flanders were initiated more than ten years ago, only recently has it proved possible to distinguish from the lateglacial sequences a number of general paleoecological trends. The main reason for the initial setback was the lack of sufficient C14-dates. Furthermore it ought to be stressed that an additional number of sites have only become available in the last few years due to sand extraction. Finally there is the time factor involved in placing the results in a broader ecological, chronological and geographic context.

Explanation of the diagrams

In the geochronological scale that is included between the depth-scale and the stratigraphical scale, one finds the numbers and letters which are used to distinguish the zones. As far as possible these are the ones in current use in NW-Europe. Their exact meaning is explained in the course of the discussion of the zones. The last zone to be discussed is zone III, the Younger Dryas. Those parts of the diagrams referring to younger zones will not be discussed in this paper.

The symbols used for sediments are explained in the accompanying legend. All taxa from the main diagram A and part B of the resolved diagram are included in the pollen sum, as well as the rare non-aquatic spermatophytic taxa cited at the end of the diagram.

The diagram for St. Andries-Beisbroek (1) is considered to be the standard diagram for the vegetational succession during the entire Lateglacial. Both the geomorphological position of the depression and the largely limnological character of the sediments lead us to believe that this area was most suitable for regional pollen rain. These conditions were also present at Moerbeke-Moervaart (2) and in part in diagram 3, but in this case zone III, the Younger Dryas, is missing. Diagrams 4 and 5 (Maldegem-Ede and Vinderhoute-Kale respectively) are complete, but are characterized by a more local vegetational history.

Diagrams 6, 7, 8 and 9 originate from thin layers of peat formed in shallow depressions and later covered by aeolian sands. As a result these layers cover only a limited timespan and reflect local conditions. However, with the help of the complete sequences we have been able to allocate these correctly. In addition, these layers have been dated with C14, so that we can be sure of their relationship to the complete successions.

A. History of the vegetation

I. Oldest Dryas

Ia1 Herb-subzone

The only clearly formulated botanical criterion that has been suggested for the start of the Lateglacial is the increase of *Artemisia* pollen to over 5 % (Van der Hammen 1951). Although it is easy to criticize the use of a single criterion such as this, on ecological and geographical grounds, it is true that all our regional sequences are characterized by an increase in *Atermisia* pollen. However, in contrast to the Dutch diagrams, which tend to begin with an immediate increase in *Artemisia*, those from Sandy Flanders are typified by an extra phase prior to the rise in *Artemisia*. For sedimentological reasons, we consider that this part of the succession belongs to the Lateglacial as well. In Moerbeke-Moervaart, where the Lateglacial deposits are underlain by Fullglacial sediments, the latter are distinguished by the allochtonous nature of the pollen assemblage. On the basis of geomorphological evidence we can conclude that the phase prior to the rise in *Artemisia* in all diagrams is referable to the Lateglacial.

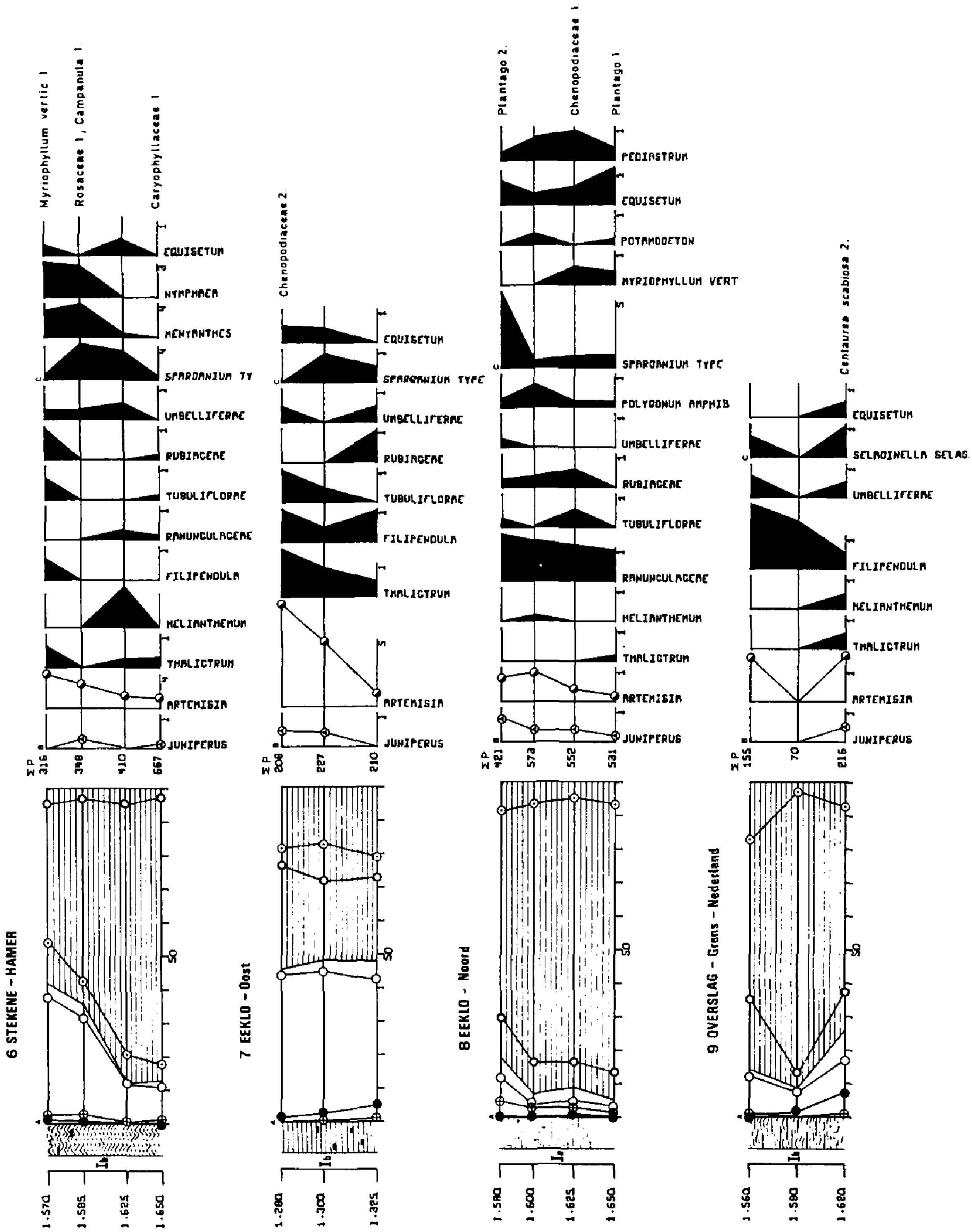
The author refers to this phase as the Herb-subzone because the vegetation that grew round the mires was composed of a species-rich herbaceous flora.

The local vegetation in the shallow bogs is typified by the presence, sometimes in enormous numbers, of *Selaginella selaginoides*. The aquatic species are those found in the Fullglacial e.g. *Sparganium, Potamogeton, Myriophyllum verticillatum, M.spicatum, M.alternifolium, Batrachium* and sometimes *Alisma*.

Ia2 Salix-subzone

In the local vegetational successions it can be seen that *Salix* species were the first shrub- or tree-species to react to climatic improvement.

On closer examination, it is possible to detect a significant increase in *Salix* in



Diagrams 6—9 For diagrams 1—5 see the plates.

the regional successions as well. It is possible to distinguish a number of *Salix* pollentypes, so that we can conclude that not only arctic species such as *Salix herbacea* were present but other species as well.

Other signs of improved ecological conditions are to be found in the aquatic flora. These include:

(a) The change in dominance *Cyperaceae* to native *Gramineae.* This trend is to be found in all the sections investigated, but is more marked in the local than the regional diagrams. This fact and the local presence of macrofossils indicate that the grass pollen was probably that of *Phragmites.* As from the end of the *Salix*-subzone, reed had apparently become established in the mires.

(b) The appearance of *Menyanthes, Nymphaea, Nuphar* and *Typha latifolia.*

1. Menyanthes

While this plant was not uncommon during the Fullglacial, it was absent at the start of the Lategiacial. Whether this was the result of microclimate or edaphic factors is uncertain. One thing is certain: *Menyanthes* appears in our diagrams in the course of the *Salix*-subzone or the start of the Bölling s.s.

2. Nymphaea

The presence of the water-lily is almost certainly indicative of rather thermophilous conditions. The presence of a number of species which prove difficult to separate palynologically complicates the matter. In Fennoscandia the common occurrence of the most *resistant* taxon, *Nymphaea candida* does not extend beyond the southern margins of the Northern boreal zone, as is evident from a comparison of the maps of Hultén (1950) and Ahti *et al.* (1968, Fig. 9). In Fennoscandia *Nymphaea candida* seems to favour continental climatic conditions — short warm summers and long cold winters (Samuelsson 1934).

3. Typha latifolia

Typha latifolia is a distinctly thermophilous species requiring July temperatures above +16°C (see Vasari 1962, p. 87 and the literature therein).

4. Nuphar

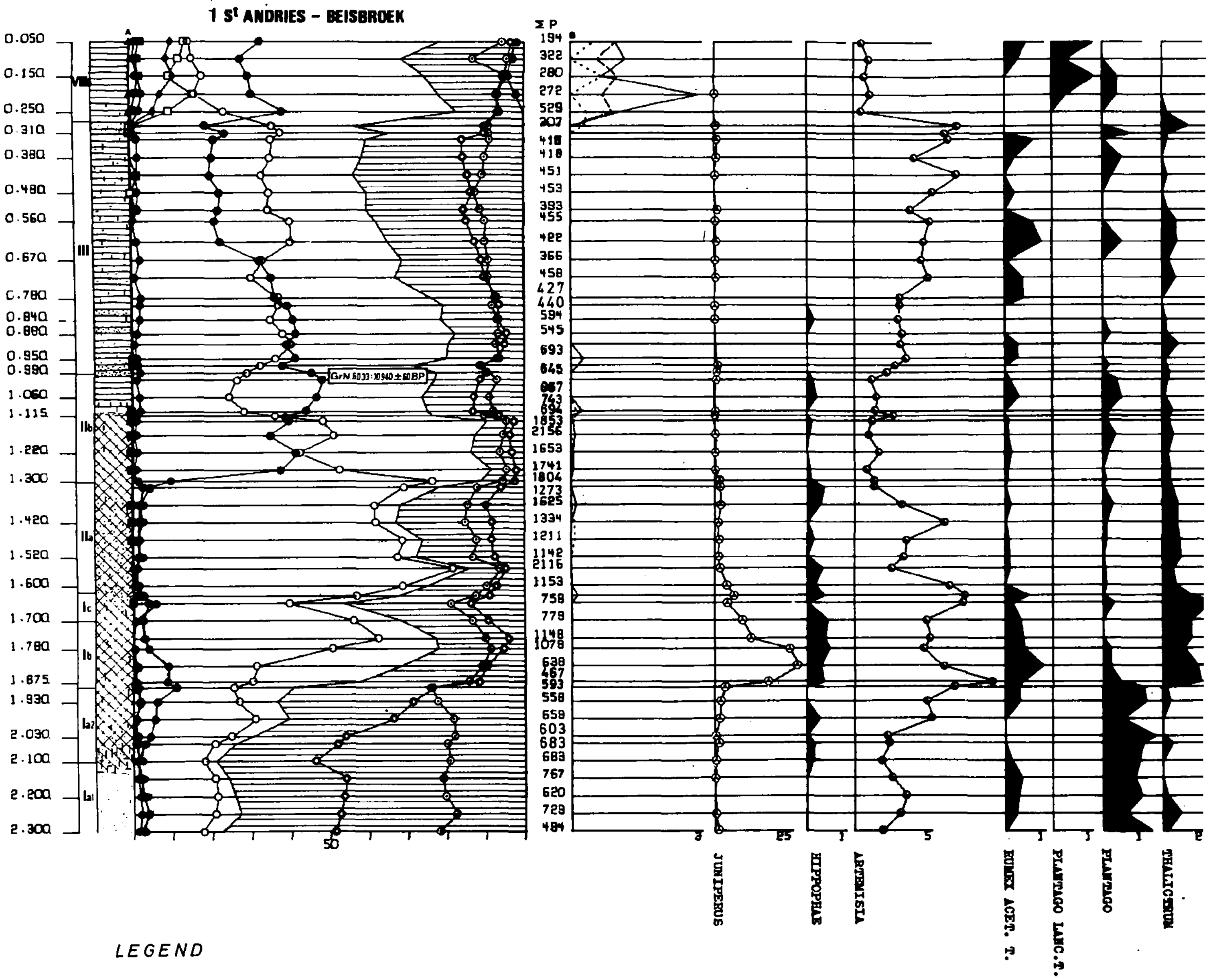
In Fennoscandia the *Nuphar* species are somewhat more northern and maritime in their distribution than *Nymphaea candida* (Hultén 1950).

