VI. Multidisciplinary analysis of Gietsenveentje sequences

VI.1 Topography and lithology

VI.1.1 Topography

The Gietsenveentje is a bog with a diameter of 200 x 160 m with some areas of open water resulting from former peat-digging. It is assumed to be a pingo scar, a remnant from a pingo formed in the late Pleniglacial. The need was felt for a detailed topographical map of this pingo scar, which would serve for the exact location of the coring points. The larger part of the Gietsenveentje was mapped during two days in March 1993. The southern part could not be mapped because of very wet weather. On April 20th, 1995, a map of this part of the Gietsenveentje was made. The result is the topographical map of fig. 38. Paths, ditches, peat pits, core locations and other relevant points are indicated.
Before the peat-digging started, it was necessary to drain the wet and inaccessible peat bog. This was done by means of a ditch, which runs north-south and bisects the Gietsenveentje (fig. 38). In the first half of the twentieth century, there even was a small drainage mill, probably a *tjasker* (KLAASSENS-PERDOK 1983, 44; STOKHUYZEN 1981), which was located where the ditch emptied into another ditch, just south of the Gietsenveentje. After drainage, the upper peat layers were dug out in some parts of the Gietsenveentje. The marshy areas and open water are the result of this peat-digging. Some peat pits seem to be only thirty to fourty years old. To reach the peat pits more towards the centre, some tracks were constructed from sand and stone debris, leading from the former Gieten-Eext road into the pingo scar. The southern part is the wettest area of the Gietsenveentje. It is only accessible via a few narrow baulks. An area of about 70 x 30 m immediately east of the ditch, in the centre of the pingo scar, is completely undisturbed, which indicates that the exploitation rights were not in one hand (see III.8.2).

VI.1.2 Contours of the surface and the Pleistocene subsoil

The position of the coring points in the Gietsenveentje, cored in the framework of this study, was defined by a grid which was laid over the topographical map. The initial coring points are located at the intersections of the grid lines, at intervals of 20 metres. For practical reasons, it sometimes was not possible to obtain a core at the exact coring point of the grid; in these cases, coring points were used which fell between the initial coring points. These coring points are marked "A" following the number. The original grid provided 88 initial coring points. The coring of 26 of these points was realized during three days in April 1993, supplemented with 5 points falling between the grid points (the "A" numbers), making 31 coring points in total (fig. 38).
The elevation of the surface was measured at each coring point. The measurements were combined with data from the existing contour map (scale 1:10,000) into a contour map of the present surface of the Gietsenveentje. This map is shown in fig. 39. With the same data, also a three-dimensional map of the surface of the Gietsenveentje was made. This map is shown in fig. 41. The present surface of the Gietsenveentje lies 1.5 to 2 metres lower than most of the surroundings, except for the south, where the difference in height is less. Within the Gietsenveentje itself, the differences in elevation of the surface are only slight.
The elevation of the Pleistocene subsoil (i.e. the "bottom" of each sequence) was measured during the coring at each coring point. The measurements were combined with data from the existing contour map (scale 1:10,000) into a contour map of the Pleistocene subsoil of the Gietsenveentje. This map is shown in fig. 40. With the same data, also a three-dimensional map of the surface of the Gietsenveentje was made. This map is shown in fig. 42. The deepest point of the pingo scar is located near core locations 49 and 60, lying more than 5 metres below the present surface. All sides except for the southern slope are quite steep. The outline of the pingo scar is more or less elliptic.

VI.1.3 Lithology transects

During the coring of the sequences at each core location, descriptions and measurements of the lithology were made. With the help of these data, four lithology transects through the Gietsenveentje were drawn. Three of these transects run north-south (transects A-C); one runs northeast-

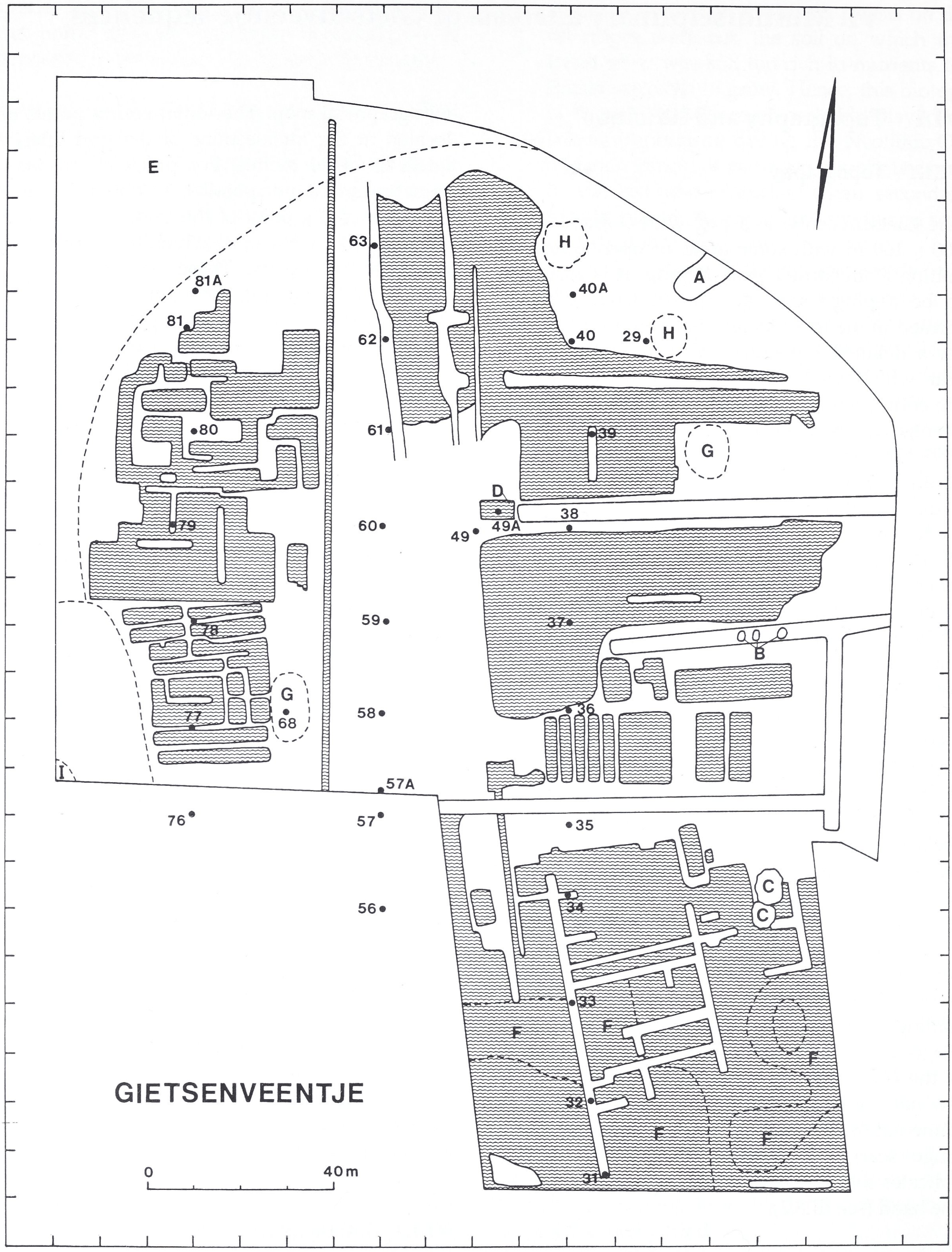


Fig. 38. Topographical map of the Gietsenveentje. All core locations are indicated. Areas with a wavy pattern: marshy area or open water; A: heap of sand; B: heaps of rubble; C: heaps of loam; D: backfilled trench; E: planted woodland; F: sedge marsh; G: field of bilberry (*Vaccinium myrtillus*); H: large elder (*Sambucus nigra*); I: large oak (*Quercus robur*).

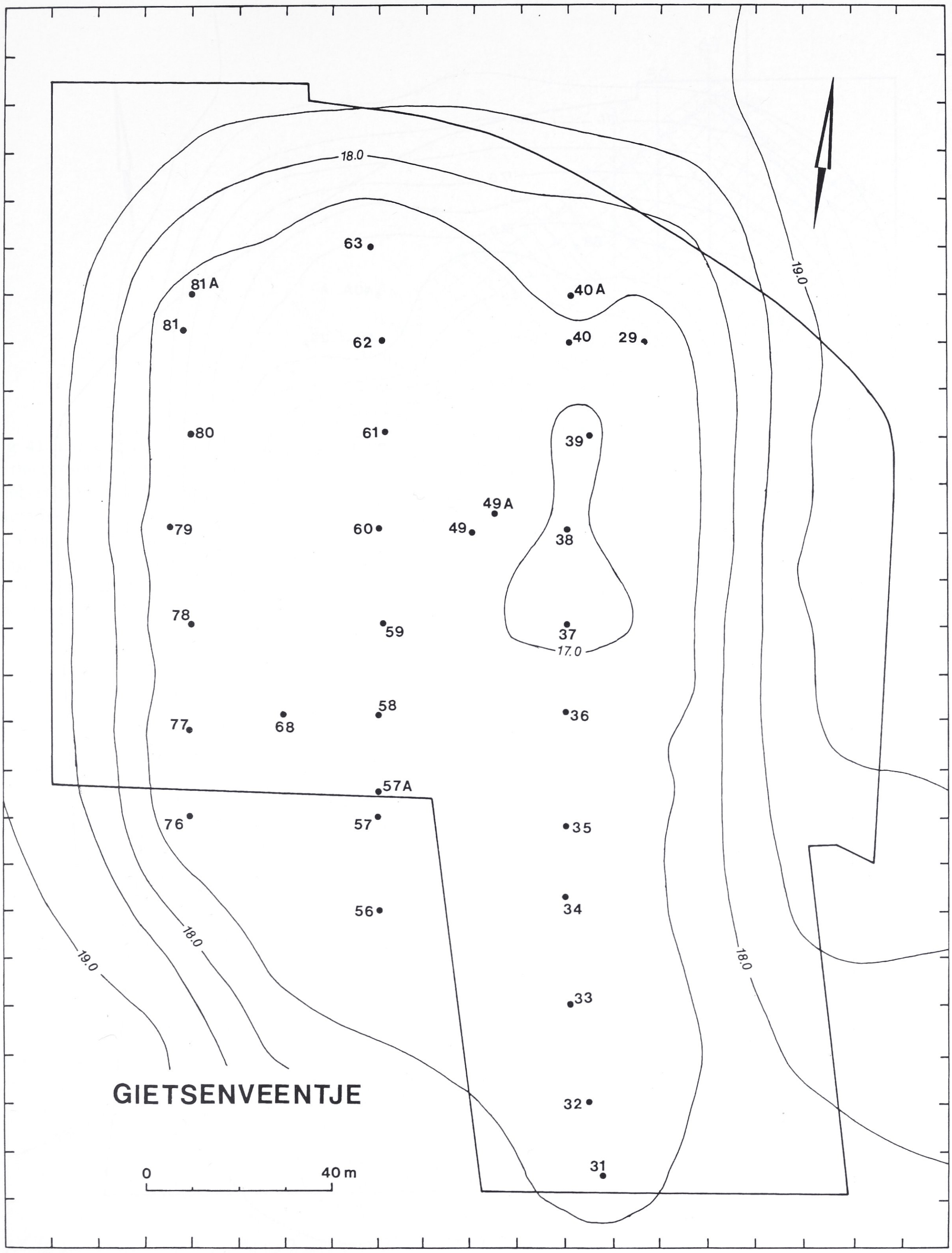


Fig. 39. Contour map of the present-day surface in the Gietsenveentje and its immediate surroundings. All core locations are indicated. Altitudes are given in metres above N.A.P.

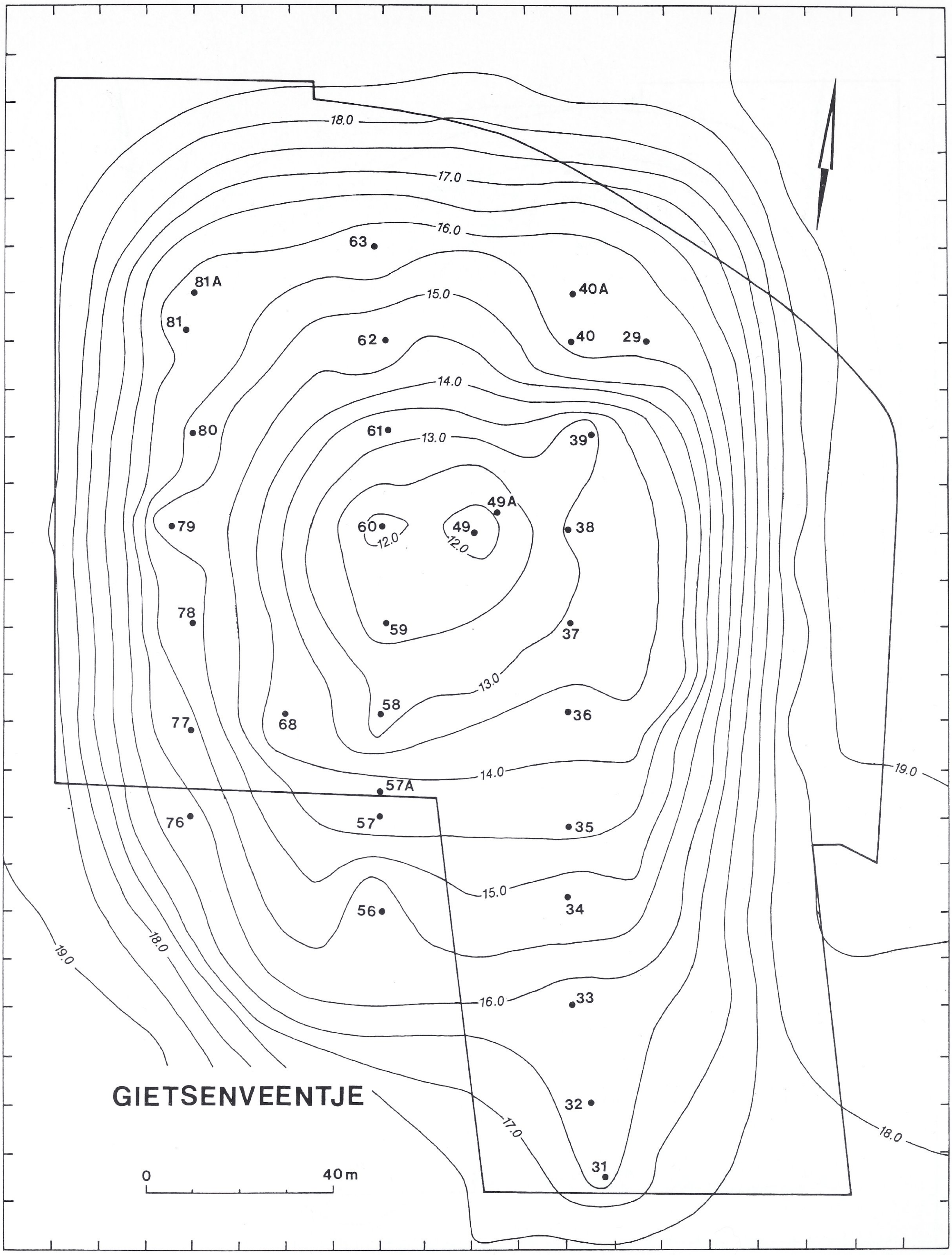


Fig. 40. Contour map of the Pleistocene subsoil in the Gietsenveentje and its immediate surroundings. All core locations are indicated. Altitudes are given in metres above N.A.P.

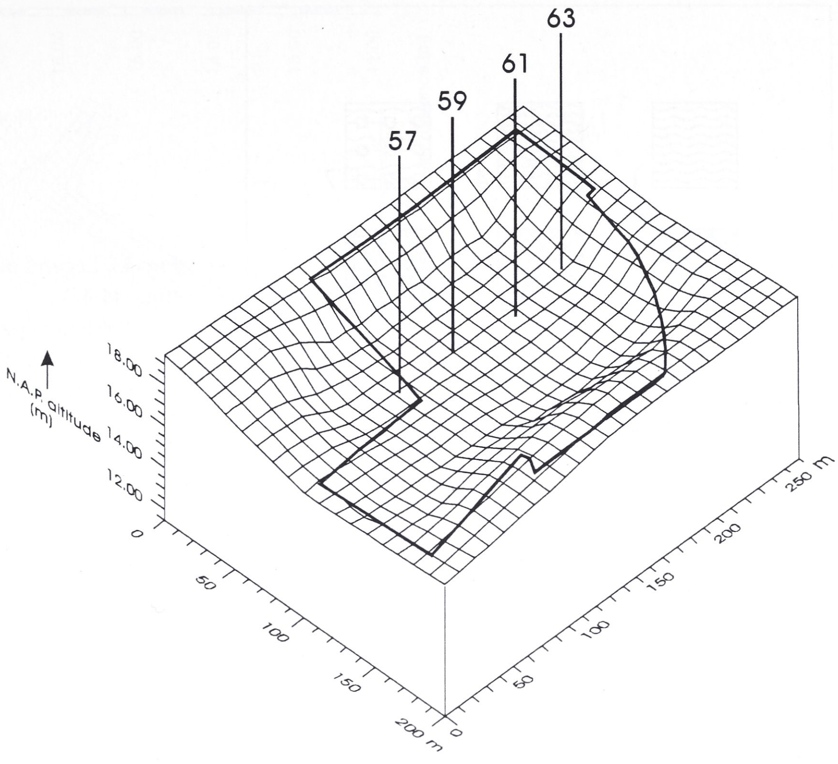


Fig. 41. Three-dimensional map of the present-day surface of the Gietsenveentje and its immediate surroundings. Four core locations of which pollen diagrams are available (sequences Gieten V-A to V-D) are indicated.

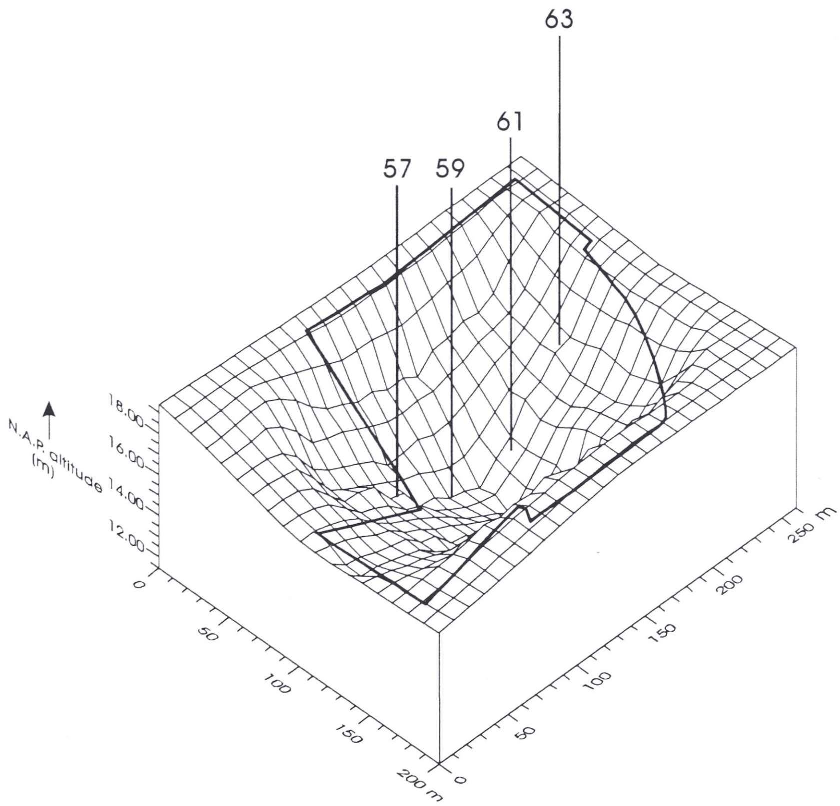


Fig. 42. Three-dimensional map of the Pleistocene subsoil in the Gietsenveentje and its immediate surroundings. Four core locations of which pollen diagrams are available (sequences Gieten V-A to V-D) are indicated.

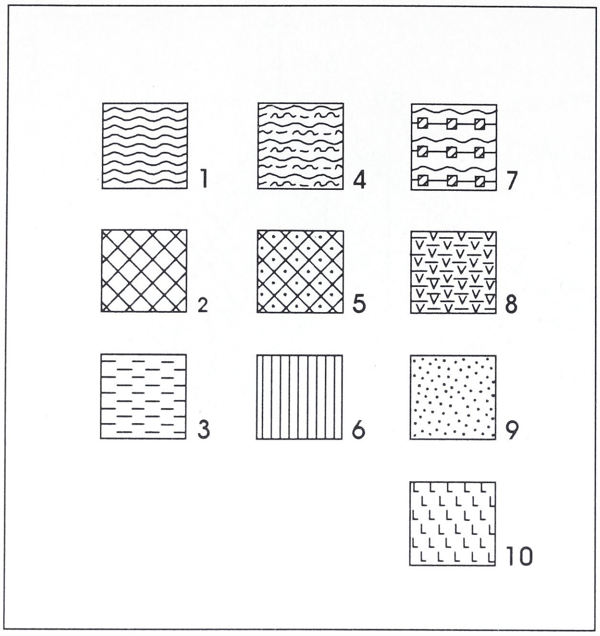


Fig. 43. Legend of the lithology transects (figs. 44-47).
1. *Sphagnum* peat
2. detritus gyttja
3. homogeneous humic substance
4. as 1, with *Eriophorum*
5. fine detritus gyttja with loam/sand
6. *Carex* peat
7. *Scheuchzeria* peat
8. as 3, with wood
9. sand (Pleistocene subsoil)
10. till (Pleistocene subsoil)

southwest (transect D). The lithology transects are shown in figs. 44-47. The legend for the lithology transects is fig. 43.

Transect A (fig. 44) cuts across the eastern part of the Gietsenveentje. Clearly, the southern edge is far less steep than the northern edge. At the northernmost core location, no. 40A, the largest part of the sequence (consisting of a homogeneous humic substance) was disturbed. At the core locations 35-40, a layer of orange-brown peat occurred between the gyttja and the *Sphagnum* peat with very coarse, fibrous plant remains, most probably of *Eriophorum*.

Transect B (fig. 45) runs through the central part of the Gietsenveentje. In the centre, more than 5 metres of sediment was deposited. At the northern edge (core locations 61-63), the gyttja layer is somewhat thinner than at the southern edge (core locations 56-58). In the northern part, the Neolithic Occupation Period as observed in the corresponding pollen diagram, occurs in peat, while in the southern part, it occurs in gyttja. In the centre (core locations 59-61), the Pleistocene subsoil consists of till.

Transect C (fig. 46) cuts across the western part of the Gietsenveentje. Up to 2.25 m of sediment was deposited here. Compared to the peat layer, the gyttja layer is very thin in this part of the pingo scar. The orange-brown layer with coarse, fibrous plant remains (*Eriophorum*) is relatively thick at some core locations along this transect.

Transect D (fig. 47) runs through the central part of the Gietsenveentje from the northeast to the southwest. The northeastern slope is much steeper than the southwestern. At core locations 49 and 49A, irregularities occurred during the deposition of the sediment: at core location 49, a thick layer of *Carex* and *Eriophorum* peat lies between two layers of *Sphagnum* peat, while at core location 49A, layers of *Carex* and *Eriophorum* peat occur within the gyttja sediment. The pollen diagrams of core location 49A (Gieten IV-P and Gieten IV-HR, see VI.3.2) indicate that a layer of sediment representing parts of the Boreal and the Atlantic is represented twice at this location. This probably is what caused the beginning of the Neolithic Occupation Period at core location 49A to occur at a relatively high level, in peat sediment. At the centre (core locations 49, 49A and 59), the Pleistocene subsoil consists of till.

According to De Gans (1981, 93), pingo scars in the Drentse Aa valley are characterized by a diameter of 150-200 m, a fill of organic material over 2 m thick and a relatively indistinct rampart. The Gietsenveentje, located in the uppermost part of the erosion valley of the Scheebroekerloop (see fig. 19), entirely conforms to De Gans' description. The lithology transects of figs. 44-47 are quite comparable to the transects across pingo scars in the Drentse Aa valley (De Gans, 1981, fig. 42; fig. 44). The collected data confirm the picture of the Gietsenveentje being a pingo

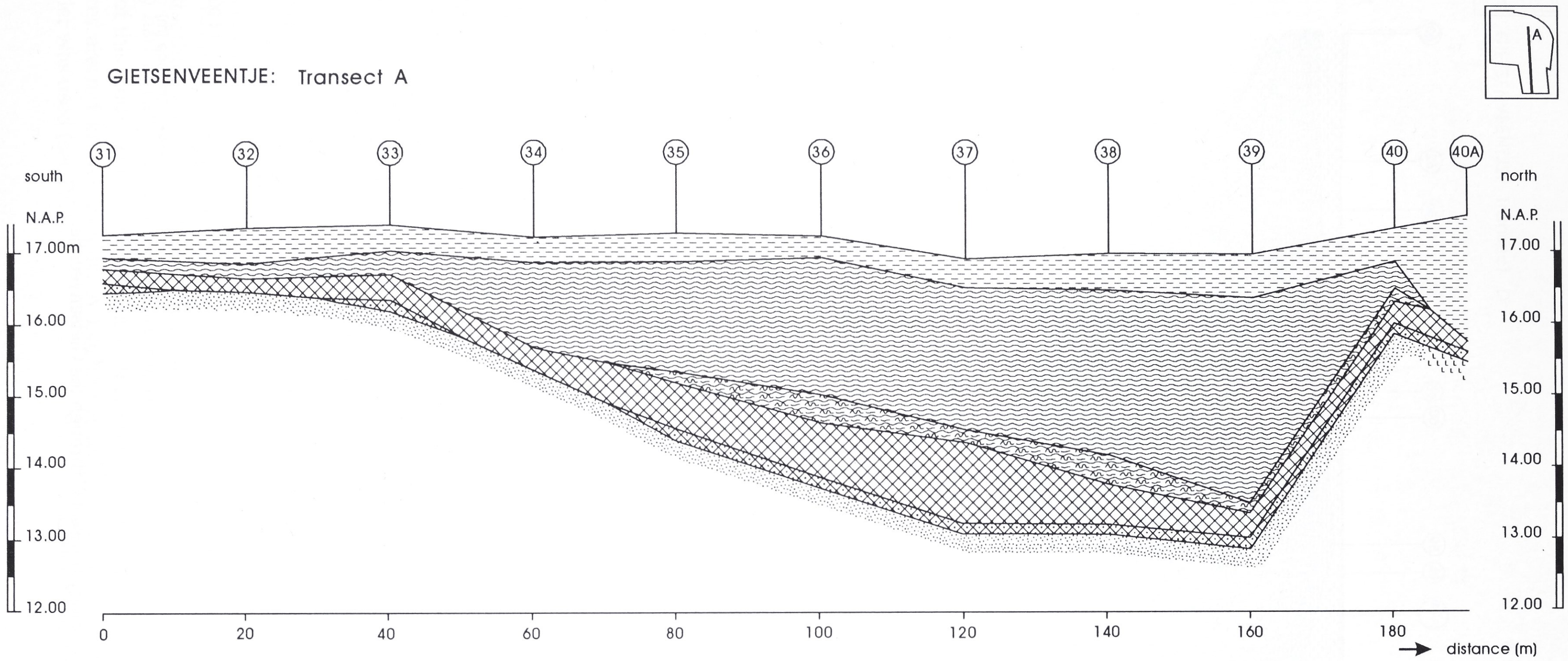


Fig. 44. Lithology transect A through the Gietsenveentje. In this figure and in figs. 45-47, the positions and numbers of the core locations are indicated above the transect. Where a pollen diagram is available of a core location, the depth of the beginning of the Neolithic Occupation Period is also marked. At the upper right, the position of the transect across the Gietsenveentje is indicated.

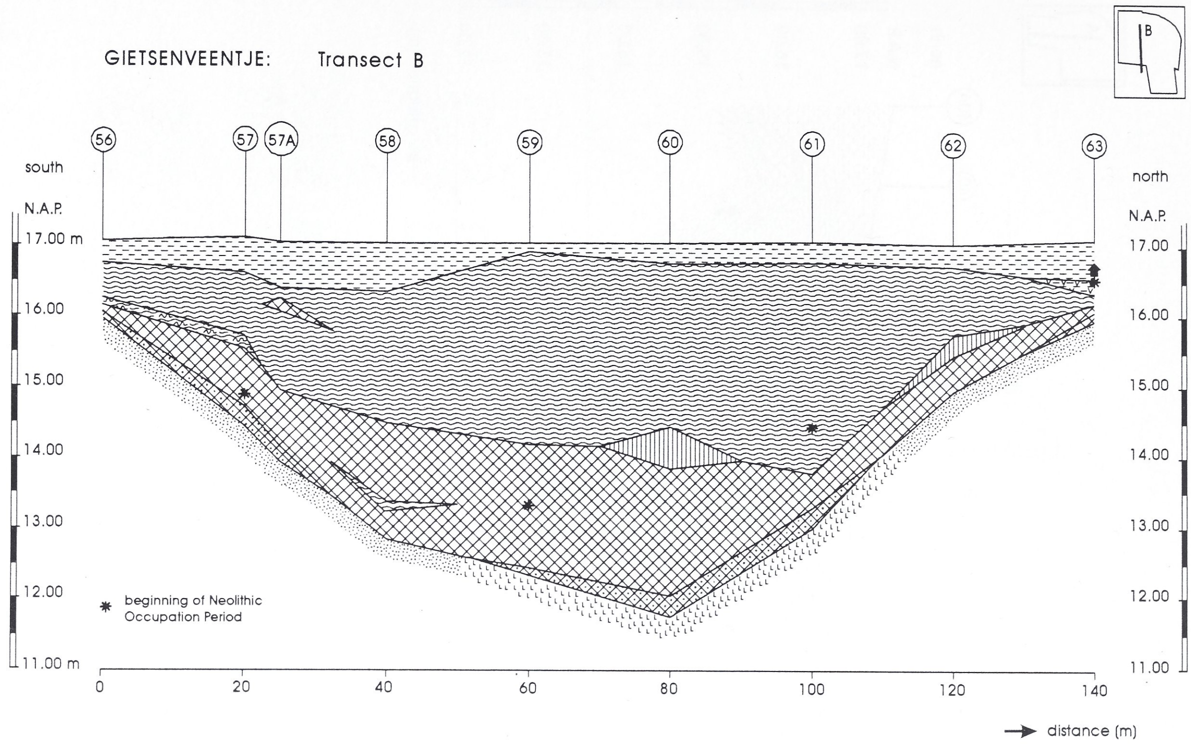


Fig. 45. Lithology transect B through the Gietsenveentje.

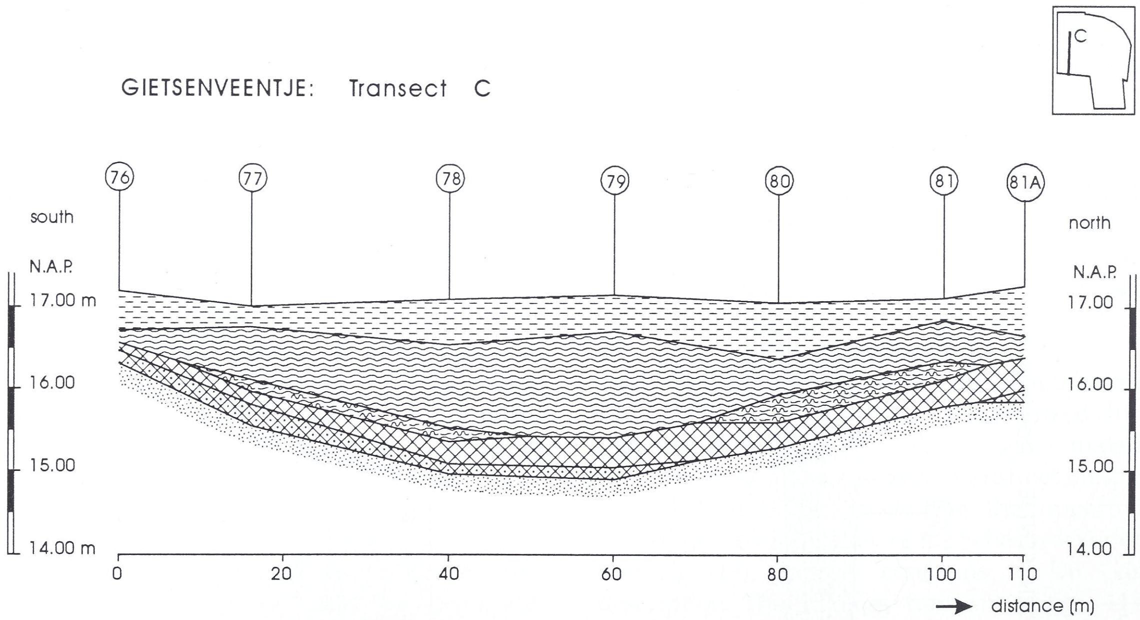


Fig. 46. Lithology transect C through the Gietsenveentje.

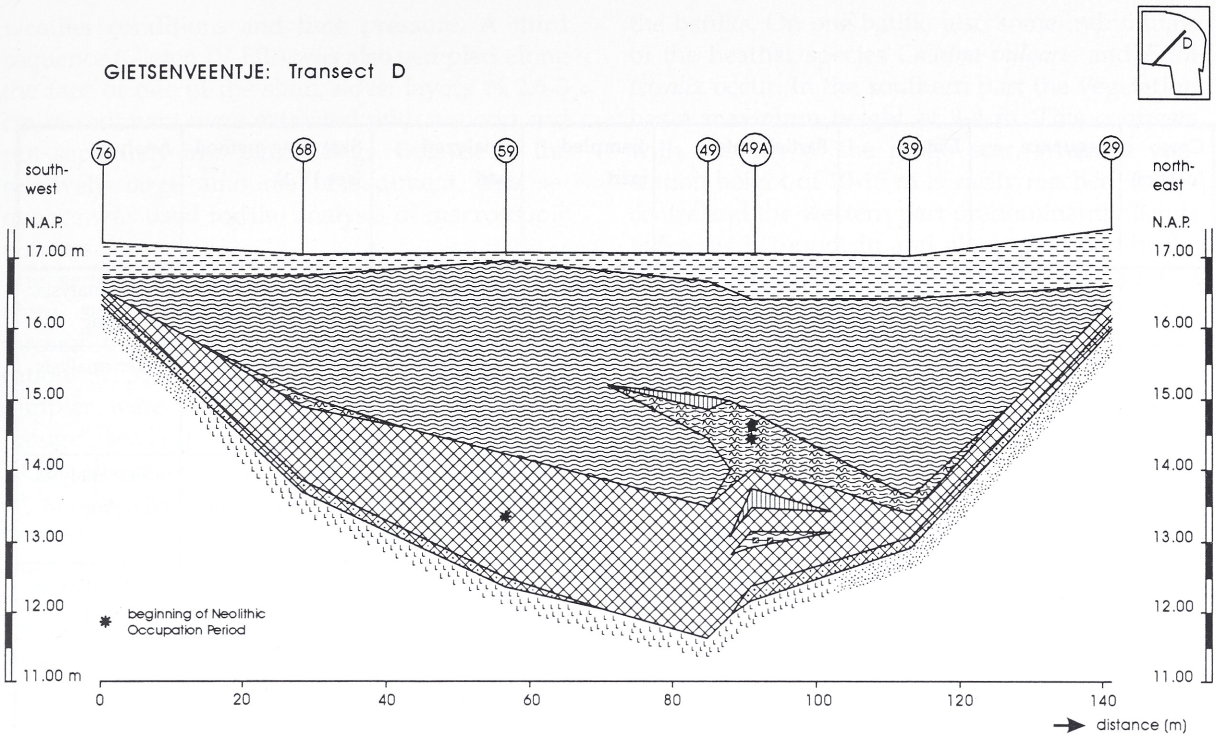


Fig. 47. Lithology transect D through the Gietsenveentje.

scar. De Gans (1981, 89) considers the pingo scars in the Drentse Aa valley to be closed-system pingos, because of the presence of till on the water divides, which rules out source areas that might supply groundwater necessary for open-system pingo growth (see III.2.2). Till is also present in the Pleistocene subsoil of the Gietsenveentje: in the deepest part of the pingo scar, till forms the upper layer of the Pleistocene subsoil (core locations 49, 49A, 59, 60 and 61: figs. 45 and 47). For this reason, the Gietsenveentje is also considered to be a closed-system pingo.

VI.1.4 Field data of the sequences

Apart from the 31 sequences which were cored for the lithology transects, 11 sequences were cored or sampled in the Gietsenveentje for various types of analysis. Field data of these 11 sequences are shown in table 6.
The first three Gietsenveentje sequences (Gieten I, II, III) had already been cored before the beginning of this study. The core locations of these sequences are not known exactly. A Dachnowsky sampler was used (see IV.1).

An open section seemed necessary to examine the stratigraphy of the bog and to sample relatively large volumes of sediment for various types of analysis. On October 5th, 1992, such an open section was created by the digging of a trench in the centre of the Gietsenveentje (at core location 49A, see fig. 38). First, two sheet-pile walls with a length of 5 m were driven parallel to each other into the bog down to the Pleistocene subsoil. Subsequently, the sediment between the two sheet-pile walls, which were placed 2 m apart, was dug away. Because of the soft peat sediment, it was necessary to support the two sheet-pile walls by placing beams between them. A disadvantage of the sheet-pile walls was that they obscured the stratigraphy; it could only be observed on the short sides of the trench. In the gyttja sediment, some layers could be clearly observed, but the peat sediment looked completely uniform. In the trench, two sequences were sampled with the help of rectangular sample tins: one sequence behind a plank pulled out of one of the sheet-pile walls (Gieten IV-P); one sequence along the face of one of the short sides (Gieten IV-HR). The upper ± 260 cm of both sequences could not be sampled because of bad

Core location	Sequence	Date	Participants	Sampled part	Analyzed part	Sampling method (see IV.1)	Analysis
?	Gieten I	11-4-1974	S. Bottema, H. Woldring	0-440 cm	220-430 cm	Dachnowsky sampler ø 3.6 cm	pollen analysis, ^{14}C dating
?	Gieten II	Jan. 1979	H. Woldring, E. Mook-Kamps, A.L.Brindley	0-490 cm	345-370 cm	Dachnowsky sampler ø 3.6 cm	pollen analysis
?	Gieten III	3-12-1985	S. Bottema, H. Woldring, A. van Klinken	300-380 cm	322-363.5 cm	Dachnowsky sampler ø 3.6 cm	pollen analysis, ^{14}C dating
49A	Gieten IV-P	6-10-1992	H. Woldring, R. Bakker	260-460 cm	262-455 cm	sample tins from open section	pollen analysis, ^{14}C dating
49A	Gieten IV-HR	5-10-1992	H. Woldring, R. Bakker	266-460 cm	266-429 cm	sample tins from open section	pollen analysis, ^{14}C dating
49A	Gieten IV-HL	6-10-1992	H. Woldring, R. Bakker	380-480 cm	380-460 cm	plastic bags from open section	analysis of macroscopic remains
59	Gieten V-A	1-6-1993	S. Bottema, H. Woldring, R. Bakker	0-510 cm	5-470 cm	Russian sampler (0-400 cm), gouge (400-510 cm)	pollen analysis, phosphorus analysis, ^{14}C dating
61	Gieten V-B	21-3-1994	H. Woldring, E. Mook-Kamps, R. Bakker	0-410 cm	175-375 cm	Russian sampler (0-380 cm), gouge (380-410 cm)	pollen analysis, phosphorus analysis, wood analysis, ^{14}C dating
63	Gieten V-C	30-11-1994	S. Bottema, H. Woldring, R. Bakker	0-132 cm	58-115 cm	Russian sampler (0-90 cm), gouge (90-132 cm)	pollen analysis, phosphorus analysis, wood analysis, ^{14}C dating
63	Gieten V-C	30-11-1994	S. Bottema, H. Woldring, R. Bakker	0-160 cm	40-115 cm	Dachnowsky sampler ø 6 cm	analysis of macroscopic remains
57	Gieten V-D	30-11-1994	S. Bottema, H. Woldring, R. Bakker	0-255 cm	135-245 cm	Russian sampler (0-230 cm), gouge ø 3.5 cm (230-255 cm)	pollen analysis, ^{14}C dating

Table 6. Field data of Gietsenveentje sequences, used for various types of analysis.

weather conditions and time pressure. A third sequence (Gieten IV-HL) was also sampled along the face of one of the short sides: layers of 2.5-3 cm of sediment were extracted with a scoop and put separately into plastic bags. Because of the relatively large amounts of sediment, this sequence was used for the analysis of macroscopic remains.

The sequences Gieten V-A, V-B, V-C and V-D were sampled along a north-south transect through the centre of the Gietsenveentje (core locations 57, 59, 61 and 63, see fig. 38). Two types of sampler were used: a Russian sampler and a "gouge" (see IV.1).

At the site of sequence Gieten V-C, core location 63, another sequence was sampled with a Dachnowsky sampler with a diameter of 6 cm. Because of its large diameter, this sequence was used for the analysis of macroscopic remains.

The eleven sequences were used for the following types of analysis: pollen analysis (see VI.3 and VI.6), radiocarbon dating (see VI.4), pollen concentration and pollen influx analysis (see VI.5), analysis of macroscopic remains and wood (see VI.6), and phosphorus analysis (see VI.7).

VI.2 Present vegetation and pollen precipitation

VI.2.1 Introduction

For a reconstruction of the past vegetation around the Gietsenveentje, it will be necessary to interpret the subfossil pollen precipitation in terms of vegetation. This relationship will be better understood with the help of a comparison between the pollen content of surface samples, collected within the pingo scar, and the recent vegetation of the Gietsenveentje. On August 23rd, 1994, a vegetation survey of the Gietsenveentje was carried out, resulting in a vegetation map (fig. 48). On November 30th, 1994, three surface samples were collected at core locations 59, 61 and 63. These three core locations are indicated on the vegetation map.

VI.2.2 Present vegetation

The present vegetation of the Gietsenveentje will be discussed on the basis of the vegetation map (fig. 48). The wettest part of the pingo scar, situated in the south, is dominated by *Salix* sp. and *Carex* sp., with predominantly *Betula pubescens* on the baulks. On one baulk, also some individuals of the heather species *Calluna vulgaris* and *Erica tetralix* occur. In the southern part the vegetation has a maximum height of 3-4 m. This contrasts with the rest of the pingo scar, where a vegetation height of 10-15 m is easily reached. In the centre and the western part predominantly *Betula pubescens* is found. In and along peat pits in the northern and eastern parts mostly *Alnus glutinosa* and *Salix* sp. occur. In a narrow belt along the edge of the pingo scar (apart from the south) predominantly *Quercus robur* is found. *Corylus avellana* is observed only in a few places in the undergrowth of oak and alder trees at the eastern and northern edge of the pingo scar. In the westernmost part of the pingo scar (west of the north-south ditch) almost no alder is observed. Conspicuous elements in the vegetation of the Gietsenveentje are two patches of *Vaccinium myrtillus* in the eastern and southwestern parts of the pingo scar, and two old individuals of *Sambucus nigra* in the northeastern part, each covering a surface of about 25 m^2.

In recent centuries people have drained the pingo scar and have dug many pits. As a result, woodland of mainly alder, willow, birch and oak now grows in the Gietsenveentje. A lowering of the water table after the Second World War further assisted the formation of this woodland. The vegetation of the direct surroundings (ca. 1 km wide) can be described as follows: to the north and west, arable land is found; to the south, meadows with scattered copses; to the east, a planted forest with mainly pines and firs. The old road from Eext to Gieten, lined with large oaks, runs north and east of the Gietsenveentje.

VI.2.3 Modern pollen precipitation

The pollen content of the three surface samples is shown in fig. 49. This diagram is constructed in the same way as the subfossil pollen diagrams (see VI.3.1). Because the samples are not related chronologically, the pollen content of the samples is shown in separate bars.

In the sample collected at core location 59, *Betula* pollen dominates; *Quercus* pollen is quite common. In the sample collected at core location 61, *Quercus* pollen dominates. In the sample collected at core location 63, *Alnus* pollen dominates. The vegetation map (fig. 48) shows that the dominant pollen types indeed correlate with the dominant trees in the direct surroundings of the sample locations. The combined percentage of

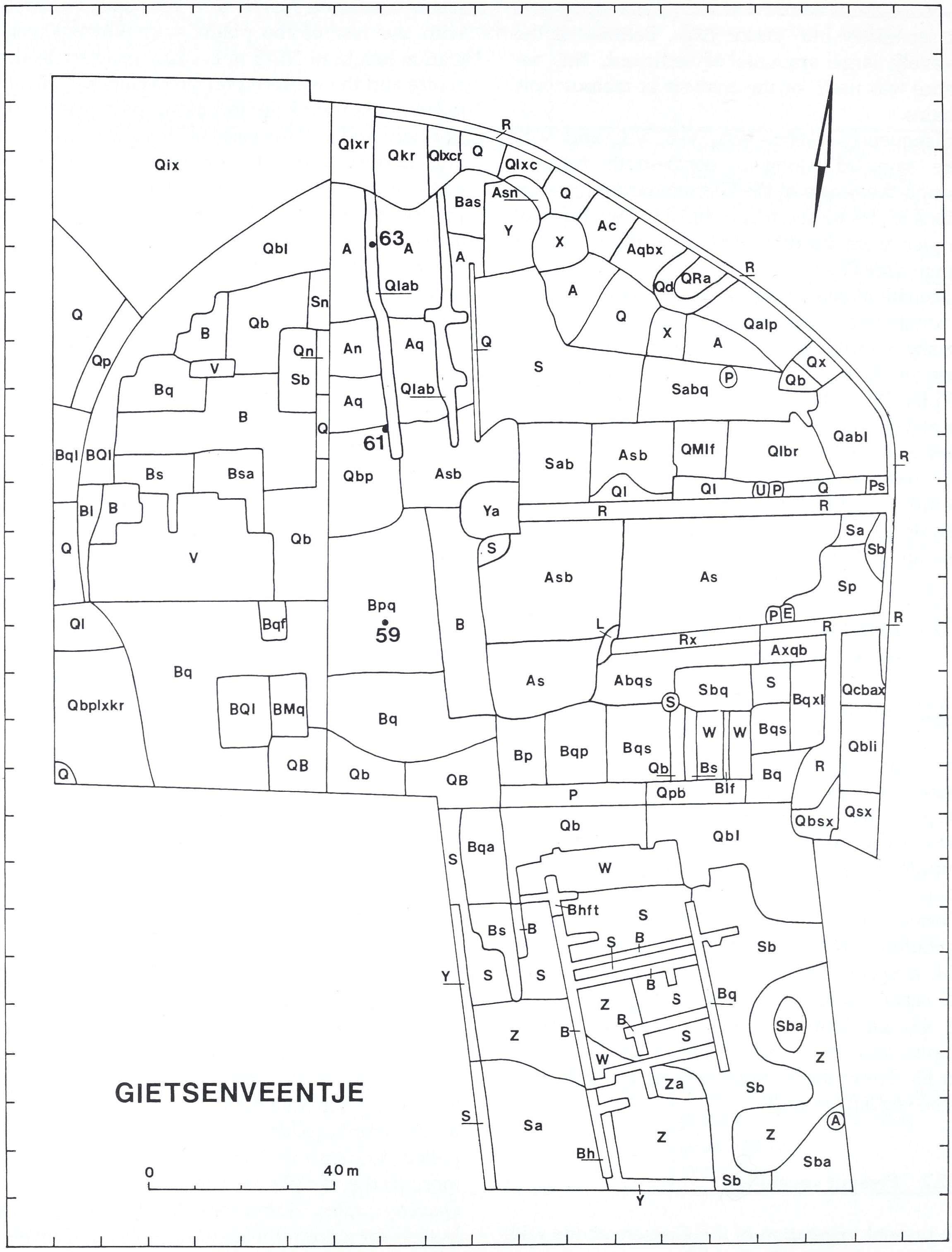

GIETSENVEENTJE
0
40 m
59
61
63

Fig. 48 (left). Vegetation map of the Gietsenveentje. The Gietsenveentje is divided into a large number of vegetation units. In each unit the dominant species or vegetation type is indicated with a capital. The remaining species are indicated in lower case. Small units with only one capital point to conspicuous individual trees. The letters refer to the following species or vegetation types:

A, a	*Alnus glutinosa*	P, p	*Populus nigra/tremula*
B, b	*Betula pubescens*	Q, q	*Quercus robur*
C, c	*Corylus avellana*	R, r	Ruderal vegetation
D, d	*Polygonum cuspidatum*	S, s	*Salix* sp.
E, e	*Fraxinus excelsior*	T, t	*Potentilla palustris*
F, f	*Frangula alnus*	U, u	*Ulmus* sp.
H, h	*Calluna vulgaris, Erica tetralix*	V, v	Peat vegetation
I, i	*Prunus padus/avium*	W, w	Open water
K, k	*Hedera helix*	X, x	*Sambucus nigra*
L, l	*Sorbus aucuparia*	Y, y	Reed (*Phragmites australis*), reedmace (*Typha latifolia*) and allied vegetation
M, m	*Vaccinium myrtillus*		
N, n	*Solanum dulcamare*	Z, z	Sedge vegetation (*Carex* sp.)

the three dominant trees - *Betula, Alnus* and *Quercus* - measures around 85% in each of the three samples. *Corylus* pollen is observed in low quantities in the samples collected at core locations 61 and 63. Although individuals of *Populus* sp., *Salix* sp., *Solanum dulcamare* and *Sorbus aucuparia* occur within 20 m of one of the three sample locations, their pollen is observed very sparsely or not at all in the surface samples. Obviously, pollen of these taxa is underrepresented. AP pollen types originating from taxa not growing in the Gietsenveentje - *Tilia, Fagus, Pinus, Picea, Abies, Acer* and *Forsythia* - together measure less than 5% in each of the three samples. *Pinus* is by far the most frequently occurring "regional" type. Most of the "regional" taxa occur within a distance of 500 m from the Gietsenveentje.

The Gramineae are the most frequent Non-Arboreal Pollen. The values of the Gramineae increase from the sample collected at core location 59 (centre of the pingo scar) to the sample collected at core location 63 (northern edge of the pingo scar). This can be explained by the presence of grassland between the northern edge of the pingo scar and the old road from Eext to Gieten, and also in an area beyond this road. In these grasslands, also typical culture indicators like *Plantago lanceolata, Rumex acetosa, Rumex acetosella,* Compositae Liguliflorae and *Ranunculus acris/repens* are observed (see V.3). Pollen of these taxa is also found in some of the three samples. The pollen of *Rumex acetosa* is separated from that of *Rumex acetosella,* pollen of *Rumex acetosa* being the most frequent. The pollen picture of Cerealia-type resembles that of the Gramineae: they increase from the sample collected at core location 59 to the sample collected at core location 63. Possibly this pollen originates from the arable land about 200 m north of core location 63. Although practically no Ericaceae are found in the Gietsenveentje and wide surroundings, pollen of *Calluna*-type occurs in each sample. This pollen could be subfossil, and it could originate from the soil which inevitably sticks to the moss polsters, used for the surface samples. In the sample collected at core location 63, some pollen grains of *Solanum nigrum*-type are found. They possibly originate from potatoes (*Solanum tuberosum*), which are cultivated in the neighbourhood.

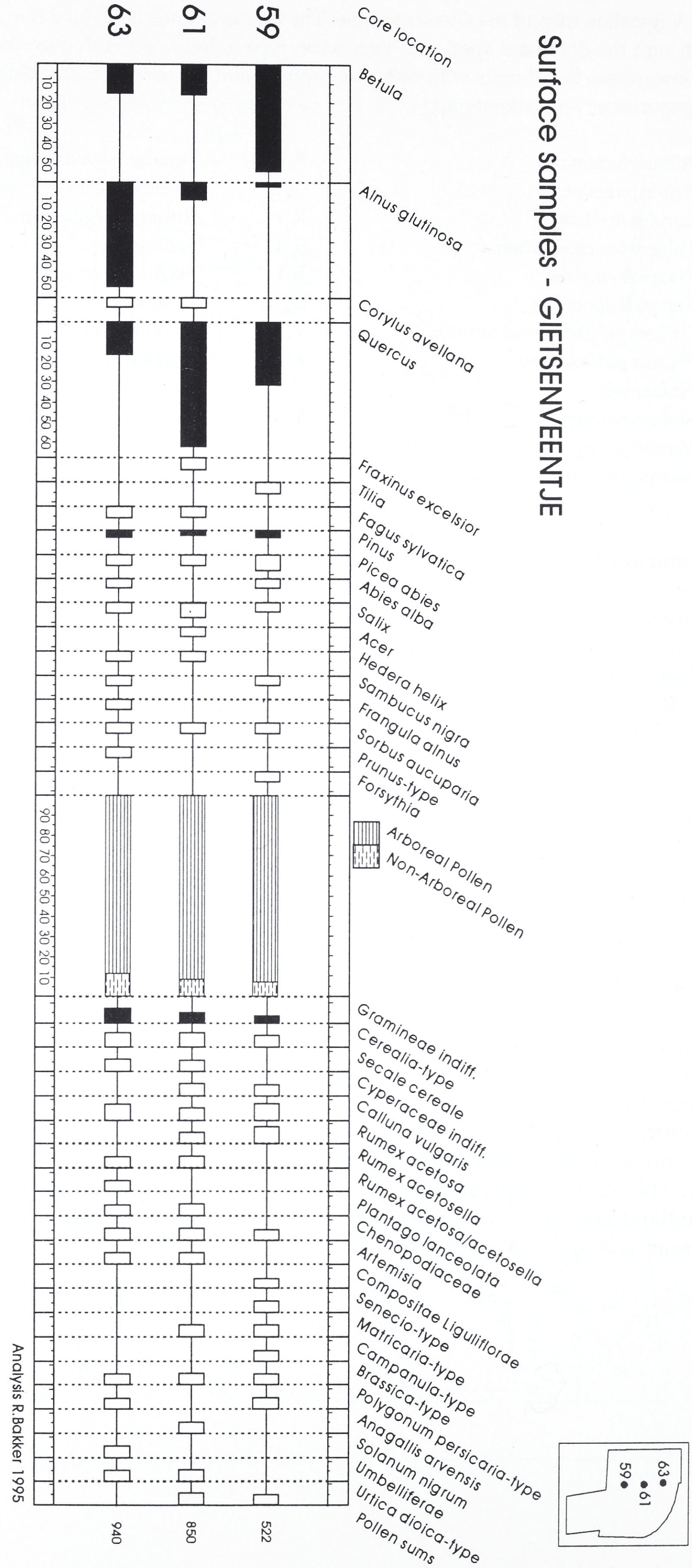


Fig. 49. Surface samples from the Gietsenveentje. Top right: the location of these samples in the Gietsenveentje.

VI.3 Subfossil pollen analysis (regional pollen types)

VI.3.1 Introduction

Subfossil pollen analysis is one of the most important tools which can be used for the reconstruction of the palaeo-environment. For this reason, the results of the subfossil pollen analysis, consisting of nine pollen diagrams, form the core of this study. In this section, only the regional pollen types are treated; the local pollen types are discussed together with the macroscopic remains in VI.6. The sequence Gieten V-A, originating from a core location in the centre of the pingo scar, is the only sequence which is analyzed from the Pleistocene subsoil up to the surface. For this reason, the Gieten V-A pollen diagram is used as a reference diagram for the eight other diagrams: the pollen assemblage zones which are defined in the Gieten V-A diagram, are as far as possible also used in the other eight diagrams. The pollen diagrams are shown in figs. 51-60. The pollen diagrams of Gieten I and Gieten III were already included in a somewhat different form in undergraduate theses by Van der Knaap (1974) and Hagedoorn (1986), respectively. All core locations of the Gietsenveentje pollen diagrams are shown in fig. 38. Furthermore, in the right upper corner of each diagram, a small simplified map of the Gietsenveentje is shown with the core location of the sequence of the diagram concerned. Now first some explanation will be given about the pollen diagrams. In each diagram, from left to right are given:

^{14}C dates (BP). The results of uncalibrated ^{14}C dates are shown. The black rectangle represents the layer of sediment out of which the material for the ^{14}C date was taken. In the Gieten II diagram, this column is absent, because Gieten II is the only sequence without ^{14}C dates. In VI.4, the ^{14}C dates are discussed in detail; calibration is also given there.

Depth in cm. The second column gives the depth in centimetres below the surface. The elevations of the surfaces and the bases of the sequences are given in VI.1.

