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Ronald Bakker

The emergence of agriculture on the Drenthe Plateau

– A palaeobotanical study supported by high-resolution ^{14}C dating

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I. General introduction

I.1 Introduction

The first farmers in the Netherlands were people of the Linear Pottery Culture (LBK), who occupied the loess soils of southern Limburg, the southernmost part of the Netherlands, between 5300 and 5000 cal BC (LOUWE KOOIJMANS 1998). From 4900 cal BC onwards, groups who practised stock keeping and some time later also cereal cultivation occupied the lower and wetter parts of the central and western Netherlands. These groups, which seem to have had a preference for natural levees and river dunes in the Alblasserwaard (province of Zuid-Holland) and the Flevopolders (province of Flevoland), are considered to represent the Swifterbant Culture (RAEMAEKERS 1999). There are faint indications that representatives of this culture also occupied the higher sandy soils of the northern and eastern Netherlands (KROEZENGA et al. 1991; GEHASSE 1995; LOUWE KOOIJMANS 1998). From ca. 3400 cal BC onwards, the Drenthe Plateau, which comprises the higher sandy soils of the province of Drenthe and adjacent provinces, saw a relatively dense occupation by farmers of the Funnel Beaker Culture (TRB). Their presence is demonstrated in the first place by characteristic burial monuments, the megalithic tombs (*hunebedden*). But also settlements of this culture are known (J.A. BAKKER 1979; 1982; 1992).

In pollen diagrams, the presence of farmers on the Drenthe Plateau is demonstrated by an increase or first appearance of the so-called culture-indicator pollen types and by a decrease of certain tree pollen types. Generally, these changes in the pollen diagrams are summarized by the term *landnam*. This term was first used by the Danish palynologists Johs. Iversen and J. Troels-Smith, to designate the impact of early farming cultures on the virgin forests (IVERSEN 1941; 1949; 1973; TROELS-SMITH 1954; KALIS & MEURERS-BALKE 1998). The earliest indication of human influence on the vegetation on the Drenthe Plateau is generally attributed to the agricultural activities of farmers of the Funnel Beaker Culture, after 3400 cal BC (VAN ZEIST 1959; 1967; CASPARIE & GROENMAN-VAN WAATERINGE 1980).

In the Netherlands, the effect of early agricultural activities on the composition of the vegetation, as well as the presence of cultivated crops themselves, is deduced mainly from pollen diagrams originating from large bogs (VAN ZEIST 1955a; 1955b; 1959; JANSSEN & TEN HOVE 1971; VAN GEEL 1978; CASPARIE 1992). However, the Neolithic farmers resided at a large distance from these bogs, so that the changes in the pollen rain which indicate their activity are diluted. Theoretically, small bogs, many of which are so-called pingo scars, are a much better source of information, if they are located in the vicinity of Neolithic settlements. However, in most small bogs, the so-called Neolithic Occupation Period (NOP) occurs in *Sphagnum* peat sediment. In the more recent past, this peat was often dug away to be used as fuel (*turf*). In these small bogs, below the peat sediment, often lake sediment is found, called gyttja, which could not be used as fuel and was therefore not exploited. At present, only very few pingo scars on the Drenthe Plateau are known in which the Neolithic Occupation Period is recorded in gyttja. One of these pingo scars is the Gietsenveentje, which is located near the village of Gieten in the province of Drenthe.

The pollen picture of the beginning of the Neolithic Occupation Period in the Gietsenveentje as known from preliminary studies (VAN DER KNAAP 1974; HAGEDOORN 1986), does not correspond to that described by Iversen and Troels-Smith for the Funnel Beaker Culture. Furthermore, the ^{14}C date of the first signs of human activity in the sediment, ca. 3600 cal BC (LANTING & BOTTEMA 1991), cannot be correlated with dates of the earliest agricultural settlements in the area: in the direct neighbourhood of the Gietsenveentje, there are several settlements of the Funnel Beaker Culture, which can be dated ca. 3300 cal BC. Possibly, the beginning of the Neolithic Occupation Period in the Gietsenveentje can be correlated with a late phase of the Swifterbant Culture. Several authors have already suggested a form of agriculture preceding that of the Funnel Beaker Culture in northern Germany, Denmark and southern Sweden (GÖRANSSON 1988a; 1988b; KOLSTRUP 1988; KALIS & MEURERS-BALKE 1998). The possibility of pre-TRB agriculture on the Drenthe Plateau will be considered in the present study.

I.2 Research strategy and approach

The aim of this study is to describe and explain the changes in the natural environment caused by the earliest farmers on the Drenthe Plateau, by means of a detailed palaeobotanical study of the Neolithic Occupation Period (NOP) in the sediment of the Gietsenveentje. A model of the Neolithic Occupation Period will be framed for the northern Netherlands and adjacent areas, which will be comparable to Iversen's *landnam* model for Denmark. Answers will be sought to the following questions:

- What was the natural environment like just before and during the Neolithic Occupation Period?
- What forms of interference affected the original vegetation?
- Which types of agricultural economy were practised during the Neolithic Occupation Period?
- Which cultures can be connected with the various phases of the Neolithic Occupation Period in the pollen diagrams?
- What was the role of the culture-indicator species *Rumex acetosa* (common sorrel) and *R. acetosella* (sheep's sorrel) in the vegetation during the Neolithic Occupation Period?
- What factors influence the manifestation of a land-occupation phase in a pollen diagram?

In the centre of the Gietsenveentje, a trench was dug to create an open section. It was possible to sample relatively large volumes of sediment from this section. Furthermore, a series of sequences were cored from the centre to the edges of the Gietsenveentje. The sediment samples from the open section and from the sequences were used for various types of analysis: pollen analysis, ^{14}C dating, pollen concentration and pollen influx analysis, analysis of macroscopic remains and wood, and phosphorus analysis. In order to get a very detailed chronology of the Neolithic Occupation Period, a large number of samples were ^{14}C-dated. For a study of the structure of the pingo basin, a factor which may have influenced the reflection of agricultural activities in the pollen diagrams, a large number of sequences were cored for lithological descriptions. The morphology of the culture-indicator pollen types *Rumex acetosa* and *R. acetosella* was examined in detail. For a study of the role of *Rumex acetosa* and *R. acetosella* in the Neolithic Occupation Period, vegetation plots were recorded and surface samples collected in modern vegetation types with these two *Rumex* species.

I.3 Context

This study was carried out in the framework of project group no. 2 of the Groningen Institute of Archaeology of the University of Groningen, the Netherlands. The research of this project group is focused on farming and early urban societies in the Netherlands. The project manager of the project group is Prof. Dr. H.R. Reinders.

I.4 Definition of the most important terms and concepts

I.4.1 Stratigraphical classification

Most data used in this study were obtained from various sediment cores of the Gietsenveentje. One of the tools for classifying these data is stratigraphy, by which layers of the sediment can be compared with similar deposits elsewhere (JANSSEN 1980). There are various types of stratigraphical classification. Here two types of biostratigraphical classification will be used, in which zones are defined on the basis of differences in the pollen content of the sediment:

A. Blytt/Sernander classification.
   Periods: **Atlantic** and **Subboreal**.
   The terms Atlantic and Subboreal were originally defined in the climatostratigraphic classification of Blytt (1876) and Sernander (1908) as warm and humid, and warm and dry periods, respectively. In later times, when the climatic typifications of these periods were no longer tenable, they were defined biostratigraphically, viz. on the basis of the pollen record (see, for example, FIRBAS 1949; VAN ZEIST 1955a, 8). When biostratigraphical definitions are used, the Atlantic-Subboreal transition does not occur synchronously everywhere.
B. Anthropo-stratigraphical classification.
   This classification subdivides the sediment into zones on the basis of traces of human presence, as seen in the pollen picture.
   Period: **Neolithic Occupation Period (NOP)**, subdivided into three Neolithic Occupation Phases.
   The beginning of the Neolithic Occupation Period (NOP) is defined palynologically as a decrease of tree pollen, especially *Ulmus*, and an increase of herb pollen, especially the culture-indicator pollen types (see I.4.2). The Neolithic Occupation Period is subdivided into three Neolithic Occupation Phases, which

are roughly defined as follows:
NOP-1: still high percentages of tree pollen, low percentages of culture-indicator types;
NOP-2: lower percentages of tree pollen, high percentages of culture-indicator types;
NOP-3: stabilization of tree pollen percentages, somewhat lower percentages of culture-indicator types.
As already mentioned, these phenomena or at least some of them in pollen diagrams are often summarized by the term ***landnam***. This term was first used by Iversen (1941; see II.1.2), because he saw a parallel between the immigration and land reclamation of the Neolithic people and the immigration of Viking settlers into Iceland and Greenland, which was traditionally referred to by the Old-Icelandic word *landnam*. Since then, the term *landnam* has been adopted by many palynologists to describe palynological phenomena connected with the first appearance of agriculture. Unfortunately, in the course of time, the original meaning of the term *landnam* almost disappeared from sight. The term was defined definitively by another famous Danish palynologist, Jørgen Troels-Smith (1942, 207): "We may speak of a *landnam*, when the course of the curves reflects large-scale forest clearances, undertaken by a newly immigrated people making use of agriculture, to create the facilities for practising arable farming and stock keeping." In the opinion of Iversen and Troels-Smith, the various phases of a *landnam* (see II.1.2) only represented a relatively short-lasting, local cycle of clearance, agriculture and forest regeneration. However, when for the first time large numbers of ^{14}C dates became available, it became clear that the phases of the *landnam* represented long-lasting, regional phenomena, which were found in many pollen diagrams of northwestern Europe (see for example ROWLEY-CONWY 1982; GÖRANSSON 1988c, 34; MADSEN 1990, 29; KALIS & MEURERS-BALKE 1998). For this reason, the "charged" term *landnam* will not be used in this study, but it will be replaced by the term Neolithic Occupation Period (NOP) (see also KALIS & MEURERS-BALKE 1998, 5).

On the basis of several series of ^{14}C dates, the aim is to obtain an absolute chronology of the Neolithic Occupation Period and its phases as seen in the Gietsenveentje pollen diagrams. The Gietsenveentje ^{14}C dates will be compared with dates of archaeological finds, in order to correlate the Neolithic Occupation Period and its phases as seen in the Gietsenveentje pollen diagrams with cultural periods or even cultures in archaeology. As the name already indicates, the Neolithic Occupation Period as observed in the pollen diagrams is expected to coincide with the Neolithic as it is known from archaeological finds. The beginning of the **Neolithic**, or New Stone Age, is conventionally defined as the appearance of the first domestic crops and livestock. The period is also marked by the first widespread use of pottery and ground stone tools, by a substantial increase in the number of settlement sites and the quantity of material remains and by the first field monuments (FAGAN 1996, 215). It has to be emphasized that in different areas, the beginning of the Neolithic does not occur synchronously (see II.5).
In fig. 1, the relevant periods of the two types of biostratigraphical classification are put next to the corresponding cultural periods known from archaeology. On the basis of this figure, the following question can be asked: were the beginning of the Neolithic, the Atlantic-Subboreal transition and the beginning of the Neolithic Occupation Period synchronous events in the part of Drenthe where the Gietsenveentje is located? An answer to this question will be sought with the help of high-resolution ^{14}C dating of sediments from the Gietsenveentje.

I.4.2 The detection of the beginning of the Neolithic Occupation Period in pollen diagrams

Apart from its localization in time, there is the problem of how the beginning of the Neolithic Occupation Period (NOP) manifests itself in pollen diagrams. This problem will be analyzed in two steps. The first step is to consider the question how an agricultural economy affects the vegetation. Many cultivated plants are domesticated steppe plants from the Near East (see II.5); to grow these plants in northwestern Europe, it is necessary to create and maintain open areas in the forest. In these new biotopes, next to the cultivated plants, a flora of heliophytes can develop, the so-called synanthropic species. A result of the keeping of animals is that natural biotopes are changed, because generally more individuals per area are kept than the natural forests would support. Because of the need for fodder, this inevitably leads to the creation and preservation

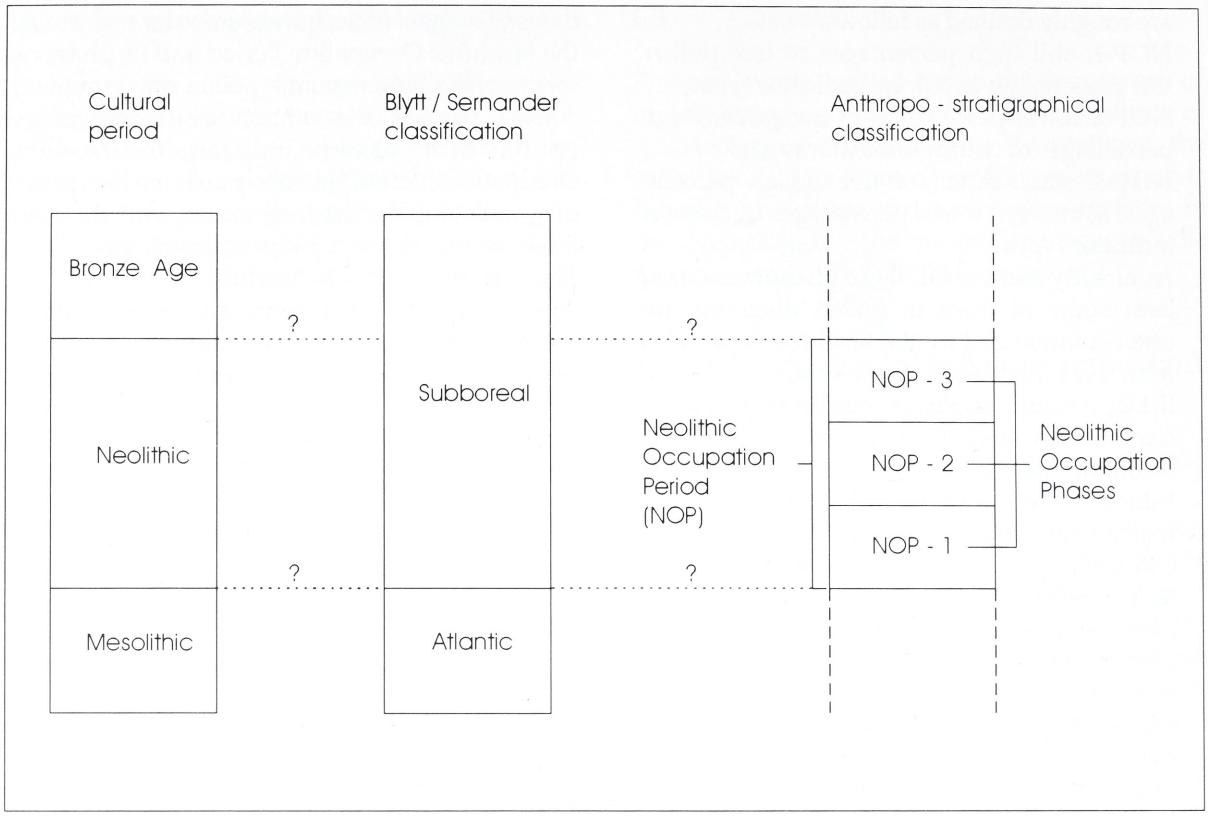


Fig. 1. Periods used in this study of two types of biostratigraphical classification and the corresponding cultural periods known from archaeology.

of plant communities with a large biomass production (KALIS & MEURERS-BALKE 1998).
The second step concerns the question how the man-made changes in the vegetation are observed in subfossil pollen diagrams. Generally, phenomena observed in subfossil pollen diagrams are interpreted on the basis of the "modern analogue" approach. The basic assumption of this method is that the situation of the present can be used to reconstruct the situation of the past. Within this method, two approaches are possible (BIRKS & BIRKS 1980, 231):

A. the indicator-species approach: this approach involves the application backwards in time of known ecological and sociological preferences of taxa. Those with a well-defined, narrow ecological tolerance can be used as indicator species.
B. the comparative approach: this approach involves the characterization of a range of modern vegetation types by means of contemporary pollen spectra (usually from surface samples), and then the comparison of these spectra with subfossil pollen assemblages.

In this study, these two approaches are used especially with respect to the reconstruction of man-made vegetation types. The indicator-species approach involves the use of culture-indicator pollen types, also called anthropogenic indicator pollen types (BEHRE 1981; 1986); the comparative approach involves the use of modern pollen/land-use relationships for the reconstruction of past land-uses and cultural landscapes (GAILLARD et al. 1992). The use of these two approaches in this study will now be explained in greater detail.

Use of culture-indicator pollen types

Culture-indicator pollen types are pollen types which may indicate human activity. Of course, the best culture-indicator pollen types are those of cultivated plants, the so-called primary indicators. In the Neolithic of northwestern Europe, the only identified pollen types of cultivated plants are *Hordeum* (barley), *Triticum* (wheat) and *Linum* (flax). Somewhat later, in the Iron Age, *Secale* (rye) was first cultivated in northwestern Europe (BEHRE 1992a). *Hordeum*

and *Triticum* are autogamous cereals, producing pollen which for the larger part remains in the hulls and hence is poorly dispersed. As a result, *Hordeum* and *Triticum* may occur very scarcely or not at all in peat or gyttja sequences cored even in close proximity to prehistoric cultivation areas. In contrast, *Secale*, as an allogamous species, has high pollen productivity and good dispersal capacity and hence is among the most reliable indicators of cultivation. Apart from cultivated plants, there are several species with readily distinguishable pollen which serve as culture indicators. These so-called synanthropic species tend to occur in man-made plant communities like arable land, meadow or heath. In specific cases, it is sometimes very difficult to determine whether these species occurred in natural or man-made biotopes; the decision can only be made when several culture-indicator pollen types are found together. Another problem is that in the early stages in the development of agriculture, when mixed farming was normal practice, the weed communities of cultivation as known today had not yet developed. The occurrence of culture-indicator species is also to a large extent influenced by the agricultural implements used: in the Neolithic, only the ard was known, a plough which does not turn the soil, so that perennating organs such as roots and rhizomes are not destroyed (see for example DRENTH & LANTING 1997). This favours the spread of perennial taxa like Gramineae and *Plantago lanceolata*.

Despite the large differences between prehistoric and modern agricultural methods, the interpretation of cultural periods in pollen diagrams will be guided in the first instance by the present-day pattern of occurrence of the culture-indicator species. Behre (1981) made a list of culture-indicator pollen types and their occurrence in various farming contexts in Europe north of the Alps. This list is reproduced in fig. 2. Besides evidence from modern communities, also information gained from many palynological investigations was incorporated. Fig. 2 will be an important guide for the recognition of cultural periods in the pollen diagrams of this study. Without doubt, the most important culture-indicator pollen types, besides the pollen types of cultivated plants, are *Plantago lanceolata* and *Rumex*-type. *Plantago lanceolata* was originally considered a pure indicator of pasture land; from its abundance, the extent of stock keeping could be estimated. However, because of its high light requirement, it would not grow in grazed forests (IVERSEN 1973, 84); apart from pastures, it grows optimally in hay-meadows which are mown once a year. However, it has been argued by several authors (BEHRE 1981; BEHRE & KUČAN 1994, 148; GROENMAN-VAN WAATERINGE 1986, 200) that *Plantago lanceolata* could also have grown as an arable weed among the crops. The dynamic system of an arable field of summer cereals is much the same as that of a meadow mown once a year in late summer; if the preparation of the field was done only with an ard, as was the case in the Neolithic, *Plantago lanceolata* could easily maintain itself. A second important culture-indicator pollen type is *Rumex*-type. In the Netherlands, small grains of *Rumex*-type originate almost exclusively from *Rumex acetosa* or *Rumex acetosella*. Because their ecology differs considerably, an attempt will be made in this study to separate the pollen of these two species (see V.2). *Rumex acetosa* is considered to be an indicator of pasture land, while *Rumex acetosella* is indicative of (former) arable land (BEHRE 1981, 236). The ecology of these two *Rumex* species and their significance for the interpretation of cultural periods in the pollen diagrams will be treated in sections V.3 and V.4.

Use of modern pollen/land-use relationships for the reconstruction of past land-uses and cultural landscapes

Up till now, the indicator-species approach has been the common method used for interpretation of pollen diagrams in terms of past land-uses (see BEHRE 1986). However, in recent years several large-scale studies have been carried out using the comparative approach for the reconstruction of past human-influenced plant communities and vegetation-landscape units (GAILLARD et al. 1992; BROSTRÖM et al. 1998). In this study, the comparative approach is used in combination with the indicator-species approach for a reconstruction of the landscape in the Neolithic Occupation Period. Because the two culture-indicator species *Rumex acetosa* and *Rumex acetosella* are clear indicators of two different types of agriculture, they have been used for a small-scale modern pollen/land-use study: recent human-influenced and natural plant communities in which these two species play an important role have been studied (see V.3). The results will be used for interpreting the course of the pollen curves at the beginning of, and during the Neolithic Occupation Period.

		Life form	Winter cereals	Summer cereals and coppice cultures	Fallow land	Moist grass vegetation	Dry grass vegetation and heaths	Grazed forest	Footpath and ruderal communities
Primary indicators									
Ce	*Secale*	T	◯	+	+				
	Hordeum	T	○	○	+				
	Triticum	T	∘	○	+				
	Avena	T		◯	+				
	Zea	T		◯	+				
Cu	*Fagopyrum*	T		○	+				
	Linum (usitatissimum)	T		○	+				
	Vicia faba	T		∘	+				
	Cannabis (type)	T		∘	+				
Secondary indicators									
Ad	*Centaurea cyanus*	T	∘	+	+				
	Lychnis/Agrostemma (type)	T	∘	+	+	∘			
	Scleranthus annuus	T	∘	+	+		+		
	Spergula arvensis	T	∘	∘	∘				+
	Polygonum convolvulus	T	∘	∘	∘				∘
	Polygonum aviculare	T	∘	∘	∘	∘		∘	∘
	Polygonum persicaria (type)	T	∘	∘	∘			+	∘
	Plantago lanceolata	H			∘	○	+	+	+
	Plantago major/media	H		+	∘	○	∘	∘	◯
Ap	*Rumex acetosella*	H	○	∘	○	+	○	∘	∘
	Rumex acetosa	H			∘	○		∘	+
	Trifolium repens	H	+	∘	∘	○	+	○	○
	Succisa pratensis	H				○	∘		
	Jasione/Campanula (type)	H			∘	+	○	∘	
	Urtica	H		∘	∘			∘	◯
	Artemisia (vulgaris)	H			∘			∘	○
	Melampyrum (pratense)	T					∘	○	
	Pteridium aquilinum	G			+	∘	∘	○	
	Polypodium vulgare	Ch					∘	∘	
	Calluna vulgaris	Ch					◯	∘	
	Juniperus communis	P					○	∘	
Fa	Gramineae		∘	∘	○	◯	○	○	∘
	Cyperaceae				∘	○	∘	∘	
	Caryophyllaceae p.p.		∘	∘	∘	∘	+	+	∘
	Cruciferae		∘	○	○	∘	+	∘	○
	Ranunculaceae		+	+	∘	○		∘	○
	Umbelliferae				∘	○	+	○	∘
	Chenopodiaceae			○	○				○
	Compositae		∘	∘	○	○	∘	∘	○

Fig. 2. Culture-indicator pollen types and their occurrence in various farming contexts in Europe north of the Alps (after BEHRE 1981 and LANG 1994). A five-part scale is used, from a plus (weak indicator for the biotope concerned) to a large circle (strong indicator for the biotope concerned). Ce: cereals. Cu: dicotylous culture plants. Ad: adventive plants. Ap: apophytes. Fa: apophytic plant families. T: therophytes. H: hemicryptophytes. G: geophytes. Ch: chamaephytes. P: phanerophytes (terminology: see LANG 1994, 227-229 and LANJOUW et al. 1968, 11).

II. Occupation phases in the Neolithic as represented in pollen diagrams: a review

II.1 Iversen's *landnam* model and Troels-Smith's leaf-fodder model

II.1.1 Introduction

The first scientists who made archaeopalynological models of the Neolithization process as early as the 1940s and the 1950s, are the Danish palynologists Johannes Iversen and Jørgen Troels-Smith. They developed their respective models not only on a theoretical, but also on a practical basis, with the help of the archaeologist Axel Steensberg and the palynologist Sven Jørgensen. Recently, the models of Iversen and Troels-Smith were critically reviewed and revalued by Kalis & Meurers-Balke (1998). The following discussion about the models is mainly based on this publication.

II.1.2 Iversen's *landnam* model

In 1941, Iversen published his classical study *Landnam i Danmarks Stenalder - Land Occupation in Denmark's Stone Age, A Pollen-Analytical Study of the Influence of Farmer Culture on the Vegetational Development*. He was the first to use the method of pollen analysis for the study of cultural history. Iversen (1973, 82) summarized the characteristics of primitive agriculture in pollen diagrams as follows:

1. agriculture causes characteristic changes in the forests, which are reflected in the tree pollen curves;
2. agriculture causes the presence of culture followers like *Plantago major, Plantago lanceolata, Artemisia vulgaris* and representatives of the family of Chenopodiaceae;
3. indicator plants for arable farming are in the first place the cultivated plants themselves (the primary indicators), but also arable weeds like *Rumex acetosella, Cruciferae* and *Polygonum* sp. (the secondary indicators);
4. indicator plants for pasture, pointing to stock keeping, are *Rumex acetosa, Plantago lanceolata* and *Trifolium repens*.

Iversen found these characteristics in Danish pollen diagrams just above the Atlantic-Subboreal transition in sediments which were deposited during the fourth Litorina transgression. In 1937, Iversen had demonstrated on geological-stratigraphical grounds that this transgression occurred simultaneously with the Funnel Beaker Culture (TRB) (IVERSEN 1937). In this way, Subboreal pollen spectra could be connected with Neolithic cultures (KALIS & MEURERS-BALKE 1998). Iversen (1949, 16 and legend of fig. 8; 1973, 87) divided his *landnam* model into three phases (fig. 3):

Phase 1: The pollen curves of three common species of the Atlantic forest, *Tilia, Ulmus* and *Fraxinus*, show a slight decline, while the pollen curves of herbaceous plants, especially Gramineae, *Pteridium aquilinum* and Compositae, suddenly increase. Occasional pollen grains of Cerealia and *Plantago* species already appear here. Phase 1 is subdivided into two subphases:

Phase 1a: Maxima of *Pteridium aquilinum* and Compositae; appearance of *Plantago lanceolata* and *P. major* in very low numbers;

Phase 1b: Increase in the curves of the pioneer species *Salix, Populus* and *Betula*; decline in the curves of herbaceous plants.

Phase 2: The pioneer species *Betula* is dominant in the pollen picture, while *Corylus* is strongly increasing. Pollen values of *Tilia, Ulmus* and *Fraxinus* drop to minimum values; values of *Salix, Populus* and *Pteridium aquilinum* decline. The pollen curves of *Plantago lanceolata, Artemisia* and Cerealia reach maximum values.

Phase 3: *Corylus* is dominant in the pollen picture; pollen values of *Ulmus, Tilia* and *Fraxinus* increase; the light-demanding species *Fraxinus* and *Quercus* reach higher values than before phase 1. The curves of the culture-indicator types strongly decline. Phase 3 is subdivided into two subphases:

Phase 3a: rise of *Corylus* curve, all other curves are falling;

Phase 3b: *Corylus* curve descending steeply, increase of *Ulmus, Tilia* and *Fraxinus*.

In the opinion of Iversen, the above-described changes in the vegetation appeared as a result of clearances by early farmers using flint axes and burning: the "slash-and-burn" method (IVERSEN 1973, 88). Iversen put forward several arguments in favour of clearance by burning:

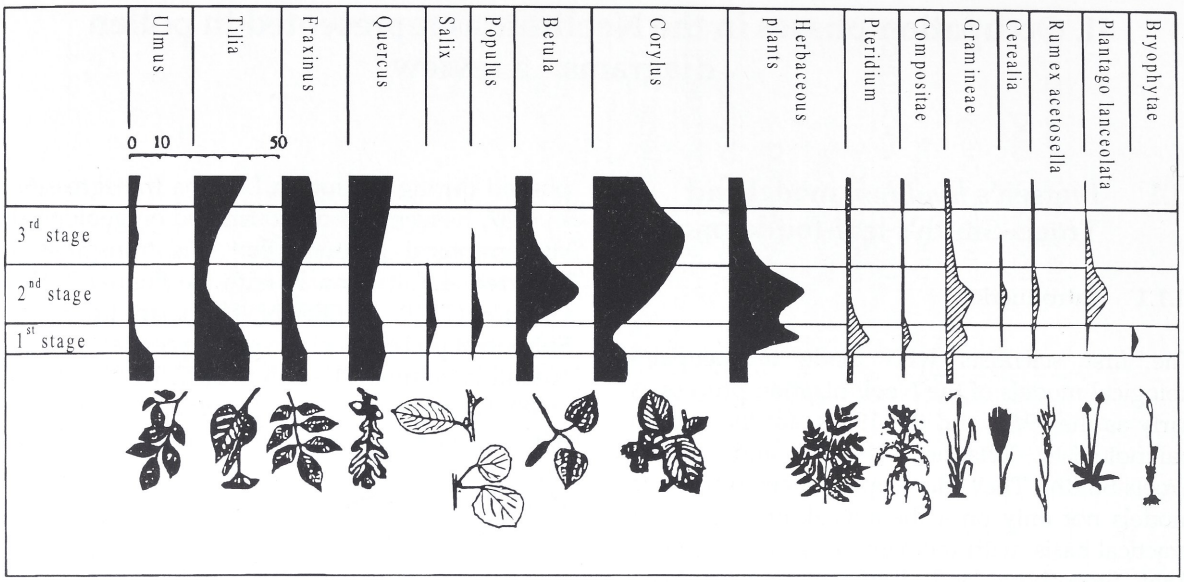


Fig. 3. Generalized pollen diagram of Iversen's *landnam* with its three phases (after IVERSEN 1973).

1. in the sediment of the type site Ordrup Mose, he found a distinct charcoal layer, which occurred contemporaneously with his phase 1a (IVERSEN 1949, 20; 1973, 89);
2. he explained the *Betula* maximum in phase 2 as follows: usually, *Betula* does not occur after ordinary forest clearances on the fertile forest mull in Denmark, because its seed germinates only when soil conditions are favourable. On ashy soil, however, the conditions for *Betula* are exceptionally favourable (IVERSEN 1941, 25);
3. he believed the maximum of *Pteridium aquilinum* in phase 1a also to point to burning: this species is not harmed by fire, because its rhizomes are deep in the ground (IVERSEN 1949, 20).

Iversen connected clearances by burning partly with arable farming: he imagined that the burnt-off forest area between the stubs was sown with grain after only the most superficial ploughing (IVERSEN 1941, 29). However, Iversen thought that the clearance fires were first of all intended for securing food for the animals: after burning, a forest regeneration started, and the fresh leaves of the emerging herbs, bushes and trees were welcome fodder for the livestock, which was free to roam about (IVERSEN 1941, 30). In Iversen's opinion, stock keeping must have been the most important agricultural activity. The free-ranging livestock prevented a real regeneration of the forest; only *Betula* and, in a later stage, *Corylus* scrub could persist. This may explain the *Betula* maximum in phase 2 and the *Corylus* maximum in phase 3 (KALIS & MEURERS-BALKE 1998). As already mentioned, Iversen connected his *landnam* model with the immigration of people of the Funnel Beaker Culture (TRB) ("Dolmen Period Culture"; IVERSEN 1941, 49).

II.1.3 Troels-Smith's leaf-fodder model

As early as 1954, Jørgen Troels-Smith questioned whether the Iversen *landnam* and the Funnel Beaker Culture really represented the earliest farming culture of Denmark. He noticed that the first pollen grains of the culture-indicator types, especially *Plantago major*, but also *Plantago lanceolata*, Chenopodiaceae and even Cerealia, occurred in his pollen diagram from Aamosen before the Iversen *landnam*. He also recognized this phenomenon in several of the pollen diagrams published by Iversen (TROELS-SMITH 1954).
Troels-Smith noticed that the earliest culture-indicator pollen types appeared simultaneously with the decline of *Ulmus*. In his opinion the *Ulmus* decline was caused by the collection of fodder in *Ulmus* forests by prehistoric stock farmers. The leaves and bark of *Ulmus* are superior to those of all other trees as fodder. Troels-Smith assumed that the *Ulmus* decline reflected the pollarding of the trees for the purpose of reaping their leaves and twigs for

fodder. The pollarding prevented the trees blooming and producing pollen or fruit, because *Ulmus* shoots will only flower when they are seven or eight years old. According to Troels-Smith, fodder-gathering arose out of stable feeding: the livestock were stabled throughout the year and the fodder was collected and brought to them. Troels-Smith puts forward palynological evidence to prove this theory: in his opinion, the low values of *Plantago lanceolata* and Gramineae point to the absence of pasture (TROELS-SMITH 1954, 54).

Because the cultural phase recognized by Troels-Smith appeared before the Iversen *landnam*, Troels-Smith assumed that it was caused by agricultural activities of the Ertebølle Culture, the culture which precedes the Funnel Beaker Culture in Denmark: *Ertebøllekultur - Bondekultur* (farming culture) (TROELS-SMITH 1954; KALIS & MEURERS-BALKE 1998). Troels-Smith tried to connect events in his pollen diagrams directly with archaeological finds. He found that funnel beakers of Type A (*sensu* BECKER 1947) as well as finds from the settlement excavation Muldbjerg (in Aamosen), could be located in time between the *Ulmus* decline and the Iversen *landnam*. In the excavation of Muldbjerg, together with Type A funnel beakers, also thick-walled Ertebølle potsherds were found. Because pollen spectra from material adhering to Type A funnel beakers all pointed to the phase between the *Ulmus* decline and the Iversen *landnam*, Troels-Smith saw these Type A beakers as part of the Ertebølle Culture (TROELS-SMITH 1954, 56; 60; KALIS & MEURERS-BALKE 1998). Hence Troels-Smith connected the cultural phase between the *Ulmus* decline and the Iversen *landnam* with the "semi-agricultural" Ertebølle Culture (TROELS-SMITH 1954, 56; 60). Later, this phase was called the "Troels-Smith occupation phase".

II.1.4 Alternatives to Troels-Smith's leaf-fodder model and Iversen's *landnam* model

Before alternatives to the models of Iversen and Troels-Smith will be discussed, it has to be emphasized that these models are framed for the Danish young-moraine landscape and therefore they are only valid for this or a comparable type of landscape with a comparable settlement history. Much criticism against the models of Iversen and Troels-Smith is based on inappropriate applications of the models to other types of landscape and to other archaeological connections (KALIS & MEURERS-BALKE 1998).

Through the years, several non-anthropogenic models have been framed as alternatives to Iversen's and Troels-Smith's models. Nilsson (1948, 1961) has emphasized that the decrease of *Ulmus* and *Tilia* occurs everywhere at the same point in time. In his opinion, such a synchronous, large-scale phenomenon could only be caused by a climatic change. He suggests that warmth-demanding ecotypes or varieties of *Ulmus* and *Tilia* were severely affected by a sudden series of abnormally cold winters. Less sensitive ecotypes would recover first after a transitional period. The regeneration of *Ulmus* and *Tilia* could be explained by the return of more favourable climatic conditions (GÖRANSSON 1988a). The possibility of a climatic change at the beginning of the Neolithic is discussed in II.4.

According to Göransson (1988a, 48), the late Atlantic (Mesolithic) forests were already utilized by man: a garden cultivation of cereals could have taken place below girdled trees. He suggested that the decrease of *Ulmus* and other trees was caused by several interacting factors, abiotic, such as climate, and/or biotic (e.g. disease combined with browsing). He emphasized that these factors were beyond man's control. The Neolithic people would merely have utilized the changed circumstances. He believed no expansion of cultivation to have occurred at the beginning of the Neolithic (GÖRANSSON 1988a, 49). He named the first part of the Neolithic (up to the regeneration phase) the "Early Neolithic Destruction Phase" (GÖRANSSON 1988a, 53). The so-called "catastrophe model" is also supported by Berglund (1991, 315; 428).

According to Groenman-van Waateringe (1968), the appearance of pollen grains of *Plantago lanceolata* and *P. major* in pollen diagrams before and contemporary with the *Ulmus* decline, unless accompanied by pollen of Cerealia and archaeological material, is not necessarily an indication of the presence of Neolithic man in the immediate vicinity. The pollen of these two *Plantago* species in this period may originate from "natural pastures", which occurred in unstable boundary zones - areas at the transition between freshwater and saline environments, wet and dry, and poor and rich in nutrients - along the sea coast and in river valleys. For this reason, Groenman-van Waateringe rejects Iversen's statement that *Plantago major* is so closely related to the appearance of man that this plant would disappear if human cultivation ceased.

From an archaeological point of view, the models

of Iversen and Troels-Smith have been severely criticized. The criticism focused mainly on two points: the stall-feeding of cattle, postulated by Troels-Smith and the use of the "slash-and-burn" method postulated by Iversen.

Rowley-Conwy (1982, 205) made some calculations concerning the scale of tree pollarding and leaf foddering of permanently stalled cattle needed to explain the *Ulmus* decline in the Danish pollen diagrams. He reaches the conclusion that the total number of cattle would have been between 500,000 and 1,000,000. This number of animals seems impossibly high for the prehistoric period. However, he does admit that calculations of this nature are fraught with problems, because they are based on many assumptions. Rackham (1980, 266) made comparable calculations for Britain. In his opinion the pollarding of Britain's huge area of *Ulmus* so efficiently as to halve its pollen production would require a population much larger and more elm-centred than any archaeologist has hitherto proposed. Rackham's estimate is that a minimum population of about 500,000 adults would be needed, a population at least ten times too large for Early Neolithic Britain.

New evidence for leaf foddering of stalled cattle was found by Troels-Smith himself in Switzerland: near a Neolithic settlement at Weier, in an outwash layer of a field, besides charred grains of wheat also pupae of the house fly *Musca domestica* were found. These pupae could not derive from cowpats of cows grazing in the harvested fields because house flies do not place their eggs in cowpats. The manure must have been carried out from the byres into the field (TROELS-SMITH 1984, 22). On the basis of an analysis of goat/sheep faeces from Egolzwil, also in Switzerland, Rasmussen (1993) has demonstrated that the local Neolithic farmers harvested leafless twigs and branches (mainly of *Corylus*, *Alnus* and *Betula*) in the early spring, which they used for foddering their livestock.

Rowley-Conwy (1981; 1982) also criticizes Iversen's ideas of the use of the "slash-and-burn" method in the Neolithic. In his opinion, there is no need for "slash-and-burn" on adequate, fertile soils like those of the Danish young-moraine landscape (ROWLEY-CONWY 1981, 89). Furthermore, there is no need for domestic animals in a shifting-cultivation system. In a permanent field system, however, sheep, cattle and pig are essential for weeding and manuring. In spite of these objections, the high values of *Betula* and *Pteridium aquilinum* in the pollen diagrams and the charcoal layers point indirectly and directly to the use of fire. Possibly, only the initial clearance was aided by fire, either to burn felled trees or to remove trees ringbarked and left standing; however, it would not seem necessary for this to be done cyclically, particularly if agriculture was on a more permanent basis than that envisaged by the shifting-cultivation theory (ROWLEY-CONWY 1982, 208). As already mentioned, Iversen himself (1941, 30) thought that the Neolithic clearance fires were in the first place intended for securing food for the animals. The use of the cleared areas for stock keeping would explain why forest regeneration was stopped in an early stage and remained in the *Betula* forest phase with lush undergrowth for about two hundred years (KALIS & MEURERS-BALKE 1998).

II.1.5 Recalculation of the original diagrams of Iversen and Troels-Smith

Because the leaf-fodder model of Troels-Smith and the *landnam* model of Iversen today still have a great significance for the archaeopalynological interpretation of pollen diagrams, Kalis & Meurers-Balke (1998) have critically examined the original diagrams of Iversen and Troels-Smith. It concerns Iversen's diagram of Ordrup Mose, a filled-up bay in the northern city area of Copenhagen (fig. 6, no. 1) (IVERSEN 1949) and Troels-Smith's diagram of Aamosen (Øgårde complex), a raised-bog area in the western part of Zealand (fig. 6, no. 2) (TROELS-SMITH 1954). In order to compare these diagrams with more recent pollen diagrams, it was necessary to recalculate the pollen percentages, because Iversen and Troels-Smith used tree pollen sums with corrected values for most trees. The updated versions of the diagrams of Ordrup Mose and Aamosen are shown in figs. 4 and 5. It can still be seen that in the diagram of Troels-Smith, a distinct cultural phase occurs before the Iversen *landnam*. In several Danish pollen diagrams, including Iversen's diagram of Ordrup Mose, pollen grains of Cerealia occur before the Iversen *landnam*. J. Stockmarr (cited in KOLSTRUP 1988) dated the first pollen grains of *Triticum*-type at Aamosen to 4200 cal BC, which is clearly within the time range of the Ertebølle Culture. The recalculation of the diagrams of Iversen and Troels-Smith also leads to the following conclusions (KALIS & MEURERS-BALKE 1998, 13):

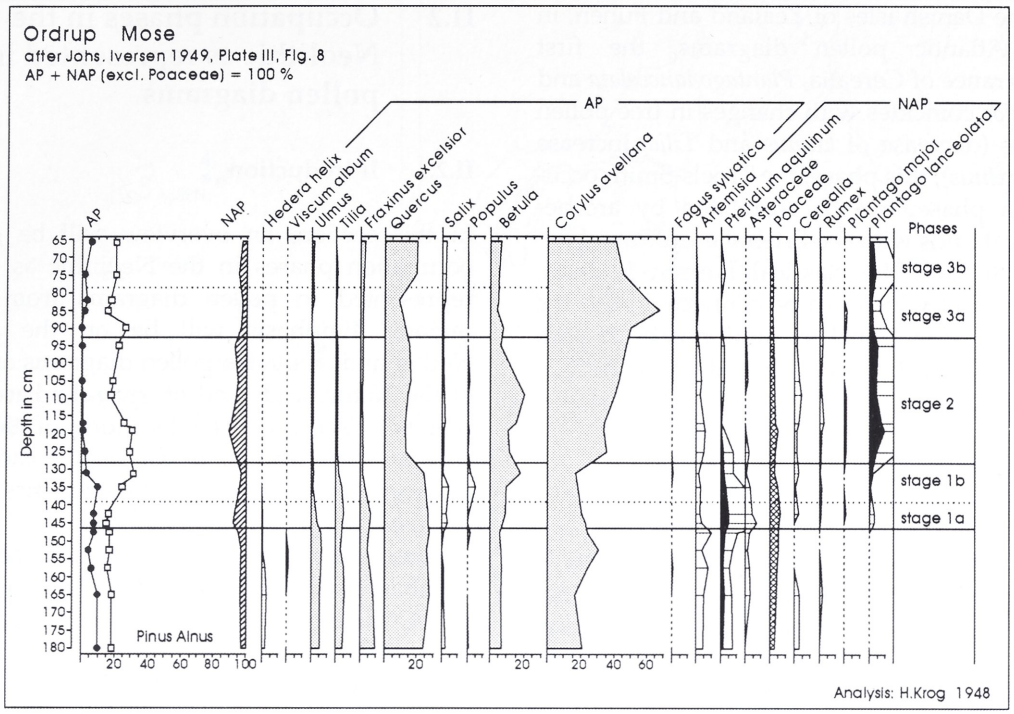


Fig. 4. Recalculated version of Iversen's pollen diagram of Ordrup Mose, with indication of PREFACT phases (after KALIS & MEURERS-BALKE 1998, Abb. 2).

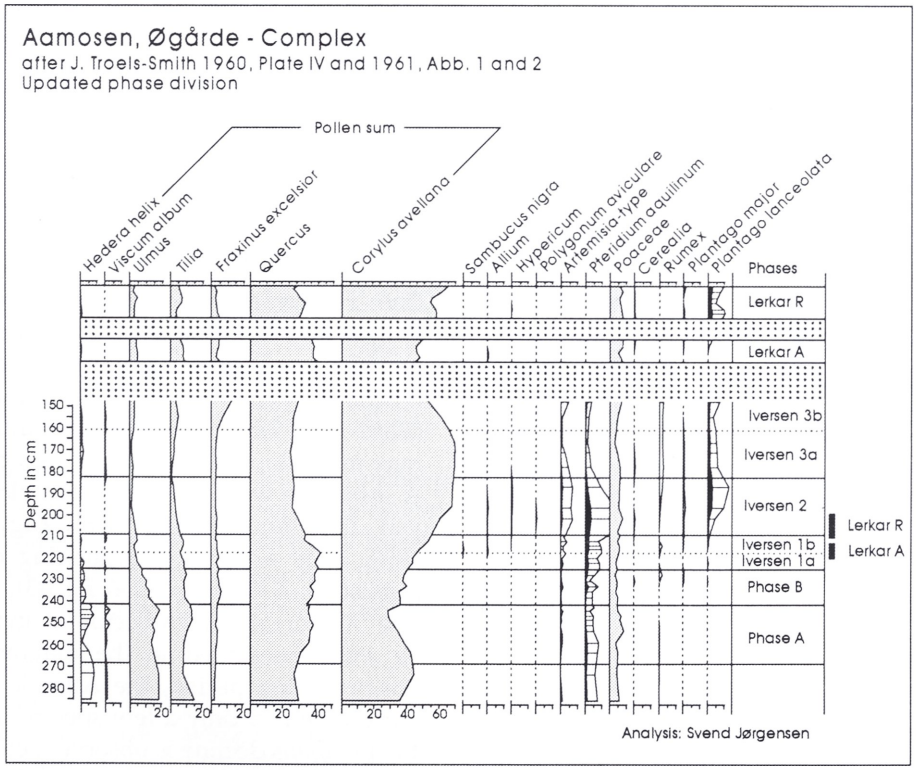


Fig. 5. Recalculated version of Troels-Smith's pollen diagram of Aamosen, with indication of PREFACT phases (after KALIS & MEURERS-BALKE 1998, Abb. 4).

1. On the Danish isles of Zealand and Fünen, in late Atlantic pollen diagrams, the first appearance of Cerealia, *Plantago lanceolata* and *P. major* coincides with changes in tree pollen values (decrease of *Ulmus* and *Tilia*, increase of *Fraxinus*); this phase, the Troels-Smith occupation phase, can be correlated by archaeological finds with the Ertebølle Culture.
2. Then follows the classical Iversen *landnam*, phase 1a of which can be connected with the Type A funnel beakers, and phase 1b with Type B funnel beakers (*sensu* BECKER 1947).

II.1.6 A regional *landnam* model for the western Baltic area

Kalis & Meurers-Balke (1998) have attempted to correlate the pollen diagrams of Ordrup Mose and Aamosen with diagrams of neighbouring eastern Holstein (northeastern Germany; see II.2.9). They divided the Neolithic period in the pollen diagrams into PREFACT phases (**P**alynological **R**eflection of **E**arly **F**arming **ACT**ivities). As for the Iversen *landnam* phase, the PREFACT phases follow Iversen's 1949 subdivision into five phases (the so-called Iversen-PREFACT phases 1a, 1b, 2, 3a, 3b). The Troels-Smith occupation phase, which precedes the Iversen *landnam*, is subdivided into two phases: Troels-Smith-PREFACT phase A, characterized by an initial decrease of *Ulmus* and *Tilia* and sporadic occurrence of *Artemisia, Pteridium aquilinum* and *Rumex*, and Troels-Smith-PREFACT phase B, characterized by a pronounced decrease of *Ulmus* and the first occurrence of *Plantago major, P. lanceolata* and Cerealia. The PREFACT model of Kalis & Meurers-Balke (1998) gives a very good description of the vegetation development during the Neolithic and its relation to archaeology in the western Baltic area. The present study aims to formulate a comparable model for the northern Netherlands and northwestern Germany.

II.2 Occupation phases in the Neolithic as represented in pollen diagrams

II.2.1 Introduction

In this section, an overview will be given of occupation phases in the Neolithic as they are represented in pollen diagrams from various regions. Emphasis will be on the northern Netherlands, but also pollen diagrams of the rest of the Netherlands and of several adjacent areas will be discussed. The locations of the pollen diagrams are shown in fig. 6. Of each pollen diagram, the following characteristics will be discussed:

1. description and interpretation of occupation phases occurring during the Neolithic;
2. ^{14}C dates of the occupation phases, when available (a global calibration table of ^{14}C dates is shown in appendix IV);
3. connection of the occupation phases with Neolithic cultures.

This overview by no means pretends to be complete, but it is hoped that it will sketch a representative picture of the course of the Neolithic as observed in pollen diagrams of the Netherlands and some adjacent parts of northwestern Europe.

II.2.2 Pingo scars in the northern and central Netherlands

Hijkermeer (province of Drenthe)

The Hijkermeer, located near the village of Hijken, is a large pingo scar with a diameter of ca. 250 m. Today, it still for the larger part contains open water. The coordinates of the centre are 229.35/545.28. The infill reaches a maximum depth of 5.10 m, and consists of gyttja. A sequence was analyzed palynologically by T. van der Hammen and W.H. Zagwijn in 1951-1953. Only a small summarizing diagram was published (ZAGWIJN 1956, fig. 43).

The Subboreal, which occurs in gyttja, seems to be well-represented in the diagram. However, the preceding period, the Atlantic, seems to be represented by only a few spectra. In spectra 13-14, an *Ulmus* decline is observed, coinciding with a decrease of *Betula*. *Tilia* reaches maximum values. A few spectra higher up, *Plantago lanceolata* and *Rumex acetosa/acetosella* appear; they remain present in each subsequent spectrum in

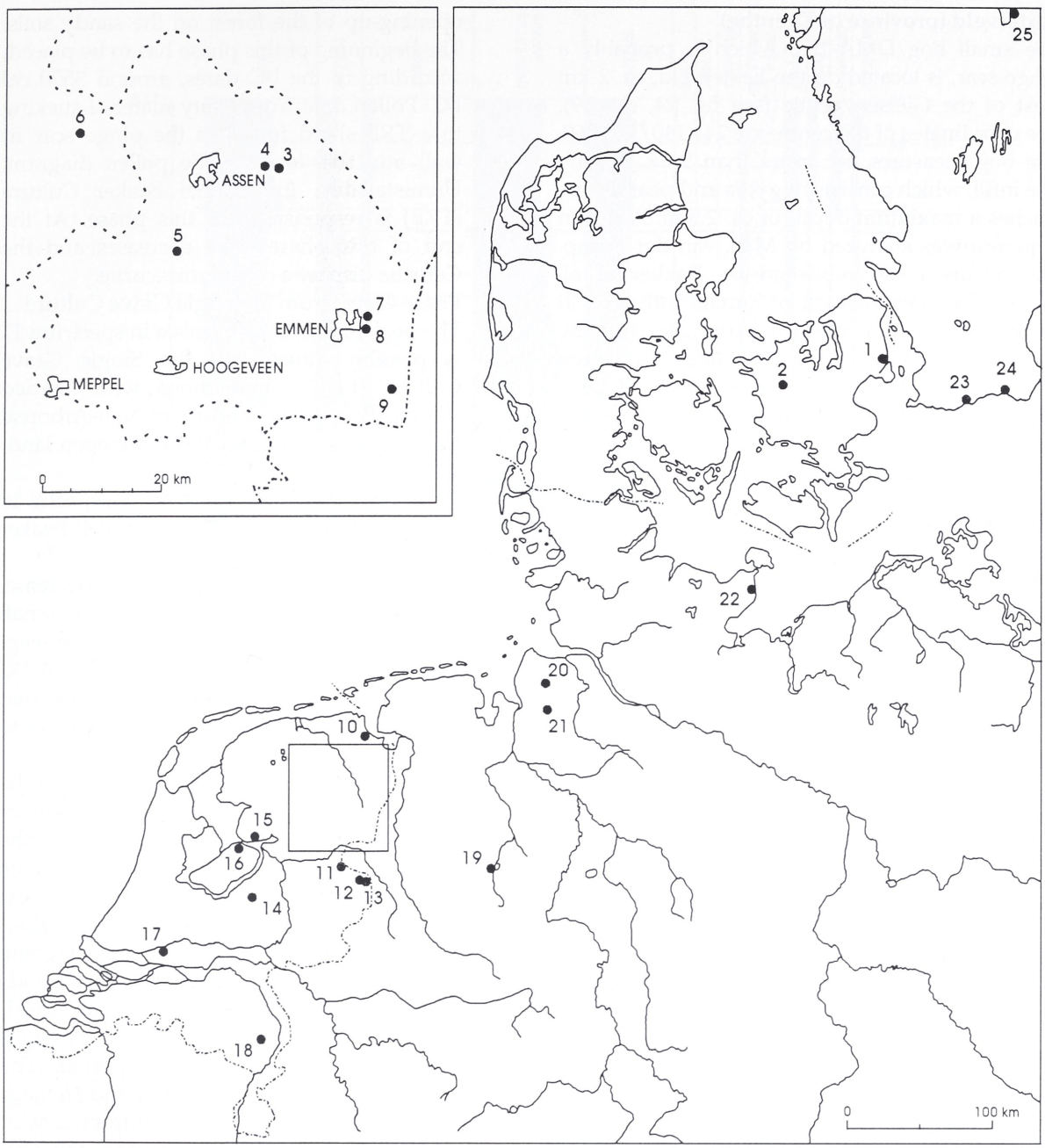


Fig. 6. Locations of pollen diagrams with occupation phases attributed to Neolithic cultures discussed in this chapter: 1. Ordrup Mose; 2. Aamosen; 3. Gietsenveentje; 4. Eexterveld; 5. Hijkermeer; 6. Wijnjewoude; 7. Emmererfscheidenveen; 8. Bargeroosterveld; 9. Meerstalblok; 10. Farmsum; 11. Engbertdijksvenen; 12. De Borchert; 13. De Klokkenberg; 14. Uddelermeer; 15. Schokland; 16. Swifterbant; 17. Hazendonk; 18. De Peel; 19. Hüde; 20. Flögeln; 21. Herrenhof; 22. Siggeneben-Süd; 23. Skateholm; 24. Ystad; 25. Alvastra.

low values. In spectrum 19, *Quercus* and especially *Tilia* decrease, while Cerealia-type appears, only occurring sporadically afterwards. In spectra 27-28, the culture-indicator types decrease again. An increase of *Fagus* to ca. 5% of the total AP in spectrum 33 seems to mark the end of the Subboreal. Generally, the Hijkermeer diagram is characterized by a lack of sudden changes in the course of the curves. During the first part of the Subboreal, the Ericaceae show relatively high values, while the Gramineae show relatively low values.

Eexterveld (province of Drenthe)

The small bog DMA-15a, which is probably a pingo scar, is located on the Eexterveld, ca. 2 km west of the Gietsenveentje (see fig. 24, no. 19). The coordinates of the centre are 244.140/558.560. The bog measures not more than 24 x 10.5 m. The infill, which consists of gyttja and peat layers, reaches a maximum depth of ca. 2.5 m. A pollen sequence was analyzed by M.D. van der Kamp. The results were published by Bakker et al. (1999). The interpretation of human influence in the pollen diagram seemed extremely difficult, because according to the ^{14}C dates the entire Neolithic is compressed into ca. 30 cm of peat, while the TRB period covers only a few spectra. Despite this, several phases of human activity could be traced in the diagram (it has to be remarked that spectrum 1 is the youngest and spectrum 20 is the oldest spectrum):

- Phase 1: spectra 17-20, date just below spectrum 16: 5394 ± 41 BP [UtC-6012]: Mesolithic.
  A decline of Quercus and Tilia and an increase of *Betula* seem to indicate the earliest phase of human activity, which is dated before 5400 BP/4200 cal BC. At this level also charcoal particles of *Quercus* were found. However, no culture-indicator pollen types were traced. These activities may be attributable to Mesolithic people.
- Phase 2: spectra 15-16: Swifterbant or pre-megalithic TRB.
  Just above the ^{14}C date of 5400 BP/4200 cal BC, the first Cerealia pollen, identified as *Triticum*-type, was found. Simultaneously, *Ulmus* and *Tilia* decrease, while the Non-Arboreal Pollen (NAP) increases, except for the Gramineae. High values of Rosaceae possibly point to the existence of a natural shrub vegetation along the forest edge. Possibly, the Swifterbant Culture or pre-megalithic TRB (Early Neolithic TRB) are responsible for this phase of human activity. The first possibility is more likely, because so far the Early Neolithic TRB Culture is not known from the northern Netherlands and northwestern Germany.
- Phase 3: spectra 12-14, date just below spectrum 12: 4410 ± 49 BP [UtC-6011]: Funnel Beaker Culture.
  This phase begins with a decline in *Quercus* and *Ulmus*, an increase in *Tilia* and the first occurrence of *Plantago lanceolata*. The Non-Arboreal Pollen, including Gramineae, and *Pteridium* increase. This points to a further opening-up of the forest on the sandy soils. The beginning of this phase has to be placed, according to the ^{14}C dates, around 3500 cal BC. Pollen data from peaty material sticking to a TRB sherd found in the pingo scar fit well into this level of the pollen diagram. Unmistakably, the Funnel Beaker Culture (TRB) is responsible for this phase. At the end of this phase, *Tilia* decreases and the Cerealia display a continuous curve.
- Phase 4: spectrum 11: Single Grave Culture.
  The peak of *Plantago lanceolata* in spectrum 11 is possibly caused by the Single Grave Culture (EGK; synonymous with Corded Ware Culture). The increase of Non-Arboreal Pollen points to a more and more open landscape.
- Phase 5: spectra 9-10, date between spectra 10 and 11: 4000 ± 37 BP [UtC-6010]: Bell Beaker Culture.
  Cerealia and *Plantago lanceolata* decrease, while *Betula*, *Quercus* and *Tilia* show small peaks. The human influence on the vegetation has become quite insignificant. A ^{14}C date of 4000 BP/2500 cal BC indicates that this level should probably be attributed to the Bell Beaker period (BB).

Bakker et al. (1999) emphasize that because of the small size of the bog, the pollen data are only of local significance and that general trends in the cultural development of the region will only be reflected in rather weak signals. Furthermore, they conclude that the Arboreal Pollen values remain extremely high in the entire diagram, compared to the spectra from TRB burial mounds (see II.2.4). This should indicate that the woodland vegetation extended towards the very edges of the bog itself throughout the period. The regular presence of pollen of *Lemna* and *Hottonia palustris* indicates the presence of eutrophic open water in the Neolithic. For this reason, the TRB remains found in the bog itself cannot be interpreted as ordinary domestic waste; they are supposed to be sacrificial.

Wijnjewoude (province of Friesland)

Near Wijnjewoude, a pingo scar was discovered almost entirely filled with peat (coordinates of the centre 205.80/563.80); the peat in the uppermost layer is level with that in the nearby Boorne valley, so that it is difficult to notice the pingo scar in the landscape. Its size is ca. 150 x 100 m. The infill reaches a maximum depth of 5.50 m. The results of the pollen analysis were published by Ploeger & Groenman-van Waateringe (1964).

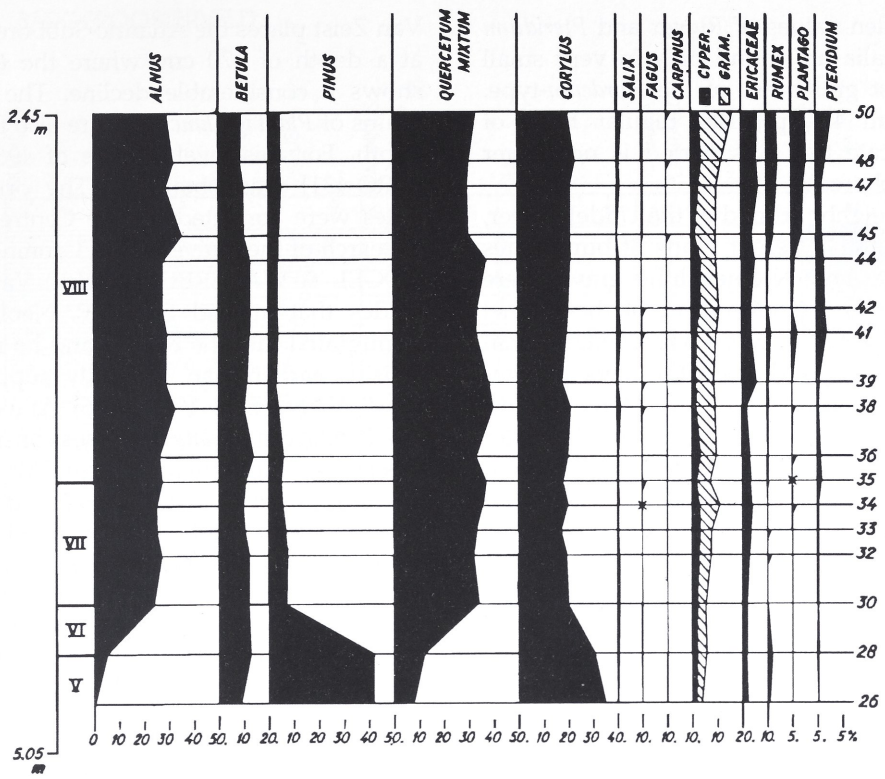


Fig. 7. Summarizing pollen diagram of the Uddelermeer (after POLAK 1959, diagram IV). Only the Arboreal Pollen is included in the pollen sum.

In the diagram, the first part of the Subboreal is compressed into the upper 75 cm. The last part of the Subboreal seems to be missing. The sediment in this part of the sequence consists of forest peat (0.75-0.50 m) and Cyperaceae peat (0.50-0 m). The *Ulmus* curve declines at 0.70 m. One pollen grain of *Plantago lanceolata* was found just above this level.

According to Ploeger & Groenman-van Waateringe, the upper five spectra (0.50-0 m) record an Iversen *landnam*: an increase is seen of Gramineae, Ericales, *Plantago lanceolata*, *Rumex* and Compositae. Ploeger & Groenman-van Waateringe, following Waterbolk (1956) and Van Zeist (1959, see II.2.3), conclude that this Iversen *landnam* was due to the Protuding Foot Beaker Culture (Single Grave Culture, EGK). In their opinion, the occurrence of several barrows of this culture in the district support this theory. However, also many finds of the preceding Funnel Beaker Culture (TRB) are known from the district (see FOKKENS 1990).

Uddelermeer (province of Gelderland)

The Uddelermeer, located in the Veluwe in the central Netherlands, is a very large pingo scar with a size of 420 x 260 m, which has always contained open water. The infill reaches a maximum thickness of 4.40 m, and consists of gyttja (0-245 cm) and dark brown dy (245-440 cm). Results of a pollen analysis were published by Polak (1959). A summarizing pollen diagram is shown in fig. 7.

The Subboreal, which occurs in dark brown dy, is well-represented in the diagram. The preceding period, the Atlantic, is compressed into a few spectra. In spectra 34-35, a decline of *Ulmus* is observed, while *Tilia* reaches maximum values. In the same spectra, Gramineae increase, *Plantago lanceolata* appears and also one pollen grain of *Hordeum* measuring 42 µm was found. *Plantago lanceolata* occurs only sporadically in the following spectra. Polak (1959, 564) located the Atlantic-Subboreal transition at spectrum 35; however, the *Ulmus* decline already starts in spectrum 34, so that it seems better to place this transition between spectra 33 and 34. From spectrum 41 upwards, *Plantago lanceolata* forms a continuous

curve; the pollen values of *Rumex* and *Pteridium* increase. Cerealia are found only in very small numbers; most grains are of the *Hordeum*-type. From spectrum 45 upwards, regular finds of *Carpinus* indicate that this period is no longer part of the Subboreal.
In the direct neighbourhood of the Uddelermeer, dwelling pits and different kinds of burial sites have been excavated. No megalithic graves were found, but artefacts and pottery of the Funnel Beaker Culture (TRB) have been recovered within the region. Also protruding-foot beakers (belonging to the Single Grave Culture, EGK) and especially bell beakers (belonging to the Bell Beaker Culture, BB) occurred. It appears that different cultures followed each other and that the material became mixed. The bank and the surroundings of the Uddelermeer were inhabited from Early Neolithic up to Carolingian times. Human occupation is reflected in the pollen picture. However, a pronounced Iversen *landnam* is not seen. Most pollen grains of Cerealia were identified as *Hordeum*. Possibly, on the poor soils of this part of the Veluwe, *Hordeum*, which is ecologically less susceptible than the various *Triticum* species, was the most important crop during the first part of the Neolithic. According to the relatively low Ericaceae percentages, no extensive heathland was present in this part of the country during the Neolithic; probably there were open spaces covered with grasses and patches of heather.

II.2.3 Large raised bogs of southeastern Drenthe

Emmererfscheidenveen
The raised bog near Emmererfscheidenveen forms part of the formerly extensive raised bog east of the Hondsrug, the Bourtanger Moor. This raised bog lies in the primeval valley of the Hunze (fig. 14). In the lowest parts, peat formation already started in Late-Glacial times. The natural drainage of this raised bog took place by a stream called Runde which ran in a northerly direction. Peat-digging was practised in this area up to the 1950s. The only dated pollen sequence from this area is Emmererfscheidenveen V (VAN ZEIST 1955b) (coordinates 262.08/534.78). The sediment reaches a depth of ca. 3.40 m, and consists of a very thin layer of gyttja, followed by thick layers of mainly *Sphagnum* peat. The Subboreal, which occurs in *Sphagnum* peat, is well-represented in the diagram.
Van Zeist places the Atlantic-Subboreal transition at a depth of 170 cm, where the *Ulmus* curve shows a considerable decline. The first pollen grains of *Plantago lanceolata* are also found at this depth. For this level, a date of 4965 ± 135 BP [GRO-431] was obtained. (The original GRO-dates were corrected by the Centre for Isotope Research of the University of Groningen, see also VOGEL & WATERBOLK 1963.) Van Zeist concludes that around 5000 BP, Neolithic people immigrated into the region, and he remarks that "this is earlier than generally supposed up to now" (VAN ZEIST 1955b, 116). At a depth of 115 cm, *Plantago lanceolata* increases considerably, but reaches not more than 1% of the AP, and forms a continuous curve. For this level, a date of 4185 ± 140 BP [GRO-428] was obtained. Van Zeist compares the *Plantago lanceolata* values in this diagram with *Plantago lanceolata* values in palynological spectra from Neolithic burial monuments - megalithic tombs from TRB times and tumuli from EGK times. In contrast to spectra from megalithic tombs, the spectra from tumuli are characterized by high percentages for *Plantago lanceolata* and other herbs (see II.2.4). For this reason, Van Zeist concludes that the increase of *Plantago lanceolata* at 115 cm marks the "arrival" of the EGK people. He ascribes the rather scarce pollen grains of *Plantago lanceolata* below a depth of 120 cm to the activity of TRB people. At a depth of 62 cm, *Fagus* reaches a value of about 1%. According to Van Zeist, this level corresponds approximately with the Neolithic-Bronze Age transition. For this level, a date of 3350 ± 140 BP [GRO-424] (ca. 1660 cal BC) was obtained. By present-day standards, this date is already well into the Bronze Age, which begins ca. 1900 cal BC.

Bargeroosterveld
A few years after the collection of the Emmererfscheidenveen sequence, a sequence was collected at another location in the Bourtanger Moor near Emmen: Bargeroosterveld (coordinates 262.11/533.31) (VAN ZEIST 1959; 1967). This location is in the border zone of the raised bog, only a short distance from the higher ground of the Hondsrug. Van Zeist expected that in pollen diagrams from this site the influence of prehistoric man on the vegetation would appear more clearly than it would in diagrams from the more central parts of the raised bog. The Bargeroosterveld sequence reaches a maximum depth of ca. 3 m, and consists of layers of wood peat, *Scheuchzeria* peat and *Sphagnum* peat. A sum-

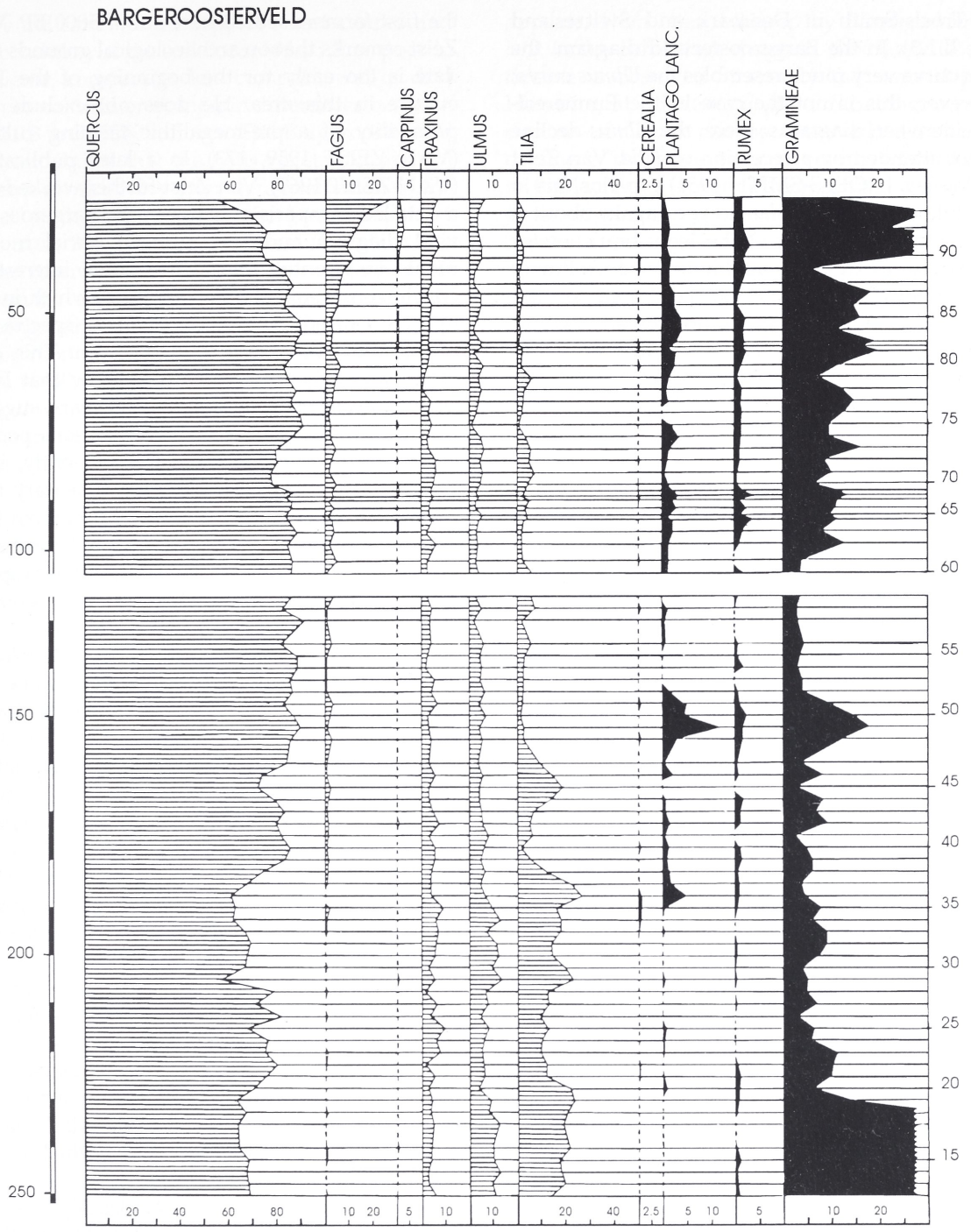


Fig. 8. Pollen diagram of Bargeroosterveld (after VAN ZEIST 1967, fig. 4). Only the pollen types with hatched curves are included in the pollen sum.

marizing pollen diagram is shown in fig. 8.
In spectrum 19, a pollen grain of *Plantago major* was found. Between spectra 20 and 35, *Plantago lanceolata* is very scarce, whereas the pollen of Cerealia-type is present. Simultaneously with the appearance of these culture indicators, the *Ulmus* curve declines. According to Van Zeist, these phenomena were caused by the first farmers in Drenthe, whose agricultural practices would have shown a great similarity to those described

by Troels-Smith in Denmark and Switzerland (see II.1.3). In the Bargeroosterveld diagram, the *Tilia* curve very much resembles the *Ulmus* curve; however, this is not the case in the Emmererf-scheidenveen diagrams: there, the *Ulmus* decline is not attended by a recession of *Tilia*. Van Zeist (following TROELS-SMITH 1954) explains this in the following way: *Tilia* flowers again about 4 years after the cutting of the leafy branches for fodder, while *Ulmus* is unable to produce flower buds within 7 or 8 years. Van Zeist assumes that before flowering, they would mostly be cut again. He reaches the conclusion that in conesquence of the cutting of leafy branches by prehistoric man, the share of *Ulmus* in the pollen rain would decrease considerably more than that of the other trees.

According to Van Zeist (1959, 169), the high value of *Plantago lanceolata* in spectrum 36 and upwards represents the *landnam* type described by Iversen (see II.1.2): rather large areas were cleared with the help of axe and fire. He believed a small part of the clearings to have been used for cereal cultivation, while the larger part was used as grazing for the numerous livestock. In contrast to the farmers of the preceding period, Van Zeist considers these "new immigrants" to be herdsmen. *Rumex* shows an increase together with *Plantago lanceolata*. Also an increase of Gramineae might be expected; but no such change is seen in the diagram, possibly because it is masked by pollen of Gramineae growing on the peat. According to Van Zeist, *Tilia* shows a clear response to the *landnam*: he interprets the *Tilia* declines around spectrum 37 and spectrum 46 as "waves of large-scale forest clearance". When the third wave struck the area, around spectrum 48, *Tilia* had not yet recovered, so that there was no third decline (VAN ZEIST 1959, 169). Van Zeist therefore distinguishes two Neolithic *landnam* types in the Bargeroosterveld diagram: below, that of a farming culture; above, that of herdsmen. By comparing the Bargeroosterveld diagram with the results of palynological investigations of Neolithic burial monuments (see II.2.4) - as he did in his 1955 article (VAN ZEIST 1955b) - he reaches the conclusion that the first *landnam*, which is characterized by low values of *Plantago lanceolata* (spectra 20-35), has to be attributed to farmers of the Funnel Beaker Culture (TRB), while the second *landnam*, which is characterized by relatively high values of *Plantago lanceolata* (spectra 36-52), has to be attributed to farmers of the Single Grave Culture (EGK). According to the date of the *Ulmus* decline in the Emmen region, the first farmers settled here about 5000 BP. Van Zeist remarks that on archaeological grounds this date is too early for the beginning of the TRB culture in this area. He does not exclude the possibility of a pre-megalithic farming culture (VAN ZEIST 1959, 173). In a later publication (VAN ZEIST 1967), Van Zeist further worked out a detailed comparison between the Bargeroosterveld diagram and spectra from burial monuments in Drenthe. He draws some interesting conclusions about the EGK culture, which in his opinion caused the Iversen *landnam* (spectra 36-52) in the Bargeroosterveld diagram. This diagram, and other diagrams too, show that Iversen's *landnam* phase lasted 200-300 years, suggesting that for at least 8 to 10 generations people stayed in a restricted area. Consequently, it is likely that the EGK people were sedentary to a large extent. Farming practice differed from that of the Funnel Beaker and Bell Beaker Cultures in that the EGK farmers made large clearings to provide their livestock with sufficient grazing (VAN ZEIST 1967, 59).

According to Casparie & Groenman-van Waateringe (1980, 58), the "considerable decline" in *Ulmus* and *Tilia* taking place at the beginning of the Troels-Smith occupation phase (spectra 20-35) suggests that this phase of Neolithic intervention was already quite extensive, which is not what one would expect with a Troels-Smith type of occupation phase. The TRB people, who in the opinion of Casparie & Groenman-van Waateringe caused the Troels-Smith occupation phase, probably cleared mainly *Ulmus*- and *Tilia*-rich forests on the weathered till ridge. The open spaces made by the TRB farmers were not extremely small. However, in the regenerating forest and in the open spaces lying fallow, *Plantago lanceolata* was not able to expand because the soil conditions were not favourable for this plant: in compact soils like till, *Plantago lanceolata* germinates poorly and with difficulty (BLOM 1974).

During the Iversen *landnam* (spectra 36-52), forest was cleared also on coversand soils. On these soils, *Plantago lanceolata* was able to expand considerably. This marked expansion, well represented in the Emmererfscheidenveen V diagram and the Bargeroosterveld diagram, is not accompanied by a corresponding expansion of other light-demanding herbs of open vegetation types.

Casparie & Groenman-van Waateringe (1980, 59) conclude that the characteristic features of Neolithic activity in pollen diagrams are much

more indicative of the type of forest cleared and the condition of the soil occupied (rich or poor in nutrients, compact or less compact, wet or dry) than of cultural or economic differences between the TRB and EGK cultures. The Bargeroosterveld diagram shows that the herb vegetation did not expand considerably after the reclamation of the forest at the beginning of the Iversen *landnam* (spectrum 36). Perhaps the forest floor in many places received so much light that no large-scale systematic reclamation was necessary to create clearings suitable for cultivation and grazing. In the opinion of Casparie & Groenman-van Waateringe (1980, 59), a *landnam* of the Iversen type - with the aid of fire - would have had a more pronounced effect on the herb composition than is shown by the pollen diagrams.
The Troels-Smith occupation phase and the Iversen *landnam* are seen by Casparie & Groenman-van Waateringe as two extreme forms of agricultural systems. It seems more likely that prehistoric man largely adapted his methods of reclamation to the available opportunities, possibly in such a way that no culturally-linked pattern is evident (CASPARIE & GROENMAN-VAN WAATERINGE 1980, 62).

Meerstalblok
Dupont (1986) carried out pollen analysis on peat sections from Meerstalblok, one of the last remnants of the formerly extensive Bourtanger Moor (coordinates 266.75/523.98). Meerstalblok is located far from the Hondsrug ridge and consequently far from prehistoric occupation. Hence the signals in the pollen diagrams pointing to human activity are expected to be rather weak. The infill reaches a maximum depth of ca. 3 m, and mainly consists of thick layers of *Sphagnum* peat. Apart from a pollen percentage diagram, also a pollen influx diagram was constructed, which is based on only a few ^{14}C dates: two of the Atlantic period and three of the Subboreal. Peat spectra of only 1 cm thick were dated.
Between 6000 and 4500 BP, the total arboreal influx increases. Possibly the earliest, modest human activities caused a more open structure of the forest, favouring increased pollen production. After 4500 BP, increasing human influence reduced the forest area to such an extent that the overall pollen production began to decline. The increased anthropogenic influence can be observed in the curve of the total pollen influx of indicators of human influence (DUPONT 1986, fig. 7).
At a depth of 225 cm (ca. 5000 BP), *Rumex* appears, 1 cm later followed by *Plantago lanceolata*. In the percentage diagram, the classic *Ulmus* decline is observed at exactly the same depth. However, at this level in the influx diagram, no decline of *Ulmus* can be observed; the *Ulmus* decline in the percentage diagram is attributable to the increased absolute representation of other trees, especially *Quercus* and *Corylus*. The increase of *Quercus* and *Corylus* may well be the result of enhanced pollen production due to a more open structure of the forest, probably caused by small-scale human activities, but *Ulmus* flowering apparently did not benefit from this (DUPONT 1986, 100). Following Van Zeist (1967) and Casparie & Groenman-van Waateringe (1980), Dupont ascribes this phase to activities of the Funnel Beaker Culture (TRB). At a depth of 209 cm (ca. 4250 BP), *Ulmus*, *Quercus* and *Betula* decrease sharply in the influx diagram. According to Dupont, this decrease is caused by increasing human disturbance. However, the total pollen influx of indicators of human influence does not increase at this level. Dupont ascribes this phase to activities of the Single Grave Culture (EGK).

II.2.4 Barrow spectra from the northern and central Netherlands

In the Netherlands, there is a strong tradition in the study of pollen spectra from burial mounds. In the 1950s already, the first studies about this subject were published (WATERBOLK 1954; 1956; VAN ZEIST 1955a). Later, more extensive studies were published by Van Zeist (1967) and Casparie & Groenman-van Waateringe (1980). In palynological studies of funerary monuments, samples from the upper 1-2 cm of the fossil soil (both from the old surface under the monument and from the sods used for the construction of the mound) are analyzed. It is assumed that these samples reflect the local and regional vegetation of the period just before the construction of the monument (VAN ZEIST 1967, 49-50). Two important points have to be kept in mind when barrow spectra are compared with spectra from lake deposits: a. the pollen frequencies in the upper part of the buried soil profile may have changed as a consequence of selective corrosion and selective outwash; b. the pollen picture of barrow spectra to a large extent reflects the local vegetation, which may lead to strongly fluctuating frequencies especially for herb pollen (NAP) and *Betula*. For this reason, *Betula* and the NAP

were left out of the pollen sum (ΣP) in barrow spectra (VAN ZEIST 1967, 53-54).
Casparie & Groenman-van Waateringe (1980) summarize the results of the analysis of pollen spectra from burial monuments of three Neolithic cultures in the northern Netherlands (the Drenthe Plateau): the Funnel Beaker Culture (TRB), the Single Grave Culture (EGK) and the Bell Beaker Culture (BB). The pollen picture of these barrow spectra is shown in fig. 9. Compared to pollen diagrams from lake deposits, all spectra are characterized by high to very high percentages of especially *Calluna*, *Succisa* and Compositae. According to Casparie & Groenman-van Waateringe (1980, 60) the phenomenon that TRB and BB barrow spectra have on average lower herb values than EGK spectra, especially lower values of *Plantago lanceolata*, *Rumex* and Gramineae, cannot be ascribed merely to different methods of reclamation; within each culture, also considerable differences in pollen values are observed. Apparently, even during the TRB period different types of open space could be chosen for burial of the dead. The pollen picture of the Neolithic barrow samples points to arable land abandoned for varying lengths of time, to grazing, to expansion of heath and - to a far lesser extent - to regeneration of the forest. In most cases, the burial monuments seem to have been erected on abandoned fields, which could no longer be used because of the exhausted soil. In some barrow samples, many charcoal particles are found. Here the local vegetation was destroyed by fire shortly before the barrow was constructed. The environment in the immediate vicinity of a barrow varied from only slightly degraded forest to extremely degraded, heath-rich vegetation types, with all possible intermediate stages. It seems difficult to demonstrate differences in methods of reclamation, in use of open spaces and in the production of animal fodder on the basis of barrow spectra. It is difficult even to demonstrate with certainty the cultivation of grain or the use of land as pasture. The general picture obtained from the barrow spectra is that in general the pressure of man on the environment continually increased from the TRB period, throughout the EGK and BB periods, into the Bronze Age, resulting in progressive degradation of the natural forest (CASPARIE & GROENMAN-VAN WAATERINGE 1980, 61).
In pollen spectra from barrows of the sandy areas of the central Netherlands (the Veluwe, the Gooi and the Utrechtse Heuvelrug), almost no evidence for arable and stock farming was found. This suggests that large open areas, cleared by man, did not yet occur during the Neolithic in the central Netherlands. The same picture emerges from pollen diagrams of various locations on the Veluwe, published by Polak (1959; 1967; see II.2.2) and Maarleveld & De Lange (1977). In none of these diagrams can a *landnam* type as described by Iversen be observed. Casparie & Groenman-van Waateringe (1980) assume that the original vegetation was already rather open woodland, on account of activities in these woods for several thousand years. In the Neolithic, the forests became increasingly open as a result of grazing; however, this seems to have been a gradual process, without the use of burning. The high values of *Tilia* in the barrow spectra are interpreted by Casparie & Groenman-van Waateringe as a further indication of the openness of the forest, because *Tilia*, especially under favourable light conditions, is a great pollen producer. When *Tilia* grows in dense forest, however, flowering is greatly reduced (IVERSEN 1960, note 11). The influence of Neolithic man on the vegetation led to impoverishment of the soils and of the vegetation. This resulted in an expansion of taxa which were strong enough to resist long-term human interference: Gramineae and Ericaceae.

II.2.5 The eastern Netherlands

De Klokkenberg (province of Overijssel)
Van der Hammen (1965) studied deposits in a small gully below plaggen-soil layers at De Klokkenberg near Denekamp palynologically. Only four spectra in the diagram of section P_1 seemed to represent the Atlantic and the first part of the Subboreal. The sediment of spectra 2, 3 and 5 consisted of dark grey humic sand; the sediment of spectrum 4, which contained no pollen, consisted of light grey humic sand.
In spectra 2 and 3, dated to 6810 ± 60 BP [GrN-2813], which is in the Atlantic, Cerealia pollen and large quantities of charcoal seem to reflect human activity. However, the other culture-indicator types are not present or do not show an increase. According to Van der Hammen (1965, 130), we have to be careful drawing conclusions, because there is a possibility of illuviation from above or the selective destruction of pollen grains. In spectrum 5, dated to 4405 ± 55 BP [GrN-2814], which is in the Subboreal, the values of *Tilia* and *Ulmus* are lower than in spectra 2 and 3. The Gramineae reach relatively high values.

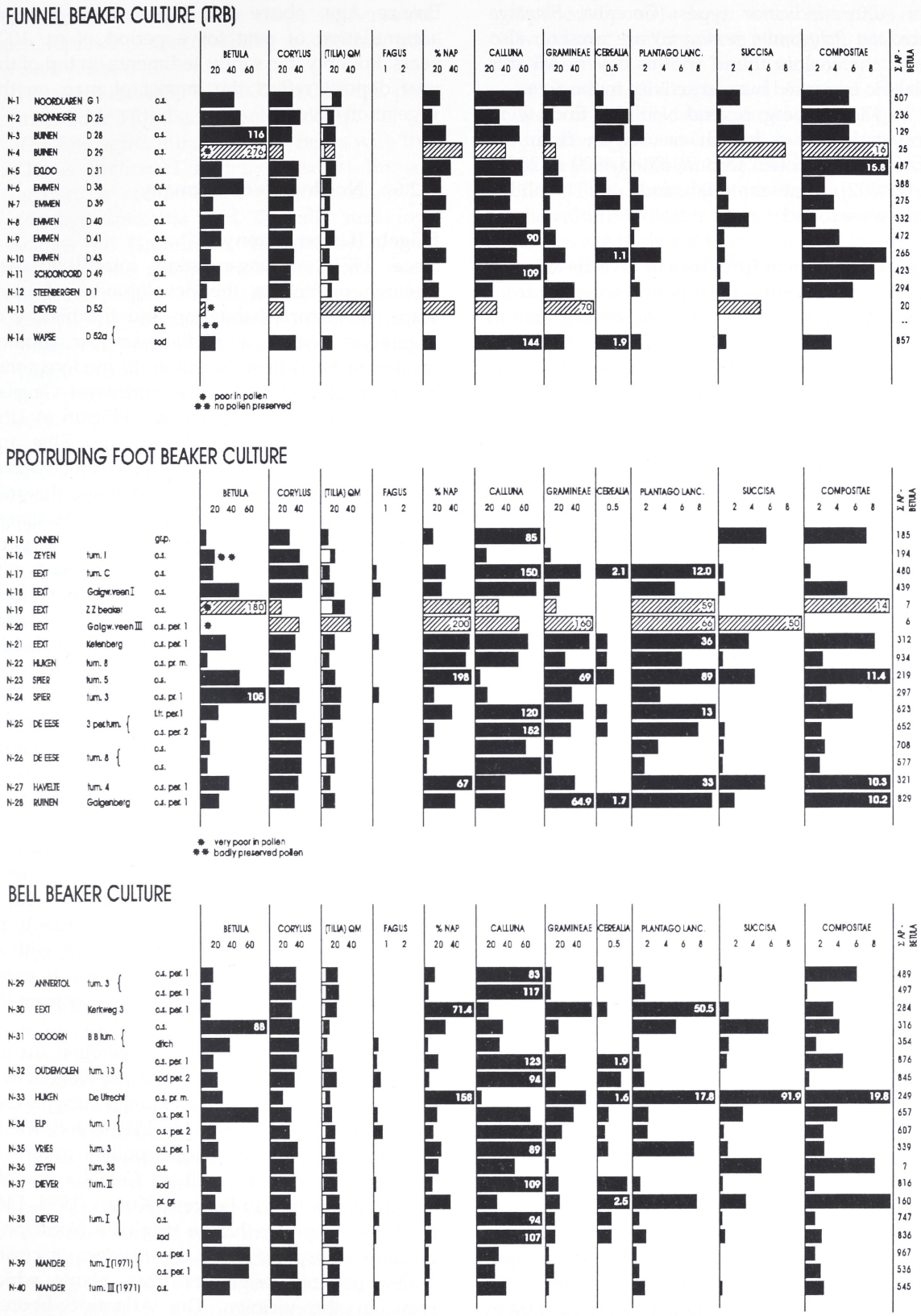


Fig. 9. Barrow spectra of the TRB, EGK and BB periods (north of the river IJssel) (after CASPARIE & GROENMAN-VAN WAATERINGE 1980, figs. 2-4).

The culture-indicator types (Cerealia, *Plantago lanceolata, Polygonum persicaria*) are present; also much charcoal is found in this layer. All this points to increased human activity in the area.
At De Klokkenberg, several Neolithic finds were excavated: near a hearth ca. 100 m from the location of the pollen section, dated 4930 ± 120 BP [GrN-4092], flint material and one Neolithic sherd were found.

Engbertdijksvenen (province of Overijssel)
Van Geel (1978) analyzed a pollen sequence from the Engbertdijksvenen, a large raised-bog area in the province of Overijssel. In spectra 34 and 40, which are of late Atlantic age, Cerealia pollen is found. The Atlantic-Subboreal transition, which is located at spectrum 47, is characterized by a decline of *Ulmus* and *Tilia* (date of spectrum 47: 4815 ± 40 BP [GrN-6815]). From spectrum 47 upwards, Cerealia are regularly observed in low frequencies. *Plantago lanceolata* appears in spectrum 50. According to Van Geel (1978, 8), the presence of pollen of *Plantago lanceolata* is not necessarily indicative of human activity, but may sometimes reflect an unstable climate. The local vegetation succession in the ENG-I section supports this idea for the early Subboreal period. During the entire Subboreal, the percentages of the culture-indicator types remain relatively low (less than 1%). Possibly this means that the location was situated far from prehistoric settlements.

De Borchert (province of Overijssel)
Van Geel et al. (1981) studied a peat section from a filled-in river branch at De Borchert near Denekamp in the province of Overijssel. The exact position of the Atlantic-Subboreal transition is uncertain, because there are no clear declines of *Ulmus* and *Tilia*. In spectrum 253, an increase of Gramineae is observed. Only in spectrum 263 does pollen of *Plantago lanceolata* and Cerealia appear; at the same point, the *Rumex* curve becomes continuous. The estimated age of the sediment at this depth is ca. 3900 BP. If the dates are correct, the pollen diagram reflects no human activity in the neighbourhood of this location in the first part of the Neolithic, between 5000 and 3900 BP. During the second part of the Neolithic and also during the Bronze Age, the percentages of the culture-indicator types are very low (less than 1%), pointing to a modest level of human activity or activities at a large distance. The top of the amorphic Subboreal layer is dated 3425 ± 25 BP [GrN-7915], which indicates that it is already Bronze Age; above this layer, there was no accumulation of peat for a period of ca. 1000 years. Possibly, the sandy sediments on top of the peat deposit reflect the impact of man on the vegetation cover.

II.2.6 Northwestern Germany

Flögeln (Lower Saxony)
Since 1971, a long-running interdisciplinary research project on the development of landscape, prehistoric habitation and the history of vegetation within a *Siedlungskammer* (limited habitation area) from Neolithic to modern times has been carried out in the northwest German lowlands. The *Siedlungskammer* Flögeln is situated between the rivers Weser and Elbe and comprises about 23.5 km². It is an isolated Pleistocene area surrounded by raised bogs, the soils mainly consisting of poor sands. The *Siedlungskammer* Flögeln is characterized by a good number of kettleholes, most of them filled with peat. Some of these kettleholes originate from pools formed by falling meltwater in the Saalian (BEHRE & KUČAN 1994, 15; 94). From the kettleholes as well as from the margins of the surrounding raised bogs, 13 pollen diagrams were compiled (BEHRE & KUČAN 1994). In the following six sequences, the last part of the Atlantic and the Subboreal are present: Swienskuhle, a small kettlehole of 42.6 x 27.5 m with an infill of up to 2.37 m; Jagen 20, a peat bog of 170 x 54 m, with an infill of up to 2.60 m; Silbersee, a kettlehole of 190 x 110 m, with an infill of up to 4.16 m; Flögelner Holz, a kettlehole with a diameter of 270 m, with an infill of up to 6.10 m; Fuhrenkamp, a kettlehole of 180 x 110 m, with an infill of up to 3.41 m; and finally Flögeln V, cored in the large raised-bog area, 280 m away from the Pleistocene sand.
The human influence on the vegetation during the Neolithic in the *Siedlungskammer* Flögeln as it is reflected in the pollen diagrams is summarized by Behre & Kučan (1994, 146-152) as follows. In the Atlantic, already single pollen grains of *Plantago lanceolata* as well as Cerealia are observed. According to Behre & Kučan (1994, 146), the Cerealia pollen has to originate from long-distance transport, while the *Plantago lanceolata* pollen possibly originates from plants which grew in the vicinity. The Atlantic-Subboreal transition, which here coincides with the beginning of the Neolithic (BEHRE & KUČAN 1994, Abb. 40), is located at the decline of *Ulmus*

(which is not always very clear). The period which represents the Neolithic is divided into two clear phases:

- Phase 1: 5150-4450 BP/4000-3100 cal BC, pre-megalithic TRB (Early Neolithic TRB).
  The first agricultural activities begin with the *Ulmus* decline. The first phase of human activity is characterized by low values of *Plantago lanceolata* and Cerealia and low values of Gramineae. Apparently, forest grazing was not practised here, nor were pastures present. According to Behre & Kučan (1994), *Plantago lanceolata* here points to small-scale arable farming: because a plough which turns the soil was not yet invented, this perennial species with its long roots could easily persist in the fields. In this period, the forests were cleared only on a small scale. This points to the type of occupation phase first described by Troels-Smith (see II.1.3): probably, the livestock were fed on leaf fodder, especially of *Ulmus*. The leaf-fodder economy was practised especially in the western part of the *Siedlungskammer* (Swienskuhle, Jagen 20). Sequences in the eastern part (Flögelner Holz, Fuhrenkamp) must have been located at the edge of the area used by these farmers. Unfortunately, there are no archaeological remains of the people who caused this phase in northern Lower Saxony. Behre & Kučan (1994, 151) ascribe this phase to the pre-megalithic TRB, which is equivalent to the Danish Early Neolithic TRB. However, so far there is no evidence at all that this culture ever established itself in northwestern Germany and the northern Netherlands (LANTING & VAN DER PLICHT 1999/2000).
- Phase 2: 4450-? BP/3100-? cal BC, Middle Neolithic TRB Culture.
  Very suddenly, the leaf-fodder economy was replaced by a new type of economy: the *landnam* phase as described by Iversen (see II.1.2). This phase also is most clearly observed in diagrams of the western part of the *Siedlungskammer* (Swienskuhle, Jagen 20). Evidently, at this time the most important settlements must have been located here. However, up till now these have not been found. This phase is characterized by a strong decrease of *Tilia* and *Quercus*, and by high values of Gramineae and the culture-indicator types. Cultivation of crops must have taken place in the direct vicinity of especially Swienskuhle. The forests were opened up on a large scale, especially for woodland grazing; here, there are no indications of clearance by burning. The curves of *Plantago lanceolata* and Cerealia follow more or less the same course, which suggests that *Plantago lanceolata* is an indicator for crop cultivation (BEHRE 1981; BEHRE & KUČAN 1994, 149). During this phase, the values of the culture-indicator types in the various diagrams are fairly constant: probably the fields were not shifted much, perhaps they were even more or less permanent. At the end of this phase, a regeneration of the *Quercus* forests is observed; *Fagus* partly took the place of *Tilia* in these forests. The *Tilia* decline, which marks the beginning of this phase, does not occur synchronously at various locations. In the *Siedlungskammer* Flögeln it occurs between 4650 and 4150 BP; at other locations in northwestern Germany, it occurs between 4700 and 3700 BP (BEHRE & KUČAN 1994, 150). The duration of the Iversen *landnam* phase varies in the various diagrams of *Siedlungskammer* Flögeln, but it can last more than 1000 years; sometimes it reaches into the Bronze Age. Clearly, no shifting of the settlement took place (BEHRE & KUČAN 1994, 151). The Iversen *landnam* phase can be clearly connected with the Middle Neolithic TRB Culture. By comparing their dates for the beginning of this phase with dates from Denmark (MADSEN 1990) and the Netherlands (VAN ZEIST 1959; 1967), Behre & Kučan (1994) conclude that this type of economy developed in Denmark (earliest date: 4800 BP/3500 cal BC) and spread from there to the west. In the *Siedlungskammer*, apart from several megalithic tombs, also three houses of the TRB culture were excavated (ZIMMERMANN 1980). However, the sequences located nearest to these houses (Flögeln V, Fuhrenkamp) do not show a very clear *landnam* phase.

It has to be remarked that the situation in the *Siedlungskammer* Flögeln closely resembles the situation in Drenthe: both are Pleistocene areas with predominantly poor sandy soils, bordered by large raised bogs, located not far from the coast; in both areas, many small circular depressions are found, formed during the Saalian or Weichselian Ice Ages; in both areas, the same archaeological cultures are found. For these reasons, a model which describes the Neolithic as represented in pollen diagrams in Drenthe may be also valid for northwestern Germany.

Herrenhof (Lower Saxony)

Dörfler (1989) analyzed a pollen sequence from the small peat bog Herrenhof in the centre of the Elbe-Weser triangle (northern Lower Saxony). The diameter of the bog is ca. 70 m, while the infill reaches a maximum depth of 9.20 m. The zone representing the Neolithic occurs in *Sphagnum/Equisetum* peat. In earlier times, a rampart surrounded the bog, which indicates that it is most probably a pingo scar.

At 656 cm, a decline of *Ulmus* is observed; *Tilia* and *Quercus* reach relatively high values; *Plantago lanceolata* appears for the first time (date of 677-667 cm: 4870 ± 80 BP [KI-2727.672]). Cerealia-type pollen is first found at a depth of 612 cm. Around 606 cm, *Tilia* decreases strongly, while *Plantago lanceolata*, *Rumex acetosa/acetosella*, Cerealia-type and Gramineae increase considerably (date of 610-600 cm: 4670 ± 90 BP [KI-2727.605]). However, already at 592 cm, these types decrease again. From 560 cm upwards, *Tilia* reaches the same values as before its decrease of 612-600 cm, pointing to an almost complete regeneration of this tree in the forests in the neighbourhood. *Corylus* reaches relatively high values. The culture-indicator types are almost absent in this phase, while Gramineae remain more or less constant.

The *Ulmus* decline at 656 cm is only very weak in Herrenhof. For this reason, Dörfler does not think that this decline was caused by human intervention in the vegetation. He sees no evidence of an occupation phase as described by Troels-Smith for Denmark and Switzerland. The *Tilia* decline around 606 cm is clearly caused by human intervention. Because *Tilia* grows on the better soils, clearance of these areas for agriculture is a good explanation for the abrupt decline of its values. Leaf foddering to livestock is another explanation. Dörfler did not find any evidence of clearance by burning in this phase. Apart from the absence of evidence for burning, the phase between 606 and 568 cm in the Herrenhof diagram resembles the occupation phase described by Iversen for Denmark (DÖRFLER 1989, 37). At a distance of 4.5 km from the Herrenhof bog, megalithic tombs from TRB times occur, pointing to the presence of TRB people in the area.

Hüde (Lake Dümmer)

The area around Lake Dümmer in southern Lower Saxony was inhabited intensively in the Mesolithic as well as the Neolithic. The most important findspot in the area is Hüde I. This site, which was excavated between 1961 and 1967, is situated at the southern edge of the lake, directly east of the place where the river Hunte enters the lake. In the Neolithic, the findspot was surrounded by watercourses, reed and sedge swamps and carr forests (SCHÜTRUMPF 1988). Because the Hüde pottery has many characteristics in common with Swifterbant pottery, it seems justified to classify Swifterbant and Hüde pottery in one supra-regional group: the Hüde-Swifterbant Group (TEN ANSCHER, cited in GEHASSE 1995, 199). The zonation of Hüde I is problematic, because of disturbances in the cultural layers and the occurrence of very gradual transitions in the pottery characteristics (TEN ANSCHER, cited in GEHASSE 1995). Still, Kampffmeyer (1988, 241; 284; Abb. 250; see also STAPEL 1991, 15 for a more or less comparable division) distinguished four occupation phases:

1. Hüde-Swifterbant horizon (6100-5900 BP); pottery characterized by Ertebølle/Ellerbek elements and Rössen imports; separated by a hiatus from the next horizon; this phase can be correlated with phase SW-1 of the Swifterbant Culture (GEHASSE 1995, 210; see III.7.3);
2. Rössen-Bischheim horizon (5600-5500 BP); the most intensive habitation occurred in this period; finds of Rössen pottery and Bischheim variants; gradually transforming into the next horizon;
3. early TRB horizon (5500-5200 BP); earliest and early TRB pottery (of Rosenhof and Satrup type); according to Lanting & Van der Plicht (1999/2000), Kampffmeyer's "Early Neolithic TRB pottery" is in fact Swifterbant pottery; this horizon transforms with an interruption into the next horizon; phases 2 and 3 together can be correlated with phases SW-2/3/4 of the Swifterbant Culture (GEHASSE 1995, 210; see III.7.3);
4. TRB West Group (Middle Neolithic) horizon (4950-4750 BP); Drouwen A-C pottery.

Kampffmeyer rejects dates based on charred food remains, since the content of a pot may be considerably younger than the pot itself. By eliminating these dates, he is able to distinguish the above-mentioned four occupation phases, the first and the last of which are separated by hiatuses from the second and third occupation phases. However, even if a ^{14}C date is not related to the manufacture of a specific pot, the date is still an indication of activity at a certain time and therefore may bridge a presumed hiatus. As a result, Raemaekers (1999, 73) does not consider Kampffmeyer's hiatuses as relevant. With the

chronological resolution provided by the pottery and ^{14}C dates, no gaps in the occupation history need be postulated. According to Raemaekers (1999, 74), this means that the potential of the Hüde I site in establishing rather than illustrating developments in subsistence and material culture is limited. The ^{14}C dates of Hüde I were examined critically by Lanting & Van der Plicht (1999/2000). They reject most of the dates, for differing reasons. Finally, only 20 Neolithic dates seem to be reliable. These dates can be divided into three groups: two of 5875 ± 100 and 5860 ± 70 BP, fourteen between 5615 ± 95 and 5170 ± 90 BP and four between 4920 ± 100 and 4735 ± 75 BP. According to Lanting & Van der Plicht (1999/2000), there is a possibility that these three phases represent three settlement phases of the Swifterbant Culture: the Early, Middle and Late Phases. In Kampffmeyer's phase 2, impressions of cereal grains in sherds and quernstones have been found. According to Kampffmeyer (1988), these finds only indicate that the inhabitants of that period had cereals at their disposal, but they do not demonstrate the cultivation of cereals. Given the wet local environment, any cultivation of cereals on the site is unlikely. Because of the large numbers of bones of hunted deer, fishes and birds, the absence of local cereal cultivation, the wet conditions and the relatively small horizontal distribution of finds, phases 2-4 of Hüde I are interpreted as a hunting camp which was used repeatedly, and which was visited in late summer and autumn. However, there are some indications that the camp may sometimes have been used in winter.

A palynological study of Hüde was published by Schütrumpf (1988). The most important event, which can be recognized in almost all Hüde diagrams, is the *Ulmus* decline. On the basis of analysis of pollen spectra associated with archaeological finds from known periods, Schütrumpf concludes that this decline occurs between the "cultural horizons" K_2 (which comprises the above-mentioned phases 2 and 3) and K_1 (which comprises the above-mentioned phase 4). Schütrumpf (1988, 19) mentions a ^{14}C date of 5300 ± 165 BP for the K_2 horizon. On the basis of this date, Kampffmeyer (1988, 328) estimates the *Ulmus* decline to have taken place between 5300 and 5100 BP. When the data of Schütrumpf and Kampffmeyer are combined, the conclusion has to be drawn that the early TRB horizon (the above-mentioned phase 3) already occurs before the *Ulmus* decline.

In several diagrams, pollen grains of *Plantago lanceolata* are found before the *Ulmus* decline (SCHÜTRUMPF 1988, Abb. 4; 7; 9; 11; 12); in one small diagram (SCHÜTRUMPF 1988, Abb. 7), a few grains of Cerealia are found before the *Ulmus* decline. Nowhere is an increase of Gramineae observed. After the *Ulmus* decline, the situation does not change very much: still, the culture-indicator types are observed very sporadically or not at all. To my mind, this observation confirms that Hüde was inhabited only seasonally, because the inhabitants of a seasonal camp leave fewer traces in the landscape than inhabitants of permanent settlements.

II.2.7 The low-lying parts of the Netherlands

Farmsum (province of Groningen)

Jelgersma (1960) analyzed pollen sequences from the so-called basal peat layer between Meedhuizen and Farmsum, just south of Delfzijl. According to ^{14}C dates, the basal peat layer in this area was formed on the Pleistocene sands between the Middle Atlantic and the Late Subboreal. In the Subatlantic, a transgression ended the peat growth and effected the sedimentation of a thick layer of clay. At the time of Jelgersma's study, almost nothing was known about Neolithic habitation of this area. In the 1980s, during the excavation of the *terp* of Heveskesklooster, which is located a few kilometres from the core locations of the pollen sequences, a megalithic tomb and a stone cist from the Funnel Beaker Culture (TRB) were discovered in the Pleistocene subsoil (BOERSMA 1988; J.A. BAKKER 1992; CAPPERS 1994). Apparently, the TRB people inhabited the small sandy outcrops between Groningen and Delfzijl, even in the time when as a result of a rising sea level and water table, the largest part of this area became overgrown by peat.

In Jelgersma's pollen diagrams, no real occupation phases can be recognized. In diagram Farmsum A, Cerealia-type is found near a ^{14}C date of 4995 ± 120 BP [GRO-655]; in diagram Farmsum B, *Plantago lanceolata* is found at a ^{14}C date of 5250 ± 170 BP [GRO-637]. (The original GRO-dates were corrected by the Centre for Isotope Research of the University of Groningen, see VOGEL & WATERBOLK 1963.) In the diagrams Farmsum A and B, an *Ulmus* decline is observed around 5000 BP. In diagram Farmsum A, a continuous curve of *Plantago lanceolata* occurs from ca. 4250 BP upwards. Possibly, the sporadic early finds of Cerealia-type and *Plantago*

lanceolata pollen point to the presence of people of the Swifterbant Culture in the Delfzijl area. No archaeological remains of this culture are known from this area.
Recent excavations in the Wetsingermaar, ca. 10 km north of the city of Groningen, have revealed not only TRB sherds but possibly also sherds of the Late Phase of the Swifterbant Culture (FEIKEN et al. 2001). Charcoal from the occupation layer was dated 4700 ± 40 BP [GrA-16659] (ca. 3500 cal BC). This suggests that Swifterbant people were also present in the coastal areas of the northern Netherlands.

Schokland (province of Flevoland)
During excavations at site P14, situated near the former island of Schokland in the present-day Noordoostpolder, several pollen sequences were sampled (GEHASSE 1995, 6-7). The findspot lies on the edge of a till ridge, covered by sand, and directly adjacent to a former course of the river Vecht. The site was inhabited between 4900 and 1700 cal BC by people of, successively, the Swifterbant Culture, the Funnel Beaker Culture (TRB), the Single Grave Culture (EGK), the Bell Beaker Culture (BB) and the Bronze Age. The pollen sequences were taken in clayey and peaty deposits on the flanks of the ridge.
No clear occupation phases can be distinguished in the pollen diagrams, although P14 is regarded as a permanent, year-round settlement (GEHASSE 1995, 271). Because in this area mixed oak forest was only present on the higher ridges, possible forest clearances must have taken place on a far smaller scale than in the Pleistocene sandy areas, which were for the larger part covered with mixed oak forests. Furthermore, the influence of local vegetation (alder carr, sedge marshes) is far more important here than in the Pleistocene sandy areas. Possibly, the local pollen partly obscures the effect of the first agricultural activities on the pollen picture. However, the frequent occurrence of Cerealia-type pollen even before 3700 cal BC (for example in phase sp200 of diagram wp89-17 (GEHASSE 1995, diagram II)) demonstrates that the people of at least the Late Phase of the Swifterbant Culture cultivated cereals locally.

Swifterbant (province of Flevoland)
Near Swifterbant, in the East Flevoland polder, Mesolithic and early Neolithic dwelling-places were excavated in the 1970s. The culture responsible for the early Neolithic occupation layers was named after this site: the Swifterbant Culture (see III.7.3). Near the site, there are a few peat deposits, which were used for the coring of pollen sequences (CASPARIE et al. 1977). The sequence H 46 was sampled in a dammed-up gully, 4 km east of site S_3; the sequence G 43 was sampled in the upper part of a filled-up creek, site S_5, next to S_3. The base of the peat layer of H 46 was dated to 5610 ± 60 BP [GrN-5067]; the base of the peat layer of G 43 was dated to 4955 ± 35 BP [GrN-7505]. This indicates that most of the peat formation at H 46 took place shortly before the occupation of the site S_3 (dated about 5300 BP), whereas the peat deposition at G 43 must be dated some time after the Neolithic habitation (CASPARIE et al. 1977, 30). No effects of agricultural activities can be traced in either of the pollen diagrams: no culture-indicator types are found. Nor is any decline of *Ulmus* observed around 5000 BP. The values of *Ulmus* in both diagrams are always below 5%. The conclusion must be that the scale of any agricultural activities in the neighbourhood of the sites of the Swifterbant Culture was too small for detection in the pollen diagrams. Furthermore, possible traces of agriculture in the pollen diagrams may have been obscured by large quantities of local pollen from the nearby *Alnus* carr and sedge marshes.

Hazendonk (province of Zuid-Holland)
Louwe Kooijmans (1974) and Van der Wiel (1982) published pollen diagrams of core locations at the foot of the river dune Hazendonk near Molenaarsgraaf (province of Zuid-Holland). Between 5250 and 3650 BP/4200 and 2000 cal BC, human settlements were repeatedly established on the Hazendonk, the river dune being one of the few dry places in a marshy river valley. Louwe Kooijmans distinguishes several phases of anthropogenic influence. In phase HAZ-1 (pollen zone 2), dated ca. 5300 BP [GrN-6215], one Cerealia grain was found, while *Plantago lanceolata* appears for the first time. It is believed that in this zone occupation at some distance is reflected. Louwe Kooijmans assumed that the activities in this zone were attributable to a culture related to the Swifterbant Culture. Later on, phase HAZ-1 was found to be contemporary and strongly related to phase SW-3 of the Swifterbant Culture (GEHASSE 1995, 202; see III.7.3).
In phase HAZ-3 (pollen zone 3), dated ca. 4900 BP [GrN-6214], pollen of *Plantago lanceolata* and Cerealia is present in very low values; *Urtica* and *Artemisia* reach high values; *Quercus* and *Fraxinus* decrease. According to Louwe Kooijmans, this proves occupation in the immediate vicinity of

the core location of the diagram. In Van der Wiel's opinion, the beginning of the HAZ-3 phase coincides with the Atlantic-Subboreal transition and is defined by a *Tilia* fall. Van der Wiel remarks that in the western Netherlands, this transition is seldom characterized by an *Ulmus* decline. At the time of Louwe Kooijmans' publication (1974), no comparable archaeological finds were known from that period; he labels this phase as the "Hazendonk pottery" phase. In later times, it was discovered that the HAZ-2 and HAZ-3 phases form a northwestern outlier of the Michelsberg Culture (LOUWE KOOIJMANS 1998). Above the HAZ phases, a cultural phase occurs attributable to the Vlaardingen Culture, VL-1b (dated ca. 4500 BP [GrN-5175,GrN-6213]). Still, the culture-indicator types do not reach very high values. The Vlaardingen Culture, which is found in the Holocene delta and the higher sandy regions south of the large rivers between ca. 4700 and 4100 BP (see VAN REGTEREN ALTENA et al. 1963), is more or less contemporary with the Funnel Beaker Culture in the northern and central Netherlands.

II.2.8 The southern Netherlands

The Peel raised bogs (province of Noord-Brabant)

Janssen & Ten Hove (1971) studied three cores from the Peel bogs, a large raised bog complex in southeastern Noord-Brabant, comparable to the Bourtanger Moor in the northern Netherlands. They located the Atlantic-Subboreal transition at a minimum of the *Ulmus* curve; at this level, *Plantago lanceolata* and Cerealia appear, while *Pteridium* rises. A ^{14}C date of the *Pteridium* maximum, which occurs just above the first appearance of *Plantago lanceolata*, is 4510 ± 85 BP [GrN-5619]. *Ulmus* thus starts to decline even before that date. Janssen & Ten Hove conclude from this that this decline of *Ulmus* may not be connected with human interference. In the Subboreal, the *Ulmus* curve shows three maxima. There is a correlation between *Pteridium-Rumex acetosella* (sic)-Cerealia and *Ulmus*; however, there is no correlation between *Plantago lanceolata* and *Ulmus*; *Plantago lanceolata* remains low throughout the Subboreal. Janssen & Ten Hove conclude that apparently three land-occupation phases are connected with a decline of *Ulmus* (or two in the case of an overlap, because a ^{14}C date just above the second *Ulmus* decline yielded a result of 4470 ± 30 BP [GrN-5163]). The low *Plantago lanceolata* values suggest a type of occupation phase as described by Troels-Smith. According to Janssen & Ten Hove, these low *Plantago lanceolata* values in the Subboreal are also found in small bogs in brook valleys west of the Peel region and in adjacent Belgium and Germany. A striking feature in the diagrams of Janssen & Ten Hove is that after the first land occupation phase, there is almost complete regeneration of *Ulmus*. The *Fraxinus* and *Tilia* curves display a faintly similar trend to the *Ulmus* curve. This may indicate a connection with the land-occupation phases. *Corylus* reaches relatively high values in the Subboreal. Generally *Corylus* rises markedly in pollen diagrams that show land-occupation phases of the Iversen type. Shifting agriculture, responsible for the Iversen type of *landnam*, apparently was not practised during the Subboreal in Brabant. One would therefore expect smaller percentages of *Corylus* (JANSSEN & TEN HOVE 1971, 49). The date of ca. 4500 BP for the first occupation phase most probably points to the Stein Group, which is strongly related to the Vlaardingen Culture. The second occupation phase is probably attributable to the Single Grave Culture (EGK); the third one falls in the Bronze Age (JOOSTEN & BAKKER 1987, 25).

Evidently, the occupation phases caused by the Vlaardingen Culture in pollen diagrams of the Pleistocene sandy areas south of the large rivers as well as the low western part of the Netherlands, are of the Troels-Smith type. This is in contrast with the occupation phases from roughly the same period attributed to the Funnel Beaker Culture in pollen diagrams of the Pleistocene sandy areas in the northern and central Netherlands, which are of the Iversen type.

II.2.9 Northeastern Germany

Siggeneben-Süd (Schleswig-Holstein)

Kalis & Meurers-Balke (1998) published a pollen diagram of the archaeological findspot Siggeneben-Süd, in the Dahmer Bucht, part of the Baltic area. In this area, which is near the probable area of origin of the Funnel Beaker Culture (see MIDGLEY 1992, fig. 10), there is an opportunity to study occupation phases associated with very early TRB groups. However, it has to be emphasized that the landscape differs completely from that in the northern Netherlands and northwestern Germany: the soils are richer, there is more relief and the climate is more continental.

In the Siggeneben-Süd diagram, which originates

from marine gyttja sediments, the late Atlantic and early Subboreal are well-represented. Kalis & Meurers-Balke connected events in the pollen diagram with subsequent Neolithic cultures which resided in the area, on the basis of pollen spectra associated with archaeological finds from Siggeneben-Süd and its direct vicinity (see MEURERS-BALKE 1983). In accordance with their regional *landnam* model for the western Baltic area (see II.1.6), Kalis & Meurers-Balke (1998) distinguished the following occupation phases. I have added new data and ^{14}C dates from Hartz et al. (2000) and Kalis & Meurers-Balke (2001):

- Troels-Smith-PREFACT phase A: 217.5-162.5 cm: Ellerbek Group (Ertebølle/Ellerbek Culture: 5100-4100 cal BC).
  Quercus and *Tilia* decrease, while *Corylus* and the NAP (especially *Artemisia* and *Pteridium*) increase; *Plantago major*, *Rumex* and Cerealia occur sporadically. At the neighbouring findspot Rosenhof, early Cerealia grains in a horizon with comparable pollen spectra were dated to 5780 ± 60 BP.
- Troels-Smith-PREFACT phase B: 162.5-149 cm: Ellerbek Group (Ertebølle/Ellerbek Culture).
  Fraxinus reaches high values; *Quercus* increases; grains of Cerealia are found more frequently.
- Iversen-PREFACT phase 1a: 149-141 cm: Rosenhof Group / Wangels Group (Early Neolithic Funnel Beaker Culture: 4100-3900 cal BC).
  A small decline of *Ulmus* is observed; *Corylus* reaches minimum values, while *Quercus* and *Pteridium* reach maximum values. *Plantago lanceolata* appears for the first time.
- Iversen-PREFACT phase 1b: 141-127.5 cm: Siggeneben Group (Early Neolithic Funnel Beaker Culture: 3900-3700 cal BC).
  Ulmus and *Fraxinus* decrease considerably, *Betula*, *Corylus* and *Alnus* increase; sporadic occurrence of the culture-indicator types.
- Iversen-PREFACT phase 2a: 127.5-107.5 cm: Satrup Group (Early Neolithic Funnel Beaker Culture: 3700-3400 cal BC).
  Tilia, *Quercus* and *Fraxinus* decrease markedly; *Corylus* and *Alnus* increase, while *Betula* reaches maximum values. *Plantago lanceolata* increases (but the percentage is still less than 1%) and forms a continuous curve.
- Iversen-PREFACT phase 2b: 107.5-77.5 cm: Middle Neolithic Funnel Beaker Culture II-IV (3400-3150 cal BC).
  Alnus reaches maximum values; *Quercus*, *Corylus* and *Betula* decrease; the culture-indicator types increase.
- Iversen-PREFACT phase 3a: 77.5-47.5 cm: later Middle Neolithic Funnel Beaker Culture (3150-2900 cal BC).
  Corylus reaches maximum values; *Quercus* and *Betula* reach minimum values. Cerealia reach their highest values in the diagram.
- Iversen-PREFACT phase 3b: 47.5-20 cm: end phase of Middle Neolithic Funnel Beaker Culture (from 2900 cal BC).
  Quercus and *Fraxinus* increase, while *Corylus* and the culture-indicator types decrease.

According to the pollen picture, the people of the Ertebølle/Ellerbek Culture had an economic strategy which was oriented towards large mammals (domesticated and/or wild): they created forest clearings of unknown size and used the leaves of especially *Ulmus* and *Fraxinus* as fodder. The Ertebølle/Ellerbek people must also have cultivated cereals: in eastern Holstein cereal pollen is found as early as around 5800 BP/4700 cal BC, while in southern Sweden it is found only from 4200 cal BC onwards. The pollen picture of the Ertebølle/Ellerbek Culture very much resembles that of the Rössen Culture, which was present on the loess soils between 4700 and 4300 cal BC (KALIS & MEURERS-BALKE 1988; see II.5). Connections between the two cultures are also visible in the archaeological material: the *durchlochten Breitkeile* (perforated wedges), which are adzes produced by the Rössen Culture, were found in Ertebølle/Ellerbek layers during the excavation at Rosenhof (KALIS & MEURERS-BALKE 1998, 20). In Drenthe also, several specimens of *durchlochten Breitkeile* have been found (see III.7.3). Possibly, the resemblance between the pollen pictures of the two cultures points to similar forms of agricultural economy.

With the beginning of the earliest Funnel Beaker Culture (Rosenhof Group), the relationship between man and his environment was modified: the extensive, anthropo-zoogenic use of the forest by the Ertebølle/Ellerbek people seems to be replaced by a more intensive use of certain parts of the landscape. People of the Siggeneben Group were the first to use burning to clear the forest: this is documented by high values of *Betula*, *Pteridium* and charcoal in this period (see II.1.2). The burnt areas were used to cultivate cereals and to keep livestock. Compared to the preceding period, cereal cultivation was not expanded. During the next period, when people of the Satrup and Fuchsberg Groups resided in the area, much of the natural forests with predominantly

Tilia disappeared, and were replaced by open forests with predominantly *Betula*. The use of fire was still an important method for creating open spaces. In the open forests, *Plantago lanceolata* could establish itself permanently. However, the indicators for cereal cultivation still did not increase. This seems to indicate that the newly cleared areas were predominantly used for the keeping of livestock. In this period, man for the first time changed the natural landscape on a large scale, to create completely artificial fields. In fact, the cultural landscape originates from this time (KALIS & MEURERS-BALKE 1998, 19). The cultural landscape in the next period, when people of the Middle Neolithic Funnel Beaker Culture resided in the area, was dominated by *Corylus* and *Alnus*. The role of forest burning was still important in this period. The decrease of *Pteridium* and the increase of the culture-indicator types indicate that the intervals between the fires must have been longer than in the preceding period. Given the higher values of Cerealia, the role of cereal cultivation has become more important. Kalis & Meurers-Balke conclude that the Iversen *landnam* is a more than regional phenomenon in vegetation history, which can be observed in the entire young-moraine area of the western Baltic (see II.1.6).