The most complete picture of the aquatic plants is to be found in diagram 4, for Vinderhoute-Kale. However a similar picture emerges from the other diagrams where one or more species are present. Their presence in the diagrams adds to our knowledge of the past climatic conditions.

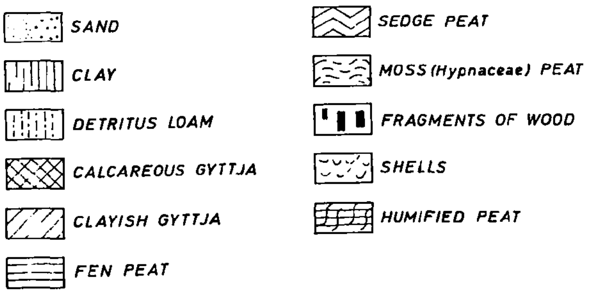
(c) Finally it should be pointed out that it was during the *Salix*-subzone that an increase in *Artemisia* to over 5 % took place.

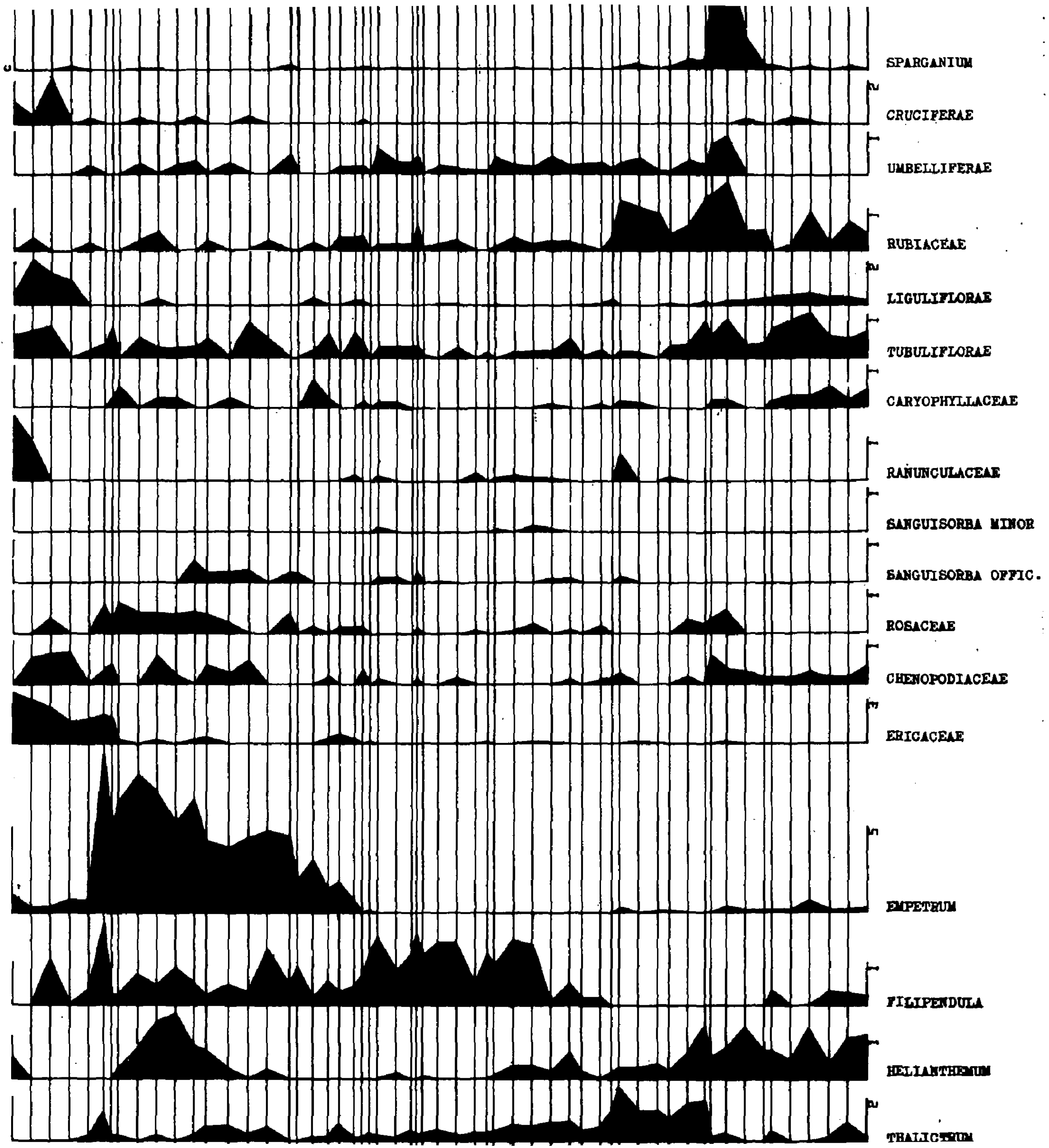
Ib: Bölling sensu stricto

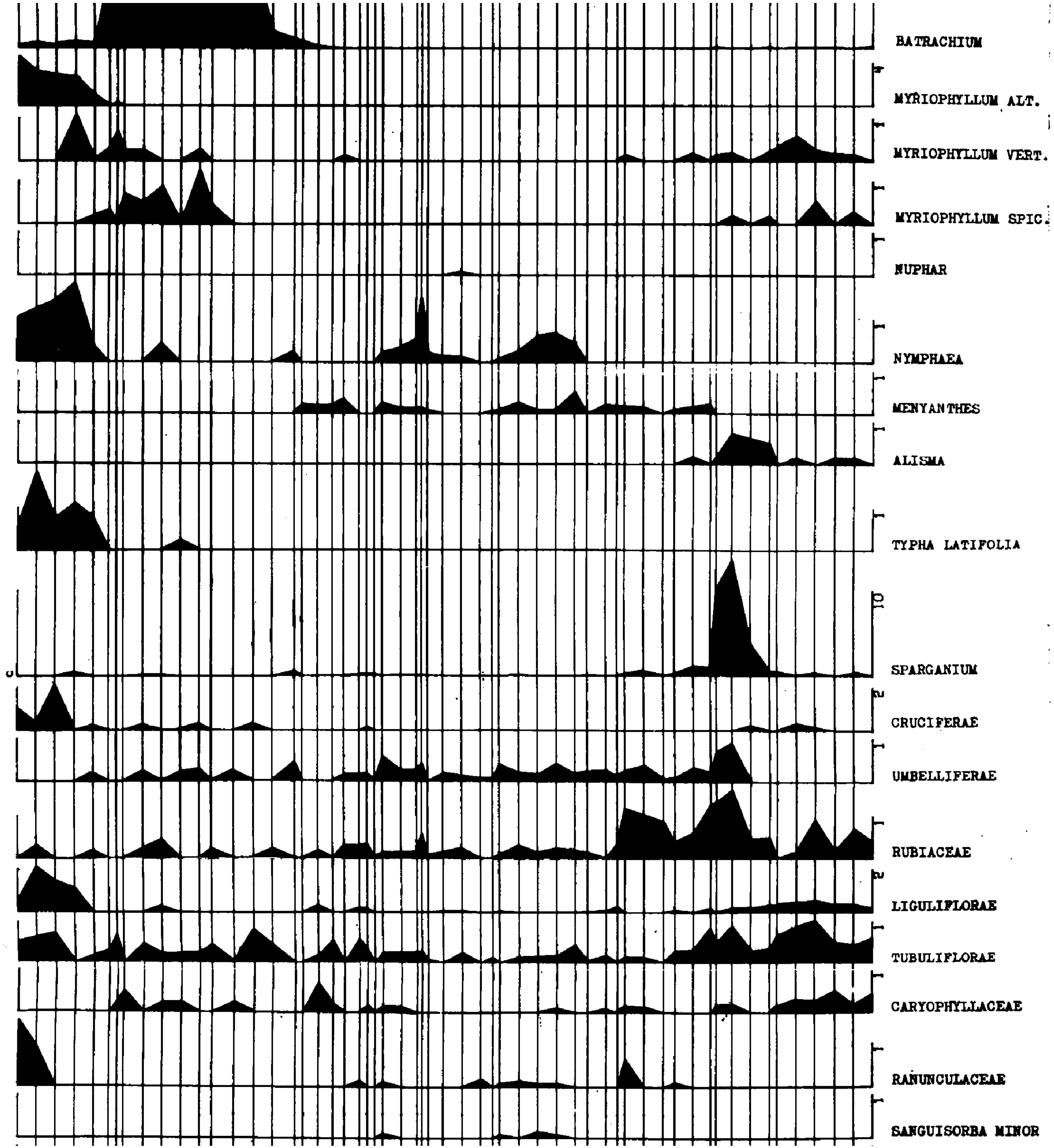
Even though it seems unlikely that the migration of the treeline was a synchronous event, it would be better to place the start of the Bölling s.s. at the point where the AP. (*Salix* excluded) begins to rise sharply.