Lithology. The third column presents the lithology of the part of the sequence on which pollen analysis has been performed. The legend for this column is shown in fig. 50. The lithology of the complete sequences and of sequences on which no pollen analysis has been performed, combined into lithology transects, has already been discussed in VI.1.

Pollen curves. Then follow the columns with the pollen curves. The values of the pollen curves are given as a percentage of the total pollen sum, ΣP, which represents all regional pollen types and is a sum of the Arboreal Pollen (trees and shrubs) and the Non-Arboreal Pollen (upland herbs): $\Sigma P = AP + NAP$. The black scale is the base scale: when no scale indication is given, a small mark represents 5%, a large mark 10%. Always a white scale is added to the black scale. The white scale is a five times magnification of the black scale. In a few cases, when very large amounts of local pollen or charcoal are found, a different scale is used.

First the ratio of Arboreal Pollen to Non-Arboreal Pollen is stated, expressed in percentages. The pollen curves themselves are separated into five major groups (see IV.5): trees and shrubs (Arboreal Pollen), representing all regional tree pollen types; upland herbs (Non-Arboreal Pollen), representing all regional herb pollen types; local plants, representing all local pollen types, divided into three subgroups: local trees, local herbs (non-aquatics) and local herbs (aquatics); Van Geel palynomorphs; and finally, charcoal particles.

Pollen sums. The total pollen sum (ΣP) of each spectrum, used to calculate the pollen curves, is given here.

Pollen zones. The last column indicates the pollen assemblage zones, discussed in this section. These pollen assemblage zones are local zones, distinguished on the basis of the pollen content of the Gietsenveentje diagrams (see IV.5). Pollen zone 4a is equivalent to the Neolithic Occupation Period, as defined in I.4.1, which is subdivided into three Neolithic Occupation Phases.

VI.3.2 Description of the pollen zones

The pollen assemblage zones of the Gietsenveentje diagrams will be described on the basis of the master diagram of sequence Gieten V-A (fig. 56) and a detailed diagram of the largest part of the Neolithic Occupation Period of sequence Gieten V-A (fig. 57). The pollen assemblage zones are summarized in table 7. At the end of the description of each zone, any deviating events in the corresponding zones in the other diagrams are briefly discussed.

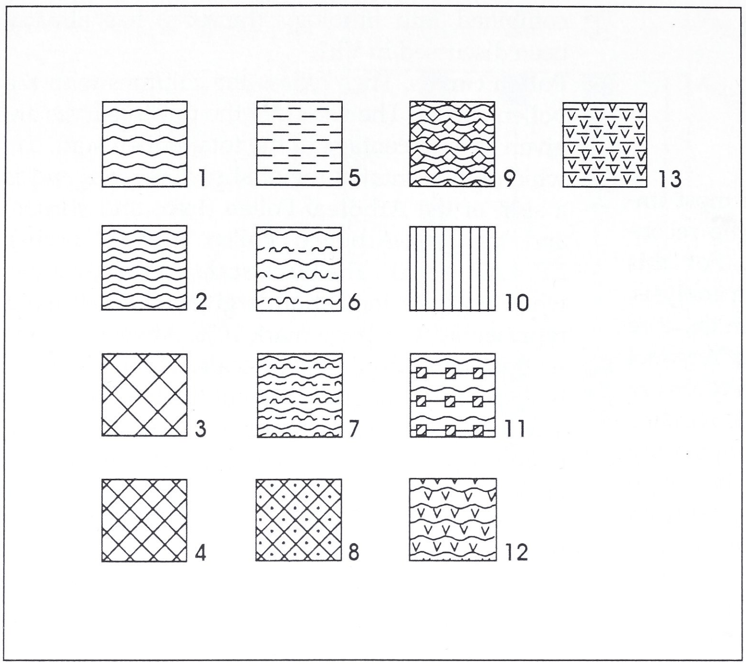


Fig. 50. Legend of the lithology column of the pollen diagrams.
1. poorly humified *Sphagnum* peat
2. moderately to highly humified *Sphagnum* peat
3. coarse detritus gyttja
4. fine detritus gyttja
5. homogeneous humic substance
6. as 1, with *Eriophorum*
7. as 2, with *Eriophorum*
8. fine detritus gyttja with loam/sand
9. transitional phase between 2 and 3
10. *Carex* peat
11. *Scheuchzeria* peat
12. as 2, with wood
13. as 5, with wood

Zone 1 - *Betula* zone
Gieten V-A: 470-465 cm

AP. Pollen of *Betula,* which most probably had no local origin here, dominates; considerable amounts of *Pinus* pollen are found. Also small amounts of pollen of *Corylus, Alnus* and *Quercus* occur. Considering the facts that the only pollen spectrum which represents this zone was collected near the Pleistocene subsoil and that the lithology at this depth consists of a sandy gyttja, the *Corylus, Alnus* and *Quercus* pollen has to be secondary. It may originate from an earlier warm period.

NAP. Pollen of Gramineae indiff. dominates the NAP; a small peak of *Artemisia* is observed.

Zone and period definition. The sediment between 470 and 465 cm represents the *Betula* zone, local zone 1. Placed in a regional perspective, the local zone 1 represents the Preboreal (see III.6.2). Contrary to most pingo scars in Drenthe, in the Gietsenveentje evidently no sedimentation took place in the Late Glacial.

Zone 2 - *Pinus-Betula* zone
Gieten V-A: 465-445 cm

Gieten I: 430-425 cm; Gieten III: 363.5-353 cm; Gieten IV-P: 455-440 cm and 400-370 cm; Gieten IV-HR: 400-365.5 cm

AP. *Pinus* increases to fairly high percentages (60-70%), while *Betula* decreases substantially to about 30%; the values of *Corylus* pollen increase markedly. Around a depth of 445 cm, conspicuous changes occur in the AP: *Pinus* sharply decreases; *Ulmus* markedly increases; *Quercus* and *Alnus* appear. Assuming that the pollen of *Alnus, Corylus* and *Quercus* in pollen zone 1 is secondary, it can be observed that the pollen of these trees appears for the first time in the following order: *Corylus, Quercus, Alnus.*

NAP. Pollen of Gramineae indiff. is the most frequent non-arboreal pollen.

Zone and period definition. The sediment between 465 and 445 cm represents the *Pinus-Betula* zone, local zone 2. Placed in a regional perspective, this local zone represents the Boreal (see III.6.2).

Other diagrams: Gieten III (fig. 53). The zone division of the lower part of sequence Gieten III presents serious problems. Because of the low pollen sum (125) the percentages of the sample of 363.5 cm are probably not very reliable. Some characteristics of the spectra of 363.5 and 353.2 cm point to local zone 2, especially the high values of *Pinus.* Other characteristics point more to local zone 3a, especially the relatively high values of *Corylus, Quercus* and *Ulmus.* Most probably, the spectra of 363.5 and 353.2 cm cover the very last part of local zone 2: the values of *Pinus* are still fairly high but not as high as in the first and central part of the zone, while *Corylus* and *Quercus* are already present. The transition to local zone 3a is located between the spectra of 353.2 and 352.7 cm, when *Pinus* drops below 25%.

depth	**pollen assemblage zone**	**zone number**	**presumed Blytt/ Sernander period**
470 - 465 cm	*Betula* zone	1	Preboreal
465 - 445 cm	*Pinus-Betula* zone	2	Boreal
445 - 405 cm	*Corylus-Ulmus* zone	3a	Atlantic I
405 - 370.5 cm	*Alnus-Ulmus-Fraxinus* zone	3b	Atlantic II
370.5 - 285 cm	*Quercus-Fraxinus* zone	4a	Subboreal I
285 - 175 cm	*Alnus-Corylus*-Ericaceae zone	4b	Subboreal II
175 - 125 cm	Ericaceae-*Alnus* zone	4c	Subboreal III
125 - 65 cm	Ericaceae-*Fagus* zone	5a	Subatlantic I
65 - 7.5 cm	Gramineae-Cerealia-Ericaceae zone	5b	Subatlantic II
7.5 - 5 cm	*Quercus*-Gramineae zone	5c	Subatlantic III

Table 7. Pollen assemblage zones which can be distinguished in the master diagram of Gieten V-A (fig. 56). On the basis of these zones, a local zonation system is suggested.

Gieten IV-P (fig. 54). A strange phenomenon is observed in sequence Gieten IV-P: the pollen picture between 400 and 370 cm very much resembles the pollen picture between 455 and 440 cm, which most closely corresponds to the *Pinus-Betula* zone, local zone 2. This means that local zone 2 occurs twice in this sequence! The lithology can help us to solve this problem: around a depth of 400 cm, a layer of *Scheuchzeria* peat has been deposited, while below and above this layer, the lithology consists of a smooth fine detritus gyttja. Apparently, a certain layer of sediment was deposited twice at this spot. Hanging or floating layers of sediment could have caused this phenomenon. It can be deduced from the pollen picture that the spectrum at 395 cm is the oldest spectrum in the diagram, because of the *Pinus* maximum and the absence of *Quercus* and *Ulmus*. Apparently, the sediment between 400 and 370 cm represents a larger part of local zone 2 than the sediment between 455 and 440 cm, where the *Pinus* maximum is missing. **Gieten IV-HR (fig. 55).** The same phenomenon as in sequence Gieten IV-P is observed here: gyttja sediment attributed to the older local zone 2 (400-365.5 cm) is deposited above gyttja sediment attributed to the younger local zone 3a (429-400 cm). These two layers of sediment are separated by a thin layer of *Scheuchzeria* peat (around 400 cm). Just as in diagram Gieten IV-P, the conclusion is that apparently a certain layer of sediment was deposited twice at this spot. It can be deduced from the pollen assemblage that the spectrum of 398 cm is the oldest spectrum in the diagram, because of the *Pinus* maximum and the almost complete absence of *Quercus* and *Ulmus* in this spectrum.

Zone 3a - *Corylus-Ulmus* zone
Gieten V-A: 445-405 cm

Gieten I: 425-395 cm; Gieten III: 353-348.1 cm (entire zone 3); Gieten IV-P: 440-400 cm and 370-312.5 cm; Gieten IV-HR: 429-402 cm and 365.5-306.5 cm; Gieten V-C: 115-107.5 cm; Gieten V-D: 245-240 cm

AP. The pollen of *Corylus* (between 445 and 430 cm) and *Alnus* (from 430 cm upwards) is the most frequent pollen, followed by *Quercus*. *Ulmus* reaches the relatively high percentage of about 5%. Pollen of *Tilia* and *Fraxinus* appears for the first time.

NAP. Pollen of Gramineae indiff. is the most frequently occurring non-arboreal pollen. *Dryopteris*-type reaches relatively high values. In the sequences Gieten I, V-C and V-D *Pteridium* attains fairly high values. In Gieten V-C and V-D, small maxima of Compositae Liguliflorae are observed.

Charcoal particles. Maxima of charcoal particles are found in Gieten V-C and V-D.

Zone definition. Summarizing the described phenomena, the sediment between 445 and 405 cm forms the *Corylus-Ulmus* zone, local zone 3a.

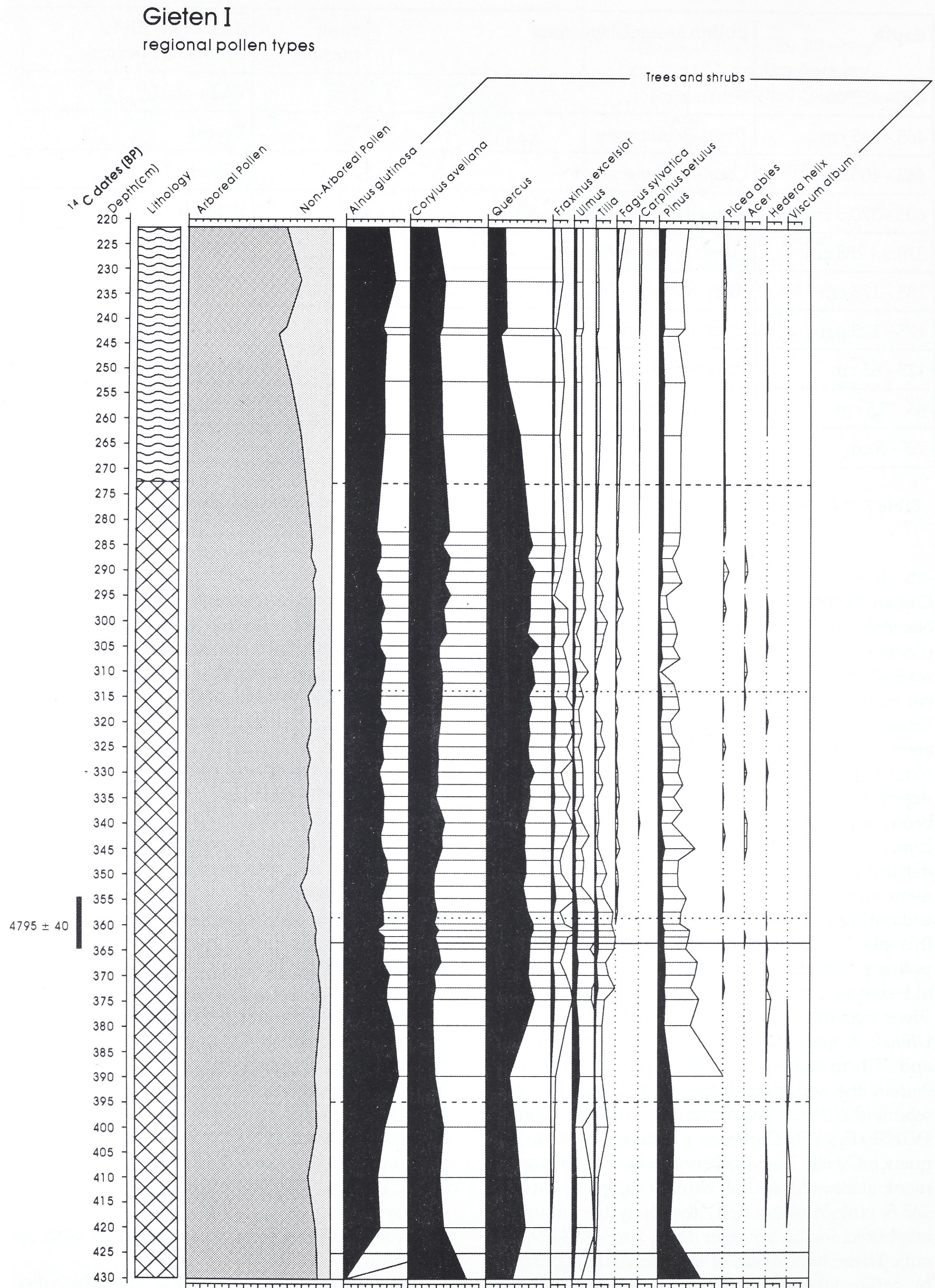
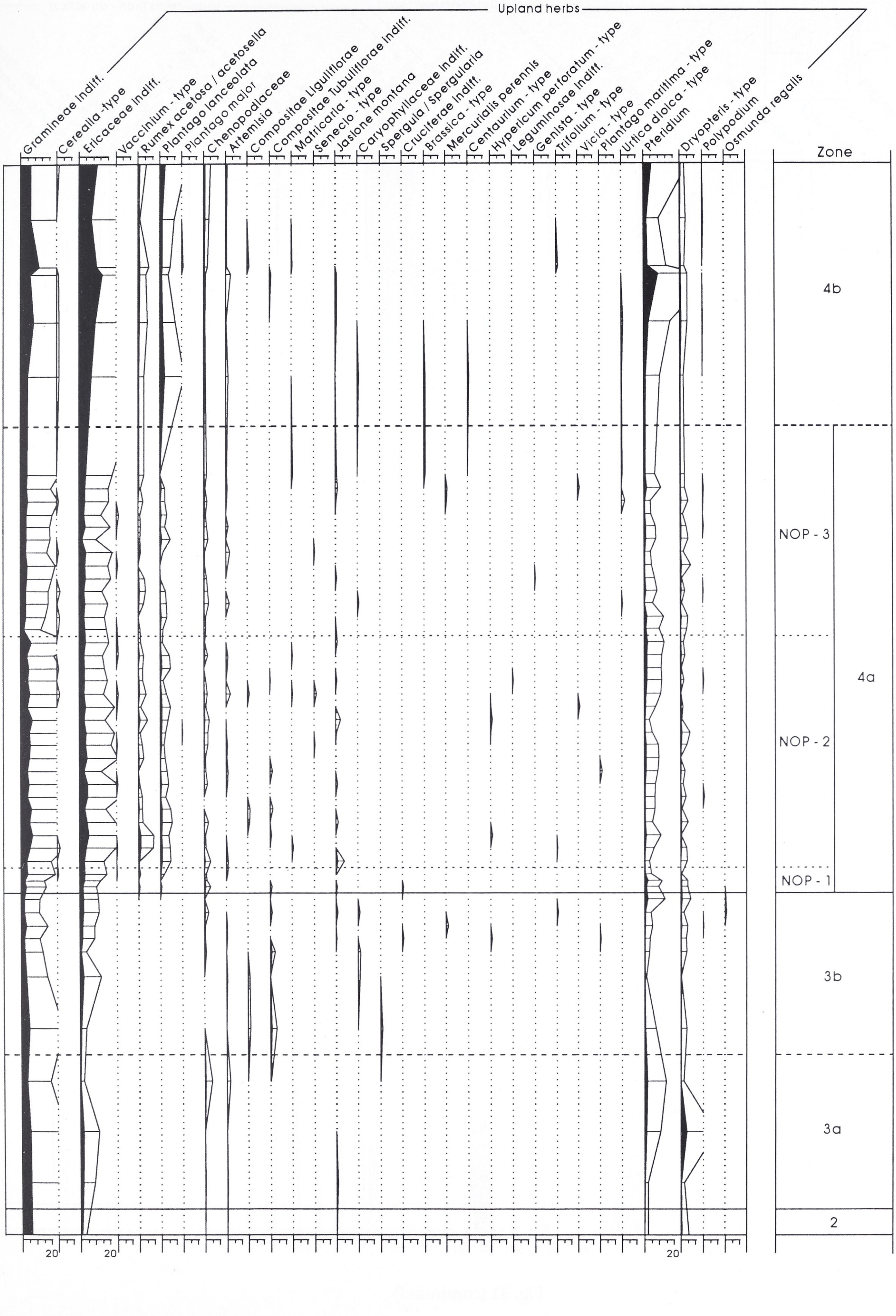


Fig. 51. Pollen diagram of sequence Gieten I.


Upland herbs
Gramineae indiff.
Cerealia -type
Ericaceae indiff.
Vaccinium - type
Rumex acetosa / acetosella
Plantago lanceolata
Plantago major
Chenopodiaceae
Artemisia
Compositae Liguliflorae
Compositae Tubuliflorae indiff.
Matricaria - type
Senecio - type
Jasione montana
Caryophyllaceae indiff.
Spergula / Spergularia
Cruciferae indiff.
Brassica - type
Mercurialis perennis
Centaurium - type
Hypericum perforatum - type
Leguminosae indiff.
Genista - type
Trifolium - type
Vicia - type
Plantago maritima - type
Urtica dioica - type
Pteridium
Dryopteris - type
Polypodium
Osmunda regalis
Zone
4b
NOP - 3
NOP - 2
NOP - 1
4a
3b
3a
2
20
20
20

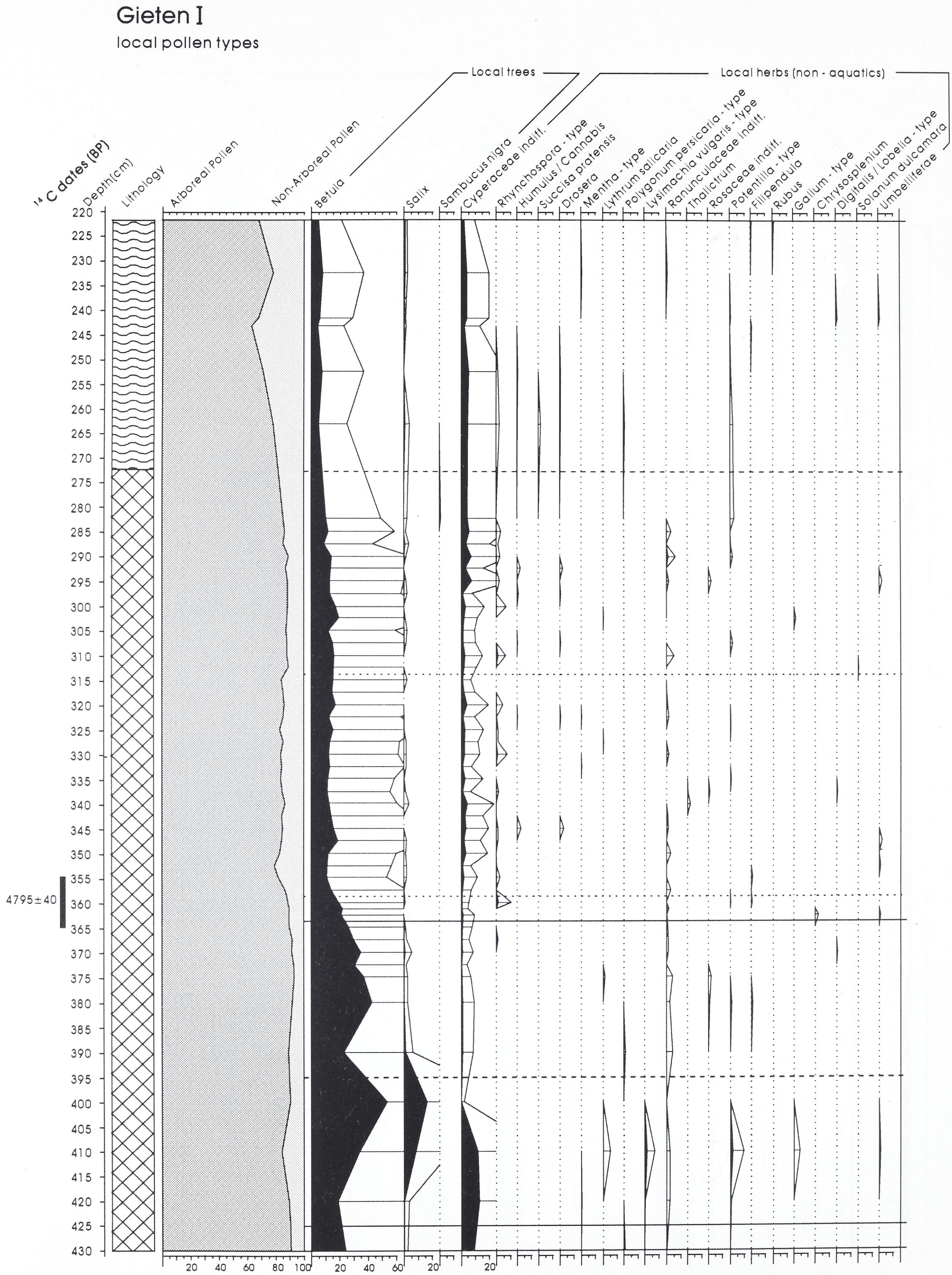
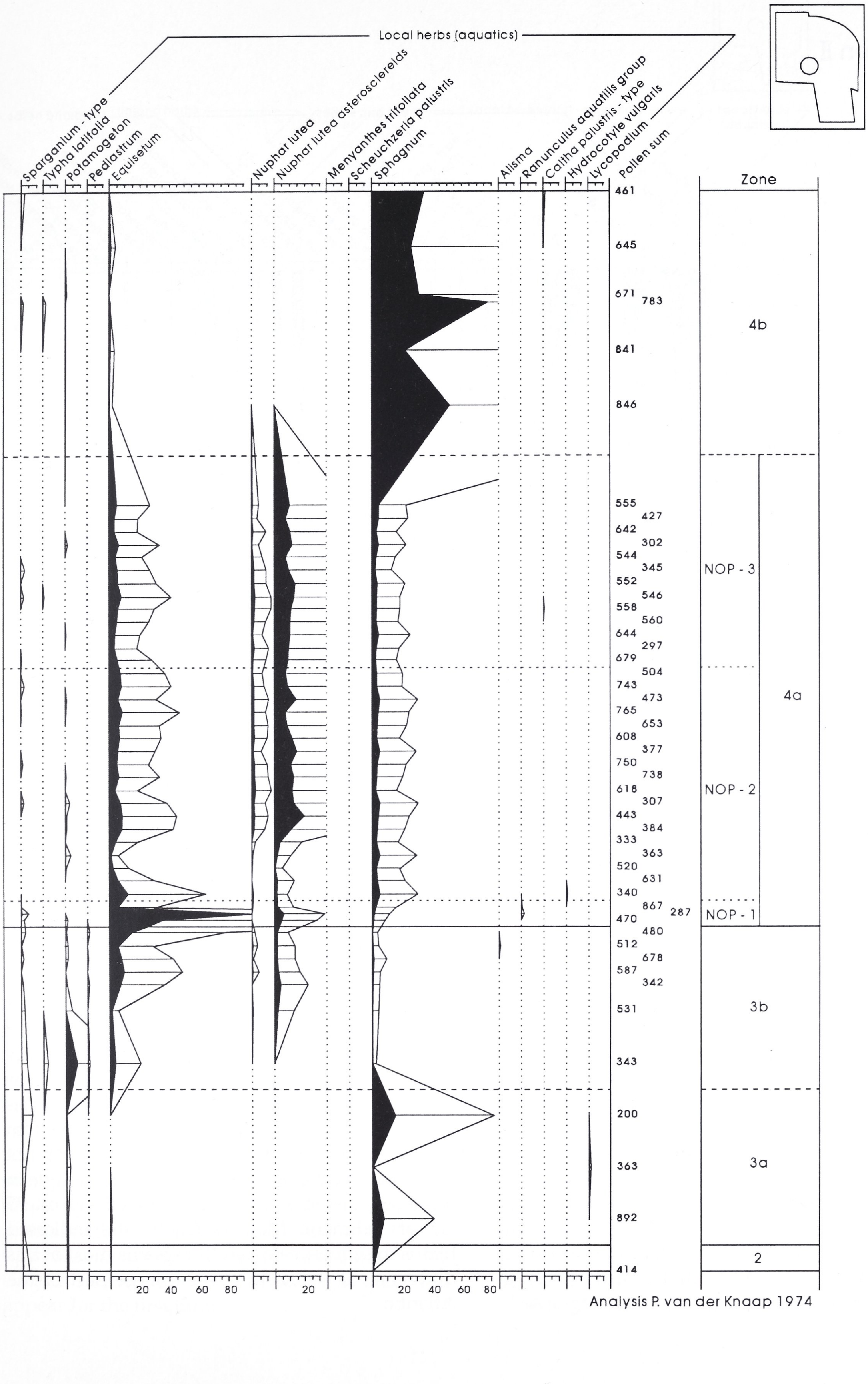


Fig. 51 (continued).



Local herbs (aquatics)
Sparganium - type
Typha latifolia
Potamogeton
Pediastrum
Equisetum
Nuphar lutea
Nuphar lutea asterosclereids
Menyanthes trifoliata
Scheuchzeria palustris
Sphagnum
Alisma
Ranunculus aquatilis group
Caltha palustris - type
Hydrocotyle vulgaris
Lycopodium
Pollen sum
Zone
4b
NOP - 3
4a
NOP - 2
NOP - 1
3b
3a
2
20 40 60 80
20
20 40 60 80
Analysis P. van der Knaap 1974

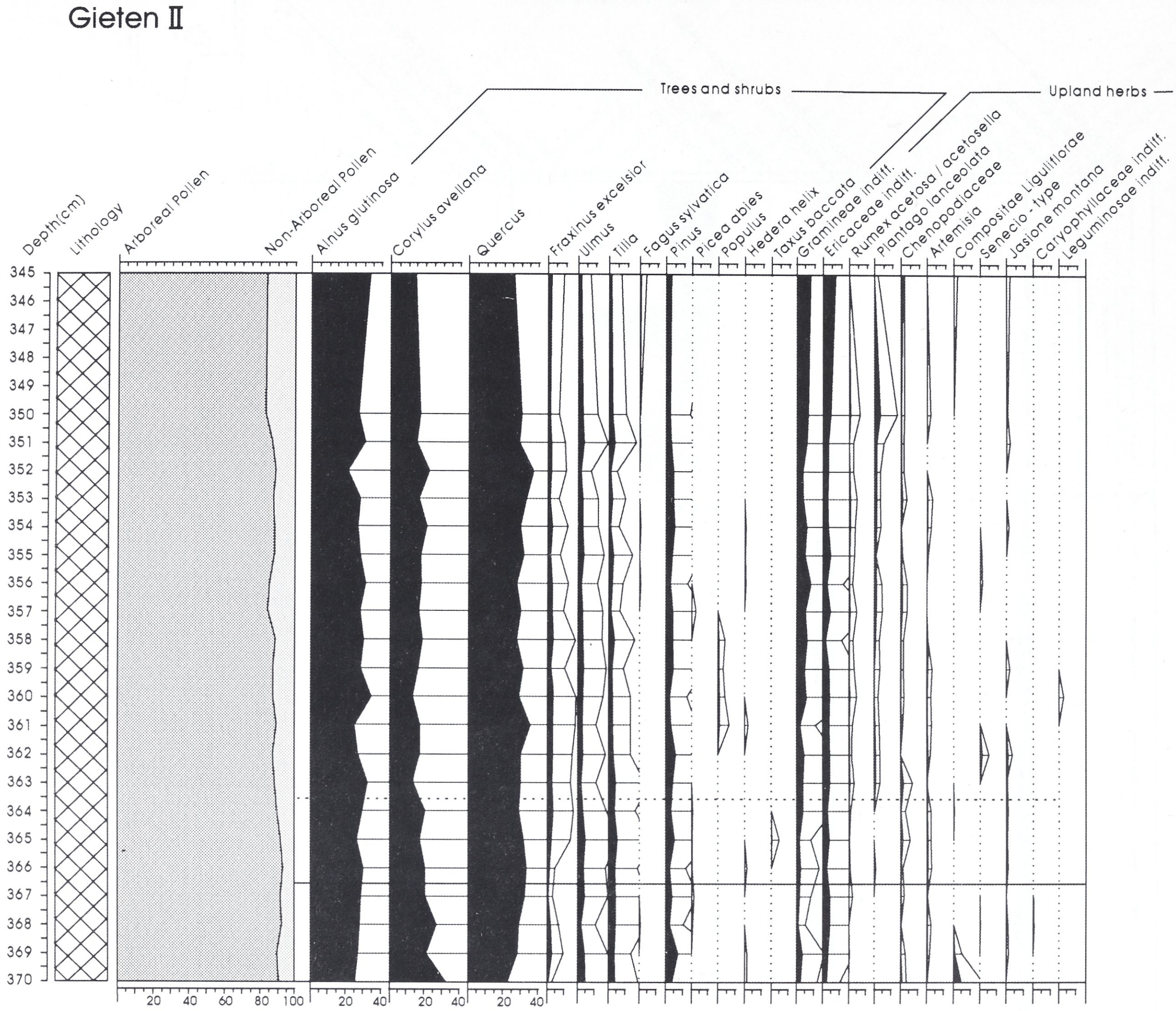
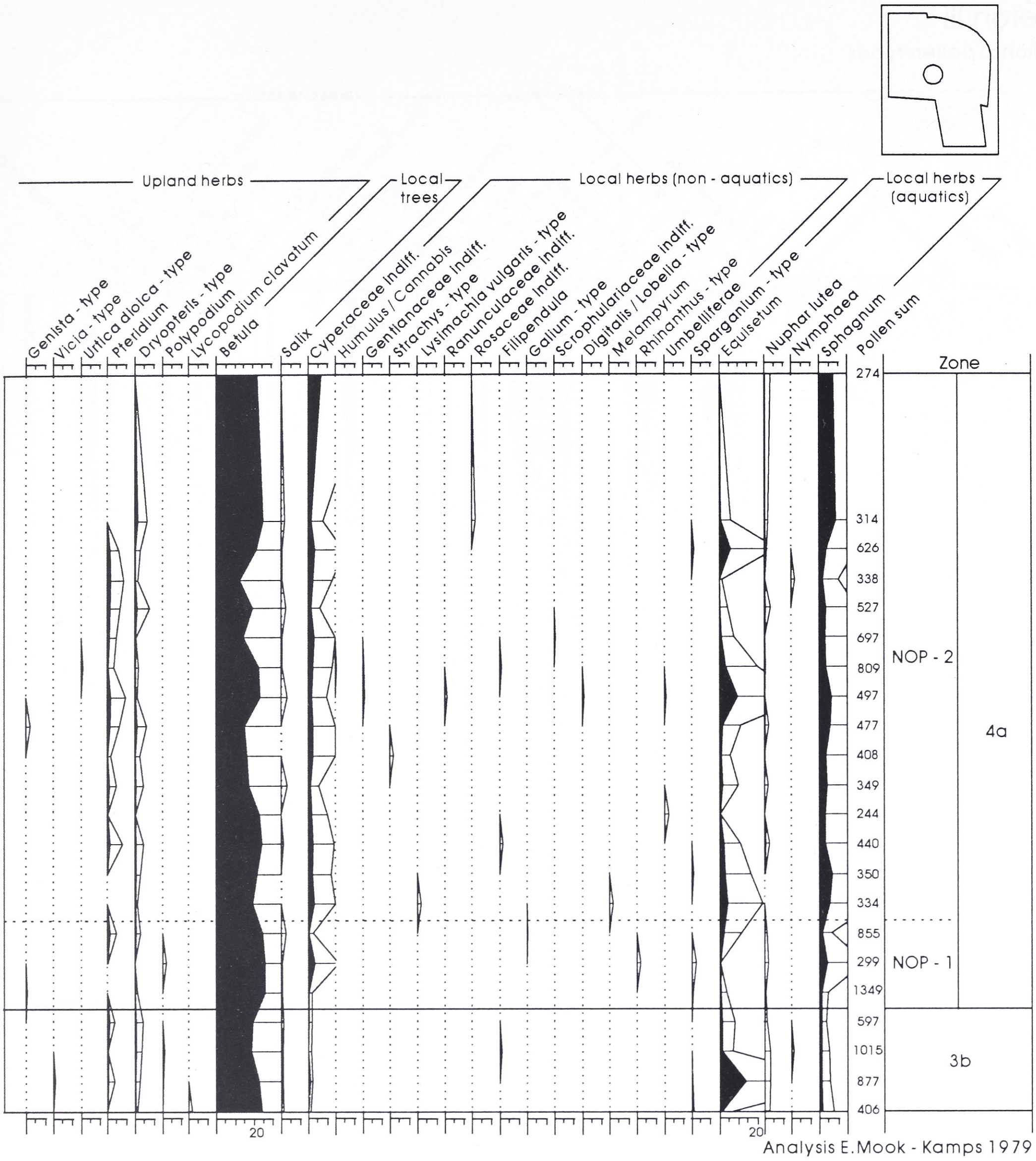


Fig. 52. Pollen diagram of sequence Gieten II.

Other diagrams: Gieten III (fig. 53). Again the zone division encounters problems. ^{14}C dates of the sediment between 351 and 347.8 cm and between 347.8 and 344.5 cm yield a result of 6990 ± 120 BP and 4800 ± 110 BP, respectively. This points to a considerable hiatus around 348 cm. This hiatus cannot be detected in the lithology, which consists of a smooth fine detritus gyttja. In most Gietsenveentje diagrams, the transition from local zone 3a to 3b is marked by a clear increase of *Fraxinus*. In this diagram, *Fraxinus* appears only from 349.4 cm upwards. Only a general local zone 3 has been distinguished, which is called the *Corylus-Ulmus* zone. It is characterized by a very high AP percentage; it ends between the spectra of 348.3 and 347.8 cm, when a decrease of *Betula* and an increase of the NAP begins. Placed in a regional perspective, this zone represents the Atlantic. It is remarkable that in this sequence, the Atlantic accounts for not more than 5 cm of sediment, while for example in sequence Gieten V-A, the Atlantic covers ca. 75 cm of sediment. Most probably, the indicated hiatus in sequence Gieten III explains most of this difference: it seems to cover a large part of the Atlantic.



Zone 3b - *Alnus-Ulmus-Fraxinus* zone
Gieten V-A: 405-376.5 cm

Gieten I: 395-363.8 cm; Gieten II: 370-366.5 cm; Gieten III: 353-348.1 cm (entire zone 3); Gieten IV-P: 312.5-262 cm; Gieten IV-HR: 306.5-266 cm; Gieten V-B: 375-262.5 cm; Gieten V-C: 107.5-64.5 cm and 62.5-58 cm; Gieten V-D: 240-222 cm

AP. The AP dominates even more than in the preceding zone. *Alnus, Ulmus* and *Fraxinus* reach relatively high values, while *Quercus* increases considerably. *Tilia* increases slightly from 378 cm upwards. *Pinus* decreases to values of ca. 5%; *Corylus* shows a small decrease. *Fagus* and *Picea* appear for the first time.

NAP. Gramineae indiff. and *Calluna* are the most frequently occurring NAP types.

Zone and period definition. A zone boundary is located at 376.5 cm because of the beginning of the "classic" *Ulmus* decline and an increase of Gramineae indiff. and *Calluna*. Because of maxima of *Corylus, Ulmus* and *Fraxinus*, the zone between 405 and 376.5 cm is called the *Corylus-Ulmus-Fraxinus* zone, local zone 3b. The most important difference between this zone and the preceding one is the *Fraxinus* maximum in zone 3b. The local zones 3a and 3b are characterized by a very high percentage of tree pollen (AP). Placed

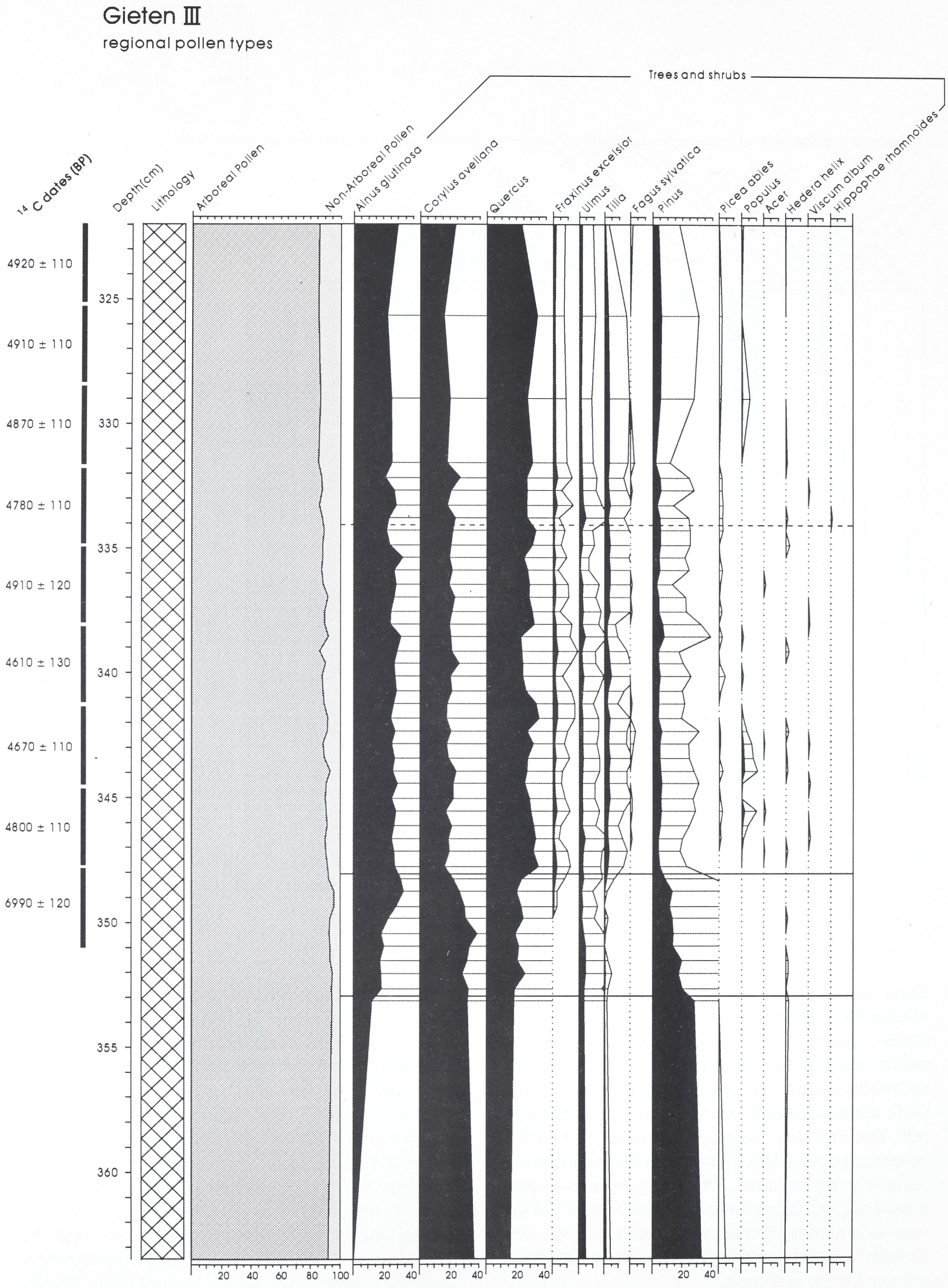
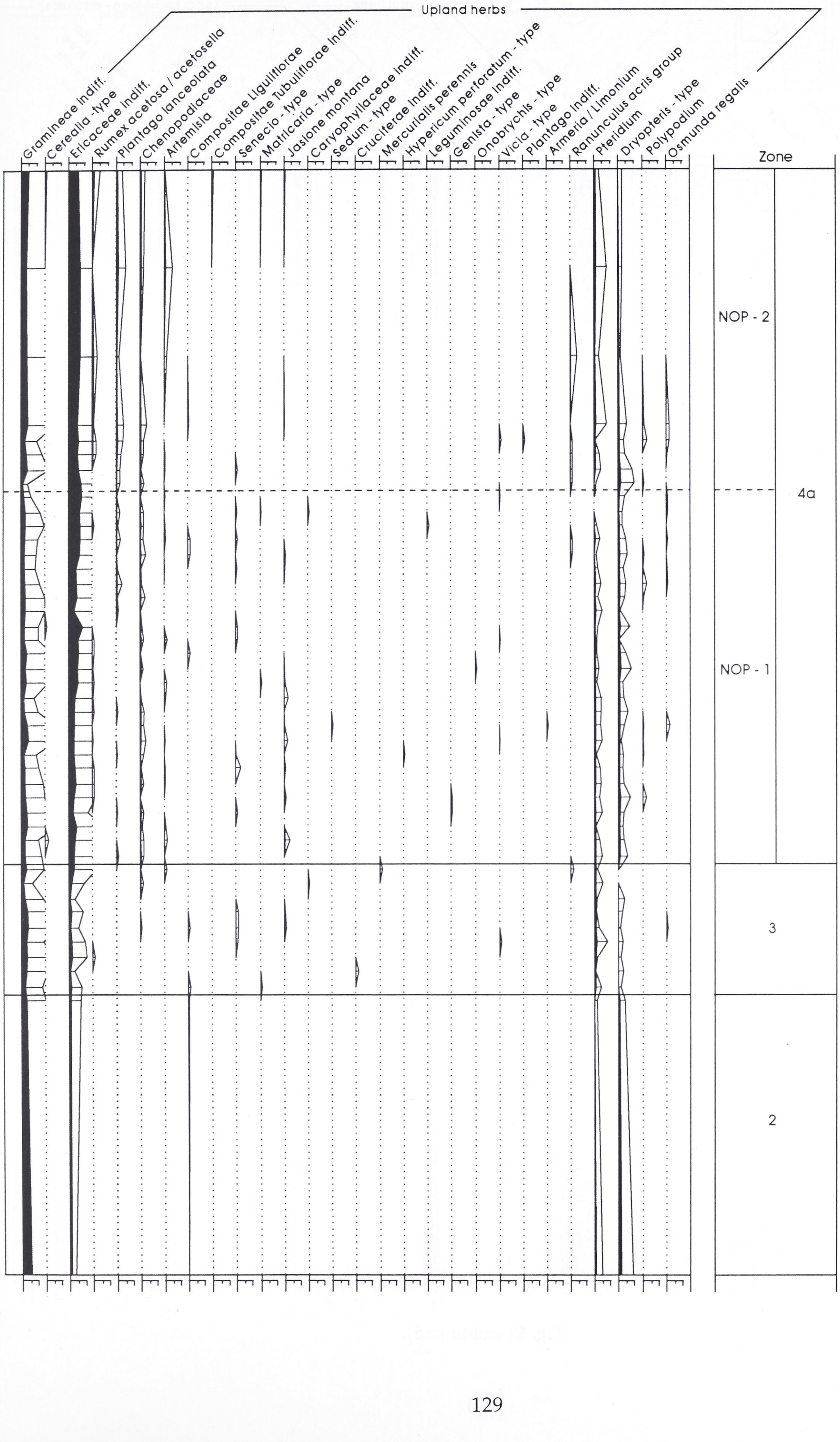


Fig. 53. Pollen diagram of sequence Gieten III.


Upland herbs
Gramineae indiff.
Cerealia -type
Ericaceae indiff.
Rumex acetosa / acetosella
Plantago lanceolata
Chenopodiaceae
Artemisia
Compositae Liguliflorae
Compositae Tubuliflorae indiff.
Senecio - type
Matricaria - type
Jasione montana
Caryophyllaceae indiff.
Sedum - type
Cruciferae indiff.
Mercurialis perennis
Hypericum perforatum - type
Leguminosae indiff.
Genista - type
Onobrychis - type
Vicia - type
Plantago indiff.
Armeria / Limonium
Ranunculus acris group
Pteridium
Dryopteris - type
Polypodium
Osmunda regalis
Zone
NOP - 2
4a
NOP - 1
3
2

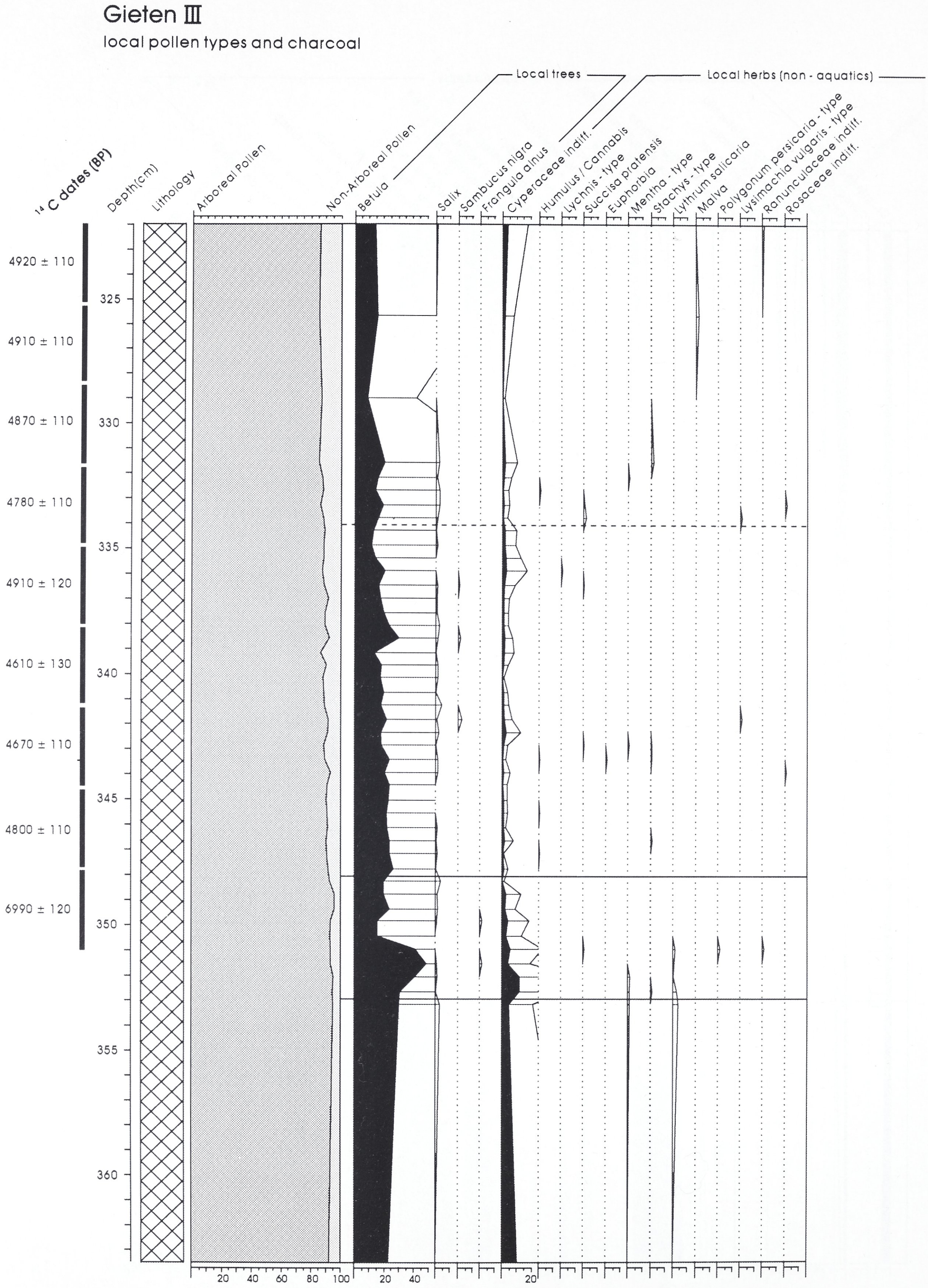
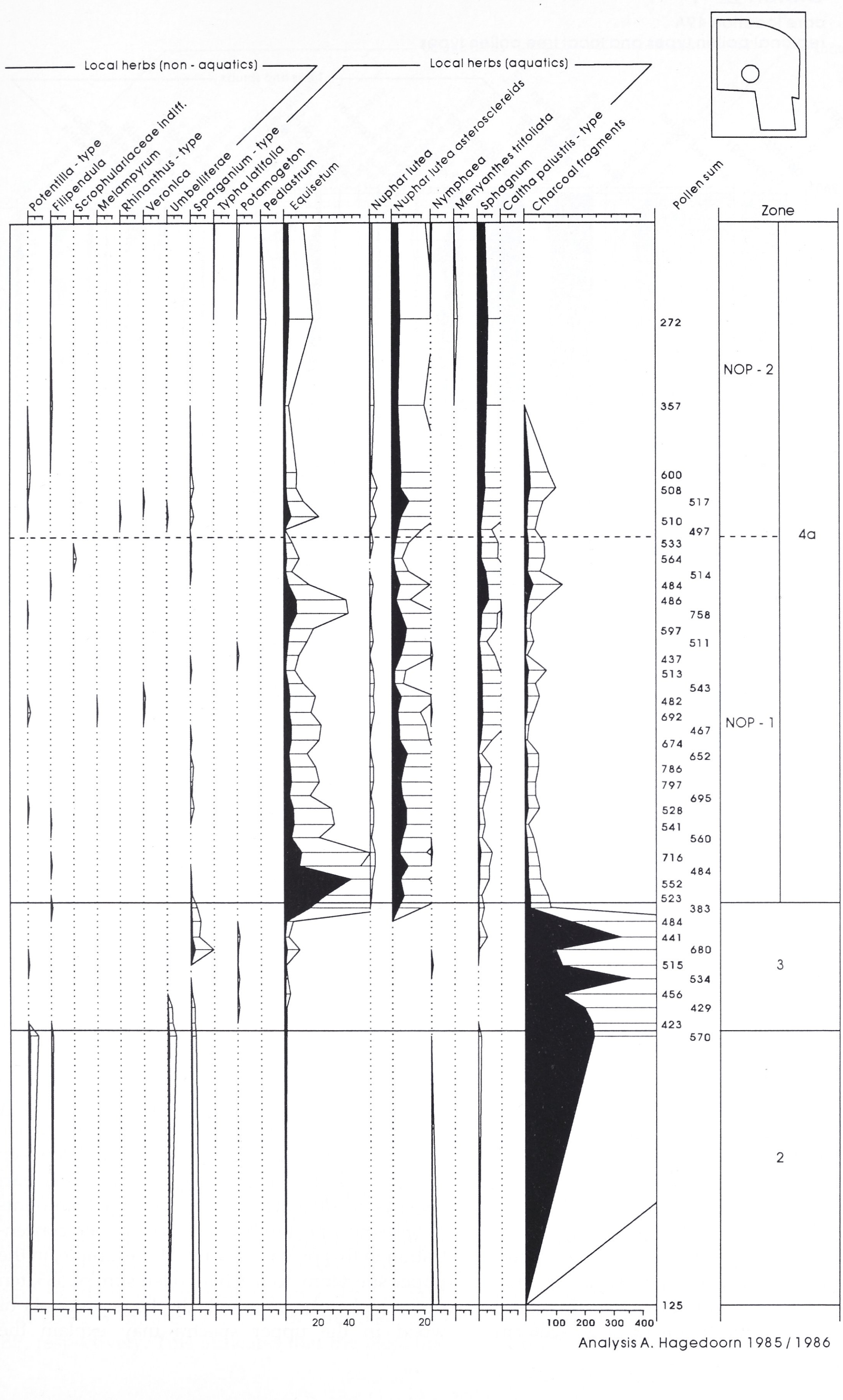


Fig. 53 (continued).



