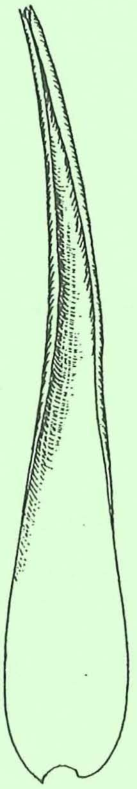
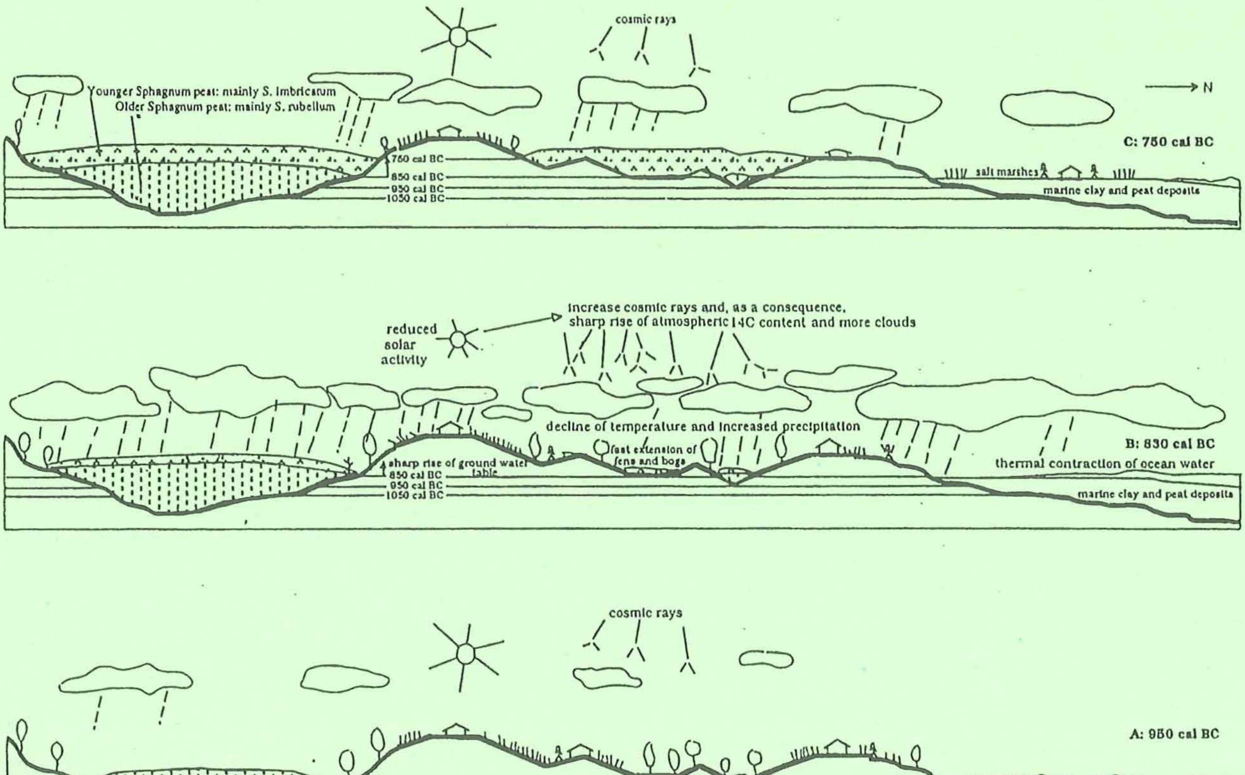


XXIII. Moorexkursion

The Netherlands

29 August to 8 September 1999



XXIII. Moorexkursion, The Netherlands, 29 August to 8 September 1999

(23rd University of Bern International Vegetation-historical Bog and Mire Excursion)

Amsterdam, 26 August 1999

Dear colleagues,

Long ago the surface of the Netherlands was for a considerable part still characterised by forest, fens, bogs and open water. But there is not very much left of the original situation. When the English started to use the word 'landscape', it was based on the Dutch word 'landschap' (in Noord-Holland it is pronounced as 'landskap'), which has to do with the verb 'scheppen' (to create; schaffen). And in this case it was not in the first place God who created, but Man (in fact the Dutch representatives of that species).

When travelling around during our excursion we will see that the results are evident. Apart from the salt marshes, there are hardly any other undisturbed areas in the Netherlands. But fortunately this does not mean that our landscapes are not attractive. In the southern and eastern part of the Netherlands we will see the effects of land use in areas that were formed mostly during the Pleistocene. In the provinces of Groningen and Noord-Holland we will see how different types of polders were made out of salt marshes, former bogs and lakes.

At many places on Pleistocene soils, raised bog deposits were completely used for fuel, but also - especially in the western part (Holland) - wetlands on top of several-meters-thick peat deposits were reclaimed, drained and most of these areas are now in use as grasslands for dairy cattle and sheep. Also the expansion of villages and towns - at many places at the cost of natural, or semi-natural wetlands - was considerable. During this Moorexkursion the Dutch participants, together with local guides, will give you an impression of the different landscapes and their history. In the programme the emphasis will be on bogs, Quaternary geology, history of vegetation and climate, and archaeological aspects. On behalf of all guides: we hope that you will enjoy your stay!

Bas van Geel

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Kruislaan 318 1098 SM Amsterdam
The Netherlands

There was no time left for careful screening and editing of the text of this excursion guide book. Therefore you will see some inconsistencies (e.g., mediaeval, but also medieval). There is also a strong difference (detailed - superficial) in the texts for the various excursion sites. Some of the information is about sites which at present are not worth visiting. We hope you do not mind.

Jacqueline

Hotels:

29 and 30 August: **Tulip Inn**. De Maas 2, 5684 PL Best. Tel.: 0499 390100.

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31 August, 1 and 2 September: **Apart Hotel**, Sportlaan 7, 7491 DG Delden, Tel.: 074 3777666.

3-6 September **Hotel Weeva**, Gedempte Zuiderdiep 8, 9711 HG Groningen, Tel.: 050 3129919.

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7 September: **Hotel Het Slothuys**, Zaagmolenweg 14, 1715 GB Spanbroek. Tel.: 0226 360160

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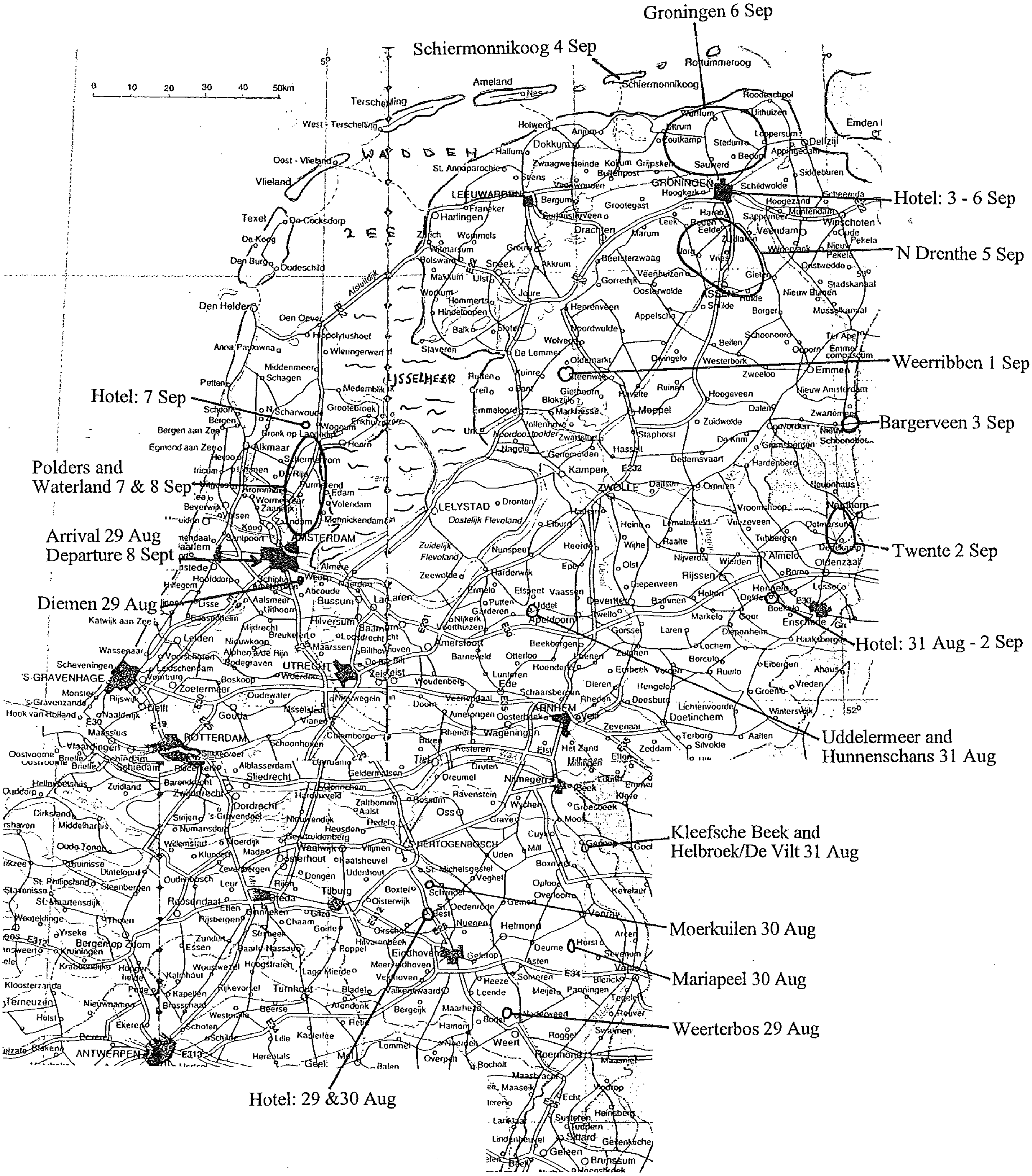
Main themes and excursion points


Groningen 6 Sep
Schiermonnikoog 4 Sep
Hotel: 3 - 6 Sep
N Drenthe 5 Sep
Weerribben 1 Sep
Hotel: 7 Sep
Bargerveen 3 Sep
Polders and
Waterland 7 & 8 Sep
Arrival 29 Aug
Departure 8 Sept
Twente 2 Sep
Diemen 29 Aug
Hotel: 31 Aug - 2 Sep
Uddelermeer and
Hunnenschans 31 Aug
Kleefsche Beek and
Helbroek/De Vilt 31 Aug
Moerkuilen 30 Aug
Mariapeel 30 Aug
Weerterbos 29 Aug
Hotel: 29 &30 Aug

Sunday 29 August:

- Departure from Amsterdam Central Railway Station, northern exit, by minibus.

Temporal and spatial shifts of oak populations in wet forests near Amsterdam around 850 cal BC: new evidence for abrupt climate change around the Subboreal/Subatlantic transition?

In the Gemeenschapspolder and the Overdiemerpolder (municipality of Diemen; fig. 1) the subsoil consists of 3-4 meters of peat (*Phragmites* peat and wood peat) on top of marine clay. The upper ca 30 cm of the profiles shows inundation clays (mediaeval and later inundations from the nearby Zuiderzee).

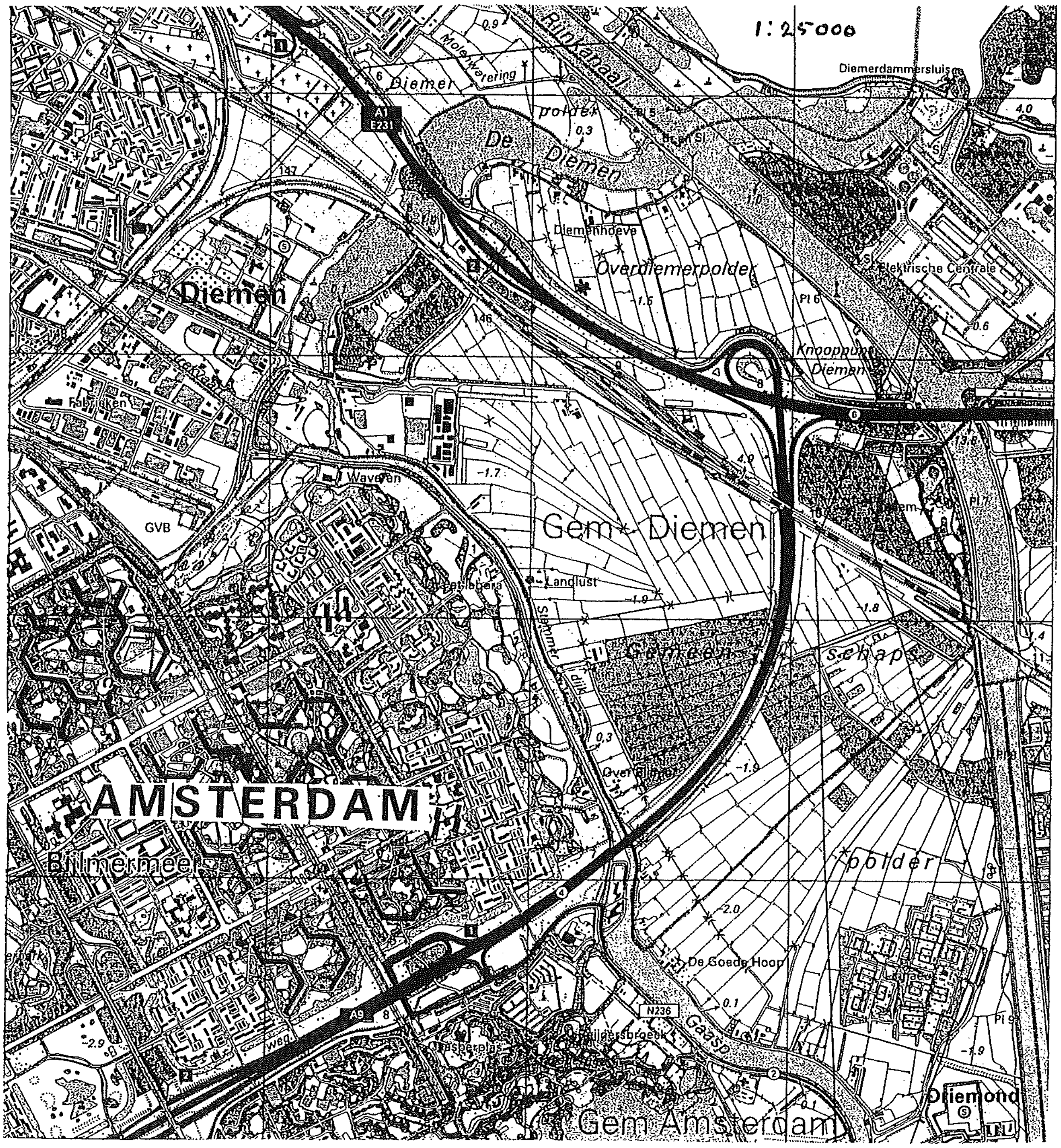


Fig. 1: In the Overdiemerpolder and Gemeenschapspolder fossil oaks were found

In 1997 new recreation areas were made in both polders. Before planting trees and shrubs, the grass sods and the upper clay layer were removed, and new ditches were made. During these activities many fossil oak trunks were discovered. Forty-eight trees were sampled for dendrochronological dating, which was done by by Dr Esther Jansma and colleagues, and then it appeared that two groups of trees were present (fig. 2). In the more central part of the mire (Gemeenschapspolder) the trees had a late Subboreal age, whereas in the marginal (near rivulet) area of the Overdiemerpolder almost all oaks were of Subatlantic age.

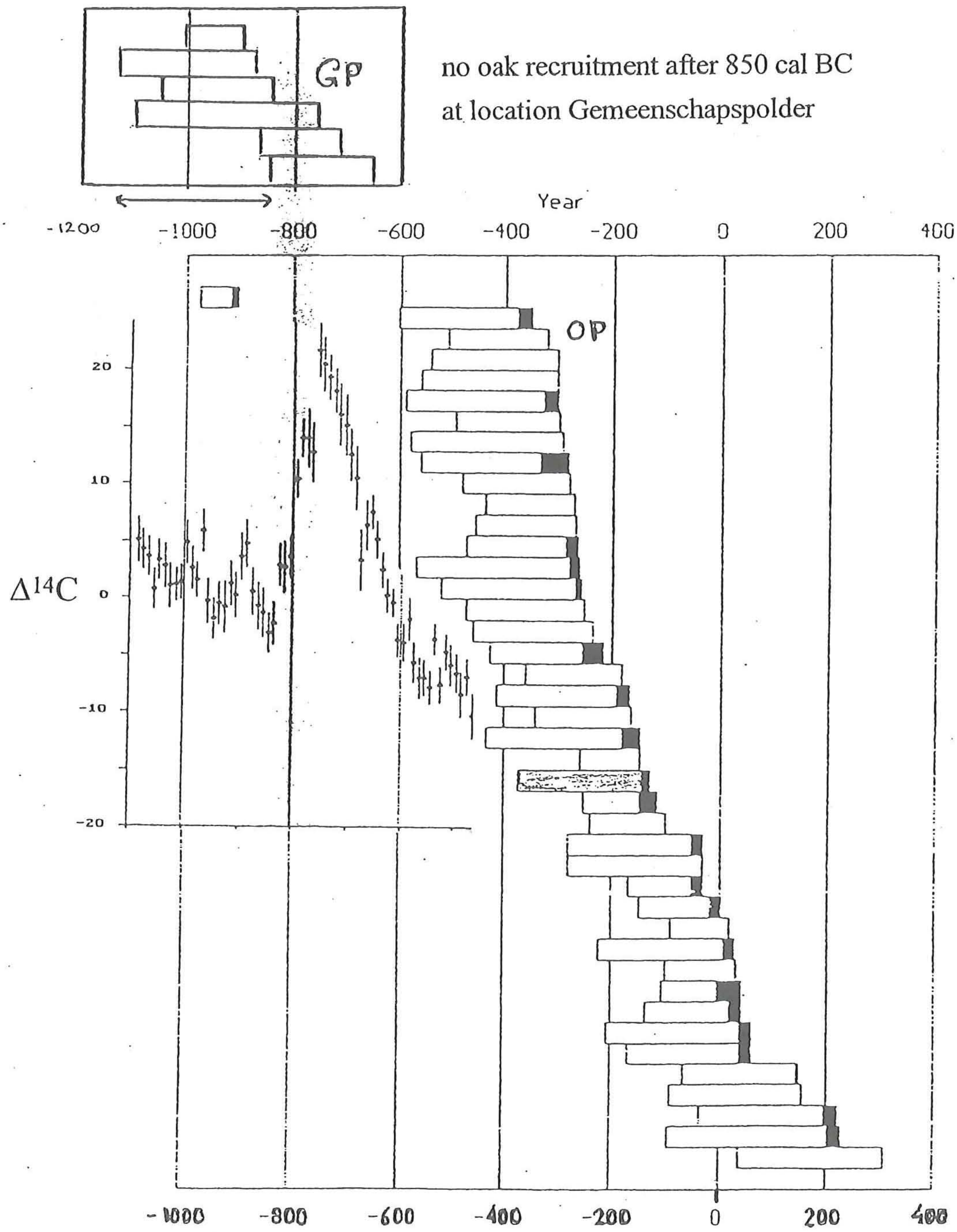


Fig. 2: The dendrochronological record of the oak trunks found in the Gemeenschapspolder (GP) and the Overdiemerpolder (OP). Please note that no new trees started to grow between ca 850 and 600 cal BC. The start of this phase goes together with the sharp rise of delta ^{14}C. Compare that phenomenon with the evidence for climate change in raised bogs, elswhere in the NW-Europe, during the Subboreal/Subatlantic transition.