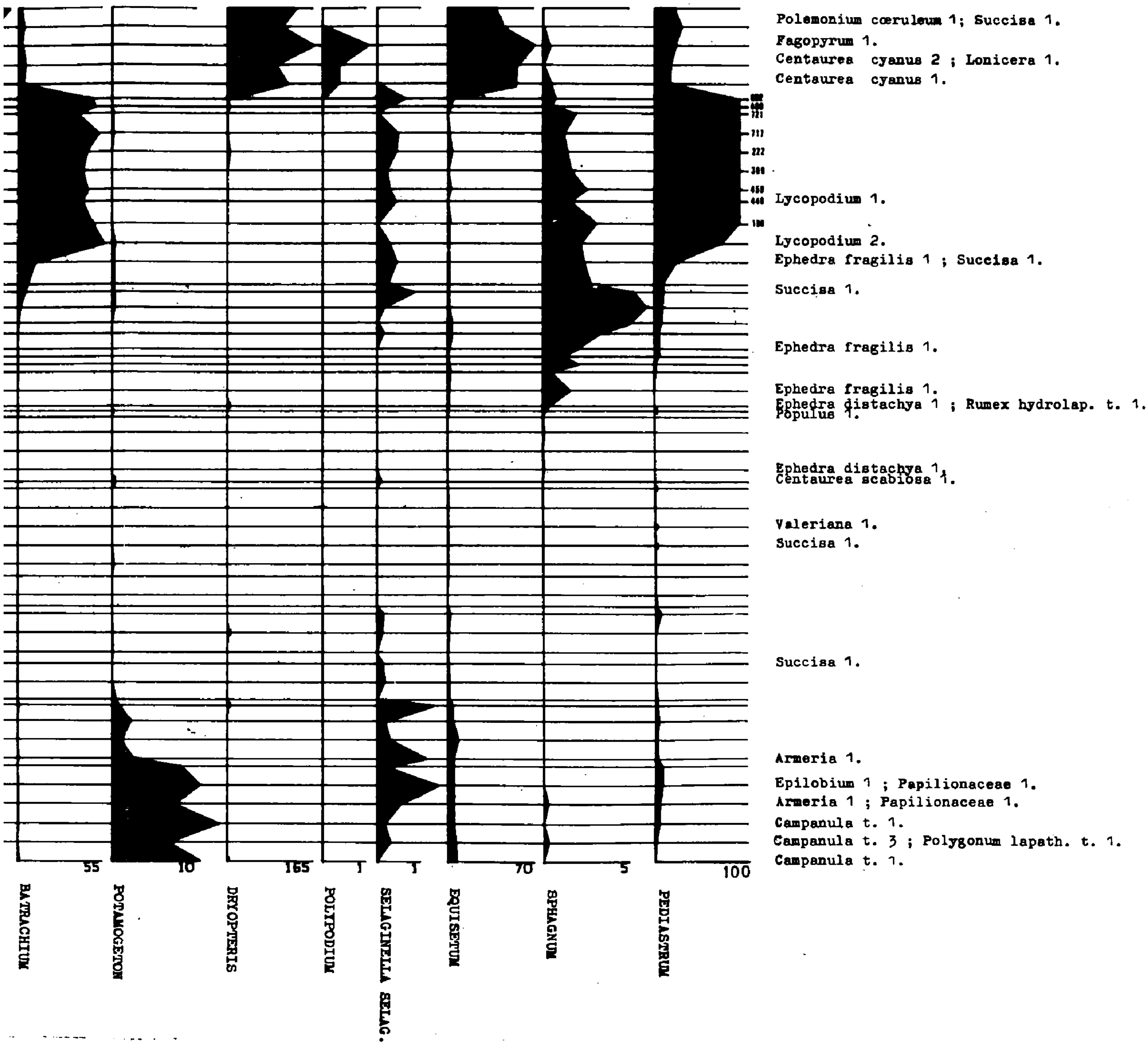

1 St ANDRIES - BEISBROEK
Σ P
0.050
0.150
0.250
0.310
0.380
0.480
0.560
0.670
0.780
0.840
0.880
0.950
0.990
1.060
1.115
1.220
1.300
1.420
1.520
1.600
1.700
1.780
1.875
1.930
2.030
2.100
2.200
2.300
VIII
III
IIb
IIa
Ic
Ib
Ia2
Ia1
GrN 6033: 10940 ± 60 BP
50
JUNIPERUS
HIPPOPHAE
ARTEMISIA
RUMEX ACET. T.
PLANTAGO LANC.T.
PLANTAGO
THALICTRUM

LEGEND

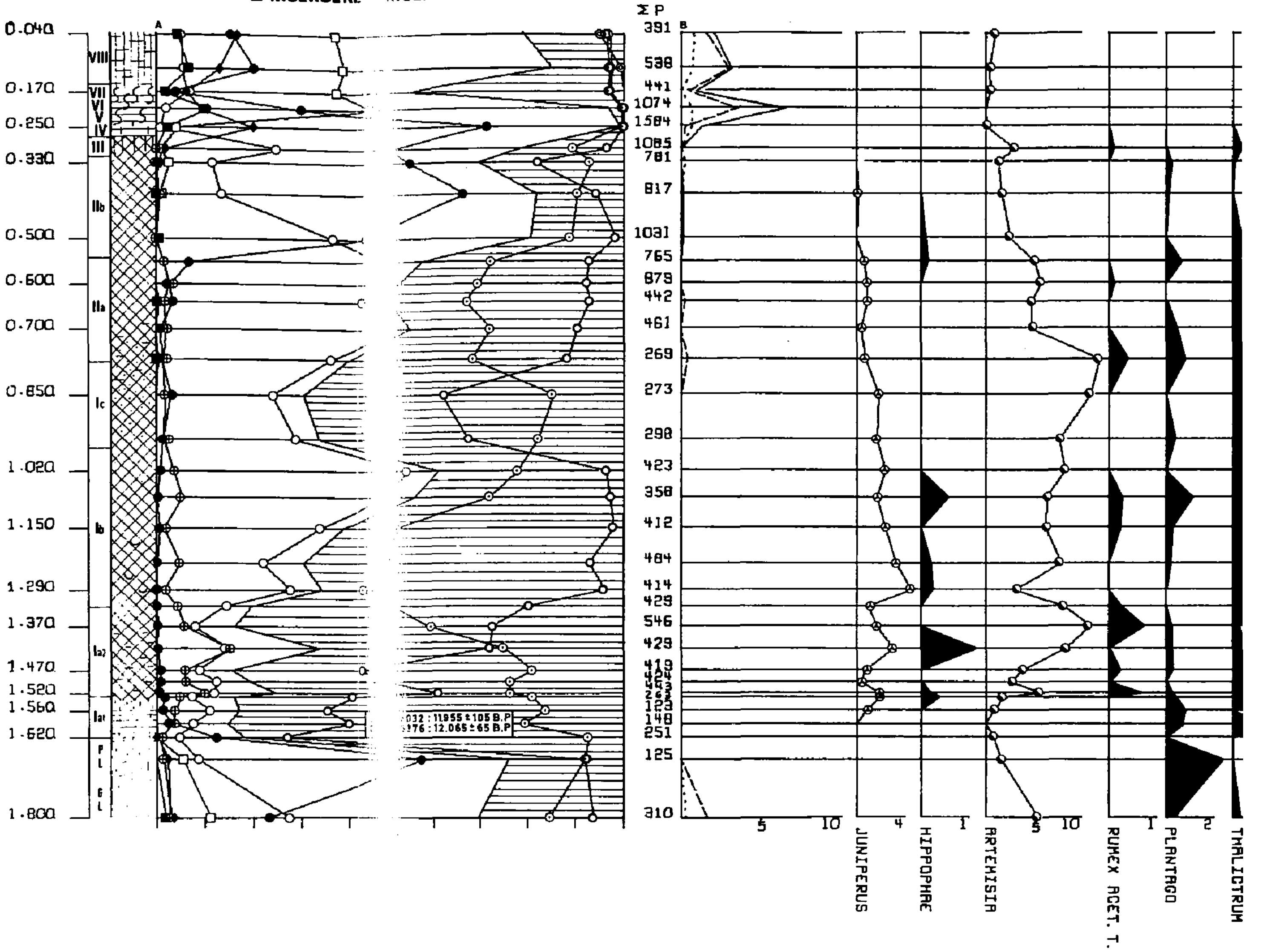

SAND
CLAY
DETRITUS LOAM
CALCAREOUS GYTTJA
CLAYISH GYTTJA
FEN PEAT
SEDGE PEAT
MOSS (Hypnaceae) PEAT
FRAGMENTS OF WOOD
SHELLS
HUMIFIED PEAT


SPARGANIUM
CRUCIFERAE
UMBELLIFERAE
RUBIACEAE
LIGULIFLORAE
TUBULIFLORAE
CARYOPHYLLACEAE
RANUNCULACEAE
SANGUISORBA MINOR
SANGUISORBA OFFIC.
ROSACEAE
CHENOPODIACEAE
ERICACEAE
EMPETRUM
FILIPENDULA
HELIANTHEMUM
THALICTRUM