Analysis A. Hagedoorn 1985 / 1986

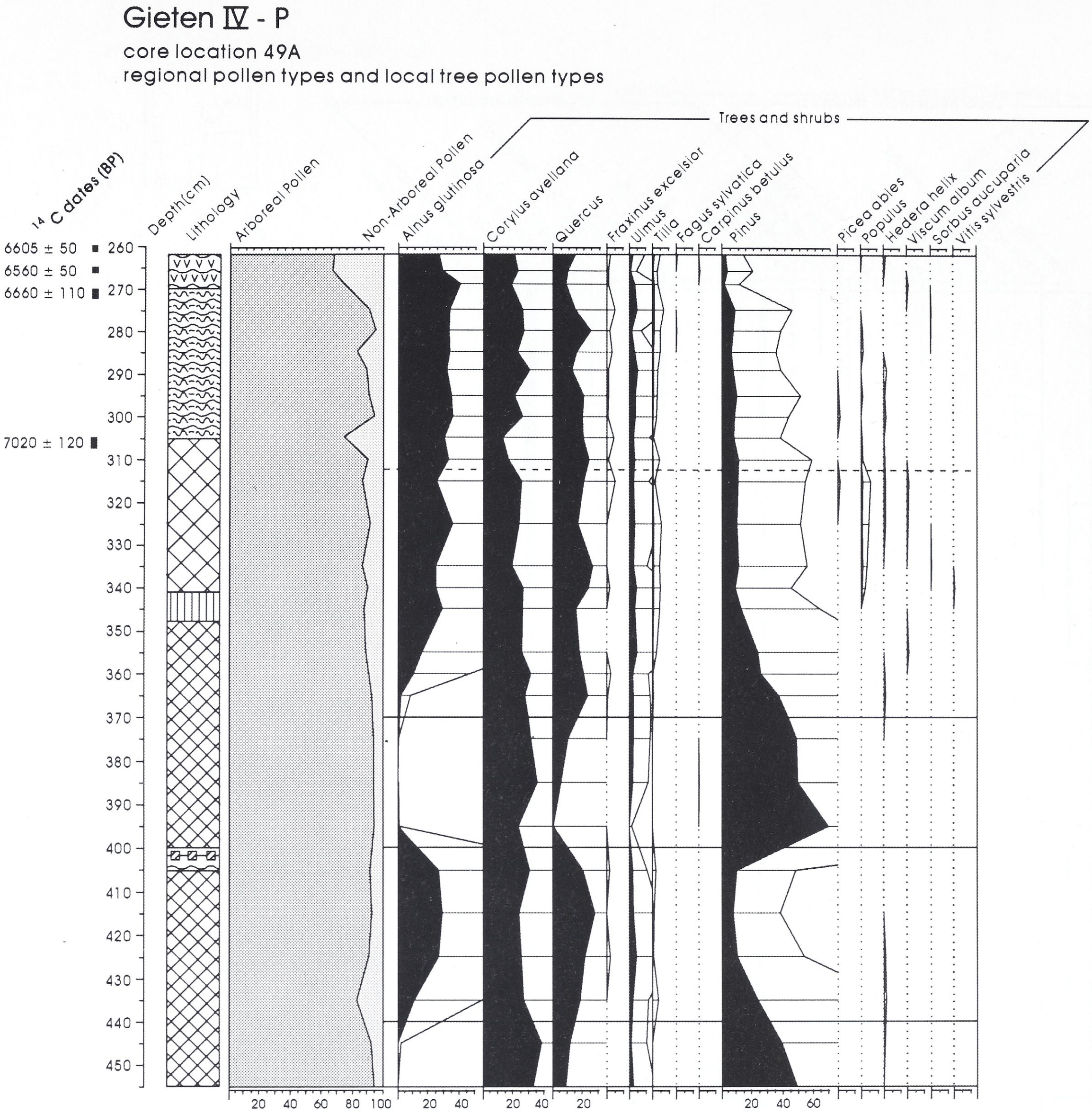
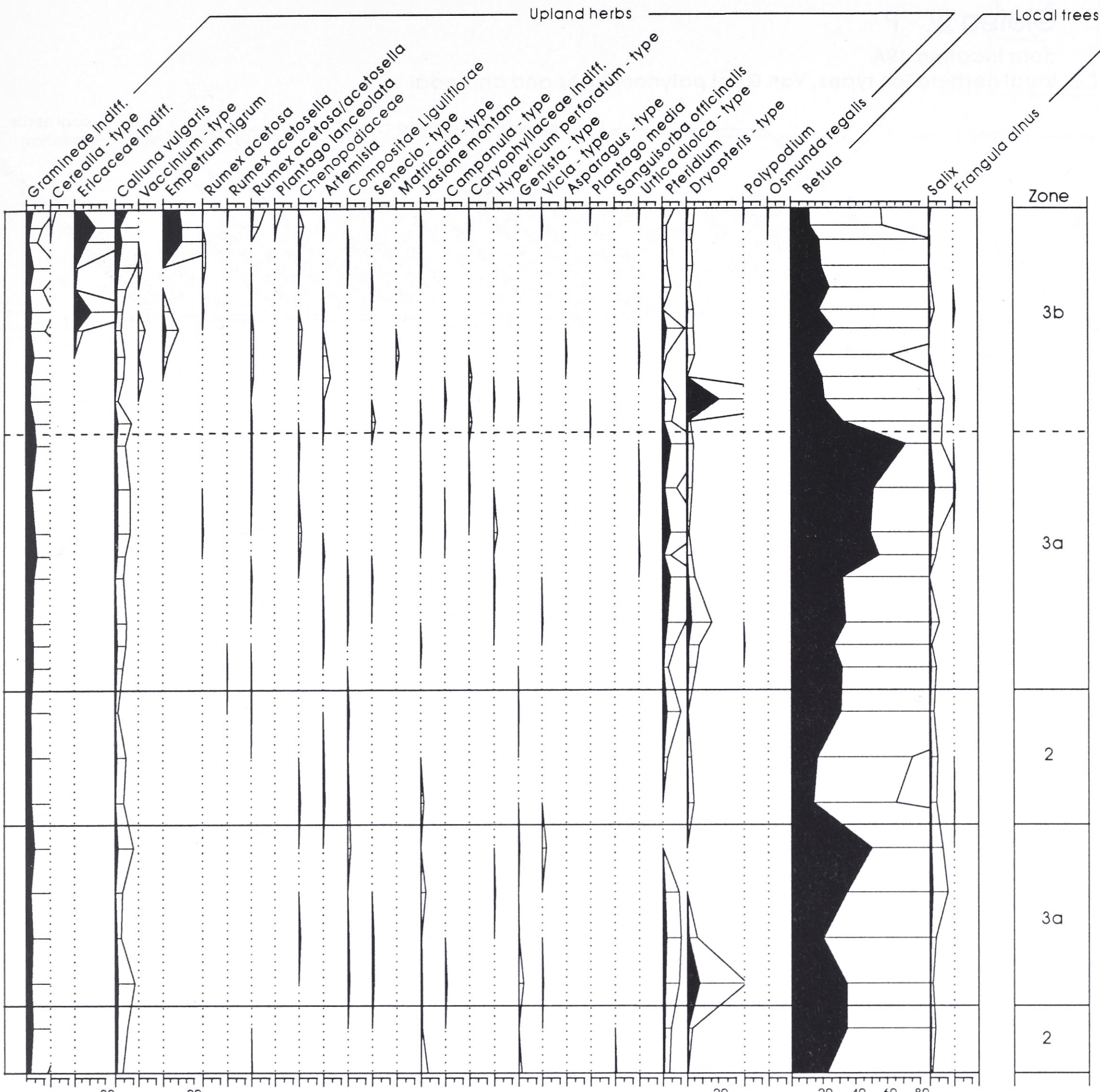


Fig. 54. Pollen diagram of sequence Gieten IV-P.

in a regional perspective, these two zones represent the Atlantic (see III.6.2).

Other diagrams: Gieten IV-P (fig. 54). Considering the NAP, the pollen content of the upper three spectra (269-262 cm) of diagram Gieten IV-P is rather different from the preceding spectra: especially the large amounts of Ericaceae indiff., *Calluna* and *Empetrum* attract attention. Surprisingly, also two typical culture-indicator types appear in the upper two spectra (266-262 cm): Cerealia-type and *Plantago lanceolata*. *Rumex acetosa/ acetosella* reaches maximum values in these spectra. ^{14}C dates of the sediment of 265-266 cm and 260-261 cm are 6560 ± 50 BP and 6605 ± 50 BP, respectively. This indicates that the Neolithic Occupation Period is not reflected in the diagram. The lithology may help us to explain why yet a few grains of the culture-indicator pollen types are found in the upper spectra. Between 270 and 262 cm, the lithology for the larger part consists of *Alnus* wood, with only small amounts of *Sphagnum* peat in between. The pollen concentration in this peat is very low: for example, in the upper spectrum, to reach a pollen sum of 685, ten slides had to be counted! The large amounts of wood in the upper spectra may explain the



presence of culture-indicator pollen types (Cerealia-type, *Plantago lanceolata*) in sediment which is far too old to represent the Neolithic Occupation Period: water with pollen of a younger age in it could have washed downwards along the stem of the tree from which the wood originates. **Gieten IV-HR (fig. 55).** In the two uppermost spectra of diagram Gieten IV-HR (271-266 cm), *Calluna* reaches values of 10-15%. One grain of *Plantago lanceolata* is observed in the top spectrum (266 cm). ^{14}C dates of the sediment at 270.5-271.5 cm and 265-266 cm are 5995 ± 55 BP and 5885 ± 45 BP, respectively. This indicates that the Neolithic Occupation Period is not reflected in the Gieten IV-HR diagram. Compared to the diagram of Gieten IV-P, pollen of the Ericaceae family increases less in the upper spectra, Cerealia-type is not found at all, only one grain of *Plantago lanceolata* is found; in short: the Gieten IV-HR diagram does not reveal any signs of the Neolithic Occupation Period, and confirms the above-mentioned ^{14}C dates. **Gieten V-C (fig. 59).** In the diagram of Gieten V-C, a considerable decrease of *Ulmus* is observed between 84 and 80 cm. ^{14}C dates of the sediment at 85-86 cm and 80-81 cm yield results of 6330 ± 55 BP and 6245 ± 55 BP, respectively.

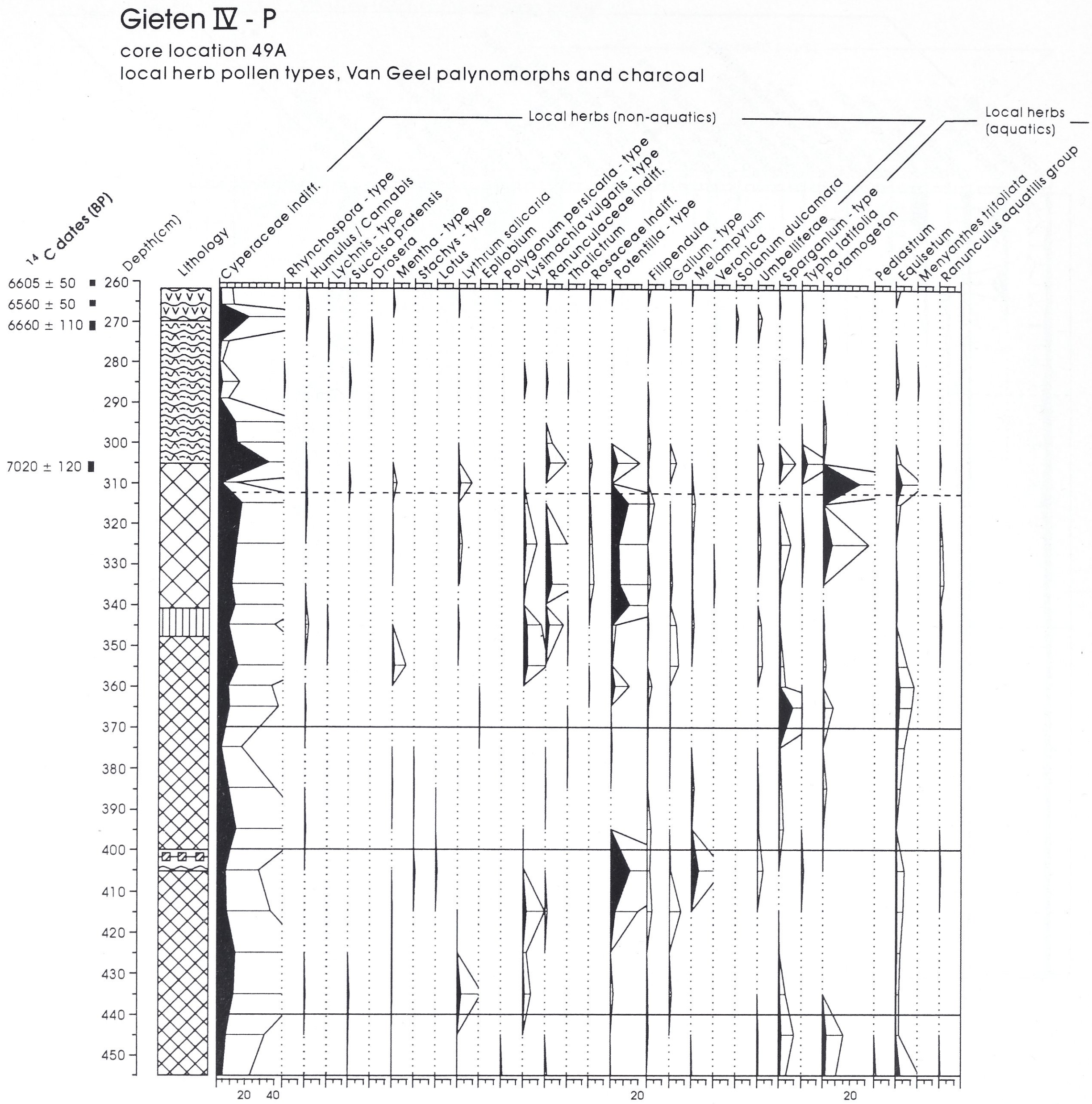
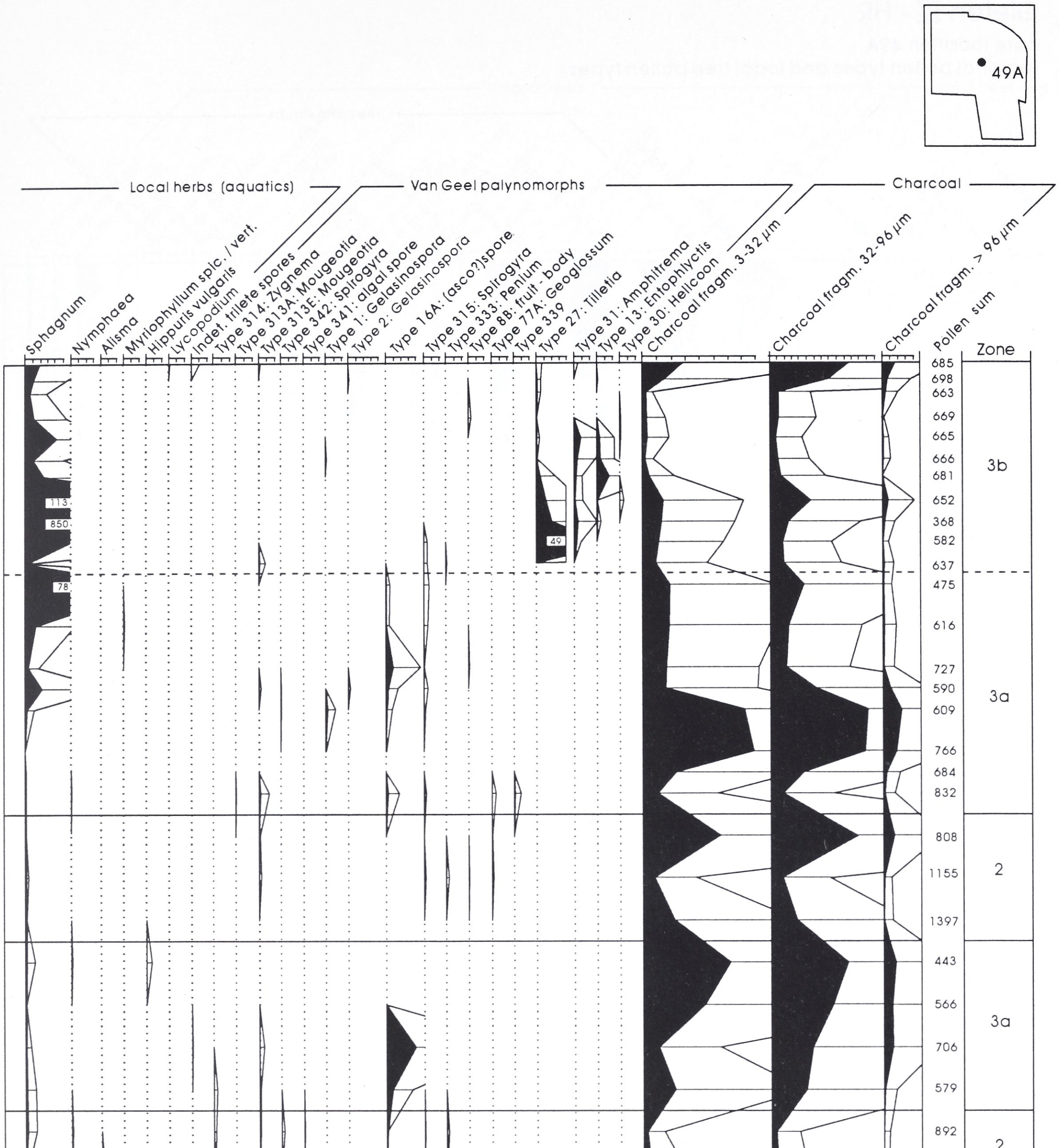


Fig. 54 (continued).

This seems to indicate a very early *Ulmus* decline. Somewhat higher up in the diagram, also culture-indicator types occur: a few grains of *Plantago lanceolata* are found in the spectra of 75 cm (one grain), 67 cm (one grain) and 65 cm (two grains). From 74 cm upwards, Cerealia-type occurs in low quantities in almost every spectrum: grains belonging to the *Hordeum* group as well as *Triticum* sp. are found (see table 8). The *Ulmus* decline and the presence of culture-indicator types seems to indicate the beginning of the Neolithic Occupation Period somewhere between 85 and 75 cm. However, ^{14}C dates of the sediment at 75-76 cm and 70-71 cm are 6045 ± 55 BP and 6055 ± 55 BP, respectively. These dates are considered to be too old to represent the Neolithic Occupation Period. The AP curves and the curves of Gramineae indiff. and *Calluna* also do not point to the Neolithic Occupation Period at this depth. These changes may have been caused by disturbed sediment



from 75 cm upwards. Here the sediment consists of a homogeneous humic substance with large pieces of wood. The sediment may have been disturbed by tree roots growing into the peat. In the sediment between 62.5 and 58 cm, there are clear signs of disturbance: the general pollen picture points to zone 3b, but Cerealia-type and *Plantago lanceolata* occur in very low quantities. Furthermore, one grain of *Centaurea cyanus* was found in the spectrum of 62 cm and one *Carpinus* grain in the spectrum of 61 cm. Normally these types are not found until far later. A ^{14}C date of the sediment at 60-61 cm, 6530 ± 80 BP, does not fit into the chronological order of the ^{14}C dates of Gieten V-C: it seems to be too old. This is additional evidence for disturbed sediment. However, because disturbances of sediment usually take place from above, and because the sediment below 75 cm is certainly not disturbed, a date with a too young an age would be sooner expected.

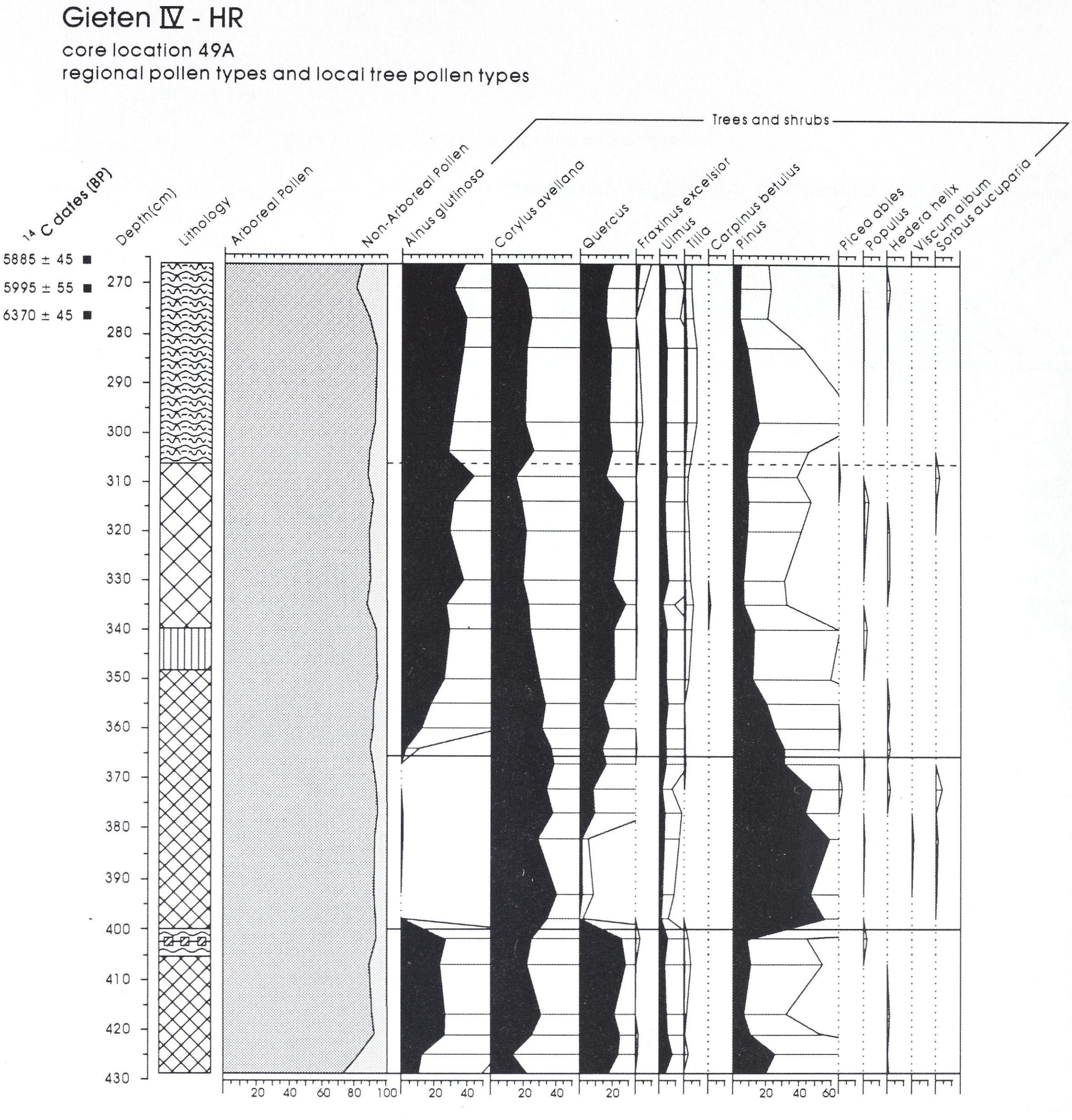


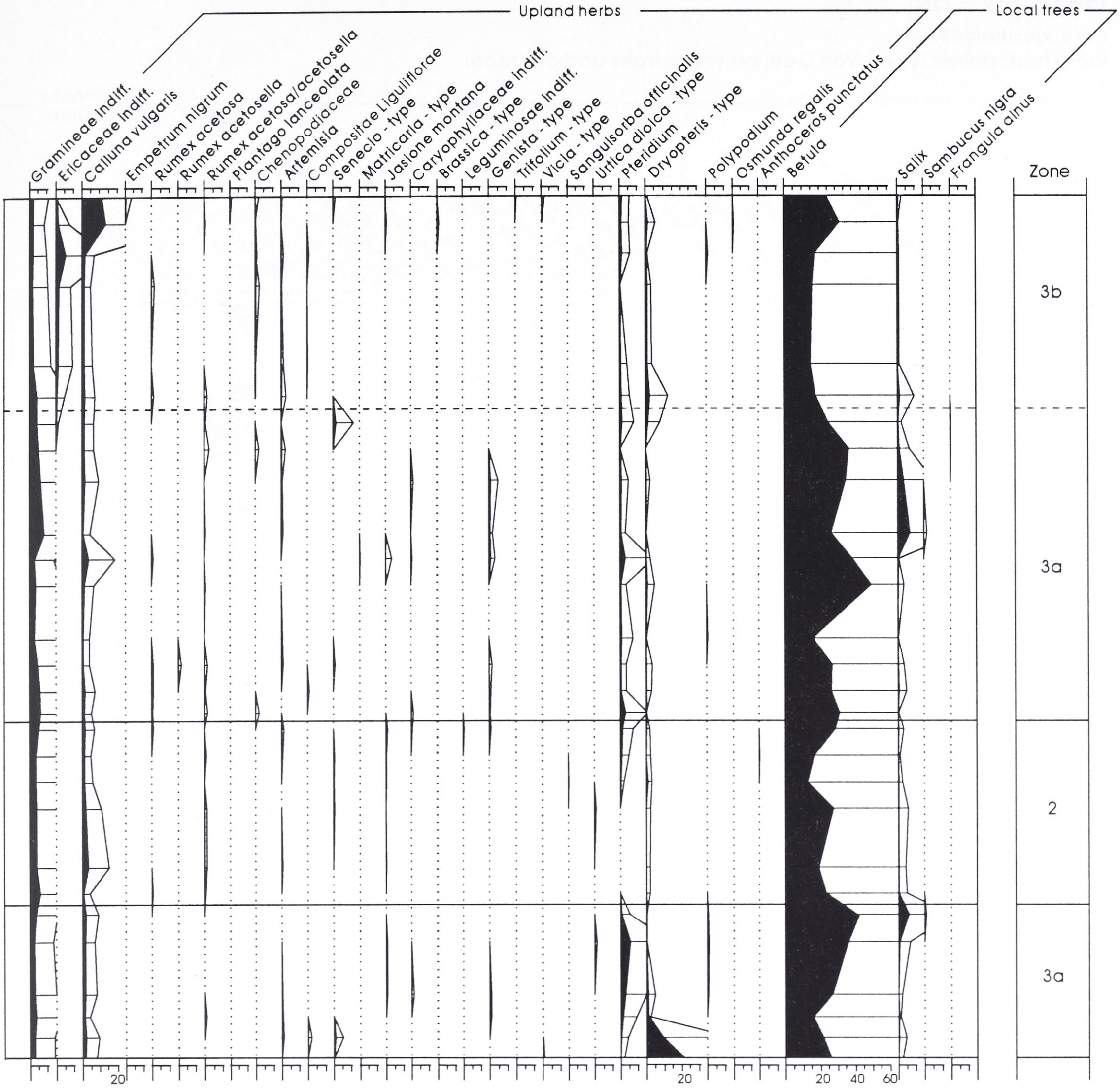
Fig. 55. Pollen diagram of sequence Gieten IV-HR.

Zone 4a - ***Quercus-Fraxinus*** **zone**
Gieten V-A: 376.5-285 cm

Gieten I: 363.8-272.9 cm; Gieten II: 366.5-345 cm; Gieten III: 348.1-322 cm; Gieten V-B: 262.5-175 cm; Gieten V-C: 64.5-62.5 cm (entire zone 4); Gieten V-D: 222-135 cm

The spectra of sequence Gieten V-A between 380 and 355 cm will be described on the basis of the detailed diagram of fig. 57. From 350 cm upwards, the description of the pollen content continues on the basis of the master pollen diagram (fig. 56).

AP. *Quercus* and *Alnus* are the dominant pollen types. *Quercus* reaches maximum values in the first part of the zone, between 376.5 and 373.5 cm. *Corylus* increases slowly towards values of ca. 25% at the end of the zone. *Fraxinus* reaches its highest values in the entire diagram. *Ulmus* decreases very slowly, from 4.3% at 377 cm to 1.3% at 356 cm. *Tilia* reaches its maximum value (3.3%) between 378 and 363 cm. Pollen of *Fagus* occurs more frequently from 372 cm upwards. *Carpinus* is found at 366 and 363 cm (one grain in each spectrum). In sequences Gieten I and V-B, also grains of *Carpinus* are found in this zone. Between 365 and 280 cm, *Tilia, Ulmus, Fraxinus* and *Quercus* all successively decline. Most conspicu-



ous is the sharp decrease of *Quercus* between 290 and 280 cm. *Betula* drops from 41.7% at 377 cm to 10.8% at 366 cm. This decrease probably represents an event in the local vegetation.

NAP. The total NAP percentage shows a considerable change in this period: it increases from 8.6% at 374 cm to 20.8% at 363 cm. This increase is for the larger part caused by an increase of Gramineae indiff., *Calluna* and *Rumex acetosa*. Interestingly, these pollen types do not increase simultaneously: the first to increase is *Calluna* (373 cm), followed by Gramineae indiff. and *Rumex acetosa* (367 cm). With regard to *Rumex acetosa* and *Rumex acetosella* it has to be remarked that in the Gieten V-A diagram these two types are only identified separately between 379 and 356 cm and from 90 cm upwards. The unidentified small *Rumex* pollen grains fall within the *Rumex acetosa/acetosella* pollen type. A few centimetres before the beginning of zone 4a, two other pollen types show a slight increase: Chenopodiaceae and *Artemisia*, which occur more regularly from 380 cm and 378 cm upwards, respectively. At a depth of 370 cm, two important pollen types appear. The first is *Plantago lanceolata*. As indicated in I.4.2, *Plantago lanceolata* is a clear indicator

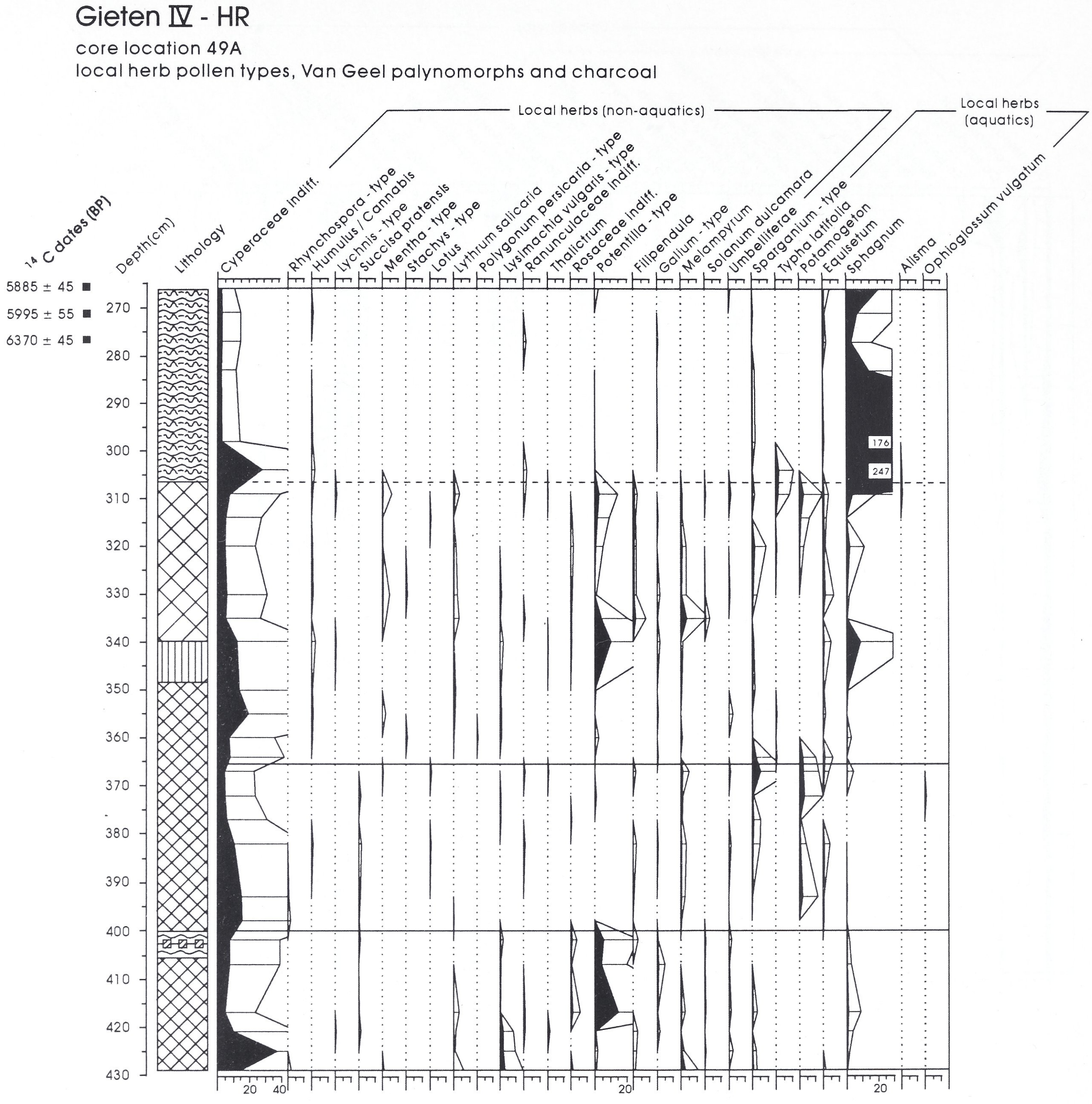
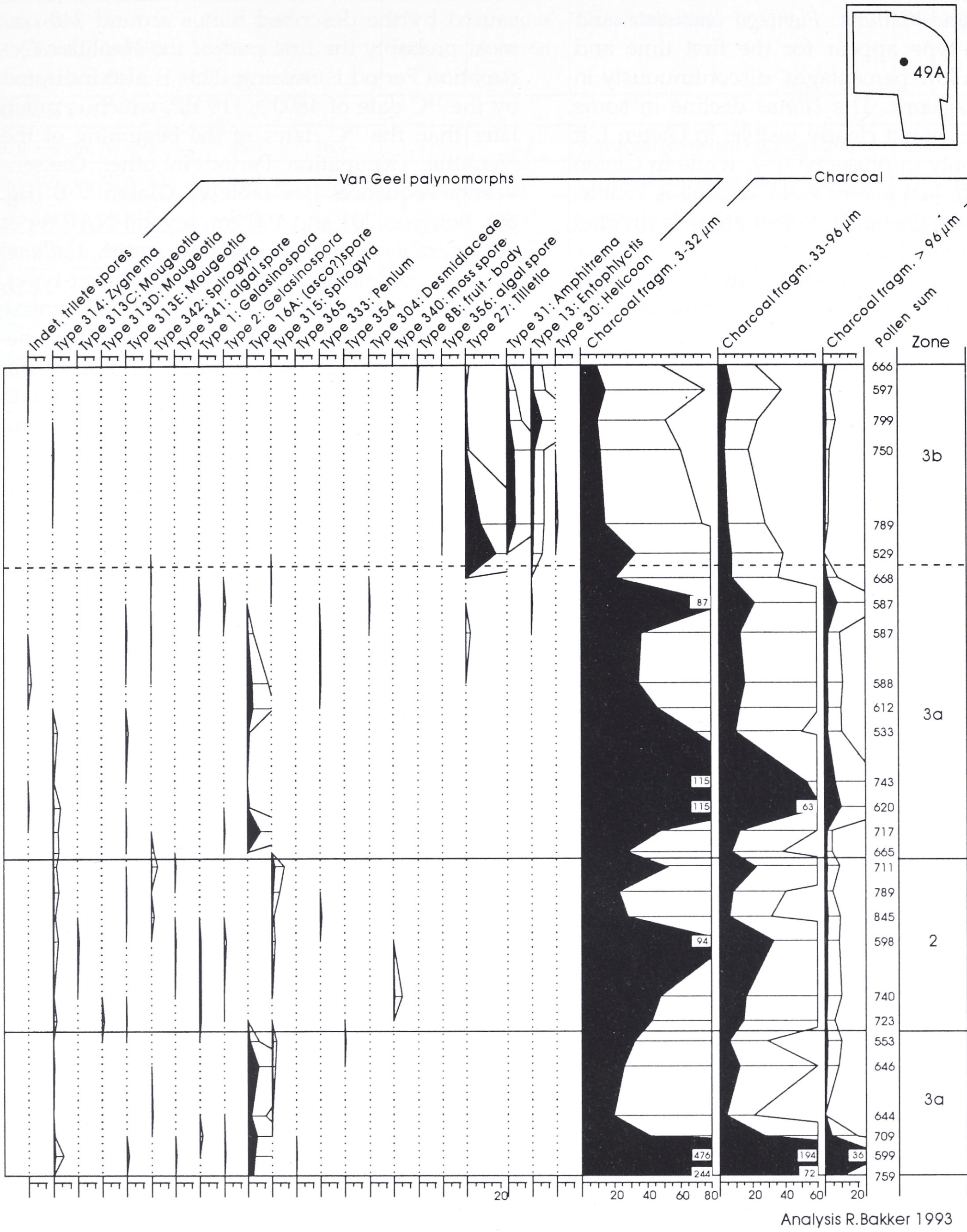


Fig. 55 (continued).

species for human agricultural activity. The second is Cerealia-type, originating from cereals. Between 370 and 362 cm, all pollen grains belonging to Cerealia-type are identified as *Triticum* sp. Between 361 and 290 cm, there are grains belonging to *Triticum* sp. as well as to the *Hordeum* group (see table 8). Between 367 and 365 cm, *Plantago lanceolata* increases from 0.3 to 2.1%. Between 300 and 280 cm, the most common NAP types (Gramineae indiff. and *Calluna*) increase. Already some time earlier, from 320 cm upwards, *Vaccinium*-type, like *Calluna* belonging to the Ericaceae family, begins to appear more frequently. The culture-indicator pollen types, namely Cerealia-type, *Rumex acetosa/acetosella* and *Plantago lanceolata*, also increase in this period. *Pteridium* reaches relatively high values around 357 cm.

Charcoal. The percentage of small charcoal particles (3-32 µm) and medium-sized charcoal particles (32-96 µm) increases substantially from



370 cm upwards. Between 290 and 270 cm, the percentage of charcoal particles (small and medium-sized) decreases.

Subdivision of the Neolithic Occupation Period. The Neolithic Occupation Period (NOP) is equivalent to local zone 4a. It is subdivided into three Neolithic Occupation Phases (these phases are also indicated in the pollen diagrams):

❑ **Phase NOP-1**
Gieten V-A: 376.5-366.5 cm

Gieten I: 363.8-358.3 cm; Gieten II: 366.5-363.5 cm; Gieten III: 348.1-334.1 cm; Gieten V-B: 262.5-222.5 cm; Gieten V-D: 222-206 cm

Decrease of *Ulmus* and *Betula*. *Quercus* and *Tilia* reach maximum values. Beginning of the increase of Gramineae indiff., *Rumex* *acetosa* and *Calluna*. *Plantago lanceolata* and Cerealia-type appear for the first time and occur in low percentages, discontinuously in most diagrams. The *Ulmus* decline in some diagrams is not clearly visible: in Gieten I, it occurs only in phase NOP-2, while in Gieten II and III, just a very weak decline is visible. In diagram Gieten V-A, this phase is divided into two subphases:

Phase NOP-1a: 376.5-370.5 cm. Beginning of the *Ulmus* decline. Beginning of the increase of Gramineae indiff. and *Calluna*. *Plantago lanceolata* and Cerealia-type are absent.

Phase NOP-1b: 370.5-366.5 cm. The *Ulmus* decline continues, as does the increase of Gramineae indiff. and *Calluna*. *Plantago lanceolata* and Cerealia-type (all *Triticum* sp., see table 8) appear for the first time. *Rumex acetosa* clearly increases.

If the beginning of the *Ulmus* decline together with the increase of Gramineae indiff. and *Calluna* coincide with the first appearance of *Plantago lanceolata*, as is the case in the other Gietsenveentje diagrams, only a general phase NOP-1 is distinguished.

- **Phase NOP-2**

  Gieten V-A: 366.5-345 cm

  Gieten I: 358.3-313.8 cm; Gieten II: 363.5-345 cm; Gieten III: 334.1-322 cm; Gieten V-B: 222.5-207.5 cm; Gieten V-D: 206-160 cm

  Betula stabilizes at values of ca. 15%. *Tilia* decreases considerably. *Pteridium*, Gramineae indiff., *Calluna*, Cerealia-type (*Triticum* sp. and *Hordeum* group, see table 8), *Rumex acetosa* and *Plantago lanceolata* reach relatively high values. From now on, *Plantago lanceolata* forms a continuous curve.

- **Phase NOP-3**

  Gieten V-A: 345-285 cm

  Gieten I: 313.8-272.9 cm; Gieten V-D: 160-135 cm

  The AP types stabilize. Gramineae indiff., *Calluna*, Cerealia-type, *Rumex acetosa/acetosella* and *Plantago lanceolata* all decrease. In Gieten I and V-D, *Pteridium* also decreases.

Zone definition. A zone boundary is located at a depth of 285 cm, because of the considerable changes in the values of especially *Quercus* and the NAP. Because of maxima of *Quercus* and *Fraxinus*, the zone between 376.5 and 285 cm is called the *Quercus-Fraxinus* zone, local zone 4a.

Other diagrams: Gieten III (fig. 53). The beginning of the Neolithic Occupation Period in this sequence differs completely from the picture in other Gietsenveentje sequences. This may be caused by the described hiatus around 348 cm: most probably the first part of the Neolithic Occupation Period is missing. This is also indicated by the ^{14}C date of 4800 ± 110 BP, which is much later than the ^{14}C dates of the beginning of the Neolithic Occupation Period in other Gietsenveentje sequences (see table 9). **Gieten V-B (fig. 58).** Between 201 and 190 cm, several NAP types considerably decline (Gramineae indiff., *Calluna*) or even completely disappear (all *Rumex*-types, *Plantago lanceolata*), causing a temporary decrease of total NAP to less than 15%. The lithology between 205 and 190 cm consists of poorly humified *Sphagnum* peat, around 205 cm also with *Eriophorum* remains. This layer of poorly humified *Sphagnum* peat is deposited between two layers of moderately to highly humified *Sphagnum* peat. Two ^{14}C dates of this layer, at 205-206 cm and 195-196 cm, are 4740 ± 50 BP and 4755 ± 50 BP, respectively. When these dates are compared to the ^{14}C date of the sediment at 215-216 cm, 4455 ± 50 BP, there seems to be an inconsistency: sediment of an older age seems to be deposited above sediment of a younger age. A possible explanation for the ^{14}C dates which are apparently too old and the different pollen picture of 201-190 cm is that a slab of hanging or floating material ended up on top of chronologically deposited sediment. **Gieten V-C (fig. 59).** At first sight, (a part of) the Neolithic Occupation Period seems to occur in the spectra of 64 and 63 cm. There are no ^{14}C dates of these two spectra, but ^{14}C dates of the sediment at 65-66 cm and 60-61 cm are 5995 ± 55 BP and 6530 ± 80 BP, respectively. Apart from the fact that these two dates are not chronologically in the right order, they are both far too old to represent the Neolithic Occupation Period. The pollen percentages of the various trees cannot be correlated with the corresponding figures in the Neolithic Occupation Period of other Gietsenveentje diagrams: notably the percentage of *Quercus* remains far too low (increases to 25-30% in most other diagrams) and the percentage of *Betula* remains high (decreases to 10-15% in most other diagrams). The presence of grains of *Secale cereale* seems to indicate that the sediment is of a younger age, because in Drenthe, *Secale cereale* was cultivated only from the Roman Age onwards (VAN ZEIST 1976). Possible disturbance of the sediment from 75 cm upwards may be responsible for the contradictory data. For this reason, it is not clear whether the Neolithic Occupation Period occurs at all in the spectra of 64 and 63 cm.

Sequence, depth and Neolithic Occupation Phase	Polar and equatorial diameter (µm)	P/E ratio	Annulus diameter (µm)	Ornamentation	Identification
Gieten V-A					
370-371 cm, NOP-1	48.0 x 46.4	1.03	12.8	verrucate (crowded/aggreg. col.)	Triticum sp.
364-365 cm, NOP-2	44.8 x 43.2	1.04	12.8	verrucate (crowded/aggreg. col.)	Triticum sp.
363-364 cm, NOP-2	59.2 x 54.4	1.09	16.0	verrucate (crowded/aggreg. col.)	Triticum sp.
362-363 cm, NOP-2	48.0 x 40.0	1.20	9.6	verrucate (crowded/aggreg. col.)	Triticum sp.
361-362 cm, NOP-2	44.8 x 41.6	1.08	8.0	scabrate	Hordeum group
359-360 cm, NOP-2	54.4 x ± 48.0	1.13	14.4	verrucate (crowded/aggreg. col.)	Triticum sp.
358-359 cm, NOP-2	± 44.8 x 38.4	1.17	9.6	scabrate	Hordeum group
350-351 cm, NOP-2	± 44.8 x 38.4	1.17	9.6	scabrate	Hordeum group
350-351 cm, NOP-2	44.8 x 41.6	1.08	12.8	verrucate (crowded/aggreg. col.)	Triticum sp.
Gieten V-B					
235-236 cm, NOP-1	40.0 x ± 38.4	1.04	9.6	scabrate	Hordeum group
235-236 cm, NOP-1	41.6 x 41.6	1.00	10.2	scabrate	Hordeum group
225-226 cm, NOP-1	44.8 x ± 32.0	1.40	12.2	verrucate (crowded/aggreg. col.)	Triticum sp.
210-211 cm, NOP-2	± 48.0 x 41.6	1.15	9.6	scabrate	Hordeum group
210-211 cm, NOP-2	45.4 x 35.2	1.29	10.2	verrucate (crowded/aggreg. col.)	Triticum sp.
205-206 cm	48.0 x 38.4	1.25	10.2	verrucate (crowded/aggreg. col.)	Triticum sp.
205-206 cm	46.4 x 40.0	1.16	9.6	scabrate	Hordeum group
201-202 cm	48.0 x 34.2	1.40	9.6	scabrate	Hordeum group
Gieten V-C					
74-75 cm	43.2 x 40.0	1.08	10.2	scabrate	Hordeum group
72-73 cm	± 48.0 x 40.0	1.20	8.0	indistinct	Hordeum group
67-68 cm	48.0 x 38.4	1.25	10.2	indistinct	Triticum sp.
66-67 cm	48.0 x 38.4	1.25	11.2	verrucate (crowded/aggreg. col.)	Triticum sp.
66-67 cm	46.4 x 41.6	1.12	8.0	scabrate	Hordeum group
64-65 cm	± 48.0 x 38.4	1.25	12.8	indistinct	Triticum sp.
64-65 cm	44.8 x 32.0	1.40	9.6	scabrate	Hordeum group
63-64 cm	48.0 x ± 32.0	1.50	9.6	scabrate	Hordeum group
63-64 cm	45.4 x 34.6	1.31	9.6	scabrate	Hordeum group
63-64 cm	48.0 x 34.6	1.39	9.6	scabrate	Secale cereale
63-64 cm	48.0 x 28.8	1.67	9.0	scabrate	Secale cereale
63-64 cm	44.8 x 24.0	1.87	9.6	scabrate	Secale cereale
63-64 cm	48.0 x 40.0	1.20	10.2	scabrate	Hordeum group
Gieten V-D					
203-204 cm, NOP-2	± 41.6 x 38.4	1.08	8.6	scabrate	Hordeum group
203-204 cm, NOP-2	40.0 x 28.3	1.41	8.0	indistinct	Hordeum group

Table 8. Identifications of Cerealia-type pollen in Gietsenveentje sequences (see GROHNE 1957; BEUG 1961; S.T. ANDERSEN 1979; DICKSON 1988). All measurements are in silicone oil. ±: measurement is influenced by crumpling or folding. P/E ratio: ratio between polar and equatorial diameter. Crowded/aggreg. col.: crowded/aggregated columellae.

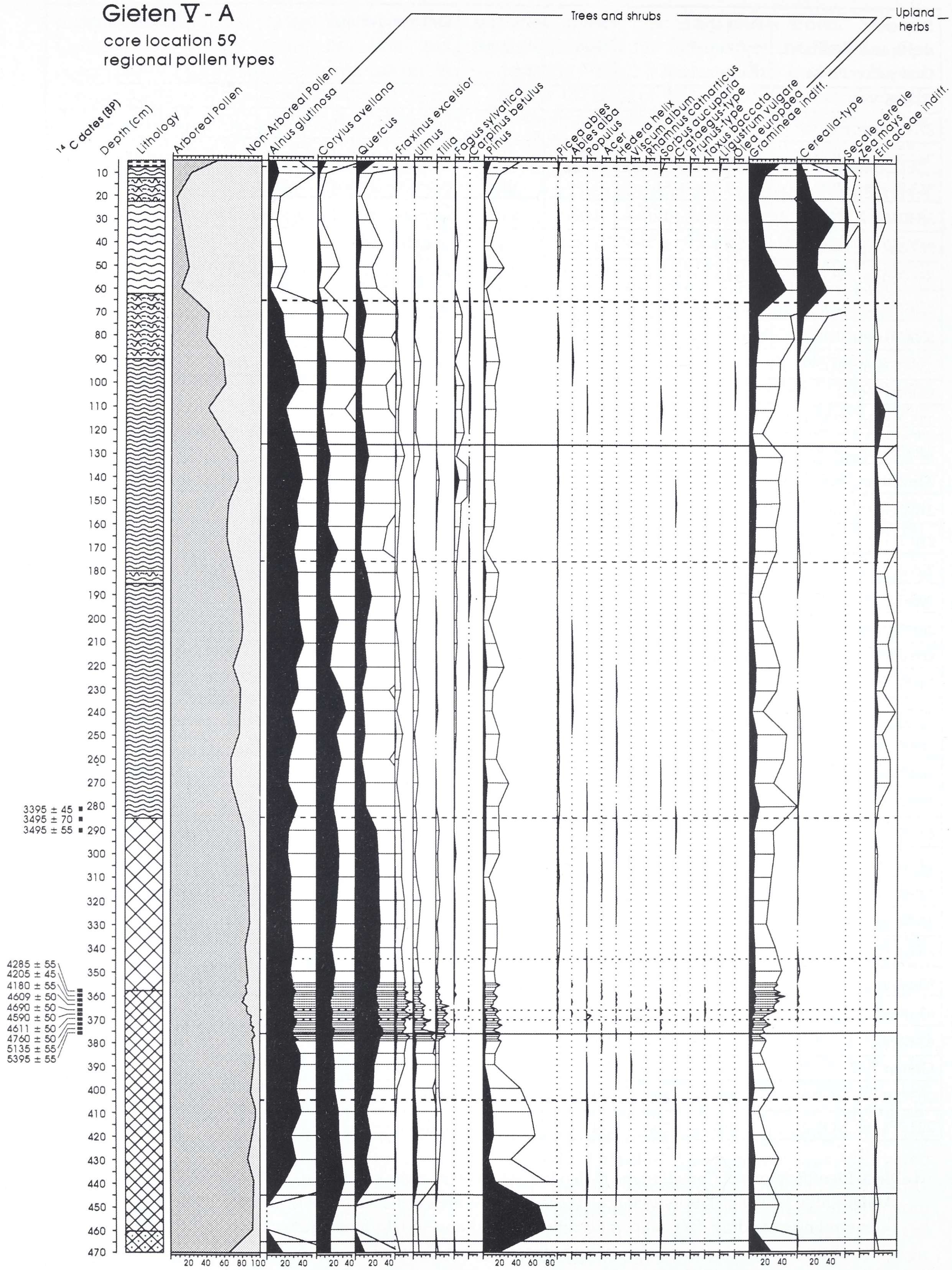
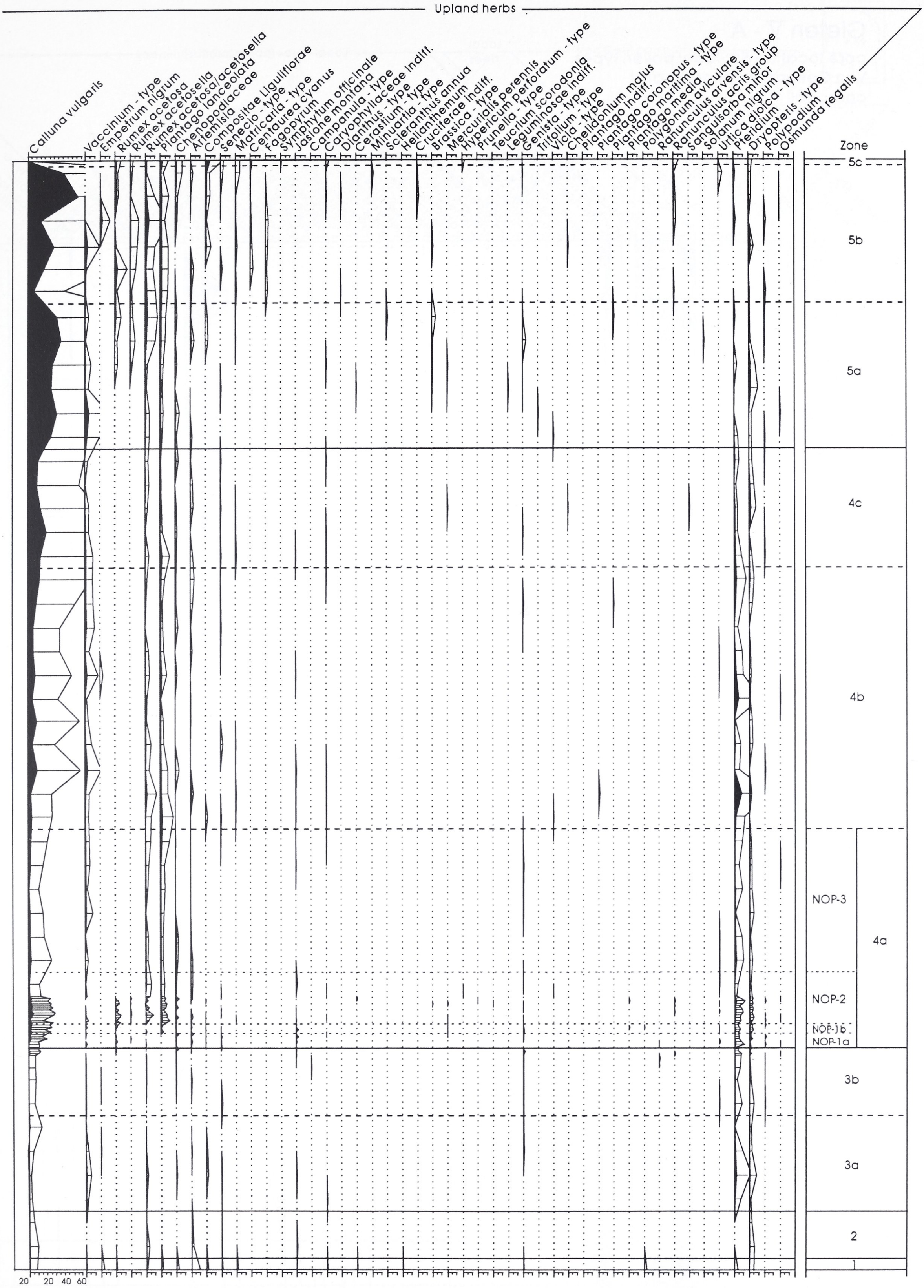


Fig. 56. Pollen diagram of sequence Gieten V-A, the Gietsenveentje master pollen diagram.



Upland herbs
Calluna vulgaris
Vaccinium - type
Empetrum nigrum
Rumex acetosa
Rumex acetosella
Rumex acetosa/acetosella
Plantago lanceolata
Chenopodiaceae
Artemisia
Compositae Liguliflorae
Senecio - type
Matricaria - type
Centaurea cyanus
Fagopyrum
Symphytum officinale
Jasione montana
Campanula - type
Caryophyllaceae indiff.
Dianthus - type
Cerastium - type
Minuartia - type
Scleranthus annua
Helianthemum
Cruciferae indiff.
Brassica - type
Mercurialis perennis
Hypericum perforatum - type
Prunella - type
Teucrium scorodonia
Leguminosae indiff.
Genista - type
Trifolium - type
Vicia - type
Chelidonium majus
Plantago indiff.
Plantago coronopus - type
Plantago maritima - type
Plantago media
Polygonum aviculare
Ranunculus arvensis - type
Ranunculus acris group
Sanguisorba minor
Solanum nigrum
Urtica dioica - type
Pteridium
Dryopteris - type
Polypodium
Osmunda regalis
Zone
5c
5b
5a
4c
4b
NOP-3
4a
NOP-2
NOP-1b
NOP-1a
3b
3a
2
1
20
20 40 60

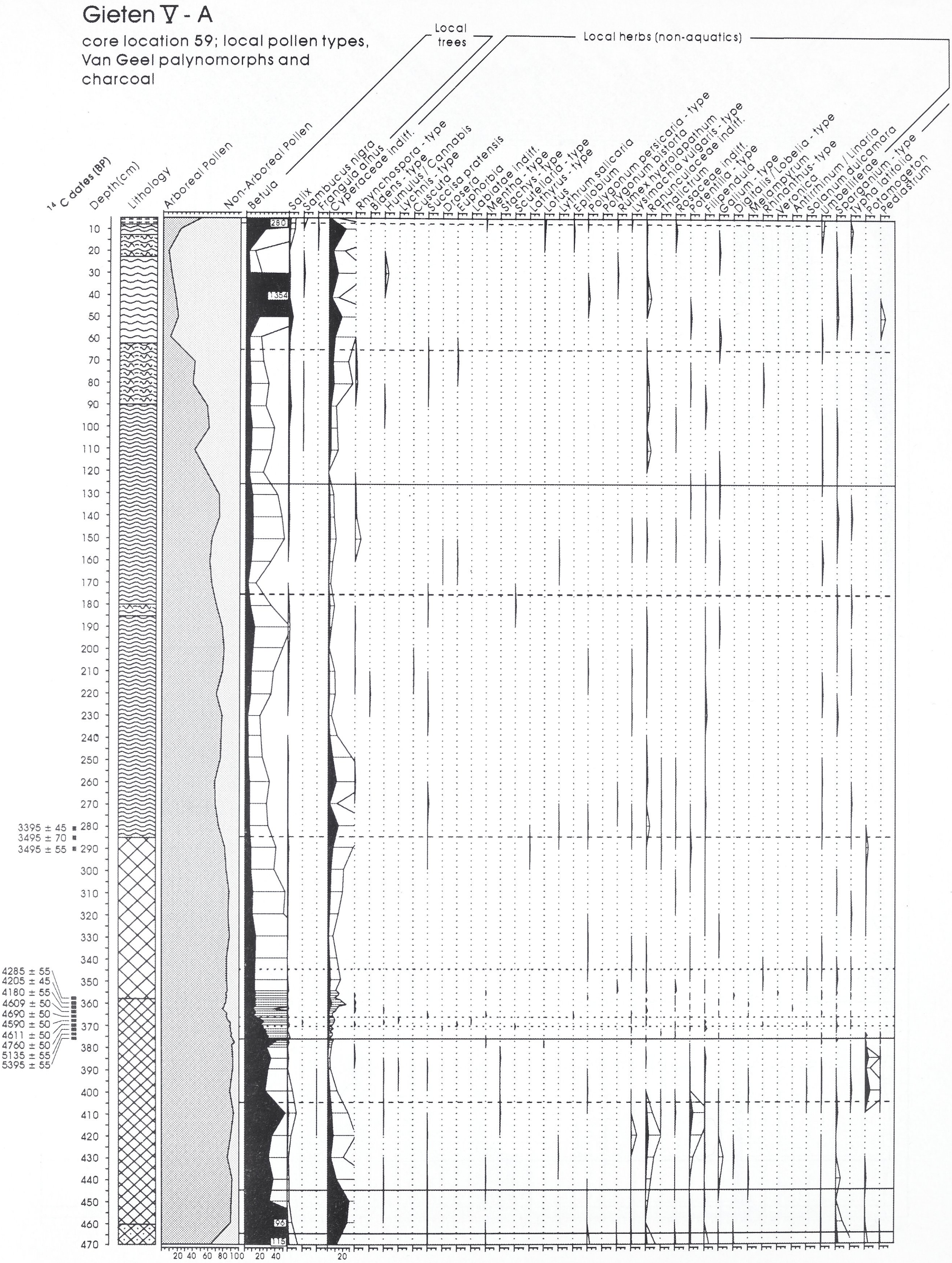
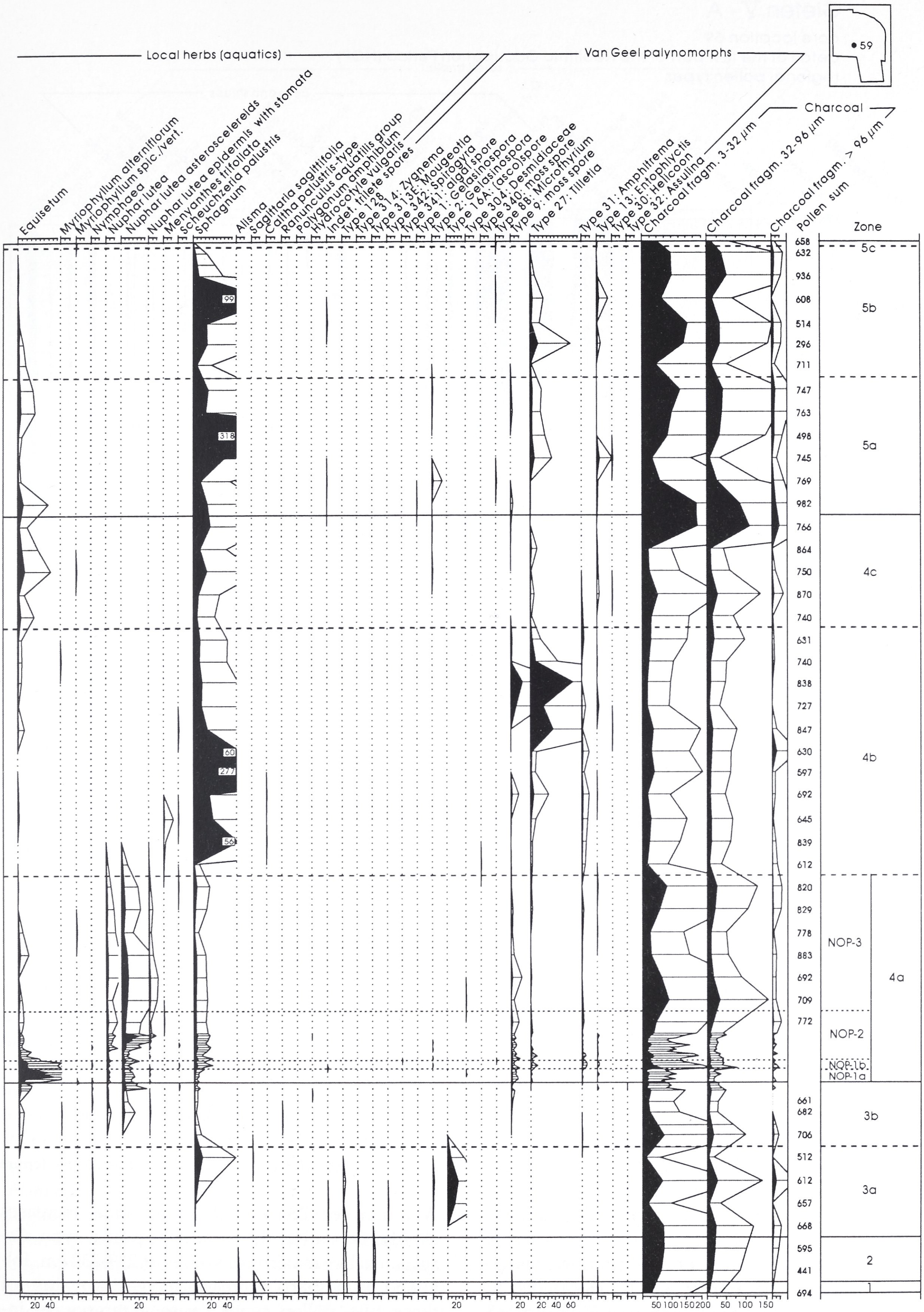


Fig. 56 (continued).