See also p. 86

Figure 2 also shows the changes of $\Delta^{14}C$ around the Subboreal-Subatlantic transition. The sharp increase of the atmospheric ^{14}C content between 850 and 760 cal BC was caused by increased cosmic ray intensity as a consequence of reduced solar activity. Many proxy data indicate that the climate changed to cooler and wetter conditions (van Geel, 1978; Kilian et al., 1995; van Geel et al., 1996, 1998; see separate copies of reprints).

In figure 2 we see that, although the existing trees in the Gemeenschapspolder area could continue their lives, the reproduction (flowering, seed production, growth of seedlings?) was strongly hampered after the solar induced shift to cooler and wetter climatic conditions around 850 cal. BC. A minimum in bog oak representation as a consequence of climate change around 850 cal. BC only becomes visible in fig. 2 around 650 cal BC (when the old, 'pre-climate-change' trees had died in the absence of a new generation of oaks). In the Overdiemerpolder (see fig. 2) a new generation of oaks appears shortly after 600 cal BC.

Figure 3 shows the complete bog oak data for the Netherlands and the minimum representation around 650 cal BC is evident.

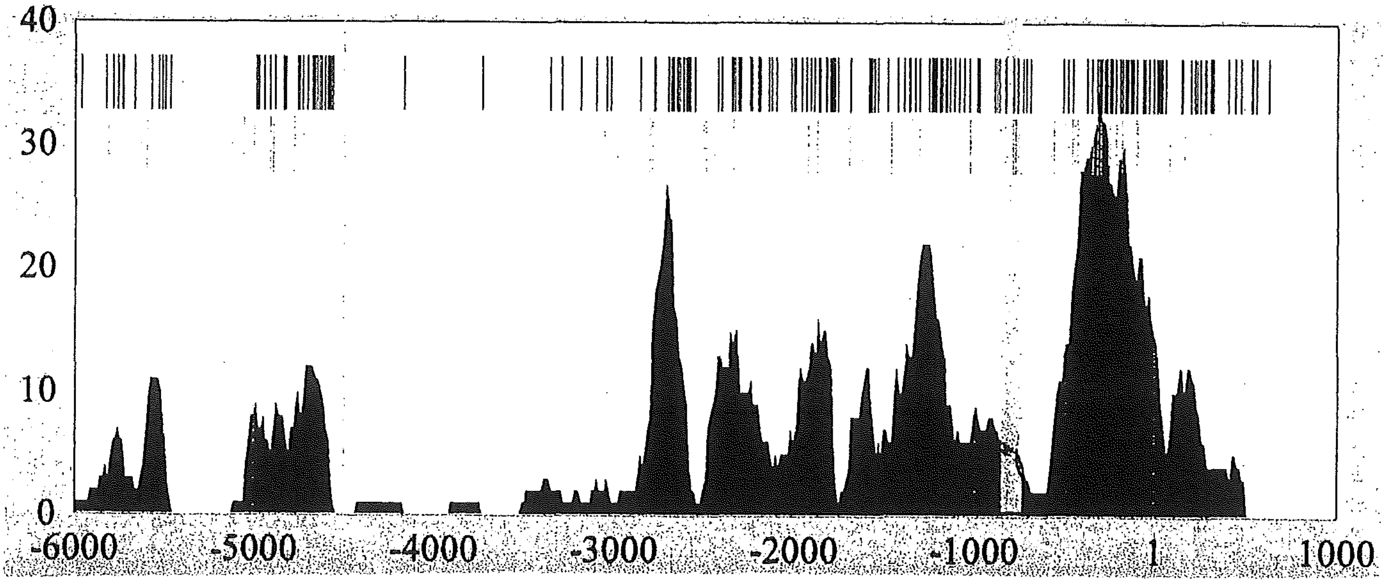


Fig. 3: 'Bog oaks' (number of trees) dated by RING (record d.d. 1/2/1999)

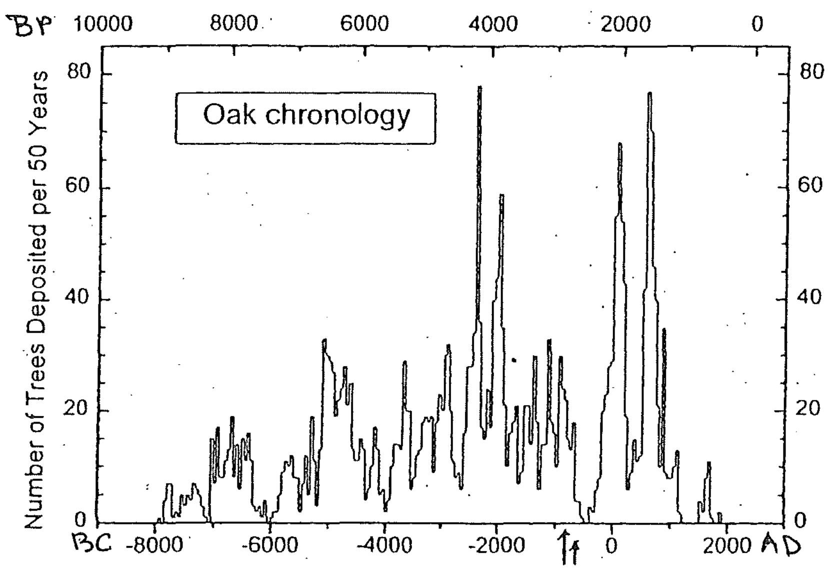


Fig. 4: Distribution of end-years summed over intervals of 50 years, of the subfossil river-oak chronology (Hohenheim Tree-Ring Laboratory; Becker and Kromer, 1993). Note the sharp decline around 700 cal BC. The start of the problems for Auenwälder oaks (too long inundations of the young ones?) will have dated from an 'oak life-time' earlier. Arrows indicate the period of sharp increase of $\Delta^{14}C$ (reduced solar activity and climatic shift too cooler, wetter conditions).

Figure 4 shows that also the central European Auenwälder-oaks show a deep minimum in representation around 650 cal BC, which also seems to have been caused by a preceding phase of hampered recruitment of the last generation of Subboreal oaks.

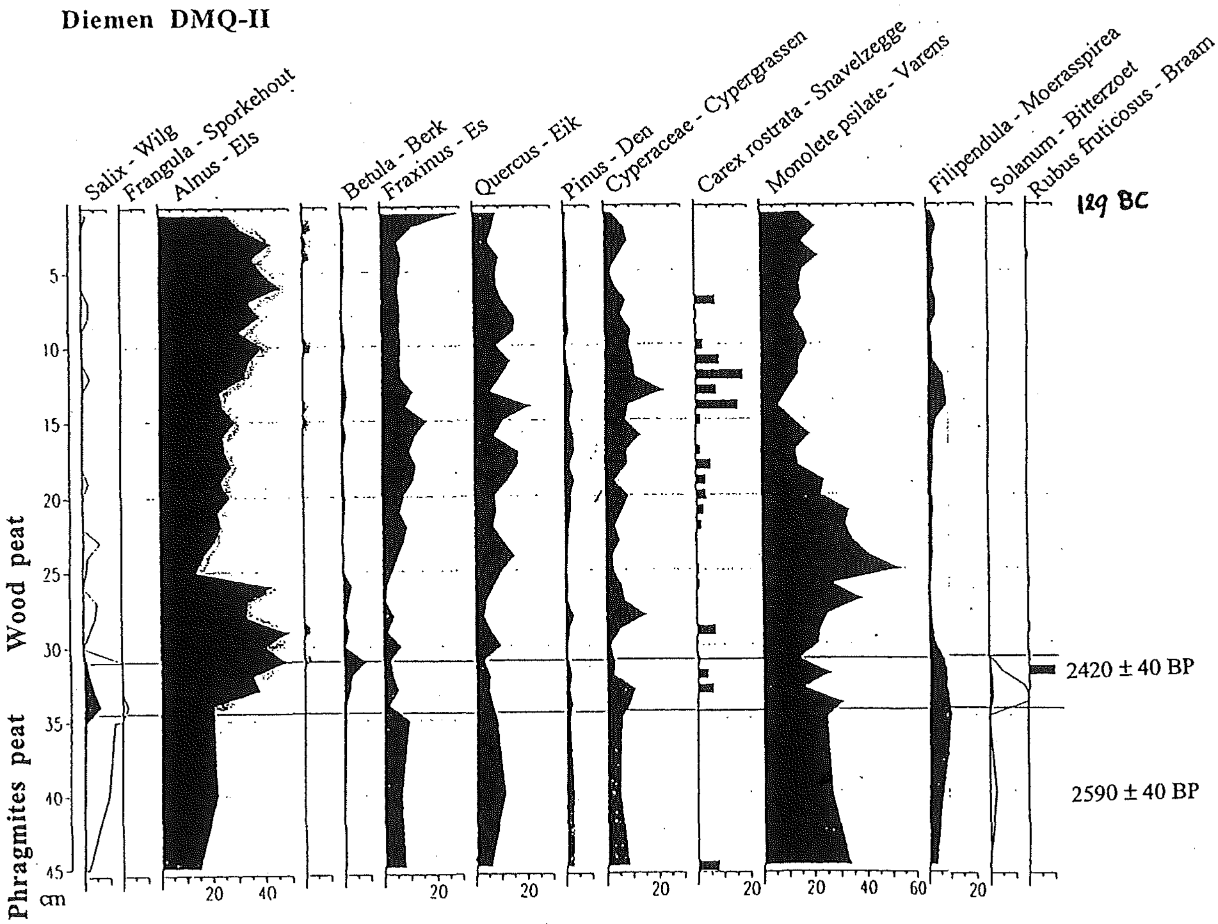


Fig. 5: Selection of taxa, based on a study by Fokma (1998). The peat deposit was sampled directly under an *in situ* trunk of an oak which died 129 cal BC.

A selection of curves of micro and macrofossils of a peat sequence in the Overdiemerpolder (Fokma, 1998) is given in fig.5. Two radiocarbon dates indicate that the transition of *Phragmites* peat to wood peat (local development to drier conditions) took place around the Subboreal-Subatlantic transition. *Salix*, *Solanum dulcamara* and *Rubus* characterise the transition from *Phragmites*-peat to wood peat. Better drainage by the rivulet Diem, as a consequence of a lowering of the sea level (thermal contraction of ocean water??; see van Geel *et al.*, 1996) may have caused this hydrological change.

Some remaining questions to be solved:
- Why had oaks, growing in mires and in Auenwälder, such a difficult time after 850 cal BC?
- Was it because of an increased frequency of inundations, being desastrous for the small ones which could not continue to assimilate and died? Was it frost that caused damage?

We realise that the number (6) of oaks of the relatively old 'Gemeenschapspolder-population' is still too low to form a firm base for our ideas concerning temporal and spatial developments of the oak populations (important role of changes in hydrology as the effect of climate change?). Therefore we have planned to extend the record by dating more oak trunks from the Gemeenschapspolder as soon as possible.

Bas van Geel, Esther Jansma, Ute Sass-Klaassen, Ank Fokma and Jan Peter Pals

8 See also Appendix I

Weerterbos: Registration of Lateglacial Palaeoclimate in a combined Vegetation and Oxygen-Isotope Record

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INTRODUCTION

Termination 1 marks an important change in climate mode over the period between 15,000 and 10,000 cal years BP. Until now, the Greenland Ice-core records (GISP2/GRIP) provide the best climate proxy for the North Atlantic region (Johnsen *et al.*, 1992; Grootes *et al.*, 1993). In northwestern Europe, a large number of terrestrial records have been analyzed for several proxies in great detail, presenting a comprehensive picture of environmental changes on the continent. The climatic coolings recognized in oxygen isotope records from the Greenland ice-cores can be compared to events recorded in the terrestrial environment. Although a good comparison can be made between the vegetation development and other palaeoclimate signals such as oxygen isotope curves (Lotter *et al.*, 1992; Stuiver *et al.*, 1995; Hoek, 1997a), questions remain about absolute chronology and causal relations between events in terrestrial, ice-core and marine records (Björck *et al.*, 1996).

Calcareous lake deposits permit the study of environmental changes with different tools applied on the same stratigraphic level. For instance, palynological and stable isotope analyses can be performed and the combined evidence can be used to reconstruct regional and local environmental changes. Especially the oxygen isotope composition has proved to document palaeoclimate fluctuations in calcareous lake sediments (Eicher and Siegenthaler, 1976; Lotter *et al.*, 1992; Yu and Eicher, 1998; von Grafenstein *et al.*, 1999; Hoek and Bohncke, subm.), which can be correlated with those from Greenland ice-cores (Johnsen *et al.*, 1992; Grootes *et al.*, 1993). Below we show that the oxygen-isotope signal of Weerterbos compares in detail to the Greenland ice-core signal and thus, we have the opportunity to correlate ice-core and terrestrial records based on oxygen-isotope stratigraphy.

MATERIAL AND METHODS

In the province of Limburg, southern Netherlands, some sites exist where Lateglacial calcareous deposits are present at shallow depth (Fig. 1). These calcareous deposits consist of authigenic calcareous gyttjas or lake-marls, formed in the former lakes as a result of oversaturation with calcium carbonate derived from groundwater bicarbonate. Most of the calcareous deposits are situated in the Roer Valley Graben, where hydrostatic pressure is, even at present, responsible for groundwater seepage. The Weerterbos 'Groot Ven' lacustrine record has been sampled with a Livingstone piston corer (diameter 8cm) from a shallow basin filled with calcareous and organic gyttja from the north-western part of Limburg. In the neighbourhood of the investigated site (05°40'E, 51°18'N, altitude +28.3m) some other small pingo remnants occur (Fig. 2). The shallow depression in which the calcareous gyttja was

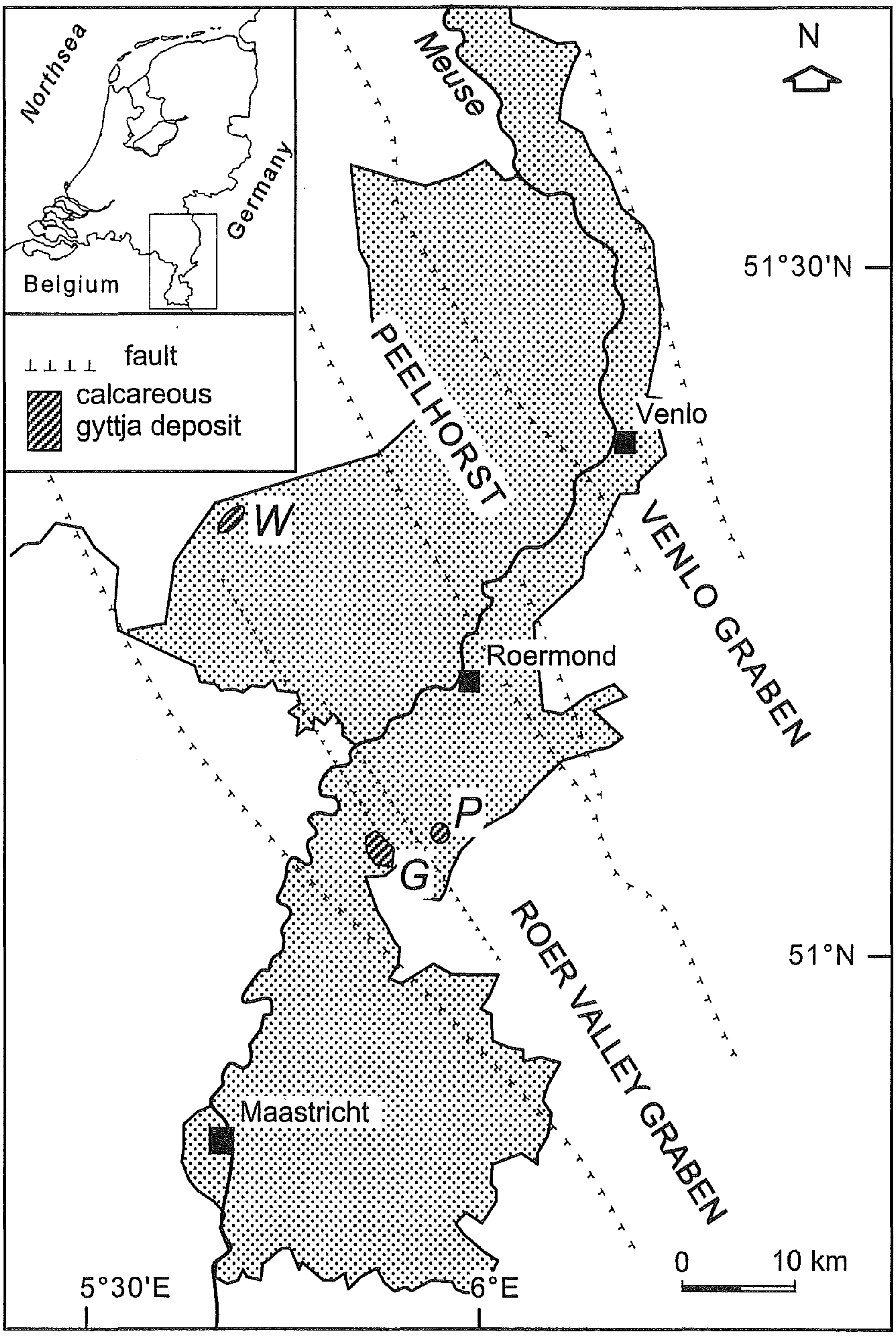

***Figure 1** Map showing location of Weerterbos (this study), Gulickshof (Hoek et al., in press) and Putbroek (Janssen and Ijzermans-Lutgerhorst, 1973).*

deposited lies within a nature reserve and antropogenic influence is considered to be negligible (Hoek and Joosten, 1995). In view of the geomorphology, detailed cross-sections (Fig. 3), calcareous lithology, and the Lateglacial age of the basal infill, the depressions may be interpreted as remnants of a Pleniglacial ground-ice lenses, a common feature in the northern Netherlands, but more rare in the south. A similar origin has been suggested for the circular depression near Putbroek (Janssen and IJzermans-Lutgerhorst, 1973) and Gulickshof (Hoek *et al.*, in press). These sites show a typical Lateglacial vegetation development that can be correlated with many other radiocarbon dated Lateglacial sites in The Netherlands (Hoek, 1997b).