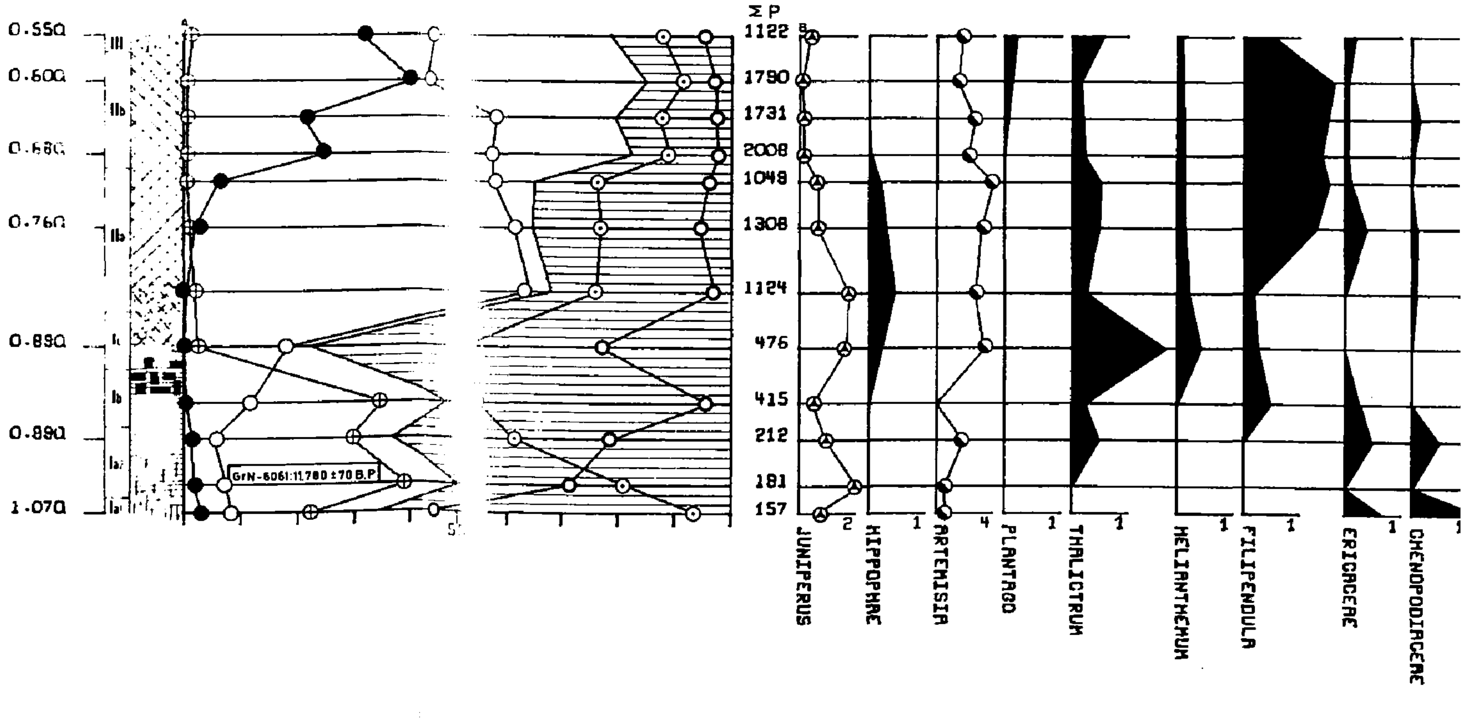

BATRACHIUM
MYRIOPHYLLUM ALT.
MYRIOPHYLLUM VERT.
MYRIOPHYLLUM SPIC.
NUPHAR
NYMPHAEA
MENYANTHES
ALISMA
TYPHA LATIFOLIA
10
SPARGANIUM
CRUCIFERAE
UMBELLIFERAE
RUBIACEAE
LIGULIFLORAE
TUBULIFLORAE
CARYOPHYLLACEAE
RANUNCULACEAE
SANGUISORBA MINOR

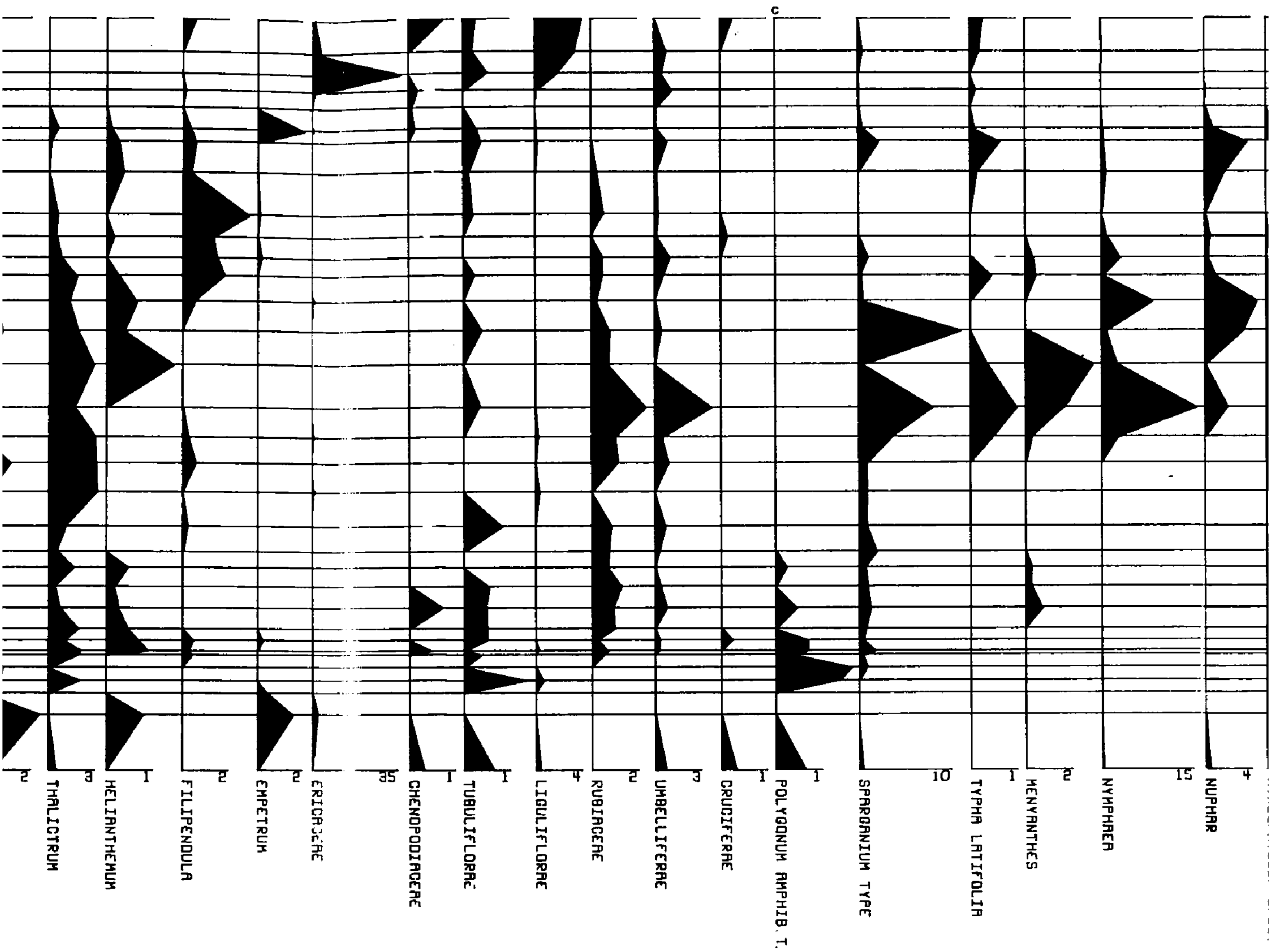

Polemonium cœruleum 1; Succisa 1.
Fagopyrum 1.
Centaurea cyanus 2 ; Lonicera 1.
Centaurea cyanus 1.
Lycopodium 1.
Lycopodium 2.
Ephedra fragilis 1 ; Succisa 1.
Succisa 1.
Ephedra fragilis 1.
Ephedra fragilis 1.
Ephedra distachya 1 ; Rumex hydrolap. t. 1.
Populus 1.
Ephedra distachya 1.
Centaurea scabiosa 1.
Valeriana 1.
Succisa 1.
Succisa 1.
Armeria 1.
Epilobium 1 ; Papilionaceae 1.
Armeria 1 ; Papilionaceae 1.
Campanula t. 1.
Campanula t. 3 ; Polygonum lapath. t. 1.
Campanula t. 1.
55
10
165
1
1
70
5
100
BATRACHIUM
POTAMOGETON
DRYOPTERIS
POLYPODIUM
SELAGINELLA SELAG.
EQUISETUM
SPHAGNUM
PEDIASTRUM

2 MOERBEKE - MOERVAART



3 SNELLEGEM - MOLENBROEK




THALICTRUM
HELIANTHEMUM
FILIPENDULA
EMPETRUM
ERICACEAE
CHENOPODIACEAE
TUBULIFLORAE
LIGULIFLORAE
RUBIACEAE
UMBELLIFERAE
CRUCIFERAE
POLYGONUM AMPHIB. T.
SPARGANIUM TYPE
TYPHA LATIFOLIA
MENYANTHES
NYMPHAEA
NUPHAR