Local herbs (aquatics)
Van Geel palynomorphs
Charcoal
59
Equisetum
Myriophyllum alterniflorum
Myriophyllum spic./vert.
Nymphaea
Nuphar lutea
Nuphar lutea asterosclereids
Nuphar lutea epidermis with stomata
Menyanthes trifoliata
Scheuchzeria palustris
Sphagnum
Alisma
Sagittaria sagittifolia
Caltha palustris-type
Ranunculus aquatilis group
Polygonum amphibium
Hydrocotyle vulgaris
Indet. trilete spores
Type 128
Type 314: Zygnema
Type 313E: Mougeotia
Type 342: Spirogyra
Type 341: algal spore
Type 1: Gelasinospora
Type 2: Gelasinospora
Type 16A: (asco)spore
Type 304: Desmidiaceae
Type 340: moss spore
Type 8B: Microthyrium
Type 9: moss spore
Type 27: Tilletia
Type 31: Amphitrema
Type 13: Entophlyctis
Type 30: Helicoon
Type 32: Assulina
Charcoal fragm. 3-32 µm
Charcoal fragm. 32-96 µm
Charcoal fragm. > 96 µm
Pollen sum
Zone
5c
5b
5a
4c
4b
4a
NOP-3
NOP-2
NOP-1b
NOP-1a
3b
3a
2
1
99
318
60
277
56
20 40
20
50 100 150 200
50 100 150
Analysis R.Bakker 1993/1994

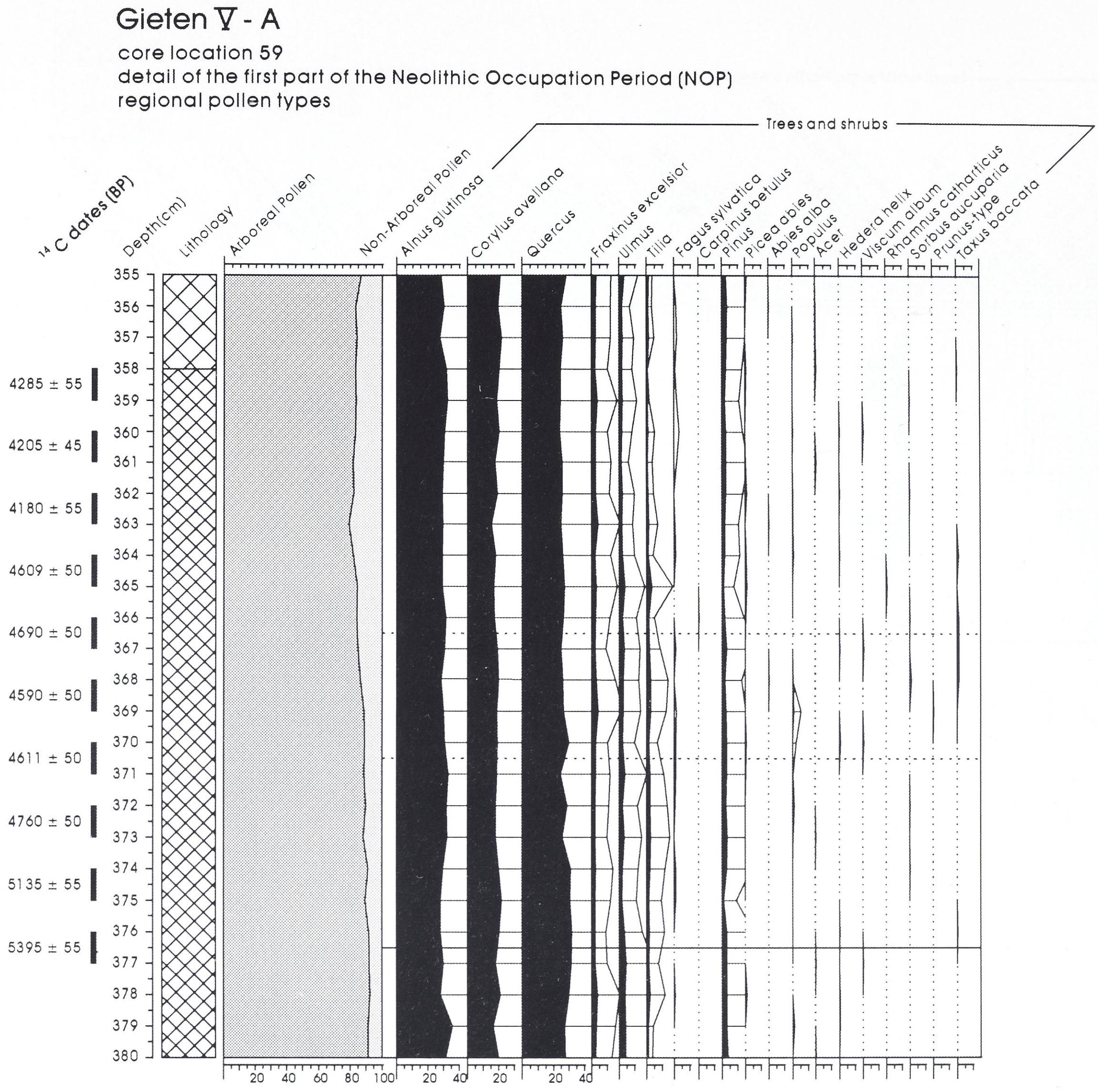


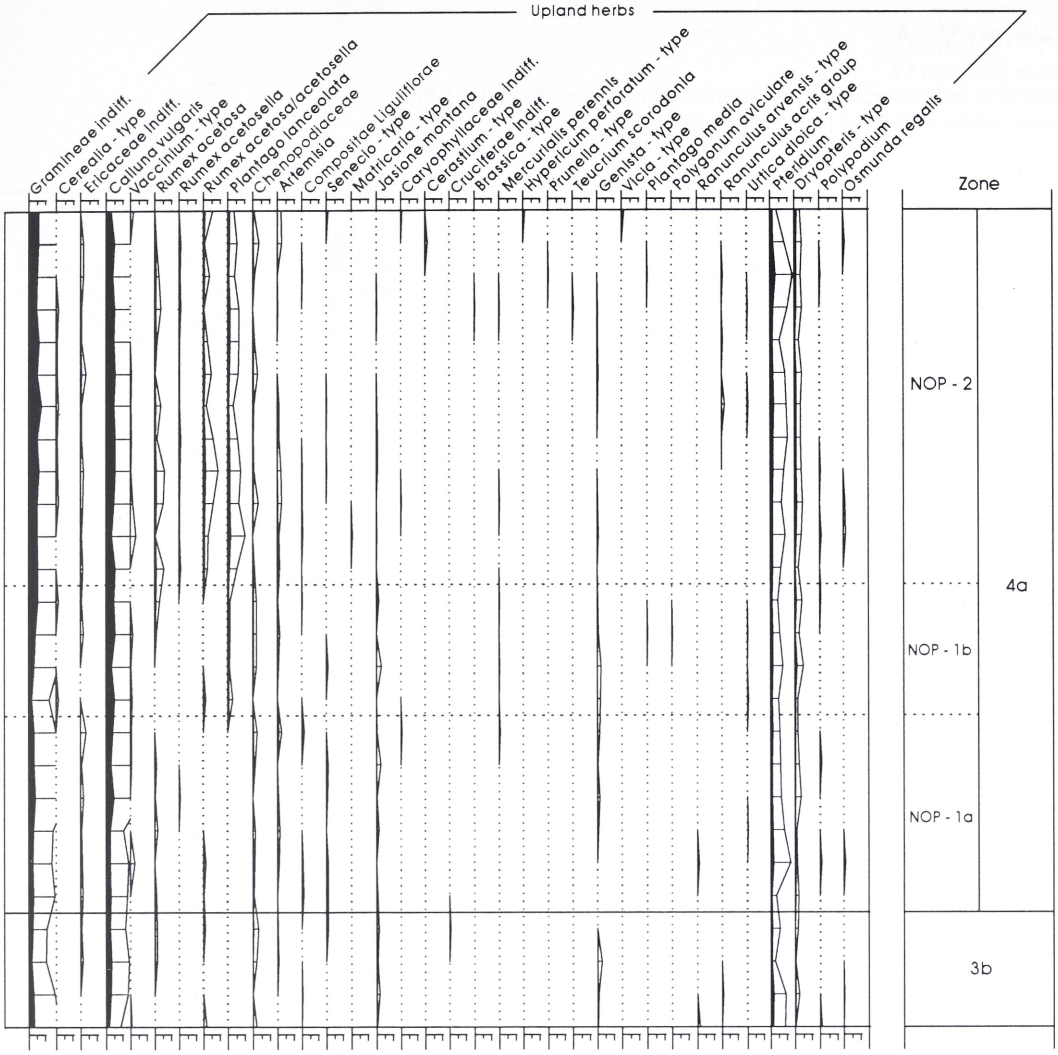
Fig. 57. Detailed pollen diagram of sequence Gieten V-A: the first part of the Neolithic Occupation Period.

Gieten V-D (fig. 60). In the upper three spectra of the diagram (155-135 cm) some conspicuous changes are observed: at 155 cm, *Alnus* reaches a percentage of more than 55%, *Quercus* decreases to less than 10%, Gramineae indiff. decrease to (almost) zero and *Calluna* reaches its maximum value; at 145 cm, Ericaceae indiff. and *Vaccinium*-type reach maximum values; at 135 cm, *Calluna* again dominates the NAP. Apparently lithology changes are responsible for these fluctuations. Between 180 and 158 cm, a fine detritus gyttja gradually changes into a poorly humified *Sphagnum* peat. The two spectra which are situated in the poorly humified *Sphagnum* peat (155 and 145 cm) show a different pollen content, not only as regards local types, but also in the AP and NAP. Most conspicuous is a very large *Sphagnum* peak (384%) at 155 cm, but also peaks of small and medium-sized charcoal particles are observed.

Zone 4b - *Alnus*-*Corylus*-Ericaceae zone
Gieten V-A: 285-175 cm

Gieten I: 272.9-221.8 cm; Gieten V-C: 64.5-62.5 cm (entire zone 4)

AP. Between 285 and 210 cm, *Alnus* increases slowly, becoming the dominant pollen type. *Corylus* reaches maximum values at 239-230 cm, followed by a sharp decrease. Increasing values of these two pollen types cause a temporary increase of total AP. At 190-170 cm, *Quercus* de-



creases for the second time. The pollen values of *Fagus* rise very slowly from 249 cm upwards, while the values of *Tilia* drop to almost zero. From 220 cm upwards, pollen of *Carpinus* occurs more regularly. Pollen percentages of this type never exceed 0.3% in this sequence.

NAP. In the first spectra of this zone (280-260 cm), Gramineae indiff., *Rumex acetosa/acetosella*, *Plantago lanceolata* and *Pteridium* reach their highest values so far. A comparable picture is found in zone 4b of sequence Gieten I. From 260 cm upwards, the named types decrease again. Pollen types representing the Ericaceae family increase in this zone: *Calluna* at 270-260 cm and again at 190-160 cm, Ericaceae indiff. (possibly originating from *Erica*) from 270 cm upwards, and *Vaccinium*-type from 260 cm upwards.

Zone definition. Because of the decrease of *Quercus* and the increase of *Calluna*, a zone boundary is located at 175 cm. The zone between 285 and 175 cm is typified by a dominance of *Alnus* and *Corylus* in the AP and a dominance of *Calluna* (Ericaceae family) in the NAP: it is called the *Alnus*-*Corylus*-Ericaceae zone, local zone 4b.

Zone 4c - Ericaceae-*Alnus* zone
Gieten V-A: 175-125 cm

AP. Between 175 and 140 cm, the pollen values of most trees are more or less constant; only *Corylus* decreases somewhat, while *Fagus* increases: at

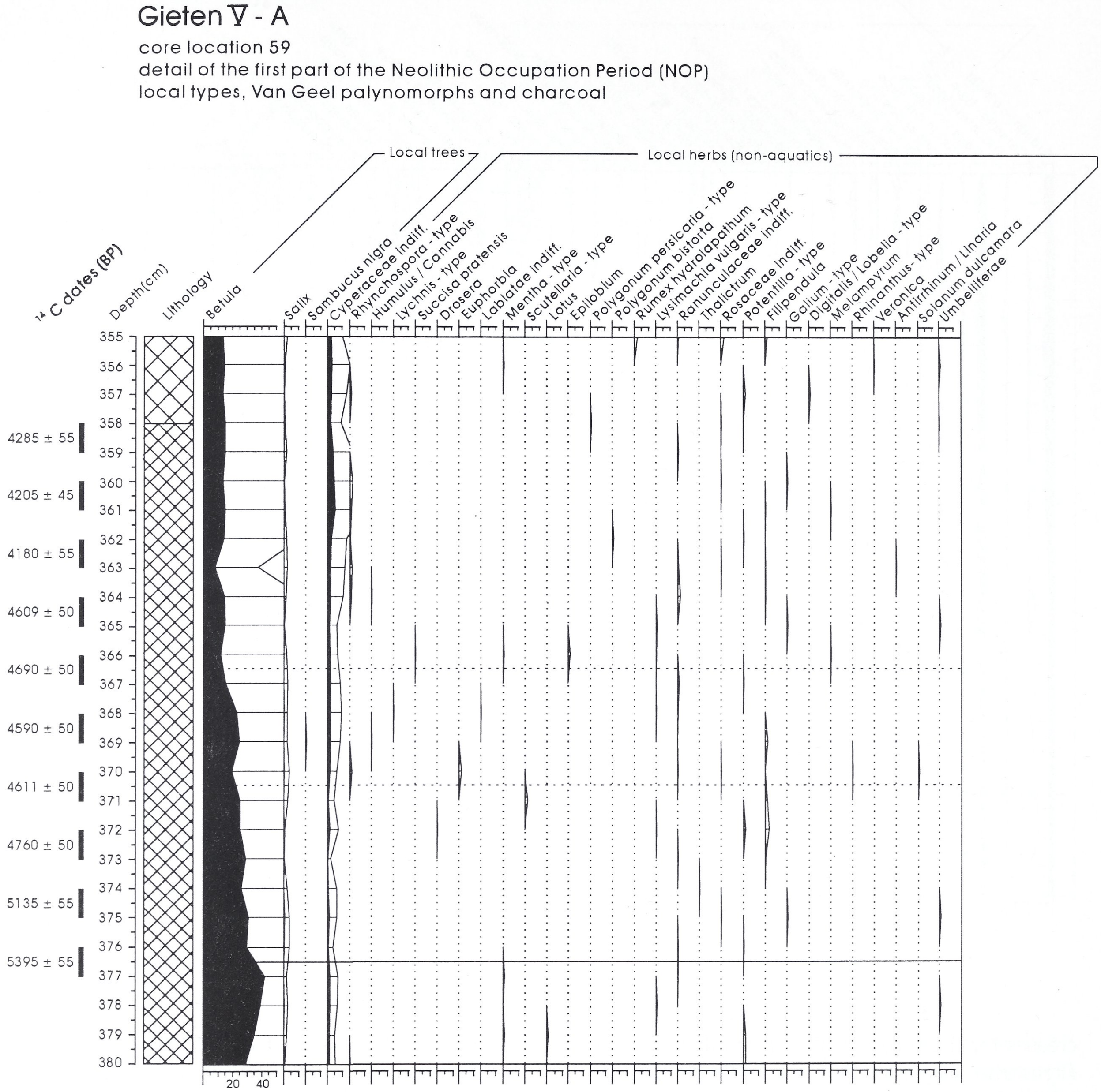


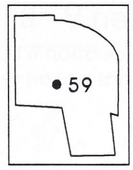
Fig. 57 (continued).

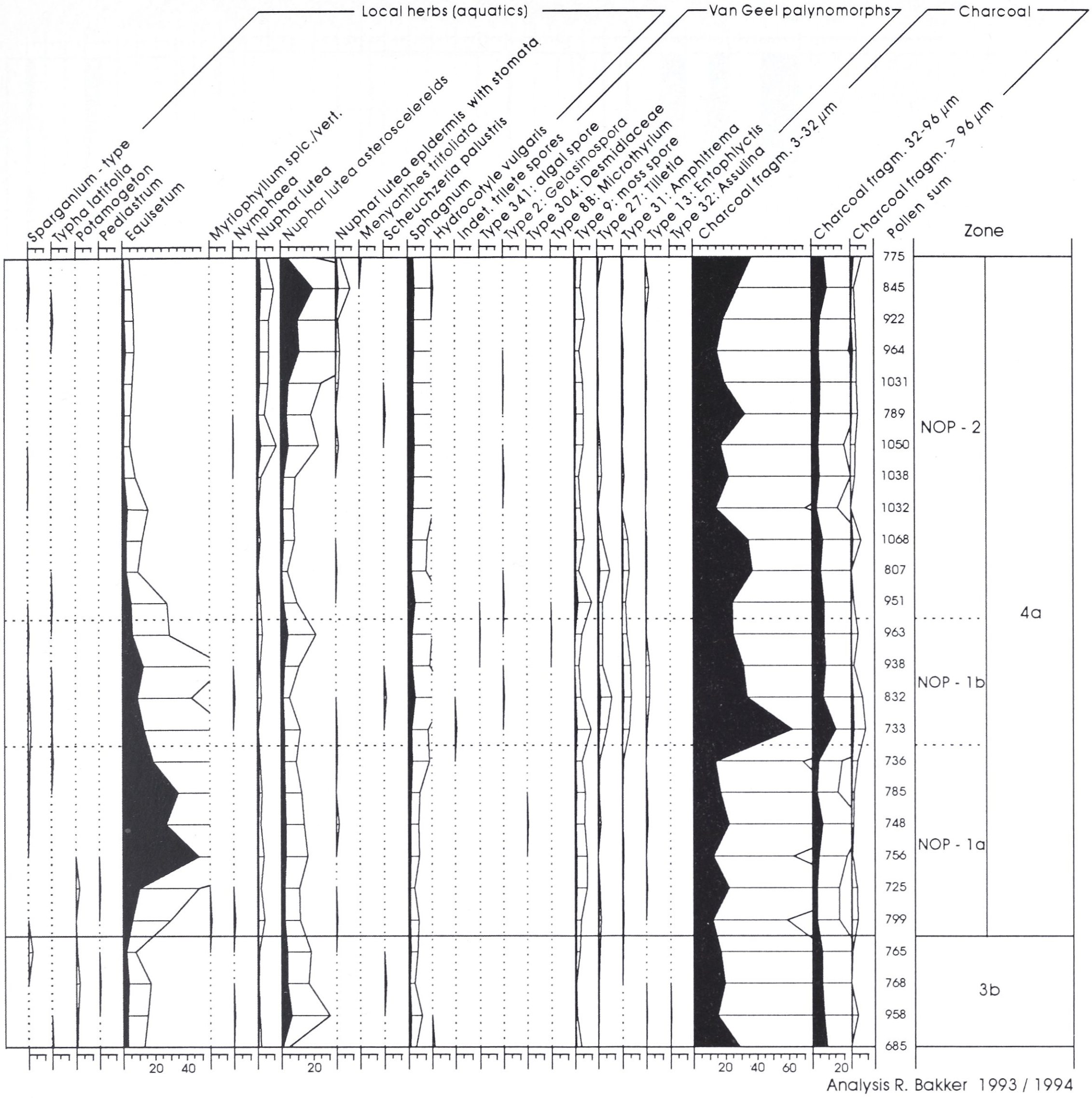
140 cm, the latter reaches a maximum value of 6.2%. Between 130 and 120 cm, the pollen values of *Alnus*, *Corylus* and *Quercus* all decrease.

NAP. Among the NAP types, a sharp increase of *Calluna* between 130 and 120 cm attracts attention. Ericaceae indiff. and *Vaccinium*-type also increase. Gramineae indiff. and the culture-indicator pollen types remain more or less constant. *Pteridium* decreases slowly to almost zero.

Charcoal. A very conspicuous feature is the enormous increase in the values of charcoal particles (all size categories) between 140 and 130 cm. From this increase upwards, the values of charcoal particles on average remain at a higher level.

Zone and period definition. Between 130 and 120 cm, the AP markedly decreases, while the NAP increases explosively from 26.8% to 44.1%, largely caused by an increase of pollen types of the Ericaceae family. For this reason, a zone boundary is drawn at 125 cm. The zone between





175 and 125 cm is called the Ericaceae-*Alnus* zone, local zone 4c.

The local zones 4a to 4c (376.5-125 cm) can be characterized by a general decrease of AP types, except for *Alnus* and *Fagus*, and a general increase of NAP types including the culture-indicator types. Placed in a regional perspective, these zones together represent the Subboreal (see III.6.2).

Zone 5a - Ericaceae-*Fagus* zone
Gieten V-A: 125-64.5 cm

AP. *Alnus* and *Corylus* decrease, from 100 cm and 90 cm upwards, respectively. Apart from the maximum at 140 cm, *Fagus* reaches its highest values in these spectra (ca. 2%). Between 70 and 59 cm, nearly all AP types strongly decline.

NAP. Ericaceae indiff. and *Vaccinium*-type decrease considerably to almost zero in the spec-

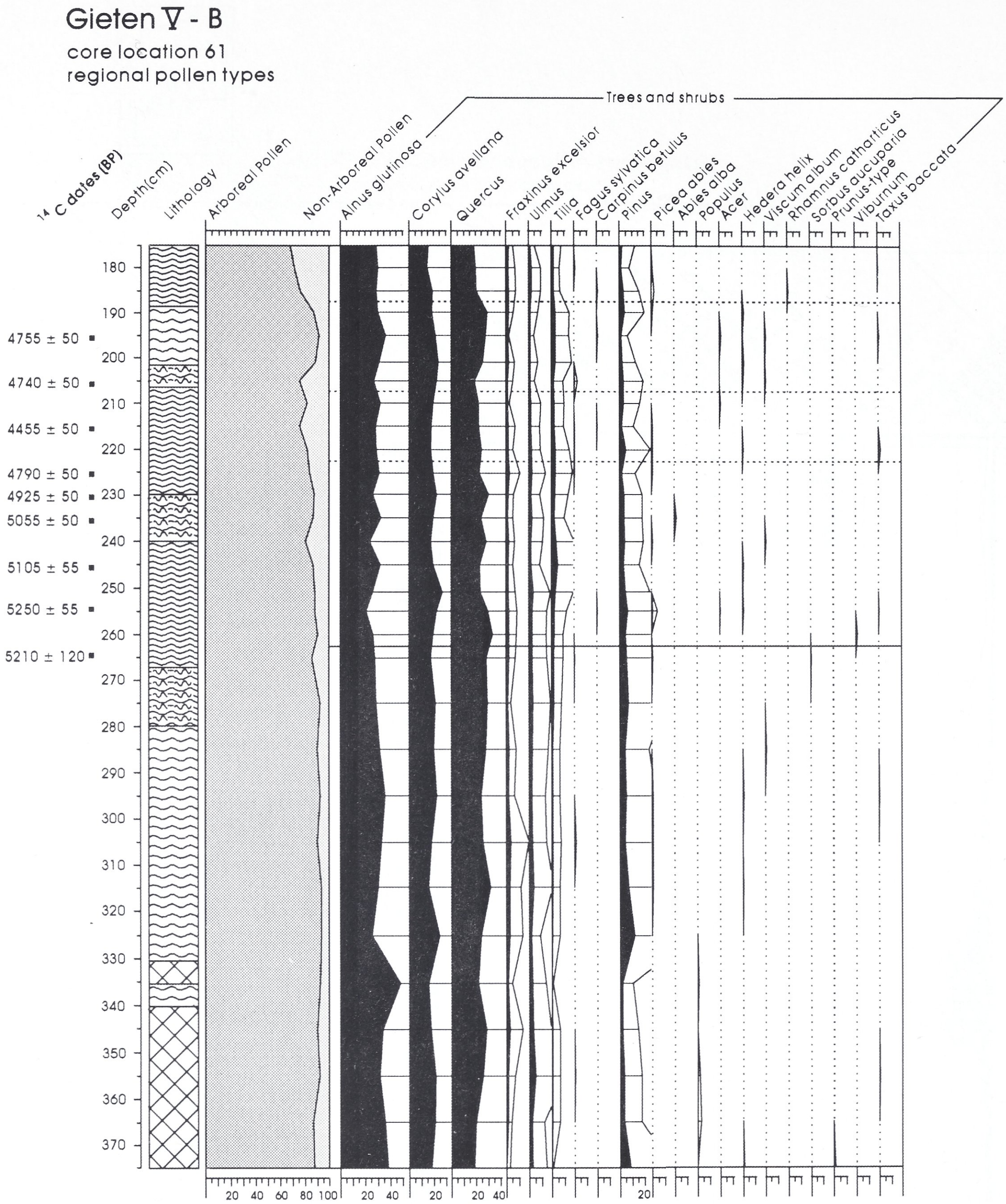


Fig. 58. Pollen diagram of sequence Gieten V-B.

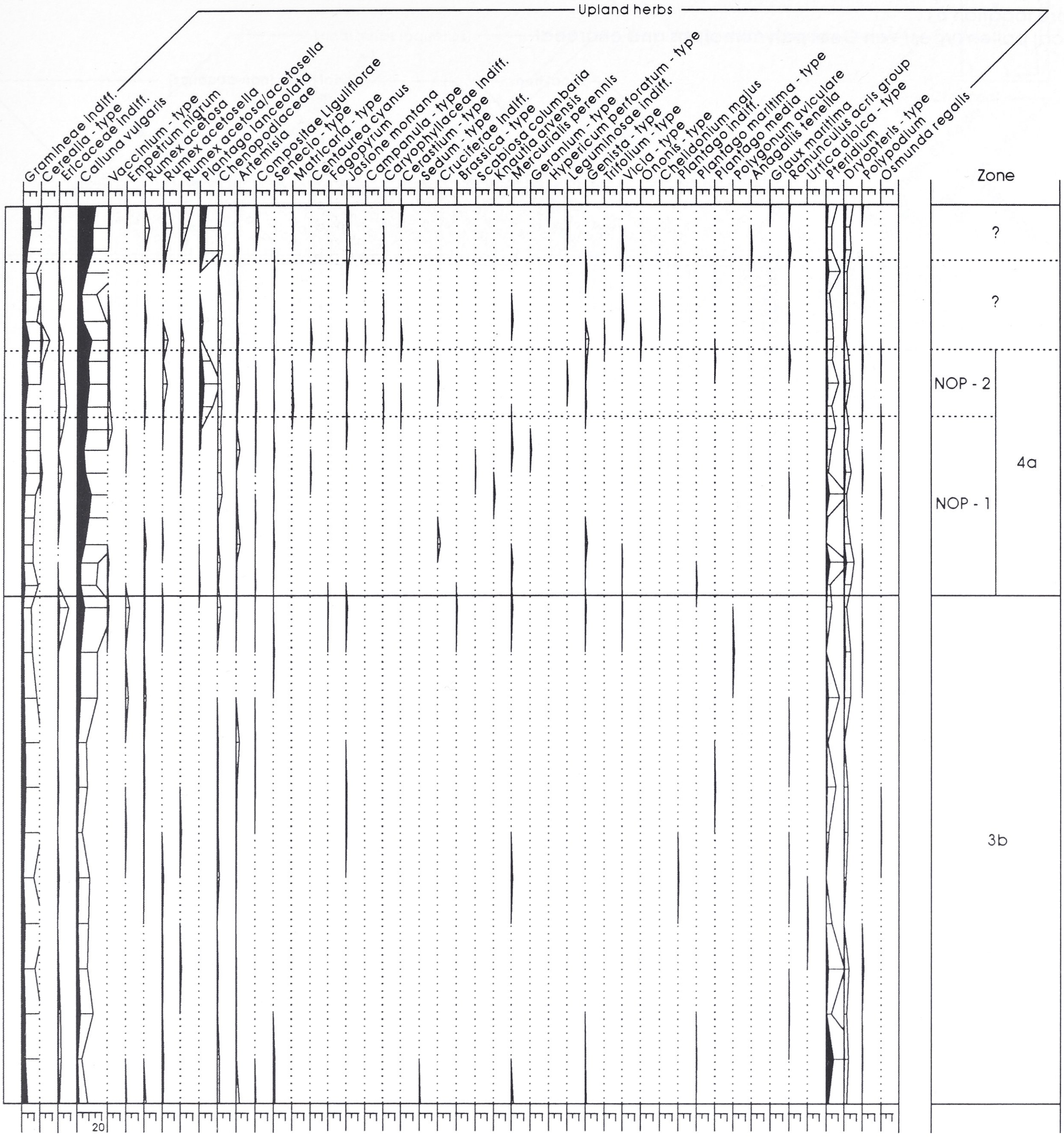
trum of 100 cm. Unidentified small *Rumex* pollen grains, united in *Rumex acetosa/acetosella*, and *Plantago lanceolata* increase from 90 cm upwards. From this depth upwards, an attempt has been made to separate *Rumex acetosa* and *Rumex acetosella*. Between 90 and 50 cm, they seem to occur more or less equally. Between 70 and 59 cm, Gramineae indiff. and Cerealia-type rise sharply, while *Calluna* decreases equally sharply.

Zone definition. Because of the decrease of almost all AP types and *Calluna* as well as the sharp increase of Gramineae indiff. and Cerealia-type between 70 and 59 cm, a zone boundary is located at 64.5 cm. The zone between 125 and 64.5 cm is called the Ericaceae-*Fagus* zone, local zone 5a.

Zone 5b - Gramineae-Cerealia-Ericaceae zone Gieten V-A: 64.5-7.5 cm

AP. The AP types do not play a significant role.

NAP. Between 64.5 and 7.5 cm, NAP types dominate the pollen picture, especially Grami-



neae indiff. and Cerealia-type, and to a smaller extent *Calluna*. By this time, the arable fields must have advanced to the edge of the pingo scar. Two distinct culture-indicator pollen types first appear in this period: *Centaurea cyanus* (from 50 cm upwards) and *Fagopyrum* (59 to 20 cm). Between 50 and 41 cm, *Rumex acetosa* decreases, while *Rumex acetosella* and unidentified small *Rumex* grains (*Rumex acetosa/acetosella*) increase. Two other pollen types, originating from species that often occur in ruderal places or fallow land (WEEDA et al. 1991, 25), also increase in this period: Compositae Liguliflorae and *Matricaria*-type (Compositae Tubuliflorae). Ericaceae indiff. and *Vaccinium*-type again display maximum values at 30 and 20 cm, respectively, but further up they rapidly decrease to (almost) zero.

Charcoal. The small charcoal particles (3-32 μm) again reach high values at 50-41 cm. The larger charcoal particles do not increase significantly.

Zone definition. Because of the increasing AP (from 20 to 50%) and the strongly decreasing

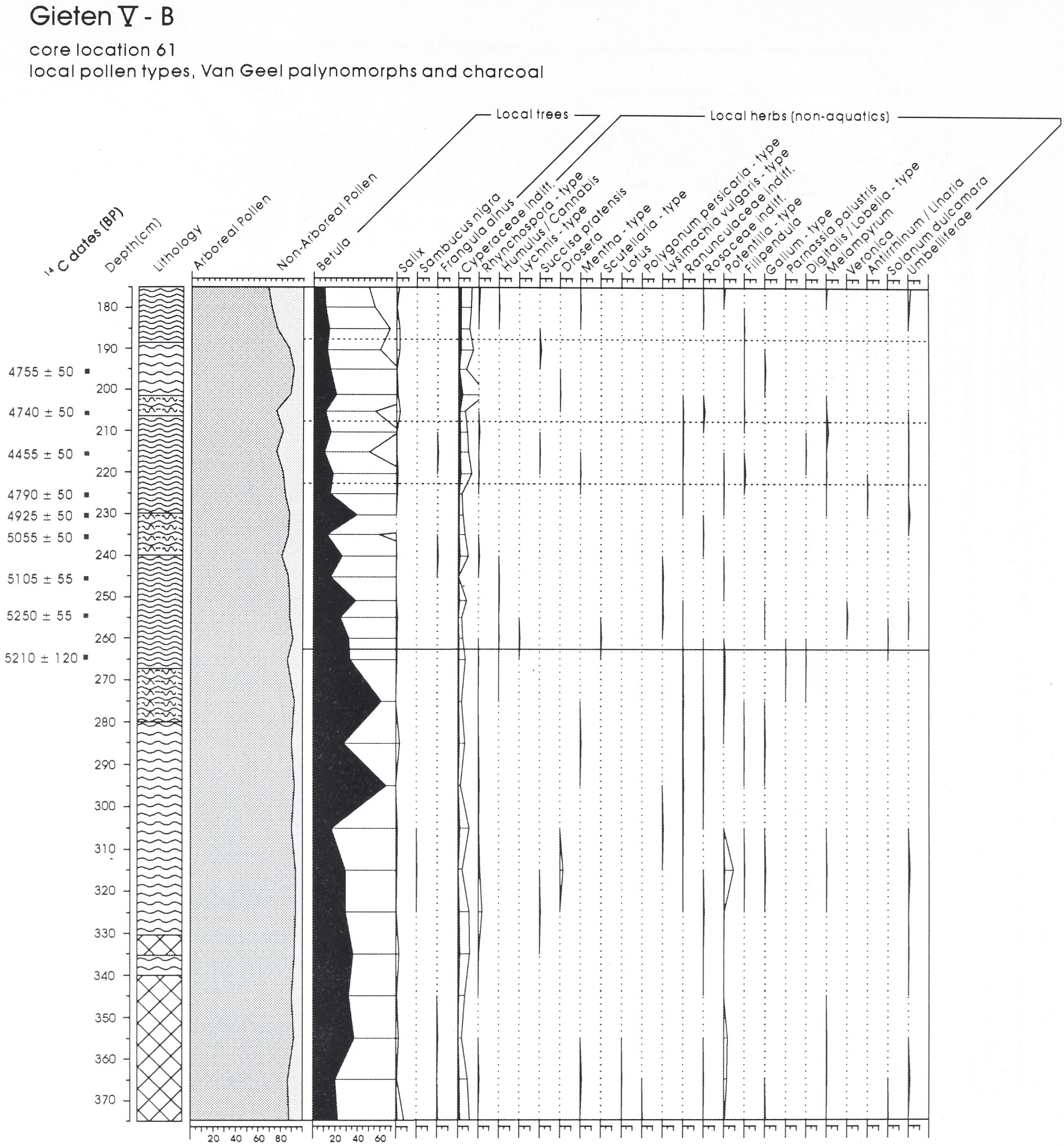


Fig. 58 (continued).

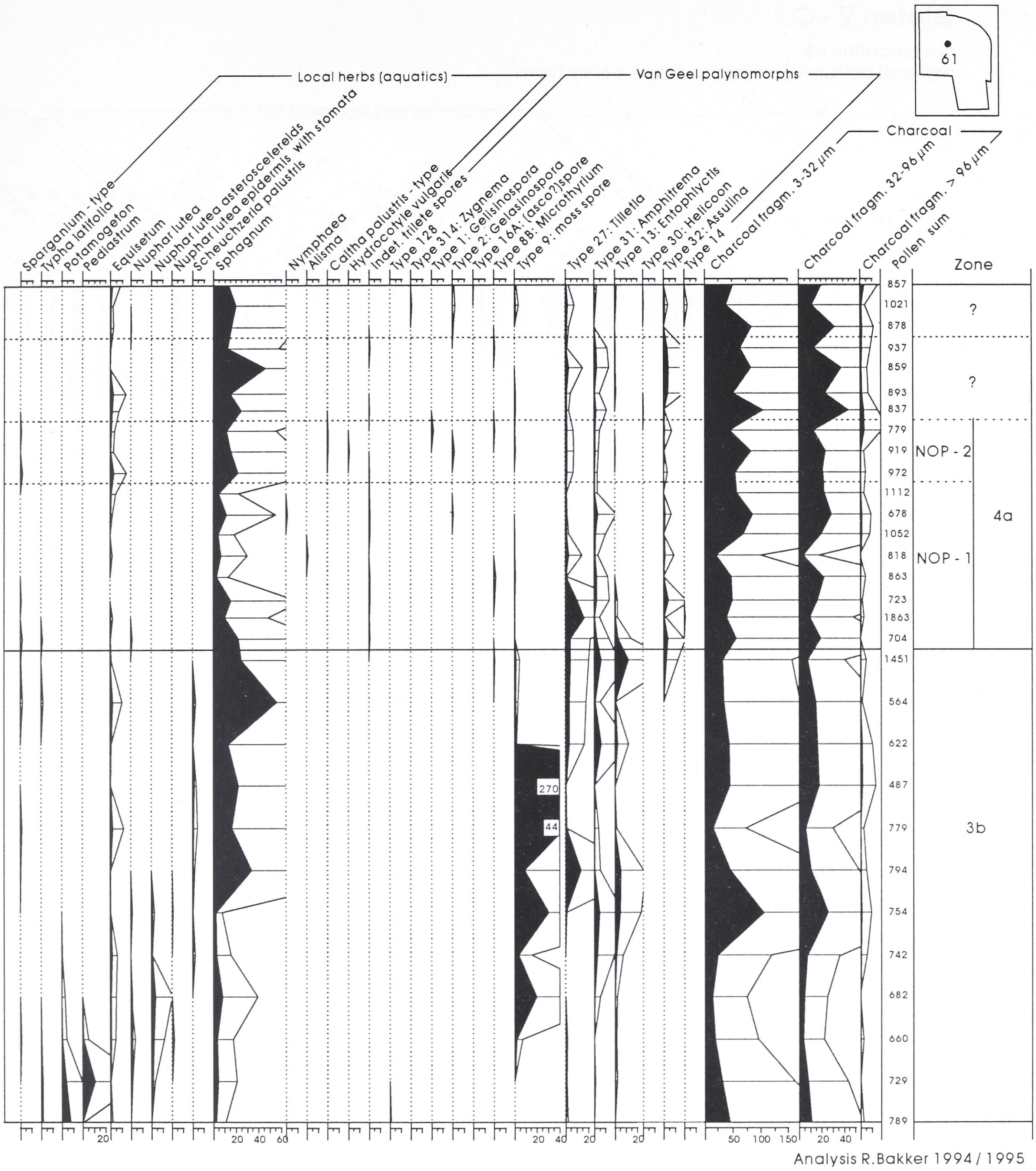
NAP (except Gramineae indiff.) a zone boundary is located between 10 and 5 cm. The zone between 64.5 and 7.5 cm is called the Gramineae-Cerealia-Ericaceae zone, local zone 5b.

Zone 5c - *Quercus*-Gramineae zone
Gieten V-A: 7.5-5 cm

AP. The spectrum of 5 cm, the uppermost spectrum of the sequence, displays a pollen assemblage completely different from the preceding spectra. Many AP types suddenly increase between 10 and 5 cm: *Alnus, Corylus, Quercus, Pinus* and even *Sorbus aucuparia*.

NAP. Among the NAP types, only Gramineae indiff. and some less frequent types like Chenopodiaceae, Compositae Liguliflorae, *Matricaria*- and *Senecio*-types, *Ranunculus acris* group and Umbelliferae increase; Cerealia-type and *Calluna* decrease to almost zero.

Zone and period definition. The zone formed by



the spectrum of 5 cm on its own, is called the *Quercus*-Gramineae zone, local zone 5c.

The local zones 5a to 5c (125-5 cm) are characterized by a further increasing influence of NAP types, particularly the culture-indicator types. Placed in a regional perspective, these zones together represent the Subatlantic (see III.6.2).

Comparison with surface sample. The pollen content of the spectrum of 5 cm, sampled near the surface of sequence Gieten V-A, can be compared with the pollen content of a surface sample from core location 59 (fig. 49), the spot where sequence Gieten V-A was cored (fig. 38). The pollen content of these two samples is quite similar: *Betula* pollen dominates (excluded from the pollen sum in sequence Gieten V-A), followed by *Quercus*; Gramineae indiff. are the most frequent NAP type.

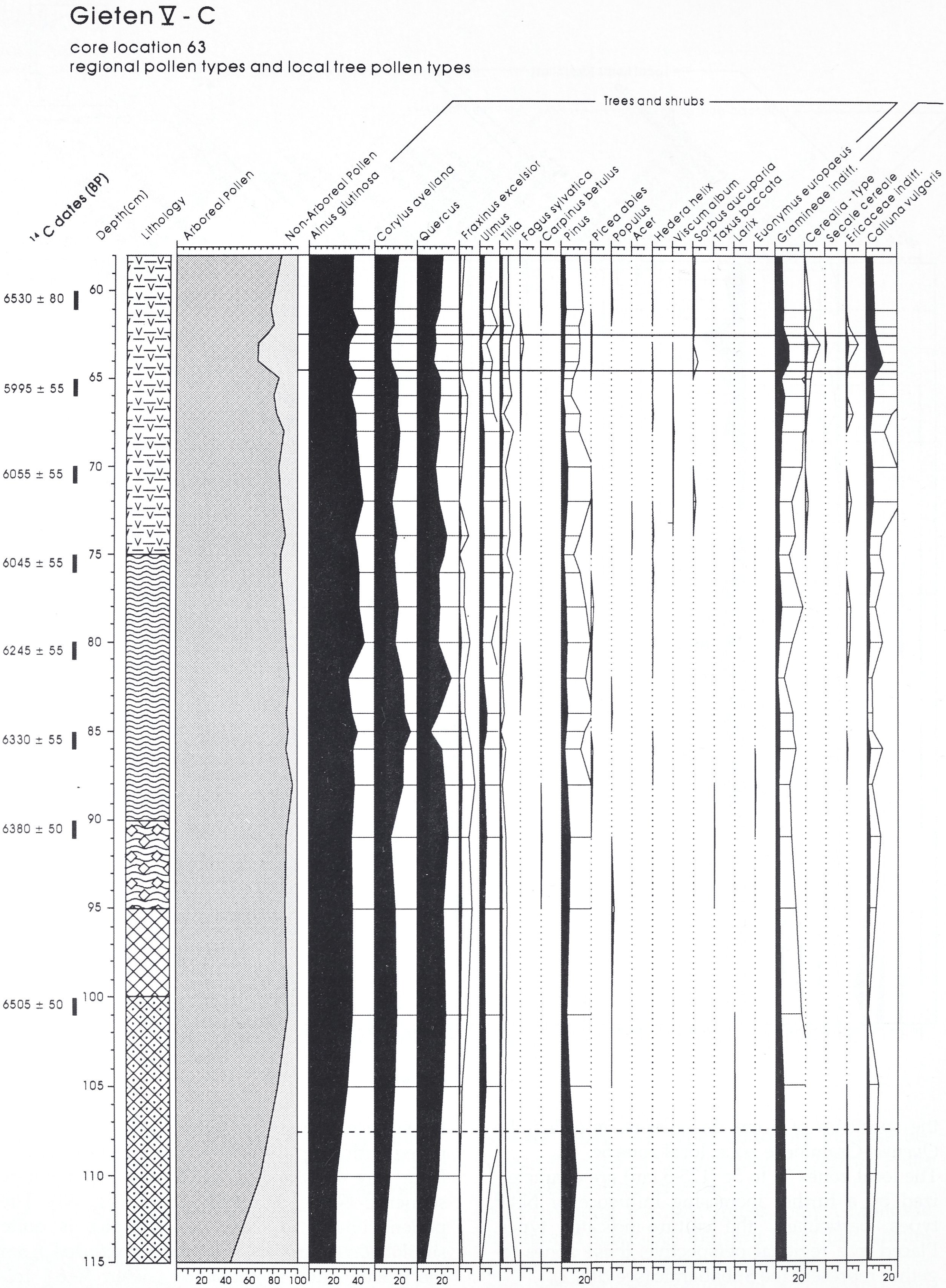
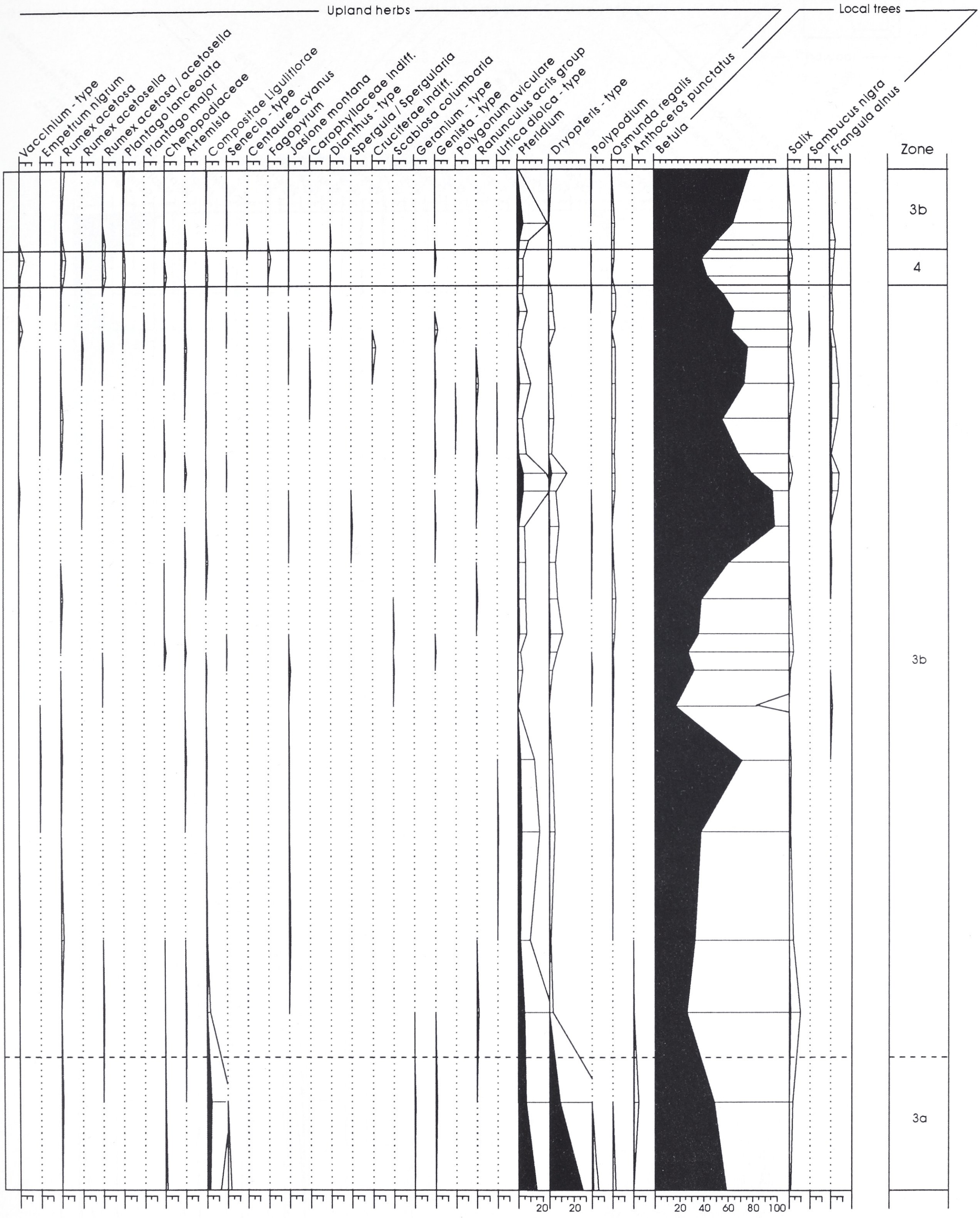


Fig. 59. Pollen diagram of sequence Gieten V-C.


Upland herbs
Local trees
Vaccinium - type
Empetrum nigrum
Rumex acetosa
Rumex acetosella
Rumex acetosa / acetosella
Plantago lanceolata
Plantago major
Chenopodiaceae
Artemisia
Compositae Liguliflorae
Senecio - type
Centaurea cyanus
Fagopyrum
Jasione montana
Carophyllaceae indiff.
Dianthus - type
Spergula / Spergularia
Cruciferae indiff.
Scabiosa columbaria
Geranium - type
Genista - type
Polygonum aviculare
Ranunculus acris group
Urtica dioica - type
Pteridium
Dryopteris - type
Polypodium
Osmunda regalis
Anthoceros punctatus
Betula
Salix
Sambucus nigra
Frangula alnus
Zone
3b
4
3b
3a
20
20
20 40 60 80 100

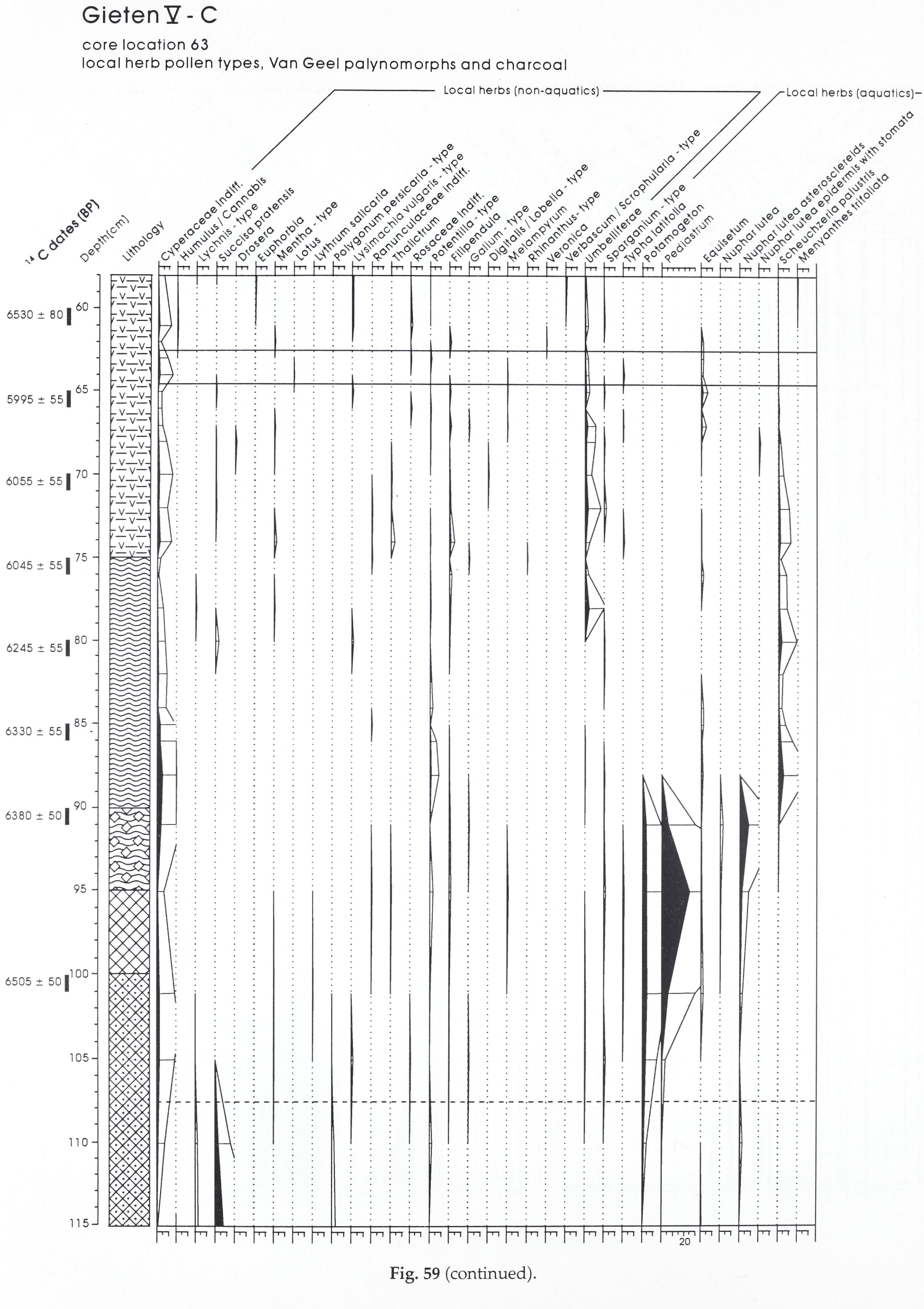
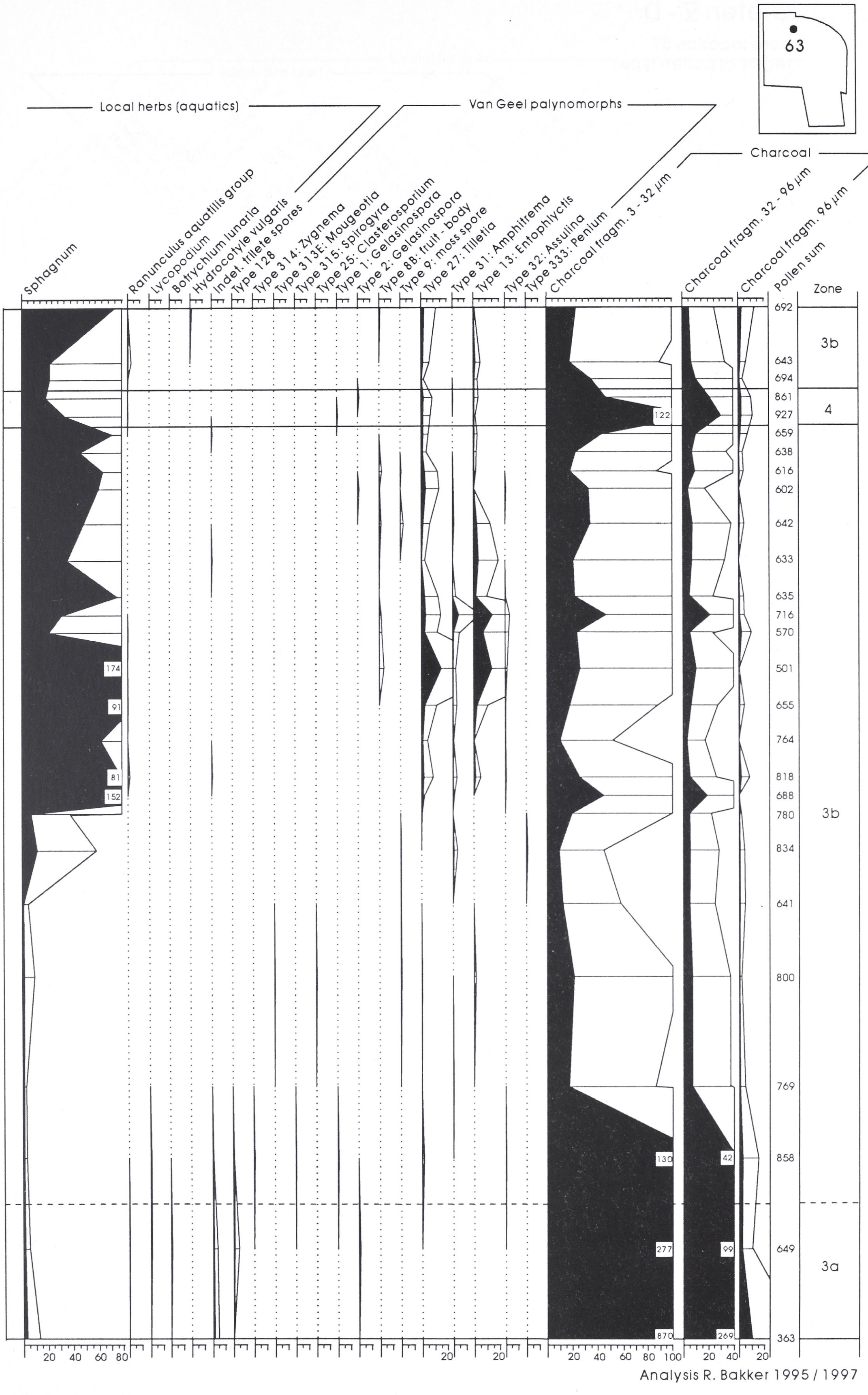


Fig. 59 (continued).