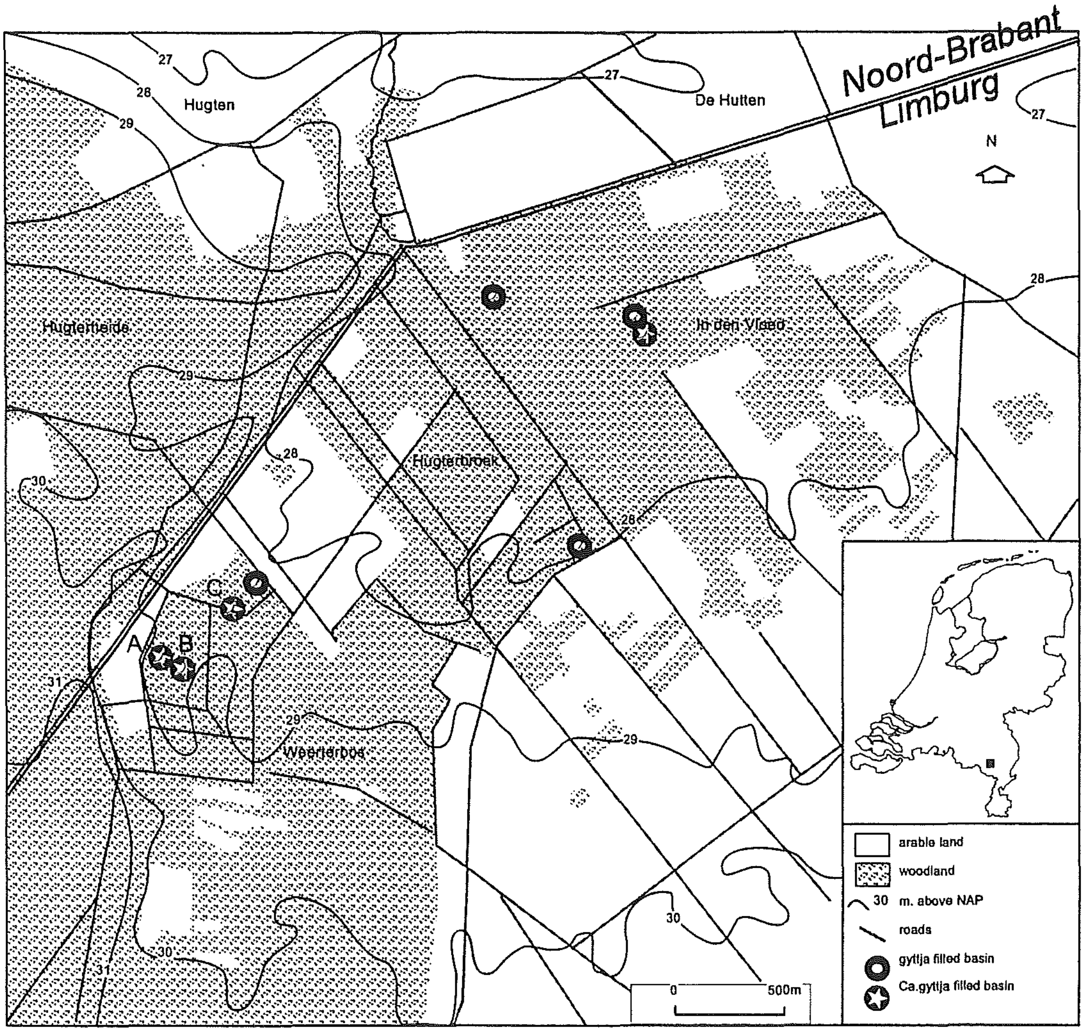

Figure 2 *The Weerterbos area with locations of the circular depressions. A: Klein Ven, B: Groot Ven, C: Berken Ven (after Hoek and Joosten 1995).*

From the Weerterbos 'Groot Ven' core samples were taken for pollen, $CaCO_3$ and isotope analysis. Pollen samples were treated according to standard procedures (Faegri and Iversen, 1989). After mounting in glycerine jelly, determinations were made under 630x magnification. In the pollen diagram 7 major pollen assemblage zones can be recognized based on the region pollen composition (Fig. 4). For the $CaCO_3$-analysis, the calcium carbonate content was measured using the Scheibler-method. For the analysis of stable oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) composition of the carbonate, untreated samples were used (Siegenthaler and Eicher, 1986).

Only very small amounts of terrestrial macrofossils were present in the Weerterbos core, which were even too small for AMS-dating. Furthermore, as calcareous deposits cannot

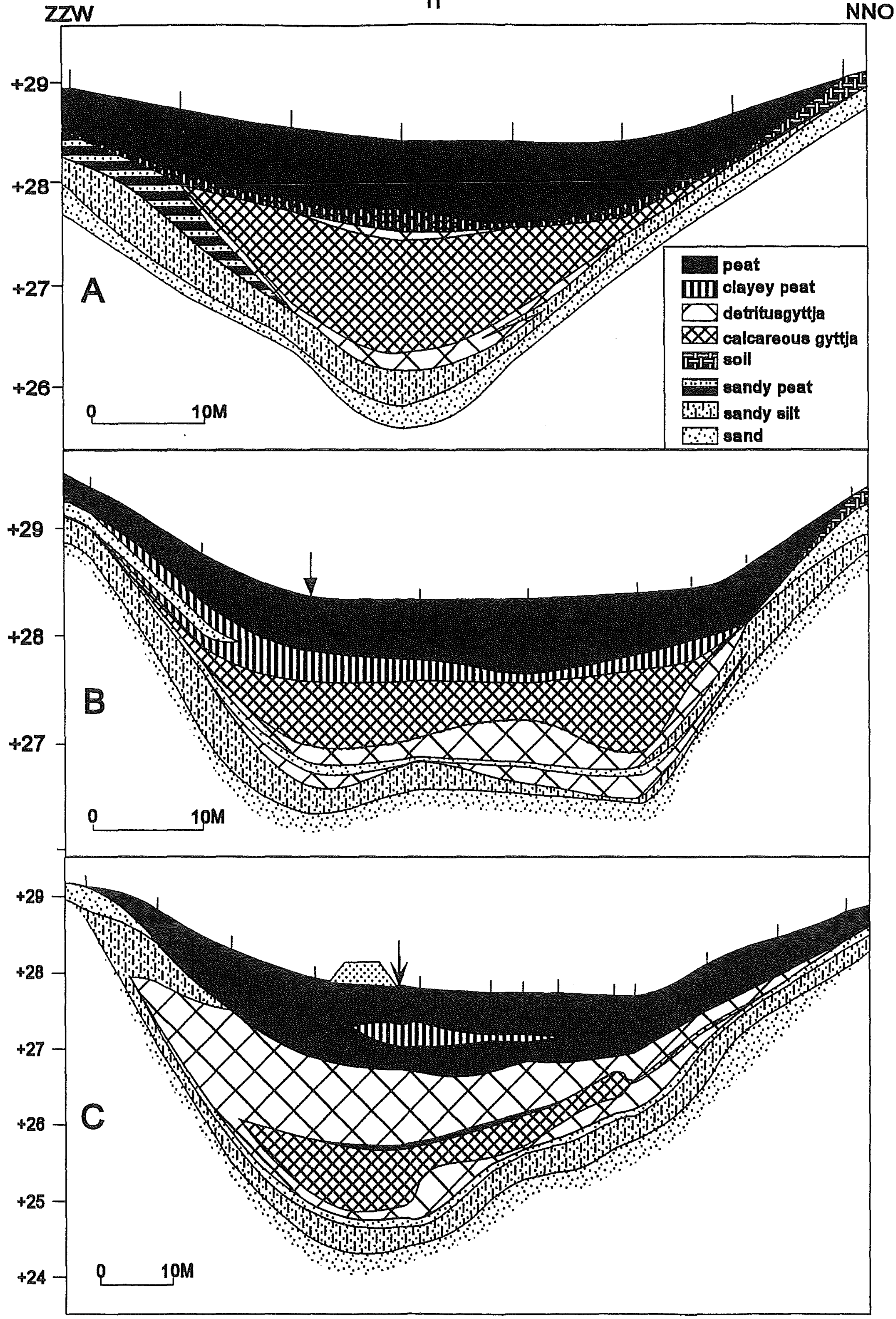

Figure 3 lithological cross-section through the circular depressions with position of the investigated profile marked with an arrow. A: Klein Ven, B: Groot Ven, C: Berken Ven.

be dated accurately with conventional ^{14}C methods, an absolute radiocarbon chronology was difficult to establish. However, the Lateglacial vegetational record from Weerterbos compares well to the Lateglacial vegetation development of The Netherlands. Therefore, the chronostratigraphy for Weerterbos has been established by biostratigraphical correlation with the regional vegetation development for The Netherlands (table 1). This method proved to be successful for many other sites in The Netherlands (Hoek, 1997a). Furthermore, the start of calcareous gyttja deposition in the Weerterbos basin can be correlated to many other locations in the Netherlands where this change in lithology, from siliciclastic to organic, has been dated round 12,500 BP (van Geel *et al.*, 1989; Bohncke, 1993; Hoek, 1997c). Another marked change in lithology is given by the change from calcareous gyttja to organic gyttja dated at the Allerod-Younger Dryas boundary, round 10,950 BP (Hoek, 1997c).
Although uncertainties with the calibration of radiocarbon dates from the Lateglacial period occur, the radiocarbon ages of the zone boundaries have been calibrated to calendar years (cal. years BP: Stuiver and Reimer, 1993; Stuiver *et al.*, 1998)

Table 1. Correlation between Weerterbos pollen assemblage zones and the regional vegetation zones in The Netherlands Hoek, 1997a) on a conventional radiocarbon and calibrated time-scale(Stuiver and Reimer, 1993; Stuiver et al., 1998).

^{14}C age BP	cal. yrs BP	PAZ	zone
10,150	11,745		
		WB-~~5~~ 6	3
10,950	12,980		
		WB-~~4~~ 5	2b
11,250	13,165		
		WB-~~3~~ 4	2a
11,900	13,960		
		WB-~~2~~ 3	1c
12,100	14,100		
		WB-~~1~~ 2	1b
12,450	14,885		

RESULTS

In the pollen diagram (Fig. 4) 7 major pollen assemblage zones can be recognized based on the region pollen composition. The Lateglacial vegetational record from Weerterbos compares well to the Lateglacial vegetation development of The Netherlands. Therefore, we have no doubt that timing of the palynological shifts in Weerterbos correlates to the regional Lateglacial chronology (Table 1).

In zone WB-1 (below 149 cm) high values of *Pinus* are characteristic with total AP values varying round 60%. Together with the occurrence of thermophilous taxa as *Carpinus* this may reflect a temperate forest community. The nature of the deposits (sands and silt) and the relatively high values of heliophilous taxa as *Artemisia*, *Helianthemum* and Chenopodiaceae points towards a more open herbaceous vegetation type and reworking of older Interglacial deposits which explains the presence of thermofilous taxa. Zone WB-1 compares with regional zone LP or sub-zone 1a (Hoek 1997a).

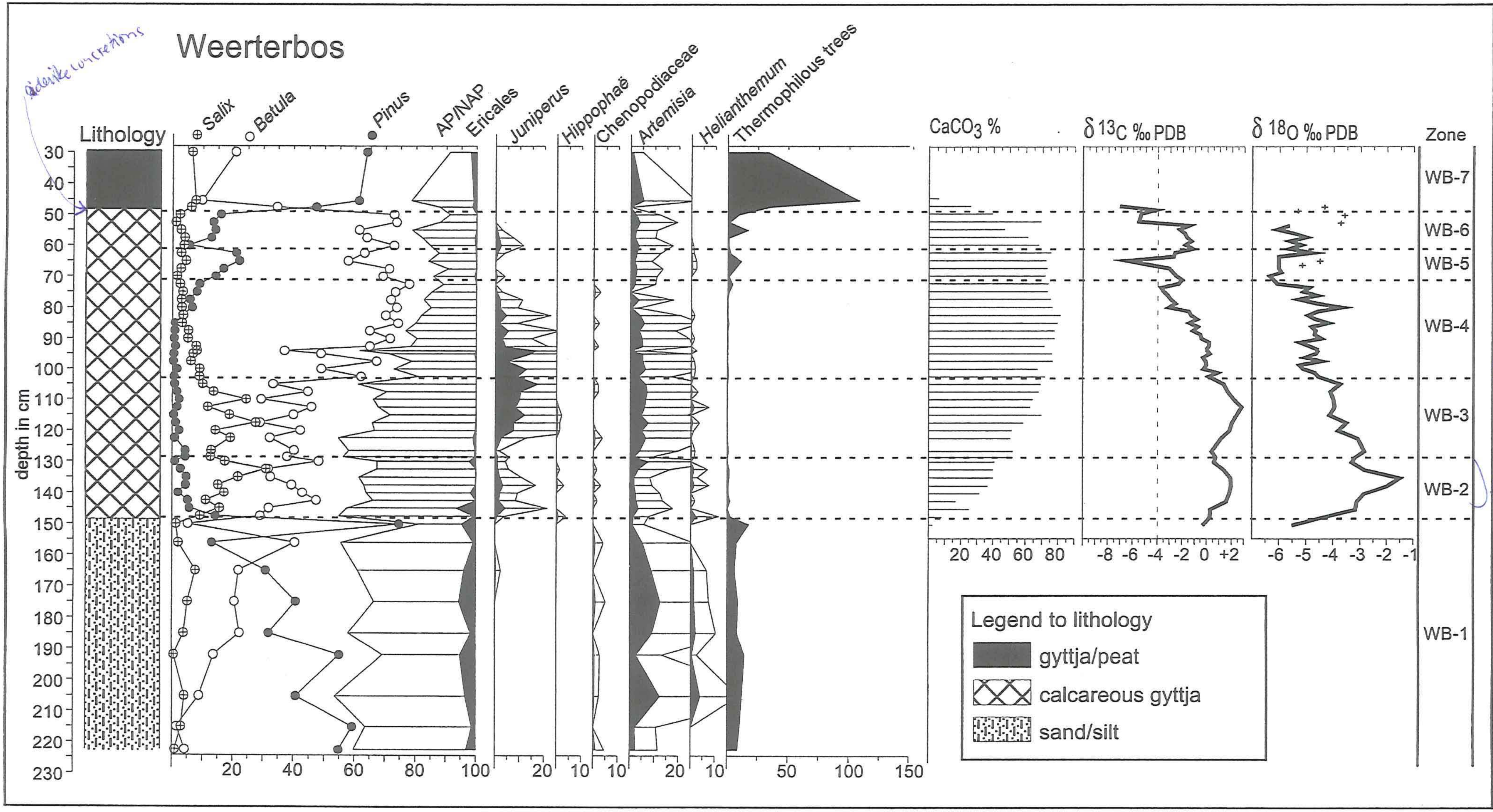

Figure 4 *Percentage pollen diagram from Weerterbos with selected taxa, calcium carbonate content, given as percentages of $CaCO_3$, and stable isotope values plotted against depth. The isotope results for $\delta^{18}O$ and $\delta^{13}C$ are presented as ‰ deviations from the international PDB-standard. Samples with low $\delta^{13}C$ values (+), as a result of a considerable groundwater contribution have been omitted in the main $\delta^{18}O$ curve.*

At the beginning of zone WB-2 (149-129 cm), *Pinus* and thermophilous tree pollen percentages drop to very low values. Arboreal pollen, still with values round 60%, consist of mainly *Betula* (40%) and *Salix* (15%). *Juniperus* is present in low values during the first part of this zone, while heliophilous taxa as *Helianthemum* and Chenopodiaceae disappear. This sub-zone coincides with regional sub-zone 1b (Hoek, 1997a).

During zone WB-3 (129-104 cm) *Betula* decreases slightly (35%) in favour of *Juniperus* (15%). The presence of *Hippophaë*, Chenopodiaceae and *Rumex*, in combination with a decrease in aquatics suggests drier conditions recorded frequently for regional sub-zone 1c (Bohncke and Hoek, in press).