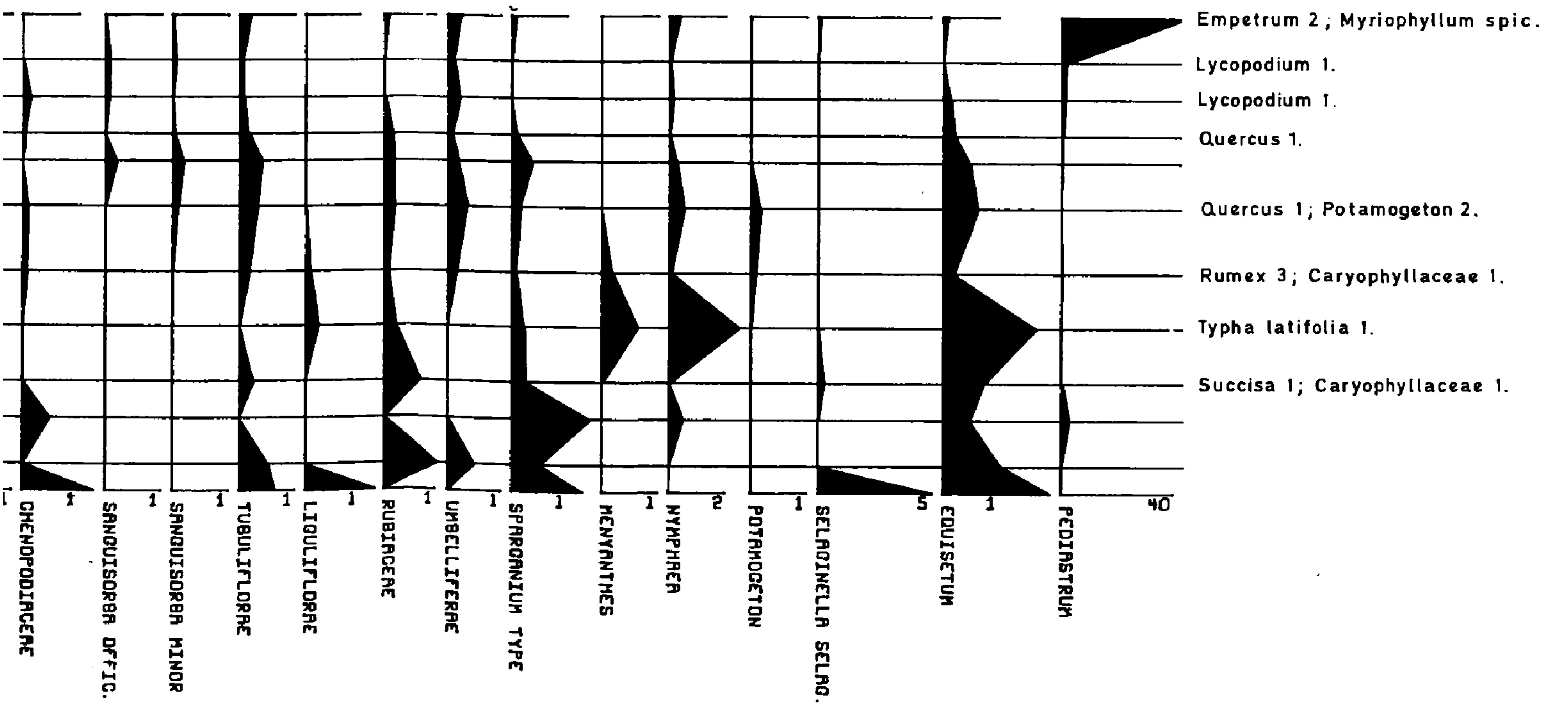
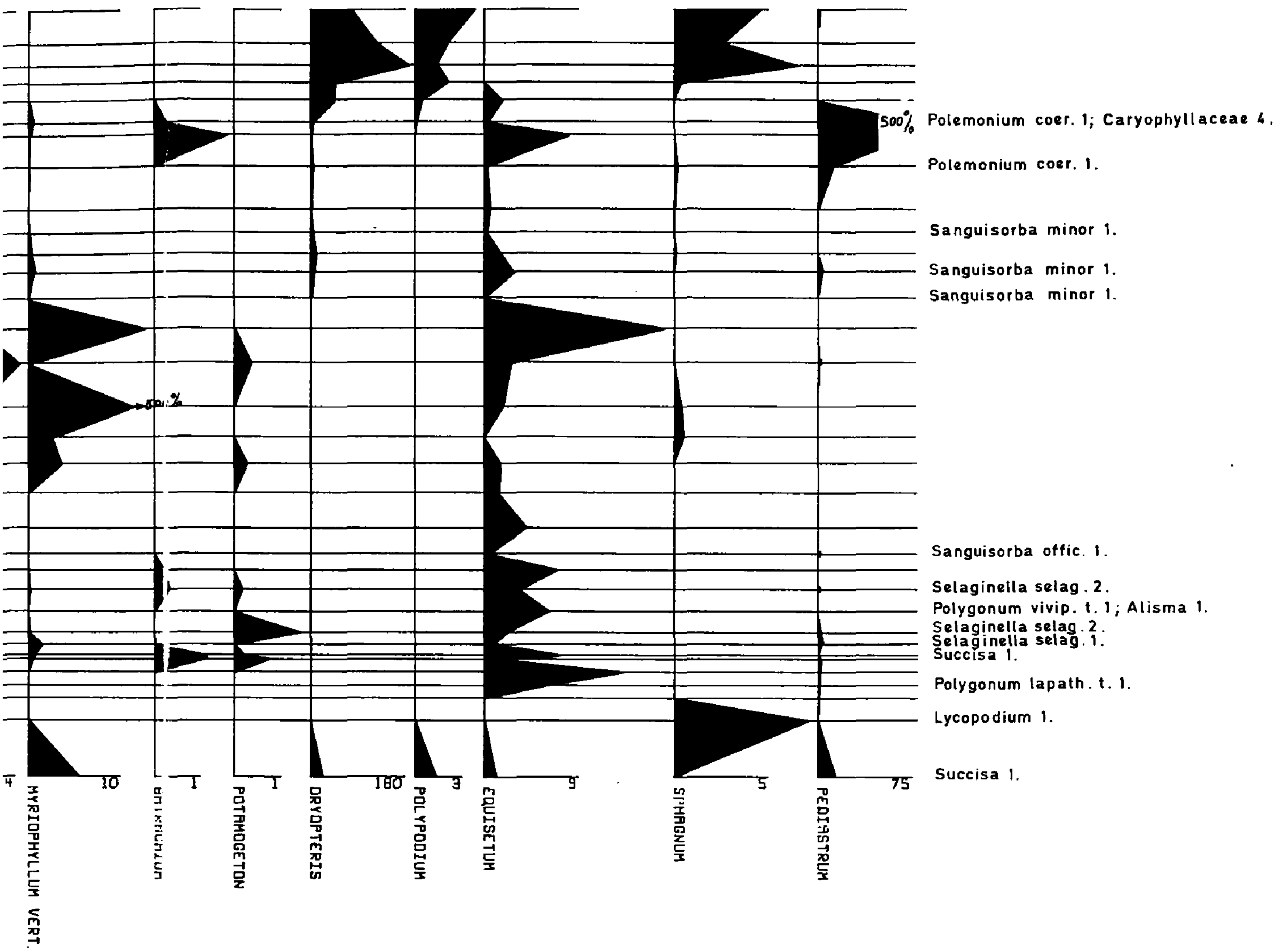
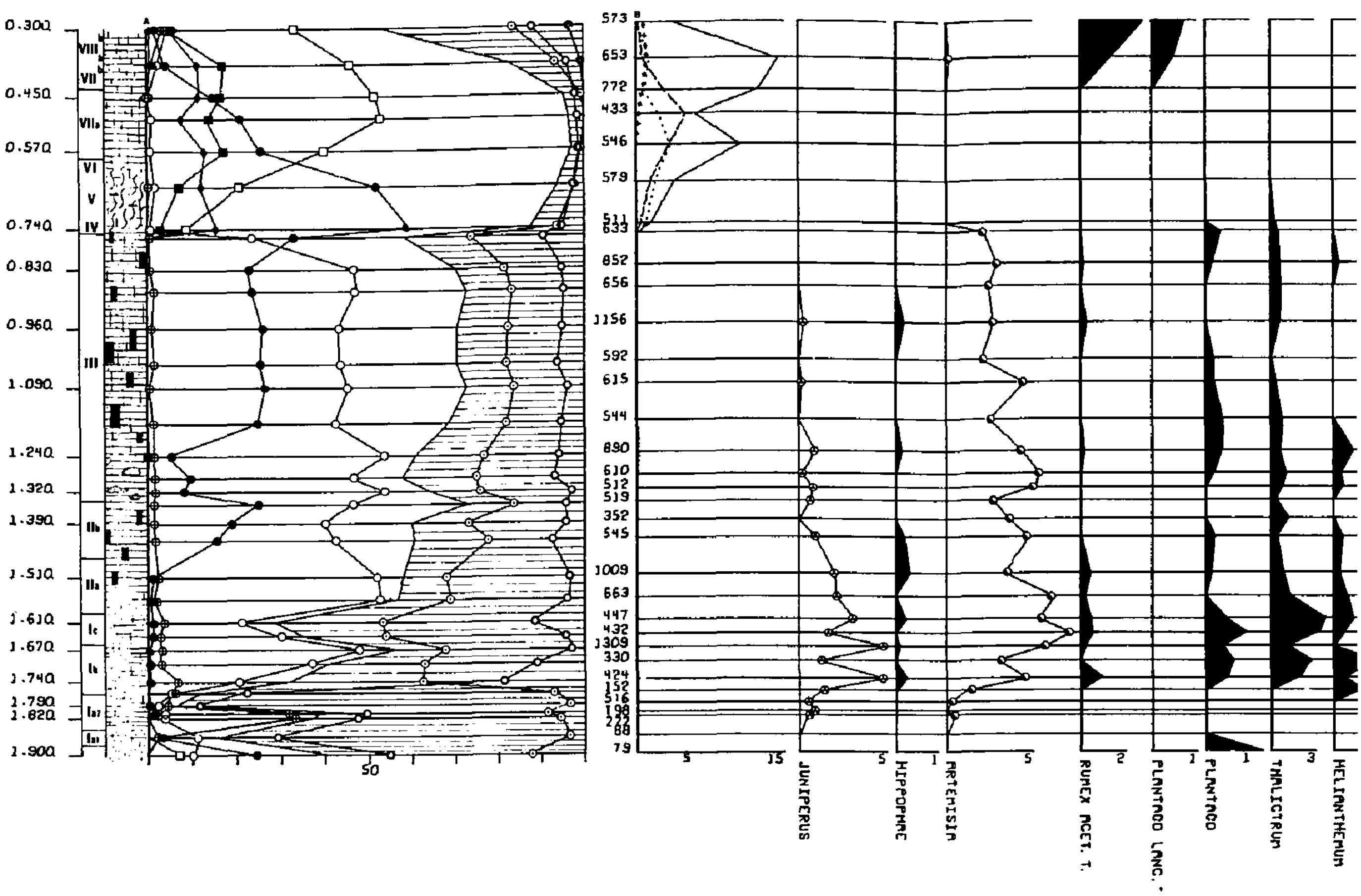

CHENOPODIACEAE
SANGUISORBA OFFIC.
SANGUISORBA MINOR
TUBULIFLORAE
LIGULIFLORAE
RUBIACEAE
UMBELLIFERAE
SPARGANIUM TYPE
MENYANTHES
NYMPHAEA
POTAMOGETON
SELAGINELLA SELAG.
EQUISETUM
PEDIASTRUM
Empetrum 2; Myriophyllum spic.
Lycopodium 1.
Lycopodium 1.
Quercus 1.
Quercus 1; Potamogeton 2.
Rumex 3; Caryophyllaceae 1.
Typha latifolia 1.
Succisa 1; Caryophyllaceae 1.