II.2.10 Southern Sweden

In Sweden, many palynologists have studied the problem of the beginning of agriculture in their country. Here the extensive studies by Göransson (1988a, 1988b) and Berglund (1991) will be discussed briefly. Göransson studied a series of sequences from marshes in the neighbourhood of the Alvastra pile dwelling (province of Östergötland, central Sweden) (GÖRANSSON 1988a) and sequences from the former Skateholm lagoon (province of Scania, southern Sweden) (GÖRANSSON 1988b). An impressive study edited by Berglund (1991) gives a very good description of the development of the cultural landscape in the Ystad area (province of Scania, southern Sweden), including several pollen diagrams and maps with all known archaeological finds of the area. Both Göransson and Berglund distinguish three cultural phases before the Bronze Age:

- Phase I: Mesolithic Time (MT), before 5100 BP, Ertebølle Culture?
  In this phase, the forests on high ground were dominated by *Tilia*, while *Ulmus* occurred on the moister soils; Göransson (1988a, 48) found relatively high values of charcoal and *Pteridium*, which possibly point to clearance fires. In his opinion, the Mesolithic forests were already exploited by man: by a combination of burning and girdling of trees, small clearings were created, which were used for a kind of garden cultivation of cereals. Göransson bases this conclusion on his finds of two pollen grains of *Triticum*-type in the Dags Mosse diagram (Alvastra), which were dated ca. 5400 BP (GÖRANSSON 1988a, 85). In the diagram of Kragehölmssjön (Ystad area), also Cerealia pollen grains were found in this phase: one *Hordeum*-type grain and one *Triticum*-type grain (BERGLUND 1991, 223). In the diagram of Kurarp (also Ystad area), Kolstrup (1990) found a few grains of *Plantago lanceolata* and *P. major/media* in this phase. In her opinion, this points to grazing, trampling and/or woodland clearance (KOLSTRUP 1990, 253). According to Göransson (1988a, 49), burning and girdling also created patches of coppice wood in this phase. Archaeological evidence to the effect that cereals were known during the late Atlantic period is provided by impressions in sherds from the Löddesborg site in western Scania (BERGLUND 1991, 315).
- Phase II: Early Neolithic (EN), 5100-4500 BP, Early Neolithic TRB Culture: "Early Neolithic Destruction Phase" (GÖRANSSON 1988a, 53); Landnam phase (GÖRANSSON 1988a, 48).
  This phase is characterized by low values of *Ulmus*, *Tilia* and *Fraxinus*, and increasing values of *Betula*, *Corylus* and charcoal. This indicates that the forests became more open; probably they were partly transformed into open scrubland because of several interacting factors. According to Göransson (1988a, 49), these factors may have been both abiotic (e.g. climate), and/or biotic (e.g. disease combined with browsing). In this phase, no greater amount of Cerealia pollen is found than in the preceding phase. From this, Göransson concludes that no expansion of cultivation took place in the Early Neolithic. Possibly the most important form of livelihood was animal husbandry, although in most diagrams the Gramineae do not increase in this phase, while *Plantago lanceolata* and *Rumex* only occur sporadically. The high values of *Betula* and charcoal indicate that forest fires (clearance fires or

natural fires) were very characteristic of this phase. However, according to Berglund (1991, 168), the slash-and-burn technique was certainly not necessary for the cultivation of cereals during the Early Neolithic. The nutrient-rich soils of the south Swedish deciduous forests of the late Atlantic were of sufficient quality for early agriculture. For this reason, Berglund (1991, 168) rejects the *landnam* hypothesis as described by Iversen, involving slash-and-burn cultivation (see II.1.2). As an alternative, he proposes a system of cereal cultivation in small "wandering arable fields" in *Corylus* coppice woods. These differ from shifting arable fields in that they do not involve burn-beating.

The most conspicuous archaeological remains from this period are the huge numbers of dolmens in (adjacent) eastern Denmark (GÖRANSSON 1988b, 32). The oldest Neolithic phase in the Ystad area is characterized by a local group, the Mossby Group, which was named after a site at Mossby. At this site, which was dated around 5100 BP, also a house plan was excavated (BERGLUND 1991, 316). We are here dealing with one of the oldest sites of the TRB Culture in Scandinavia.

- Phase III: Middle Neolithic (MN), 4500-3800 BP, Middle Neolithic TRB Culture: Regeneration Phase (Alvastra Phase).

  This phase is characterized by a regeneration of the forests with *Tilia*, *Ulmus* and *Quercus*; however, the curves of *Plantago lanceolata* and Cerealia do not decrease. According to Berglund (1991, 69-70) the woodland regeneration was caused by natural recovery after the earlier deforestation crisis on the one hand, and decreased human impact in inland woodland on the other. The concentration of settlement on the coast, however, meant a locally intensified human impact during this same time. According to Göransson (1988b, 32), no regression in the cultivation occurred in this phase, but the forests were utilized in a more efficient way than during the preceding period: the forest farmer transformed the regenerating forests into coppice woods, but now on a larger scale than in Phase I. The coppice wood was used as an important source of winter fodder for the livestock. As Göransson (1988a, 73) demonstrated, the wood of the Alvastra pile dwelling, which was built during this phase, originates from stumps. This proves the presence of coppice-wood groves in this period.

  Many archaeological remains are known from this phase. The most impressive remains are passage graves, which are known from Scania, including the Ystad area, as well as the Falbygden area in Västergötland (GÖRANSSON 1988b, 32). Furthermore, the first signs of the ard plough begin to emerge in this phase (BERGLUND 1991, 320).

The palynological evidence for early agriculture in Sweden can be summarized in a simplified way as follows: in the Mesolithic Time (Phase I), there are very weak indications for cereal cultivation as well as animal husbandry; in the Early Neolithic (Phase II), compared to the preceding period, only an increase in animal husbandry occurred, but no increase in cereal cultivation; in the Middle Neolithic (Phase III), compared to the preceding period, only an increase in cereal cultivation occurred, but no increase in animal husbandry.

One may try to incorporate the above-mentioned phases into the regional *landnam* model for the western Baltic area (see II.1.6). The Swedish Phase I can be correlated with the Troels-Smith-PREFACT phase A. In the Swedish diagrams, the pronounced *Ulmus* decline occurring at the beginning of Phase II seems to coincide with an occupation phase which can be related to the occupation phase described by Iversen for Denmark, although Göransson and Berglund explain the pollen picture in a different way to Iversen. Apparently, Troels-Smith-PREFACT phase B and Iversen-PREFACT phase 1a are not present in the Swedish diagrams. The Swedish Phase II can be correlated with the Iversen-PREFACT phases 1b and 2; the Swedish Phase III can be correlated with the Iversen-PREFACT phase 3.

II.2.11 The British Isles

Ireland

Since the early investigations by Jessen (1949), many studies have been dedicated to the beginning of agriculture in Ireland. The early work of Mitchell (1956) especially deserves mention. He studied fifteen raised bogs in central and eastern Ireland. He was one of the first researchers who subdivided the Subboreal into several occupation phases and who attempted to connect these phases with Neolithic cultures. Mitchell's work was followed by important studies by Morrison (1959) and Smith (1964) on

the same subject. Here these early studies will be briefly discussed, completed with information from more recent studies by Hirons & Edwards (1986), who examined pollen from four sites in Co. Tyrone, northern Ireland, and Molloy & O'Connell (1991) who analyzed pollen from Lough Sheeauns, a small lake in Connemara, Co. Galway, western Ireland.

Mitchell (1956) distinguished three phases of human activity in the late Atlantic and early Subboreal. These three phases can be found in many Irish pollen diagrams:

- Phase I: Late Atlantic, until ca. 5100 BP:
  Long before the classic *Ulmus* decline, the first indications for agriculture occur: grains of *Plantago lanceolata* and *P. major* were found in this phase by Mitchell (1956, 236) in his diagram of Leigh (Co. Tipperary), by Morrison (1959) and Smith (1964) in pollen diagrams of locations in northern Ireland, by Hirons and Edwards (1986) and by Molloy and O'Connell (1991). Hirons and Edwards (1986) found Cerealia pollen at a level 365 ^{14}C years prior to the classic *Ulmus* decline; Molloy and O'Connell recorded Cerealia pollen grains in spectra 3 and 5 cm below the classic *Ulmus* decline. Apparently, small woodland clearances were made to facilitate arable farming. The low values of Gramineae and *Plantago lanceolata* suggest that the openings in the wooded landscape were distinctly limited. Another possibility is that *Plantago lanceolata* at that time was primarily a coloniser of fallow ground rather than a pasture species (see GROENMAN-VAN WAATERINGE 1986). According to Morrison (1959, 190), this phase has affinities with the occupation phase described by Troels-Smith for Denmark. Groenman-van Waateringe (1983), who collected much evidence for agriculture before the classic *Ulmus* decline, states that it is incorrect to regard the *Ulmus* decline in Ireland as marking the start of farming activities. Owing to the mechanics of dispersal, the presence of the culture indicators is only seldom recorded. A direct consequence of the opening up of the forest due to the disappearance of *Ulmus* (most probably as a result of disease) is improved representation of low-growing herb pollen in the diagrams. Although the amount of pollen from arable and meadow vegetation has indeed increased in the deposit, the increase of this pollen at the same time as the *Ulmus* decline spuriously suggests an increase in agricultural activity (GROENMAN-VAN WAATERINGE 1983, 223).
  According to Mitchell (1956, 241), the agricultural activities described above may be attributable to people of the "Bann Culture". Nowadays, this "Bann Culture" is considered to be part of the late Mesolithic Larnian Phase.
- Phase II: Neolithic *landnam*/Iversen occupation phase, ca. 5100-4500 BP.
  The beginning of this phase is characterized by the start of a sustained fall in *Ulmus* pollen frequencies: this is the classic *Ulmus* decline. Mitchell locates the Atlantic-Subboreal transition at this *Ulmus* decline. In many Irish diagrams, simultaneously with the *Ulmus* decline (MITCHELL 1956) or a short time later (MOLLOY & O'CONNELL 1991) an occupation phase of the Iversen type is observed: *Plantago lanceolata* and Cerealia-type occur more regularly, Gramineae increase. According to Hirons & Edwards (1986, 145), the record at the *Ulmus* decline represents a radical change in the scale of farming: apparently the tree canopy was opened more extensively than before (cf. the above-cited quite opposite opinion of Groenman-van Waateringe (1983)). Hirons & Edwards (1986, 146) dated the periods of open canopy in this phase: they were open for periods of around 70 to 365 ^{14}C years. Hirons & Edwards suggest that the diagrams possibly represent a composite record produced by multiple events, each single *landnam* possibly lasting between 50 and 100 years, as suggested by Iversen (see GÖRANSSON 1988c, 34). At the end of this phase, an almost complete regeneration of *Ulmus* and also other trees occurs. Hirons & Edwards (1986) put the duration of the recovery of the *Ulmus* percentages at 150-560 ^{14}C years. During the regeneration phase, evidence for human activities, including possible cereal cultivation, remains present. An explanation for this could be that agriculture during and after *Ulmus* recovery continued at a similar intensity to that during the period of low *Ulmus* percentages.
  Pilcher et al. (1971; see also SMITH 1975) have ^{14}C-dated the three stages of the Iversen occupation phase at three sites in northeastern Ireland. Stage A is the "clearance and farming type 1" phase, characterized by increased amounts of Gramineae pollen and

sporadic occurrence of pollen of *Plantago lanceolata* and Cerealia; it seems likely that the emphasis was on arable agriculture. Stage B is the "farming type 2" phase, characterized by relatively high values of *Plantago lanceolata*, while Cerealia pollen is absent; emphasis seems to have shifted to pastoral farming. Stage C is the regeneration phase, characterized by increasing AP values. Pilcher et al. (1971) obtained the following durations of the stages at the three sites (the boundaries of the stages are dated from deposition-rate graphs and must not be taken as fixed points):

Ballynagilly, Co. Tyrone:
- Stage A 5200-4775 BP: 425 years
- Stage B 4775-4600 BP: 175 years
- Stage C 4600-4500 BP: 100 years
- Total duration of the Iversen occupation phase: 700 years

Beaghmore, Co. Tyrone:
- Stage A 5150-4850 BP: 300 years
- Stage B 4850-4700 BP: 150 years
- Stage C 4700-4650 BP: 50 years
- Total duration of the Iversen occupation phase: 500 years

Ballyscullion, Co. Antrim:
- Stage A 5050-4975 BP: 75 years
- Stage B 4975-4750 BP: 225 years
- Stage C 4750-4650 BP: 100 years
- Total duration of the Iversen occupation phase: 400 years

Molloy & O'Connell (1991) put the duration of the Iversen occupation phase at ca. 340 calendar years: an intensive part of 150 years and a less intensive part of 190 years.

Mitchell (1956) ascribed this phase to people of the Western Neolithic Culture. Molloy & O'Connell (1991, 104) connect this phase with several megalithic tombs found less than a kilometre from their core location, which were dated to the early Neolithic (5200-4500 BP, see HARBISON 1988, 51-52).

- Phase III: Late Neolithic/Early Bronze Age, after ca. 4500 BP.

  A second decline of *Ulmus* marks the beginning of this phase. This decline, which is dated 4500-4300 BP, is more or less similarly dated in Ireland and Britain (HIRONS & EDWARDS 1986, 149).

England

To a certain extent, the beginning of the Iversen occupation phase as reflected in English pollen diagrams resembles the same event in Irish diagrams. However, there are also some remarkable differences. On the basis of ten pollen sites in the Lake District (northwestern England), Pennington (1975) made a detailed study of the *Ulmus* decline and the Iversen occupation phase. In several diagrams, the presence of *Plantago lanceolata* and a small increase of Gramineae between 5700 and 5100 BP points to small forest clearings before the classic *Ulmus* decline. At all of Pennington's sites, there is evidence of increased run-off from the catchments and of a rising water table, coinciding almost exactly with the steep fall in *Ulmus* pollen. The *Ulmus* decline is observed also in absolute pollen diagrams, indicating that it is a real decrease. The presence of *Plantago lanceolata* at all sites in this period can be fairly reliably attributed to the presence of man, but the pollen evidence cannot indicate whether the *Ulmus* decline is a direct effect of a leaf-foddering economy (PENNINGTON 1975, 84). Following Pilcher et al. (1971), Pennington distinguishes three stages of cultural activity after the *Ulmus* decline: Stage A is the period of declining *Ulmus*; Stage B is the period of continuous *Plantago lanceolata*, and Stage C is the forest regeneration phase. At two sites, these phases were also ^{14}C-dated:

Blea Tarn:
- Stage A 5260-5050 BP: 210 years
- Stage B 5050-4750 BP: 300 years
- Stage C: no ^{14}C dates
- Total duration of the occupation phase: more than 500 years

Ennerdale:
- Stage A 5250-5100 BP: 150 years
- Stage B 5100-4900 BP: 200 years
- Stage C 4900-4800 BP: 100 years
- Total duration of the occupation phase: 450 years

In my opinion, it can be questioned whether the three stages of the Iversen occupation phase distinguished by Pilcher et al. (1971) in northern Ireland, can be correlated with the three stages distinguished by Pennington in northwestern England. As described above, in Ireland the *Ulmus* decline more or less coincides with the beginning of the Iversen occupation phase. An increase of indicators for pastoralism, especially Gramineae, points to an Iversen occupation phase (see II.1.2). However, Oldfield has demonstrated (1963, 28) that in northwestern England the *Ulmus* decline and the beginning of the Iversen occupation phase do not coincide, but are even separated by a short regeneration phase. During the *Ulmus* decline, there is no increase in

weed pollen percentages, and only in some diagrams an increase of Gramineae. Possibly, an occupation phase with affinity to that described by Troels-Smith for Denmark, which starts at or even before the *Ulmus* decline, precedes the Iversen occupation phase in northwestern England. Because Pennington's stage A starts at the *Ulmus* decline, it is possible that a "Troels-Smith occupation phase" forms the first part of this stage. There are indications for this in Pennington's pollen diagrams: in most of her diagrams, the Gramineae do not increase exactly at the level of the *Ulmus* decline, but only some time later (see for example PENNINGTON 1975, fig. 8).
Greig (1996) presents an overview of more than thirty pollen diagrams from all parts of England. Only at very few sites has he demonstrated possible evidence for early Neolithic activity before the *Ulmus* decline by changes in some pollen values, charred layers or isolated finds of Cerealia pollen grains (see also EDWARDS 1989). In England the classic *Ulmus* decline is dated between 5600 BP (southern England) and 4500 BP; most dates are around 5100-5000 BP. Evidence of human impact around the *Ulmus* decline is often rather slight, consisting of a decline in AP, particularly *Quercus* and *Tilia*, and involving only few culture-indicator types, like *Plantago lanceolata*, *Rumex* and *Artemisia*. Cerealia-type pollen at this point only appears in a few pollen diagrams. Cerealia-type records often seem to reflect the closeness of the pollen site to the occupied landscape (GREIG 1996, 71). At only three sites is a second *Ulmus* decline observed, but this second *Ulmus* decline is far less pronounced than in Ireland: after its initial fall, *Ulmus* never fully recovered.
In most English diagrams, also a clear decline of *Tilia* is observed. In most cases, this *Tilia* decline is associated with increases in frequencies of Gramineae, *Plantago lanceolata*, *Rumex* and *Pteridium*. According to Turner (1962, 338), it is quite clear that human interference in woodland was the immediate cause of the *Tilia* decline. Turner (1962, 339) summarized the (then available) ^{14}C dates of the *Tilia* decline: in southern England, it occurs in the Late Neolithic, between 4015 and 3920 BP; in central England, it occurs in the Middle/Late Bronze Age, between 3440 and 2971 BP. According to Turner, this shows that the *Tilia* decline was not a single synchronous event throughout Britain and must indeed be attributed to people of several prehistoric cultures. In the pollen sites discussed by Greig (1996), a *Tilia* decline sometimes occurs together with the classic (first) *Ulmus* decline, at ca. 5500-5000 BP, and sometimes at ca. 3800-3700 BP, where it seems to represent an extensive clearance phase in the Late Neolithic/Early Bronze Age (GREIG 1996, 69).

II.2.12 Synthesis

In the preceding sections, the Neolithic as it is observed in pollen diagrams of many different locations has been discussed. In most cases, several occupation phases could be observed in the Neolithic. When also ^{14}C dates were available, it was possible to connect these occupation phases with archaeological cultures.
In fig. 10, all dated occupation phases in pollen diagrams which have been discussed in the preceding sections are put together. Table 1 lists data of occupation phases in pollen diagrams of many of the locations discussed in the preceding sections. In both fig. 10 and table 1, a simplified picture of the various occupation phases is given: they are all reduced either to an occupation phase as first described by Iversen for Denmark (see II.1.2), or to an occupation phase as first described by Troels-Smith for Denmark and Switzerland (see II.1.3). Put in a simplified way, the Iversen occupation phase is characterized by a considerable reduction of tree pollen values and high values of *Plantago lanceolata*, *Rumex* and Gramineae, pointing to large-scale clearance, while the Troels-Smith occupation phase is characterized by a modest reduction of the tree pollen values and low values of *Plantago lanceolata*, *Rumex* and Gramineae, pointing to small-scale clearings. Of course it might be dangerous to use these simplified definitions: the models of Iversen and Troels-Smith were framed for the Danish young-moraine landscape, and it may not be appropriate to use them for other types of landscape and other archaeological cultures (KALIS & MEURERS-BALKE 1998, 5). Furthermore, not much is known about the factors which create an Iversen or a Troels-Smith occupation phase in pollen diagrams. It is assumed that the most important factor is the agricultural methods used by the archaeological culture concerned. However, also the type of the basin, the type of sediment in which the pollen occurs, the location within the basin and the distance from the core location to the ancient settlements or fields may have influenced the pollen picture of an occupation phase. Apart from the location within the basin, which in most studies is not indicated,

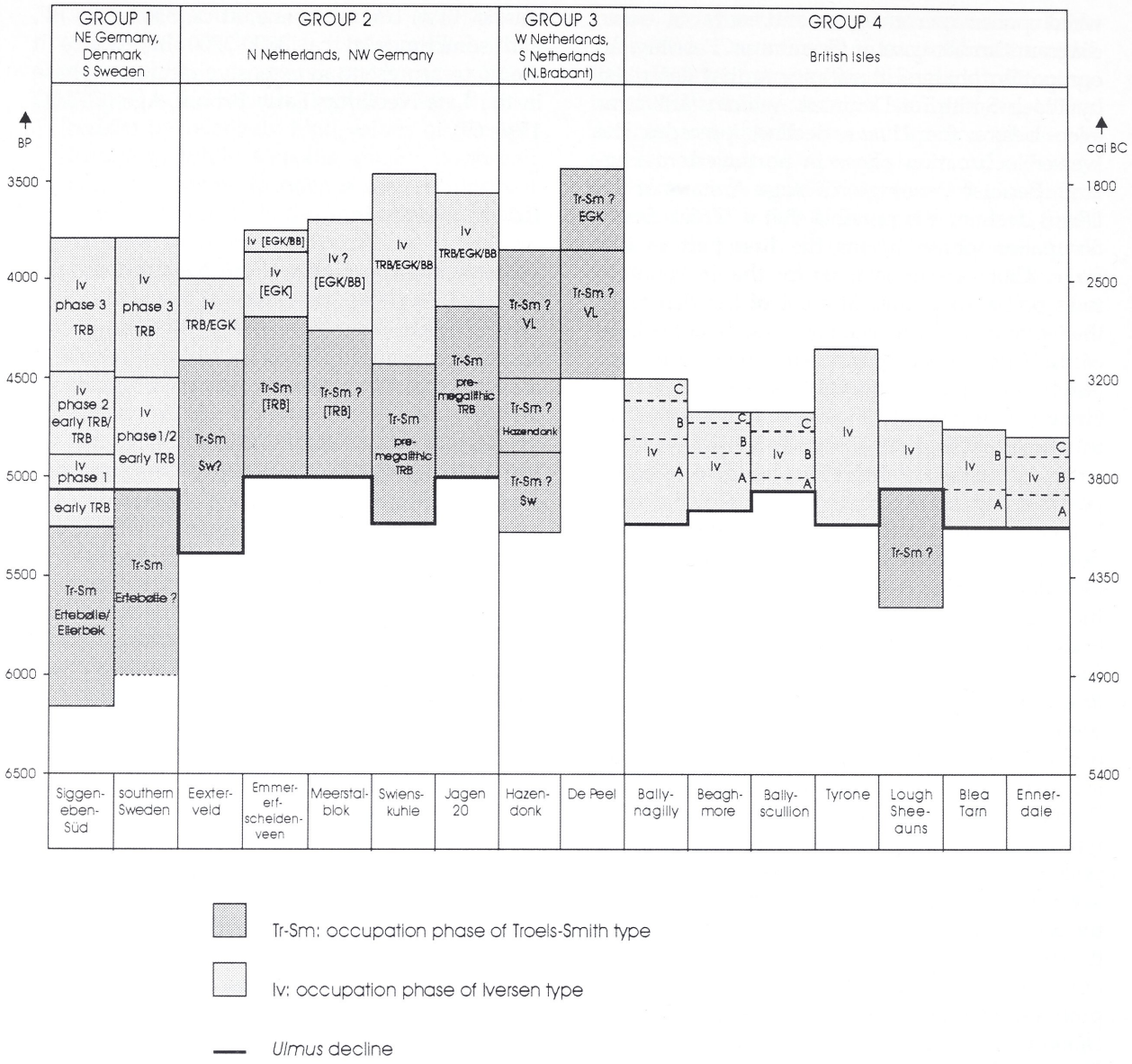


Fig. 10. Dated occupation phases of the Neolithic in pollen diagrams from various parts of Europe.

these factors are also mentioned in table 1. In spite of these objections, it does seem justified to use the above-mentioned simplified definitions, if only to obtain an overview of the global course of the Neolithic as observed in pollen diagrams from various areas. Because the classic *Ulmus* decline (see also II.3) seems in many cases connected with the beginning of occupation phases, this *Ulmus* decline (as far as it occurs in the pollen diagrams) is also shown in fig. 10.

On the basis of similarity of landscape, the discussed locations are divided into four groups, which feature in fig. 10 and table 1. On the map of fig. 11, the geographical position of each of these groups is indicated:

Group 1: areas near the coast of the western Baltic: northeastern Germany, Denmark, southern Sweden.

The classic *Ulmus* decline more or less coincides with the beginning of the Iversen occupation phase (5200-5100 BP); however, smaller declines of *Ulmus* are already detected from the beginning of the Troels-Smith occupation phase (ca. 6000 BP) onwards. A very

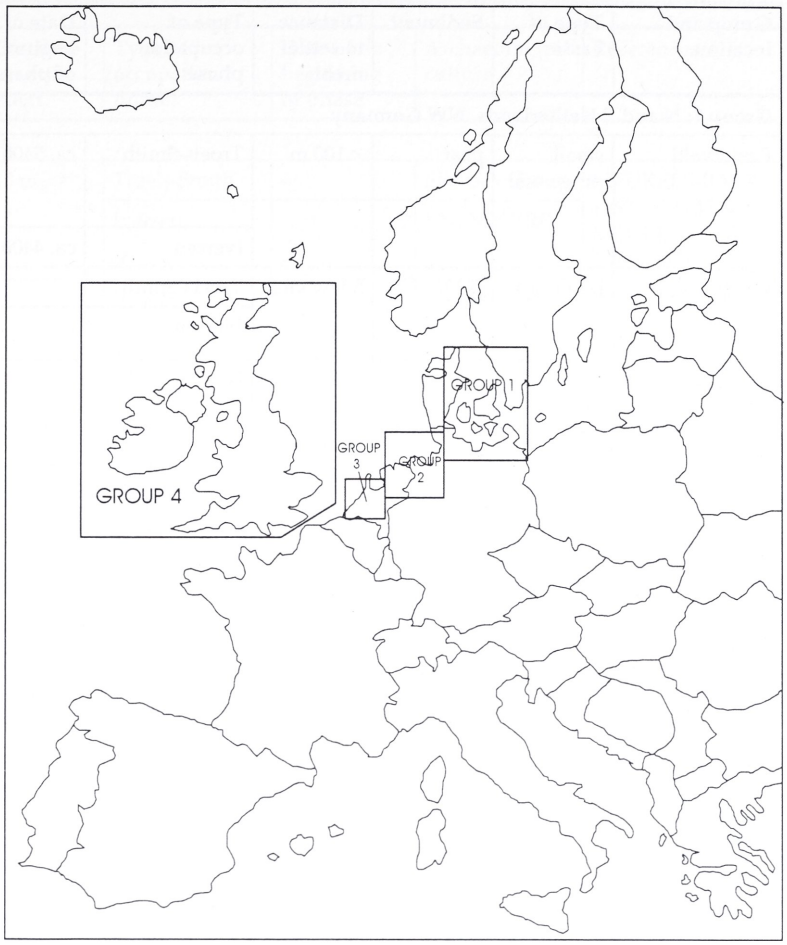


Fig. 11. Map of Europe indicating the various groups with approximately corresponding occupation phases in the Neolithic as represented in pollen diagrams (see fig. 10 and table 1).

good model describing the various Neolithic occupation phases in the western Baltic area has been constructed by Kalis & Meurers-Balke (1998, see II.1.6).

Group 2: Pleistocene areas near the North Sea coast: the northern and eastern Netherlands, northwestern Germany.

The *Ulmus* decline coincides with the beginning of the Troels-Smith occupation phase (5400-5000 BP). The Iversen occupation phase begins between 4700 and 4200 BP. Some authors connect the Troels-Smith occupation phase with the TRB Culture and the Iversen occupation phase with the EGK Culture, but in more recent publications, the Troels-Smith occupation phase is connected with the Swifterbant Culture or with the Early Neolithic TRB Culture, while the Iversen occupation phase is connected with the Middle Neolithic TRB Culture and subsequent cultures. Because the Gietsenveentje also belongs to this group, it is hoped that this problem will be resolved as a result of this study.

Group 3: the Holocene delta and the higher sandy grounds south of the large rivers in the Netherlands: western Netherlands, southern Netherlands (Noord-Brabant).

No clear *Ulmus* decline is observed in these areas. All occupation phases of the Neolithic have closest affinity with the Troels-Smith type; large-scale clearances do not occur before the Bronze Age.

Group 4: the British Isles (Ireland and England).

The classic *Ulmus* decline occurs between 5300 and 5000 BP. In many diagrams, occasional grains of culture-indicator types are found much earlier. It is not clear whether these occasional grains represent real occupation phases. In diagrams from Lough Sheeauns (western Ireland) and Tyrone (northern Ireland), a cultural phase can be recognized before 5000 BP which has a weak affinity with a Troels-Smith occupation phase. In all diagrams, an occupation phase of the Iversen type is observed immediately or shortly after the *Ulmus* decline.

Group and location	Type of basin	Sediment	Distance to settlement	Type of occupation phase	Date of beginning of phase	Archaeological culture	References
Group 1: N and E Netherlands, NW Germany							
Eexterveld	small pingo scar	peat	< 100 m	Troels-Smith	ca. 5400 BP	Swifterbant/ pre-megalithic TRB	BAKKER et al. 1999
				Iversen	ca. 4400 BP	TRB	
Wijnjewoude	pingo scar	peat	a few kms	Troels-Smith	-	?	PLOEGER & GROENMAN-VAN WAATERINGE 1964
				Iversen	-	?	
Hijkermeer	large pingo scar	gyttja	far	Iversen	-	?	ZAGWIJN 1956
Uddelermeer	large pingo scar	gyttja	< 500 m	Troels-Smith	-	?	POLAK 1959
				Iversen	-	?	
Emmererf-scheidenveen V	large raised bog	peat	> 3 km	Troels-Smith	ca. 5000 BP	[TRB]	VAN ZEIST 1955b
				Iversen	ca. 4200 BP	[EGK]	
Bargerooster-veld	large raised bog	peat	> 1 km	Troels-Smith	-	[pre-megalithic culture/TRB]	VAN ZEIST 1959
				Iversen	-	[EGK]	
Meerstalblok	large raised bog	peat	> 5 km	Troels-Smith	ca. 5000 BP	[TRB]	DUPONT 1986
				Iversen?	ca. 4000 BP	[EGK]	
De Klokkenberg	small gully	humic sand	a few 100 ms	Iversen?	ca. 4400 BP	?	VAN DER HAMMEN 1965
Engbertdijks-venen	large raised bog	peat	far	Iversen	ca. 4800 BP	?	VAN GEEL 1978
De Borchert	filled-in river branch	peat	far	Iversen?	ca. 3900 BP	?	VAN GEEL et al. 1981
Swienskuhle	kettle-hole	sedge peat	2400 m	Troels-Smith	ca. 5200 BP	pre-megalithic TRB	BEHRE & KUČAN 1994
				Iversen	ca. 4450 BP	TRB	
Jagen 20	peat bog	*Sphagnum* peat	2750 m	Troels-Smith	ca. 4700 BP	pre-megalithic TRB	BEHRE & KUČAN 1994
				Iversen	ca. 4150 BP	TRB	
Silbersee	kettle-hole	*Sphagnum* peat	2100 m	Troels-Smith?	-	?	BEHRE & KUČAN 1994
				Iversen?	-	?	
Flögelner Holz	kettle-hole	*Sphagnum* peat	1600 m	Troels-Smith	-	?	BEHRE & KUČAN 1994
				Iversen	ca. 4400 BP	?	
Fuhrenkamp	kettle-hole	*Sphagnum* peat	2000 m	Troels-Smith	ca. 5050 BP	pre-megalithic TRB	BEHRE & KUČAN 1994
				Iversen	after 4650 BP	TRB	
Flögeln V	large raised bog	*Sphagnum* peat	600 m	Troels-Smith	-	?	BEHRE & KUČAN 1994
				Iversen	-	?	
Herrenhof	small pingo scar	peat	> 1400 m	Troels-Smith?	ca. 4800 BP	?	DÖRFLER 1989
				Iversen	ca. 4650 BP	?	

Table 1. Data of occupation phases in the Neolithic as represented in pollen diagrams from north-western Europe.

Group and location	Type of basin	Sediment	Distance to settlement	Type of occupation phase	Date of beginning of phase	Archaeological culture	References
Group 2: NE Germany, Denmark, S Sweden							
Siggeneben-Süd	terrestrialized bay	marine gyttja	10 m	Troels-Smith	-	Ellerbek Group	MEURERS-BALKE 1983 ; KALIS & MEURERS-BALKE 1998 ; 2001
				Iversen	-	EN/MN TRB	
Ordrup Mose	terrestrialized bay	gyttja	?	Iversen	-	EN/MN TRB	IVERSEN 1949; KALIS & MEURERS-BALKE 1998
Aamosen	large raised bog	peat	?	Troels-Smith	-	Ertebølle	TROELS-SMITH 1960; 1961; KALIS & MEURERS-BALKE 1998
				Iversen	-	EN/MN TRB	
Group 3: W Netherlands, S Netherlands (N.Brabant)							
Hazendonk	marshy river valley	wood peat	< 50 m	Troels-Smith	ca. 5300 BP	Swifterbant	LOUWE KOOIJMANS 1974
				Troels-Smith	ca. 4900 BP	Hazendonk	
				Troels-Smith	ca. 4500 BP	Vlaardingen	
De Peel	large raised bog	peat	far	Troels-Smith	ca. 4500 BP	Vlaardingen?	JANSSEN & TEN HOVE 1971
				Troels-Smith	ca. 3850 BP	EGK	

Table 1 (continued).

II.3 The relation between occupation phases in the Neolithic and the *Ulmus* decline

In many pollen diagrams from western and northern Europe, a fairly severe and sudden decline of *Ulmus* is observed around 5000 BP/3800 cal BC. From the time of Iversen and Troels-Smith onwards, much has been written about this *Ulmus* decline and several hypotheses have been proposed to explain it (a summary of the literature about these various hypotheses is given by PEGLAR 1993). These include climatic change (see II.1.4), human activity (see II.1.3), soil deterioration and disease. Other authors have argued that a combination of factors were responsible for the decline (see II.1.4). In II.2.12, it has already been outlined that in many pollen diagrams the *Ulmus* decline could be connected with the first occupation phase or with subsequent occupation phases of the Neolithic as represented in pollen diagrams (see fig. 10). Here the results of some recent, very detailed studies on the cause, the duration and the point in time of the *Ulmus* decline (or declines) in England, Denmark, Sweden and Germany and their relation to human activities will be discussed.

Peglar (1993) sampled annually laminated sediments from a small steep-sided lake, Diss Mere, in Norfolk, England. In a section known to include the *Ulmus* decline, the laminae were sampled separately, as far as possible. At the *Ulmus* decline, *Ulmus* pollen values drop from an average of 5.8% to 1.6%, a 73% decrease, over six years. The extreme rapidity of the *Ulmus* decline strongly suggests that a pathogenic attack is responsible, most probably Dutch elm disease. Dutch elm disease is caused by the ascomycete fungus *Ceratocystis ulmi*. It is carried mainly by two bark-beetles, *Scolytus scolytus* and *Scolytus multistriatus*. The *Ulmus* decline in Diss Mere is comparable in rate and magnitude with the fall, as recorded palynologically, in *Castanea dentata* from North America known to have been caused by a pathogen early in the 20th century, with the mid-Holocene *Tsuga canadensis* decline also attributed to a pathogen, and with the present-day *Ulmus* decline caused by Dutch elm disease in Scords Wood, England. This supports the hypothesis of a pathogenic attack having caused the *Ulmus* decline at Diss Mere. Peglar (1993, 11) reaches the conclusion that the *Ulmus* decline was caused by a combination of disease and human

activity, a virulent attack taking place in disturbed woodland, where the *Ulmus* trees had already been disturbed by human activity for at least 160 years. Grazing, fodder collection and related activities may have prevented regeneration of the *Ulmus* population after the pathogenic outbreak.

Andersen & Rasmussen (1993) studied *Ulmus* declines in a pollen diagram from Hassing Huse Mose, a small lake in northwestern Denmark. Four *Ulmus* declines were found. By applying the method of "wiggle matching" (see VI.4), a reservoir effect of 120 years was found, and dates for the four *Ulmus* declines of 4530, 4130, 3870 and 3410 cal BC were obtained. The start of the third *Ulmus* decline at Hassing Huse Mose (3870 cal BC) is likely to correspond to the start of the principal (classic) *Ulmus* decline. The first two *Ulmus* declines are accompanied by slight increases of Gramineae and *Rumex acetosella*, while also a few grains of *Triticum*-type are found. However, the evidence for vegetation disturbance and agricultural activity at this site before the major *Ulmus* decline is weak. The third (classic) *Ulmus* decline coincides with the beginning of the Early Neolithic Funnel Beaker Culture. Gramineae and *Rumex acetosella* increase, *Plantago lanceolata* appears, there is a single *Hordeum*-type pollen grain, and charcoal dust increases conspicuously. Hence there is some evidence of agricultural activity. The beginning of the fourth (very weak) *Ulmus* decline coincides with the transition from the Early to the Middle Neolithic Funnel Beaker Culture. *Ulmus* and *Tilia* are now low, *Betula* decreases and *Corylus* increases. Gramineae and *Plantago lanceolata* increase slightly. As causes of the first three *Ulmus* declines, Andersen & Rasmussen, following Peglar (1993), suggest outbreaks of elm disease provoked by stress from human activity. It is difficult to explain why only *Ulmus* was affected by man during the first three *Ulmus* declines. Selective exploitation of *Ulmus* woodland may have been due to the establishment of fields on particular (fertile) soils or to the promotion of pig pannage. Curiously, Andersen & Rasmussen nowhere mention the term Iversen occupation phase or *landnam*, nor the term Troels-Smith occupation phase. In my opinion, the first two *Ulmus* declines represent occupation phases of the Troels-Smith type (Troels-Smith-PREFACT phases A and B in the model of Kalis & Meurers-Balke, see II.1.6 and II.2.9), while the third *Ulmus* decline represents an occupation phase of the Iversen type (Iversen-PREFACT phases 1b and 2 in the model of Kalis & Meurers-Balke).

Skog & Regnéll (1995) sampled a *Sphagnum*-peat sequence from Ageröds Mosse in southernmost Sweden. Pollen samples were analyzed at 1 cm intervals. The *Ulmus* decline is very distinct in the pollen diagram: the *Ulmus* percentage falls from 9 to 2%, amounting to a 78% decrease in a time span corresponding to 2 cm of sediment at most. The peat accumulation rate for this interval was estimated to be ca. 0.5 mm/year. The 2 cm interval of the two samples at the *Ulmus* decline accordingly corresponds to ca. 40 years, which is a maximum value for the duration of the decline, as closer pollen sampling may reveal an even narrower interval. On the basis of the pollen analysis, nine peat samples were picked out for ^{14}C analysis. The width of each sample was 2 cm. By applying the method of "wiggle matching" (see VI.4) it was found that the *Ulmus* decline in Ageröds Mosse occurred within a few decades at ca. 3770 cal BC. This date is in agreement with that of the principal *Ulmus* decline found by Andersen & Rasmussen (1993), which suggests that at this location the *Ulmus* decline likewise coincides with the beginning of the Early Neolithic Funnel Beaker Culture (TRB) (see II.2.10).

Digerfeldt (1997) analyzed a sequence from Lake Kalvsjön in southern Sweden (province of Scania). Here the *Ulmus* decline occurs in a gyttja layer between two sedge-peat layers. *Ulmus* declines abruptly, the percentage representation decreasing from about 5% to 1% within a sample interval of 2.5 cm. There are only two dates of the sedge peat layers below and above the gyttja layer (5190 ± 80 BP and 4780 ± 80 BP, respectively). Based on these two dates, the average rate of gyttja accumulation is estimated to be 0.9 mm/year. Thus the decline in *Ulmus* may have occurred within less than 25-30 years. The rapidity of the *Ulmus* decline here strongly suggests a pathogenic attack to be primarily responsible for the decline. At the level of the decline, *Plantago lanceolata* appears, but Gramineae do not increase, indicating that human activity was still insignificant (DIGERFELDT 1997, 12). Human interference and climate-induced palaeohydrological change probably interacted by disturbing the forests, and consequently increasing the susceptibility of *Ulmus* to pathogenic attack. According to Digerfeldt, the climate-induced disturbance in the Lake Kalvsjön area is more severe and accordingly more conductive to the outbreak of elm disease than any human interference.

Kalis & Meurers-Balke (1998) also discuss the possible causes of *Ulmus* declines in the Neolithic. The decline of *Ulmus* most probably attributable to the Ertebølle Culture (Troels-Smith-PREFACT phase A/B, see II.1.6 and II.2.9) lasts for a few centuries, which makes it unlikely that this was caused by a pathogenic attack. Nor is climatic change a plausible cause of this *Ulmus* decline, because in the western Baltic area the *Ulmus* species concerned do not occur near the climatically determined limit of their distribution area (KALIS & MEURERS-BALKE 1998, 16). According to Kalis & Meurers-Balke, an anthropo-zoogenic cause seems more plausible. An increase of large leaf-eating mammals, which preferred the nutritious and tasty leaves of *Ulmus* and *Fraxinus*, must have had a differential effect on the numbers of these trees: *Ulmus* decreased, while the pioneer tree *Fraxinus* increased, taking advantage of the opening up of the forest. In the zone in the pollen diagrams which reflects the beginning of the Early Neolithic Funnel Beaker Culture (Iversen-PREFACT phase 1a), the *Ulmus* curve continues to decline. According to Kalis & Meurers-Balke (1998, 17), this decline is not caused by a pathogenic attack either, because the disappearance of complete *Ulmus* stands would have led to the development of substituting communities with *Corylus*, *Alnus* and *Hedera*. However, the pollen diagrams record not an increase, but a decrease of these three taxa. An anthropogenic cause of this *Ulmus* decline is more probable: apparently, the TRB people particularly exploited the rich soils on which *Ulmus* preferably grew. The "classic" *Ulmus* decline in northeastern Germany coincides with the presence of the Siggeneben Group of the Early Neolithic Funnel Beaker Culture (Iversen-PREFACT phase 1b). It is possible that elm disease played a role in the decrease of *Ulmus* in this period; because of the already quite severe human disturbance of the forests, the remaining *Ulmus* trees became more susceptible to pathogenic attack (KALIS & MEURERS-BALKE 1998, 18).

In summary, it can be stated that a widely held opinion nowadays is that the *Ulmus* decline is best explained by an interaction between human impact and the spread of elm disease, i.e. a pathogenic attack on forests disturbed by human interference (DIGERFELDT 1997). In some areas, a rapid *Ulmus* decline is recorded, indicating that a pathogenic attack must have been involved (for example, PEGLAR 1993; SKOG & REGNÉLL 1995); however, in other areas a slow and progressive decline is recorded, which has been explained by human impact, climatic or edaphic change or interactions between such factors (for example, GÖRANSSON 1988a; BERGLUND 1991; KALIS & MEURERS-BALKE 1998). Probably there is no universal explanation, and the decline may demand explanations specific to each region (SMITH 1961; PENNINGTON 1979). Climatic and edaphic change, human activity and elm disease may have been responsible for the decline, but the importance of each of these factors is likely to have varied from region to region (DIGERFELDT 1997).

II.4 The relation between the beginning of the Neolithic in pollen diagrams and climatic change

The possibility of a climatic change more or less coinciding with the Atlantic-Subboreal transition and consequently also with the beginning of the Neolithic in northwestern Europe as represented in pollen diagrams (see I.4.1) was already suggested by Iversen (1944). In the opinion of several authors, the classic *Ulmus* decline was caused primarily by a change of climate around the Atlantic-Subboreal transition (for example NILSSON 1948; 1961; see II.1.4). It is now generally accepted, however, that any plausible, universal climatic explanation of the classic *Ulmus* decline cannot be found. Yet climate in different combinations of interactions may have contributed to the decline (DIGERFELDT 1997). Iversen used three indicator species to demonstrate climatic change: *Hedera helix*, *Viscum album* and *Ilex aquifolium*. Because in northwestern Europe these species occur near the limit of their area of distribution, they are very sensitive to climatic change in this area. *Hedera* and *Ilex* are oceanic species, sensitive to winter frost; *Viscum* is a continental element, requiring warm summers (IVERSEN 1944). At the Atlantic-Subboreal transition, the relative amount of *Hedera* and *Viscum* decreased. From this, Iversen concluded that in wide parts of central Europe not only did the winters become cooler, but also summer temperatures may have been lowered. In his opinion, and in the opinion of numerous subsequent investigators, the climate changed towards increased continentality and increased dryness around 5000 BP/3800 cal BC (DIGERFELDT 1997). Although at the end of the Atlantic

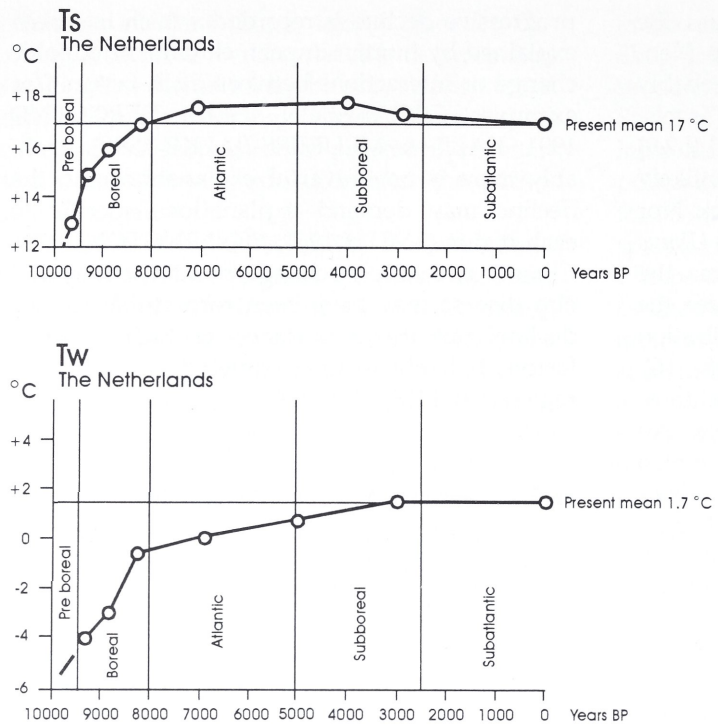


Fig. 12. Hypothetical temperature curves of mean summer and winter temperatures in the area of Amsterdam, the Netherlands, since the Preboreal (after ZAGWIJN 1994, adapted). Ts: mean summer temperature; Tw: mean winter temperature.

the significance of the three named species decreased, they were still part of the central and northwest European flora. From this, Frenzel (1966) concludes that if climate indeed changed at the Atlantic-Subboreal transition, then this change cannot have been very great.

On the basis of distribution maps showing the first pollen occurrences in the Holocene of the climate indicators *Hedera, Ilex* and *Viscum* as well as data for *Corylus*, Zagwijn (1994) constructed a series of maps that show summer and winter isotherms at various points in time during the Holocene. On the basis of these maps, climate curves for Amsterdam (the Netherlands) were compiled, which are shown in fig. 12. The mid-Holocene climatic optimum occurs between 7000 and 4000 BP, when the mean temperature in July reaches 18°C (1°C more than nowadays). However, the mean temperature in January continues to increase until it reaches its maximum value of 1.7°C at 3000 BP. Between 3000 BP and now, the mean temperature in January has remained constant. From Zagwijn's climate curves it can be seen that around 5000 BP the mean temperature in July was not changing, while the mean temperature in January was still rising. Zagwijn (1994, fig. 23) concludes that seasonality was stronger at the beginning of the Holocene, the climate being more continental. Later, seasonality decreased and the climate became more oceanic.

Apart from palynological evidence, many additional types of evidence can be used to demonstrate a climatic change at the Atlantic-Subboreal transition. In mountainous regions, the effects of a climatic change will be visible more clearly than in lowlands, where a more stable equilibrium between various plant communities is reached and where human impact on the vegetation is much stronger. Here the results of some studies from the Swiss Alps and Norway will be discussed. Just before 5000 BP, a short-term climatic oscillation towards cold climate could be demonstrated in Switzerland, the so-called Piora oscillation (FRENZEL 1966, 103). However, Frenzel emphasizes that the Piora oscillation was only a minor oscillation, which only slightly modified the general trend in the post-Glacial evolution of climate, i.e. from cold and dry phases of late-Glacial times to the post-Glacial warm period and again to cooler and moister conditions (FRENZEL 1966, 106). In a more recent study in the Swiss Alps, Gamper (1993) found increased geomorphological activity setting in around 5000 BP. Whereas geomorphological activity was very slight around 8000-5000 BP, the following period, lasting from 5000 BP up to the present, has been characterized by a rapid succession of brief soil development phases and phases of geomorphological activity. According to Gamper (1993), the change in geomorpho-

logical activity around 5000 BP probably reflects a change of climate from more oceanic to increasingly continental. Unfortunately, he could not answer the question of how much this change was also due to human impact. Veit (1993) found a comparable phase of increasing geomorphological activity setting in around 5000 BP in the Austrian Alps. Burga (1993) gives an outline of the Swiss alpine Holocene palaeoclimate, mainly using palynological data. He concludes that the Piora oscillation in the pollen diagrams, which is dated between 5200 and 4200 BP, coincides with glacier advances and intensified solifluction phases. In conclusion, the studies by Gamper, Veit and Burga all point to a climatic change to a colder (more continental) climate around 5000 BP in the Alps. A study in the mountain-foot zones in western Norway demonstrated glacier advances from 5200 BP onwards and increasing avalanche activity from 4600 BP onwards, also pointing to the setting in of a colder climate after 5000 BP (BLIKRA & NEMEC 1993).

Very recently, several articles were published which present evidence for a world-wide cold period between ca. 5200 and 4400 BP (O'BRIEN et al. 1995, fig. 2; STEIG 1999; SANDWEISS et al. 1999). This can be seen most clearly in the polar regions: in an ice core from Summit, Greenland, the GISP 2 ice core, increased concentrations of sea salt and terrestrial dusts were found during five periods since the Younger Dryas (O'BRIEN et al. 1995). One of these periods is the period between 5200 and 4400 BP (4100-3000 cal BC). During these periods, temperatures in the mid to high northern latitudes were potentially the coldest since the Younger Dryas event. Between 5200 and 4400 BP, most tropical and subtropical land areas either cooled or became more arid, or both; at temperate latitudes, some areas experienced a mid-Holocene dry period followed by increasingly cool and wet conditions. In addition to these changes in land air temperatures and precipitation, the period between 5200 and 4400 BP also saw substantial change in atmospheric and ocean circulation patterns (STEIG 1999; SANDWEISS et al. 1999). Sandweiss et al. (1999) correlate climatic change and cultural change in the mid-Holocene (7100-2800 BP/6000-1000 cal BC) in various parts of the world. They conclude that the presented evidence confirms that the mid-Holocene was a time of increasing climatic variability and cultural change in many parts of the world, but that climatic and cultural trends were neither global nor synchronous. In general, climate was warmer and less variable for several millennia before 5000 BP/3800 cal BC than in the immediately following period. Cultural complexity generally increased where climate change was most apparent. Faced with change, humans have the capacity to alter their behaviour, not all of which leads in the same direction or is equally successful.

Concluding, it can be stated that there is evidence from multiple disciplines and many locations that a climatic change took place around 5000 BP. The scale and duration of this change are still under discussion, but it is most probable that a change towards continentality and increased dryness took place in this period. Only the results of a study by Zagwijn (1994) point to decreasing continentality after 5000 BP. When the human influence on the vegetation around 5000 BP is studied, a date which more or less marks the beginning of the Neolithic in northwestern Europe as represented in pollen diagrams, it always has to be remembered that a climatic change in this period may have caused at least part of the changes in the vegetation. However, climate-induced changes in the vegetation are unlikely to have a very sudden character: it is more probable that these changes took place over a period of hundreds of years.

II.5 Archaeology of the Neolithic in the Netherlands and the process of Neolithization

In the preceding sections it has been outlined that in many pollen diagrams, several occupation phases representing the Neolithic could be correlated with archaeological cultures, usually on the basis of ^{14}C dates. The cultures which are most probably involved in the beginning of the Neolithic of the northern Netherlands as represented in pollen diagrams are the Swifterbant Culture and the Funnel Beaker Culture (TRB). In this section, the archaeology of the Neolithic in the Netherlands will be discussed, with an emphasis on these two cultures; furthermore, some general remarks will be made concerning the process of Neolithization in the Netherlands.

In the course of the first part of the Holocene, approximately between 10,000 and 5,000 BP, farming cultures with permanent settlements, arable farming and stock keeping spread from the Near East and southeastern Europe all over Europe. The transition from a nomadic subsist-

ence of hunting and gathering to a sedentary subsistence of farming is one of the largest steps forward in human history, so that it is justified to speak of the "Neolithic Revolution" (CHILDE 1951), although by this term not a catastrophic, but rather a gradual event in the sense of an "Evolution" is designated. The progressive expansion of Neolithic cultures throughout Europe results in varying starting dates for the Neolithic, dependent on geographical position: it starts in the southeast, and eventually reaches the northwest and north (fig. 13). The origin of Neolithic cultures has to be sought in the Near East, more precisely in the so-called Fertile Crescent (fig. 13). Here, the transition from hunting and gathering to farming took place around 9400 cal BC. Even before the later confirmation by archaeological finds, it was assumed that the origins of arable farming and stock keeping lay in the Fertile Crescent, because the natural habitat of wild ancestors of several domesticates, plants as well as animals, is found in that area. Examples are *Triticum dicoccoides* (wild emmer), *Triticum boeoticum* (wild einkorn), *Hordeum spontaneum* (wild barley), *Pisum humile* (wild pea), *Lens orientalis* (wild lentil) and *Capra aegagrus* (wild goat) and *Ovis orientalis* (wild sheep) (UERPMANN 1983).

The first real farming culture in the Netherlands was the Linear Pottery Culture (LBK). This culture colonized the loess areas of Central Europe (fig. 13), where it replaced local Mesolithic groups. According to Zvelebil (1998), the spread of the LBK is a classical example of farming colonization and replacement of local foragers. However, in recent years, also the possibility of Neolithization of the Mesolithic society is considered with respect to the Linear Pottery Culture (LANTING & VAN DER PLICHT 1999/2000). In the Netherlands, the Linear Pottery Culture occupied the loess soils of the southern part of the province of Limburg between 6400 and 6100 BP (5300-5000 cal BC). There must have been contacts between the LBK people of Limburg and foragers living further north: LBK adzes are found up to 100 km north of the settled loess area (LOUWE KOOIJMANS 1998). However, the foragers did not adopt the Neolithic subsistence strategy of the LBK people, possibly because the LBK lifestyle of sedentism and intensive agriculture was incompatible with the mobile lifestyle and broad-spectrum economy of the late-Mesolithic hunter-gatherers (RAEMAEKERS 1999).

The outcome of contacts between hunter-gatherers and farmers becomes archaeologically visible from 6000 BP/4900 cal BC onwards, during the periods of the Grossgartach Culture (6000-5800 BP/4900-4700 cal BC) and the Rössen Culture (5800-5400 BP/4700-4300 cal BC), which followed the Linear Pottery Culture on the loess soils (THOMAS 1998; LÜNING 2000). From this moment onwards, pottery production and animal husbandry were to a certain extent incorporated in the subsistence strategy of the hunter-gatherer communities of the western part of the North European Plain, defining the start of the Swifterbant Culture (RAEMAEKERS 1999). The contacts between the Rössen Culture on the loess soils and the Mesolithic foragers must have been fairly intensive, because Rössen-type adzes have been found frequently in the eastern and northern Netherlands (VAN DER WAALS 1972; RAEMAEKERS 1999); from Drenthe, ca. 200 km from the nearest Rössen settlement, also some 15 Rössen-type adzes are known (see III.7.3). Lanting & Van der Plicht (1999/2000) suggest the possibility that these Rössen-type adzes were produced locally by people of the Swifterbant Culture. As a result of long-term interaction, pottery production and animal husbandry may have become less alien concepts to the Mesolithic foragers.

The Rössen Culture was followed by the Bischheim Culture (5400-5300 BP/4300-4200 cal BC) and the Michelsberg Culture (5300-5000 BP/4200-3800 cal BC). Apart from the loess areas, representatives of the latter culture also colonized the sandy areas adjacent to the loess areas, including the southern Netherlands. In this period, crop cultivation was included in the subsistence strategy of the Swifterbant Culture from at least 5300 BP/4100 cal BC (RAEMAEKERS 1999) or between 5700 and 5200 BP (4600-4000 cal BC) (BRINKKEMPER et al. 1999, 82). The start of crop cultivation in the area of the Swifterbant Culture indicates that potential problems relating to the shift of cereal cultivation from loess to sandy soils were resolved at the latest around this time (RAEMAEKERS 1999). From this time onwards, the subsistence base of the Swifterbant Culture can be described as broad-spectrum hunting and gathering, to which animal husbandry and crop cultivation were added, combined with a residential mobility strategy which involved the regular moving of residential sites among a series of resource patches (LOUWE KOOIJMANS 1998; RAEMAEKERS 1999). Cultural groups like the Swifterbant Culture in the Netherlands, the Dümmer-Hüde

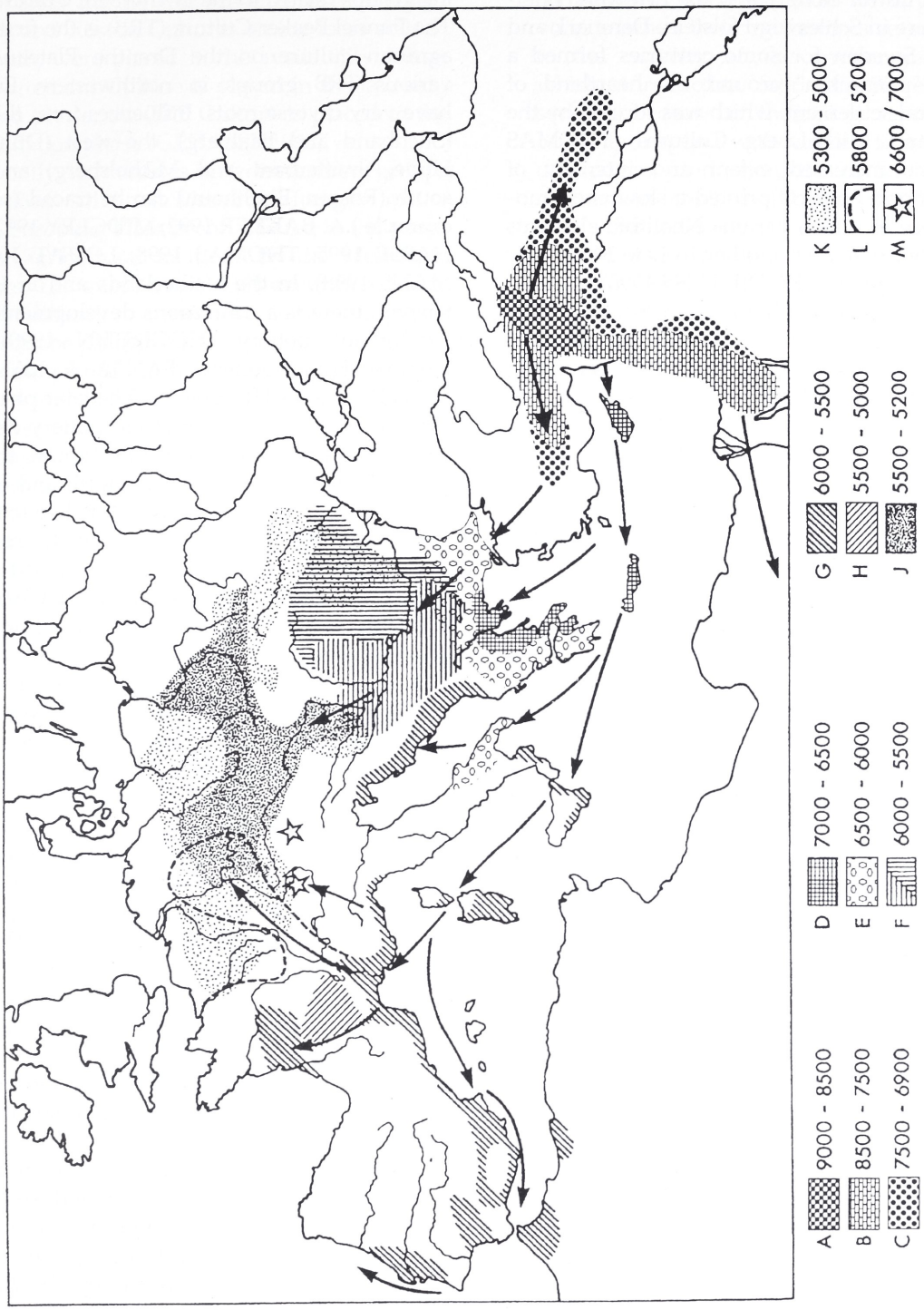


Fig. 13. The geographical origin of forms of farming economy and their expansion until 5000 cal BC. A and B: preceramic Neolithic A and B (PPN A/B); C: Late PPN B and early ceramic; D: first expansion to Europe (eastern Greece) and to mediterranean islands (Cyprus, Crete); E: western and northern Greece, Bulgaria, southeastern Italy; F: Starčevo-Körös-Criš; G: Impressa and Cardial; H: Roucadourien; I: oldest Linear Pottery Culture (LBK); K: old to young Linear Pottery Culture (LBK); L: La Hoguette (northern and eastern border); M: Late Mesolithic cereal cultivation. All dates are expressed in cal BC (after LÜNING 2000).

Group in Lower Saxony and the Ertebølle/Ellerbek Culture in Schleswig-Holstein, Denmark and southern Sweden for some centuries formed a kind of "penumbra" around the heartland of agricultural settlement, which was formed by the Rössen and Michelsberg Cultures (THOMAS 1998). The increased extent and intensity of south-to-north contacts primed a slow and gradual process in which various Neolithic elements were added one after another to Late Mesolithic economies (LOUWE KOOIJMANS 1998).

There are indications that around 6200 BP/5100 cal BC, Mesolithic foragers abandoned the river dunes in the central Netherlands. The beginning of the Calais II transgression could be one reason for this migration (HOGESTIJN 1990), but also social factors or exhaustion of the environment could have played a role (GEHASSE 1995, 196). Gehasse (1995, 196) suggests that the Mesolithic foragers moved to the Pleistocene sandy soils of the northern and central Netherlands. Gehasse assumes that it was here and at this time that the transition to farming occurred (6200-6000 BP/ 5100-4900 cal BC), because the people who migrated back to the central Netherlands after 6000 BP/4900 cal BC were fully-fledged farmers. She bases this conclusion on finds of cereal remains at the base of layer A at the site Schokland P14, which is dated 6000-5300 BP (4900-4100 cal BC) (GEHASSE 1995, 59-60). However, Brinkkemper et al. (1999) question the dates of these cereal remains. According to them, these finds probably are substantially younger than 4900 cal BC. Therefore Brinkkemper et al. (1999, 83) reject Gehasse's hypothesis that between 6200 and 6000 BP a radical change took place on the sandy soils outside the IJssel-Vecht basin, from a hunting-and-gathering to a broad-spectrum farming subsistence. With regard to the adoption of agricultural practices, Brinkkemper et al. (1999, 85) consider the possibility of intra-group variation an important issue: there may well have been areas where adoption of crop plants occurred much later or on a different scale than elsewhere. Maybe the diffusion of crop plants should be regarded as a kind of percolation process.

There are only very few Mesolithic dates of the Drenthe Plateau between 6700 and 6000 BP (5600-4900 cal BC) (LANTING & VAN DER PLICHT 1997/1998). Possibly, the Drenthe Plateau at that time was inhabited very sparsely or even not inhabited at all (FOKKENS 1990). However, a few scattered finds (see III.7.3) suggest that between ca. 6000 and 4650 BP (4900-3400 cal BC), Drenthe was inhabited by foraging and/or farming groups related to the Swifterbant Culture.

The Funnel Beaker Culture (TRB) is the first fully agrarian culture on the Drenthe Plateau. The various TRB groups in northwestern Europe have very diverse roots. Influences from the east (Stichband and Baalberg), the west (Dümmer-Hüde, Swifterbant and Michelsberg) and the south (Rössen, Bischheim) can be traced (see for example J.A. BAKKER 1992; MIDGLEY 1992; GEHASSE 1995; THOMAS 1998; LOUWE KOOIJMANS 1998). In the Netherlands and in Lower Saxony, there is a continuous development from Swifterbant pottery (HOGESTIJN 1990) and Dümmer-Hüde pottery (FANSA & KAMPFF-MEYER 1985) to TRB pottery. The later phases of Swifterbant and Dümmer-Hüde pottery demonstrate characteristics which are typical for the oldest TRB pottery in the area north and east of the Elbe. For this reason, Ten Anscher (cited in GEHASSE 1995, 199) assumes that the roots of the earliest TRB groups lie north and east of the Elbe (the Altmark region, see MIDGLEY 1992, fig. 10). Only around 4650 BP/3400 cal BC do large changes take place on the Drenthe Plateau, when several characteristics of the TRB North Group are incorporated here. This event marks the beginning of the TRB West Group, west of the Elbe (J.A. BAKKER 1979; 1992).

Zvelebil & Rowley-Conwy (1984; see also ZVELEBIL 1986) formulated a three-phase model for the transition to agriculture: the availability model. In the view of these authors, the process towards the adoption of farming passes through several "frontier" situations, which may occur simultaneously in geographical space. The entire zone of foraging-farming interaction is regarded as a frontier, rather than merely the line of forager-farmer contact. In the availability model, the following three phases are distinguished (ZVELEBIL 1986):

1. availability phase: farming is known to the foraging groups in question and some exchange of materials and information goes on between farming and foraging settlements, yet farming is not adopted by the hunter-gatherer communities.
2. substitution phase: foragers have added elements of farming to their range of subsistence strategies.
3. consolidation phase: arable farming and stock keeping become dominant over hunting and gathering.

In terms of the Dutch situation, the foragers living in the central and northern parts of the

Netherlands during the presence of the Linear Pottery and Rössen Cultures on the loess soils in the south, were placed in the availability phase; the Swifterbant Culture is placed in the late substitution phase; the TRB Culture is placed in the consolidation phase (GEHASSE 1995).

Apparently, the contacts between farming groups of the loess soils and Mesolithic foragers of the North European Plain eventually led to the adoption of agricultural methods by the Mesolithic foragers. The question *why* this event took place, is as yet difficult to answer. Three types of explanation can be put forward:

1. environmental reasons: Potential environmental factors that might have affected the balance between people and available food include changes in climate, sea level, marine resources, usable land area and vegetation (PRICE et al. 1995).
2. social reasons: Cereals and livestock might have been introduced into Mesolithic societies as prestige goods. Gradually, their importance increased until they became dominant in the food economy. Parallel to this slow development, an adaptation of the social structure of the society occurred (JENNBERT 1985).
3. combination of environmental and social reasons: After the withdrawal of the ice cap, the biomass of the primary producers steadily increased, followed by those of the primary consumers, like the large herbivores. Because of the abundance of food, the social inhibition mechanism on population growth was switched off and group size increased. At a certain time, the populations of large herbivores reached their maximum size in relation to the capacity of the environment, after which a reduction followed. Since human societies because of their slow reproduction can only respond with a delay to a decrease of biomass production, the social inhibition mechanism could not be applied immediately. This led to overpopulation, food shortages and social stress. Solutions to this situation were a partial migration of the population to other areas or the transition to farming (GROENMAN-VAN WAATERINGE 1988).

For the Dutch situation, a combination of environmental and social reasons seems the best explanation (GEHASSE 1995, 193). Concluding, it can be stated that in the Netherlands, the incorporation of arable farming and stock keeping into subsistence economies formerly based on hunting and gathering did not follow a fixed and straightforward course. Instead, it was a strongly fluctuating process, in which sometimes arable farming and stock keeping, sometimes hunting and gathering were more important, dependent on environmental and social factors (GEHASSE 1995). In the Netherlands, interaction, exchange, adoption and acculturation are sufficient to explain the transformation from hunting-gathering to farming. Apart from the initial Neolithic (the Linear Pottery Culture), no migrations or physical expansions are needed. There is enough positive evidence for demographic continuity (LOUWE KOOIJMANS 1998).

III. The Drenthe Plateau: physical environment, vegetation and archaeology

III.1 Topography

The subject of this study is the Gietsenveentje, presumably a pingo scar, situated near the village of Gieten in the province of Drenthe, the Netherlands. The location of the Gietsenveentje in the Netherlands is shown in fig. 14. The Gietsenveentje is situated on the Hondsrug, a ridge that is part of the Drenthe Plateau (fig. 14). The Drenthe Plateau is the visible part of a till complex, formed during the Saalian glaciation (see III.2.1). In the north and west, the till plain disappears under marine and fen-peat deposits formed in the Holocene. In the east and south, the Drenthe Plateau is bounded by two originally deep valleys, which were also formed during the Saalian glaciation and which since have largely filled up: the Hunze valley and the Vecht valley.
Fig. 15 shows a recent topographical map of the Gietsenveentje and near surroundings. This map represents an area of ca. 4.5 x 4.5 km; the Gietsenveentje lies in the centre. The coordinates of the centre of the Gietsenveentje are 246.30/558.90. Possibly, the name of the Gietsenveentje is derived from the Proto-Germanic water name "Gets". This suggests that the Gietsenveentje and also the village of Gieten are named after a stream, called "Giets", which in earlier times ran along the western side of the village (KLAASSENS-PERDOK 1983, 8).

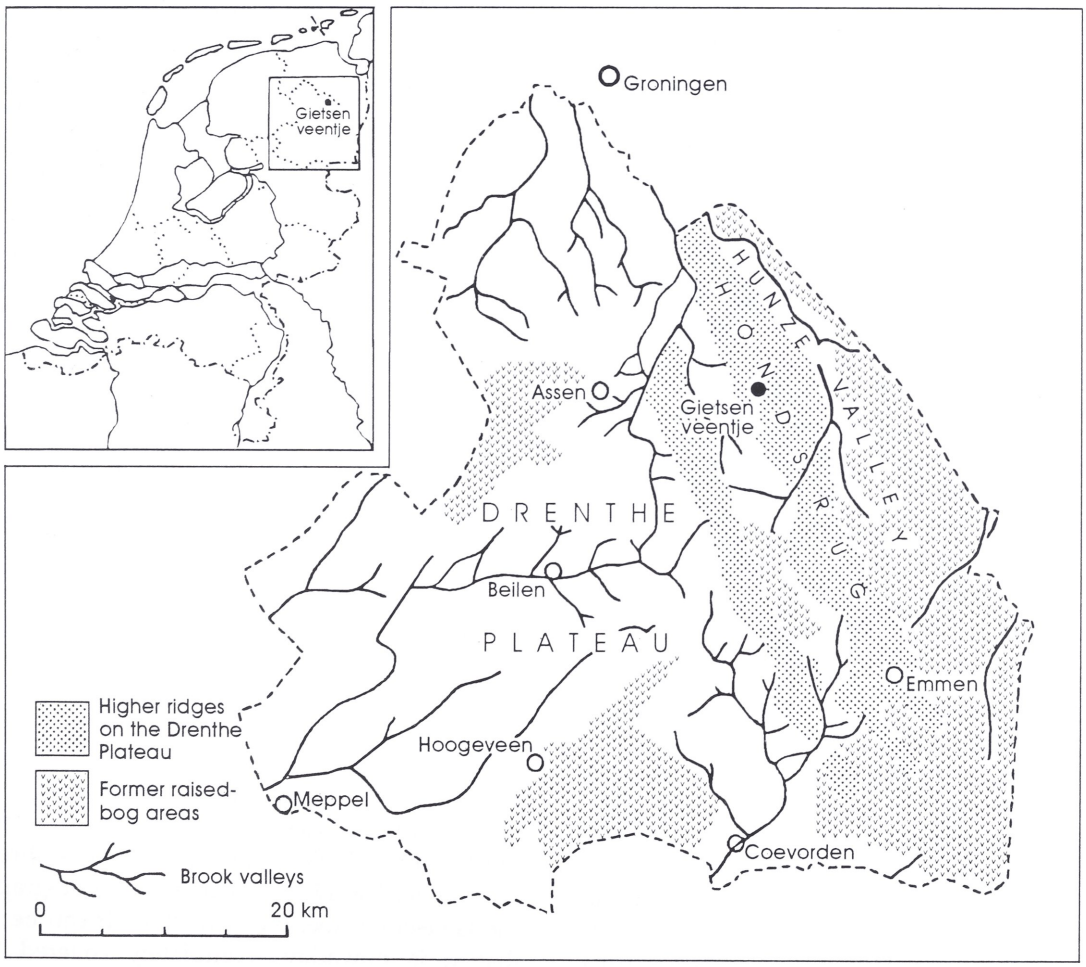


Fig. 14. Location of the Gietsenveentje in the Netherlands and overview of the part of the Drenthe Plateau located in the province of Drenthe (after TER WEE 1984, adapted).

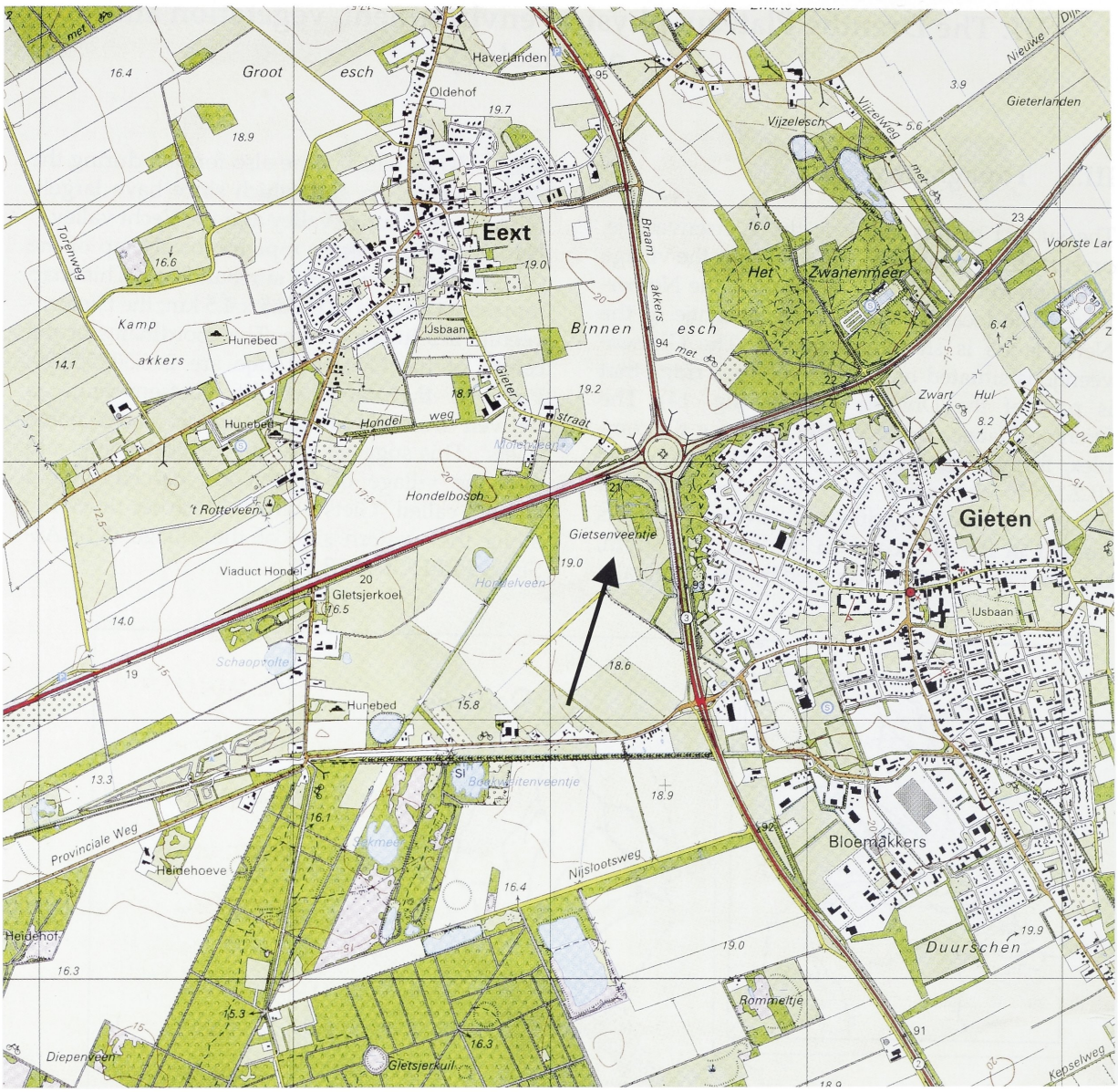


Fig. 15. Topographical map of 2001 of the Gietsenveentje and its surroundings, scale 1:25,000, made by the Dutch Topographical Service. © Topografische Dienst, Emmen.

In fig. 16, a contour map of the same area is shown. The Hondsrug ridge can be easily recognized: it extends from southeast to northwest. The highest parts of the Hondsrug are formed by man-made plaggen soils (*essen*, see III.3.2). The Gietsenveentje lies in the midst of these elevated plaggen soils; within a few hundred metres of the Gietsenveentje, heights of more than 20 metres occur. To the northeast, the Hondsrug dips steeply to the Hunze valley; to the southwest, it slopes far more gently. In the west, the embranchments of an ancient valley system can be recognized. Probably the above-mentioned stream called "Giets" once ran through this valley. Further downstream (outside the map), the Scheebroekerloop nowadays flows through this valley. Fig. 17 shows an aerial photograph of the Gietsenveentje, taken in 1995. It can be seen that it is nowadays completely covered with woodland of various types.

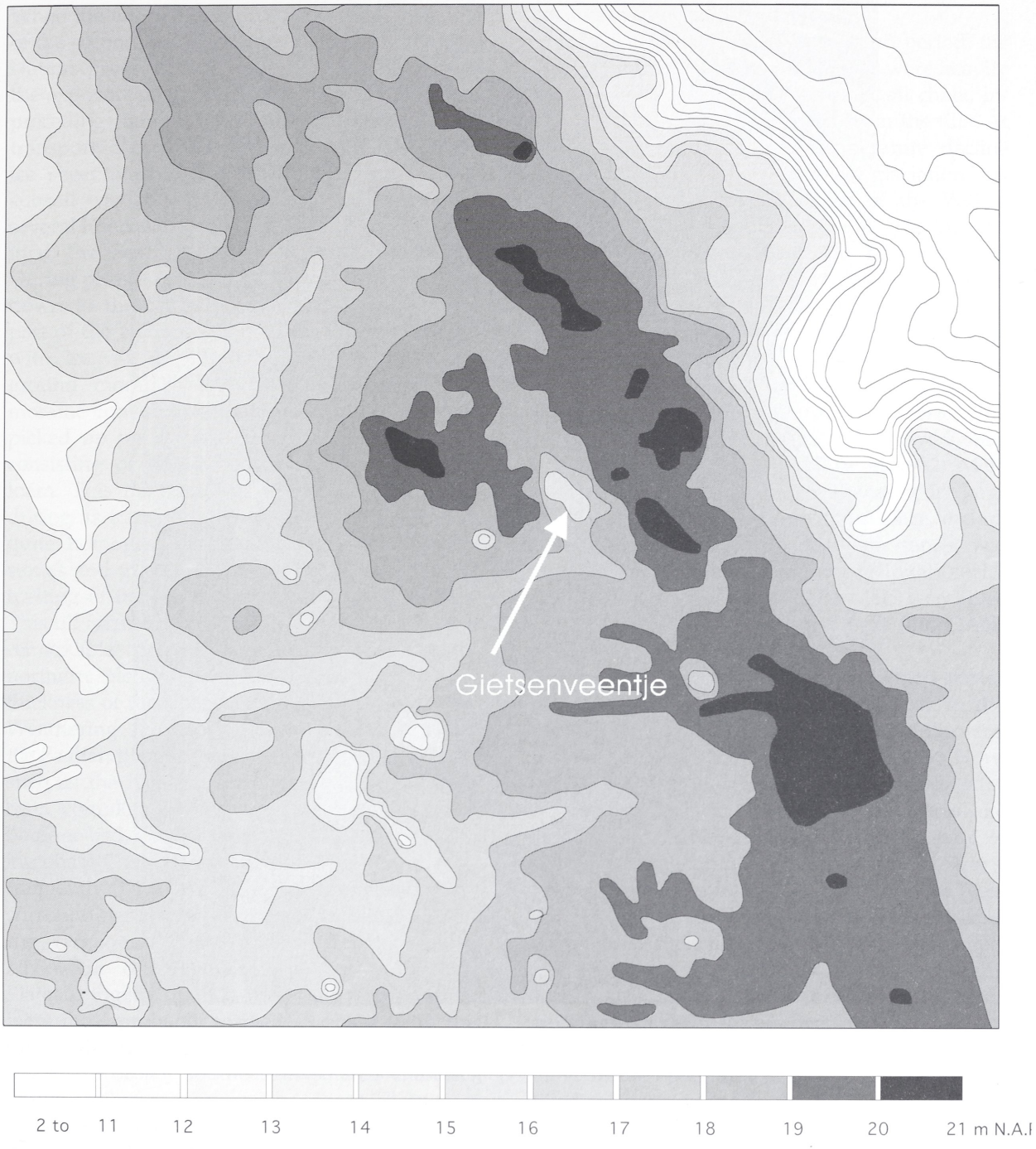


Fig. 16. Contour map of the Gietsenveentje and its surroundings, scale 1:25,000. The map covers the same area as the map of fig. 15. The location of the Gietsenveentje is indicated.



Fig. 17. Aerial photograph of the Gietsenveentje, taken in 1995 by the Dutch Topographical Service. © Topografische Dienst, Emmen.

III.2 Geology and geomorphology

III.2.1 Geological history

When the geological history of Drenthe is reconstructed, it can be seen that the ice sheets of the Saalian glaciation laid the foundation for the landscape as it is today. However, also older sediments, the so-called pre-Saalian sediments, played a role in the formation of the landscape (NIJLAND et al. 1982). In some places, these sediments even occur at or very near the surface.

In the Tertiary, the activities of large river systems prevailed, resulting in the deposition of thick sand layers. Later, from the beginning of the Pleistocene onwards, cold periods, called glaciations, dominated the climate. During the third last glaciation, the Elsterian, the ice sheet came very close to the northern part of the Netherlands (TER WEE 1983b), or even covered the area (BOSCH 1992, 67). Fine sand layers were deposited, as well as the so-called pottery clay (Dutch: *potklei*). These sediments were both deposited by meltwater from the ice sheet.

When the temperature dropped at the beginning of the second last glaciation, the Saalian, the vegetation progressively disappeared. This caused the exposure of the fine-sanded sediments of the preceding interglacial. These sediments were transported by wind and meltwater. When the ice sheet reached Drenthe, the already frozen subsoil was covered in ice with a thickness of several hundred metres. Ter Wee (1983a) has divided the Saalian glaciation into five phases. During phases A, B and C, the ice sheet advanced down to the central Netherlands; the northern part of the Netherlands was completely covered with ice. At the interface of land and ice, a ground moraine was deposited. This ground moraine consisted of material which the ice had picked up on its way down from Scandinavia, consisting of boulders, gravel, sand, clay and loam. This material was crushed and kneaded during its transportation under the ice layer to a quite homogeneous mass of sandy loam with stones and gravel and a few boulders. After the melting of the ice, this material remained as till. This till formed the rather flat Drenthe Plateau, a remarkable geomorphological feature in the northern Netherlands (TER WEE 1983a). The thickness of the till deposit varies from 2 to 8 m. Weathering and erosion have removed part of the Saalian tills. In some parts of the higher areas such as the Hondsrug ridge, the tills may have been completely removed, leaving only a thin boulder bed. The bluish-grey till deposited during phase C of the Saalian occurs in Drenthe most frequently (DE GANS 1981); it occurs also in the surroundings of the Gietsenveentje. The Hondsrug ridge and some other, less pronounced, NNW-SSE orientated ridges on the Drenthe Plateau, together called the Hondsrug complex, were most probably formed in phase C. In this phase, the ice did not move uniformly: a part moved in broad, southeast-orientated channels, while another part moved hardly at all or even stagnated. The Hondsrug complex was formed at the edge of these channels (VAN DEN BERG & BEETS 1986, fig. 9). During phase D of the Saalian, the ice sheet advanced only down to the line Coevorden-Hoogeveen-Steenwijk. Glacier lobes eroded tongue basins and pushed older material into ridges. The meltwater eroded a deep ice-marginal valley: the Proto-Vecht valley. During phase E of the Saalian, the ice sheet advanced even less far, and reached only the line Sellingen-Vlagtwedde-Delfzijl. Here also tongue basins and ridges were formed by the ice sheet. Also an ice-marginal valley was eroded by the meltwater: the Proto-Hunze valley.

The Saalian was followed by a warm period, the Eemian. During the Eemian, the tills were heavily weathered and leached. Practically all chalk, including limestone, disappeared from the tills. At the end of the Eemian, a temperature decline marked the beginning of the last glaciation, the Weichselian. The coldest phase of the Weichselian is also called Pleniglacial. During the Weichselian, the ice sheet did not reach the Netherlands. In Drenthe, only indirect effects of the ice expansion were noticeable. Because of the storage of water in the form of ice in the ice cap, the sea level dropped. This enabled rivers and streams to incise their courses deeper and further inland. On the Hondsrug, numerous erosion valleys were formed, including the cross-watershed channel near Borger (NIJLAND et al. 1982). Meltwater was flowing through the area in large quantities, so that material at the surface, including the Eemian soil and meltwater sands, was removed. Later, under cold but precipitation-rich conditions, the river and brook valleys were filled up by gravel, sand, loam and peat (DE GANS 1981).

The last phase of the Weichselian, which started ca. 12,800 BP, is also called Late Glacial. In this period, the climate became drier and the temperature already increased considerably. However, this rise in temperature occurred saltatorally: in the Late Glacial, various warm and cold periods can be recognized. During the cold periods, degeneration of the vegetation transformed Drenthe into a polar desert. Under these conditions, the dry sand of the valley plains, which were sparsely covered with vegetation, and of the weathered and leached till plateaus, was taken up by the wind and deposited elsewhere in the form of coversand. As its name already indicates, the coversand was deposited like a blanket over almost the entire landscape. It filled up depressions in the till surface, but also created coversand ridges. The thickness of the coversand locally varies strongly, from ca. 0.5 to more than 2 m. The gently undulating character of the coversand points to an aeolian origin and is characteristic for the coversand landscape. During the somewhat warmer periods, peaty sediments were deposited.

The landscape in Drenthe reached its present form during the Holocene. The Holocene began ca. 10,150 BP (see appendix II) and continues up to the present day. As a consequence of the climatic improvement, the tundra landscape of the Late Glacial could develop into an open forest

with birch and pine. Later on in the Holocene, under the influence of an increasingly warmer and more humid climate, Drenthe saw the development of a deciduous forest with many species. The continuously rising sea level caused a rising water table inland, which subsequently caused the formation of marsh vegetation in wetter places and the consequent development of peat sediments. In the Holocene, three important types of sediment were formed: brook valley and fen peat sediments, ombrogenous peat sediments and driftsand sediments (CASTEL 1992). In the central part of the brook valleys, fen peat developed, made up of reed and sedge peat, in deposits with a thickness of up to a few metres. Ombrogenous peat consists particularly of peat moss (*Sphagnum*). Until a century ago, extensive raised-bog complexes occurred on the lower and flat parts of the Drenthe Plateau (RAPPOL 1992, fig. 1.1). Most of the peat has been removed to be used as fuel (*turf*). Driftsands are Holocene sands, deposited by the wind, formed by local shifting of the underlying Pleistocene sediments. They can be easily recognized by their chaotic relief: over short distances, relatively large differences in elevation can occur. Most of the present driftsands in Drenthe are man-made: because man destroyed the vegetation, the subsoil was exposed and the Pleistocene sand was taken up by the wind and deposited elsewhere.

III.2.2 The growth and decay of pingos

A conspicuous periglacial phenomenon is the growth of pingos. Because the Gietsenveentje is most probably a pingo scar, the growth of pingos will be discussed more in detail. The term "pingo" is an Inuit word for mound, which in the 1930s was adopted by geologists to indicate mounds with a core of ice. These mounds are common appearances in certain parts of Alaska, Canada, Siberia and Greenland (CASTEL & RAPPOL 1992). Pingos arise mostly in permafrost areas, through the forming of an ice lens a few metres below the surface. This lens grows gradually, but it cannot extend downwards because of the permanently frozen soil, so it can only grow upwards. In this process, the overlying soil is pushed up, so that a mound is formed. These mounds range in height from 3 to 70 m and in diameter from 30 to 600 m (MACKAY 1962). The ice lens mostly occurs between depths of 2 and 10 m beneath the surface. Two types of pingo can be distinguished:

- open-system (hydraulic) pingos, which are related to discontinuous permafrost conditions and are located on weak slopes and in valleys (HOLMES et al. 1968). They receive the water to grow their ice cores from artesian pressure (seepage);
- closed-system (hydrostatic) pingos, which are related to continuous permafrost conditions and are located on flat ground in former lake environments. They receive the water to grow their ice cores from pore-water expelled in advance of an aggrading lower permafrost surface (MACKAY 1979).

Continuous growth of a pingo leads to the sliding down of the covering soil layers under the influence of gravity. Consequently, the ice core is exposed to sunlight and begins to melt. The result will be that a depression remains, surrounded by a rampart of slope material: a so-called "pingo scar". However, the presence of a rampart around a depression is no clear criterion, because many pingo scars do not or no longer have a rampart, while aeolian depressions of later age may indeed have a rampart, built up of coversand (T.W.M. BAKKER et al. 1986).

On the Drenthe Plateau, there are hundreds of depressions filled with gyttja, peat and/or water. If these depressions have a depth of more than 2 metres, they are nearly always pingo scars (DE GANS 1981, 93). According to De Gans (1981, 89), the pingos on the Drenthe Plateau were formed during the last part of the Pleniglacial, the coldest period of the Weichselian, between ca. 25,000 and 18,000 BP. At that time, most probably a continuous permafrost prevailed in the Netherlands. So far, the earliest organic infilling of pingo scars is variously dated between the Upper Pleniglacial and early phases of the Late Glacial (DE GANS 1981, 89). However, the earliest infilling of a pingo scar does not necessarily indicate the point in time when the transformation from pingo to pingo scar was completed. Some pingo scars situated on high parts of the Hondsrug never even contained any water, so that no sediment was deposited at all (MOOKKAMPS & BOTTEMA 1987). On the Drenthe Plateau, the transformation from pingo to pingo scar is thought to have taken place between ca. 18,000 and 13,000 BP (T.W.M. BAKKER et al. 1986).

De Gans (1981) studied the locations of a large number of pingos on the Drenthe Plateau. He demonstrated that these pingos always lie in former, generally indiscernable, upstream parts of tributary valleys. During the Pleniglacial these

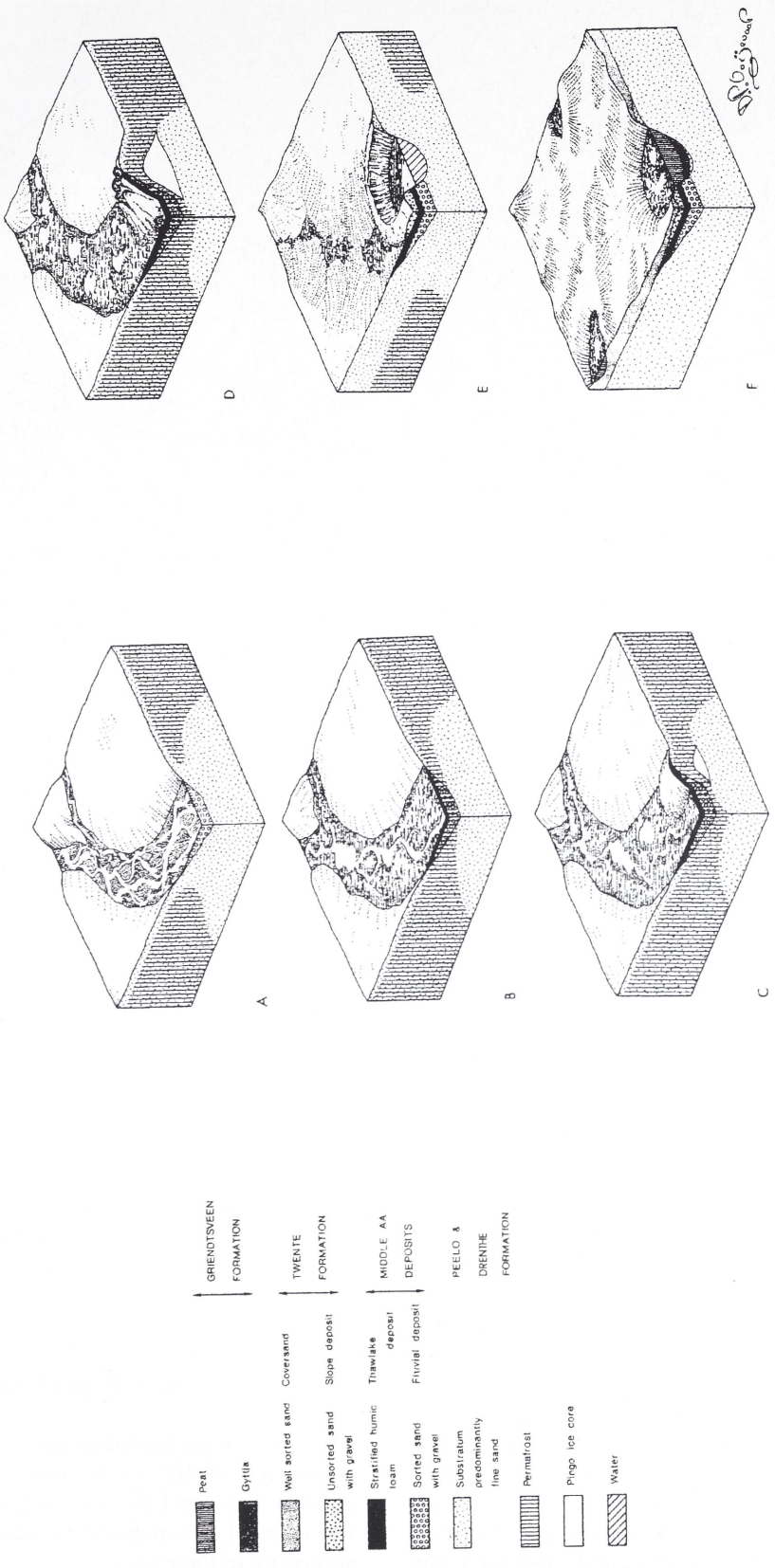
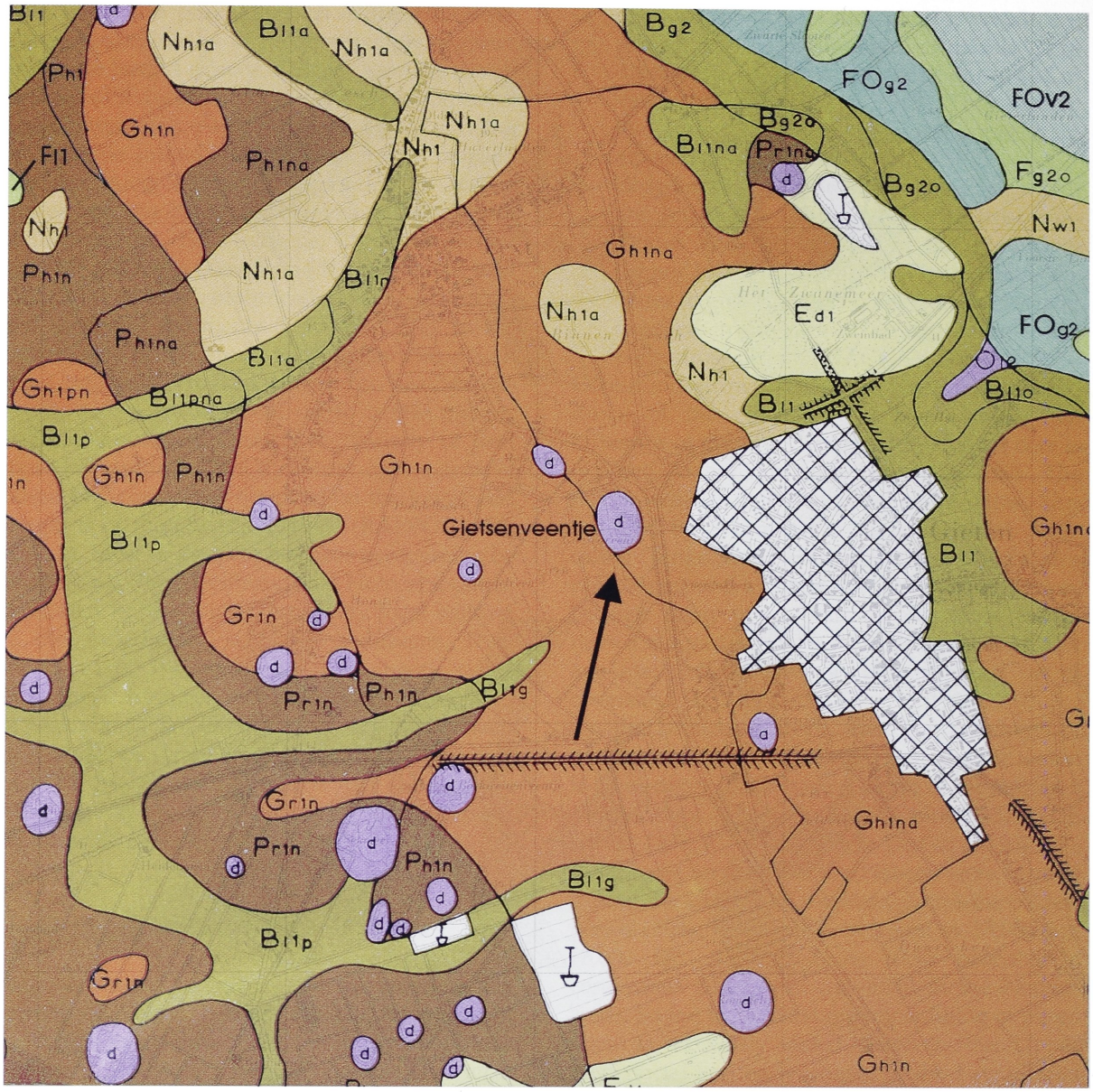


Fig. 18. Growth and decay of a closed-system pingo (after DE GANS 1981).



valleys were filled with fluvial sediments. At the top of these deposits, humic or peaty loam layers occur, which are thought to have been deposited in thaw lakes (DE GANS 1981, 45 ff.). The growth of pingos is believed to have occurred predominantly in a thaw lake environment. However, the presence of thaw lakes in Drenthe during the Pleniglacial is questioned nowadays (pers. comm. P. Cleveringa). The low relief on the Drenthe Plateau, the assumed presence of continuous permafrost and the occurrence of till on the watersheds which prevents the development of source areas for groundwater necessary for open-system pingo growth: all these circumstances seem to indicate that the pingos on the Drenthe Plateau, including the Gietsenveentje, are closed-system (hydrostatic) pingos. In fig. 18, the growth and decay of such a closed-system pingo is illustrated.

III.2.3 The surroundings of the Gietsenveentje

Fig. 19 is a geomorphological map of the surroundings of the Gietsenveentje, showing the genesis and the form of the present landscape. The units of this map will be discussed, classified according to their age.

Pre-Saalian. In the eastern part of the map area, where the Hondsrug descends gently, pre-

Fig. 19 (left). Geomorphological map of the Gietsenveentje and its surroundings, scale 1:25,000, made by the Planning Service of the Province of Drenthe (NIJLAND et al. 1982). The map covers the same area as the map of fig. 15. The map shows two aspects of the landscape: the genesis and the form (morphology). The following units can be distinguished, classified according to their age:

Pre-Saalian (Elsterian, beginning of Saalian)
P pre-Saalian deposits within 120 cm below the surface

Saalian
G till within 120 cm below the surface: glacial

Weichselian
N coversand with a thickness of more than 120 cm: niveo-aeolian
...n coversand with a thickness of 40-120 cm on top of other deposits: niveo-aeolian
Bl forms created by the effects of water and soil ice in a cold climate: periglacial: erosion valley
Bg forms created by the effects of water and soil ice in a cold climate: periglacial: talus slope

Holocene
E forms created by wind in a temperate climate: aeolian: driftsand
O deposits and forms created by peat forming and peat digging: organogenic
F stream deposits created under the influence of running water: fluviatile
FO peat deposits created under the influence of running water
...a cultural layer thicker than 40 cm on top of other deposits

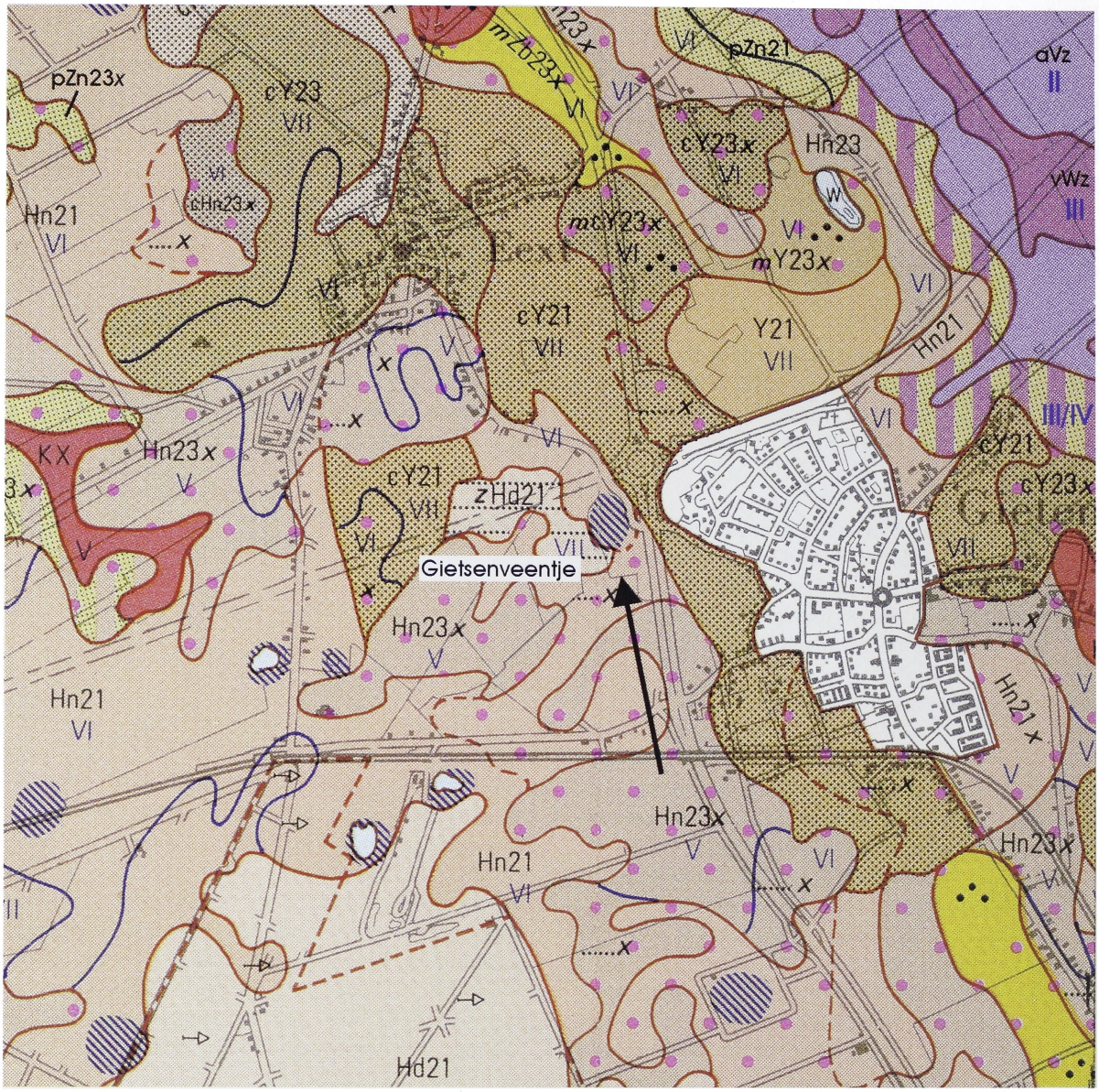
d circular depression (often a pingo scar)

Saalian sands occur within 120 cm below the surface. Here, the once present Saalian till has disappeared completely through erosion.

Saalian. On the highest parts of the Hondsrug (cf. fig. 16), including the Gietsenveentje, an extensive complex of Saalian till occurs within 120 cm below the surface.

Weichselian. In the eastern part of the map area, the contours of a Weichselian periglacial erosion valley are clearly visible. During the Weichselian, this valley, an embranchment of which almost reaches the Gietsenveentje, was part of the Drentse Aa valley. As a consequence of erosion in the Weichselian, pottery clay from the Elsterian (pre-Saalian) occurs near the surface in the lower part of the valley (see the soil map, fig. 20). Until about a century ago, the Scheebroekerloop flowed through the lower part of this valley (see fig. 27). Many circular depressions (mostly pingo scars) occur in the neighbourhood of the erosion valley, thus confirming the hypothesis that pingos are formed in upstream parts of tributary valleys (DE GANS 1981; see III.2.2). Another, smaller periglacial erosion valley occurs northeast of the village of Gieten. On part of the steep slope between the Hondsrug and the Hunze valley, the shape of a Weichselian talus slope can be recognized. At some places on the Hondsrug, particularly in the northern part of the map, the Weichselian coversand reaches a thickness of more than 120 cm. The pre-Saalian and Saalian deposits are mostly covered by a coversand layer of 40-120 cm.

Holocene. North of the village of Gieten, a Holocene driftsand area occurs, which in later times was planted with oak forest, in order to fix the sand. In the northwestern part of the map area, Holocene fluviatile deposits, sometimes mixed with peat, occur in the low-lying Hunze valley. In the vicinity of the villages of Gieten and Eext, a culture layer thicker than 40 cm occurs on top of the other sediments. These so-called plaggen soils (Dutch: *essen*) are artificial elevations in the neighbourhood of villages (see III.3.2).



III.3 Soil

III.3.1 General remarks

Soil is defined as the upper part of the earth's crust, with properties which differ from the underlying parent material as a consequence of the effects of climate, relief and living organisms. In the Netherlands, the parent material is to a large extent supplied from elsewhere by wind, sea, rivers and ice. The parent material can also be formed locally, for example by the accumulation of organic material (peat) (STIBOKA 1977). The most important soil-formation processes on the higher sandy soils of the Drenthe Plateau are podzolization, the forming of gley and pseudogley, disintegration of mineral compounds and homogenization by plant roots and soil fauna. Podzolization involves the eluviation of predominantly humic acids, formed by the decomposition of plants; as a consequence, various layers are formed, the soil horizons: the A horizon is the eluvial layer, the B horizon the illuvial layer (DE BAKKER & SCHELLING 1989).

Fig. 20 (left). Soil map of the Gietsenveentje and its surroundings, scale 1:25,000, made by the Dutch Foundation for Soil Mapping (STIBOKA 1977). The map covers the same area as the map of fig. 15. The soils are classified according to the classification by De Bakker & Schelling (1989).

Peat soils
aVz earthy, clay-poor peat soils: *made* peat soils on sand

Earth soils
vWz peaty earth soils on sand
pZn21/23 sandy hydroearth soils: *goor* earth soils

Glacial clay soils
KX glacial clay soils: till or pottery clay (*potklei*) within 50 cm below the surface

Vague soils
*m*Zb23*x* sandy xerovague soils: *vorst* vague soils

Podzol soils
Y21/23 moder podzol soils: *holt* podzol soils
cY21/23 moder podzol soils: *loo* podzol soils
Hn21/23 humus podzol soils: *veld* podzol soils
Hd21 humus podzol soils: *haar* podzol soils

code 21 in all units: fine sand with little or no loam
code 23 in all units: loamy fine sand

z... sand cover of 15-40 cm
...*x* and purple-stippled areas:
till or pottery clay beginning between 40 and 120 cm below the surface and at least 20 cm thick

hatched: circular depression

Groundwater stages
I-IV average highest level less than 40 cm below surface, average lowest level less than 120 cm below surface
V average highest level less than 40 cm below surface, average lowest level more than 120 cm below surface
VI average highest level 40-80 cm below surface, average lowest level more than 120 cm below surface
VII average highest level more than 80 cm below surface, average lowest level more than 160 cm below surface

Gley and pseudogley phenomena occur when the groundwater level is located near the surface. Gley appears as grey-coloured layers, formed as a consequence of a lack of oxygen, often with red-brown rust spots, which arise where air can penetrate into the layer. Pseudogley demonstrates an opposite rust picture: a red-brown, rusty matrix with grey spots. Pseudogley can be found near surfaces where rainwater temporarily stagnates, for example because of the presence of a till layer. Pseudogley is an indicator of water stagnation (SPEK 1993).

III.3.2 Soil types in the surroundings of the Gietsenveentje

Fig. 20 is a soil map of the surroundings of the Gietsenveentje. The units of this map will be discussed.

Peat soils. In the low-lying Hunze valley in the northeast, *made* peat soils occur: soils with a well-developed earthy layer (A1 horizon) on top of a more than 40 cm thick layer of mainly sedge peat.

Earth soils. Earth soils form the transition between peat soils and mineral soils. In the Hunze valley in the northeast, peaty earth soils occur: earth soils with a peaty layer of less than 40 cm. On the steep slope between the Hondsrug

and the Hunze valley and on the slopes of the valley of the Scheebroekerloop (western part of the map area), *goor* earth soils occur. These soils have a distinct humic top layer, but lack a podzol profile. During the formation of these soils, the groundwater level regularly reached a level just below the surface. In *goor* earth soils, almost no gley is observed; they occur in areas without seepage (NIJLAND et al. 1982).

Glacial clay soils (pottery clay and till soils). In the former valley of the Scheebroekerloop in the western part of the map area, pottery clay occurs within 50 cm below the surface. In two locations on the Hondsrug, at the northern and eastern edge of the map area, till occurs within 50 cm below the surface. Because of the impermeable pottery clay or till layers not far below the surface, wet pseudogley profiles rich in stagnation rust were formed at these locations.

Vague soils. Locations where a more sandy and permeable till occurs within 50 cm below the surface may have brown earth soils. These soils, belonging to the *vorst* vague soils, occur in the map area on high parts of the Hondsrug in the north and southeast.

Podzol soils. Podzol soils, which can be formed in any type of sandy soil, are characterized by a clear illuvial layer (B horizon). They are by far the most common soil type in the vicinity of the Gietsenveentje. Two main types can be distinguished on the basis of the form of humus in the illuvial layer: moder podzols and humus podzols.

Moder podzol soils. In moder podzol soils, the illuviated humus is granular and loose-structured. Moder podzols show characteristics of podzolization as well as mineral disintegration. They occur high above the groundwater at locations which have traditionally been forested or where the soil characteristics have been conserved by a manure cover on top of the soil (NIJLAND et al. 1982). Two types of moder podzol are distinguished. *Holt* podzols are moder podzols with a thin (up to 30 cm) humic top layer. They are characteristic of ancient forest remnants, but also occur in the younger parts of the plaggen soils (*essen*). They are found north of the village of Gieten, in an area where a relatively old forest occurs (see figs. 25-28). *Loo* podzols are moder podzols with a moderately thick (30 to 50 cm) humic top layer (manure layer). They were formed by centuries of fertilizing with manured heather sods (plaggen). These soils occur near the villages of Gieten and Eext: they are equivalent to the plaggen soils (*essen*).

Humus podzol soils. In humus podzol soils, the illuviated humus is amorphous, i.e. it has no clear structure. The B horizon is often so much compressed, that it is almost impermeable to water and plant roots. The most common group of humus podzol soils is formed by the *veld* podzol soils. These soils are characteristic of moist heathfields, most of which are reclaimed nowadays (NIJLAND et al. 1982). *Veld* podzols, moist to wet, poor podzols, are formed when the groundwater level has regularly reached a level near the surface, but when net water movement has still occurred in a downward direction (SPEK 1993, 181). They show characteristics of podzolization as well as gley. In the map area, *veld* podzols occur on the high parts of the Hondsrug and also further west, in locations where heathfields have occurred in the recent past (see fig. 27). In better-drained sandy areas, where the groundwater level never reached the B horizon, *haar* podzol soils occur. *Haar* podzols, which have a strongly eluviated A2 horizon and a well-developed B horizon, are characteristic of dry heathfields and heath reclamations. All *haar* podzols under (former) heathfields are secondary podzols, formed by the degradation of moder podzol soils. In the map area, *haar* podzols occur in the south, on the western slope of the Hondsrug, and in a small area directly west of the Gietsenveentje; these also are locations where heathfields occurred in the more recent past (see fig. 27).

III.3.3 Determination of potential natural vegetation on the basis of occurring soil types

The process of soil formation depends on climate, relief, parent material and vegetation. The effects of parent material and vegetation on soil forming are strongly interrelated. The vegetation history is also heavily dependent on the influence of man. This means that there is an indirect relationship between occupation history and soil formation (SPEK 1993). An example is the forming of secondary podzols under heathfields, which have been created by man. The profile characteristics of the various soil types in the direct surroundings of the Gietsenveentje give a picture of soil genesis and, indirectly, also of vegetation history and man's influence on it.

Spek (1993, 178) has classified the modern soil types of the higher parts of the Drenthe Plateau

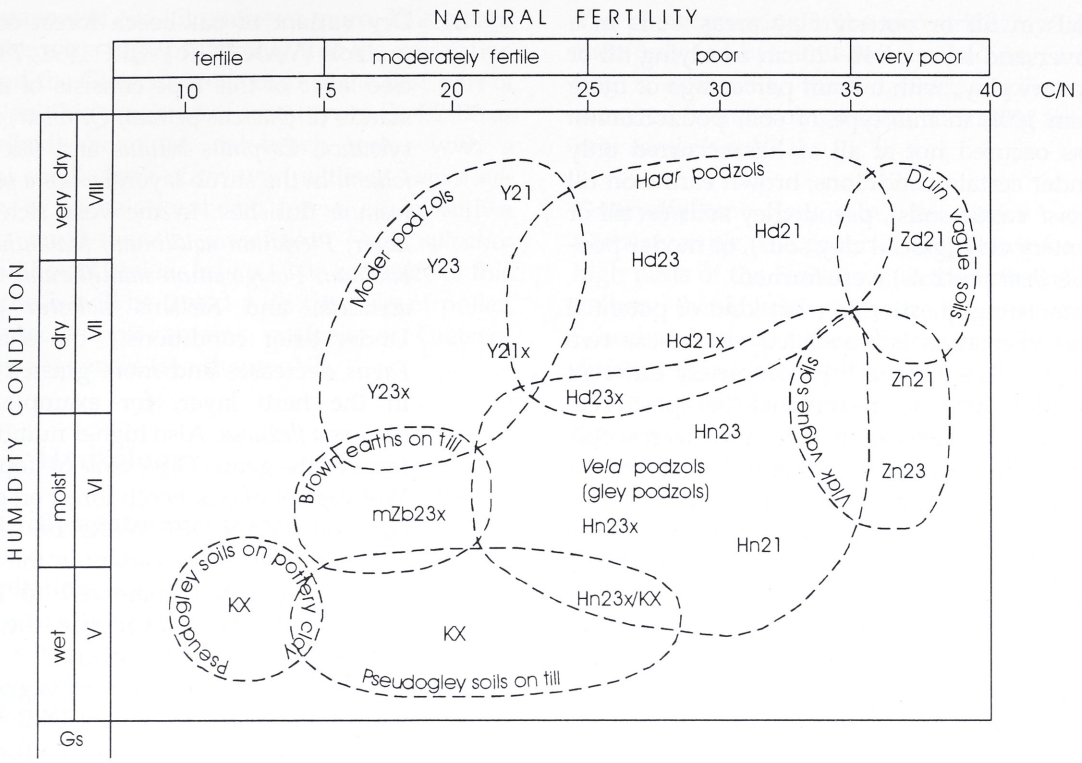


Fig. 21. Ecological soil diagram of the higher sandy parts of the Drenthe Plateau (after SPEK 1993). On the horizontal axis, the C/N ratio of the upper soil layer is plotted as a measure of natural soil fertility. On the vertical axis, the humidity condition is indicated, represented by the groundwater stage. The broken lines indicate the 70% confidence interval per soil group, which means that 70% of observations will fall within the envelope.

according to moisture conditions and soil fertility. The result is a so-called ecological soil diagram. This diagram is shown in fig. 21. The soil fertility is measured by the C/N ratio (C: carbon, N: nitrogen) of the upper soil layer: the poorer a soil is, the less nitrogen it contains, and the higher the C/N ratio. To characterize moisture conditions, groundwater stages (also indicated on the soil map of fig. 20) are used.

The poorest soils in the surroundings of the Gietsenveentje are the humus podzols: *haar* podzols, occurring under dry conditions, and *veld* podzols, occurring under moist to wet conditions. Somewhat more fertile are the moder podzols, occurring under dry conditions. The most fertile soils in the vicinity of the Gietsenveentje occur where pottery clay or till is present near the surface: brown earths on till (*vorst* vague soils), and pseudogley soils on till (glacial clay soils). The most fertile (but very wet) area in the surroundings of the Gietsenveentje is the former valley of the Scheebroekerloop, where pottery clay occurs near the surface. Pseudogley soils on pottery clay are somewhat more fertile than pseudogley soils on till (fig. 21). We have to keep in mind that man has played a very important role in soil formation around the Gietsenveentje: the *loo* podzols occur in man-made plaggen soils (*essen*); the *veld* and *haar* podzols occur in man-made heathland. It is likely that all recent *veld* and *haar* podzols in this area are secondary podzols. When the soil types occurring in this area at the beginning of the Neolithic are considered, the *loo* podzols and the secondary humus podzols can be discounted. A division of the "natural" soil types of the higher parts of the Hondsrug, which is essential with regard to the vegetation which in the past grew on these soils, is the following:

A. Soils in coversand or pre-Saalian sand areas: soils in a coversand or pre-Saalian sand layer of more than 120 cm, with a loam percentage of less than 10%; in this type of soil, podzolization has always occurred (primary podzolization); primary humus podzols (*veld* and *haar* podzols) were formed;

B. Soils in till or pottery clay areas: soils in a coversand layer of 40-120 cm overlying till or pottery clay, with a loam percentage of more than 10%; in this type of soil, podzolization has occured not at all or has occurred only under certain conditions; brown earths on till (*vorst* vague soils), pseudogley soils on till or pottery clay (glacial clay soils), or moder podzols (*holt* podzols) were formed.

An interesting question is what kind of potential natural vegetation is associated with these two soil types. This approach is completely different from attempting to reconstruct the past vegetation on the basis of pollen and macroscopic remains. The potential natural vegetation is defined as the highest developed natural vegetation which is possible in a certain location under the present environmental conditions (SPEK 1993, 181).

A. Potential natural vegetation of coversand or pre-Saalian sand areas: birch-common oak forest (*Betulo-Quercetum roboris*; VAN DER WERF 1991; STORTELDER et al. 1999): an open-structured forest rather poor in species. The wetter the soil, the larger the share of *Betula* compared to *Quercus*.
   A1. Dry variant of birch-common oak forest on *haar* podzols (VAN DER WERF 1991, 64): domination of *Quercus robur* and *Betula pendula*. In the shrub layer, *Sorbus aucuparia* and *Rhamnus frangula* occur in small numbers. The herb layer is also rather poor, and is often dominated by the grass species *Deschampsia flexuosa* or by *Vaccinium myrtillus*.
   A2. Wet variant of birch-common oak forest on *veld* podzols (VAN DER WERF 1991, 73): compared to the dry variant, the numbers of *Betula pendula* and particularly *Betula pubescens* increase. The shrub layer does not differ very much from the dry variant; however, in the herb layer, the grass species *Molinia caerulea* dominates; sometimes *Vaccinium myrtillus* and *Erica tetralix* occur in larger numbers.

B. Potential natural vegetation of till or pottery clay areas: on the most fertile, moist to wet soils, oak-hornbeam forest (*Stellario-Carpinetum*; VAN DER WERF 1991; STORTELDER et al. 1999); on the moderately fertile, dry to wet soils, oak-beech forest (VAN DER WERF 1991: *Fago-Quercetum petraea*; STORTELDER et al. 1999: *Fago-Quercetum*). These forest types have a more closed structure and are richer in species than the *Betulo-Quercetum roboris*.
   B1. Dry variant of oak-beech forest on *holt* podzols (VAN DER WERF 1991, 78): the tree layer of this type consists of mixed stands of *Quercus petraea*, *Q. robur*, *Fagus sylvatica*, *Carpinus betulus* and *Ilex aquifolium*. In the shrub layer, *Lonicera periclymenum* florishes. In the very rich herb layer, *Pteridium aquilinum*, *Maianthemum bifolium*, *Polygonatum multiflorum*, *Oxalis acetosella* and *Stellaria holostea* occur. Under drier conditions, the share of *Fagus* decreases and more grasses occur in the herb layer, for example *Deschampsia flexuosa*. Also higher numbers of ferns of the genus *Dryopteris* are found.
   B2. Wet variant of oak-beech forest on glacial clay soils (VAN DER WERF 1991, 95): it differs from the dry variant in the larger share of *Quercus* compared to *Fagus*, while in the herb layer also the grass species *Molinia caerulea* occurs.
   B3. Oak-hornbeam forest on *vorst* vague soils and glacial clay soils (VAN DER WERF 1991, 147): the tree layer of this type consists of *Quercus robur*, *Carpinus betulus*, *Fagus sylvatica*, and sometimes also *Fraxinus excelsior*, *Ulmus* sp. and *Tilia* sp.. On the wettest soils, the share of *Fagus sylvatica* markedly decreases, while the share of *Fraxinus excelsior* and *Alnus glutinosa* increases.