The beginning of zone WB-4 (104 - 61 cm) is marked by a strong increase in arboreal pollen to values over 80% consisting of particularly *Betula*. Later *Pinus* values slightly increase to 10%. WB-4 compares to regional sub-zone 2a.

In zone WB-5 (71-61 cm) *Pinus* values rise to values round 20%, AP values remain high while Juniperus reaches its lowest values. Zone WB-5 can be correlated with regional sub-zone 2b.

The beginning of zone WB-6 (61-49 cm) is marked by a sharp decrease of *Pinus*, a common signal in many pollen diagrams in the Netherlands associated with the Younger Dryas event. The increasing values of thermophilous tree taxa are the result of reworking from older deposits (Bohncke, 1993; Hoek, 1997a) indicating unstable soil conditions. The dry conditions during the second phase of the Younger Dryas will have caused registration to stop. Siderite concretions found at 50 cm indicate a low water level or even dry conditions with associated soil formation. This zone coincides with the first part of regional zone 3.

Zone WB-7 (above 49 cm) represents a younger Holocene Boreal vegetation type thus indicating the presence of a hiatus between the first part of Younger Dryas and Boreal zone.

At first look, the Weerterbos oxygen isotope record compares quite well to other records from for instance Switzerland (Lotter *et al.,* 1992) with high Interstadial values stepwise decreasing towards the Younger Dryas.

If the time axis of the lacustrine record based on dated zone-boundaries is scaled linearly to calendar years BP (Stuiver and Reimer, 1993; Stuiver *et al.,* 1998), the Weerterbos oxygen-isotope signal can be correlated in detail to the GISP2 bidecadal $\delta^{18}O$ curve (Stuiver *et al.*, 1995; Meese *et al.*, 1997), as can be seen in Fig. 5. This implies that despite the uncertainties with the calibration of radiocarbon dated zone boundaries to calendar years BP, the calibrated ages more or less equal the ice-core years. It appears that oxygen-isotope variations are recorded synchronously in the different environments, arguing for an atmospherically and thus climatically controlled mechanism.

Another indication for a major atmospheric control of the signal in this case of a shallow lake with authigenic $CaCO_3$ production can be obtained from the $\delta^{13}C$ record. $\delta^{13}C$ values round 0‰ indicate a good mixing with the atmosphere and $\delta^{18}O$ values from the same sample will thus be in equilibrium with the atmosphere, while samples with $\delta^{13}C$ values round -10‰ will provide a ground water controlled $\delta^{18}O$ value (Hoek et al., in press).

From this perspective, the $\delta^{13}C$-curve in Fig. 4 shows only a minor groundwater influence during most of the record. Typically atmospheric signatures are recorded from 150-68 and 63-53 cm. The $\delta^{18}O$-record can therefore be considered as a good palaeoclimatic signal. From 68-63 and above 53 cm, the $\delta^{18}O$-record will supposedly show a biased atmospheric signal, as a result of a substantial ground water contribution.

Ideally, the atmospheric signal thus should be comparable in both ice-core and terrestrial records. If we consider the oxygen-isotope signal as common in both environments, we can use isotope stratigraphy to correlate ice-core and terrestrial records. We attempted to match the lacustrine to the ice-core isotope signal (Meese *et al.*, 1997) by visual correlation (Fig. 6).

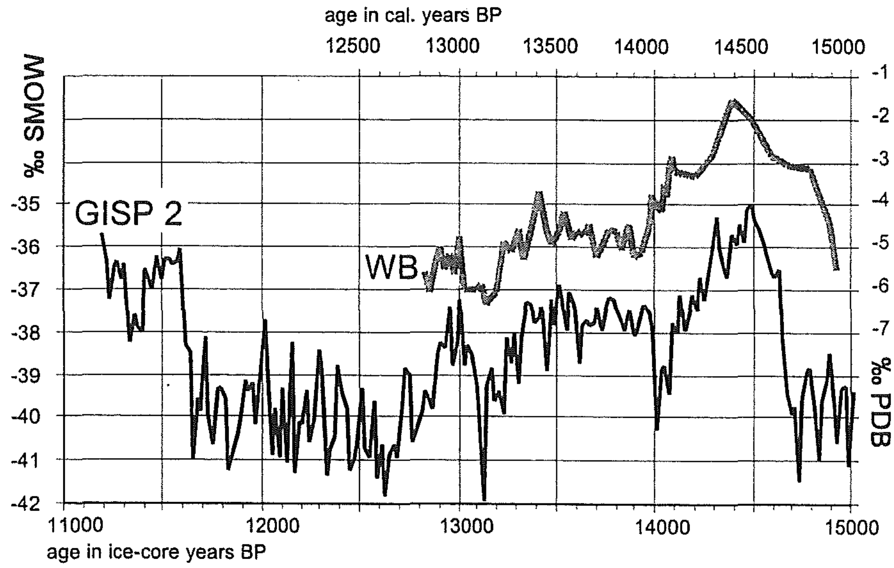

Figure 5 Comparison between GISP2 oxygen-isotope record on an ice layer count time-scale (Data provided by the National Snow and Ice Data Center, University of Colorado at Boulder, and the WDC-A for Paleoclimatology, National Geophysical Data Center, Boulder, Colorado) with oxygen isotope events (Björck et al., 1998) and the Weerterbos oxygen isotope record on an INTCAL98 calibrated time-scale.

Compared to the interpolated calibrated time-scale, the positions had to be shifted only a few decades in most cases. Remarkably, the amplitude in permille values of both records is almost equal, although extreme excursions in the ice-core seem to be reflected less pronounced in the terrestrial environment.

Generally, vegetation is considered to have lagged behind the climate signal at the beginning of the Lateglacial. In Britain, a time-lag of over 500 years between climate and vegetation for the very early Lateglacial has been reported (Walker *et al.*, 1993). Although the climate was sufficiently warm for woodland, *Juniperus* and *Betula* trees did not respond immediately to climatic warming for a variety of reasons (van Geel *et al.*, 1989; Walker *et al.*, 1993; Walker, 1995). In southern Sweden, however, vegetation seems to react almost directly to climatic warming in the early Lateglacial (Berglund *et al.*, 1994; Coope and Lemdahl, 1995). Regressive vegetation development caused by a climatic cooling is considered to be isochronous.

Remarkably, large climate shifts recorded in the oxygen isotope curves e.g. the beginning of the Lateglacial Interstadial (GI-1) (Björck *et al.*, 1998) en Younger Dryas Stadial (GS-1) are both reflected synchronously in the palynological record. The Gerzensee oscillation (GI-1b) might be reflected in the increase of *Pinus*, a species well-adapted to more continental conditions (Bohncke, 1993). A smaller isotope event such as the Aegelsee oscillation (GI-1d) is clearly out of phase with the vegetational change from *Betula* woodland to a more herbaceous vegetation during the Older Dryas. It appears that this vegetational event recorded in The Netherlands reflects a period of regional drought, caused by the disappearance of permafrost, a delayed effect of Interstadial temperature rise (Hoek et al., in press).

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Monday 30 August:
In the eastern part of the province of Noord-Brabant, near the river Dommel, Roel Janssen will present the detailed paleoecological results of the Moerkuilen sites. In the afternoon we will visit the Maria Peel. In this raised bog area Hans Joosten and co-workers did interesting research, also on very recent bog deposits. We will meet Rike Wagner and she will explain her reconstruction of changing atmospheric CO_2 levels in the past, based on the study of *Betula*-stomata.

Everse Moerkuilen Roel Janssen

The site of Everse Moerkuilen is a Late-Glacial oxbow that was in the course of the time filled-in with lake sediments and various kinds of peat.The present-day lake is arteficial. It arose because of peat digging activities during the last few centuries.
Cores were collected for pollen analysis of Late Holocene deposits in the early seventies and later for pollen- and macrofossil analysis of Early Holocene deposits. The location of the cores is shown in fig. 1.
We would like to demonstrate:
-- The role of a stratigraphic arrangement of late-Holocene pollen curves for ecological purposes and
-- The role of radiocarbon dating in the reconstruction of the fine-scale pattern of Early Holocene vegetation.

1. Pollen stratigraphic groups in deposits of the Late Holocene.

In any ecological interpretation of pollen sequences pollen curves can be arranged according to the present-day ecology of plant taxa. However, in doing so, present-day ecological amplitues of the various plant species are imposed on past conditions, that may be different from that of today because of differences of, among others, climate and competing plant species.
Experiences in comparing stratigraphic arrangements of pollen curves in a core and surface samples with present-day (syn)ecological groups of plant species in Minnesota (Janssen, 1966, 1967a, 1967b) were encouraging factors in trying to stratigraphically arrranging pollen curves in a dutch sequence.
Pollen comes from various plant communities in the landscape that are part of different successional lines. In our area there are three main succesional lines:
-- succession on the dry upland
-- succession on the valley floor
-- succession in the infilling basin

The participating plant species of these lines are ecologically not alike and by a stratigraphical arrangement of the total number of of pollen types types from plant species that at the same time occurred in the landscape, but not in the same community, are placed together. The ensuing groups of pollen types do not reflect a particular plant community, but it reflects a mix of communities, consisting of plant species with widely different ecological amplitudes.
In figs. 2 and 3 therefore a stratigraphical arrangement of pollen types within the three main habitats, viz.upland trees (group 2), dry upland herbs (groups 3 and 4), valley floor (group 5) (fig. 2) and the environment of the infilling oxbow (group 6, fig. 3) has been carried out.

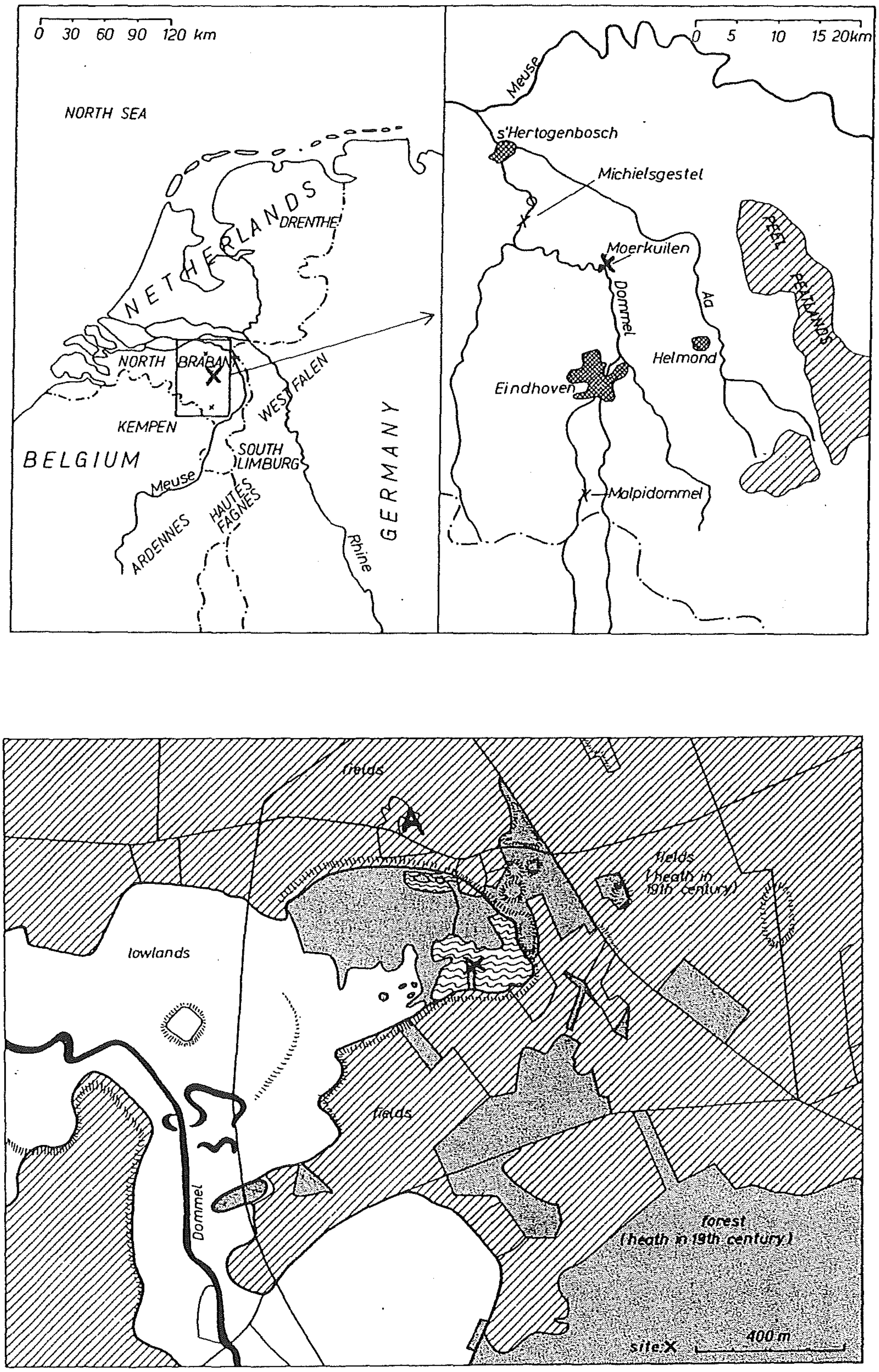
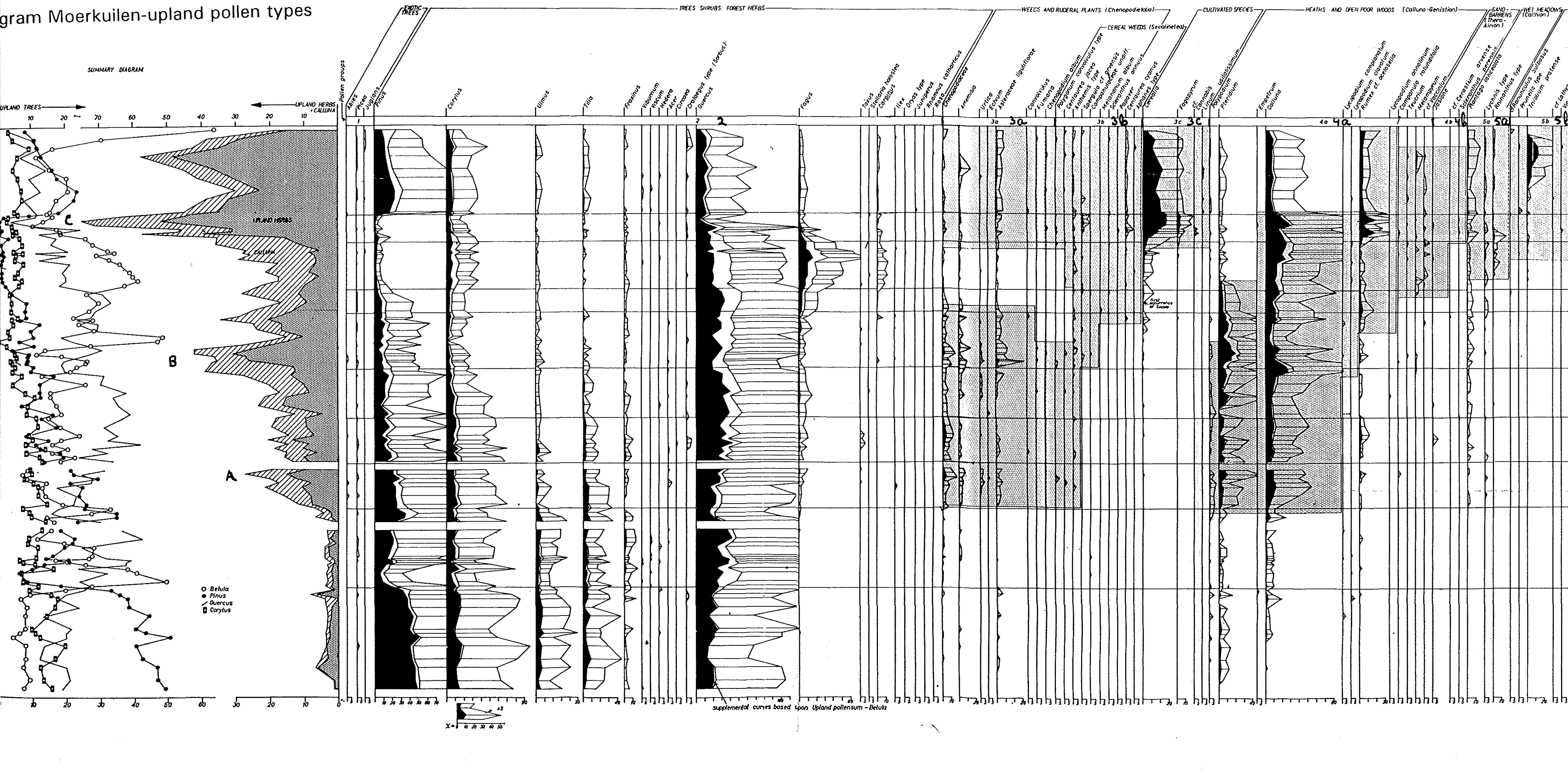
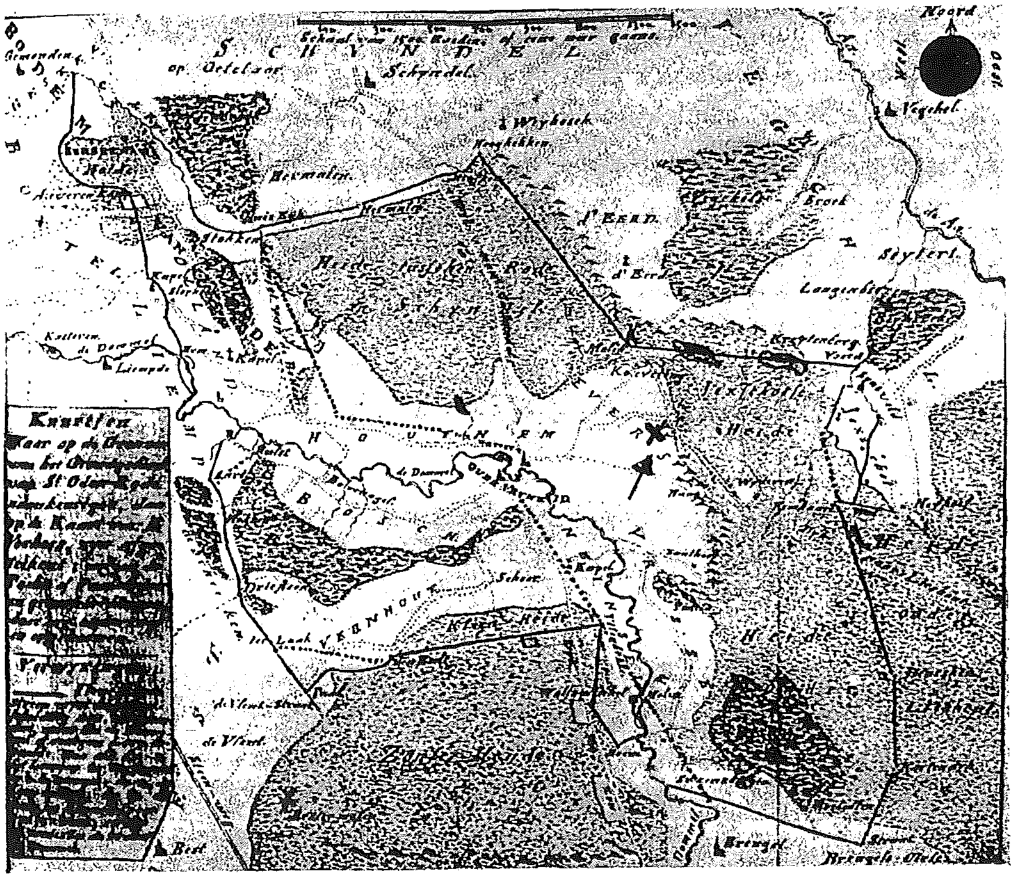