63
Local herbs (aquatics)
Van Geel palynomorphs
Charcoal
Sphagnum
Ranunculus aquatilis group
Lycopodium
Botrychium lunaria
Hydrocotyle vulgaris
Indet. trilete spores
Type 128
Type 314: Zygnema
Type 313E: Mougeotia
Type 315: Spirogyra
Type 25: Clasterosporium
Type 1: Gelasinospora
Type 2: Gelasinospora
Type 88: fruit - body
Type 9: moss spore
Type 27: Tilletia
Type 31: Amphitrema
Type 13: Entophlyctis
Type 32: Assulina
Type 333: Penium
Charcoal fragm. 3 - 32 µm
Charcoal fragm. 32 - 96 µm
Charcoal fragm. 96 µm
Pollen sum
Zone
692
643
694
861
927
659
638
616
602
642
633
635
716
570
501
655
764
818
688
780
834
641
800
769
858
649
363
3b
4
3b
3a
174
91
81
152
122
130
277
870
42
99
269
20 40 60 80
20
20
20 40 60 80 100
20 40
20
Analysis R. Bakker 1995 / 1997

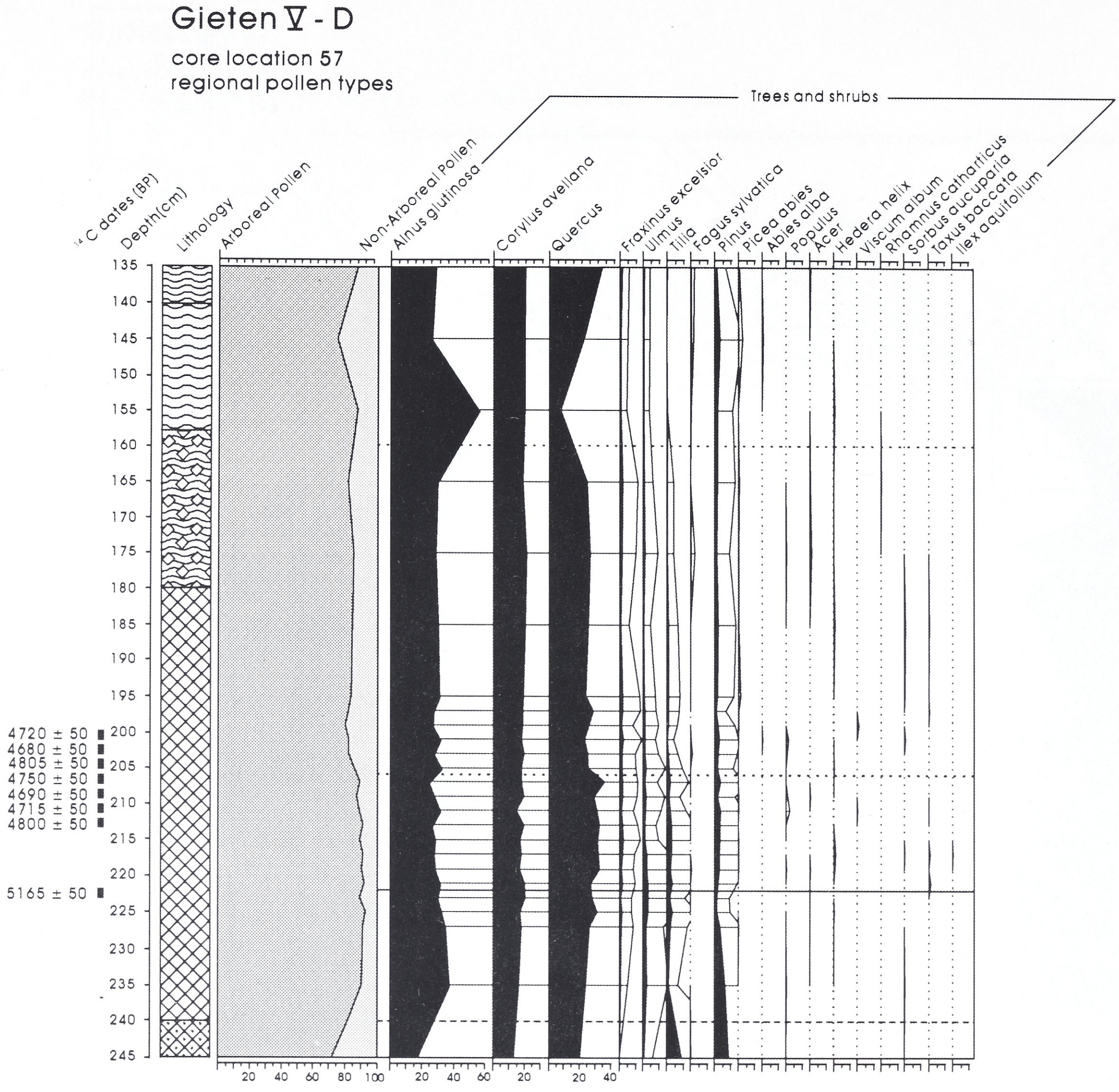
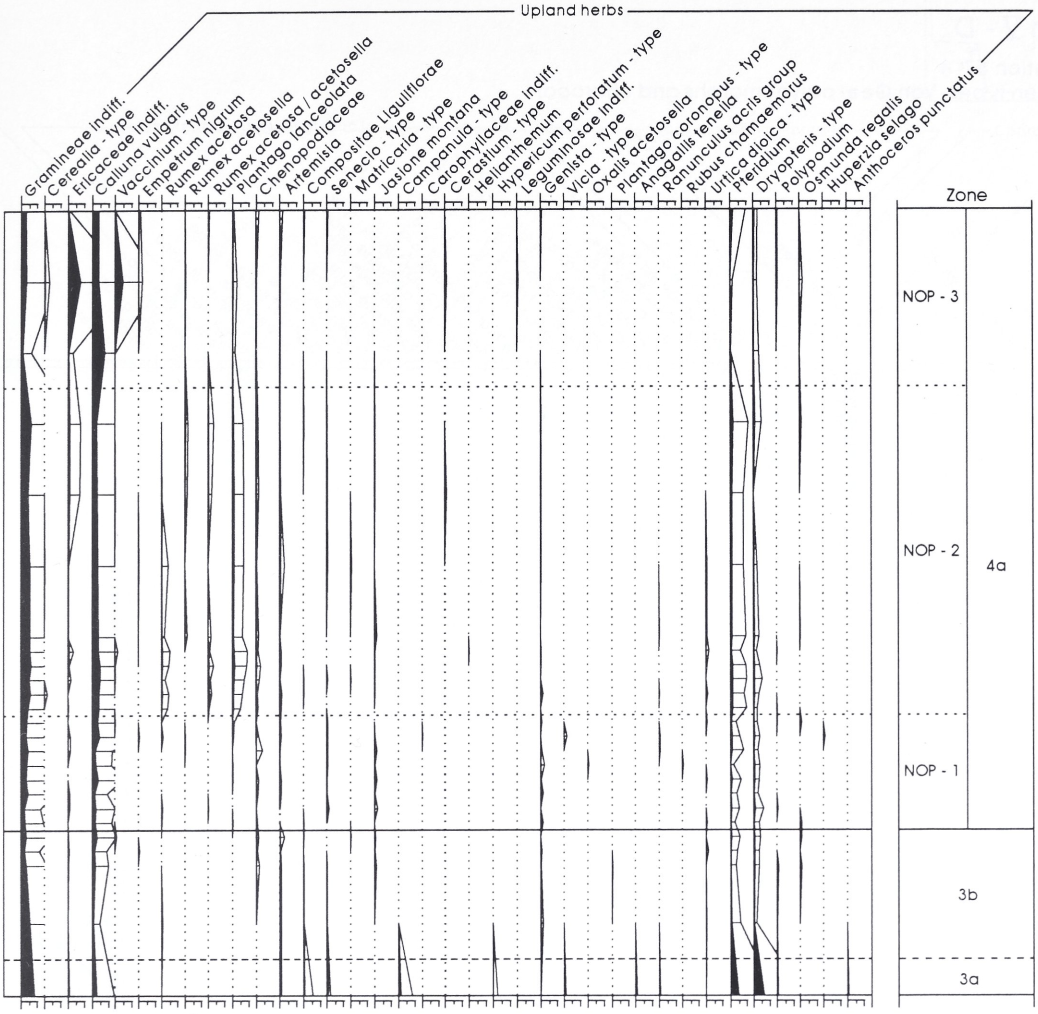


Fig. 60. Pollen diagram of sequence Gieten V-D.

VI.3.3 Overall differences between the master diagram and the other diagrams

The master diagram of Gieten V-A (fig. 56) covers the entire period between the Preboreal and the present day. The other diagrams cover only small parts of these period, mostly (parts of) the Atlantic and the Subboreal. Here an attempt will be made to correlate the period of time representing each diagram and its length in the sediment core with the corresponding period and core length in the master diagram. Furthermore, the most conspicuous differences in pollen composition between each diagram and the master diagram will be briefly discussed.

Gieten I (fig. 51). The diagram of sequence Gieten I, representing 208.2 cm of sediment, corresponds quite well to the spectra between 450 and 270 cm of the master diagram, representing 180 cm of sediment. One important difference between the two diagrams is the Neolithic *Ulmus* decline: in Gieten I, this decline takes a very short time, and occurs a considerable time after the appearance of *Plantago lanceolata*; in Gieten V-A, the *Ulmus* decline takes quite a long time, and even begins well before the occurrence of *Plantago lanceolata*. Anyway, no large differences between the two diagrams were expected, because the two sequences were cored at more or less the same location.



Gieten II (fig. 52). The diagram of Gieten II, representing 25 cm of sediment, corresponds quite well to the spectra between 400 and 361 cm of the master diagram, representing 39 cm of sediment. The following differences are noted between the two diagrams:

- in Gieten V-A, *Betula* decreases at the beginning of the Neolithic Occupation Period, while in Gieten II, it remains constant;
- the *Equisetum* peak at the beginning of the Neolithic Occupation Period of Gieten V-A is absent in Gieten II.

Gieten III (fig. 53). It is rather difficult to compare the diagram of sequence Gieten III with the master diagram, because of the assumed hiatus around 348 cm in Gieten III. The diagram of Gieten III, representing 41.5 cm of sediment, more or less corresponds to the spectra between 450 and 330 cm of the master diagram of Gieten V-A, representing 120 cm of sediment. There are striking differences between the two diagrams:

- in contrast to the picture of Gieten V-A, Gramineae indiff. in Gieten III do not increase when *Plantago lanceolata* appears;
- in Gieten V-A, *Plantago lanceolata* after its appearance occurs in relatively high values in each spectrum, while in Gieten III, *Plantago lanceolata* after its first appearance occurs only sporadically, and not in each spectrum;
- in Gieten V-A, *Betula* decreases strongly at the beginning of the Neolithic Occupation Period, while in Gieten III, this decrease is far less clear. Most probably, this drop represents a local event.

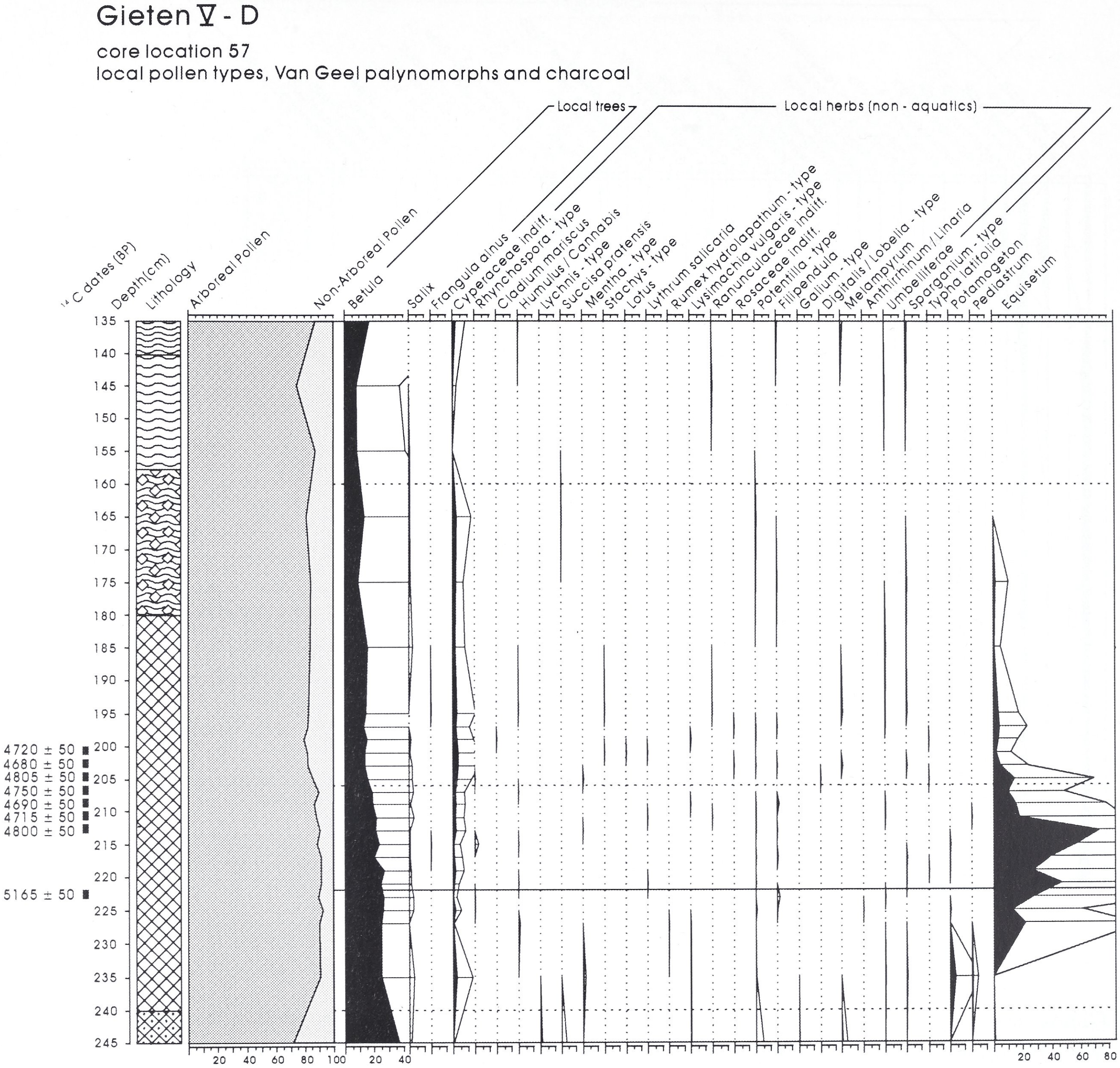
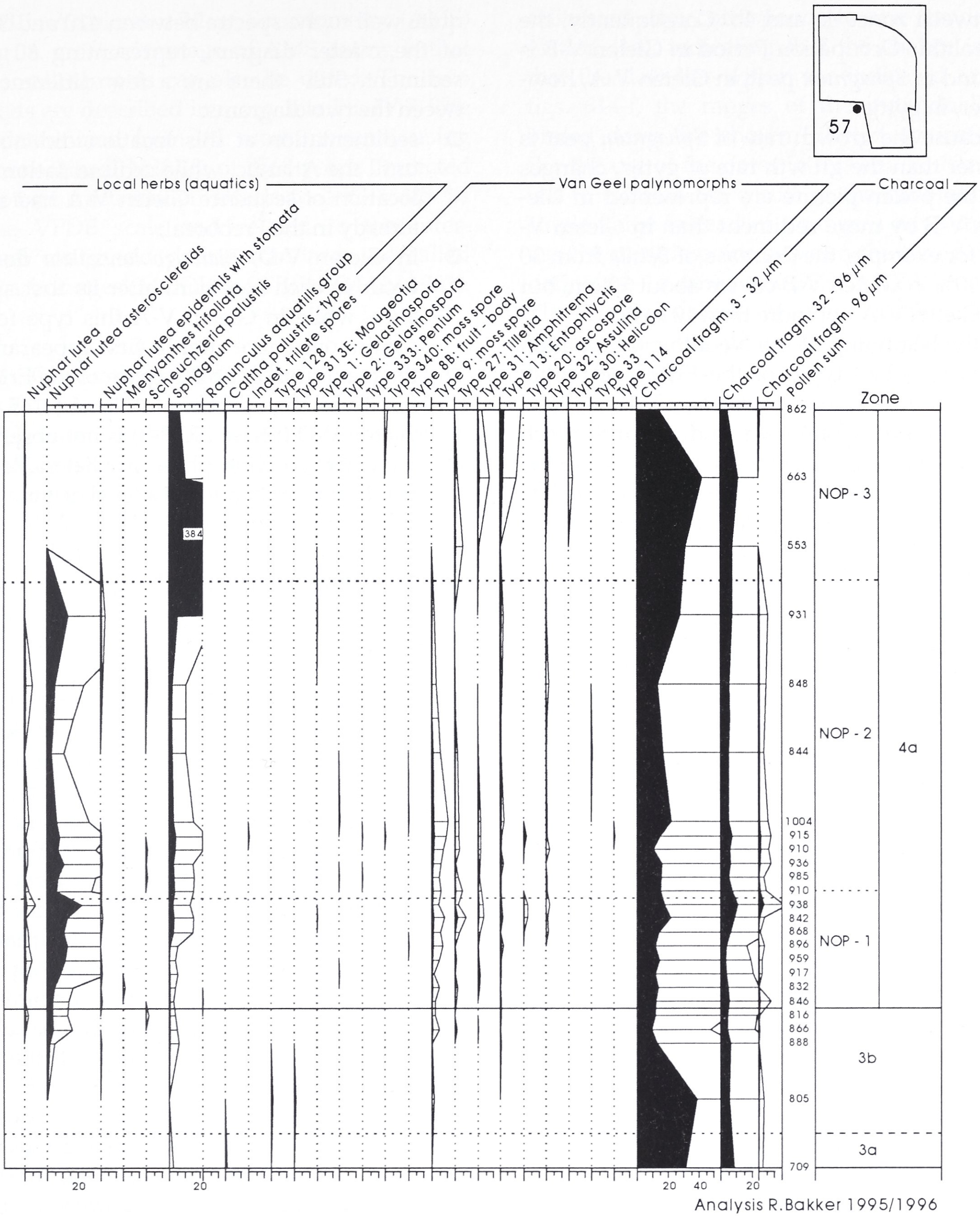


Fig. 60 (continued).

Gieten IV-P (fig. 54). The diagram of sequence Gieten IV-P, which is representing 133 cm of sediment (the "double" part between 455 and 400 cm is excluded), corresponds with the spectra between 450 and 380 cm of the master diagram, representing 70 cm of sediment. There are two major differences between the two diagrams:

- in Gieten IV-P, *Corylus* reaches higher values in zone 2 than in zone 3a, whereas in Gieten V-A, the situation is the inverse;
- the maximum of pollen types of the Ericaceae family in zone 3b in Gieten IV-P is not observed in Gieten V-A. Probably this maximum is caused by local Ericaceae.

Gieten IV-HR (fig. 55). First it has to be remarked that the diagram of Gieten IV-HR is very similar to the diagram of Gieten IV-P. This seems not very surprising, because the sample locations of the two sequences are a few metres apart. However, the ^{14}C dates indicate that the



upper part of the Gieten IV-HR diagram is about 700 ^{14}C-years younger than the upper part of the Gieten IV-P diagram. In neither of the two diagrams does the Neolithic Occupation Period occur. If the "double" part between 429 and 400 cm is excluded, the diagram of Gieten IV-HR covers 132 cm of sediment. Just like the Gieten IV-P diagram, it corresponds with the spectra between 450 and 380 cm of the master diagram, representing 70 cm of sediment. The differences between the diagrams of Gieten IV-HR and Gieten V-A are the same as those between Gieten IV-P and Gieten V-A.

Gieten V-B (fig. 58). The diagram of Gieten V-B, representing 200 cm of sediment, corresponds with the spectra between 390 and 356 cm of the master diagram, which represent 34 cm of sediment. The following differences are observed between the two diagrams:

- the transition from gyttja to *Sphagnum* peat in Gieten V-B occurs in zone 3b, while in Gieten V-A, this transition occurs at the boundary between zones 4a and 4b. Consequently, the Neolithic Occupation Period in Gieten V-B is found in *Sphagnum* peat, in Gieten V-A, however, in gyttja;

- because the growth rate of *Sphagnum* peat is faster than the growth rate of gyttja, changes in the pollen picture are represented in Gieten V-B by more sediment than in Gieten V-A: for example, the decrease of *Betula* from 30 to 10% in Gieten V-B covers about 50 cm, but in Gieten V-A not more than 10 cm!
- at the beginning of the Neolithic Occupation Period, pollen types of the Ericaceae family (especially *Calluna*) in Gieten V-B increase well before Gramineae indiff., and reach higher values, whereas in Gieten V-A, the Ericaceae pollen types increase more or less together with Gramineae indiff. and reach a similar value;
- in Gieten V-B, only a few grains of *Plantago lanceolata* occur at the beginning of the Neolithic Occupation Period; then the type disappears to appear again a few spectra farther upwards in substantially higher quantities than before; in Gieten V-A, *Plantago lanceolata* once it appears maintains a continuous presence.

Gieten V-C (fig. 59). When the spectra of 64 and 63 cm (possibly representing zone 4) are left aside, the diagram of Gieten V-C, representing 57 cm of sediment, corresponds to the spectra between 410 and 372 cm of the master diagram, representing 38 cm of sediment. However, a number of striking differences are observed between the two diagrams:

- sedimentation at this location did not start until the Atlantic, while sedimentation at the location of sequence Gieten V-A had started already in the Preboreal;
- the *Ulmus* decline in this sequence occurs already halfway through zone 3b, while in Gieten V-A it begins at the transition of zone 3b to 4a;
- a few pollen types which are scarcely observed in Gieten V-A form continuous curves in this sequence: *Osmunda regalis* (regional pollen type), *Frangula alnus*, Umbelliferae, and *Scheuchzeria palustris* (all local pollen types). Because the core location of Gieten V-C is near the edge of the pingo scar (see fig. 38), it is assumed that the plants producing these pollen types grew just outside the pingo scar.

Gieten V-D (fig. 60). The diagram of Gieten V-D, representing 110 cm of sediment, corresponds quite well to the spectra between 410 and 330 cm of the master diagram, representing 80 cm of sediment. Still there are a few differences between the two diagrams:

- sedimentation at this location did not start until the Atlantic, while sedimentation at the location of sequence Gieten V-A had started already in the Preboreal;
- in Gieten V-D, *Plantago lanceolata* does not occur in each spectrum after its first appearance, while in Gieten V-A this type forms a continuous curve after its first appearance;
- the maximum of pollen types of the Ericaceae family in the spectra of 155 and 145 cm in Gieten V-D (phase NOP-3) is not observed in the corresponding phase in Gieten V-A; this maximum probably has a local origin.

VI.4 Radiocarbon dating

VI.4.1 Introduction

One of the most important issues of this study is the absolute dating of the beginning of the Neolithic Occupation Period in the various Gietsenveentje sequences. Absolute dates can be obtained by radiometric dating. Radiometric dating is based on the disappearance or development of an isotope as a result of radioactive decay. When an isotope is trapped in some medium, it constitutes a closed system, which means that there is no gain or loss of the isotope except by radioactive decay. By measuring the remaining activity one can determine the time that has elapsed since the initial isolation, provided the initial activity is known (OLSSON 1986). For radiometric dating of Holocene deposits, radiocarbon dating is the most widely used method, using the decay of the radioactive ^{14}C isotope. In nature, three isotopes of the element carbon occur: the stable isotopes ^{12}C (ca. 99%) and ^{13}C (ca. 1%), and the radioactive isotope ^{14}C ($< 10^{-12}$) (MOOK & STREURMAN 1983; MOOK & WATERBOLK 1985). The half-life of the ^{14}C isotope is 5730 years, which makes it particularly suitable for dating Holocene deposits.

In the Gietsenveentje, radiocarbon dating has been used to date the organic sediments (gyttja as well as *Sphagnum* peat) which were deposited during the Neolithic Occupation Period. Two methods are used to measure the remaining ^{14}C activity in the organic sediments: the first is conventional dating, also called "bulk dating", because relatively large samples are needed; the second is Accelerator Mass Spectrometry (AMS) dating. A great advantage of AMS dating is that very small samples can also be dated. The two methods are described in more detail in IV.7. The ages determined from ^{14}C measurements, using the conventional half-life of 5568 years, corrected for isotope fractionation effects to $\delta^{13}C$ = -25 ‰ on the VPDB scale and related to the international oxalic-acid dating standard, are called radiocarbon ages (MOOK & STREURMAN 1983).

VI.4.2 Calibration of the dates

The ^{14}C content of the atmosphere is not constant: it is influenced by factors such as changes in the Earth's magnetic field and fluctuations in solar activity (STUIVER 1965; OLSSON 1986). With the help of dendrochronologically dated samples, calibration curves have been constructed showing the variations. The calibration curve used in this study was published by Stuiver et al. in 1998. With the help of the calibration curve, the radiocarbon ages can be transformed to calendar ages. In this study, uncalibrated dates, reflecting radiocarbon ages, are always expressed in BP (before present), while calibrated dates are expressed in cal BC (before Christ) by convention (MOOK 1986).
The Gietsenveentje ^{14}C dates are shown in tables 9a and b. In total, 56 dates are available from eight sequences. In the first column of the tables, the sequence and the depth of the dated sediment are shown. In the case of conventional dating, 2-10 cm of sediment is needed to obtain a reliable date; for AMS dating, 1 cm of sediment is sufficient. In the second column, the type of the dated sediment is shown. The accuracy of a date seems to a large extent determined by the type of sediment (see VI.4.3). The third column shows the code of each date, given by the Centre for Isotope Research of the University of Groningen. A GrN code indicates a conventional date, while a GrA code indicates an AMS date. The fourth column presents the radiocarbon ages in BP. In the other columns of tables 9a and b, calibrated dates are given, reflecting calendar ages. Three calibration methods have been used, which will be discussed in greater detail below.

Calibration of individual dates

The fifth column of tables 9a and b shows the results of individual calibrations. Calibration is performed with the help of the OxCal computer program, version 3.5 (2000). The error of each calibrated date corresponds to one standard deviation (1σ), indicating that the chance is 68.2% that the date lies within the indicated range. In figs. 61a-f, the ranges of the individually calibrated dates are shown, plotted against depth. For the use of the dates in this study, a need was felt to express the result of the calibration as a single value instead of a range. I have chosen to use the middle point between the two dates that define the 1σ range (see SPERANZA et al. 2000). The single values of the individually calibrated dates are given in the sixth column of tables 9a and b.

Calibration of series of dates in a fixed stratigraphical sequence

The calibration curve has a very irregular shape; it contains many "wiggles", representing changes in the ^{14}C content of the atmosphere. Because of these "wiggles", the Gaussian distribution of an individual date of organic sediment often corresponds to a rather irregular calendar-age probability distribution, which in some cases encompasses quite a long period (VAN DER PLICHT et al. 1990). By using a series of ^{14}C ages of stratigraphically successive samples, a much better age assignment of a sequence can be obtained (VAN GEEL & MOOK 1989). For this reason, in five Gietsenveentje sequences (Gieten III, V-A, V-B, V-C, V-D), series of at least eight samples, located at relatively short distances from each other, have been dated. In four of these sequences, the beginning of the Neolithic Occupation Period is located within the series of dates. Only in sequence Gieten V-C, the beginning of the Neolithic Occupation Period seemed not to fall within the series of dates.
There are various methods to use the fixed stratigraphical sequence of a series of samples to improve the assignment of the calendar ages of each individual sample. Two methods are used here:

Method I

The dates are calibrated taking into account only the fixed stratigraphical sequence of the dated samples. Different distances between the samples and any differential in sedimentation rates are not incorporated in the calibration. The option SEQUENCE of the OxCal calibration program is used to incorporate the stratigraphical evidence. The calibrated dates are obtained with the help of a statistical method called "Gibbs sampling" (BRONK RAMSEY 1995). This method, which estimates constrained distributions, involves a large number of iterations (BUCK et al. 1992).

Sequence and depth	Sediment type	Code	Uncali-brated date (BP)	Date calibrated individually (cal BC) (1σ)	Middle point of 1σ range of calibrated date (cal BC)
Gieten I					
355-365 cm	gyttja	GrN-8075	4795 ± 40	[3650-3620] [3590-3520]	3585
Gieten III					
322-325.2 cm	gyttja	GrN-13699	4920 ± 110	[3940-3870] [3810-3630] [3560-3530]	3735
325.2-328.4 cm	gyttja	GrN-13691	4910 ± 110	[3920-3870] [3810-3620] [3590-3530]	3725
328.4-331.7 cm	gyttja	GrN-13692	4870 ± 110	[3790-3520]	3655
331.7-334.9 cm	gyttja	GrN-13693	4780 ± 110	[3660-3490] [3460-3370]	3515
334.9-338.1 cm	gyttja	GrN-13694	4910 ± 120	[3940-3870] [3810-3620] [3590-3530]	3735
338.1-341.3 cm	gyttja	GrN-13698	4610 ± 130	[3650-3600] [3550-3100]	3375
341.3-344.6 cm	gyttja	GrN-13695	4670 ± 110	[3640-3340]	3490
344.6-347.8 cm	gyttja	GrN-13696	4800 ± 110	[3700-3500] [3440-3370]	3535
347.8-351 cm	gyttja	GrN-13697	6990 ± 120	[5990-5940] [5930-5740]	5865
Gieten IV-P					
260-261 cm	wood/peat	GrA-4982	6605 ± 50	[5620-5580] [5560-5510] [5500-5480]	5550
265-266 cm	wood	GrA-4983	6560 ± 50	[5610-5590] [5560-5470]	5540
270-272 cm	peat/wood	GrN-19684	6660 ± 110	[5670-5480]	5575
305-307 cm	peat/gyttja	GrN-19685	7020 ± 120	[6000-5770] [5760-5750]	5875
Gieten IV-HR					
265-266 cm	peat	GrA-1395	5885 ± 45	[4810-4710] [4700-4690]	4750
270.5-271.5 cm	peat	GrA-1493	5995 ± 55	[4950-4800]	4875
276-277 cm	peat	GrA-1526	6370 ± 45	[5470-5450] [5420-5400] [5380-5300]	5385
Gieten V-A					
280-281 cm	peat	GrA-1524	3395 ± 45	[1750-1620]	1685
285-286 cm	peat/gyttja	GrA-1403	3495 ± 70	[1920-1900] [1890-1730] [1710-1690]	1805
290-291 cm	gyttja	GrA-1402	3495 ± 55	[1890-1740]	1815
358-359 cm	gyttja	GrA-1396	4285 ± 55	[3020-2950] [2930-2870] [2810-2780] [2770-2760] [2720-2710]	2865
360-361 cm	gyttja	GrA-1489	4205 ± 45	[2890-2850] [2820-2740] [2730-2690]	2790
362-363 cm	gyttja	GrA-1399	4180 ± 55	[2880-2840] [2820-2670]	2775
364-365 cm	gyttja	GrA-1397	4609 ± 50	[3510-3420] [3380-3330] [3210-3190] [3150-3130]	3320
366-367 cm	gyttja	GrA-1494	4690 ± 50	[3620-3600] [3530-3490] [3470-3370]	3495
368-369 cm	gyttja	GrA-1398	4590 ± 50	[3500-3450] [3440-3430] [3380-3330] [3220-3180]	3310
370-371 cm	gyttja	GrA-1487	4611 ± 50	[3510-3420] [3390-3330] [3210-3190] [3150-3130]	3320
372-373 cm	gyttja	GrA-1488	4760 ± 50	[3640-3510] [3400-3380]	3510
374-375 cm	gyttja	GrA-1490	5135 ± 55	[4040-4020] [3990-3930] [3880-3800]	3920
376-377 cm	gyttja	GrA-1525	5395 ± 55	[4340-4220] [4200-4160] [4120-4110]	4225

Table 9a. Gietsenveentje ^{14}C dates (I). Calibration is performed according to STUIVER et al. 1998.

Sequence and depth	Date calibrated by Method I (cal BC) (1σ) (* agreement index < 60%)	Middle point of 1σ range of Method I-calibrated date	Date calibrated by Method II (cal BC) (complete dataset of each sequence)	Date calibrated by Method II (cal BC) (sub-datasets, indicated by letters A-E)
Gieten I				
355-365 cm	-	-	-	-
Gieten III				
322-325.2 cm	[3530-3520] [3440-3360]*	3445	3543	-
325.2-328.4 cm	[3560-3510] [3460-3380]*	3470	3548	-
328.4-331.7 cm	[3580-3500] [3460-3440] [3430-3410]	3495	3568	-
331.7-334.9 cm	[3600-3510]	3555	3580	-
334.9-338.1 cm	[3610-3535]	3573	3591	-
338.1-341.3 cm	[3635-3565]	3600	3612	-
341.3-344.6 cm	[3655-3585]	3620	3626	-
344.6-347.8 cm	[3770-3610]	3690	3635	-
347.8-351 cm	-	-	-	-
Gieten IV-P				
260-261 cm	[5535-5475]	5505	5486	-
265-266 cm	[5610-5580] [5560-5500]	5555	5524	-
270-272 cm	[5710-5680] [5670-5560]	5635	5567	-
305-307 cm	[6000-5770] [5760-5750]	5875	5837	-
Gieten IV-HR				
265-266 cm	[4800-4690]	4745	4754	-
270.5-271.5 cm	[4940-4800]	4870	5009	-
276-277 cm	[5460-5450] [5420-5400] [5380-5300]	5380	5264	-
Gieten V-A				
280-281 cm	[1740-1620]	1680	-	1682 A
285-286 cm	[1830-1730] [1720-1690]	1760	-	1769 A
290-291 cm	[1930-1780]	1855	-	1857 A
358-359 cm	[2800-2750] [2730-2670]*	2735	2641	2790 B
360-361 cm	[2820-2740] [2730-2700]	2760	2786	2802 B
362-363 cm	[2890-2830] [2820-2785]	2838	2931	2815 B/C
364-365 cm	[3390-3330] [3220-3180] [3160-3120]	3255	3076	3357 C/D
366-367 cm	[3445-3370]	3408	3221	3402 D
368-369 cm	[3490-3443]	3462	3367	3447 D
370-371 cm	[3504-3468]	3486	3512	3492 D
372-373 cm	[3640-3550] [3540-3520]	3580	3657	3537 D/E
374-375 cm	[3990-3930] [3920-3910] [3880-3800]	3895	3802	3847 E
376-377 cm	[4340-4220] [4200-4160] [4060-4050]	4195	3947	4172 E

Table 9a (continued).

Sequence and depth	Sediment type	Code	Uncali-brated date (BP)	Date calibrated individually (cal BC) (1σ)	Middlepoint of 1σ range of calibrate date (cal BC)
Gieten V-B					
195-196 cm	peat	GrA-4984	4755 ± 50	[3640-3510] [3400-3380]	3510
205-206 cm	peat	GrA-4985	4740 ± 50	[3640-3550] [3540-3500] [3430-3380]	3510
215-216 cm	peat	GrA-4986	4455 ± 50	[3330-3210] [3180-3150] [3130-3020]	3175
225-226 cm	peat	GrA-4987	4790 ± 50	[3650-3620] [3610-3520]	3585
230-231 cm	peat	GrA-4988	4925 ± 50	[3760-3650]	3705
235-236 cm	peat	GrA-4989	5055 ± 50	[3950-3790]	3870
245-246 cm	peat	GrA-4992	5105 ± 55	[3970-3910] [3880-3800]	3885
254-255 cm	peat	GrA-4993	5250 ± 55	[4220-4190] [4170-4120] [4110-4090] [4070-4060] [4050-3970]	4095
264-265 cm	peat	GrA-4113	5210 ± 120	[4230-4180] [4170-3930] [3860-3810]	4020
Gieten V-C					
60-61 cm	peat	GrA-7155	6530 ± 80	[5610-5590] [5560-5460] [5450-5380]	5495
65-66 cm	peat/wood	GrA-4994	5995 ± 55	[4950-4800]	4875
70-71 cm	peat	GrA-4995	6055 ± 55	[5040-4900] [4890-4850]	4945
75-76 cm	peat	GrA-4996	6045 ± 55	[5030-5010] [5000-4840] [4820-4810]	4920
80-81 cm	peat	GrA-4997	6245 ± 55	[5300-5200] [5180-5140] [5120-5080]	5190
85-86 cm	peat	GrA-4998	6330 ± 55	[5460-5450] [5420-5410] [5370-5250] [5240-5230] [5220-5210]	5335
90-91 cm	gyttja	GrA-6715	6380 ± 50	[5470-5440] [5420-5400] [5380-5300]	5385
90-91 cm	*Betula* seeds	GrA-7149	5720 ± 80	[4690-4460]	4575
100-101 cm	gyttja	GrA-6716	6505 ± 50	[5520-5460] [5450-5370]	5445
100-101 cm	*Betula* seeds	GrA-7150	5430 ± 80	[4360-4220] [4200-4160] [4130-4110] [4060-4050]	4205
Gieten V-D					
200-201 cm	gyttja	GrA-6720	4720 ± 50	[3630-3580] [3540-3490] [3440-3370]	3500
202-203 cm	gyttja	GrA-6721	4680 ± 50	[3620-3610] [3520-3370]	3495
204-205 cm	gyttja	GrA-6741	4805 ± 50	[3650-3620] [3600-3520]	3585
206-207 cm	gyttja	GrA-6742	4750 ± 50	[3640-3510] [3410-3380]	3510
208-209 cm	gyttja	GrA-6743	4690 ± 50	[3620-3600] [3530-3490] [3470-3370]	3495
210-211 cm	gyttja	GrA-6737	4715 ± 50	[3630-3580] [3540-3490] [3460-3370]	3500
212-213 cm	gyttja	GrA-6717	4800 ± 50	[3650-3620] [3600-3520]	3585
222-223 cm	gyttja	GrA-6718	5165 ± 50	[4050-3940] [3850-3810]	3930

Table 9b. Gietsenveentje ^{14}C dates (II). Calibration is performed according to STUIVER et al. 1998.

Sequence and depth	Date calibrated by Method I (cal BC) (1σ) (* agreement index < 60%)	Middle point of 1σ range of Method I-calibrated date	Date calibrated by Method II (cal BC) (complete dataset of each sequence)	Date calibrated by Method II (cal BC) (sub-datasets, indicated by letters A-B)
Gieten V-B				
195-196 cm	-	-	-	-
205-206 cm	-	-	-	-
215-216 cm	[3340-3210] [3180-3150] [3130-3020]	3180	3320	3166 A
225-226 cm	[3650-3620] [3610-3520]	3585	3510	3541 A
230-231 cm	[3760-3650]	3705	3605	3729 A
235-236 cm	[3910-3770]	3840	3700	3916 A/B
245-246 cm	[3980-3900] [3880-3840]	3910	3890	3954 B
254-255 cm	[4140-4120] [4110-4090] [4080-3970]	4055	4061	3988 B
264-265 cm	[4320-4300] [4250-4070] [4050-4020]	4170	4252	4026 B
Gieten V-C				
60-61 cm	-	-	-	-
65-66 cm	[4910-4780]	4845	4834	-
70-71 cm	[4980-4850]	4915	4926	-
75-76 cm	[5050-4920]	4985	5018	-
80-81 cm	[5290-5200] [5180-5140] [5120-5070]	5180	5110	-
85-86 cm	[5360-5255]	5308	5203	-
90-91 cm	[5470-5450] [5420-5400] [5390-5310]	5390	5295	-
90-91 cm	-	-	-	-
100-101 cm	[5530-5460] [5450-5380]	5455	5479	-
100-101 cm	-	-	-	-
Gieten V-D				
200-201 cm	[3430-3370]	3400	3464	3465 A
202-203 cm	[3530-3410]	3470	3495	3494 A
204-205 cm	[3570-3515]	3543	3527	3524 A
206-207 cm	[3605-3545]	3575	3559	3553 A
208-209 cm	[3621-3580]	3601	3591	3583 A
210-211 cm	[3632-3600]	3616	3623	3612 A
212-213 cm	[3656-3619]	3638	3654	3642 A/B
222-223 cm	[4050-3940] [3860-3810]	3930	3813	3964 B

Table 9b (continued).

Fig. 61 (pp. 169-174). Comparison of various calibration methods of the Gietsenveentje ^{14}C dates by plotting the calibrated dates against depth in the sediment. The results of three calibration methods are shown: individual calibration, Method I calibration, which incorporates the fixed stratigraphical sequence of a series of dates into the calibration, and Method II calibration, in which an attempt is made to obtain the best fit of a series of stratigraphically fixed dates on the calibration curve, assuming a constant sedimentation rate (wiggle matching). In sequences Gieten V-A, V-B and V-D an attempt was made to improve the results of Method II calibration, viz. the fit of the dates on the calibration curve, by dividing the complete dataset into several sub-datasets with different sedimentation rates (shown by different inclination angles in the figures) (see fig. 62). Series of dates from the following sequences are shown: a. Gieten III; b. Gieten IV-P/IV-HR; c. Gieten V-A; d. Gieten V-B; e. Gieten V-C; f. Gieten V-D.

The results of the Method I calibration are shown in the eighth and ninth columns of tables 9a and b and in figs. 61a-f. Some dates are excluded from calibration by this method, because they are not part of a series (the only date of Gieten I, the dates of *Betula* seeds in Gieten V-C) or because they do not fit at all into the chronological sequence (a few dates in Gieten III, V-B and V-C; see VI.4.3). These dates are also excluded from calibration by Method II. In the eighth column of tables 9a and b, the given error of each Method I-calibrated date corresponds to one standard deviation (1σ), indicating that the chance is 68.2% that the date lies within the indicated range. As with the individually calibrated dates, the middle point between the two dates that define the 1σ range is calculated for each Method I-calibrated date. These figures are given in the ninth column of tables 9a and b. By comparing the fifth and the eighth column of tables 9a and b, it can be observed that the error of the dates is in most cases strongly reduced when the fixed stratigraphical sequence of the samples is taken into account.

For each date that is part of a series, an **agreement index** is calculated by the OxCal program. This agreement index, which is expressed as a percentage, indicates the goodness of fit of the date in the series. It is a measure for the extent to which the final (posterior) distribution, calculated by the "Gibbs sampling" method, i.e. the results of Method I calibration, overlaps the original distribution, i.e. the results of individual calibration. An unaltered distribution will have an index of 100%, but it is possible for the value to rise above this if the final distribution only overlaps the very highest part of the initial distribution. If the value of the final distribution for any individual item is below 60%, it is worth questioning its position in the stratigraphy (BRONK RAMSEY 1995). Of all Gietsenveentje Method I-calibrated dates, two dates in Gieten III (fig. 61a) and one in Gieten V-A (fig. 61c) have an agreement index below 60%.

For each series of dates, the OxCal program calculates an **overall agreement**, which is a function of all indices making up the series. If this falls below 60% it may be worth re-evaluating the assumptions made. Of all Gietsenveentje sequences with Method I-calibrated dates, only the series of Gieten III has an overall agreement index considerably below 60%: 31.7%. This may indicate that the dated samples of this sequence are chronologically not in the right order, and this may point to disturbance of the sediment (the far too old date of 347.8-351 cm, which has been excluded from the series, also points to irregularities in the deposition of the sediment of this sequence). The overall agreement of the Gieten V-A series is 80.4%; the overall agreement values for the other sequences are still higher, lying between 97 and 111% (since the agreement index of the individual dates can rise above 100%, the overall agreement can also do so).

Method II: wiggle matching

An attempt is made to obtain the best fit of a series of stratigraphically fixed dates on the calibration curve, assuming a constant sedimentation rate. As already mentioned, "wiggles" in the ^{14}C calibration curve are caused by varying atmospheric ^{14}C activity in the course of time, yielding short-term variations with a magnitude of 1 to 2% (equivalent to apparent ages of around 100 to 200 years) over periods of a few hundred years. This pattern of ^{14}C wiggles may be recognized in all time series derived from atmospheric CO_2, such as tree rings and peat deposits (KILIAN et al. 1995). Since each ring represents one year, the annual rings of thousands of subfossil trees have been used to construct a complete calibration curve, giving the variations in the ^{14}C content of the atmosphere since the Late Glacial. When a series of dates from a subfossil tree is to be calibrated, it is easy to match the particular wiggles found in the dates of the wood to the same wiggles in the calibration curve, because the relation between radiocarbon years and tree-ring (calendar) years is fixed. This method is called **wiggle matching**. However, when a series

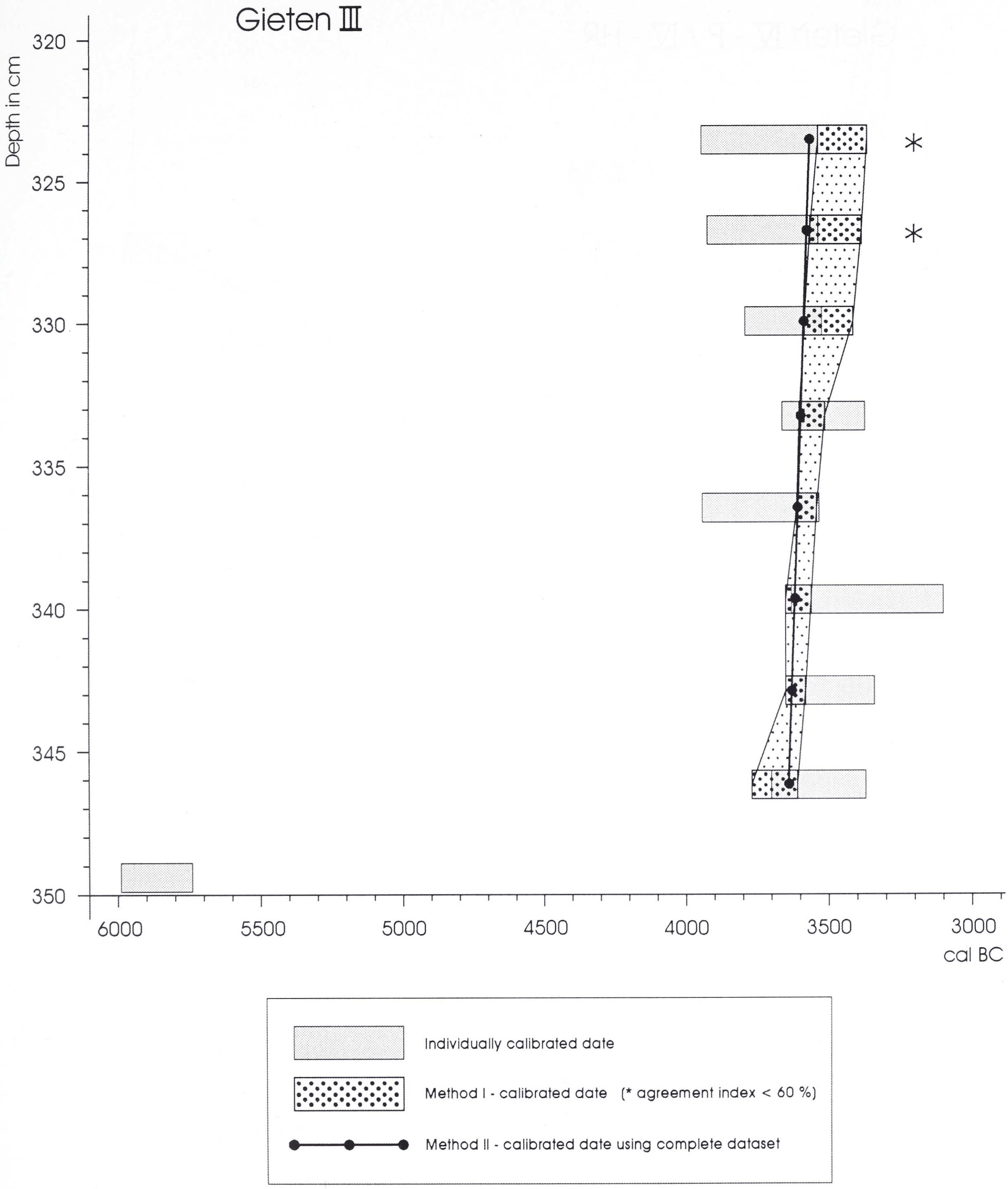

Gieten III
Depth in cm
320
325
330
335
340
345
350
6000
5500
5000
4500
4000
3500
3000
cal BC
*
*
Individually calibrated date
Method I - calibrated date (* agreement index < 60 %)
Method II - calibrated date using complete dataset

Fig. 61a.

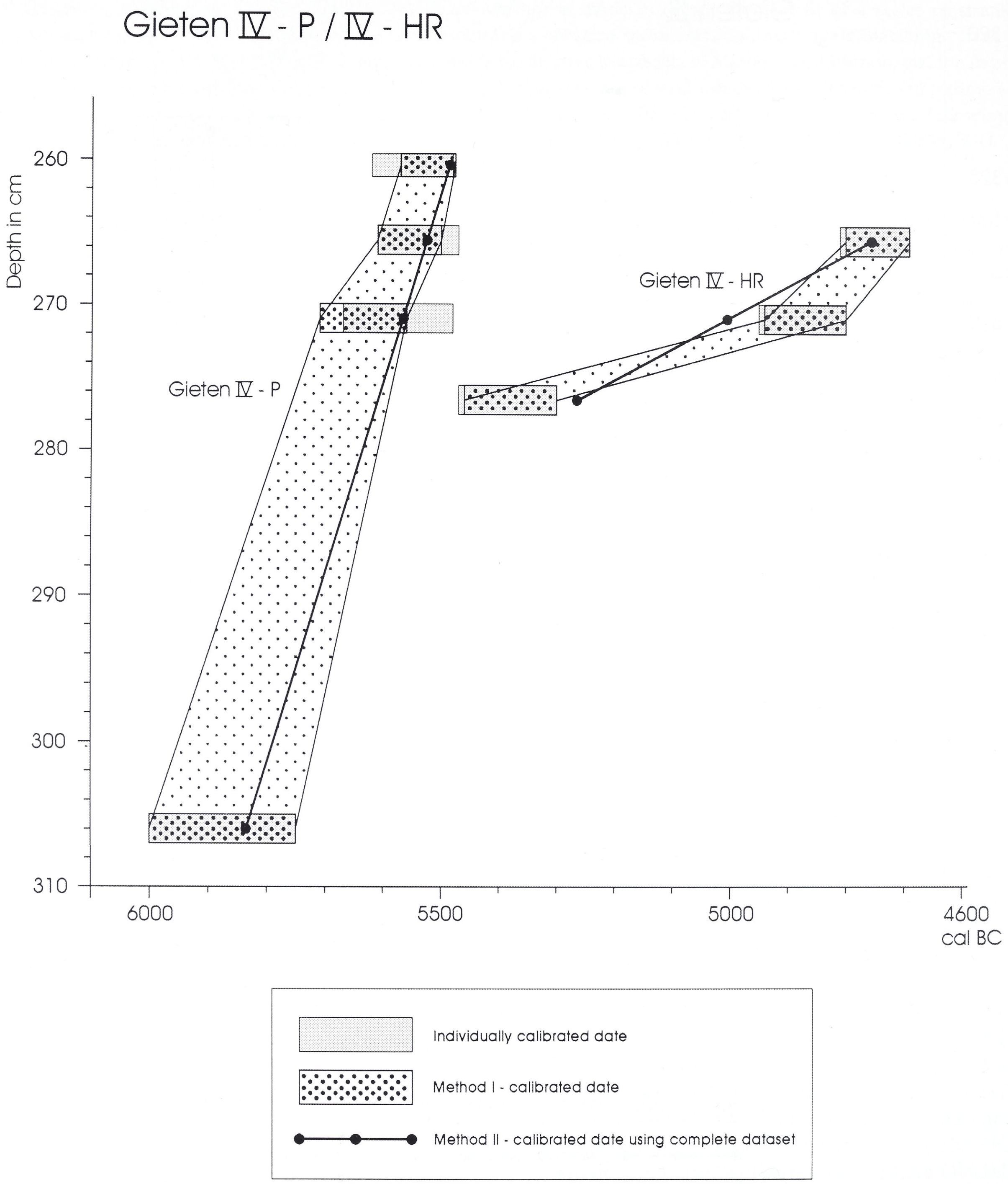

Gieten IV - P / IV - HR
Depth in cm
260
270
280
290
300
310
6000
5500
5000
4600
cal BC
Gieten IV - P
Gieten IV - HR
Individually calibrated date
Method I - calibrated date
Method II - calibrated date using complete dataset

Fig. 61b.