It has to be emphasized that the potential natural vegetation cannot be equated with the actual vegetation as it occurred during the Neolithic. A first limitation is that in many locations the soil type has changed in the course of time. Most important among these are all man-made soils, which did not exist at the beginning of the Neolithic. A second limitation is the migration of tree species in the course of time. At the beginning of the Neolithic, *Fagus sylvatica* had only just arrived in northwestern Europe (LANG 1994, 160), while *Carpinus betulus* was not present at all (LANG 1994, 154). In spite of these limitations, defining the potential natural vegetation on the basis of soil types is very useful in the process of reconstructing the vegetation of the Drenthe Plateau during the Neolithic.

With the help of the geomorphological map (fig. 19) and the soil map (fig. 20) the method can be applied to the surroundings of the Gietsenveentje. It can be seen that the Gietsenveentje is situated in the centre of an extensive till plateau, covered by only a thin layer of coversand. Thick coversand or pre-Saalian sand layers occur only

at distances of one kilometre or more. This means that there is a high probability that the vegetation around the Gietsenveentje during the first part of the Neolithic consisted of forest types B1-B2-B3 as described above: an oak-beech forest with a (very) small share of or even without *Fagus sylvatica*, or an oak-hornbeam forest, again with a (very) small share of or without *Fagus sylvatica* and without *Carpinus betulus*. The accuracy of this hypothesis will be tested with the help of pollen and macroscopic-remains analysis of Gietsenveentje sequences (see chapter VI).

III.4 Hydrology

III.4.1 General remarks

Precipitation surplus. In Drenthe, the modern average annual precipitation is ca. 800 mm (see III.5), while the average annual evaporation is estimated to be ca. 460 mm (NIJLAND et al. 1982, 39). This means that the average annual precipitation surplus is ca. 340 mm. This precipitation surplus is strongly seasonal: in most years, a small evaporation surplus occurs in summer, while the precipitation surplus is limited to the colder seasons.

Groundwater. Groundwater is defined as water in the saturated zone of the ground, i.e. the zone where no air occurs between the soil particles. A system of seven groundwater stages (I-VII) was developed for the Netherlands by Stiboka (1977). These groundwater stages are indicated on the soil map of fig. 20 and explained in the corresponding legend. In the Hunze valley (north-eastern part of the map area), stages with the highest groundwater level occur: stage II and III. In the rest of the mapped area, only stages with a quite low groundwater level occur: stages V to VII. In the direct vicinity of the Gietsenveentje, the groundwater level is low: stages VI and VII. The lowest groundwater level (stage VII) is found particularly in plaggen soil (*essen*) and driftsand areas. The groundwater which stagnates above impermeable layers in the soil is called shallow groundwater. Impermeable layers can result from geological as well as soil formation processes. Gyttja (lake sediment), consisting of silt particles and organic material, may form such an impermeable layer (NIJLAND et al. 1982, 44). As the gyttja layer becomes thicker, at a certain moment the water accumulating above the gyttja layer is closed off from the deeper groundwater. The plants growing in the terrestrializing lake are then only fed by rainwater. In this way, a raised bog is eventually formed. Such a process has occurred in most pingo scars, including the Gietsenveentje (see VI.1).

Groundwater flow. In the area of the Gietsenveentje, the groundwater flows from the high parts of the Hondsrug to the (former) brook valleys: the Hunze valley in the east and the Scheebroekerloop valley in the west. Because of differences in electric potential between deep and shallow groundwater, flowing under and above the impermeable till layer, potential infiltration and seepage areas are formed (T.W.M. BAKKER et al. 1986; NIJLAND et al. 1982): in potential infiltration areas the net movement of groundwater is downwards while in potential seepage areas the net movement of groundwater is upwards. The higher parts of the Hondsrug, including the location of the Gietsenveentje, form a potential infiltration area, while potential seepage areas are found in the Hunze valley and Scheebroekerloop valley (see NIJLAND et al. 1982, 46). Since the soil resistance may differ strongly because of differences in the composition of the underground, the actually occurring infiltration or seepage may differ substantially within potential infiltration or seepage areas. In potential seepage areas with till, the seepage will occur mainly where the till is interrupted or sandy. On the other hand, when nearly impermeable layers occur in potential infiltration areas, some seepage of shallow groundwater may locally occur.

III.4.2 Hydrological changes in the past

The specific hydrological situation of an area is not only important with respect to soil formation, but it is also of vital importance for the vegetation growing in that area. This means that changes in the hydrological situation in the past caused changes in the environment, particularly in the vegetation. Important phenomena which may have caused hydrological changes in the past are climatic change, raised-bog growth and forest clearance (SPEK 1993). In the framework of this study, the effects of the Neolithic forest clearances on the hydrological situation deserve particular attention. Different vegetation types have different evaporation rates: forest evaporates more water than heath, farmland or grassland. Furthermore, in forest vegetation more

precipitation is intercepted by the leaves, branches and stems of the trees, causing even higher evaporation. Consequently, the precipitation surplus in an open landscape is considerably higher than in a forested landscape. The hydrological effects of forest clearance differ for each type of landscape (SPEK 1993). In the moist parts of the coversand landscape and on the till plateaus, forest clearances may have caused a rising of the water table with tens to maybe even hundreds of millimetres. In some cases, this increase may have caused local peat growth. Because the Gietsenveentje is located on an extensive till plateau, possible forest clearances in the neighbourhood could have caused a considerable rise of the water table. However, in the drier parts of the coversand landscape, where the groundwater level lies far beneath the surface, forest clearances did not cause the soils to become wetter. On the contrary, the disappearance of the strongly buffering forest vegetation, in which a large amount of water was stored, caused the soils to become drier. In these areas, forest clearances could eventually even lead to driftsand (SPEK 1993, 184). Such a driftsand area with a very low water table (stage VII) occurs just north of the village of Gieten (see figs. 19-20).

III.5 Climate

Climate of the Netherlands. The present climate of the Netherlands can be characterized as a moderately oceanic climate with rainy summers, mild winters and prevailing westerly winds. Walter (1984, 44; 188) classifies the climate of the Netherlands in the "zonobiome" (ecological climatic zone) of the temperate-nemoral climate (zonobiome VI). The climate of this zonobiome, with a vegetational season of 4-6 months with adequate rainfall and a mild winter lasting 3-4 months, is especially suitable for the deciduous tree species of the temperate climatic zone. Such trees avoid the extreme maritime as well as the extreme continental regions and favour what is termed the "nemoral" zone (WALTER 1984).

Ecological climate diagram of Eelde. In fig. 22, a so-called ecological climate diagram (WALTER et al. 1975; WALTER 1984) of the weather station of Eelde Airport is shown. Eelde Airport is located in the northernmost part of the province of Drenthe, ca. 16 km northwest of the Gietsenveentje. In ecological climate diagrams, the mean monthly temperature and the mean monthly precipitation are plotted in a single diagram, in which 10°C is equivalent to 20 mm of precipitation. When the precipitation curve is above the temperature curve, a relatively humid season occurs; when the temperature curve is above the precipitation curve, a dry season occurs. It is clear to see that in Eelde (as in the rest of the Netherlands), the humid season persists throughout the year. In the right upper corner of the diagram, the mean annual temperature and mean annual precipitation are given: the mean annual temperature at Eelde is 8.5°C; the mean annual precipitation is 783 mm (KÖNNEN 1983). In the bar under the curves, information is given which is important for vegetation growth: the cold season (black) lasts from December to February; the months with incidental frosts (hatched) are March to May and October and November. The months in which the vegetation can grow optimally, also because the highest amounts of precipitation occur, are June to September.

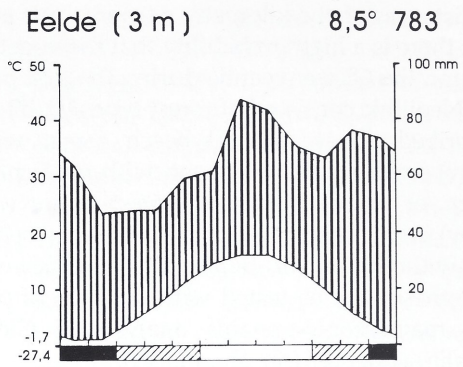


Fig. 22. Ecological climate diagram of Eelde (see WALTER et al. 1975; WALTER 1984)

Climate of Drenthe compared to the rest of the Netherlands. Although the climate in all parts of the Netherlands is characterized as a moderate oceanic climate, still considerable differences in climate can be distinguished. The influence of the sea rapidly diminishes towards the interior; the more continental character of the climate becomes noticeable at ca. 50 km from the coast. In the province of Drenthe, this is best expressed by the relatively high number of days with frost (70-90, against less than 80 in the rest of the Netherlands) and the relatively high number of summery days (20-25, against less than 20 in the coastal areas of the Netherlands) (NIJLAND et al. 1982, 14). The temperature fluctuations occurring at the change of the seasons are generally larger

in Drenthe than in the rest of the Netherlands, which is caused particularly by the comparatively cold winter climate of Drenthe. This holds to an even larger extent for the eastern part of the province. The central part of Drenthe, together with parts of the Veluwe and southern Limburg, belongs to the most precipitation-rich areas of the Netherlands, with a mean annual precipitation of around 800 mm (BUISHAND & VELDS 1980). This high precipitation can be explained by the relief: the clouds supplied by the prevailing westerly winds are pushed up by the Hondsrug ridge, as a result of which they produce more rain (T.W.M. BAKKER et al. 1986). There is a striking difference regarding the distribution of precipitation over the year between the eastern and western parts of the Netherlands: in the eastern part, most precipitation falls in summer; in the west, most precipitation falls in autumn (BARKMAN & WESTHOFF 1969).

III.6 Vegetation

III.6.1 General remarks

As we saw in the preceding sections, the most important abiotic factors influencing the growth conditions of vegetation are geology, soil, hydrology and climate. As we shall see in the following two sections, the influence of man on Drenthe's vegetation, which first became noticeable at the beginning of the Neolithic, increased in the course of time. Nowadays, man is the most important factor influencing the vegetation in Drenthe. In this section, first a rough outline of the vegetation development in Drenthe since the last glaciation will be given. This will be followed by a short characteristic of the present vegetation of Drenthe.

III.6.2 Holocene vegetation history

The vegetation development of the Drenthe Plateau in the Holocene will be described on the basis of the Blytt/Sernander classification as described in I.4.1. The Blytt/Sernander periods and their durations are given in appendix II.

Preboreal. A strong increase of *Betula* at the end of the Younger Dryas announces the definitive transition to a warmer climate and marks the beginning of the Holocene. In the Preboreal, the first period of the Holocene, the climate was still dry. Trees were still dependent on the presence of moisture and were restricted to moister areas like stream valleys (BOTTEMA 1988). In these areas, open birch-pine forests occurred with an undergrowth of *Artemisia* among other plants. Because a dry climate prevailed, the evidence we have is restricted by a scarcity of sediment; only when local humid conditions allowed sedimentation could a pollen record be built up (MOOK-KAMPS & BOTTEMA 1987). In the course of this period, *Ulmus* and *Corylus* immigrated into Drenthe, but their pollen values remain very low.

Boreal. The first conspicuous increase of *Corylus* marks the beginning of the next period of the Holocene, the Boreal. In only a few hundred years, *Corylus* spread from southern to northern Europe; because the autonomic spread of hazelnuts is not very efficient and very slow, it seems probable that hazelnuts were spread by water (for example the Rhine), birds or even Mesolithic people (BOTTEMA & WALSWEER 1997). During the Boreal, the conditions for tree growth were definitely better than during the previous period. In Drenthe, trees spread from the river valleys and the depressions to the uplands (BOTTEMA 1988). *Corylus* occupied more and more open spots, as a result of which *Betula* seeds especially could no longer germinate (IVERSEN 1973; BOTTEMA 1988). The pollen picture of the Boreal is dominated by *Pinus* and *Corylus*; the values of Non-Arboreal Pollen are low. In the course of this period, *Quercus, Alnus, Tilia* and *Fraxinus* immigrated into Drenthe. On the poorer soils, subarctic-looking forests developed with *Pinus, Betula* and *Populus*, to a greater or lesser extent mixed with *Corylus*. *Quercus, Tilia* and *Fraxinus* only grew on more favourable soils. On moist, peaty soils, carr forests with *Pinus* and *Betula* occurred, which later were displaced by *Alnus*. The Boreal is characterized by a lack of balance between climate, soil and vegetation, mainly because several important tree species were still immigrating into Drenthe (WATERBOLK 1954).

Atlantic. A decrease of *Pinus* and to a lesser extent of *Betula*, accompanied by an increase of *Alnus, Tilia, Fraxinus* and *Quercus*, marks the beginning of the Atlantic. This period is characterized by a dominance of mixed deciduous forest with mainly *Quercus, Ulmus, Tilia* and *Fraxinus*. Because of optimal climatic conditions, a stable climax forest was formed, which maintained itself for thousands of years, and was only affected by the activities of the first farmers (IVERSEN 1973; BOTTEMA 1988). In the second half of the Atlantic, pollen of *Fagus* is found for the first time, in very low percentages (VAN

ZEIST 1955a). It is not known whether small numbers of *Fagus* were really present in the Atlantic forests of Drenthe, or whether *Fagus* pollen grains reached Drenthe by long-distance transport (see WATERBOLK 1954, 10; BOTTEMA 1988; LANG 1994, 160). In the Atlantic, the forming of the large raised bogs began, partly by the drowning of forests, partly by the terrestrialization of eutrophic waters. The landscape in the Atlantic can be characterized by primeval forests of varying composition, and marshes which displayed all transitional stages from open water to alder and birch carr and real raised bogs (WATERBOLK 1954).

Subboreal. A decrease of *Ulmus* and somewhat later also *Tilia* and an increase of the culture-indicator pollen types, especially *Plantago lanceolata*, mark the beginning of the Subboreal. The Atlantic-Subboreal transition in Drenthe coincides with the beginning of the Neolithic Occupation Period. These phenomena have already been exhaustively described in chapter II. Here only some general remarks will be made. The Subboreal is the first period in which human influence on the landscape becomes visible in the pollen picture. The diversity of the vegetation increased, because the first farmers created new biotopes by opening up the dense Atlantic forest (WATERBOLK 1954). In the course of the Subboreal, *Tilia* disappeared from the forests; most probably it was displaced by *Fagus*, which shows slowly increasing pollen values. Because the migration pattern of *Fagus* through Europe resembles the spread of farming cultures throughout Europe, Bottema (1988) states that the expanding farming cultures brought *Fagus* in their wake as an oversized weed, passively or maybe even actively. *Alnus* and *Corylus* reach high pollen values; after a maximum with several peaks, *Corylus* strongly decreases at the end of the Subboreal. The maxima are possibly caused by an increase of open spots, which were created by the first farmers. The decrease might be explained by the beginning of the degradation of soils (WATERBOLK 1954; IVERSEN 1973). In the course of the Subboreal, also *Carpinus* appeared in the vegetation (LANG 1994, 154). The Subboreal landscape of Drenthe most probably consisted of extensive primeval forests, especially in the areas where till or pottery clay occurred near the surface (see III.3.3), with the settlements of the first farmers surrounded by grass-rich vegetation, arable and all kinds of intermediate forms between grass-rich vegetation, heath and deciduous forest (WATERBOLK 1954).

Subatlantic. Generally, the transition from the Subboreal to the Subatlantic is placed where *Fagus* for the first time occurs regularly or shows its first increase (VAN ZEIST 1955a, 10). However, in pollen diagrams from Drenthe, this level seems to be somewhat ambiguous, which is partly caused by the consistently low *Fagus* values, even in the Subatlantic. According to several authors (VAN ZEIST 1955a, 17; KILIAN et al. 1995; VAN GEEL et al. 1996), a level which much better indicates the Subboreal-Subatlantic transition, is the transition from the so-called Older *Sphagnum* Peat (mainly *Sphagnum cuspidatum* and *S. papillosum*) to Younger *Sphagnum* Peat (mainly *Sphagnum imbricatum*) in northwest European raised bogs, which indicates the transition to a more oceanic climate. A more humid climate probably benefited *Fagus* (VAN ZEIST 1959). According to ^{14}C dates of a large number of bogs in northern Germany, collected by Overbeck (1975, 608), the *Schwarztorf-Weisstorf-Kontakt*, as the transition is called in Germany, occurs between 1000 cal BC and cal AD 1000, which seems to indicate that this transition does not represent the same event everywhere. Characteristics of the Subatlantic in pollen diagrams are the increasing values of *Carpinus* and the culture-indicator types (VAN ZEIST 1955a). The increase of the culture-indicator types could occur because of strongly decreased forest areas on the one hand and increased areas of abandoned farmland on the other; the soils became poorer as a result of grazing by cattle and sheep, which caused an increase of especially *Calluna*. In the humid brook valleys, *Alnus* was cut and displaced by meadowland or summer pasture. The only type of landscape which was left undisturbed until a few hundred years ago, were the large raised-bog complexes (BOTTEMA 1984). The development of the landscape near the Gietsenveentje in the past two centuries will be discussed in section III.8.

III.6.3 Present vegetation

The Drenthian district. The Gietsenveentje is located in the province of Drenthe, which is part of the botanical Drenthian district (VAN DER MEIJDEN 1996; BARKMAN & WESTHOFF 1969). In the Netherlands, the Drenthian district encompasses the Drenthe Plateau; the neighbouring Pleistocene parts of northern Germany also belong to the Drenthian district. Up to the recent past, the most characteristic vegetation types of the Drenthian district were (anthropo-

genic) *Erica tetralix* heathfields and large raised bogs consisting of thick layers of *Sphagnum* peat. However, nowadays most of the heathfields and raised bogs are reclaimed and displaced by large-scale agricultural fields. Only small areas remain, which are all designated as nature reserves. The flora of the Drenthian district is characterized by Boreal and Atlantic species. These species are not only favoured by the relatively humid climate, but also by the predominantly poor soils of Drenthe, because most Atlantic and Boreal species are oligotraphent and acidophilous. Examples of typical Boreal species having their greatest density in the Drenthian district are *Andromeda polifolia, Drosera longifolia, Eriophorum vaginatum, Oxycoccus palustris* and *Sparganium angustifolium*; examples of typical Atlantic species having their greatest density in the Drenthian district are *Erica tetralix* and *Ilex aquifolium* (BARKMAN & WESTHOFF 1969). Within the Drenthian district, northern Drenthe, the part of Drenthe where the Gietsenveentje is located, is remarkable because of a conspicuous abundance of plants of brook valleys and of deciduous forests on till and pottery clay.

III.7 Archaeology

III.7.1 General remarks

In this section, an overview will be given of the archaeology of the Drenthe Plateau in the Mesolithic and Neolithic. The archaeology of the Swifterbant Culture and the Funnel Beaker Culture will be discussed in greater detail, because these cultures were involved in early agriculture on the Drenthe Plateau. A chronological overview of the various periods and cultures on the Drenthe Plateau from the Mesolithic onwards is given in appendix III.

III.7.2 Mesolithic (9000-4900 cal BC)

At the end of the Weichselian glaciation, the sea level began to rise slowly from 100 m below N.A.P. (Dutch datum) to 8 m below N.A.P. in the Atlantic (ZAGWIJN 1986). The amelioration of the climate made possible a considerable growth of the human population in the northern Netherlands (NEWELL 1975, 50). The inhabited area extended not only as far as the present clay areas of Friesland and Groningen, but also into the present North Sea. On the Drenthe Plateau, remains from this period, the Mesolithic, are common on coversand elevations, particularly on those along the brook valleys, pingo scars and blown-out depressions (NEWELL 1973; PRICE 1980; WATERBOLK 1985a). The Mesolithic people most probably hunted red deer, elk, wild boar and roe deer. Fishing was also important. Furthermore, eggs, berries and nuts were gathered.

The most typical finds of the Mesolithic are small objects with a geometric form, the microliths. They were used as arrowheads. Most probably, the Mesolithic people lived in dome-shaped tents, covered by hides or vegetal material. Generally, very few organic remains are left: usually only hearths with charcoal and large numbers of flint tools are found. An exceptional find from this period is the more than 9500-year-old tree-trunk canoe of Pesse (VAN ZEIST 1957; BEUKER & NIEKUS 1997). The most extensive habitation of the Drenthe Plateau by Mesolithic people occurred in the Boreal; in the Atlantic, the forest which became ever denser caused the Mesolithic people to migrate from the higher parts of the plateau to lake shores, valleys of large rivers and edges of the plateau near the coast. The Mesolithic people lived in small, wandering groups of ca. 20 people; from base-camps, food expeditions lasting several days were undertaken. There must have been regular contacts with other groups; the cultural basis units consisted of 200-500 persons. The distance between winter and summer camps would have been at most 100-200 km. The total population of the Drenthe Plateau numbered no more than a few hundred individuals (WATERBOLK 1985a). At the end of the Atlantic, the Mesolithic cultures may have been influenced by Neolithic cultures established on loess soils in the southern Netherlands and Germany, only a few hundred kilometres from the Drenthe Plateau: the Linear Pottery Culture (5300-5000 cal BC) and the Rössen Culture (4700-4300 cal BC) (LANTING & VAN DER PLICHT 1999/2000; LÜNING 1996).

III.7.3 Swifterbant Culture (4900-3400 cal BC)

The transition from a subsistence based on hunting, fishing and gathering to one based on arable farming and animal husbandry was a landmark in human history. On the Drenthe Plateau, agriculture may have been introduced by representatives of the Swifterbant Culture. The most important sites of this culture are found

in the coastal areas; many of these areas are nowadays covered by marine clay because since 5000 cal BC the sea level has risen ca. 8 m (ZAGWIJN 1986). However, when parts of the IJsselmeer were impoldered, some of these sites could be excavated. Most settlement sites of the Swifterbant Culture are located on river dunes of the then IJssel river. It is clear that the Swifterbant Culture was influenced by various cultures that were simultaneously present in the southern Netherlands and in bordering parts of Germany and Belgium: these include not only the already mentioned Rössen Culture (4700-4300 cal BC), but also the subsequent Bischheim Culture (4300-4200 cal BC) and Michelsberg Culture (4200-3800 cal BC) (LANTING & VAN DER PLICHT 1999/2000; LÜNING 1996). In recent years, several new sites of the Swifterbant Culture have been discovered, most of which are located in the lower parts of the central and western Netherlands; however, also a few sites are known on the higher sandy soils of the eastern and northern Netherlands (RAEMAEKERS 1999, 108-111). Furthermore, pottery of the Hüde I site in Lower Saxony, Germany, has so many characteristics in common with Swifterbant pottery, that Ten Anscher (cited in GEHASSE 1995, 199) classifies Swifterbant and Hüde pottery in one group: the Hüde-Swifterbant Group. Raemaekers (1999) has distinguished the following three phases of the Swifterbant Culture:

- **Early Phase (SW-1): 4900-4600 cal BC.**
  The excavation of 1994-1995 at the Hoge Vaart, Almere (South Flevoland) has shown that this location was inhabited by small groups of people with pottery (partly produced locally), who practised not only hunting, but also animal husbandry (cattle, pig, sheep/goat). The habitation site reflects temporary and possibly even seasonal activities. Maybe this location was used as a base camp for hunting expeditions and possibly also for animal husbandry. So far no indications for arable farming have been found at this location (HOGESTIJN & PETERS 1996). In the subdivision of Ten Anscher (cited in GEHASSE 1995, 199), this phase is called SW-1, with pottery which is characterized by original Swifterbant elements and by Rössen influences.
- **Middle Phase (SW-2 and SW-3/Dronten phase): 4600-3850 cal BC.**
  The large excavation of 1971-1979 at Swifterbant, near the village of Dronten (East Flevoland), revealed habitation on river dunes, now lying 5 m below N.A.P.. The inhabitants of these locations processed cereal products, although it is not clear whether cereals were also cultivated locally. Pottery was produced, also partly locally; furthermore, not only animal husbandry was practised, but also hunting, fishing and gathering of nuts and fruits. On the basis of the range of activities, the group composition (adults and children) and the supposed duration of habitation, these sites are interpreted as semi-permanent principal settlements (DECKERS et al. 1980; HOGESTIJN & PETERS 1996). Ten Anscher (cited in GEHASSE 1995, 199), divides this phase into two subphases: SW-2 and SW-3. The pottery of SW-2 (4600-4350 cal BC) is characterized by Swifterbant elements and by Rössen and Bischheim traits. The pottery of SW-3 (4350-3850 cal BC), in addition to the already mentioned elements, displays faint Michelsberg influences. The finds of Rössen-type adzes also prove contacts between the Swifterbant Culture and the cultures in the southern Netherlands (HOGESTIJN & PETERS 1996). According to Lanting & Van der Plicht (1999/2000), these adzes were produced locally by people of the Swifterbant Culture.
- **Late Phase (SW-4/Nagele phase): 3850-3400 cal BC.**
  The excavation of 1984-1988 near Schokkerhaven (Noordoostpolder, Flevoland) revealed the first permanent principal settlements of the Swifterbant Culture: several sizeable house plans and an accompanying cemetery were discovered. At another location, a habitation area surrounded by a double row of oak posts was excavated. The finds from Schokkerhaven must be seen as the products of a further typological and technological development of the Swifterbant Culture (HOGESTIJN 1990; HOGESTIJN & PETERS 1996). According to Ten Anscher (cited in GEHASSE 1995, 199), the pottery from this phase is characterized, in addition to the already mentioned elements, by early TRB elements. However, Lanting & Van der Plicht (1999/2000) consider these "early TRB-elements" to be simply products of the late Swifterbant Culture; there is no connection with the development in Denmark and northeastern Germany, where indeed an Early Neolithic TRB phase occurs.

The Early and Middle Phases of the Swifterbant Culture are part of the Dutch Early Neolithic B, while the Late Phase of the Swifterbant Culture belongs to the Dutch Middle Neolithic A (LANTING & VAN DER PLICHT 1999/2000, 12). Hogestijn et al. (1995) have made a subdivision of the Swifterbant Culture into three phases, which differs only slightly from Raemaekers' subdivision (1999): Hogestijn's Early Phase coincides with phases SW-1 and SW-2 of Ten Anscher, his Middle Phase with phase SW-3, and his Late Phase with Ten Anscher's phase SW-4.

Traces of habitation on the Drenthe Plateau between 4900 and 3400 cal BC. On the Drenthe Plateau, some scattered finds are known which can be related to the Swifterbant Culture. These finds are indicated on the map of fig. 23. They mainly occur in the brook valleys. The finds can be divided into three categories:

A. *finds of Swifterbant pottery, most probably indicating the presence of Swifterbant people on the Drenthe Plateau:*

1-1. sherds of a Swifterbant pot, found in combination with two red-deer antlers in the canal Voorste Diep (Kanaal Buinen-Schoonoord) near Bronneger. This is the only dated find of Swifterbant pottery from the Drenthe Plateau: the date of organic remains which stuck to the pot is 5890 ± 90 BP [OxA-2908]; the dates of the two antlers are 5720 ± 90 BP and 5970 ± 90 BP [OxA-2909 and OxA-2910]. Combined calibration of these dates yields a result of ca. 4700 cal BC. This means that this find belongs in the Early Phase of the Swifterbant Culture (KROEZENGA et al. 1991; LANTING 1992; VAN DER SANDEN 1997);

1-2. a single sherd of a Swifterbant pot, found in the Weerdingerveen peat bog in 1943 (VAN DER SANDEN 1997); most probably, the sherd dates from the Middle Phase of the Swifterbant Culture (LANTING & VAN DER PLICHT 1999/2000);

1-3. pottery, flint material and T-shaped antler tools, found at De Gaste near Meppel, on the edge of the Drenthe Plateau (CLASON 1983; WATERBOLK 1985a). Part of the pottery unmistakably belongs to the Swifterbant Culture; some characteristics of the pottery point to the Early Phase (LANTING & VAN DER PLICHT 1999/2000);

1-4. pottery, flint material, red deer antlers, bone tools and remains of domesticated animals (cattle, pig, sheep/goat) and several wild animals, found at Heemse (near Hardenberg, Vecht valley) (CLASON 1984; WATERBOLK 1985a); the material seems to originate from various periods; according to Lanting & Van der Plicht (1999/2000) it is far from certain that it is Swifterbant material.

B. *finds of adzes, most probably imported from the Rössen Culture, which was established on the loess soils of the southern Netherlands and Germany between ca. 4700 and ca. 4300 cal BC; these indicate contacts between the Rössen Culture and contemporary inhabitants of the Drenthe Plateau:*

2. stray finds of Rössen-type adzes, used for woodworking. Two types can be recognized:

2-1. *Hohe durchlochte Schuhleistenkeile* (high perforated adzes), which were found at the following locations in Drenthe: Nieuw-Buinen, Gees and Bargererfscheidenveen (VAN DER WAALS 1972). Since 1972, specimens have been found near Donderen (1979), Diever (1983), Ellertshaar (1984), Bronneger (1986) and Eerste Exloërmond (1988). In adjacent parts of the province of Groningen, also two specimens turned up: one near De Wilp (Van der Waals, 1972) and one near Mussel (GROENENDIJK 1993). These adzes are also indicated on the map (fig. 23).

2-2. *Durchlochte Breitkeile* (perforated wedges), which were found at the following locations in Drenthe: Eext (see III.7.6), Veenoord, Zwiggelte, Hijken, Berkmeer (near Dalen) and Oud-Schoonebeek (VAN DER WAALS 1972). In 1974, another was found near Zwinderen. In the bordering part of the province of Overijssel, a specimen was found near Aneveld (VAN DER WAALS 1972).

3. stray finds of *Plättbolzen*, adzes with the shape of a flat-iron; one was found near Fochteloo (JAGER 1981); a second was found near Siegerswoude (FOKKENS 1990, 193: nr. 186); most probably, they were imported from the Linear Pottery or Rössen Cultures, and are related to the Rössen-type adzes.

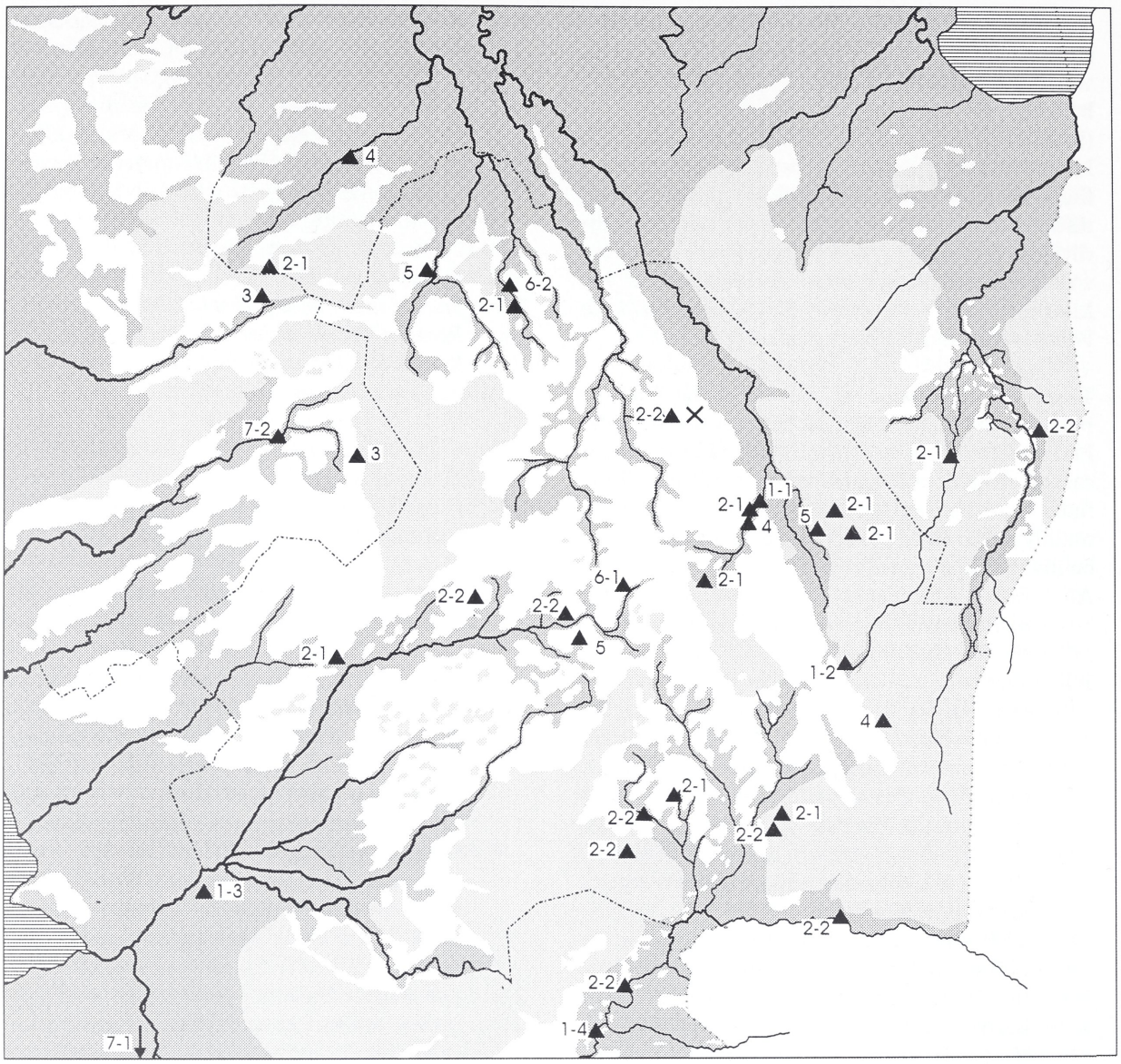


Fig. 23. Map with archaeological finds from the period 4900-3400 cal BC, indicated by triangles, on the Drenthe Plateau and its margins. The numbers of the findspots correspond with the numbers of the list used in the text. The cross indicates the location of the Gietsenveentje. In the dark-grey areas, raised-bog sediments are found; in the light-grey areas, stream valley sediments are found.

C. *finds that cannot be related to any culture, but which at least indicate habitation on the Drenthe Plateau between 4900 and 3400 cal BC:*

4. stray finds of T-shaped antler tools, which are most probably of early Neolithic age; several specimens were found in the canal Voorste Diep near Borger and east of the Hondsrug near Emmen (ELZINGA 1962); one was found near Tolbert (FOKKENS 1990, 190: nr. 136).

5. stray finds of horn sheaths of cattle: four horn sheaths, found in bogs in Drenthe, were dated to the period of the Swifterbant Culture (PRUMMEL & VAN DER SANDEN 1995):
Een, horn sheath of aurochs (*Bos primigenius*), 5530 ± 30 BP [GrN-20381];
"Drenthe" (findspot unknown, not indicated on the map of fig. 23), horn sheath of aurochs (*Bos primigenius*), 5360 ± 60 BP [GrN-20386];

Buinerveen, horn sheath of domesticated cattle (*Bos taurus*), 4960 ± 40 BP [GrN-20373];
Westerbork, horn sheath of domesticated cattle (*Bos taurus*), 4880 ± 60 BP [GrN-20384];
Prummel & Van der Sanden (1995) believe the horn sheaths to have been deposited deliberately in the bogs and to represent votive gifts. They reflect a sacrificial tradition which started in the early Neolithic and continued until the Middle Ages.

6. hoards of flint tools and material:

6-1. a hoard of one axe with an oval section and two large blades, found near Elp; the blade technique especially points to an early Neolithic origin (HARSEMA 1975; WATERBOLK 1985a);

6-2. one arrowhead, several large blades, flakes and core material, found near Donderen; here too, the blade technique points to an early Neolithic origin (HARSEMA 1974);

7. large collections of bone and/or antler tools:

7-1. a large collection of bone and antler tools and objects, found at Spoolde, in the IJssel valley near Zwolle. The findspot is located ca. 15 km from the Drenthe Plateau and ca. 32 km from the site of Swifterbant. Apparently, the material originates from various periods. One T-shaped antler tool was ^{14}C-dated to 6050 ± 30 BP [GrN-8800] (ca. 4900 cal BC) (CLASON 1983).

7-2. a large collection of animal bones, including twelve T-shaped antler tools, which are usually dated between 6000 and 5000 BP, found near Donkerbroek in the province of Friesland (FOKKENS 1990, 97; 197: nr. 268). The material originates from various periods; a worked humerus of domesticated cattle was dated to 4770 ± 80 BP [GrA-12712] (ca. 3520 cal BC) (PRUMMEL 2001).

Furthermore, there are two types of artefact which are found in late Mesolithic as well as in early Neolithic contexts: *Geröllkeulen* and *Spitzhauen* (these are not indicated on the map of fig. 23). A few dozen specimens of *Geröllkeulen*, which are perforated or unperforated pebbles, have been found in Drenthe and bordering provinces (HULST & VERLINDE 1976). In the Swifterbant excavation too, fragments of *Geröllkeulen* were found (VAN DER WAALS 1972). Of the *Spitzhauen*, which are hammer axes with one end blunt and the other pointed, about one dozen specimens have been found in Drenthe, notably at Zeyerveld, Een and Exloërmond (HULST & VERLINDE 1979). The *Spitzhauen* are dated between 7000 and 4300 cal BC (BEUKER et al. 1992, 126). Finally, a recent find of sherds of possibly the Late Phase of the Swifterbant Culture in the Wetsingermaar, ca. 10 km north of the city of Groningen (well north of the area covered by fig. 23), should be mentioned (FEIKEN et al. 2001). The occupation layer was dated to 4700 ± 40 BP [GrA-16659] (ca. 3500 cal BC). The scattered finds together indicate at least a temporary penetration into the North by people whose home territory was in the delta area. Unfortunately, no settlements of these people have so far been found on the Drenthe Plateau.

III.7.4 Funnel Beaker Culture (3400-2800 cal BC)

The first fully Neolithic culture on the Drenthe Plateau is the Funnel Beaker Culture (TRB), belonging to the Dutch Middle Neolithic B. The most conspicuous remnants of this culture are the famous megalithic tombs (*hunebedden*). In the direct vicinity of the Gietsenveentje there are several megalithic tombs (see III.7.6). Some aspects of this culture will be treated in more detail.

Settlements. So far, no TRB house plans have been found in Drenthe. In adjacent Germany, houses with axial posts have been excavated with a length of up to 15 m and a width of up to 5 m. The wall was made by wattle and daub. The roof must have been thatched with straw and/or reed. The settlements must have consisted of only a few houses, inhabited by no more than a few dozen people (WATERBOLK 1985a; BEUKER 1992). Southeast of the village of Anloo, only 4 km from the Gietsenveentje, traces of two enclosures (inner enclosure: 2150 m^2; outer enclosure: 4300 m^2) have been excavated. Within the enclosures, no house plans were found, but many TRB potsherds, quernstones, flints and organic remains. Probably the foundation of the TRB buildings was not very deep. Given the homogeneous pottery, this settlement from the middle Funnel Beaker Culture was probably used for only a short time. There has been much discussion about the function of the enclosures (see WATERBOLK 1960; HARSEMA 1982; JAGER 1985). According to Harsema (1982), their most important function was fortification of the settlement; their second function might have been to keep the livestock within or outside the settlement

area. The presence of cattle locks in the outer enclosure points to this second function.

Stone and flint artefacts. TRB people used bowl-shaped querns of locally found granite (HARSEMA 1979), perforated stone battle-axes, and sickles, scrapers, trapezoidal arrowheads, and axes of flint (J.A. BAKKER 1979, 76-110).

Pottery. The most typical pottery form is that of the funnel beaker, which gave its name to the culture. Other forms were collared flasks, biberons, shouldered pots, necked bowls and pails (J.A. BAKKER 1979, table VI). The pottery was often provided with beautiful, deeply incised ornamentation which was filled up with a white paste made of burned and ground bone. Various authors have tried to make a typochronology of TRB pottery: Van Giffen (1925/27) distinguished a Drouwen and a Havelte phase; J.A. Bakker (1979) distinguished seven phases (A to G); Brindley (1986) identified seven horizons (1 to 7).

Funerary monuments. The most conspicuous monuments of the TRB period are the megalithic tombs (*hunebedden*), of which nowadays more than 50 are known in Drenthe (WATERBOLK 1985a, 32; VAN GINKEL et al. 1999). These tombs must have been built as follows: first the side-stones were placed in pairs, with their flat sides facing each other. At either end an endstone was set up. Then the capstones were placed by an ingenious use of rollers and an earth mound. The gaps between side stones and capstones were filled up with smaller stones. Finally, the whole was covered by an earth mound; the upper part of the capstones remained visible. On the southern side of the mostly east-west orientated tomb, a closable entrance was built. The megalithic tombs could take several bodies and were used for many generations. Many grave goods were put in the tombs, like pottery, axes and beads. Apart from the megalithic tombs, two other grave types are known from the TRB period: flat graves and stone cists, the latter being flat graves containing a small cist built of stones (J.A. BAKKER 1992; BEUKER 1992).

Society. The TRB people were the first people in Drenthe that practised arable farming and animal husbandry on a relatively large scale. Products of hunting and gathering supplemented the menu. The most important cultivated crops were einkorn wheat (*Triticum monococcum*), emmer wheat (*Triticum dicoccon*) and the naked form of barley (*Hordeum vulgare ssp. vulgare*). The land was ploughed probably with an ard, a primitive plough which did not turn the soil (DRENTH & LANTING 1997). Besides agriculture, TRB society is characterized by permanent settlements, the use of ground stone axes and the production of high-quality pottery for domestic use (J.A. BAKKER 1982). The original total number of megalithic tombs in Drenthe is estimated at ca. 100. On this basis, the total size of the TRB population in Drenthe must have comprised at least many hundreds, maybe even two or three thousand people (LOUWE KOOIJMANS 1983; HARSEMA 1984).

III.7.5 Single Grave Culture and Bell Beaker Culture (2800-1900 cal BC)

Single Grave Culture or Protruding Foot Beaker Culture (EGK) (2800-2450 cal BC). On the Drenthe Plateau, the Funnel Beaker Culture was followed by the Single Grave Culture (the Dutch Late Neolithic A). The most conspicuous traces of this culture are its graves. The dead were buried in single graves lying in a crouched position; the grave was sometimes covered by a mound. The nature of the grave goods depended on the sex and age of the deceased person. Axes, flint daggers and battle-axes are considered to be typical male attributes. Beakers with an S-shaped profile and a protuding foot, which are characteristic of this culture, are found with male as well as female burials (BEUKER 1992).

There is no evidence for population growth in the EGK period compared to the TRB period; if we consider the number of known settlements, the number of people even appears to have markedly decreased: as against hundreds of TRB settlements, only a negligible number of EGK and BB settlements are known (VAN GINKEL & HOGESTIJN 1997, 78).

Bell Beaker Culture (BB) (2600-1900 cal BC). The next culture, the Bell Beaker Culture (the Dutch Late Neolithic B), is also for the greater part known from its graves; about BB settlements only little is known. Just as in the Single Grave Culture, the dead were buried in flat graves or under burial mounds; burial in a crouched position continued, but cremation also occurred. Among the grave goods, next to stone hammers, wrist-guards and flint arrowheads, also some copper and even gold objects are found. The typical pottery of this period has the form of an inverted bell and is often decorated (BEUKER 1992).

III.7.6 Archaeological finds in the surroundings of the Gietsenveentje

In the surroundings of the Gietsenveentje many archaeological findspots are known. In the 1920s and 1930s, several megalithic tombs (*hunebedden*) and burial mounds were excavated by Prof. A.E. van Giffen, the famous founder and director of the Biologisch-Archaeologisch Instituut of the University of Groningen. After the Second World War, many finds were collected by local amateur archaeologists, such as G. Holtrop and P. Kroezenga. The map of fig. 24 shows all archaeological findspots in the neighbourhood of the Gietsenveentje. The map was made on the basis of the archive of the Drents Museum in Assen and the archive of Dr J.A. Bakker. The most interesting findspots will be discussed in greater detail per period. The emphasis will be on the Neolithic finds.

Palaeolithic and Mesolithic. Most Palaeolithic and Mesolithic material is found in the vicinity of circular depressions, many of which are pingo scars. It seems obvious that late Palaeolithic and Mesolithic people should want to make their camps in the neighbourhood of (then) lakes.

Swifterbant Culture. Only one clear find dated to the period of the Swifterbant Culture is known from near the Gietsenveentje: in 1877, a *durchlochter Breitkeil*, a perforated wedge of the Rössen type, made of amphibolite was found "on the heath near Eext". Unfortunately, the exact findspot of this wedge is not known (fig. 24: no. 1). In a former pingo scar on the Eexterveld, which was filled up with sand for the construction of a road (fig. 24: no. 19), sherds of a funnel beaker with a globular body were found. Theoretically, this type of funnel beaker may originate from the (Danish) Early Neolithic TRB, dating from ca. 4000 cal BC onwards (J.A. BAKKER et al. 1999). However, there is no corroborating archaeological evidence at all of the Early Neolithic TRB in the northern Netherlands and northwestern Germany (LANTING & VAN DER PLICHT 1999/2000).

Funnel Beaker Culture (TRB). Many TRB remains are known from the neighbourhood of the Gietsenveentje. The most spectacular remains are three *hunebedden* (D-12, D-13 and D-14) and three destroyed small *hunebedden* or stone cists (D-13a to c):

D-12 (fig. 24: no. 2). This *hunebed*, a passage grave, was not investigated archaeologically. However, still a collared flask is known to originate from it (VAN GIFFEN 1943).

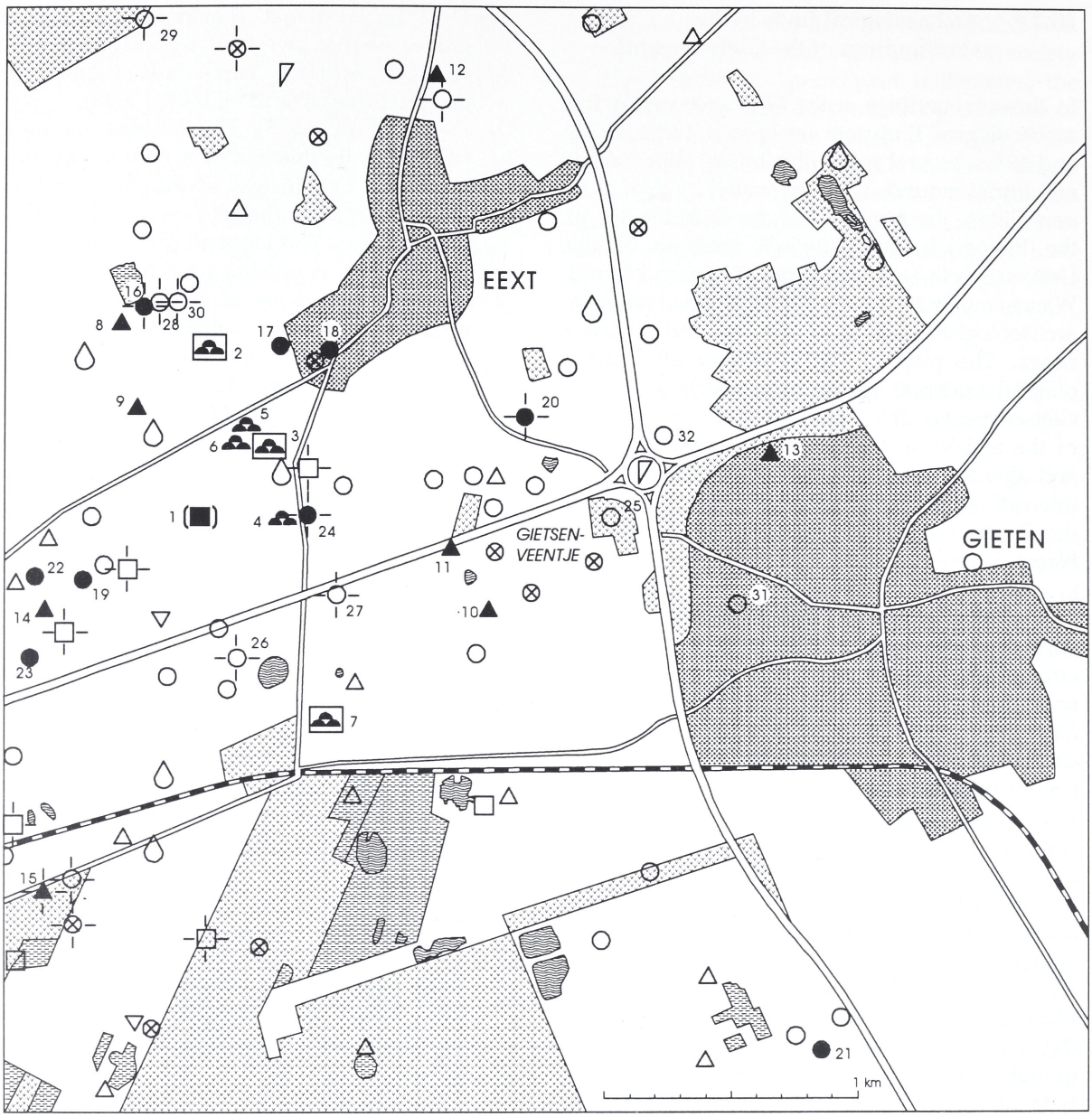
D-13 (fig. 24: no. 3). This *hunebed*, the only *hunebed* in the Netherlands with steps leading down into it, was investigated by Van Giffen in 1927. In the 18th century, however, the antiquary Van Lier had preceded him, so that the 1927 excavations yielded hardly any finds. D-13 consists of six sidestones, two endstones and one capstone. The underground consists of plain sand; no heath-podzol profile was found (VAN GIFFEN 1943).

D-13a (fig. 24: no. 4). The site of D-13a was dug over by the discoverer. Therefore, the later excavation by Van Giffen (1944a) only revealed a number of boulders, several TRB sherds and a virtually intact collared flask. Because of the inhomogeneous pottery (belonging to phases C, possibly B, and G), J.A. Bakker (1979, 155) concluded that D-13a may have been a long-dismantled *hunebed*. However, because there are no visible traces in the ground, it seems more plausible that D-13a was a shallow stone cist (JAGER 1985, 239).

D-13b (fig. 24: no. 5). In 1927, Van Giffen discovered remains of two small *hunebedden* not far from the *hunebed* D-13. The sites of these *hunebedden*, which were destroyed long ago, were recognizable only as patches of rock-debris. In D-13b, only some TRB material and the sherds of a Bell Beaker were discovered (VAN GIFFEN 1944b).

D-13c (fig. 24: no. 6). Here it seemed possible to reconstruct the plan of the small destroyed *hunebed*, because extraction pits of eight side stones and one endstone could be recognized in the ground: it must have had a length of 4,00 m and a width of 2,60 m. The finds consisted of TRB material and some EGK/BB sherds (VAN GIFFEN 1944b).

D-14 (fig. 24: no. 7). This *hunebed*, a large passage grave, consists of 27 stones: nine pairs of side stones, two endstones and seven capstones. D-14 is one of the few *hunebedden* with a more or less intact kerb of stones around it. The earliest pottery found in this *hunebed* dates from TRB phases Drouwen B and C. However, the larger part of the pottery belongs to later phases (TRB phases Drouwen D to G: J.A. BAKKER 1979, 155).



built-up area
water
forest
heath

Palaeolithic
Mesolithic
Swifterbant

TRB finds:
hunebed
hunebed, destroyed
TRB settlement
other TRB find

other Neolithic
Bronze Age
Iron Age
Middle Ages

burial mound
age unknown
( ) exact findspot unknown

Fig. 24 (left). Map with archaeological finds of the Gietsenveentje and its surroundings, scale 1:25,000. The map covers the same area as the map of fig. 15. More information about the most interesting Neolithic finds is given in the table below. The numbers correspond to the numbers on the map. Swifterbant: Swifterbant Culture (Early Neolithic B/Middle Neolithic A); TRB: Funnel Beaker Culture (Middle Neolithic B); EGK: Single Grave Culture (Late Neolithic A); BB: Bell Beaker Culture (Late Neolithic B). Most information about the findspots and finds was provided by the Drents Museum, Assen.

No.	Period(s)	Description	Reference(s)
1	Swifterbant	a *durchlochter Breitkeil* (perforated wedge), found on the heath near Eext	VAN DER WAALS 1972, 172
2	TRB	*hunebed* D-12 "Kampakkers"	JAGER 1985, 239: nr. 44
3	TRB	*hunebed* D-13 "Eext burial-vault"	VAN GIFFEN 1943; JAGER 1985, 239: nr. 47
4	TRB	*hunebed* D-13a, destroyed	VAN GIFFEN 1944a; J.A. BAKKER 1979, 155; JAGER 1985, 239: nr. 49
5	TRB	*hunebed* D-13b, destroyed	VAN GIFFEN 1944b; JAGER 1985, 239: nr. 45
6	TRB	*hunebed* D-13c, destroyed	VAN GIFFEN 1944b; JAGER 1985, 239: nr. 46
7	TRB	*hunebed* D-14 "Eexterhalte"	J.A. BAKKER 1979, 155; JAGER 1985, 240: nr. 55
8	Mesolithic, TRB	settlement: flint material	archive J.A. Bakker, 12E: 29
9	TRB	settlement: flint material, undecorated sherds	archive J.A. Bakker, 12E: 30
10	TRB	settlement: scrapers, undecorated sherds, one sherd with deeply incised ornamentation	archive J.A. Bakker, 12E: 38
11	TRB	settlement 13 x 8 m: scrapers, TRB sherd (Bakker phase D)	archive J.A. Bakker, 12E: 37
12	TRB	settlement: stone material	archive J.A. Bakker, 12E: 26
13	TRB, Iron Age	settlement: pottery, stone, flint, iron, bronze: rim sherds of TRB pottery	(partly) VAN ES 1964, 205
14	Palaeolithic, Mesolithic, TRB, EGK, BB	settlement: flint, pottery: TRB sherd (Brindley horizon 4-5?), green-black stone with 5 cupmarks	G. Holtrop, Rolde (amateur archaeologist); J.A. BAKKER et al. 1999
15	TRB, EGK, BB	burial mound "Ketenberg"; pit with TRB sherds (Brindley horizon 6) just outside foot of hill; traces of post holes in subsoil: settlement?	JAGER 1985, 240: nr. 57; CUYPERS et al. 1994, 111; CASPARIE & GROENMAN-VAN WAATERINGE 1980, pollen spectrum N-21
16	TRB, EGK	burial mound; TRB material S and W of the tumulus	JAGER 1985, 233: nr. 41
17	TRB	pottery, flint	ROB 12G N34
18	TRB	pottery	ROB 12G N37
19	TRB	pingo scar Eexterveld: sherds of 5-6 TRB pots (Brindley horizon 1-3 or earlier, 3-4 and 7), flint material	VAN DER KAMP 1995, 72; J.A. BAKKER et al. 1999
20	TRB, BB, Bronze Age	burial mound; TRB sherds (Drouwen A phase) found in the primary mound's body and subsoil	JAGER 1985, 231: nr. 40
21	TRB, Bronze Age	flint material	Kaspers (amateur archaeologist)
22	TRB	flint axe	J.A. BAKKER et al. 1999
23	TRB	flint axe	J.A. BAKKER et al. 1999
24	TRB?, BB, Bronze Age	burial mound; stone with cupmarks of pink-red granite; battle-axe of "Emmen" type (BB)	G. Holtrop, Rolde (amateur archaeologist)
25	EGK	horn sheath of domesticated cattle, found in the Gietsenveentje; ^{14}C date: 4140 ± 35 BP [GrN-20374] (ca. 2750 cal BC)	PRUMMEL & VAN DER SANDEN 1995, 92; 128
26	EGK	burial mound	VAN GIFFEN 1930, 44; JAGER 1985, 240: nr. 54
27	EGK, Bronze Age	burial mound	HARSEMA 1977, 251; JAGER 1985, 239: nr. 51
28	EGK, Bronze Age	burial mound	JAGER 1985, 234: nr. 42
29	EGK?	burial mound	JAGER 1985, 229: nr. 37
30	BB, Bronze Age	burial mound	JAGER 1985, 235: nr. 43
31	Neolithic, Iron Age, Middle Ages	Neolithic flint material; one rim sherd of EGK/BB pottery	Drents Museum, Assen
32	Palaeolithic, Mesolithic, Neolithic, Bronze Age	flint, pottery, bronze, iron	G. Holtrop, Rolde (amateur archaeologist)

According to J.A. Bakker, there are at least five probable locations of TRB settlements in the area of the map of fig. 24. At these locations, TRB sherds and often also flint material have been found. Of these five locations, two (fig. 24: nrs. 10 and 11) lie within 500 m of the Gietsenveentje. At a site in the northern part of the village of Gieten (fig. 24: no. 13), sherds from several periods were discovered, including some TRB sherds. In or near several burial mounds originating from later periods, also TRB material was discovered. Below a burial mound very near the Gietsenveentje (fig. 24: no. 20), TRB pottery of the earliest known phase (Drouwen A) was found. In the subsoil of the burial mound "Ketenberg" (fig. 24: no. 15), traces of postholes were discovered that probably point to a TRB settlement. In several places within and under the mound, TRB sherds were found, some of which could be placed in Brindley's horizon 6 (Late TRB) (CUIJPERS et al. 1994). A former pingo scar on the Eexterveld (fig. 24: no. 19) contained TRB sherds of five or six pots, originating from different periods, ranging from Brindley's horizon 1-3 or earlier to 7 (VAN DER KAMP 1995; J.A. BAKKER et al. 1999). Finally, two locations (fig. 24: nos. 14 and 24) produced stones with cupmarks; at location no. 14, such a stone was found together with a TRB sherd. Cupmarks are sometimes found on the sides of megalithic tomb boulders, suggesting that they are of TRB origin. However, J.A. Bakker (1992, 32) found that cupmarks also originate from the Late Neolithic (EGK/BB), and even from the Early Bronze Age.

Single Grave Culture (EGK) and Bell Beaker Culture (BB). Several finds of the Single Grave Culture (EGK) are known from the neighbourhood of the Gietsenveentje. Most EGK material was found in four burial mounds (fig. 24: nos. 26-29). The most remarkable find from the EGK period is a horn sheath of domesticated cattle (*Bos taurus*, male), found in 1943 at a depth of 1.75 m, on the transition of *Sphagnum* peat ("brown peat") and gyttja ("black peat") in the Gietsenveentje itself (fig. 24: no. 25; PRUMMEL & VAN DER SANDEN 1995). Below the horn sheath, still 25 cm of gyttja occurred. According to a ^{14}C date (ca. 2750 cal BC), the horn sheath was thrown into the then lake by EGK people. Material of the Bell Beaker Culture (BB) was found in one burial mound (fig. 24: no. 30).

Two findspots very near the Gietsenveentje (fig. 24: nos. 31 and 32) produced a lot of material of various periods including the Neolithic, possibly pointing to settlements at these locations. However, as far as known, no TRB material was found. At the Neolithic findspots without a number in fig. 24, mostly only flint material is found, which could not be dated more exactly than as Neolithic.

Bronze Age. The most conspicuous remains of the Bronze Age are several burial mounds, located in the western and southwestern part of the map area.

Iron Age and Roman Period. From the Iron Age, three complexes of Celtic fields are known, located west of the *hunebedden* D-12 and D-13, and west of *hunebed* D-14 (BRONGERS 1976). An Iron Age urnfield was excavated very near *hunebed* D-13. An Iron Age and Roman Period settlement lay north of the village of Gieten ("Vijzelkampen"), on the slope of the Hondsrug ridge.

Middle Ages. Sherds of the typical *kogelpotten* (*Kugeltöpfe*, globular pots) were found in the centre of the village of Eext. During the construction of the roundabout next to the Gietsenveentje in the 1960s, a large number of sherds of *kogelpotten* were found among other sherds. Unfortunately, no more is known about this find immediately next to the Gietsenveentje (see Nieuwe Drentse Volksalmanak 1968, p. 290).

Age unknown. At three locations just south and east of the Gietsenveentje, the amateur archaeologist G. Holtrop has found flint tools of unknown age. Finally, the diary of the Conservator of the Pre- and Protohistoric Department of the Drents Museum in Assen (J.D. van der Waals), on March 24, 1959 contains the following vague and mysterious notice: "In the bog - the Gieter Veentje [sic] - on the western side of the Gieten-Eext road (...), which is also called Bolleveentje, a drowned settlement is located which is very similar to the drowned settlement in the 'real' Bolleveen near Zeijen [north of Assen]". The Bolleveen near Zeijen is known because of its (ritual?) finds from the Roman Period (oral comm. J.N. Lanting). Unfortunately, at the Drents Museum no finds are known from the Gietsenveentje, nor is any additional information available about Van der Waals' remark.

Preferred settlement locations. The TRB people seem to have had a strong preference for elevated and dry coversands and pre-Saalian sands: their favourite settlement locations were high coversand ridges, dry erosion areas and well-drained edges of brook valleys (J.A. BAKKER 1982; BAKKER & GROENMAN-VAN WAATERINGE 1988; SPEK 1993). Furthermore, the TRB settlements are always located in the neighbour-

hood of brooks or water-containing depressions (like pingo scars). Finally, TRB settlements are also often located at the edges of till plateaus, on the transition to coversand areas or erosion valleys. The *hunebedden* were nearly always built within 300 m of a till erosion edge. The boulders which were released from the till by erosion at the edges of the plateaus were used for building the *hunebedden* (BAKKER & GROENMAN-VAN WAATERINGE 1988, 153).

In order to discover the preferred settlement locations of the TRB people, the map of fig. 24 will be compared in the first place with the geomorphological map (fig. 19) rather than with the soil map: the current soils were in large part formed after TRB times (see III.3.3; BAKKER & GROENMAN-VAN WAATERINGE 1988, 161), while the geomorphology has been less subject to change.

The TRB finds are concentrated in two areas:

1. all *hunebedden* as well as several settlements and stray finds occur in the middle western part of the map area. The *hunebedden* are located on small coversand or pre-Saalian sand ridges at the western edge of the till plateau, on the transition to the low-lying erosion valley of the Scheebroekerloop (fig. 19). Because the coversand layer is not very thick in these areas, the sands on which the *hunebedden* were built are rich in loam (see the soil map, fig. 20: the soils in this area all have code 23, indicating the presence of loamy fine sand). The locations completely comply with the above-mentioned settlement factors. Also nearly all funerary monuments from later periods are located in this area.
2. several settlements (fig. 24: nos. 10, 11, 13) and one burial mound (no. 20) are located in the central part of the map area, on the highest part of the till plateau, near water-containing depressions (Gietsenveentje, Hondelveen, Molenveen). According to the soil map, the loam content of the sand is low or even zero in part of this area (fig. 20: soils with code 21), which points to a relatively thick layer of coversand.

III.8 The Gietsenveentje and its surroundings in the past two centuries

III.8.1 History of the landscape around the Gietsenveentje since 1812

Since the Middle Ages, and especially in the last few centuries, the landscape in Drenthe has undergone dramatic changes. Nowadays, the most typical elements of the landscape of the Drenthe Plateau, the large expanses of heath and raised bog, have been transformed into large-scale agricultural areas apart from small nature reserves. This development of the landscape of the Drenthe Plateau will be illustrated on the basis of four topographical maps of the surroundings of the Gietsenveentje.

Topographical map of 1812 (fig. 25). Although several older maps of the area are known (for example maps of 1794 and 1797, stored in the State Archives of Drenthe, Assen), the topographical map made by the French Ministry of War in 1812 is the oldest map on which the Gietsenveentje is shown. The pingo scar is indicated as a marshy area, surrounded by small pieces of arable land. Around the villages of Eext and Gieten, many small pieces of arable land occur; the plaggen soils (*essen*) are located somewhat further away from the villages. Also small patches of (ancient?) forest occur, for example north of the village of Gieten ("De Vijzelkampen"). In the low-lying Hunze valley to the northeast, pasture land is indicated, divided into narrow plots. The largest part of the area was covered with extensive heathfields, only interrupted by several water-containing depressions, mostly pingo scars. In Drenthe, the old agricultural system, in which the heath played an important role, was practised well into the 19th century (THISSEN 1994). Also some very old roads are indicated, which may date back to the Iron Age (WATERBOLK 1985a, 75), and the boundary between the *marken* (common land) of Gieten and Eext, which runs just north of the Gietsenveentje. The *hunebedden* D-12 and D-14, already discovered in the 18th century, are also shown.

Topographical map of 1855 (fig. 26). From 1850 onwards, parts of the extensive heathfields in Drenthe were reclaimed, mostly on a small scale (THISSEN 1994, 25). However, the topographical map of 1855 shows that the heath area has not decreased compared to the situation in 1812: the

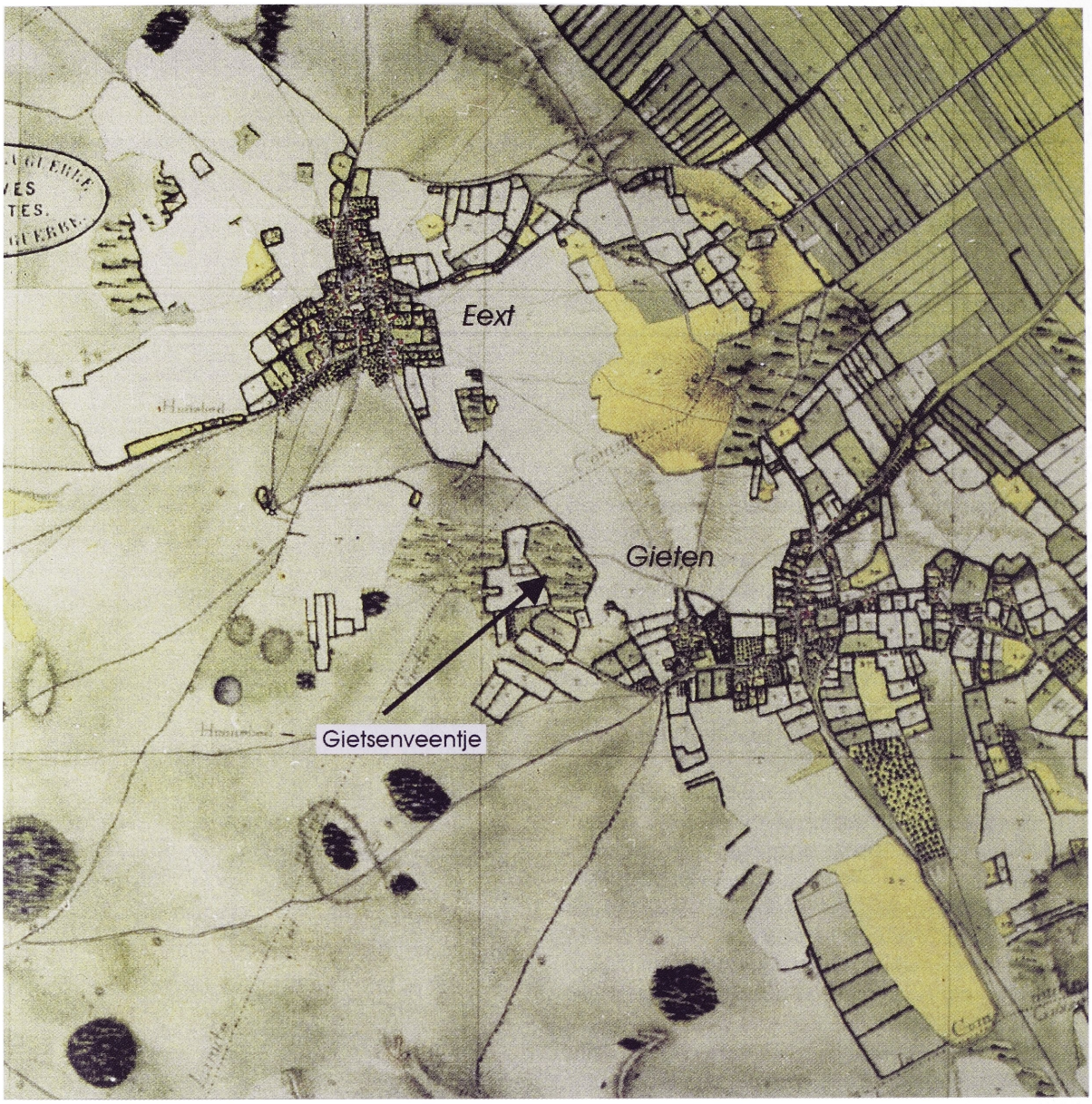


Fig. 25. Topographical map of 1812 of the Gietsenveentje and its surroundings, scale 1:25,000, made by the French Ministry of War. The map covers the same area as the map of fig. 15.

agricultural area has not or only slightly been extended. The Gietsenveentje is not shown very clearly on this map; however, it can be seen that a short road was constructed through it, indicating that the extraction of peat from the Gietsenveentje had started (see III.8.2). In this period, also several new "long-distance" roads were constructed, while some old roads fell into disuse. Besides *hunebedden* D-12 and D-14, also *hunebed* D-13 (indicated as *grafkelder*) is indicated.

Topographical map of 1896 (fig. 27). In the last part of the 19th century, the railway between Assen and Stadskanaal was constructed, with a stop near *hunebed* D-14 ("Eexterhalte") and a station near Gieten. Compared to the map of 1855, the agricultural area seems not to have been extended very much; the large heathfields are still unaffected. The Gietsenveentje (here called "Gieterveentje") is indicated as a marshy area, covered with (carr) forest. This seems to indicate

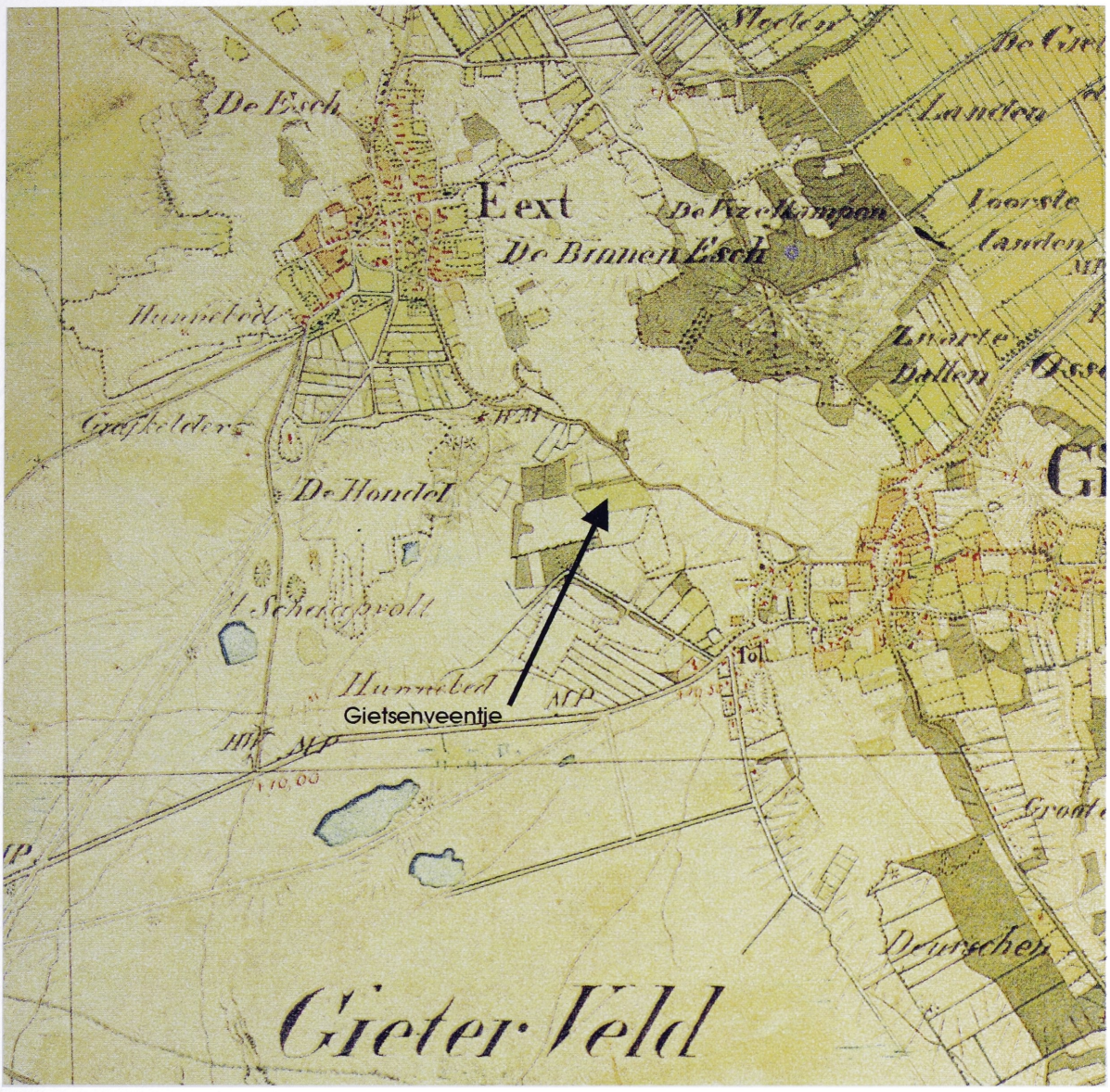


Fig. 26. Topographical map of 1855 of the Gietsenveentje and its surroundings, scale 1:25,000, made by the Dutch Topographical Service. The map covers the same area as the map of fig. 15. © Topografische Dienst, Emmen..

that no large-scale exploitation of the peat in the Gietsenveentje had taken place before 1896, because otherwise, areas of open water would occur. The Gietsenveentje is largely surrounded by agricultural land: on the western and eastern side, plaggen soils (*essen*) occur, the Grietsche Akkers and the Noordakkers, respectively. In the southwest, several old roads can be recognized, which had already fallen into disuse. In the west and northwest, marshy areas occur, which are part of the erosion valley of the Scheebroekerloop. The uppermost part of the Scheebroekerloop itself even occurs on the map. Curiously, this part of the brook is not shown on the maps of 1812 and 1855.

Topographical map of 1958 (fig. 28). Between 1896 and 1958, the landscape in the neighbourhood of the Gietsenveentje totally changed. As a consequence of reclamation, supported by the government (THISSEN 1994), the extensive



Fig. 27. Topographical map of 1896 of the Gietsenveentje and its surroundings, scale 1:25,000, made by the Dutch Topographical Service. The map covers the same area as the map of fig. 15. © Topografische Dienst, Emmen.

heathfields disappeared almost completely and were replaced by farmland. At various locations, for example in the south and far northwest, (mostly pine) forests were planted. In the wettest parts of the erosion valley of the former Scheebroekerloop (middle western part of the map area), pasture was created. In the Gietsenveentje itself, two short roads can be recognized, as well as small areas of open water, pointing to small-scale cutting of peat. The western and southern part of the Gietsenveentje are indicated as (marshy) heath, the central part as (carr) forest. At this time, the Gietsenveentje was also used as rubbish dump (unpublished notes by J.D. van der Waals, 1959).

Topographical map of 2001 (fig. 15). After 1958, the railway between Assen and Stadskanaal fell into disuse; two motorways were constructed, intersecting at the roundabout just north of the Gietsenveentje; the villages of Eext and especially Gieten were extended considerably; and because of land consolidation, the agricultural fields became larger in scale.



Fig. 28. Topographical map of 1958 of the Gietsenveentje and its surroundings, scale 1:25,000, made by the Dutch Topographical Service. The map covers the same area as the map of fig. 15. © Topografische Dienst, Emmen.

III.8.2 History of the Gietsenveentje since 1832

The history of the Gietsenveentje itself can be traced back as far as 1832, when a land registration system (*kadaster*) was introduced by the government. On the cadastral map of 1832, the Gietsenveentje is divided into five plots, owned by various farmers and one mayor. The largest part of the Gietsenveentje is indicated as "heath"; a small part at its northwestern edge is marked "meadow". On the most recent cadastral map, the Gietsenveentje is divided into 12 parcels. Three have been acquired by the Dutch State Forestry. Other parcels have various owners, some of whom live in Australia or Canada. The increased number of owners is the result of successive divisions of estate. Nowadays, the largest part of the Gietsenveentje is indicated as wasteland, except for two parcels: at the northwestern edge, the State Forestry has planted a plot of forest,

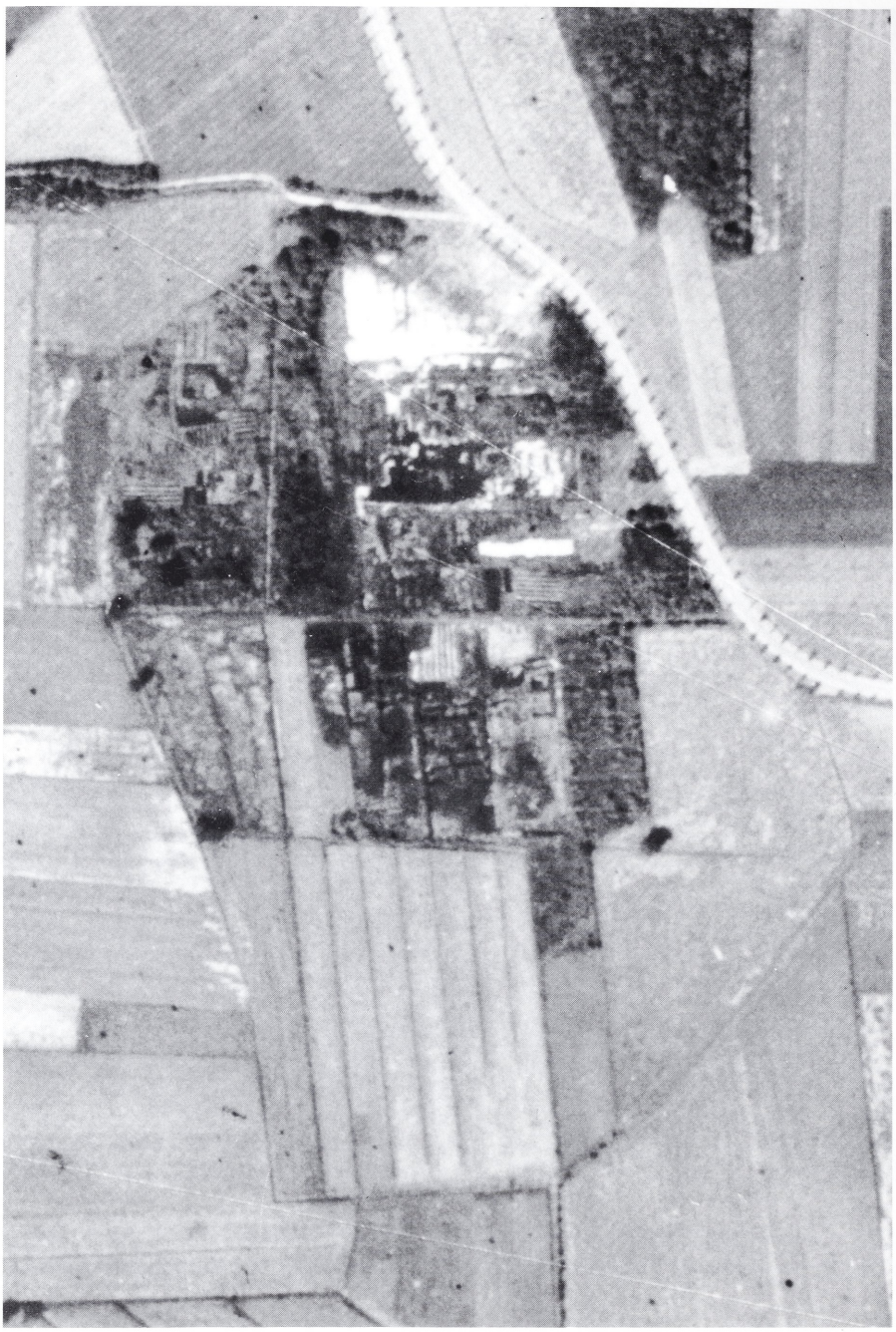


Fig. 29. Aerial photograph of the Gietsenveentje, taken in 1935 by the Dutch Topographical Service. © Topografische Dienst, Emmen.

while in the southwestern part there is grassland. By using the cadastral records, the history of each parcel can be followed from 1832 up till today. From these data, it appears that the first peat-cutting in the southern part of the Gietsenveentje took place between 1856 and 1871. Before this exploitation, the parcel was indicated as "heath", and afterwards, curiously, as "meadowland" rather than "peat" or "open water". Possibly further exploitation took place between 1887 and 1903: the indication of the parcel then changes from "heath" to "peat". The first exploitation of the northern part of the Gietsenveentje possibly took place between 1864 and 1868, because before 1864, the parcel concerned was indicated as "heath", and after 1864 as "peat".

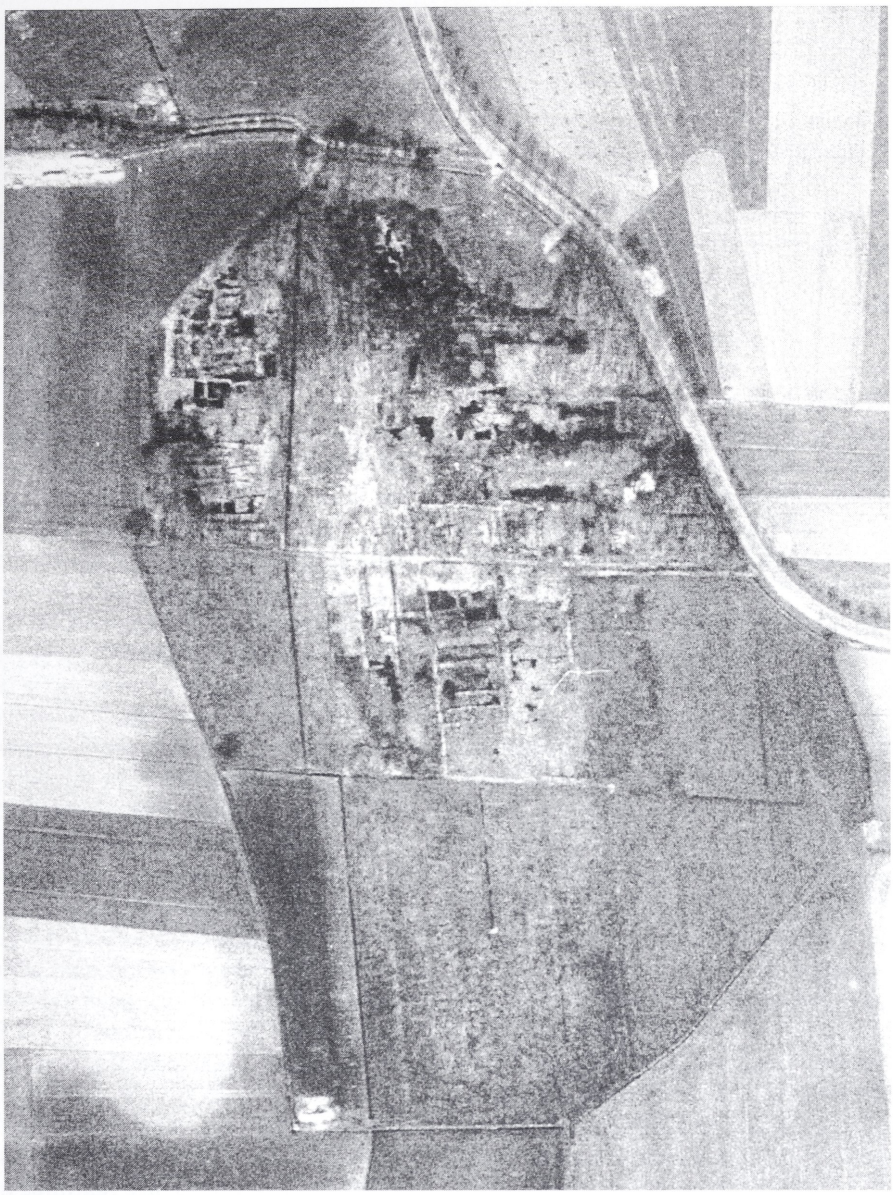


Fig. 30. Aerial photograph of the Gietsenveentje, taken in 1957 by the Dutch Topographical Service. © Topografische Dienst, Emmen.

Another source of information about the history of the Gietsenveentje are aerial photographs. The oldest aerial photograph of the Gietsenveentje, shown in fig. 29, dates from 1935. The presence of many areas of open water, especially in the central and northern parts, indicates small-scale peat-digging activities. An aerial photograph of 1957 is shown in fig. 30. It can be seen that the peat-digging activities have decreased since the 1930s: for instance, the northern part is already partly overgrown by (carr) forest. However, many small peat pits can be distinguished, especially in the western and southern parts, and a large part of the pingo scar is not covered by forest. In the 1960s, peat-cutting in the Gietsenveentje came to an end. Together with the lowering of the water table in the course of land consolidation, this has led to the Gietsenveentje being totally overgrown by forest. The situation in 1995 is shown in fig. 17. The current topography and vegetation of the Gietsenveentje are further discussed in sections VI.1 and VI.2, respectively.

IV. Material and methods

IV.1 Sequence corings

Two types of sequence were cored in the Gietsenveentje: sequences for lithological descriptions and sequences for various types of analysis. The first type of sequence was described in the field, while the second type of sequence was sampled, packed in plastic and transported to the laboratory.

Some of the sequences used for lithological descriptions were cored by two employees of the Dutch Geological Survey, Mr De Vries and Mr Warkor. They used an Edelman sampler. The other sequences used for lithological descriptions were cored with a Russian sampler with a length of 50 cm and a diameter of 5 cm (AABY & DIGERFELDT 1986, 183; LANG 1994, 39).

In total, eleven sequences were sampled for various types of analysis. Three of these, viz. Gieten I, II and III, were cored with a Dachnowsky sampler with a length of 25 cm and a diameter of 3.6 cm (WEST 1968, 103; LANG 1994, 40). Another three sequences, viz. Gieten IV-P, IV-HR and IV-HL, were sampled from an open section, which was dug in the centre of the Gietsenveentje (see VI.1.4). Gieten IV-P and Gieten IV-HR were sampled with the help of rectangular sample tins, while Gieten IV-HL was sampled with a scoop: layers of 2.5-3 cm of sediment were cut out and put separately into plastic bags. Finally, four sequences, viz. Gieten V-A, V-B, V-C and V-D, were cored with two types of sampler. The largest part of each of these sequences was cored with a Russian sampler. The part near the Pleistocene subsoil, where the sediment is more compact and sandy, was sampled with a gouge (in German: *Holländischer Marschenlöffel*) with a length of 100 cm and a diameter of 3.5 cm (COUTEAUX 1962; AABY & DIGERFELDT 1986, 188; LANG 1994, 42).

Attemps were made also to sample cores with a large diameter for the analysis of macroscopic remains. A Dachnowsky sampler with a length of 40 cm and a diameter of 6 cm was used. Because of the presence of fibrous and loose peat sediment, it proved difficult to sample a complete core with this sampler; sampling was successful only at the location of sequence Gieten V-C.

IV.2 Sampling techniques

The samples to be used for various types of analysis were taken out of the sequences with the help of various techniques.

In sequences Gieten I and II, pollen samples with a thickness of 1 cm were taken. No volume measurements were made. In sequence Gieten III, pollen samples with a thickness of 0.5 to 0.7 cm were taken: they were sliced with the help of a cutting machine. Volume measurements of each pollen sample were conducted with the help of a cylindrical punch with a diameter of 1.05 cm.

In sequences Gieten IV-P, IV-HR and V-A to V-D, pollen samples with a thickness of 1 cm were taken, also with the help of the cylindrical punch. When a layer of sediment with a thickness of 1 cm was punched, the volume of the sediment in the punch measured 0.8659 cm^3.

In sequence Gieten IV-HL, large macroscopic samples with a thickness of 2.5-3 cm were taken from an open section. The macroscopic sample core of Gieten V-C, which has a diameter of 6 cm, was completely divided into pieces with a thickness of 5 cm.

The wood samples were collected from the pollen sequences. When relatively large pieces of wood were recognized, they were taken out of the core and stored separately.

The samples used for radiocarbon dating were collected from the pollen sequences. For conventional dating, relatively large samples are needed. In sequence Gieten I, a sample with a thickness of 10 cm was used for conventional dating. In sequence Gieten III, the sediment between 322 and 351 cm, which remained after the pollen samples had been taken, was divided into seven parts of 3.2-3.3 cm. These seven parts were dated conventionally. In sequence Gieten IV-P, two samples with a thickness of 2 cm were used for conventional dating. For AMS dating, only very small samples are needed (see IV.7). In sequences Gieten IV-P, IV-HR and V-A to V-D, samples with a thickness of 1 cm were used for AMS dating. These samples were taken out of the sediment with the help of the above-named cylindrical punch, at exactly the same level as the pollen samples.

The phosphorus samples were also collected from the pollen sequences. In sequences Gieten V-A, V- B and V-C, samples with a thickness of 1 cm were collected, again with the help of the cylindrical punch. The samples were always taken at a level not more than 1 cm from a pollen sample.

IV.3 Sample processing

All samples were processed in the laboratory of the Groningen Institute of Archaeology. The pollen samples were processed following the method described by Faegri & Iversen (1989). Two tablets with *Lycopodium* spores were added to each sample for the determination of pollen concentration and influx (see IV.8). The samples were mounted in silicone oil.

The macroscopic samples with volumes of 1 or 2.5 litres were put in water for a few weeks. By stirring, the samples were made to disintegrate. In the case of compact gyttja samples, this proved to be quite difficult. Subsequently, the samples were put through three sieves with meshes of 2, 0.5 and 0.2 mm respectively, so that three different fractions were obtained. These fractions were analyzed separately. In most cases, the relatively small 2 mm sieved sample was analyzed completely, while the larger 0.5 and 0.2 mm sieved samples were analyzed only partly. The results of the samples from the various sieves were combined and converted to a content of 1 litre.

The wood samples were used for making hand-cut sections with a razor blade along the transversal, radial and tangential planes. The sections were placed in water on an object slide and covered with a coverslip.

IV.4 Sample analysis

The microscopic slides with the pollen samples were analyzed with a light-transmitting Zeiss binocular microscope at 400x magnification. For difficult identifications, oil immersion was used at a magnification of 1000x. Several works were used for identifying pollen and spore types, including Faegri & Iversen (1989), Moore et al. (1991), Reille (1992) and Punt et al. (1976; 1980; 1981; 1984; 1988; 1991). Palynomorphs were identified with the help of publications of Van Geel (1978) and Van Geel et al. (1981; 1989). The reference collection at the Groningen Institute of Archaeology, containing modern pollen of thousands of species, was used to check the identifications. The nomenclature of the pollen types follows the standardized nomenclature of Birks (BIRKS 1973, 225; BERGLUND & RALSKA-JASIEWICZOWA 1986, 457):

Umbelliferae	Family identification certain, types or subgroups unidentified or unidentifiable.
Ericaceae indiff.	Family identification certain, one or more types are identified within the family, this is the "rest group".
Betula	Genus identification certain, types or subgroups unidentified or unidentifiable.
Jasione montana	Species identification certain.
Rumex acetosa/ acetosella	One fossil type present; only two taxa are considered likely candidates, but further distinctions are not possible on the basis of pollen or spore morphology alone.
Potentilla-type	One fossil type present, three or more taxa are possible candidates, but further distinctions are not possible on the basis of pollen or spore morphology alone.

The pollen morphology of *Rumex acetosa* and *Rumex acetosella* is discussed in chapter V.

The macroscopic samples were analyzed with a Wild M5 binocular microscope with incident light at magnifications of 6 to 50x. Several works were used to identify the macroscopic remains, including Beijerinck (1947) and Körber-Grohne (1964). The reference collection at the Groningen Institute of Archaeology, containing modern seeds of many species, in dry, charred and waterlogged conditions, was used to check the identifications.

The wood samples were analyzed with a Zeiss binocular microscope with coaxial illumination at magnifications of 40 to 400x. The reference work by Schweingruber (1978) was used to identify the wood remains. Also comparisons with recent material were made.

IV.5 The construction of the pollen diagrams

The principal part of the present study is formed by pollen analysis. The result of a pollen analysis is the pollen record, consisting of a very large

matrix of raw data. This matrix is much too unwieldy to be of direct use. Results are therefore presented in a simpler, graphic form: the pollen diagram. In a pollen diagram, the vertical axis represents depth and the horizontal axis the abundance of the pollen taxon in either proportional or absolute terms. The first type of diagram is a pollen percentage diagram, the second is a pollen influx diagram (discussed in IV.8). In the pollen percentage diagrams presented here, the curves are divided into five major groups (BERGLUND & RALSKA-JASIEWICZOWA 1986):

1. **Arboreal Pollen**: Ligneous terriphytic spermatophytes (trees, shrubs and climbing plants);
2. **Non-Arboreal Pollen**: Non-ligneous terriphytic spermatophytes (herbs) and pteridophytes (ferns);
3. **Local types**: Helophytes (plants of lake shores, fens and bogs) and limnophytes (aquatic plants);
4. **Van Geel palynomorphs**: Palynomorphs, predominantly bryophytes (mosses) and fungi, which have been assigned a type number by Van Geel (1978) and Van Geel et al. (1981; 1989).
5. **Charcoal particles**: Charcoal particles, subdivided into three size categories.

The Arboreal and Non-Arboreal Pollen together form the pollen sum ($\Sigma P = AP + NAP$). All pollen percentages, including the percentages of the last three groups, are calculated on the basis of the pollen sum. The **regional pollen** includes all pollen types included in the pollen sum; the **local pollen** includes all pollen types excluded from the pollen sum. According to Faegri & Iversen (1989), the pollen rain consists of three components:

(1) the gravity component: pollen falling straight down;

(2) the local pollen: that part of the pollen output which went into a diffusion cloud the centreline of which remained more or less parallel to the ground, increasing in diameter and being intercepted by the ground cover;

(3) the regional pollen: the truly airborne pollen, caught by updraughts and transported via greater altitudes than the tree-tops and the air currents created by the latter.

However, the terminology used by different authors is not consistent. As used by Janssen (1966), "local" corresponds to the gravity component of Faegri & Iversen and "extra-local" to the local pollen as defined by Faegri & Iversen. "Regional" and "extra-regional" both correspond to Faegri & Iversen's regional pollen. Because the definitions put forward by Faegri & Iversen are difficult to apply in actual practice and because the used terminology is not consistent, the best solution seems to be to use convenient, practical definitions of local and regional pollen. However, the problem of which pollen type belongs to local pollen and which to regional pollen, is a difficult one and each solution is subjective. In this study, the following definitions of regional and local pollen are used:

Regional pollen: pollen of plants generally growing outside the basin, at a fairly large distance from the core locations. Except for *Betula*, all common tree pollen types are included in the regional pollen. Because herbs and ferns that prefer more or less dry conditions are not thought to have occurred in the basin, and consequently in the neighbourhood of the core locations, they are included in the regional pollen.

Local pollen: pollen of plants growing within the basin, in the direct neighbourhood of the core locations. All pollen types of aquatic plants and of plants of lake shores, fens and bogs are considered to belong to this category.

All pollen percentage diagrams were drawn by the TILIA computer program, which was developed by Dr. E.C. Grimm of the Illinois State Museum, Springfield (USA).

IV.6 Processing of samples for the assessment of phosphorus content

The phosphorus samples were processed following the molybdenum blue method (MURPHY & RILEY 1962; BENGTSSON & ENELL 1986). In this procedure, a blue phosphomolybdate compound is developed in an aqueous solution. All phosphorus samples were processed at the Laboratory of Plant Ecology of the University of Groningen.

IV.7 Radiocarbon dating methods

The absolute age of Gietsenveentje samples was assessed at the Centre for Isotope Research of the University of Groningen with the help of two fundamentally different methods of radiocarbon dating:

1. the conventional method, which entails the measurement of the radioactivity of ^{14}C (MOOK & STREURMAN 1983);
2. the AMS method (Accelerator Mass Spectrometry), which entails the measurement of the $^{14}C/^{12}C$ ratio by mass spectrometry. Because the number of ^{14}C atoms can be measured directly, instead of only those atoms which decay radioactively (ELMORE & PHILLIPS 1987), it is possible considerably to reduce the amount of material needed for an analysis - roughly by a factor 1000. The AMS tandem in Groningen, which was used for the Gietsenveentje AMS dates, is of the new generation Tandetron (WIJMA & VAN DER PLICHT 1997).

IV.8 Assessing pollen concentration and pollen influx

In order to assess pollen concentration and pollen influx, tablets with a known number of a *tracer*, in this case *Lycopodium* spores, were added to each pollen sample with a known volume (STOCKMARR 1971). Each tablet contains ca. 12,542 spores (BERGLUND & PERSSON 1994). 2 Tablets were dissolved in warm water and added to each Gietsenveentje pollen sample (except for the samples of Gieten I and II). All Gietsenveentje pollen samples were taken with a punch with a volume of 0.8659 cm^3. The *Lycopodium* spores were counted in routine pollen analysis. With the help of the following formula, pollen concentration was calculated (BIRKS & BIRKS 1980, 207):

$$A = \frac{L_A \times P_C}{L_C \times V_S}$$

in which:
A = concentration in grains/cm^3
L_A = number of *tracer* units (*Lycopodium* spores) added to each sample
P_C = number of counted pollen grains
L_C = number of counted *tracer* units (*Lycopodium* spores)
V_S = sample volume in cm^3

Pollen influx was calculated as follows:

$$I = A \times v_S$$

in which:
I = influx in grains/cm^2/year
A = concentration in grains/cm^3
v_S = sedimentation rate in cm/year

The sedimentation rate was calculated as follows:

$$v_S = \frac{\text{date of depth B} - \text{date of depth A}}{\text{depth B} - \text{depth A}}$$

in which the dates are calibrated ^{14}C dates, expressed in cal BC; the depths are expressed in cm.

IV.9 Recording of recent vegetation plots and collection of surface samples

Vegetation plots were recorded following the (extended) method of Braun-Blanquet (1964). For practical reasons, the dimensions of the chosen examination areas were determined at 2 x 2 m (EVANS & MOORE 1985). A species list of each examined area was made. Subsequently, the contribution of individuals of each species to the vegetation cover was estimated on the basis of the combined estimation method, developed by Braun-Blanquet (1964) and extended by Barkman et al. (1964; see also SCHAMINÉE et al. 1995a, 72). This method implies that when a species covers an area less than 5%, its abundance, viz. the number of individuals, is estimated; when it covers an area of 5% or more, its cover area, viz. the percentage of the total area which is occupied by the species when the outline of its individuals is projected on the ground, is estimated.
Surface samples, which are a reflection of the modern pollen present in the air, were obtained by the sampling of moss polsters: in the moist and acid environment of a moss polster, pollen apparently is preserved very well (BOTTEMA 1995). As far as possible, only green moss stems and leaves were collected. Bradshaw (1981, 50) states that in this way, a pollen assemblage reflecting perhaps the last 5 years will be taken, the precise period depending on the growth rate of the moss. However, inevitably some remains of older moss organs and some soil parts will be collected together with the green moss parts, so that it cannot be excluded that pollen older than 5 years occurs in the surface samples.

V. Pollen morphology and representation in surface samples of *Rumex acetosa* and *Rumex acetosella*

V.1 Introduction

A pollen type which often increases at the beginning of the Neolithic as represented in pollen diagrams and for that reason is considered a useful indicator of human activity, is *Rumex*-type (BEHRE 1981; see I.4.2). *Rumex acetosa* and *Rumex acetosella* are nowadays by far the most common and widespread species falling within this type. These two species are wind pollinators and produce very large amounts of pollen: for example, one inflorescence of *Rumex acetosa* produces ca. 393,000,000 pollen grains (POHL 1937). The two *Rumex* species are always well represented in surface pollen samples (see for example BRADSHAW 1981, table 4).

Some authors have regarded *Rumex*-type as indicative of pasture (TURNER 1964; DONALDSON & TURNER 1977), while other authors have selected it as indicative of arable land (RIEZEBOS & SLOTBOOM 1978). A first step leading towards the solution of this disagreement is the separation of the pollen of *Rumex acetosa* and *Rumex acetosella*. A second step comprises a study of the ecology of these two species. These steps are worked out in the next two sections: in V.2, the pollen morphology of these two species is studied; V.3 deals with the representation of the two species in surface pollen samples and in vegetation plots from vegetation types in which they play an important role. Section V.4 discusses how the results of this study can be used for the interpretation of the subfossil pollen diagrams.

V.2 Pollen morphology

Rumex species produce 3-zono- or (4-9) pantocolporate pollen grains. The ectocolpi are narrow and slit-like, long to very long. The endopori are circular, slightly lalongate (elongated in equatorial direction) or more or less lolongate (elongated in polar direction) in outline, with narrow but distinct costae, which are sometimes interrupted at the equator. The ornamentation is microreticulate (VAN LEEUWEN et al. 1988). Although the pollen of *Rumex* species are very similar, it is possible to recognize distinct pollen groups and sometimes even species (VAN LEEUWEN et al. 1988). In table 2, a small identification key is shown, used in this study for the subdivision of *Rumex*-type. All *Rumex* grains larger than 22 µm belong to *Rumex hydrolapathum*-type. In the subfossil pollen diagrams of the Gietsenveentje, only a few grains of this type were observed. All *Rumex* grains smaller than 22 µm belong to *Rumex acetosa/acetosella*. According to Van Leeuwen et al. (1988), not only *Rumex acetosa* and *Rumex acetosella* belong to this group, but also four other species. In table 4, some characteristics of these four species are summarized. *Rumex thyrsiflorus* and *Rumex triangulivalvis* are no native species of northwestern Europe, but are imported from central/eastern Europe and North America, respectively. *Rumex alpestris* and *Oxyria digyna* only occur in mountainous areas of Europe and arctic regions. The likelihood that any of these four species ever grew near the

Rumex-type
- < 22 µm: *Rumex acetosa/acetosella*
  Species: *R. acetosa, R. acetosella, R. alpestris, R. thyrsiflorus, R. triangulivalvis, Oxyria digyna* (see table 3 and 4)
- > 22 µm: *Rumex hydrolapathum*-type
  Species: *R. aquaticus, R. bucephalophorus, R. conglomeratus, R. crispus, R. hydrolapathum, R. longifolius, R. maritimus, R. obtusifolius, R. palustris, R. patientia, R. pulcher, R. rupestris, R. sanguineus, R. scutatus*

Table 2. Subdivision of pollen of *Rumex*-type in this study. All measurements are in silicone oil.

Rumex acetosa L.	*Rumex acetosella* L.	Reference
relatively short colpi	long colpi	VAN LEEUWEN et al. 1988
non-intruding colpi	intruding colpi	VAN LEEUWEN et al. 1988
endoporus interrupted, circular or slightly lalongate	endoporus usually distinctly interrupted, often lalongate	VAN LEEUWEN et al. 1988
microreticulate	reticulate	MOORE et al. 1991
not dupli- or pluricolumellate; no slightly winding muri	dupli- or pluricolumellate with slightly winding muri	MOORE et al. 1991

Table 3. Characteristics of pollen of *Rumex acetosa* and *Rumex acetosella*.

Species	Biotope	Present distribution	Origin	Pollen resembles:	Differences in pollen
Rumex alpestris Jacq. (= *R. arifolius* All.)	meadows, mainly in the mountains	mountains of Europe	mountains of Europe	*Rumex acetosa*	lolongate endoporus
Rumex thyrsiflorus Fingerh.	moderately dry grassland, esp. along rivers	recently spreading as an alien into W. Europe	C. and E. Europe, Siberia	*Rumex acetosa*	none
Rumex triangulivalvis (Danser) Reichb. f.	brooksides	naturalized in N., W. and C. Europe	N. America	*Rumex acetosella*	lolongate endoporus
Oxyria digyna (L.) Hill	stony pastures, near melting snow	mountains of Europe, arctic regions	mountains of Europe, arctic regions	*Rumex acetosella*	distinct, circular endoporus; never 4-colporate

Table 4. Characteristics of *Rumex* and *Oxyria* species producing pollen which resembles pollen of *Rumex acetosa* or *Rumex acetosella* (TUTIN et al. 1964; VAN LEEUWEN et al. 1988).

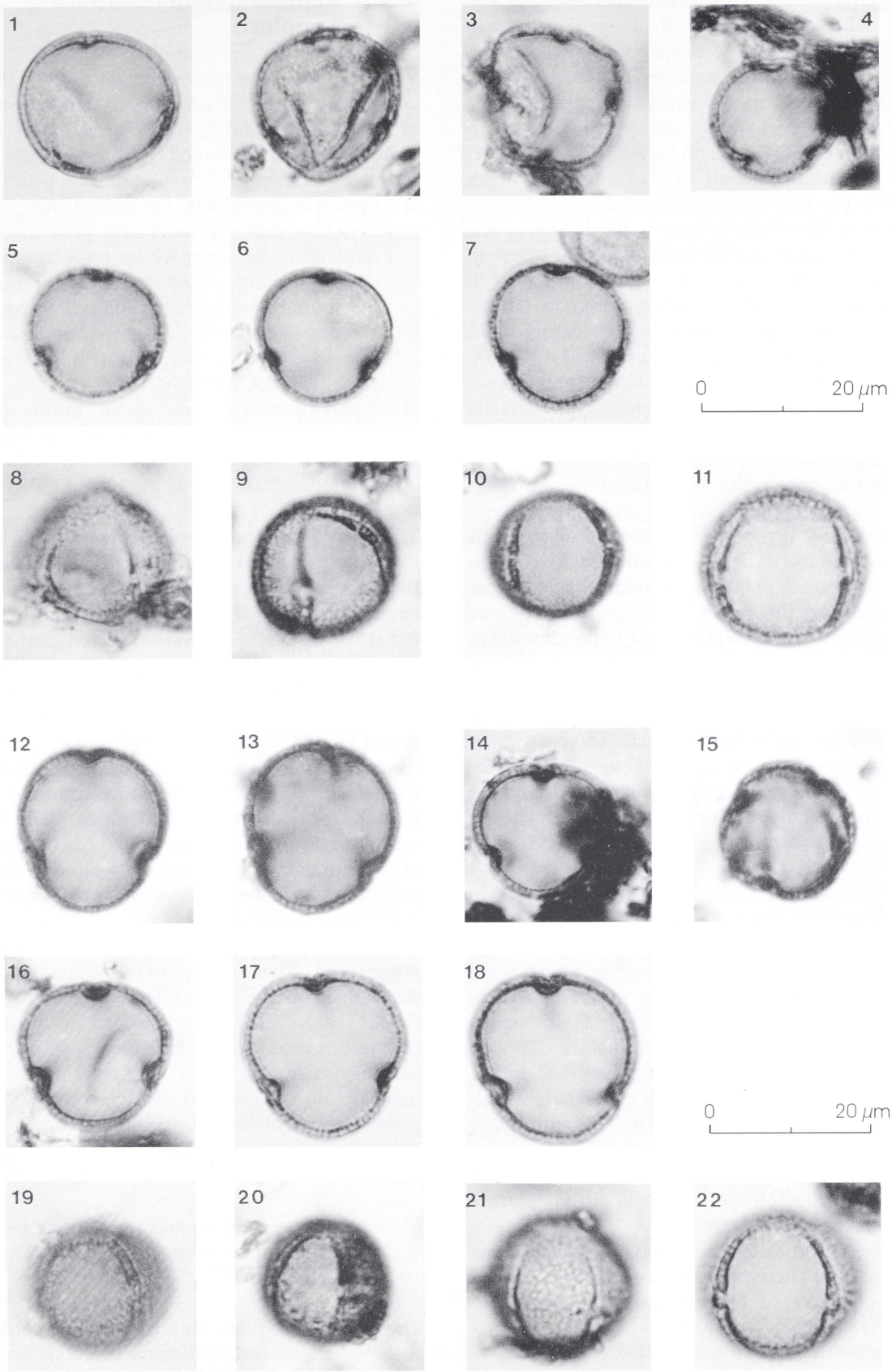
Fig. 31 (right). Pollen grains of *Rumex acetosa* and *Rumex acetosella*. Magnification 1250 x.

1-11 *Rumex acetosa*:

1. Gieten V-A 377-378 cm; 2. Gieten IV-P 335-336 cm; 3. Gieten V-B 215-216 cm; 4. Gieten V-A 366-367 cm; 5. surface sample N5; 6. surface sample N5; 7. reference sample BAI 4989; 8. Gieten V-B 215-216 cm; 9. Gieten V-A 366-367 cm; 10. surface sample N5; 11. reference sample BAI 4989.

12-22 *Rumex acetosella*:

12. Gieten V-A 59-60 cm; 13. Gieten V-A 59-60 cm; 14. Gieten V-A 366-367 cm; 15. Gieten IV-HR 355-356 cm; 16. surface sample H3; 17. reference sample BAI 4991; 18. reference sample BAI 4991; 19. Gieten V-A 59-60 cm; 20. Gieten IV-HR 355-356 cm; 21. surface sample H3; 22. reference sample BAI 4991.


1
2
3
4
5
6
7
0
20 µm
8
9
10
11
12
13
14
15
16
17
18
0
20 µm
19
20
21
22

Gietsenveentje, is very small. Therefore the *Rumex* pollen smaller than 22 µm in the Gietsenveentje diagrams very probably originates from *Rumex acetosa* or *Rumex acetosella*.
In table 3, the differences between pollen of *R. acetosa* and *R. acetosella* as described by Van Leeuwen et al. (1988) and by Moore et al. (1991) are shown. According to Van Leeuwen et al. (1988), the most important difference between pollen of these two species is the length of the colpi and the degree of intrusion of the colpi: *R. acetosa* has relatively short, non-intruding colpi; *R. acetosella* has long, intruding colpi. The outline of the endoporus is a less clear identification characteristic. The differences indicated by Moore et al. (1991) concern ornamentation type (microreticulate and reticulate, respectively) and the presence in *R. acetosella* of dupli- or pluricolumellate, slightly winding muri.
In the reference collection at Groningen, 6 reference samples of *R. acetosa* and 10 reference samples of *R. acetosella* are present. Pollen grains in each of these samples were studied. The identification characteristics mentioned in table 3 were checked. The differences in the length and degree of intrusion of the colpi seemed to be quite clear; the other identification characteristics could not be confirmed. It has to be emphasized that not each pollen grain of the *Rumex acetosa/acetosella* group can be identified to species level: the grain has to be well-preserved and it has to be possible to observe the grain from a polar perspective. In some cases, only a minority of the grains of the *Rumex acetosa/acetosella* group can be identified to species level.
With the key of table 2 and the identification characteristics listed in table 3, attempts have been made to separate pollen of *Rumex acetosa* and *R. acetosella* in surface samples which were collected in vegetation types in which *Rumex acetosa* and/or *Rumex acetosella* play an important role (see V.3), and also in the subfossil pollen diagrams of the Gietsenveentje (see VI.3). In fig. 31, photographs are shown of characteristic pollen grains of *Rumex acetosa* (nos. 1-11) and *Rumex acetosella* (nos. 12-22). Some originate from the subfossil Gietsenveentje samples (nos. 1-4, 8-9, 12-15, 19-20); others originate from surface samples from Nietap (nos. 5-6, 10; locations see fig. 32d) and the Hijkerveld (nos. 16, 21; locations see fig. 32b). These photographs can be compared with photographs of reference samples (nos. 7, 11, 17-18 and 22).

V.3 Representation in surface samples

With respect to the reconstruction of the palaeoenvironment, it is very important that the pollen of *Rumex acetosa* and *Rumex acetosella* can be separated, because the ecology of these species differs considerably:

- *Rumex acetosella* only occurs on poor, acid, dry, lime-deficient sand and peat. There it often grows in places where organic material rapidly decomposes because it is exposed to full sunlight, mixed with sand or burned. *Rumex acetosella* benefits from the "enrichment" of acid soil with ammonia (WEEDA et al. 1985; OBERDORFER 1990);
- *Rumex acetosa* prefers more nutrient-rich, slightly acid soils. On very acid or heavily fertilized soils, it easily gets an overdose of ammonia (WEEDA et al. 1985; OBERDORFER 1990).

The study of recent vegetation types can help us to elucidate the role of these two *Rumex* species in the vegetation during the Neolithic. Recent vegetation types in which *Rumex* species naturally occur were studied, as well as recent man-made vegetation types in which *Rumex* species play an important role. Vegetation plots were recorded in different vegetation types with *Rumex*, using the Braun-Blanquet method (see IV.9). To study the contribution of *Rumex* to the pollen precipitation, a moss sample was collected in the centre of each plot. The modern pollen content of these moss samples was examined (see IV.9). Also the effect of increasing distance from the source of *Rumex* pollen and the effect of the seasons on the *Rumex* pollen rain was studied.
The results of the ecological study will be used to interpret the *Rumex* values in the subfossil pollen diagrams. Because nowadays *Rumex acetosa* and *Rumex acetosella* often occur in pastures and in (former) arable land (BEHRE 1981), possibly also conclusions can be drawn about the nature and intensity of farming and the distance from the pingo scar at which agriculture took place in Neolithic times.

V.3.1 Surface samples and vegetation plots from four locations in the northern Netherlands

The vegetation plots and the surface samples were taken at four different locations in the northern part of the Netherlands: Nietap (near

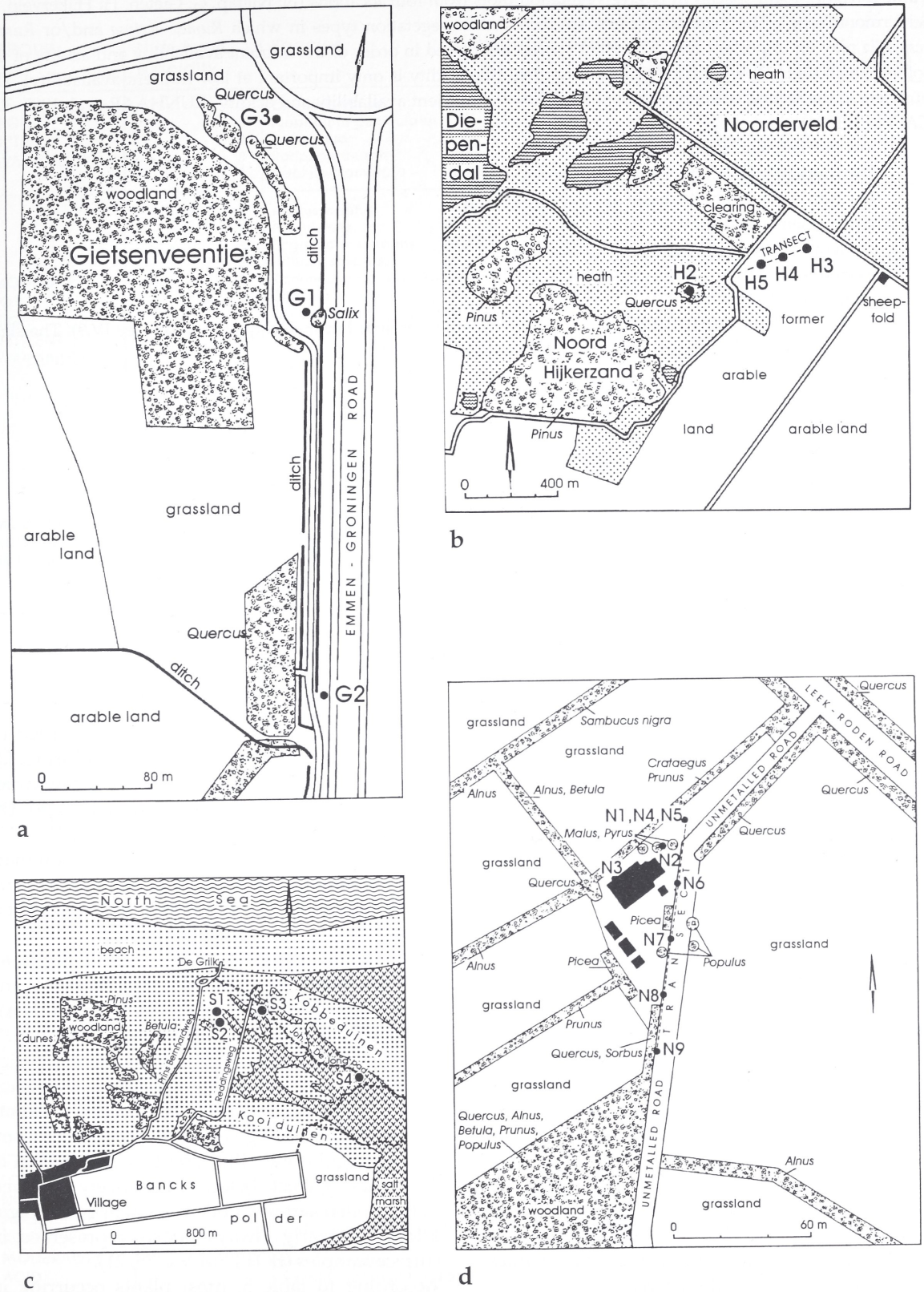


Fig. 32. Maps with the locations of the vegetation plots and the corresponding surface samples: a. Gieten; b. Hijkerveld; c. Schiermonnikoog; d. Nietap.

Table 5 (right). Plant species in twelve vegetation plots from four locations (N: Nietap, G: Gieten, H: Hijkerveld, S: Schiermonnikoog). The vegetation plots are recorded in vegetation types in which *Rumex acetosa* and/or *Rumex acetosella* play an important role. The plant species are placed in order of the nutrient availability and acidity of the soil at which their growing conditions are optimal (the acidity is only important at low nutrient availability). The numbers in the second column represent the following nutrient availability and acidity (RUNHAAR et al. 1987, 301; CAPPERS 1994):

1 low nutrient availability, acid
2 low nutrient availability, moderately acid to neutral
3 low nutrient availability, basic
4 low nutrient availability
7 moderate nutrient availability
9 moderate to high nutrient availability
8 high nutrient availability

The vegetation plots have been recorded according to the (extended) Braun-Blanquet method (see IV.9). The signs represent the cover of the different species within the plots:

r one or a few individuals
\+ < 25 individuals
1 < 100 individuals
2m > 100 individuals
2a 5 ≤ cover < 12.5%
2b 12.5 ≤ cover < 25%
3 25 ≤ cover < 50%
4 50 ≤ cover < 75%

In plot H2, the Braun-Blanquet method has not been used; only two categories have been recognized:

M present with many individuals
P present

Roden, northwestern part of the province of Drenthe), Gietsenveentje, Hijkerveld (near Beilen, central part of Drenthe) and Schiermonnikoog (an island in the Wadden Sea, province of Friesland). At the first three locations, the vegetation is strongly influenced by man; however, the dune and salt-marsh vegetation of the island of Schiermonnikoog is hardly exposed to human influence.

In total, 12 vegetation plots were recorded. Table 5 lists all plant species observed in the plots. On the basis of the observed plant species, the plots are classified from nutrient-rich, which means a high nutrient availability in the soil (left) to nutrient-poor, which means a low nutrient availability in the soil (right). The pollen values from the corresponding pollen samples are shown in fig. 33. The order of the samples is the same as in table 5, ranging from nutrient-rich (above) to nutrient-poor (below). In principle, the diagram is constructed the same way as the subfossil pollen diagrams (see VI.3.1). Because the samples are not related chronologically, the pollen values of the samples are reproduced in bars.

Nietap

At Nietap, one vegetation plot was recorded on June 9th, 1994 near the home of H. Woldring, J.P. Santeeweg 117, in a nutrient-rich meadow, which was manured each year until nine years ago. The location of this plot is indicated in fig. 32d.

Vegetation plot N1. *Rumex acetosa* is dominant (25-50% cover), together with *Ranunculus acris/repens*. The most common grass is *Anthoxanthum odoratum*.

Pollen sample N1. The pollen picture correlates with the vegetation plot data: *Rumex acetosa* and *Rumex acetosa/acetosella* are dominant, Gramineae and *Ranunculus acris* group are quite common. It is notable that about 70% of the *Rumex* pollen could not be identified beyond *Rumex acetosa/acetosella*. Although *Taraxacum officinale* occurs quite frequently in the vegetation plot, pollen of Compositae Liguliflorae, the type to which pollen of *Taraxacum officinale* belongs, is scarcely observed in the pollen sample. Pollen of Compositae Liguliflorae is nearly always poorly represented in surface samples (BOTTEMA 1975, 21).

According to table 5, most plants occurring in this plot, including *Rumex acetosa*, prefer a moderate to high or moderate nutrient availability.