Fig. 1 Location of the Moerkuilen site (X)

gram Moerkuilen-upland pollen types



Briefly the vegetation development on the upland is characterized by three peaks (A,B, and C) in the NAP (weeds, ruderal plant species heathland species and open woods) values, showing in increasing degree, the impact of Man. These peaks are separated by two phases with minimum NAP values, one in the Iron-Age, another during the time of the Migrations after the Roman period. Maxima in the values of *Quercus*, *Fagus* and *Carpinus* suggest that forest vegetation regenerated.
After this phase of regeneration forest was cleared once again and replaced by heathland (group 4a), sand barrens (group 4b) and by agricultural fields (group 3). Heathlands were still a characteristic feature in the landscape only a few centuries ago (fig. 4). Fig 5 gives an impression of the density of prehistoric sites along the Dommel river.



Vicinity of the Moerkuilen in 1753 showing the extent of heath areas (from Brock 1832).

Fig. 4

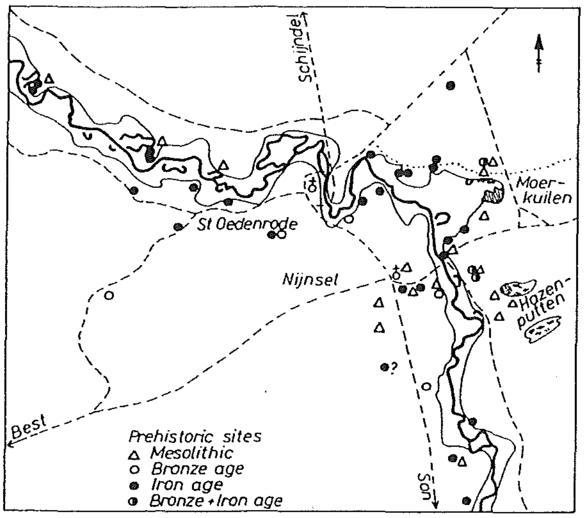


FIG. 5. Prehistoric sites along the Dommel River in the St Oedenrode area. Based on data collected by Father W. Heesters.

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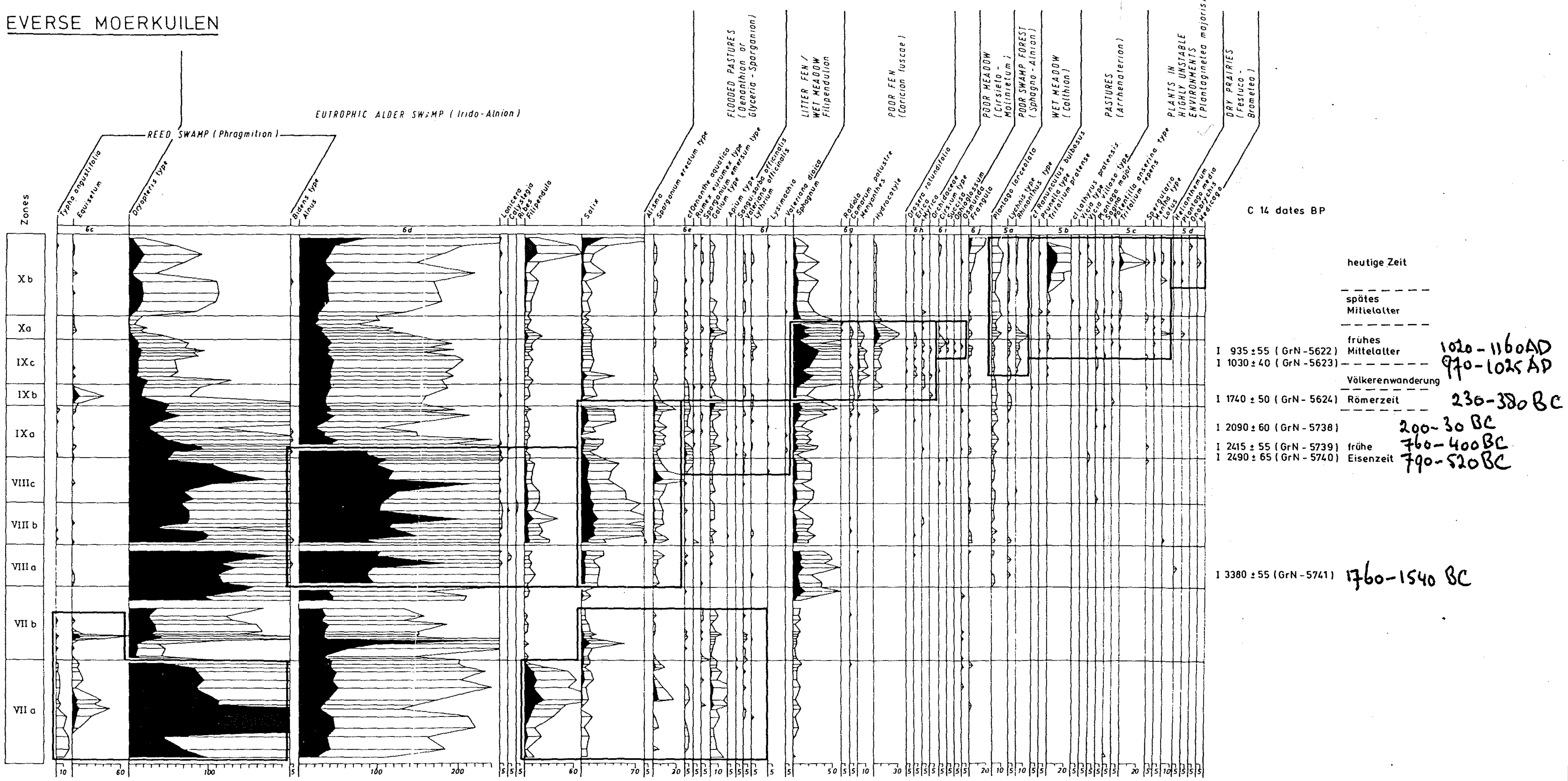

Abb.1. Stratigraphische Anordnung lokaler Pollentypen in Sedimenten einer Altwasserbucht. Umgezeichnet nach JANSSEN 1972

Fig. 3 Pollen diagram Moerkuilen-lowland pollen types

During Medieval Time plaggen from heather or grass sods from the heathland were used as bedding material in cowsheds during the winter. In the spring the mixture of dung and plaggen was used to fertilize the fields. The ensuing accumulation of material resulted gradually in the formation of raised fields, the socalled "Essen" areas around the villages.
Pollen (although crumpled) preservation in plaggen soils is rather good, but pollen sequences in these soils can not be compared to those of peatbogs due to the uncertain origin of pollen. However, W. Groenman van Waateringe (1995) has shown that a meaningfull pollen succession is present in plaggen soils when enough material has been added to the fields.
Fig. 6 is a pollen diagram from a plaggen soil on top of a buried wet podzol near Dommelen, located along the Dommel river more to the south of the Moerkuilen. The appearance of pollen of *Fagopyrum* and the rise in the pine pollen values indicates that the plaggen soil postdates the 14th century.
According to Groenman the extremely low AP values below the plaggen soil indicates that the landscape was already quite open. Written sources indicate that the pine rise would be due to the introduction of *Pinus* seed for pine cultivation between 1514 and 1516 AD. Extrapolation of the C14 dates from the Moerkuilen core gives a date between the 12th and 14th century for the maximum in the Cereal pollen curve and a date around 1500 AD for the transition of pollen zones Xa/10b. These dates agree with the dates from written sources for the early pine cultivation.
Large-scale rye cultivation thus dates from a period before the formation of plaggen soils; it is not the cause of these soils.

The excursion will pass through an area just north of the Moerkuilen site (A in fig. 1.) where bronze-age, Iron-age and medieval farm houses were discovered below the plaggen soils. Maps and photographs of cross-sections as they appeared during excavations in the early seventies are available for study, perhaps better tonight than right now in the field.

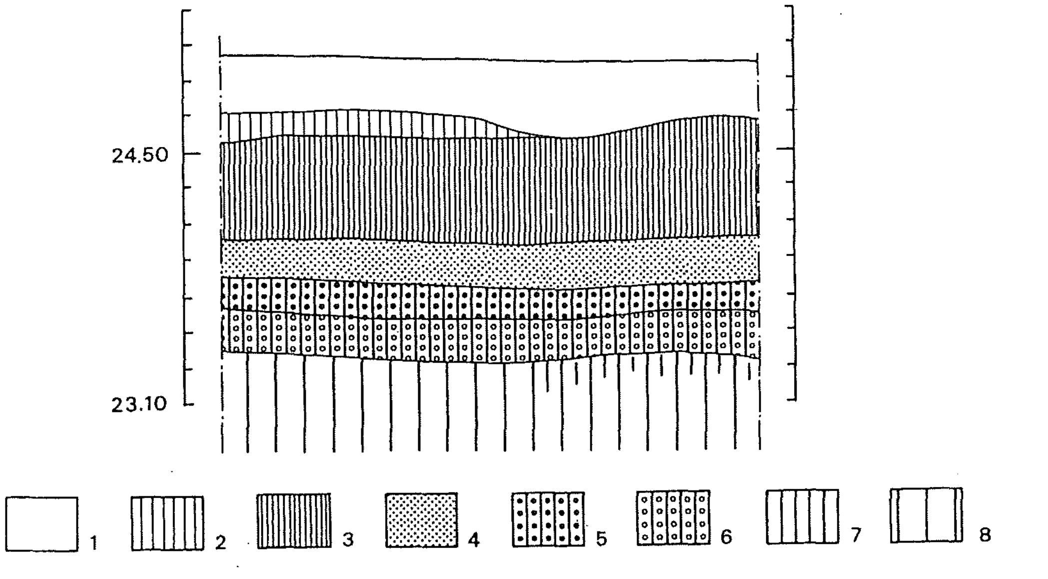

Figure
Dommelen section wall 2 (Theuws et al., 1988, p. 254)
Drawing IPP.
Legend:
1 recent plough soil,
2 light brown humic sand (Aan2),
3 dark brown humic sand (Aan3),
4 greyish-brown homogeneous humic sand (Apb),
5 Ah horizon of a wet podzol soil,
6 E horizon of a wet podzol soil,
7 B horizon,
8 undisturbed parent material.

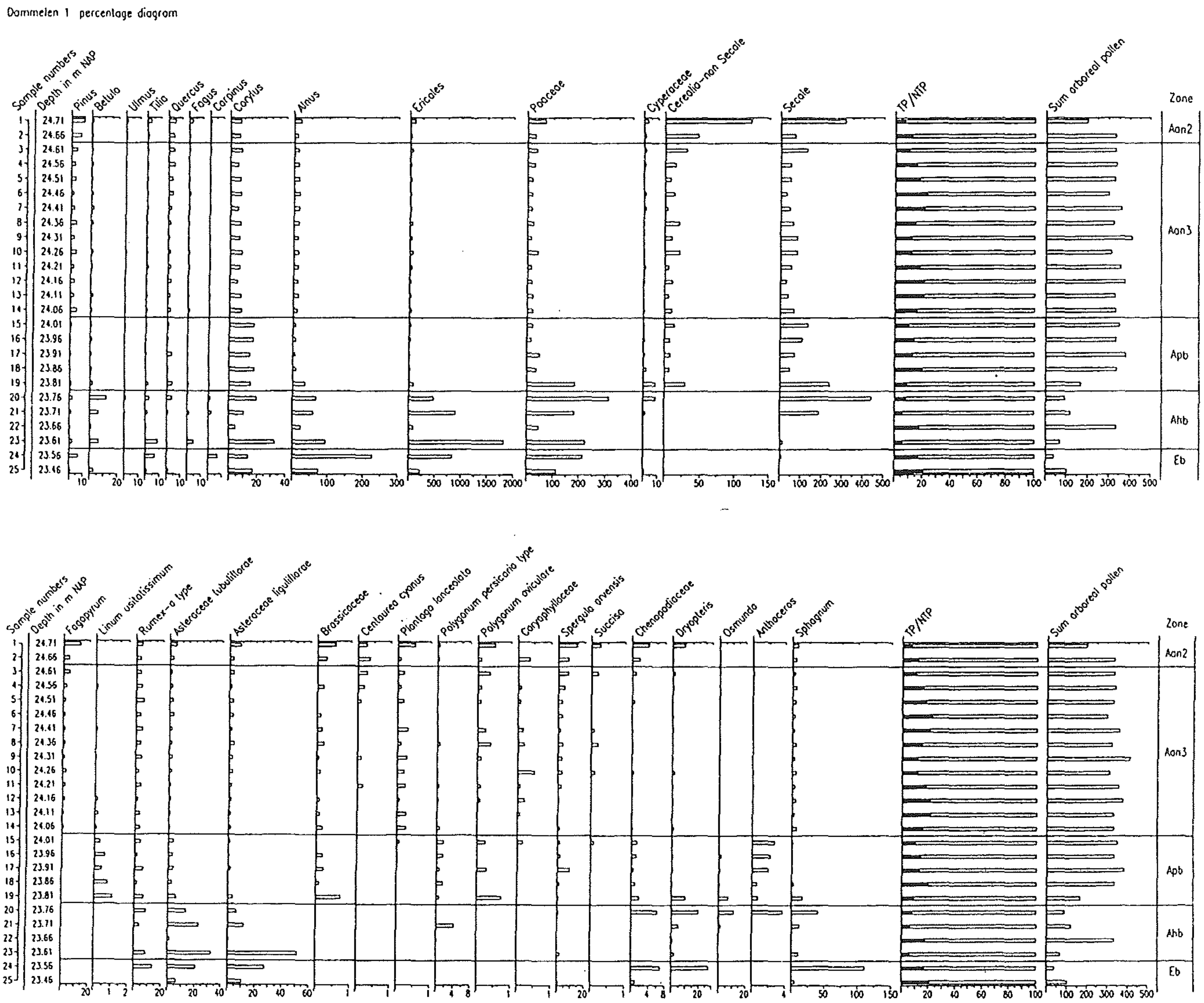

Figure 6
Dommelen 1, pollen diagram of section wall 2 (Theuws et al., 1988, appendix 1): selection of curves.

Lowland vegetation development.

Fig 3 is the pollen diagram of the plant taxa that occurred in the oxbow and on the valley floor. For most of the time covered by the pollen diagram the vegetation in the oxbow was an alder swamp with various amounts of alder, ferns, *Filipendula* and *Salix* (pollen groups 6b, 6c and 6d).
The first important impact of Man beginns during the second (B) NAP peak, just before 790-520 BC. The alder swamp was (partly) transformed into flooded pastures and wet fens (pollen groups 6e and 6f). During the time of upland forest regeneration at the time of The Migrations the river regime stabilised and the local vegetation changed into a poor fen (CARICION NIGRAE: pollen groups 6g and 6h), a development possible perhaps because of a greater water capacity of soils in the catchement area. This may have resulted in a diminishing frequency of floodings and a diminished acces of nutrient-rich water into the oxbow.
At the end of this phase the poor fen was transformed into a poor meadow (pollen group 6i) followed first by wet meadows (CALTHION:(pollen group 5a) later by pastures (ARRHENATERION: pollen groups 5b and 5c).

2. Fine scale vegetation patterns in the early Holocene revisited.

The Ph.D. Thesis of W. van Leeuwaarden (1981) dealt with the fine-scale vegetation patterns in this area during the Lateglacial and Early Holocene.
The idea was to contrast pollen diagrams from-small sized basins on the valley floor with those on the upland.
Time control is all important in the detection of spatial patterns in the landscape. We were influenced by E.J. Cushing (1967), who on the large-scale of regional vegetation (i.e. plant formations) of Minnesota) suggested that regional pollen assemblages over large distances are time-transgressive, diachronous, caused by the feature of plant migration of plant taxa.
Differences in migration in a small-sized area like here does not seem likely. But could it be that insight in the mosaic of plant communities can be gained by dating of more or less similar pollen assemblage zones?
Contrary to some palynologists who sometimes reject radiocarbon dates when they do not fit conventional dates of zone boundaries, we accepted in principle every date. This attitude was welcomed by radiocarbonists, who generally do not like rejection of the outcome of their precious work.