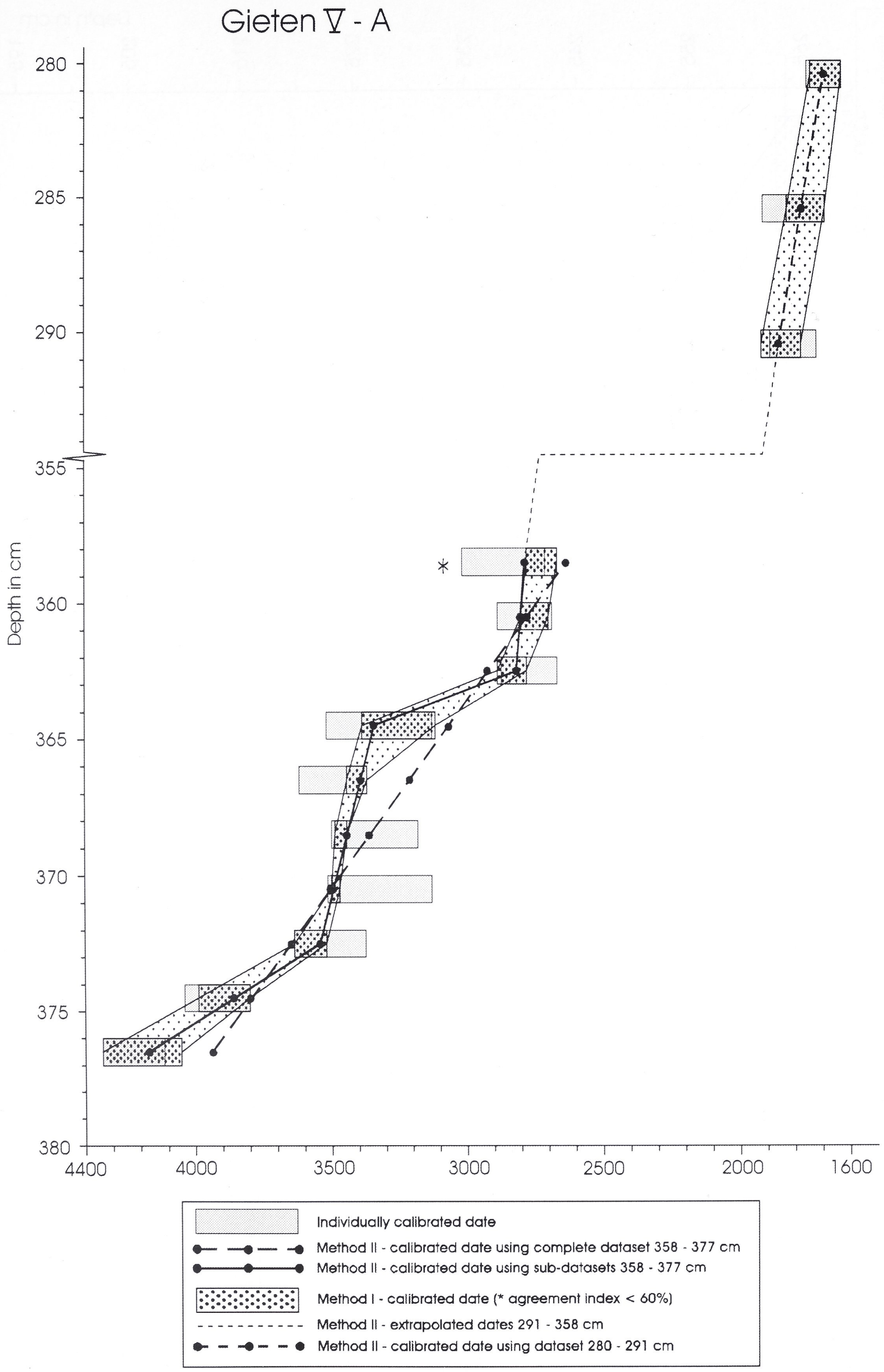

Gieten V - A
Depth in cm
280
285
290
355
360
365
370
375
380
4400
4000
3500
3000
2500
2000
1600
*
Individually calibrated date
Method II - calibrated date using complete dataset 358 - 377 cm
Method II - calibrated date using sub-datasets 358 - 377 cm
Method I - calibrated date (* agreement index < 60%)
Method II - extrapolated dates 291 - 358 cm
Method II - calibrated date using dataset 280 - 291 cm

Fig. 61c.

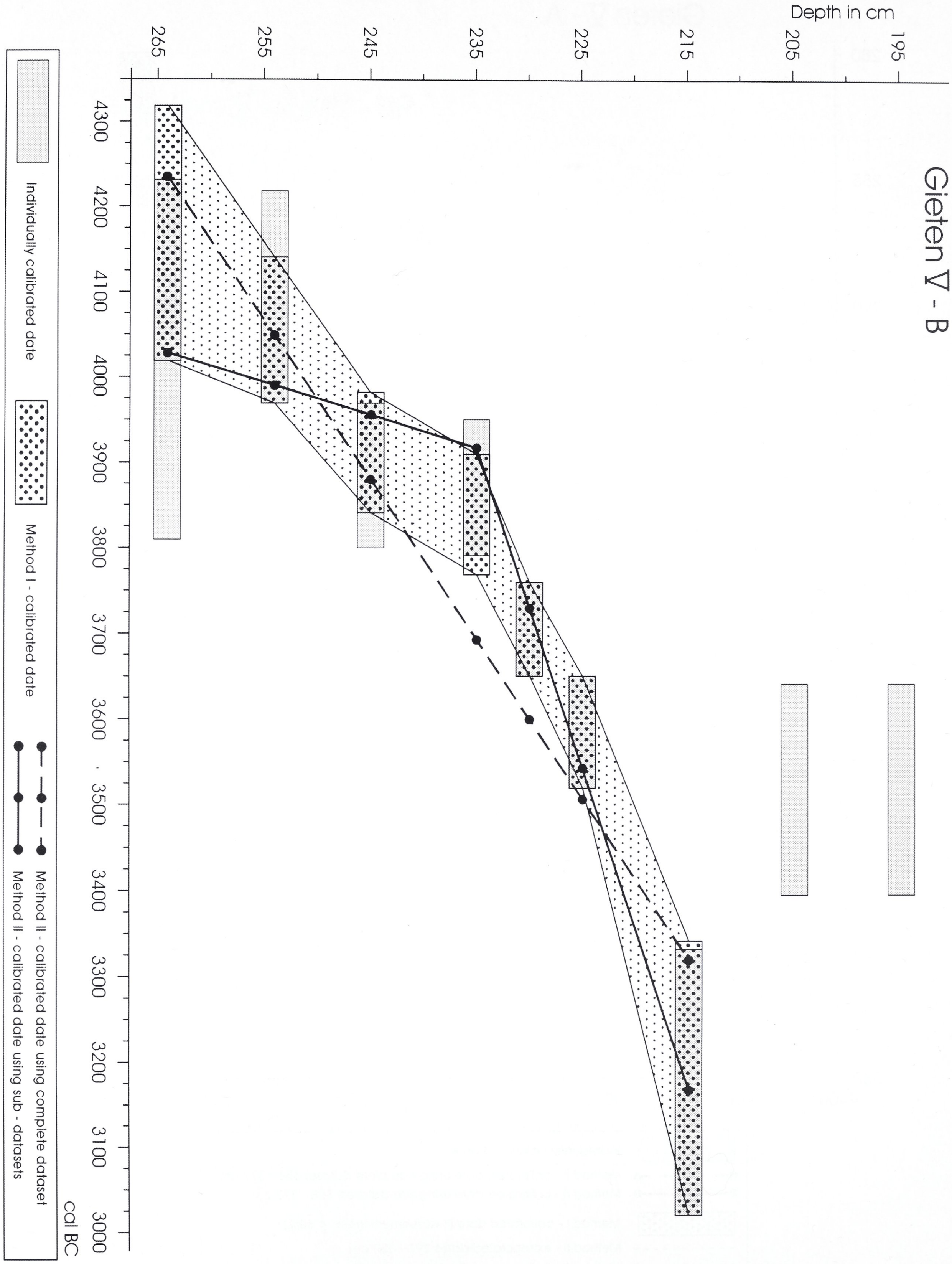

Gieten ∇ - B
Depth in cm
195
205
215
225
235
245
255
265
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
cal BC
Individually calibrated date
Method I - calibrated date
Method II - calibrated date using complete dataset
Method II - calibrated date using sub - datasets

Fig. 61d.

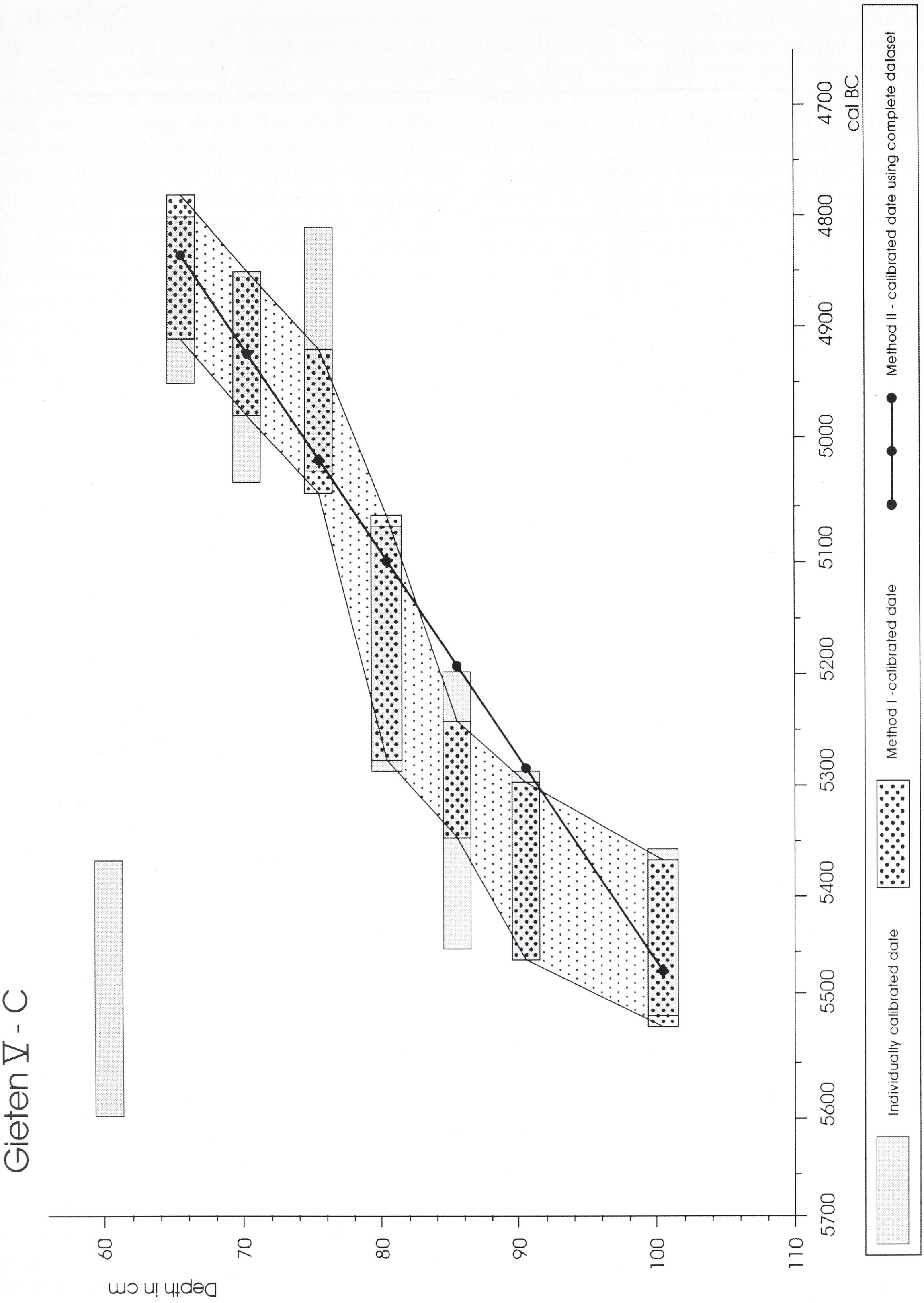

Gieten V - C
Depth in cm
60
70
80
90
100
110
cal BC
5700
5600
5500
5400
5300
5200
5100
5000
4900
4800
4700
Individually calibrated date
Method I - calibrated date
Method II - calibrated date using complete dataset

Fig. 61e.

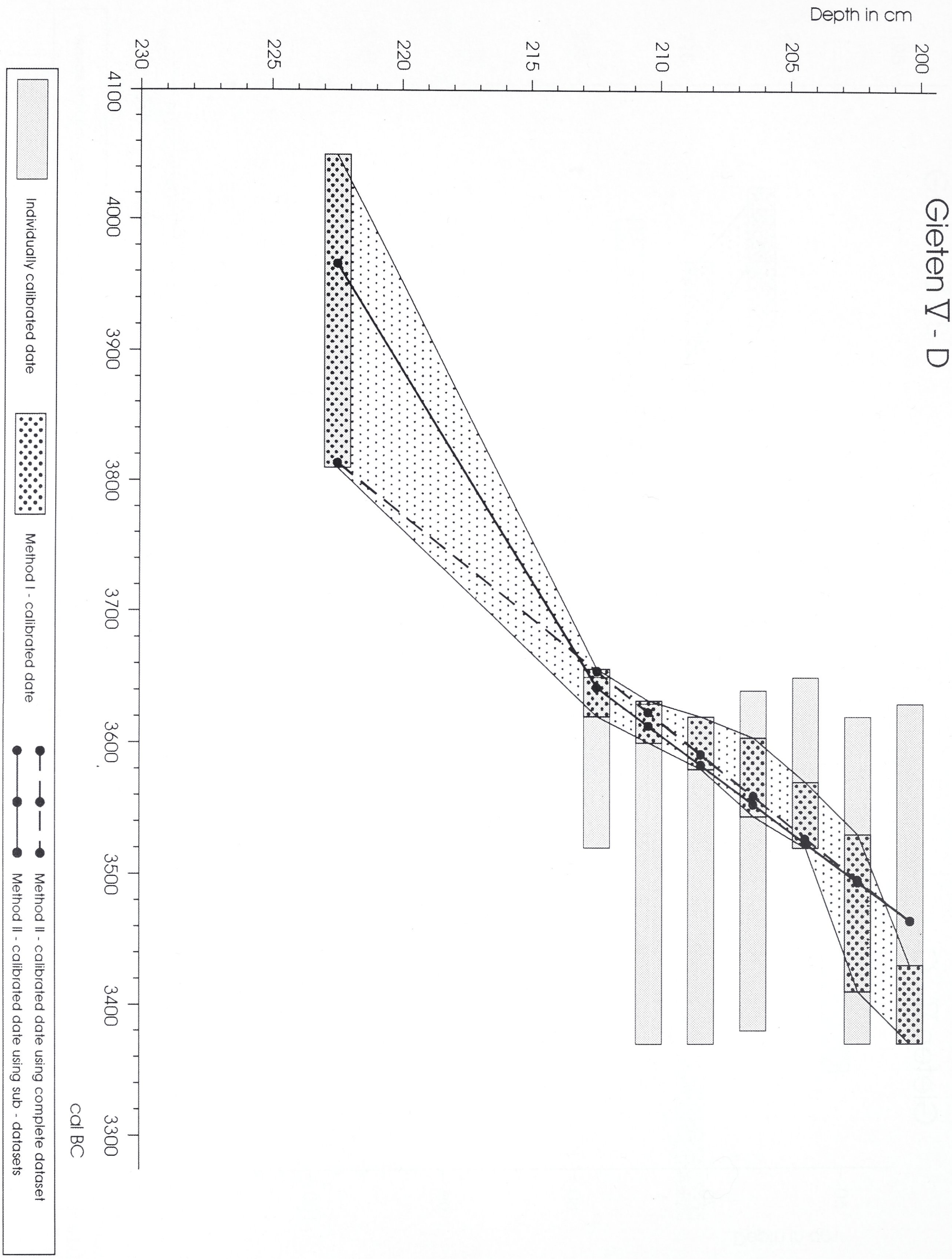

Gieten V - D
Depth in cm
200
205
210
215
220
225
230
4100
4000
3900
3800
3700
3600
3500
3400
3300
cal BC
Individually calibrated date
Method I - calibrated date
Method II - calibrated date using complete dataset
Method III - calibrated date using sub - datasets

Fig. 61f.

of dates from a peat or gyttja sequence is to be calibrated, and no annually laminated sediments are present, as is the case in the Gietsenveentje, there is only a relation between radiocarbon years and sampling depth. The depths of the dated samples are related to chronology by the accumulation rate of the sediment, which is unknown. When the method of wiggle matching is applied to peat or gyttja sequences, the assumption has to be made that the accumulation rate between the dated samples is constant. So, when a series of radiocarbon dates from a peat or gyttja sequence are to be matched to the calibration curve, in order to find the corresponding age in calendar years, there are two unknown factors:

- location of the series of dates on the calibration curve;
- absolute distance in calendar years between the individual dates (this depends on the accumulation rate; the relative distance between the dates is assumed to be constant).

It is a matter of one equation in two unknowns. Mathematically, such an equation is insolvable: there is an infinity of ways to solve it. The best solution can only be approximated.

Initially, it was attempted to match the complete dataset of each Gietsenveentje sequence to the calibration curve of Stuiver et al. (1998). With the help of the CAL25 computer program (VAN DER PLICHT 1993), updated with the 1998 calibration curve, as close as possible an approximation to the above-mentioned "best solution" was sought: the CAL25 program calculates a goodness-of-fit parameter, which expresses the extent to which the series of dates matches the calibration curve. As in the study by Pearson (1986), this parameter represents the residual sum of squares, but in this approach it is divided by the number of dates N, and its square root is extracted, yielding a standard deviation s (SOKAL & ROHLF 1981, 53). A minimum s (the "best solution") can be obtained in CAL25 by manually shifting the series of dates in calendar age and increasing or decreasing its total calendar age range (KILIAN et al. 1995). The wiggles in the calibration curve can be very useful in this process, because individual wiggles often show particular features (VAN GEEL & MOOK 1989). When particular wiggles can be recognized in a series of dates, the attribution of the calendar ages of these dates is hugely improved. A condition for the use of wiggle matching is that the series of dates is taken from small samples which are located at short distances from each other in the sediment. The Gietsenveentje samples, having a volume of less than 1 cm^3, in most sequences located no more than a few centimetres from each other, comply with this condition.

The results of the Method II calibration (wiggle matching) of the complete datasets of each sequence are the dates in the tenth column of tables 9a and b. Because these numbers are only approximations, made under the assumption of a constant sedimentation rate, the total error of each date cannot be calculated and is therefore not given in the table. There is a method for making a rough estimate of the total error of each date. Because there are many (in fact, infinite) "best solutions" to fit the series of dates on the calibration curve, one may try to find the margins within which the most "best solutions" occur: these margins are considered to approximate the total error of the "very best solution". This can be accomplished by manually shifting the series of dates along the calibration curve until margins are reached which are acceptable to the researcher. This method has been applied to some Gietsenveentje sequences; the results differed per date, but at a rough estimate, the total error of each Method II-calibrated date is the same as the (known) total error of each uncalibrated date.

In figs. 61a-f, in which calibrated dates are plotted against depth, the results of Method II calibration of the complete dataset of each sequence are shown as a series of dates lying on a straight line. This is no surprise, because a linear time-depth relation, i.e. a constant sedimentation rate, was assumed for this calibration method. However, it can be seen that in some sequences, Method II-calibrated dates fall outside the range of the individually calibrated dates. This may indicate that the assumption of a constant sedimentation rate in the part of the sediment covered by the complete dataset of these particular sequences, is incorrect. To show this problem in more detail, figs. 62a, b, d and f show the best fit of the complete dataset of four Gietsenveentje sequences on the calibration curve. When we look at these figures, it becomes clear that the complete dataset of sequence Gieten III can be fitted reasonably well to (a very small part of) the calibration curve, but it seems impossible to fit the complete datasets of sequences Gieten V-A, V-B and V-D to the curve with a reasonable degree of accuracy. When it is not possible to fit a series of dates fairly exactly to the curve, other factors are playing a role. Probably changing sedimentation rate is the most important of these factors. To solve this problem, the complete

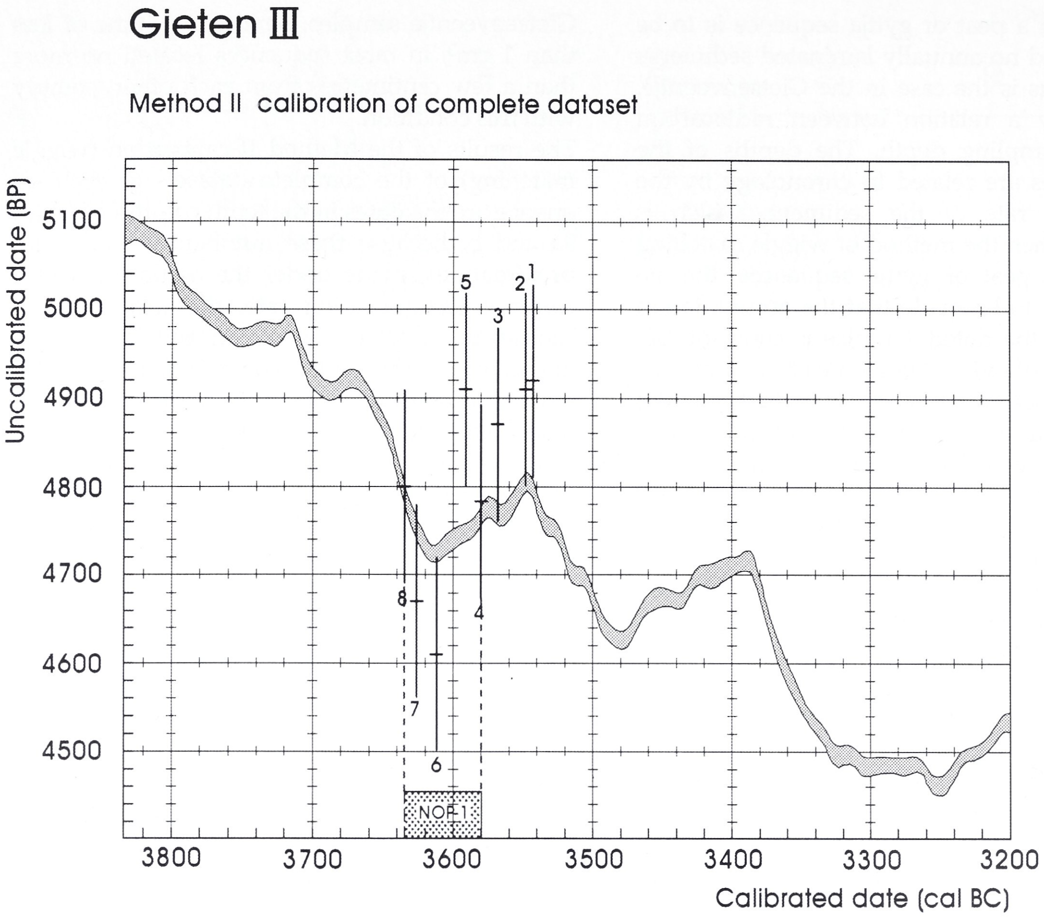


Fig. 62a.

Fig. 62 (pp. 176-179). Method II calibration (wiggle matching) of Gietsenveentje ^{14}C dates of four sequences in which the Neolithic Occupation Period occurs. In Gieten V-A, V-B and V-D, better results are obtained by dividing the complete dataset into several sub-datasets which are separately matched to the calibration curve. For each sequence and calibration result, the corresponding period covered by the first phase of the Neolithic Occupation Period (NOP-1) is indicated:

a. Gieten III, complete dataset. 1-8: series of dates between 322-325.2 cm and 344.6-347.8 cm (see table 9a).
b. Gieten V-A, complete dataset. 1-10: series of dates between 358-359 cm and 376-377 cm (see table 9a).
c. Gieten V-A, sub-datasets. 1-10: as b.
d. Gieten V-B, complete dataset. 1-7: series of dates between 215-216 cm and 264-265 cm (see table 9b).
e. Gieten V-B, sub-datasets. 1-7: as d.
f. Gieten V-D, complete dataset. 1-8: series of dates between 200-201 cm and 222-223 cm (see table 9b).
g. Gieten V-D, sub-datasets. 1-8: as f.

datasets have to be divided into sub-datasets, each of which has to be individually wiggle-matched (see KILIAN et al. 2000; SPERANZA et al. 2000). With the help of figs. 61a-f, it was decided for each sequence into how many sub-datasets the complete dataset had to be divided; where a straight line, indicating a linear time-depth relation, can be drawn through the ranges of all individually calibrated dates (erroneous dates excluded), there is no need to subdivide the dataset. This is the case in sequences Gieten III, IV-P and Gieten V-C. In Gieten IV-HR, no straight line can be drawn through the individually calibrated dates, but because there are only three dates, it makes no sense to subdivide the dataset. In Gieten V-A, V-B and V-D, obviously far better calibration results are obtained when the complete datasets are divided into sub-datasets. The number of sub-datasets is determined by the minimum number of straight lines

Gieten V - A

Method II calibration of complete dataset 358 - 377 cm

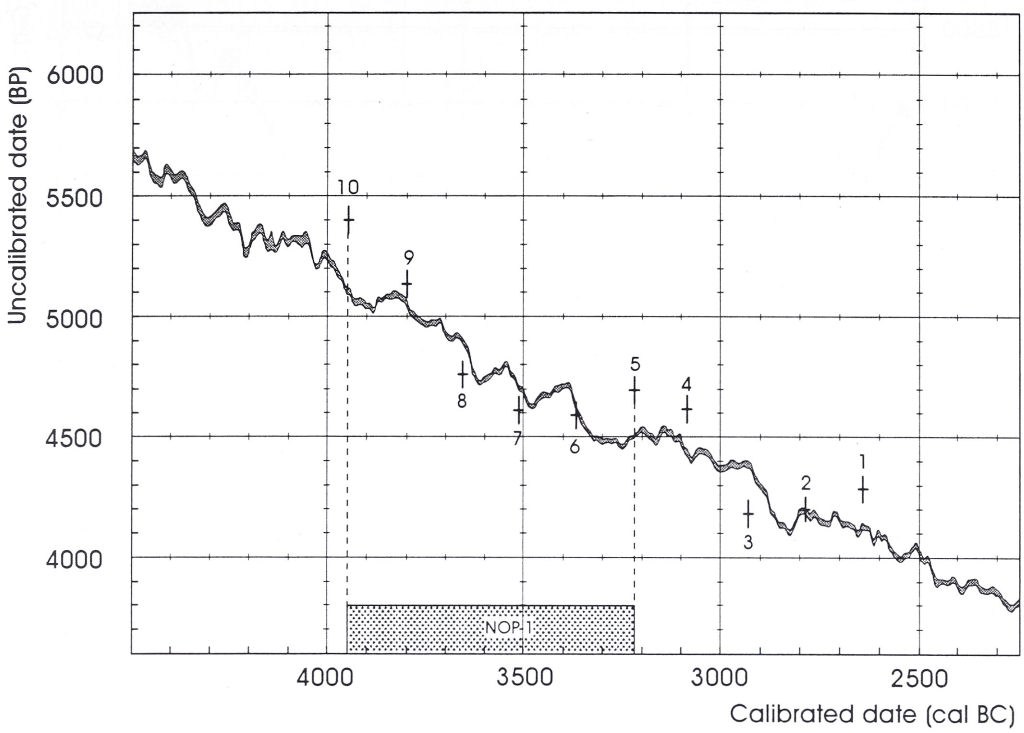


Fig. 62b.

Method II calibration of sub - datasets

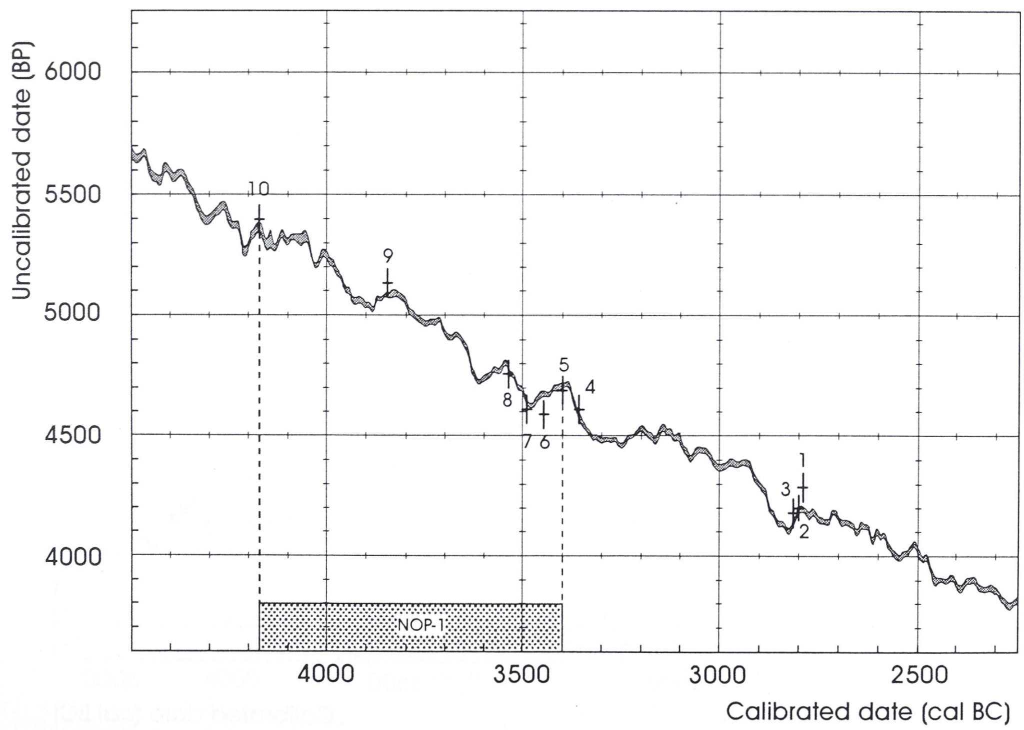


Fig. 62c.

Gieten V - B

Method II calibration of complete dataset

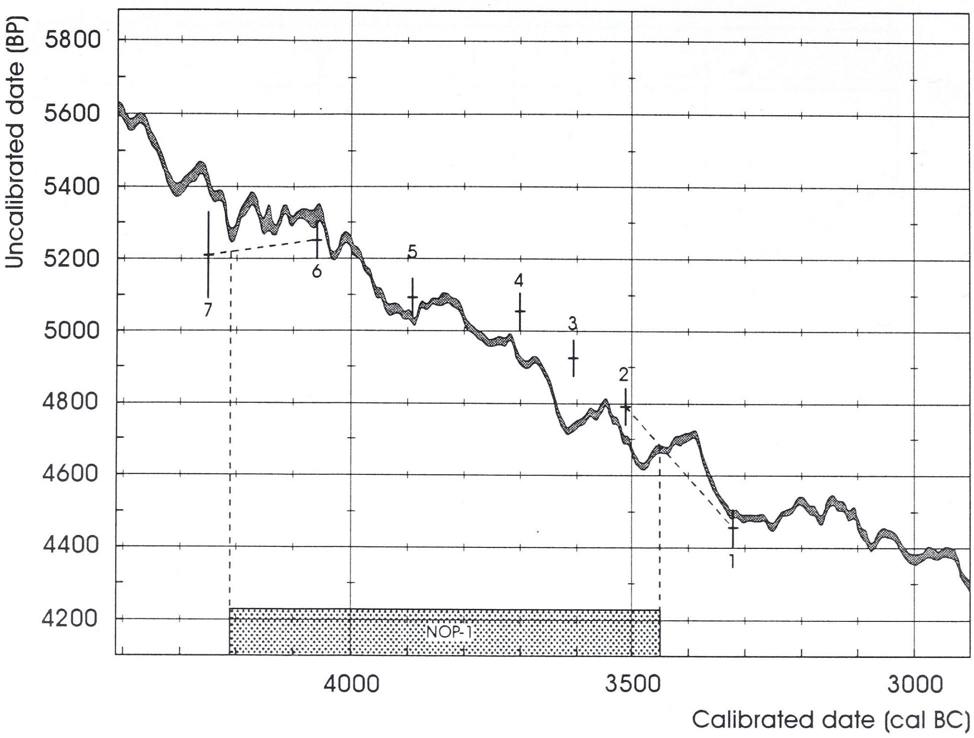


Fig. 62d.

Method II calibration of sub - datasets

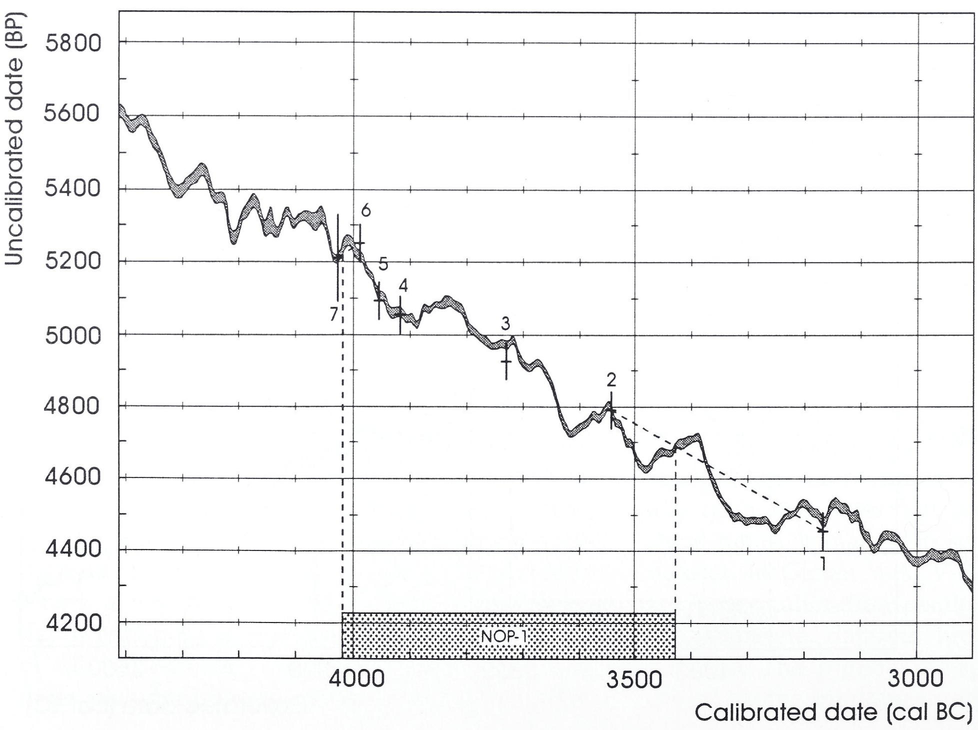


Fig. 62e.

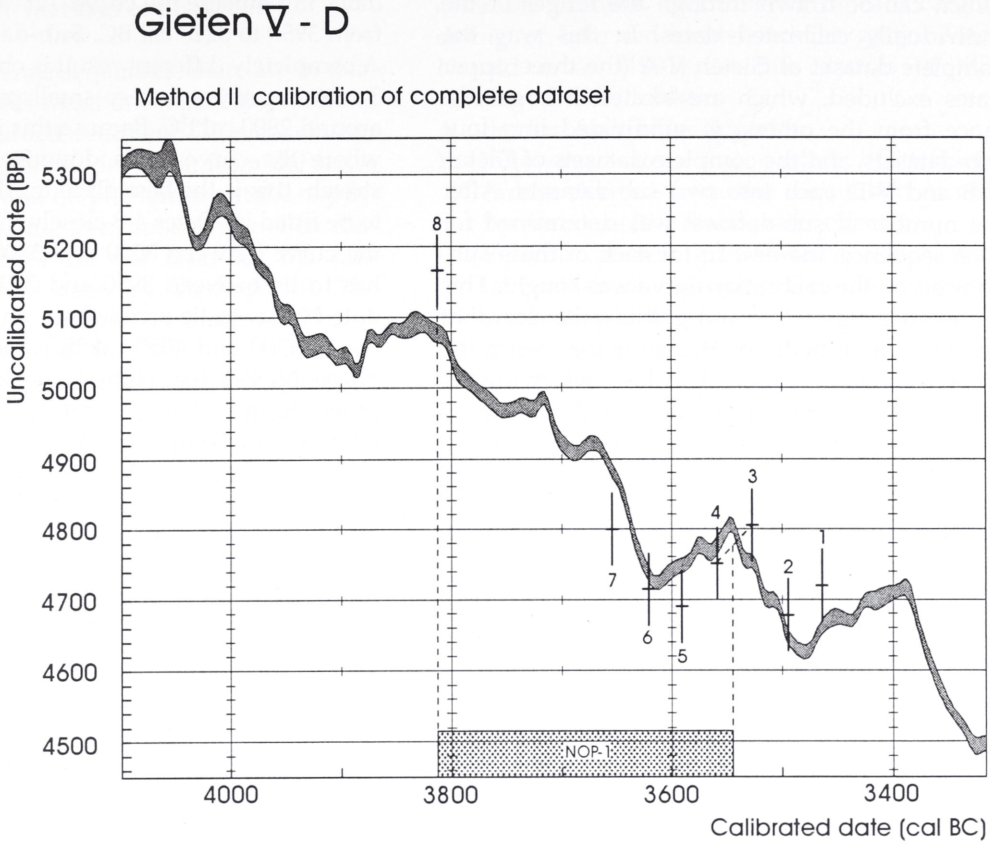


Fig. 62f.

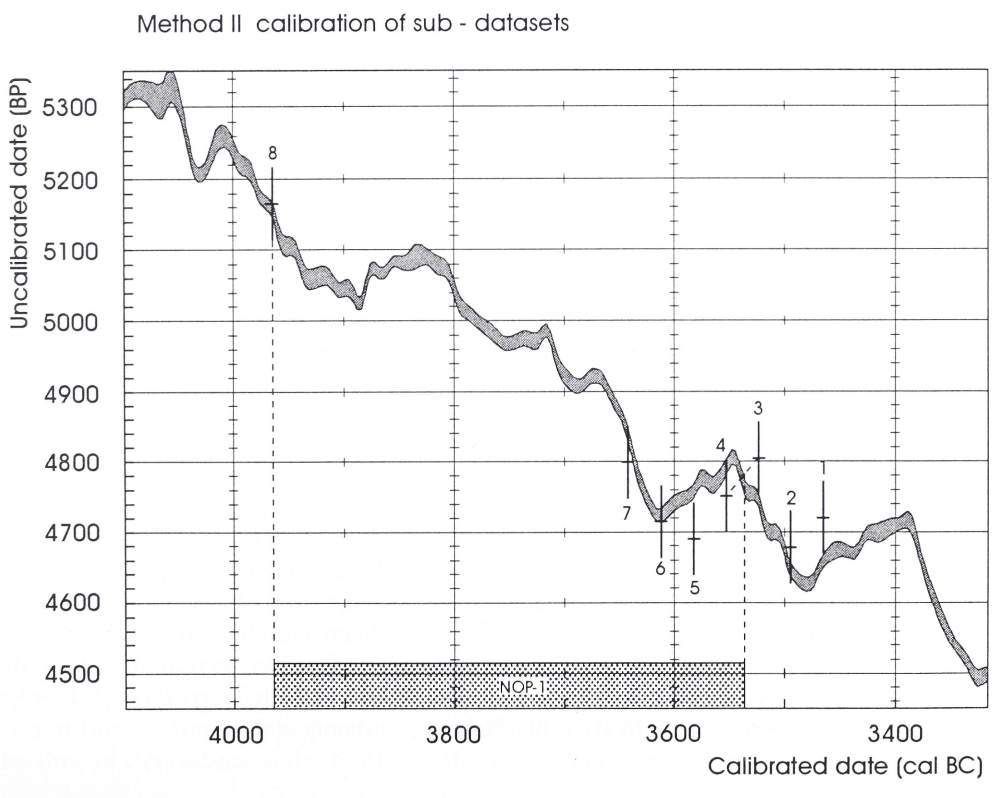


Fig. 62g.

which can be drawn through the ranges of the individually calibrated dates. In this way the complete dataset of Gieten V-A (the three upper dates excluded, which are located a large distance from the others) is subdivided into four sub-datasets, and the complete datasets of Gieten V-B and V-D each into two sub-datasets. After the number of sub-datasets was determined for each sequence, the best fit for each of these sub-datasets on the calibration curve was sought. This is shown in figs. 62c, e and g. It is quite clear that the dates fit far better on the curve than when the complete dataset is used. The dates which are the result of Method II calibration (wiggle matching) of sub-datasets of dates from sequences Gieten V-A, V-B and V-D are given in the eleventh column of tables 9a and b.

Each diagram of fig. 62 also shows the period covered by the first phase of the Neolithic Occupation Period, NOP-1, as recognized in the corresponding pollen diagram (see VI.3). These dates are calculated by the CAL25 program on the basis of the uncalibrated dates of the sediment at the depth where the beginning and the end of NOP-1 occur in the corresponding pollen diagram. In the case of the beginning and the end of NOP-1 in Gieten V-B and the end of NOP-1 in Gieten V-D, there are no dates from the exact depths where these events are reflected; extrapolated dates are calculated here, based on the first date below and the first date above the depth concerned. The dates which were used for the extrapolations, are up to 5 centimetres away from the depth of the beginning of the phase. Unfortunately, the period covered by the second phase of the Neolithic Occupation Period, NOP-2, could not be determined, because there are no dates for the end of this phase.

Below, the results of the Method II calibration (wiggle matching) of series of dates representing the first part of the Neolithic Occupation Period, shown in figs. 62a-g, will be briefly discussed.

Gieten III. Complete dataset (fig. 62a). The uncalibrated dates fit best on a very small part of the calibration curve between 3635 and 3543 cal BC (a similar diagram of these dates has already been published by Lanting & Bottema (1991)). The duration of phase NOP-1 cannot determined with certainty, because of the hiatus around 348 cm (see VI.3.2). The date of the end of NOP-1 (3580 cal BC) is probably reliable.

Gieten V-A. Complete dataset (fig. 62b). The uncalibrated dates fit best on a relatively large part of the curve between 4000 and 2600 cal BC. Seven dates fall outside the curve. Phase NOP-1 ranges from 3950 to 3220 cal BC. **Sub-datasets (fig. 62c).** A completely different result is obtained. Dates 1-3 now represent a very small part of the curve around 2800 cal BC. Because this is the only place where the curve turns downwards for a short stretch, this is the best place for these three dates to be fitted in. Dates 4-8 closely match a wiggle in the curve between 3600 and 3300 cal BC; date 9 has to lie between 3950 and 3800 cal BC, while date 10 has to lie somewhere on the plateau between 4300 and 4050 cal BC. The chronology of phase NOP-1 has shifted considerably: here it ranges from 4170 to 3400 cal BC.

Gieten V-B. Complete dataset (fig. 62d). The uncalibrated dates fit best on a relatively large part of the curve between 4250 and 3300 cal BC. Four dates fall outside the curve. Phase NOP-1 ranges from 4210 to 3450 cal BC. **Sub-datasets (fig. 62e).** When two sub-datasets are wiggle-matched, all dates can be fitted onto the curve. Date 1 lies somewhere on the large plateau of 3350-3000 cal BC, dates 2 and 3 can be placed in more narrow areas around 3550 and 3750 cal BC, respectively, while dates 4-7 can be placed quite adequately on a small and steep part of the curve between 4050 and 3900 cal BC. Especially the date of the beginning of phase NOP-1 has changed: here phase NOP-1 runs from 4020 to 3430 cal BC.

Gieten V-D. Complete dataset (fig. 62f). Dates 1-7 quite well match a wiggle in the curve between 3650 and 3450 cal BC. However, two dates still fall outside the curve. Phase NOP-1 ranges from 3810 to 3540 cal BC. **Sub-datasets (fig. 62g).** When the full dataset is divided into two subsets, dates 1-7 can be matched almost exactly to the wiggle of 3650-3450 cal BC. Date 8 has to lie somewhere between 4050 and 3950 cal BC. Only the beginning of phase NOP-1 has changed: here NOP-1 runs from 3960 to 3540 cal BC.

VI.4.3 Sources of error in the Gietsenveentje dates

Even from the earliest days of radiocarbon dating, it has been recognized that ^{14}C dates cannot be easily transformed into calendar dates. Numerous sources of error hamper this transformation. In recent years, many studies have been carried out to elucidate these sources of error. This section discusses the sources of error which may have influenced the Gietsenveentje dates.

Dates pointing to hiatuses or disturbed sediment

In the Gietsenveentje sequences, there are in total four dated samples which most probably point to hiatuses or disturbed sediment. This conclusion is based on these dates' deviation from the series they are part of, and on phenomena at the depths of these dates in the corresponding pollen diagrams. These dates are not used for the calibration of series of dates by Methods I-II. The following four dates are involved (see table 9):

- Gieten III: GrN-13697.
  This date indicates a hiatus of more than 2000 years at this depth. Large changes in most pollen curves at this depth in the pollen diagram (fig. 53) confirm this picture.
- Gieten V-B: GrA-4984 and GrA-4985.
  These two dates do not fit into the chronological order of the series of dates of Gieten V-B: they seem to be a few hundred years too old. At the depths of these two dates, a different lithology from the rest of the sequence occurs (a poorly humified *Sphagnum* peat). The values of the pollen curves at the depths of the two dates in the pollen diagram (fig. 58) resemble the values found about half a metre deeper in the sediment, confirming the excessive age of these samples.
- Gieten V-C: GrA-7155.
  This date, located at a depth of 60 cm, does not fit into the chronological order of the series of dates of Gieten V-C: it seems to be about 500 years too old. The lithology of the sediment of Gieten V-C from 75 cm upwards (homogeneous humic substance with large pieces of wood) probably indicates disturbance. Two other dates, GrA-4994 and GrA-4995, located at depths of 65 and 70 cm, respectively, are also in this part of the sequence, but their values fit very well into the series of dates. From 75 cm upwards, some pollen curves in the pollen diagram (fig. 59) show rather strange fluctuations, confirming the impression of disturbed sediment.

Sources of error in gyttja dates

It has been argued by different researchers (e.g. OLSSON & FLORIN 1980; OLSSON 1986) that *Sphagnum* peat is ideal for radiocarbon dating, because the exchange with the atmosphere is maximal and there is no possibility of old carbon ending up in the sediment. The "old-carbon" error, in which the samples are deficient in ^{14}C relative to the proportion of the isotope in the atmosphere at the time of deposition, is the most common problem encountered in radiocarbon dating of lake sediments such as gyttja. MacDonald et al. (1991) list five sources of ^{14}C-deficient carbon in lakes:

A. detritus from older deposits;
B. inflowing waters that contain ^{14}C-deficient carbon derived from the dissolution of carbonate rocks (the "hard-water effect");
C. input of ancient groundwater, which may take millennia to progress through an aquifer and enter a lake;
D. gaseous emissions of ^{14}C-free CO_2 from volcanoes;
E. introduction of old, dissolved carbon by glacial meltwater into lakes in recently deglaciated terrain.

When living organisms assimilate carbon that is deficient in ^{14}C because of any of these causes, dating errors will occur, which are referred to as reservoir effects (STUIVER & POLLACH 1977; MACDONALD et al. 1991). Several researchers have tried to quantify reservoir effects in lake sediments. Some examples are given below.

Pazdur et al. (1994) have determined a reservoir effect of ca. 2000 years in Lake Gościąż, Poland. This is a lake with inflow; its area is 0.45 km^2; its present depth is 25.8 m; there is an 18-m layer of lake sediment. Håkansson (1979) determined a reservoir effect of ca. 1400 years in Lake Odensjön, Sweden. This is a lake without inflow; it is fed almost entirely by groundwater; its area is 0.015 km^2; its present depth is ca. 20 m; it has steep edges, more than 30 m high; the surroundings are non-calcareous. Olsson & Florin (1980) determined a reservoir effect of ca. 390 years in Lake Långa Getsjön, Sweden. This is a lake without inflow; its area is 360 m^2 (0.00036 km^2); its present depth is 7 m; it has steep edges. The largest reservoir effect is measured in a lake with inflow; it has already been demonstrated by Pennington (1979) that the contribution from inflowing streams to lake sediment can be more than 80%. There is a distinct possibility that the inflowing water contains ^{14}C-deficient carbon (see source B discussed above). It can also be observed that in deep lakes the reservoir effect is substantially larger than in shallow lakes. In deep lakes, the low ^{14}C activity which causes the reservoir effect may depend in part on a slow CO_2 exchange between the atmosphere and the lake water due to a large *depth-to-surface ratio* (HÅKANSSON 1979). Probably, the major part of the depletion in ^{14}C in deep lakes is caused by the relative slowness of the CO_2 exchange between the atmosphere and the lake water.

Fig. 63 (right). Comparison of the ranges of series of calibrated ^{14}C dates from 8 Gietsenveentje sequences. For each sequence, the calibration results of Methods I and II are shown next to each other. In the case of Gieten V-A, V-B and V-D, the Method II-calibration results of sub-datasets are used (see fig. 62). For the sequences with a range which covers the Neolithic Occupation Period, also the calibrated dates for the beginning of the first (NOP-1) and the second phase (NOP-2) of the Neolithic Occupation Period are given for each calibration method. The periods in which most probably the beginning of NOP-1 and NOP-2 are located, are indicated by shaded belts. Also the ^{14}C dates of the *Betula* seeds from the gyttja sediment of Gieten V-C are shown. In the upper part of the figure, the sediment type of the dated part of each sequence is recorded.

In the Gietsenveentje, four dated sequences of the Neolithic Occupation Period occur in gyttja: Gieten I (only one date), Gieten III, Gieten V-A and Gieten V-D (table 9). Of course there is a possibility that these gyttja dates are influenced by a reservoir effect, caused by ^{14}C-deficient carbon. The five possible sources of ^{14}C-deficient carbon, which have been discussed above, will now be considered in the specific case of the Gietsenveentje:

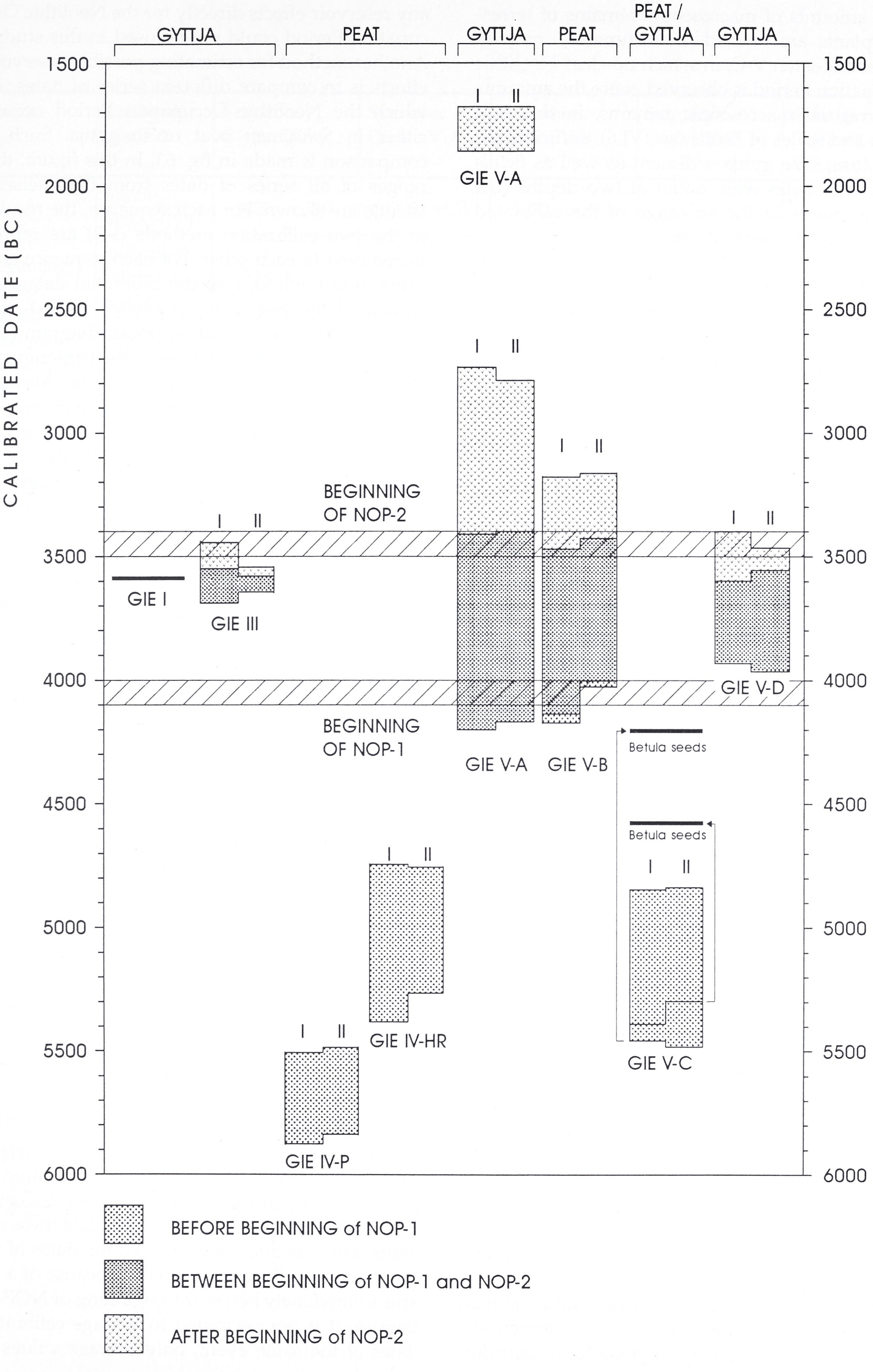
A. *detritus from older deposits*: the sediment could be contaminated with carbonates from a former warm period; this factor is of importance only near the bottom of the sequences, where also secondary pollen is found;
B. *inflowing waters that contain ^{14}C-deficient carbon derived from the dissolution of carbonate rocks (the "hard-water effect")*: there are no inflowing streams in the Gietsenveentje: it is located relatively high on the Hondsrug; it has relatively gentle slopes; the surroundings are non-calcareous.
C. *inputs of ancient groundwater, which may take millennia to progress through an aquifer and enter a lake*: the Gietsenveentje is situated on the higher part of the Hondsrug; here an impermeable till is present which has prevented seepage (DE GANS 1981); the most nearby seepage areas around the Gietsenveentje are located in the valleys of the Hunze and Scheebroekerloop (see III.4.1). The till is also demonstrated in the Pleistocene subsoil under the Gietsenveentje (fig. 45, fig. 47). The Gietsenveentje itself is a closed-system pingo (see III.2.2 and VI.1.3): because of the presence of the till, seepage has not played a role in its formation.
D. *gaseous emissions of ^{14}C-free CO_2 from volcanoes*: there have not been any active volcanoes in northwestern Europe in the last 10,000 years;
E. *introduction of old carbon by glacial meltwater into lakes in recently deglaciated terrain*: this factor only plays a role at the end of the last glaciation; however, the Neolithic Occupation Period occurs far later.

At first sight, in the specific case of the Gietsenveentje, none of these five factors seems to have much affected the accuracy of the gyttja dates of the Neolithic Occupation Period. Furthermore, the *depth-to-surface ratio* of the Gietsenveentje must have been very low in the time the gyttja was deposited: the maximum depth of the then lake was less than 5 metres (see fig. 45), while the area of the lake at that time was about half the area of the total Gietsenveentje, which equals 0.016 km^2. This stimulated the CO_2 exchange between the atmosphere and the lake water, resulting in an equilibrium between the ^{14}C content of the atmosphere and the lake, and minimalizing any reservoir effect. Emergent marshy plants like *Carex* sp. and *Typha* sp., which grew massively in the shallow margins of the then lake, further advanced the CO_2 exchange between atmosphere and lake water. In the upper part of the gyttja sediment zone of all sequences, the gyttja becomes increasingly organic, containing also macroscopic remains of these emergent marshland plants.

Comparison of gyttja dates with dates of *Betula* seeds from the same depth

A well-established method for measuring the apparent age of a certain sediment is to compare dates of macroscopic remains of terrestrial plants from the sediment with dates of the sediment itself (e.g. MACDONALD et al. 1987). The ^{14}C content of terrestrial plants represents the ^{14}C content of the atmosphere at the time the remains of these plants were embedded in the sediment; in contrast to dates from remains of submerged plants, those of terrestrial plants cannot be influenced by the reservoir effect. However, at a "soft-water locality", i.e. where no ^{14}C-deficient carbon is incorporated in the sediment, the submerged plants will yield the same, correct ^{14}C values as the terrestrial plants (DEEVEY et al. 1954).