PLATE II

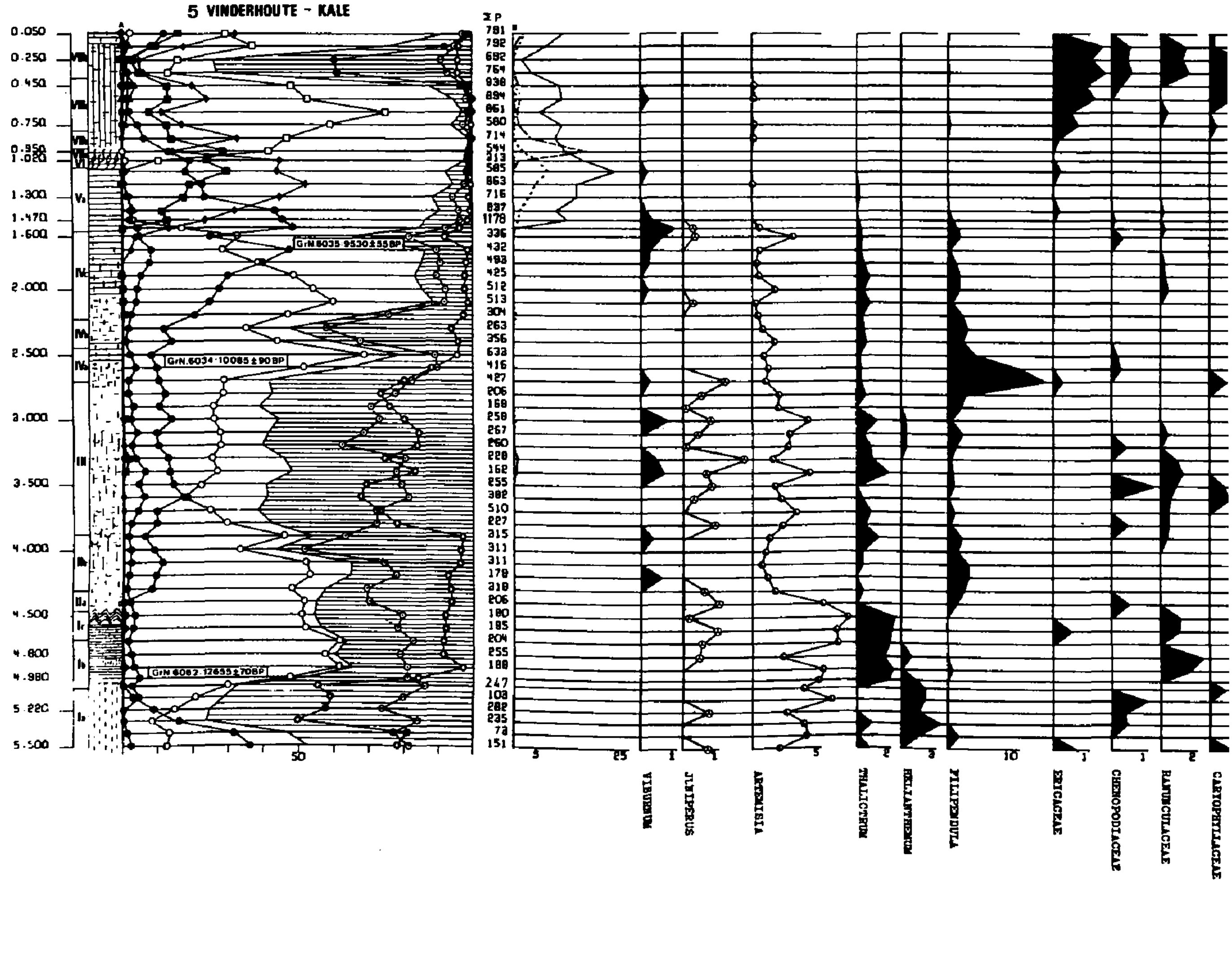


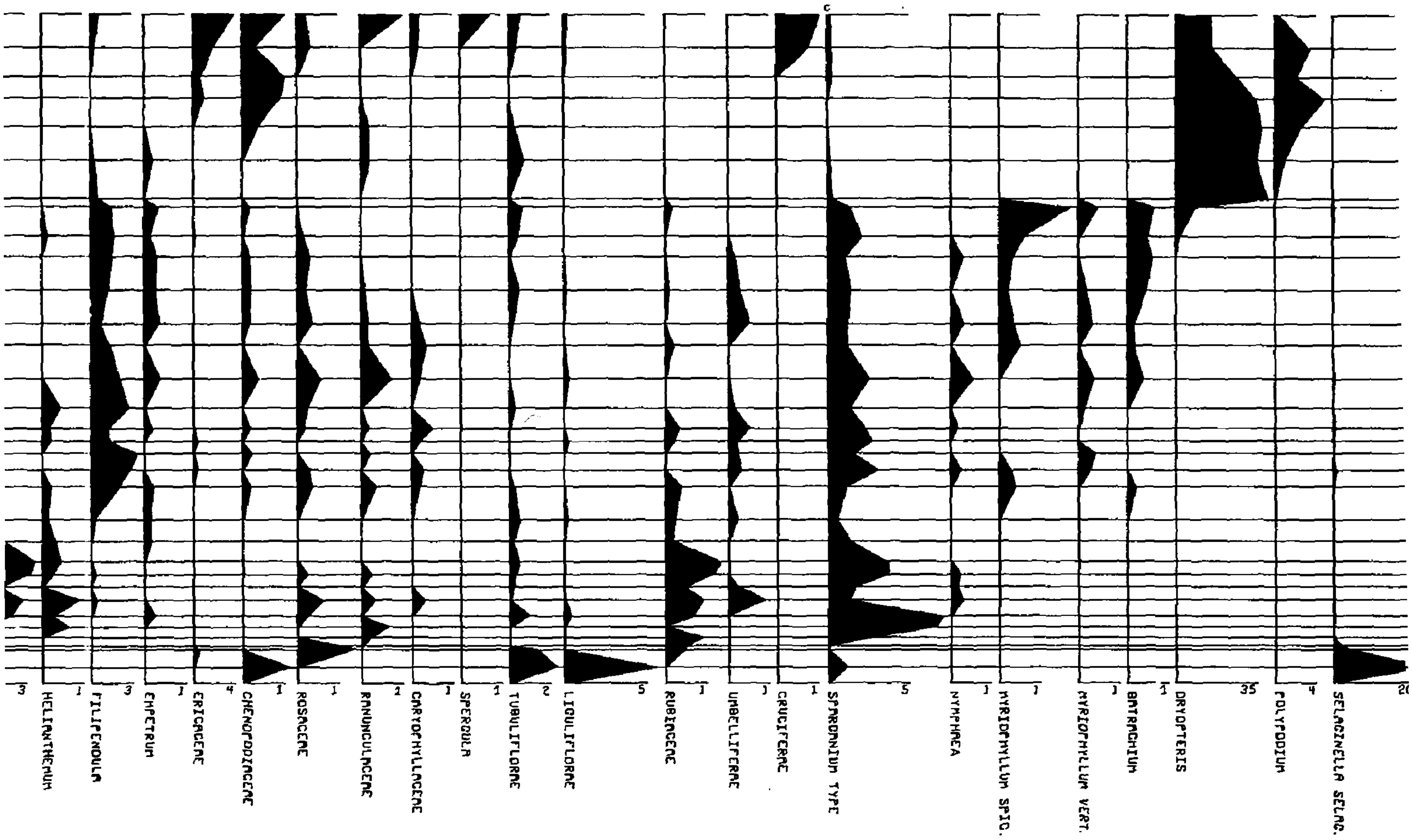
500%
Polemonium coer. 1; Caryophyllaceae 4.
Polemonium coer. 1.
Sanguisorba minor 1.
Sanguisorba minor 1.
Sanguisorba minor 1.
Sanguisorba offic. 1.
Selaginella selag. 2.
Polygonum vivip. t. 1; Alisma 1.
Selaginella selag. 2.
Selaginella selag. 1.
Succisa 1.
Polygonum lapath. t. 1.
Lycopodium 1.
Succisa 1.
10
1
1
180
3
9
5
75
MYRIOPHYLLUM VERT.
POTAMOGETON
DRYOPTERIS
POLYPODIUM
EQUISETUM
PEDIASTRUM