Pollen assemblage zones in- and outside the valley are not always the same, but they all can be characterized by the establishment of the main tree genera *Pinus*, *Corylus*, *Tilia*, *Alnus* and by the fern *Pteridium*. The beginning of the expansion of these genera was dated by dating of the lower boundaries of the assemblage zones The result is shown in fig. 7 : The expansion of these genera occurred in the valley

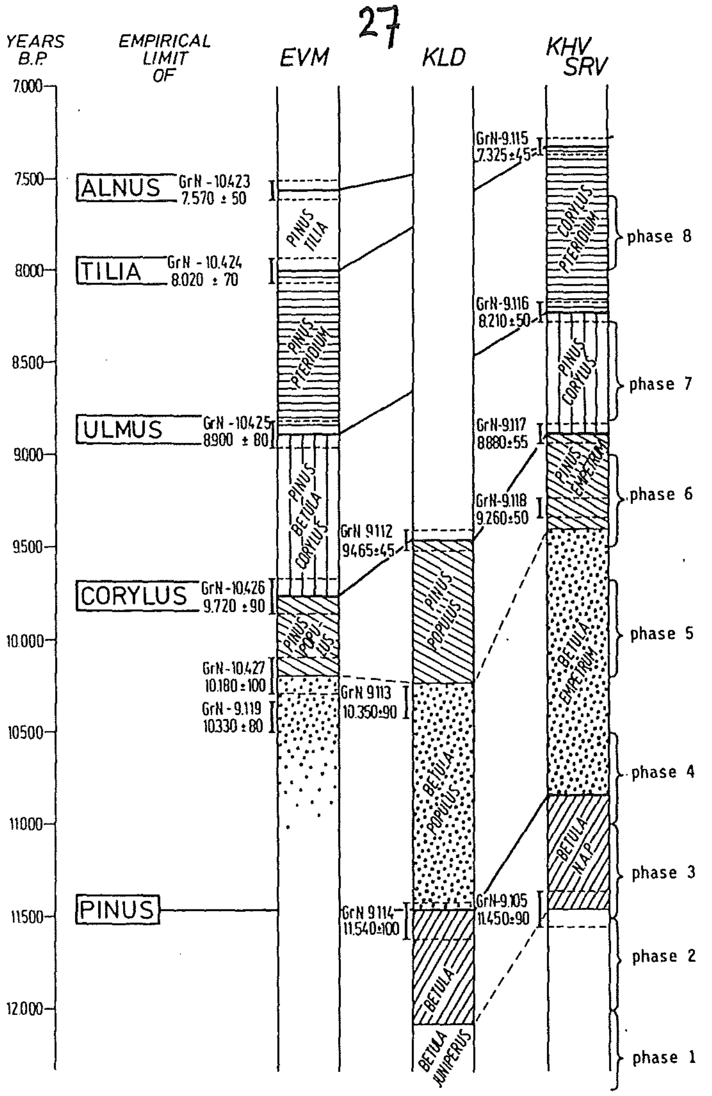

Fig. 7 Time correlation of the assemblage zones of the valley cores Everse Moerkuilen (*EVM*) and Keldonk (*KLD*) and those of the pingo melt holes Strabrechts Rond Veen and Klein Hassels Ven (*SRV*/*KHV*).

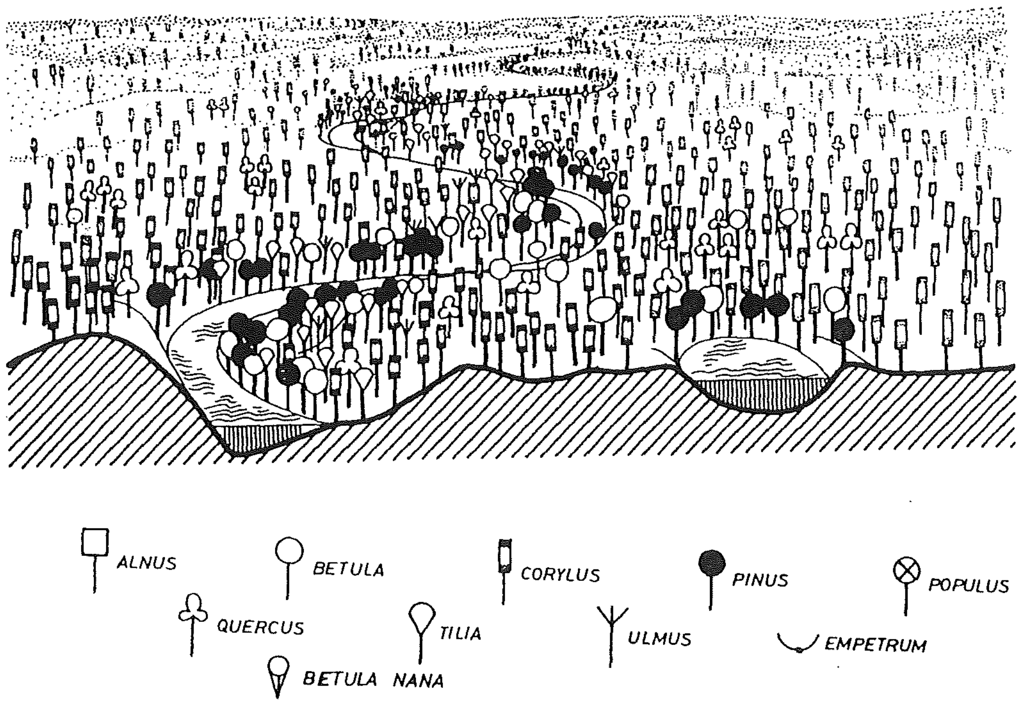

Fig. 8 Spatial reconstruction of vegetation around 8500 BP.

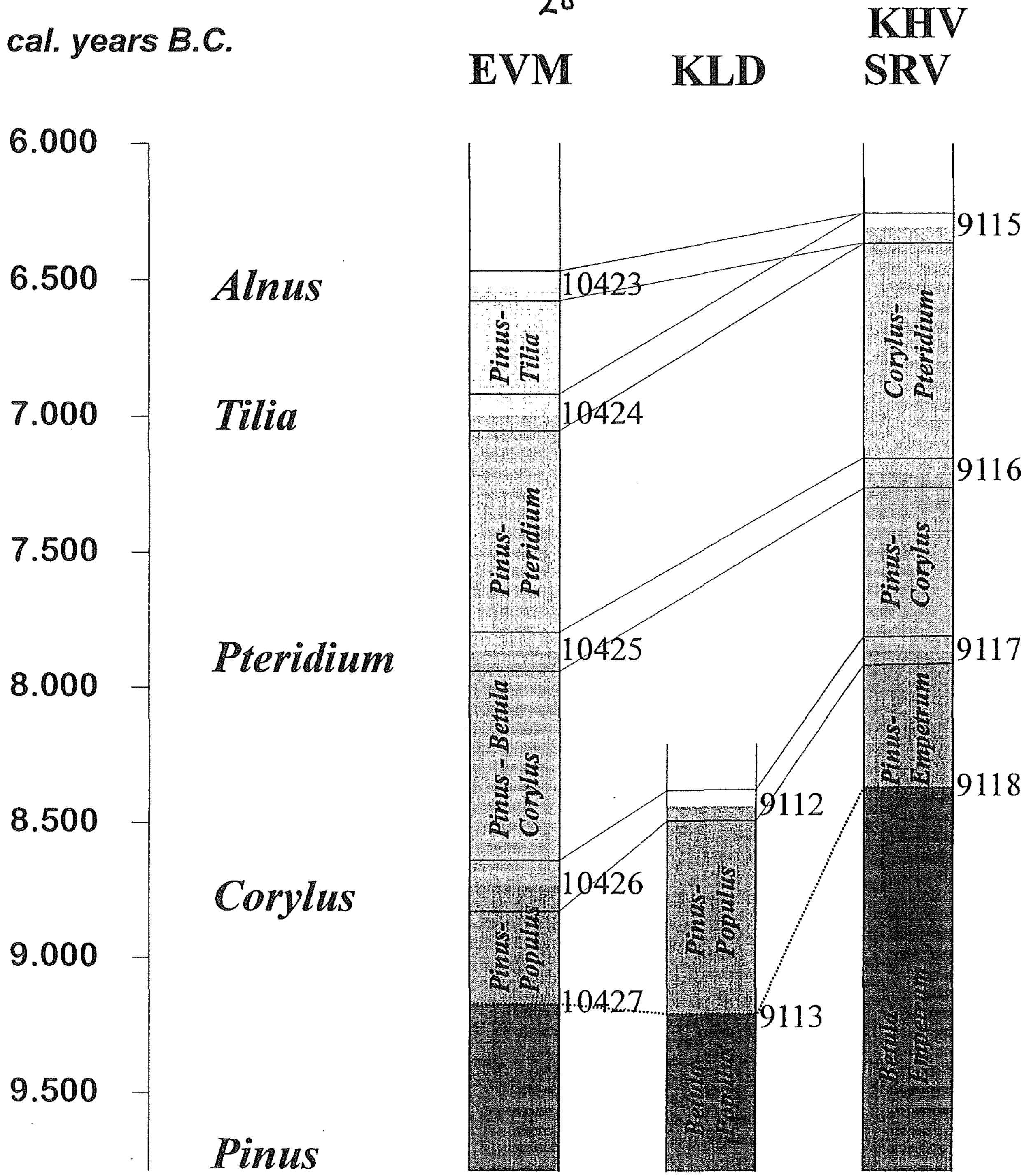

Fig. 9 **Calibrated time correlations of the early Holocene pollen assemblage zones at the lowland sites De Moerkuilen (EVM) and Keldonk (KLD) and the upland sites Klein Hasselsven (KHV) and Strabrechts Rondveen (SRV). Numbers at the right site of the columns refer to Groningen C_{14} measurements (GrN).**

some 500 years earlier than outside the valley, on the upland.
Thus, for instance in the Early Holocene between 9600-9000 BP when *Pinus*, *Populus* and *Corylus* were present on the valley floor, the upland was still in a "Lateglacial" *Betula-Empetrum* phase. Fig. 8 portrays the vegetational interpretation around 8500 BP.

Since the early eighties radiocarbondating has acquired a new dimension: calibration of conventional dates into calender years.
Does the delay in expansion on the uplands still holds when the radiocarbon dates are calibrated into calender years?
The calibrated data (carried out by A. Speranza, Amsterdam) were replotted on a linear time-scale in fig. 9. The outcome is essentially the same. It seems thus that the delay is a real feature.

As to the reasons of the delay in expansion on the uplands: perhaps the local climate is different from that on the valley floor, but we would prefer to hold soil conditions responsible. Soils on the upland are dryer than those in the valley.

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Mire development in the Netherlands

Hans Joosten

Mire development in the western and northern part of the Netherlands (the "Low Countries" s.s.) was strongly influenced by rising sea levels and associated marine and fluviatile flooding. Starting from Late-glacial times, fens and swamps originated in depressions in the "higher" eastern and southern part. In the Atlantic and Subboreal, large bog complexes came into being. The continuously expanding mires reached their maximum extent around 3000 yr ago, when approximately 10,000 km^2 of bogs and 5,000 km^2 of fens covered half of the current extent of the Netherlands.

After 3000 BP, the mires in the lower parts of the Netherlands started to degrade as a result of anthropogenic deforestations in the catchment areas of the rivers. This led to widening of the estuaries, partial destruction of the coastal barriers, and subsequent marine transgressions and erosion.
The first extensive drainage systems were constructed by the Romans. From the 8th century on, the western mires were colonized and used as meadow, pasture, and arable land. As time passed, the effectiveness of simple drainage technology declined because of continuous peat subsidence. The construction of dikes and regional waterworks became necessary to avert the permanent threath of being flooded. The "polder" system was introduced, at first based on gravity-flow drainage and since the 15th century based on windmills.

The urban and commercial revival of the high Middle Ages (Flanders) and the exhaustion of the woodlands due to overexploitation were the driving forces behind the increase in peat extraction in the southwestern part of the Netherlands (Western-Brabant). During the 15th century peat cutting expanded in the western provinces. "Dredging" was introduced in the 16th century as a new technique for extracting peat from below the water level. Many of the resulting lakes were later drained to polders. Extensive peat cutting spread over the Netherlands in the 16th and 17th century in order to satisfy the demands of the fast-growing cities of Holland. Holland's Golden Age (17th century, Rembrandt!) was largely founded on the availability of this cheap fuel. Companies opened up the large bogs in the northeastern parts of the Netherlands and gradually moved southwards to reach the Peel bogs in the 19th century.
Initially, all bogs were exploited for fuel. At the end of the 19th century, the production of moss litter from slightly humified *Sphagnum* peat became the more important economic activity. In the second half of the 20th century, peat winning focussed on the preparation of substrates for horticulture and the production of active coal. Large-scale peat extraction stopped in 1992.

The impacts of all these developments have been immense. Enormous areas of mire have vanished, leaving virtually no trace. Not one bog or fen has stayed untouched, even no square meter of mire has been saved from draining, cutting, burning, farming, building. What is left of the formerly dominant landscape types of the Netherlands are a 2000 km^2 large area of intensively used grasslands on deep peat soils, 250 km^2 of "fen" reserves (including 100 km^2 of open water and intensively used grasslands), and 100 km^2 of "bog" reserves, dominated by purple moorgrass (*Molinia caerulea*) and birches (*Betula* sp.).

Peatland conservation in the Netherlands

Nature conservation in the Netherlands started in 1905 with the acquisition of the fen area "Naardermeer" by the private "Society for the Conservation of Nature Monuments". In 1929 nature conservation was also recognized as a task of the government. Since then, all remaining "mire" relics have been purchased by governmental and private conservation organisations.
From the beginning, conservation was confined to passive protection. Existing human activities in the nature reserves continued, however, as an economic necessity to regain the investments of acquiring the area. These on-going agricultural practises kept many mires in a herbaceous state.
Changing socio-economic conditions gradually resulted in the abandonment of these activities. The following uncontrolled succession led to an elimination of many valuable species and landscape features. It became clear that most of these values are "semi-natural" and need some kind of active

"internal" management. Since World War II, the traditional activities (grazing, mowing, cutting, etc.) have more or less been re-introduced.
The reinstatement of "internal management", confined to the often small and scattered reserves, soon proved to be inadequate in preserving species and habitat diversity. Increasing impacts from "the outside" stimulated research into the relationships between conservation areas and their surroundings, especially with respect to hydrology. It was recognized that "buffer zones" outside a nature reserve may play an important role in safe-guarding the conservation values.
In a densily populated and intensively used country as the Netherlands, nature conservation had to start with the "left-overs" of socio-economic development. As a result of this negative selection, the location, extent, and shape of the reserves are often unfavourable for effective nature conservation. New insights from island biogeography and landscape ecology in the 1980's showed the necessity of enlarging the natural and semi-natural areas and of better separating conflicting types of land use ("nature development"). In the 1990's, the Dutch government adopted an offensive long-term strategy (the Nature Policy Plan), aiming a.o. at the development of approximately 15,000 ha of new wetlands on present-day agricultural land in the next 15 years. Furthermore a "Nature Survival Plan" was taken in execution to mitigate the negative effects of air pollution and desiccation.

The Peel bogs

The Peel bogs constitute the southernmost bogs of the Westeuropean lowlands. They are located in an area with much tectonic activity, resulting in specific geohydrological conditions. Peat growth started at the end of the Weichselian and continued up to historical times.
Peat excavation started around AD 1400 in a primitive way, giving rise to peasant peat pit complexes. In 1853, the society "Helenaveen" started to mine strongly humified peat for fuel on an industrial scale. At the same time, buckwheat fire cultivation was introduced. The society "Griendtsveen" and several other companies started the production of mosslitter from slightly humified *Sphagnum* peat in the 1880's. Following excavation, large areas were reclaimed for agriculture.
After the Second World War (in which the Peel bogs had some military importance), horticultural peat was produced until all peat extraction ended in 1984. Since 1951 the remaining, largely cut-over areas were gradually declared nature reserves. At present all Peel bog reserves (>4000 ha) are also internationally protected by the Ramsar-Convention and the EU-Habitat-Directive.

The Peel area is known for its long-lasting and severe conflicts between intensive agriculture and nature conservation. These conflicts have a.o. led to changes in national legislation with respect to emissions from intensive cattle husbandry, and to the installment of a 2 km wide hydrological bufferzone surrounding the Groote Peel National Park. Since some years, national and provincial governments are planning and implementing far-reaching concepts for restructuring the Peel countryside. Landscape ecological analysis showed, that the area around the Mariapeel and Deurnese Peel reserves can easily be isolated from surrounding areas with conflicting land use. This isolation is based on the presence of the impermeable tectonic Peelrand fault, two important waterdivides, and on the superficial lay of the geohydrological basis. In the "Verheven Peel" ("Exalted Peel"), as the area is called now, in the next 15 years 1100 ha of intensively used agricultural lands will be rewetted and converted into nature reserves to melt together and strengthen the existing mire reserves.

Bog restoration and peat consumption

The central aims of the Verheven Peel are bog regeneration and the development of a large wilderness area. Bog restoration is one of the oldest types of ecosystem restoration (cf. Schoockius, Groningen, 1658) and has experimentally been applied in the Netherlands since the 1960's. Experience showed that adequate hydrological conditions are a central issue. Therefore, large hydrologic measures are currently prepared and implemented in and around all bog reserves in the Netherlands.
The developments in fine-scaled peat pits resulting from peat extraction point to good perspectives for regeneration of bog vegetation and their peat deposits. Long-term accumulation rates of regeneration peat amount to 100 - 500 g dry weight.m^{-2} a^{-1}. These high accumulation rates make the development of sustainable peat "production" techniques for future peat extraction plausible.
Peat extraction has been a major cause of the disappearance of bogs (and fens) in the Netherlands. Large-scale extraction stopped in the Peel in 1984 and in the Netherlands in 1992. At the same time, however, the Dutch peat industry restructured itself to become the prime redistributor of peat in the world. Peat imports have increased with over one million tonnes in the past ten years. The

Netherlands have a total area of greenhouses close to 10,000 hectares and they lead the world in horticultural technology. Most of this peat was imported from Germany, but imports from the Baltic states and elsewhere are growing rapidly. Half of the imported peat is exported again (the Netherlands export more peat than Ireland!).