GROUP	Nutr. Avail. & acidity	Species	Vegetation plot											
			N1	G1	G3	G2	H3	H4	H5	H2	S4	S3	S2	S1
HIGH NUTRIENT AVAILABILITY	- - - - - - 8	Cirsium arvense					1		3		1			
	- - - - - - 8	Alopecurus geniculatus					r							
	- - - - - - 8	Poa annua					r	r	1	P				
	- - - - - - 8	Rorippa palustris						r	r					
	- - - - - - 8	Dactylis glomerata	+											
MODERATE TO HIGH NUTRIENT AVAILABILITY	- - - - 7 - 8	Holcus lanatus		2b	2a	2b	2b	r	+		+	3	r	2a
	- - - - 7 - 8	Poa trivialis	1											
	- - - - 7 - 8	Sagina procumbens									2m	r		r
	- - - - 7 - 8	Lythrum salicaria												+
	- - - - 7 - 8	Ranunculus acris/repens	4	2a										
	- - - - 7 - 8	Trifolium repens	r					r			1			
	- - - - 7 - 8	Bellis perennis	r											
	- - - - 7 - 8	Potentilla reptans												r
	- - - - 7 - 8	Cerastium fontanum	1						+		1	+	r	+
	- - 3 - 7 - 8	Bromus hordeaceus									2a			
	- 2 3 - 7 - 8	Taraxacum officinale s.l.	2a		r		2a	+	r					
	- 2 3 - 7 - 8	Poa pratensis	+								1	1	+	1
	1 2 3 - 7 9 8	Quercus robur								M				
	- - - - 7 9 -	Galeopsis tetrahit								P				
	- - 3 - - 9 -	Asparagus officinalis										r		
MODERATE NUTRIENT AVAILABILITY	- - - - 7 - -	Achillea millefolium		r		r								
	- - - - 7 - -	Plantago lanceolata		r	1									
	- - - - 7 - -	Rumex acetosa	3	2b	2a	+								
	- - - - 7 - -	Linaria vulgaris			1									
	- - - - 7 - -	Hypericum perforatum			r									
	- - - - 7 - -	Stellaria graminea		r	2a									r
	- - - - 7 - -	Veronica chamaedrys			1									
LOW TO MODERATE NUTRIENT AVAILABILITY	- - 3 - 7 - -	Erodium cicutarium											r	
	- - 3 - 7 - -	Myosotis ramosissima										+		r
	- - 3 - 7 - -	Veronica arvensis					r	r				r		r
	- - 3 - 7 - -	Senecio jacobea									r			r
	- 2 3 - 7 - -	Hypochaeris radicata			r	r								
	- 2 3 - 7 - -	Luzula campestris										2a	2b	2a
	- 2 3 - 7 - -	Festuca rubra		+	+	2b					2b			
	- 2 3 - 7 - -	Lotus corniculatus												+
	- 2 3 - 7 - -	Cerastium semidecandrum					1	2a	2a					
	- 2 - - 7 - -	Anthoxanthum odoratum	2a	1	1	2a								
	- 2 - - 7 - -	Campanula rotundifolia			2a									
	- 2 - - 7 - -	Rhinanthus angustifolius		r		r								
	- 2 - - 7 - -	Cirsium palustre										+		r
	- 2 - - 7 - -	Agrostis capillaris						r	2b					
	- 2 - - 7 - -	Chamerion angustifolium					r	r	1					
	1 2 - - 7 - -	Festuca ovina		+	3	3	2b	r		M			2a	2b
	1 2 - - 7 - -	Betula pubescens							r					
	1 2 - - 7 - -	Holcus mollis		3	1									
	1 2 - - 7 - -	Rumex acetosella			2a	+	2b	4	1	P	2b	2b	2a	2m
LOW NUTRIENT AVAILABILITY: MODERATELY ACID TO BASIC	- - - 4 - - -	Ammophila arenaria											+	1
	- - 3 - - - -	Cochlearia danica									+			
	- 2 3 - - - -	Aira praecox					3	2b	2b			1		
	- 2 3 - - - -	Polygala vulgaris												1
	- 2 3 - - - -	Carex arenaria									+	3	3	2a
	- 2 3 - - - -	Leontodon saxatilis											r	r
	- 2 3 - - - -	Galium verum											1	
	- 2 3 - - - -	Viola curtisii												+
	- 2 3 - - - -	Veronica officinalis			r							+		+
	- 2 3 - - - -	Stellaria holostea									1			
LOW NUTRIENT AVAILABILITY: ACID TO MODERATELY ACID	- 2 - - - - -	Teesdalia nudicaulis						r						
	- 2 - - - - -	Filago minima												r
	- 2 - - - - -	Viola canina										+	+	r
	- 2 - - - - -	Ophioglossum vulgatum												1
	- 2 - - - - -	Luzula multiflora		r										
	1 2 - - - - -	Galium saxatile								P				
	1 - - - - - -	Ceratocapnos claviculata								P				

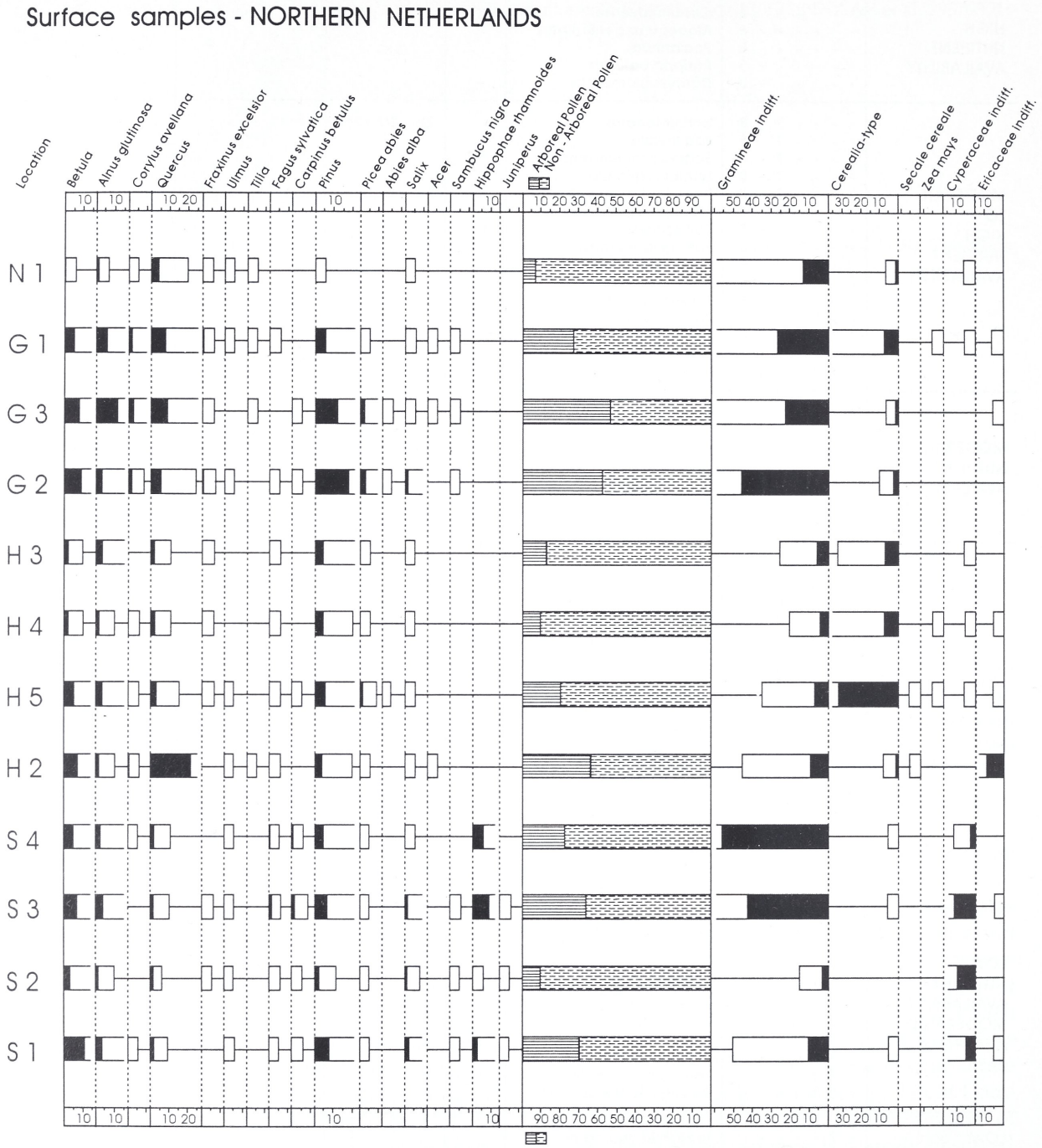
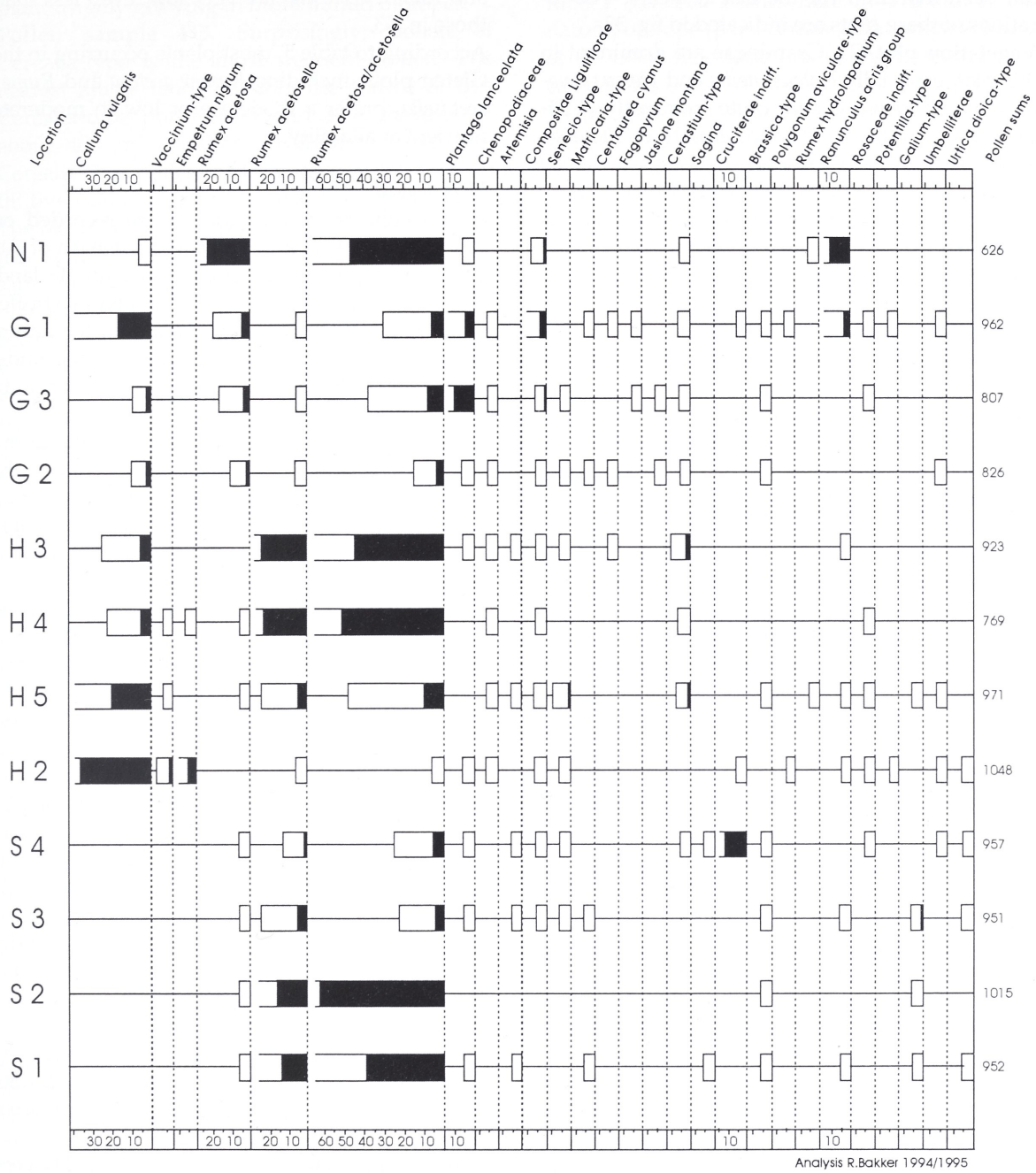


Fig. 33. Surface samples from four locations in the northern Netherlands: N: Nietap, G: Gieten, H: Hijkerveld, S: Schiermonnikoog.


Location
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
Jasione montana
Cerastium-type
Saginа
Cruciferae indiff.
Brassica-type
Polygonum aviculare-type
Rumex hydrolapathum
Ranunculus acris group
Rosaceae indiff.
Potentilla-type
Galium-type
Umbelliferae
Urtica dioica-type
Pollen sums
30 20 10
20 10
20 10
60 50 40 30 20 10
10
10
10
N 1
G 1
G 3
G 2
H 3
H 4
H 5
H 2
S 4
S 3
S 2
S 1
626
962
807
826
923
769
971
1048
957
951
1015
952
Analysis R.Bakker 1994/1995

Gieten

In the direct neighbourhood of the Gietsenveentje, near the village of Gieten, three vegetation plots were recorded on June 9th, 1994 in moderately nutrient-rich grassland, which had not been manured for the last 20 years. The locations of these plots are indicated in fig. 32a.

Vegetation plot G1. Gramineae are dominant in this plot, especially *Holcus mollis* and *Holcus lanatus*. *Rumex acetosa* occurs quite frequently (12.5-25% cover). Also a few individuals of *Plantago lanceolata* occur. The absence of *Rumex acetosella* and the common presence of *Ranunculus acris/repens* in G1 point to more nutrient-rich conditions compared to the other Gietsenveentje plots.

Pollen sample G1. In the pollen picture, Gramineae play a dominant role too. The *Rumex* types are scarcely observed: *Rumex acetosa* occurs more frequently than *Rumex acetosella*. The occurrence of pollen of *Ranunculus acris* group and *Plantago lanceolata* corresponds to the plot data. Pollen of *Calluna vulgaris* occurs very frequently in the sample, although practically no Ericaceae are found in the wide surroundings of the plots. Possibly this Ericaceae pollen is of an older date, probably of the time that heathland dominated the landscape in this area (the early 20th century). Although the aim was to collect the moss samples without any substrate (see IV.9), it is not impossible that some soil still stuck to the moss samples. Soil could be a possible source of subfossil heather pollen (BOTTEMA 1995).

Vegetation plot G3. Gramineae are again dominant: *Festuca ovina* and again *Holcus lanatus*. *Rumex acetosa* and *Rumex acetosella* occur in equal numbers (each 5-12.5% cover). The frequent occurrence of *Stellaria graminea* and *Campanula rotundifolia* is conspicuous. *Plantago lanceolata* occurs in relatively large numbers.

Pollen sample G3. G3 shows higher AP values than G1, caused by higher percentages of *Betula*, *Alnus*, *Quercus*, *Pinus* and *Picea*. The first three occur in the direct surroundings of the Gieten vegetation plot locations, for example in the nearby Gietsenveentje (fig. 32a; see also VI.2). *Calluna vulgaris* occurs very sparsely in this sample. Values of *Rumex acetosa* as well as *Rumex acetosella* are low. Just as in the vegetation plot, *Plantago lanceolata* reaches a relatively high value.

Vegetation plot G2. Gramineae are even more dominant than in G1 and G3: *Festuca ovina*, *Festuca rubra*, *Anthoxanthum odoratum* and *Holcus lanatus* together cover almost 100% of the plot! *Rumex acetosa* and *Rumex acetosella* occur in very low numbers (each less than 25 individuals).

Pollen sample G2. Gramineae are dominant by far, correlating to the plot data. Some trees, especially *Betula*, *Pinus* and *Picea*, reach relatively high values. The last two occur about 200 m east of the Gietsenveentje. Values of *Rumex acetosa* and *Rumex acetosella* are very low, even less than those in G3.

According to table 5, most plants occurring in the Gieten plots, including *Rumex acetosa* and *Rumex acetosella*, prefer a moderate or low to moderate nutrient availability.

Hijkerveld

In the Hijkerveld, four plots were recorded on May 31st, 1994 on a transect with a length of 500 m. This transect leads from former arable land, which for the last five years has served as a buffer zone between present arable land and the nature reserve Hijkerveld, to an oak grove in the midst of heather. The locations of these plots are indicated in fig. 32b.

Vegetation plot H3. *Rumex acetosella* is the dominant species (12.5-25% cover), together with the grasses *Aira praecox*, *Holcus lanatus* and *Festuca ovina*. The presence of two species which strongly prefer nutrient-rich soils, *Taraxacum officinale* and *Cirsium arvense*, is of particular interest.

Pollen sample H3. As might be expected, pollen of *Rumex acetosella* and *Rumex acetosa/acetosella* is dominant. Together these two types comprise nearly 70% of the pollen sum. In spite of the abundance of Gramineae in the plot, only small quantities of Gramineae pollen are observed in the pollen sample. This can be explained possibly by the fact that the most frequent grass in the plot is *Aira praecox*, a very small species which had finished flowering by the time the sample was collected. Pollen of *Cerastium*-type most probably originates from *Cerastium semidecandrum*, occurring in the plot. Pollen of Cerealia-type, originating from nearby arable land, occurs quite frequently. The AP plays a minor role in this sample.

Vegetation plot H4. The plot is characterized by an absolute dominance of *Rumex acetosella* (50-75% cover). *Aira praecox* and *Cerastium semidecandrum* occur frequently.

Pollen sample H4. The pollen content of H4 very much resembles that of H3. *Rumex acetosella* and *Rumex acetosa/acetosella* comprise more than 70% of the pollen sum.

Vegetation plot H5. This plot is located relatively close to the heather. Surprisingly, the plot is dominated by a species which strongly prefers nutrient-rich soils, *Cirsium arvense*. Grasses

usually occurring on less nutrient-rich soils, *Aira praecox* and *Agrostis capillaris*, are quite frequent. *Rumex acetosella* occurs in fairly low quantities (less than 100 individuals). Also specimens of *Rorippa palustris* were observed in this plot, a plant usually growing in more humid biotopes.

Pollen sample H5. Surprisingly, pollen of Cerealia-type is the most frequent pollen. The nearest arable land, possibly the source of this Cerealia-type pollen, is found at a distance of about 400 m. Another possibility is that this Cerealia-type pollen is of greater age, because up till five years ago, this area had been arable land. The old Cerealia-type pollen could originate from the soil, which possibly stuck to the moss samples used for surface sample analysis. The high values of *Calluna vulgaris* are less surprising, because heather occurs at a distance of about 80 m. The most frequent plants in the plot are *Cirsium arvense* and *Agrostis capillaris*. The pollen types that these plants produce, *Cirsium*-type and Gramineae, respectively, do not occur at all (*Cirsium*-type) or occur in low quantities (Gramineae) in the pollen sample. This can be possibly explained by the fact that *Cirsium arvense* and *Agrostis capillaris* were not flowering at the time that the vegetation plots were recorded.

Vegetation plot H2. This plot shows a vegetation completely different from the other Hijkerveld plots: it is recorded in an oak grove with an estimated age of 30 years in the midst of heather. Oak trees (*Quercus robur*) dominate this plot. On the forest floor, *Festuca ovina* is the most common species. *Rumex acetosella* occurs very sporadically.

Pollen sample H2. Ericaceae pollen is dominant: *Calluna* as well as Ericaceae indiff. reach maximum values. *Empetrum nigrum* also occurs quite frequently. As might be expected, *Quercus* is the dominant AP type. It is remarkable that the value of *Calluna vulgaris* is twice as high as the *Quercus* value, although the nearest heather plants occur at a distance of about 50 m. Possibly, the Ericaceae pollen is again of an older date: before the oak grove was planted, heather occurred at this location. In spite of the abundance of *Festuca ovina*, only low quantities of Gramineae pollen are observed.

According to table 5, some plants occurring in the Hijkerveld plots prefer a high or moderate to high nutrient availability, while other plants, including *Rumex acetosella*, prefer a low or low to moderate nutrient availability. Because this area has not been manured for five years, the plants of the latter category will get the upper hand in the future.

Schiermonnikoog

On the island of Schiermonnikoog, four plots were recorded on June 20th, 1995 in dune and salt-marsh vegetation types in which *Rumex acetosella* plays an important role. It is assumed that *Rumex acetosella* occurs here in a more or less natural biotope (pers. comm. S. Bottema; WEEDA et al. 1985). The locations of the plots are indicated in fig. 32c.

Vegetation plot S4. *Rumex acetosella* (12.5-25% cover) and *Festuca rubra* dominate. This plot was recorded next to a cycle track (Joh. de Jongpad) in a salt-marsh area. Probably sand was supplied for the construction of this track. This could explain the presence of species normally not growing in salt marshes, including some species pointing to disturbance: *Cirsium arvense*, *Trifolium repens* and *Bromus hordeaceus*. These species are absent in the other Schiermonnikoog plots.

Pollen sample S4. Gramineae are dominant by far. Surprisingly, pollen of *Rumex acetosella* and *Rumex acetosa/acetosella* is scarcely observed. Cruciferae pollen reaches a maximum value. Probably this pollen originates from *Cochlearia danica*, a typical coastal species, occurring in the vegetation plot. Pollen of *Hippophae rhamnoides*, a shrub characteristic of dune areas, dominates the AP. Individuals of *Hippophae rhamnoides* grew near the plot.

Vegetation plot S3. This plot is dominated by species growing predominantly on nutrient-rich soils, especially *Holcus lanatus*, as well as species growing predominantly on nutrient-poor soils, especially *Aira praecox*, *Carex arenaria* and *Luzula campestris*. *Rumex acetosella* occurs quite frequently (12.5-25% cover).

Pollen sample S3. Although the vegetation of plots S3 and S4 differs widely, the pollen picture of the two pollen samples is quite similar: Gramineae dominate, *Rumex acetosella* and *Rumex acetosa/acetosella* occur sparsely. In sample S3, the AP type *Hippophae rhamnoides* reaches higher values than in sample S4. Cyperaceae reach a maximum value in S3. Most probably this pollen originates from *Carex arenaria*, a very common species in and just outside the vegetation plot.

Vegetation plot S2. The plot is dominated by species predominantly growing on nutrient-poor soils, especially *Carex arenaria*, *Festuca ovina* and *Luzula campestris*. *Rumex acetosella* occurs less frequently than it does in plots S3 and S4 (5-12.5% cover).

Pollen sample S2. *Rumex acetosella* and *Rumex acetosa/acetosella* are dominant by far. Together they comprise more than 75% of the pollen sum!

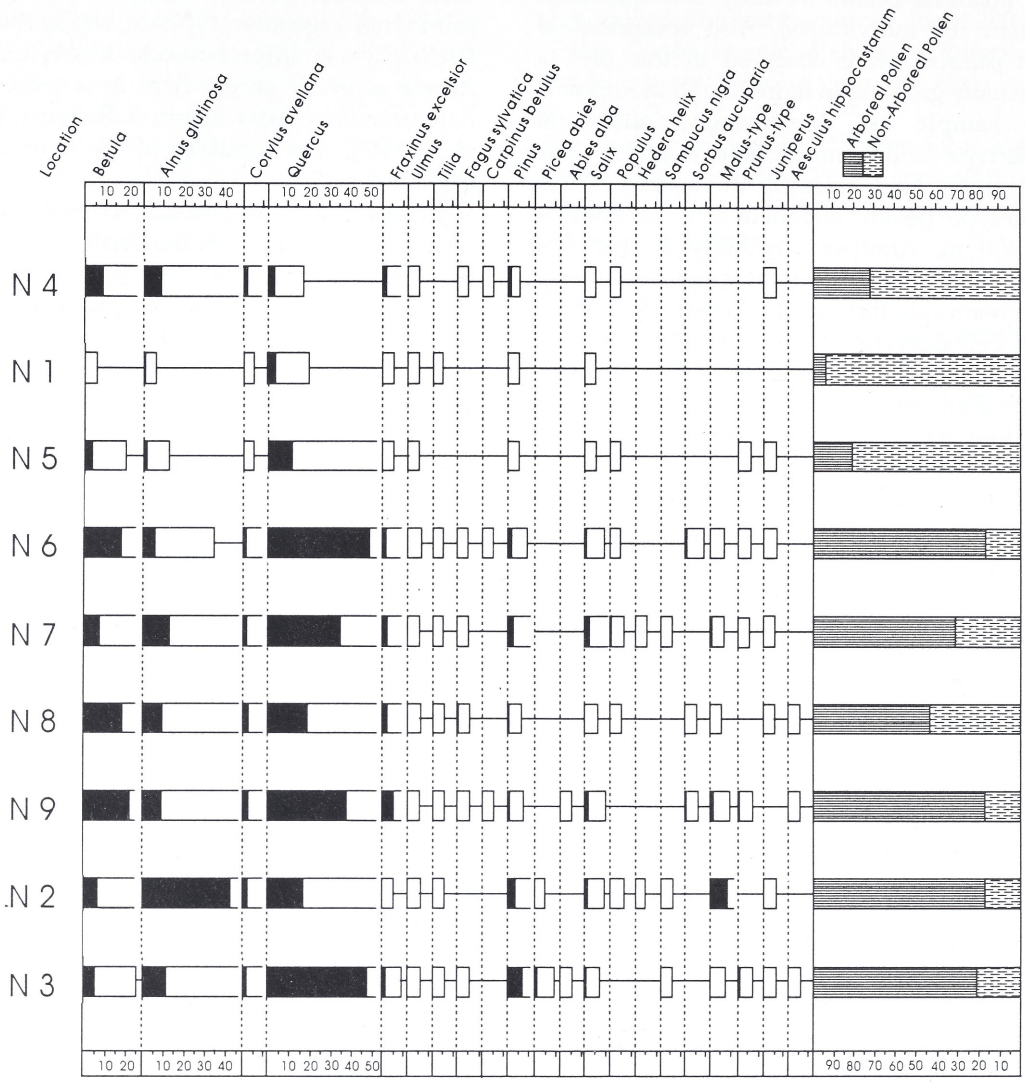
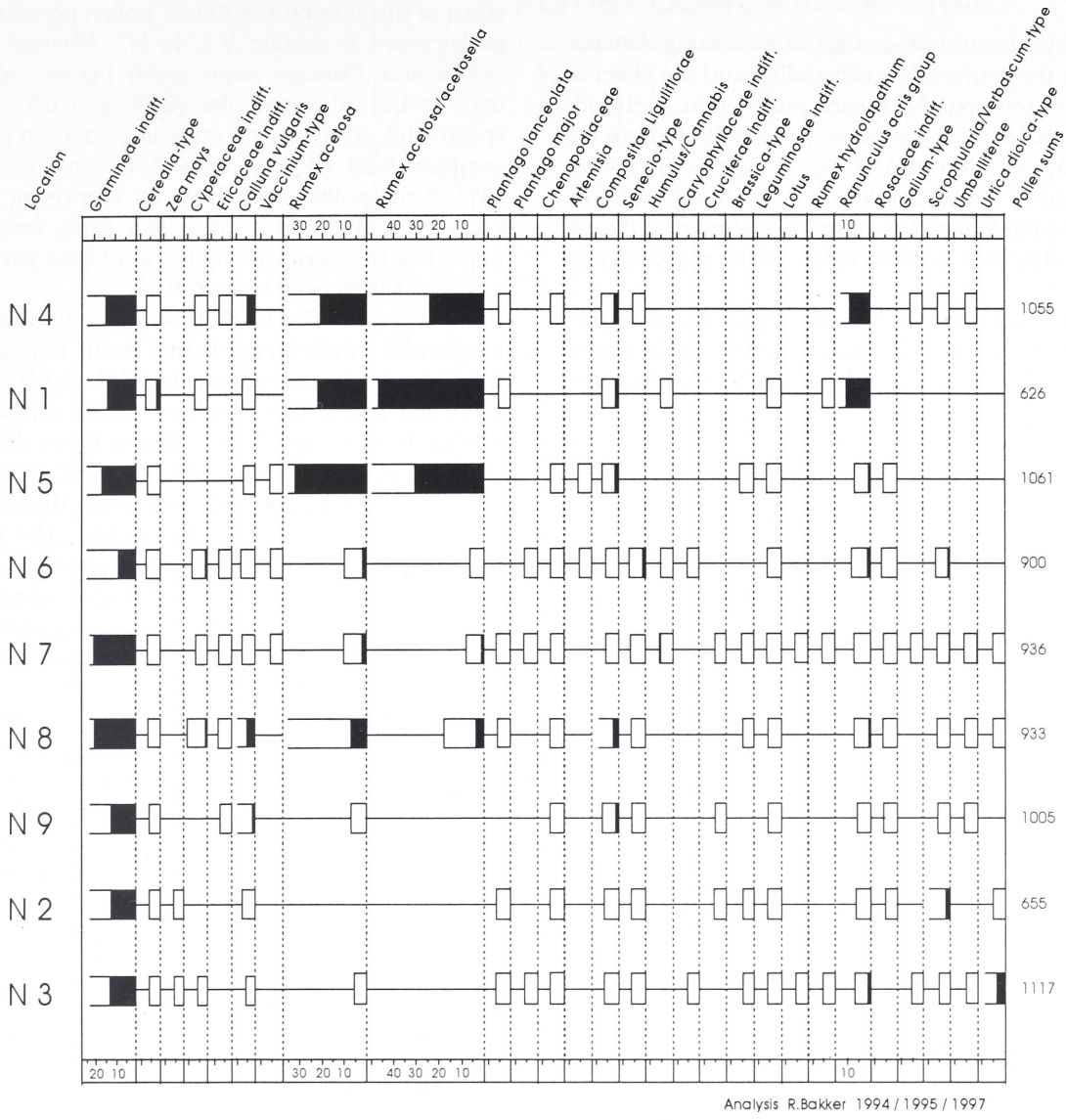


Fig. 34. Surface samples from Nietap.

Gramineae pollen scarcely occurs. This corresponds to the plot data: in S2, Gramineae reach the lowest cover of all twelve plots. The frequently occurring Cyperaceae pollen again seems to originate from *Carex arenaria*, a species which is very common in the plot. Although the sample was taken on a dune top, very few regional pollen seems to occur in the sample. The AP types, of which most are regional because almost no trees occur in the neighbourhood, make up only 10 % of the pollen sum.

Vegetation plot S1. In this plot, recorded in a dune valley, a very species-rich dune vegetation occurs. It is by far the richest of the twelve recorded plots: as many as 24 species were observed. Concerning the dominant species, plot S1 resembles plot S2. *Rumex acetosella* occurs less in S1 than in S2 (< 5% cover, more than 100 individuals); *Holcus lanatus* occurs more often in S1 than in S2. In S1, a few rare species are observed, predominantly growing on nutrient-poor soils: *Filago minima* and the fern *Ophioglossum vulgatum*.

Pollen sample S1. Although in general the pollen picture of S1 resembles the pollen picture of S2, there are also some differences. *Rumex acetosella*,



Rumex acetosa/acetosella and Cyperaceae occur less frequently in sample S1 than in sample S2. This corresponds to the vegetation plot data: in plot S1, *Rumex acetosella* and *Carex arenaria* occur less frequently than in plot S2. Also a few pollen grains of *Rumex acetosa* are observed - just as in the three other Schiermonnikoog samples. Gramineae pollen occurs more frequently in sample S1 than in sample S2; it probably originates from *Holcus lanatus* and *Festuca ovina*.

Some AP types reach relatively high values, especially *Betula*, *Salix* and *Pinus*. The first two occur within about 20 m from the plot, but the nearest *Pinus* trees grow at a distance of 1 km!

According to table 5, some plants occurring in the Schiermonnikoog plots prefer a moderate to high nutrient availability; most plants however, including *Rumex acetosella*, prefer a low or low to moderate nutrient availability.

V.3.2 Surface samples from Nietap

In order to study the effect of increasing distance from the source of *Rumex* pollen and the effect of the seasons on the *Rumex* pollen rain, eight additional surface samples were collected at the Nietap location in 1995-96. A map with the locations of these samples is shown in fig. 32d. The pollen content of the samples is shown in fig. 34. This diagram is constructed in the same way as fig. 33.

Pollen samples N4, N1, N5. These three samples were collected at the same location, in the centre of the *Rumex acetosa* meadow (fig. 32d). N4 was collected on April 28th, 1996, a few weeks before *Rumex acetosa* begins to flower. N1 and N5 were collected on June 9th, 1994 and June 7th, 1996, respectively, at the height of the flowering period of *Rumex acetosa*. Pollen of *Rumex acetosa* and *Rumex acetosa/acetosella* dominates: in N1 and N5 these two types together make up more than 60%; in N4, their combined percentages are significantly lower, about 45%. Pollen of Gramineae and *Ranunculus acris* group occurs frequently. This is not surprising, because different grass species and *Ranunculus acris/repens* occur massively in the meadow. It is conspicuous that *Ranunculus acris* group scarcely occurs in N5. Pollen of Compositae Liguliflorae, for the larger part originating from *Taraxacum officinale*, occurs in all three samples. Although different tree species grow within 25 m of the meadow, the total AP in the three samples always is less than 30%. This must be a relative effect: because at this location the local *Rumex* types totally dominate the pollen picture, the arboreal pollen becomes relatively less important. A consequence of this is that AP types should become more important outside the flowering season of *Rumex acetosa*: N4 indeed has the highest AP percentage of the three samples.

Pollen samples N6, N7, N8, N9. These four samples form a transect, together with N5; they are located at ca. 25 m, ca. 50 m, ca. 75 m and ca. 100 m from the *Rumex acetosa* meadow (fig. 32d). They were collected on June 7th, 1996, at the height of the flowering season of *Rumex acetosa*. These four samples can be correlated quite well, but their pollen content differs widely from that of the previous three samples. In samples N6-N9, the values of the *Rumex* types are very low. In N8, *Rumex acetosa* and *Rumex acetosa/acetosella* make up nearly 10%. This pollen most probably originates from the few individuals of *Rumex acetosa*, occurring at the N8 sample location. The effect of distance on the *Rumex* pollen percentage is discussed in section V.4. In N7, *Plantago lanceolata* and *Plantago major* reach higher values than in the other samples (0.3% and 0.5%, respectively). AP types are quite important in these samples: total AP comprises between 56% and 83% of the pollen sum. It is not surprising that *Quercus* is the dominant pollen type, because many oak trees grow along the sand road parallel to which the transect was plotted.

Pollen sample N2. This sample was collected at a height of 2.5 m in an apple tree about 15 m from the *Rumex acetosa* meadow (fig. 32d), at May 5th, 1995, just before the flowering period of *Rumex acetosa*. In this sample, the *Rumex* types do not occur at all! Gramineae are the most frequent NAP. The total AP comprises more than 80%. *Alnus* pollen occurs most frequently. The high percentage of *Malus*-type pollen naturally originates from the apple tree. At a higher sampling location, the influence of regional pollen increases: *Pinus* and *Picea* reach higher percentages here than in the previous samples.

Pollen sample N3. This sample was collected at a height of 3 m in the roof gutter of the home of H. Woldring, about 40 m from the *Rumex acetosa* meadow (fig. 32d), in January 1995. In total, only three pollen grains of the *Rumex* types were observed. Gramineae dominate the NAP. Although *Urtica dioica*-type nearly never reaches high percentages in surface samples from moss polsters (SPIEKSMA & BOTTEMA 1989), this type reaches a maximum value of 3.3% in sample N3. *Quercus* by far dominates the AP. The regional types *Pinus* and *Picea* reach higher percentages than they do in sample N2.

V.4 Using the surface-sample study for the interpretation of the subfossil pollen diagrams

First some remarks will be made about the biotopes of *Rumex acetosa* and *Rumex acetosella* on the basis of the vegetation-plot data. Then the representation of *Rumex acetosa* and *Rumex acetosella* in surface samples will be discussed using the surface-sample data. Finally, the use of this evidence for the reconstruction of past biotopes of *Rumex acetosa* and *Rumex acetosella* from subfossil pollen diagrams will be discussed.

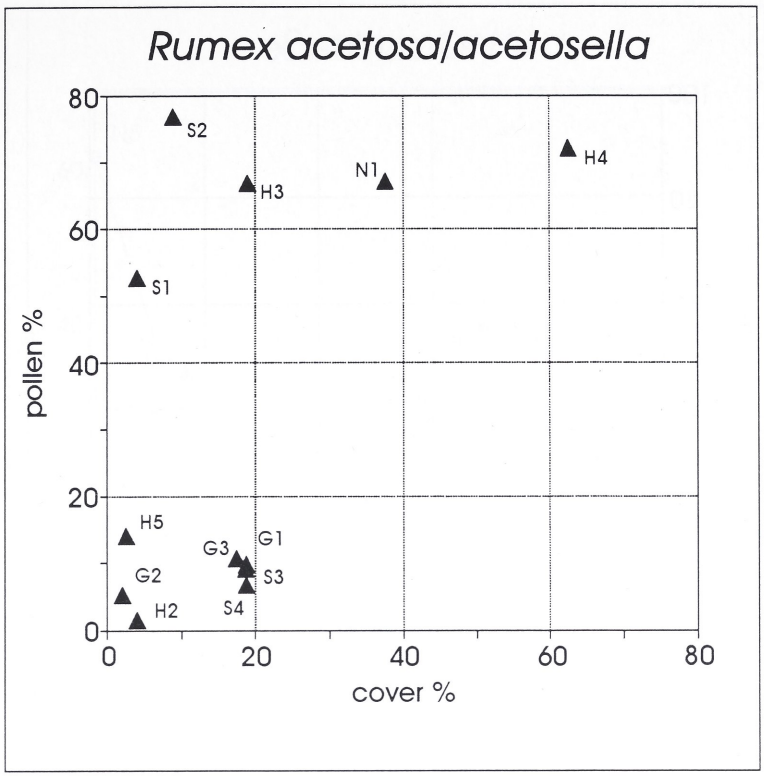


Fig. 35. The total cover percentage of *Rumex acetosa* and *Rumex acetosella* in each vegetation plot, plotted against the total pollen percentage of the *Rumex* types in each corresponding surface sample collected from the centre of the vegetation plot.

Biotopes of *Rumex acetosa*

Brooksides and light spots in the forest are the natural biotopes of *Rumex acetosa* (WEEDA et al. 1985). Nowadays, *Rumex acetosa* occurs for the larger part in strongly human-influenced biotopes. The vegetation plots with *Rumex acetosa* (N1, G1-G3) are all recorded in grassland with a moderate to high availability of nutrients. In these grasslands, the growth conditions for *Rumex acetosa* are optimal. There it often occurs together with *Ranunculus acris/repens* and *Plantago lanceolata*.

Biotopes of *Rumex acetosella*

Leached dune sand and sand drifts are the most important natural biotopes of *Rumex acetosella* (WEEDA et al. 1985). The Schiermonnikoog vegetation plots S1 and S2 (table 5), characterized by a large number of species and by species growing optimally on nutrient-poor soils, represent one of the most natural biotopes of *Rumex acetosella*. The vegetation of the Hijkerveld plots H3 and H4, located in former arable land, shows similarities to the vegetation of plots S1 and S2 (table 5): in all four plots, *Holcus lanatus*, *Festuca ovina* and *Rumex acetosella* are among the most frequent species. There are also some differences: *Taraxacum officinale*, *Cerastium semidecandrum* and *Aira praecox* are present only in H3/H4; *Luzula campestris* and *Carex arenaria* are present only in S1/S2. The pollen content of the Schiermonnikoog samples S1/S2 is very similar to the pollen content of the Hijkerveld samples H3/H4 (fig. 33).

Apparently, optimal growth conditions for *Rumex acetosella* occur in former arable land (plots H3-H5), because the abiotic and/or biotic conditions there resemble the conditions in at any rate one natural biotope: leached dune sand (plots S1-S4). *Rumex acetosella* does not occur at all (plots N1, G1) or only sporadically (plots G3, G2) in grassland with a moderate to high availability of nutrients. *Rumex acetosella* also occurs only sporadically on soils with a very low nutrient availability (plot H2).

Effect of local *Rumex* on the *Rumex* pollen percentage

The influence of the local vegetation on the pollen picture of surface samples can be studied with the help of diagrams in which the cover percentage of a species or group of species in a Braun-Blanquet vegetation plot (2 x 2 m) is plotted against the pollen percentage of that species or group of species in a surface sample collected in the centre of the vegetation plot (EVANS & MOORE 1985). Two such diagrams

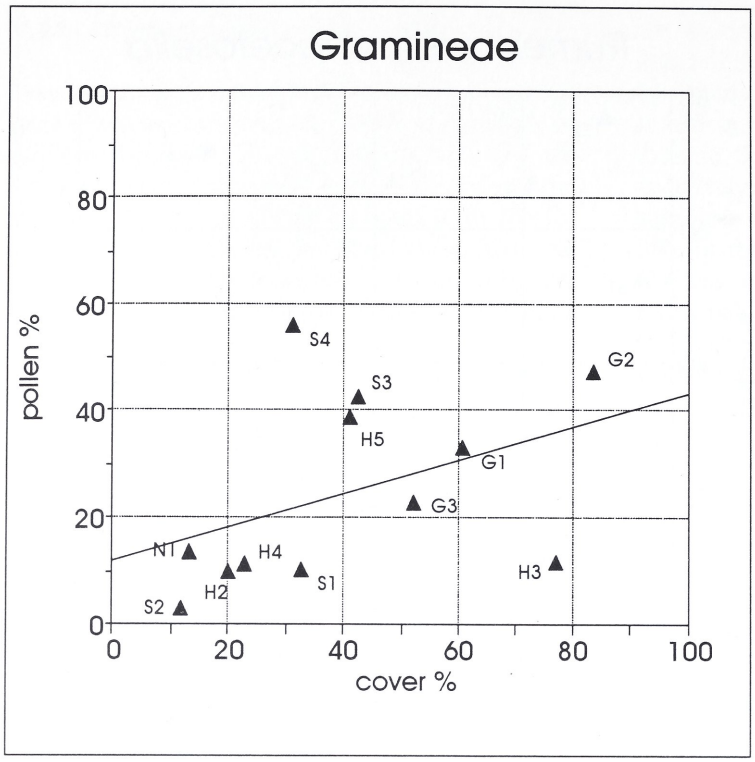


Fig. 36. The total cover percentage of Gramineae in each vegetation plot, plotted against the pollen percentage of Gramineae in each corresponding surface sample collected from the centre of the vegetation plot.

have been drawn, using the data of table 5 and fig. 33: one for *Rumex acetosa/acetosella*, and, for general comparison, one for Gramineae.

In the *Rumex acetosa/acetosella* diagram (fig. 35), the total cover percentages of *Rumex acetosa* and *Rumex acetosella* in each vegetation plot (x-axis) were plotted against the total pollen percentages of the *Rumex* types (*Rumex acetosa*, *Rumex acetosella* and *Rumex acetosa/acetosella*) in each corresponding surface sample (y-axis). When most of the pollen originates from vegetation in the plot, the correlation between the two variables is expected to be linear (PRENTICE 1982). In the *Rumex acetosa/acetosella* diagram, the correlation is certainly not linear. This probably means that most of the *Rumex* pollen originates from outside the vegetation plots. It has to be emphasized that many factors can influence the correlation between vegetation cover and pollen percentage, for example the ratio between male and female plants, the number of flowering plants, the homogeneity of the vegetation, etc.

A conclusion that may be relevant to the interpretation of the subfossil pollen diagrams is that when the *Rumex* pollen percentage is less than 10% (this is always so in the subfossil pollen diagrams), the **local** cover percentage of *Rumex* never exceeds 20%. Of course, in this estimate the effect of distance, which will be discussed below, is not included.

In the Gramineae diagram (fig. 36), the total cover percentages of all grasses in each vegetation plot (x-axis) have been plotted against the pollen percentage of Gramineae in each corresponding surface sample (y-axis). In this diagram, the correlation is more or less linear. This means that most of the Gramineae pollen originates from vegetation in the plot. A linear regression line was computed for the data in which

$$y = a + bx$$

where $a = 12$ and $b = 0.32$.

This regression line has been drawn in the diagram (fig. 36). (This diagram closely resembles fig. 79 in EVANS & MOORE 1985.)

A large difference between the *Rumex acetosa/acetosella* diagram and the Gramineae diagram is that the Gramineae pollen percentage gives a more or less reliable picture of the local vegetation cover, while the *Rumex* pollen percentage largely represents extra-local (regional?) vegetation. Tinsley & Smith (1974, 564) had already noted that Gramineae pollen in surface samples closely reflects the surrounding vegetation.

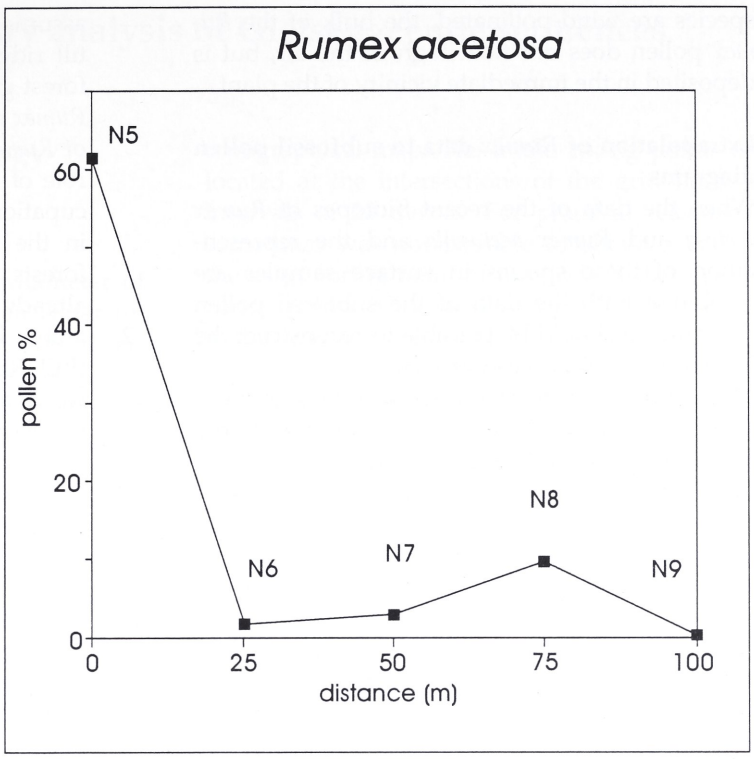


Fig. 37. The total pollen percentage of the *Rumex* types in surface samples, collected at distances of 0, 25, 50, 75 and 100 m from the *Rumex acetosa* meadow at Nietap.

Effect of distance on the *Rumex* pollen percentage

The effect of distance on the pollen percentage of *Rumex acetosa* is studied with the help of pollen samples N5-N9, which were collected along a transect of about 100 m (fig. 34). In fig. 37, the distance from the *Rumex acetosa* meadow at Nietap is plotted against the total pollen percentages of *Rumex acetosa* and *Rumex acetosa/acetosella* (it is assumed that the pollen of *Rumex acetosa/acetosella* originates from *Rumex acetosa*, because no specimens of *Rumex acetosella* occur in the neighbourhood). The samples on the transect do not show a gradient of gradually decreasing *Rumex* values: even in sample N6, only about 25 m from the *Rumex acetosa* meadow, the values of the two *Rumex* types are reduced to a few percent. The other samples also show low values of the *Rumex* types. A conclusion which may be drawn from these five samples is that when the two *Rumex* types reach a total pollen percentage between 1 and 10%, considerable amounts of *Rumex* plants occur within 25 m of the sample location. Data of Caseldine & Gordon (1978, fig. 4) show the same picture: outside areas where *Rumex acetosa* occurs, the percentage of *Rumex* pollen nowhere reaches values of more than 1%.

Effect of the seasons on the *Rumex* pollen percentage

Seasonal effects on the *Rumex* pollen rain were studied with the help of surface samples N2-N4, which were collected in different times of year (fig. 34). Although it is not assumed that the modern pollen content of a moss sample covers only one year or less (BRADSHAW 1981; BOTTEMA 1995), the results of the *Rumex* study indicate that pollen deposited in the last months before sampling plays the most important role in the pollen picture: the *Rumex* values of a sample collected in the *Rumex acetosa* meadow a month before the flowering period of *Rumex acetosa* (N4) are 15% lower than the *Rumex* values of samples collected at the same location in the flowering period (N1, N5). In two other samples, collected at distances of 15 and 40 m from the *Rumex acetosa* meadow outside the flowering period of *Rumex acetosa* (N2, N3), almost no *Rumex* pollen occurs. These two samples were collected at a height of 2.5 and 3 m, respectively; of course, the height of the sample location is also a factor which affects the pollen picture: at a higher location the influence of regional pollen increases.
Not much *Rumex* pollen seems to be deposited outside the flowering period. Although *Rumex*

species are wind-pollinated, the bulk of the *Rumex* pollen does not float high in the air, but is deposited in the immediate vicinity of the plant.

Extrapolation of *Rumex* data to subfossil pollen diagrams

When the data of the recent biotopes of *Rumex acetosa* and *Rumex acetosella* and the representation of these species in surface samples are combined with the data of the subfossil pollen diagrams, it should be possible to reconstruct the former biotopes of these species.

When pollen of *Rumex acetosa* occurs in very small quantities (< 1%), in combination with low Gramineae percentages, and **without** typical culture indicators, notably *Plantago lanceolata*, this pollen originates most probably from *Rumex acetosa* in its natural biotope: brooksides and light spots in the forest.

When pollen of *Rumex acetosa* occurs **in combination with** relatively large quantities of Gramineae, *Plantago lanceolata* and sometimes *Ranunculus acris* group, this pollen probably originates from *Rumex acetosa* in grass-rich vegetation with a moderate to high availability of nutrients (cf. plot G1-G3). The existence of grass-rich vegetation types points to stock keeping.

In surface-sample diagrams of Tinsley & Smith (1974, fig. 4) and Caseldine & Gordon (1978, figs. 2-3) high values of *Rumex*-type (they did not separate *Rumex acetosa* and *R. acetosella*) coincide with high values of Gramineae. The surface samples concerned were collected in nutrient-rich pastures where *Rumex acetosa* occurred. This indicates that the *Rumex* pollen originated from *Rumex acetosa*. These results confirm that the combination of relatively high values of Gramineae and *Rumex acetosa* in pollen diagrams points to grass-rich vegetation with a moderate to high availability of nutrients.

The natural biotopes of *Rumex acetosella*, dune valleys and sand drifts, do not occur in the wide surroundings of the Gietsenveentje (cf. plot S1-S4). When pollen of *Rumex acetosella* is observed in the Gietsenveentje diagrams, it must originate from one of the following, man-made biotopes:

1. areas where dry deciduous and pine forests have been cut (WEEDA et al. 1985). It is assumed that when the virgin forests on the till ridges were cut, the soil on which this forest grew was still too rich in nutrients for *Rumex acetosella* to grow. Hence, this biotope of *Rumex acetosella* most probably played no role of importance during the Neolithic Occupation Period. It gained in importance only in the last few centuries, when secondary forests, planted by man and growing on soils already poor in nutrients, were cut.
2. arable land with *Secale* on acid sandy soils (BEHRE 1981). *Rumex acetosella* grew as a weed among the *Secale* plants. Nowadays, this biotope of *Rumex acetosella* has practically disappeared. In the neighbourhood of the Gietsenveentje, this biotope was of little importance, because *Secale* pollen is only observed in the very upper part of the Gieten V-A diagram (fig. 56), while pollen of *Rumex acetosella* occurs much earlier.
3. former arable land that has been used for a long period, as a result of which the soil is leached (moderate to low availability of nutrients) (cf. plots H3-H5). Most *Rumex acetosella* pollen in the Gietsenveentje diagrams must originate from this biotope. *Rumex acetosella* pollen often reaches a maximum just before a maximum of Ericaceae pollen. This can be explained as follows: as the already nutrient-poor soils on which *Rumex acetosella* thrives become more and more leached, eventually only Ericaceae can grow on these poor soils: a phase with relatively large quantities of *Rumex acetosella* can be considered a precursor of an Ericaceae phase.

In a surface-sample diagram by Tinsley & Smith (1974, fig. 5) a peak of *Rumex*-type coincides with high values of Ericaceae. The surface sample was collected in a *Calluna*-dominated area where *Rumex acetosella* colonized a small burned patch within 2 m of the sampling point. This indicates that the *Rumex* pollen must originate from *Rumex acetosella*. These results confirm that the combination of relatively high values of Ericaceae (particularly *Calluna*) and *Rumex acetosella* in pollen diagrams points to nutrient-poor soils, which can develop in arable land that has been used for a long period.

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-

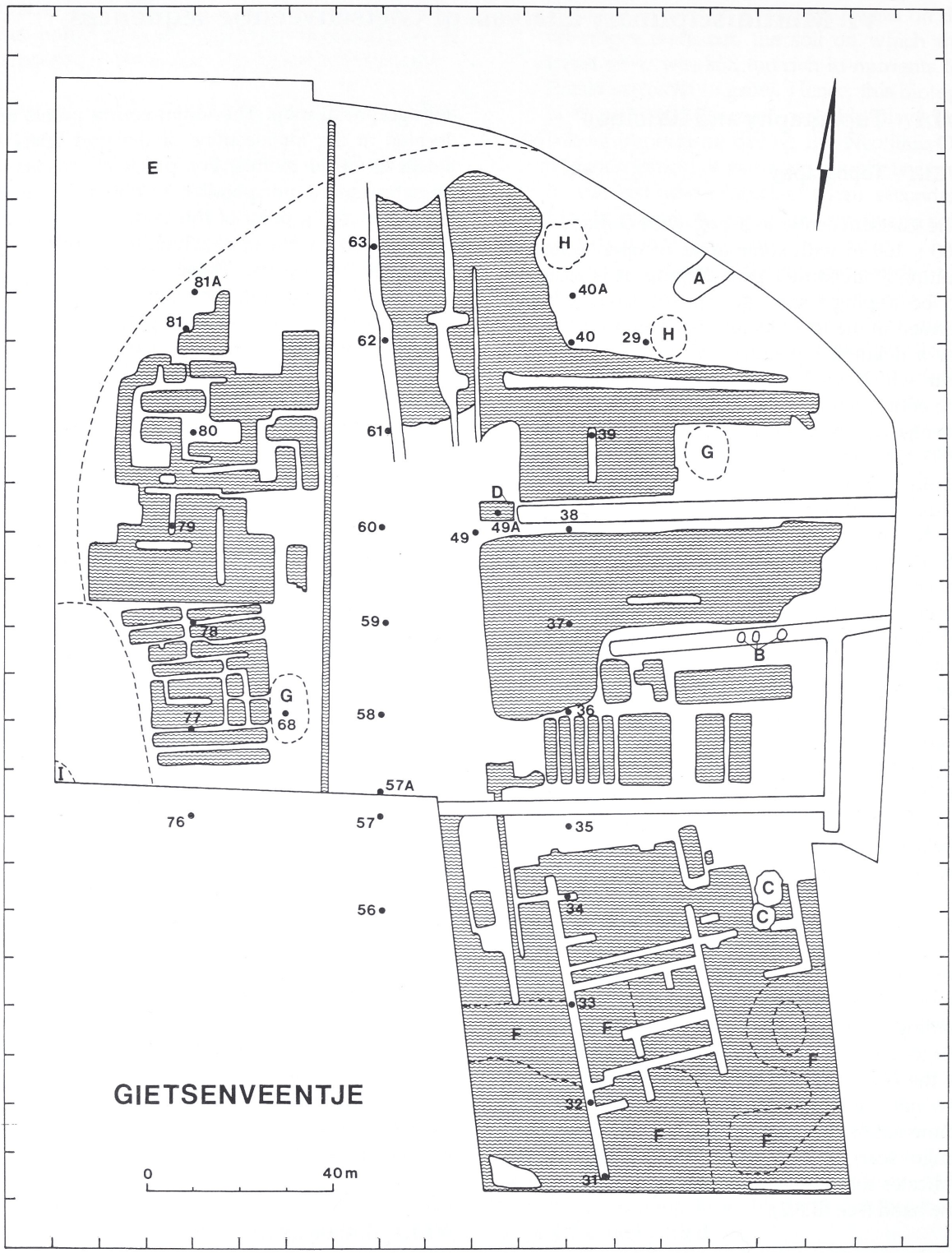


Fig. 38. Topographical map of the Gietsenveentje. All core locations are indicated. Areas with a wavy pattern: marshy area or open water; A: heap of sand; B: heaps of rubble; C: heaps of loam; D: backfilled trench; E: planted woodland; F: sedge marsh; G: field of bilberry (*Vaccinium myrtillus*); H: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

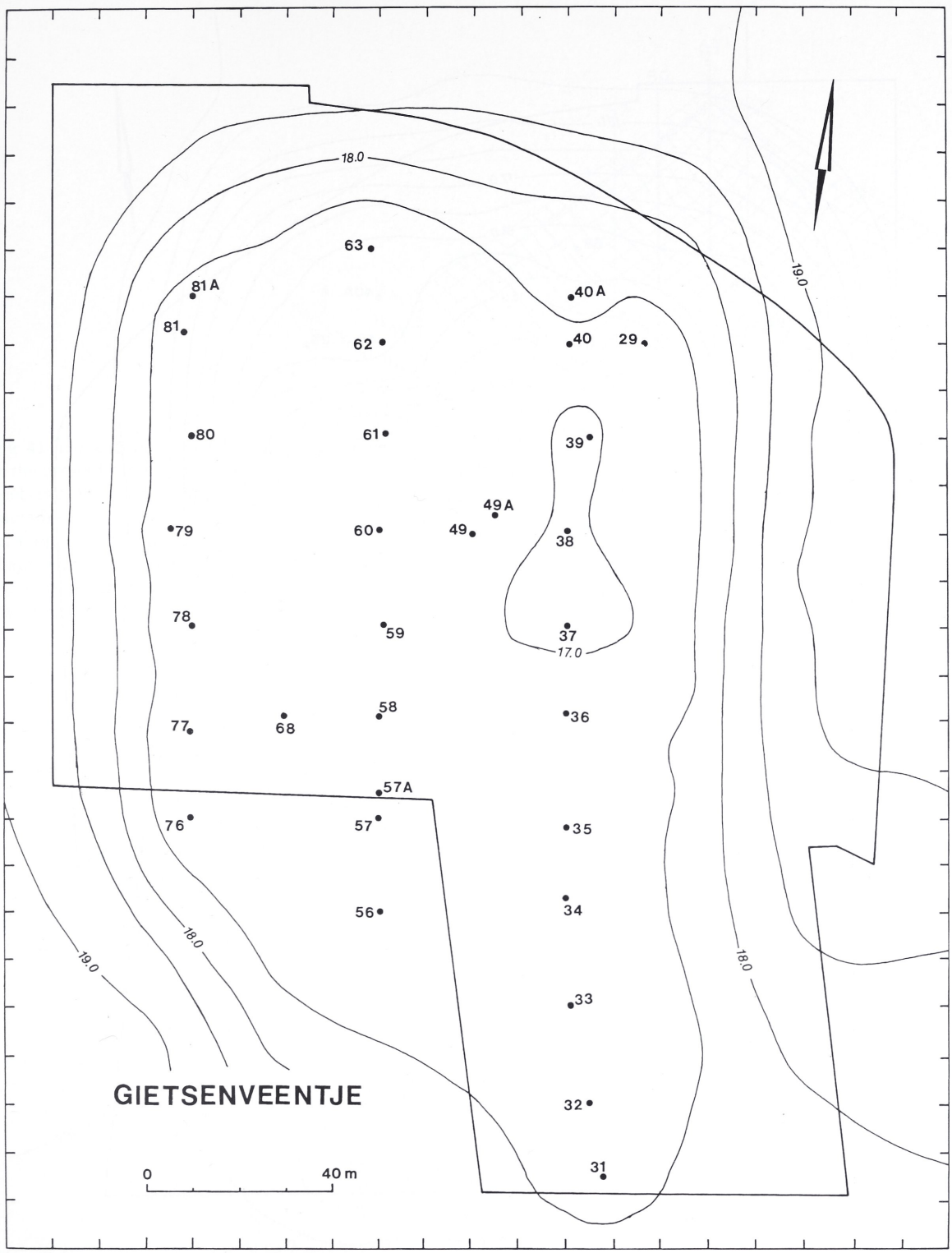


Fig. 39. Contour map of the present-day surface in the Gietsenveentje and its immediate surroundings. All core locations are indicated. Altitudes are given in metres above N.A.P.

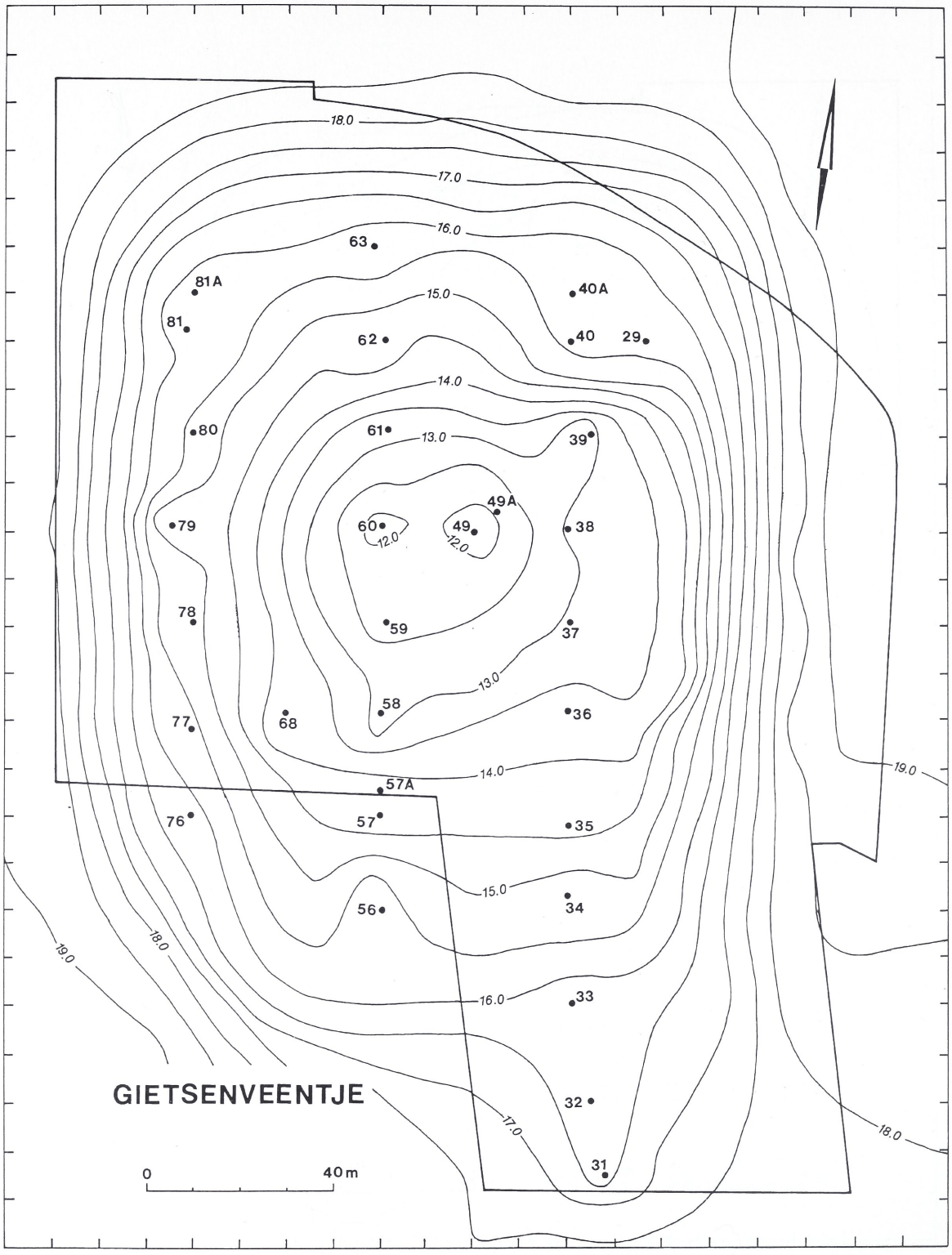


Fig. 40. Contour map of the Pleistocene subsoil in the Gietsenveentje and its immediate surroundings. All core locations are indicated. Altitudes are given in metres above N.A.P.

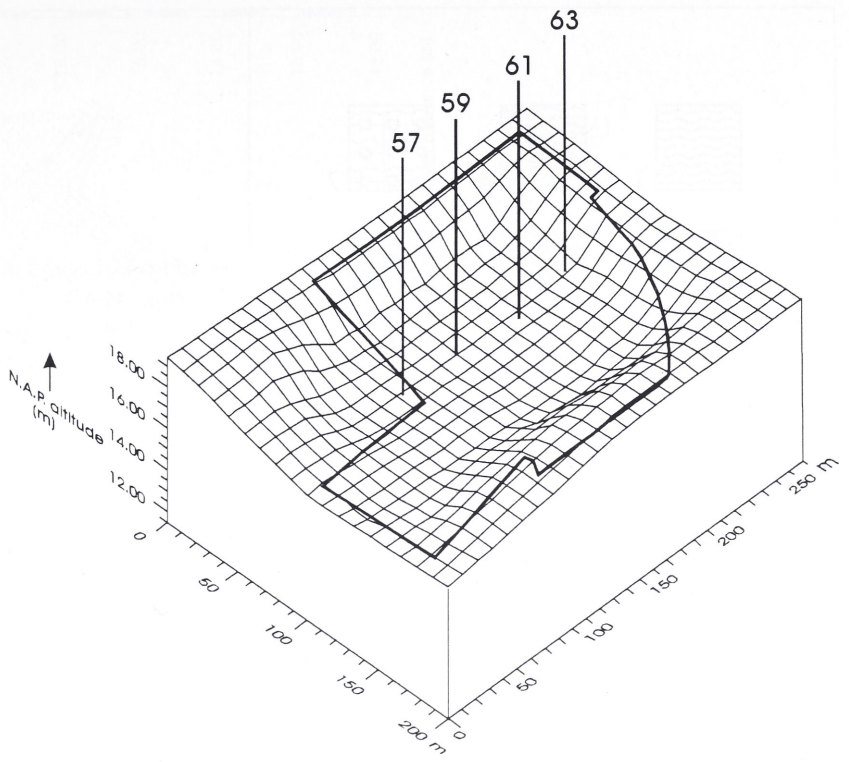


Fig. 41. Three-dimensional map of the present-day surface of the Gietsenveentje and its immediate surroundings. Four core locations of which pollen diagrams are available (sequences Gieten V-A to V-D) are indicated.

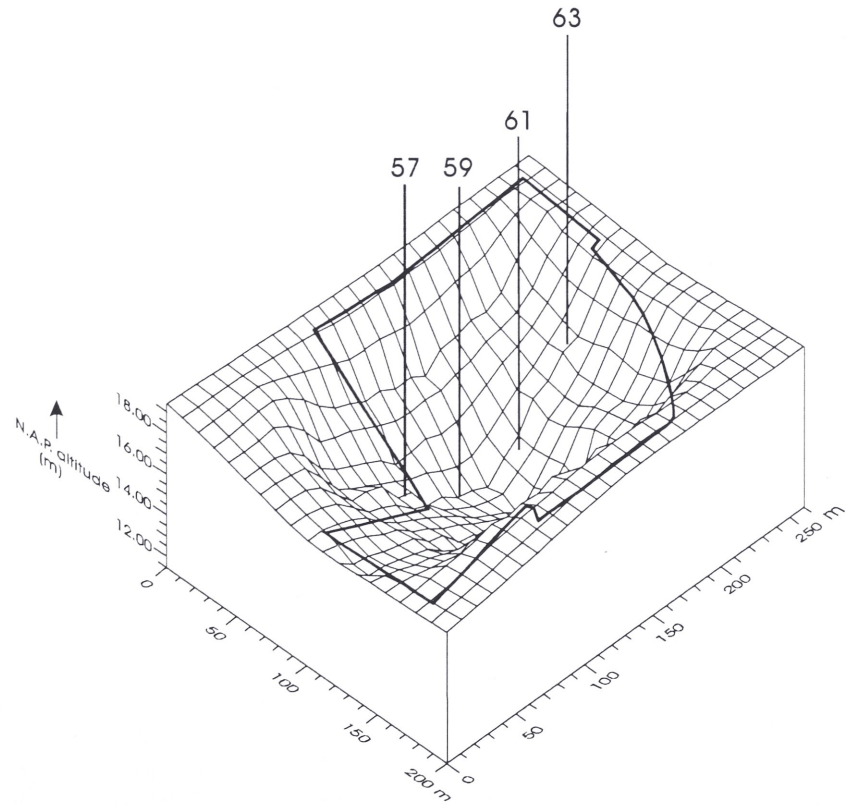


Fig. 42. Three-dimensional map of the Pleistocene subsoil in the Gietsenveentje and its immediate surroundings. Four core locations of which pollen diagrams are available (sequences Gieten V-A to V-D) are indicated.

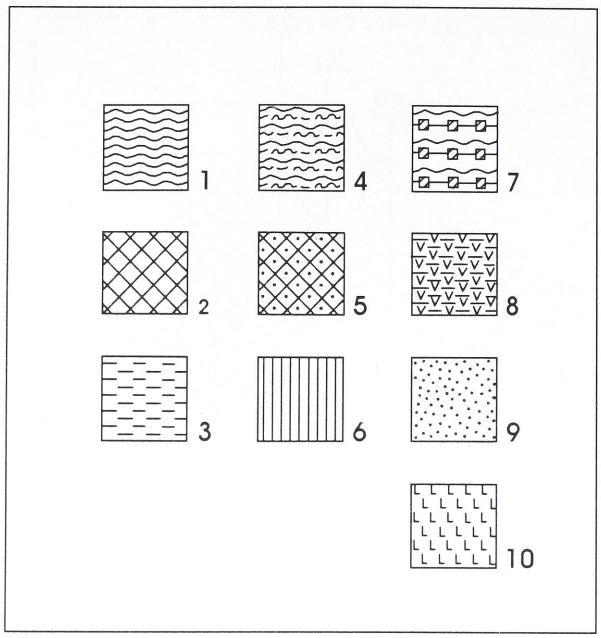


Fig. 43. Legend of the lithology transects (figs. 44-47).
1. *Sphagnum* peat
2. detritus gyttja
3. homogeneous humic substance
4. as 1, with *Eriophorum*
5. fine detritus gyttja with loam/sand
6. *Carex* peat
7. *Scheuchzeria* peat
8. as 3, with wood
9. sand (Pleistocene subsoil)
10. till (Pleistocene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

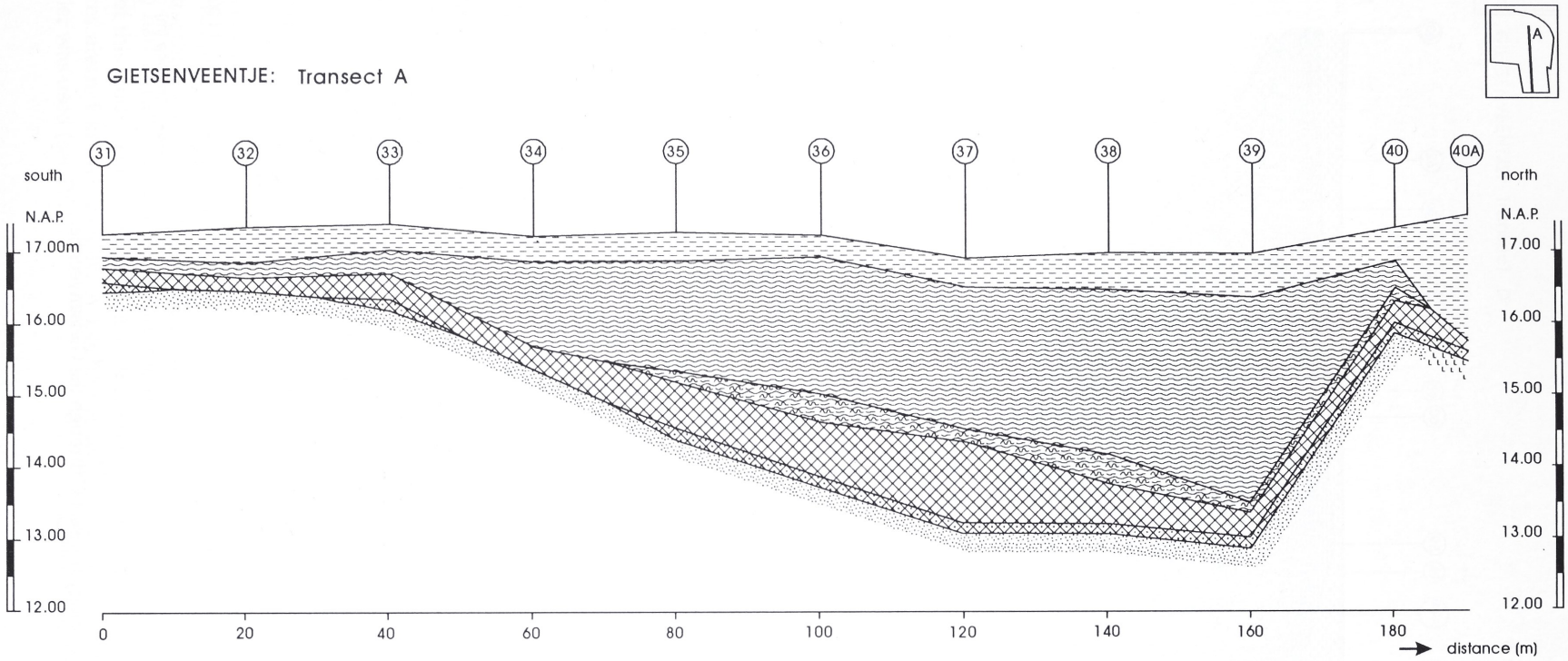


Fig. 44. Lithology transect A through the Gietsenveentje. In this figure and in figs. 45-47, the positions and numbers of the core locations are indicated above the transect. Where a pollen diagram is available of a core location, the depth of the beginning of the Neolithic Occupation Period is also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

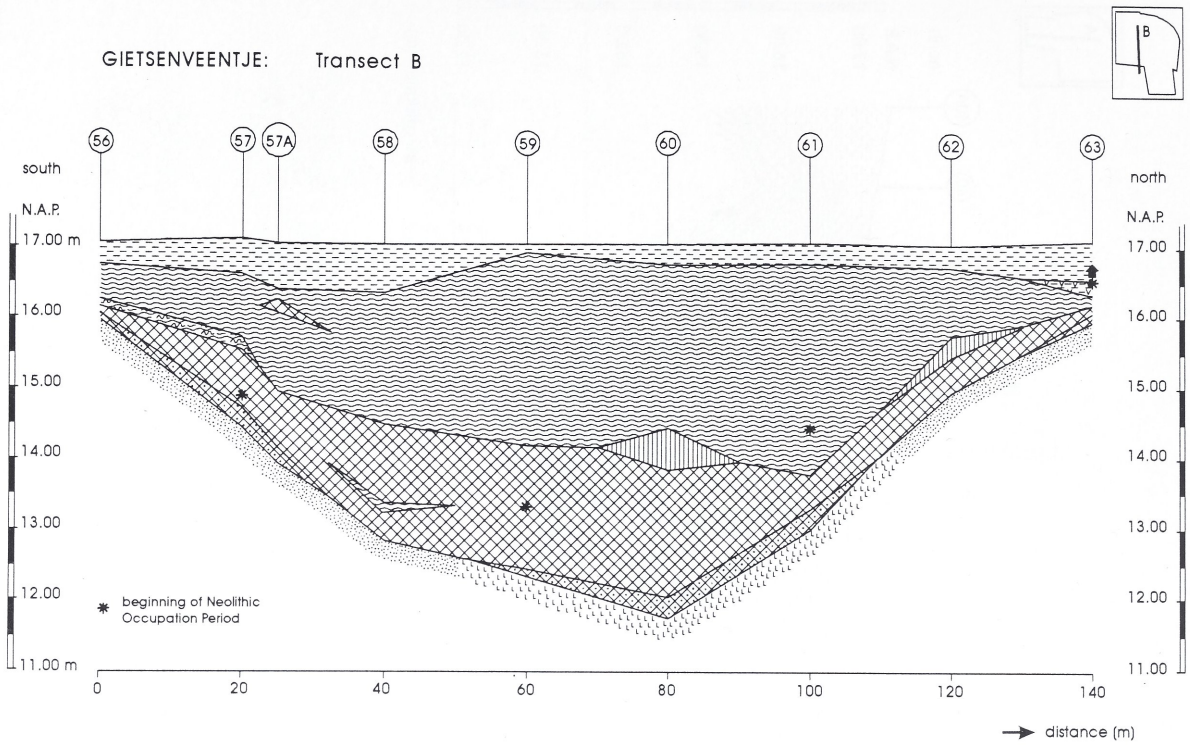


Fig. 45. Lithology transect B through the Gietsenveentje.

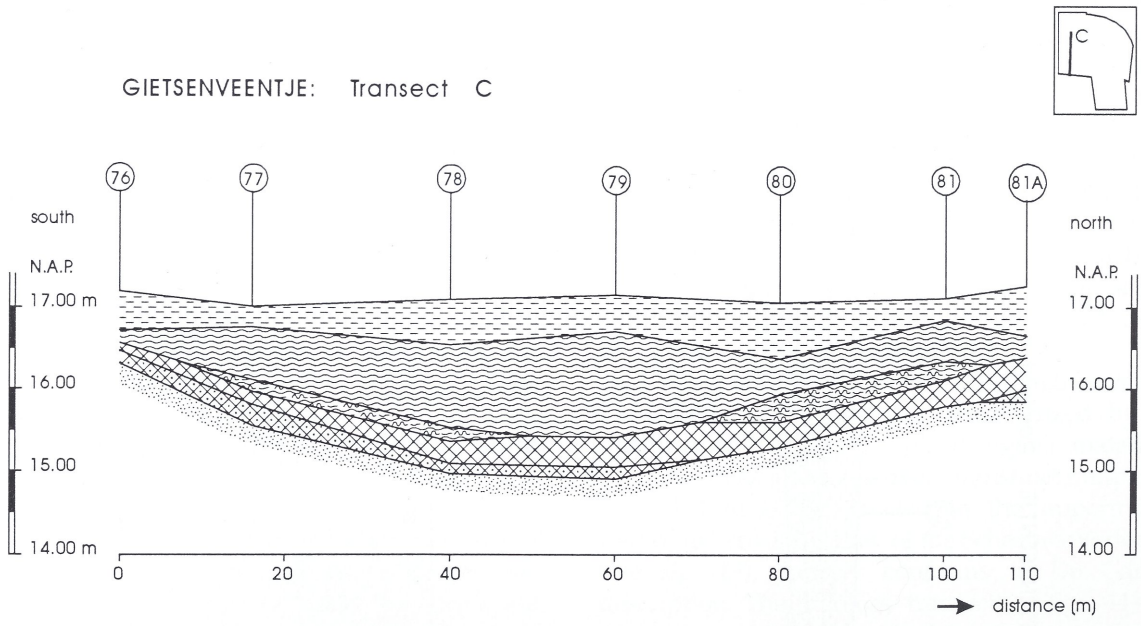


Fig. 46. Lithology transect C through the Gietsenveentje.

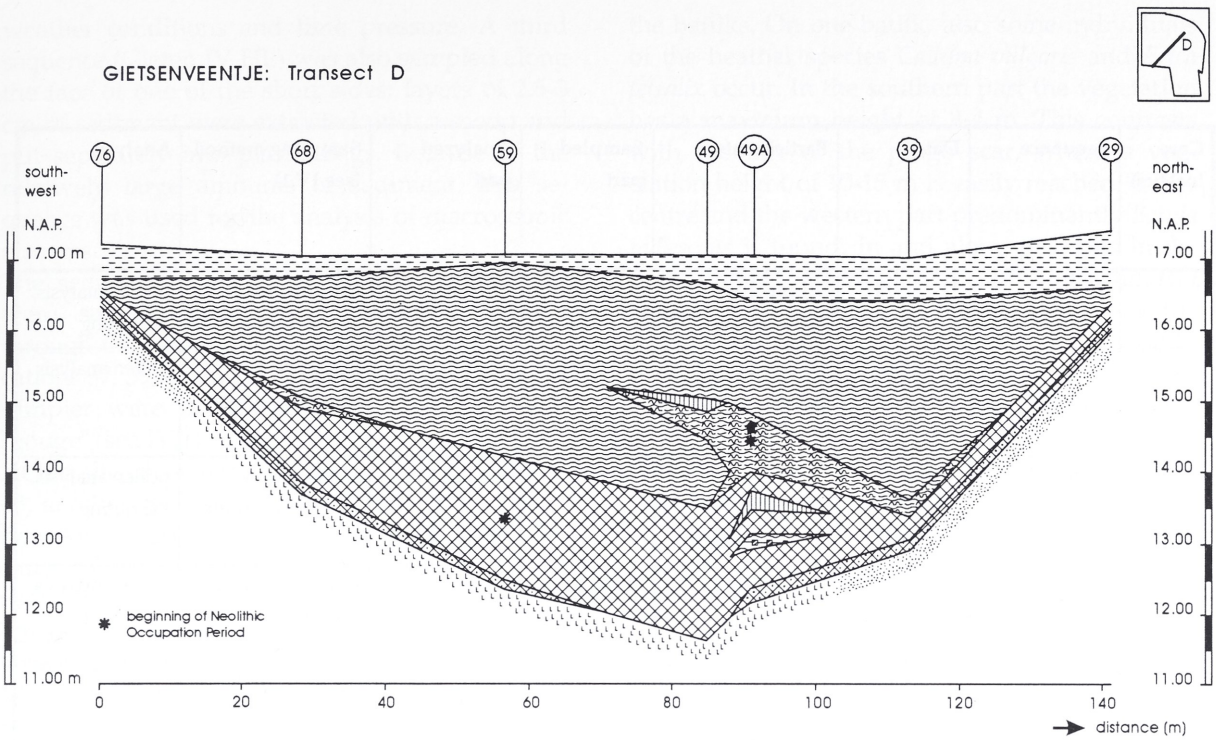


Fig. 47. Lithology transect D through the Gietsenveentje.

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
63
61
59
Qix
Qlxr
Qkr
Qlxcr
Q
Qlxc
Bas
Asn
Y
X
Ac
Aqbx
Qd
QRa
Qbl
A
Qlab
Sn
Qb
B
Qn
An
Aq
Qp
V
Sb
Bq
S
Qalp
Qx
Sabq
P
Qabl
Bql
BQl
Bs
Bsa
Qbp
Asb
Sab
QMlf
Qlbr
Ql
U
Ps
Bl
Ya
Sa
Sp
Bpq
Bqf
L
Rx
Axqb
Qbplxkr
BQl
BMq
Abqs
Sbq
Bqxl
Qcbax
Bp
Bqp
Bqs
W
Qbli
QB
Qpb
Blf
Qsx
Qbsx
Bqa
Bhft
Z
Sba
Za
Sa
Bh

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.

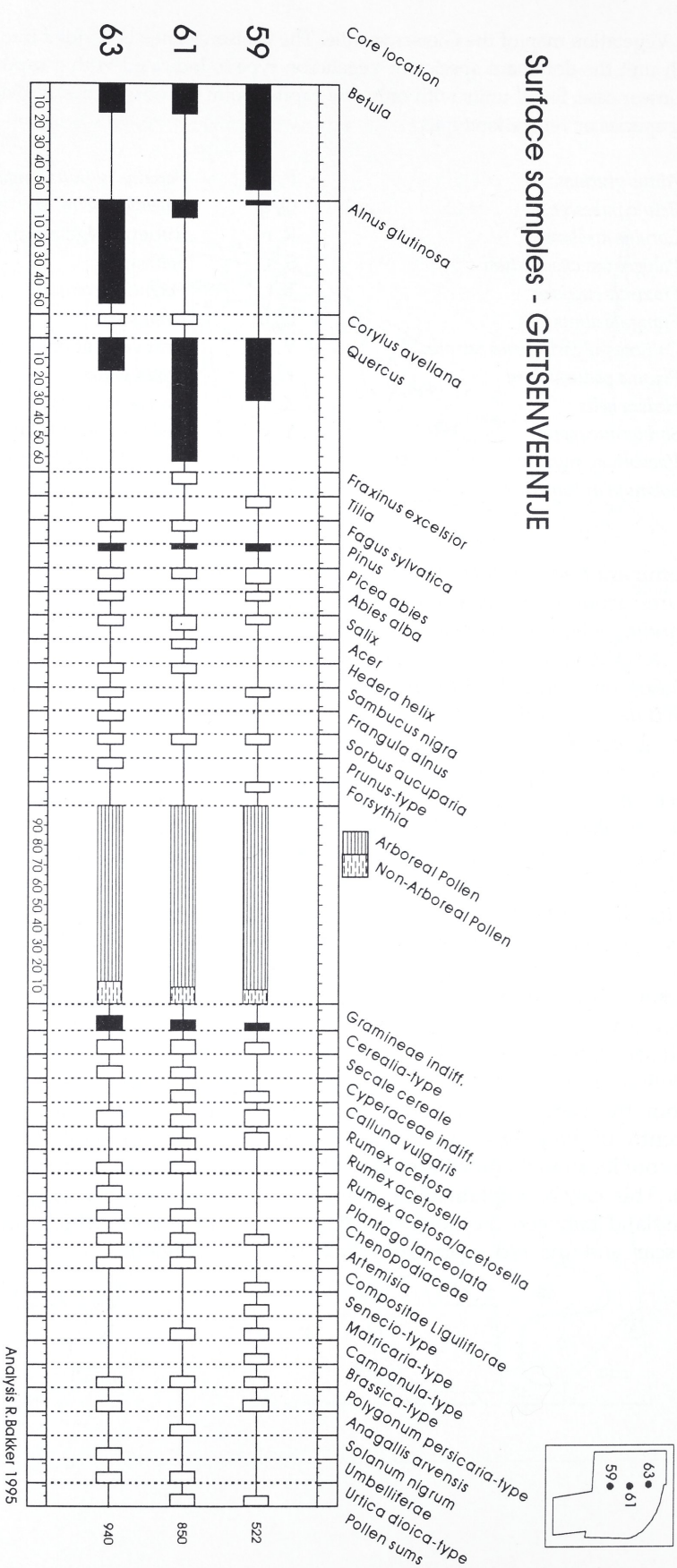


Fig. 49. Surface samples from the Gietsenveentje. Top right: the location of these samples in the Gietsenveentje.

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): ΣP = 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.

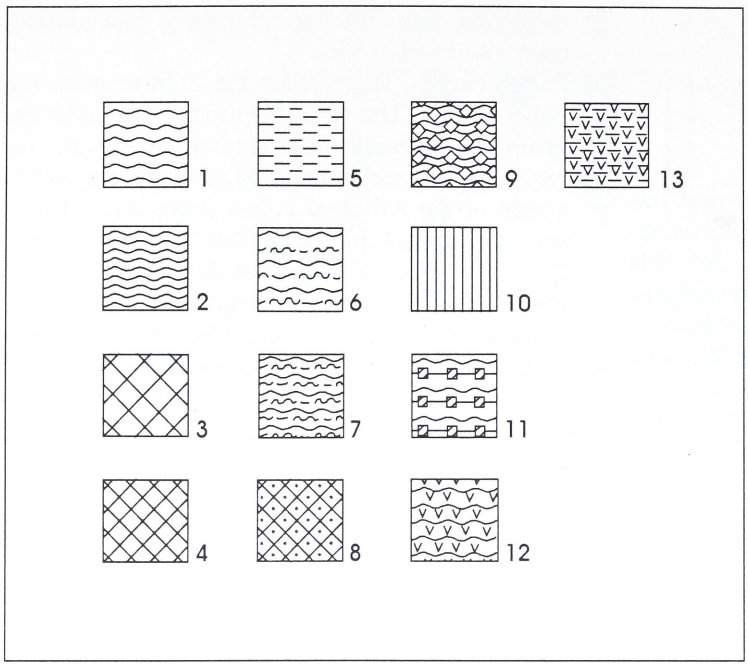


Fig. 50. Legend of the lithology column of the pollen diagrams.
1. poorly humified *Sphagnum* peat
2. moderately to highly humified *Sphagnum* peat
3. coarse detritus gyttja
4. fine detritus gyttja
5. homogeneous humic substance
6. as 1, with *Eriophorum*
7. as 2, with *Eriophorum*
8. fine detritus gyttja 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.

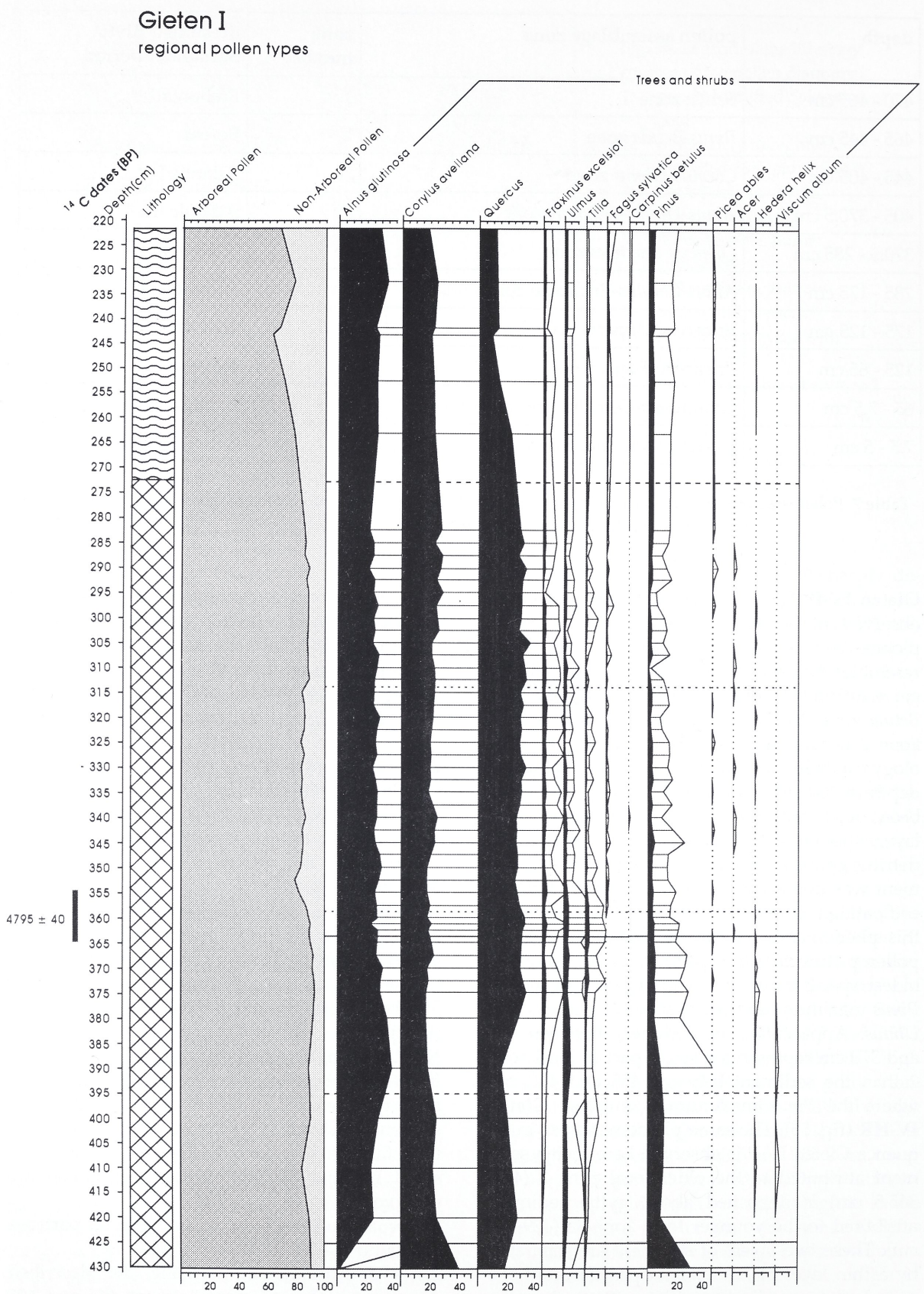
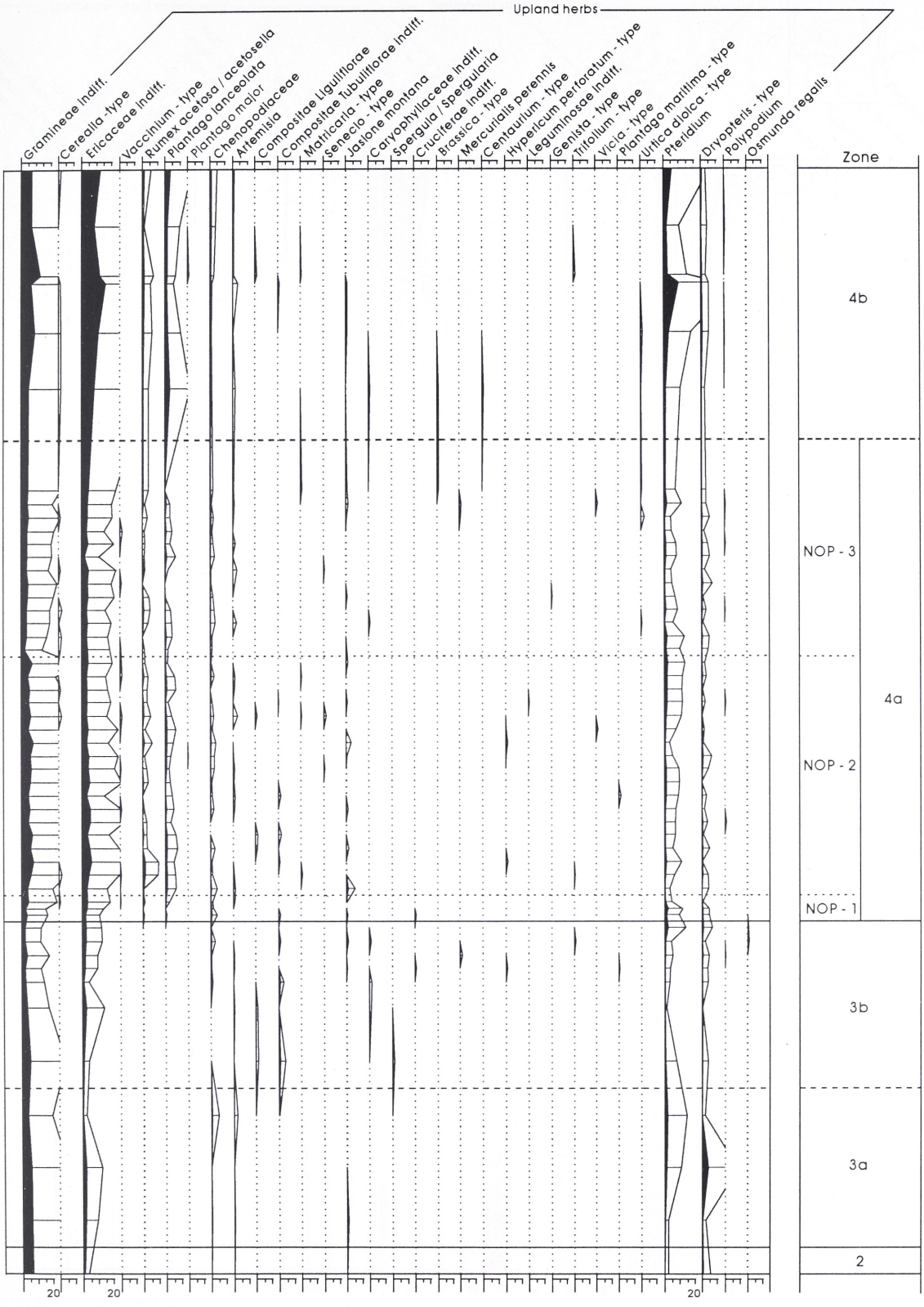


Fig. 51. Pollen diagram of sequence Gieten I.


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.
Sperguia / 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
20
20
20
Zone
4b
NOP - 3
NOP - 2
NOP - 1
4a
3b
3a
2

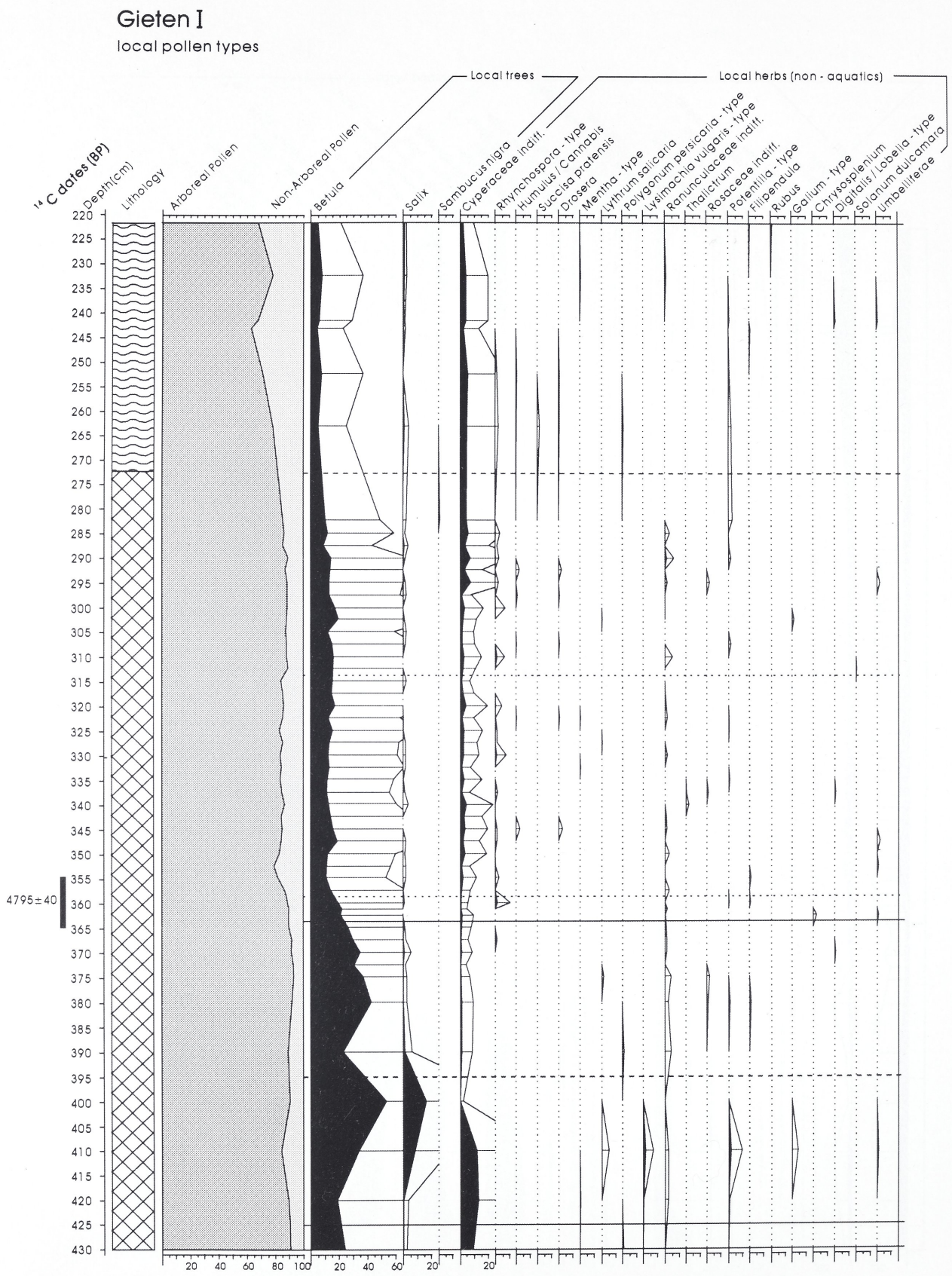
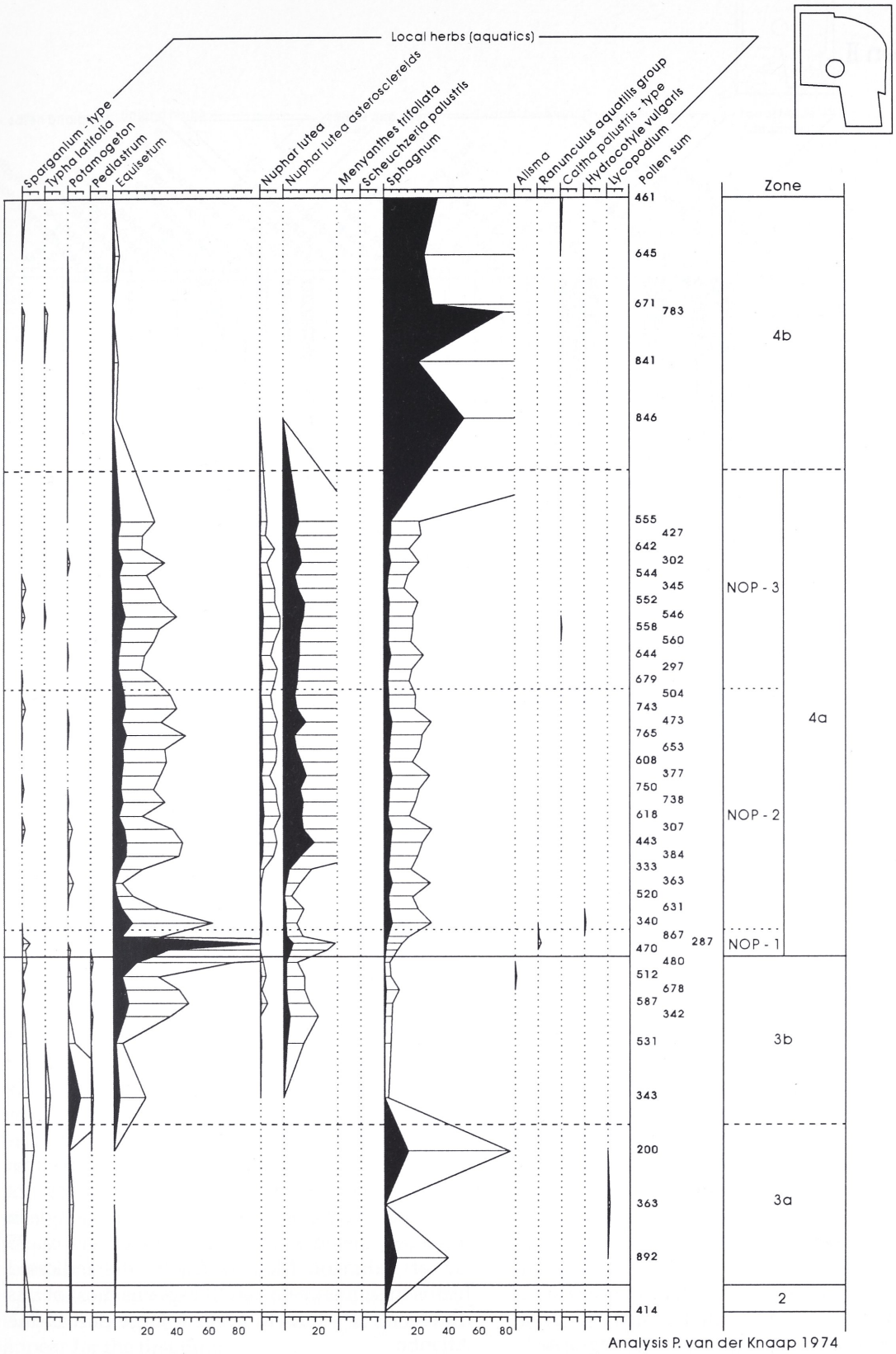


Fig. 51 (continued).


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
461
645
671
783
841
846
555
427
642
302
544
345
552
546
558
560
644
297
679
504
743
473
765
653
608
377
750
738
618
307
443
384
333
363
520
631
340
867
287
470
480
512
678
587
342
531
343
200
363
892
414
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

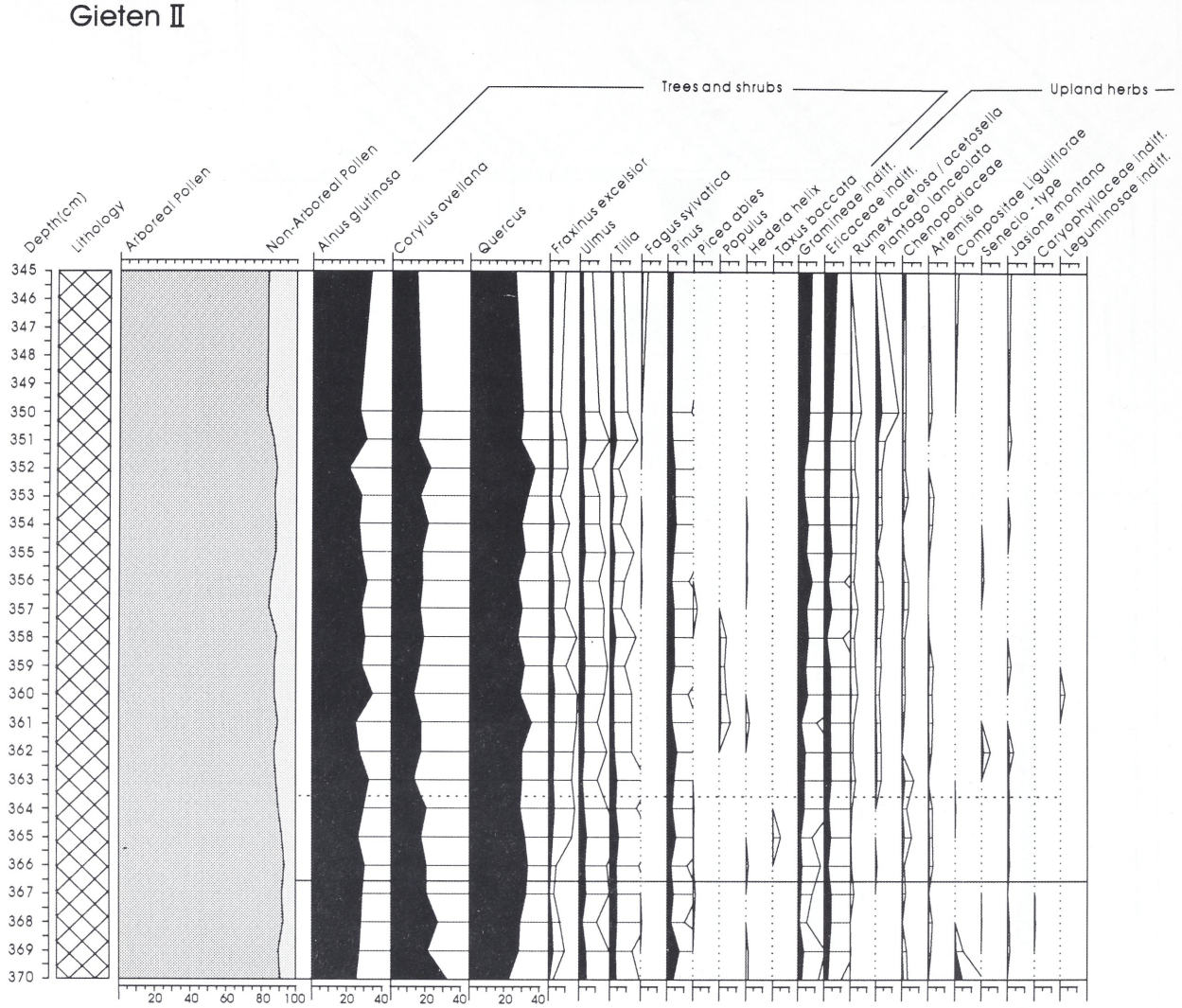
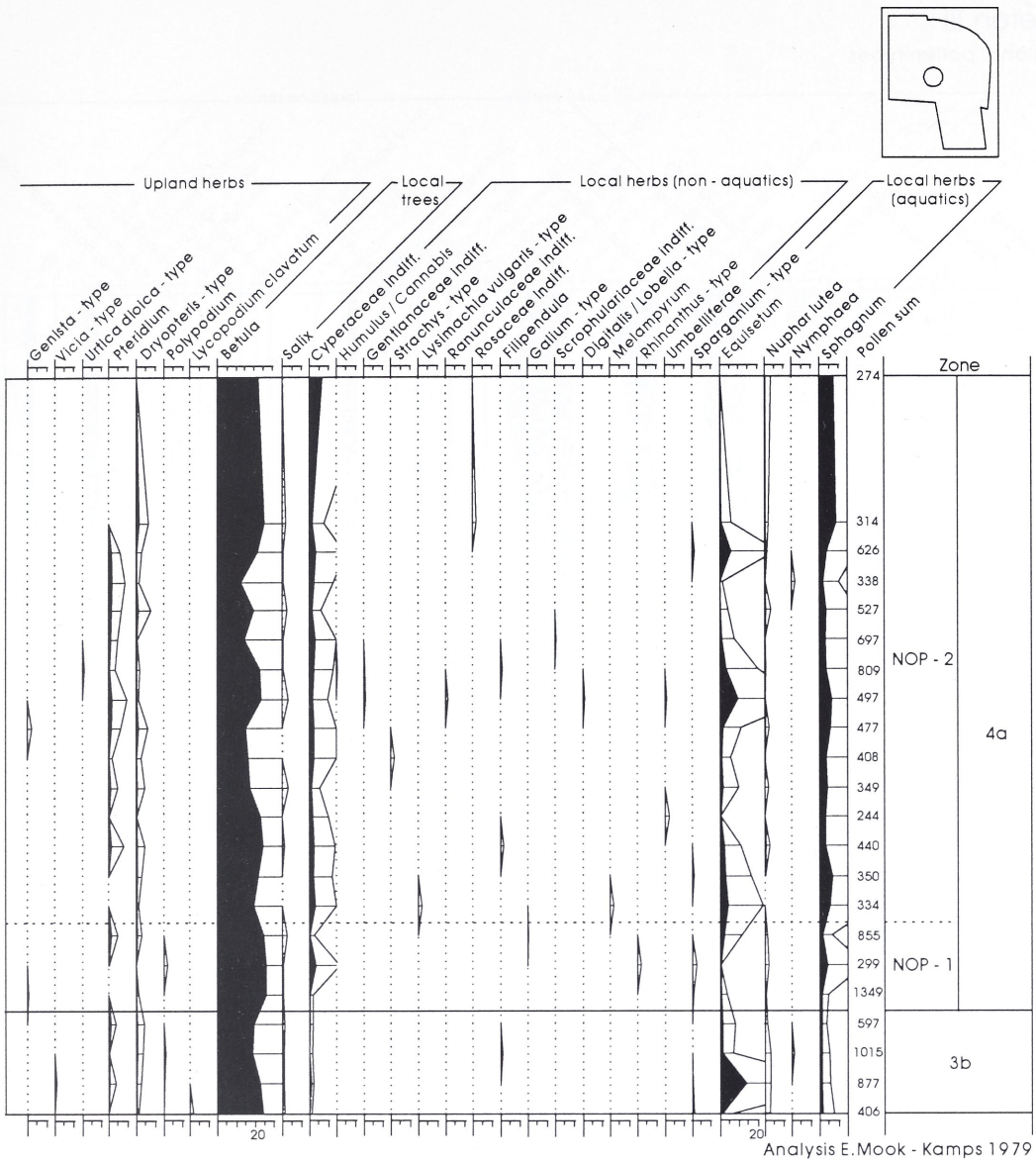


Fig. 52. Pollen diagram of sequence Gieten II.

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

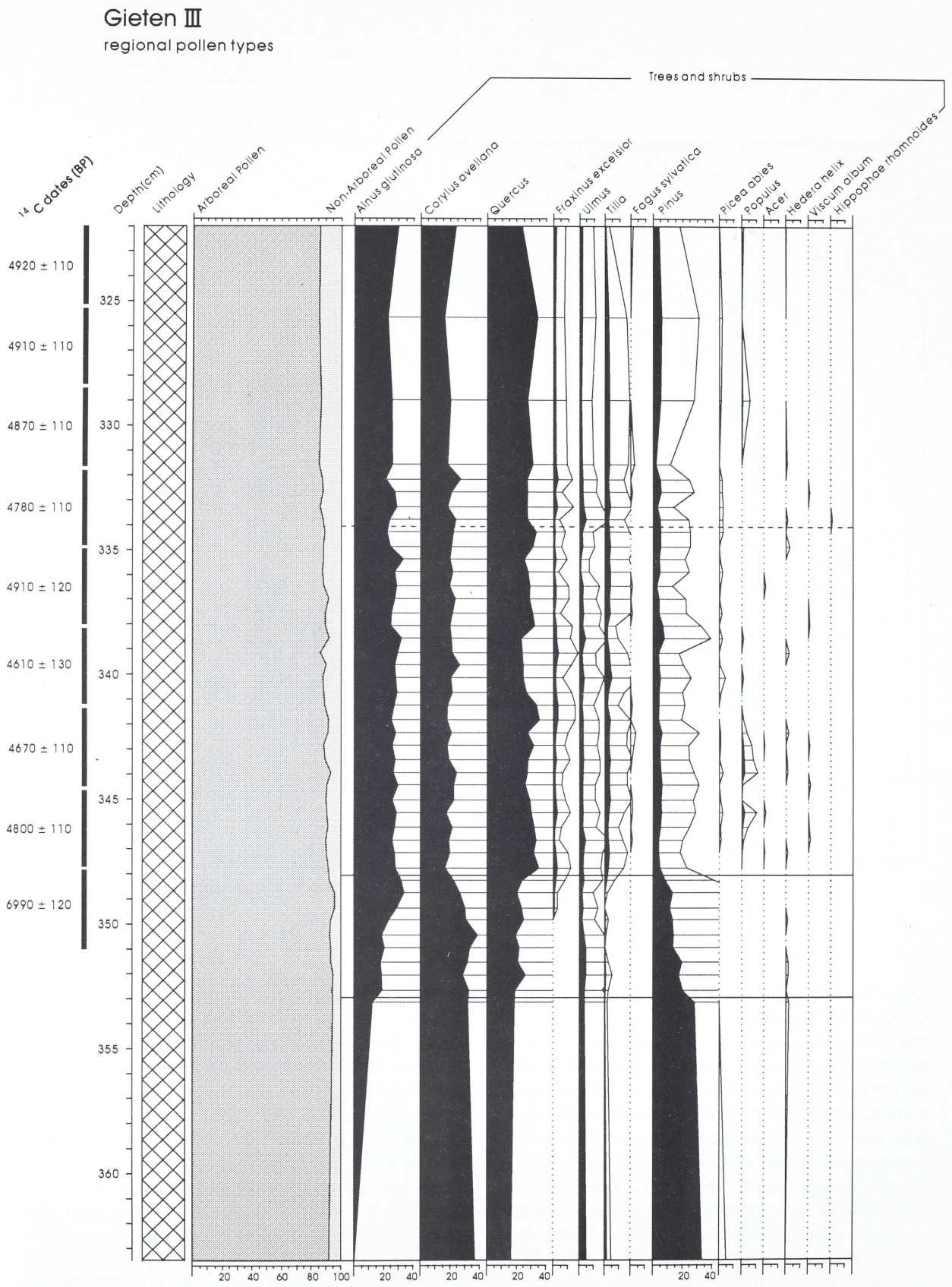
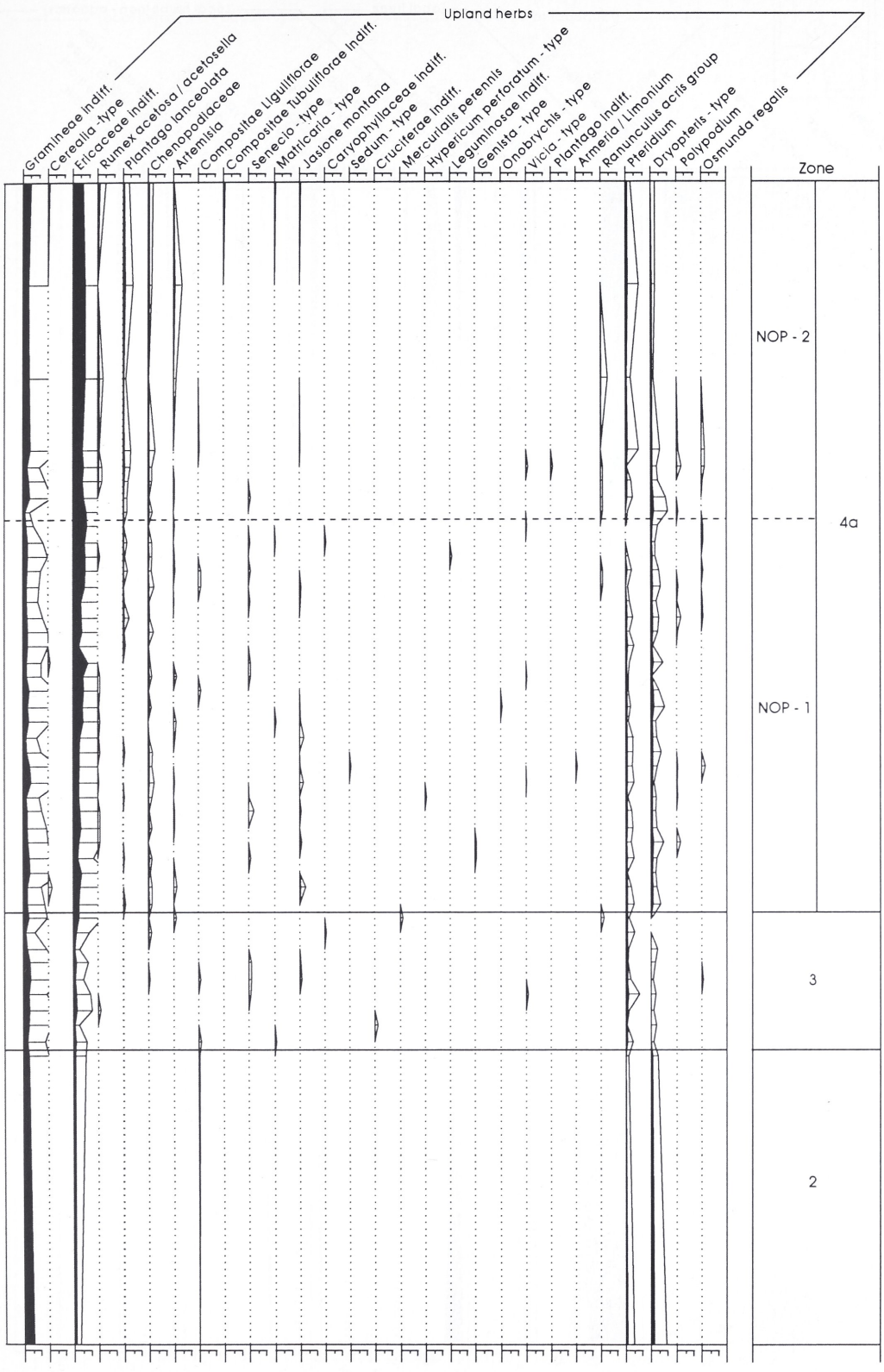


Fig. 53. Pollen diagram of sequence Gieten III.


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

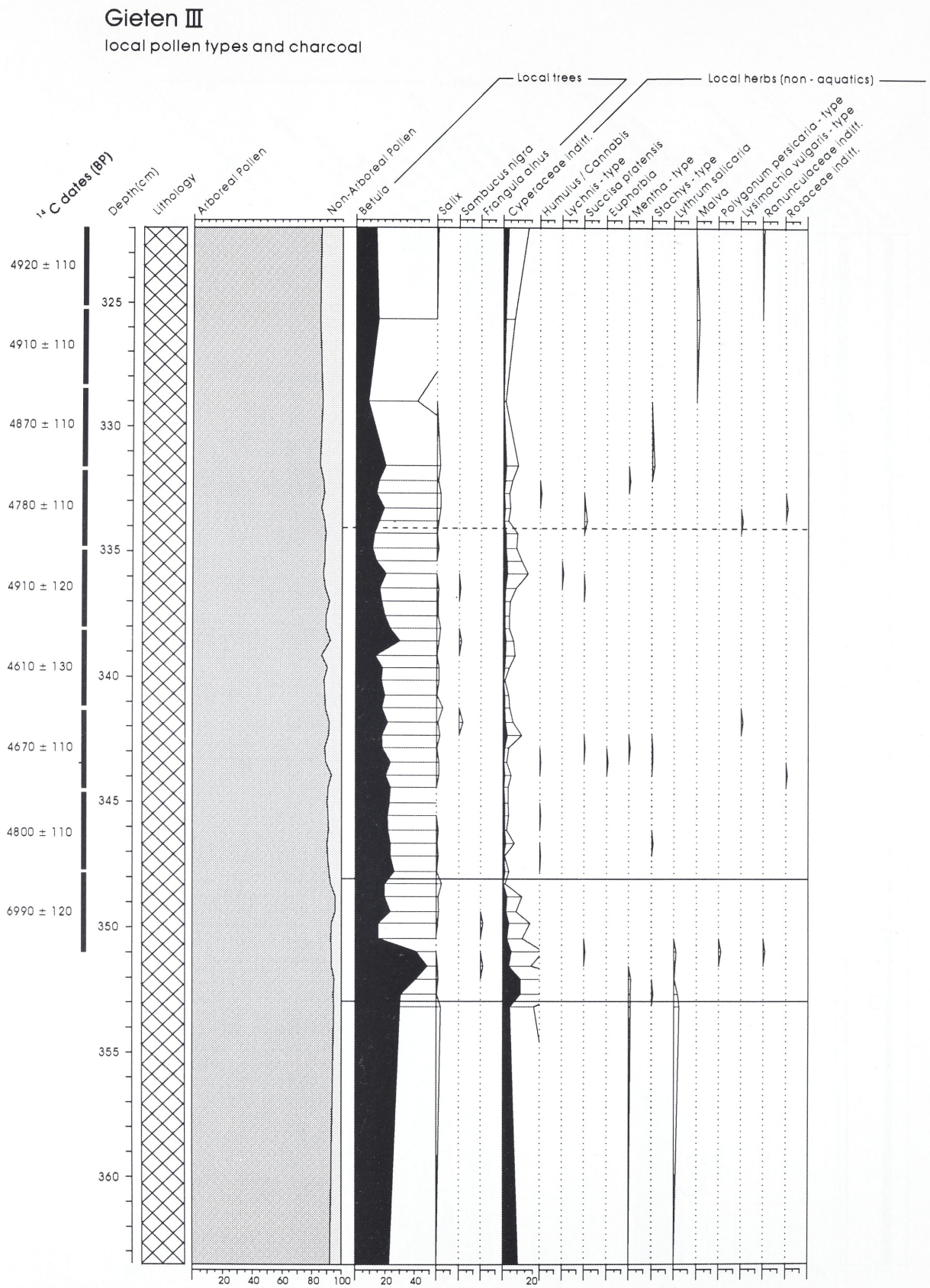
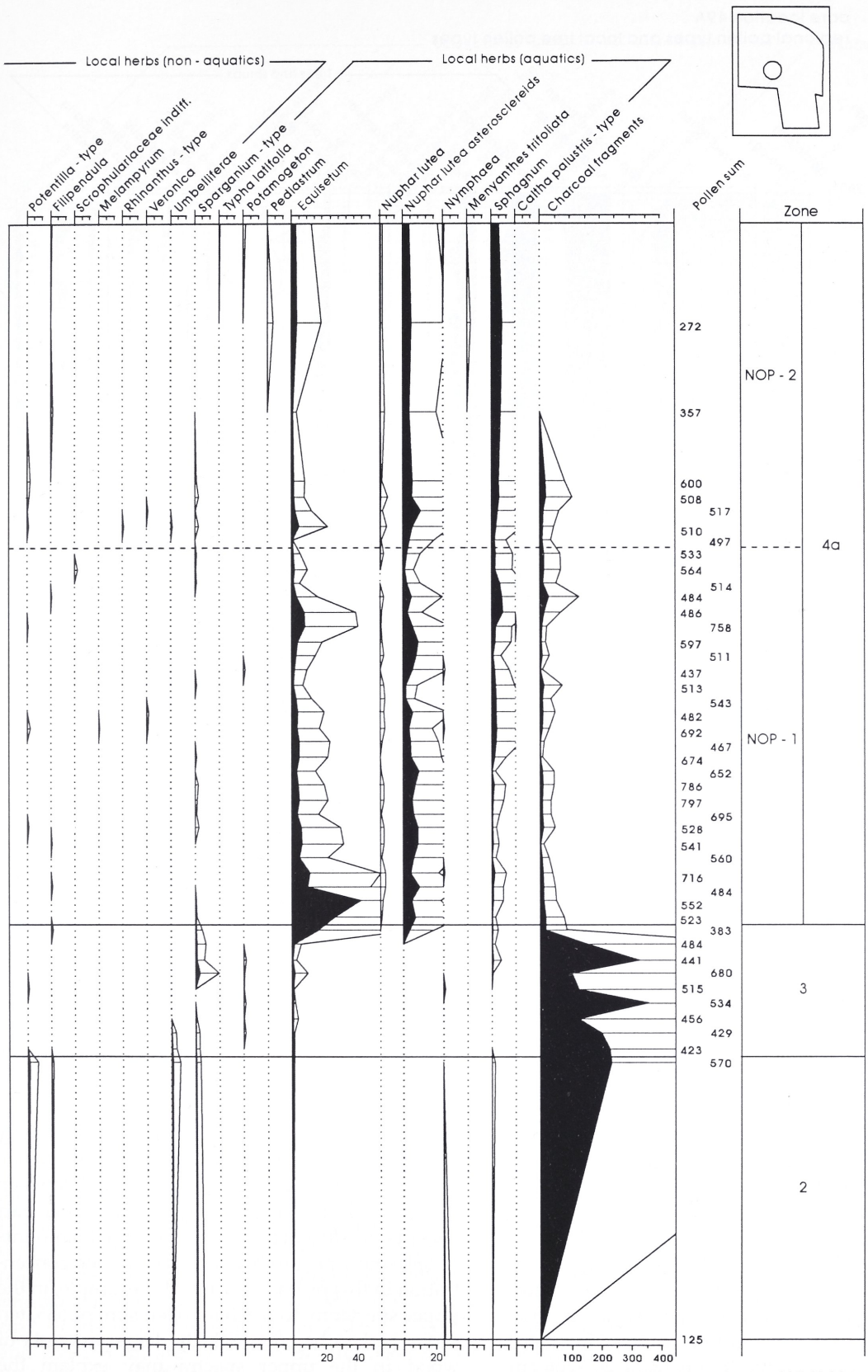


Fig. 53 (continued).