In the Gietsenveentje, the method described above has been used to measure the apparent age of the gyttja sediment. For this method, relatively


GYTTJA
PEAT
GYTTJA
PEAT
PEAT / GYTTJA
GYTTJA
CALIBRATED DATE (BC)
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
I II
GIE V-A
BEGINNING OF NOP-2
BEGINNING OF NOP-1
GIE I
GIE III
GIE V-A
GIE V-B
GIE V-D
Betula seeds
Betula seeds
GIE IV-HR
GIE IV-P
GIE V-C
BEFORE BEGINNING of NOP-1
BETWEEN BEGINNING of NOP-1 and NOP-2
AFTER BEGINNING of NOP-2

large amounts of macroscopic remains of terrestrial plants are needed. Unfortunately, only in sequence Gieten V-C, in which no clear Neolithic Occupation Period is observed, were the amounts of terrestrial macroscopic remains, in this case seeds and scales of *Betula* (see VI.6), sufficient for ^{14}C dating. The gyttja sediment as well as *Betula* seeds and scales were dated at two depths (the middle points of the 1σ range of the calibrated dates are given, see table 9):

Gieten V-C, 90-91 cm:		
gyttja sediment	5390	cal BC (A)
Betula seeds and scales	4575	cal BC (B)
difference:	815	calendar years

Gieten V-C, 100-101 cm:		
gyttja sediment	5455	cal BC (A)
Betula seeds and scales	4205	cal BC (B)
difference:	1250	calendar years

(A) Method I-calibrated
(B) individually calibrated

A considerable reservoir effect seems to occur at these depths of this sequence. However, it must be kept in mind that the dated sediment occurs near the bottom of sequence Gieten V-C, which is located at 115 cm: the lithology at 100-101 cm consists of sandy gyttja, the lithology at 90-91 cm consists of a transitional phase between gyttja and peat. Because the dated sediment is near the bottom of the sequence, it is not impossible that ^{14}C-deficient carbon from an earlier, carbonate-rich period was embedded in the sediment (source A mentioned above). It is expected that this effect is largest in the dated samples nearest to the bottom: indeed, the reservoir effect in the sample from 100-101 cm is 400 years greater than the reservoir effect in the sample from 90-91 cm. In the sequences with a Neolithic Occupation Period, the beginning of this period is nowhere located near the bottom, but much higher up in the sequence, in a more organic gyttja (see fig. 45). For this reason, these measurements of a possible reservoir effect cannot be used to estimate any reservoir effect in the Neolithic Occupation Period of other Gietsenveentje sequences.

Other ways of estimating a possible reservoir effect

It will be clear from the above discussion that it is difficult to exclude the possibility of reservoir effects, especially in gyttja. Methods for measuring any reservoir effects directly for the Neolithic Occupation Period could not be used in this study. Another method for estimating possible reservoir effects is to compare different series of dates, in which the Neolithic Occupation Period occurs either in *Sphagnum* peat or in gyttja. Such a comparison is made in fig. 63. In this figure, the ranges of all series of dates from the Gietsenveentje are shown. For each sequence, the results of the two calibration methods (I-II) are reproduced next to each other. For each sequence and calibration method, also the calibrated dates are shown of the beginning of phases NOP-1 and NOP-2 in the corresponding pollen diagram (see VI.3). Table 10 shows all dates of the beginning of NOP-1 and NOP-2 in the Gietsenveentje. Also the time in calendar years between the beginning of NOP-1 and the beginning of NOP-2 is given according to the two calibration methods. As already mentioned, the dates of the beginning of NOP-1 and NOP-2 in Gieten V-B and the starting date of NOP-2 in Gieten V-D are extrapolated dates (in the table indicated by †).
The only sequence with a series of dates from *Sphagnum* peat for the Neolithic Occupation Period is Gieten V-B. A very important observation is that the *Sphagnum* peat dates of Gieten V-B of the beginning of NOP-1 and NOP-2 are not younger than the gyttja dates of Gieten III, V-A and V-D of the same events. The conclusion from this comparison is that for the Neolithic Occupation Period there is no evidence of a reservoir effect in the gyttja dates.

VI.4.4 Absolute dating of the beginning of phases NOP-1 and NOP-2 and comparison with archaeological dates

On the basis of the calibrated dates of all Gietsenveentje sequences with a Neolithic Occupation Period, absolute dates for the beginning of phases NOP-1 and NOP-2 of the Neolithic Occupation Period in the Gietsenveentje will now be sought. In the far right column of table 10, average dates are given of the beginning of NOP-1, the beginning of NOP-2 and the time between these two events, which is the total duration of phase NOP-1. Only the dates of sequences Gieten V-A, V-B and V-D are used to calculate these average dates; as already indicated, the dates of sequence Gieten III are less reliable because of a hiatus immediately before the beginning of NOP-1. Because it is not permitted to average calibrated dates of the same event, only average values of

Event	Calibration method	Sequence Gieten III	Sequence Gieten V-A	Sequence Gieten V-B	Sequence Gieten V-D	Average of Gieten V-A, V-B and V-D
beginning of first Neolithic Occupation Phase: NOP-1	uncali-brated (BP)	4800 ± 110	5395 ± 55	5230 ± 88 †	5165 ± 50	5263 ± 34
	individual calibration (cal BC)	3535 *	4225 *	4095 †*	3930 *	4100 @*
	Method I calibration (cal BC)	3690 *	4195 *	4147 †*	3930 *	
	Method II calibration (cal BC)	3635 #	4172 #	4018 †#	3964 #	
beginning of second Neolithic Occupation Phase: NOP-2	uncali-brated (BP)	4780 ± 110	4690 ± 50	4623 ± 50 †	4778 ± 50 †	4697 ± 28
	individual calibration (cal BC)	3515 *	3495 *	3430 †*	3580 †*	3495 @*
	Method I calibration (cal BC)	3555 *	3408 *	3464 †*	3559 †*	
	Method II calibration (cal BC)	3580 #	3402 #	3429 †#	3539 †#	
duration of first Neolithic Occupation Phase: NOP-1	uncali-brated (BP)	20	705	607	387	566
	individual calibration (cal BC)	20	730	665	350	582
	Method I calibration (cal BC)	135	787	683	371	
	Method II calibration (cal BC)	55	770	589	425	

Table 10. Gietsenveentje ^{14}C dates of the beginning of Neolithic Occupation Phases NOP-1 and NOP-2.
† extrapolated value; * in order to improve the readability of these values, not the ranges of the calibrated value are given, which are the result of individual calibration and Method I calibration, but only the middle points of the 1σ range; # no standard errors of these values can be calculated (see main text); @ individual calibration of the mean uncalibrated date of the values of sequences Gieten V-A, V-B and V-D.

Dated event/culture/ object	Location	Uncalibrated date	Calibrated date	References
beginning of first Neolithic Occupation Phase: NOP-1	Gietsenveentje, Drenthe Plateau	5263 ± 34 BP	4100-4000 cal BC	this study
Middle Phase of Swifterbant Culture	lower parts of central and western Netherlands	5750-5050 BP	4600-3850 cal BC	RAEMAEKERS 1999; LANTING & VAN DER PLICHT 1999/2000
pot from Early Phase of Swifterbant Culture	Bronneger, Drenthe Plateau	5970-5720 BP	4710 cal BC	KROEZENGA et al. 1991; LANTING 1992
beginning of second Neolithic Occupation Phase: NOP-2	Gietsenveentje, Drenthe Plateau	4697 ± 28 BP	3500-3400 cal BC	this study
West Group of Funnel Beaker Culture (TRB)	Drenthe Plateau/ Veluwe	4650-4200 BP	3400-2800 cal BC	BRINDLEY 1986; LANTING & VAN DER PLICHT 1999/2000
duration of first Neolithic Occupation Phase: NOP-1	Gietsenveentje, Drenthe Plateau	566 ^{14}C years	500-700 cal. years	
time between beginning of Middle Phase of Swifterbant Culture and beginning of TRB West Group	the Netherlands	1100 ^{14}C years	1200 cal. years	

Table 11. Comparison between Gietsenveentje dates of Neolithic Occupation Phases and archaeological dates.

the uncalibrated dates are given; these average values are calibrated individually to achieve an average value for the calibrated dates. In table 10, these averaged values are shown immediately below the averaged uncalibrated values in the far right column. They can be summarized as follows:

beginning of NOP-1:	ca. 4100 cal BC
beginning of NOP-2:	ca. 3500 cal BC
duration of NOP-1:	ca. 600 calendar years

However, in these averaged calibrated dates, the improvements obtained by calibration according to Methods I-II are not incorporated. When the results of calibration by Methods I-II, as summarized in table 10, are used to adjust the above-mentioned values, the following calibrated dates are obtained:

beginning of NOP-1:	4100-4000 cal BC
beginning of NOP-2:	3500-3400 cal BC
duration of NOP-1:	500-700 calendar years

The advantage of AMS dating becomes quite clear from these results: because very small samples can be dated, individual calibration of samples with a length of 1 cm taken exactly at the beginning of the Neolithic Occupation Phases will yield very accurate results; when a series of dates is taken with small distances between the samples, covering the beginning of the various occupation phases, the accuracy of the dates can be improved considerably if the method of wiggle matching is used. This proves that wiggle matching is not only very useful for the absolute dating of tree rings, but also for the absolute dating of certain levels in peat and gyttja sequences.

The average dates for the beginning of NOP-1 and NOP-2 are also indicated in fig. 63. When these dates are compared to archaeological dates, it may become clear which cultures caused the two Neolithic Occupation Phases. In table 11, such a comparison is made.

The average date of the beginning of phase NOP-1 falls within the dates that delimit the Middle Phase of the Swifterbant Culture: 4600-3850 cal BC (table 11). People of the Swifterbant Culture predominantly lived on river dunes in the lower central and western parts of the Netherlands. It is certain that people of the Middle Phase of this culture practised agriculture (RAEMAEKERS 1999; BRINKKEMPER et al. 1999). On the Drenthe Plateau, only very few artefacts from Swifterbant times have been found (see fig. 23). Only one of these artefacts, a fragmentary Swifterbant pot found in combination with two red-deer antlers in the Voorste Diep near Bronneger, about 10 km SE of the Gietsenveentje, has been dated (KROEZENGA et al. 1991; LANTING 1992). The date of organic remains which adhered to the pot is 5890 ± 90 BP. The dates of the two antlers were 5720 ± 90 BP and 5970 ± 90 BP. Combined calibration of these three dates by the OxCal program yields a result of 4710 cal BC (middle point of 1σ range of calibrated date). This indicates that the pot is contemporary with the Early Phase of the Swifterbant Culture (4900-4600 cal BC), a phase in which most probably no arable farming was practised (RAEMAEKERS 1999). However, the importance of the Bronneger find should not be overestimated, because it is an isolated find without any clear context.

The average date of the beginning of phase NOP-2 corresponds most closely to the date of the beginning of the West Group of the Funnel Beaker Culture (TRB) in the Netherlands: ca. 3400 cal BC (table 11). Generally, phase NOP-2 is more obvious in the Gietsenveentje pollen diagrams than phase NOP-1; the dates marking the beginning of NOP-2 in the different Gietsenveentje sequences differ less from each other than the dates of the beginning of NOP-1 (table 10). These facts are consistent with the massive presence of the TRB West Group on the Drenthe Plateau, which is demonstrated by the finds of much pottery and flint material as well as the famous megalithic tombs (*hunebedden*) (see III.7.4). In the direct vicinity of the Gietsenveentje, also several TRB "settlements" (concentrations of pottery and flint) and megalithic tombs have been excavated (see fig. 24).

In the Gietsenveentje, the duration of NOP-1 amounts to 500-700 calendar years. On the basis of macroscopic remains from Swifterbant sites in the lower parts of the central and western Netherlands, it is estimated that stock keeping was adopted around 4750 cal BC and arable farming only around 4200 cal BC (RAEMAEKERS 1999; BRINKKEMPER et al. 1999). These dates suggest that most probably arable farming was first practised by people of the Middle Phase of the Swifterbant Culture, which is dated between 4600 and 3850 cal BC. This means that if Swifterbant people were responsible for phase NOP-1 in the Gietsenveentje pollen diagrams, indicating arable farming from ca. 4050 cal BC onwards, arable farming was introduced on the Drenthe Plateau only 100 to 200 years later than in the western and central parts of the Netherlands.

VI.5 Pollen concentration and pollen influx analysis

VI.5.1 Introduction

Palynological reconstructions of changes in the past vegetation are mainly based on percentage diagrams. Although they are very useful and meet most requirements, the limitation that the values of each pollen type depend on other types cannot be resolved. To overcome this inherent problem, concentration and influx pollen diagrams are used to achieve a more realistic picture of the composition and abundance of the past vegetation and how it has changed (AABY 1988). In these types of diagram, the pollen values are independent of each other. Estimation of pollen influx involves calculation of the sedimentation rate with the help of ^{14}C dates (AABY 1988). As a consequence, all sources of error influencing ^{14}C dates (see VI.4.3) also affect pollen influx values. In addition, depositional and post-depositional processes have considerable influence on the observed pollen concentration values (BIRKS & BIRKS 1980).

The aim is to describe overall variations in pollen influx and to investigate whether human activities could be responsible for these variations. Pollen concentration and pollen influx curves of five Gietsenveentje sequences are presented. Three tree pollen types (*Alnus, Corylus, Quercus*) dominate the pollen sum used for calculating percentage values, and variations in the influx of these types therefore influence the frequencies obtained in relative pollen diagrams. Pollen influx curves of these three tree pollen types are presented together with influx curves of *Betula* pollen, which is found very frequently but excluded from the pollen sum, and total NAP pollen.

Sequence, depth and Neolithic Occupation Phase	Sediment type	Sedimentation rate according to Method I (mm/year)	Sedimentation rate according to Method II (complete dataset) (mm/year)	Sedimentation rate according to Method II (sub-datasets) (mm/year)
Gieten III				
323.6-326.8 cm, NOP-2	gyttja	1.28	2.46	-
326.8-330.1 cm, NOP-2	gyttja	1.32	2.46	-
330.1-333.3 cm, NOP-2	gyttja	0.53	2.46	-
333.3-336.5 cm, NOP-1	gyttja	1.78	2.46	-
336.5-339.7 cm, NOP-1	gyttja	1.19	2.46	-
339.7-343.0 cm, NOP-1	gyttja	1.65	2.46	-
343.0-346.2 cm, NOP-1	gyttja	0.46	2.46	-
Gieten IV-P				
260.5-265.5 cm	wood/peat	1.00	1.30	-
265.5-271 cm	peat/wood	0.69	1.30	-
271-306 cm	peat/gyttja	1.46	1.30	-
Gieten IV-HR				
265.5-271 cm	peat	0.44	0.22	-
271-276.5 cm	peat	0.11	0.22	-
Gieten V-A				
280.5-285.5 cm	peat/gyttja	0.63	-	0.70
285.5-290.5 cm	gyttja	0.53	-	0.70
290.5-358.5 cm, NOP-2/3	gyttja	0.77	-	0.70
358.5-360.5 cm, NOP-2	gyttja	0.80	0.14	1.60
360.5-362.5 cm, NOP-2	gyttja	0.26	0.14	1.60
362.5-364.5 cm, NOP-2	gyttja	0.05	0.14	0.04
364.5-366.5 cm, NOP-1b	gyttja	0.14	0.14	0.44
366.5-368.5 cm, NOP-1b	gyttja	0.37	0.14	0.44
368.5-370.5 cm, NOP-1b	gyttja	0.83	0.14	0.44
370.5-372.5 cm, NOP-1a	gyttja	0.21	0.14	0.44
372.5-374.5 cm, NOP-1a	gyttja	0.06	0.14	0.06
374.5-376.5 cm, NOP-1a	gyttja	0.07	0.14	0.06
Gieten V-B				
215.5-225.5 cm, NOP-2	peat	0.25	0.53	0.27
225.5-230.5 cm, NOP-1	peat	0.42	0.53	0.27
230.5-235.5 cm, NOP-1	peat	0.37	0.53	0.27
235.5-245.5 cm, NOP-1	peat	1.43	0.53	2.64
245.5-254.5 cm, NOP-1	peat	0.62	0.53	2.64
254.5-264.5 cm, NOP-1	peat	0.87	0.53	2.64

Table 12. Sedimentation rates in Gietsenveentje sequences. The numbers are calculated on the basis of the ^{14}C dates of table 9.

Sequence, depth and Neolithic Occupation Phase	Sediment type	Sedimentation rate according to Method I (mm/year)	Sedimentation rate according to Method II (complete dataset) (mm/year)	Sedimentation rate according to Method II (sub-datasets) (mm/year)
Gieten V-C				
65.5-70.5 cm	peat/wood	0.71	0.54	-
70.5-75.5 cm	peat	0.71	0.54	-
75.5-80.5 cm	peat	0.26	0.54	-
80.5-85.5 cm	peat	0.39	0.54	-
85.5-90.5 cm	peat/gyttja	0.61	0.54	-
90.5-100.5 cm	gyttja	1.54	0.54	-
Gieten V-D				
200.5-202.5 cm, NOP-2	gyttja	0.29	0.63	0.68
202.5-204.5 cm, NOP-2	gyttja	0.27	0.63	0.68
204.5-206.5 cm, NOP-2	gyttja	0.63	0.63	0.68
206.5-208.5 cm, NOP-1	gyttja	0.77	0.63	0.68
208.5-210.5 cm, NOP-1	gyttja	1.33	0.63	0.68
210.5-212.5 cm, NOP-1	gyttja	0.91	0.63	0.68
212.5-222.5 cm, NOP-1	gyttja	0.34	0.63	0.31

Table 12 (continued).

VI.5.2 Sedimentation rates of different types of Gietsenveentje sediment

The pollen concentration in a certain type of sediment is determined by two factors, apart from preservation conditions: the pollen influx, i.e. the number of pollen grains falling on a certain area in a certain unit of time, and the growth rate of the sediment. In most types of sediment, sedimentation rate is likely to be the main factor determining pollen concentration (MIDDELDORP 1982). On the basis of ^{14}C dates (table 9), the sedimentation rate of different types of sediment in seven Gietsenveentje sequences has been determined. The formula used for this is given in IV.8. Table 12 indicates all sedimentation-rate values. Because two different calibration methods have been used to calibrate the ^{14}C dates, also different values for the sedimentation rate are obtained. Calibration by Method I was performed without taking account of sedimentation rate (see VI.4.2). As a consequence, strongly differing sedimentation-rate values are obtained, even within a few centimetres, which are given in the third column of table 12. In the calibration by Method II (wiggle matching) a constant sedimentation rate was assumed (see VI.4.2). First the complete dataset of each sequence was matched to the calibration curve, assuming a constant sedimentation rate for the entire dated part of the sequence. These sedimentation rates are given in the fourth column of table 12. In sequences Gieten V-A, V-B and V-D it proved impossible to match the complete dataset exactly to the curve, which indicated differences in sedimentation rate in the dated part of the sequence. For this reason, the datasets in these sequences were divided into various sub-datasets. In this way it became possible to match the dates almost exactly to the curve (see figs. 62c, e and g). Each sub-dataset has its own, constant sedimentation rate, which is given in the fifth column of table 12. The determination of pollen influx was based on the sedimentation rates calculated from dates obtained by Method II calibration of sub-datasets (Gieten V-A, V-B and V-D) or complete datasets (other sequences). These dates must represent the best calibration result, since they are matched as exactly as possible to the ^{14}C calibration curve.

The sedimentation rates of various types of sediment can differ strongly; in each type of sediment, specific sources of error may appear. For this reason, sedimentation rates of *Sphagnum* peat and gyttja will now be discussed separately.

Sedimentation rate of *Sphagnum* peat

It is assumed that the sedimentation rate of peat is in the first place determined by the net production on the bog surface and the degree of aerobic decomposition. Once the peat layers are embedded in the anaerobic zone, secondary processes can influence (apparent) sedimentation rate. Among these secondary processes are autocompaction, creep and anaerobic decomposition (AABY & TAUBER 1975). However, these processes are of minor importance compared to the secondary processes which can influence sedimentation rate of lake sediments (see below).

There are four Gietsenveentje sequences in which the sedimentation rate of *Sphagnum* peat has been determined: Gieten IV-P, IV-HR, V-B and V-C (table 12). Unfortunately, the Neolithic Occupation Period appears clearly only in Gieten V-B. The mean sedimentation rate (according to Method II calibration) of *Sphagnum* peat in these four sequences is 0.99 mm/year. This value is comparable to sedimentation rates of north European raised bogs, as summarized by Aaby & Tauber, 1975, fig. 5. It has to be emphasized that such a comparison has only limited value, because the influence of the above-named secondary processes is different everywhere, and because at the time of the publication by Aaby & Tauber, no complete calibration curve was available so that no wiggle matching could be performed. However, when this comparison is made all the same, the mean sedimentation rate of Gietsenveentje *Sphagnum* peat seems to be somewhat higher than the sedimentation rates of most other bogs; for example, the sedimentation rate of the large raised bog at Emmererfscheidenveen in the southern part of the province of Drenthe (VAN ZEIST 1955b) was ca. 0.63 mm/year.

Sedimentation rate of gyttja

In lakes, the sedimentation rate and the pollen concentration, and consequently the pollen influx, are influenced to a large extent by secondary, within-lake processes. Birks & Birks (1980) have summarized the within-lake processes which may influence the sedimentation rate of lake sediment. The following two factors are relevant in the case of the Gietsenveentje:

A. mass movement of bodies of sediment towards the centre of the lake: here, sedimentation rate and pollen influx strongly increase, while pollen percentages remain more or less constant; such a process will also be detected in the lithology and the ^{14}C dates. This kind of process took place in the sequences Gieten IV-P and Gieten IV-HR, a long time before the Neolithic Occupation Period (see VI.3.2).

B. soil disturbance, for example through forest clearance, can lead to the inwashing of soil and the pollen it contains, resulting in a strongly increased sedimentation rate and pollen influx (HYVÄRINEN 1976). This factor may have been important in Gietsenveentje sequences during the Neolithic Occupation Period. However, such an event will probably also be detectable in the lithology and ^{14}C dates.

There are three Gietsenveentje sequences in which the sedimentation rate of gyttja has been determined: Gieten III, V-A and V-D (table 12). The Neolithic Occupation Period occurs in all three sequences. The mean sedimentation rate of gyttja (based on Method II calibration of subdatasets) in sequences Gieten V-A and V-D is 0.55 mm/year. The sedimentation rate of the gyttja in Gieten III is very high compared to the other gyttja sequences and even compared to the peat sequences. In VI.4.2, it already was noted that probably the dates of Gieten III are not fully reliable, because of disturbances of the sediment. This conclusion is confirmed by the spurious sedimentation rates which are calculated on the basis of the ^{14}C dates.

As expected, the reliable mean sedimentation rate of the gyttja of sequences Gieten V-A and V-D, 0.55 mm/year, is lower than the mean sedimentation rate of the peat sequences.

VI.5.3 Pollen concentration and pollen influx data of Gietsenveentje sequences

Pollen concentration and influx were determined with the help of tablets with a fixed number of a *tracer*, in this case *Lycopodium* spores, which were added to pollen samples of a fixed volume (see IV.8).

First, the mean concentration and the mean influx of all pollen grains forming the pollen sum (ΣP) of five Gietsenveentje sequences were calculated (table 13). A distinction has to be made between the peat sequences (Gieten V-B and V-C) and the gyttja sequences (Gieten III, V-A and V-D). It can be observed from the table that the mean ΣP pollen concentration in the peat sequences is six

Sequence	Depth (cm)	Mean concentration (grains cm^{-3} x 10^5)	Range of concentration (grains cm^{-3} x 10^5)	Mean influx (grains cm^{-2}year^{-1})	Range of influx (grains cm^{-2} year^{-1})
Gieten V-C	65 - 101	2.53	0.64 - 4.86	1368	550 - 2620
Gieten V-B	215 - 265	1.96	0.80 - 4.67	2831	290 - 7520
Gieten III	322 - 348	4.86	1.35 - 12.30	11953	3320 - 30260
Gieten V-A	280 - 376	20.33	3.55 - 91.75	9474	460 - 40370
Gieten V-D	201 - 223	12.49	5.52 - 40.13	5449	1710 - 12440

Table 13. Mean values and ranges of pollen concentration and pollen influx of the total number of pollen participating in the pollen sum (ΣP = AP + NAP) of various Gietsenveentje sequences. The types of sediment of these parts of the sequences are given in table 12. The sequences are classified according to the location of their core locations: from north (Gieten V-C) to south (Gieten V-D) (see VI.1).

to ten times lower than the mean ΣP pollen concentration in the gyttja sequences (the probably unreliable values of Gieten III are left aside). This can be explained by the higher sedimentation rate of peat compared to gyttja. However, the mean ΣP pollen influx of the peat sequences is two to seven times lower than the mean ΣP pollen influx of the gyttja sequences. This is more difficult to explain, because it is assumed that pollen influx is independent of the sedimentation rate.

The mean pollen influx values of table 13 can be compared with pollen influx data from the literature. Mack et al. (1979) state that total pollen influx in Holocene peat is generally ca. 5000 grains/cm^2/year, with a minimum of 1000 grains/cm^2/year. This is a very generalized figure, which is dependent on many local factors such as vegetation type and sedimentary processes. It can only be concluded that this figure is in the same order of magnitude as the mean ΣP pollen influx of Gietsenveentje peat sequences, which is ca. 2100 grains/cm^2/year (table 13).

The ΣP pollen influx of Gietsenveentje gyttja sequences can be compared with data collected by Hyvärinen (1976, table 2) and Birks & Birks (1980, table 10.8; table 10.9). According to Hyvärinen (1976), the mean total pollen influx of coniferous forest and woodland in lake sediment is ca. 3000 grains/cm^2/year. M.B. Davis et al. (1973) put the mean total pollen influx of different vegetation types in 29 lakes in Michigan (U.S.A.) at ca. 35,000 grains/cm^2/year. These very different figures again illustrate the influence of local factors on the total pollen influx. The mean ΣP pollen influx of Gietsenveentje gyttja sequences, which is ca. 7500 grains/cm^2/year (Gieten III excluded; table 13), lies between these two values.

Pollen influx of the most common pollen types

In figs. 64a-f, pollen influx values of the four most common tree pollen types (*Alnus, Corylus, Quercus* and *Betula*) and total NAP of five Gietsenveentje sequences are shown. For comparison, also the ΣP pollen concentration and ΣP pollen influx values of each sample are shown.

When all diagrams are considered (figs. 64a-f), a conspicuous general trend can be observed: all pollen influx curves more or less follow the course of the ΣP pollen influx. In a concentration diagram it is expected that curves of different pollen types all follow the same course; this can be explained by differences in sedimentation rate. However, pollen influx values are in principle independent of sedimentation rate. When all pollen influx curves follow roughly the same course, a single underlying process seems responsible for this. This process has to be a within-lake or within-peat process, not representing changes in the vegetation. Middeldorp (1984) already remarked that variations in pollen concentration caused by a strongly fluctuating sedimentation rate do not disappear in an influx diagram, even one based on ^{14}C dates located a few centimetres from each other, because fluctuations in sedimentation rate may occur within centimetres.

In order to trace trends in the various pollen influx curves which represent real changes in the vegetation, the pollen influx curve of each pollen type (the third to the seventh curve in figs. 64a-f) has to be compared with the ΣP pollen influx curve (the second curve in figs. 64a-f). The trends which follow the general trend of the ΣP pollen influx can be ignored; the remaining trends will represent real changes in the vegetation. These "real" trends in each sequence are described below. Emphasis will be laid on linking these

Fig. 64 (pp. 193-195). Pollen concentration and pollen influx diagrams of five Gietsenveentje sequences. First, pollen concentration and pollen influx curves of all pollen participating in the pollen sum (ΣP) are given, followed by pollen influx curves of the four most common AP types and total NAP. It has to be remarked that *Betula* is not included in the pollen sum. The various phases of the Neolithic Occupation Period (NOP-1a, NOP-1b, NOP-2 and NOP-3) are also indicated. Diagrams of the following sequences are shown: a. Gieten III; b. Gieten V-A; c. Gieten V-A (detail); d. Gieten V-B; e. Gieten V-C; f. Gieten V-D.

trends with the appearance of the Neolithic Occupation Period. The Neolithic Occupation Period is subdivided into 3 phases: NOP-1, NOP-2 and NOP-3. In sequence Gieten V-A, phase NOP-1 is subdivided into NOP-1a and NOP-1b.

Gieten III (fig. 64a): High influx values of all types are observed at 348-342 cm, during NOP-1. *Quercus* shows the highest influx values, followed by *Alnus*. The following general trends can be observed (compared to ΣP pollen influx): *Alnus*, *Corylus* and *Quercus* remain constant; *Betula* decreases and total NAP increases.

Gieten V-A (figs. 64b and c): Three large peaks in influx values of all types occur at 371 cm (NOP-1a), 366 cm (border of NOP-1b and NOP-2) and 361 cm (NOP-2). *Alnus* and *Quercus* show the highest influx values. The following general trends can be observed in NOP-1 and NOP-2 (fig. 64c): *Alnus*, *Corylus* and *Quercus* very closely follow the ΣP influx curve (i.e. remain constant); *Betula* increases less than the ΣP influx curve (i.e. decreases) and total NAP increases more than the ΣP influx curve (i.e. increases). During NOP-3 (fig. 64b), all curves decrease except for the total NAP curve, which remains more or less constant.

Gieten V-B (fig. 64d): A peak in influx values of all types occurs at 240 cm, during NOP-1. Before the peak, *Betula* and *Quercus* show the highest influx values, while after the peak, *Alnus* and *Quercus* display the highest influx values. The following general trends can be observed: *Alnus* and *Corylus* remain constant; *Quercus* decreases slightly, *Betula* decreases fairly strongly; total NAP increases.

Gieten V-C (fig. 64e): In this sequence, no clear Neolithic Occupation Period is observed. All influx values are more or less constant, except for *Betula*, which reaches a large peak between 80 and 75 cm. *Betula* reaches by far the highest influx values, followed by *Alnus*.

Gieten V-D (fig. 64f): A peak in influx values of all types occurs at 219 cm, which is in phase NOP-1; from 211 cm upwards, which is still in NOP-1, the influx values of all types increase. *Alnus* and *Quercus* show the highest influx values. The following general trends can be observed: *Alnus*, *Corylus* and *Quercus* very closely follow the ΣP influx curve (i.e. remain constant), the increase of *Betula* at 211 cm is smaller than the increase of ΣP (i.e. influx decreases), while the increase of total NAP at 211 cm is considerably larger than the increase of ΣP (i.e. influx increases quite strongly).

A conspicuous similarity between all diagrams in which the Neolithic Occupation Period occurs, is the influx peak in NOP-1. This influx peak varies in height between very high (Gieten V-A) and fairly small (Gieten V-B), but it is unmistakably present in the gyttja as well as in the peat sequences. Because this peak occurs in all pollen types, it probably does not reflect changes in the vegetation: it is difficult to imagine that as a result of a certain event, all trees and plants in the neighbourhood should start to produce more pollen. The cause of the influx peak in all curves has to be a secondary, within-lake or within-peat process (see VI.5.2). The possibility has to be considered that a small-scale forest clearance not far from the Gietsenveentje was the cause of the inwashing of soil and the pollen it contained, resulting in a strongly increased sedimentation rate and pollen influx of the Gietsenveentje sediment. Indeed, it can be observed from table 12 that on the whole, the highest sedimentation rates of the Gietsenveentje sediment occur during the first phase of the Neolithic Occupation Phase (NOP-1). However, the inwashed soil itself should be detectable in the lithology, and this seems not to be the case in the various Gietsenveentje sequences. In the sequences with a Neolithic Occupation Period, the influx peak in phase NOP-1 is globally dated as follows (Method II-calibrated dates of complete dataset (Gieten III) and of sub-datasets (other sequences), see table 9):

Gieten III:	3630 cal BC
Gieten V-A:	3515 cal BC
Gieten V-B:	3935 cal BC
Gieten V-D:	3870 cal BC

On average, the peak can be dated around 3700 cal BC. Because the peak generally covers only a small part of phase NOP-1, its duration has to be much shorter than the duration of phase NOP-1, which is ca. 600 years. The relatively short duration of the influx peak can be explained as fol-

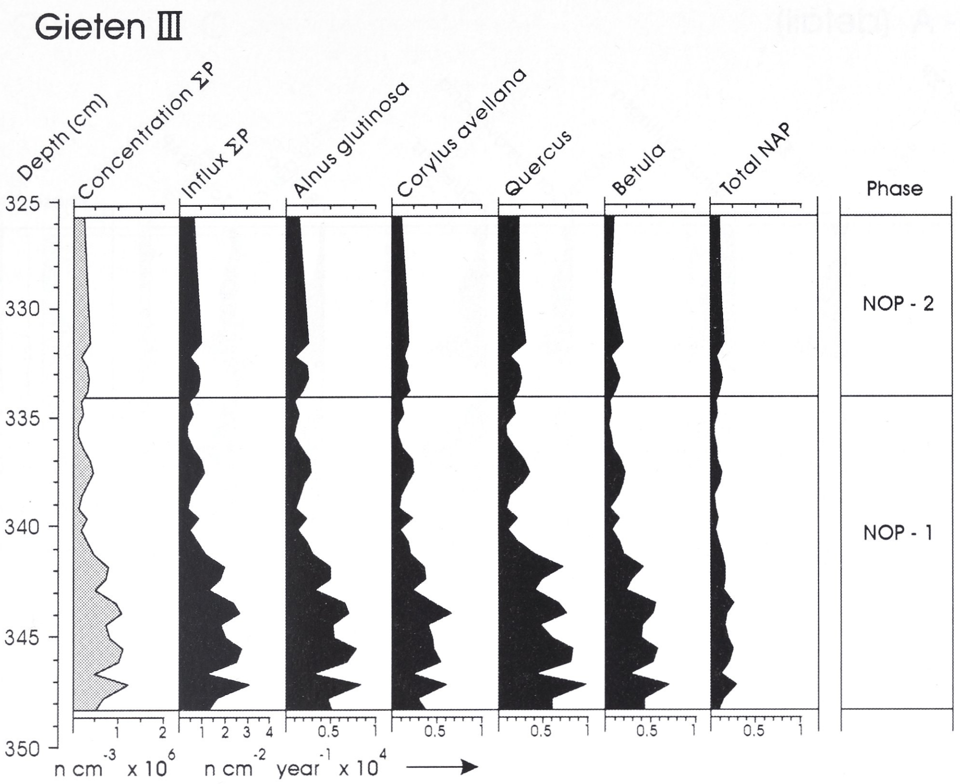


Fig. 64a.

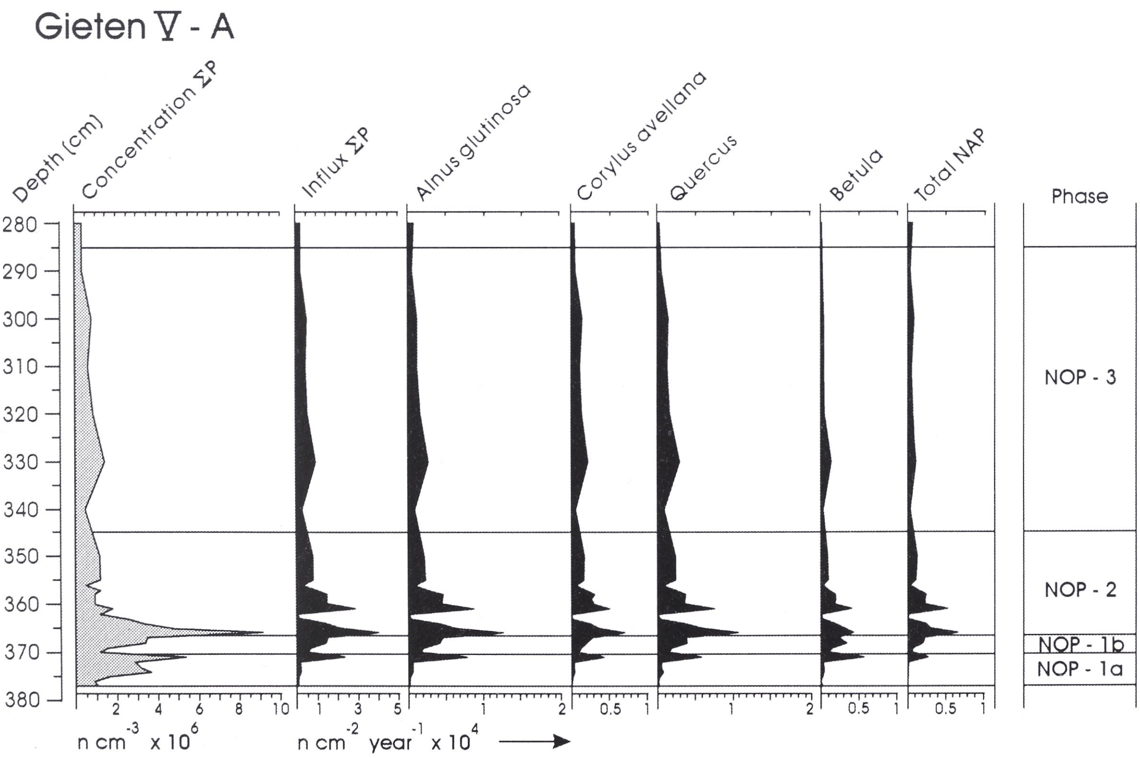


Fig. 64b.

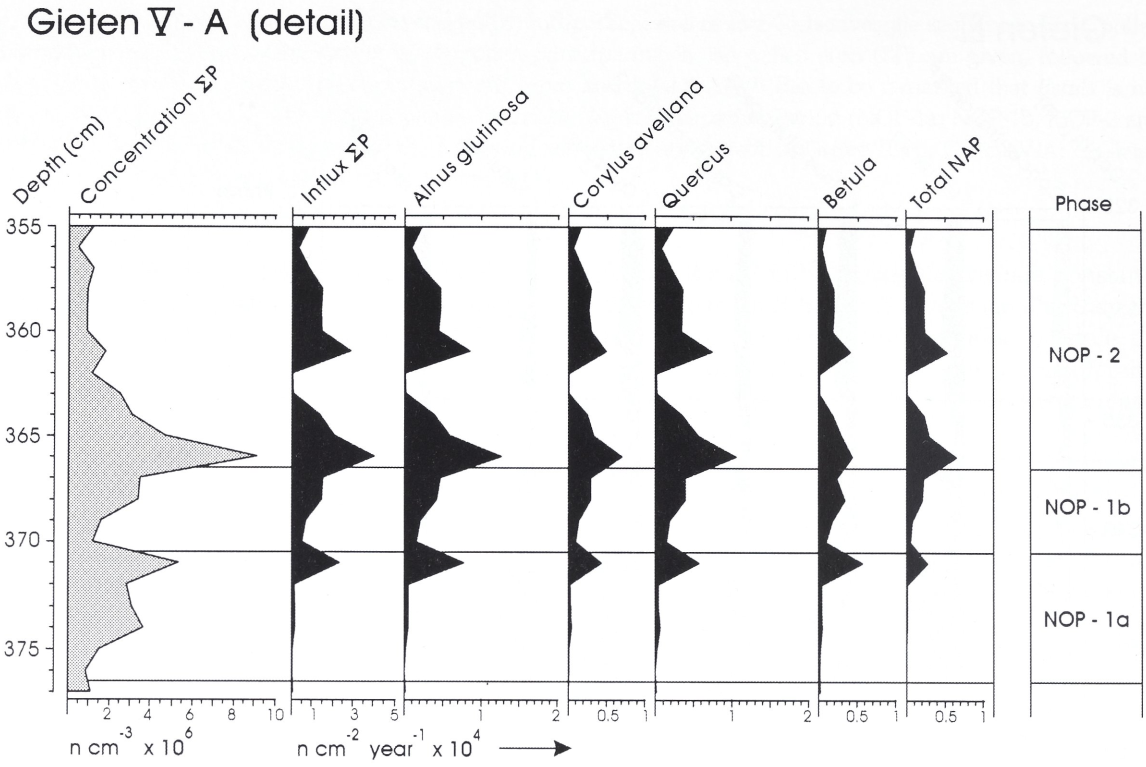


Fig. 64c.

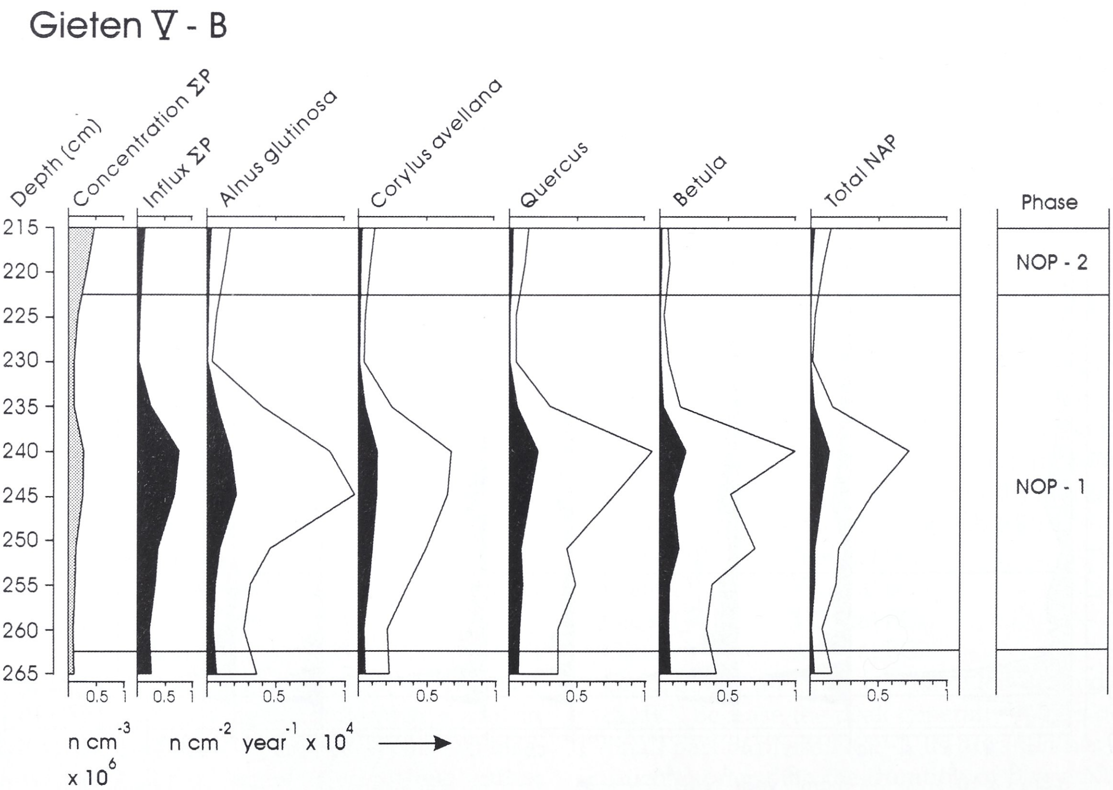


Fig. 64d.

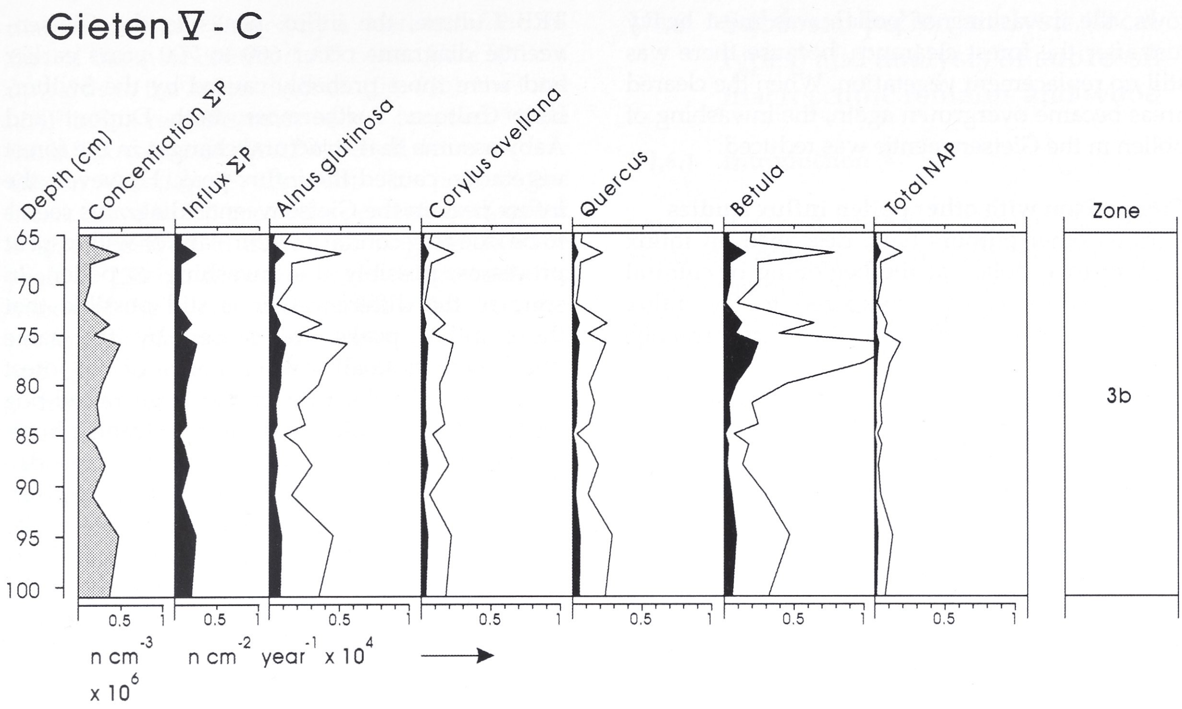


Fig. 64e.

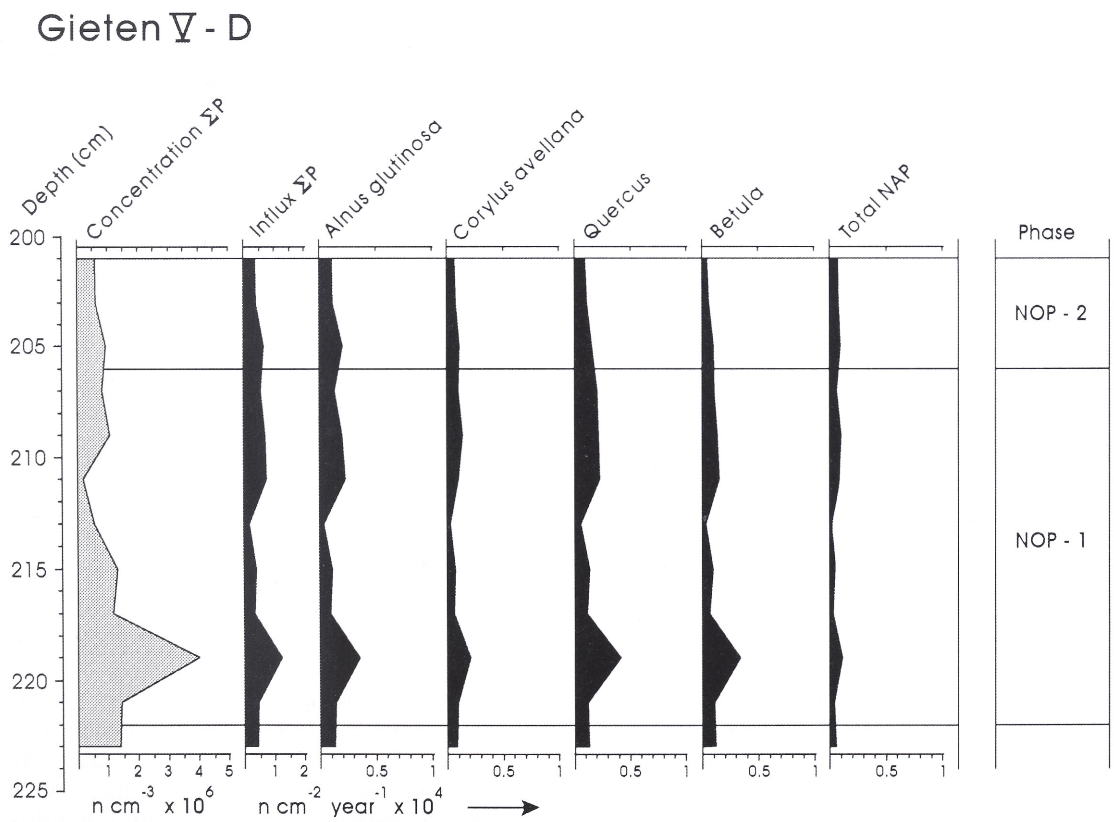


Fig. 64f.

lows: the inwashing of pollen was most heavy just after the forest clearance, because there was still no replacement vegetation. When the cleared areas became overgrown again, the inwashing of pollen in the Gietsenveentje was reduced.

Comparison with other pollen influx studies

Various other authors have described an influx peak of total pollen at the beginning of cultural phases, which can be compared to the influx peak in phase NOP-1 in the Gietsenveentje diagrams.

Dupont (1986) constructed influx diagrams from a hummock and a hollow sequence, cored at Meerstalblok in southeastern Drenthe, which is part of the formerly very large raised-bog area Bourtanger Moor. In both the hummock and the hollow sequences, influx peaks of 6000 and 4000 grains/cm^2/year, respectively, occurred around 4400 BP (ca. 3000 cal BC). Dupont (1986, 96) explains this influx peak as follows: the earliest, small-scale human activities caused a more open structure of the forest, favouring pollen production, but after 3000 cal BC the increasing human influence reduced the forest area to such an extent that overall pollen production after the initial increase switched to a decline.

Aaby (1988) constructed influx diagrams of two sequences cored in large raised bogs in Denmark, one in Holmegaard Bog (Zealand) and one in Abkær Bog (Jutland). In both influx diagrams, a peak in total AP influx occurs around 4500 BP (ca. 3100 cal BC). In this period, the total AP constitutes ca. 95% of the pollen sum. For that reason, it is permissible to compare total AP influx values of these two bogs with ΣP (AP+NAP) influx values of Gietsenveentje and Meerstalblok. In Holmegaard Bog, the total AP influx peak measures ca. 6000 grains/cm^2/year, while in Abkær Bog, it is ca. 8000 grains/cm^2/year. Aaby (1988, 223) explains the influx peaks as follows: AP influx was low in the Atlantic, when the forest is believed to have been dense (cf. IVERSEN 1973). Because Neolithic people felled trees and created openings, the forest vegetation had a higher pollen-production capacity because the open-structured forest enabled a larger part of the tree's crown to flower. In later times, when the nemoral landscape was changed into an open landscape, AP influx declined. The remaining trees were unable to compensate for the loss in pollen production of felled trees.

According to the ^{14}C dates, both the influx peak in southeastern Drenthe and the influx peaks in Denmark were caused by the Middle Neolithic TRB Culture; the influx peaks in the Gietsenveentje diagrams occur 600 to 700 years earlier and were most probably caused by the Swifterbant Culture. Furthermore, both Dupont and Aaby assume that structural changes in the forest vegetation caused the influx peak. However, the influx peak in the Gietsenveentje diagrams seems to be due to secondary within-lake or within-peat processes, possibly the inwashing of pollen. In spite of the differences, it is still possible that these influx peaks are caused by the same phenomenon: small-scale clearance of the forest by farmers. In the case of the large raised-bog areas of Meerstalblok and the two Danish bogs, the clearance occurred at a relatively large distance, so that inwashing of pollen after the clearance did not play a role. But in the case of the Gietsenveentje pingo scar, any clearance is likely to have occurred in the immediate vicinity of the bog, so that in the influx diagram, the effect of inwashing of pollen overshadows the effect of structural changes in the vegetation.

VI.5.4 Comparison between influx and percentage diagrams of the Neolithic Occupation Period

When the Gietsenveentje pollen influx diagrams (figs. 64a-f) are compared with the pollen percentage diagrams (figs. 53-60), spurious trends in certain curves of the percentage diagrams, which are only caused by trends in other curves, can be traced. Such a comparison will be made now: for each sequence, the main trends in the curves of the four commonest AP types and total NAP in the influx and the percentage diagram will be compared. When the trends in the pollen influx diagrams are discussed, these are always trends compared with the ΣP influx curve and the other influx curves.

Gieten III (fig. 53, fig. 64a): *Alnus*, *Corylus* and *Quercus* remain constant in both the influx and the percentage diagram; the decrease of *Betula* is more clearly observed in the percentage diagram, while the increase of total NAP is evident from the influx diagram as well as the percentage diagram.

Gieten V-A (fig. 56, fig. 64b; detail: fig. 57, fig. 64c): In both the influx and the percentage diagram, *Alnus*, *Corylus* and *Quercus* remain constant; the decrease of *Betula* and the increase of total NAP are clearly observed in both the influx and the percentage diagram. The increase of NAP between 300 and 280 cm in the percentage

diagram is partly caused by a decrease of the influx of the most common AP types: from 300 cm upwards in the influx diagram (fig. 64b), the total NAP influx remains more or less constant, while the influx values of the AP types all decrease.
Gieten V-B (fig. 58, fig. 64d): The peak of the *Betula* curve at 250 cm in the percentage diagram is also observed in the influx diagram, but the peak of 230 cm is absent there. In general, the trends of the curves in both the influx and the percentage diagram are the same: *Alnus*, *Corylus* and *Quercus* remain more or less constant, *Betula* decreases and total NAP increases.
Gieten V-C (fig. 59, fig. 64e): In this sequence, no clear Neolithic Occupation Period occurs. Only the Atlantic period is represented. The strong increase of *Betula* between 84 and 78 cm occurs in both the influx and the percentage diagram. From 75 cm upwards, all curves in both diagrams remain more or less constant. The increase of total NAP between 75 and 72 cm in the percentage diagram does not occur in the influx diagram.
Gieten V-D (fig. 60, fig. 64f): Both the influx and the percentage diagram display the same trends: *Alnus*, *Corylus* and *Quercus* remain constant, *Betula* decreases and total NAP increases.
Concluding, it can be stated that the general trends in influx and percentage diagrams in the Neolithic Occupation Period are roughly similar: *Alnus*, *Corylus* and *Quercus* remain more or less constant, *Betula* decreases and total NAP increases. The influx values of less common AP types like *Ulmus* or *Tilia* and culture indicators like *Plantago lanceolata* or Cerealia-type do not provide additional information compared to the percentage values. For this reason, no influx curves of these pollen types are reproduced here.

VI.6 Subfossil pollen analysis (local types) and analysis of subfossil macroscopic remains and wood

VI.6.1 Introduction

One of the most important aims of the present study is to combine different disciplines to obtain a more complete picture of the events which took place during the Neolithic Occupation Period. Bearing this in mind, also an analysis of the larger botanical and animal remains, together called macroscopic remains, as well as an analysis of large wood pieces has been performed. Here the results of the macroscopic-remains and wood analysis are presented together with a description of the local pollen types of the Gietsenveentje pollen diagrams (figs. 51-60). By combining these three types of analysis, it is hoped to obtain a picture as complete as possible of the local vegetation succession in and near the Gietsenveentje.
The advantage of macroscopic analysis lies in the possibility of identifying the species with frequently greater accuracy than in pollen analysis (WASYLIKOWA 1986). For example, macroscopic remains of the genus *Potentilla* (Rosaceae) - in the Gietsenveentje remains of *Potentilla palustris* were found - can be identified to species level, while it is not possible to identify pollen of *Potentilla*-type beyond genus level. Another specific feature of macroscopic remains is their local character. Most seeds are dispersed close to the parent plant, and macroscopic assemblages are composed mostly of plants growing near the sampling site. These are, first of all, aquatic and bog herbs. Trees and shrubs from nearby places may also be well-represented (WASYLIKOWA 1986). Because of their local character, macroscopic remains can help us to separate local pollen from regional pollen. For example, when at a certain location relatively large amounts of *Betula* pollen are found and also large amounts of *Betula* seeds, the *Betula* pollen can for the larger part be regarded as local. When, on the other hand, no seeds are found, the pollen can be considered more regional.
In the Gietsenveentje, macroscopic analysis has been performed on material from two locations: one near the centre (Gieten IV-HL) and one near the northern edge (Gieten V-C). All Gietsenveentje macroscopic remains are preserved in a waterlogged condition, apart from a few small (unidentifiable) charcoal fragments. In general, it

can be stated that the seeds and other macroscopic remains from the Gietsenveentje sequences are preserved rather badly: many unidentifiable seeds and fragments were recovered. All macroscopic identifications were checked by Prof. Dr. W. van Zeist, Dr. R.T.J. Cappers and R.M. Palfenier-Vegter. The wood analysis was performed by J.N. Bottema-MacGillavry.