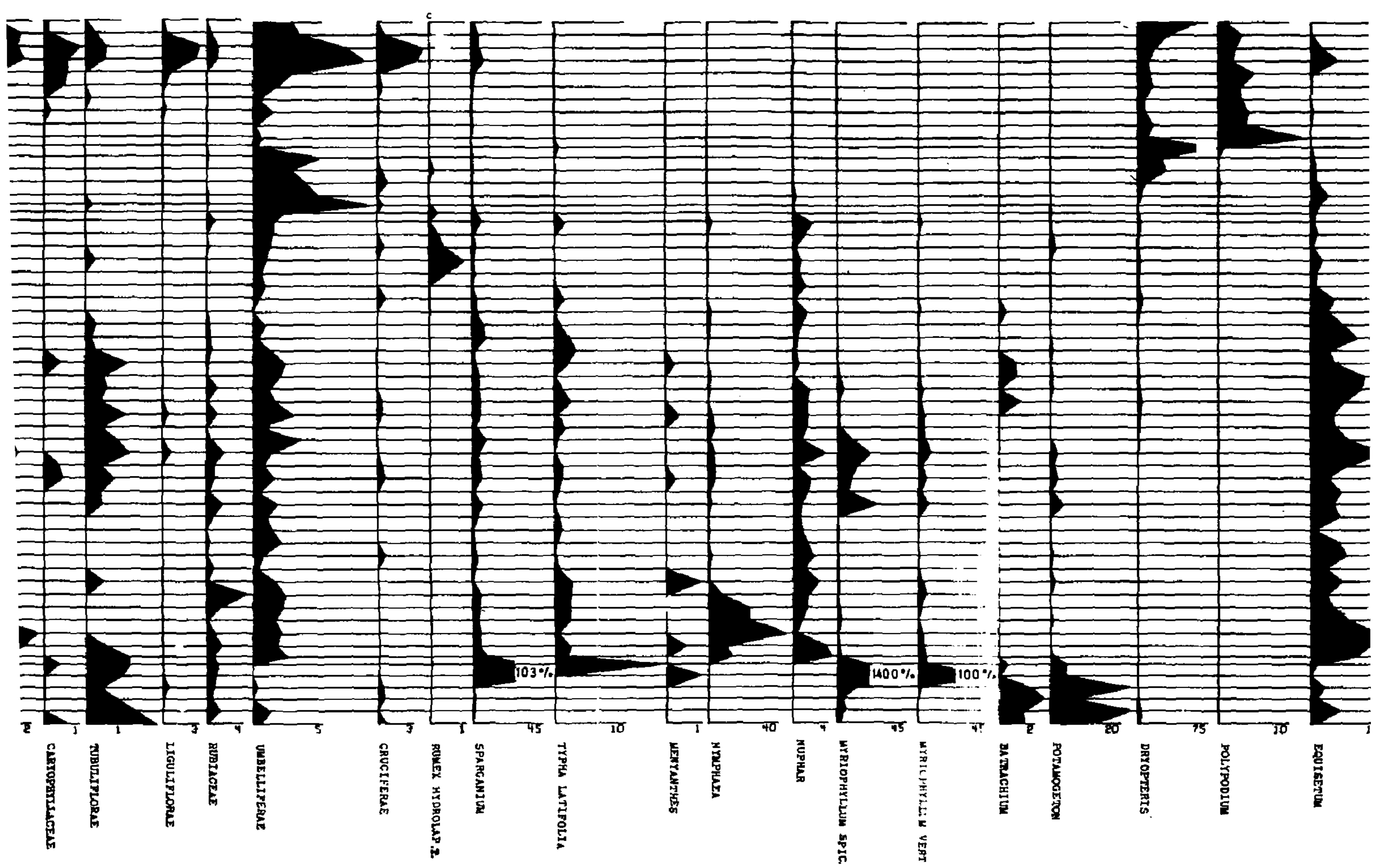
4 MALDEGEM EDE

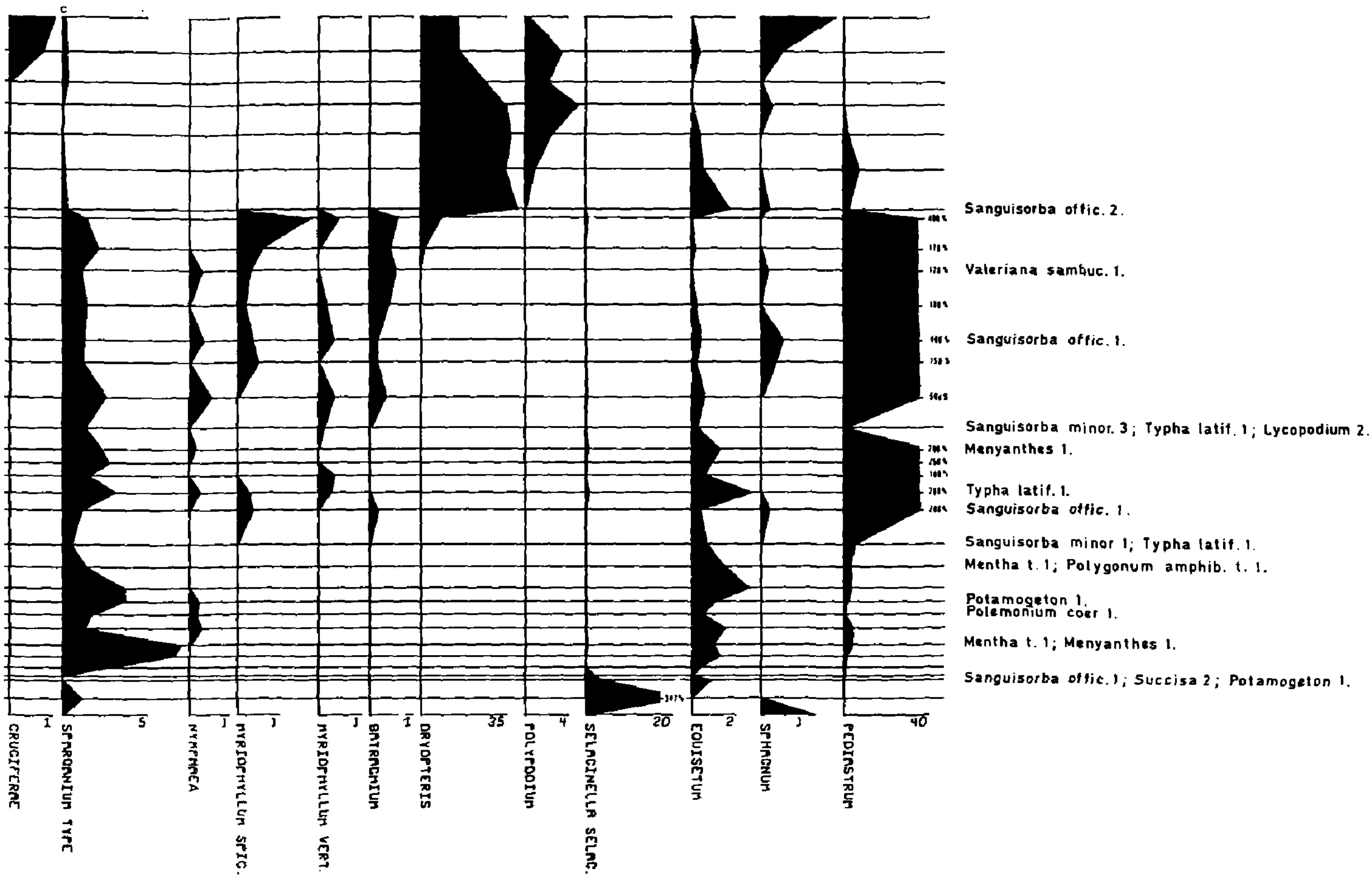


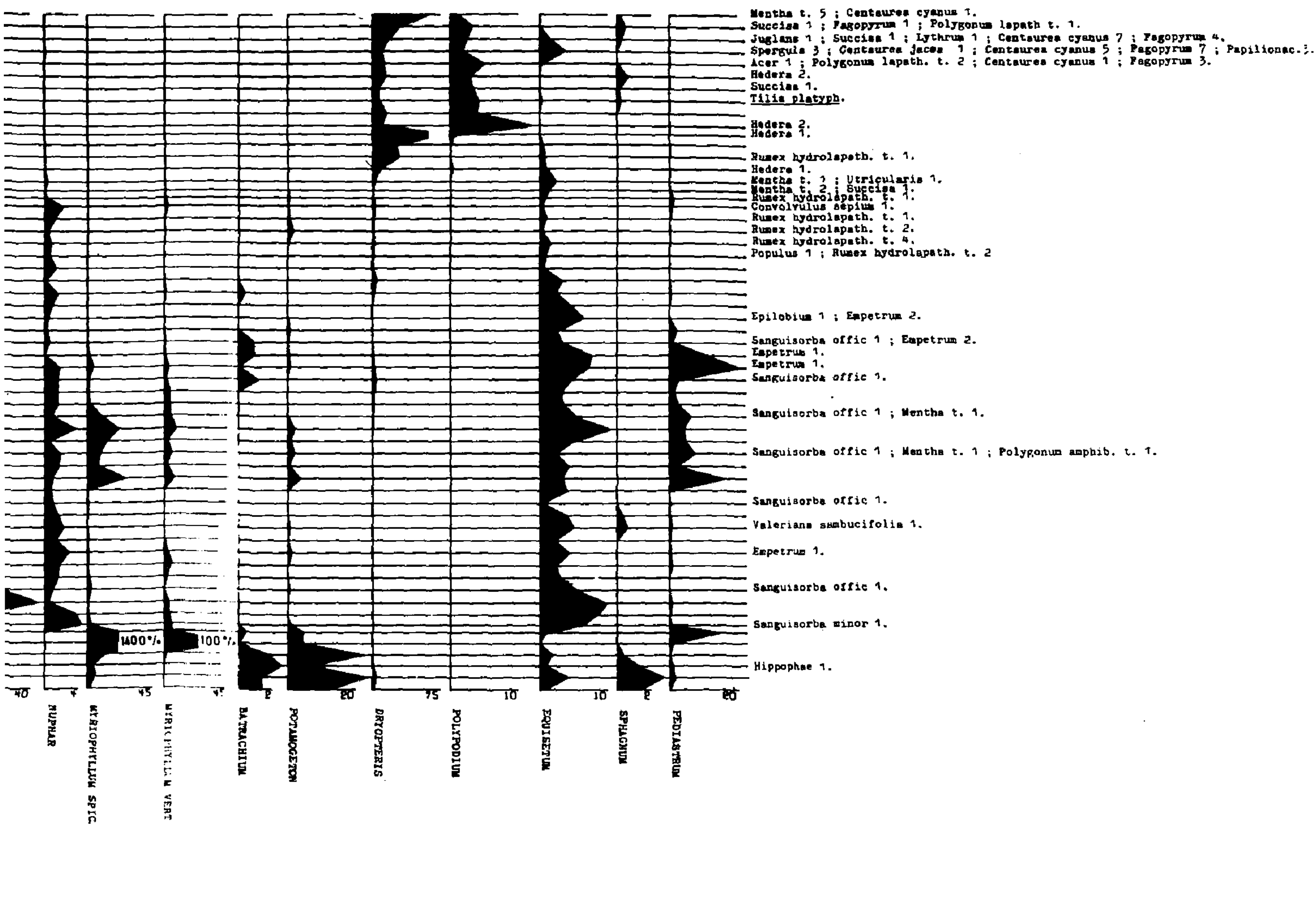
5 VINDERHOUTE - KALE




HELIANTHEMUM
FILIPENDULA
EMPETRUM
ERICACEAE
CHENOPODIACEAE
ROSACEAE
RANUNCULACEAE
CARYOPHYLLACEAE
SPERGULA
TUBULIFLORAE
LIGULIFLORAE
RUBIACEAE
UMBELLIFERAE
CRUCIFERAE
SPARGANIUM TYPE
NYMPHAEA
MYRIOPHYLLUM SPIC.
MYRIOPHYLLUM VERT.
BATRACHIUM
DRYOPTERIS
POLYPODIUM
SELAGINELLA SELAG.


CARYOPHYLLACEAE
TUBULIFLORAE
LIGULIFLORAE
RUBIACEAE
UMBELLIFERAE
CRUCIFERAE
RUMEX HYDROLAP.T.
SPARGANIUM
103 %
TYPHA LATIFOLIA
MENYANTHES
NYMPHAEA
NUPHAR
MYRIOPHYLLUM SPIC.
1400 %
MYRIOPHYLLUM VERT
100 %
BATRACHIUM
POTAMOGETON
DRYOPTERIS
POLYPODIUM
EQUISETUM


Sanguisorba offic. 2.
Valeriana sambuc. 1.
Sanguisorba offic. 1.
Sanguisorba minor. 3; Typha latif. 1; Lycopodium 2.
Menyanthes 1.
Typha latif. 1.
Sanguisorba offic. 1.
Sanguisorba minor 1; Typha latif. 1.
Mentha t. 1; Polygonum amphib. t. 1.
Potamogeton 1.
Polemonium coer 1.
Mentha t. 1; Menyanthes 1.
Sanguisorba offic. 1; Succisa 2; Potamogeton 1.
CRUCIFERAE
SPARGANIUM TYPE
NYMPHEA
MYRIOPHYLLUM SPIC.
MYRIOPHYLLUM VERT.
BATRACHIUM
DRYOPTERIS
POLYPODIUM
SELAGINELLA SELAG.
EQUISETUM
SPHAGNUM
PEDIASTRUM


Mentha t. 5 ; Centaurea cyanus 1.
Succisa 1 ; Fagopyrum 1 ; Polygonum lapath t. 1.
Juglans 1 ; Succisa 1 ; Lythrum 1 ; Centaurea cyanus 7 ; Fagopyrum 4.
Spergula 3 ; Centaurea jacea 1 ; Centaurea cyanus 5 ; Fagopyrum 7 ; Papilionac. 3.
Acer 1 ; Polygonum lapath. t. 2 ; Centaurea cyanus 1 ; Fagopyrum 3.
Hedera 2.
Succisa 1.
Tilia platyph.
Hedera 2.
Hedera 1.
Rumex hydrolapath. t. 1.
Hedera 1.
Mentha t. 1 ; Utricularia 1.
Mentha t. 2 ; Succisa 1.
Rumex hydrolapath. t. 1.
Convolvulus sepium 1.
Rumex hydrolapath. t. 1.
Rumex hydrolapath. t. 2.
Rumex hydrolapath. t. 4.
Populus 1 ; Rumex hydrolapath. t. 2
Epilobium 1 ; Empetrum 2.
Sanguisorba offic 1 ; Empetrum 2.
Empetrum 1.
Empetrum 1.
Sanguisorba offic 1.
Sanguisorba offic 1 ; Mentha t. 1.
Sanguisorba offic 1 ; Mentha t. 1 ; Polygonum amphib. t. 1.
Sanguisorba offic 1.
Valeriana sambucifolia 1.
Empetrum 1.
Sanguisorba offic 1.
Sanguisorba minor 1.
Hippophae 1.
1400%
100%
NUPHAR
MYRIOPHYLLUM SPIC
MYRIOPHYLLUM VERT
BATRACHIUM
POTAMOGETON
DRYOPTERIS
POLYPODIUM
EQUISETUM
SPHAGNUM
PEDIASTRUM

Such a solution is preferable to the use of a completely synchronous boundary which would be difficult to define on palynological criteria.

It is worth mentioning that a short stagnation or regression in the AP is always observed between Ia and Ib. This phenomenon is sufficiently distinct to be remarked upon.

Hippophaë and *Juniperus* were the first to play a significant role in the open landscape of the drier parts. It seems likely that the *Hippophaë*-peak occurred somewhat prior to that of *Juniperus*, but the percentages of *Hippophaë* are usually too small to state this with absolute certainty. *Juniperus* may be considered one of the most reliable indicators of woodland and the start of the Bölling s.s. In regional spectra one can encounter percentages of 5-25. In the latter case one refers to a *Juniperus* scrub vegetation. We paid considerable attention to this pioneer role in our first discovery of high values for both these plants in 1969 (Vanhoorne, Verbruggen 1969). A similar study on *Hippophaë* was recently published by Reynaud (1976). Why both these heliophilous plants only managed to retain their favourable position for a very short time remains a problem. We can only explain it by the fact that this expansion was immediately followed by the immigration of *Betula*.