Analysis A. Hagedoorn 1985 / 1986

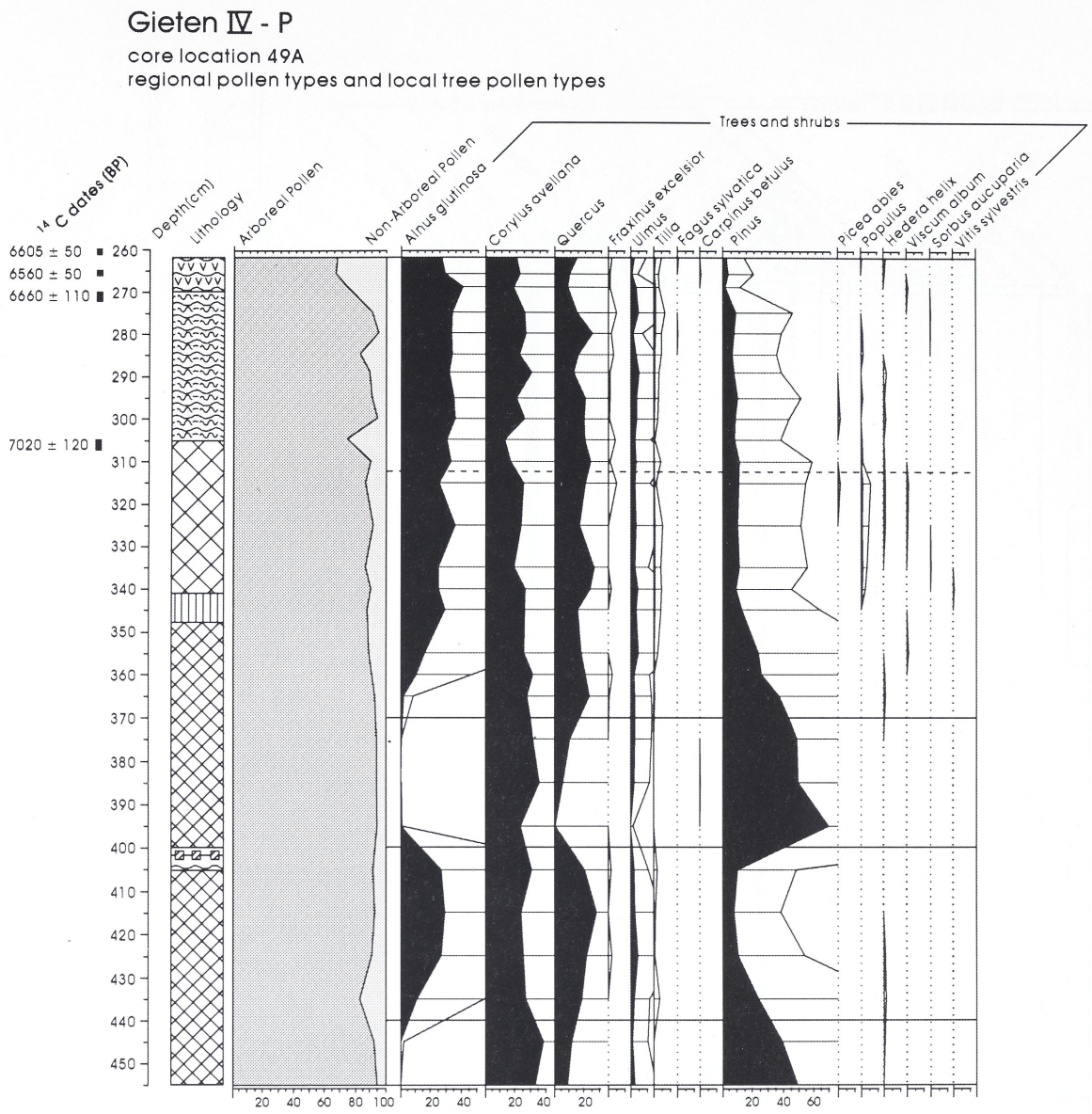
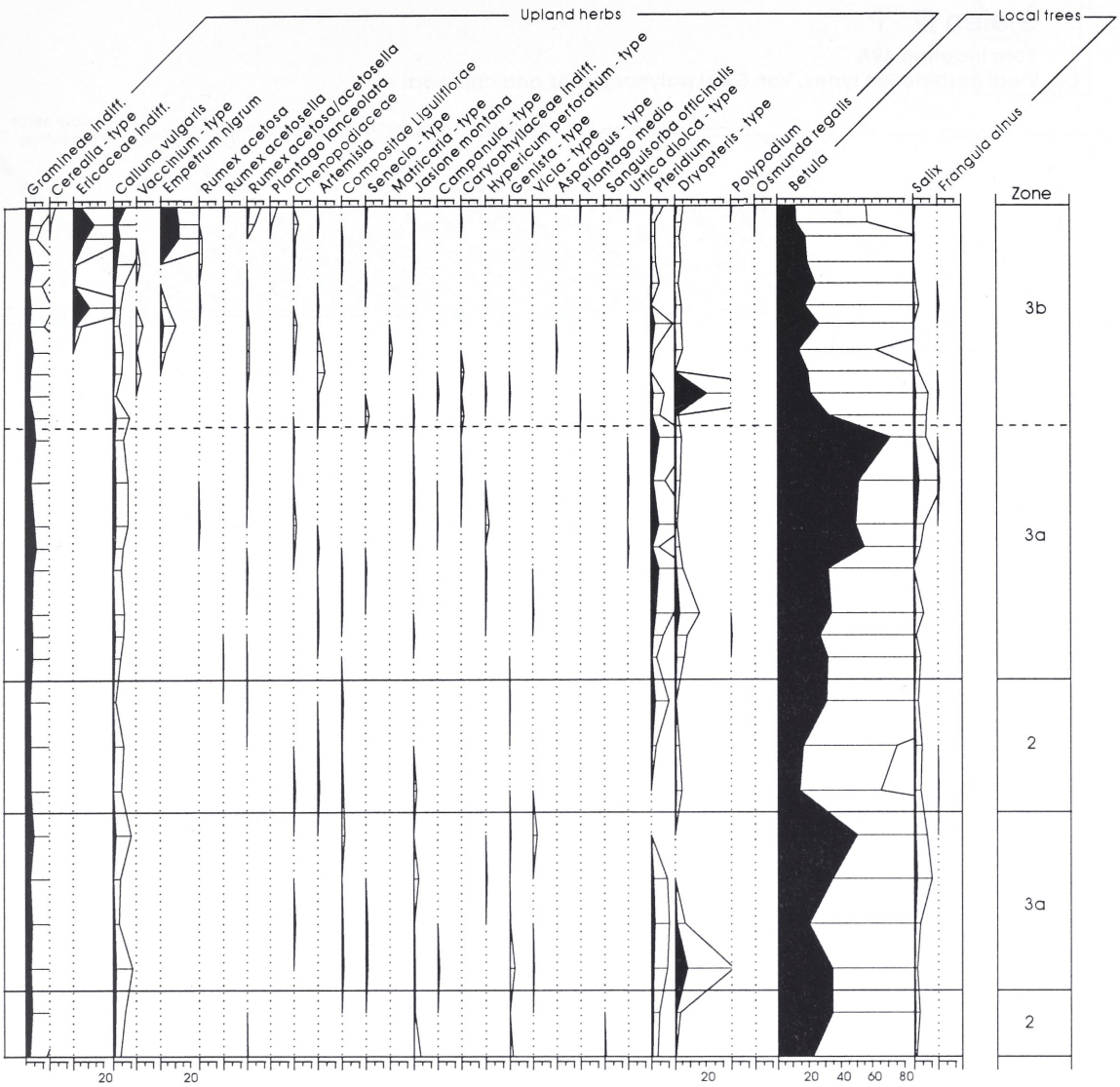


Fig. 54. Pollen diagram of sequence Gieten IV-P.

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.

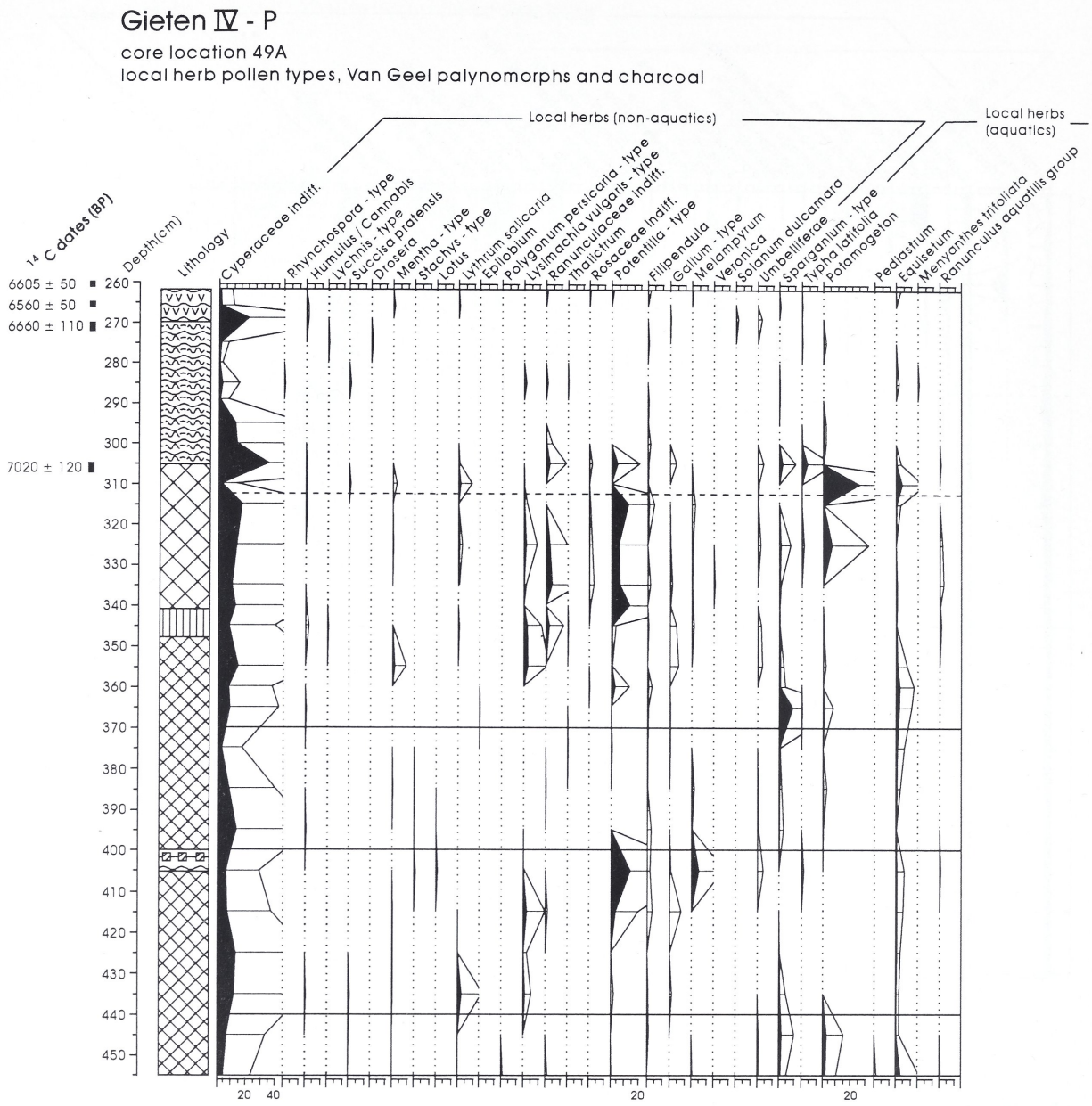
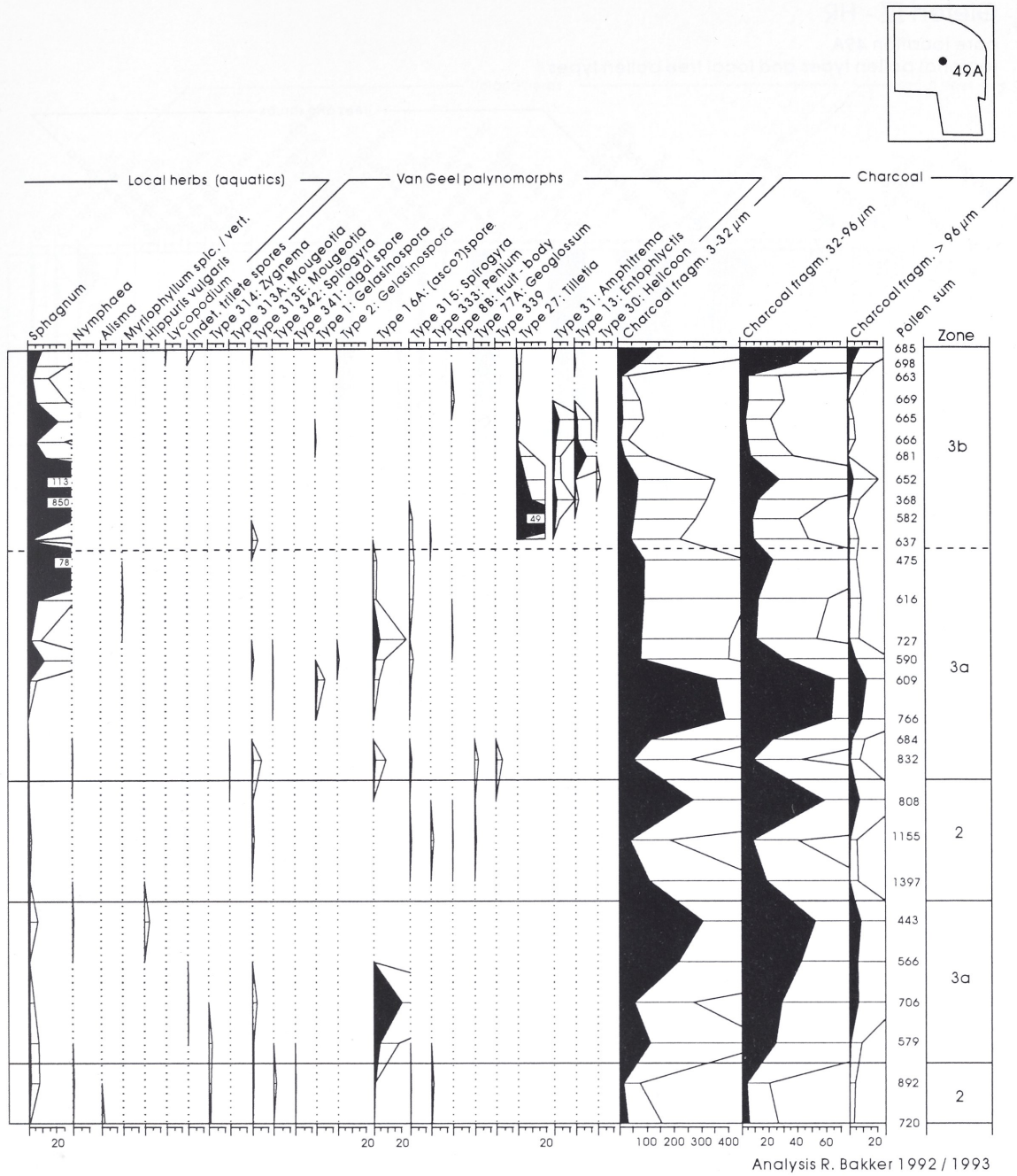


Fig. 54 (continued).

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.

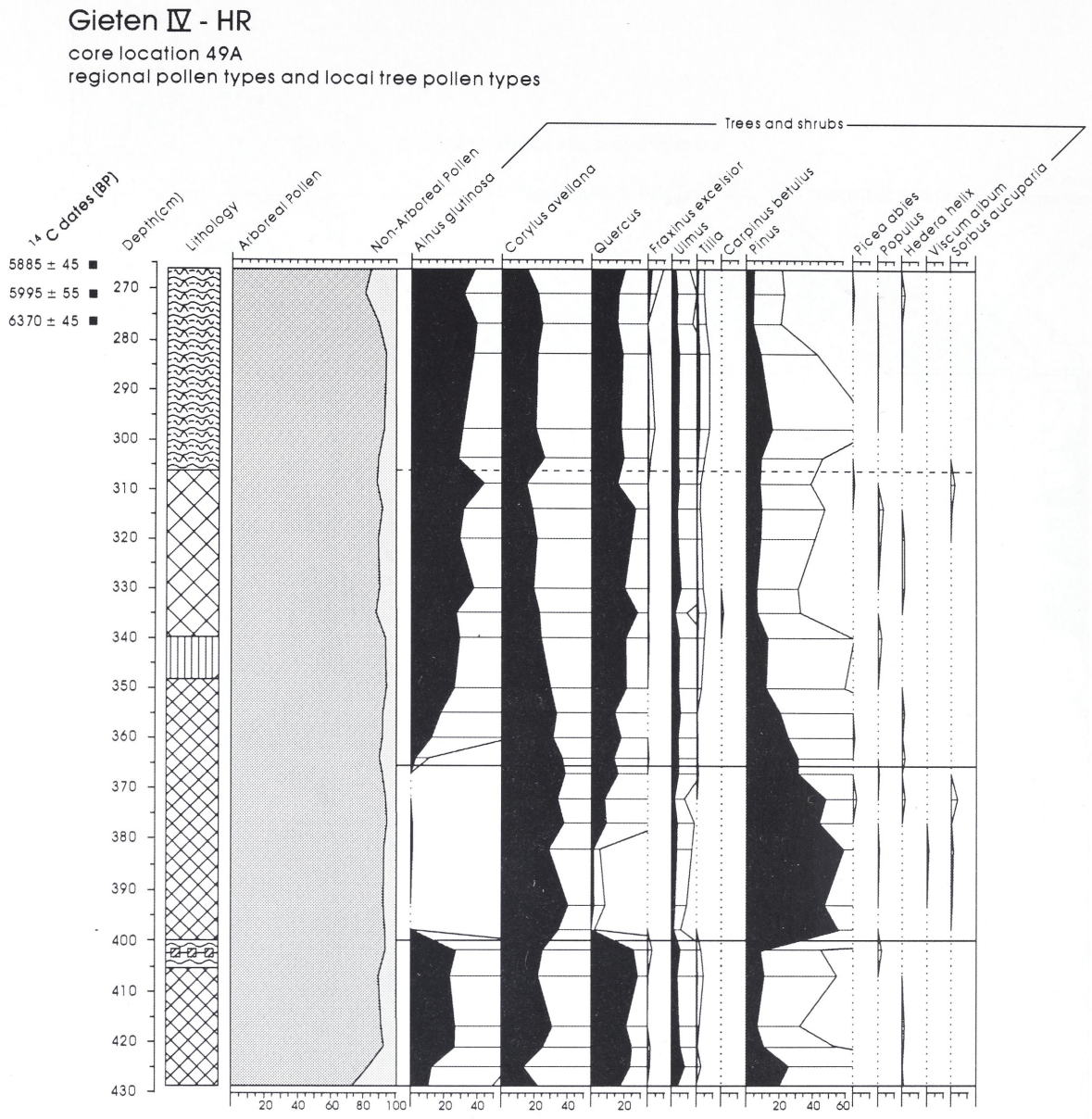


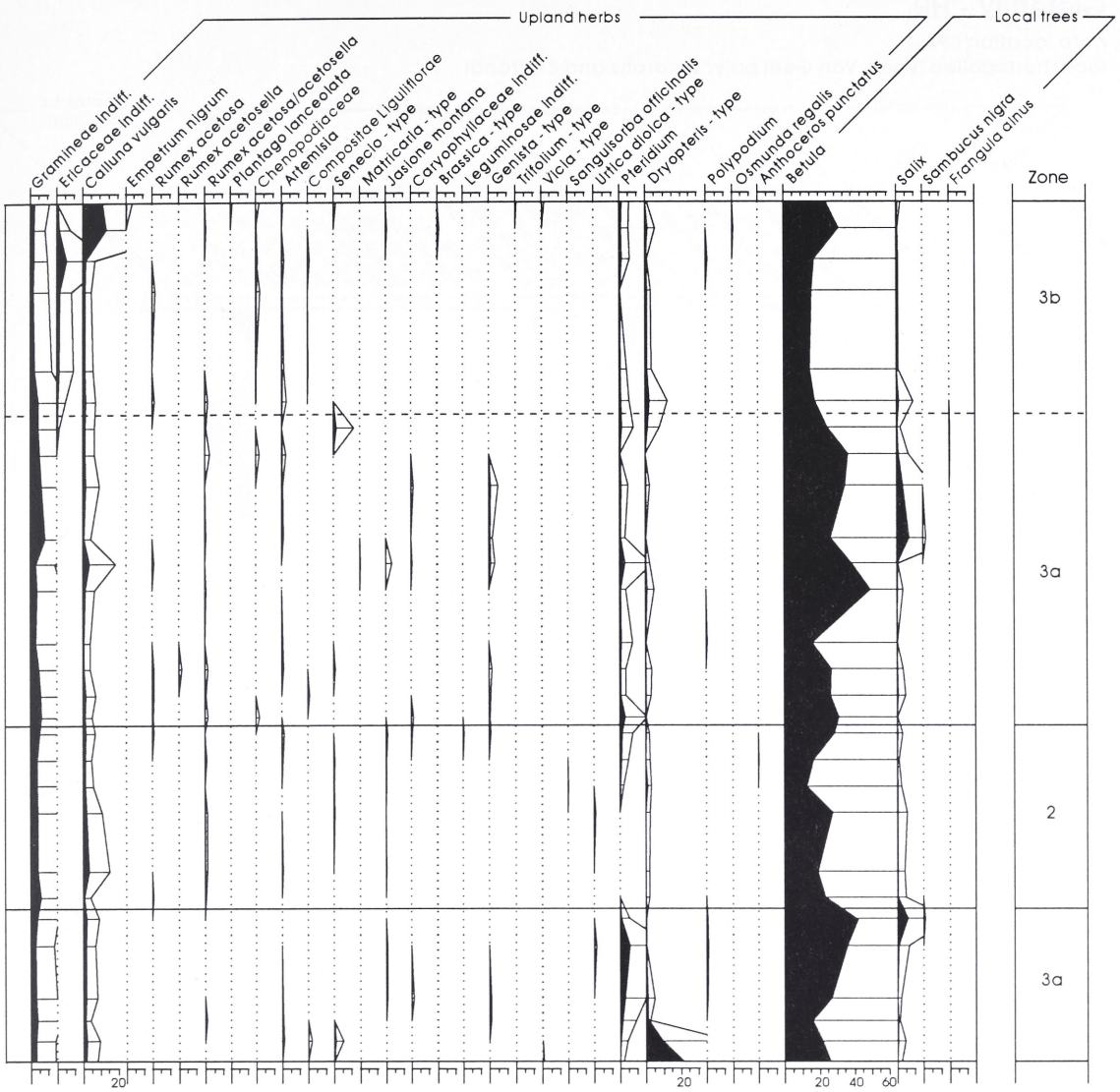
Fig. 55. Pollen diagram of sequence Gieten IV-HR.

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

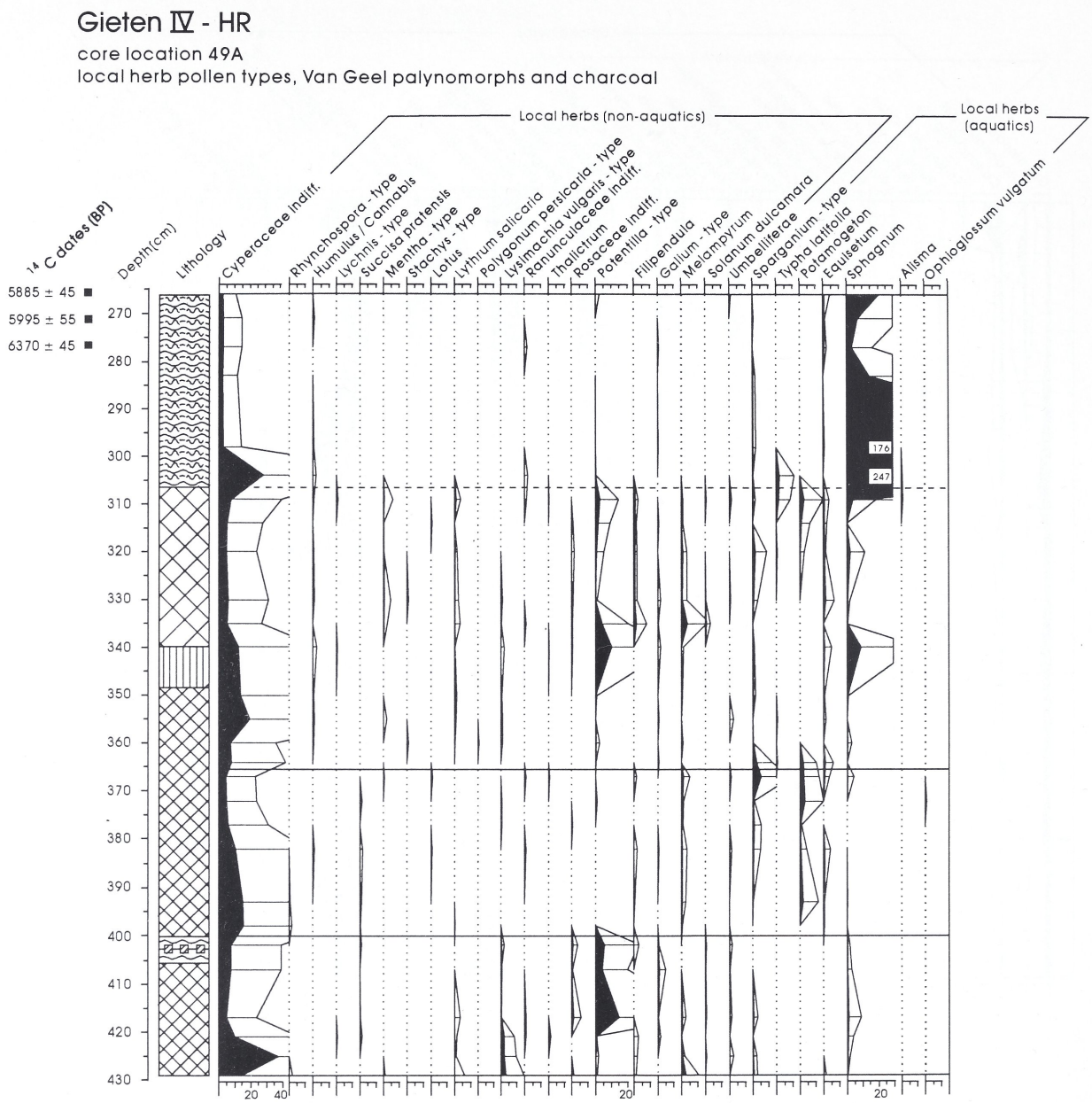
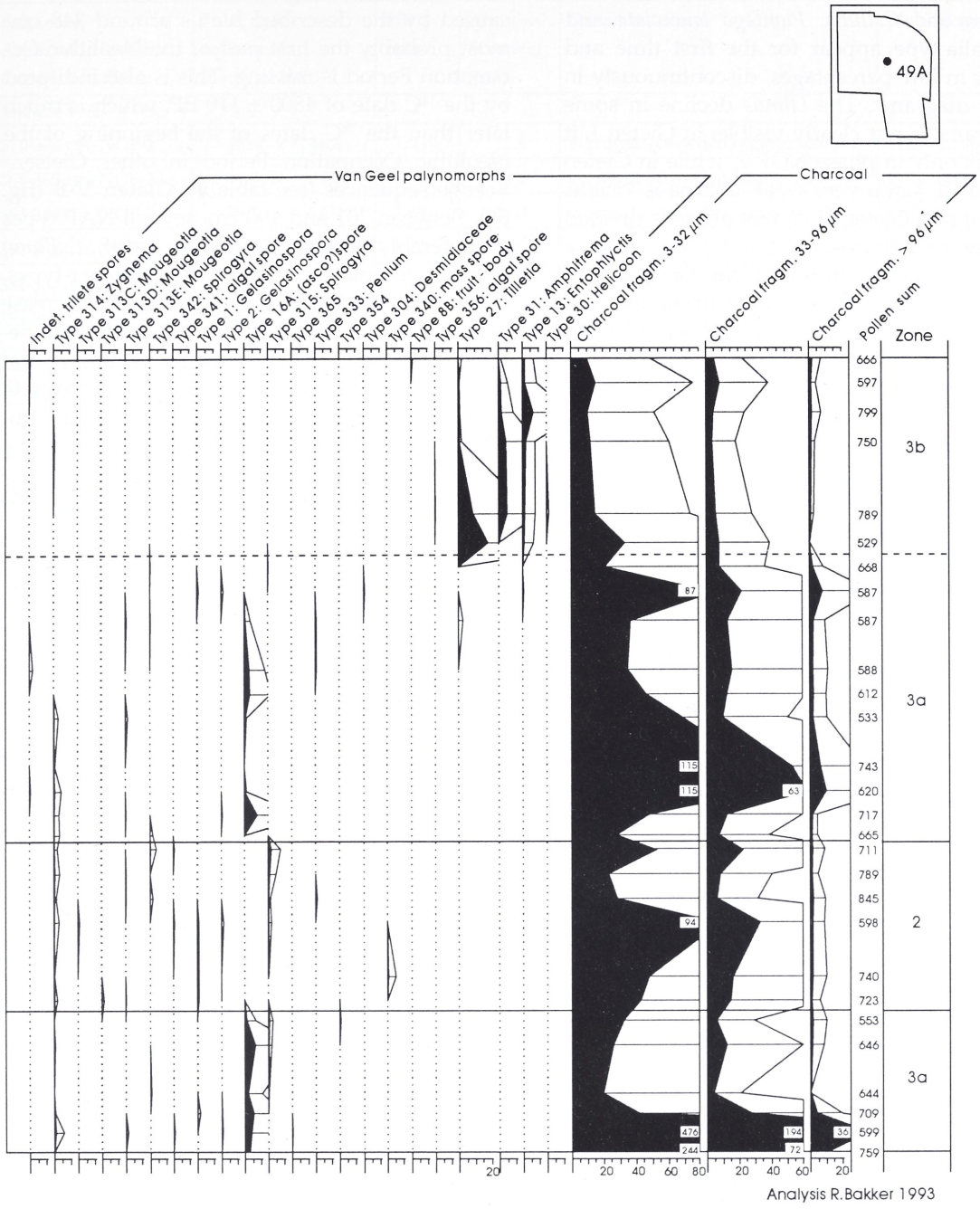


Fig. 55 (continued).

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.

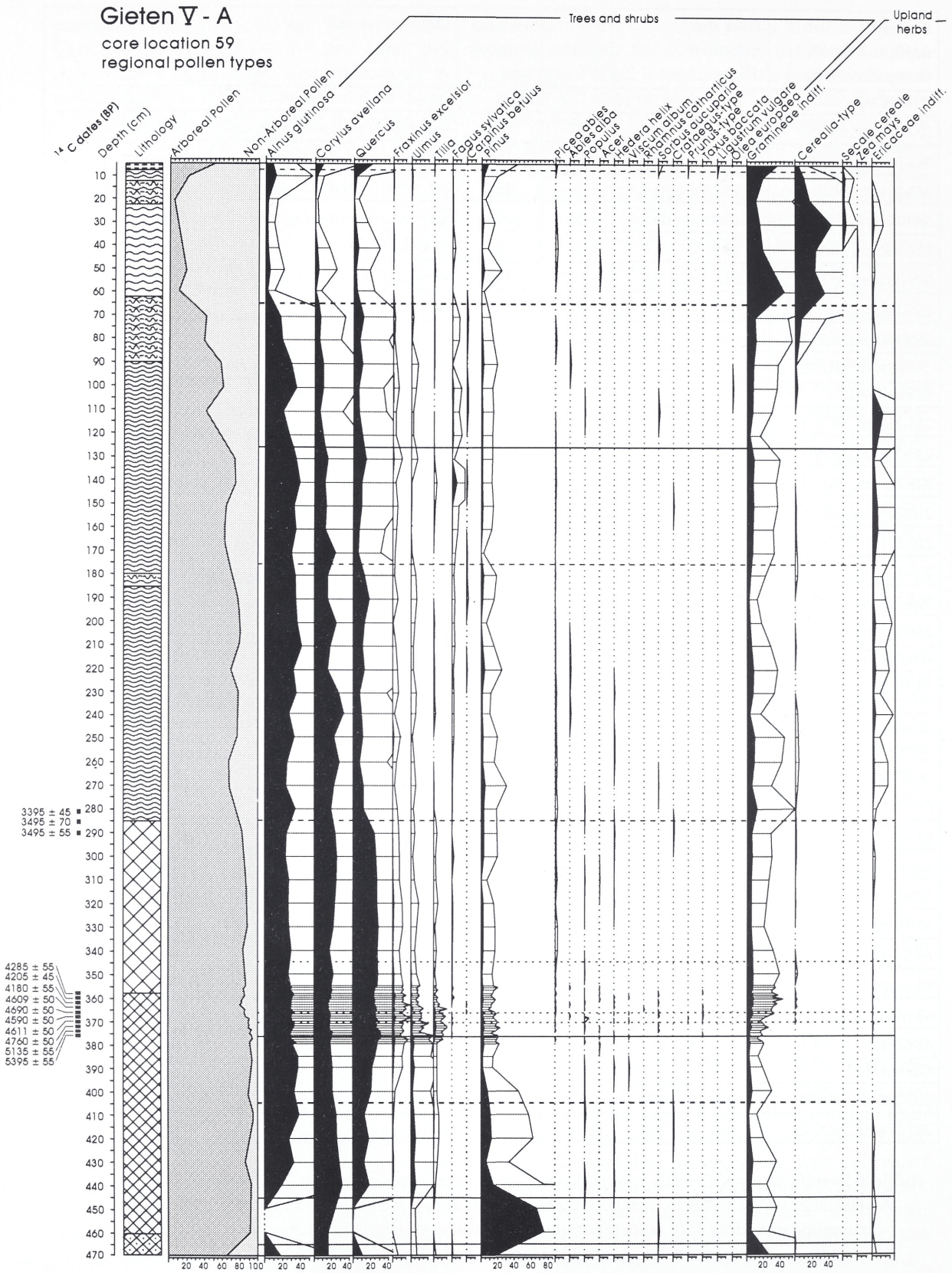
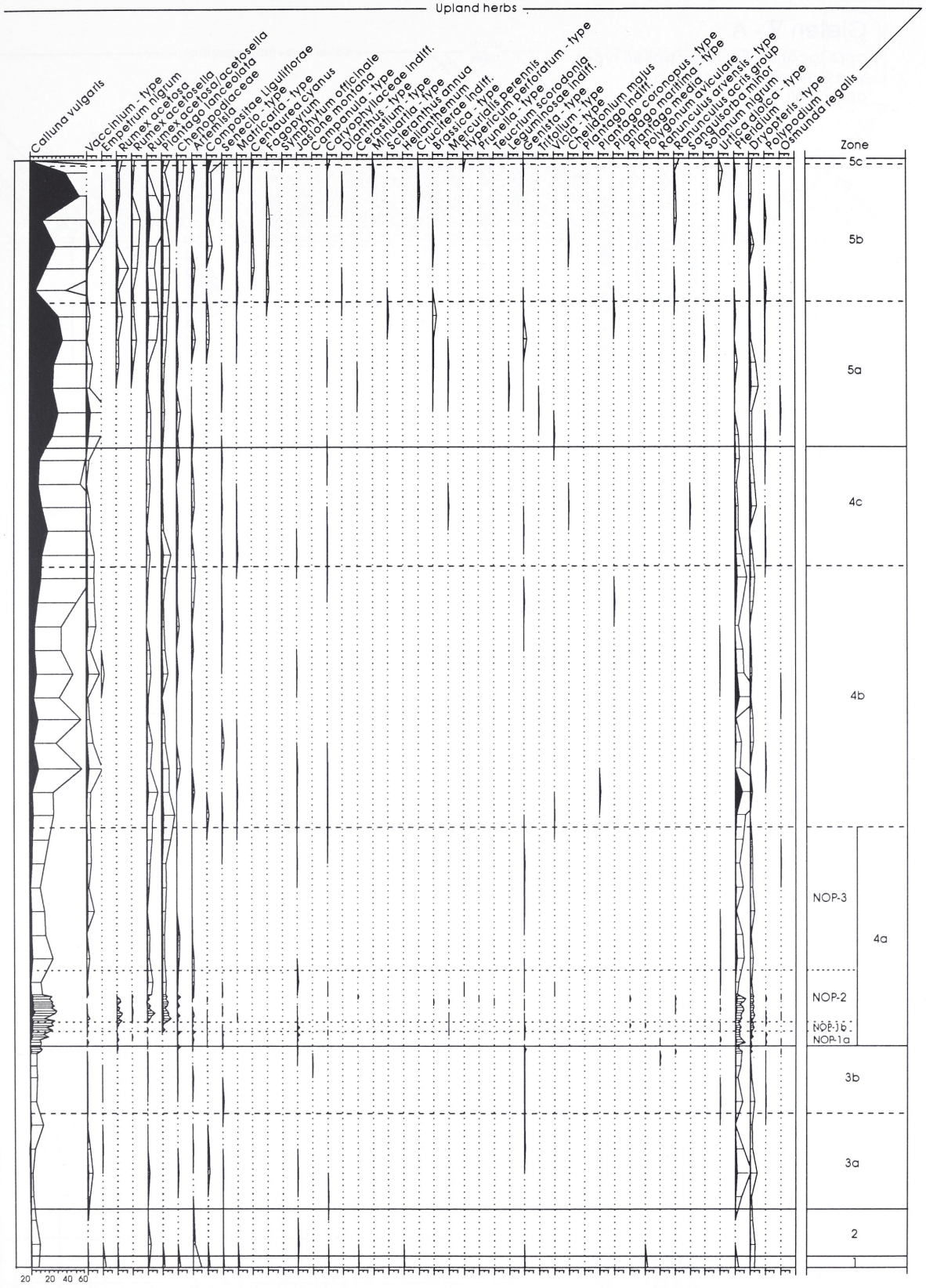


Fig. 56. Pollen diagram of sequence Gieten V-A, the Gietsenveentje master pollen diagram.


Upland herbs
Calluna vulgaris
Vaccinium - type
Empetrum nigrum
Rumex acetosa
Rumex 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

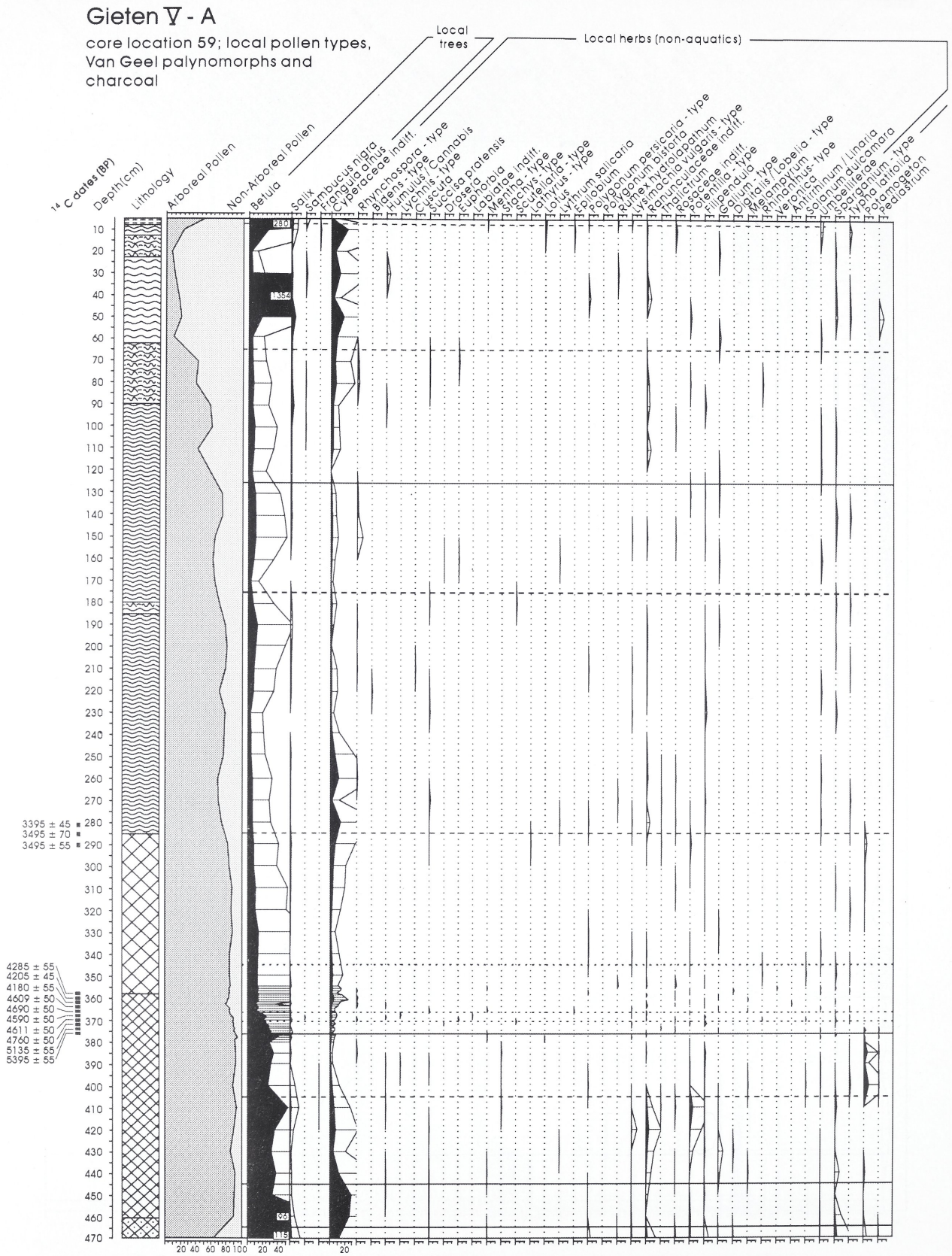
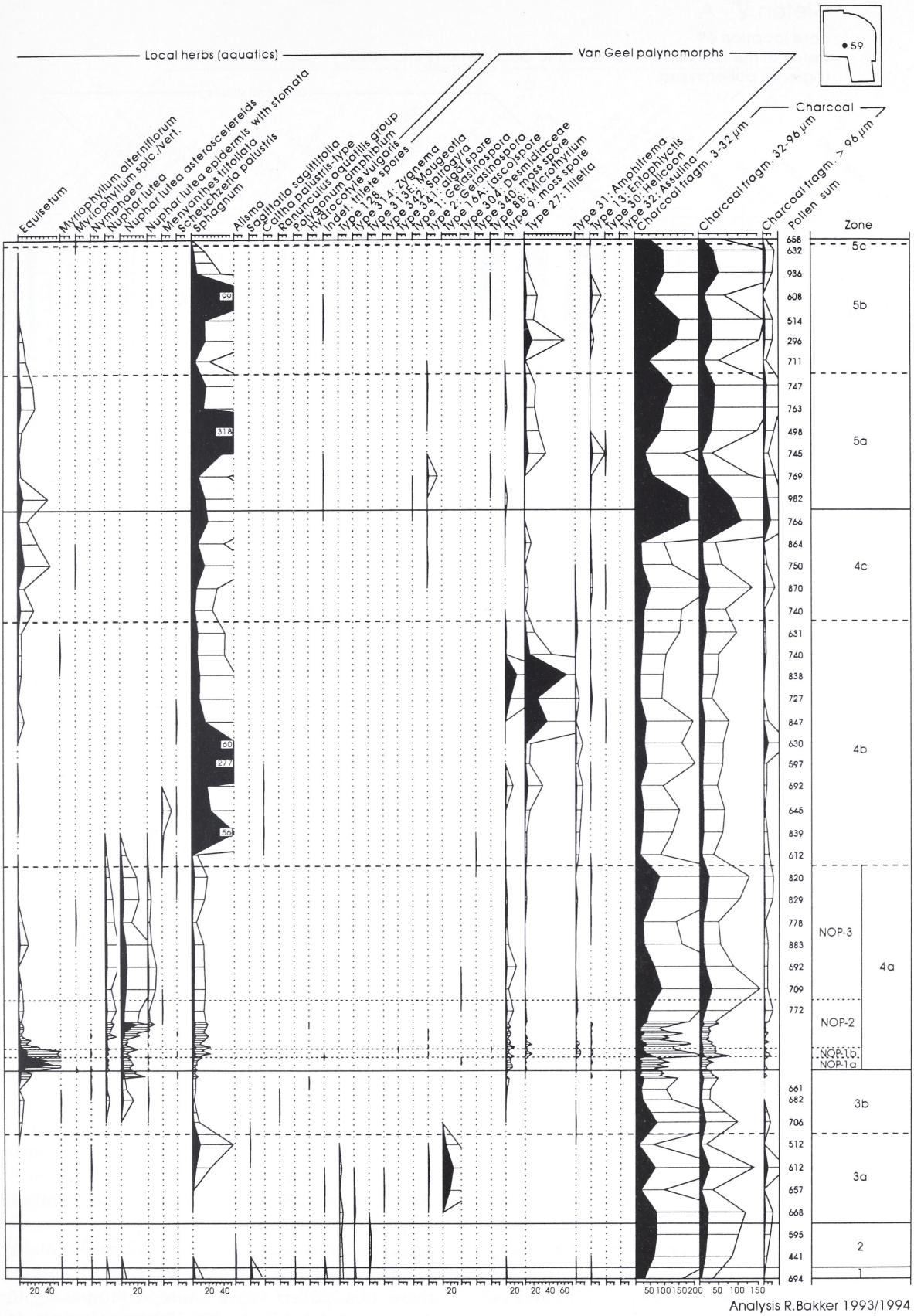


Fig. 56 (continued).


Local herbs (aquatics)
Van Geel palynomorphs
Charcoal
59
Equisetum
Myriophyllum alterniflorum
Myriophyllum spic./vert.
Nymphaea
Nuphar lutea
Nuphar lutea asteroscelereids
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 313; Zygnema
Type 342; Mougeotia
Type 341; spirogyra
Type 7; algal spore
Type 2; Gelasinospora
Type 16A; Gelasinospora
Type 304; Ascospore
Type 340; Desmidiaceae
Type 88; moss spore
Type 9; Microthyrium
Type 27; Tilletia
Type 31; Amphilrema
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
99
31.8
9.0
2.7
5.6
658
632
936
608
514
296
711
747
763
498
745
769
982
766
864
750
870
740
631
740
838
727
847
630
597
692
645
839
612
820
829
778
883
692
709
772
661
682
706
512
612
657
668
595
441
694
5c
5b
5a
4c
4b
NOP-3
4a
NOP-2
NOP-1b
NOP-1a
3b
3a
2
1
20 40
20
20 40
20
20 40 60
50 100 150 200
50 100 150
Analysis R.Bakker 1993/1994

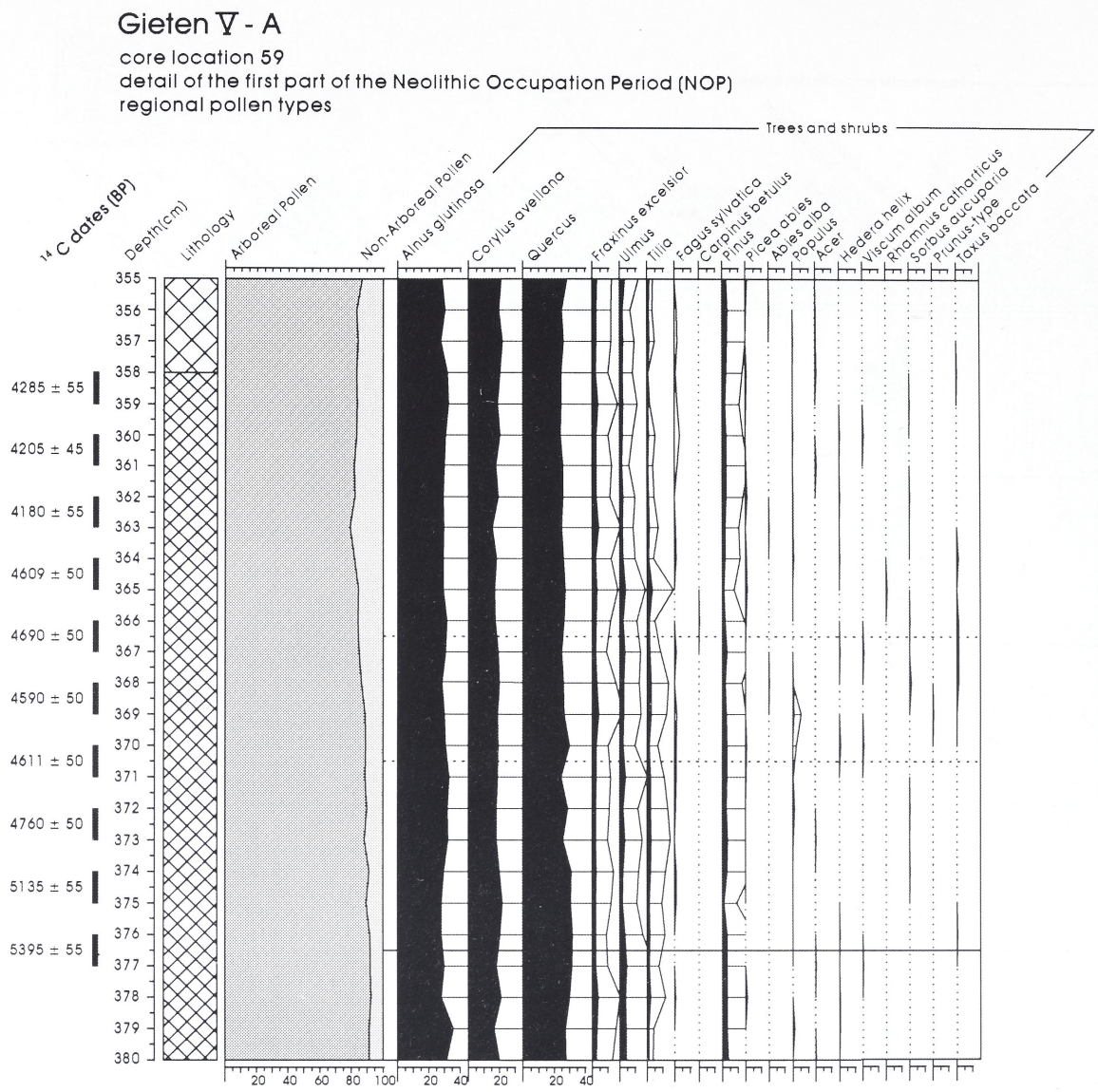


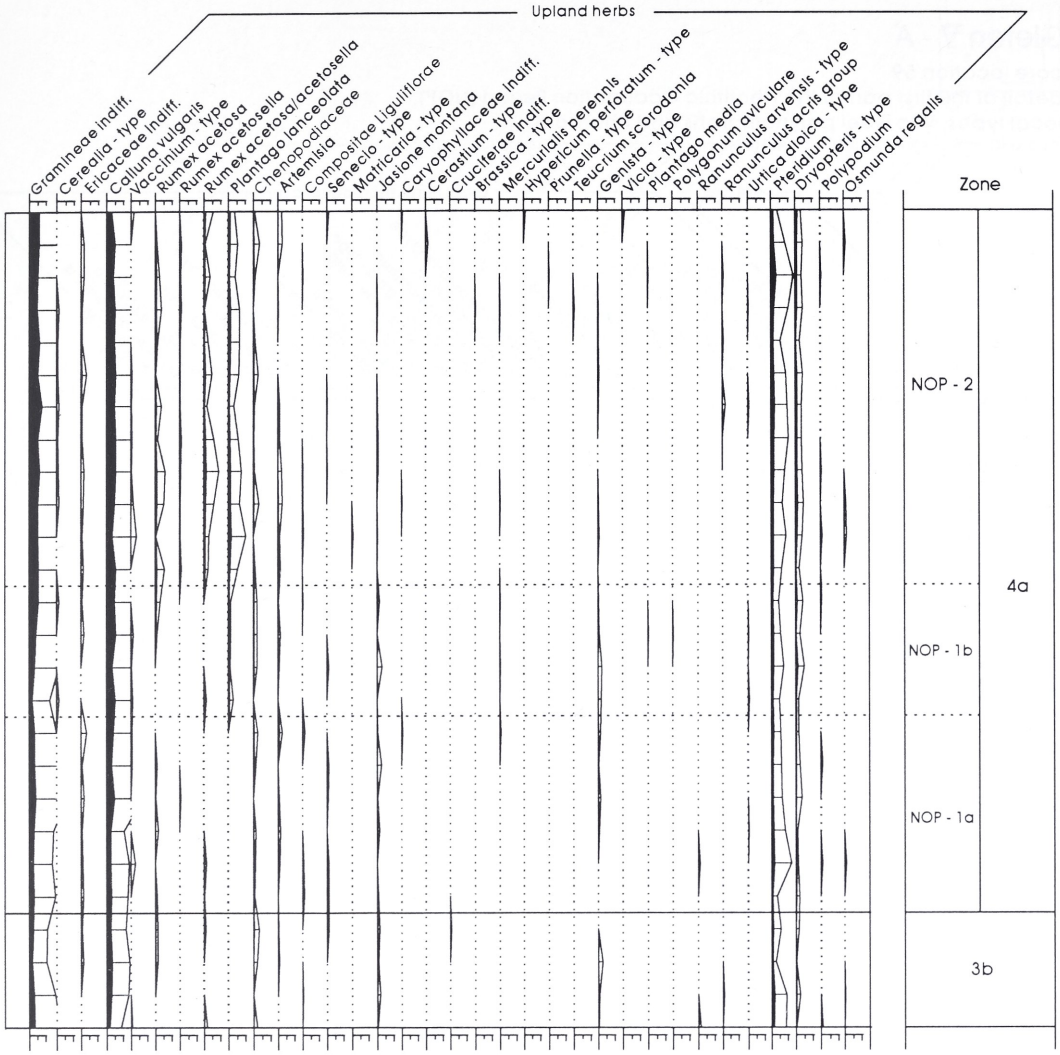
Fig. 57. Detailed pollen diagram of sequence Gieten V-A: the first part of the Neolithic Occupation Period.

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

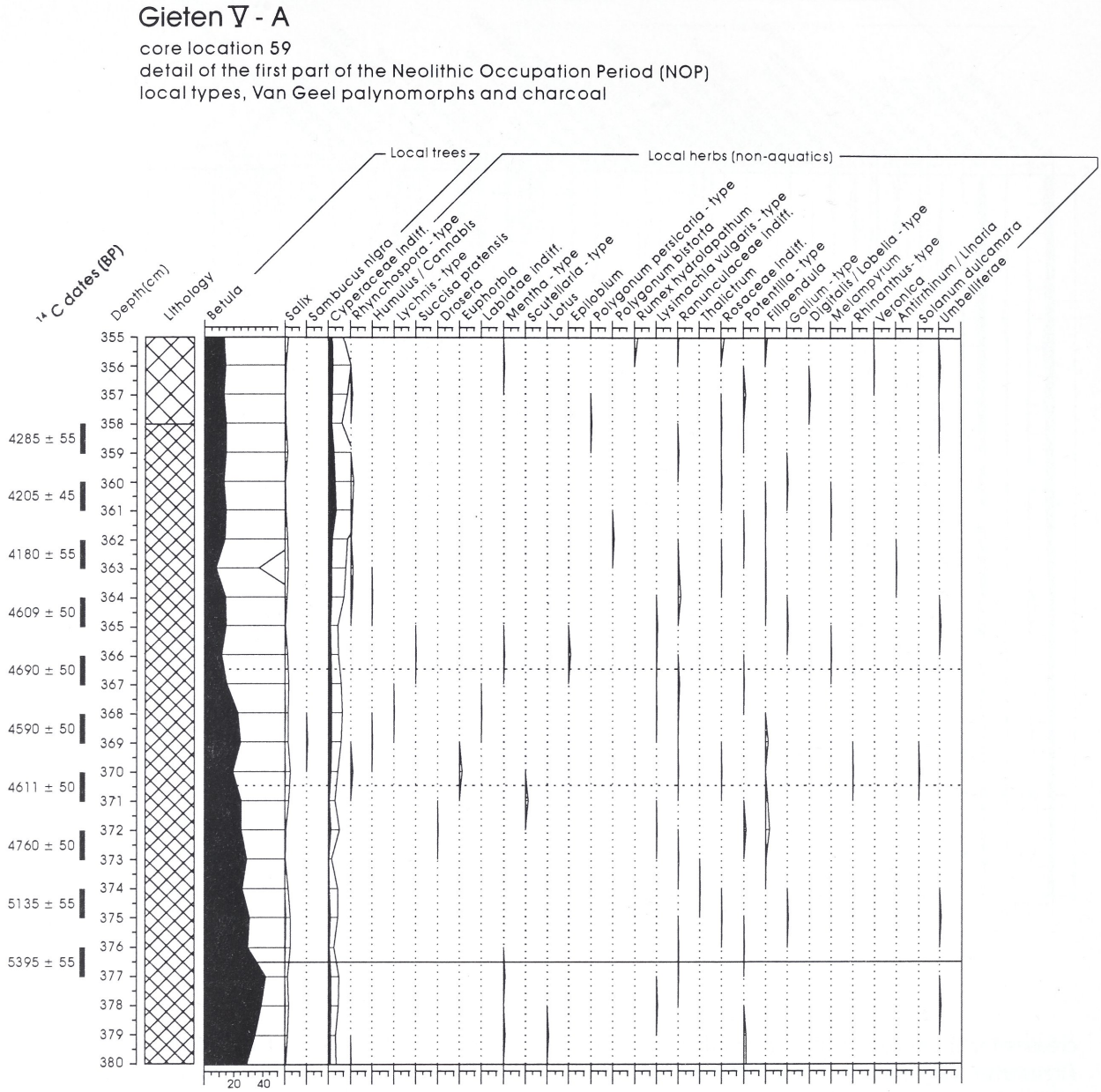


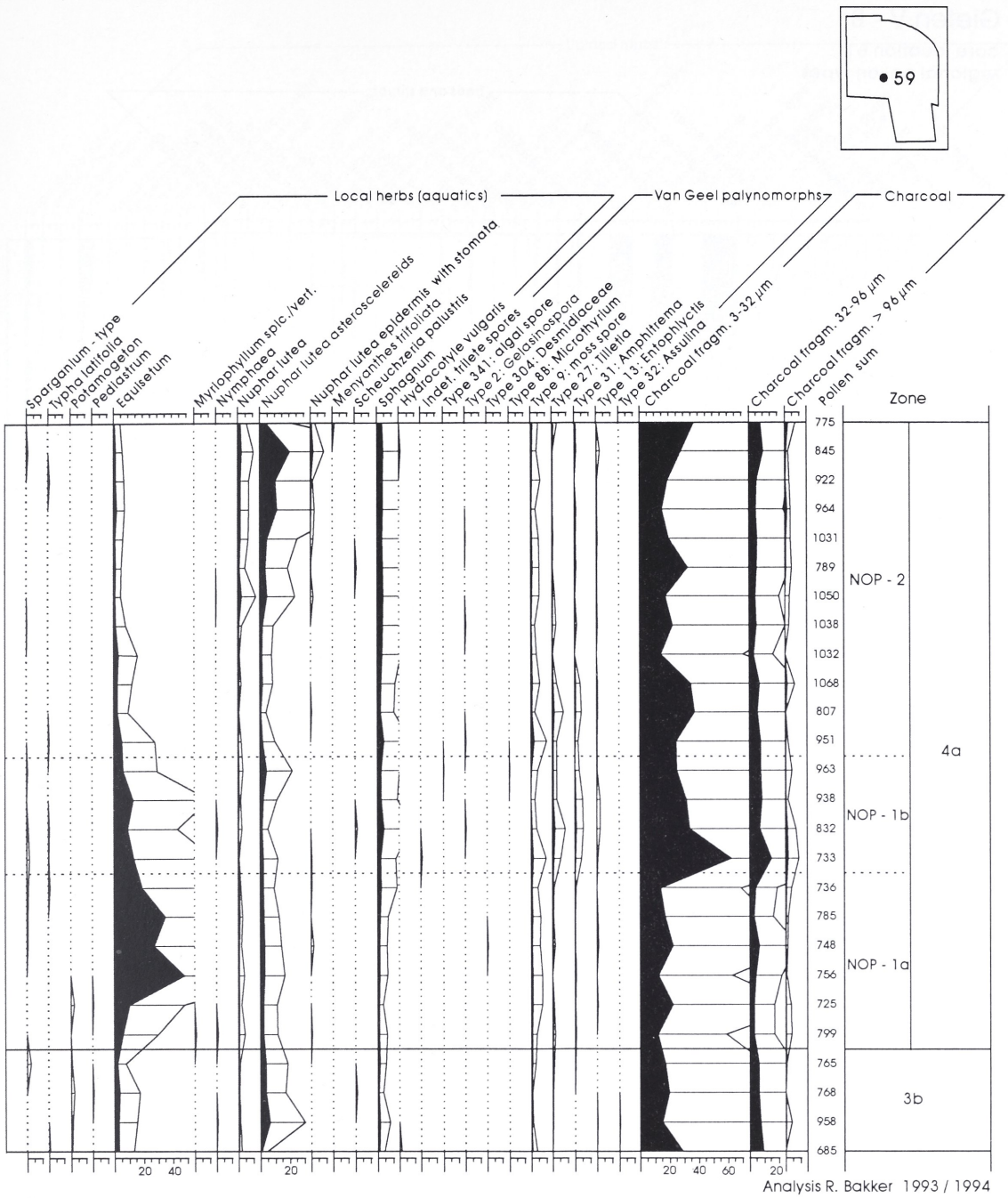
Fig. 57 (continued).

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-

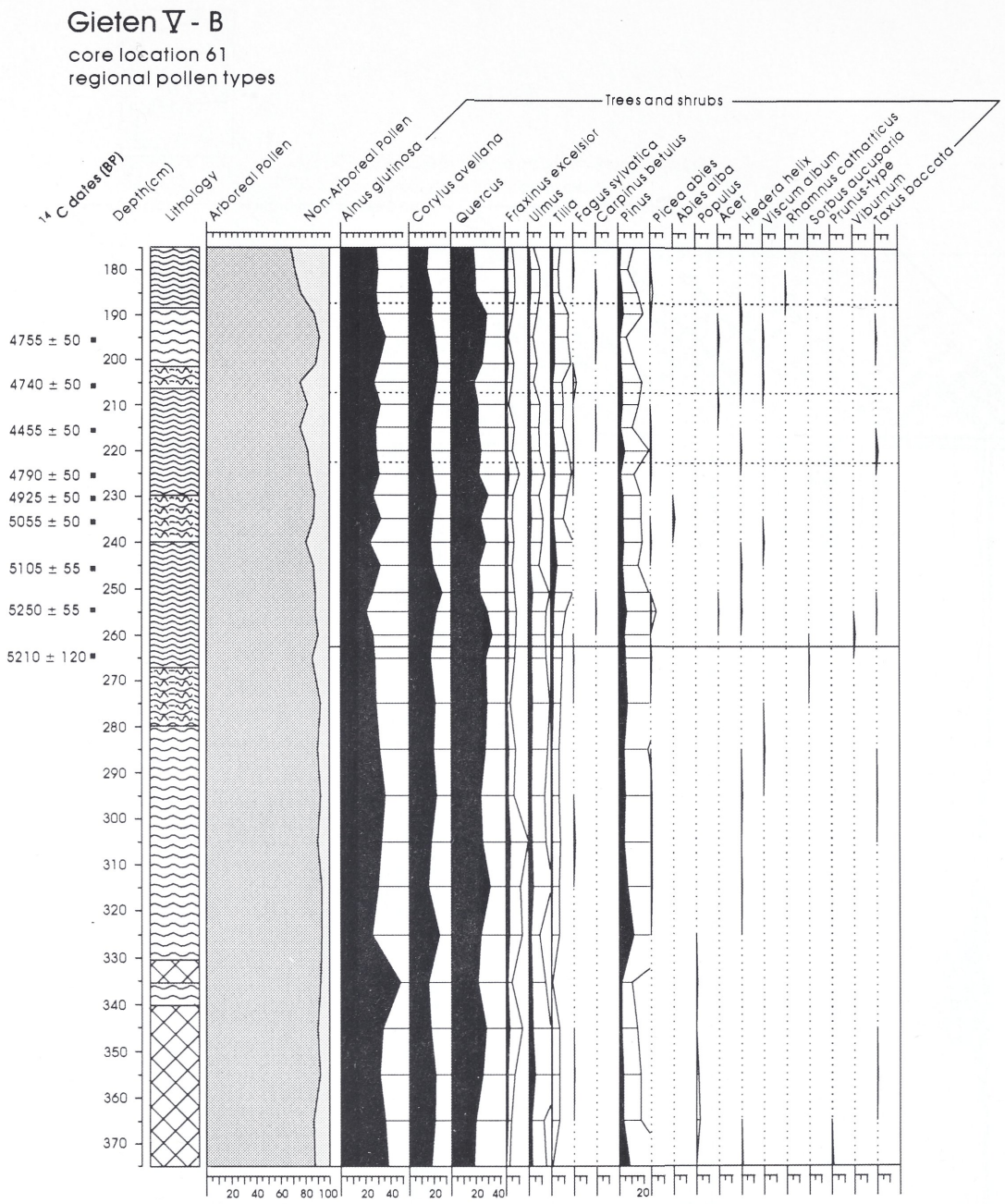


Fig. 58. Pollen diagram of sequence Gieten V-B.

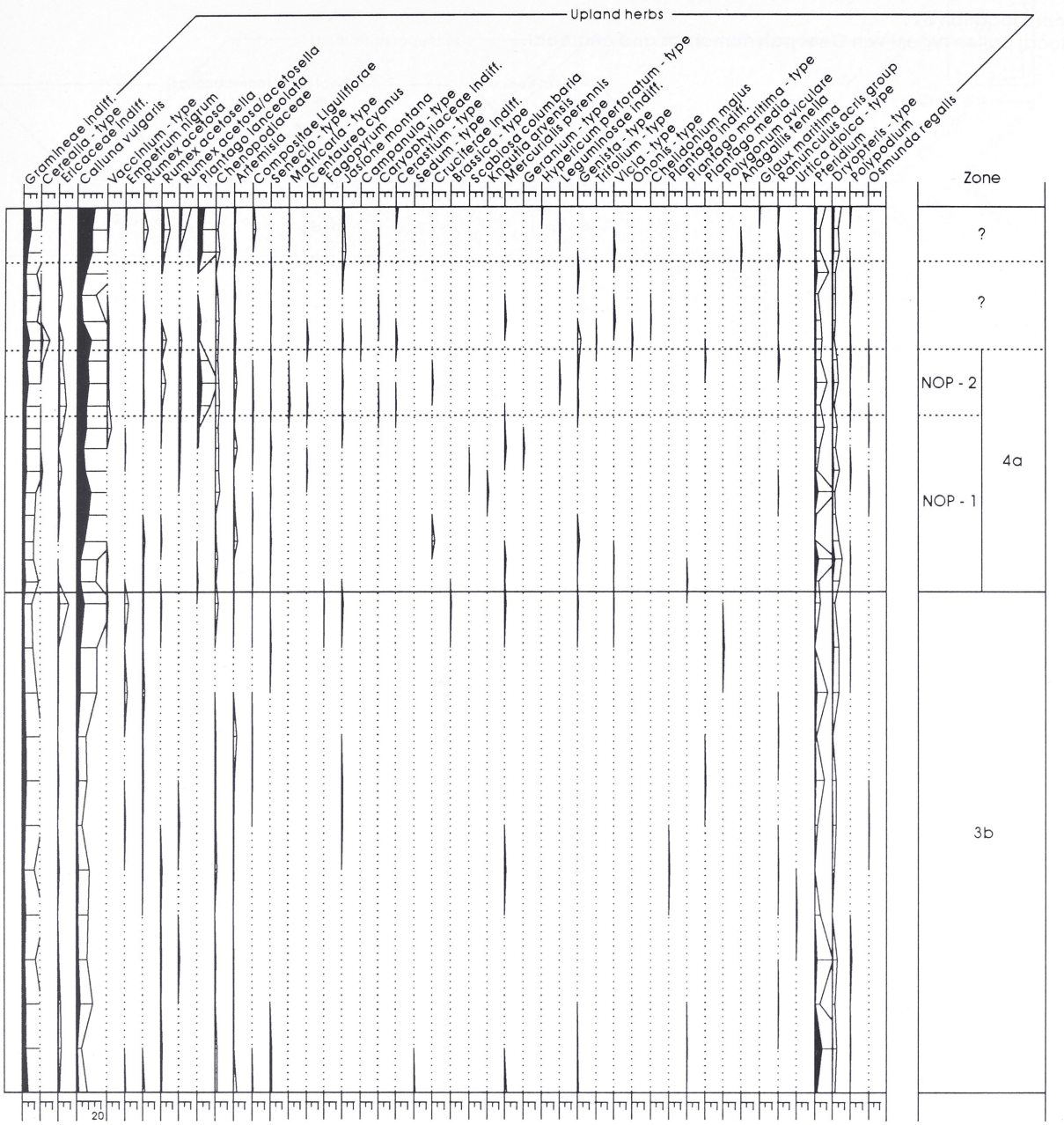
trum of 100 cm. Unidentified small *Rumex* pollen grains, united in *Rumex acetosa/acetosella*, and *Plantago lanceolata* increase from 90 cm upwards. From this depth upwards, an attempt has been made to separate *Rumex acetosa* and *Rumex acetosella*. Between 90 and 50 cm, they seem to occur more or 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

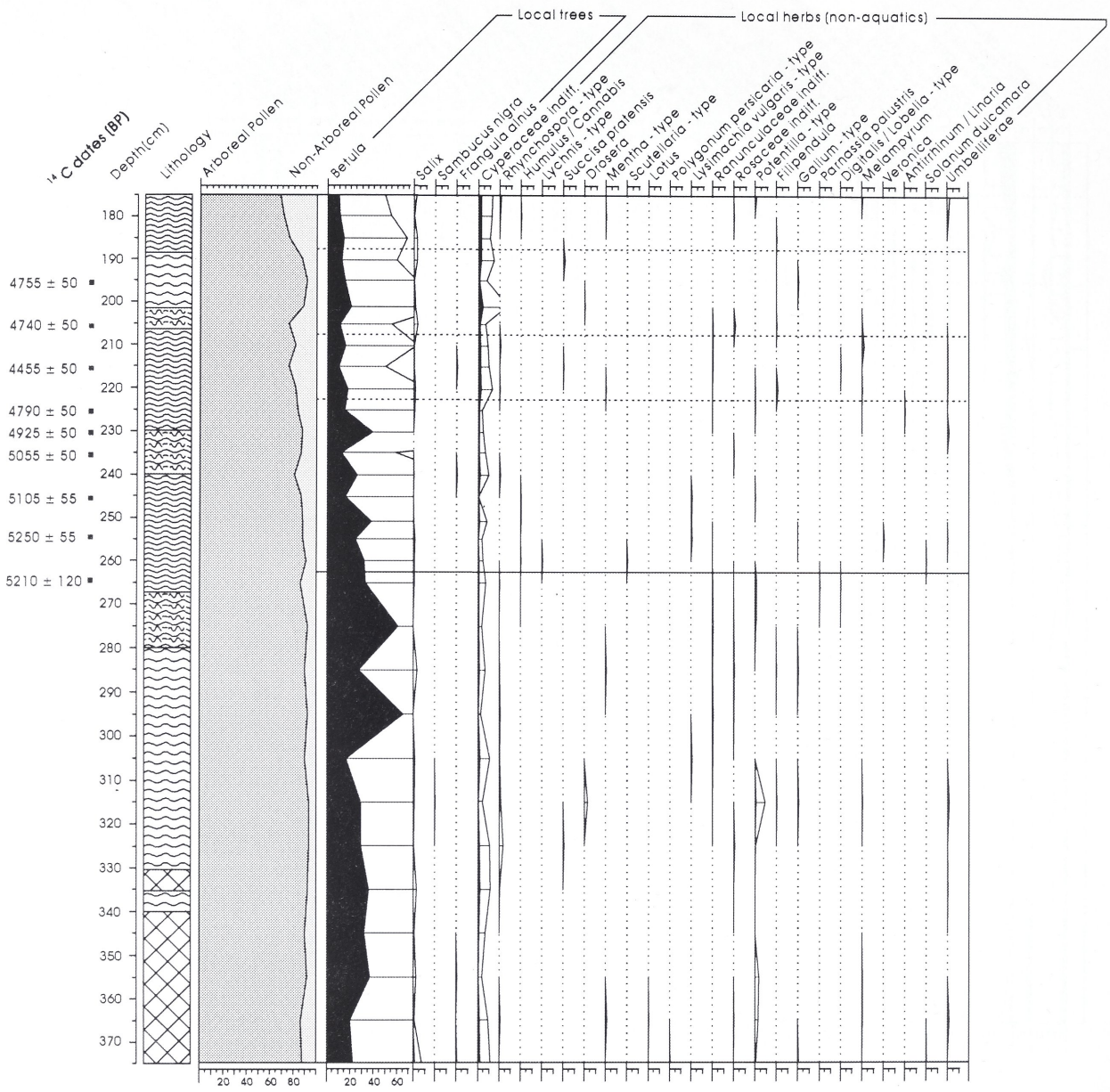


Fig. 58 (continued).

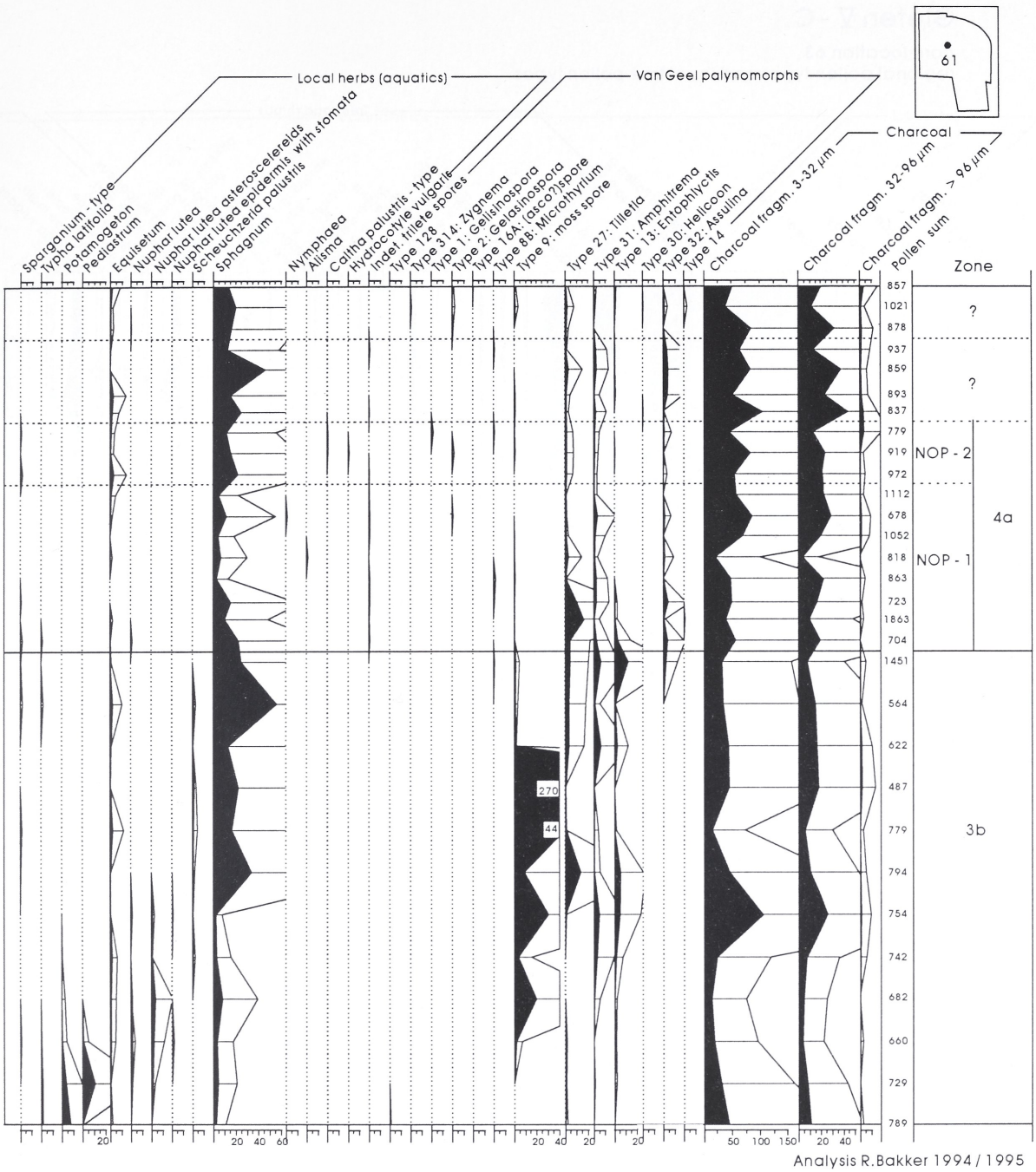
NAP (except Gramineae indiff.) a zone boundary is located between 10 and 5 cm. The zone between 64.5 and 7.5 cm is called the Gramineae-Cerealia-Ericaceae zone, local zone 5b.

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.

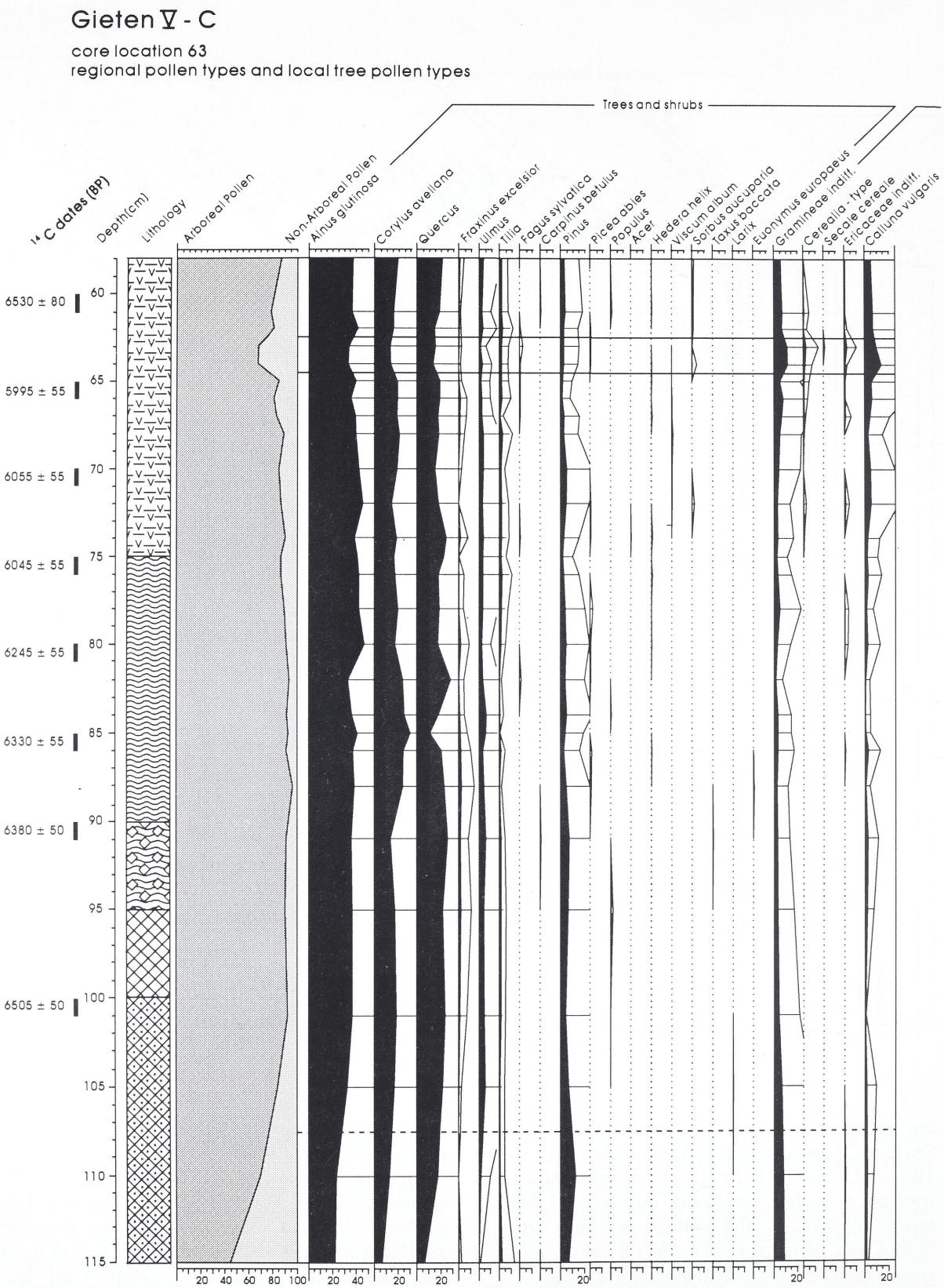
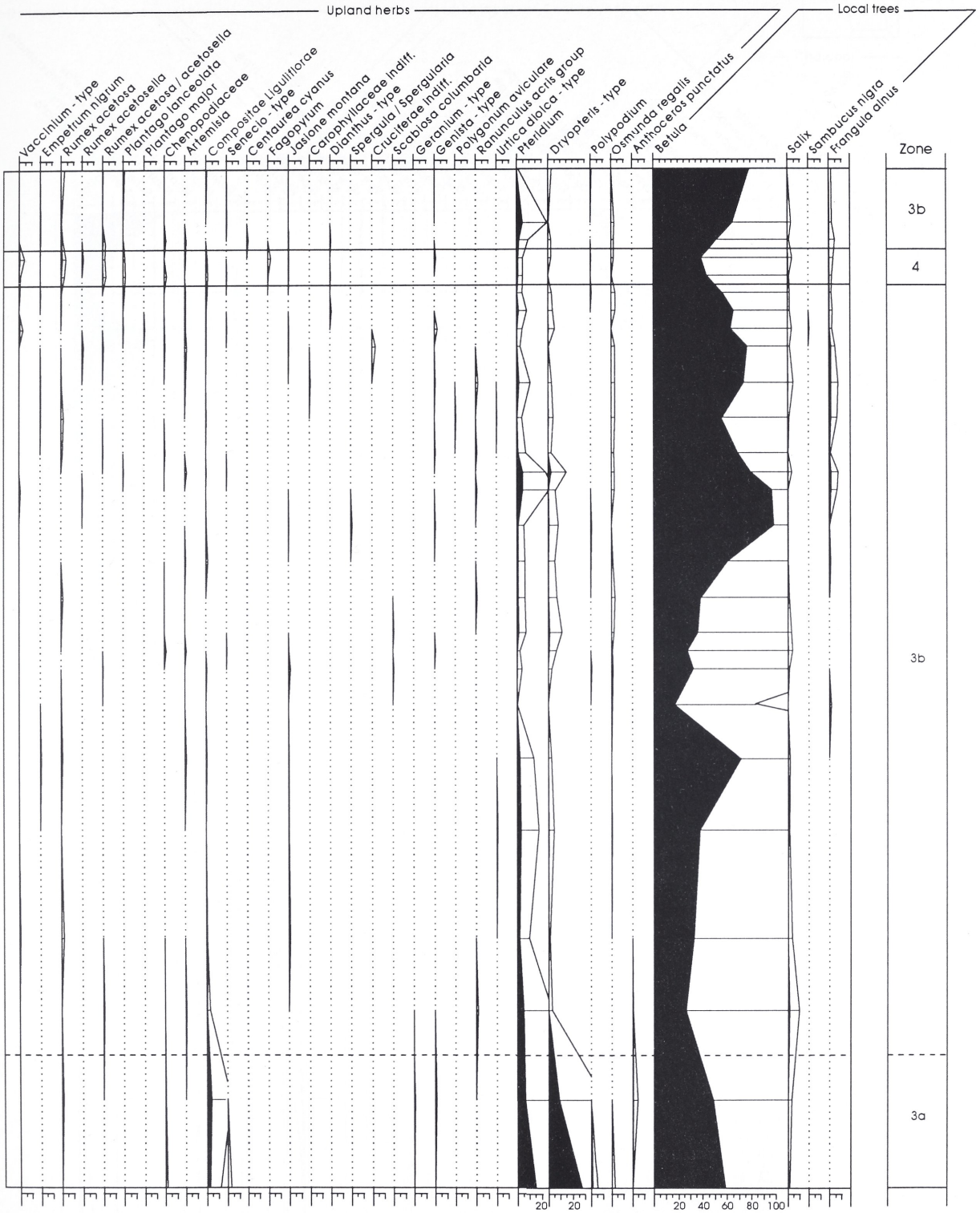


Fig. 59. Pollen diagram of sequence Gieten V-C.


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
Caryophyllaceae 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

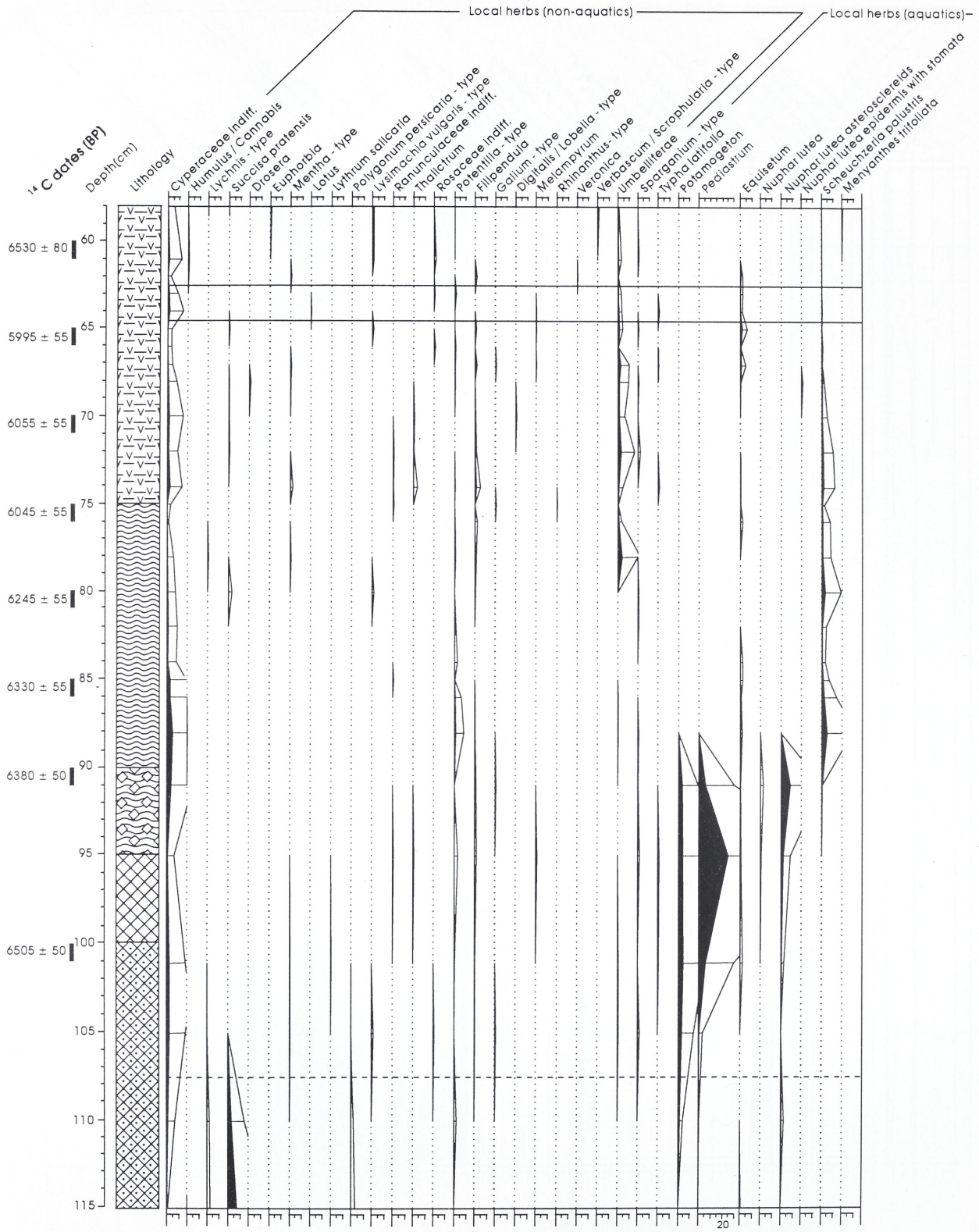
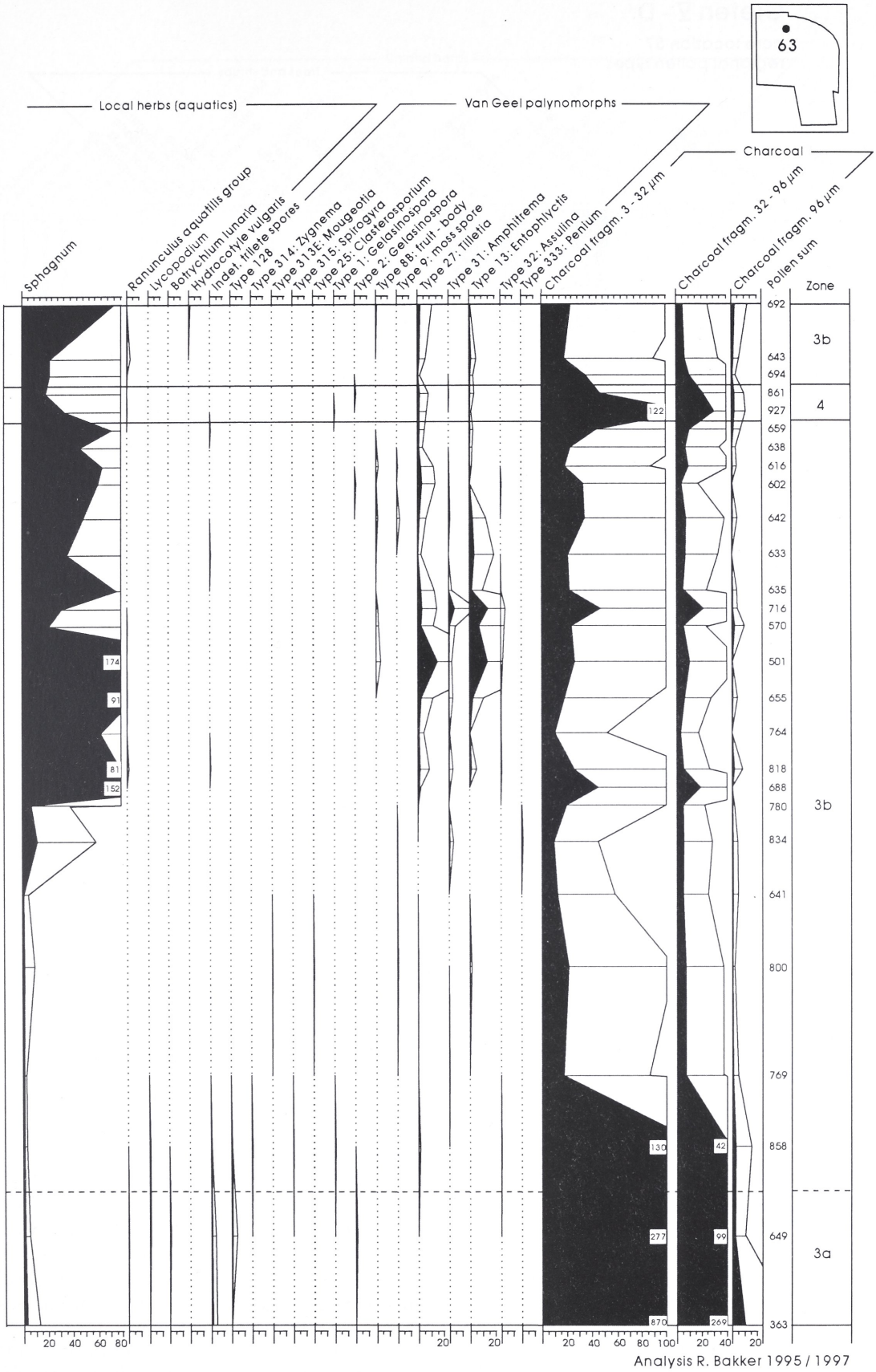


Fig. 59 (continued).


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; Cl.asterosporium
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
9
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

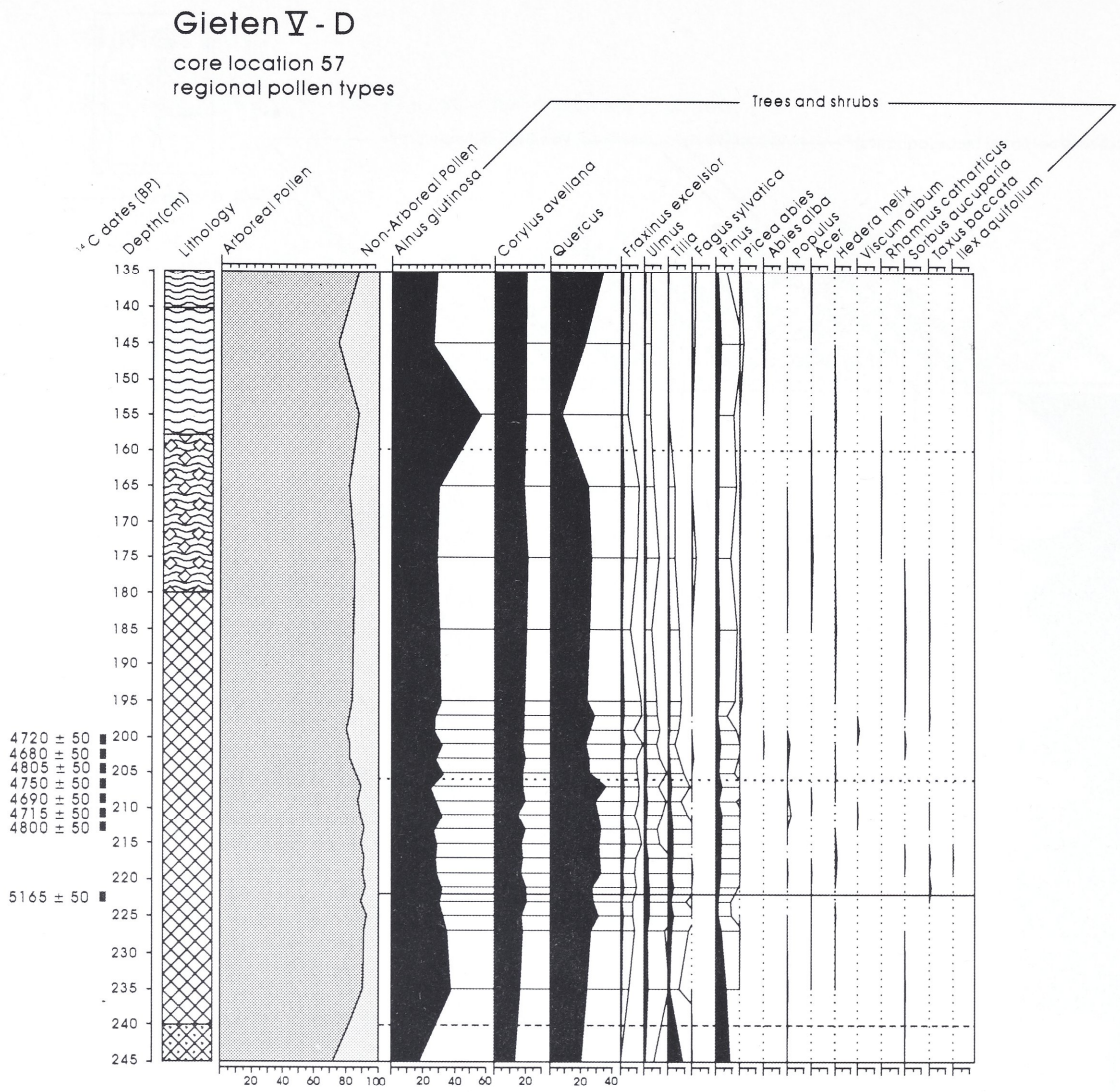
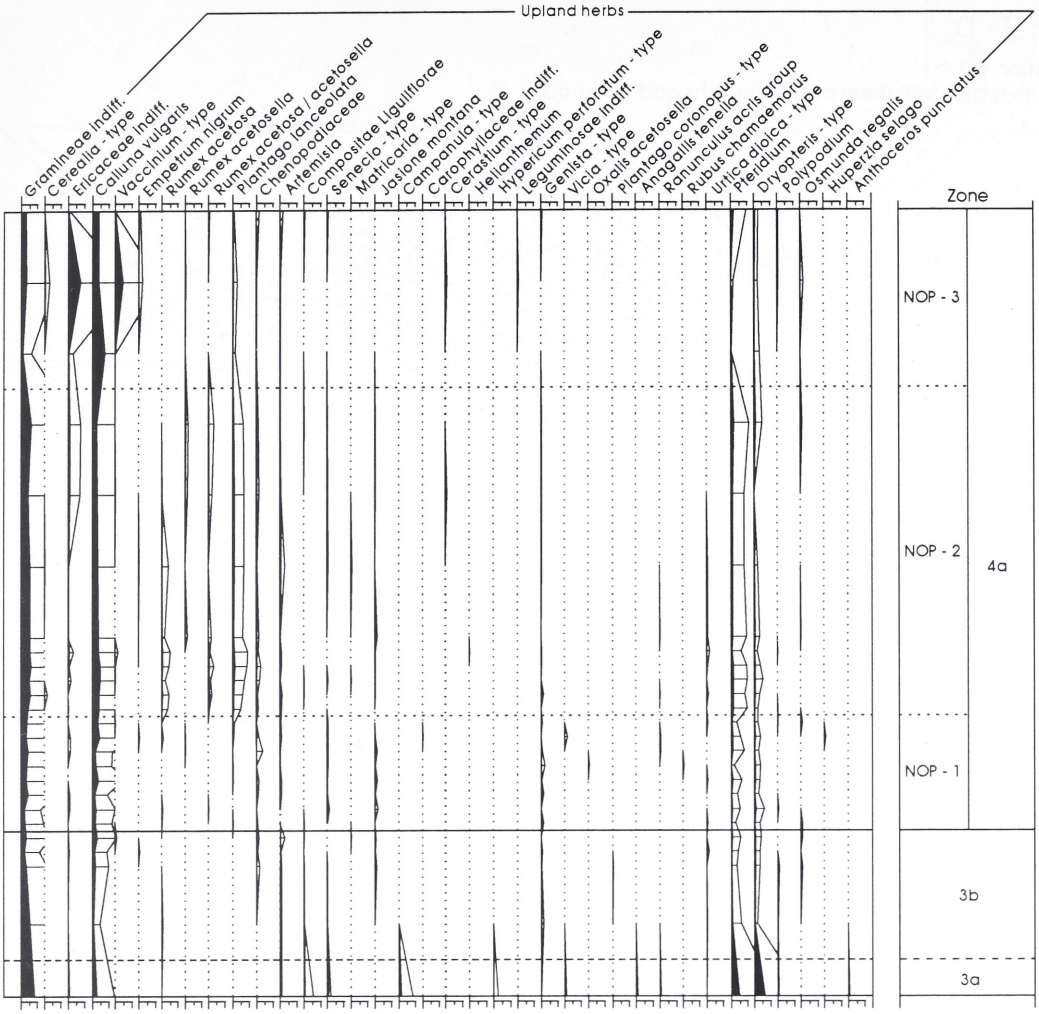


Fig. 60. Pollen diagram of sequence Gieten V-D.

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.

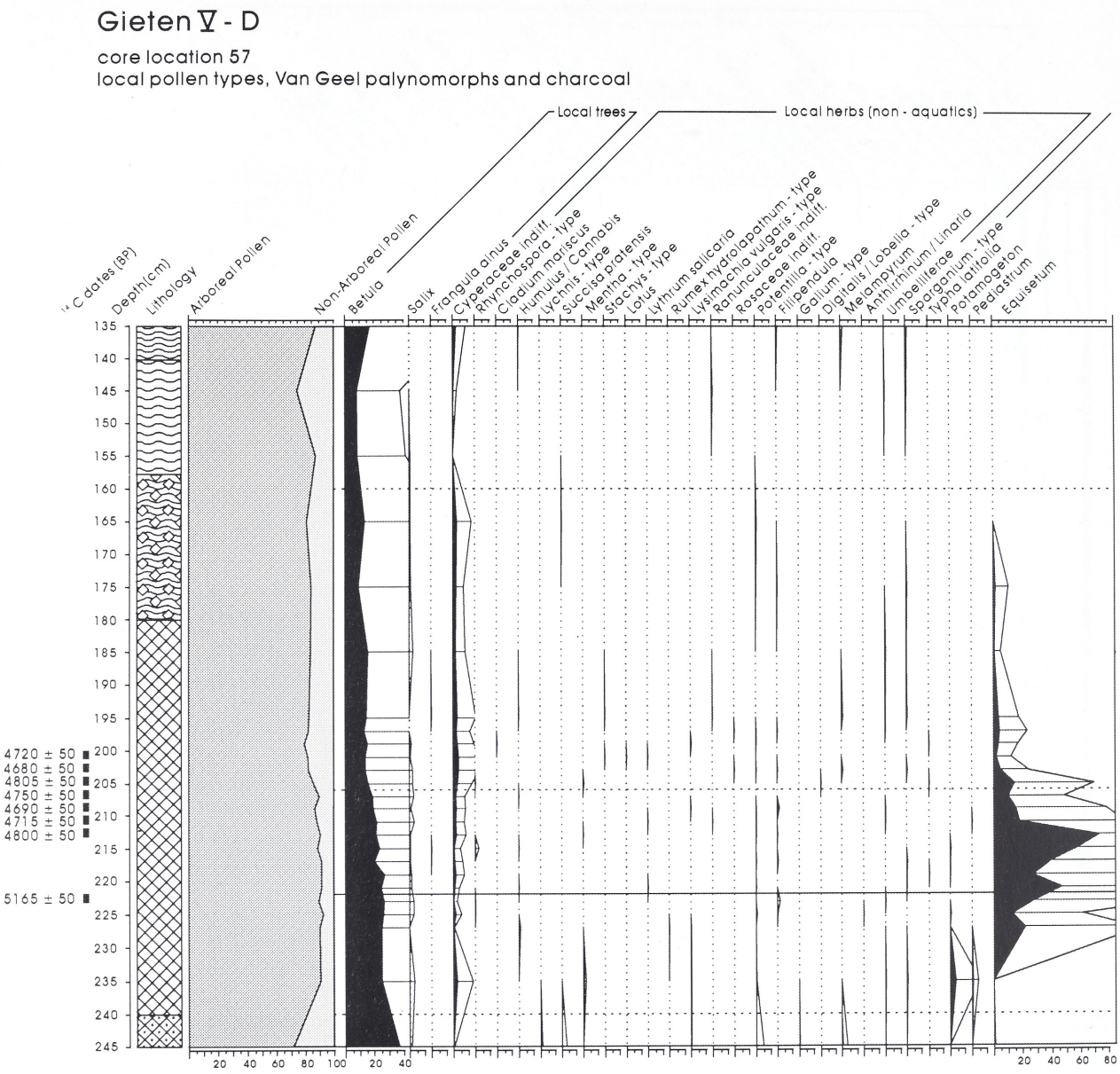
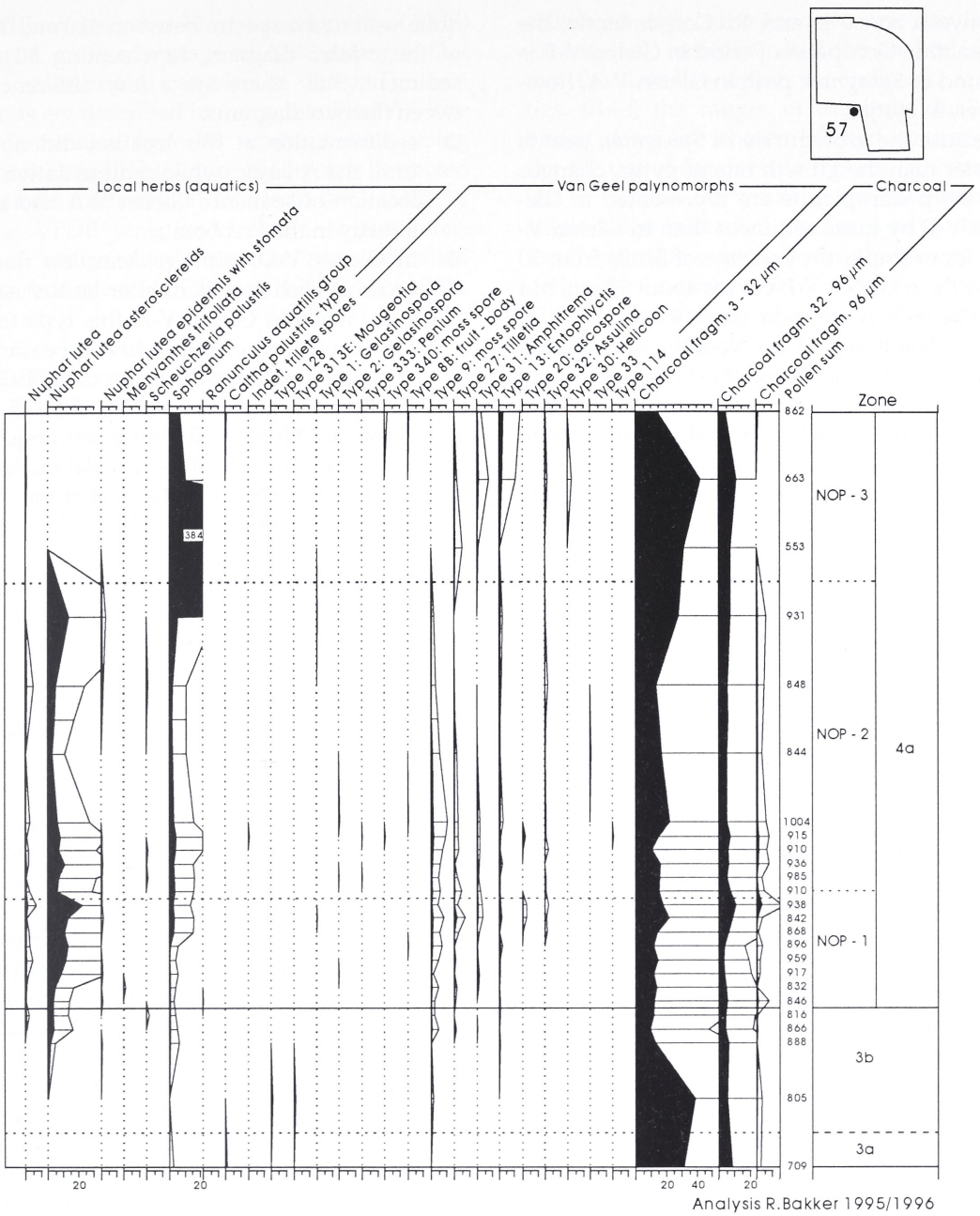


Fig. 60 (continued).

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	Uncalibrated 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

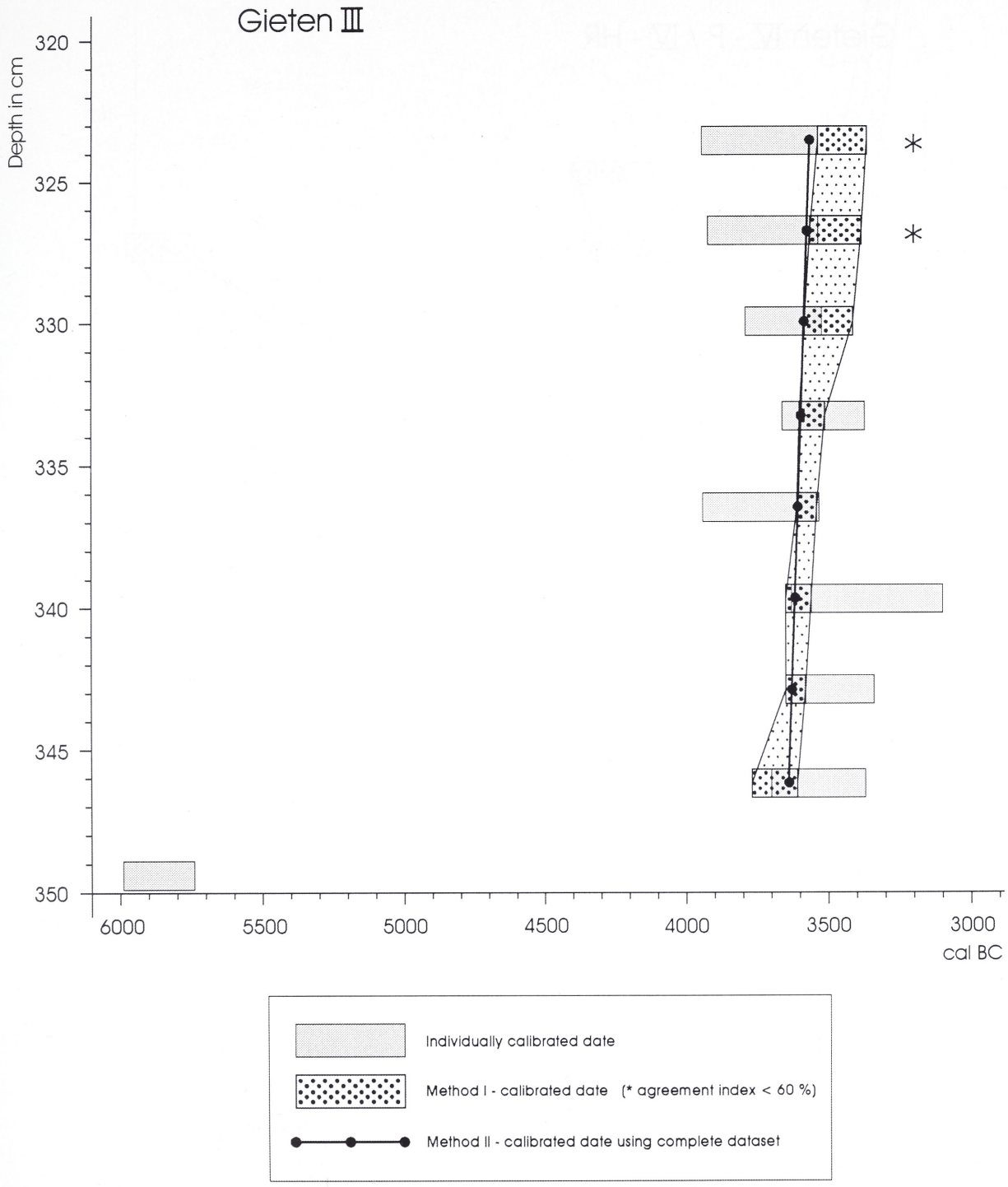

Gieten III
Depth in cm
320
325
330
335
340
345
350
6000
5500
5000
4500
4000
3500
3000
cal BC
*
*
Individually calibrated date
Method I - calibrated date (* agreement index < 60 %)
Method II - calibrated date using complete dataset

Fig. 61a.

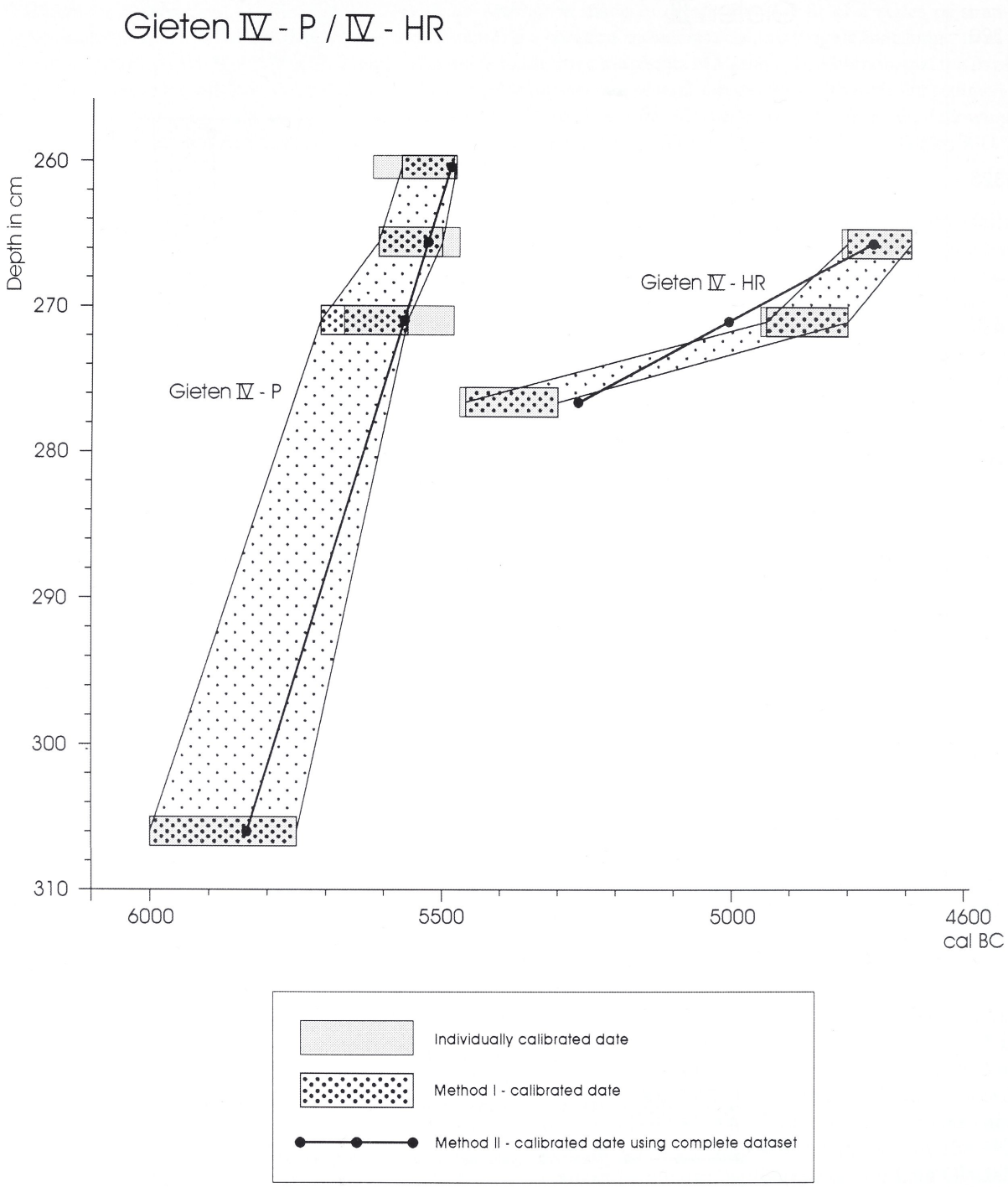

Gieten Ⅳ - P / Ⅳ - HR
Depth in cm
260
270
280
290
300
310
Gieten Ⅳ - P
Gieten Ⅳ - HR
6000
5500
5000
4600
cal BC
Individually calibrated date
Method I - calibrated date
Method II - calibrated date using complete dataset

Fig. 61b.

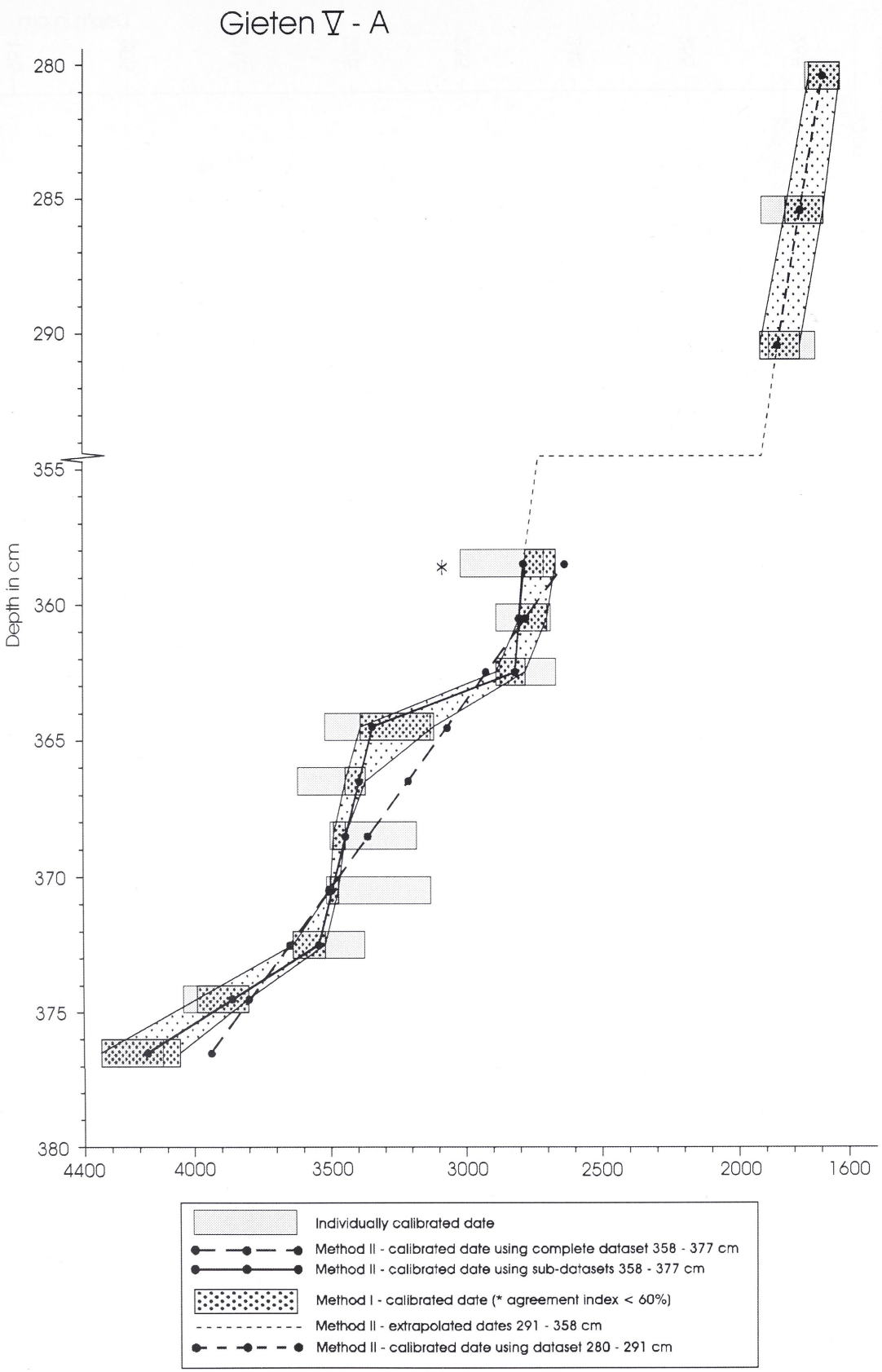

Gieten ∇ - A
Depth in cm
280
285
290
355
360
365
370
375
380
4400
4000
3500
3000
2500
2000
1600
*
Individually calibrated date
Method II - calibrated date using complete dataset 358 - 377 cm
Method II - calibrated date using sub-datasets 358 - 377 cm
Method I - calibrated date (* agreement index < 60%)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

Fig. 61c.