Palaeoecological research in the Peel

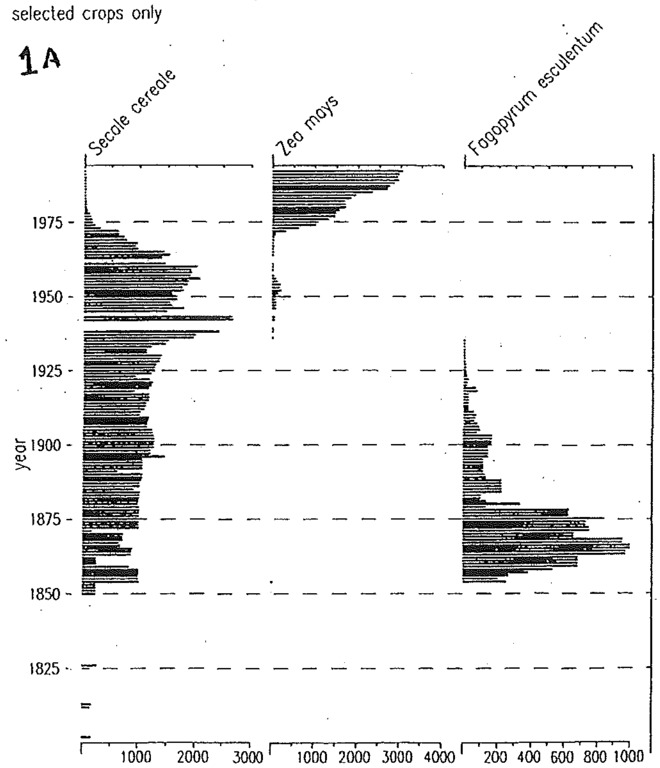
Martinet, the son of the preacher of Deurne, published illustrations of pollen in his "Katechismus der Natuur" (1777-1779). Systematic observations on peat stratigraphy in the Peel bogs were performed and published by Staring (1856) and Borgman (1890). Weber analysed peat and published the first 6 pollen counts from a profile "Helenaveen" (in: Van Baren 1927). The first Dutch pollendiagram is the diagram "De Peel. Limburg, Holland" (from NE of Griendtsveen) of Erdtman (1928). In the same year, Florschütz started with Dutch palynology. He and his Utrecht students studied the major bogs in the Netherlands in the 1930's and 1940's. Duyfjes studied profiles from Liessel and Nederweert. His data were published by Eshuis (1946) in his "Palynologisch en stratigrafisch onderzoek van de Peelvenen". In this dissertation, Eshuis also presented a large number of new pollendiagrams from all over the Peel area and established a first thorough overview on the forest history of the Peel region. The first "modern" (Iversen) pollendiagrams from the Peel (Helenaveen and Venray) were published by Van der Hammen (1951) in his dissertation "Late glacial flora and periglacial phenomena in the Netherlands". Except for studies on Eem-deposits ("Asten-Formation": Van der Vlerk & Florschütz 1953, Florschütz & Anker-Van Someren 1956, Menke 1961, cf. Onneweer 1980) and cover sand soils (Havinga 1962), a quiet period for Peel palynology followed.
In 1971 Janssen & Ten Hove published "Some late-Holocene pollen diagrams from the Peel raised bogs (the Netherlands". They included herb pollen typesin their analysis and presented the first ^{14}C dates from the Peel. Consequently, the human impact on the landscape could be reconstructed. Their findings led tot the appointment of the "Griendtsveen-Formation". The results were largely confirmed by practica of students of Teunissen (Nijmegen, 1981, 1986).
Students of Janssen refined the work in several time slices and with different objectives. Van Leeuwaarden (PhD thesis 1982) made a reconstruction of the vegetation mosaic in Eastern North-Brabant in Late-glacial and early Holocene times and presented ^{14}C-dates that showed differential immigration in brooklet valleys and the upland (Peel), and influx diagrams that illustrated competition between taxa. Joosten (1985 e.v.) focussed on the recent centuries and compared palaeoecological data with historical data in a detailed way. This work also provided material and a detailed chronology for the leave stomata/CO_2 work of Wagner (Wagner et al. 1996, PhD-thesis 1998). Joosten (Joosten & Bakker 1987) and his students furthermore studied mire development of the Groote Peel especially by analysing numerous samples from the transition between peat and mineral subsoil. A pingo remnant discovered in this way was analysed palynologically by Kasse & Bohncke (1992). Late-glacial and early holocene landscape development in relation to archeology was studied by Bos (Bos & Janssen 1996, Bos PhD-thesis 1998). A detailed overview of the recent Utrecht work in the Peel is given by Janssen & Punt (1998).

Palaeoecological research of regeneration peat in peasant peat pits

Regeneration peat in peasant peat pits are excellently suited for reconstructing environmental changes in the last centuries. A detailed chronology of these deposits is reached by comparing historical and palaeoecological data.
Figs. 1A and 1B present historical data on the cultivated area of selected crops in the municipalities of Deurne and Sevenum.
A pollendiagram of the MPN-site (Fig. 2) shows similar changes in the cultivation of *Secale*, *Zea*, and *Fagopyrum*. Other conspicuous phenomena in the diagram include the decrease of *Ulmus* after 1920 (as a result of the Dutch Elm Disease) and of *Plantago lanceolata* somewhat later (as a result of an increased use of artificial fertilizers), the increase in values of Picea at the same time (as a result of plantation by unemployment relief works), and the illegal cultivation of nederweed (*Cannabis*) in the second part of the 1970's.
Fig. 3 is a similar diagram from a nearby pit, that goes back further in time. *Castanea* appears to be a good indicator for distinguishing regeneration peat from older peat. In contrast to the MPN-diagram, the increase in *Pinus* as a result of plantations in the first half of the 19th century is clearly visible, as well as the increasing cereal cultivation with the starting agricultural boom around 1850. Very conspicuous are the traces of *Cannabis* cultivation in the 19th century.

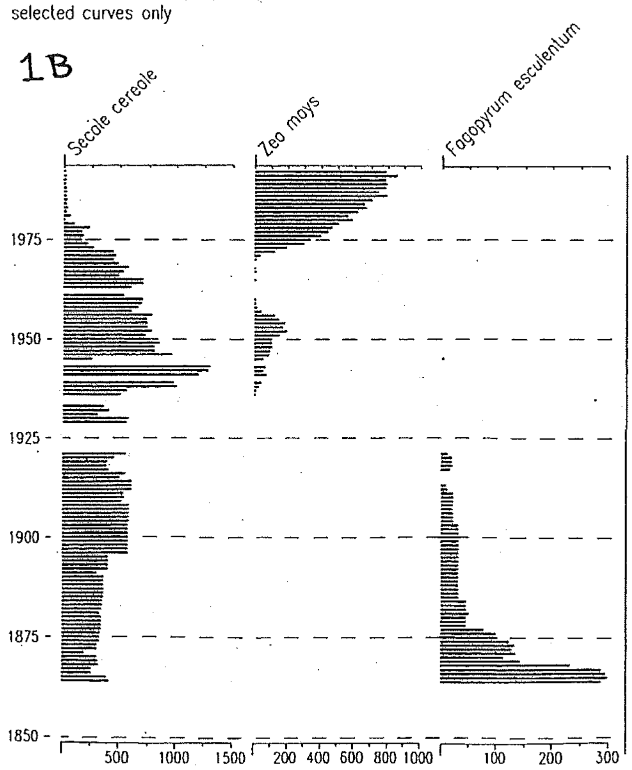
Municipality of Deurne
area of cultivated crops (in ha)
selected crops only

1A



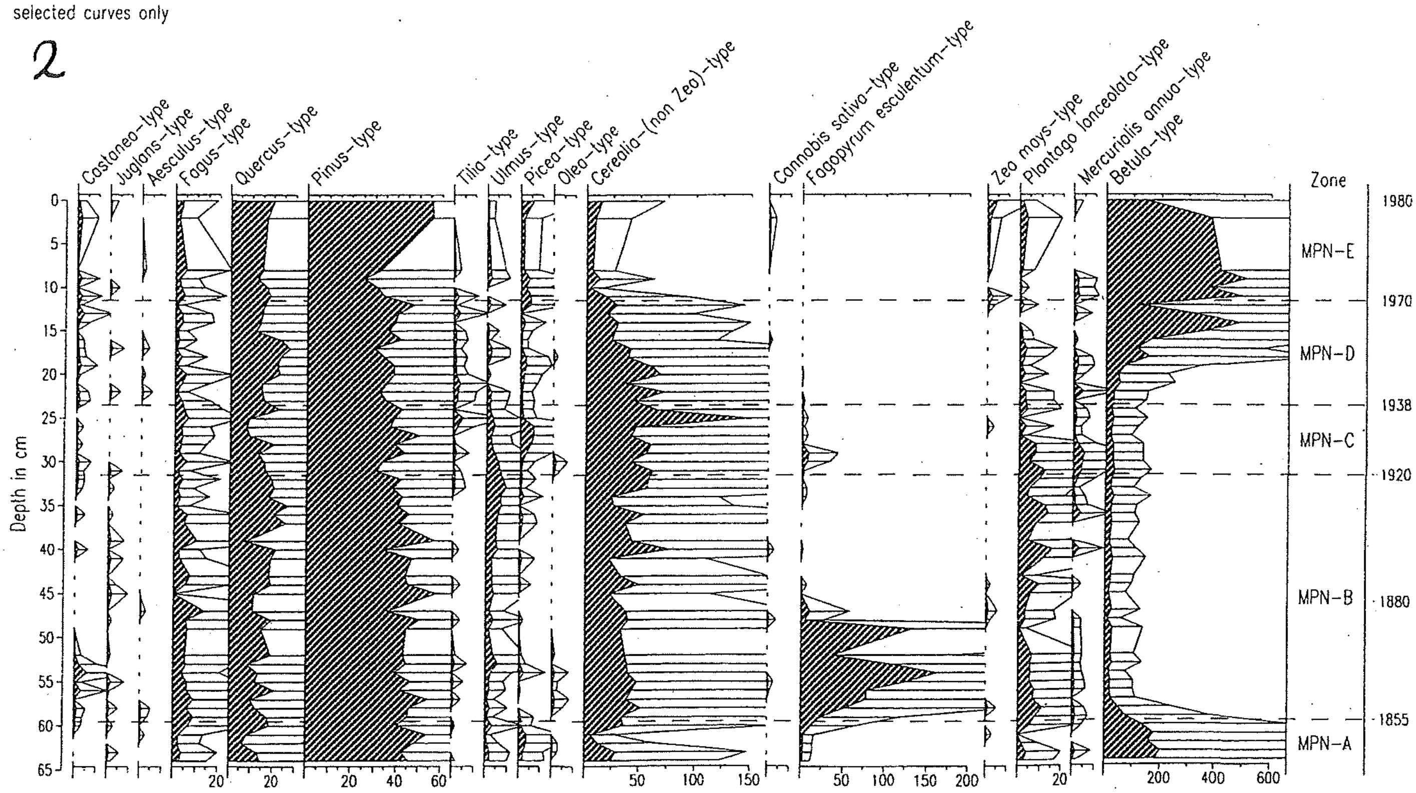
Municipality of Sevenum
area of cultivated crops (in ha)
selected curves only

1B



Mariapeel Noord (MPN)
(tree pollensum minus Betula and Salix)
selected curves only

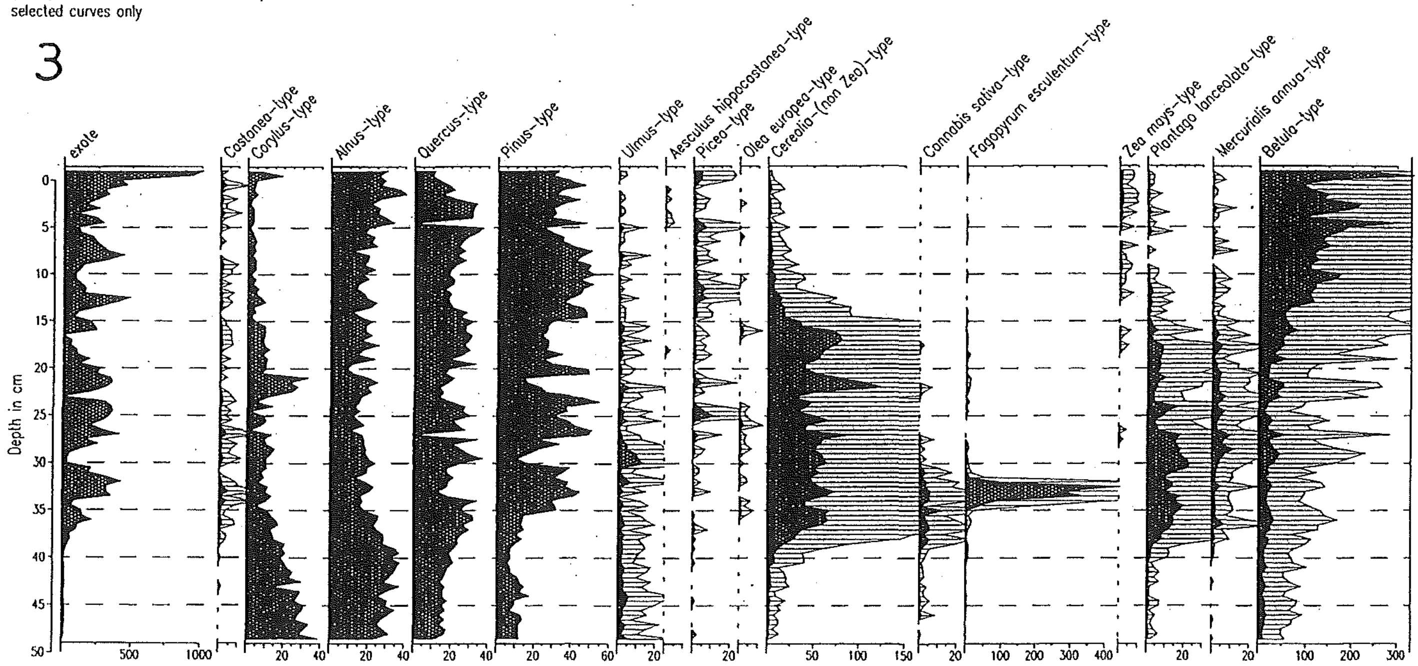
2



Analysis: Hans Joosten, Ruud Lutgerink, Wies van de Brink

Mariapeel Magellanicum (MPM)
(tree pollensum excl. Betula and Salix)
selected curves only