Ic: Older Dryas

Typical of this zone are:

(a) Noticeable differences between the sites with regard to the NAP-expansion. These differences are expressed in the percentage representation as well as in the length of the sequence covered by the NAP-rise.

(b) No increase in plants typical of the coldest zones of the Late Glacial i.e. the Oldest and Younger Dryas, such as *Salix, Selaginella, Batrachium* and *Potamogeton.* However there is an expansion in the herbs such as *Artemisia, Helianthemum* and *Thalictrum.*

(c) Strong variations in the curves of aquatic plants (see in particular, diagram nr. 2).

II Alleröd

II a: Betula-subzone

The NAP-rise, which is equated with the Older Dryas, sometimes represents no more than a short interval of time and in other cases a more lengthy period (see above). Consequently the Alleröd no longer covers a comparable interval when only the NAP percentages are used. To resolve this problem we place the beginning of the Alleröd at the start of the rising *Filipendula* curve.

This phenomenon has been noticed by other investigators in our regions, e.g. Behre (1966) for Ost-Friesland (NW. Germany) and Munaut (1973) for the Belgian Kempenland. (It is my firm belief that in Munaut's diagrams the start of the Alleröd has to be placed in phase C of the Alleröd-subdivision, while the phases A and B represent respectivily the Bölling s.s. and the Older Dryas.)

Both authors accept a restricted thermophilous nature for *Filipendula.* They find support in Van der Hammen (1951) and Iversen (1954). On the other hand Godwin (1975) rejects the thermophilous nature as well as the shade tolerance of the plant on the basis of several Glacial records and Hultén's distribution map (Hultén, 1950). We agree with the first point but have to be sceptical about the rejection of the shade tolerance, when looking to the distinct presence of *Filipendula* together with the forest expansion in the Alleröd and in the beginning of the Preboreal.

II b: Pinus-Betula subzone

Pinus appeared in our area roughly in the middle of the Alleröd. Detailed analysis shows that a large-scale expansion must have taken place in a comparatively short space of time.

The first effect of this was a further increase in the percentage of AP sometimes to as much as 90 %, so that it is possible to speak of almost completely closed *Pinus-Betula* woodlands. In this connection we must not lose sight of the exaggerated role of *Pinus* in the pollen rain.

Attempts have been made to distinguish a certain trend in the behavior of *Pinus*. However, the enormous differences in pollen percentages at different sites prevents one from coming to any general conclusions. *Pinus* will almost certainly have reacted to edaphic conditions. From the positive correlation between *Pinus* and *Empetrum* during the Younger Dryas, one can assume that while *Pinus* was dominant on acidic terrain it only played a minor role on calcareous soils.

The presence of thermophilous plants and *Ephedra*. In diagrams in which large numbers of pollen were counted (1, 2, 3) *Ulmus* and *Quercus* pollen is encountered in small (—2 °/₀₀) but nevertheless fairly constant numbers. This could indicate that these thermophilous trees were present not far from the area under investigation. On the other hand, long-distance transport cannot be entirely ruled out. The presence of *Alnus, Corylus, Quercus, Ulmus* and *Tilia*, recorded in fairly large numbers as from Central and Northern Belgium by Mullenders (1956) and Munaut (1968) cannot be confirmed in any of our numerous Lateglacial diagrams. (However in 1973 Munaut mentions the same small numbers as this author.)

It is my belief that detailed analysis in more southerly areas such as France should yield more clarity with regard to the migration of thermophilous trees.

Close to Lake Garda (Northern Italy) Beug (1964) has been able to demonstrate small, but constant values for *Ulmus, Tilia* and *Quercus* throughout the Alleröd. *Ephedra:* Pollen grains of *Ephedra distachya* as well as of *Ephedra fragilis* have been found with the same frequency as those of *Quercus* and *Ulmus*. If a choice between the two possible explanations, that of a long-distance transport and that of a more northerly range than the present-day Mediterranean, has to be made, we opt for the latter. Our thesis is based on the regularity of the records in West and North-Western Europe and the determination that it is a well-defined period, viz. the Alleröd during which *Ephedra* occurred.

III Younger Dryas

There is general agreement that this zone represented a return to cold conditions. The return sometimes of the great numbers of *Batrachium, Myriophyllym spicatum, M.verticillatum, Sparganium* and *Pediastrum* in the mires is considered by us as evidence for cold conditions. Since the Oldest Dryas these plants had no longer played a dominant role in the aquatic vegetation. On land there was an expansion in most of the herbs, but a decrease in *Filipendula*. The rise in the *Artemisia* curve is normally taken to represent the start of the Younger Dryas. As far as the trees are concerned, there was a gradual decrease in the AP. The replacement of *Pinus* by *Betula* which was to be expected, was so gradual that it would lead one to assume that the conditions were still not unfavourable for *Pinus*. However the woodlands were under continual pressure so that by the end of the Younger Dryas the AP had been reduced to a minimum.

By this stage *Betula* had reassumed dominance. This would tend to suggest that the unfavourable conditions continued right up to the end of the Younger Dryas.

By way of conclusion for the Lateglacial the names of some characteristic taxa are included. These taxa are rarely, if ever, encountered in Holocene diagrams. So far as possible we ranked them in a chronological order.
Armeria martima ; *Plantago sp.* (other than *Plantago lanceolata* and *P.major)* ; *Helianthemum sp.* ; *Thalictrum* ; *Scleranthus, Lycopodium sp., Selaginella selaginoides* : ever since Ia
Sanguisorba officinalis, Sanguisorba minor, Polemonium coeruleum, Valeriana sambucifolia : ever since Ib
Empetrum nigrum : ever since Ia, often very frequent in III.

Palaeoecological conclusions

1. Chronological aspects

The total timespan of the complete vegetational sequence of the Lateglacial covers no more than 2.000 years. Indeed, according to the considerable number of ^{14}C-dates for the initial part of the Late Glacial so far available the greater part does not exceed 12 000 B.P. Taking into account some »older» dates (see Vanhoorne, R. & Verbruggen, C., 1975) and GrN-6062 : 12655 ± 70 B.P. in diagram 5, which is the most extreme case, we cannot place the start of our sequences before 12 300 B.P. The appearance of *Pinus* can be dated to the middle of the Lateglacial, i.e. ± 11 300 B.P. This date finds confirmation in the statement of Munaut (1973) that the Alleröd *Pinus*-phase is equivalent to one generation of trees only. From the stratigraphical viewpoint it ought to be stressed that the *Pinus*-rise also occurs in the middle of the Lateglacial sequences.

The main conclusions concerning the vegetational evolution that follow from this chronology are:

(a) That only 1000 years were required for the vegetation to evolve from an arctic situation to a boreal wood.

(b) As the start of the Postglacial climatic improvement is generally placed several hundred years earlier : ± 13 000 B.P., there must have been an important retardation in the botanical evolution compared to the climatic one.

2. Morphological aspects

We have evidence that ever since the Oldest Dryas and before 12 300 B.P. landdune complexes came into existence especially along the rivers. Aeolian activity was almost continuous in the first part of the Lateglacial. This fact and the knowledge that there are no signs of climatic change in the vegetation lead us to the conclusion that the plant cover was highly dependent upon the amount of blowing sand. The NAP-rise in the Oldest Dryas and the differences in the NAP-expansion during the Older Dryas have to be explained in this way.

3. Climatological aspects

It is fair to say that only the Younger Dryas represented a period of climatic regression. In this respect the terms Oldest- and Older Dryas are incorrect and misleading. Nevertheless, the NAP-expansion, typical of the Older Dryas is too widespread in our regions to be accounted for simply by aeolian action (see above). It would appear that a more refined climatic factor such as changes in summer-winter temperature- or precipation ratio, has to be taken into consideration.

Finally we agree to some extent with Coope (1970), that the climate during the Lateglacial reached its optimal conditions rather early, i.e. prior to the Alleröd. Indeed there may have been a time-lag in the order of two or three centuries between the rapid climatic change and the consequent vegetational evolution.

4. Palaeohydrological aspects

The greater part of the investigated sequences were formed in shallow depressions, left by Weichselian morphological processes.

Since organic glacial sediments are completely absent in these depressions, we conclude that there was a clear rise in the ground water level since the Oldest Dryas. As the mires reached their greatest extension in the Alleröd and as the sediments remain telmatic to limnic in character until then, it is evident that the groundwater continued to rise. Further evidence comes from the presence of superposed Bölling and Alleröd layers separated by more than 1 m of aeolian sands. The fact that many of these layers are now up to 2 m above the ground water level would suggest that during the whole Postglacial the watertable was at its highest in the Alleröd.

An initial lowering of the watertable is encountered at the beginning of the Younger Dryas when sediment changes occurred and some of the mires even dried out.

The second lowering which led to the natural Holocene situation took place in the beginning of the Preboreal, when all sedimentation in the mires stopped. The deep abandoned riverbed of diagram 5 forms an exception, but here a distinct sediment change is visible.

It has to be stressed that our visit to Lapland constituted a great help to explain this palaeohydrological evolution.

Indeed we are convinced now that only climatological factors played a role. In this respect we believe that:

1. The rise of the ground water level in the beginning of the Lateglacial is due to an increase in precipitation.

2. The first lowering at the start of the Younger Dryas is due to a decrease in precipitation.

3. The second lowering of the Preboreal is due to an increase of the evapotranspiration, when the temperature quickly increased and the forest cover developed.

The general conclusion is that the Lateglacial period in this region was:

1. A period of marked change that must be looked upon as the initial stage of the Holocene rather than as the final phase of the Fullglacial.

2. Together with the Preboreal the period which can give us the most refined details on a Glacial/Interglacial transition.

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Discussion

P. Cleveringa:

In our infillings of pingoremnants we find on the transition from Alleröd to Younger Dryas a changing of the gyttja into a peat layer. Could this changing also indicate a lowering of the grondwater-table?

C. Verbruggen:

Our answer is affirmative. The text has been completed on this point.

E. Lappalainen:

1. I would like to know, what are the most typical plants in the vegetation of the Younger Dryas and Alleröd periods?
2. What is the age of the oldest peat layers met in your country?

C. V.:

1. So far we can give no more information than included in this text as only palynological investigation has been done. However it should be one of the aims of an IGCP 158-B-working group to analyse macrorests.
2. The ^{14}C date GrN 6062 : 12655 ± 70 B.P. is the oldest one known. For more comment we refer to the text.

J. Stockmarr:

Concerning the sediment which was dated to 12 655 ± 70 B.P. I would like to know what is the type of organic sediment?

C. V.:

It concerns a thin organic layer at the base of the infilling of an abandoned riverbed. We suppose that the layer was formed by drifting material that sank to the bottom when the water stagnated.