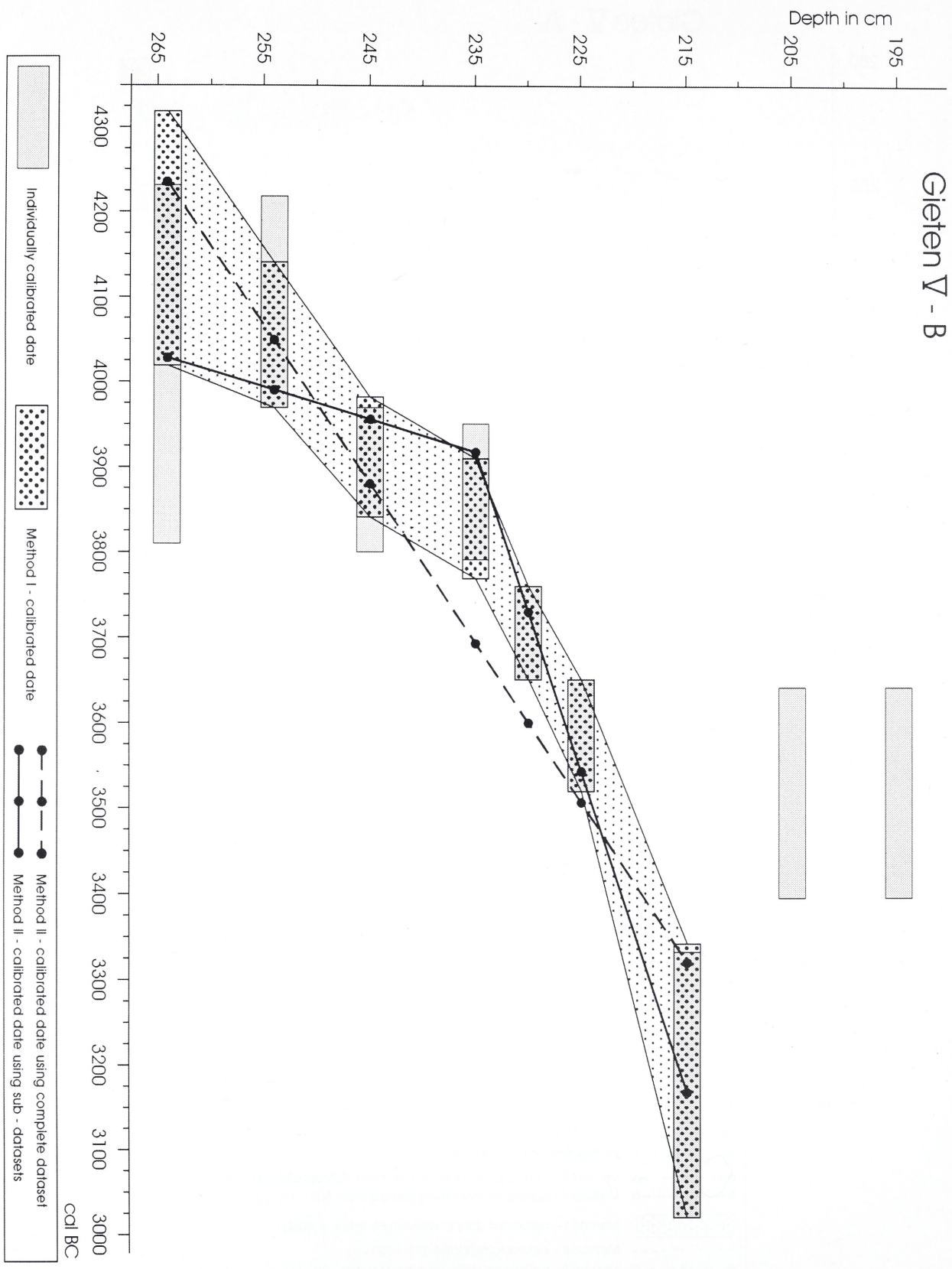

Gieten V - B
Depth in cm
195
205
215
225
235
245
255
265
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
cal BC
Individually calibrated date
Method I - calibrated date
Method II - calibrated date using complete dataset
Method II - calibrated date using sub - datasets

Fig. 61d.

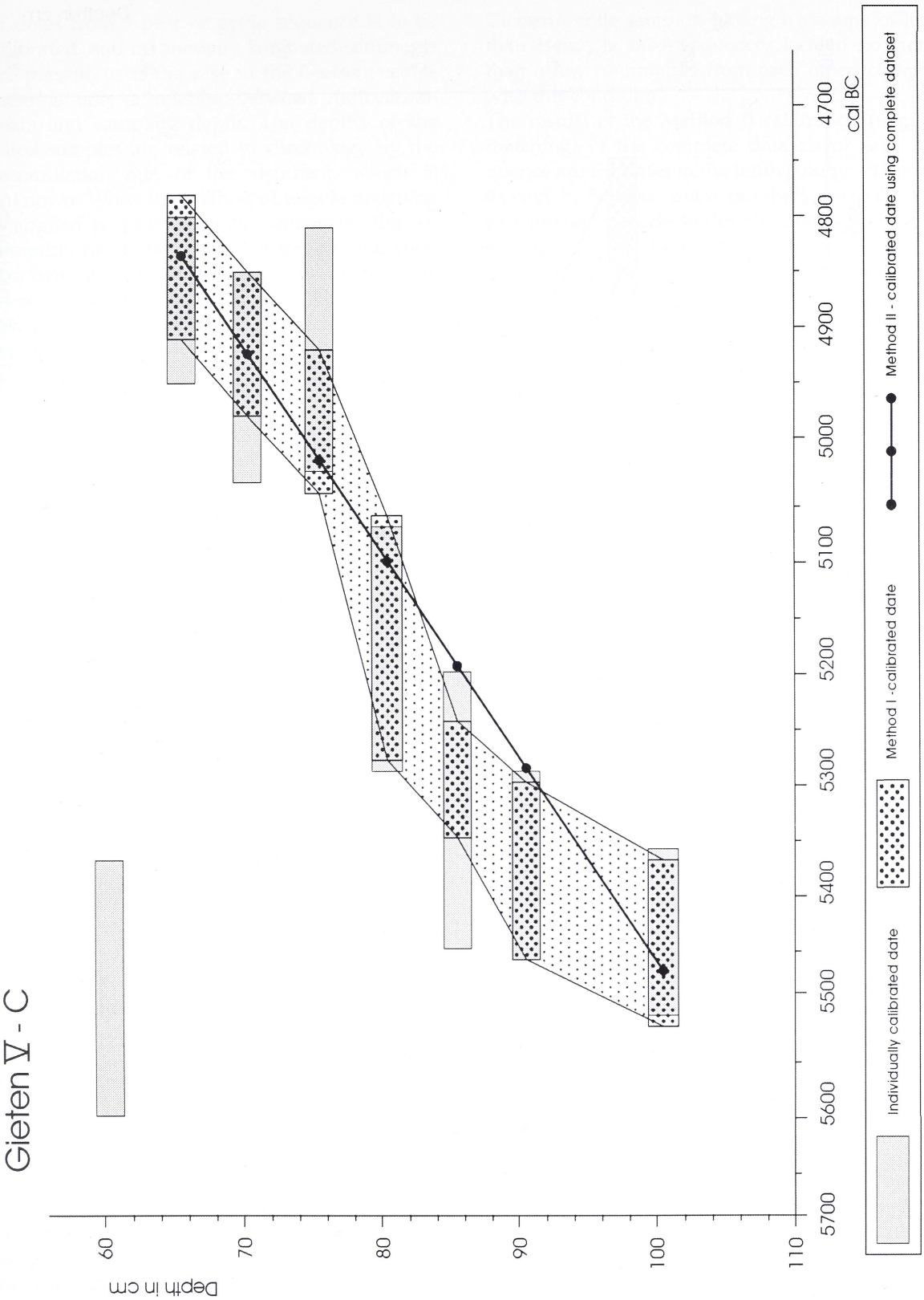

Gieten V - C
Depth in cm
60
70
80
90
100
110
5700
5600
5500
5400
5300
5200
5100
5000
4900
4800
4700
cal BC
Individually calibrated date
Method I -calibrated date
Method II - calibrated date using complete dataset

Fig. 61e.

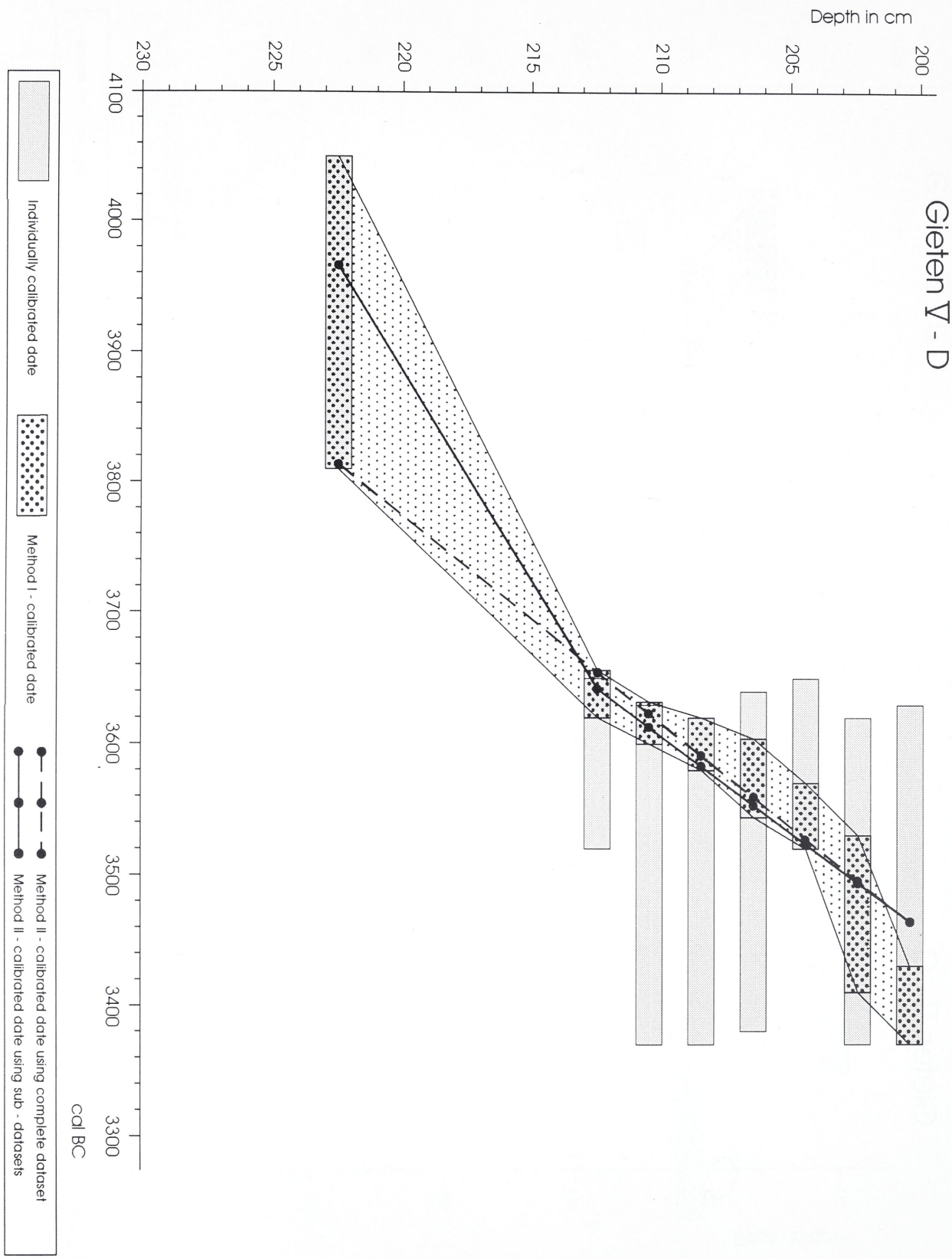

Gieten V - D
Depth in cm
200
205
210
215
220
225
230
4100
4000
3900
3800
3700
3600
3500
3400
3300
cal BC
Individually calibrated date
Method I - calibrated date
Method II - calibrated date using complete dataset
Method II - calibrated date using sub - datasets

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

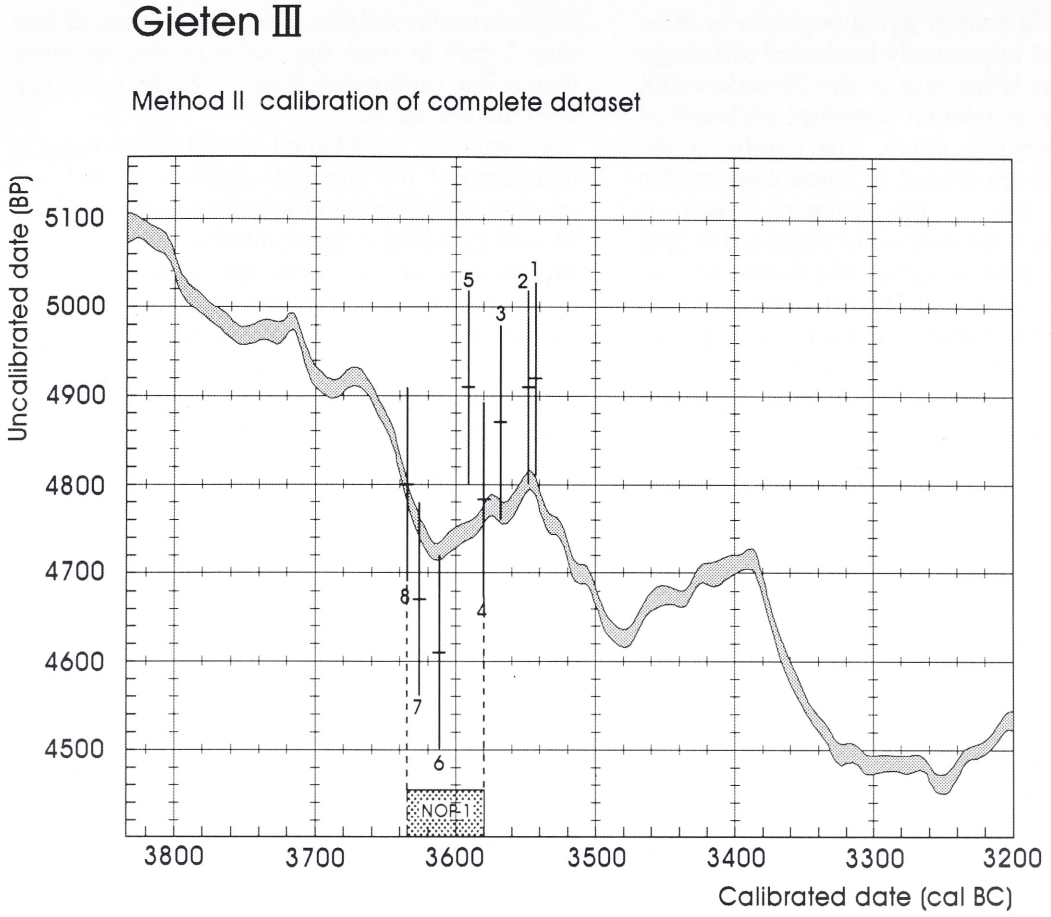


Fig. 62a.

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

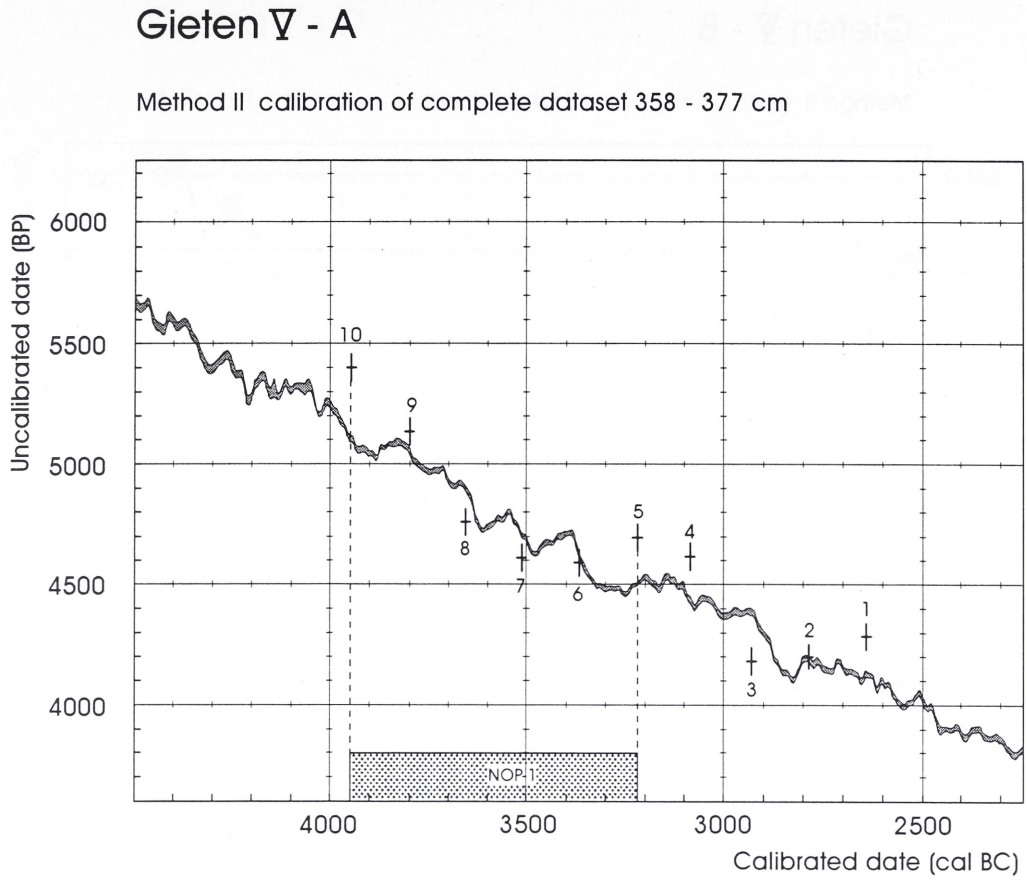


Fig. 62b.

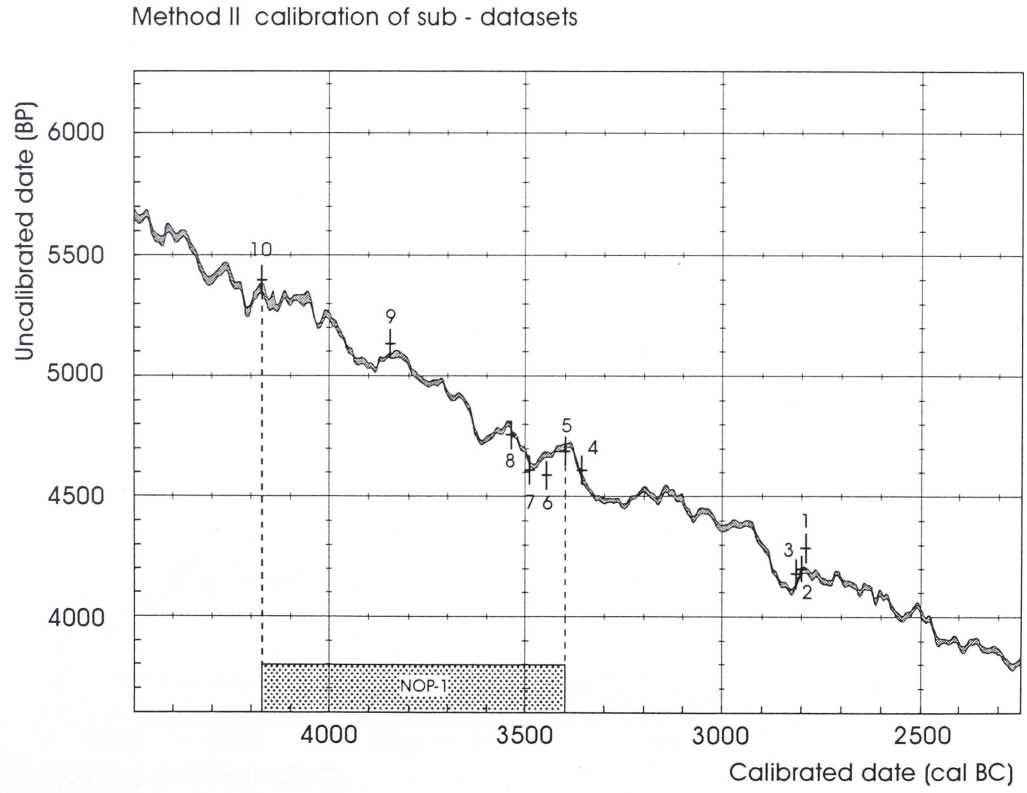


Fig. 62c.

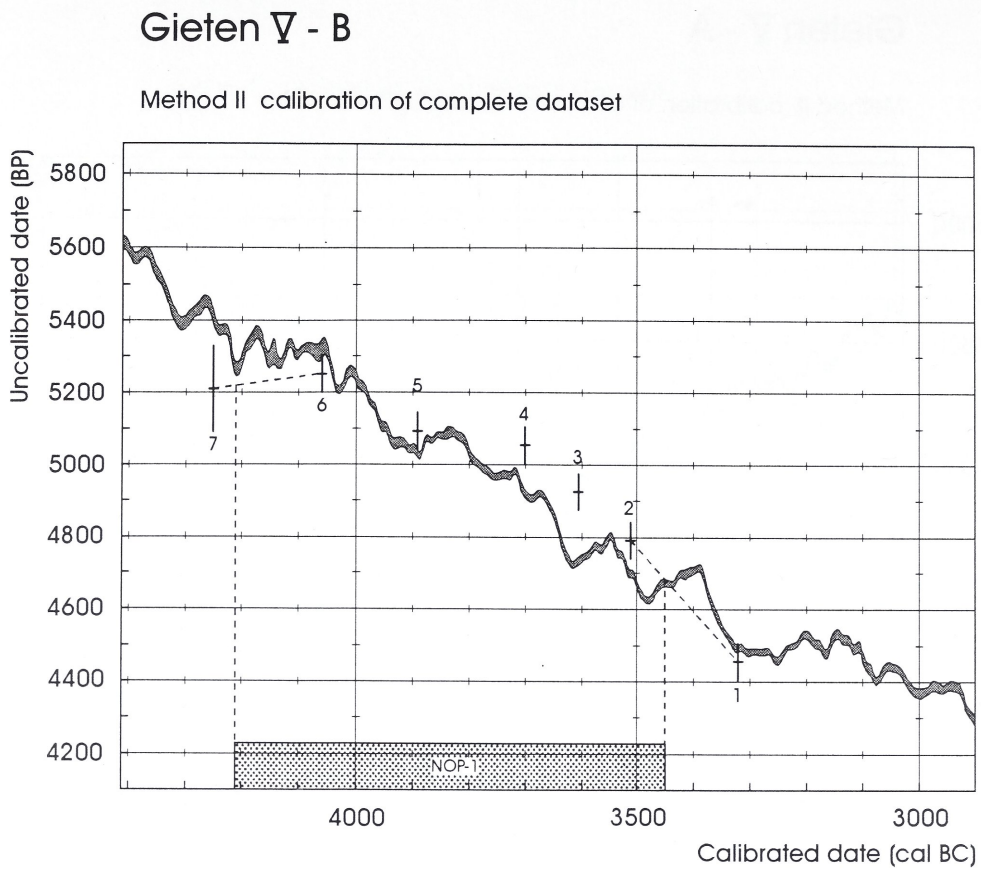


Fig. 62d.

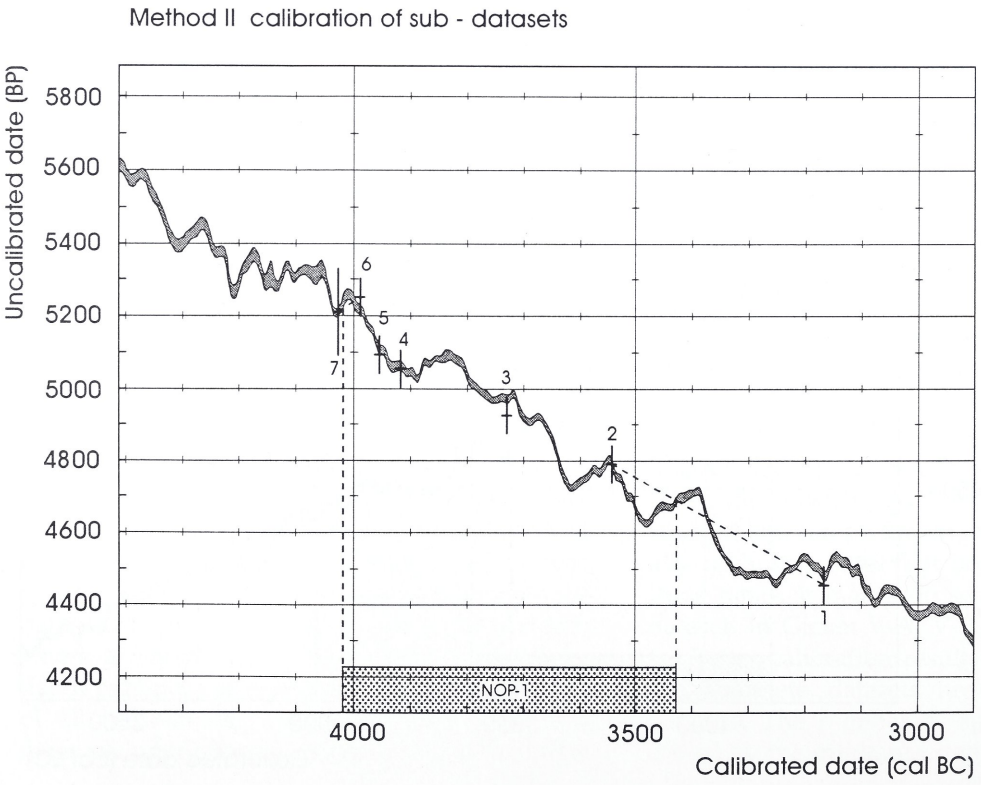


Fig. 62e.

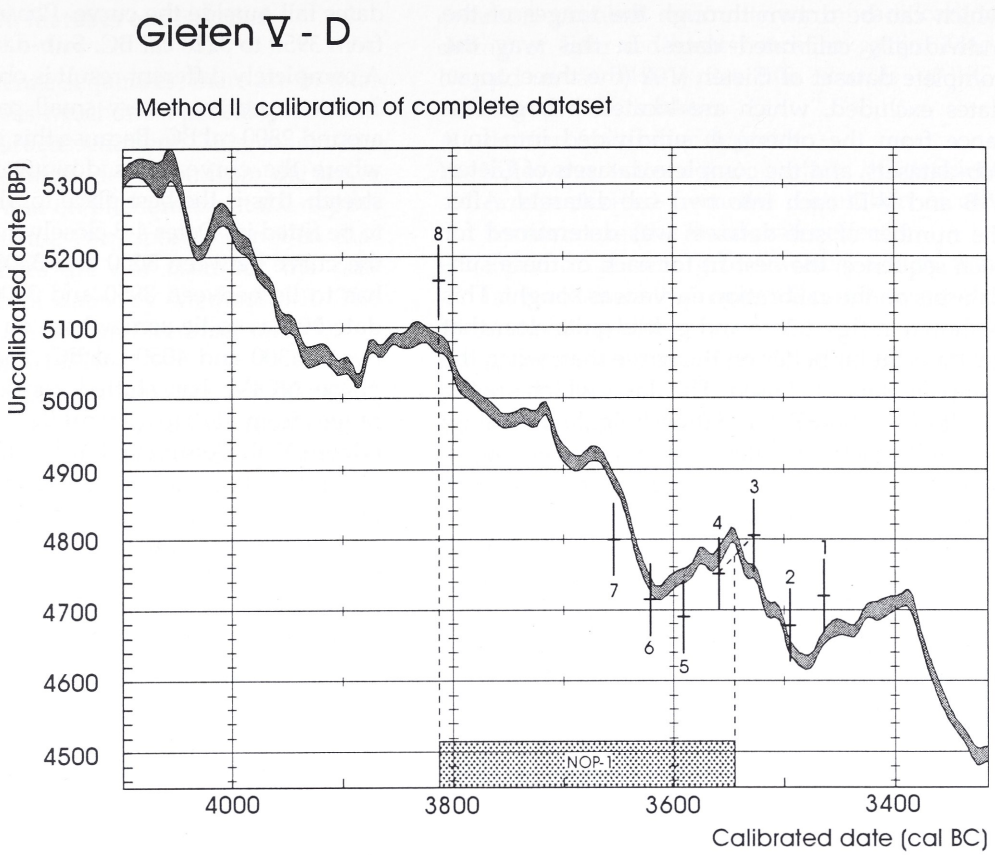


Fig. 62f.

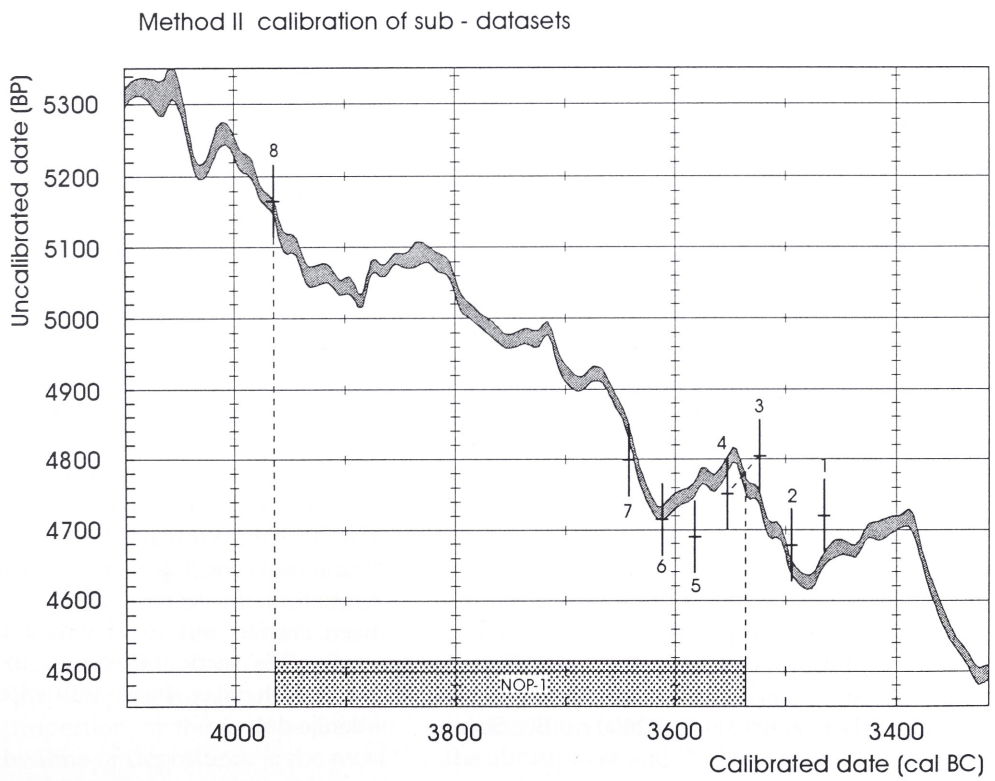


Fig. 62g.

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:

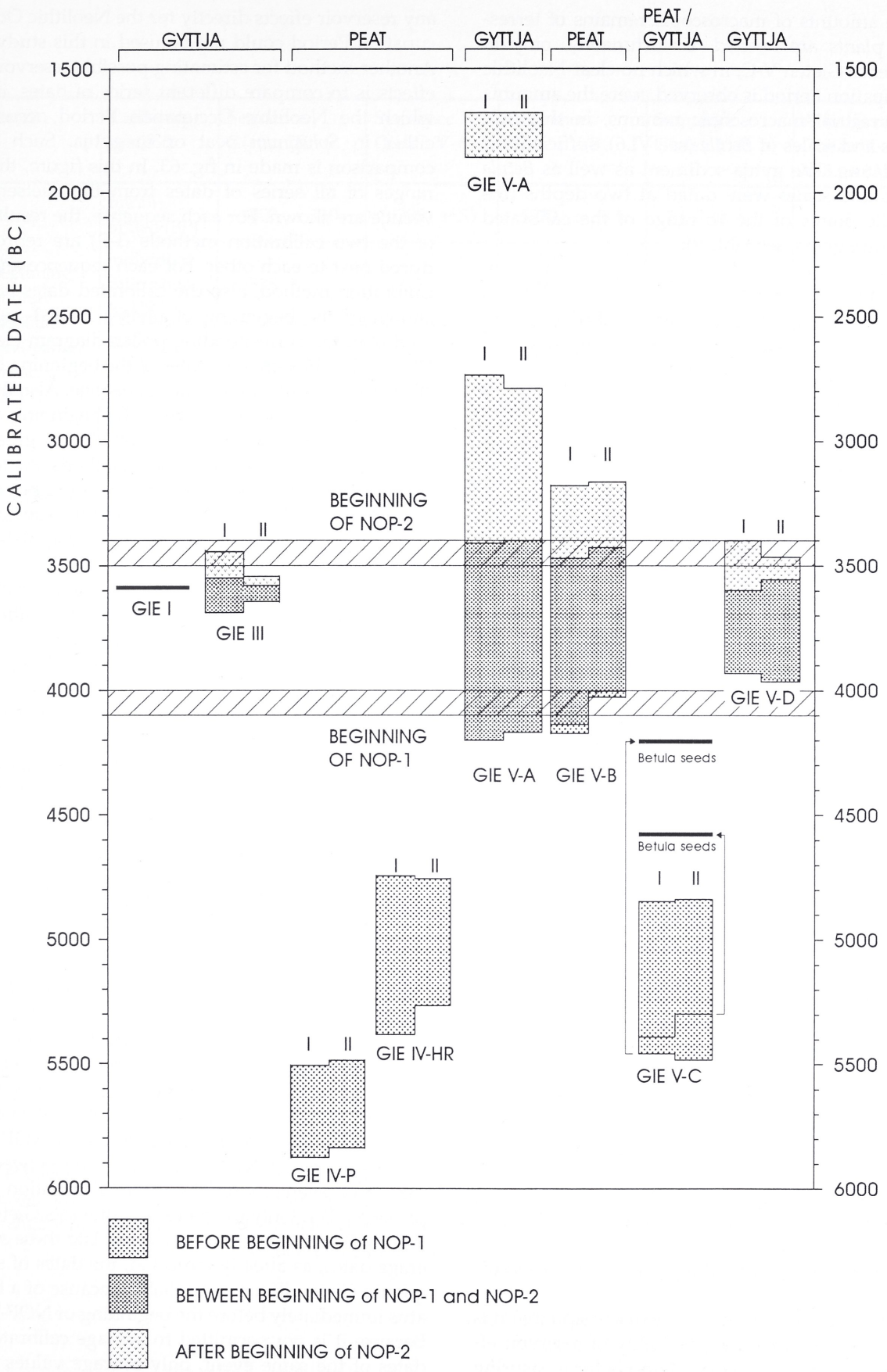
A. *detritus from older deposits*: the sediment could be contaminated with carbonates from a former warm period; this factor is of importance only near the bottom of the sequences, where also secondary pollen is found;
B. *inflowing waters that contain ^{14}C-deficient carbon derived from the dissolution 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
GIE I
GIE III
GIE V-D
BEGINNING OF NOP-1
GIE V-A
GIE V-B
Betula seeds
Betula seeds
GIE IV-HR
GIE V-C
GIE IV-P
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 sedi-

ment, 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 $cm^{-3} \times 10^5$)	Range of concentration (grains $cm^{-3} \times 10^5$)	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-

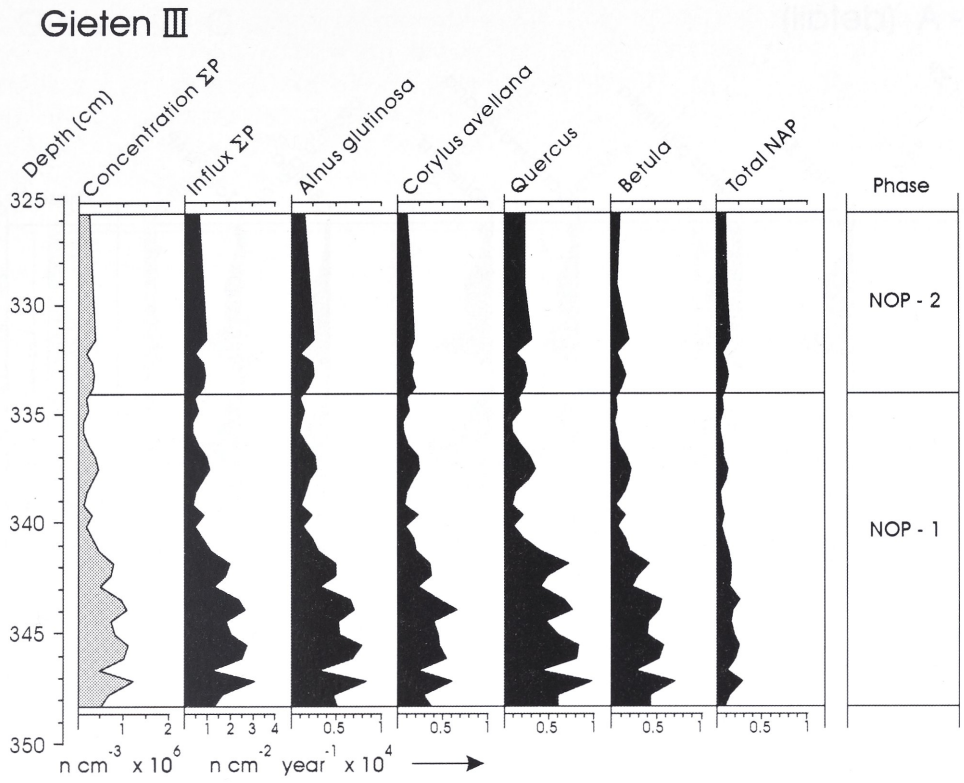


Fig. 64a.

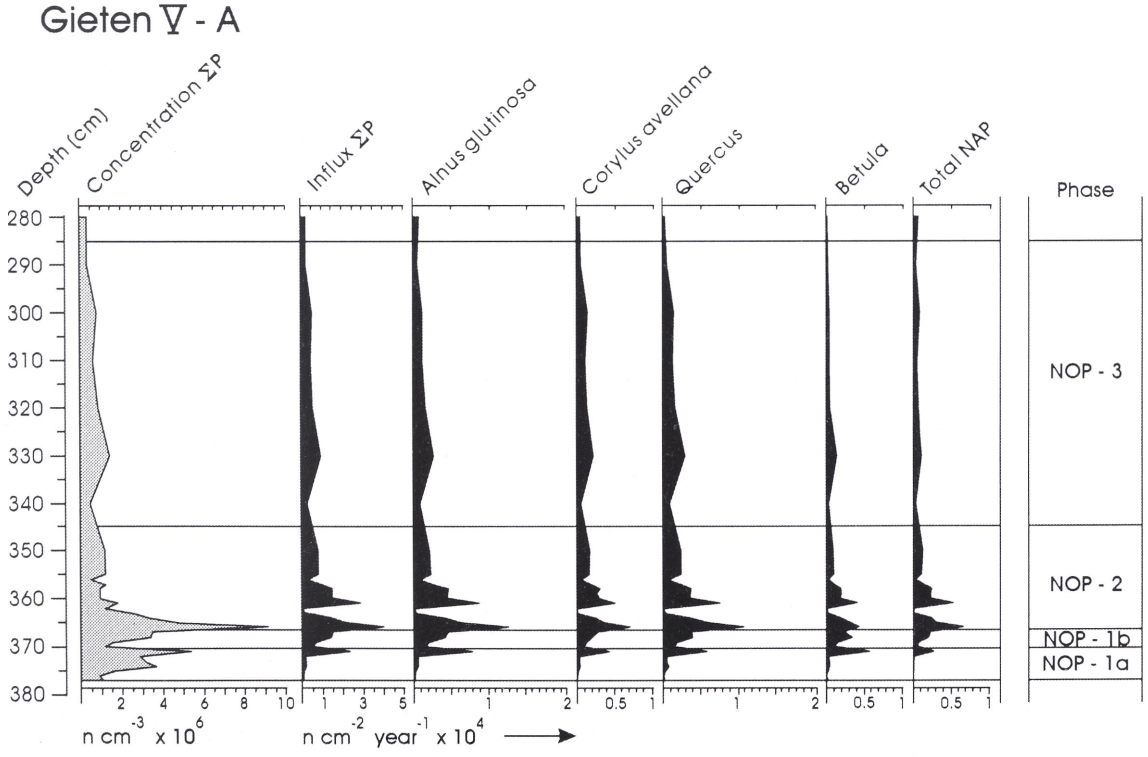


Fig. 64b.

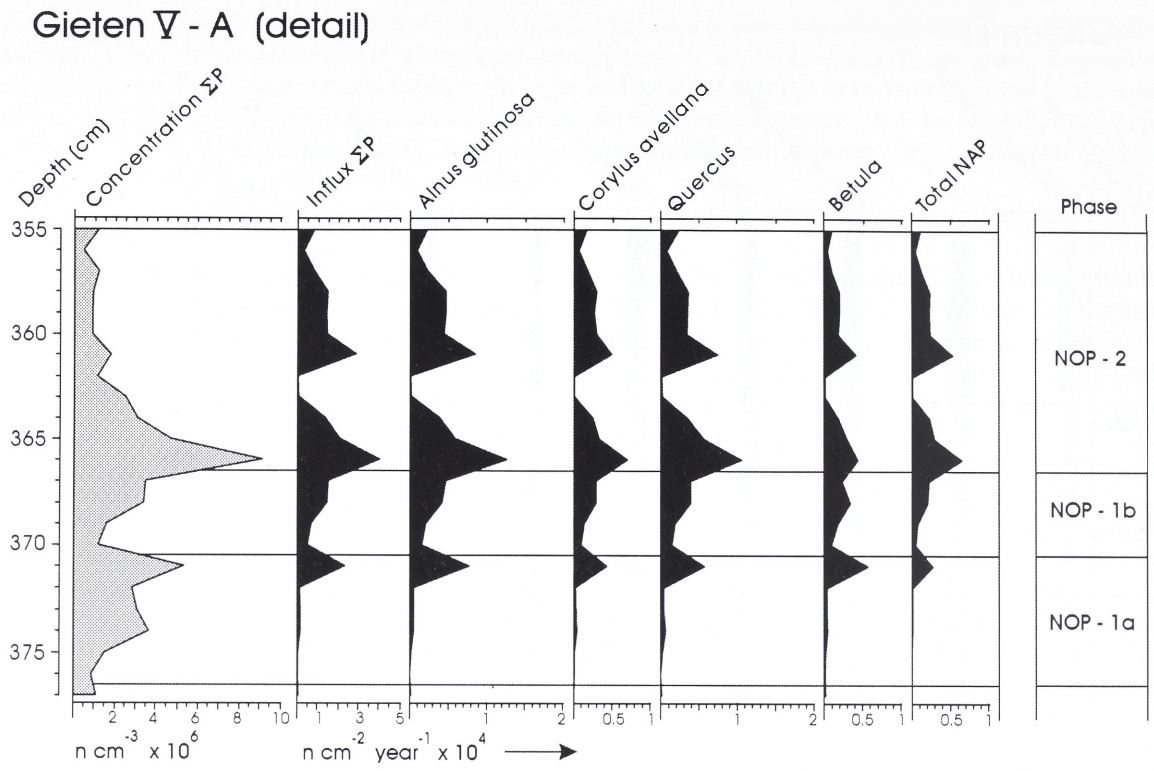


Fig. 64c.

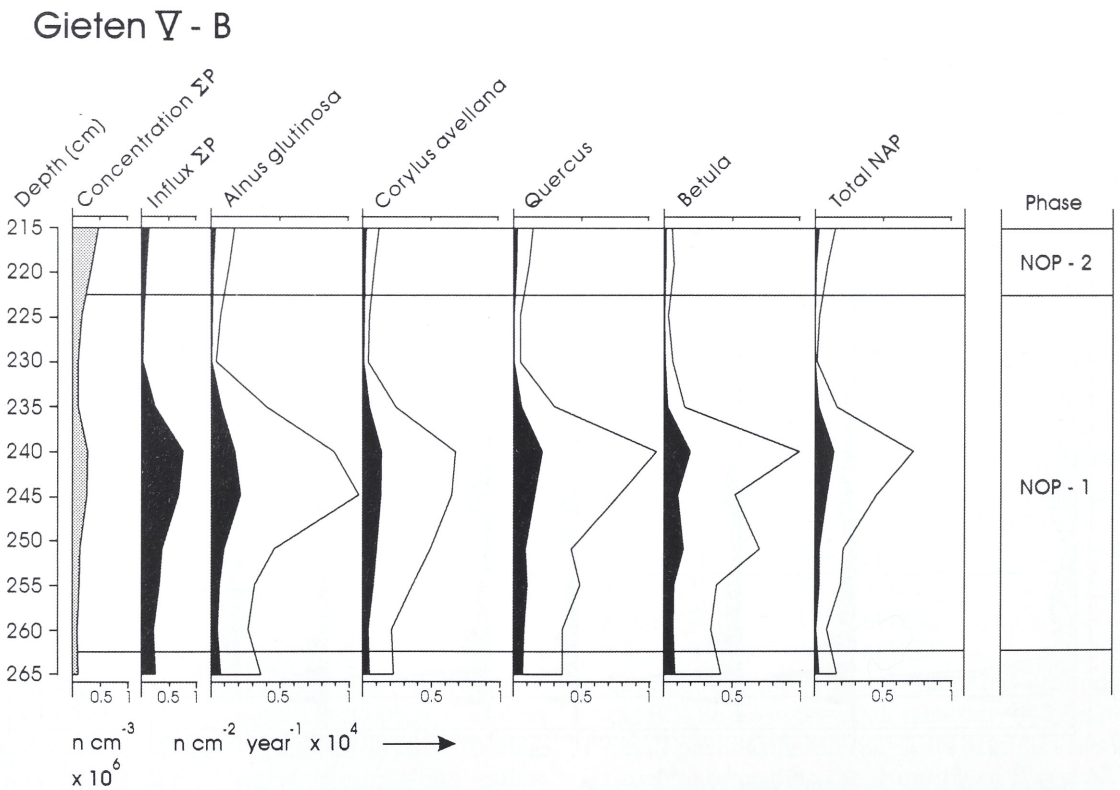


Fig. 64d.

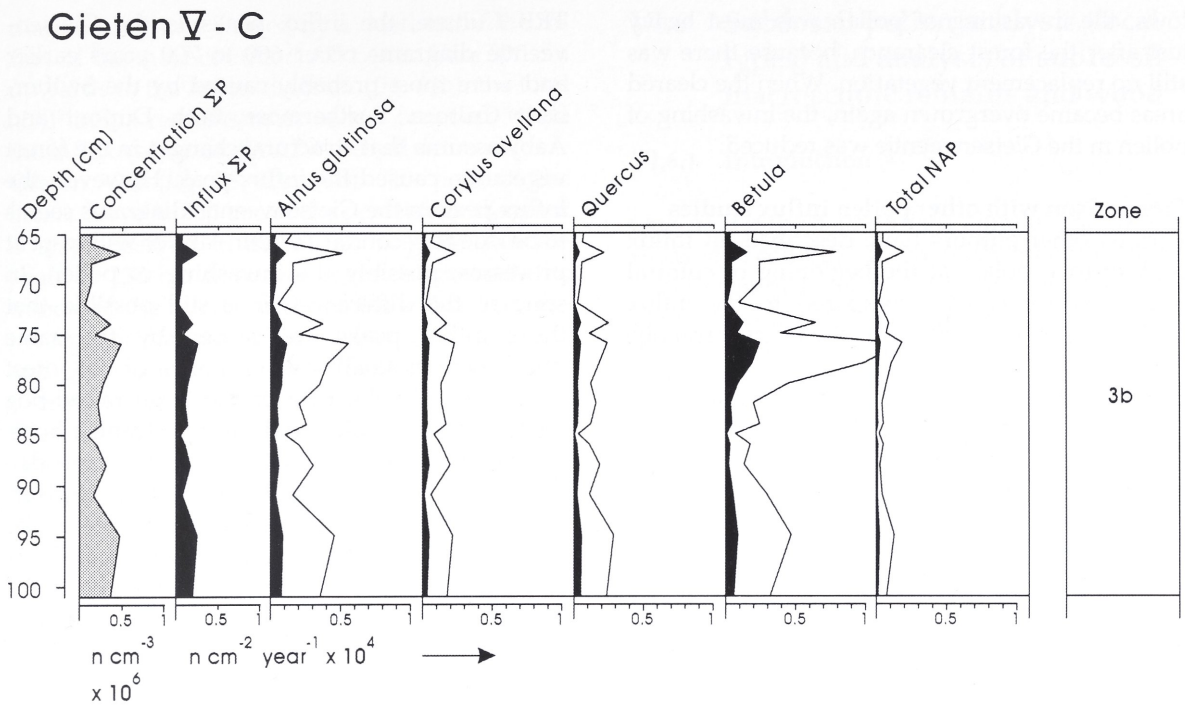


Fig. 64e.

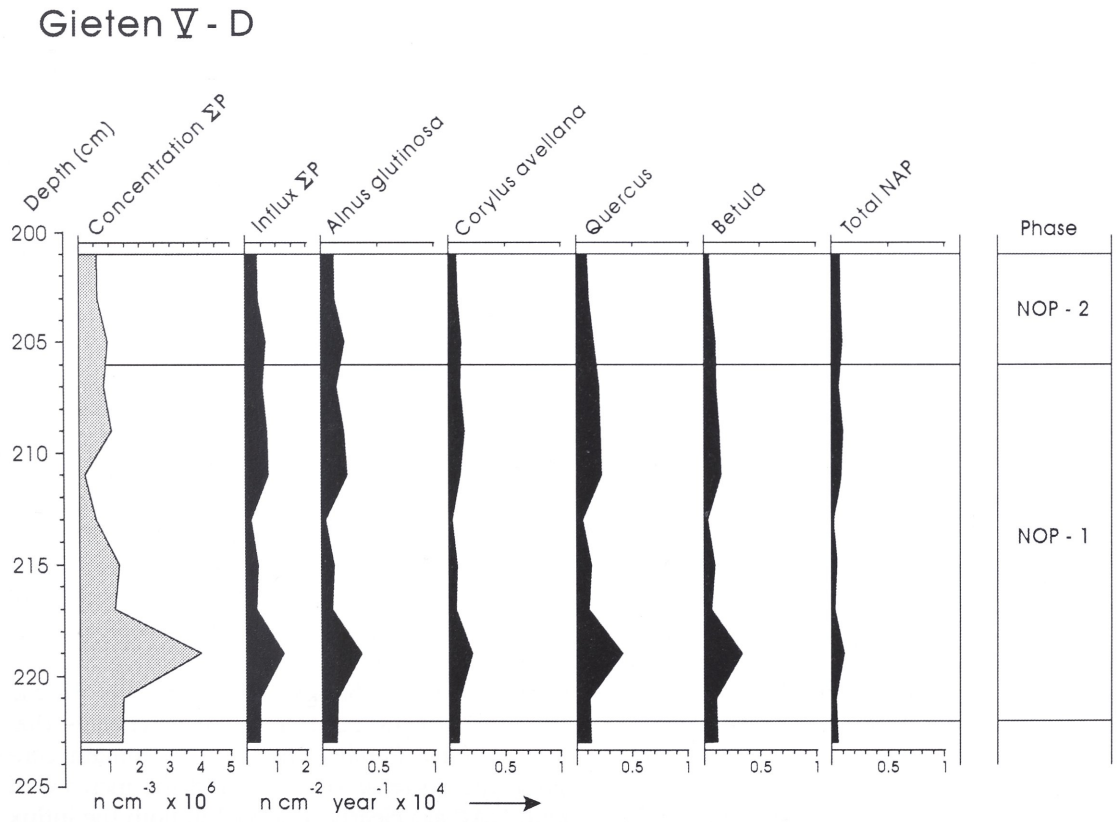


Fig. 64f.

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

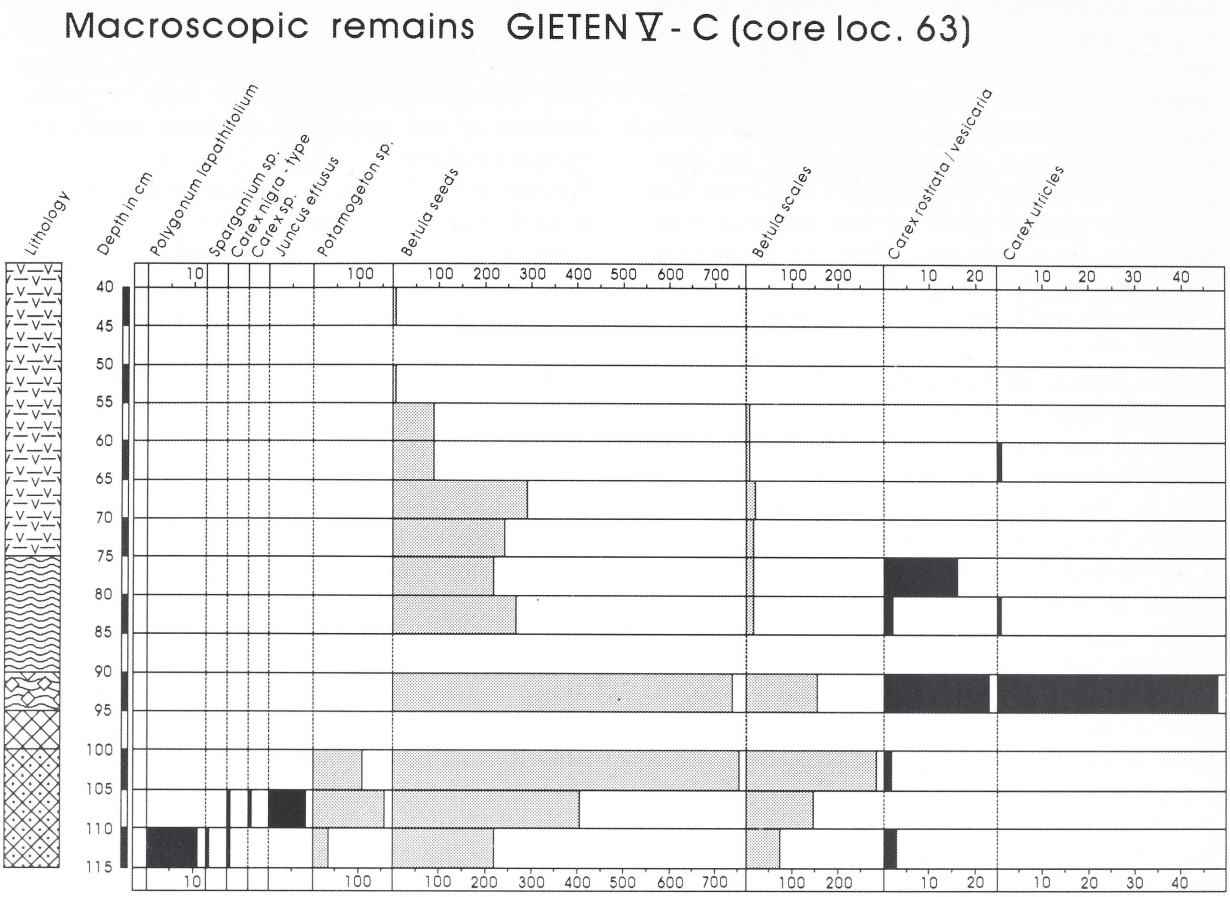


Fig. 65. Macroscopic-remains diagram of sequence Gieten V-C. It should be noted that the taxa indicated by black bars are drawn to a different scale from those with grey bars. For the legend of the lithology, see fig. 50.

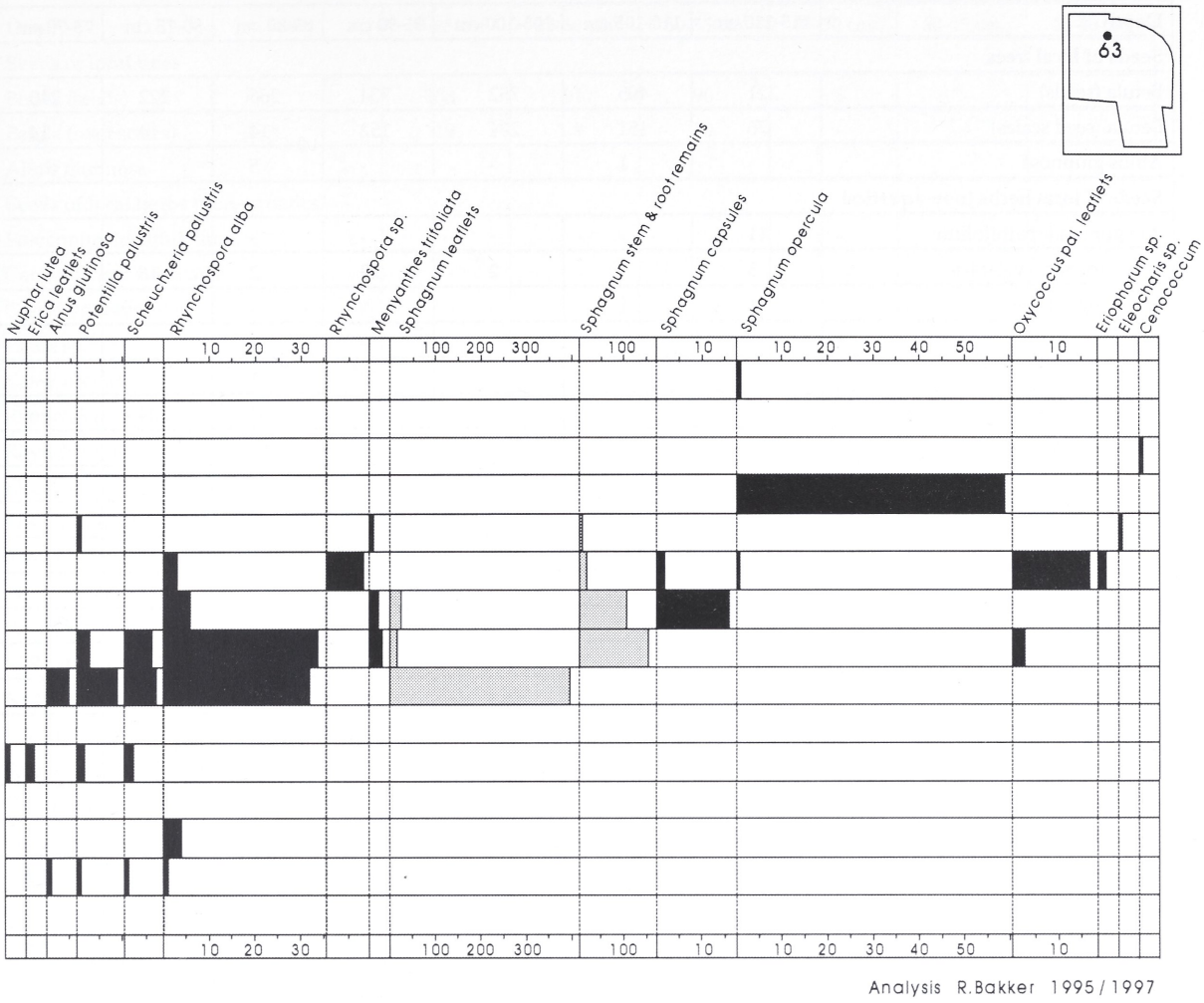
(400-370/364 cm), the *Pinus-Betula* zone, representing a part of the Boreal. This means that the upper macroscopic sample (383-380 cm) is older than the middle macroscopic sample (422.5-420 cm).

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

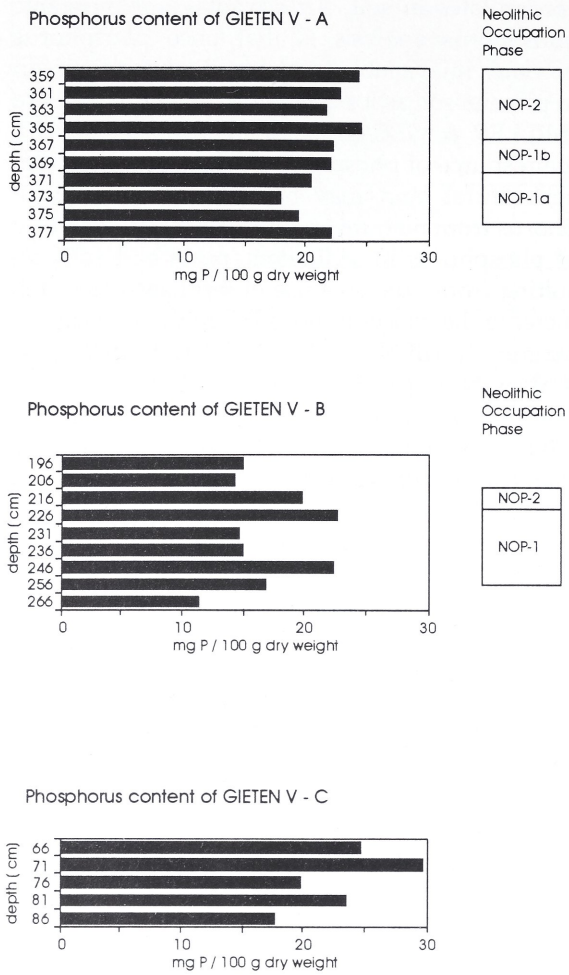


Fig. 66. Phosphorus content of 24 samples from three Gietsenveentje sequences. Where applicable, also the phases of the Neolithic Occupation Period are indicated.

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.

VII. Vegetation development in and around the Gietsenveentje since the Preboreal

VII.1 Regional vegetation development

When all data presented in the preceding chapters are combined, a general description can be made of the vegetation development in and around the Gietsenveentje since the Preboreal. This section discusses the development of the regional vegetation; in VII.2, the development of the local vegetation will be treated.

The regional vegetation development in the neighbourhood of the Gietsenveentje will be described on the basis of the pollen zones distinguished in VI.3 (table 7). These pollen zones are connected with the Blytt/Sernander periods (see I.4.1). When the dates of the zones are in *italics*, they are estimated by comparison with other studies (see appendix II; LANTING & VAN DER PLICHT 1995/1996; 1997/1998; 1999/2000) or by extrapolation; when the dates are in regular type, they are ^{14}C dates from this study (see VI.4). This description of the regional vegetation development can be compared with the general description of the vegetation development of the Drenthe Plateau in III.6.2.

Emphasis is put on the vegetation development during the Neolithic Occupation Period. Following Spek (1993), maps are presented showing the vegetation around the Gietsenveentje in the Atlantic and in the three phases of the Neolithic Occupation Period (figs. 67-70). The potential natural vegetation is reconstructed on the basis of the soil map (fig. 20; see III.3.3). On each map, the archaeological finds of the contemporary cultures are indicated (see fig. 24). The Gietsenveentje pollen diagrams reveal the changes in the vegetation caused by the people of these cultures. The maps are intended to offer a global idea of the scale of human interference in the Neolithic Occupation Period.

Zone 1 - *Betula* zone, *9800-8700* cal BC: Preboreal

The oldest sediments in the Gietsenveentje date from the Preboreal. In this period, open *Betula* forests, in which *Pinus* also played an important role, dominated the landscape. These forests predominantly occurred in damp places (BOTTEMA 1988), like the valleys of the Hunze and the Scheebroekerloop, and near circular depressions with water, like the Gietsenveentje. *Corylus* and *Ulmus*, two taxa which immigrated into the Netherlands during the Preboreal, were already present in the vicinity of the Gietsenveentje. In the relatively rich undergrowth of these forests, Gramineae and Cyperaceae species dominated, while *Artemisia* species also occurred frequently.

Zone 2 - *Pinus-Betula* zone, *8700-6950* cal BC: Boreal

Because of more favourable climatic conditions, in the Boreal, trees spread also to the drier parts (BOTTEMA 1988), like the coversand areas southwest of the Gietsenveentje (see fig. 19). *Pinus* became dominant in the still rather open forests. The open spots were for a large part colonized by *Corylus*, which partly replaced *Betula*. *Betula* was pushed back to the moist, peaty soils. *Quercus* now first appeared in the neighbourhood of the Gietsenveentje. Compared to the Preboreal, the share of herbs in the vegetation became smaller. In moist places, like those near depressions, Cyperaceae and to a lesser extent Gramineae species dominated.

Zone 3a - *Corylus-Ulmus* zone, *6950*-5850 cal BC: Atlantic I

Because of optimal climatic conditions, stable climax forests were formed. In this period, *Alnus*, *Fraxinus* and *Tilia* occurred for the first time in the neighbourhood of the Gietsenveentje.

Different soil types would carry different types of forest (see III.3.3). In fig. 67, the potential natural vegetation of the Gietsenveentje area is shown for the Atlantic (zone 3a/3b). Findspots of Mesolithic artefacts are indicated. It can be seen that most Mesolithic sites are located near open water, either circular depressions or brooks.

In the pollen diagrams, *Alnus*, *Corylus* and *Quercus* are the dominant AP types in this period. *Alnus* most probably occurred (together with *Betula*) in carr forests in the direct neighbourhood of the Gietsenveentje. On the till plateau, which forms the highest part of the Hondsrug ridge near the Gietsenveentje, fairly dense forests rich in species occurred, possibly forest types related to the present oak-hornbeam forest (*Stellario-Carpinetum*, but without *Carpinus*) and the oak-

beech forest (*Fago-Quercetum*, but without *Fagus*) (STORTELDER et al. 1999). In these forests, *Quercus*, *Ulmus*, *Tilia* and *Fraxinus* were the most common trees, but *Corylus* and *Pinus* also occurred quite frequently. The coversand areas, which are located to the west and the southwest of the Gietsenveentje, carried more open forests, less rich in species, possibly forest types related to the present birch-common oak forest (*Betulo-Quercetum roboris*). In these forests, *Quercus* and *Betula* were the most common trees (STORTELDER et al. 1999).
In the Atlantic forests, only a very scanty undergrowth was present, including Gramineae species. In all pollen diagrams, spores of *Pteridium aquilinum* reach relatively high values in this zone. *Pteridium aquilinum* especially grows in the undergrowth and in light spots in forests of the *Betulo-Quercetum roboris* and the *Fago-Quercetum* (WEEDA et al. 1985). According to Iversen (1949), *Pteridium* maxima are indicative of burning. Evidence for the presence of fires in this zone is also given by high peaks of charcoal particles in several pollen diagrams. Presumably, natural fires are the cause of these peaks; however, the possibility cannot be excluded that Mesolithic people burnt vegetation in the neighbourhood of the pingo scar in order to create open spaces.

Zone 3b - *Alnus-Ulmus-Fraxinus* zone, 5850-4050 cal BC: Atlantic II
The pollen picture of this zone very much resembles that of zone 3a. The share of *Pinus* and *Betula* in the forests slowly fell, while the share of *Quercus* and *Ulmus* increased. At the end of this zone, a few grains of *Fagus* are found in several diagrams. Possibly, *Fagus* was already present somewhere in the neighbourhood; because of the relatively poor distribution of *Fagus* pollen grains - they are only seldom found in surface samples -, the possibility of long-distance transport of *Fagus* pollen seems small (oral comm. A.J. Kalis).

Zone 4a - *Quercus-Fraxinus* zone, 4050-1770 cal BC: Subboreal I
The Subboreal is the first period in which human influence on the landscape becomes visible in the pollen picture. There is also a possibility that a world-wide climatic change, which occurred around 3800 cal BC, caused changes in the pollen assemblage (see II.4). However, the changes observed in the pollen diagrams are only small. It seems as if the influence of the first farmers as well as the influence of a climatic change on the vegetation was limited: the major part of the forests remained unaltered. *Quercus* and *Alnus* are the dominant AP types in this zone. *Quercus* occurred in the forests on the till plateau as well as the coversand areas; *Tilia* and *Fraxinus*, which grew in the forests on the till plateau, reach relatively high values, while *Ulmus*, which occurred in the same type of forest, slowly decreases. *Alnus* grew in carr forests at the edge of the Gietsenveentje. A strong decrease of *Betula* pollen demonstrates that *Betula* lost ground in these carr forests. *Fagus* pollen is frequently present in this zone, indicating that this tree became more important in the forests on the till plateau. Furthermore, the first pollen grains of *Carpinus* are found in this zone. These possibly indicate the immigration of this tree into Drenthe, but they may also originate from long-distance transport.
The influence of the first farmers on the vegetation is predominantly reflected in the Non-Arboreal Pollen: Gramineae, Cyperaceae, *Calluna* and *Rumex acetosa* increase, while *Plantago lanceolata* and Cerealia-type appear. As mentioned before, in Drenthe the Atlantic-Subboreal transition coincides with the beginning of the Neolithic Occupation Period (NOP). Pollen zone 4a coincides with the complete NOP. The NOP is subdivided into three phases:

Phase NOP-1: 4050-3450 cal BC, Swifterbant Culture (Middle and Late Phase)
In this phase, *Ulmus* very slowly decreases. However, the other components of the forests on the till plateau, *Quercus*, *Tilia* and *Fraxinus*, do not decrease; *Tilia* and *Quercus* even reach maximum values in this phase. Because the *Ulmus* decline is so slow, it is unlikely to have been caused by a pathogenic attack (see II.3). Just as Kalis & Meurers-Balke (1998) assumed for the western Baltic area, an anthropo-zoogenic cause seems more plausible. Large leaf-eating mammals prefer the nutritious leaves of *Ulmus*, *Fraxinus* and *Tilia*; most probably, the branches of these trees were cut and fed to the cattle. Apparently, *Ulmus* is the only tree which suffers from this treatment, because the pioneer tree *Fraxinus* takes advantage of the opening up of the forest (KALIS & MEURERS-BALKE 1998) and *Tilia* regenerates much faster than *Ulmus*, flowering again just four years after the cutting of the branches (VAN ZEIST 1959; see II.2.3).
Apart from *Ulmus*, the only other tree which decreases considerably in this phase is *Betula*. This decrease is a real decrease, because it is also visible in the influx diagrams (see VI.5). It is assumed that *Betula* grew close to the edge of the

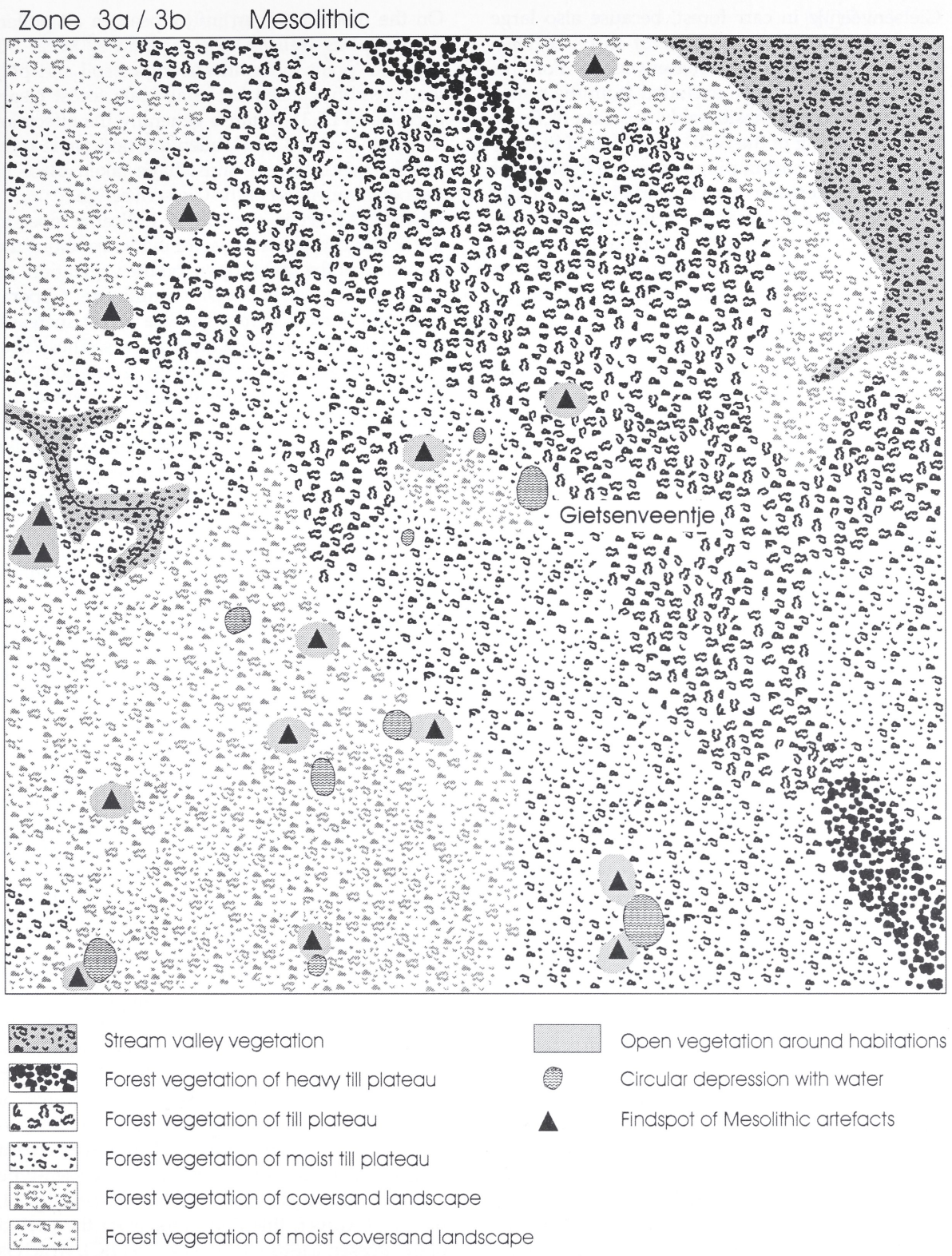


Fig. 67. Reconstruction of the landscape in the surroundings of the Gietsenveentje in pollen zones 3a/3b (Atlantic). This map and the following three maps represent the same area as fig. 15. The potential natural vegetation of the area is constructed on the basis of the soil map of fig. 20 (SPEK 1993; see III.3.3). The findspots of Mesolithic artefacts are indicated.

Gietsenveentje in carr forest, because also large numbers of seeds and wood of this tree have been found inside the Gietsenveentje. For this reason, *Betula* has been excluded from the pollen sum. However, a considerable decrease of *Betula* at the beginning of the NOP is also found in other pollen diagrams from pingo scars in Drenthe (for example Hijkermeer and Eexterveld, see II.2.2), indicating that this may be a regional phenomenon which deserves further explanation. First it has to be remarked that the *Betula* decrease is not accompanied by an increase of another tree pollen type, not in the influx diagrams either; the values of all other trees (except *Ulmus*) remain constant. However, the value of the NAP increases, also in the influx diagrams. From this, it may be concluded that *Betula* stands were replaced by open spaces which were colonized by various kinds of herbs. *Alnus* carr forest (*Alnetea glutinosae*) nowadays grows in marshy habitats, for example at the edges of fens and raised bogs, where the vegetation has contact with mineral-rich surface or groundwater; *Betula* carr forest (*Vaccinio-Betuletea pubescentis*) nowadays grows in peaty habitats where the vegetation has no contact with surface water or groundwater (STORTELDER et al. 1999). Changes in the water balance may cause a renewed contact with surface water or groundwater. When mineral-rich water reaches carr forest in this way, eutrophication will occur and *Alnus* will become more important in these forests, eventually allowing the development of *Alnus* carr forest. In the Atlantic, carr forests with *Alnus* as well as *Betula* seem to have occurred at the edge of the Gietsenveentje. There must have been contact with surface water and groundwater in that period. At the beginning of the NOP, *Betula* slowly decreases. As we saw above (see III.4.2), forest clearances on a till plateau can lead to a considerable rise of the water table. Possibly, mineral-rich water could thus have reached the carr forests, which benefited *Alnus* at the expense of *Betula*. The source of this mineral-rich water was possibly the dung of livestock that was kept by the first farmers. This dung may have been used to manure the arable fields. A small increase in the phosphorus content of the sediment in this phase also points to the inwashing of mineral-rich water into the Gietsenveentje. Because the increase is only very small, the source of this mineral-rich water seems to be located beyond the immediate vicinity of the Gietsenveentje (see VI.7.3).

On the other hand, an influx peak in all pollen types, AP as well as NAP, around 3700 cal BC seems to point to the inwashing of soil and pollen, possibly caused by small-scale forest clearance (see VI.5.3). Because generally the effects of inwashing of soil and pollen are noticeable only locally, this clearance must have taken place in the neighbourhood of the Gietsenveentje.

Of the NAP types, the culture-indicator types in particular can provide useful evidence about the influence of the first farmers on the vegetation. At the beginning of the NOP, Gramineae, Cyperaceae and *Rumex acetosa* show a slight increase, while *Plantago lanceolata* first appears. These taxa point to the presence of moist grass-rich vegetation with a moderate to high nutrient availability (BEHRE 1981; see fig. 2). Pollen of Cerealia-type (*Hordeum* group as well as *Triticum* sp.) appears and occurs in low values, pointing to the presence of arable fields. A small increase of *Calluna* and maximum values of *Genista*-type and *Jasione montana* are indicative of dry grass-rich vegetation with a low nutrient availability (BEHRE 1981; RUNHAAR et al. 1987).

The NAP types point to the presence of arable fields and various types of grass-rich vegetation that were most probably maintained by livestock. However, the extent of this arable and grass-rich vegetation must have been very small, because almost no decrease of AP can be seen in this phase.

According to very accurate ^{14}C dates (see VI.4), the pollen picture probably reflects the agricultural activities of people belonging to the Middle and Late Phase of the Swifterbant Culture. The presence of Swifterbant people on the Drenthe Plateau is also demonstrated by more and more archaeological finds (see fig. 23).

Fig. 68 shows the landscape in the neighbourhood of the Gietsenveentje as it might have been in phase NOP-1. The larger part of the Atlantic forest was undisturbed. Only a few small-scale clearances in the forests on the till plateau and on the poorer, sandy soils revealed the presence of Swifterbant people. Up till now, the only archaeological find contemporary with the Swifterbant Culture near the Gietsenveentje is a Rössen-type adze, found "on the heath near Eext" (see fig. 24, no. 1). However, this find dates from the period of the Rössen Culture (4700-4300 cal BC), which is a few hundred years before the beginning of NOP-1. Habitations of Swifterbant people have so far not been found on the Drenthe Plateau.

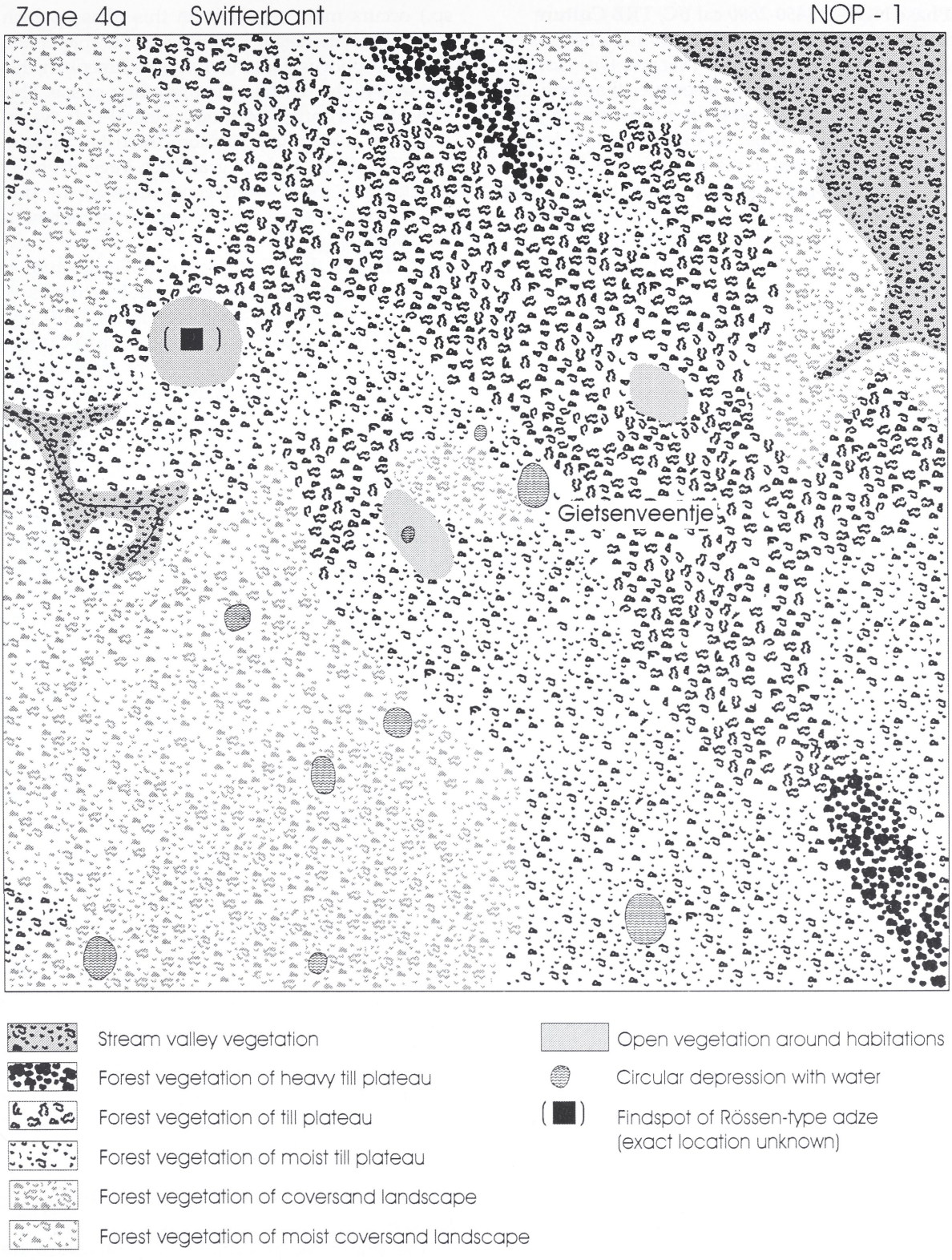


Fig. 68. Reconstruction of the landscape in the surroundings of the Gietsenveentje in phase NOP-1, which is a part of pollen zone 4a (Subboreal I). Phase NOP-1 is connected with the Swifterbant Culture. The only findspot (approximate) of a possible Swifterbant artefact is indicated.

Phase NOP-2: 3450-*2600* cal BC, TRB Culture

In this phase, the AP values do not change, except for small decreases of *Tilia* and *Quercus*. The decline of these two taxa resembles that found by Behre and Kučan (1994) in northwestern Germany (see II.2.6). Most probably, more extensive clearances occurred in the dense forests on the till plateau. Obviously, not only *Ulmus*, but now also *Tilia* and *Quercus* suffered from these clearances. However, the values of *Fraxinus*, another component of the forests on the till plateau, remain constant. Possibly, the branches of *Ulmus*, *Tilia* and *Fraxinus* were still fed to the livestock; owing to more intensive branch-cutting than in the preceding phase, *Tilia* too could not properly regenerate. The more open forests were to the advantage of *Fraxinus*, a tree which prefers light forests (WEEDA et al. 1988). Pollen of *Fagus* occurs more regularly in this phase, but still only sporadically, and therefore it seems unlikely that this tree was replacing *Tilia*. This conclusion was also reached by Van Zeist (1959, 177).

Of the NAP types, Gramineae, Cyperaceae, *Calluna*, *Pteridium*, *Plantago lanceolata*, *Rumex acetosa* and Cerealia-type (*Hordeum* group as well as *Triticum* sp.) reach relatively high values. Also a small increase in the number of charcoal particles is observed. Maxima of charcoal particles and *Pteridium* spores might point to burning (IVERSEN 1949). However, the values of *Pteridium* in this phase reach only 3-4%. Only very small-scale burning could have taken place. Burning would also benefit *Quercus*, because this tree has a thicker bark than most other trees (WEEDA et al. 1985). However, the low values of *Betula* in this phase argue against the use of burning: Iversen (1941) states that the pioneer tree *Betula* is one of the first trees to regenerate after fire in the ashy soil. The increase of Gramineae, Cyperaceae, *Rumex acetosa* and *Plantago lanceolata* points to larger areas of grass-rich vegetation with a moderate to high availability of nutrients. In the pollen diagrams of Gieten I, V-A and V-D, *Rumex acetosa/acetosella* reaches values of more than 1% in this phase; not all pollen grains of *Rumex acetosa/acetosella* were attributable to either *Rumex acetosa* or *Rumex acetosella*, but those which could be identified nearly all belonged to *Rumex acetosa*. According to a study of modern vegetation types with *Rumex* (see V.4), this indicates that considerable amounts of *Rumex* plants must have grown not far from the southern edge of the pingo scar (see fig. 71).

Cerealia-type (*Hordeum* group as well as *Triticum* sp.) occurs more regularly in this phase, which points to an increased importance of arable fields. The phosphorus content of the sediment in this phase is higher than in the preceding phase. This indicates an influx of more mineral-rich water, which in turn points to more intensive agriculture. The fields and/or grass-rich vegetation lay no closer to the Gietsenveentje than in the preceding phase, since the phosphorus content is only slightly higher.

According to the ^{14}C dates, the pollen picture of this phase reflects the agricultural activities of people of the Funnel Beaker Culture (TRB) and possibly the first part of the Single Grave Culture (EGK). Unfortunately, there are no dates of the NOP-2/NOP-3 transition; the date of 2600 cal BC is an extrapolated value, and therefore far less reliable than the date of the NOP-1/NOP-2 transition. It seems probable that the NOP-2/NOP-3 transition coincides with the transition from TRB to EGK, but as long as there are no accurate ^{14}C dates, no definitive statement can be made about this. Still it seems safe to conclude that the largest part of phase NOP-2 has to be ascribed to the TRB Culture. The presence of TRB people in the neighbourhood of the Gietsenveentje is documented by many archaeological finds (see fig. 24). In fig. 69, the landscape around the Gietsenveentje is shown as it might have been in phase NOP-2. All TRB "settlement sites" (findspots of flint and pottery) and megalithic tombs (*hunebedden*) are shown. The megalithic tombs and also most "settlements" are located on the western edge of the till plateau (western part of the map area), near the valley of the Scheebroekerloop. To create the necessary open spaces, TRB people predominantly cleared forest vegetation on the till plateau, of a type related to the present-day oak-beech forest (*Fago-Quercetum*). A few "settlements" are located on the highest part of the till plateau (eastern and northern part of the map area). Here, it was mostly forest on heavy till, of a type related to the present-day oak-hornbeam forest (*Stellario-Carpinetum*), that was cleared (see III.3.3). However, the major part of the Atlantic forest remained undisturbed.

Phase NOP-3: *2600*-1770 cal BC, EGK/BB Culture

In this phase, the percentage diagrams show no changes in the AP values except for a small increase of *Corylus*, while the total NAP value decreases slightly. In the influx diagrams, however, the influx of all AP types declines (see fig. 64b),

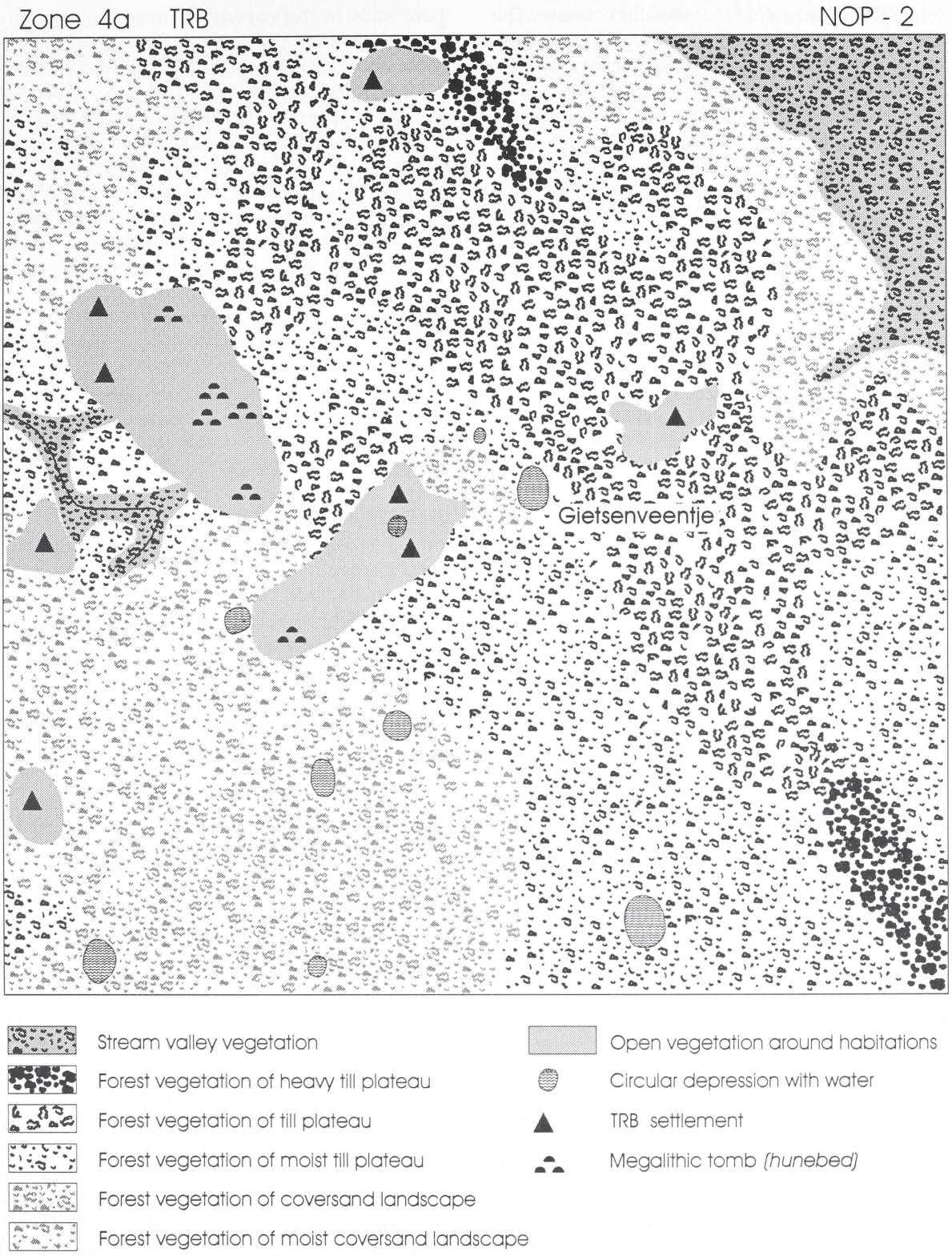


Fig. 69. Reconstruction of the landscape in the surroundings of the Gietsenveentje in phase NOP-2, which is a part of pollen zone 4a (Subboreal I). Phase NOP-2 is connected with the Funnel Beaker Culture (TRB). The locations of megalithic tombs (*hunebedden*) and possible settlements are indicated.

while that of the total NAP remains constant. The values of Gramineae, *Calluna* and the culture-indicator pollen types in the percentage diagrams remain constant or slightly decrease. The pollen picture reflects a period of temporarily reduced pressure on the vegetation: apparently not much new forest clearance took place in this phase.
According to the ^{14}C dates, this phase reflects the agricultural activities of people of the Single Grave Culture (EGK), the Bell Beaker Culture (BB) and possibly the first part of the Bronze Age. There are only a few dates of the NOP-3/zone 4b boundary; for this reason, the date of 1760 cal BC is less accurate than the dates of the beginning of NOP-1 and the NOP-1/NOP-2 boundary. The NOP-3/zone 4b boundary probably coincides with the BB/Bronze Age boundary; however, in this case too more ^{14}C dates are needed to provide clarity. It is clear that the major part of phase NOP-3 is attributable to the EGK and BB Cultures.
In fig. 70, the landscape in the vicinity of the Gietsenveentje is shown as it might have been in phase NOP-3. Also the archaeological finds from this period are shown: one EGK/BB "settlement" and a number of burial mounds. Compared to the TRB period, the density of habitation seems to be less. The burial mounds are situated on the western edge of the till plateau, very close to the megalithic tombs. Possibly, part of the land which for several centuries had been cultivated by TRB people, was by now exhausted, resulting in the first, small, grass-rich heathfields. The presence of EGK people on the very edge of the Gietsenveentje is documented by the find of a horn sheath in the pingo scar itself; according to Prummel & Van der Sanden (1995), this horn sheath was thrown into the water for ritual purposes.

Zone 4b - *Alnus-Corylus*-Ericaceae zone, 1770-*1100* cal BC: Subboreal II

A strong decrease of *Quercus*, *Fraxinus* and *Tilia* at the beginning of this zone shows that the forests on the till plateau were cleared on a much larger scale than in the preceding period. Most probably, also parts of the forest in the coversand areas were now cleared. In these forests, *Quercus* also played an important role (see III.3.3). *Corylus* reaches its highest values in this zone: because of the rapidly increasing number of open spaces, *Corylus* could easily expand. However, at the end of this zone, the values of *Corylus* fall considerably. This possibly marks the beginning of the widespread degradation of soils. The already poor soils in the coversand areas were rapidly exhausted after being used for agriculture for some time. Eventually, these soils became too poor in nutrients for *Corylus* to grow, which led to the disappearance of this shrub (WATERBOLK 1954; IVERSEN 1973). The exhausted, abandoned arable fields which were still quite intensively grazed by livestock, formed a very suitable habitat for *Calluna vulgaris*; this is very clear in the pollen diagrams: *Calluna* increases considerably in this zone and becomes the dominant NAP type.
The pollen of *Alnus* dominates the AP: the carr forests in the immediate vicinity of the Gietsenveentje consisted largely of this tree. Expanding agriculture caused an influx of more and more nutrient-rich water into the pingo scar. A nutrient-rich environment is very suitable for *Alnus* (RUNHAAR et al. 1987). Pollen of *Carpinus* is found more frequently than in the preceding zone, although its values are still very low. The pollen values of *Fagus* are the same as in the preceding zone, which indicates that the share of *Fagus* in the forest vegetation did not increase.
The values of most culture-indicator pollen types rise. In the diagrams of Gieten I and Gieten V-A, *Rumex acetosa/acetosella* reaches values of more than 1%, which means that considerable numbers of *Rumex* plants must have grown in the direct neighbourhood of the pingo scar.

Zone 4c - Ericaceae-*Alnus* zone, *1100-800* cal BC: Subboreal III

In this zone, *Quercus* and *Corylus* decrease, while *Fagus* reaches relatively high values. Most probably, *Fagus* had established itself in the remaining forests on the till plateau, having partly replaced *Quercus*. In this period the oak-beech forest (*Fago-Quercetum*; VAN DER WERF 1991; STORTELDER et al. 1999) on the Drenthe Plateau may for the first time have occurred in its present-day form, that is with a dominant role of *Fagus*. Given the high values of *Alnus*, the direct surroundings of the Gietsenveentje were still dominated by *Alnus* carr forest.
As for the NAP types, a considerable increase of *Calluna* is noted. Because of the ongoing exhaustion of soils and grazing pressure of livestock, heathfields could progressively expand. However, the culture-indicator pollen types do not increase in this zone. This seems to indicate that, compared to the preceding zones, there was no increase in the total area of cultivated fields and pastures. This implies that the human population did not grow in this period. Because of the

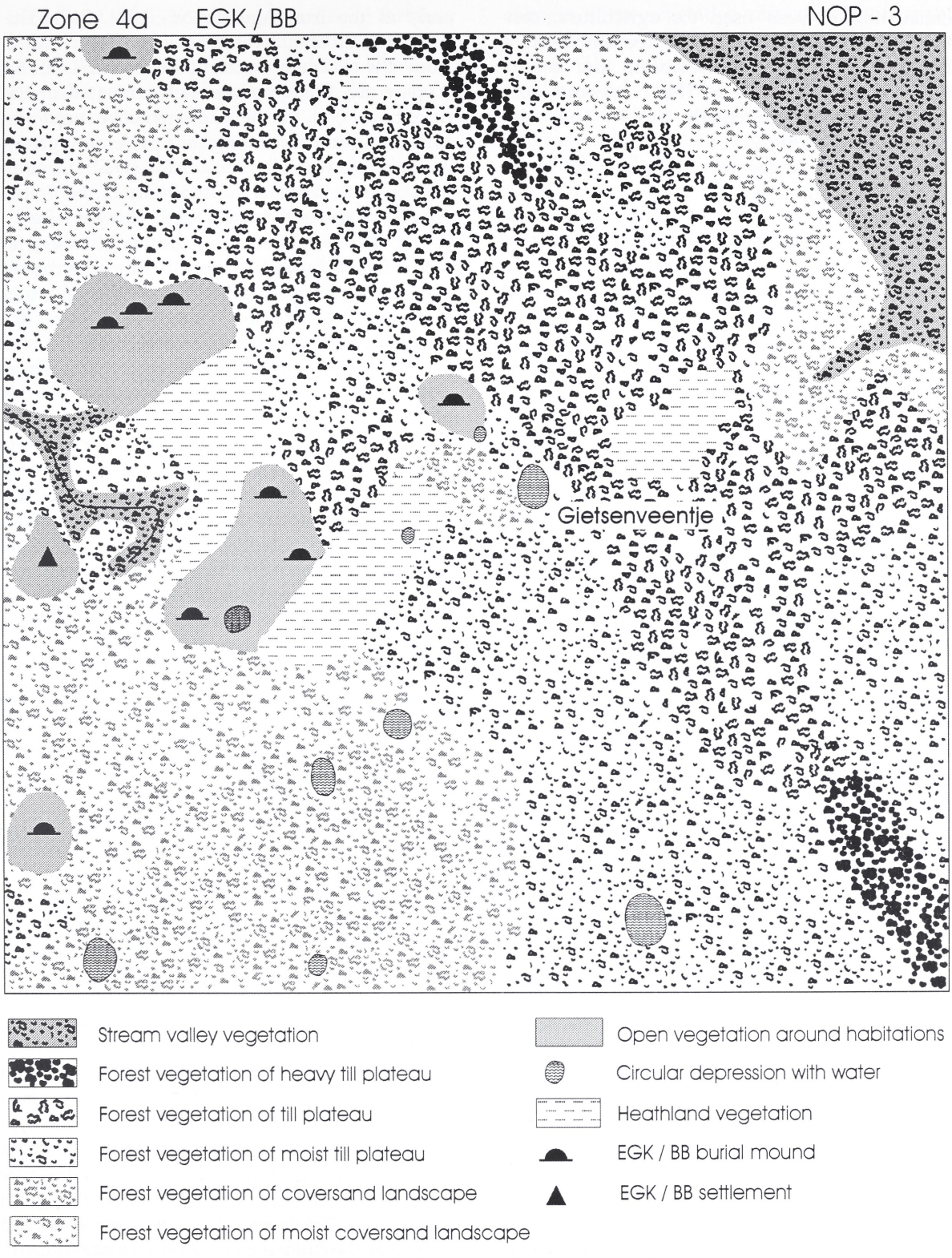


Fig. 70. Reconstruction of the landscape in the surroundings of the Gietsenveentje in phase NOP-3, which is a part of pollen zone 4a (Subboreal I). Phase NOP-3 is connected with the Single Grave Culture (EGK) and the Bell Beaker Culture (BB). The locations of burial mounds and a possible settlement are indicated.

exhaustion of soils used for agriculture, continually new areas had to be reclaimed. As a result, the total area of exhausted and useless fields steadily increased. The coversand soils were exhausted particularly rapidly (*veld* and *haar* podzols, see fig. 21).
Zones 4b and 4c together represent the larger part of the Bronze Age.

Zone 5a - Ericaceae-*Fagus* zone, *800* cal BC-*1500* cal AD: Subatlantic I
The Subboreal-Subatlantic transition is marked by a large increase of *Calluna* and by the beginning of a period with constantly high values of *Fagus*. In this period, most remaining forests on the Drenthe Plateau were cleared. Even the *Alnus* carr forests near the Gietsenveentje largely disappeared. Gramineae, *Plantago lanceolata* and *Rumex acetosa/acetosella* increase, but Cerealia-type occurs only very sporadically. This indicates an increase of grass-rich vegetation but no increase of arable fields. Most of the former forest, however, was replaced by extensive heathfields. The *Rumex acetosa/acetosella* pollen values exceed 1% in this zone. Relatively high values of *Rumex acetosa/acetosella* (here most probably originating from *Rumex acetosella*) together with high values of *Calluna* may well point to abandoned arable fields (see V.4) which have become so poor in nutrients that they form a suitable habitat for *Calluna vulgaris* and *Rumex acetosella*.
Although there are no ^{14}C dates of this zone from the Gietsenveentje, it most probably covers the Iron Age, the Roman Period and the Middle Ages. From the Gietsenveentje pollen diagrams, no radical changes in agricultural methods can be traced in this period.

Zone 5b - Gramineae-Cerealia-Ericaceae zone, *1500-1900* cal AD: Subatlantic II
In this zone, the AP pollen values have decreased to an absolute minimum: 10-15%. *Fraxinus*, *Ulmus* and *Tilia* have practically disappeared. It seems as if all forest up to the very edge of the Gietsenveentje was cleared. In part of this zone, pollen of *Betula* occurs massively. This most probably points to *Betula* trees growing within the pingo scar itself, which may indicate a lowering of the water table.
Pollen of *Fagopyrum* occurs for the first time in this zone. This crop was introduced in western Europe in the late Middle Ages (LANG 1994, 246). Furthermore, pollen of *Secale* and *Centaurea cyanus* makes its first appearance. The winter cereal *Secale* was introduced in central Europe as early as the Iron Age (LANG 1994, 240). The earliest finds of cultivated *Secale* in Drenthe date from the Roman Period (VAN ZEIST 1976). Apparently, this crop was not cultivated in the neighbourhood of the Gietsenveentje until the Middle Ages. *Centaurea cyanus* preferably grows as an arable weed in *Secale* fields (WEEDA et al. 1991), which explains the similarity of the pollen curves of these two taxa. According to Behre (1981), *Rumex acetosella* also grows as a weed in *Secale* fields. Indeed, pollen of *Rumex acetosella* occurs frequently in this zone. However, other biotopes of this species include areas where dry deciduous and pine forests have been cut and former arable land (WEEDA et al. 1985). These man-made biotopes gained in importance in this zone. It is difficult to establish from which of these three biotopes the pollen of *Rumex acetosella* in this zone originates. Very high values of Gramineae and Cerealia-type (*Hordeum* group and *Triticum* sp.) attract attention. In this period, arable fields must have been located directly on the edge of the pingo scar. Topographical maps of the 19th century (figs. 25-27) indeed show a complex of arable fields called "Grietsche Akkers" immediately west and south of the Gietsenveentje. The poor soils of the coversand landscape were covered with extensive heathfields (see fig. 27). Relatively high values of Compositae Liguliflorae and *Matricaria*-type point to increased areas of fallow land, ruderal communities and/or wet meadows (BEHRE 1981).

Zone 5c - *Quercus*-Gramineae zone, *1900* cal AD-present: Subatlantic III
This zone is represented by only one sample from sequence Gieten V-A, which was cored in the centre of the Gietsenveentje (core location 59). The pollen picture of this sample very much resembles that of a surface sample from the same location (see VI.2.3). In the 20th century, the pingo scar was drained for the cutting of peat. The Gietsenveentje is now for the larger part overgrown with woodland. In an undisturbed part in the centre, where also the core location of Gieten V-A is situated, *Betula* nowadays is the dominant tree (see fig. 48). According to the large numbers of *Betula* pollen in this zone in diagram Gieten V-A, *Betula* must have been the dominant tree since the drainage of the pingo scar.
Many AP types increase markedly, especially *Quercus*, *Corylus* and *Pinus*. This pollen may originate from trees which in the course of the 20th century were planted in the neighbourhood of the Gietsenveentje.

Because of the introduction of artificial fertilizer at the beginning of the 20th century, the vast heathfields could be transformed into farmland. This is reflected in the pollen picture by a strong decrease of *Calluna*.
NAP types which increase in this zone are Gramineae, *Ranunculus acris* group, Compositae Liguliflorae, *Senecio*-type, *Matricaria*-type, Caryophyllaceae and Umbelliferae. Most probably, the pollen of these taxa originates from wet meadows which nowadays border the Gietsenveentje on its northern and eastern sides.

A comparison between pollen diagrams of various locations within the Gietsenveentje

In the Gietsenveentje, a number of sequences were cored on a north-south transect through the centre of the pingo scar (see VI.1). Four of these sequences were used for pollen analysis, resulting in four pollen diagrams: Gieten V-A to V-D. By comparing the pollen record of the four locations, it may become more clear which pollen came from local sources and which from regional sources. Local (non-aquatic) pollen is expected to display higher values in diagrams near the edge of the pingo scar. Regional pollen will show either similar values in all diagrams or higher percentages in diagrams in the centre of the pingo scar, where the influence of local pollen is less.
Fig. 71 shows histograms of the average values of twelve pollen types in the four pollen diagrams on the transect in three global periods: the last part of the Atlantic (ca. 5500-4050 cal BC), which can be connected with the Mesolithic, NOP-1 (4050-3450 cal BC), which corresponds with the Swifterbant Culture, and NOP-2 (3450-ca. 2600 cal BC), which can be linked with the TRB Culture (and possibly the beginning of the EGK Culture). The characteristics of the pollen histograms in fig. 71 will now be discussed in greater detail.
Quercus. The pollen values are generally quite similar, which points to a regional origin of the pollen. In the Atlantic and NOP-1, slightly higher pollen values are found at the southern edge. Generally, the values of *Quercus* do not decrease in NOP-1 and NOP-2.
Tilia. In the Atlantic, the highest values are found near the southern edge; in NOP-1 and NOP-2, the highest values are found more towards the centre. The values of *Tilia* more or less follow the pattern of *Quercus*. It is remarkable, that especially at the locations in the centre, the highest *Tilia* values are found in NOP-1. Apparently, the changes in the vegetation caused by Swifterbant people were to the advantage of *Tilia*.
Ulmus. The pollen values are generally quite similar, which points to a regional origin of the pollen. The *Ulmus* values at all locations slightly decrease in NOP-1 and again in NOP-2. This decrease is ascribed to the "classic" *Ulmus* decline (see II.3).
Corylus avellana. The values of *Corylus* are quite constant, both in the three periods and at the four locations. This points to a regional origin of the pollen. Even during TRB times and later, when larger areas of forest were cleared, the values of *Corylus* do not increase.
Calluna vulgaris. In NOP-1, the first increase in the pollen of *Calluna* is observed, especially in Gieten V-B. In NOP-2, the values increase further. In all three periods, the highest values of *Calluna* are found in Gieten V-B. It cannot be excluded that this has something to do with the local situation: Gieten V-B is the only sequence in which the NOP occurs in *Sphagnum* peat (see fig. 45), which indicates the presence of raised-bog vegetation at this spot in the Gietsenveentje. It is possible that *Calluna vulgaris* grew locally in small numbers on hummocks in this narrow raised-bog zone within the Gietsenveentje (WEEDA et al. 1988). However, because the highest values of *Calluna* are found in the centre, it is supposed that the majority of the pollen has a regional origin.
Cerealia-type. Pollen of Cerealia-type is found only very sporadically in all periods and at all locations. The highest values (only 0.1%!) are observed during the TRB period and later. It is difficult to determine the origin of the Cerealia-type pollen on the basis of a few grains. Yet it might be concluded that the Cerealia-type pollen has a regional origin, because most grains are found in the centre.
Alnus glutinosa. The values of *Alnus* are generally quite constant, only its values in Gieten V-C and V-D (northern and southern edge, respectively) are slightly higher. It is expected that *Alnus* grew mainly at or near the edges of the pingo scar, which means that it is a local tree, but in the pollen diagrams *Alnus* behaves very "regionally": at various locations and in various periods, its values are almost constant.
Gramineae indiff. The values of the Gramineae only slightly rise in NOP-1; a considerable increase at all locations is observed in NOP-2. In all periods, the highest values of Gramineae are found in Gieten V-A and V-D, which indicates that the source of most Gramineae pollen must

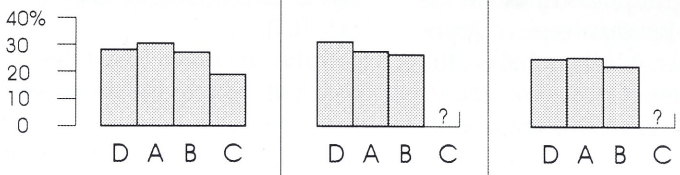
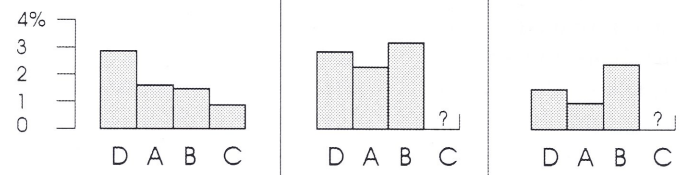
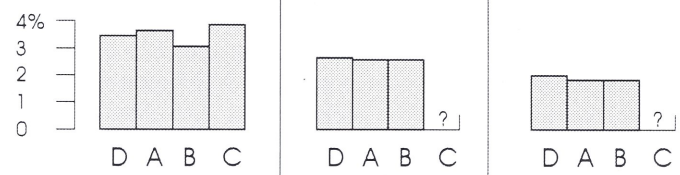
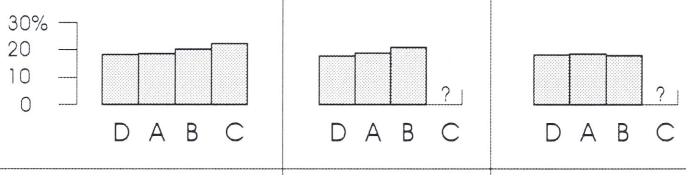
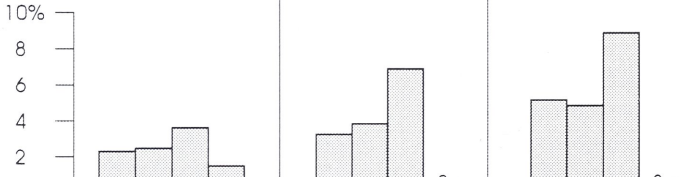
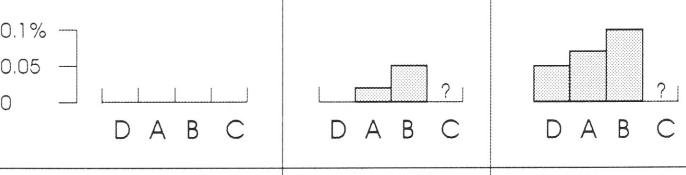
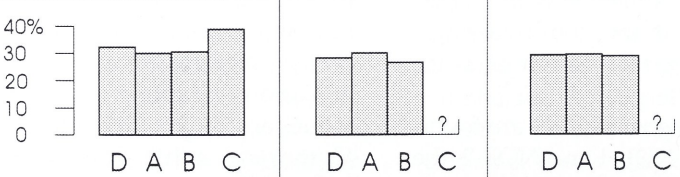
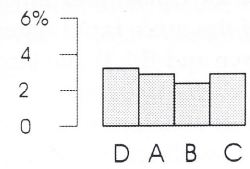
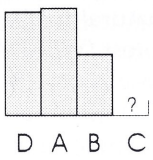
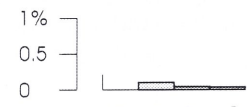
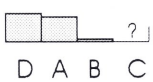
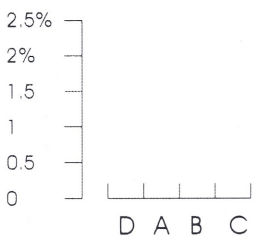
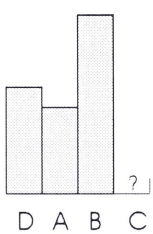
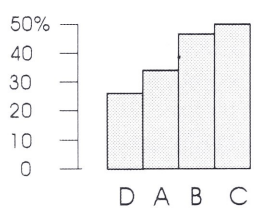
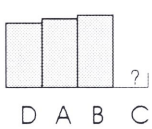
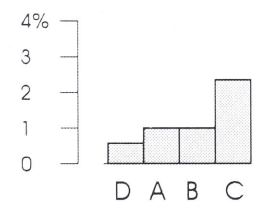
Pollen type	Period, core location and pollen percentage			Probable origin of the majority of the pollen
	Atlantic ca.5500 - 4050 cal BC	NOP - 1 4050 - 3450 cal BC	NOP - 2 3450 - ca.2600 cal BC	
Quercus				regional
Tilia				regional
Ulmus				regional
Corylus avellana				regional
Calluna vulgaris				regional
Cerealia - type				regional
Alnus glutinosa				local ?

Fig. 71. Average pollen values of a selection of twelve pollen types in four pollen diagrams in three periods. The pollen diagrams originate from four core locations on a transect through the Gietsenveentje. This transect with the core locations is shown at the bottom.

Pollen type	Period, core location and pollen percentage			Probable origin of the majority of the pollen
	Atlantic ca.5500 - 4050 cal BC	NOP - 1 4050 - 3450 cal BC	NOP - 2 3450 - ca.2600 cal BC	
Gramineae indiff.				local (S)
Rumex acetosa				local (S)
Plantago lanceolata				local (S) ?
Betula (excluded from ΣP)				local (N)
Cyperaceae indiff. (excluded from ΣP)				local

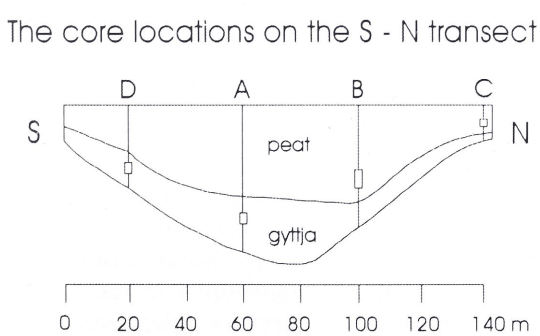


Fig. 71 (continued).

have been close to the gently sloping southern edge of the pingo scar. Especially from TRB times on, considerable areas of grass-rich vegetation must have been located near the southern edge.

Rumex acetosa. Pollen of *Rumex acetosa* occurs only very sporadically in the Atlantic and NOP-1. Possibly, this pollen originates from *Rumex acetosa* growing in its natural habitat: brookside and light spots in the forest (WEEDA et al. 1985). In NOP-2, a clear increase is observed, especially in Gieten V-A and V-D (southern edge). The values of *Rumex acetosa* more or less follow the pattern of the Gramineae. This suggests that *Rumex acetosa* grew in the grass-rich vegetation which occurred not far south of the Gietsenveentje especially from TRB times on.

Plantago lanceolata. Pollen of *Plantago lanceolata* appears for the first time in NOP-1 in very low values at all locations. In NOP-2, the values increase explosively: they are 11 to 44 times as high as in NOP-1! The values of *Plantago lanceolata* follow a pattern which more closely resembles that of the Gramineae than that of Cerealia-type. This may mean that *Plantago lanceolata* occurred in the grass-rich vegetation types where the livestock grazed, and was not an arable weed (BEHRE 1981; GROENMAN-VAN WAATERINGE 1986).

Betula (excluded from ΣP). The highest values of *Betula* are found in Gieten V-B and V-C, near the northern edge. At the location of Gieten V-C, also many macroscopic remains of *Betula* were found (see VI.6.2). For this reason, *Betula* was excluded from the pollen sum. At all locations, *Betula* decreases in NOP-1 and decreases further in NOP-2. *Betula* must have grown mainly on or near the steep northern slope of the pingo scar. It probably disappeared because mineral-rich water, originating from settlements and agricultural areas of the first farmers, reached the pingo scar.

Cyperaceae indiff. (excluded from ΣP). In NOP-1 and NOP-2, Cyperaceae values follow the same pattern as those of the Gramineae: the highest Cyperaceae values are found in NOP-2, especially towards the southern edge (Gieten V-D). The low and stable values of Cyperaceae indicate that probably no Cyperaceae grew inside the pingo scar in these three periods. Since in other periods far higher values of Cyperaceae (up to 25%) are found, pointing to Cyperaceae growing inside the pingo scar, it was decided to remove the Cyperaceae from ΣP. But in NOP-2 especially, during TRB times, most Cyperaceae appear to have grown together with *Plantago lanceolata* and *Rumex acetosa* in the grass-rich vegetation not far south of the Gietsenveentje.

The conclusion from fig. 71 may be put as follows. In NOP-1, which can be linked with the Swifterbant Culture, very small-scale agriculture was practised with an emphasis on cereal cultivation. Possibly, branches of *Ulmus* and *Tilia* were collected and fed to livestock, which led to a decrease of *Ulmus* and an increase of *Tilia*, because of the more rapid regeneration of the latter (see above and II.2.3). No large areas of grass-rich vegetation were present.

In NOP-2, which can be connected with the TRB culture, small-scale agriculture was practised with an emphasis on stock keeping. Probably the area of arable land was the same as in the preceding period, while the area of moist grass-rich vegetation with Gramineae, Cyperaceae, *Plantago lanceolata* and *Rumex acetosa* increased considerably. This grass-rich vegetation was located somewhere south of the Gietsenveentje, possibly close to its southern edge. A small increase of *Calluna* shows that the area of dry grass-rich vegetation also increased in this period. However, this vegetation with *Calluna* was situated further away than the moist grass-rich vegetation to the south.

VII.2 Local vegetation development

The development of the vegetation within the Gietsenveentje and the vegetation growing directly on its edges is described on the basis of the curves of local pollen types and macroscopic remains. The definitions of regional and local pollen types are given in IV.5. The local vegetation development of the Gietsenveentje will be described in units parallel to the regional pollen zones proposed in VI.3, and also used in VII.1. By comparing trends in the local vegetation with the regional pollen zones, it may be easier to trace any (direct or indirect) human influence on the local vegetation.

In the Gietsenveentje, sedimentation started in the Preboreal. Of the sequence Gieten IV-HL, which is located near the centre of the pingo scar (core location 49A, see fig. 38), a macroscopic sample from the base of the sequence was analyzed. Most macroscopic remains belonged to *Carex rostrata/vesicaria*; no remains of aquatic plants were found. Probably a kind of sedge marsh developed in the Gietsenveentje before the depression filled with water and a lake was formed. Possibly, the plant community forming this sedge marsh was related to the present-day *Caricetum vesicariae* association, which occurs in depressions

that in winter are flooded, on moderately nutrient-rich, moderately acid, humic soils (SCHAMINÉE et al. 1995b, 208).

Zone 1 - *Betula* zone, *9800-8700* cal BC: Preboreal

In the Preboreal, sedimentation in the Gietsenveentje started in the centre, near core location 59, the site of pollen diagram Gieten V-A.

Pollen of *Sparganium*, probably originating from *Sparganium angustifolium*, reaches maximum values in this zone. Nowadays, *Sparganium angustifolium* occurs in heath pools with a varying water table, especially in western Drenthe. It occurs in moderately nutrient-rich water up to 1 metre deep and grows optimally at a summer water depth of ca. 0.5 m (WEEDA et al. 1994). Unidentified microfossils of Type 128 (VAN GEEL et al. 1989), which may be algal spores, are found regularly in this zone. These occur in eutrophic to mesotrophic open water. Zygo- or aplanospores of Type 314 (*Zygnema* type) reach maximum values in this zone. The occurrence of this type indicates shallow, mesotrophic to eutrophic open water (VAN GEEL et al. 1981).

This period saw a small, shallow, mesotrophic to eutrophic lake in the centre of the Gietsenveentje.

Zone 2 - *Pinus-Betula* zone, *8700-6950* cal BC: Boreal

In the Boreal, sedimentation in the Gietsenveentje extended to core location 49A (pollen diagrams Gieten IV-P and IV-HR: figs. 54-55; macroscopic-remains table Gieten IV-HL: table 14), which is located near the centre of the pingo scar.

The finds of pollen as well as considerable amounts of seeds of *Sparganium* sp. and *Potamogeton* sp. at core locations 49A and 59 document the presence of open water in this period. The finds of spores of Types 128 and 314 (VAN GEEL et al. 1981; 1989) also indicate mesotrophic to eutrophic open water. The presence of zygospores of Type 315 (*Spirogyra* sp.) is another indication for open, relatively eutrophic water in this zone (VAN GEEL et al. 1981). At core location 49A, many seeds were found of *Carex nigra*-type (most probably originating from the species *C. acuta* and *C. elata*) and of *Carex rostrata/vesicaria*. Around the small lake in the centre of the Gietsenveentje a sedge marsh developed, with a plant community related to the present-day *Caricetum vesicariae*. At core location 49A, seeds of *Polygonum lapathifolium* are found in this zone. Core location 63 (Gieten V-C) produced seeds of this species at the beginning of zone 3a. *Polygonum lapathifolium* belongs to pioneer communities which prefer nutrient-rich, particularly nitrogen-rich places, which are flooded or very wet in winter, and almost dry out in summer (SCHAMINÉE et al. 1998).

In this period, the centre of the Gietsenveentje held a shallow, relatively eutrophic lake, bordered by a sedge marsh fringe, which possibly flooded in winter and almost dried out in summer (fig. 72a).