VI.6.2 Results of the analysis arranged by sequence

Gieten V-A: local pollen (figs. 56-57)
Between 470 and 445 cm (local zones 1 and 2), Cyperaceae indiff. are the dominant local pollen type, reaching their highest values in the entire diagram. Between 445 and 405 cm, which are the exact limits of local zone 3a, the following local types reach relatively high percentages (in brackets, the species which are the most likely source of the pollen): *Potentilla*-type (*Potentilla palustris*), Ranunculaceae indiff. (*Ranunculus lingua*, *R. flammula*), *Lysimachia vulgaris*-type (*Lysimachia thyrsiflora*, *L. nummularia*, *L. vulgaris*) and *Galium*-type (*Galium palustre*). Most probably, the pollen was produced by plants which were part of a semi-aquatic helophytic vegetation (RUNHAAR et al. 1987), i.e. plants growing on shores of lakes, in swampy places and in other moist biotopes. In the following, this group of plants will be called "shore weeds". *Sphagnum* appears at 430 cm and remains present in low percentages, although the sediment at this depth still consists of fine detritus gyttja. Type 16A (asco?)spores are found only at 430-410 cm in relatively high percentages (up to 14%); in the rest of the diagram, these spores are absent. *Potamogeton* reaches maximum values between 400 and 385 cm. Pollen of *Nuphar lutea* appears at 390 cm; from this depth onwards, also other microscopic remains of *Nuphar lutea* are found, viz. asterosclereids, which are star-shaped hairs, as well as pieces of epidermis with stomata. These aquatic species point to the presence of open water in this period. Type 9 moss spores also appear at 390 cm. Between 375 and 366 cm, which are almost exactly the limits of the first phase of the Neolithic Occupation Period, NOP-1, two conspicuous events are observed in the local pollen diagram: the first is a dramatic fall of the *Betula* percentage from ca. 30% to ca. 10%; the second is a short but very high peak of *Equisetum*, reaching a maximum percentage of 48% at 374 cm. The spores originate most probably from *Equisetum fluviatile*, a pioneer of terrestrialization (WEEDA et al. 1985). *Sphagnum* increases from ca. 1% at 373 cm to almost 5% at 369 cm. The sediment at this depth still consists of a fine detritus gyttja. A few palynomorphs, recognized by Van Geel (1978), increase together with *Sphagnum*: Type 27: *Tilletia*, Type 31: *Amphitrema* and Type 13: cf. *Entophlyctis*. Cyperaceae indiff. increase to above 3% from 361 cm upwards, which is during the second phase of the Neolithic Occupation Period, NOP-2. Somewhat higher in the diagram, at 280-260 cm, which is in local zone 4b, Cyperaceae indiff. reach their highest values (11-14%) since their maximum in local zones 1-2. *Menyanthes* and *Scheuchzeria* occur predominantly between 290 and 270 cm. In this period, *Potamogeton* and *Nuphar* disappear, while *Sphagnum* quickly increases, reaching maximum values (up to 277%) between 270 and 230 cm. At 285 cm, the lithology of the sediment changes from coarse detritus gyttja into moderately to highly humified *Sphagnum* peat. These events mark the transition from open water to raised-bog vegetation. Apparently there is a certain delay between the first occurrence of *Sphagnum* peat (280 cm) and the massive presence of *Sphagnum* spores in the sediment (270 cm). Maximum values of Type 31: *Amphitrema* exactly coincide with the *Sphagnum* maximum of 270-230 cm. Just after the *Sphagnum* maximum follows a peak of Type 27: *Tilletia* and Type 9 moss spores at a depth of 200 cm. It is strange that the *Tilletia* peak does not occur together with the *Sphagnum* peak, because *Sphagnum* and *Tilletia* seem to grow optimally under the same conditions (VAN GEEL 1978). Between 170 and 120 cm, *Equisetum* reaches its highest values (up to 8.5%) since the maximum around 374 cm. A large peak of *Sphagnum* around 90 cm is accompanied by small peaks of Type 27: *Tilletia* (100-70 cm) and Type 13: cf. *Entophlyctis* (100 cm). At this depth, the lithology still consists of moderately to highly humified *Sphagnum* peat, with (between 90 and 64.5 cm) also macroscopic remains of *Eriophorum*. Between 85 and 7.5 cm, which are the limits of local zone 5b, Cyperaceae indiff. reach maximum values. These Cyperaceae must have been part of a marshy vegetation in the increasingly terrestrialized pingo scar. In the spectra of 41 and 5 cm, very large amounts of local *Betula* pollen were found: by this time, the terrestrialization of the pingo scar must have been more or less completed, so that *Betula* could grow within the pingo scar, just as the situation is today. The percentages of *Betula* at 41 and 5 cm are 1354% and 280%, respectively. Again a large peak of

Sphagnum at 30 cm is accompanied by peaks of Type 27: *Tilletia* and Type 13: cf. *Entophlyctis*. The lithology between 64.5 and 7.5 cm consists of poorly humified *Sphagnum* peat. In the topmost spectrum (5 cm), the percentage of *Sphagnum* spores decreases to almost zero, which is caused by a lithology change: at a depth of 7.5 cm, poorly humified *Sphagnum* peat is replaced by a homogeneous humic substance (forest soil). This lithology change marks the transition from marshy vegetation to forest.

Gieten I: local pollen (fig. 51)

Between 430 and 405 cm, which is in local zones 2 and 3a, Cyperaceae indiff. reach their highest values of the diagram (ca. 13%). In the spectrum of 400 cm, a peak of *Salix* occurs. At 420-410 cm, which is in the middle of local zone 3a, small maxima are observed of "shore weed" pollen types: *Lythrum salicaria*, *Lysimachia vulgaris*-type (from *Lysimachia thyrsiflora*, *L. nummularia*, *L. vulgaris*), *Potentilla*-type (from *Potentilla palustris*) and *Galium*-type (from *Galium palustre*). Maxima of *Sphagnum* at 420 and 400 cm are remarkable, because the lithology at this depth still consists of a fine detritus gyttja. From 400 cm upwards, the following types successively reach relatively high values: *Sparganium*-type (400-390 cm), followed by *Typha latifolia*, *Potamogeton* and *Pediastrum* (390 cm), *Equisetum* (from 390 cm upwards), *Menyanthes* and *Scheuchzeria* (380 cm) and finally *Nuphar* pollen and asterosclereids (from 380 cm upwards). The aquatic species (*Potamogeton*, *Nuphar*) point to the presence of open water in this period. Between 380 and 355 cm, which includes the second half of local zone 3b and the succeeding phase NOP-1, *Betula* falls from ca. 40 to ca. 10%. Between 365 and 360 cm, which exactly corresponds to phase NOP-1, a very high peak of *Equisetum* occurs, with a maximum percentage at 361.3 cm of almost 90%! This peak, most probably from *Equisetum fluviatile*, points to the beginning of terrestrialization. A Cyperaceae indiff. increase to almost 4% is observed at 355-350 cm, which is during phase NOP-2. *Sphagnum* increases from less than 1% at 365 cm to more than 6% at 357.5 cm, although the sediment at this depth still consists of a fine detritus gyttja. Around 273 cm, major changes occur in several local types: *Equisetum* decreases to almost zero, *Nuphar* pollen and asterosclereids disappear completely, while *Sphagnum* strongly increases to a maximum of 77%. Around 273 cm, also a lithology change occurs: a fine detritus gyttja is replaced by moderately to highly humified *Sphagnum* peat. These events point to a transition from open water to raised-bog vegetation.

Gieten II: local pollen (fig. 52)

A brief *Equisetum* peak (14.7%) occurs at 369 cm, which is in local zone 3b. Several smaller peaks of this type (5-10%) appear between 363 and 351 cm, representing phase NOP-2. Cyperaceae indiff. increase to ca. 3% at 365 cm, which is during phase NOP-1. Although the sediment of this part of the sequence consists of a fine detritus gyttja, *Sphagnum* increases to ca. 6.9% at 362 cm.

Gieten III: local pollen (fig. 53)

Around the spectrum of 353.2 cm, which is on the interface of local zones 2 and 3, some pollen types of the "shore weeds" reach maximum values: *Lythrum salicaria*, *Potentilla*-type (from *Potentilla palustris*) and Umbelliferae. From 352.7 to 348.3 cm, Cyperaceae indiff. decrease from ca. 11% to less than 1%, slowly increasing again from 336.5 cm upwards, which is at the end of phase NOP-1. Around 351 cm, *Betula* falls from 40 to 15% within just half a centimetre. As already mentioned in VI.3.2, a hiatus around 348 cm means that the pollen percentages in this part of the diagram may not be fully reliable. A large peak of *Equisetum* (43%) appears at 347.2 cm, which is in phase NOP-1. This peak possibly marks the beginning of the terrestrialization of the pingo scar. *Nuphar* pollen and asterosclereids appear at 347.8 and 348.3 cm, respectively.

Gieten IV-P: local pollen (fig. 54)

As already mentioned in VI.3.2, a layer of sediment representing local zones 2 and 3a in sequence Gieten IV-P was deposited twice. Several representatives of the "shore weeds" reach maximum values at 440-400 cm and again at 360-305 cm, both times in local zone 3a: *Lythrum salicaria*, *Lysimachia vulgaris*-type (from *Lysimachia thyrsiflora*, *L. nummularia*, *L. vulgaris*), Ranunculaceae indiff. (from *Ranunculus lingua*, *R. flammula*), *Potentilla*-type (from *Potentilla palustris*) and *Galium*-type (from *Galium palustre*). (Asco?) spores of Type 16A occur in two short phases at 445-425 cm and 370-312.5 cm, reaching a maximum of ca. 20%. At 315 cm, still in coarse detritus gyttja sediment, there is a fairly large peak of *Sphagnum* (78%). At 310 cm, a rather large peak of *Potamogeton* occurs; at 305 cm, a peak of Type 27: *Tilletia* coincides with an increase of *Sphagnum*; at 300-295 cm, we see a large peak of *Sphagnum*. These events are accompanied by a lithology change: around 305 cm, coarse detritus gyttja is

Depth	460-457.5 cm	422.5-420 cm	383-380 cm
Seeds of local trees			
Betula	-	15	40
Seeds of local herbs (non-aquatics)			
Labiatae	-	-	2
Polygonum lapathifolium	-	-	5
Lycopus europaeus	-	26	2
Lythrum salicaria	-	64	2
Mentha aquatica	-	396	5
Glyceria fluitans	-	8	-
Cyperaceae	-	8	-
Carex rostrata/vesicaria	31	11	25
Carex nigra-type	-	209	75
Carex panicea	-	-	2
Carex sp.	3	-	2
Carex seed contents	1	4	25
Carex utricles	-	-	5
Cladium mariscus	-	76	-
Scirpus cf. mucronatus	-	19	-
Seeds of local herbs (aquatics)			
Potamogeton sp.	-	62	215
Sparganium sp.	-	-	54
Alisma plantago-aquatica	-	-	2
Potentilla palustris	-	15	-
Other plant remains			
Sphagnum capsules	-	8	-
Sphagnum leaves	-	4	-
bud scales	-	-	12
stem/rhizome remains	-	54	-
root remains	-	-	28
charcoal fragments	-	2	15
Animal remains			
Daphnia (eggs)	-	325	18
insect parts	-	26	-
other Invertebrata	34	65	40
indeterminable seeds	2	52	14

Table 14. Macroscopic remains from sequence Gieten IV-HL.

replaced by moderately to highly humified *Sphagnum* peat with *Eriophorum* remains, indicating the transition from open water to raised-bog vegetation. There is a certain delay between the deposition of *Sphagnum* peat (305 cm) and the ample occurrence of *Sphagnum* spores in the sediment (300 cm). Possibly, the Cyperaceae indiff. maximum around 305 cm is caused by *Eriophorum* pollen. Not only Type 27: *Tilletia* reaches maximum values more or less together with *Sphagnum*, but also two other palynomorphs recognized by Van Geel (1978), namely Type 31: *Amphitrema* and Type 13: cf. *Entophlyctis*.

Gieten IV-HR: local pollen (fig. 55)

Just as in sequence Gieten IV-P, a certain layer of sediment representing local zones 2 and 3 was twice deposited in sequence Gieten IV-HR (see VI.3.2). This is hardly surprising, because the sample locations of these two sequences are only a few metres apart (see VI.1). In Gieten IV-HR, pollen of several "shore weeds" reaches maximum values at 429-402 cm and again at 365.5-306.5 cm, both times in zone 3a: *Lythrum salicaria*, *Lysimachia vulgaris*-type (from *Lysimachia thyrsiflora*, *L. nummularia*, *L. vulgaris*), *Potentilla*-type (from *Potentilla palustris*) and *Galium*-type (from *Galium palustre*). (Asco?)spores of Type 16A reach maximum values at exactly the same depths as the "shore weeds". Around 306.5 cm, the lithology changes from a coarse detritus gyttja to a moderately to highly humified *Sphagnum* peat with *Eriophorum* remains, indicating the transition from open water to raised-bog vegetation. At 304-298 cm, large amounts of *Sphagnum* spores are observed (up to almost 250%). Again, together with *Sphagnum*, some palynomorphs reach maximum values: Type 27: *Tilletia*, Type 31: *Amphitrema* and Type 13: cf. *Entophlyctis*.

Gieten IV-HL: macroscopic remains (table 14)

Sequence Gieten IV-HL was sampled at core location 49A (see VI.1), in the centre of the present Gietsenveentje, only a few metres south of the sample locations of sequences Gieten IV-P and Gieten IV-HR. Between the depths of 480-380 cm, each 2.5-3 cm of sediment was sampled separately. The part of the sequence above 380 cm was not sampled. Unfortunately, the Neolithic Occupation Period seemed to occur in this part. Still it seemed useful to analyze a few macroscopic samples from pre-Neolithic deposits, for comparison with Neolithic samples from other sequences. Three macroscopic samples, all located in gyttja sediment, were analyzed: one sample of 1.5 l (460-457.5 cm) and two samples of 2.5 l (422.5-420 cm and 383-380 cm). The results of these analyses, converted to a content of 1 l, are shown in table 14. These results are correlated with the pollen diagrams of sequences Gieten IV-P/IV-HR (figs. 54-55) on the basis of depth, because of the proximity of these sequences' sample locations.

Sample 460-457.5 cm. In the lowermost sample, located at the base of the sequence, only very few macroscopic remains were observed, for the most part *Carex rostrata/vesicaria*; no seeds of aquatic plant species were found. Probably the remains of this sample represent a sedge marsh; apparently, at this time, there was no open water in this part of the pingo scar. In the lower part of pollen diagram Gieten IV-P (which ends at 455 cm), Cyperaceae indiff. values of 5-10% are found; in many of the Gietsenveentje pollen diagrams, high Cyperaceae values are recorded near the Pleistocene subsoil (*Carex rostrata/vesicaria* produces pollen of Cyperaceae indiff. type).

Sample 422.5-420 cm. In the middle sample, a very large amount of macroscopic remains were found. Substantial quantities of seeds of "shore weeds" (*Lythrum salicaria, Mentha aquatica, Carex nigra*-type, *Cladium mariscus*) especially attract attention. The presence of large quantities of *Potamogeton* seeds and eggs of water fleas (*Daphnia*) points to open water in this period. At the corresponding depths of sequences Gieten IV-P and IV-HR, much pollen of "shore weeds" was found, but, curiously, no pollen of *Potamogeton* at all. Nonetheless, this sample falls within local zone 3a of the pollen diagrams, the *Corylus-Ulmus* zone, representing the first part of the Atlantic.

Sample 383-380 cm. In the topmost sample, quite a large amount of macroscopic remains were found. *Betula* seeds were found frequently, pointing to the presence of *Betula* trees in the neighbourhood of the sample location. Compared to the middle sample, fewer seeds of "shore weeds" and *Daphnia* eggs appeared and far more seeds of aquatic plants, especially *Potamogeton* and *Sparganium*. At the corresponding depths in pollen diagrams Gieten IV-P/IV-HR, *Betula* percentages of 15-30% were recorded, lower than those found at the depth of the middle macroscopic sample, which were 20-50%. In accordance with the macroscopic sample are the far lower values of "shore weeds" and the higher values of *Potamogeton* and *Sparganium* around 380 cm in the pollen diagrams. The upper macroscopic sample falls within the second appearance of local zone 2 of the pollen diagrams

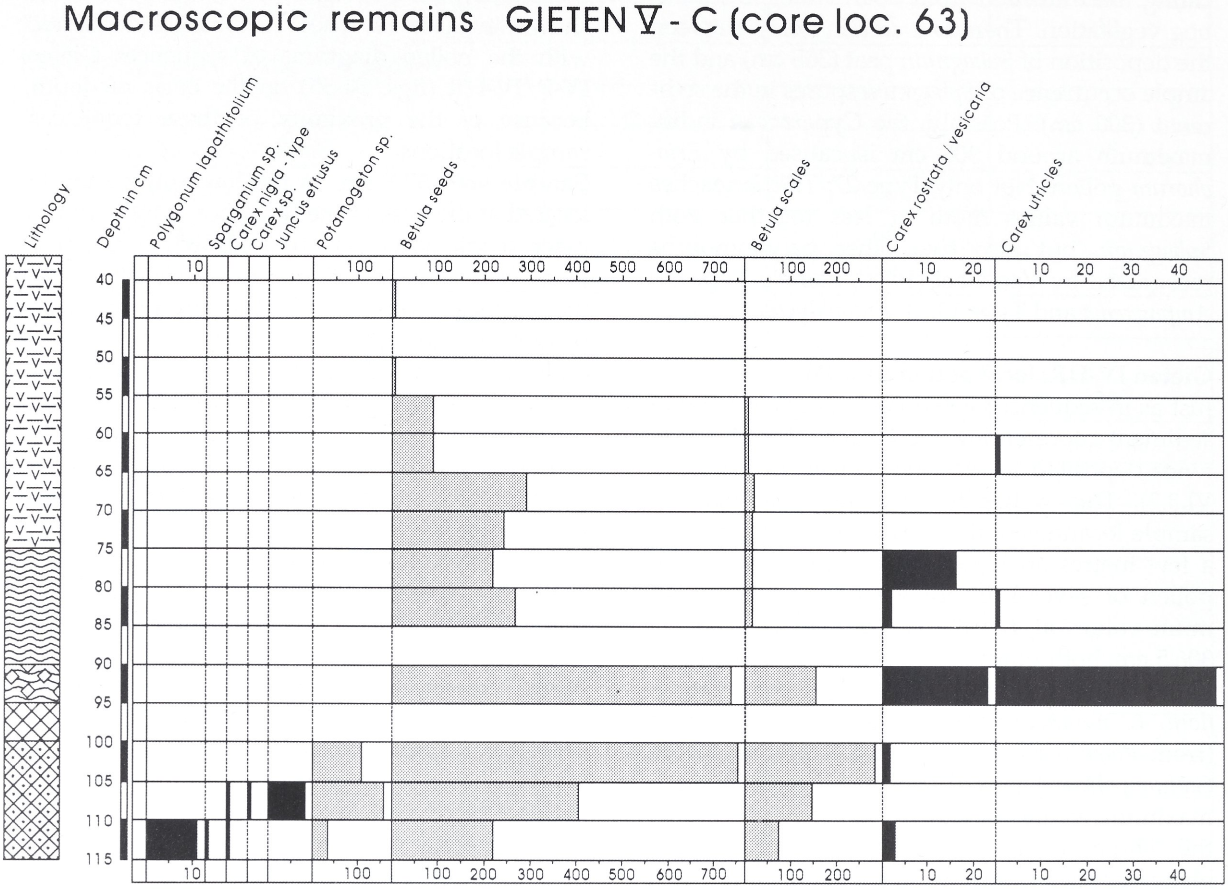


Fig. 65. Macroscopic-remains diagram of sequence Gieten V-C. It should be noted that the taxa indicated by black bars are drawn to a different scale from those with grey bars. For the legend of the lithology, see fig. 50.

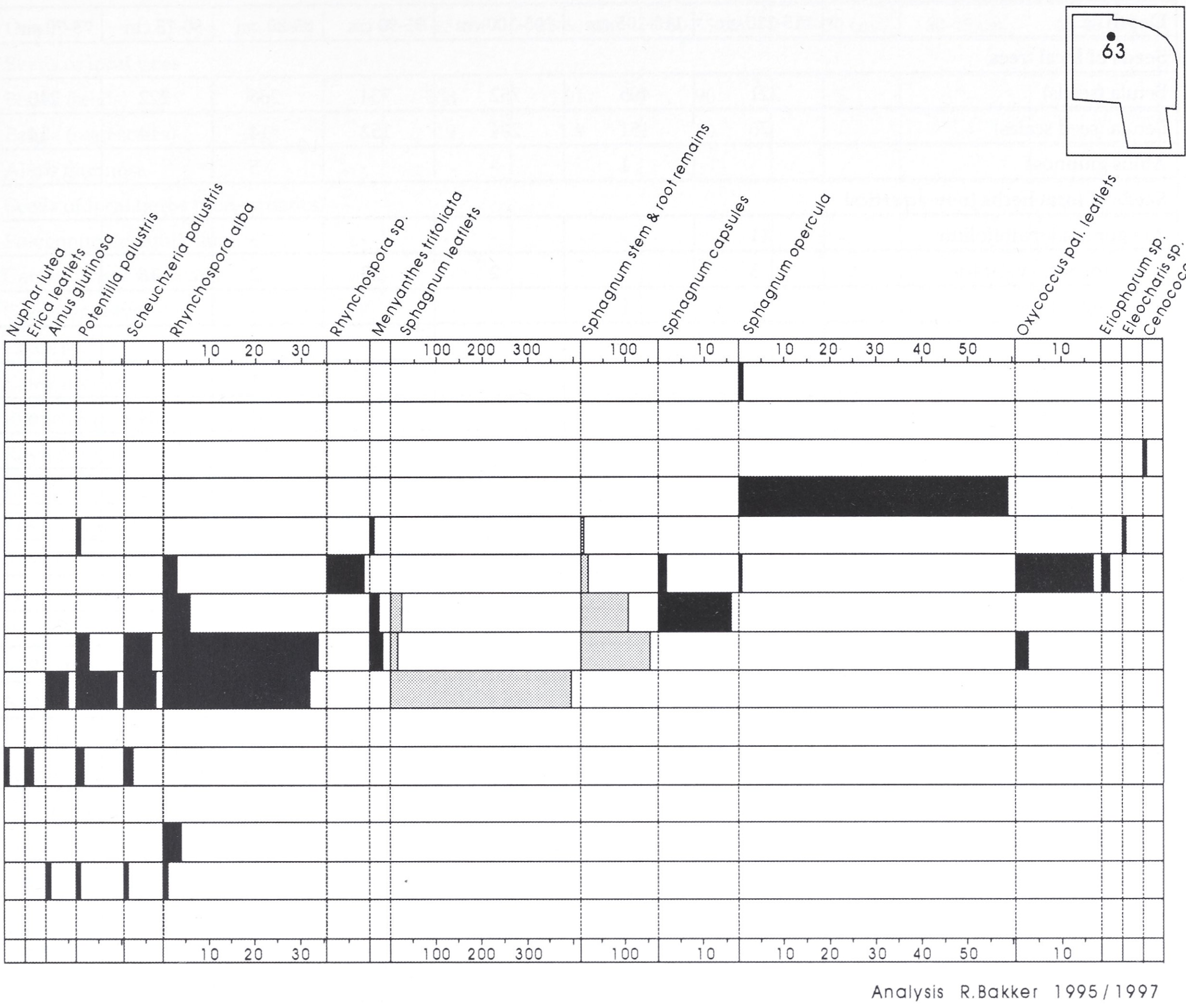
(400-370/364 cm), the *Pinus-Betula* zone, representing a part of the Boreal. This means that the upper macroscopic sample (383-380 cm) is older than the middle macroscopic sample (422.5-420 cm).

Gieten V-B: local pollen (fig. 58)

Between 375 and 315 cm, *Potentilla*-type (most probably originating from *Potentilla palustris*) occurs regularly, but in very low quantities. Successively, the following local types reach maximum values: *Potamogeton* (375-365 cm), *Nuphar* pollen and asterosclereids (365-345 cm), Type 9 moss spores (355-295 cm), Type 31: *Amphitrema* and Type 13: cf. *Entophlyctis* (from 335 cm upwards), *Sphagnum* and Type 27: *Tilletia* (from 315 cm upwards). Just as in other Gietsenveentje diagrams, there is a certain delay between the lithology change to poorly humified *Sphagnum* peat around 330 cm, representing the change from open water to raised-bog vegetation, and the massive occurrence of *Sphagnum* spores in the sediment at 315 cm. At 195 cm, in the centre of the poorly humified *Sphagnum* peat layer, *Sphagnum* reaches its maximum value of almost 50%.

Gieten V-B: wood (table 15)

In the pollen sequence Gieten V-B, wood of *Frangula alnus* was found at three different depths. The sediment at all three depths consists of poorly humified *Sphagnum* peat. The wood data can be correlated to the Gieten V-B pollen diagram (fig. 58). Single pollen grains of *Frangula alnus* were observed at depths of 375 cm, 355 cm, 240 cm and 215 cm. In sequence Gieten V-C, near the edge of the Gietsenveentje, pollen of *Frangula alnus* appears more frequently. In the upper part of the pollen diagram, it forms a continuous



curve (fig. 59). It seems likely that *Frangula alnus* grew at the edges of the lake, which as a whole was terrestrializing. *Frangula alnus* is one of the pioneer trees in the development from peat bog to forest (WEEDA et al. 1987).

Sequence	Depth	Species
Gieten V-B	265-264 cm	probably *Frangula alnus*
Gieten V-B	246-245 cm	roots of *Frangula alnus*
Gieten V-B	186-185 cm	*Frangula alnus*
Gieten V-C	64-61 cm	*Betula* sp.

Table 15. Wood remains from Gietsenveentje sequences.

Gieten V-C: local pollen (fig. 59)

In the lowest two samples (115 and 110 cm), *Succisa*, *Lychnis*-type and *Polygonum persicaria*-type (possibly originating from *Polygonum lapathifolium*, of which macroscopic remains were found in the corresponding macroscopic analyses) reach relatively high values. From 91 cm upwards, *Scheuchzeria* forms a continuous curve, reaching values of more than 3%. This is not observed in any of the other Gietsenveentje diagrams. *Scheuchzeria palustris* particularly occurs in terrestrializing oligotrophic bogs (WEEDA et al. 1991). From 78 cm upwards, Umbelliferae appear in relatively high quantities. This pollen must originate from "shore weed" genera of the Umbelliferae, i.e. *Sium*, *Berula*, *Oenanthe*, *Apium*, *Cicuta* or *Peucedanum*. However, no macroscopic remains of Umbelliferae were found. Successively, the following local types reach maximum values:

Depth	115-110 cm	110-105 cm	105-100 cm	95-90 cm	85-80 cm	80-75 cm	75-70 cm
Seeds of local trees							
Betula (seeds)	221	405	752	734	266	222	240
Betula (seed scales)	76	151	284	152	14	14	14
Alnus glutinosa	-	1	-	-	5	-	-
Seeds of local herbs (non-aquatics)							
Polygonum lapathifolium	11	-	-	-	-	-	-
Carex rostrata/vesicaria	3	-	2	23	2	16	-
Carex nigra-type	1	1	-	-	-	-	-
Carex sp.	-	1	-	-	-	-	-
Carex utricles	-	-	-	48	1	-	-
Rhynchospora alba	-	1	4	-	32	34	6
Rhynchospora sp.	-	-	-	-	-	-	-
Eleocharis sp.	-	-	-	-	-	-	-
Eriophorum sp.	-	-	-	-	-	-	-
Juncus effusus	-	8	-	-	-	-	-
Seeds of local herbs (aquatics)							
Potamogeton sp.	31	157	106	1	-	-	-
Menyanthes trifoliata	-	-	-	-	-	3	2
Nuphar lutea	-	-	-	1	-	-	-
Potentilla palustris	-	1	-	2	9	3	-
Sparganium sp.	1	-	-	-	-	-	-
Scheuchzeria palustris	-	1	-	2	7	6	-
Other plant remains							
Sphagnum capsules	-	-	-	-	-	-	16
Sphagnum opercula	-	-	-	-	-	-	-
Sphagnum leaves	2	-	-	-	>400	12	22
Sphagnum stem and root remains	-	-	-	-	-	158	106
Cenococcum	-	-	-	-	-	-	-
Erica leaves	-	-	-	2	-	-	-
Oxycoccus palustris leaves	-	-	-	-	-	3	-
Betula twigs	-	-	5	-	-	-	-
Cyperaceae (?) fibre remains	13	6	1	-	-	28	18
bud scales	12	19	29	15	-	2	4
buds	-	-	2	-	-	11	-
other leaves	-	-	-	-	-	3	26
other twigs	3	-	-	-	-	-	-
bark pieces	-	-	-	-	-	-	-
stem/rhizome remains	-	-	-	-	-	-	-
other fibre remains	-	-	-	-	-	8	12
charcoal fragments	-	-	-	-	-	-	2
Animal remains							
beetles	-	-	-	-	-	-	-
other Invertebrata	41	-	6	172	-	-	-
indeterminable seeds	5	-	9	-	17	6	22

Table 16. Macroscopic remains from sequence Gieten V-C.

Depth	70-65 cm	65-60 cm	60-55 cm	55-50 cm	50-45 cm	45-40 cm
Seeds of local trees						
Betula (seeds)	288	91	90	5	-	5
Betula (seed scales)	19	9	10	-	-	-
Alnus glutinosa	-	-	-	-	-	-
Seeds of local herbs (non-aquatics)						
Polygonum lapathifolium	-	-	-	-	-	-
Carex rostrata/vesicaria	-	-	-	-	-	-
Carex nigra-type	-	-	-	-	-	-
Carex sp.	-	-	-	-	-	-
Carex utricles	-	1	-	-	-	-
Rhynchospora alba	3	-	-	-	-	-
Rhynchospora sp.	8	-	-	-	-	-
Eleocharis sp.	-	1	-	-	-	-
Eriophorum sp.	2	-	-	-	-	-
Juncus effusus	-	-	-	-	-	-
Seeds of local herbs (aquatics)						
Potamogeton sp.	-	-	-	-	-	-
Menyanthes trifoliata	-	1	-	-	-	-
Nuphar lutea	-	-	-	-	-	-
Potentilla palustris	-	1	-	-	-	-
Sparganium sp.	-	-	-	-	-	-
Scheuchzeria palustris	-	-	-	-	-	-
Other plant remains						
Sphagnum capsules	2	-	-	-	-	-
Sphagnum opercula	1	-	59	-	-	1
Sphagnum leaves	-	-	-	-	-	-
Sphagnum stem and root remains	10	3	-	-	-	-
Cenococcum	-	-	-	1	-	-
Erica leaves	-	-	-	-	-	-
Oxycoccus palustris leaves	17	-	-	-	-	-
Betula twigs	1	-	-	-	-	-
Cyperaceae (?) fibre remains	12	2	28	5	-	-
bud scales	3	-	3	-	-	-
buds	-	-	-	-	-	-
other leaves	-	-	-	-	-	-
other twigs	2	3	3	-	-	-
bark pieces	-	-	-	-	-	3
stem/rhizome remains	10	10	7	1	-	-
other fibre remains	12	-	-	-	-	3
charcoal fragments	-	-	-	-	-	-
Animal remains						
beetles	-	3	2	-	-	-
other Invertebrata	14	-	4	7	10	-
indeterminable seeds	14	3	-	-	-	2

Table 16 (continued).

Potamogeton and *Pediastrum*, a genus of green open-water algae (CRONBERG 1986) (110-91 cm), followed by *Nuphar* asterosclereids (maximum at 91 cm), *Scheuchzeria* (maximum at 88 cm), *Sphagnum* (85-78 cm), and Type 27: *Tilletia*, Type 31: *Amphitrema* and Type 13: cf. *Entophlyctis* (78-70 cm). The lithology also changes in this period: at 100-95 cm, it consists of a fine detritus gyttja; at 95-90 cm, a transitional phase occurs, followed by a layer of moderately to highly humified *Sphagnum* peat. These events mark the transition from open water to a raised-bog vegetation. Here too, a delay is seen between the first sedimentation of *Sphagnum* peat (88 cm) and the ample occurrence of *Sphagnum* spores in the sediment (85 cm). From 75 cm upwards, the lithology consists of a loose homogeneous humic substance with large pieces of *Betula* wood (see below). This sediment looked as if it could have been disturbed. A possible consequence of this is that the pollen content from 75 cm upwards is not fully reliable.

Gieten V-C: macroscopic remains (fig. 65; table 16)

The macroscopic sequence Gieten V-C was sampled directly next to the pollen sequence Gieten V-C, at core location 63 (see VI.1), near the northern edge of the Gietsenveentje. Between depths of 115 and 40 cm, 13 macroscopic samples with a content of 1 litre were analyzed (the samples 90-85 cm and 100-95 cm were not analyzed). The results of these samples, converted to a content of 1 litre, are shown in fig. 65 and table 16. Fig. 65 is a concentration diagram: the absolute numbers of all identified taxa per litre are shown. The taxa are classified in order of the occurrence of their maximum values: the taxon which reaches its maximum value in the oldest (lower) part of the sequence, is shown at the extreme left; the taxon which reaches its maximum value in the youngest (upper) part of the sequence, at the extreme right. In this way, a possible local vegetation succession can easily be visualized. This method of reproduction of macroscopic analysis has been used by many authors, e.g. VAN GEEL 1978, VAN LEEUWAARDEN 1982 and WASYLIKOWA 1986. The concentration diagram of fig. 65 is correlated with the pollen diagram of Gieten V-C (fig. 59) on the basis of depth. The part of the pollen diagram between 115 and 58 cm represents the Atlantic, with the possible exception of the sediment at 64-63 cm, which presumably represents the Subboreal.

Samples 115-100 cm. The lower three samples are located in sandy gyttja sediment, near the Pleistocene subsoil, which is located at 115 cm. Seeds and seed scales of *Betula*, most probably *Betula pubescens*, are very frequent. The bud scales which occur fairly frequently in these three samples, most probably also originate from *Betula*. The massive occurrence of seeds of *Potamogeton* points to the presence of open water even at this location, which is quite near the edge of the pingo scar. At the corresponding depths in the pollen diagram, *Potamogeton* also reaches maximum values. Other taxa only occurring in these three samples are *Sparganium* sp., also pointing to open water, and *Polygonum lapathifolium*, *Carex nigra*-type and *Juncus effusus*, indicating wet or moist biotopes.

Sample 95-90 cm. This sample is located in transitional sediment between gyttja and peat. A very high number of *Betula* seeds are found in this sample. The presence of a few seeds of aquatic plants - one seed of *Potamogeton* sp., one of *Nuphar lutea* - indicates that open water is still present somewhere in the Gietsenveentje; around 90 cm, relatively high values of *Potamogeton* and *Nuphar* appear in the pollen diagram. Large numbers of *Carex rostrata/vesicaria* seeds and *Carex* utricles, probably originating from *Carex rostrata/vesicaria*, are found in this sample. This indicates that the Cyperaceae maximum (ca. 5%) around 90 cm in the pollen diagram is most probably caused by *Carex rostrata* or *C. vesicaria*, representing sedge marsh vegetation. The 95-90 cm sample is the only sample in which macroscopic remains of *Erica tetralix* (two leaflets) are encountered.

Samples 85-75 cm. The next two samples are located in *Sphagnum* peat sediment. *Betula* seeds and scales are far fewer than in the lower samples. This *Betula* decline in the concentration diagram of macroscopic remains corresponds to a general decrease in pollen concentration and pollen influx in the pollen concentration/influx diagram of Gieten V-C (fig. 64e), which points to an increasing sedimentation rate at this depth. The absence of a *Betula* decline at 90-85 cm in the pollen percentage diagram (fig. 59) confirms this picture, because differences in sedimentation rate are not reflected in percentage diagrams. Species reaching maximum values in these two samples are *Potentilla palustris* and *Menyanthes trifoliata*, species pointing to terrestrialization of (this part of) the bog, and *Scheuchzeria palustris* and *Rhynchospora alba*, species predominantly occurring in living peat bog. In the pollen diagram, pollen of *Potentilla*-type (originating from *Potentilla palustis*) and *Scheuchzeria palustris* reach maximum values around 88 cm. In the 85-80 cm sample, also a few seeds of *Alnus glutinosa* are found. Only vegetative parts of *Sphagnum*, viz. leaflets, stem and root remains, occur in the 85-75 cm samples. Most finds point to the presence of an oligotrophic raised-bog vegetation.

Samples 75-40 cm. The upper seven samples are located in a homogeneous humic substance, which in part may have been disturbed (see above). In these samples, only a few remains were found, apart from large numbers of *Betula* seeds in the samples of 75-65 cm and large numbers of vegetative as well as generative *Sphagnum* remains in the samples of 75-55 cm. The 70-65 cm sample contained remains of some typical representatives of living peat bog: *Oxycoccus palustris* (leaflets) and *Eriophorum* sp. (seeds). In the top three samples (55-40 cm) almost no remains were found, with the exception of the sample of 55-50 cm, which produced a sclerotium of the fungus *Cenococcum geophilum*. *Cenococcum geophilum* is a common (facultative) mycorrhiza-former on various tree species and occurs in very different soils (MIKOLA 1948; TRAPPE 1964). Observations by Van Geel (1978, 55) have demonstrated that *C. geophilum* does not occur in meso- to oligotrophic peat formed under wet conditions, but prefers drier conditions. Van Geel found sclerotia in the top layer of a section from Engbertsdijksvenen. He is of the opinion that these sclerotia could be of very recent, secondary origin (VAN GEEL 1978). The presence of *C. geophilum* in Gieten V-C probably points to drier conditions, caused by the artificial drainage of the Gietsenveentje. Given the possibly disturbed sediment from 75 cm upwards, the sclerotium of *C. geophilum* could be of very recent origin, just as in the Engbertdijksvenen.

Gieten V-C: wood (table 15)

In the pollen sequence of Gieten V-C, large pieces of *Betula* wood were found at a depth of 64-61 cm. In the pollen diagram of Gieten V-C (fig. 59), *Betula* pollen dominates at this depth; in the macroscopic-remains diagram of Gieten V-C (fig. 65), seeds and scales of (most probably) *Betula pubescens* are the most frequent macroscopic remains at nearly all depths. *Betula pubescens* trees must have grown massively at the edge of the terrestrializing lake which offered a moist, acid and nutrient-poor biotope. In this kind of biotope, *Betula pubescens* will thrive (WEEDA et al. 1985).

Gieten V-D: local pollen (fig. 60)

In the bottommost sample of the diagram (245 cm), representing local zone 3a, *Melampyrum* (most probably originating from *Melampyrum pratense*), *Succisa pratensis* and the "shore weed" pollen types *Lysimachia vulgaris*-type (from *Lysimachia thyrsiflora, L. nummularia, L. vulgaris*) and *Potentilla*-type (from *Potentilla palustris*) reach maximum values. A small peak of *Potamogeton* is observed at 235 cm. Between 227 and 205 cm, *Equisetum* reaches a huge peak, with a maximum percentage of ca. 73% at 213 cm, which is in the middle of the first phase of the Neolithic Occupation Period, NOP-1. The *Equisetum* spores, possibly originating from *E. fluviatile*, may point to the beginning of the terrestrialization of the pingo scar. At 211 cm, *Sphagnum* increases to almost 4%. *Nuphar* and its microscopic remains (asterosclereids and epidermis with stomata) as well as Type 9 moss spores reach maximum values between 225 and 165 cm. Between 180 and 158 cm, the fine detritus gyttja gradually changes into a poorly humified *Sphagnum* peat, marking the transition from open water to a raised-bog vegetation. The two spectra which are situated in the poorly humified *Sphagnum* peat (155 and 145 cm) show a different pollen content, not only in terms of local types, but also in the AP and NAP. At 155 cm, *Sphagnum* displays a very large peak (384%), followed by "peaks" of Type 31: *Amphitrema* and Type 13: cf. *Entophlyctis* at 145-135 cm. At 135 cm, the sediment changes into a moderately to highly humified *Sphagnum* peat. Here the percentage of *Sphagnum* spores strongly decreases.

VI.6.3 The use of data from macroscopic remains

In general, macroscopic remains are used to reconstruct local vegetation successions. Only when data on macroscopic remains from several localities are compared may similar local phenomena be explained by regional causes (WASYLIKOWA 1986). Because there are no comparable data from locations in the neighbourhood of the Gietsenveentje, the macroscopic data in this case can only be used for the reconstruction of the local vegetation succession. This reconstruction is made on the basis of macroscopic remains of indicator plants.

Cappers (1994) has made a compilation of groups of indicator plants, suitable for macroscopic-remains records, based on the Holocene macro-

Sequence and indicator taxon	Halophytic/ glycophytic	Moisture regime	Nutrient availability	Structure of vegetation and stage of succession
Gieten IV-HL				
Carex rostrata/vesicaria	glycophytic			
Betula sp.				scrub and woodland
Lycopus europaeus	glycophytic			
Lythrum salicaria	glycophytic			
Glyceria fluitans	glycophytic		high	
Cladium mariscus	glycophytic			
Potamogeton sp.		aquatic		water vegetation
Potentilla palustris		aquatic		semi-aquatic helophytic habitats
Polygonum lapathifolium		moist		
Sparganium sp.		aquatic		semi-aquatic helophytic habitats
Alisma plantago-aquatica		aquatic		semi-aquatic helophytic habitats
Gieten V-C				
Betula sp.				scrub and woodland
Polygonum lapathifolium		moist		
Carex rostrata/vesicaria	glycophytic			
Potamogeton sp.		aquatic		water vegetation
Sparganium sp.		aquatic		semi-aquatic helophytic habitats
Alnus glutinosa	glycophytic			scrub and woodland
Rhynchospora alba			low	
Juncus effusus		wet		
Potentilla palustris		aquatic		semi-aquatic helophytic habitats
Nuphar lutea		aquatic		water vegetation
Erica tetralix	glycophytic		low	
Menyanthes trifoliata		aquatic		semi-aquatic helophytic habitats
Oxycoccus palustris			low	
Eriophorum sp.			low	

Table 17. Indicator taxa of which macroscopic remains have been found in the Gietsenveentje.

scopic-remains record of the Netherlands and the classification of the modern flora into ecological groups by Runhaar et al. (1987). The groups of indicator plants have been compiled for the following abiotic and biotic characteristics: salinity, moisture regime, nutrient availability, the structure of vegetation and the stage of succession.

All taxa found as macroscopic remains in Gietsenveentje sequences and occurring on the indicator-taxa lists of Cappers (CAPPERS 1994, table 1-4) are presented in the first column of table 17. The indicator taxa are presented separately for each sequence and, within the sequence, in order of appearance. The next columns of the table list the abiotic or biotic characteristics, for which the taxon is an indicator. The indicator taxa will be discussed below:

- halophytic/glycophytic: all indicator taxa point to glycophytic conditions. This is not surprising, because the Gietsenveentje is and was located far from the sea.
- moisture regime: all indicator taxa point to moist to aquatic conditions. Most indicator taxa for aquatic conditions occur in the top sample of Gieten IV-HL (383-380 cm) and in the lower part of Gieten V-C (115-90 cm).

- nutrient availability: in Gieten IV-HL, only one indicator taxon points to a high availability of nutrients: *Glyceria fluitans*. In Gieten V-C, the indicator taxa for this feature, which predominantly occur in the upper part (85-60 cm), all point to low nutrient availability. This observation, together with the large quantities of *Sphagnum* remains at the same depths, leads to the conclusion that an oligotrophic peat bog occurred at that time at the location of Gieten V-C.
- structure of vegetation and stage of succession: no indicator taxa for pioneer vegetation and grassland have been observed. Most indicator taxa point to aquatic vegetation and vegetation of semi-aquatic helophytic habitats (this vegetation occurs during the process of terrestrialization). These indicator taxa illustrate the development from open water to an oligotrophic, ombrogenous peat bog.

VI.7 Phosphorus analysis

VI.7.1 Introduction

The elements in sediments, peats and soils can be grouped into five categories (KEMP et al. 1976):

1. major elements: Si, Al, K, Na and Mg, which constitute the main group in lake sediments;
2. carbonate elements: Ca, Mg and CO_3-C, which constitute the second most important group in the sediments, about 15% of the sediment;
3. nutrient elements: organic-C, N and P, constituting about 10% of recent lake sediments;
4. mobile elements: Mn, Fe and S, particularly mobile elements, which react rapidly to changes in the oxidation-reduction state of the sediment; they contribute about 5%;
5. trace elements: Hg, Cd, Pb, Zn, Cu, Cr, Ni, Ag, V, etc. which contribute about 0.1% of the sediment.

An important nutrient element is phosphorus (P): it is essential to all living organisms and occurs in, for example, phytates, nucleic acids and phospholipids. It is also important in the ADP-ATP cell energy and as a structural element in bones and shells (BENGTSSON & ENELL 1986). The usefulness of phosphorus analysis for palaeobotany and archaeology is due to the behaviour of phosphorus in soil. Phosphorus of organic origin, which is not utilized by plants, is converted to an insoluble, inorganic form that accumulates in soil. An advantage of inorganic phosphorus analysis is that once phosphorus becomes unavailable to plants, it tends to remain in place in soil as long as the sediments stay there (MILLER & GLEASON 1994). Arable land is a main source of phosphorus: drainage water from agricultural land may be enriched with phosphorus from manure and fertilizers. The build-up of phosphorus in sediments, peats and soils resulting from excessive use of fertilizers can often increase the concentrations by up to one order of magnitude (BENGTSSON & ENELL 1986; HÅKANSON & JANSSON 1983). However, phosphorus is soon depleted from unfertilized fields, which therefore exhibit lower concentrations than comparable uncultivated ground (SANDOR et al. 1990).

When samples are collected for phosphorus analysis in an archaeological site, it is very important to take reference samples outside the site, in order to detect the natural P content of the soil (BAKKEVIG 1980). In the case of the Gietsenveentje, the situation is somewhat different: here it is hoped to detect changes in the natural P content which are caused by human activities at an unknown distance from the Gietsenveentje. In the Gietsenveentje, phosphorus samples were collected from parts of three sequences, of which two contained the Neolithic Occupation Period. In this way, the P content of pre-Neolithic times can be compared with the P content of Neolithic times. An increased P content in the Neolithic Occupation Period could have several causes. One of the most important ones is the use of manure by the first farmers; another is the faeces of livestock, which were led to the lake to drink.

It has to be stressed that the P content in soils can show considerable variations over short distances, caused by soil conditions, vegetation types, land use and fertilizing in modern times. Therefore, the interpretation of P content must be closely linked to a study of the environment (BAKKEVIG 1980). One of the aims of the present study is to integrate the results of the phosphorus analysis in the results of pollen analysis, macroscopic-remains analysis and ^{14}C dating.

VI.7.2 Phosphorus analysis of parts of three Gietsenveentje sequences

In total, 24 samples for phosphorus analysis were collected from three sequences which were also used for pollen analysis: 10 samples from sequence Gieten V-A (core location 59, in the

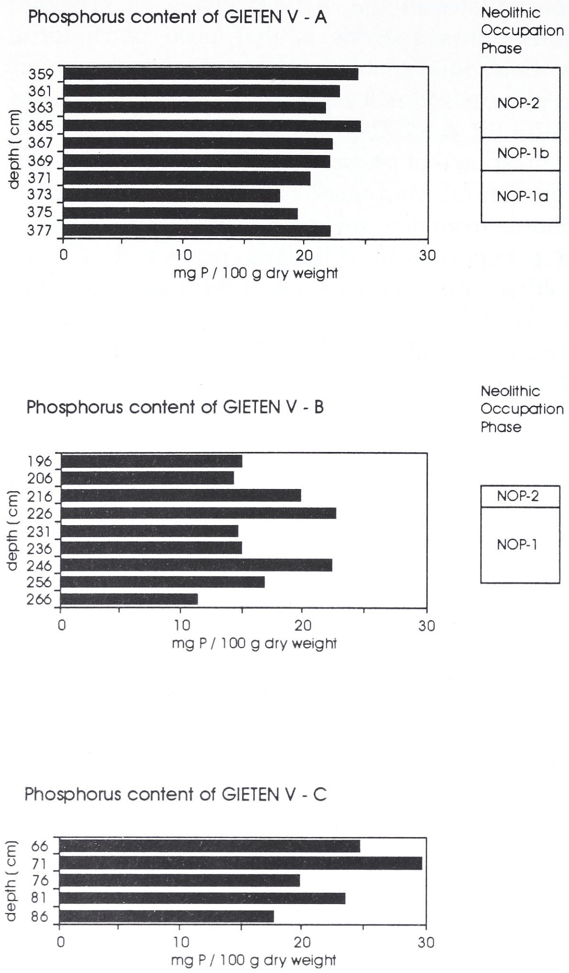


Fig. 66. Phosphorus content of 24 samples from three Gietsenveentje sequences. Where applicable, also the phases of the Neolithic Occupation Period are indicated.

centre), 9 samples from sequence Gieten V-B (core location 61) and 5 samples from sequence Gieten V-C (core location 63, near the northern edge). Each sample consisted of 1 cm^3 of sediment. With the help of the molybdenum-blue method (see IV.6), the total phosphorus content (P content) of each of these samples was determined and expressed in milligrams phosphorus per 100 g dry weight. The phosphorus content of the 24 Gietsenveentje samples is shown in fig. 66.

Gieten V-A. The phosphorus samples are all located in gyttja sediment. Between 373 and 365 cm, the phosphorus content increases from 18 to 24.5 mg P/100 g dr.w. In the Gieten V-A pollen diagram (figs. 56-57), four phases of the Neolithic Occupation Period are distinguished. As far as possible, these phases are also indicated in fig. 66.

Gieten V-B. The phosphorus samples are all located in mostly moderately to highly humified *Sphagnum* peat sediment. The bottommost sample (266 cm) displays the lowest P content of all 24 samples: 11.2 mg P/100 g dr.w. Then follow, successively, two samples with a considerably higher P content (256-246 cm; mean value: 19.5 mg P/100 g dr.w.); two samples with a lower P content (236-231 cm; mean value: 14.7 mg P/100 g dr.w.); two samples with a higher P content (226-216 cm; mean value: 21.1 mg P/100 g dr.w.) and two samples with a lower P content (206-196 cm; mean value: 14.5 mg P/100 g dr.w.). In the Gieten V-B pollen diagram (fig. 58), two phases of the Neolithic Occupation Period are distinguished. These phases are also indicated in fig. 66. At the beginning of the Neolithic Occupation Period, between the samples of 266 and 256 cm, P content increases from 11.2 to 16.8 mg P/100 g dr.w. There is a weak correlation between P content and the course of the NAP curve: at the depths of the highest P values (246, 226 and 216 cm), the total NAP, including the culture indicators, also reaches high values. Between 207.5 and 187.5 cm, the sediment of sequence Gieten V-B consists of poorly humified *Sphagnum* peat. In the pollen diagram, almost no culture indicators are found in this period. ^{14}C dates of the sediment at this depth point to probably disturbed sediment: they do not fit into the chronostratigraphy of the sequence. This short phase can be recognized in the low P content of the samples at 206 and 196 cm.

Gieten V-C. The lower three phosphorus samples are located in peat sediment; the upper two in a soft homogeneous humic substance with large pieces of wood. Between the samples of 86 and 66 cm, the P content increases with a few jumps from ca. 17 to ca. 30 mg P/100 g dr.w. The sample of 71 cm shows the highest P content of all 24 samples: 29.6 mg P/100 g dr.w. In the Gieten V-C pollen diagram (fig. 59), the Neolithic Occupation Period does not occur clearly. An increase of total NAP, including the culture indicators, is observed only in the samples of 64 and 63 cm. No phosphorus samples were collected at these depths. In VI.3.2, the possibility was discussed that the part of sequence Gieten V-C from 75 cm upwards is disturbed. This may explain the relatively high P content of the samples at 71 and 66 cm: maybe the phosphorus in these samples partly originates from higher parts of the sequence. Then it could represent a later era, when the use of fertilizers had become common.

VI.7.3 The use of phosphorus analysis to demonstrate agricultural activity

The interpretation of the phosphorus data of the Gietsenveentje can be performed in two ways:
1. the data are considered individually: the varying P values in the three sequences are interpreted, also taking into account other factors which may influence P content, like differences in lithology;
2. the data are compared to the phosphorus data of other studies. This has to be performed very carefully, because when phosphorus data from different locations, depths and sediments are compared, there are even more factors influencing P content. Different treatment methods can also yield very different results. Therefore, the use of phosphorus values should be indicative, not absolute (BAKKEVIG 1980).

Interpretation of the Gietsenveentje phosphorus data

In the Gietsenveentje, the gyttja samples show a somewhat higher P content than the peat samples. Although the differences are not very large, it seems unwise to compare the P content of different types of sediment in order to detect an increase in the P content caused by agricultural activity.
In sequence Gieten V-A, all phosphorus samples were collected in the same, more or less homogeneous gyttja sediment. For this reason, a small statistical test was performed on the Gieten V-A data, in order to test whether the P content in the first phase of the Neolithic Occupation Period (NOP-1) (samples 375-367 cm) differs significantly from the P content in the second phase of the Neolithic Occupation Period (NOP-2) (samples 365-359 cm). The result of this test is shown in table 18. The hypothesis that there are indeed two groups, is accepted with a large probability. The conclusion is that a significantly higher P content occurs in NOP-2 than in NOP-1.
In sequence Gieten V-B, this statistical test could not be performed: for this test, the smallest group has to contain at least three samples; in the Gieten V-B pollen diagram, the second Neolithic Occupation Phase (NOP-2) is represented by just one sample at 216 cm. The samples of 206 and 196 cm could not be used, because they are located in what probably is a disturbed part of the sequence.

NOP-1 samples (375-367 cm):	$n = 5$
NOP-2 samples (365-359 cm):	$m = 4$
sum of the ranks of m:	$W_X = 28$
level of significance:	$\alpha = 0.05$

H_0: all samples form one group
H_1: the samples can be divided in a NOP-1 and a NOP-2 group

When H_0 is true, $P [W_X \geq 28] = 0.0317$

Conclusion: H_0 is rejected

Table 18. The Wilcoxon-Mann-Whitney test performed on the phosphorus data of sequence Gieten V-A (SIEGEL & CASTELLAN 1988, 128). The probability of significantly different phosphorus contents of sediments from two phases of the Neolithic Occupation Period (NOP-1 and NOP-2) is tested.

Comparison with other phosphorus studies

In table 19, the mean P content of the Gietsenveentje samples, which is 20.0 mg P/100 g dr.w., is compared to the P content of various bogs in the Netherlands, studied by Koerselman and Verhoeven (1992). They determined the P content of peat sediment in two undisturbed raised bogs (Meerstalblok and Goudbergven) and of a raised bog affected by agricultural activities (Korenburgerveen). The P content was determined at the depths of 10 cm and 25 cm below the surface. As expected, the lowest P content occurred in the undisturbed raised bogs: 18-37 mg P/100 g dr.w. The raised bog affected by agricultural activity showed a P content of 48-57.5 mg P/100 g dr.w. In all three bogs, the highest P content occurred in the sediment at 10 cm depth. Clearly, the P content of the Gietsenveentje samples corresponds most to that of the undisturbed raised bogs (Meerstalblok and Goudbergven).
It is quite likely that the slowly increasing P content in the first phase of the Neolithic Occupation Period (NOP-1) was caused in some way by livestock faeces. This assumes that the first farmers were already known with stock raising and also applied it. The first possibility is that the first farmers allowed their livestock to move around freely. Possibly they led their animals to the lake to drink. The livestock faeces in the surroundings and at the shores of the lake would

Location	Description	Lithology	Depth	P content (mg P/ 100 g dr.w.)	References
Gietsenveentje, Gieten, prov. of Drenthe	pingo scar	gyttja/peat sediment	66-377 cm	20.0	this study
Meerstalblok, Bargerveen, prov. of Drenthe	raised bog: oligotrophic	peat sediment	10 cm	30	KOERSELMAN & VERHOEVEN 1992
			25 cm	18	
Goudbergven, Chaam, prov. of Noord-Brabant	raised bog: oligotrophic	peat sediment	10 cm	37	KOERSELMAN & VERHOEVEN 1992
			25 cm	28	
Korenburgerveen, Winterswijk, prov. of Gelderland	peat bog underlain by layers affected by nutrient-rich agricultural drainage water	peat sediment	10 cm	57.5	KOERSELMAN & VERHOEVEN 1992
			25 cm	48	

Table 19. Comparison of the phosphorus content (P content) of various bogs in three provinces of the Netherlands.

have caused the increased P content through inwashing. The second possibility is that the first farmers kept their livestock in stables (which in the Netherlands cannot be demonstrated archaeologically before the Bronze Age) or within enclosures. They would have used the manure for their arable fields. The manure would have caused the increased P content in the Gietsenveentje via inwashing. However, because the increase in P content is only very small, the agricultural activities apparently took place either on a very small scale or at a greater distance from the Gietsenveentje.

In the second phase of the Neolithic Occupation Period (NOP-2), the P content more or less stabilized. The P content of NOP-2 is higher than the P content of NOP-1, possibly pointing to a more intensive form of agriculture in this phase. However, since the P content in phase NOP-2 is only slightly (but significantly) higher than in NOP-1, this agriculture seems not to have been practised closer to the Gietsenveentje than in NOP-1. If that were the case, larger differences in P content between the two phases would be expected.