Zone 3a - *Corylus-Ulmus* zone, *6950*-5850 cal BC: Atlantic I

In the first part of the Atlantic, sedimentation in the Gietsenveentje extended to the very edges. In this period, gyttja was deposited at all core locations. The lake in the Gietsenveentje reached its maximum size. Finds of seeds of *Sparganium* sp. and *Potamogeton* sp. and eggs of the water flea *Daphnia* at core locations 49A and 63 demonstrate the presence of open water.

In this period, still many seeds are found of *Carex nigra*-type (most probably originating from *C. acuta* and *C. elata*) and *Carex rostrata/vesicaria*. Compared to the preceding zone, the share of *Carex nigra*-type has increased considerably. Macroscopic-remains and/or pollen values of the following taxa show maxima in this zone: macroscopic remains of *Cladium mariscus, Lycopus europaeus, Mentha aquatica, Glyceria fluitans* and *Juncus effusus*; macroscopic remains and pollen of *Lythrum salicaria* and *Potentilla palustris* (the pollen of *Potentilla*-type most probably originates from this species); pollen of *Galium*-type (most probably originating from *Galium palustre*), Ranunculaceae (from *Ranunculus lingua, R. flammula*), *Lysimachia vulgaris*-type (from *L. thyrsiflora, L. nummularia, L. vulgaris*) and *Dryopteris*-type (from *Thelypteris palustris*).

According to Runhaar et al. (1987) the species listed above are part of a semi-aquatic helophytic vegetation with a moderate nutrient availability. In VI.6 these species were called "shore weeds". Most probably, they were part of plant communities related to the present-day *Cladietum marisci* and *Caricetum elatae* associations (SCHAMINÉE et al. 1995b). These communities, which are poor in species, occur in mesotrophic to eutrophic heath pools where the water depth is less than 0.8 m. In this zone the "shore weed" communities, which formed a belt around the open water in the Gietsenveentje, may partly have replaced the sedge marshes of the preceding zone. Given the macroscopic-remains and pollen finds of *Betula* and *Alnus*, a belt of carr forest with

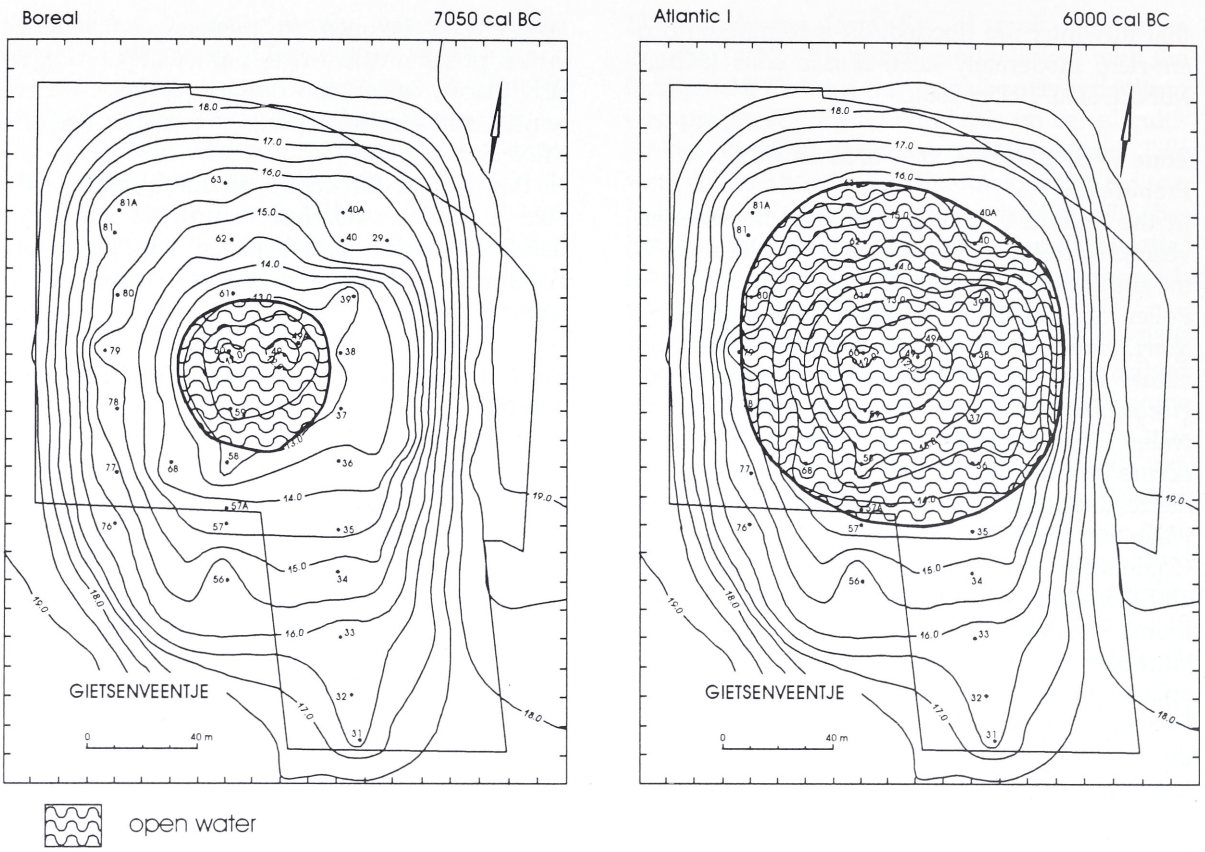


Fig. 72a.

Fig. 72b.

Fig. 72 (pp. 228-230). Vegetation development inside the Gietsenveentje between 7050 and 1500 cal BC. The vegetation development is projected onto a present-day contour map of the Pleistocene subsoil with all core locations. The estimated areas of open water as well as *Sphagnum* peat bog are indicated at five points in time: a. 7050 cal BC (Boreal); b. 6000 cal BC (Atlantic I); c. 5000 cal BC (Atlantic II); d. 2500 cal BC (Subboreal I); e. 1500 cal BC (Subboreal II).

Betula and *Alnus* occurred outside the belt of "shore weed" communities.

In several diagrams, maxima of (asco?)spores of Type 16A are observed in this zone. According to Van Geel et al. (1981), the fungus producing these spores prefers mesotrophic conditions in *Sphagnum* peat, which coincide with relatively dry phases. Possibly, the fungus develops on Graminaceous host plants (VAN GEEL 1978). In the Gietsenveentje diagrams, Type 16A only occurs in gyttja sediment, far below the earliest *Sphagnum* peat. It cannot be correlated with Gramineae maxima.

In the Atlantic I, the largest part of the Gietsenveentje was covered by a shallow, relatively eutrophic lake, bordered by a zone of "shore weed" communities. Outside this margin, carr forests with *Alnus* and *Betula* flourished (fig. 72b).

Zone 3b - *Alnus-Ulmus-Fraxinus* zone, 5850-4050 cal BC: Atlantic II

In the beginning of the second part of the Atlantic, gyttja was still being deposited at all core locations, which points to the presence of open water. In the course of this period, the gyttja sediment gradually turned into *Sphagnum* peat sediment at core locations 49A, 61 and 63, which are situated in the northern part of the Gietsenveentje. Around this transition, *Scheuchzeria* peat, *Carex* peat, and *Sphagnum* peat with *Eriophorum* were deposited at separate locations in the Gietsenveentje (see figs. 44-47).

Seeds and pollen of *Potamogeton* sp. and pollen of *Sparganium* sp. in the gyttja sediment confirm the presence of open water. For the first time pollen and macroscopic remains of *Nuphar lutea* are encountered. Not only pollen and seeds are found,

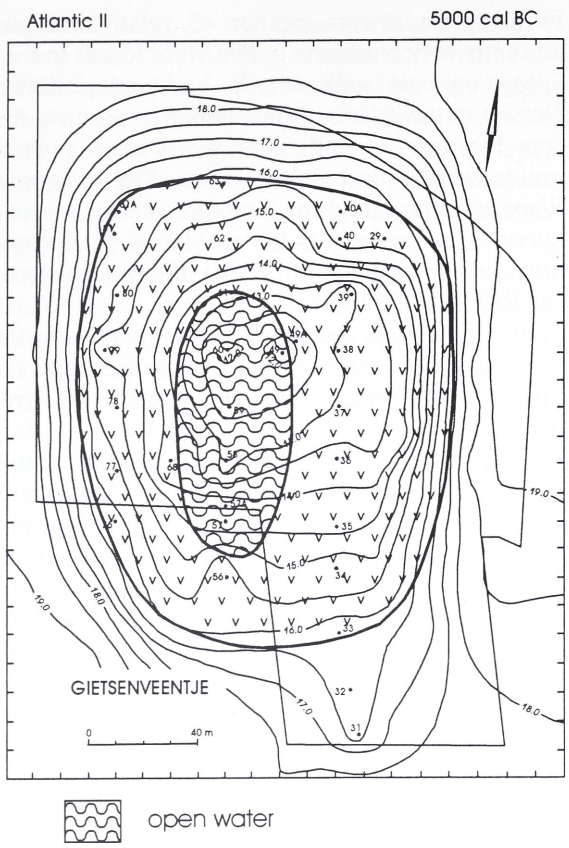


Fig. 72c.

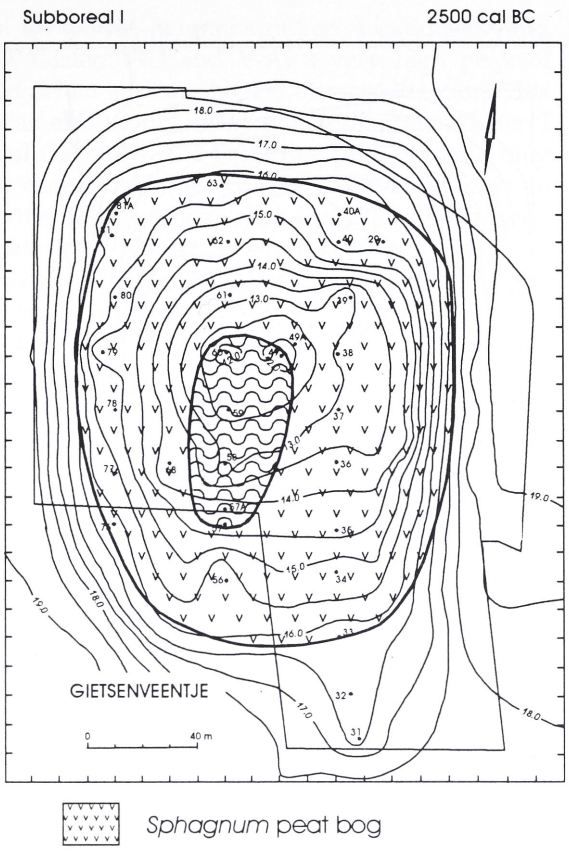


Fig. 72d.

but also asterosclereids (star-shaped hairs) and parts of the epidermis with stomata. *Nuphar lutea* grows in deep to fairly shallow, nutrient-rich water (WEEDA et al. 1985). In the gyttja sediment of core location 63, many coenobia of the green alga genus *Pediastrum* are found. Two taxa could be identified: *Pediastrum duplex* var. *asperum* and *Pediastrum boryanum* var. *brevicorne* f. *brevicorne* (see PARRA BARRIENTOS 1979). According to Nielsen & Sørensen (1992), these two taxa especially occur in slightly eutrophic to eutrophic waters. Apparently, the availability of nutrients in the Gietsenveentje had increased since the Preboreal.

The transition from gyttja to *Sphagnum* peat, which occurs at all locations in the Gietsenveentje, is explained as follows. Until the second part of the Atlantic, the Gietsenveentje was a mesotrophic to eutrophic pool. Via groundwater and surface water, it was in contact with the rich subsoil. This contact caused a relatively high availability of nutrients in the pingo scar. However, it gradually became filled with an impermeable layer of gyttja, which more and more insulated the surface water from the mineral bottom. This caused a considerable decrease in the availability of nutrients in the pool. In turn, this enabled the growth of *Sphagnum* carpets. The gyttja-*Sphagnum* peat transition occurred earlier in the northern than in the southern part of the Gietsenveentje, possibly because the northern edge is much steeper than the southern slope (see figs. 44-47).

The vegetation succession in heath pools in Drenthe, many of which are pingo scars, is described by Barkman (1992). An attempt was made to match the data from the Gietsenveentje with Barkman's description. The succession starts with the *Sphagnetum cuspidato-obesi* association (SCHAMINÉE et al. 1995b, table 10.2): a floating or barely submerged mat of *Sphagnum cuspidatum* is colonized by various species, viz. *Carex rostrata* and *Eriophorum angustifolium*. In richer pools, also *Sparganium angustifolium* and *Menyanthes trifoliata* occur in this stage. At core location 63, many seeds of *Carex rostrata/vesicaria* are found at the transition from gyttja to peat (fig. 65: 95-90 cm). At core location 49A (pollen diagrams Gieten

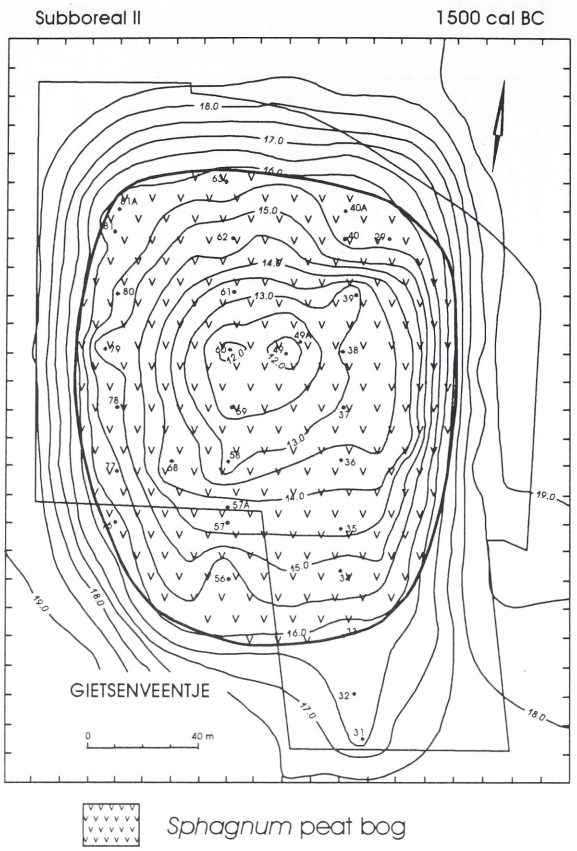


Fig. 72e.

IV-P and IV-HR: figs. 54-55), peaks are observed in the Cyperaceae pollen values at the same transition. The *Sphagnetum cuspidato-obesi* association occurs as long as the surface of the *Sphagnum* carpet lies between 16 cm below the water surface to 2 cm above it (BARKMAN 1992).

The next stage in the terrestrialization process is formed by the *Sphagno-Rhynchosporetum* and the *Caricetum limosae* associations (SCHAMINÉE et al. 1995b, table 10.2). The former occurs in more nutrient- and ion-poor biotopes than the second. The most characteristic species of these associations are *Rhynchospora alba* and *Eriophorum angustifolium*. The *Caricetum limosae* is characterized by the presence of *Scheuchzeria palustris*. At core location 63, *Sphagnum* peat sediment (fig. 65: 85-70 cm) contained macroscopic remains of the following taxa which could have been part of these two associations: *Rhynchospora alba*, *Oxycoccus palustris*, *Potentilla palustris*, *Menyanthes trifoliata*, *Carex rostrata/vesicaria*, *Scheuchzeria palustris* and also many *Sphagnum* leaflets, stem and root remains, capsules and opercula.

Furthermore, at core location 63, relatively high amounts of *Scheuchzeria* pollen were found in the *Sphagnum* peat sediment. In both associations, *Drosera rotundifolia* is a quite common species. At core locations 61 and 63, a few *Drosera* pollen grains were found in this zone. The *Sphagno-Rhynchosporetum* and the *Caricetum limosae* associations occur as long as the surface of the *Sphagnum* carpets lies 6 to 8 cm above the water surface (BARKMAN 1992).

In the *Sphagnum* peat sediment, together with maxima of *Sphagnum* spores, maximum values of the following three types of microfossils are observed:

- Type 13: sporangia of the aquatic, saprophytic fungus *Entophlyctis lobata*. They occur mainly in the oligotrophic part of *Sphagnum* peat. Generally they are found attached to leaves of *Scheuchzeria palustris*, *Calluna vulgaris*, *Andromeda polifolia*, *Oxycoccus palustris*, *Sphagnum imbricatum* and *Erica tetralix* (VAN GEEL 1978).
- Type 27: spores of *"Tilletia sphagni"*. The matrix of this fungus is formed by *Sphagnum* capsules, especially by capsules of *Sphagnum cuspidatum* (VAN GEEL 1978).
- Type 31(A): the rhizopod *Amphitrema flavum* (Thecamoebae). The increase of this type indicates increasing humidity. Generally, it points to more oligotrophic and wet phases. There is a negative correlation between this type and Type 16A (VAN GEEL 1978; VAN GEEL et al. 1981).

The occurrence of these three types of microfossils in the *Sphagnum* peat fits in with the presence of species of the *Sphagno-Rhynchosporetum* and *Caricetum limosae* associations in this phase.

The next stage in the succession is formed by the *Erico-Sphagnetum magellanici* association, which is an oligotrophic raised-bog community forming comparatively dry hummocks in terrestrializing pools (SCHAMINÉE et al. 1995b). This association is dominated by various Ericaceae species (*Erica tetralix*, *Oxycoccus palustris*, *Andromeda polifolia*, *Calluna vulgaris*) and *Eriophorum angustifolium*. At core location 63, this association can be tentatively recognized in the upper part of the macroscopic-remains sequence (fig. 65: 70-65 cm), where leaflets of *Oxycoccus palustris* and seeds of *Eriophorum* sp. were found. In the *Erico-Sphagnetum magellanici*, the water table occurs ca. 22 cm below the surface (BARKMAN 1992).

In meso-oligotrophic heath pools in Drenthe, woodland is nowadays the natural climax in the

marginal zone. In all cases such woodland is dominated by *Betula pubescens* (BARKMAN 1992). In the Gietsenveentje, from the very beginning of the Atlantic, carr forests with *Betula* as well as *Alnus* occurred in a belt around the open water. In the second half of the Atlantic, these carr forests extended further into the Gietsenveentje, especially in the northern part. This is documented by many seeds, scales and branchlets of *Betula* and seeds of *Alnus glutinosa* at core location 63 and by a large piece of *Alnus* wood at core location 49A. At core location 61, pieces of wood of *Frangula alnus* are found in this zone; pollen of *Frangula alnus* and *Sorbus aucuparia* regularly appears, especially at core location 63. These finds point to the presence of *Frangula alnus* and *Sorbus aucuparia*, species which are common in carr forests (STORTELDER et al. 1999).
In this zone, the phosphorus content (P content) of the sediment in the centre and northern part of the Gietsenveentje (core locations 59, 61 and 63) is low; it is comparable to the P content of recent oligotrophic lakes and raised bogs (table 19).
At the beginning of the Atlantic II, a shallow, relatively eutrophic lake remained in the largest part of the Gietsenveentje. In the course of time, the ongoing process of terrestrialization caused a development from open water to marsh in the northern part. Because at a certain moment groundwater and surface water could no longer reach the marsh, it developed into a raised bog. In this part of the pingo scar, the availability of nutrients decreased considerably. Most probably, this raised-bog vegetation flourished in a belt around the open water in the centre (fig. 72c). In turn, the belt of raised-bog vegetation was bordered by a belt of carr forest with *Betula* and *Alnus*. In the course of this period, the raised-bog vegetation belt extended towards the centre of the pingo scar at the expense of the open water.

Zone 4a - *Quercus-Fraxinus* zone, 4050-1770 cal BC: Subboreal I

At the beginning of the Subboreal, the human influence on the vegetation is for the first time observed very clearly in the pollen diagrams. In discussing the local vegetation development of this zone, we have to bear in mind that human influence may also have caused changes in the vegetation within and at the edges of the Gietsenveentje. In the early Subboreal, gyttja was deposited only in the centre and the southern part of the Gietsenveentje (core locations 57 and 59). Compared to the preceding period, the area of open water had become considerably smaller.
In the pollen diagrams of core locations 57 and 59, Gieten V-D and V-A, a very high peak of *Equisetum* in phase NOP-1 attracts attention. This peak also occurs in the pollen diagrams Gieten I and Gieten III. The *Equisetum* peak is found only in diagrams in which phase NOP-1 occurs in gyttja. Most probably, the *Equisetum* spores originate from *Equisetum fluviatile*. This species is a pioneer of terrestrialization in shallow, stagnant, phosphorus-poor water (WEEDA et al. 1985). It often points to seepage areas. However, as was stated already in VI.4.3, the Gietsenveentje is not a seepage area, because it is located on top of the Hondsrug. *Equisetum fluviatile* is not a characteristic species of one or a few plant communities; it is common in many plant communities of the class *Phragmitetea* (SCHAMINÉE et al. 1995b). It can form dominance communities, which are poor in species. Such communities dominated by *E. fluviatile* seem to have occurred on or near the edge of the open water of the Gietsenveentje. The presence of *E. fluviatile* points to mesotrophic conditions in this part of the pingo scar. At core location 61, wood of *Frangula alnus* is found in phase NOP-1. This species probably grew in the carr forest which occurred around the edge of the Gietsenveentje.
In the pollen diagrams from core locations 57 and 59, Gieten V-D and V-A, *Nuphar lutea* reaches maximum values in the gyttja sediment of phase NOP-2. Apart from pollen, also asterosclereids and epidermis parts with stomata of this species are found. The occurrence of *Nuphar lutea* in the central and southern parts of the Gietsenveentje points to fairly eutrophic conditions in the remaining open water.
At core location 57, which is in the southern part of the Gietsenveentje, the boundary between phases NOP-2 and NOP-3 also marks the transition from gyttja sediment to *Sphagnum* peat sediment. During phase NOP-3, open water was only present in the deepest part of the pingo scar, around core location 59.
As a result of the continuing terrestrialization of the Gietsenveentje, only a small area of open water in the centre remained by the end of the Subboreal I, bordered by a broadening belt of raised-bog vegetation. Outside this belt, there was carr forest with predominantly *Alnus* and to a lesser extent *Betula* (fig. 72d).

Zone 4b - *Alnus-Corylus*-Ericaceae zone, 1770-*1100* cal BC: Subboreal II

At core location 59 the transition from gyttja to *Sphagnum* peat sediment occurs at the interface of

zones 4a and 4b. Around this transition, small peaks of *Scheuchzeria* and *Menyanthes* pollen occur in the Gieten V-A diagram from core location 59, which demonstrate the presence of the *Sphagno-Rhynchosporetum* and *Caricetum limosae* associations in this period.
At the beginning of the Subboreal II, the open water had completely disappeared; the entire Gietsenveentje was covered by raised-bog vegetation, bordered by a belt of carr forest dominated by *Alnus* (fig. 72e).

Zone 4c - Ericaceae-*Alnus* zone, *1100-800* cal BC: Subboreal III
At core location 59, pollen of *Equisetum* reaches a second maximum, which is, however, not as high as the maximum in phase NOP-1. Pollen grains of *Rhynchospora*-type and *Drosera* are found, which demonstrate the presence of the *Sphagno-Rhynchosporetum* association at core location 59 in this period.

Zone 5 - *800* cal BC-present: Subatlantic
From 800 cal BC onwards, the human influence on the landscape in the surroundings of the Gietsenveentje strongly increased. At the end of zone 5a, minimum values of all tree pollen types show that nearly all trees in the neighbourhood of the Gietsenveentje had disappeared, including the *Alnus* carr forest. Apparently, arable fields and pastures were laid out right up to the edge of the pingo scar. A maximum of charcoal particles points to the use of fire by man. It is improbable that fire was used to clear the carr forest, because it is very difficult to set such a humid forest on fire. It is more likely that the carr forest was felled and that the waste wood was burned in the vicinity of the pingo scar.
In zones 5b and 5c, suddenly very high values of *Betula* pollen are found at core location 59. This points to the presence of *Betula* inside the Gietsenveentje. As a result of the ongoing terrestrialization and of drainage for the cutting of peat, the Gietsenveentje dried out more and more. As a result, *Betula* could invade the pingo scar. A *Betula* carr forest (belonging to one or more communities of the *Vaccinio-Betuletea pubescentis* class, see STORTELDER et al. 1999) established itself in the centre of the Gietsenveentje. Because no peat digging was practised in the central part of the pingo scar, this *Betula* carr forest still survives there (fig. 48). In a surface sample of core location 59, *Betula* reaches values of more than 50% (fig. 49). Nowadays, owing to an extreme lowering of the water table for agricultural reasons in a large area around the Gietsenveentje, some parts of the pingo scar have dried out to such an extent, that even *Quercus robur* has been able to establish itself.

Core location	Sequence	Beginning of sedimentation	Gyttja-peat transition
57	Gieten V-D	6000 cal BC	2600 cal BC
59	Gieten V-A	9800 cal BC	1770 cal BC
49A	Gieten IV-P	8700 cal BC	5850 cal BC
61	Gieten V-B	?	5000 cal BC
63	Gieten V-C	6000 cal BC	5350 cal BC

Table 20. ^{14}C dates of the beginning of sedimentation and of the gyttja-peat transition at various locations in the Gietsenveentje. A map with all the core locations is shown in fig. 38.

Table 20 summarizes ^{14}C dates indicating the beginning of sedimentation and the gyttja-peat transition at various locations in the Gietsenveentje. It was presumed that the earliest sedimentation occurred in the centre of the pingo scar. Indeed, at core location 59, sedimentation started around 9800 cal BC, in the Preboreal. At core locations 57 and 63, which are near the edges, sedimentation started only around 6000 cal BC, in the last part of the Atlantic. The gyttja-peat transition was assumed to have occurred earliest near the edges of the pingo scar, because in the shallowest parts of the pingo scar the growing gyttja layer filled the open water most rapidly, marking the beginning of *Sphagnum* peat growth. However, this expectation proves not to be entirely right in the Gietsenveentje; the earliest gyttja-peat transition occurs at core location 49A, which is near the centre of the pingo scar. The explanation of this early transition is that a certain layer of gyttja sediment was deposited twice at this location (see VI.3.2). The extra thick layer of gyttja sediment caused a more rapid filling up of the open water, resulting in an early transition to *Sphagnum* peat, even earlier than at the edges. The final gyttja-peat transition occurs at core location 59, roughly the deepest point of the pingo scar. It is remarkable that at the northern edge (core locations 61 and 63), the gyttja-peat transition occurs far earlier than at the southern edge (core location 57). One explanation for this difference is the asymmetric

shape of the pingo scar: to the north it has a steep edge, to the south the slope is more gentle (see figs. 44-47). Near the steep edge, the gyttja layer may have filled up the open water at an earlier stage. Another explanation is that the prevailing wind came from a southerly direction. This caused all floating peat carpets to end up at the northern edge of the lake, filling up the open water more rapidly there than at the southern edge.

It was hoped to detect, in one way or another, direct or indirect human influence on the local vegetation in the Neolithic Occupation Period. In fact, human influence on the local vegetation of the Gietsenveentje can be demonstrated only in zone 5, which covers the period from the Iron Age up to the present day. In the Neolithic Occupation Period (zone 4a), human presence in the area is only detectable in changes in the values of regional pollen types.

VIII. Discussion and conclusions

VIII.1 A model of the Neolithic Occupation Period in Pleistocene areas near the North Sea coast

When the data collected during the present study are combined with data from literature, it may be possible to construct a model of the Neolithic Occupation Period in pollen diagrams which is valid for a larger area than only the Gietsenveentje or the Drenthe Plateau. The ultimate aim is to construct a model of the Neolithic Occupation Period which is valid for Pleistocene areas near the North Sea coast, because these areas are not only characterized by roughly similar geological and edaphic circumstances, but also by finds of the same archaeological cultures. The diagrams of the Gietsenveentje will form the basis for the model. Furthermore, other diagrams from the province of Drenthe and diagrams from northwestern Germany (*Siedlungskammer* Flögeln) will be incorporated. On the basis of the simplified pollen diagrams in figs. 73-74, the Neolithic Occupation Period in the Gietsenveentje diagrams, which is subdivided into three Neolithic Occupation Phases, is correlated with the corresponding periods in the other diagrams from Drenthe and those from northwestern Germany. These diagrams include selected regional pollen types which show clear changes during the Neolithic Occupation Period. The Neolithic Occupation Phases in the Gietsenveentje diagrams (fig. 73a-c) are defined as follows:

NOP-1: Very gradual decline of *Ulmus*; maximum values of *Tilia* and *Quercus*; increase of Non-Arboreal Pollen, particularly Gramineae and *Calluna vulgaris*; appearance of *Plantago lanceolata* and Cerealia-type; increase of *Rumex acetosa*. When the decline of *Ulmus* does not coincide with the first appearance of *Plantago lanceolata*, this phase is subdivided into phase NOP-1a (*Ulmus* decline, no *Plantago lanceolata*) and phase NOP-1b (appearance of *Plantago lanceolata*).

NOP-2: Gradual decrease of *Tilia*; high values of *Pteridium*; relatively high values of Gramineae and *Calluna vulgaris*; maximum values of *Plantago lanceolata*, *Rumex acetosa* and Cerealia-type.

NOP-3: Decrease of *Ulmus*; decrease of Non-Arboreal Pollen; decrease of Gramineae; increase of *Calluna vulgaris*; decrease of *Plantago lanceolata*, *Rumex acetosa* and Cerealia-type.

I have been able to distinguish these Neolithic Occupation Phases also in most of the other diagrams. The similarities and differences in the pollen picture will now be briefly discussed. The locations are indicated on the map of fig. 6.

Eexterveld (fig. 73d). The *Ulmus* decline occurs before the first appearance of *Plantago lanceolata*. The values of *Ulmus* and *Tilia* are lower than in the Gietsenveentje. The NOP-1b/NOP-2 transition is marked by a strong increase of Gramineae and an increase of Cerealia-type. *Plantago lanceolata* and *Rumex acetosa*-type do not increase at the beginning of NOP-2. Gramineae reach higher values, but the culture-indicator types have far lower values here than in the Gietsenveentje.

Emmererfscheidenveen V (fig. 73e). The *Tilia* maximum in NOP-1 is rather weak. Very high values of Ericaceae indicate that this pollen has a predominantly local origin. The highest values of Gramineae occur in the Atlantic. During phases NOP-1, NOP-2 and NOP-3, Gramineae values remain constant. Pollen grains of Cerealia-type are found in the Atlantic; these grains were possibly misidentified, otherwise they must originate from wild grasses, which is not very probable (a Cerealia-type curve is not included in the pollen diagram of the original publication by Van Zeist (1955b)). Values of *Rumex acetosa*-type and *Plantago lanceolata* are lower than in the Gietsenveentje. The ^{14}C date of the NOP-1/NOP-2 boundary (ca. 2700 cal BC) is much younger than the corresponding date in the Gietsenveentje (ca. 3450 cal BC). *Quercus* reaches maximum values in NOP-3. A ^{14}C date of the end of phase NOP-3 (ca. 1700 cal BC) indicates that this phase extends into the Bronze Age.

Bargeroosterveld (fig. 73f; fig. 8). There is no clear *Ulmus* decline. The *Tilia* maximum in phase NOP-1 is pronounced. Irregular values of *Calluna vulgaris* point to a predominantly local origin of this pollen. Gramineae reach a maximum in the Atlantic, which has to be local. The culture-indicator types occur very sporadically in this diagram. Nonetheless, the *Plantago lanceolata* maximum in NOP-2 is pronounced.

Fig. 73 (pp. 237-239). Six simplified pollen diagrams of sequences from Drenthe (the northern Netherlands). Various phases of the Neolithic Occupation Period (NOP) and corresponding ^{14}C dates are indicated. The dates in the Gietsenveentje diagrams (figs. 73 a-c) are calibrated according to Method II calibration of sub-datasets (wiggle matching) (see VI.4.2 and table 9). The dates in the other diagrams of figs. 73 and 74 are calibrated according to Method I calibration, which takes into account the fixed stratigraphical sequence of the dated samples but assumes no constant growth rate (see VI.4.2); here the 1σ ranges of the calibrated dates are given. ^{14}C dates in *italics* are extrapolated dates.

Swienskuhle (fig. 74a). After its initial decline, *Ulmus* recovers in phase NOP-2. *Tilia* shows the same values in the Atlantic and in phase NOP-1; the decline at the end of NOP-2 is pronounced. *Quercus* shows maximum values in NOP-1 and again in NOP-3. The values of *Calluna vulgaris* and Gramineae are high to very high in NOP-2, which indicates that this pollen is for the most part local. The values of the culture-indicator types are relatively high in this diagram. The NOP phases can be correlated with the phases distinguished by Behre & Kučan (1994) in the diagrams of *Siedlungskammer* Flögeln (see II.2.6):
NOP-1: Phase 1 in Behre & Kučan
NOP-2: Phase 2 in Behre & Kučan
NOP-3: not distinguished by Behre & Kučan
In the Swienskuhle diagram, a date of ca. 1700 cal BC is obtained for the depth of 130 cm, which is in the middle of NOP-2. This suggests that the last part of NOP-2 and the entire phase NOP-3 are part of the Bronze Age. However, the NOP-2/NOP-3 boundary is not very clear in this diagram. It is also possible that NOP-2 ends at 130 cm, and that NOP-3 is completely missing.

Jagen 20 (fig. 74b). The *Ulmus* decline occurs before the first appearance of *Plantago lanceolata*. After its initial decline, *Ulmus* recovers for a short period at the end of NOP-1. *Quercus* reaches very high values in NOP-1 (up to 80% of the AP!). The *Tilia* and *Quercus* declines at the end of NOP-1b are very pronounced. *Calluna vulgaris* and Gramineae reach exceptionally high values in NOP-2, indicating that the pollen of these taxa has a largely local origin. The culture-indicator types are very poorly represented in this diagram. There is no increase, but a decrease of these types in NOP-2. The NOP-1b/NOP-2 boundary is dated at ca. 2750 cal BC, which is on the young side (BEHRE & KUČAN 1994, 106). The NOP-2/NOP-3 boundary is dated at ca. 1900 cal BC, which means that phase NOP-3 is part of the Bronze Age.

Flögelner Holz (fig. 74c). The *Ulmus* decline, which is fairly gradual here, occurs before the first appearance of *Plantago lanceolata*. *Ulmus* briefly recovers in phase NOP-2. The *Tilia* maximum in NOP-1 and the *Tilia* decline at the NOP-1b/NOP-2 boundary are pronounced. *Quercus* reaches no maximum in NOP-1. Irregular values of *Calluna vulgaris* and Gramineae show that the pollen originates from local plants, although Gramineae reach maximum values in NOP-2. The culture-indicator types are very poorly represented in this diagram. Cerealia-type is only found in the Atlantic (!) and in phase NOP-1b. *Rumex acetosella* (sic) is not present in each sample; *Plantago lanceolata* shows a small increase in NOP-2. The beginning of phase NOP-1 is not dated. The NOP-2/NOP-3 boundary is dated at ca. 2100 cal BC, which implies that phase NOP-3 comprises the last part of the Neolithic and the first part of the Bronze Age.

Silbersee (fig. 74d). The *Ulmus* decline is very gradual. The *Tilia* and *Quercus* maxima in NOP-1 are very pronounced, but these two types decline only gradually at the end of NOP-1. High and irregular values of *Calluna vulgaris* and Gramineae point to the mainly local origin of the pollen of these taxa. Again, the culture-indicator types are poorly represented. The increase of these types at the NOP-1/NOP-2 boundary is not very clear. A few grains of *Plantago lanceolata* are found in the Atlantic. There are no dates for the NOP phases in this diagram.

Fuhrenkamp (fig. 74e). The *Ulmus* decline is very indistinct in this diagram; the first signs of a decline occur before the first appearance of *Plantago lanceolata*. There is also no clear *Tilia* decline. *Quercus* reaches higher values in NOP-2 than in NOP-1, which is different from all the other diagrams from Flögeln. Probably most of the *Calluna vulgaris* pollen in this diagram is of local origin. Gramineae increase in NOP-2. Their comparatively stable and low values point to a regional origin of the pollen. Again, the culture-indicator types show very low values throughout the diagram, but the highest values are reached in NOP-2. A few grains of *Plantago lanceolata* are found in the Atlantic. Phase NOP-3 is missing in this diagram: after phase NOP-2, Gramineae and the culture-indicator types only increase. According to an extrapolated ^{14}C date of ca. 1550 cal BC for the end of phase NOP-2, phase NOP-2 extends into the Bronze Age.

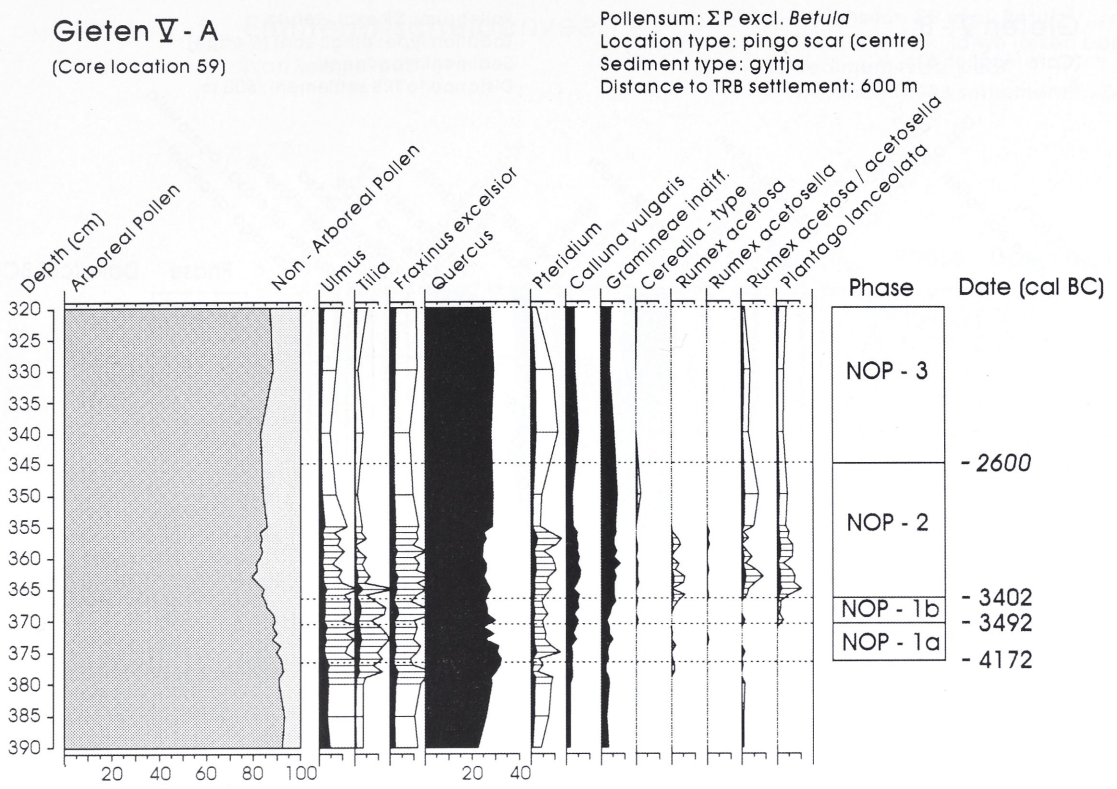


Fig. 73a.

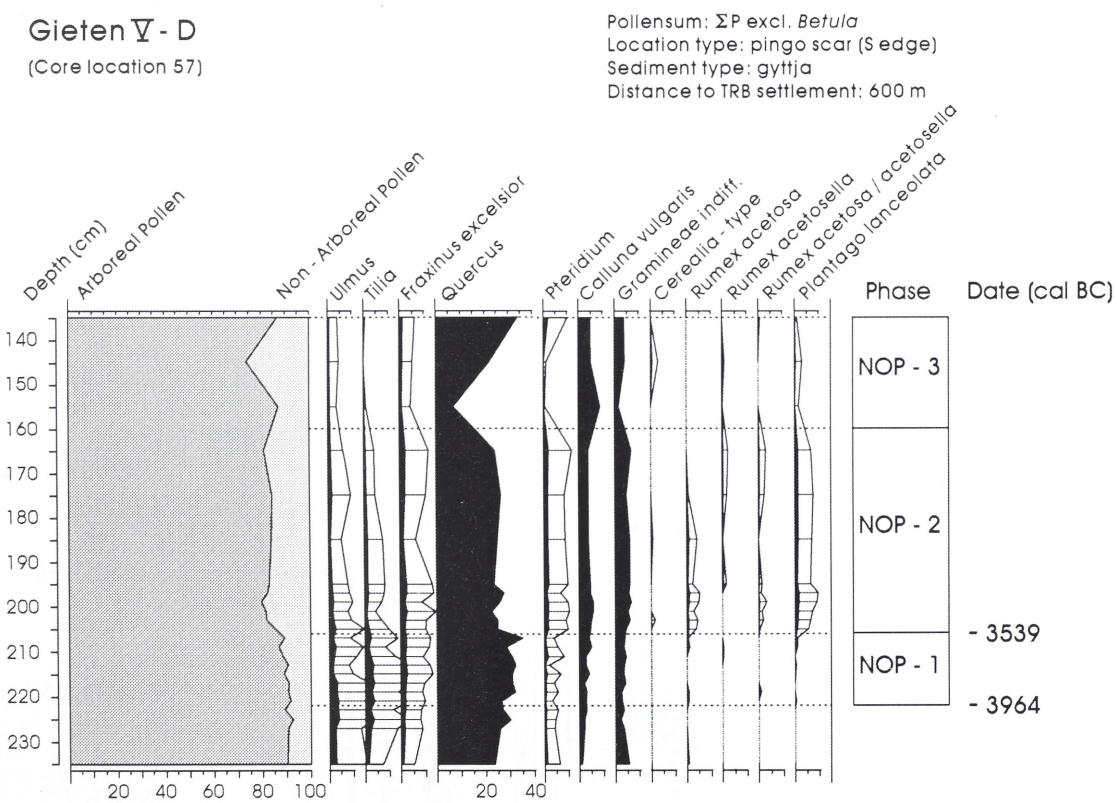


Fig. 73b.

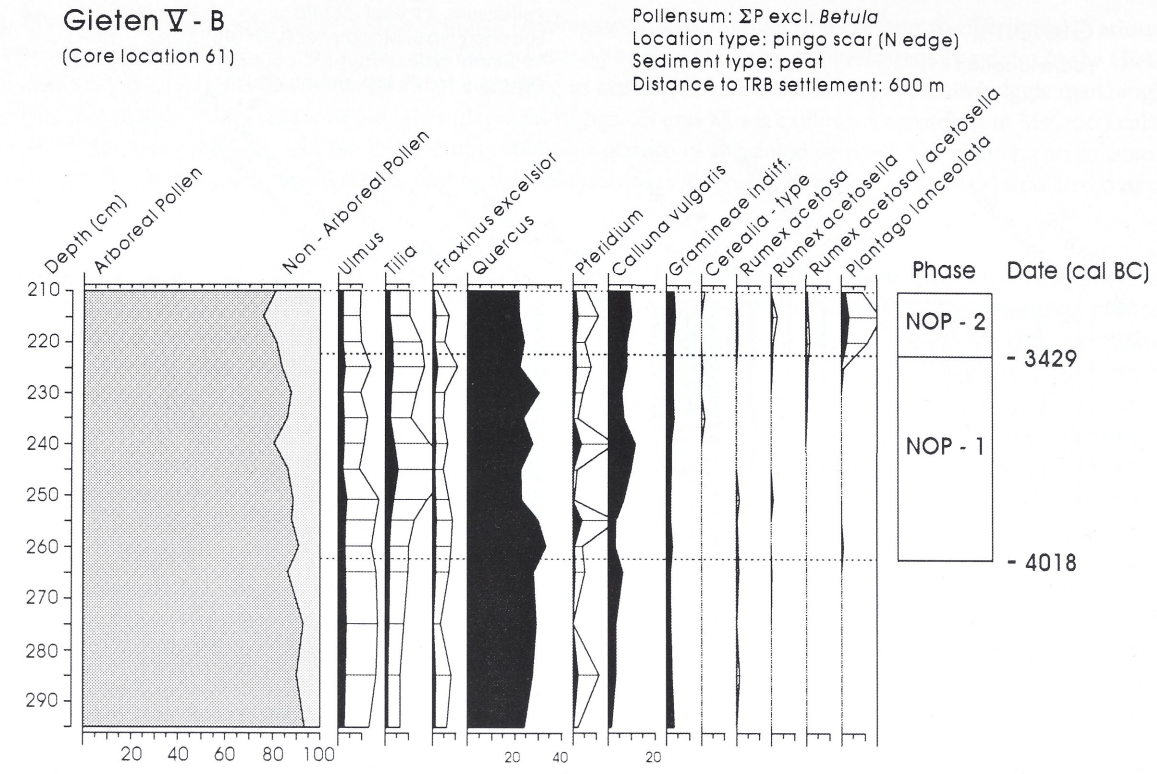


Fig. 73c.

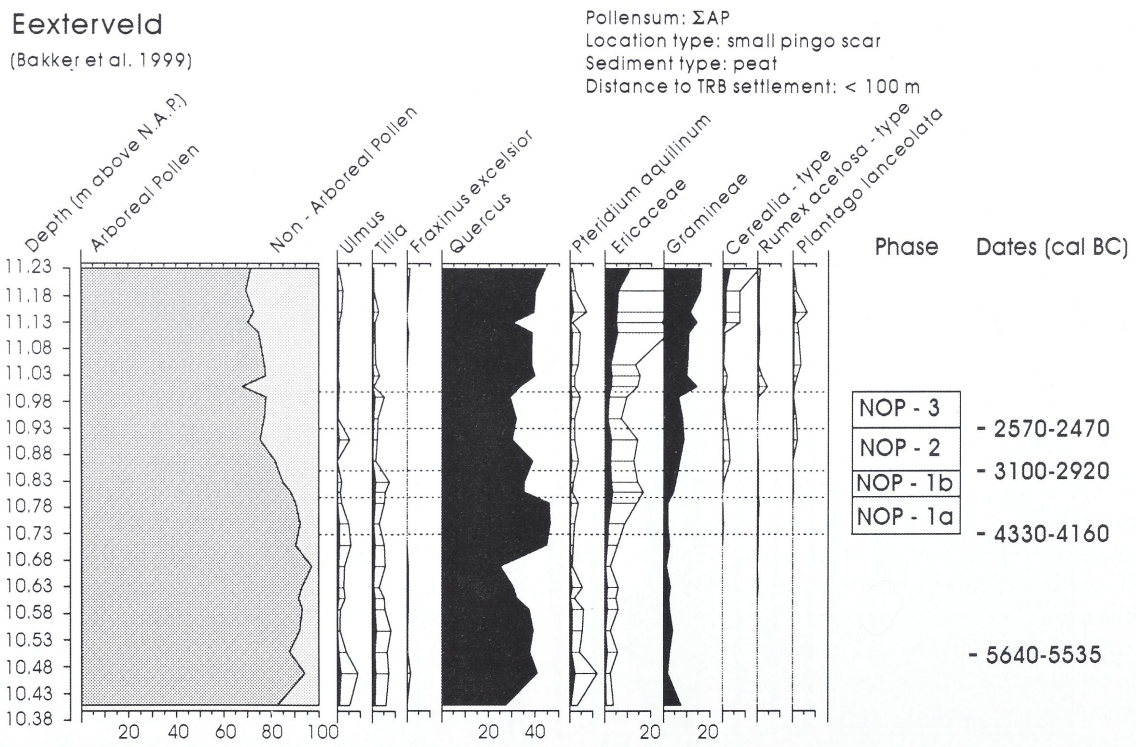


Fig. 73d.

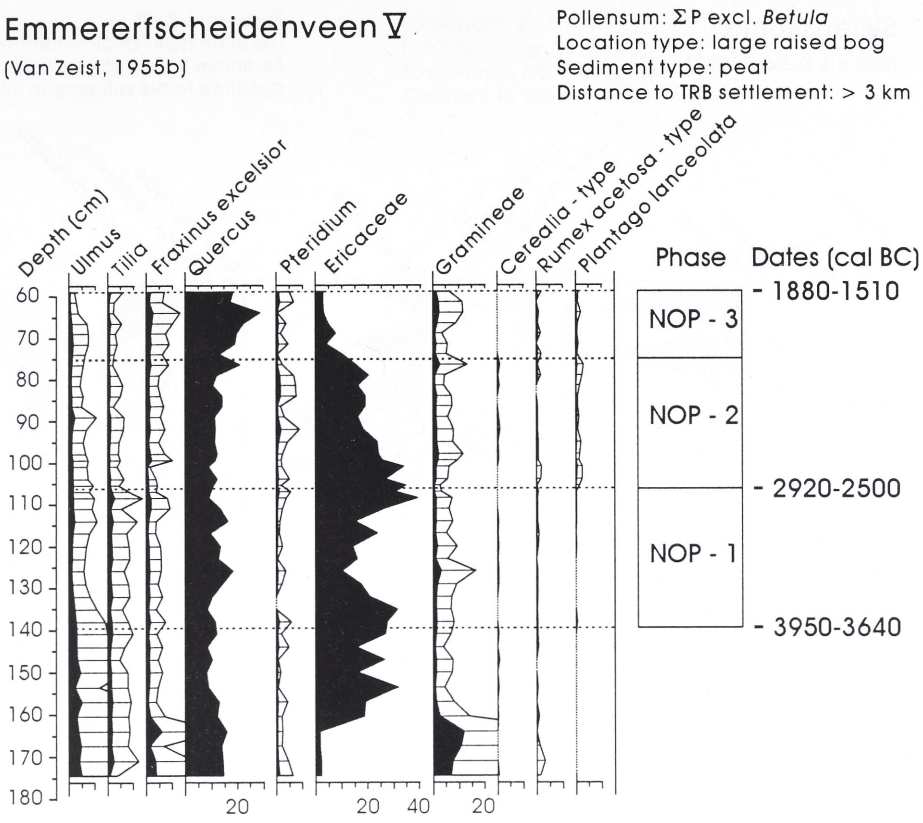


Fig. 73e.

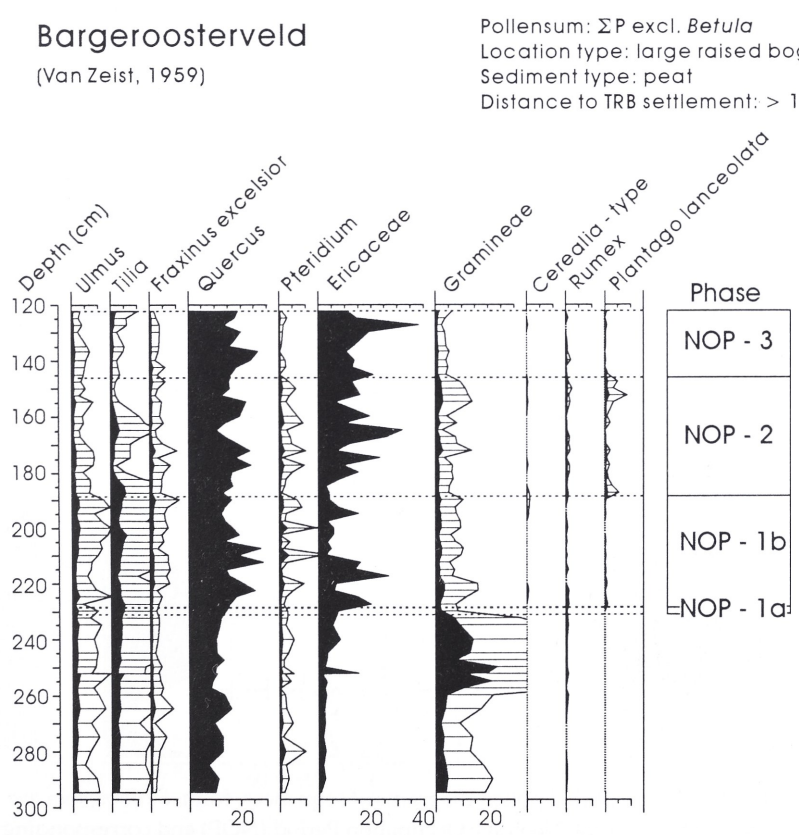


Fig. 73f.

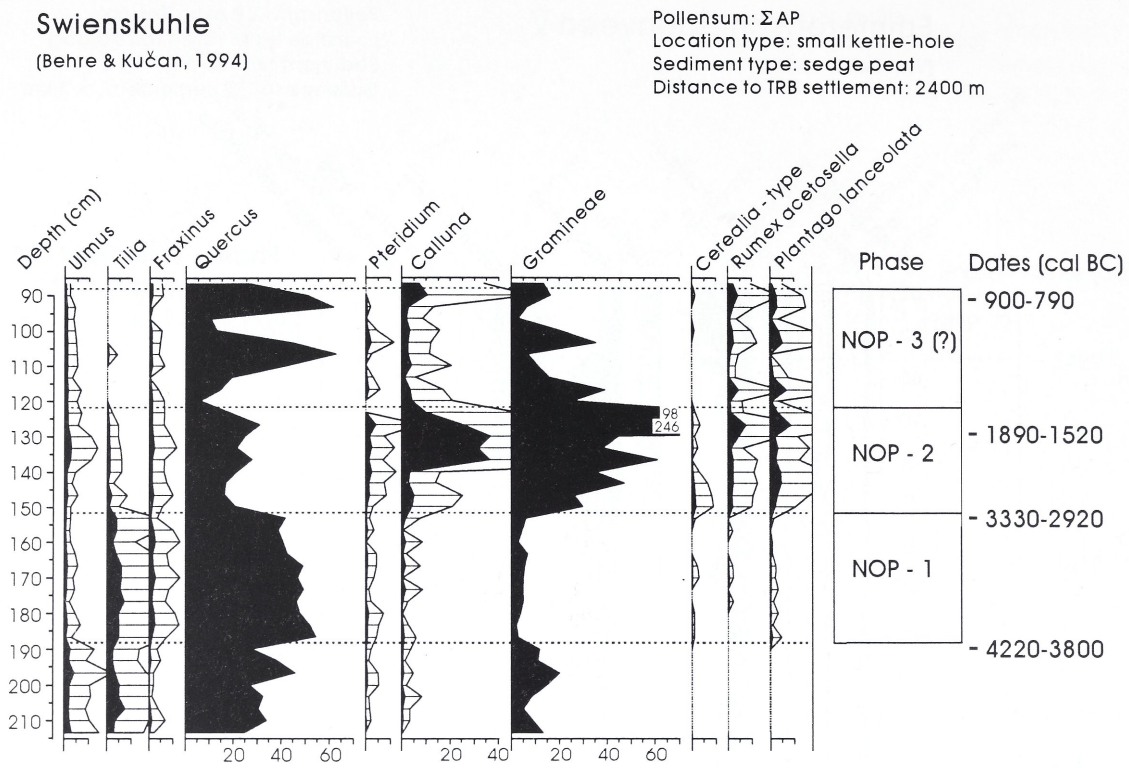


Fig. 74a.

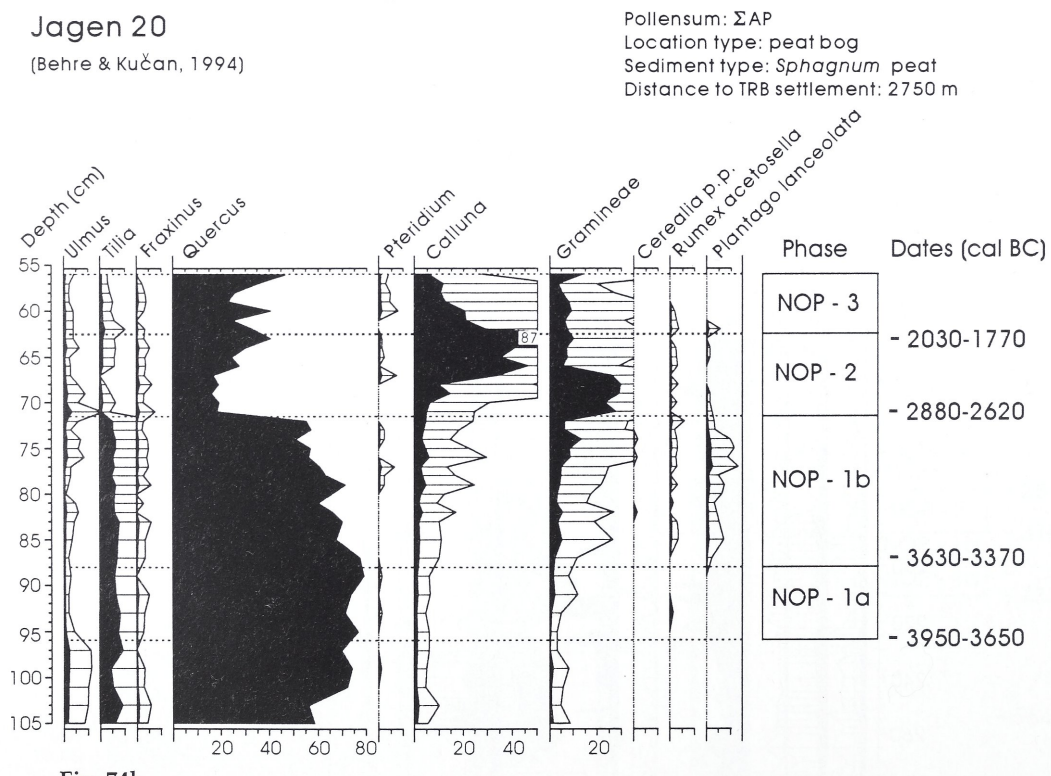


Fig. 74b.

Fig. 74 (pp. 240-242). Six simplified pollen diagrams of sequences from *Siedlungskammer* Flögeln (northwestern Germany). Various phases of the Neolithic Occupation Period (NOP) and corresponding ^{14}C dates are indicated.

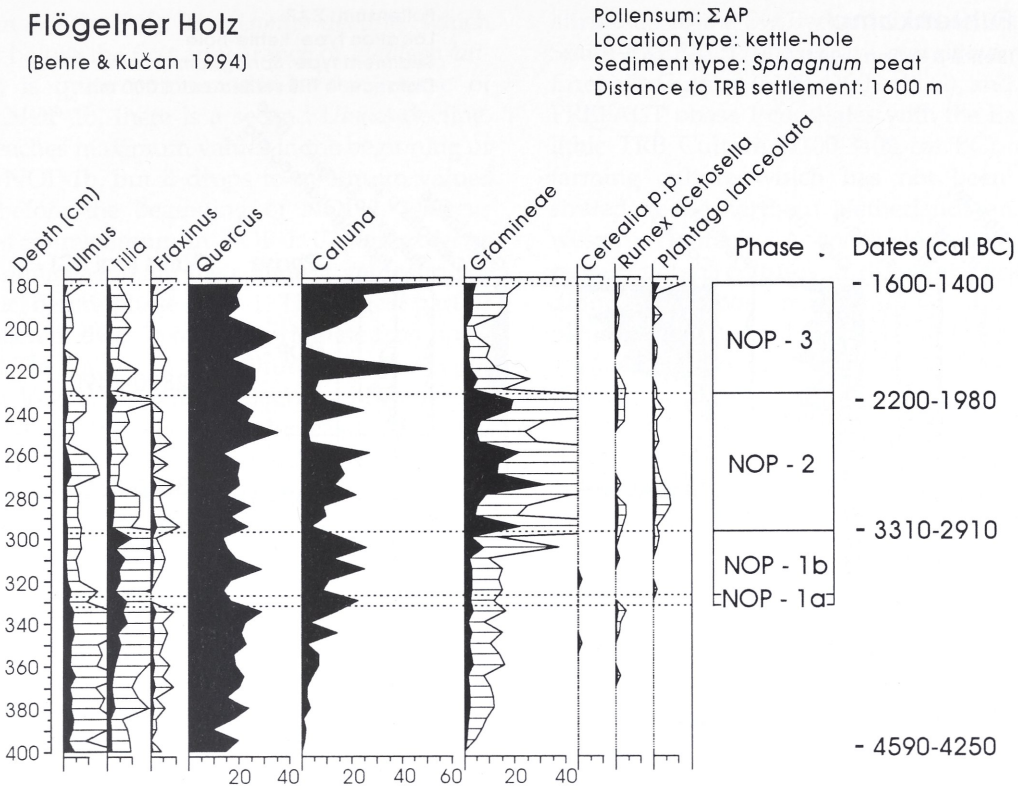


Fig. 74c.

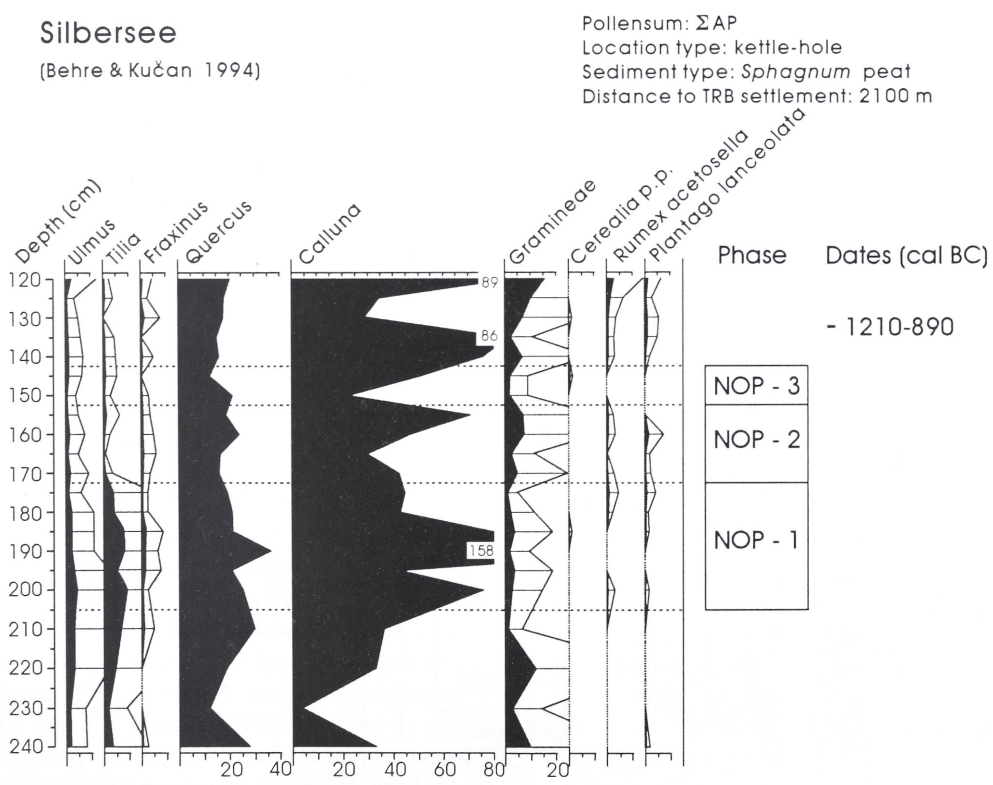


Fig. 74d.

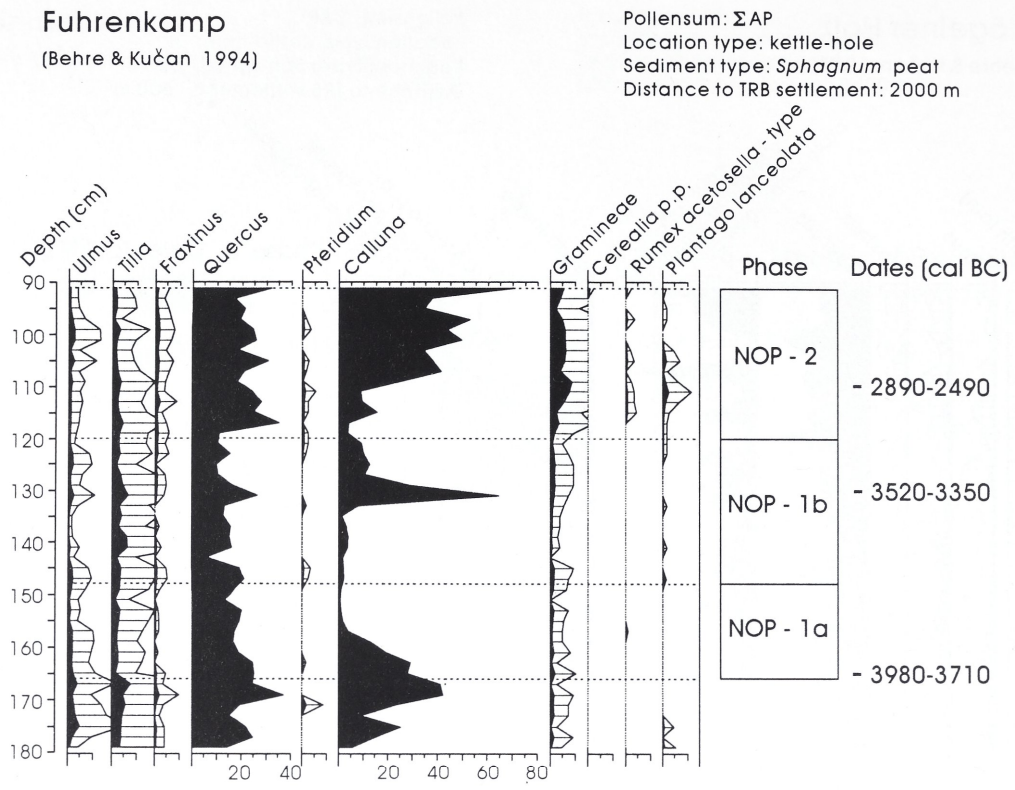


Fig. 74e.

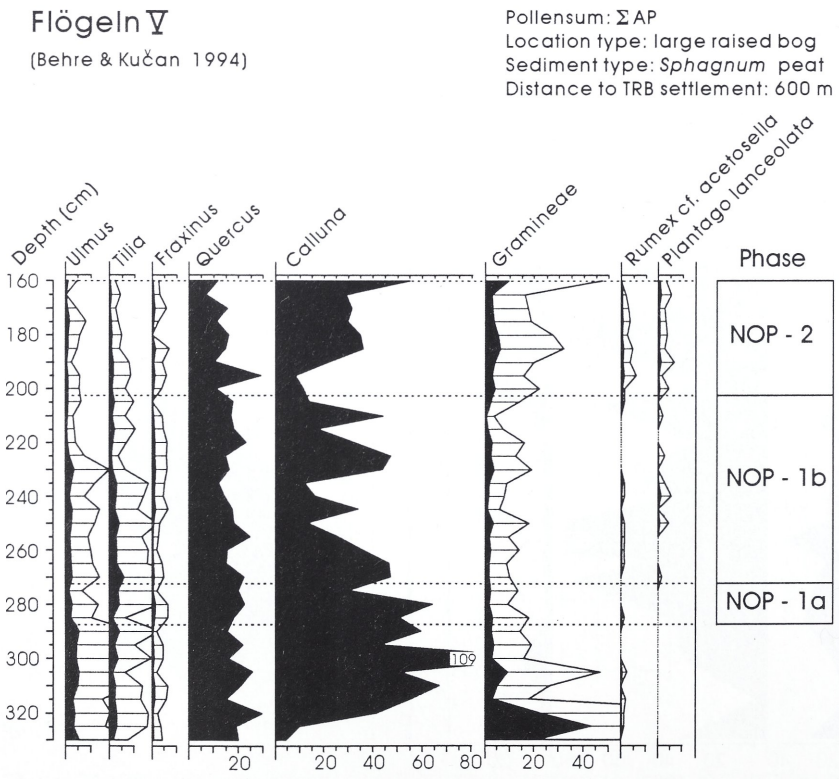


Fig. 74f.

Flögeln V (fig. 74f). The *Ulmus* decline, which occurs before the first appearance of *Plantago lanceolata*, is quite pronounced. In the course of phase NOP-1b, there is a second *Ulmus* decline. *Tilia* reaches maximum values in the beginning of phase NOP-1b, but it drops to minimum values even before the beginning of NOP-2. *Quercus* reaches no maximum in NOP-1. *Calluna vulgaris* and Gramineae attain their highest values in the Atlantic, before phase NOP-1. The largest part of the pollen of these taxa must originate from local plants. The values of the culture-indicator types remain low in the entire diagram; however, in phase NOP-2 there is a clear increase of *Plantago lanceolata* and *Rumex* cf. *acetosella*. Cerealia-type pollen grains are not found at all in the Neolithic Occupation Period. There are no dates of this part of the diagram. Phase NOP-3 seems to be completely absent; after NOP-2, Gramineae and the culture-indicator types only increase. According to Behre & Kučan (1994, 132), the entire phase NOP-2 falls in the Bronze Age. Yet it is possible that phase NOP-2 already begins at the *Tilia* decline of 230 cm, and that it ends at 200 cm. Then the part above 200 cm would belong to the Bronze Age. However, if this is true, there is no increase of Gramineae and culture-indicator types in phase NOP-2.

The Neolithic Occupation Phases as defined above will now be compared with the Iversen and Troels-Smith occupation phases which are distinguished by Kalis & Meurers-Balke (1998; 2001) for the western Baltic. In fig. 75, simplified versions of the original pollen diagrams by Iversen and Troels-Smith are shown, with updated phase indications and (extrapolated) dates added by Kalis & Meurers-Balke (see figs. 4-5). In the diagram of Aamosen, the first phase of human activity, Troels-Smith-PREFACT phase A, begins as early as 5000 cal BC, which is approximately 1000 years before the "classic" *Ulmus* decline. Phase NOP-1 in diagrams of Pleistocene areas near the North Sea coast has some affinity with the Troels-Smith-PREFACT phases and with Iversen-PREFACT phase 1 in diagrams of the western Baltic. However, a major difference is that in Pleistocene areas near the North Sea coast, the "classic" *Ulmus* decline occurs at the beginning of phase NOP-1, while in the western Baltic, the "classic" *Ulmus* decline occurs approximately halfway along Iversen-PREFACT phase 1, which is completely after the Troels-Smith-PREFACT phases. These various phases were caused by completely different cultures: phase NOP-1 is attributed to the Swifterbant Culture; the Troels-Smith-PREFACT phases are correlated with the Ertebølle Culture (5100-4100 cal BC), and Iversen-PREFACT phase 1 correlates with the Early Neolithic TRB Culture (4100-3400 cal BC), an early farming culture which has not been demonstrated in the northern Netherlands and northwestern Germany. A conclusion must be that quite different cultures in different areas and in different periods may cause similar pollen pictures. In spite of the difference in cultures, the *Ulmus* decline occurs contemporaneously both in Pleistocene areas near the North Sea coast and in the western Baltic, namely around 4000 cal BC (see fig. 10).

Kalis & Meurers-Balke correlate Iversen-PREFACT phase 2 with the last part of the Early Neolithic TRB and with the first part of the Middle Neolithic TRB (3400-3150 cal BC). The pollen picture of this phase is characterized by low values of *Ulmus* and *Tilia* and relatively high values of the culture-indicator types. Phase NOP-2 in diagrams of Pleistocene areas near the North Sea coast has some affinity with Iversen-PREFACT phase 2 in diagrams of the western Baltic. Both phase NOP-2 and the latter and major part of Iversen-PREFACT phase 2 are associated with strongly related cultures: the West Group and the North Group of the Middle Neolithic Funnel Beaker Culture (TRB), respectively.

Iversen-PREFACT phase 3 is correlated by Kalis & Meurers-Balke (2001) with the last part of the Middle Neolithic TRB (3150-2900 cal BC). The pollen picture is characterized by small increases of *Ulmus*, *Tilia* and *Fraxinus* and a decrease of Gramineae and the culture-indicator types. Phase NOP-3 in diagrams of Pleistocene areas near the North Sea coast has some affinity with Iversen-PREFACT phase 3 in diagrams of the western Baltic. A difference is that in phase NOP-3, *Ulmus*, *Tilia* and *Fraxinus* remain constant, while in Iversen-PREFACT phase 3, these taxa increase. Clearly, these two phases were caused by different cultures: phase NOP-3 by people of the Single Grave Culture (EGK), the Bell Beaker Culture (BB) and possibly the Bronze Age, and Iversen-PREFACT phase 3 by the Middle Neolithic TRB.

Factors influencing the manifestation of the NOP in pollen diagrams

The manifestation of the Neolithic Occupation Period in the various pollen diagrams can be severely affected by local conditions. In my view, the following four factors are the most important

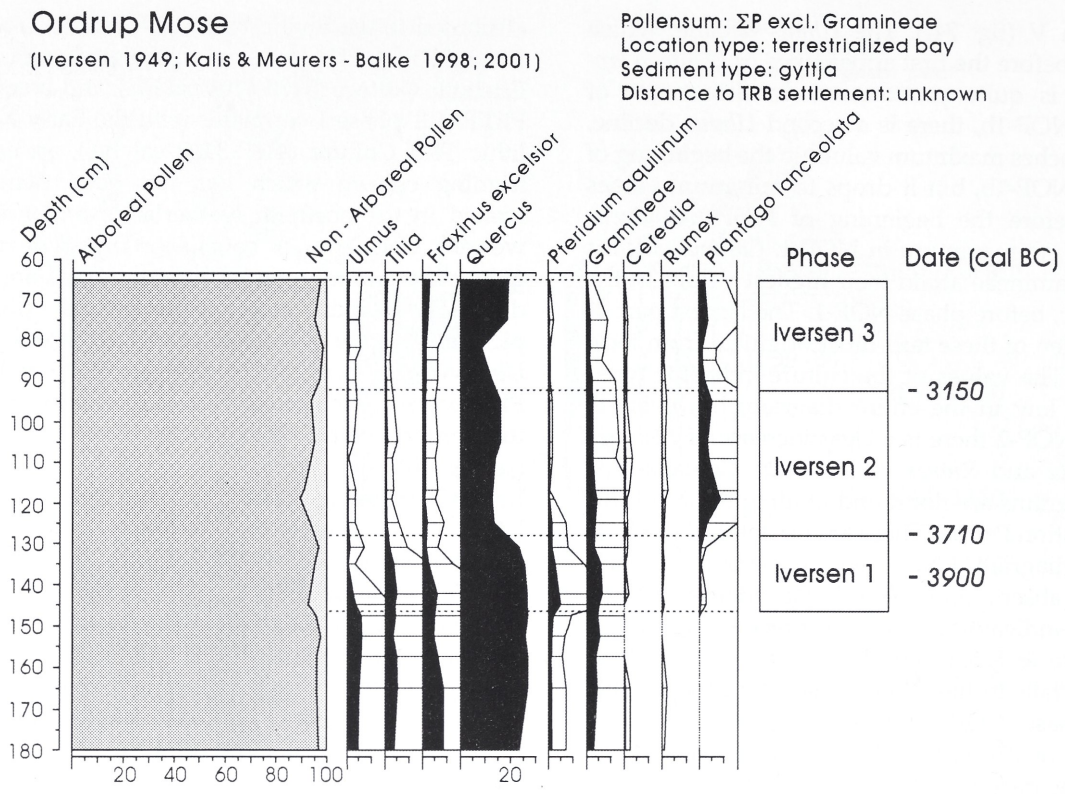


Fig. 75a.

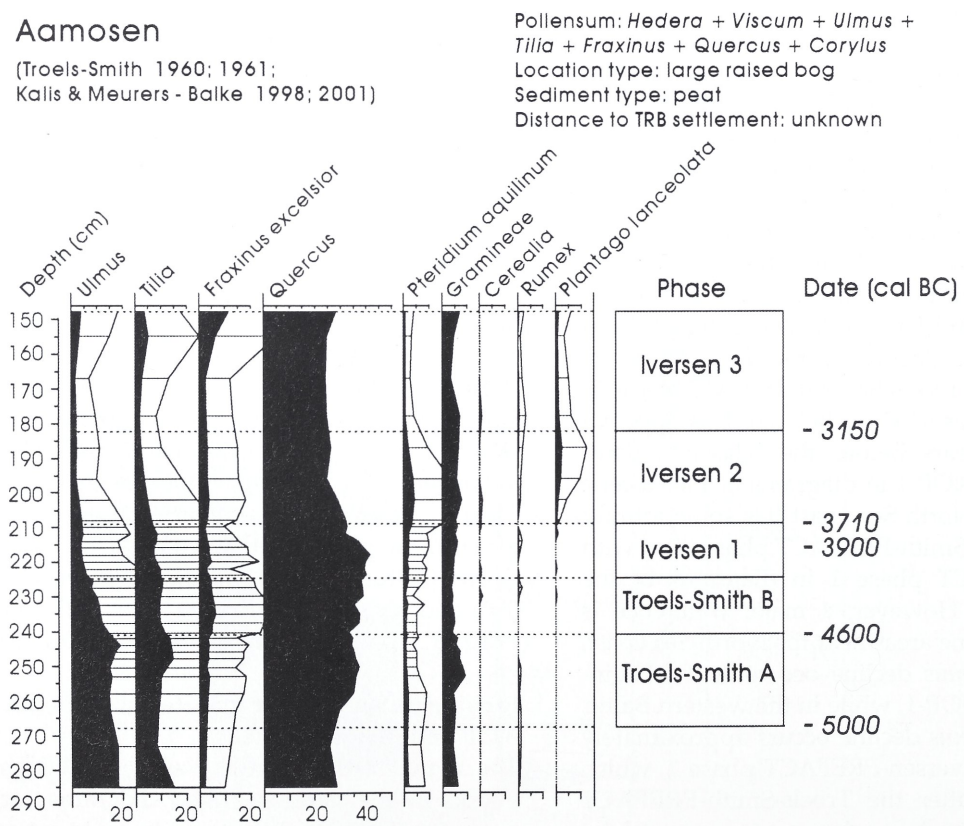


Fig. 75b.

Fig. 75 (left). Two simplified pollen diagrams of the original Danish sequences used by Iversen and Troels-Smith for the construction of their respective models of Neolithic occupation. Various Iversen and Troels-Smith occupation phases, distinguished by Kalis & Meurers-Balke (1998), and corresponding ^{14}C dates are indicated. The ^{14}C dates are all extrapolated dates from dated pollen sequences from eastern Holstein (see KALIS & MEURERS-BALKE 2001).

ones influencing human-induced changes in pollen curves in the NOP: location type, sediment type, location within the basin and distance to the settlement and/or agricultural land. Hereafter some examples will be briefly discussed, demonstrating the possible influence of these factors.

Location type:
In small and medium-sized basins (up to circa 250 m across), the local component of the pollen rain is expected to prevail (TAUBER 1965; J.A. BAKKER et al. 1999). Signals from events at a greater distance will be reflected only weakly. The smallest basin discussed in this section is the bog on the Eexterveld (24 x 10 m). When the pollen values of this pingo scar are compared with those of the medium-sized basin of the Gietsenveentje, which is located at a distance of only 2 kilometres (see fig. 24), it can be seen that in the Neolithic Occupation Period, the values of *Ulmus, Tilia, Quercus, Corylus* and the culture-indicator types are lower, while the values of *Betula, Alnus* and Gramineae are higher than in the Gietsenveentje. Most probably, *Betula, Alnus* and certain Gramineae grew on the edge or even within the pingo scar. Because the pollen of these taxa dominated the pollen rain, the pollen of regional taxa became relatively less important. A different situation is found in the two smallest basins of *Siedlungskammer* Flögeln, Swienskuhle (42 x 27 m) and Jagen 20 (170 x 54 m): especially in phase NOP-1 of the corresponding pollen diagrams, high to very high values of *Quercus* are found. Evidently, oak trees in this period grew almost at the edge of these small basins.
In large basins (diameter larger than circa 250 m), the regional component of the pollen rain is expected to have a more clear-cut expression because not much pollen-producing vegetation would grow inside the basin. The three diagrams from large raised-bog areas discussed here, Emmererfscheidenveen V, Bargeroosterveld and Flögeln V, have remarkably many characteristics in common, although these diagrams are from locations hundreds of kilometres apart. The values of *Ulmus, Tilia, Quercus*, Gramineae and the culture-indicator types are lower, while the values of *Alnus, Pinus* and *Calluna vulgaris* are higher than in most diagrams from small basins. The low values of *Ulmus, Tilia, Quercus*, Gramineae and the culture-indicator types are explained by the larger distance from the rich forests and human activities in these forests. The high values of *Calluna vulgaris* and *Alnus* are caused by plants or trees growing on the raised bog itself and at the edges. Most pollen of *Pinus* is believed to originate from long-distance transport, because of the good distribution capacity of the *Pinus* pollen grains (BIRKS & BIRKS 1980, 180). Therefore the high values of *Pinus* are explained by an increased importance of regional pollen.
Summarizing, it can be stated that it is difficult to demonstrate differences in the pollen rain due to basin size for the purpose of distinguishing small and medium-sized basins. The pollen rain in large basins, however, shows several characteristics which are clearly caused by basin size.

Sediment type:
The sedimentation of the same pollen rain in different sediment types may result in different pollen pictures. The Gietsenveentje sequences offer an excellent opportunity to compare the Neolithic Occupation Period as recorded in gyttja and in *Sphagnum* peat: in sequences Gieten V-A and V-D, the NOP occurs in gyttja, while in Gieten V-B, it occurs in *Sphagnum* peat (fig. 45). For several reasons the pollen content of peat sediment is generally considered to be more reliable than the pollen content of gyttja sediment. First, the sedimentation rate of *Sphagnum* peat is higher than that of gyttja: in the Gietsenveentje, the mean sedimentation rate of the *Sphagnum* peat is 0.99 mm/year, while the mean sedimentation rate of the gyttja is 0.55 mm/year (see VI.5.2). Because of the higher sedimentation rate, the resolution of events recorded in the pollen rain is higher in *Sphagnum* peat. Secondly, compared to gyttja, the horizontal and vertical movement of pollen in *Sphagnum* peat is very limited. The compaction of *Sphagnum* at lower levels restricts vertical movements of pollen. The compact layer is formed in 5-10 years (CLYMO 1973). In lakes, horizontal and vertical redistribution of pollen will often occur. In the Gietsenveentje lake, horizontal movement of pollen may have been caused by wind; vertical movement almost

certainly occurred when water turbulence mixed the upper, loose sediment layer and through the activities of burrowing animals, such as midge larvae and worms. These creatures can redistribute pollen over a vertical distance of up to 15 cm, although most disturbance is within 3-4 cm (R.B. DAVIS 1967; 1974). In the gyttja sediment of the Gietsenveentje, 3-4 cm on average represent 55-75 years, which is less than the confidence limits of the ^{14}C dates (see table 9). In pollen diagrams from gyttja sediment, the mixing activities of animals result in smoothed curves.
When the diagrams of Gieten V-A and V-D, in which the NOP occurs in gyttja, and Gieten V-B, in which the NOP occurs in peat, are compared, it is found not only that the curves of the first two diagrams are clearly more smoothed, but also that in diagram Gieten V-B, phase NOP-1 is represented by a considerably longer piece of sediment core than in diagrams Gieten V-A and V-D (table 21).
In spite of the different process of pollen sedimentation in gyttja and *Sphagnum* peat, the reflection of the Neolithic Occupation Period in the gyttja diagrams Gieten V-A and V-D and the peat diagram Gieten V-B is more or less the same: both the palynological characteristics and the ^{14}C dates of the various NOP phases correspond remarkably well. According to these observations, the influence of sediment type on the course of the pollen curves in the case of the Gietsenveentje seems to be limited.

Location within the basin:
Generally, sequences for pollen analysis are cored in the centre of a basin. However, the larger the basin, the greater the differences in pollen values between sequences from the centre and the edges. In only very few published studies are several pollen cores from one basin compared (for example SØNSTEGAARD & MANGERUD 1977). In the case of the Gietsenveentje, nine pollen sequences were cored at various locations within the pingo scar. It has already been outlined in VIII.1 that there are indeed differences in pollen values between diagrams from the centre and diagrams from the edges, although these differences are not fundamental. Possibly, the still fairly small basin size of the Gietsenveentje (200 x 170 m) explains the relatively minor differences in pollen content between sequences cored in different parts of the basin.

Distance to the settlement and/or agricultural land:
When the human influence on the vegetation in the Neolithic Occupation Period is studied on the basis of pollen and macroscopic-remains sequences, two important questions are: What was the nature of the human activities, and: At what distance did these human activities take place? It may be very difficult to separate these two factors. Small-scale human activities in the direct neighbourhood of a core location might cause the same changes in the pollen picture as large-scale activities at a larger distance. Archaeology can help us to resolve this problem. When there are archaeological traces of a certain culture in the direct vicinity of a core location, it is expected that this culture also left traces in the pollen diagram of that core. When the relationship between palynology and archaeology is studied, as is done in this study, core locations are selected in an area with a large density of archaeological finds from the period in which the researcher is interested; preferably, the core location is as close to the archaeological findspots as possible. The researcher hopes to find some kind of relationship between the pollen values of especially the culture-indicator types and the distance of the archaeological finds from the core location. Unfortunately, this relationship is often not very clear, sometimes even completely unclear. A few examples from the diagrams discussed in this section and in II.2 may illustrate this.
In the bog on the Eexterveld, sherds of TRB pots were found; within 200 m, there are several other TRB findspots (J.A. BAKKER et al. 1999). The TRB findspot closest to the Gietsenveentje lies at a distance of 600 m (see fig. 24). Still, the pollen values of the culture-indicator types in the Gietsenveentje diagrams are considerably higher than in the diagram of Eexterveld.
In the *Siedlungskammer* Flögeln, a TRB settlement with house plans was excavated (ZIMMERMANN 1980). Remarkably enough, the pollen sequences farthest from the TRB settlement, Swienskuhle and Jagen 20, produced the highest values of Gramineae and culture-indicator types, while in the pollen sequence Flögeln V, which is located only 600 m from the TRB settlement, only very low values of Gramineae and the culture-indicator types were observed! However, the location type of Flögeln V may also be partly responsible for the low values of Gramineae and culture-indicator types: the sequence Flögeln V was cored not far from the edge of a large raised-bog area.

Another example are two peat sequences cored near a settlement of the Vlaardingen Culture (present in the western and southern Netherlands more or less simultaneously with the TRB Culture) near Leidschendam, province of Zuid-Holland. In both pollen diagrams, only very low values of the culture-indicator types were found; in the sequence cored 40 m from the settlement, the pollen values of the culture-indicator types were lower than in the sequence cored 200 m from the settlement (GROENMAN-VAN WAATERINGE et al. 1968).

At Siggeneben-Süd in northeastern Germany, a pollen sequence was cored only 10 m from a settlement dated to the Early Neolithic Funnel Beaker Culture (MEURERS-BALKE 1983; KALIS & MEURERS-BALKE 1998; see II.2.9). In the pollen diagram, the Early Neolithic TRB is represented by Iversen-PREFACT phases 1a, 1b and 2a (KALIS & MEURERS-BALKE 1998, 7). However, the culture-indicator types in these phases show very low values. The values of *Plantago lanceolata* are even higher in Troels-Smith PREFACT phase B, which represents the Ellerbek Group (Ertebølle/Ellerbek Culture)!

These examples indicate that there is often no direct relation between pollen values of culture-indicator types and the distance of archaeological finds to the core location. This makes the interpretation of pollen values of culture-indicator types in terms of human influence on the landscape extremely difficult. Pollen diagrams in the first place reflect agricultural activities and not activities which took place in a settlement. For convenience, it is assumed that agricultural activities took place in the direct vicinity of settlements. For this reason it is believed that when core locations of pollen sequences are located in the neighbourhood of settlements, high values of culture-indicator types will be found. In practice, this seems far from true. High values of culture-indicator types more probably point to the close presence of agricultural land. The problem is, however, that it is often difficult to demonstrate the presence of agricultural land archaeologically. Direct archaeological evidence for agricultural land, like ard marks or Celtic fields, is mostly dated to the Late Neolithic or later (DRENTH & LANTING 1997; BRONGERS 1976).

In a recent study, Bakels (2000) palynologically studied a peat core at a distance of 10 m from a field or rather a series of superimposed fields with ard marks near Haarlem, the Netherlands. A few sherds showed that the fields dated from the Middle and Late Bronze Age (1500-800 cal BC). In the entire pollen diagram, the values of the culture-indicator types are low. In the period which represents the Middle and Late Bronze Age (phase 4), only one grain of Cerealia-type was found. The values of *Rumex acetosa*-type and *Plantago lanceolata* hardly exceed 1%. Of course it is possible that the period when the fields were tilled is not represented in the pollen diagram because it falls between two samples. The sedimentation rate of the peat in phase 4 of the pollen diagram, which represents the period of the fields, is ca. 1 cm in 15 years; the pollen samples were taken every 5 cm, which means that the time between the individual samples is ca. 75 years. It seems unlikely that the well-developed agricultural layers, consisting of several superimposed plough soil horizons, represent a period of less than 75 years. Assuming that the period of the fields is represented in the pollen diagram, this example demonstrates that even when fields were present in the direct vicinity of a core location, it is possible that their presence is not reflected in a pollen diagram from that core.

In the Gietsenveentje, Swienskuhle and Jagen 20, locations which are all at relatively large distances from the nearest archaeological finds pointing to a settlement (see table 1), relatively high pollen values of culture-indicator types are found in the Neolithic Occupation Period. Apparently, arable fields and/or pastures were located in the direct neighbourhood of these circular depressions. Possibly the accompanying settlements simply have not yet been found. Otherwise, these results indicate the possibility that the arable fields and grazing land for the livestock were located one or two kilometres from the settlement.

Length in the sediment and dates of the phases

Now that I have distinguished the Neolithic Occupation Phases in a number of diagrams from the northern Netherlands and northwestern Germany on the basis of changes in the pollen curves, it is interesting to compare some characteristics of these phases, namely the length of the core section in the sediment, ^{14}C dates of the boundaries and the duration in calendar years of the three phases (table 21 and fig. 76). The similarities and differences are discussed below.

NOP-1				
Location	**Type of sediment**	**Length in sediment (cm)**	**^{14}C dates (cal BC)**	**Duration in calibrated years**
Gieten V-A	fine gyttja	10	4172-3402	770
Gieten V-B	fine *Sphagnum* peat	40	4018-3429	589
Gieten V-D	gyttja	16	3964-3539	425
Eexterveld	peat	12	4245-3010	1235
Emmererfscheidenveen V	*Sphagnum* peat	35	3795-2710	1085
Bargeroosterveld	*Scheuchzeria*/ *Sphagnum* peat	44	?	?
Swienskuhle	sedge peat	36	4010-3125	885
Jagen 20	*Sphagnum* peat	24	3800-2750	1050
Flögelner Holz	*Sphagnum* peat	40	*3561*-3110	*451*
Silbersee	*Sphagnum* peat	32	?	?
Fuhrenkamp	*Sphagnum* peat	46	3845-*3062*	*783*
Flögeln V	*Sphagnum* peat	86	?	?

NOP-2				
Location	**Type of sediment**	**Length in sediment (cm)**	**^{14}C dates (cal BC)**	**Duration in calibrated years**
Gieten V-A	fine/coarse gyttja	21.5	3402-*2600*	*802*
Gieten V-B	fine *Sphagnum* peat	17.5 (incompl.)	3429-?	?
Gieten V-D	gyttja/*Sphagnum* peat	46	3539-?	?
Eexterveld	peat	8	3010-2520	490
Emmererfscheidenveen V	*Sphagnum* peat	30	2710-*2015*	*695*
Bargeroosterveld	*Sphagnum* peat	33	?	?
Swienskuhle	sedge peat	30	3125-*1540*	*1585*
Jagen 20	*Sphagnum* peat	10	2750-1900	850
Flögelner Holz	*Sphagnum* peat	66	3110-2090	1020
Silbersee	*Sphagnum* peat	32	?	?
Fuhrenkamp	*Sphagnum* peat	30	*3062-1571*	*1491*
Flögeln V	*Sphagnum* peat	40	?	?

Table 21. Characteristics of the three phases of the Neolithic Occupation Period in pollen diagrams discussed in this section. The Gietsenveentje dates are calibrated according to Method II calibration of sub-datasets (wiggle matching) (see VI.4.2 and table 9). The other dates are calibrated according to Method I calibration, which takes into account the fixed stratigraphical sequence of the dated samples but assumes no constant growth rate (see VI.4.2); here the middle points of the 1σ range of the calibrated dates are given. ^{14}C dates in *italics* are extrapolated dates. Durations in *italics* are durations based on extrapolated dates.

NOP-3				
Location	**Type of sediment**	**Length in sediment (cm)**	**^{14}C dates (cal BC)**	**Duration in calibrated years**
Gieten V-A	coarse gyttja	60	*2600*-1769	*831*
Gieten V-D	coarse *Sphagnum* peat	25 (incompl.?)	?	?
Eexterveld	peat	8	2520-?	?
Emmererfscheidenveen V	*Sphagnum* peat	16	*2015-1661*	*354*
Bargeroosterveld	*Sphagnum* peat	23	?	?
Swienskuhle	sedge peat	50	*1540-644*	*896*
Jagen 20	*Sphagnum* peat	6	1900-*1306*	*594*
Flögelner Holz	*Sphagnum* peat	50	2090-1500	590
Silbersee	*Sphagnum* peat	10	?	?

Table 21 (continued).

NOP-1: As expected, the core length of this phase in gyttja is shorter than in peat (except for the very small bog on the Eexterveld). The average length in gyttja is 13 cm; the average length in peat is ca. 40 cm. The ^{14}C dates of the beginning and end of this phase correspond quite well. The average date of the beginning in the Gietsenveentje and Eexterveld is ca. 4100 cal BC; in Emmererfscheidenveen V and the diagrams from *Siedlungskammer* Flögeln, the phase begins on average ca. 3800 cal BC. In the Gietsenveentje diagrams, the phase ends ca. 3450 cal BC; in the other diagrams, it ends on average ca. 3000 cal BC. The duration of this phase in the Gietsenveentje is on average ca. 600 years; in all diagrams, the duration is on average ca. 800 years.
In all diagrams, this phase starts hundreds of years before the beginning of the TRB Culture (fig. 76), which means that it has to be attributed to the Swifterbant Culture.

NOP-2: This phase occurs entirely in gyttja only in diagram Gieten V-A; there the core length in the sediment is 21.5 cm. The core length of this phase in the diagrams from southeastern Drenthe and *Siedlungskammer* Flögeln is on average ca. 35 cm. The ^{14}C dates of the end of this phase are not unambiguous: in the Gietsenveentje and Eexterveld, they are on average ca. 2550 cal BC, while in *Siedlungskammer* Flögeln, they are on average ca. 1825 cal BC. Because the date of the end of this phase varies considerably between the diagrams, the duration of this phase also varies significantly, between 500 and 1600 years. On average, the duration of this phase is ca. 1000 years.
In the Gietsenveentje diagrams, phase NOP-2 covers the entire TRB period and a small part of the EGK/BB period; in the Eexterveld diagram, it covers the last third part of the TRB period and a small part of the EGK/BB period; in the Emmererfscheidenveen and Jagen 20 diagrams, it falls entirely in the EGK/BB period; in the three other diagrams from Flögeln, it begins a few centuries after the beginning of the TRB period, and also covers the entire EGK/BB period. In Swienskuhle and Fuhrenkamp, phase NOP-2 even extends into the Bronze Age (fig. 76).

NOP-3: This phase could not be identified in diagram Gieten V-B because of disturbed sediment. In two diagrams from *Siedlungskammer* Flögeln, Fuhrenkamp and Flögeln V, this phase is entirely absent. The core length of this phase in the sediment varies considerably: in the gyttja sediment of Gieten V-A, it has a length of 60 cm, while in peat sediment, it has an average length of just ca. 25 cm! The

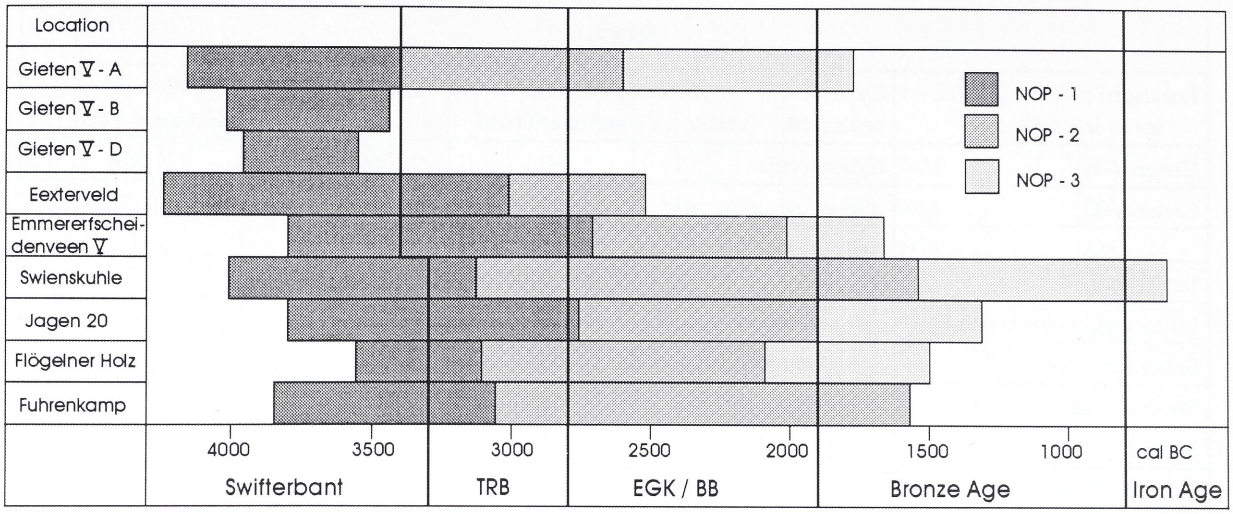


Fig. 76. Duration of the three phases of the Neolithic Occupation Period (as far as they are present) in calendar years in the pollen diagrams of figs. 73 and 74, compared to the periods of the cultures present on the Pleistocene soils near the North Sea coast. The dates are taken from table 21.

dates of the end of this phase also vary considerably, between ca. 1800 cal BC in the Gietsenveentje and as late as ca. 650 cal BC in Swienskuhle. On average, the duration of this phase is ca. 800 years.

In the Gietsenveentje, phase NOP-3 covers almost the entire EGK/BB period; in Emmererfscheidenveen and in three diagrams from Flögeln, it begins in the last phase of the EGK/BB period and extends into the Bronze Age (fig. 76).

It is remarkable that the dates of the zone boundaries, especially of the zone boundaries NOP-2/NOP-3 and NOP-3/zone 4b, differ so much. Part of these differences can be explained by uncertainties in the ^{14}C dates: all phase boundaries at all locations except for the Gietsenveentje are based on individual ^{14}C dates, most dates even on extrapolations of individual ^{14}C dates. It was already indicated in VI.4.2 that because of irregularities in the calibration curve caused by changes in the ^{14}C content of the atmosphere, an individual date often corresponds to a relatively long period in real calendar years, which makes such a date suitable only for a global period indication. But even when this is kept in mind, the differences in the dates of the boundaries of phase NOP-3 in particular seem too large. This raises the question whether this phase in the various diagrams is really the same and caused by the same type of human interference in the vegetation. At the moment, there are too few accurate dates of the boundaries of this phase to answer this question. This study has concentrated mainly on the dating of phase NOP-1 and the beginning of phase NOP-2. Since in the Gietsenveentje all zone boundaries except for NOP-2/NOP-3 are defined by series of at least three dates, the Gietsenveentje dates of the zone boundaries will be taken as a starting point for drawing up a model for the Neolithic Occupation Period in Pleistocene areas near the North Sea coast.

A model of the NOP in Pleistocene areas near the North Sea coast

On the basis of the simplified pollen diagrams of figs. 73-74, a generalized and idealized model is constructed which describes the course of selected pollen curves in the Neolithic Occupation Period. Especially those pollen types are included which are expected to have been most strongly influenced by human interference in the vegetation. Compared to the simplified pollen diagrams of figs. 73-74, two pollen types are omitted: *Fraxinus excelsior* and *Calluna vulgaris*. The changes in the pollen values of *Fraxinus excelsior* during the NOP are so slight that it is useless to include this pollen type in the model. *Calluna vulgaris*, clearly a regional pollen type in the diagrams of the Gietsenveentje and Eexterveld, shows very high and irregular values in the dia-

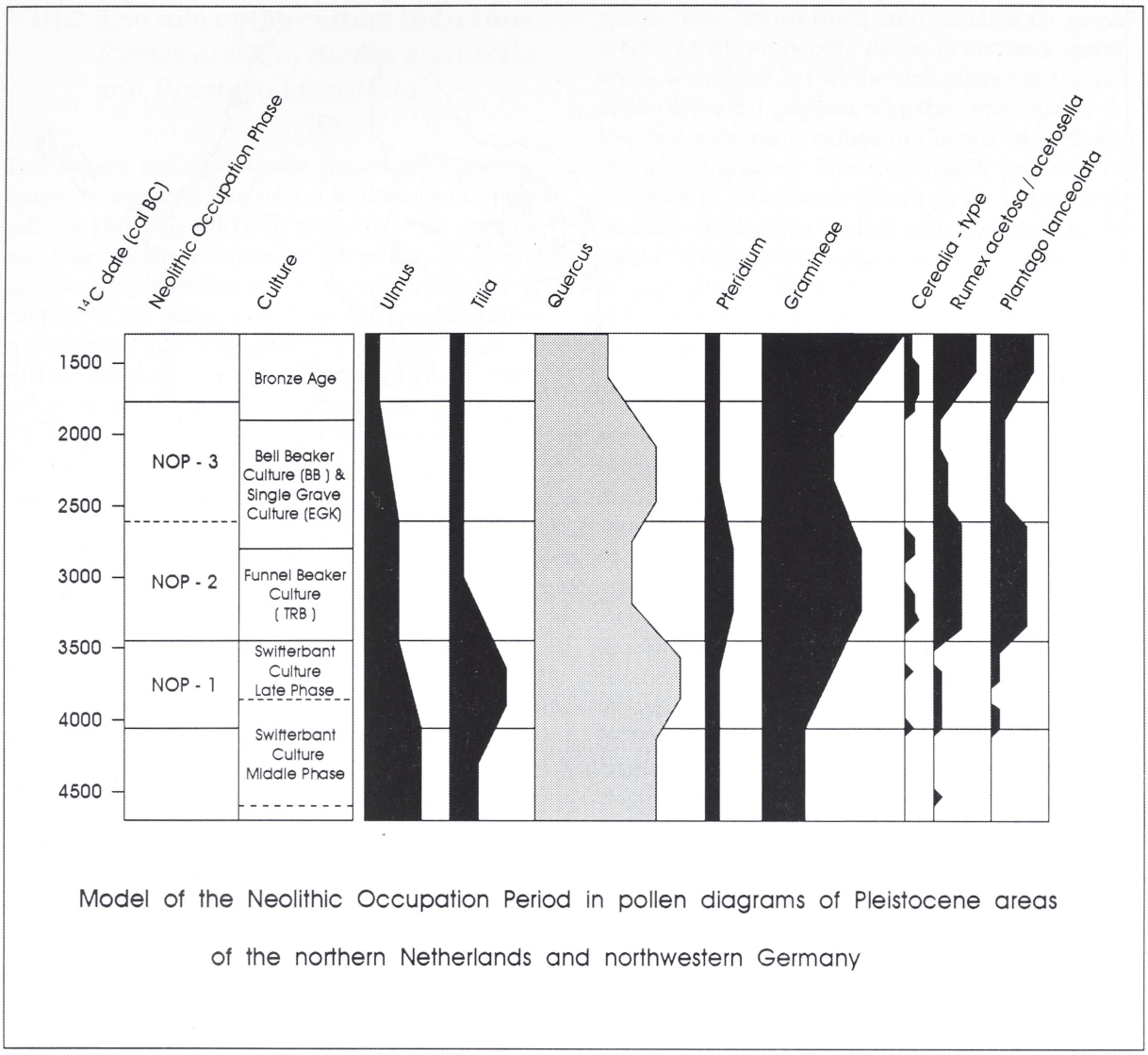


Fig. 77. Model of the Neolithic Occupation Period. The grey curve is a five times magnification of the black curves.

grams of the large raised bogs of southeastern Drenthe and in most diagrams of *Siedlungskammer* Flögeln, indicating that at these locations it is a local pollen type.

With the help of a large number of ^{14}C dates, especially from the Gietsenveentje, the various phases of the NOP are connected with archaeological cultures. The model is shown in fig. 77. It is evident from this figure that the boundaries of the Neolithic Occupation Phases do not always coincide with those of the cultures. Yet it is noteworthy that the boundary which is most accurately dated in the Gietsenveentje, namely NOP-1/NOP-2, almost exactly coincides with the Swifterbant/TRB transition. The beginning of NOP-1 is also dated quite accurately, but this date seems not to coincide with any boundary between phases of the Swifterbant Culture. As already indicated above, the NOP-2/NOP-3 and NOP-3/zone 4b boundaries are dated far less closely. It is most probable that in the northern Netherlands, phase NOP-3 coincides with the EGK/BB period. In northwestern Germany, phase NOP-2 also seems to cover the largest part of the EGK/BB period, while phase NOP-3 does not start until the end of the EGK/BB period and extends into the Bronze Age (fig. 76). As already stated, more ^{14}C dates are needed to determine



Fig. 78. Indication of the area for which the model of the Neolithic Occupation Period is valid.

the boundaries of phase NOP-3 and the correlation of this phase with archaeological cultures.
The area to which the model of fig. 77 applies, is indicated in fig. 78. Of course when any given diagram from this area is considered, deviations from the model will always be found. Often these deviations will be caused by one of the four factors discussed above. But in general, the trends as described in the model can be recognized in almost every diagram from the area of fig. 78. The archaeological implications of the model, i.e. the nature of the human interference in the vegetation in the various phases, will be discussed in VIII.4.

VIII.2 The role of the culture indicators *Rumex acetosa, Rumex acetosella* and *Plantago lanceolata*

The *Rumex acetosa/acetosella* pollen type is commonly recognized as a useful indicator of human activity (BEHRE 1981). In this study, an attempt has been made to separate the pollen of *Rumex acetosa* and *R. acetosella*. As already indicated in chapter V, the ecology of these two species differs considerably. On the basis of a detailed study of surface samples, it was concluded there that the pollen of *Rumex acetosa* in combination with pollen of *Plantago lanceolata* and Gramineae points to the presence of grass-rich vegetation with a moderate to high availability of nutrients, while the pollen of *Rumex acetosella*, often in combination with pollen of *Calluna vulgaris*, points to forest clearance, *Secale* fields or former arable land. This knowledge was used for the global description of the vegetation in the Neolithic Occupation Period. Here the specific role of the two *Rumex* species in the vegetation of the Neolithic Occupation period and later will be explored in more detail.

In fig. 79, the curves of *Rumex acetosa, R. acetosella* and a selection of other pollen types in diagram Gieten V-A are shown for the first part of the Neolithic Occupation Period and for the period from the late Middle Ages up till the present day. (In the intervening period, the pollen of *Rumex acetosa* and *R. acetosella* was not separated.)

In pollen zone 3b, which represents the Atlantic, only pollen of *Rumex acetosa* is found and no pollen of *Rumex acetosella*. Most probably, this pollen originates from *Rumex acetosa* growing in its natural biotope: brooksides and light spots in the forest (WEEDA et al. 1985). Because *Rumex acetosa* prefers relatively nutrient-rich soils, small quantities most probably occurred on lighter spots in the rich forests on the till plateau near the Gietsenveentje during the Atlantic (fig. 67).

In phase NOP-1, which represents the Swifterbant Culture, *Rumex acetosa* slightly increases; small increases of Gramineae and *Calluna vulgaris* are observed. *Plantago lanceolata* and Cerealia-type appear. Also a few grains of *Rumex acetosella* are found. Most probably, people of the Swifterbant Culture created small clearings in the forest. The finds of Cerealia-type pollen indicate that some of these open spaces were used for small-scale cereal cultivation; the low but increasing values of Gramineae, *Rumex acetosa* and *Plantago lanceolata* indicate that another part of these open spaces was transformed into small-scale grassy areas. Most probably, these fields and grassy areas were laid out in the first place on the rich soils of the till plateau. On the other hand, the low but increasing values of *Calluna vulgaris* and the appearance of *Rumex acetosella* point to the presence of small-scale clearings on poorer soils, possibly the humus-podzol soils west and southwest of the Gietsenveentje (see fig. 20). As a result of agricultural uses, these poor soils became exhausted very quickly, creating ideal conditions for *Calluna vulgaris* and *Rumex acetosella*.

In phase NOP-2, which represents the Funnel Beaker Culture, considerable increases are observed in the values of *Rumex acetosa, Plantago lanceolata* and Gramineae. *Rumex acetosella, Calluna vulgaris* and Cerealia-type increase to a much smaller extent. TRB people cleared larger pieces of forest than did their predecessors; given the remarkably increased values of *Rumex acetosa, Plantago lanceolata* and Gramineae, the new open spaces were used almost exclusively for the creation of pasture. In view of the still very low values of Cerealia-type, the use of cereals barely increased in this phase. Possibly, the slightly increased values of *Rumex acetosella* and *Calluna vulgaris* point to expanding areas of abandoned, exhausted arable fields. When arable fields were laid out on the poorer soils south and southwest of the Gietsenveentje, they were of course exhausted much sooner than those on the till plateau. The agricultural activities reflected in the pollen picture of phases NOP-1 and NOP-2 must have taken place not far from the Gietsenveentje: *Rumex acetosa* reaches values of more than 1%, which according to the surface-sample study in chapter V points to considerable amounts of *Rumex* plants within a distance of 25 m. Furthermore, the major part of the area around the Gietsenveentje was still covered with dense forest; because of the finds of pollen grains reflecting agricultural activities among the vast amount of tree pollen, these agricultural activities must have taken place in the direct vicinity of the core location.

After phase NOP-2, the diagram of fig. 79 continues with the last part of zone 5a, which represents the last part of the Middle Ages. Compared to the Neolithic Occupation Period, the values of *Rumex acetosa, Plantago lanceolata* and Gramineae are more or less the same, while the values of Cerealia-type (note the different pollen percentage scales!), *Rumex acetosella* and *Calluna vulgaris* have increased spectacularly. The landscape around the Gietsenveentje had an ut-

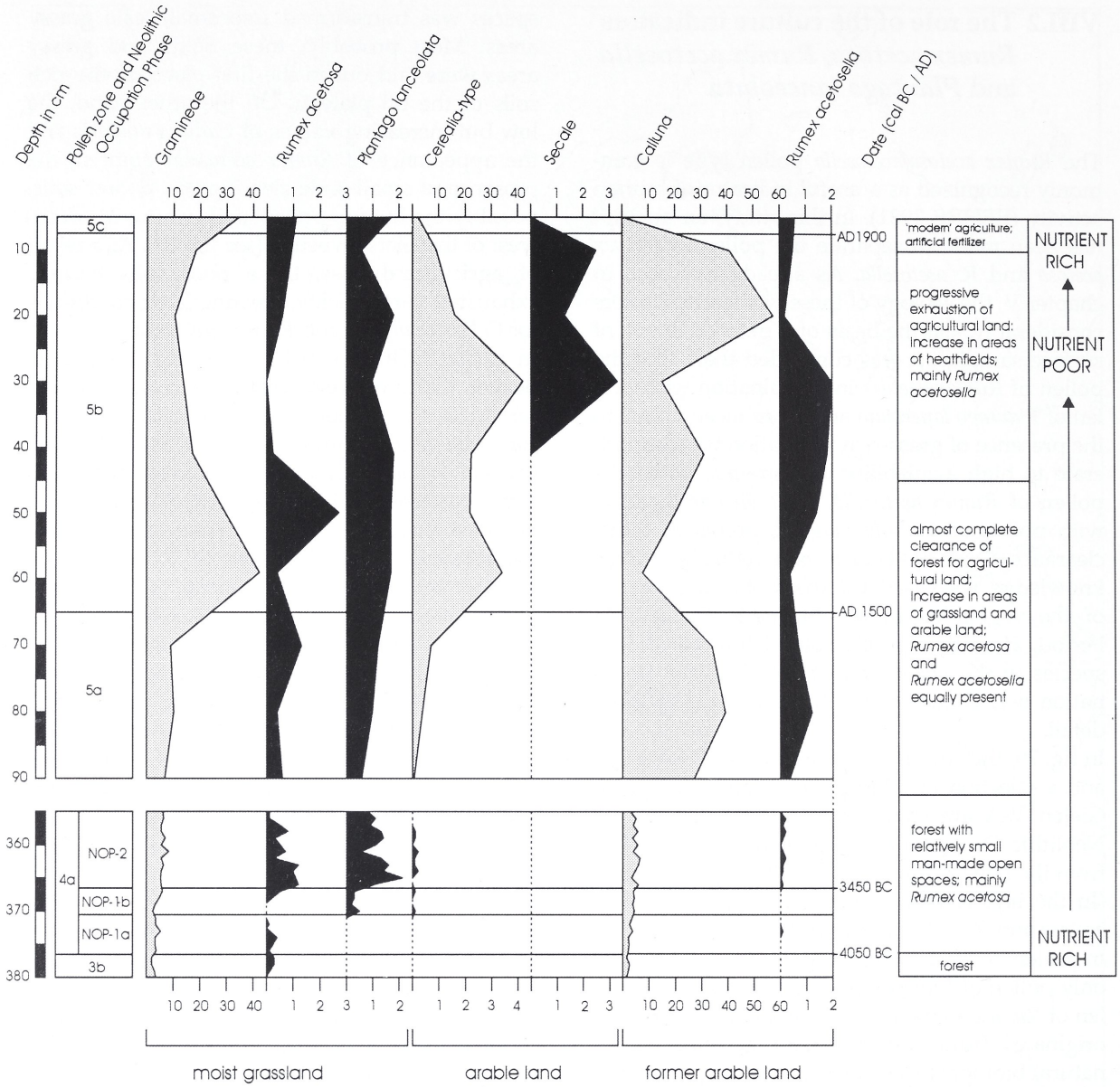


Fig. 79. Simplified pollen diagram of sequence Gieten V-A, showing the curves of *Rumex acetosa*, *R. acetosella* and a selection of other pollen types. At the right, events in the vegetation and the availability of nutrients in the soils are indicated.

terly different appearance: in the course of thousands of years, the dense primeval forests had been cleared almost completely. The cleared areas were intensively used for agricultural purposes. At the end of the Middle Ages, the area of arable land was much larger than in the Neolithic; however, the area of grass-rich vegetation had not expanded. After thousands of years of intensive agricultural use, the soils in many places were completely exhausted. These poor soils were an ideal biotope for *Rumex acetosella* and *Calluna vulgaris*. As a result, the landscape in this period was dominated by extensive heathfields with patches of *Rumex acetosella* on the somewhat less poor soils.

In the first part of zone 5b, which in total represents the period between ca. AD 1500 and ca. AD 1900, peaks are observed of *Rumex acetosa*, *Plantago lanceolata*, Gramineae and Cerealia-type, while *Calluna vulgaris* and *Rumex acetosella* reach minimum values. Obviously, in this period the area of heathfields was pushed back by ex-

panding grassland and arable land. In the second part of zone 5b, a decrease of *Rumex acetosa*, *Plantago lanceolata* and Gramineae is observed, while the values of *Rumex acetosella* and *Calluna vulgaris* increase again. *Rumex acetosella* reaches its highest values, almost 2%. These values of more than 1% indicate that in this period *Rumex acetosella* must have grown not far from the edge of the pingo scar (see V.4). The values of Cerealia-type remain very high; pollen of *Secale* appears for the first time in percentages of 1-3%. Apparently, the area of heathfields increased at the expense of grassland, while the area of arable fields remained more or less constant. There is also a possibility that in this period *Rumex acetosella* grew as a weed in *Secale* fields (BEHRE 1981); however, since the *Rumex acetosella* curve more or less follows the same pattern as the *Calluna vulgaris* curve, it seems more likely that this species occurred mainly on former arable land in combination with *Calluna vulgaris*.

Finally, in zone 5c, which represents roughly the twentieth century, the values of *Rumex acetosa*, *Plantago lanceolata* and Gramineae increase, while the values of Cerealia-type and *Calluna vulgaris* fall considerably. The values of *Rumex acetosella* remain relatively low. As a result of the introduction of artificial fertilizer, soils were markedly enriched: the areas with *Calluna vulgaris* and *Rumex acetosella* could be transformed into farmland. Given the increased values of *Rumex acetosa*, *Plantago lanceolata* and Gramineae, the heathfields near the Gietsenveentje were transformed predominantly into pastures.

It can be concluded that in the Gieten V-A diagram the *Rumex acetosa* curve generally follows the same pattern as the *Plantago lanceolata* and Gramineae curves, while the *Rumex acetosella* curve follows the same pattern as the *Calluna vulgaris* curve. When this information is compared with the results of the surface-sample study in chapter V, it is confirmed that *Rumex acetosa* is generally an indicator type for moist grass vegetation with a moderate to high availability of nutrients, while *Rumex acetosella* is an indicator type for former arable land with a low to moderate availability of nutrients.

Now that the indicator value of *Rumex acetosa* and *Rumex acetosella* is explained, the same may attempted for *Plantago lanceolata*. Generally, *Plantago lanceolata* is regarded as an indicator type for pasture (see I.4.2). However, Groenman-van Waateringe (1986, 200) considers the possibility that *Plantago lanceolata* grew as a weed in arable fields. *Plantago lanceolata* nowadays occurs both in pastures and meadows, but prefers meadows where no grazing or trampling takes place, on more nutrient-rich, humid, not compressed, untrodden soil (WEEDA et al. 1988). These meadows must be mown once a year in July/August, when the seeds of *Plantago lanceolata* are fully ripened. Under these circumstances, robust plants with long spikes will develop. On more nutrient-poor, little grazed or trampled vegetation types which remain low, another form of *Plantago lanceolata* is found: low-growing plants with short spikes. *Plantago lanceolata* is hampered, more than *Plantago major* or *P. media*, by trampling and grazing (WEEDA et al. 1988). Nowadays, hay meadows are the ideal biotope for *Plantago lanceolata*. Because hay meadows are improbable in the Neolithic, at least some of the *Plantago lanceolata* could have belonged to the arable weeds, because the dynamic system of an arable field with summer cereals is much the same as that of a meadow mown once a year in late summer, especially if the preparation of the field is only done with an ard and not with a plough (GROENMAN-VAN WAATERINGE 1986). Groenman-van Waateringe (1986, 200) names three points of possible evidence for *Plantago lanceolata* being an arable weed, which will be briefly discussed:

1. *Iron Age barrows (sic!) with* Plantago lanceolata *values of 200-300% lie on old arable.*
   These figures originate from two samples of old arable below tumulus 5 and tumulus 6 of the barrow cemetery of Hijken, province of Drenthe, the Netherlands, which are dated to the Bronze Age (VAN ZEIST 1955a, 35), and not to the Iron Age, as stated by Groenman-van Waateringe. Very distinct ard marks indicated that the barrows were constructed on old arable. However, the pollen in the samples was poorly preserved, and as a result the pollen sums were very low (total AP minus *Betula* 205 and 135). Van Zeist (1955a, 76) concludes that the poor state of preservation favoured the pollen of *Plantago lanceolata*. Indeed, it is conspicuous that high values of *Plantago lanceolata* in the barrow samples nearly always coincide with low to very low pollen sums.

2. *Neolithic barrows with high values for Plantago lanceolata, at least in the central part of the Netherlands, possess sherds in their subsoil, an indication for the fields being manured with domestic waste.*
   In the old surface below two EGK barrows at Vaassen and Putten in the Veluwe region, the central Netherlands, EGK sherds were found (CASPARIE & GROENMAN-VAN WAATERINGE 1980, S-2; S-12). Casparie & Groenman-van Waateringe (1980, 50) believe that these barrows were constructed on old settlement sites. Pollen samples of these old surfaces showed relatively high values of *Plantago lanceolata* (10-20%) and Gramineae (30-80%). *Rumex acetosa*-type (sic) shows higher values here than it does in most other barrow samples. However, only a few grains of Cerealia-type were found. The values of *Calluna vulgaris* are low to very low. Apparently, the soil of these old settlement sites was still too rich in nutrients for *Calluna vulgaris*. As we have seen, the combination of high values of *Plantago lanceolata*, *Rumex acetosa* (from which the *Rumex acetosa*-type pollen most probably originates) and Gramineae generally points to the presence of grass-rich vegetation. If these abandoned settlement sites had been used as arable land until a short time before the construction of the barrow, higher values of Cerealia-type would be found. It is more likely that these sites were left alone and used as grazing areas for the livestock.
3. *Charred grains of cereals are often found together with charred remains of* Plantago lanceolata, *especially in settlements on poor sandy soils.*
   In the excavation of a medieval settlement near Gasselte, province of Drenthe, the Netherlands, charred seed samples were collected (VAN ZEIST & PALFENIER-VEGTER 1979). In three samples, one charred seed of *Plantago lanceolata* was found among thousands of cereal grains. The other species which were found in these samples are certainly not all rated among the arable weeds, for example charred seeds of *Galium palustre* and *Carex* sp.. In charred seed samples from the excavation of medieval Dorestad (Wijk bij Duurstede, the central Netherlands; VAN ZEIST 1969) a few seeds of *Plantago lanceolata* were found among the cereals, but here also other species than arable weeds were found. Furthermore, in the Middle Ages the plough which turns the soil had been in use for a long time. When this plough is used, it is very difficult for the perennial *Plantago lanceolata* to maintain itself in a field.

In my opinion, these three examples constitute no compelling evidence for *Plantago lanceolata* being an arable weed. Of course, theoretically it is possible, as Behre & Kučan (1994, 148) indicated, that before the introduction of the "modern" plough which turns the soil, *Plantago lanceolata* grew as a weed in arable fields; it could maintain itself because its roots were not destroyed by the ard. But the palynological evidence presented in this study points in another direction: it appears from fig. 79 that the curve of *Plantago lanceolata* follows the same course as those of *Rumex acetosa* and Gramineae, and differs from the curve of Cerealia-type, which I believe to indicate that *Plantago lanceolata* grew predominantly in moist, grassy areas with a moderate to high availability of nutrients. My conclusion is that *Plantago lanceolata* is an indicator type for grass-rich vegetation with a moderate to high availability of nutrients.

VIII.3 The *Ulmus* decline

In the northern Netherlands and northwestern Germany, the beginning of the Neolithic Occupation Period more or less coincides with the "classic" decline of *Ulmus*, which occurs in many pollen diagrams from western and northern Europe (see II.3). The set of ^{14}C dates which was used to date the beginning of the NOP, also provides information about the *Ulmus* decline, clarifying when exactly it took place and how long it lasted. This information will be compared with evidence from other recent studies of the *Ulmus* decline in northern and western Europe (see II.3).

Fig. 80 shows the *Ulmus* decline in four Gietsenveentje diagrams. The pollen values of *Ulmus* are plotted next to those of *Plantago lanceolata*. On the basis of these two pollen types and a few others, the boundaries of the three Neolithic Occupation Phases were defined. These phases and all calibrated ^{14}C dates are also shown in fig. 80. The *Ulmus* decline in the Gietsenveentje diagrams appears to be very gradual and slow: the *Ulmus* percentage decreases from ca. 3.5% to ca. 1.5% over a period of several centuries. It is difficult to determine the exact beginning and end of the decline. In table 22 the approximate beginnings and endings of the *Ulmus* decline in the Gietsenveentje diagrams are shown. It is remarkable that the duration of the *Ulmus* decline varies so much between the Gietsenveentje diagrams, because

the *Ulmus* decline as reflected in the various Gietsenveentje diagrams presumably represents one and the same event in the vegetation. Since the *Ulmus* percentage is low anyhow and the decline is relatively slight, unknown random factors may have affected the *Ulmus* curve. It is certain that in diagram Gieten III the *Ulmus* decline is not completely represented because of a hiatus below the date of ca. 3650 cal BC. In the other diagrams, the *Ulmus* decline begins between 4200 and 3950 cal BC, and ends between 3400 and 2800 cal BC.

In table 22, data relating to the *Ulmus* decline in the Gietsenveentje as well as data of *Ulmus* declines from recent studies in other parts of northern and western Europe are shown (see II.3). It appears that the date of the beginning of the *Ulmus* decline in northern and western Europe lies between 4000 and 3700 cal BC. The percentage of *Ulmus* before the decline and the duration of the decline strongly vary among the various areas.

It is assumed that the *Ulmus* percentage before the decline represents the share of *Ulmus* in the Atlantic forest. From table 22 it appears that *Ulmus* reached its highest share in the Atlantic forests of Denmark and southern Sweden, and its lowest share in the Atlantic forests of the northern Netherlands. If the *Ulmus* decline were caused by elm disease, a kind of relation is expected between the share of *Ulmus* in the vegetation before the decline and the duration of the decline: the more individuals of *Ulmus* in the forest, the higher the risk of infection with the very infectious elm disease, and consequently the shorter the duration of the decline. Unfortunately, in practice this relationship is not so simple, because there are also other factors which contributed to the *Ulmus* decline. At most locations, the *Ulmus* decline can also be connected with human interference in the vegetation.

At Diss Mere, England, the *Ulmus* decline took place in only six years in woodland already disturbed by man (PEGLAR 1993). Because of the very short duration of the decline, elm disease has to be its main cause here. Possibly, regeneration of *Ulmus* was prevented by human activities like stock-grazing and fodder collection, thus accelerating the disappearance of *Ulmus*. In a pollen diagram from Kalvsjön, southern Sweden, also a very rapid *Ulmus* decline is observed (25-30 years; ANDERSEN & RASMUSSEN 1993). In this area, human interference in the vegetation appears to have been slight: almost no culture-indicator types are observed in the period of the *Ulmus* decline. Andersen & Rasmussen (1993) conclude that elm disease was primarily responsible for the decline. In Siggeneben-Süd, northeastern Germany, the major, "classic" *Ulmus* decline took place in forests which had been disturbed quite severely for 1000 years already. In the pollen diagram, the *Ulmus* decline occurs in Iversen-PREFACT phase 1b, which represents the Siggeneben Group of the Early Neolithic Funnel Beaker Culture (KALIS & MEURERS-BALKE 1998; see II.2.9). Because the decline took ca. 300 years, it seems unlikely to have been primarily caused by elm disease: human disturbance seems to be the most important cause. Probably most *Ulmus* trees were removed by the farmers for fodder collection or grazing; as the distance between the remaining *Ulmus* trees became larger, elm disease could spread less effectively.

It has already been outlined that in pollen diagrams from the northern Netherlands and northwestern Germany the beginning of the *Ulmus* decline coincides with the first signs of human interference in the natural vegetation, which are reflected by the appearance of *Plantago lanceolata* and Cerealia-type and an increase of *Rumex acetosa* and Gramineae. By definition, phase NOP-1 begins at this point in time. The *Ulmus* decline persists throughout the entire phase NOP-1 and even continues into phase NOP-2. Because of the very gradual and slow decline, it seems improbable that elm disease was the primary cause of the decline. The coincidence of the decline with the appearance or increase of certain culture-indicator types instead suggests human interference in the vegetation as the most important cause of the decline. A third possible cause is a worldwide climatic change towards continentality and increased dryness which took place around 3800 cal BC (see II.4). However, such a climatic change is expected to affect not only *Ulmus* but also other trees, which is obviously not the case, given the constant values of most tree pollen types during the *Ulmus* decline.

Most probably, *Ulmus* occurred predominantly in the rich forest vegetation of the till plateau north and east of the Gietsenveentje and of the moist till plateau south of the Gietsenveentje (see fig. 67), in forest types of the *Fago-Quercetum* and *Stellario-Carpinetum* plant communities (STORTELDER et al. 1999). At the beginning of phase NOP-1, people of the Swifterbant Culture cleared a small part of the forests of the till plateau and moist till

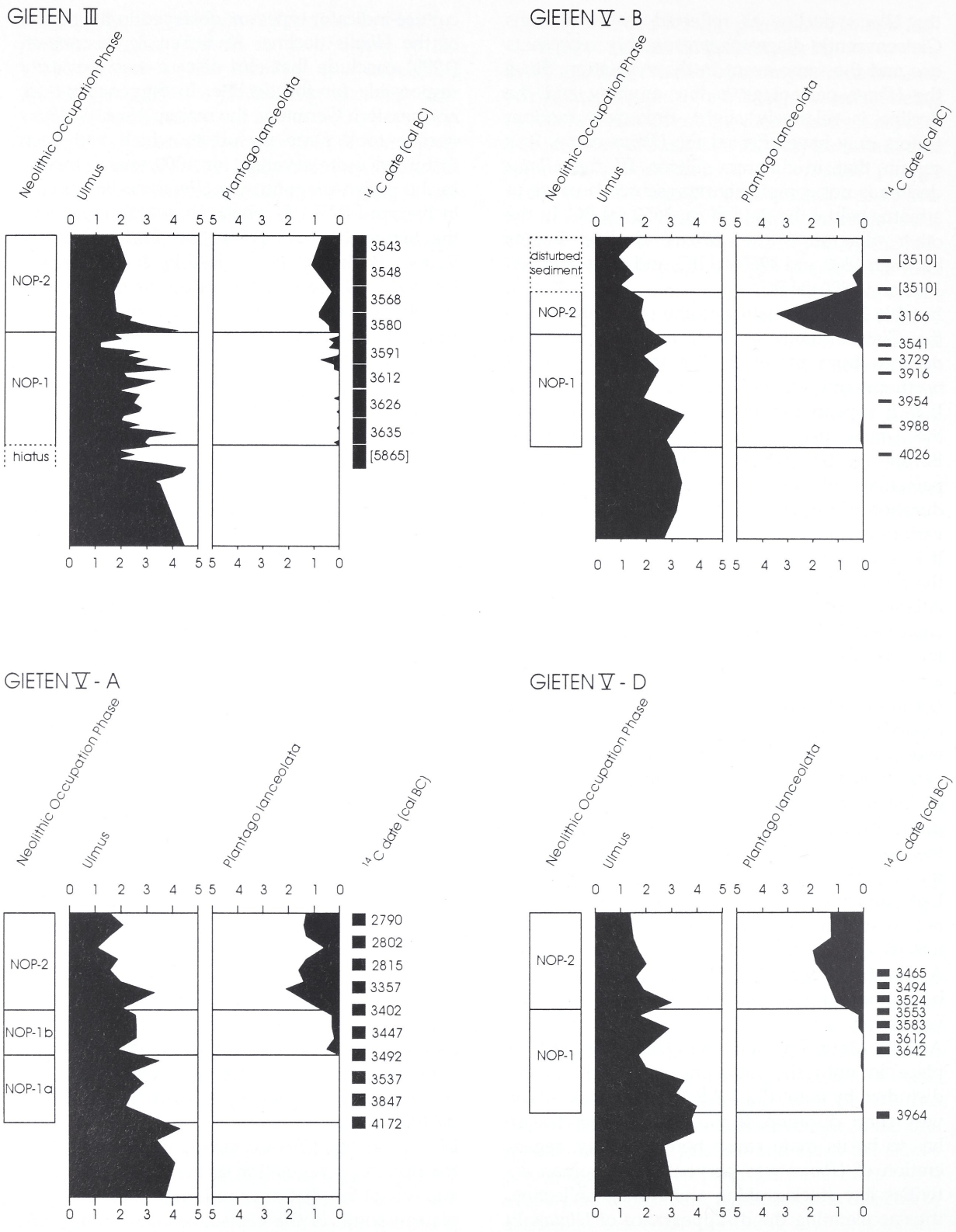


Fig. 80. The *Ulmus* decline and the first appearance of *Plantago lanceolata* in four Gietsenveentje pollen diagrams.

Country and location	*Ulmus* values before and after decline (between brackets: composition of ΣP)	^{14}C dates of beginning and end of decline	Duration of decline	Possible causes
Great Britain				
Diss Mere	5.8% → 1.6% (AP+NAP)	?	6 years	elm disease, human activity
southern Sweden				
Ageröds Mosse	9% → 2% (AP)	ca. 3770 cal BC	max. 40 years	?
Lake Kalvsjön	5% → 1% (AP+NAP)	ca. 3870 cal BC	ca. 25-30 years	elm disease; weak human interference; climate-induced palaeohydrological change
Denmark				
Hassing Huse Mose	11% → 2% (AP+NAP)	3870-3700 cal BC	170 years	agricultural activity in combination with elm disease
northeastern Germany				
Siggeneben-Süd	7.5% → 2% (AP+NAP excl. Gramineae)	ca. 4000-3700 cal BC	300 years	forests were already severely disturbed by man; elm disease (?)
Belauer See	9.5% → 1.7% (AP)	3818-3573 cal BC	245 years	interaction between elm disease and human interference
the northern Netherlands				
Gieten III	3% → 2% (AP+NAP excl. *Betula*)	3650-3550 cal BC	100 years	human disturbance, possibly in combination with elm disease
Gieten V-A	4% → 1.5% (AP+NAP excl. *Betula*)	4200-2800 cal BC	1400 years	
Gieten V-B	3% → 2% (AP+NAP excl. *Betula*)	4000-3400 cal BC	600 years	
Gieten V-D	4% → 1.5% (AP+NAP excl. *Betula*)	3950-3400 cal BC	550 years	

Table 22. Characteristics of the *Ulmus* decline in northern and northwestern Europe. The data are from Peglar (1993), Skog & Regnéll (1995), Digerfeldt (1997), Andersen & Rasmussen (1993), Wiethold (1998), Kalis & Meurers-Balke (1998) and the present study.

plateau, to create open spaces for small-scale arable fields and, to a lesser extent, pastures. The rich soils of the till plateau and moist till plateau were very suitable for agriculture. It is also possible that *Ulmus* trees were felled selectively, because the nutritious branches and leaves make excellent fodder (HEYBROEK 1963). Given the low pollen values in the Atlantic, *Ulmus* never was a very common tree in the forests on the richer soils of the Drenthe Plateau. Because of the limited appearance of *Ulmus* in these forests, any epidemic of elm disease that swept across Europe around 3800 cal BC would have had only a limited influence on the elm stands of the Drenthe Plateau.

My conclusion is that the *Ulmus* decline in the northern Netherlands was in the first place

caused by activities of the first farmers. It cannot be excluded that elm disease also played a role, but no direct palynological evidence to support this hypothesis is found in the Gietsenveentje diagrams. The only possible, but circumstantial evidence might be that ^{14}C dates of the beginning of the *Ulmus* decline in the Gietsenveentje closely correspond to ^{14}C dates of the *Ulmus* decline in other parts of northern and western Europe (table 22). As the *Ulmus* decline seems to occur everywhere at more or less the same time, this might be an argument in favour of elm disease as the primary cause of the *Ulmus* decline. However, in many areas including the northern Netherlands also human interference in the vegetation contributed to the *Ulmus* decline.

VIII.4 Interpretation of the Neolithic Occupation Period in terms of archaeology

VIII.4.1 Introduction

In section VIII.1, a model was presented which describes the courses of some selected pollen curves during the Neolithic Occupation Period (NOP). This model was constructed by comparing the pollen diagrams of the Gietsenveentje with a number of other pollen diagrams from Pleistocene areas near the North Sea coast.
Now it is time for an interpretation of the changes in the pollen curves during the NOP. As a starting point, this section describes the situation before the beginning of the NOP, when the Drenthe Plateau was covered by primeval forests. This is followed by a description of the events in the vegetation which could have been responsible for the beginning and the various phases of the NOP. It is assumed that in this period most changes in the vegetation were caused by human interference. Attempts will be made to define the nature of this interference as well as the agricultural economy practised by the people who lived on the Pleistocene soils near the North Sea coast.

VIII.4.2 The Atlantic forests

According to the master diagram of Gieten V-A the highest percentages of total Arboreal Pollen (AP) were found in the Atlantic. These high AP values were interpreted as the Drenthe Plateau being entirely covered with relatively dense forests. On the fertile till plateau, rich forests with *Quercus, Ulmus, Tilia* and *Fraxinus* occurred, while the coversand areas carried less rich forests with *Quercus* and *Betula* (see VII.1). In the opinion of Iversen and most other palynologists, these Atlantic forests must have been so dense that there was almost no undergrowth (IVERSEN 1973, 72). However, in a recent publication, Vera (1997) opposes this opinion. He believes that the Atlantic forests were park-like in appearance, maintained thus by large wild herbivores (VERA 1997, 72 ff.). In his opinion, such a relatively open landscape better explains the high values of *Quercus* and *Corylus* in the Atlantic pollen diagrams than would dense forests. According to forestry data, *Quercus* does not regenerate in closed forest, while *Corylus* will not flower below the forest canopy and consequently fails to produce any pollen (VERA 1997, 82). The high pollen values of *Corylus* in the Atlantic can be explained by the presence of *Corylus* in the following biotopes:

a. shores and edges of lakes, rivers and bogs;
b. *Corylus* woodland;
c. (grazed) park-like landscapes

Vera (1997, 77) considers the appearance of *Corylus* woodland in prehistory improbable, nor does he believe that the presence of *Corylus* was limited to shores and edges of lakes, rivers and bogs. Furthermore, Vera attributes the (very scarce) finds of *Plantago lanceolata* and *Plantago major* in the Atlantic to the presence of grassy areas, maintained by wild herbivores. However, the very low values of Gramineae in almost all Atlantic diagrams argue against Vera's theory. Because the Atlantic is very well represented in all Gietsenveentje pollen diagrams, the Gietsenveentje data may contribute to the solution of this problem. I consider the following facts as strong arguments in favour of the presence in the Atlantic of a fairly dense, closed forest in the vicinity of the Gietsenveentje:

a. The Gramineae percentage in the Atlantic is very low in all Gietsenveentje diagrams (ca. 3%). It appears from fig. 71 that, in the Atlantic, the Gramineae percentages are highest near the edges of the pingo scar (diagrams Gieten V-C and Gieten V-D), which points to a predominantly local origin of the pollen.
b. Not one pollen grain of *Plantago lanceolata* is found in the Atlantic of the Gietsenveentje diagrams.
c. Indeed, in the Atlantic, relatively high percentages of *Corylus* are found in all Gietsenveentje diagrams (ca. 20%). However, it

appears from fig. 71, that in the Atlantic, the highest *Corylus* percentages are found near the northern edge of the pingo scar (diagram Gieten V-C). This points to the presence of *Corylus* in the mantle vegetation near the northern edge of the pingo scar. In phases NOP-1 and NOP-2, the *Corylus* percentage remains more or less constant. In my opinion, this still mainly reflects *Corylus* from the mantle vegetation directly around the pingo scar.

d. At the beginning of phase NOP-1, *Quercus* and *Tilia* increase in almost all Gietsenveentje diagrams (see figs. 73a-c). This can be explained by the theory which Vera uses to reconstruct a park-like landscape in the Atlantic: because of the creation of small-scale open spaces (in the case of phase NOP-1, by the first farmers), a landscape was formed with free-standing trees or groups of trees. Especially *Quercus* and *Tilia* took advantage of this new situation: they could flower more abundantly than they did in the Atlantic forests and consequently they produced more pollen (VERA 1997, 79).

e. Almost no Mesolithic finds are known of the Drenthe Plateau which are dated to the last part of the Atlantic (WATERBOLK 1985b; LANTING & VAN DER PLICHT 1997/1998). Apparently, living conditions on the Drenthe Plateau in this period became very unfavourable for the Mesolithic people. Most probably, the forests on the Drenthe Plateau had become too dense for large herbivores and subsequently for the Mesolithic hunters to live in; the only activities took place in more open landscapes like lake and river banks or coastal areas.

Concluding, it can be stated that the Atlantic forests near the Gietsenveentje must have been fairly dense. There are no signs at all pointing to the presence of natural areas of grass-rich vegetation, maintained by large wild herbivores. It has already been outlined that the extensive forests which covered the Drenthe Plateau in the Atlantic were certainly not uniform: a kind of mosaic vegetation must have occurred, with more dense and rich forests on the till plateau and on the coversand more open and poor forests.

VIII.4.3 Combination of the pollen data with other types of archaeological evidence

As we have seen, two cultures are involved in the emergence and the early development of agriculture on the Drenthe Plateau: the Swifterbant Culture and the Funnel Beaker Culture (TRB). In the last part of the Neolithic, the EGK and BB Cultures flourished in this area.

It is obviously impossible to deduce the agricultural economies of these cultures only from pollen data. In the first place, it is far from certain that we can speak of "the" agricultural economy of for example the TRB Culture; it is plausible that this economy was strongly dependent on the local conditions and possibilities, for example with regard to soil and geomorphology. In the second place, many additional, more specifically archaeological types of evidence are necessary to obtain a reasonably clear picture of the agricultural economies of the Neolithic cultures in a certain area. For these reasons, the Gietsenveentje pollen data will be combined with three types of data: archaeological finds directly pointing to agriculture, and macroscopic remains and pollen from archaeological contexts.

Archaeological finds directly pointing to agriculture

a. ard marks

At five locations in the northern Netherlands, Neolithic ard marks have been found: Bornwird (province of Friesland; FOKKENS 1982), Emmerhout (province of Drenthe; DRENTH & LANTING 1997), site P14 near Schokland (province of Flevoland; DRENTH & LANTING 1997), and two sites in the city of Groningen (province of Groningen): Winschoterdiep (KORTEKAAS 1987) and Oostersingel (KORTEKAAS 2002). From P14-Schokland and Groningen-Winschoterdiep, also pollen samples are available (see II.2.7 and below). The exact dating of the fields is problematical, but most probably they can all be attributed to the Single Grave Culture (EGK). Although ard marks were discovered below TRB barrows in Poland and Denmark (MIDGLEY 1992), so far no ard marks have been found in Dutch TRB contexts. According to Fokkens (1990), the ard was introduced in the Netherlands only in the Late Neolithic by the Single Grave Culture. Gehasse (1995) argues that in the Netherlands, people of the Swifterbant and Funnel Beaker Cultures possibly worked the land with hoe-like implements. At the P14 site, a worked piece of red-deer antler was found in a

Swifterbant context, which may be interpreted as a kind of hoe (GEHASSE 1995, 60). According to Drenth & Lanting (1997, 62), it is not possible to say when the ard was introduced in the Netherlands nor when it became widespread, but they conclude that it is likely that ard agriculture was already common at an early stage of the TRB West Group.

b. cattle locks

Southeast of Anloo (province of Drenthe), only 4 km from the Gietsenveentje, a two-period TRB settlement was excavated (see III.7.4; WATERBOLK 1960; HARSEMA 1982; JAGER 1985). In the second period, which can be attributed to the Early Havelte E2 phase, the settlement was surrounded by two enclosures. Given the presence of cattle locks in the outer enclosure, one of the functions of this enclosure might have been to keep the cattle within or outside the settlement area.

Macroscopic remains from archaeological contexts

a. remains of crop plants and domesticated animals of the Swifterbant Culture

At one of the most representative sites of the Middle Phase of the Swifterbant Culture, S3 near Swifterbant (province of Flevoland), which was inhabited between 4200 and 4000 cal BC, macroscopic remains of three cereals were found: predominantly *Hordeum vulgare* var. *nudum*, but also *Triticum dicoccon* and *T. aestivum*. Of *Hordeum*, also threshing waste was found (CASPARIE et al. 1977; VAN ZEIST & PALFENIER-VEGTER 1981). However, in the pollen diagrams, no cereal pollen was found; moreover, no cultural influences could be distinguished at all (see II.2.7; CASPARIE et al. 1977). For this reason, Gehasse (1995, 202) believes that cereals were not cultivated locally at this site, or at most on a very small scale.

At another site of the Swifterbant Culture, P14 near Schokland, only very few macroscopic remains of cereals were found (GEHASSE 1995, 59). However, because also treshing waste and cereal pollen were found at this site, Gehasse (1995, 208) assumes that at P14, cereals were probably cultivated locally in the period of the Swifterbant Culture. Because the stratigraphy of P14 is not very clear, it is quite difficult to date the introduction of crop plants at this site. It can only be estimated to have taken place between 4900 and 4100 cal BC.

At several recently excavated sites of the Early Phase of the Swifterbant Culture (Hoge Vaart, Hardinxveld-Giessendam and Brandwijk-Het Kerkhof, which can be dated between ca. 4900 and 4500 cal BC), no remains of crop plants were found. This prompts the tentative conclusion that the incorporation of crop plants into the subsistence strategy of the Swifterbant Culture did not occur before ca. 4200 cal BC, which is halfway through the Middle Phase (RAEMAEKERS 1999, 186; BRINKKEMPER et al. 1999, 82). Domesticated cattle, however, is known from Swifterbant contexts from as early as ca. 4750 cal BC, which is in the Early Phase (RAEMAEKERS 1999, 186). In Swifterbant contexts, the ratio of domesticated to wild animals generally ranges from 30/70% to 40/60% (RAEMAEKERS 1999, 114).

b. remains of crop plants and domesticated animals of the TRB Culture

In the Netherlands, very few organic remains have been found in TRB contexts, because of the small number of excavated findspots and the poor conservation conditions in the sandy soils, the most important areas of habitation of the TRB people (GEHASSE 1995, 218). For this reason, most evidence about the subsistence economy of the TRB comes from Germany, Denmark and Poland. The most important cereal crops cultivated by TRB people were *Triticum dicoccon* and *Hordeum vulgare* and to a lesser extent *Triticum monococcum*. A ratio of domesticated to wild animals ranging from 80/20% to 90/10% points to the important share of domesticated animals, particularly cattle, but also pig and sheep/goat (MIDGLEY 1992, 370).

c. wood

At the Swifterbant site S3, a bundle of *Ulmus* twigs was found. The twigs are mostly three to four years old. Possibly, these twigs were carried in as fodder. This would imply that at least occasionally animals were fed in the settlement (CASPARIE et al. 1977, 54).

Near Nieuw-Dordrecht (province of Drenthe), a wooden trackway was discovered, which runs from a till ridge into a large raised-bog area (CASPARIE 1982; 1992). The trackway, which could be followed over a length of about 1 km, is dendrochronologically dated to 2552 cal BC, which means that it was constructed by EGK people. There is a remarkable variety in the used wood species. In the part located nearest to the till ridge, the westernmost part, primarily *Betula* was used, trees with diameters of 15-20 cm, ca. 20-40 years old. According to Casparie, this wood

originates from secondary forests, regenerating on former cultivated fields (CASPARIE 1992, 122). In the next part of the trackway, especially *Quercus* and also some *Tilia* were used (CASPARIE 1982, trench 2 G-J). A large part of the *Quercus* logs consisted of cleft wood and many had very narrow annual rings, indicating relatively slow growth, typical of trees from fairly dense forest stands. The thickness of the *Quercus* logs varied between 15 and 25 cm, coming from trees 50-70 years old. The *Quercus* and *Tilia* logs most probably originate from the richer forests on the till ridge. According to Casparie, by this time these forests were already for the larger part secondary (CASPARIE 1982, 147). However, it can be argued on the basis of the same arguments that these relatively dense stands of full-grown *Quercus* and *Tilia* trees still represent natural, virgin forest. The easternmost part of the trackway, located farthest from the till ridge, almost exclusively consisted of *Alnus* logs, originating from *Alnus* trees growing locally in bog-margin forests.

Madsen (1990) has studied timber constructions of the Early and Middle Neolithic TRB in Denmark. During the first part of the Early Neolithic TRB (Iversen-PREFACT phase 1, as defined by KALIS & MEURERS-BALKE 1998), normally huge trunks with diameters up to one metre were used in the timber constructions of the long barrows. In the later part of the Early Neolithic TRB and in the Middle Neolithic TRB (Iversen-PREFACT phase 2, as defined by KALIS & MEURERS-BALKE 1998), timber with diameters of 20-40 cm was used for the construction of mortuary houses and palisades of causewayed enclosures, suggesting a forest of comparatively young trees. Moreover, in this period rather slender pieces of wood were found, some of which definitely come from coppiced trees (MADSEN 1990, 30).

Pollen from archaeological contexts

Pollen directly originating from archaeological contexts far better reflects human activities than pollen from bogs and lakes. However, pollen samples from archaeological contexts are in most cases pollen samples from soils, and some serious disadvantages stick to the analysis of soil pollen samples (VAN ZEIST 1967, see II.2.4). Certain pollen types, such as *Tilia*, *Plantago lanceolata* and *Dryopteris*, seem to survive the mostly poor conservation conditions better than others, which results in a probably distorted pollen picture (VAN ZEIST 1955a). Furthermore, it is not known how much time is represented by a 1 cm soil sample. Waterbolk (1954, 30) assumed that a 1 cm sample of the humic layer underneath a barrow has a pollen content representing several decades. Groenman-van Waateringe (1986, 197) showed on the basis of correlations between cover percentages and the pollen content of litter samples that 1 cm samples are more likely to represent only a few years. On the other hand, Bottema (1995) found that pollen spectra from surface samples, collected in moss polsters and the upper part of plaggen soils, represented a vegetation of at least hundred years old. The samples even seemed to give more information about the old vegetation than about the recent vegetation! These contradictory results make the interpretation of subfossil soil pollen samples even more difficult. We have to be very careful in comparing soil pollen samples with pollen diagrams from bogs and lakes. Evidence is available from soil pollen samples from two types of archaeological context:

a. pollen samples from ard mark layers

Mook-Kamps & Van Zeist (1987) collected soil pollen samples in and just above a layer with ard marks, excavated near the Winschoterdiep canal in the city of Groningen, on the northernmost and narrowest part of the Hondsrug ridge. According to ^{14}C dates, the ard marks can be dated between 4550 and 3850 BP (between 3250 and 2300 cal BC); most probably, they were made by people of the Single Grave Culture (EGK). In the pollen samples taken from the ard marks, which are thought to represent the arable phase, high values of *Tilia* and very low values of *Ulmus* were found; a forest rich in *Tilia* must have grown on the richer soils in the neighbourhood. Although we have to assume that predominantly cereals were cultivated in the field, remarkably enough only one grain of *Triticum* type was found in all samples. Gramineae reach values of 5-10%, *Plantago lanceolata* occurs with values of 2-5%. These taxa might have grown in the field during the fallow periods.

Pollen samples taken just above the ard marks show a different pollen picture: Ericaceae, Gramineae and *Plantago lanceolata* reach considerably higher values than in the samples from the ard marks. This indicates that after the abandonment of the field, the area was used as grazing land for livestock; otherwise, the vegetation would have reverted to forest. Of course, a large part of the pollen originates from a far wider area than the field alone. It is impossible to say whether the

abandoned fields were already so exhausted that only Ericaceae could grow there, or that the soil was exhausted to a lesser extent so that Gramineae and *Plantago lanceolata* could colonize the abandoned fields. The overall pollen picture demonstrates ongoing deforestation in the area. A layer of driftsand which was deposited on the ard-mark layers, indicates that after a long and intensive use for agriculture, the soils in the area were completely exhausted, finally resulting in driftsand. The drifting of sand most probably started in frequently used cattle tracks. After the abandonment of exhausted soils by the farmers and their livestock, the driftsand could progressively expand. The sand originates from higher parts of the Hondsrug ridge, but it is impossible to estimate the extent of the deforested areas on the Hondsrug in this period.

b. pollen samples from barrows

Since the 1950s, soil pollen samples have been analyzed from below burial mounds in the Netherlands (see II.2.4), Germany, Denmark and Poland. An attempt is made to discover a culture-related pattern in the pollen content of these barrow samples, revealing for example that the pollen content of samples below TRB mounds differs structurally from that of samples below EGK mounds. But first some characteristics which all barrow samples have in common will be briefly reviewed.

First, the pollen values of barrow samples often fluctuate very strongly, which is partly caused by the different and often poor conservation conditions. For this reason, we have to be very careful about the interpretation of the pollen content of barrow samples.

Secondly, the pollen picture of barrow samples points to a high diversity of landscapes around the mounds. Apparently, the burial monuments were erected in all kinds of open landscapes. In many cases, they were erected in open areas which had been used as arable fields for a long time, as a result of which the soils had become exhausted and therefore useless for crop cultivation. However, also other open areas were utilized, like old settlement sites (CASPARIE & GROENMAN-VAN WAATERINGE 1980). It seems probable that abandoned settlement sites, which were very rich in nutrients, were first used for agriculture and only in a later stage for the erection of a burial mound.

Thirdly, nearly always high to very high values of Ericaceae are found in barrow samples. This indicates that the soils on which the burial monuments were erected, were relatively poor in nutrients (BAKKER & GROENMAN-VAN WAATERINGE 1988). Furthermore, grazing of some kind must have taken place in the direct neighbourhood of the burial monuments, otherwise the heathfields would have changed into forest (GROENMAN-VAN WAATERINGE 1986). The very low Ericaceae values in the barrow samples from eastern Denmark (S.T. ANDERSEN 1992a) must be due to the naturally rich soils in that area, which are a less suitable biotope for Ericaceae.

In Drenthe, pollen spectra collected from beneath barrows of four different cultures yielded the following results (see also fig. 9; WATERBOLK 1954; 1956; VAN ZEIST 1955a; 1967; CASPARIE & GROENMAN-VAN WAATERINGE 1980):

TRB: high values of *Tilia*, low values of Gramineae, *Plantago lanceolata* and *Rumex*;

EGK: lower values of *Tilia*, higher values of Gramineae, *Plantago lanceolata* and *Rumex*;

BB: fluctuating values of *Plantago lanceolata*, low values of Gramineae and *Rumex*;

Early Bronze Age: fluctuating values of *Plantago lanceolata*, lower values of Gramineae.

In the Veluwe region (central Netherlands), the pollen spectra collected beneath barrows of EGK, BB and Early Bronze Age are quite uniform: no decline of *Quercus* and *Tilia* is observed, and the values of the culture-indicator types remain low (CASPARIE & GROENMAN-VAN WAATERINGE 1980).

In Germany, pollen analysis by Groenman-van Waateringe (1979a) of samples collected beneath barrows of three different cultures yielded the following results:

TRB: Oldendorf a.d. Luhe (northwestern Germany): very high values of *Tilia*, very low values of *Quercus*, low values of Gramineae, *Plantago lanceolata* and *Rumex*;
Deinste (northwestern Germany): very low values of *Tilia*, high values of *Quercus*, higher values of Gramineae and *Plantago lanceolata*;

EGK: Ahsen (Westfalen, central western Germany): high values of *Tilia*, low values of Gramineae, *Plantago lanceolata* and *Rumex*;

BB: Altenrath (Nordrhein, central western Germany): very high values of *Tilia*, very low values of Gramineae, *Plantago lanceolata* and *Rumex*.

In eastern Denmark, S.T. Andersen (1992a; 1992b) analyzed barrow samples collected from beneath Early Neolithic and Middle Neolithic TRB barrows, obtaining the following results:

Early Neolithic TRB: high values of *Tilia*; high values of Gramineae and *Plantago lanceolata*;

Middle Neolithic TRB: lower values of *Tilia*, lower values of Gramineae and *Plantago lanceolata*.

Finally, in Poland, pollen samples from below a TRB barrow near Sarnowo and from a contemporary settlement, located only 100 m from the barrow, were analyzed (DĄBROWSKI 1971; MIDGLEY 1992, 359-360). In the barrow samples, only 20% AP was found; Gramineae, *Plantago lanceolata* and *Rumex* were common, and Cerealia reach very high values (4.6%). In the settlement samples, 60% AP was found, low values of *Plantago lanceolata* and *Rumex*, but relatively high values of Cerealia.

From this small overview it becomes clear that in pollen samples below barrows of the same culture, certainly not always the same pollen picture is found, not even approximately: it is not possible to demonstrate a culturally linked pattern. The barrow samples too strongly reflect the (very) local conditions to offer a reliable picture of "the" agricultural economy of a culture. The picture which emerges from the barrow samples is that Neolithic activities reflected in these samples are more strongly determined by the type of forest and the condition of the soil than by qualities of the culture concerned (CASPARIE & GROENMAN-VAN WAATERINGE 1980).

Now let us turn to the sometimes remarkable differences between barrow samples and samples from bogs and lakes from the same period. As we saw in II.2.3, Van Zeist (1959; 1967) attributed the first Neolithic phase with low values of Gramineae and *Plantago lanceolata* in regional pollen diagrams from southeastern Drenthe, which is equivalent to phase NOP-1 in this study, to the TRB Culture. The next phase, with high values of Gramineae and *Plantago lanceolata*, which is equivalent to phase NOP-2, he attributed to the EGK Culture. He reached this conclusion by correlating the results from regional pollen diagrams with the spectra from barrow samples referred to above. However, the very appropriate ^{14}C dates obtained during the present study demonstrate unquestionably that phase NOP-1 reflects a pre-TRB culture, namely the Swifterbant Culture, of which no barrows are known, and that phase NOP-2 must be attributed to the TRB Culture. These results leave us with a discrepancy between the pollen spectra of the barrow samples and the regional diagrams in the TRB and the EGK periods (table 23).

There are two explanations for this discrepancy. For the first solution, it is assumed that the pollen samples taken just below the burial mounds represent a period of only a few years (GROENMAN-VAN WAATERINGE 1986). The situation in the northern Netherlands can be compared with the situation in eastern Denmark, where S.T. Andersen (1992a; 1992b) has also tried to correlate the results from barrow samples with regional diagrams. He analyzed pollen samples from below barrows of the Early Neolithic TRB, a culture which did not occur in the Netherlands, and the Middle Neolithic TRB. Remarkably, in the Middle Neolithic TRB period he found the same discrepancy between barrow samples and regional diagrams as is observed in the northern Netherlands: in the barrow samples, the Gramineae and *Plantago lanceolata* values are low, while in the regional diagrams they are relatively high. In the Early Neolithic TRB period, he found the opposite: high values of Gramineae and *Plantago lanceolata* in the barrow samples and low values of these taxa in the regional diagrams (table 23). S.T. Andersen (1992a, 167-171) explains these apparent discrepancies as follows: in the Early Neolithic TRB period, *Tilia* forest was cleared and used for intensively grazed pasture in the direct vicinity of the barrows; however, these pastures were of small extent. In the Middle Neolithic TRB period, mixed woodlands with *Tilia*, *Corylus* and *Alnus* were cleared by burning. The areas with treeless vegetation were larger than in the preceding period, but the open areas were less intensively grazed. Possibly this explanation, of course only with regard to the Middle Neolithic TRB, is also valid for the situation in the northern Netherlands. The pollen picture of the EGK period in the northern Netherlands resembles that of the Early Neolithic TRB period in eastern Denmark: high values of Gramineae and *Plantago lanceolata* in the barrow samples and low values of these taxa in the regional diagrams (table 23). Possibly, the Dutch EGK period, like the Danish Early Neolithic TRB period, was characterized by intensively grazed pastures which covered a smaller area than in the Middle Neolithic TRB period.

	Early Neolithic TRB	Middle Neolithic TRB	EGK
barrow samples, eastern Denmark	Gramineae and *Plantago lanceolata* high	Gramineae and *Plantago lanceolata* low	?
regional pollen diagrams, eastern Denmark	Gramineae and *Plantago lanceolata* low	Gramineae and *Plantago lanceolata* high	?
barrow samples, the northern Netherlands	-	Gramineae and *Plantago lanceolata* low	Gramineae and *Plantago lanceolata* high
regional pollen diagrams, the northern Netherlands	-	Gramineae and *Plantago lanceolata* high	Gramineae and *Plantago lanceolata* low
explanation	intensively grazed grass-rich areas of small extent	extensively grazed grass-rich areas of large extent	intensively grazed grass-rich areas of small extent?

Table 23. Comparison between the pollen values of Gramineae and *Plantago lanceolata* in barrow samples and regional pollen diagrams covering three Neolithic cultures and in two areas: eastern Denmark (S.T. ANDERSEN 1992a; 1992b) and the northern Netherlands (CASPARIE & GROENMAN-VAN WAATERINGE 1980; this study). The Early Neolithic TRB did not occur in the Netherlands.

	Swifterbant	Middle Neolithic TRB	EGK
barrow samples, the northern Netherlands	-	Gramineae and *Plantago lanceolata* low	Gramineae and *Plantago lanceolata* high
barrow samples, the northern Netherlands, when representing the preceding culture	Gramineae and *Plantago lanceolata* low	Gramineae and *Plantago lanceolata* high	Gramineae and *Plantago lanceolata* low*
regional pollen diagrams, the northern Netherlands	Gramineae and *Plantago lanceolata* low	Gramineae and *Plantago lanceolata* high	Gramineae and *Plantago lanceolata* low

Table 24. Comparison between the pollen values of Gramineae and *Plantago lanceolata* in barrow samples and regional pollen diagrams covering three Neolithic cultures in the northern Netherlands (CASPARIE & GROENMAN-VAN WAATERINGE 1980; this study). In the second row, it is assumed that the barrow samples taken below burial mounds represent a period of more than a hundred years; as a result they represent the culture which preceded the culture that erected the burial mound. * pollen content of samples taken below burial mounds of the Bell Beaker Culture (BB).

For the second solution, it is assumed that the pollen samples taken just below the burial mounds represent a period of more than a hundred years (BOTTEMA 1995). As a result, there is a possibility that these pollen samples represent the culture preceding that which erected the burial mound. In this case, the low values of Gramineae and *Plantago lanceolata* below TRB burial mounds would have been caused by the Swifterbant Culture, and the high values of Gramineae and *Plantago lanceolata* below EGK burial mounds would have been caused by the TRB Culture. When this assumption is made, the results of the barrow samples coincide with those of the regional pollen diagrams (table 24).

VIII.4.4 The agricultural economies of the Neolithic cultures on the Drenthe Plateau

Combining the model of the Neolithic Occupation Period proposed in VIII.1 with data more directly related to archaeology, discussed in the preceding section, may finally lead us to a more complete picture of the agricultural economies of the first farming cultures on the Drenthe Plateau. As already indicated, it is not justified to speak of "the" agricultural economy of the Swifterbant Culture or the TRB Culture. The concluding remarks in the following in the first place apply to the Drenthe Plateau, and most probably also to areas with comparable geomorphological and edaphic conditions in northwestern Germany (see fig. 78), but, for example, not to the entire distribution area of the TRB Culture. For each phase of the Neolithic Occupation Period, observed phenomena will be interpreted in terms of archaeology. Finally, there is a brief discussion of the problem of quantifying human interference in the Neolithic landscape.

Phase NOP-1: 4050-3450 cal BC, Swifterbant Culture (Middle and Late Phase)

On the Drenthe Plateau, the first signs pointing to agriculture appear in the pollen diagrams around 4050 cal BC. Apparently, agriculture was introduced on the Drenthe Plateau by people of the Swifterbant Culture.

The pollen picture has some affinity with the occupation phase as described by Troels-Smith for Denmark and Switzerland (see II.1.3). Troels-Smith explained his occupation phase by the leaf-foddering theory. He linked stable feeding with the use of leaves as fodder for livestock. The possibility of leaf foddering and possibly stable feeding has to be considered for the Drenthe Plateau.

Not many changes are observed in the regional tree pollen values in this period, except for a gradual decline of *Ulmus* and an increase of *Tilia* and *Quercus*. As already put forward in VIII.3, the *Ulmus* decline in this area was most probably in the first place caused by human interference in the vegetation. Because most other tree percentages remain constant, it looks as if *Ulmus* trees were used selectively by the first farmers. It is possible that the trees were pollarded, and that the leaves and branches were fed to the cattle. Another possibility is that the cattle, which was allowed to roam freely, predominantly consumed the tasty young shoots of *Ulmus* in the natural and man-made open spaces, thus preventing the regeneration of this tree. In my opinion, the increase of *Tilia* in this phase can also be attributed to activities of the first farmers. It has already been noted by several authors (VAN ZEIST 1959; GROENMAN-VAN WAATERINGE 1992; KALIS & MEURERS-BALKE 1998) that different tree species react differently to the practice of pollarding. *Ulmus* would suffer most severely, while *Fraxinus* and *Tilia* would take advantage of the situation: when it is assumed that the branches were cut every 3-4 years, *Ulmus* would not be able to flower in the intervening period, in contrast to *Fraxinus* and *Tilia*, species which regenerate much faster than *Ulmus*. In the pollen diagrams of the northern Netherlands and northwestern Germany, a pronounced maximum of *Tilia* is found in this phase, while *Fraxinus* remains more or less constant (figs. 73-74).

S.T. Andersen (1988; 1992b) found pronounced *Tilia* maxima in two diagrams from very small hollows in eastern Denmark. He obtained a picture of local changes in the vegetation. The *Tilia* maxima were accompanied by a decrease of all other trees. His explanation for the local *Tilia* maxima is that all trees were felled except for the *Tilia* trees, which were maintained for the harvesting of leaf-fodder. The now freestanding *Tilia* trees could flower far more abundantly than they could in the dense Atlantic forests. Iversen (1960, note 11) already established that especially under favourable light conditions, *Tilia* is a great pollen producer; in dense forest, however, flowering of *Tilia* is greatly reduced. The *Tilia* maximum in the diagrams from the northern Netherlands and northwestern Germany seems to point to a more open forest. Possibly, the (freestanding?) *Tilia* trees were pollarded for fodder. The *Tilia* trees could also have been maintained for bee-keeping and the making of rope from the bark.

In historical times, the system of leaf lopping has always been closely connected with the system of forest grazing: forest grazing was used to feed the cattle in summer, while leaf lopping served to feed the animals in winter. At the end of summer, the deciduous trees would be lopped and the leaves dried for use as winter fodder (BURRICHTER & POTT 1983).

Troels-Smith (1954; 1960) explained his occupation phase by assuming that the cattle were fed exclusively on leaves. Low values of Gramineae and *Plantago lanceolata* in his opinion pointed to the absence of pastures. As argued by Groenman-van Waateringe (1986; 1992) it is very unlikely that cattle were fed exclusively on leaf fodder:

cattle are grazers and not browsers. This means that cattle must have their major food intake from grass. Leaves can only be used as a major food source for shorter periods of time, or be a minor supplement to the staple fodder. These facts make Troels-Smith's explanation for his occupation phase at least improbable. In his own diagram from Aamosen, a clear increase of Gramineae is observed in the Troels-Smith occupation phase (see fig. 75); in many diagrams from the northern Netherlands and northwestern Germany, increasing values of Gramineae and *Plantago lanceolata* are observed during phase NOP-1, which is characterized by a pollen picture strongly resembling the Troels-Smith occupation phase. These observations suggest that in these areas, this phase did see a kind of grass-rich vegetation, most probably woodland pasture. This situation can be compared to that in Switzerland, where Troels-Smith (1984) and Rasmussen (1990; 1993) convincingly demonstrated on the basis of macroscopic analysis that foddering took place in the Neolithic. The animals were held inside the settlements, in some kind of byre, during the winter. The fodder consisted of twigs and leaves. However, in contrast to northwestern and northern Europe, where in the Neolithic NAP values of more than 10% are often reached, in Switzerland the values of NAP and particularly Gramineae remain below 10% throughout the Neolithic (RASMUSSEN 1990, 76). In the Swiss Neolithic, the open areas with grass must have been very limited. Apparently, leaf foddering was practised on a far larger scale here than in northwestern and northern Europe. This is in agreement with the observation by Burrichter & Pott (1983) that in mountain districts there is more need for leaf foddering in winter than in maritime districts, because of the shorter growing season and the longer and heavier snow cover.

It must have been very difficult to harvest leaves of *Ulmus* and *Tilia* selectively in the dense Atlantic forests, because most leaves grew in the tops of the trees, and the trees lacked lateral branches. Therefore I assume that if the technique of leaf foddering was applied in phase NOP-1 by people of the Swifterbant Culture, this was done only in combination with small-scale woodland pastures. Especially leaves and twigs of *Ulmus* and *Tilia* must have been harvested; a recovered bundle of *Ulmus* twigs at the Swifterbant site S3, probably intended as fodder, supports this theory (CASPARIE et al. 1977, 54). Possibly, the woodland pastures were created by the felling of trees which were not used for pollarding. There is no indication at all that burning was used in this phase to create open spaces in the forest.

In pollen diagrams from Pleistocene areas near the North Sea coast, Cerealia-type pollen grains are first found at the very beginning of phase NOP-1, which is ca. 4050 cal BC (Eexterveld, Swienskuhle, Flögelner Holz, see figs. 73-74). In the Gietsenveentje diagrams, grains of Cerealia-type first appear only around 3500 cal BC. *Triticum* sp. and *Hordeum* group are more or less equally represented (table 8). Apart from the role of cereals in the human food supply, the remains of these plants were possibly used as winter fodder beside leaves and twigs. The date of 4050 cal BC has to be considered as a *terminus ante quem* for the introduction of cereal crops in Pleistocene areas near the North Sea coast. The date is more or less in agreement with the data published by Brinkkemper et al. (1999), who deemed the incorporation of crop plants into the subsistence strategy of the Swifterbant Culture to have taken place not before ca. 4200 cal BC.

As already indicated, the pollen picture of phase NOP-1 displays similarities both with Troels-Smith-PREFACT phases A and B, associated with the Ertebølle Culture, and with Iversen-PREFACT phase 1, caused by the Early Neolithic TRB, in northeastern Germany and Denmark (KALIS & MEURERS-BALKE 1998). In archaeological terms, the Ertebølle Culture and the (early) Swifterbant Culture do not show many similarities, but certain parallels in their pottery show that there is indeed a relationship of some kind between the Early Neolithic TRB and the (late) Swifterbant Culture (RAEMAEKERS 1999, 166). Madsen (1990) described the agricultural economy of the Early Neolithic TRB in Denmark as adaptive to the environment, resulting in only minor interference with nature; it was a system that required a dispersed and mobile society. I believe the same description also applies to the Swifterbant Culture in the northern Netherlands and northwestern Germany.

Phase NOP-2: 3450-*2600* cal BC, TRB Culture

It was already concluded from macroscopic remains found in Swifterbant and TRB contexts that crop cultivation and stock keeping played a far more important role in the subsistence strategy of the TRB Culture than they did in that of the Swifterbant Culture. This picture is confirmed by the phases attributed to these respective cultures in pollen diagrams from Pleistocene areas in the northern Netherlands and northwestern

Germany. The TRB Culture can be considered the first fully agrarian culture on the Drenthe Plateau.

In the pollen picture, a clear decline of *Tilia* attracts attention. This *Tilia* decline is particularly pronounced in the diagrams from northwestern Germany (fig. 74); it is often accompanied by a decline of *Quercus*. Behre & Kučan (1994) interpreted these phenomena as large-scale forest clearings, especially for the purpose of forest grazing. S.T. Andersen (1988; 1992a) also found a *Tilia* decline at the beginning of the Middle Neolithic TRB in eastern Denmark. According to S.T. Andersen, leaf lopping of *Tilia* was discontinued and the tree was suppressed to remove its shade (S.T. ANDERSEN 1988, 402). The forests with *Tilia* were replaced by open, secondary forests dominated by *Corylus*, which were maintained by the farmers for browsing and grazing by cattle or sheep. In the northern Netherlands and northwestern Germany, however, no evidence for such secondary forests is found in the TRB period. Here, more intensive clearances may well have been responsible for the *Tilia* decline: it seems that the cattle were now for the larger part fed on grass instead of leaves. The possibly freestanding *Tilia* trees, which had been used for pollarding or shredding, might have been cleared by the TRB farmers to eliminate their shade.

Maximum values of *Pteridium* and a small increase in the charcoal values possibly point to the use of burning for forest clearance (IVERSEN 1949). A number of barrow samples from Drenthe almost exclusively consist of charcoal particles. Apparently, the local vegetation was destroyed by fire shortly before the barrow was constructed (CASPARIE & GROENMAN-VAN WAATERINGE 1980, 60). However, in general the use of fire to clear forest was not very widespread among the TRB farmers on the Drenthe Plateau; in northwestern Germany, Behre & Kučan (1994) also failed to find clear indications for burning in this period. This seems to be different from the situation in northeastern Germany, Denmark and Sweden, where fire was more commonly used in the TRB period (IVERSEN 1949; S.T. ANDERSEN 1988; 1992a; 1992b; BERGLUND 1991; KALIS & MEURERS-BALKE 1998). In these areas, nearly always maximum values of *Betula* are found in the Middle Neolithic TRB period, which are generally connected with the use of fire; such a *Betula* maximum is completely absent in pollen diagrams from northwestern Germany and the northern Netherlands. Apparently the slash-and-burn method for clearing forest in order to create agricultural land was not commonly used in the TRB period in Drenthe. It is more likely that the forest was cleared by felling and/or girdling.

Another question which can be asked concerning agricultural methods in the TRB period, is: Was the method of shifting cultivation applied, or were the fields more permanent? There has been a lot of discussion about this topic among palynologists and archaeologists (for example ROWLEY-CONWY 1981; GROENMAN-VAN WAATERINGE 1979b). Like Midgley (1992, 386), I believe it is very difficult or even impossible to answer this question by means of pollen analysis alone. Other types of evidence are necessary, preferably including evidence from experimental archaeology (see for example MEURERS-BALKE & LÜNING 1990).

On fertile loess and clay soils, fields could have been cultivated for fairly long periods without interruption. It was demonstrated by experiments by Meurers-Balke & Lüning (1990) on loess soils in Germany, that even on permanently cultivated fields, a heavy weed flora could develop among the cereals; very intensive weed control seemed to be necessary. This weed flora consisted especially of weed species of the forest and of the forest edge. On the sandy, less fertile soils of the Drenthe Plateau, however, different conditions prevailed: after 3-5 years of cultivation, the soil was already exhausted, and a fallow period of 10-15 years was necessary before the field could be used again. During such a long fallow period, the ground became penetrated by roots of weeds to such an extent, that an ard could not break up the soil (FOKKENS 1982). Probably, it was easier to clear a new plot of forest for creating new fields, than to try to remove the roots of weeds from the former fields: the undergrowth of the Atlantic forests was composed of shrubs and especially herbs which rooted only shallowly in the loose forest soil, so that it must have been easy to remove them with an ard after felling and maybe burning the trees (GROENMAN-VAN WAATERINGE 1979b). In the experiments of Meurers-Balke & Lüning (1990) in *Stellario-Carpinetum* forests on loess soils, it seemed quite difficult to plough the forest soil with an ard, because the ard often caught on thick tree roots. However, when the ploughing was regularly repeated, it became increasingly easy, because the root network was progressively destroyed. In the opinion of Groenman-van Waateringe (1979b), no specific arable weed associations could develop when newly

created fields were used only for a period of 2-3 years. However, the results of the experiments by Meurers-Balke & Lüning (1990, 88) point in another direction: after harvesting, the fields became totally overgrown by weeds within a few weeks (!). It is clear that with the present state of knowledge, it cannot be decided whether the fields in the Neolithic were cultivated only once or on a more permanent basis. This study has demonstrated that in TRB times the larger part of the Drenthe Plateau was still covered by a relatively dense forest (see fig. 69). Without deciding between shifting cultivation or permanent fields, it can only be remarked that there was enough forest left for the TRB farmers to practise shifting cultivation for hundreds of years, even if they preferred to clear the forests on the more fertile soils of the till ridges (BAKKER & GROENMAN-VAN WAATERINGE 1988). Behre & Kučan (1994, 149) conclude from the fairly constant values of pollen types pointing to arable farming in the pollen diagrams of *Siedlungskammer* Flögeln during the TRB period, that the fields were shifted only slightly, or possibly even were permanent.

The small decrease of AP and the increase of Gramineae, Ericaceae and the culture-indicator types demonstrate the presence of more open areas than in the preceding phase. Since Cerealia-type displays a far smaller increase than Gramineae, *Plantago lanceolata* and *Rumex acetosa*, it is probable that most of the newly created treeless areas were used to keep livestock. The increased importance of stock keeping in the Middle Neolithic TRB period was already emphasized by several authors (IVERSEN 1941; VAN ZEIST 1959; MADSEN 1990; KALIS & MEURERS-BALKE 1998). The wooden fence with cattle locks excavated near Anloo shows that the TRB farmers separated the settlement and arable land from areas where the livestock were allowed to graze (WATERBOLK 1960; HARSEMA 1982; JAGER 1985). On the basis of the comparison between barrow samples and regional pollen diagrams from Drenthe, it was already suggested that the pastures in the TRB period might have been extensive and of relatively large extent, compared to the following phase. In the barrow samples from Drenthe, the Ericaceae far exceed the Gramineae; the Gramineae percentage lies mostly below 10%. Groenman-van Waateringe (1986, 198) concludes from this that in the neighbourhood of the burial mounds, the opportunities for grazing were extremely restricted and certainly would not allow grazing throughout the year. Groenman-van Waateringe indicates the possibility of winter grazing on the dry sandy soils. She believes that maybe the summer pastures are not to be found here, but more probably in the river valleys. But can the high Ericaceae values in the barrow samples not be explained simply by the fact that barrows were constructed only in open areas which had become useless for agriculture because the soils were exhausted? We should imagine the open spaces in the Atlantic forests created by the TRB farmers as a mosaic of arable fields in use, abandoned arable fields which served as (winter?) pasture and permanent grazing.

The pastures were probably in part woodland pastures. However, there is a clear link between canopy cover and grass yields: only with a reduction of canopy cover to less than 50% the grass yields will increase significantly (GROENMAN-VAN WAATERINGE 1986; 1993). Therefore, the increasing Gramineae values in the pollen diagrams of this phase in my view point either to treeless pastures or to very open woodland pastures. Given the relatively small increase of Cerealia-type compared to phase NOP-1, the use of cereals in the food economy had not much increased. Finds of macroscopic remains in northwestern Germany suggest that *Hordeum* was the commonest cereal in the TRB West Group (HOPF 1961). *Hordeum* is well suited to cultivation on the varied lowland soils and is more resistant to cold than *Triticum*. These are the most likely reasons for its increased popularity during the later TRB (MIDGLEY 1992, 366). However, this is not confirmed by the finds of Cerealia-type pollen in the Gietsenveentje diagrams: *Hordeum* and *Triticum* are more or less equally represented in the TRB period (table 8).

The beginning of phase NOP-2 marks an expansion and alteration of the agricultural economy in the sense that the adaptive strategy was changed to a manipulative one: relatively large areas of land were made suitable for livestock grazing (cf. MADSEN 1990). Nevertheless, farming settlements were widely scattered and farming still was extensive in nature.

Phase NOP-3: *2600*-1770 cal BC, EGK/BB Culture

The TRB Culture was followed by the EGK and BB Cultures. The phase in the pollen diagrams which represents these two cultures is characterized by a temporarily decreased pressure on the vegetation, which is especially evident from the constant or even slightly decreasing NAP

values. This phase has affinity with the "regeneration phase" in pollen diagrams from northeastern Germany, eastern Denmark and southern Sweden. In these areas, the "regeneration phase" is often dominated by *Corylus*. Generally this is explained as the presence of coppice woods with predominantly *Corylus* (GÖRANSSON 1988b). The following use of the coppice woods can be imagined: leaves and twigs were cut as winter fodder for the livestock, hazelnuts were gathered for human consumption and larger twigs were used for wattle. According to Göransson (1988b) this so-called "regeneration phase" does not really represent a decreasing influence of the farmers on the vegetation, but rather a more efficient use of the landscape, with a more intensive use of smaller areas.

Is there also evidence for coppice woods in this phase in the pollen diagrams from the northern Netherlands and northwestern Germany? In the diagrams Gieten I and Gieten V-A, an increase of ca. 5% of *Corylus* is observed in this phase; in the diagrams from southeastern Drenthe, relatively high values of *Corylus* are found; in northwestern Germany, however, no higher *Corylus* values are observed in this phase. Burrichter (1969) has indicated two possible interpretations of a *Corylus* increase in pollen diagrams:

a. a *Corylus* increase on sandy soils generally points to a decreasing human influence on the vegetation: in periods poor in settlements, its former biotopes became available again, and it could increase considerably, because for this pioneer species the growing conditions were much better than in a closed forest;
b. a *Corylus* increase on moist, loamy soils generally points to an increasing human influence on the vegetation: when these soils, which were not suitable for arable farming, were not too intensively used for woodland pasture, *Corylus* could increase considerably because of the favourable light conditions.

The conclusion is that a *Corylus* increase can point to increasing as well as decreasing human influence on the vegetation. The relatively small *Corylus* increase observed in certain diagrams from Drenthe certainly does not automatically point to the presence of coppice woods. It may also be caused by the abandonment of woodland pastures by the EGK and BB people. All in all, I subscribe the view of Groenman-van Waateringe (1992, 20) that there is no direct evidence for coppicing practices in the Dutch Neolithic and Bronze Age. The shifts within the AP are simply too slight to reflect a change to a woodland management based on coppicing.

In the Gietsenveentje diagrams, a small decrease is observed in the values of Gramineae and the culture-indicator types. As we have seen, this is generally explained in terms of a decreased pressure of man on the vegetation. However, Groenman-van Waateringe (1993) has demonstrated, on the basis of grazing experiments and surface samples, that continuous, intensive grazing results in a decrease of grass pollen production and a pollen picture which appears to reflect a closed forest cover! Following this reasoning, there is a possibility that the decreasing Gramineae values in this phase point to (locally?) increased grazing pressure. This fits in with the first hypothesis that was proposed to explain the difference in pollen content between barrow samples and regional pollen diagrams from the EGK period: the Dutch EGK period was characterized by intensively grazed pastures which, however, covered a smaller area than in the preceding phase (table 23). Unfortunately, nothing is known about the density of habitation of the TRB, EGK and BB Cultures in Drenthe; there seems to be a tendency towards a more concentrated habitation in the EGK/BB period (oral comm. J.N. Lanting). This is in agreement with the generally accepted interpretation of the pollen picture of the EGK and BB periods, which assumes a decreased pressure of man on the vegetation compared to the TRB period. Wiethold (1998, 267) attributed the decrease of NAP, especially Gramineae and culture-indicator types, in the EGK phase in pollen diagrams from eastern Schleswig-Holstein (northeastern Germany) to a marked population decrease and the end of the economic system of the TRB Culture.

The decrease of Gramineae and the culture-indicator types possibly also points to the ongoing exhaustion of soils, resulting in increasingly large areas which became useless for crop cultivation and in a later stage even for grazing. However, the exhaustion of soils is generally indicated by an increase of *Calluna vulgaris*. In phase NOP-3 of the various diagrams of the northern Netherlands and northwestern Germany, little if any increase of *Calluna vulgaris* is found. The last stage in the process of exhaustion is the forming of driftsand, which has been found in EGK-dated layers in a few sequences from the Drenthe Plateau (MOOK-KAMPS & VAN ZEIST 1987; CASPARIE 1992). In this period, driftsand was certainly not formed on a large scale, but only very locally.

It has already been remarked in VIII.1 that phase NOP-3 does not appear very clearly in the pollen diagrams from northwestern Germany (table 21). In some diagrams (Fuhrenkamp, Flögeln V, see fig. 74) a regeneration phase is completely absent: Gramineae and the culture-indicator types only increase higher up in the diagrams. In most pollen diagrams from Drenthe, phase NOP-3 does occur clearly and consistently (fig. 73). This situation can again be compared with the situation in Denmark, where two types of pollen diagram occur with regard to occupation history (S.T. ANDERSEN 1992b). In the first type, which is found in eastern Denmark, human occupation was abandoned in the Late Neolithic, while in the second type, which is found in northwestern Denmark, a continuous expansion of human occupation from the Neolithic to the present day is observable (ODGAARD 1988). S.T. Andersen (1992b, 6) infers a fundamental difference in the history of occupation in eastern and western Denmark. Probably this difference is linked to the difference in soil fertility between the poor sandy soils of western Jutland and the more fertile soils of the young moraine landscape in eastern Denmark. Possibly, the sandy soils in western Denmark were already so exhausted by the end of the TRB period, that forest regeneration was seriously hampered. In northwestern Germany, a comparable situation seems to have existed. Additional evidence for this hypothesis is provided by the very high values of *Calluna vulgaris* in the pollen diagrams of both areas (BEHRE & KUČAN 1994; ODGAARD 1988). In this case it is assumed that not all *Calluna vulgaris* pollen in the diagrams from northwestern Germany has a local origin. In diagrams from Drenthe, the *Calluna vulgaris* values are considerably lower; in diagrams from the Veluwe (the central Netherlands), where also relatively poor sandy soils are found, the *Calluna vulgaris* values are lower yet. According to Casparie & Groenman-van Waateringe (1980, 60-61) the higher values of *Calluna vulgaris* in Drenthe compared to the Veluwe are caused by the more rapid exhaustion of the much wetter and more acid soils in Drenthe. By comparing the situation in the Netherlands, northwestern Germany and Denmark, the following relationship between the three named factors can be determined: the higher the soil fertility, the lower the *Calluna vulgaris* values and the higher the degree of regeneration of the forest in the Late Neolithic. In conclusion, there is a possibility that the weak presence of phase NOP-3 in diagrams from northwestern Germany compared to diagrams from Drenthe can be explained by less fertile soils in the former area.

Phase NOP-3 is marked by people moving in much larger and more permanent settlement units. The agricultural economy changed from an extensive to a more intensive one: the utilisation of nearby resources was intensified, while more distant resources were dropped (cf. MADSEN 1990). Most probably, livestock were grazed on cleared land directly associated with the large settlement sites, and less in woodland pasture. The more intensive use of a smaller area would have made the use of some kind of fertilizer inevitable.

The above-mentioned characteristics of the agricultural economies of Neolithic cultures on the Drenthe Plateau are summarized in table 25.

So far, this study has only offered qualitative descriptions of the agricultural economies of the Neolithic cultures on the Drenthe Plateau. It would be interesting to see if the extent of human influence on the vegetation could also be quantified. As several authors have pointed out (GROENMAN-VAN WAATERINGE 1992; LÜNING & KALIS 1992), this is certainly not possible on the basis of pollen data alone. The maps in figs. 67-70 show rough estimations of the extent of the open areas around the Gietsenveentje at the time of the various Neolithic cultures. Besides palaeobotanical data, edaphic and archaeological data were used for these estimates. Several authors have tried to calculate the extent of open areas in the Neolithic of northwestern Europe (see FRENZEL 1992). Lüning & Kalis (1992, 43) estimate that LBK people cleared at most 8-9% of the woodlands of the loess areas. Groenman-van Waateringe (1992, 22) made some calculations with regard to the open areas needed for grain production and grazing in the Middle Neolithic, with all the basic assumptions taken as unfavourably as possible. The result was that ca. 80 km^2 was needed for grain production and ca. 1000 km^2 for grazing. This is less than 10% of the Pleistocene sandy areas at the end of the Atlantic. Behre (1992b, 157) arrived at roughly the same percentage of open areas in Germany in the Neolithic. Yet Casparie (1992, 126) found that in the Emmen region (southeastern Drenthe) 85-90% of the area was deforested in the Middle Neolithic. Casparie believes that these results also hold for other parts of Drenthe. My results indicate that the estimates of Groenman-van Waateringe and Behre better quantify the Neolithic de-

NOP phase, dates and culture	**Characteristics of the agricultural economy**
NOP-1 4050-3450 cal BC Swifterbant Culture	clearance by felling and/or girdling, not by burning harvesting of leaves and twigs, especially of *Ulmus* and *Tilia*, and use of remains of cereal plants to feed the livestock in winter small-scale wood pasture with Gramineae, *Plantago lanceolata* and *Rumex* to feed the livestock in summer small-scale cultivation of cereals: *Hordeum* sp. as well as *Triticum* sp. larger part of primeval forests untouched
NOP-2 3450-*2600* cal BC TRB Culture	diminishing use of leaves and twigs for fodder: use of grass for fodder in summer, use of heather for fodder in winter use of shifting cultivation, but with a limited use of fire increasing treeless areas and areas with woodland pasture, particularly used for livestock grazing small-scale cultivation of cereals: *Hordeum* sp. as well as *Triticum* sp. increasing areas of exhausted, abandoned fields major part of primeval forests still untouched
NOP-3 *2600*-1770 cal BC EGK/BB Culture	decreased human pressure on the vegetation possible presence of small-scale *Corylus* coppice woods; the *Corylus* leaves and twigs were used as winter fodder abandonment of areas with woodland pasture intensively grazed (and fertilized?) open areas which covered a smaller area than in the preceding phase still increasing area of abandoned fields: these changed partly into secondary woodland, partly in heathfields major part of primeval forests still untouched

Table 25. Characteristics of the agricultural economies of Neolithic cultures on the Drenthe Plateau.

forested areas in the northern Netherlands and northwestern Germany than those of Casparie: neither in the pollen percentage diagrams nor in the pollen influx diagrams was there any evidence of large-scale deforestations in the Neolithic. On the contrary, all the evidence points to only relatively small deforested areas throughout the Neolithic; the major part of the primeval forests seems to have remained untouched, even by the Late Neolithic (figs. 67-70). The first indications of large-scale deforestations on the Drenthe Plateau are not found until the Bronze Age.

VIII.4.5 Subsistence strategies of inland vs. coastal communities

This study has revealed evidence of agricultural activities on the Drenthe Plateau from at least 4050 cal BC onwards. In all probability, these activities can be attributed to people of the Swifterbant Culture. This means that the Swifterbant people apparently colonized two entirely different types of landscape: the wetland areas near the coast and the upland areas on the Pleistocene sandy soils. Because of several large-scale excavations (see III.7.3), much is known about the subsistence strategy of the Swifterbant people in the wetland areas. By contrast, almost nothing is known about their presence, let alone their subsistence strategy in the upland areas. An interesting question is whether the Swifterbant people practised the same type of subsistence strategy in the upland areas as in the wetland region. This question was already tackled by Raemaekers (1999, 121-122). He considers three possibilities:

a. the subsistence data of the wetland sites are representative for the upland subsistence base as well;
b. the wetland subsistence strategies are an adaptation to the specific natural environment, in which wild animals and plants are the major resources; the unknown upland communities would to a larger extent rely on domestic animals and crop cultivation;
c. a settlement and subsistence system in which the wetland and upland areas both play a part.

At present, it cannot be decided on the basis of the archaeological material which of these possibilities is the right one. In the opinion of Raemaekers (1999, 123), the similarities in the subsistence data of the sites of the Swifterbant Culture in different environmental settings suggest that this strategy is not specifically a wetland adaptation, but instead may be seen as representative of Swifterbant occupation in a larger area, including the Pleistocene areas bordering the wetlands. Maybe the results of this study can help to resolve the question which of the above-mentioned possibilities is the right one. But first let us briefly look at comparisons of coastal and inland sites of two other cultures: the Ertebølle Culture and the Funnel Beaker Culture (TRB).

In Schleswig-Holstein (northern Germany), a good picture of the subsistence strategies of coastal and inland populations of the Ertebølle and TRB Cultures is obtained on the basis of many finds of macroscopic remains and pollen diagrams (KALIS & MEURERS-BALKE 1998; 2001; WIETHOLD 1998; HARTZ et al. 2000). In the period of the Ertebølle Culture (5100-4100 cal BC), pollen of Cerealia-type and heliophilous plants was found in the coastal areas: the oldest finds of Cerealia-type pollen are dated to 4770 cal BC (KALIS & MEURERS-BALKE 1988). In the inland areas however, no pollen of Cerealia-type and culture-indicator types was found in this period; also no indications of stock keeping were obtained (HARTZ et al. 2000). From 4100 cal BC onwards, when the Early Neolithic TRB occurred for the first time, the differences between coastal and inland areas became greater: in the coastal pollen diagrams, pollen of Cerealia-type and *Plantago lanceolata* regularly appears, while in the inland diagrams there are still no indications for human activity. Apparently, the coastal area of eastern Holstein (western Baltic) had a lead in time over the inland areas with regard to the adoption of arable farming (WIETHOLD 1998).

According to Midgley (1992, 402), the dichotomy between coastal and inland settlement patterns and the resulting different economic adaptations of Ertebølle and TRB has always been overemphasized. Midgley argues that the coastal communities were less experienced in the manipulation of natural resources than their inland neighbours, because coastal resources simply do not lend themselves easily to human interference and management. For this reason some people suggest that in Denmark, the inland population took a leading and dominant role at the onset of the Neolithic in Denmark. Midgley (1992, 403) cannot regard the environmental changes along the Danish coast as a primary cause for the introduction of farming. It is clear that the opinion of Midgley, who assumes that the process of

Neolithization started inland, is not in accordance with the above-mentioned studies from Schleswig-Holstein, which demonstrate that the process of Neolithization definitely started in the coastal areas.

Now let us return to the Swifterbant Culture. When we want to compare the subsistence strategies of the wetland and the upland communities, macroscopic-remains and pollen data from both areas are needed. As we have seen, there are macroscopic-remains data only from the wetland areas (CASPARIE et al. 1977; VAN ZEIST & PALFENIER-VEGTER 1981; GEHASSE 1995; BRINKKEMPER et al. 1999). This study has presented a number of pollen diagrams from Pleistocene sandy areas in which an occupation phase associated with Swifterbant people is visible (fig. 77). However, in pollen diagrams from Swifterbant sites in the wetland zone, no occupation phases are observed at all (LOUWE KOOIJMANS 1974; CASPARIE et al. 1977; VAN DER WIEL 1982; GEHASSE 1995; see II.2.7). This is in contrast with the situation in northeastern Germany and Denmark, where occupation phases attributed to the Ertebølle Culture can be recognized in pollen diagrams from both coastal and inland areas (the Troels-Smith occupation phase, see II.1.3). Thus we have only macroscopic-remains data from the wetland sites and only pollen data from the upland sites to document the Swifterbant Culture. My conclusion is that on the basis of this incomplete picture, it is impossible to draw any conclusion about differences in subsistence strategies between wetland and upland communities of the Swifterbant Culture.

VIII.4.6 The spread of agriculture

The occupation phase associated with the Swifterbant Culture in pollen diagrams of the northern Netherlands and northwestern Germany (phase NOP-1) not only resembles the occupation phases of the Ertebølle Culture and the subsequent Early Neolithic TRB in pollen diagrams of northeastern Germany, Denmark and Sweden (Troels-Smith-PREFACT phases A/B, Iversen-PREFACT phase 1), but also the occupation phase of the Rössen Culture in pollen diagrams of the loess zone (KALIS & MEURERS-BALKE 1988; 1998). The finds of Rössen-type adzes in both Swifterbant and Ertebølle contexts are evidence for the presence of fairly intensive contacts between the Rössen Culture and these two cultures. At the same time also the knowledge about agricultural methods seems to have spread, which initiated the process of Neolithization in the north (KALIS & MEURERS-BALKE 1998, 20). It is interesting to compare the spread of agriculture, in space as well as in time, by the Swifterbant Culture and the Ertebølle Culture. They obtained their knowledge from the same source: the Rössen Culture of the loess areas, but the process of diffusion seems to be somewhat different. Let us first consider the Ertebølle Culture. In Denmark and southern Sweden, no macroscopic remains from Ertebølle contexts pointed to cereal cultivation or stock keeping (S.H. ANDERSEN 1998); in pollen diagrams from these areas, the Troels-Smith occupation phase clearly points to small-scale agriculture in Ertebølle time (KOLSTRUP 1988; GÖRANSSON 1988b; KALIS & MEURERS-BALKE 1998). In eastern Holstein, cattle bones were found which were dated to ca. 4850 cal BC, which is definitely within the Ertebølle period (HARTZ et al. 2000, 136). This date more or less tallies with dates of the beginning of the Troels-Smith occupation phase in the pollen diagrams (KALIS & MEURERS-BALKE 1998). This evidence shows that agriculture spread from the loess zone to the north, first reaching eastern Holstein around 4850 cal BC, then Denmark and finally Sweden. Because the situation in Denmark and Sweden is still not entirely clear, it is not possible to say how long it took for agriculture to spread from the loess zone to Sweden.

This study and some other very recent studies (e.g. GEHASSE 1995; RAEMAEKERS 1999; BRINKKEMPER et al. 1999) have shed new light on the spread of agriculture in the small country of the Netherlands. As we have seen, ^{14}C dating of macroscopic remains from the wetland sites in the western and central Netherlands has put the earliest evidence for stock keeping at ca. 4750 cal BC and the earliest evidence for crop cultivation at ca. 4200 cal BC (RAEMAEKERS 1999, fig. 5.1). The beginning of phase NOP-1 in pollen diagrams from the Pleistocene sandy areas in the northern Netherlands is dated to ca. 4050 cal BC. In phase NOP-1, evidence for crop cultivation as well as stock keeping was found. This seems to indicate that agriculture was adopted somewhat earlier by the wetland communities than by the upland communities. It is not possible to draw definitive conclusions on this point until upland sites of the Swifterbant Culture are found with macroscopic remains. However, it is quite plausible that, as in the case of the Ertebølle Culture, the use of agriculture spread from the Rössen

Culture on the loess soils first to the nearby wetland areas in the western and central Netherlands, and only in a later stage to the upland areas in the northern Netherlands, which are at a greater distance.
Thus the Rössen Culture seems to be responsible for the people of the Ertebølle and Swifterbant Cultures first encountering agriculture. But it was only in the period of the Michelsberg Culture, which extended its habitation area between 4100 and 4000 cal BC from the loess soils to nearby sandy soils, that agriculture gained considerably in importance in the Ertebølle and Swifterbant communities, to become an inextricable part of it. In the Netherlands, the expansion of the Michelsberg Culture is roughly contemporaneous with the oldest cereal finds in a Swifterbant context (RAEMAEKERS 1999, 191), while in eastern Holstein and Denmark this expansion is connected with the transition from the Ertebølle Culture to the Early Neolithic TRB (HARTZ et al. 2000).
Given the current state of knowledge, it seems as if in eastern Holstein the transition to agriculture occurred somewhat earlier than in the Netherlands, namely around 4850 cal BC, against 4750 cal BC at its earliest in the wetland areas of the Netherlands. In both the Ertebølle Culture and the Swifterbant Culture, the Neolithic elements appear to have been incorporated gradually into the subsistence strategy.

VIII.4.7 The relation between occupation phases in pollen diagrams and archaeological cultures

At first sight, it seems strange that the activities of three entirely different cultures, living in three entirely different types of landscape - the Ertebølle Culture, the Swifterbant Culture and the Rössen Culture - have yielded a more or less similar type of occupation phase in the pollen diagrams. Still it is obvious to assume purely on the basis of the pollen data that these three cultures used more or less similar agricultural methods. As already indicated, it is very likely that the knowledge of these methods was disseminated by the Rössen Culture to the Ertebølle and Swifterbant Cultures.

On the other hand, it is also possible that a single culture caused different types of occupation phase in pollen diagrams from different areas. One example may illustrate this: in Denmark, the Early Neolithic TRB Culture is connected with phase 1 and the beginning of phase 2 of the Iversen occupation phase (Iversen-PREFACT phases 1 and 2a as defined by KALIS & MEURERS-BALKE 1998; 2001), while in southern Sweden this culture is connected with a *landnam* phase which has affinity to phase 2 of the Iversen occupation phase in Denmark (GÖRANSSON 1988a; 1988b).
The type of occupation phase occurring in a pollen diagram apparently is conditioned not only by cultural factors but also to a large extent by the nature of the environment itself (CASPARIE & GROENMAN-VAN WAATERINGE 1980; MIDGLEY 1992, 392). Because of these differing environmental conditions, it is not possible to assign a particular type of occupation phase always to a particular culture. A model describing a sequence of Neolithic occupation phases in pollen diagrams is therefore valid only in an area defined by a specific type of landscape, and certainly not outside that area. Furthermore, we have to take into consideration that even within such a limited area the appearance of a certain occupation phase in different pollen diagrams may differ considerably as a result of other factors, such as location type, sediment type, location within the basin and distance to the settlement and/or agricultural land (see VIII.1). In spite of these limitations, it is possible to determine certain general trends in pollen diagrams from such a limited area, which can be used to define a sequence of occupation phases palynologically. With the help of accurate ^{14}C dates, it is possible to connect these occupation phases with archaeological cultures. Following Kalis & Meurers-Balke (1998), whose model of Neolithic occupation phases in pollen diagrams from the western Baltic is a major achievement, this study has been aimed at framing a model of Neolithic occupation phases in pollen diagrams from Pleistocene areas near the North Sea coast. I hope that this model will contribute to resolving the complex problem of the emergence of agriculture in the Netherlands.

Summary

I General introduction

The subject of this study is the emergence of agriculture as it is observed in the sediments of a pingo scar on a relatively high part of the Drenthe Plateau, the Netherlands. This pingo scar is the Gietsenveentje, located near the village of Gieten in the province of Drenthe. The sediment was used for various types of analysis: pollen analysis, radiocarbon dating, analysis of macroscopic remains and wood, and phosphorus analysis. Traditionally, it has been assumed that people of the Funnel Beaker Culture (TRB) (3400-2800 cal BC) were the first to practise agriculture on the Drenthe Plateau. However, there are faint archaeological indications that people of the Swifterbant Culture, an agrarian culture known predominantly from the lower parts of the Netherlands between 4900 and 3400 cal BC, were also present on the higher Pleistocene soils of the Drenthe Plateau. An important aim of this study is to demonstrate any presence of Swifterbant people on the Drenthe Plateau palynologically. Very detailed ^{14}C dates are necessary to achieve this. The zone in the pollen diagrams which represents the Neolithic is defined as the Neolithic Occupation Period (NOP), subdivided into three Neolithic Occupation Phases (NOP-1 to NOP-3). These features are strongly related to the phenomena identified by Iversen in Danish pollen diagrams and summarized by the term *landnam*. The manifestation of the NOP in the Gietsenveentje diagrams is analyzed by the indicator-species approach and the comparative approach.

II Occupation phases in the Neolithic as represented in pollen diagrams: a review

In Danish pollen diagrams, Iversen distinguished a *landnam* phase, caused by early farmers who cleared the Atlantic forest on a relatively large scale, particularly to create grass-rich vegetation for livestock. Troels-Smith distinguished a cultural phase preceding Iversen's *landnam*, which in his eyes pointed to clearances on a far smaller scale: the farmers possibly pollarded the trees and used the leaves as fodder. A review is presented of cultural phases dated to the beginning of the Neolithic, in pollen diagrams from different parts of Europe (the Netherlands, northern Germany, Denmark, southern Sweden, the British Isles). An attempt is made to reduce the cultural phases to either a Troels-Smith phase or an Iversen phase, although it is realised that this is a simplification. It appears that in comparable types of landscape where the same cultures were established, also a similar succession of cultural phases is found in the pollen diagrams. In many parts of Europe, the cultural phases at the beginning of the Neolithic more or less coincide with a considerable decline of pollen of *Ulmus*, an event which is reflected more or less synchronously in all northwest European pollen diagrams. This *Ulmus* decline was most probably caused by elm disease in combination with human disturbance of the vegetation. Apart from human disturbance, a climatic change may also be responsible for changes in the pollen diagrams at the beginning of the Neolithic. Indeed, there is evidence from several disciplines that a worldwide climatic change took place around 5000 BP. Most probably, the climate changed towards continentality and increased dryness. A thorough knowledge of especially the farming aspects of early Neolithic cultures is essential for the interpretation of cultural phases in pollen diagrams. The archaeological cultures which are jointly responsible for the spread of agriculture in the Netherlands are briefly discussed. An attempt is made to shed more light on the difficult questions of how and why the transition to agriculture in the Netherlands took place.

III The Drenthe Plateau: physical environment, vegetation and archaeology

The geology, soils, hydrology, climate, vegetation and archaeology of the Drenthe Plateau are briefly discussed. The Gietsenveentje and its surroundings are described in greater detail on the basis of a series of maps which all display the same area of ca. 20 km^2. Since the Gietsenveentje is a pingo scar, the formation of these relics from the last ice age, the Weichselian, is explained. An attempt is made to reconstruct the potential natural vegetation around the Gietsenveentje on the basis of current soil types. This is followed by an overview of finds from the period of the Swifterbant Culture (4900-3400 cal BC) on the Drenthe Plateau, which range from pottery, flint tools (especially the Rössen-type adzes) and horn sheaths to antler tools. In the surroundings of the Gietsenveentje, only one find from the Swifterbant period is known, but many finds from the Funnel Beaker Culture, i.e. megalithic tombs,

concentrations of flint and pottery and many stray finds, and the subsequent Single Grave and Bell Beaker Cultures. The changes in the landscape around the Gietsenveentje in the last two centuries are sketched on the basis of a number of historical topographical maps.

IV Material and methods

Chapter IV describes the method of coring of the sequences, the techniques used for sampling the sequences, the processing and analysis of samples used for various types of analysis and the construction of a pollen diagram. This is followed by an explanation of the two methods used for radiocarbon dating, the conventional method and the AMS method. Formulas used for calculating pollen concentration and influx are presented, as are techniques used for collecting surface samples and for recording recent vegetation plots.

V Pollen morphology and representation in surface samples of *Rumex acetosa* and *Rumex acetosella*

Pollen grains of *Rumex*-type are considered useful indicators of human activity. Ways are sought to subdivide pollen of *Rumex*-type smaller than 22 µm into pollen of *Rumex acetosa* (common sorrel) and pollen of *Rumex acetosella* (sheep sorrel) on the basis of the length and the degree of intrusion of the colpi. The ecology of these two sorrel species fundamentally differs. On the basis of a study of surface samples involving recent vegetation types in which these two species occur at Nietap, Gieten, Hijkerveld and Schiermonnikoog, it is concluded that pollen of *Rumex acetosa* together with pollen of Gramineae, *Plantago lanceolata* and sometimes *Ranunculus acris* group often points to relatively nutrient-rich grass-rich vegetation, whereas pollen of *Rumex acetosella* points to clearances on poor soils, *Secale* fields or abandoned arable land. This knowledge will be used for reconstructing the biotopes of the two sorrel species during the NOP.

VI Multidisciplinary analysis of Gietsenveentje sequences

Contour maps of the surface and of the Pleistocene subsoil of the Gietsenveentje are presented, based on a large number of corings; also four lithology transects were constructed, giving cross sections of different parts of the pingo scar. The recent vegetation inside the Gietsenveentje was mapped and surface samples were collected for comparison with subfossil pollen samples. Nine sequences from different parts of the Gietsenveentje were used for pollen analysis. The NOP seemed to be present in six of the nine resulting pollen diagrams. On the basis of the regional pollen types in the master diagram Gieten V-A, a pollen zonation system is proposed. The zones are correlated with the Blytt/Sernander periods. The local pollen types together with macroscopic remains and wood are used for a reconstruction of the local vegetation succession. In order to connect the NOP in the pollen diagrams with archaeological cultures, 56 ^{14}C dates were taken in eight sequences. Two different methods are used to calibrate these ^{14}C dates to calendar ages. Because series of dates are available in fixed stratigraphical sequences, more accurate calendar ages are obtained by applying the method of wiggle matching. The possible sources of errors in the ^{14}C dates are extensively discussed. The beginning of phase NOP-1 is dated 4100-4000 cal BC; the beginning of phase NOP-2 is dated 3500-3400 cal BC. Pollen concentration and pollen influx diagrams, which were constructed for five sequences, do not provide much additional information compared to the percentage diagrams. An influx peak around 3700 cal BC in all curves of four diagrams may point to a local small-scale forest clearance, which led to inwashing of soil and pollen. Phosphorus analysis of samples from three Gietsenveentje sequences showed a gradually increasing phosphorus content during phase NOP-1, extending into phase NOP-2, which may have been caused by the dung left by livestock at the edges of what was then a lake or by manure from arable fields.

VII Vegetation development in and around the Gietsenveentje since the Preboreal

In the Preboreal (zone 1), open *Betula* forests dominated the landscape. In the Boreal (zone 2), *Pinus* became dominant together with *Betula*; the share of *Corylus* and *Quercus* in the vegetation increased. In the Atlantic (zones 3a and 3b), stable climax forests were formed: on the till plateau, *Quercus*, *Ulmus*, *Tilia* and *Fraxinus* were the most common trees; in the coversand areas, *Quercus* and *Betula* were the most prevalent. At the beginning of the Subboreal (zones 4a, 4b and 4c), human influence becomes visible in the pollen picture. Zone 4a coincides with the Neolithic Occupation Period, which is subdivided into three phases. In phase NOP-1, the primeval forests were opened on a small scale. Apparently this was to the advantage of *Quercus* and *Tilia*, which reach maximum pollen values. There must have

been small-scale arable fields and various types of grass-rich vegetation, maintained by livestock. In phase NOP-2, more widespread clearances occurred, especially in the rich forests on the till plateau. Now also *Quercus* and *Tilia* were affected. Phase NOP-3 reflects a period of temporarily decreased pressure on the vegetation. In the later part of the Subboreal (zones 4b and 4c) and in the next period, the Subatlantic (zones 5a, 5b and 5c), a development can be seen towards complete clearance of the forests, and their replacement by agricultural land. Simultaneously, the area of exhausted, abandoned arable fields, dominated by *Calluna vulgaris*, progressively increased, finally producing the extensive heathfields which dominated the Drenthe Plateau until the early 20th century.

The local vegetation development of the pingo scar can be followed from the Preboreal, when a small, eutrophic lake was present in the centre. This lake expanded until it reached its maximum size in the first part of the Atlantic, around 6000 cal BC. After that time, a process of terrestrialization started, which gradually transformed the open water, bordered by "shore weed" vegetation, into oligotrophic raised-bog vegetation dominated by *Sphagnum*. By 1500 cal BC, the open water had completely disappeared.

VIII Discussion and conclusions

On the basis of pollen diagrams from Drenthe and *Siedlungskammer* Flögeln, a model is constructed which describes the course of selected pollen curves during the NOP in Pleistocene areas near the North Sea coast. It is emphasized that the manifestation of the NOP in a pollen diagram can be severely influenced by local conditions, viz. basin size, sediment type, location of the coring within the basin and distance to the site of former human activity.

Concerning the culture-indicator types, it appears from the Gietsenveentje master diagram that in the NOP *Rumex acetosa* occurred in nutrient-rich grass-rich vegetation, while *Rumex acetosella*, increasing only after the NOP together with *Calluna vulgaris*, most probably grew on exhausted soils, formerly used as arable fields. *Plantago lanceolata* is considered to be an indicator type for grass-rich vegetation, not for arable land.

The "classic" *Ulmus* decline in the Gietsenveentje diagrams took hundreds of years; it probably was mainly caused by activities of the first farmers. No evidence is found for elm disease.

On the basis of the Gietsenveentje pollen data, combined with archaeological data and macroscopic-remains and pollen data from archaeological contexts, an attempt is made to reconstruct the agricultural economies of the cultures involved in the emergence and early development of agriculture on the Drenthe Plateau. In phase NOP-1 (4050-3450 cal BC), people of the Swifterbant Culture foddered their livestock partly with leaves and twigs of *Ulmus* and *Tilia* in particular; however, also small-scale woodland pastures must have been employed. The cultivation of cereals started ca. 4050 cal BC at the earliest. Phase NOP-2 (3450-2600 cal BC) is connected with the Funnel Beaker Culture, the first fully agrarian culture on the Drenthe Plateau. Apparently, stock keeping became more important: the area of woodland pasture increased. No large-scale burning was used to clear the forest. It cannot be determined whether the arable fields were used only once or on a more permanent basis. Phase NOP-3 (2600-1770 cal BC) is connected with the Single Grave Culture (EGK) and the Bell Beaker Culture (BB). More concentrated habitation and more intensively grazed pastures, covering a smaller area than in phase NOP-2, probably caused an overall decrease of human pressure on the vegetation. Locally, the exhaustion of soils gave rise to an increase of vegetation types with *Calluna vulgaris*.

People of the Swifterbant Culture obtained their knowledge of agriculture from the Rössen Culture, but it was not until the period of the subsequent Michelsberg Culture that agriculture gained considerably in importance. In the wetland communities, stock keeping was adopted around 4750 cal BC, and crop cultivation only around 4200 cal BC. This study has demonstrated that farming was practised by what appear to be upland communities of the Swifterbant Culture, from 4050 cal BC onwards.

Zusammenfassung

I Einleitung

Vorliegende Arbeit beschäftigt sich mit dem Beginn der Landwirtschaft, wie er sich durch die Untersuchung von Sedimenten in einem Pingorest auf einem relativ hohem Teil des Drenthe-Plateaus in den Niederlanden zu erkennen gibt. Der Pingorest ist das Gietsenveentje, dicht bei dem Dorf Gieten in der Provinz Drenthe gelegen. An dem Sediment wurden verschiedene Untersuchungsmethoden angewendet: Pollenanalyse, Radiokarbondatierung, Makrorest- und Holzanalyse sowie Phosphatanalyse. Allgemein wird angenommen, daß die ersten Bauern auf dem Drenthe-Plateau zur Trichterbecherkultur (TRB) (3400-2800 cal BC) gehörten. Es gibt allerdings schwache archäologische Hinweise darauf, daß sich bereits Siedler der Swifterbantkultur – eine hauptsächlich aus den tiefgelegenen Teilen der Niederlande bekannte agrarische Kultur zwischen 4900 und 3400 cal BC – auf den höher gelegenen Geestböden des Drenthe-Plateaus aufgehalten haben. Ein wesentliches Ziel dieser Arbeit ist, eine mögliche Präsenz der Swifterbantsiedler auf dem Drenthe-Plateau palynologisch nachzuweisen. Sehr detaillierte ^{14}C-Datierungen sind erforderlich, um das zu erreichen.

Die Zone in den Pollendiagrammen, welche das Neolithikum repräsentiert, ist als Neolithische Okkupationsperiode (NOP) definiert, die wiederum unterteilt wird in drei Neolithische Okkupationsphasen (NOP-1 bis NOP-3). Die pollenanalytischen Merkmale dieser Phasen gleichen in vielem den Phänomenen, die Iversen in dänischen Pollendiagrammen gefunden hat und die er mit dem Begriff *landnam* verbunden hat. Bei der Definition und Abgrenzung der NOP in den Gietsenveentje-Diagrammen wurden die sog. Siedlungszeiger berücksichtigt sowie die komparative Methode.

II Neolithische Okkupationsphasen in Pollendiagrammen: ein Überblick

Iversen erkannte in dänischen Pollendiagrammen eine *landnam*-Phase, die durch frühe Bauern verursacht sei, welche den atlantischen Wald in relativ großem Umfang gerodet haben – vor allem, um eine grasreiche Vegetation für das Vieh zu fördern. Troels-Smith unterschied eine Iversens *landnam* vorangehende kulturelle Phase, die seiner Meinung nach Rodungen in viel kleinerem Umfang zeigt: die Bauern schneitelten das Laub und nutzten es als Viehfutter. Es wird ein Überblick über die Kulturphasen zu Beginn des Neolithikums in Pollendiagrammen aus verschiedenen Teilen Europas (aus den Niederlanden, Norddeutschland, Dänemark, Südschweden und von den Britischen Inseln) gegeben. Dabei wurde versucht, die Kulturphasen entweder auf eine Troels-Smith Phase oder auf eine Iversen Phase zu beziehen, obwohl dies naturgemäß eine Vereinfachung sein muß. Es zeigte sich, daß in ähnlichen Landschaftstypen, in denen sich dieselben Kulturen ausgebildet hatten, auch in den Pollendiagrammen eine ähnliche Folge von Kulturphasen gefunden wird. In viele Teilen Europas fallen die Kulturphasen am Beginn des Neolithikums mehr oder weniger mit einem deutlichen Rückgang von *Ulmus*-Pollen zusammen – ein Ereignis, das fast gleichzeitig in allen nordwesteuropäischen Pollendiagrammen zu sehen ist. Dieser *Ulmus*-Fall war höchstwahrscheinlich durch eine Ulmenkrankheit in Kombination mit anthropogenen Eingriffen in die Vegetation verursacht. Es kann auch eine Klimaänderung für die Veränderungen in den Pollenkurven am Beginn des Neolithikums verantwortlich sein. Es gibt tatsächlich Belege aus verschiedenen Disziplinen, daß eine weltweite Klimaänderung um 5000 BP stattgefunden hat. Es wird angenommen, daß sich das Klima zu mehr kontinentalen Verhältnissen hin veränderte mit zunehmender Trockenheit. Für die Interpretation der Kulturphasen in den Pollendiagrammen ist eine gründliche Kenntnis besonders der landwirtschaftlichen Aspekte der frühneolithischen Kulturen unerläßlich. Daher werden die archäologischen Kulturen, die gemeinsam für die Verbreitung der Landwirtschaft in den Niederlanden verantwortlich sind, hier kurz diskutiert. Dabei wurde versucht, gerade die schwierigen Fragen zu beleuchten, wie und warum der Übergang zur Landwirtschaft in den Niederlanden stattgefunden hat.

III Das Drenthe-Plateau: Landschaft, Vegetation und Archäologie

Geologie, Böden, Hydrologie, Klima, Vegetation und Archäologie des Drenthe-Plateaus werden kurz diskutiert. Das Gietsenveentje und seine Umgebung werden unter Zugrundelegung einer Reihe von Karten, die alle den gleichen Ausschnitt von zirka 20 km² zeigen, im Detail be-

schrieben. Weil das Gietsenveentje ein Pingorest ist, wird die Bildung solcher Eiszeitrelikte aus der letzten Eiszeit, der Weichsel-Kaltzeit, erklärt. Es wurde versucht, die potentielle natürliche Vegetation in der Nähe des Gietsenveentjes auf der Grundlage der heutigen Bodentypen zu rekonstruieren. Darauf folgt eine Übersicht über die archäologische Funde aus der Zeit der Swifterbantkultur (4900-3400 cal BC) auf dem Drenthe-Plateau, unter denen sich außer Keramik und Flintgeräten (insbesondere Rössener Breitkeile) auch Hornzapfen und Hirschgeweihgeräte befinden. Aus der Nähe des Gietsenveentjes ist nur eine Fundstelle der Swifterbantperiode bekannt, dagegen aber viele Funde der Trichterbecherkultur, nämlich Megalithgräber, Konzentrationen von Flint und Keramik und viele Einzelfunde, sowie der darauffolgenden Einzelgrab- und Glockenbecherkulturen. Die Landschaftsveränderungen in den letzten zwei Jahrhunderten in der Nähe des Gietsenveentjes werden durch einer Anzahl historischer topographische Karten dargestellt.

IV Material und Methoden

Kapitel IV beschreibt die Verfahren, mit denen die Profile erbohrt wurden, die Technik der Probenentnahme, die Aufbereitungs- und Analyseverfahren, denen die Proben unterzogen wurden, sowie die Darstellungsweise der Pollendiagramme. Anschließend werden die beiden hier angewendeten Verfahren der Radiokarbondatierung vorgestellt, nämlich die konventionelle Methode und die AMS-Methode. Die Formeln, die für die Berechnung von Pollenkonzentration und Polleninflux benutzt wurden, sind angegeben ebenso wie die Techniken für die Entnahme von Oberflächenproben und für die Aufnahme der rezenten Vegetation.

V Pollenmorphologie von *Rumex acetosa* und *Rumex acetosella* und ihr Vorkommen in Oberflächenproben

Pollenkörner vom *Rumex*-Typ werden als brauchbare Indikatoren für menschliche Aktivitäten angesehen. Es wurde versucht, Pollen vom *Rumex*-Typ, die kleiner als 22 µm sind, zu unterteilen in Pollen von *Rumex acetosa* (Großer Ampfer) und Pollen von *Rumex acetosella* (Kleiner Ampfer) aufgrund der Länge und der Tiefe ihrer Colpi. Die Ökologie dieser beiden Ampferarten ist fundamental verschieden. Die Untersuchung von Oberflächenproben aus Vegetationstypen, in denen diese beiden Arten heute vorkommen, von Nietap, Gieten, Hijkerveld und Schiermonnikoog hat gezeigt, daß Pollen von *Rumex acetosa* zusammen mit Pollen von Gramineae, *Plantago lanceolata* und manchmal *Ranunculus acris* group meist auf eine relativ nährstoffreiche gräserreiche Vegetation deutet, während der Pollen von *Rumex acetosella* auf Rodungen auf armen Böden, *Secale*-Felder oder verlassenes Ackerland hinweist. Diese Erkenntnis wird bei der Rekonstruktion von den Biotopen der beiden Ampferarten während der NOP angewendet.

VI Multidisziplinäre Analyse der Gietsenveentje-Profile

Es wurden Höhenlinien-Karten von der Oberfläche und vom pleistozänen Untergrund erarbeitet, die auf der Auswertung einer großen Anzahl von Bohrungen beruhen; darüber hinaus wurden vier Lithologietransekte konstruiert, die Querschnitte durch mehrere Teile des Pingorestes zeigen. Die heutige Vegetation im Gietsenveentje wurde kartiert; zum Vergleich mit den subfossilen Pollenspektren wurden Oberflächenproben entnommen. Neun Profile aus mehreren Teilen des Gietsenveentjes wurden pollenanalytisch bearbeitet. Die NOP fand sich in sechs der neun erstellten Pollendiagramme. Auf der Grundlage der regionalen Pollentypen im Hauptdiagramm Gieten V-A wurden Pollenzonen erarbeitet, die mit den Blytt/Sernander Perioden korrelliert wurden. Die Rekonstruktion der lokalen Vegetationsentwicklung basiert auf der Auswertung der lokalen Pollentypen gemeinsam mit den pflanzlichen Großresten und Holz. Um die NOP in den Pollendiagrammen mit archäologischen Kulturen verknüpfen zu können, wurden 56 ^{14}C-Daten von acht Gietsenveentje-Profilen ermittelt. Zwei verschiedene Kalibrationsmethoden wurden angewandt, um die ^{14}C-Daten in Kalenderjahre zu übertragen. Da Reihen von Daten in bekannten stratigraphischen Abfolgen verfügbar sind, ließen sich über das "Wigglematching" der Daten relativ genaue Kalenderdaten ermitteln, wobei mögliche Fehlerquellen umfangreich diskutiert wurden. Der Beginn von Phase NOP-1 wurde um 4100-4000 cal BC datiert, der Beginn von Phase NOP-2 um 3500-3400 cal BC. Zusätzlich wurden Pollenkonzentrations- und Polleninfluxdiagramme für fünf Profile errechnet, die jedoch im Vergleich mit den Prozentdiagrammen kaum zusätzliche Informationen erbrachten. Ein Influxmaximum um 3700 cal BC in allen Kurven der vier Diagramme deutet möglicherweise auf lokale, kleinräumige Waldrodungen hin, die zur Einbringung von Bodenmaterial – und damit von Pollenkörnern – ge-

führt haben. Phosphatanalysen an Proben von drei Gietsenveentje-Profilen zeigen einen allmählich ansteigenden Phosphatgehalt während der Phase NOP-1, der in Phase NOP-2 weiter zunimmt; der Phosphatanstieg ist möglicherweise durch Viehdung verursacht, der am Ufer des damaligen Sees hinterlassen wurde, oder durch Dünger, der im Ackerland eingebracht wurde.

VII Vegetationsentwicklung in und um das Gietsenveentje vom Präboreal an

Im Präboreal (Zone 1) dominieren offene *Betula*-Wälder die Landschaft. Im Boreal (Zone 2) wurde *Pinus* dominant zusammen mit *Betula*; der Anteil von *Corylus* und *Quercus* in der Vegetation nahm zu. Im Atlantikum (Zonen 3a und 3b) bildeten sich stabile Klimaxwälder aus: auf dem Geschiebelehmplateau stockten vor allem *Quercus*, *Ulmus*, *Tilia* und *Fraxinus*, in den Decksandgebieten waren *Quercus* und *Betula* vorherrschend. Am Beginn des Subboreals (Zonen 4a, 4b und 4c) wird der menschliche Einfluß im Pollenbild erkennbar. Zone 4a fällt mit der Neolitischen Okkupationsperiode zusammen, die wiederum in drei Phasen unterteilt werden kann. In Phase NOP-1 wurden die Urwälder in geringem Umfang geöffnet. Das war offensichtlich zum Vorteil für *Quercus* und *Tilia*, die hier maximale Pollenwerte erreichen. Es dürfte relativ kleine Äcker gegeben haben und verschiedene Typen von grasreicher Vegetation, die durch das Vieh erhalten wurde. In Phase NOP-2 fanden ausgedehntere Rodungen statt, besonders in den reichen Wäldern auf dem Geschiebelehmplateau; nun wurden auch *Quercus* und *Tilia* in Mitleidenschaft gezogen. Phase NOP-3 reflektiert einen Zeitabschnitt, in welchem der anthropogene Druck auf die Vegetation zeitweise nachließ. Im späteren Abschnitt des Subboreals (Zonen 4b und 4c) und in der darauffolgenden Periode, im Subatlantikum (Zonen 5a, 5b und 5c), wird eine Entwicklung zu großflächigen Rodungen der Wälder und ihr Ersatz zu Wirtschaftsflächen sichtbar. Gleichzeitig nahmen die Areale mit verarmtem und dann aufgegebenem Ackerland zu, auf denen sich *Calluna vulgaris* immer mehr ausbreiten konnte, was letztendlich zu den extensiven Heideflächen führte, die das Drenthe-Plateau bis zu Beginn des 20. Jahrhunderts beherrschten.

Die lokale Vegetationsentwicklung des Pingorestes kann seit dem Präboreal verfolgt werden, als ein kleiner, eutropher See im Zentrum bestand. Dieser See vergrößerte sich, bis er im ersten Abschnitt des Atlantikums um 6000 cal BC seine maximale Ausdehnung erreichte. Nach dieser Zeit setzte der Verlandungsprozeß ein, das offene, von einer Ufervegetation gesäumte Gewässer verschwand und machte einer oligotrophen, von *Sphagnum* dominierten Hochmoorvegetation Platz. Um 1500 cal BC war das offene Wasser vollständig verschwunden.

VIII Diskussion und Schlußbetrachtung

Auf der Grundlage der Pollendiagramme von Drenthe und aus der Siedlungskammer Flögeln wurde ein Schema erarbeitet, das den Verlauf ausgewählter Pollenkurven während der NOP im pleistozänen Gebiet nahe der Nordseeküste beschreibt. Dabei wurde deutlich, daß die Ausbildung der NOP im Pollendiagramm stark durch lokale Faktoren beeinflußt wird, wie Beckengröße, Sedimenttyp, Lage der Bohrung im Becken und Abstand zur den damals anthropogen geprägten Biotopen.

Betrachtet man die Pollentypen der Siedlungszeiger, so zeigt sich im Gietsenveentje-Hauptdiagramm, daß *Rumex acetosa* in der NOP in nährstoffreichen, grasreichen Vegetationstypen wuchs, während *Rumex acetosella*, der nur nach der NOP zusammen mit *Calluna vulgaris* zunimmt, höchstwahrscheinlich auf erschöpften Böden wuchs, die vorher als Ackerland genutzt wurden. *Plantago lanceolata* kann als Zeiger für grasreiche Vegetation angesehen werden, nicht für Ackerland.

Der "klassische" *Ulmus*-Rückgang in den Gietsenveentje-Diagrammen dauerte mehrere Jahrhunderte; er war wahrscheinlich hauptsächlich durch Aktivitäten des ersten Bauern verursacht. Beweise für eine Ulmenkrankheit fehlen.

Auf der Grundlage der Gietsenveentje-Pollendiagramme, und in Zusammenschau mit archäologischen Daten und Makrorest- und Pollendaten aus archäologischen Zusammenhängen, ist der Versuch gemacht worden, die Landwirtschaftssysteme derjenigen Kulturen zu rekonstruieren, die an der Entstehung und der frühen Entwicklung der Landwirtschaft auf dem Drenthe-Plateau beteiligt waren. In Phase NOP-1 (4050-3450 cal BC) fütterten Siedler der Swifterbantkultur ihr Vieh teilweise mit Laub und Zweigen von besonders *Ulmus* und *Tilia*, jedoch dürften auch kleinflächige Waldweiden genutzt geworden sein. Auch der Getreidenanbau begann hier frühestens um 4050 cal BC. Phase NOP-2 (3450-2600 cal BC) ist verbunden mit der Trichterbecherkultur, die erste reine Bauernkultur auf dem Drenthe-Plateau. Der Anteil der Viehhaltung wurde nun offenbar bedeutender, das

zur Waldweide dienende Gebiet vergrößerte sich. Brandrodung wurde wohl nicht eingesetzt. Es kann nicht festgestellt werden, ob die Ackerflächen nur einmal benutzt wurden oder ob sie permanent waren. Phase NOP-3 (2600-1770 cal BC) konnte mit der Einzelgrabkultur (EGK) und der Glockenbecherkultur (BB) verbunden werden. Eine stärkere Siedlungskonzentration und intensiver begraste Weiden, die nun kleinere Flächen als in der Phase NOP-2 einnahmen, verminderten in breiter Linie den menschlichen Druck auf die Vegetation. Die Bodenerschöpfung führte lokal zur Zunahme von Vegetationstypen mit *Calluna vulgaris*.

Die Siedler der Swifterbantkultur erhielten ihre Kenntnisse von der Landwirtschaft von der Rössener Kultur, aber es dauerte bis in die Zeit der Michelsberger Kultur, bis die Landwirtschaft wesentlich an Bedeutung zunahm. Im Küstenraum der Niederlande ist mit Viehhaltung ab 4750 cal BC zu rechnen, Getreidenutzung jedoch erst um 4200 cal BC. Diese Arbeit konnte nachweisen, daß auf dem Drenthe-Plateau die Landwirtschaft von Siedlern übernommen wurde, die sich als Inlandsiedler der Swifterbantkultur (ab 4050 cal BC) erwiesen.

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Appendices

Appendix I

Abbreviations

Pollen diagrams

ΣP	pollen sum
AP	Arboreal Pollen
NAP	Non-Arboreal Pollen
PREFACT	Palynological Reflection of Early Farming ACTivities
NOP	Neolithic Occupation Period, subdivided into Neolithic Occupation Phases

Cultural groups

LBK	Linear Pottery Culture (*Linearbandkeramik*)
SW	Swifterbant Culture
HAZ	Hazendonk Group (part of the Michelsberg Culture)
VL	Vlaardingen Culture
TRB	Funnel Beaker Culture (*Trichterbecher*)
EGK	Single Grave Culture/Protuding Foot Beaker Culture/Corded Ware (*Einzelgrabkultur*)
BB	Bell Beaker Culture
EN TRB	Early Neolithic Funnel Beaker Culture (Danish chronological system)
MN TRB	Middle Neolithic Funnel Beaker Culture (Danish chronological system)

Altitude

N.A.P.	*Nieuw Amsterdams Peil*, Dutch sea level datum

Dates

BP	uncalibrated ^{14}C date "before present", i.e. before AD 1950 on the conventional ^{14}C scale
cal BC	calibrated ^{14}C date before Christ
cal AD	calibrated ^{14}C date Anno Domini

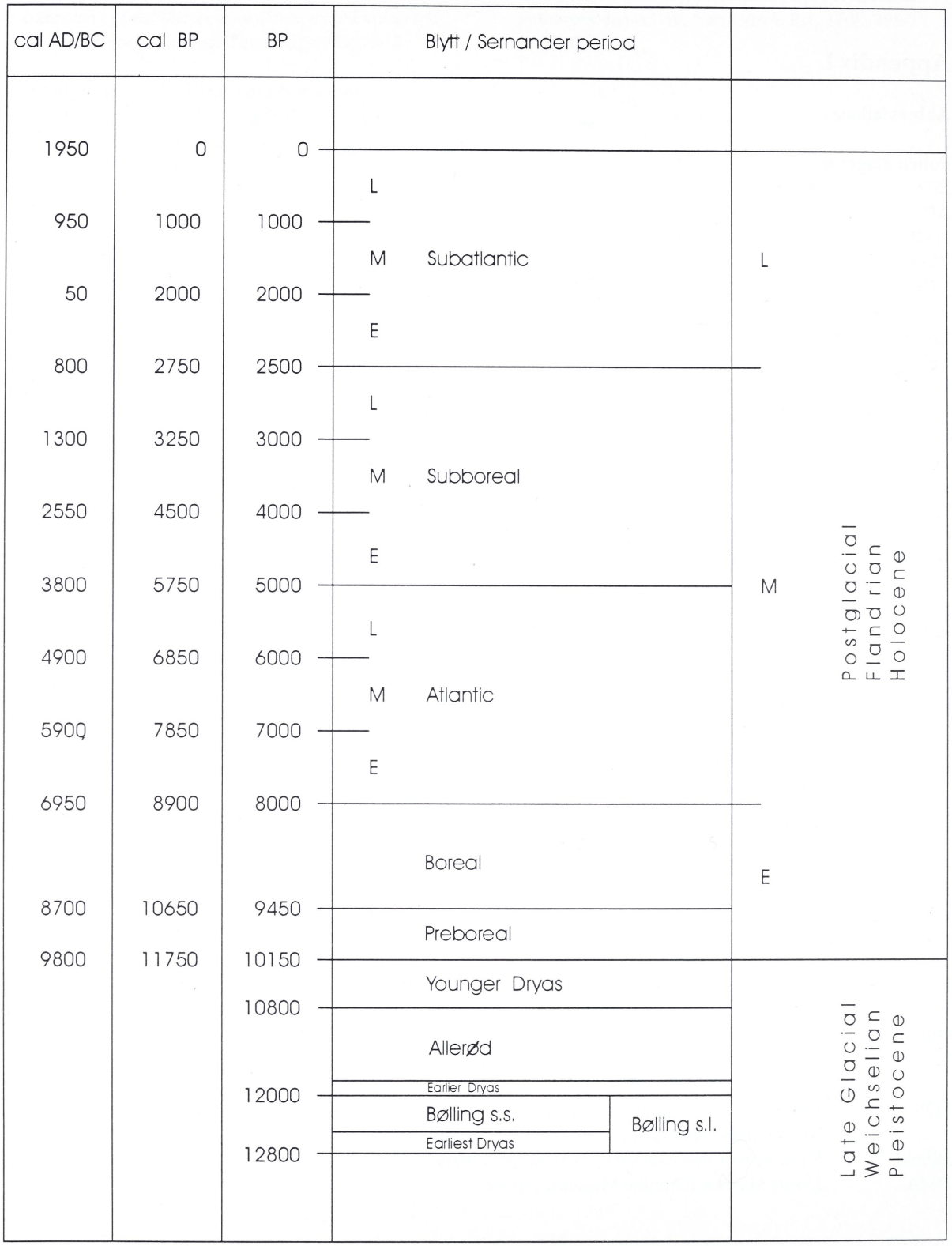
Institutes for ^{14}C dating

GRO	Groningen, the Netherlands, before 1963
GrN	Groningen, the Netherlands, conventional date
GrA	Groningen, the Netherlands, AMS date
UtC	Utrecht, the Netherlands
Hv	Hannover, Germany
KI	Kiel, Germany
KN	Cologne, Germany

Other institutes in the Netherlands

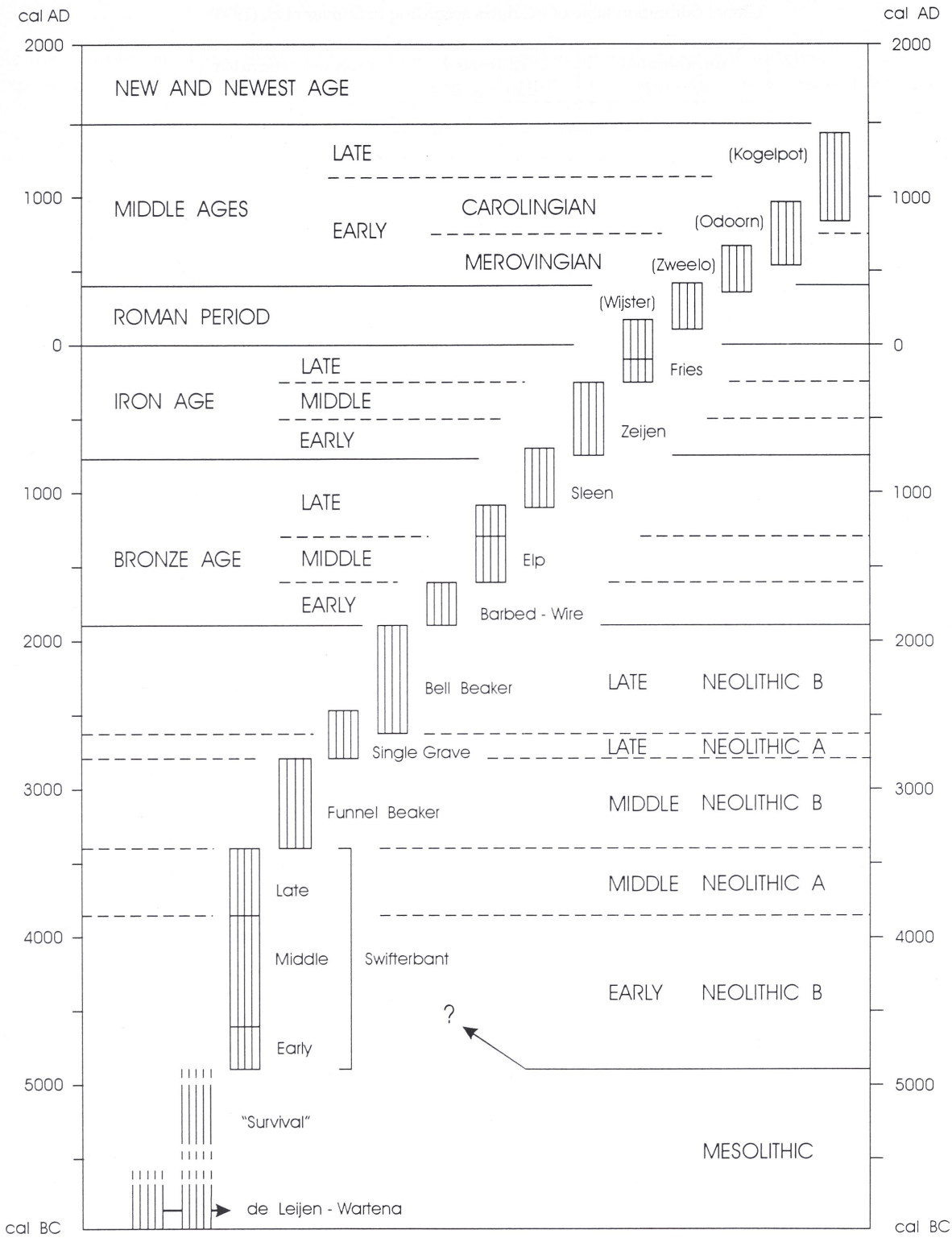
BAI	the former *Biologisch-Archaeologisch Instituut*, now the Groningen Institute of Archaeology, University of Groningen
ROB	*Rijksdienst voor Oudheidkundig Bodemonderzoek* (State Service for Archaeological Investigation in the Netherlands), Amersfoort
Stiboka	*Stichting voor Bodemkartering* (Soil Survey), Wageningen
DMA	*Drents Museum* (Drenthe Museum), Assen

Appendix II



Division in Blytt/Sernander periods of the Late Glacial and the Holocene, after Lanting & Van der Plicht (1995/1996; 1997/1998; 1999/2000). E: Early, M: Middle, L: Late.

Appendix III



Overview of cultural groups on the Drenthe Plateau from the end of the Mesolithic up to the present day, after Waterbolk (1985a), with adaptations after Raemaekers (1999) and Lanting & Van der Plicht (1999/2000).

Appendix IV

Global calibration table of ^{14}C dates according to Stuiver et al. (1998).

uncalibrated date (BP)	calibrated date (cal BC)	rounded calibrated date (cal BC)
7000	5900	5900
6900	5775	5800
6800	5675	5700
6700	5600	5600
6600	5550	5550
6500	5450	5450
6400	5400	5400
6300	5250	5250
6200	5150	5150
6100	5025	5000
6000	4875	4900
5900	4775	4800
5800	4650	4650
5700	4525	4500
5600	4425	4400
5500	4350	4350
5400	4250	4250
5300	4125	4150
5200	4100	4100
5100	3875	3900
5000	3825	3800
4900	3700	3700
4800	3575	3600
4700	3500	3500
4600	3325	3300
4500	3225	3200
4400	3000	3000
4300	2950	2950
4200	2775	2800
4100	2675	2700
4000	2525	2500
3900	2375	2400
3800	2225	2200
3700	2100	2100
3600	1950	1950
3500	1825	1800
3400	1700	1700
3300	1600	1600
3200	1475	1500
3100	1350	1350
3000	1250	1250

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Ronald Bakker
Groningen, January 2003

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Ronald Bakker

The emergence of agriculture on the Drenthe Plateau
– A palaeobotanical study supported by high-resolution ^{14}C dating

Sediments from a pingo scar, a relic from the last glaciation, in the province of Drenthe (the Netherlands) are studied for their content of pollen and macroscopic remains. On the basis of nine pollen diagrams, the author reconstructs the vegetation from the Preboreal up till the present. Special attention is given to the beginning of the Neolithic, which marks the beginning of agriculture. A model is developed which describes changes in human-influenced pollen types during the Neolithic in pollen diagrams from Pleistocene areas near the North Sea coast.

The so-called Neolithic Occupation Period (NOP) is divided into three phases, which represent three different types of farming economy. By means of high-resolution ^{14}C dating, the three phases are correlated with archaeological cultures. Phase NOP-1, characterized by small-scale arable farming and livestock foddering with leaves and twigs, is dated to 4050-3450 cal BC, which is in the period of the Swifterbant Culture. This shows that the first farmers on the Drenthe Plateau belonged to the Swifterbant Culture. Phase NOP-2, characterized by more large-scale, grass-based stock keeping, is connected with the Funnel Beaker Culture. Phase NOP-3, in which agriculture was concentrated in smaller areas, is contemporary with the Single Grave and Bell Beaker Cultures.

Der Beginn der Landwirtschaft auf dem Drenthe Plateau
– Eine durch hoch auflösende ^{14}C-Datierungen gestützte paläobotanische Studie

Für diese Studie wurden die Sedimente aus einem eiszeitlichen Pingorest in der Provinz Drenthe in den Niederlanden auf ihren Pollengehalt und ihre botanischen Makroreste hin untersucht. Auf der Basis von neun Pollenprofilen rekonstruiert der Autor die Vegetationsgeschichte vom Präboreal bis heute. Besonders berücksichtigt wird die Phase der Neolithisierung und der Beginn der Landwirtschaft. Auf der Grundlage von Pollendiagrammen aus der norddeutschen und niederländischen Altmoränenlandschaft wird ein Schema erarbeitet, das den Verlauf ausgewählter Pollenkurven während des Neolithikums beschreibt.

Die sogenannte Neolithische Okkupationsperiode (Neolithic Occupation Period, NOP) wird in drei Phasen gegliedert, die drei verschiedene Formen der bäuerlichen Wirtschaft repräsentieren. Mit Hilfe hoch auflösender ^{14}C-Datierungen werden diese drei Phasen mit archäologischen Kulturen verbunden. Die Phase NOP1 wird von 4050 bis 3450 cal BC datiert. Sie ist durch geringe ackerbauliche Aktivitäten und Tierhaltung mit Laub- und Zweigfütterung charakterisiert. Sie fällt in die Zeit der Swifterband Kultur, deren Träger also die ersten Bauern auf dem Drenthe-Plateau gewesen sind. Für die Phase NOP 2, die mit der Trichterbecher Kultur verbunden werden kann, ist eine großräumige Viehhaltung charakteristisch. In der Phase NOP 3 dagegen haben die Menschen der Einzelgrab- und der Glockenbecher-Kultur ihre Landwirtschaft auf eher kleinen Arealen betrieben.

Die **DEUTSCHE GESELLSCHAFT FÜR UR- UND FRÜHGESCHICHTE (DGUF)** ist die einzige in ganz Deutschland tätige Personengesellschaft auf dem Gebiet der Ur- und Frühgeschichte. Sie fördert dieses Fachgebiet und angrenzende archäologische Wissenschaften in Forschung und Lehre, verbreitet gesichertes Wissen auf dem Gebiet der Ur- und Frühgeschichte, veranstaltet Tagungen, unterstützt die wissenschaftlichen Einrichtungen des Faches im Rahmen ihrer Möglichkeiten und beteiligt sich an der Klärung von Berufs-, Fach- und Studienfragen.

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