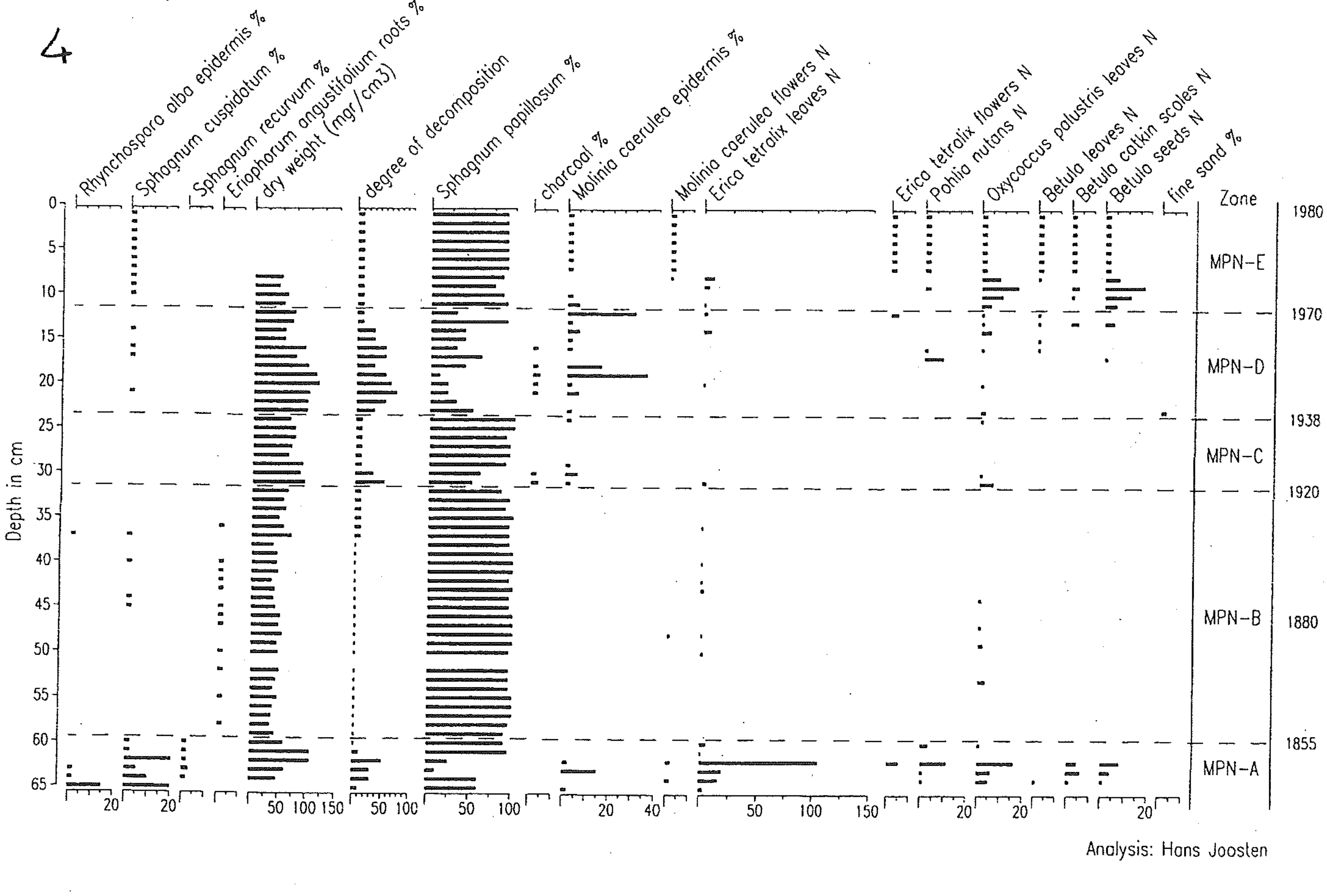
3



Analysis: Jacqueline van Leeuwen

Mariapeel Noord (MPN)
macroremains
selected curves only

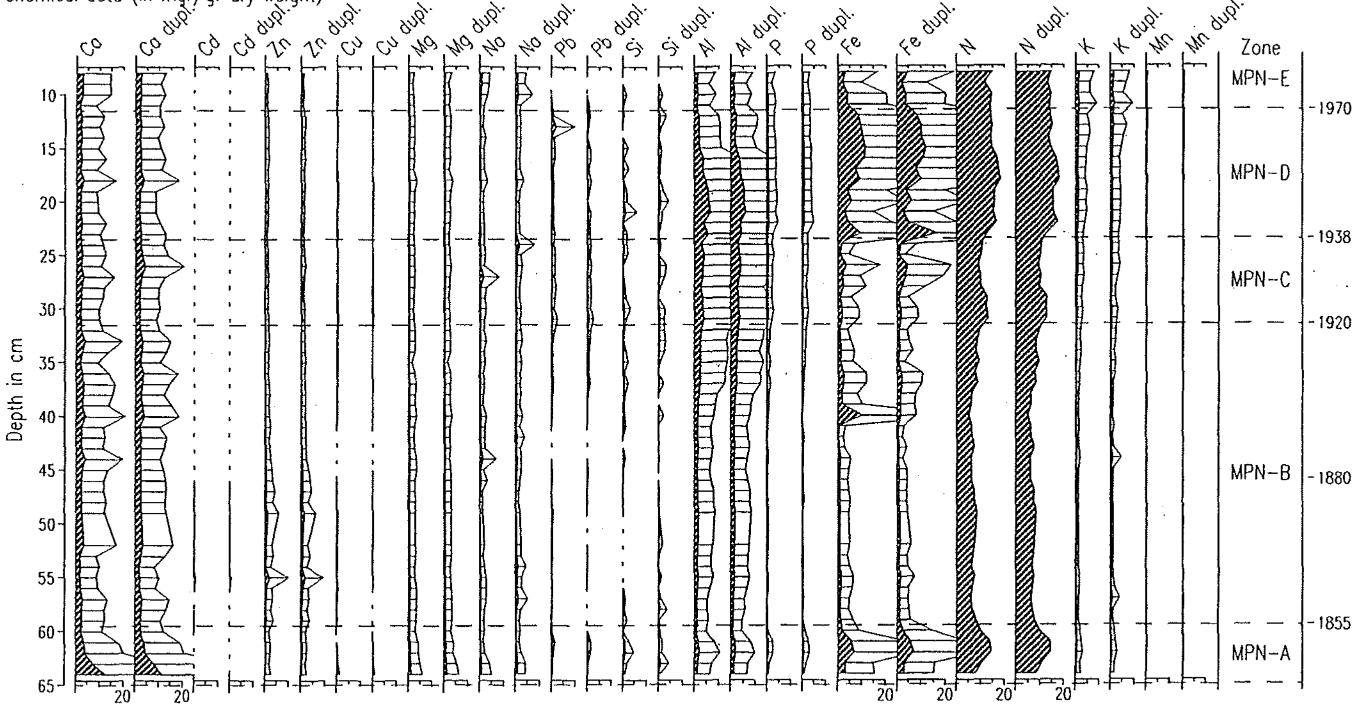
4



Analysis: Hans Joosten

Mariapeel Noord (MPN) 5

chemical data (in mgr/gr dry weight)

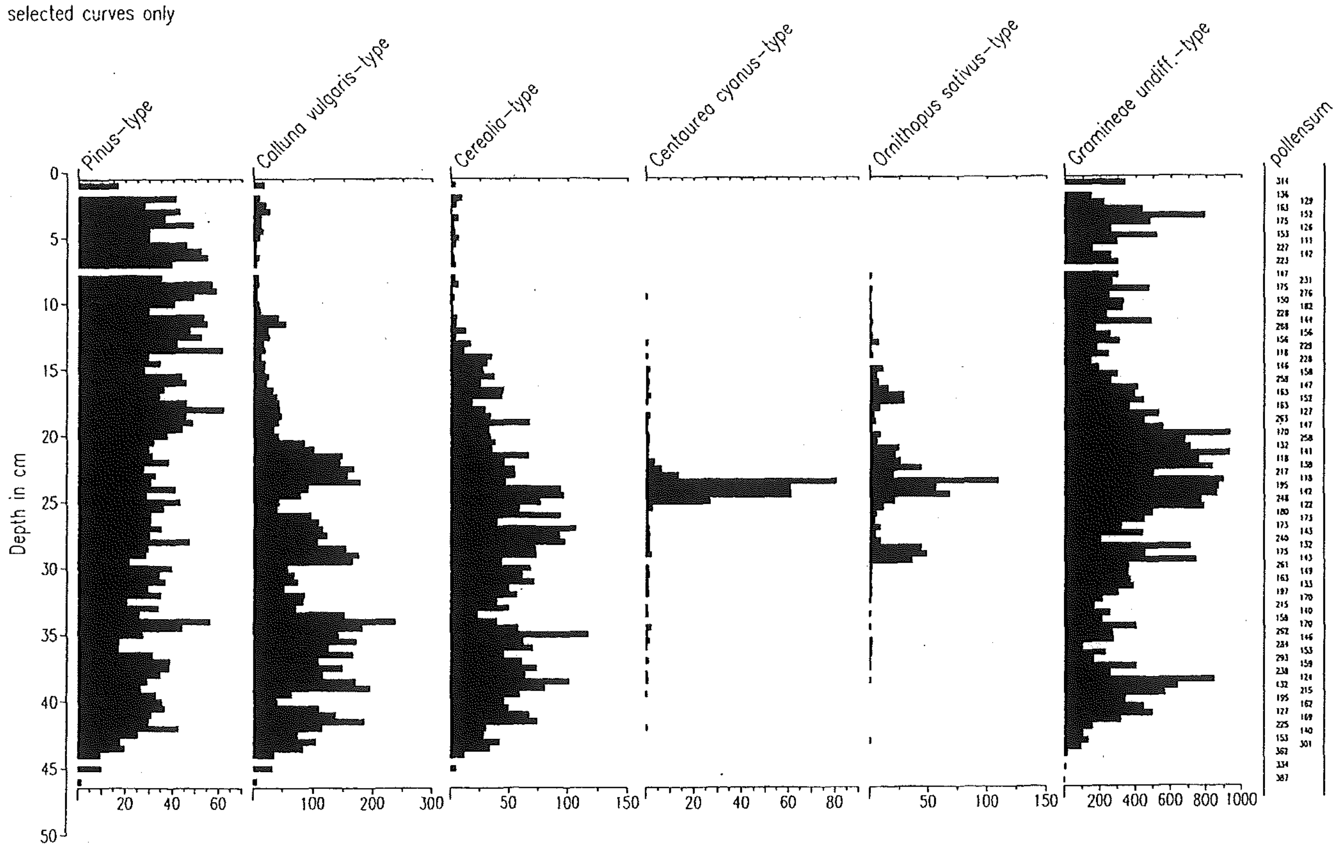


Analysis: Hans Joosten & Ben Paffen

Heidse Peel (HPV) 6

(tree pollensum minus Betula and Salix)

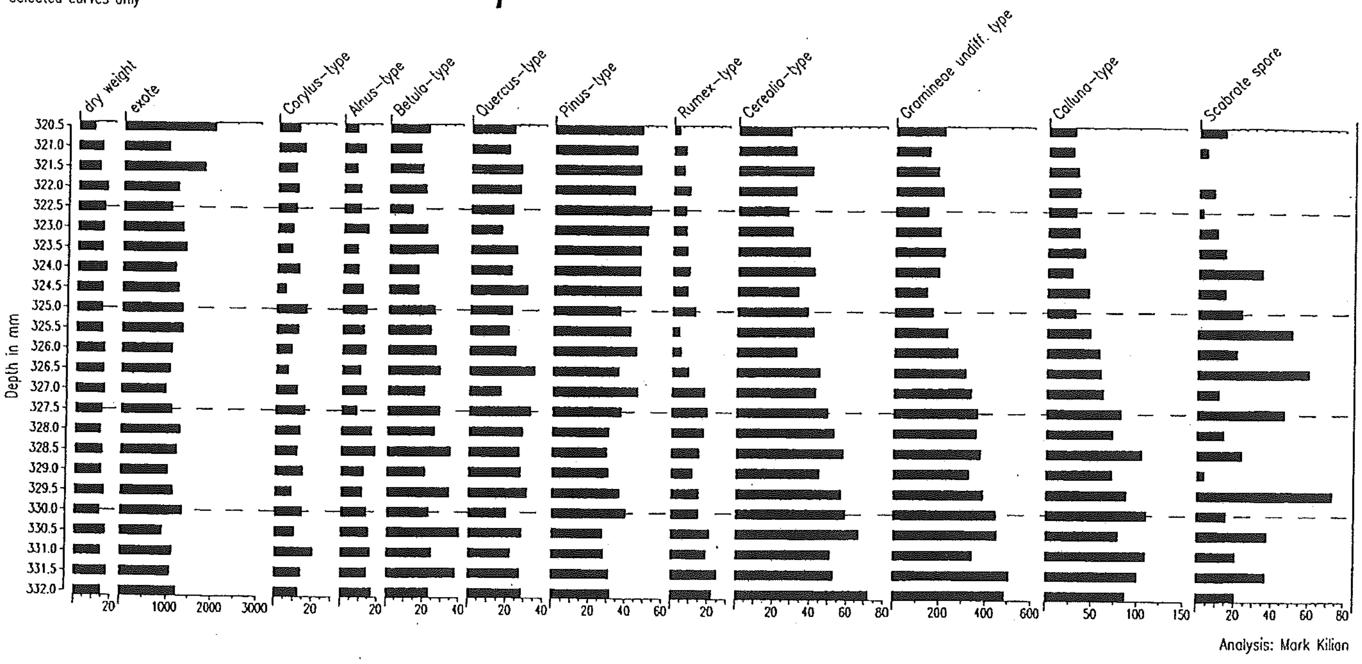
selected curves only



Analysis: Hans Joosten, Boena van Noorden, Ruud Lutgerink

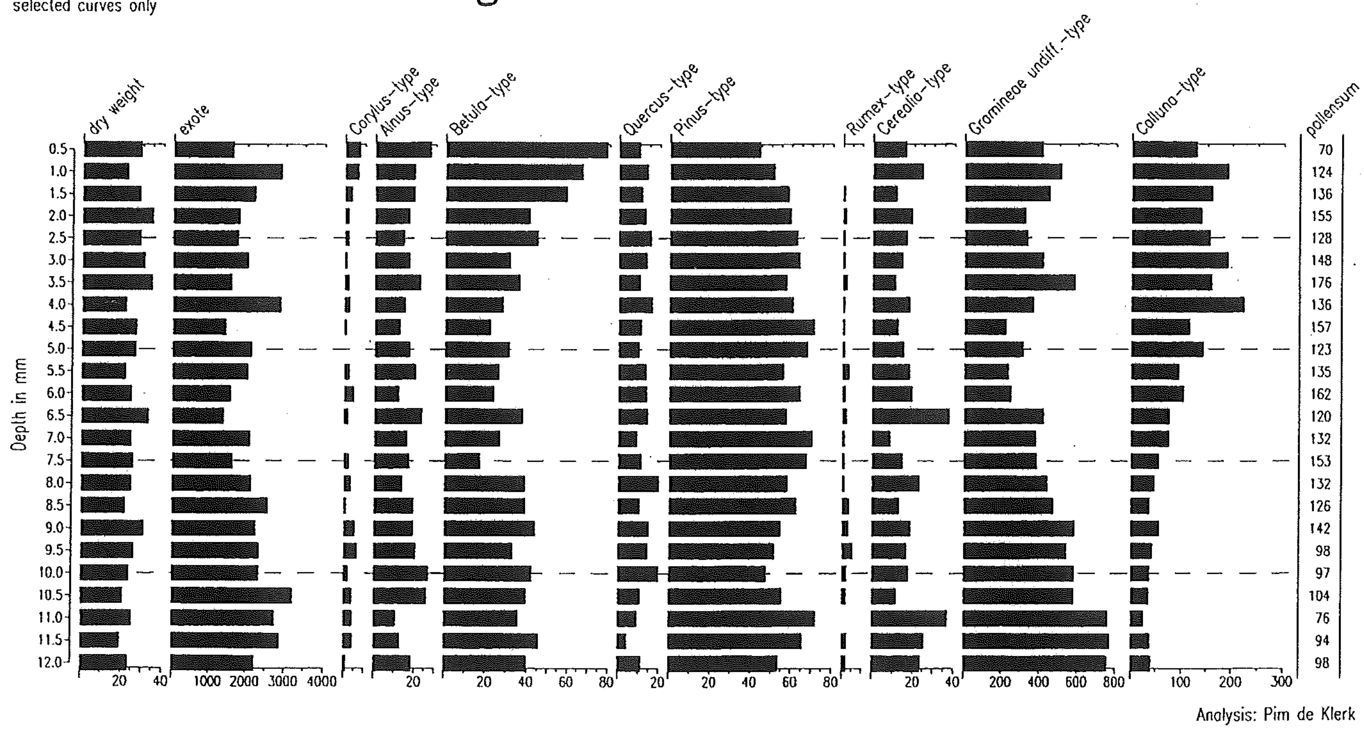
Mariapeel Magellanicum (MPM) in 0.5 mm
(tree pollensum excl. Betula and Salix)
selected curves only

7



Liesselse Peel Oost (LPO) in 0.5 mm
(tree pollensum excl. Betula and Salix)
selected curves only

8



8

The presence of *Olea* pollen in both diagrams points at the importance of long-distance transport in the "modern" open landscape. Both diagrams show the increase of *Betula* after World War II.
Fig. 4 illustrates (extra)local vegetation developments.
Zone MPN-A consists mainly of species indicating a wet to humid environment (*Rhynchospora alba*, *Sphagnum cuspidatum*, *S. papillosum*, *S. recurvum*, *Pohlia nutans* (incl. var. *sphagnetorum*). Several microfossil types point at strongly fluctuating water levels (Joosten 1985). Remains of *Molinia caerulea*, *Erica tetralix*, and *Oxycoccus palustris* appear and disappear simultaneously with those of *Betula*. The birches near the pit probably disappeared as a consequence of buckwheat fire culture on nearby tracks. Removal of the birches may have resulted in a higher and more stable water level, favouring the more light-demanding *Sphagnum papillosum*. The abrupt change suggests a complete "drowning" of the floating bog-mat. This event took place around 1855. MPN-B consists almost entirely of remains of *Sphagnum papillosum*. The growth form, robust with feathery formed branches, suggests that *Sphagnum papillosum* has been growing under very wet conditions; the microfossils in this zone also point to a very wet environment (Joosten 1985). The transition to zone MPN-C can be dated to 1920. The small charcoal- and *Molinia*-peaks near that transition reflect the extremely dry years of 1920 and 1921 when enormous bog fires swept the Peel area. The transition to zone MPN-D can be dated at 1938. In 1939 the nearby Defence Canal was dug and parts of the adjacent bog were reclaimed to agricultural land, as illustrated by the presence of sand in the lowermost spectrum of zone MPN-D. This may have resulted in a lowering and destabilization of the water level in the nearby pit. As a consequence *Molinia caerulea* could expand in and after the dry years in the 1940s and the extremely dry year 1959. The transition of zone MPN-D and MPM-E must be fixed around 1970. The nature reserve Mariapeel was founded in 1963, leading to a stabilization of the water level in the Defence Canal (which became part of the reserve), favouring the development of bog vegetation in the nearby pit. Zone MPM-E is characterized by an increase in macroscopic remains of *Betula*, indicating nearby presence of birches. Like zone MPM-A, there is a conspicuous simultaneous and parallel occurrence of remains of *Oxycoccus palustris* and *Betula*.
Fig. 5 presents chemical data from the same profile. The presence of *Rhynchospora* remains is paralleled by a relatively high Ca content of the peat. High Fe contents in zone MPN-A might indicate the rapid drowning of the bog-mat. High N-concentrations reflect the high degree of decomposition. The highest values of Cd and Zn have to be dated before 1880, indicating post-depositional relocation, as the largest deposition of these elements (stemming from zinc-melters some 30 km to the SE) has taken place in the periode 1925 - 1937. Relocation is furthermore likely, because the measured maximum retention of appr. 25 μgr Cd m^{-2} y^{-1} is twice as much as the largest historically reconstructed annual imput.
Higher values of P after 1920 may reflect increased use of artificial fertilizers. The sand input from 1939 is reflected by a high Fe peak.

The rapid changes in pollendiagrams with contiguous 1,0 - 0,5 cm samples raises the question of the limits of palynological resolution in *Sphagnum* peat deposits. In "normal" *Sphagnum* peat, 1 cm samples usually cover 10 - 30 years and the individual pollen samples represent the means of influx values that may vary largely on an annual and subannual time scale.
Fig. 6 shows a diagram in which every 0,5 cm sample represents 1 year. While still rapid changes can be observed (e.g. *Centaurea cyanus*!), two profiles were analysed every 0,5 mm, i.e. almost a sample per month, to test the finiteness of resolution. Fig. 7 and fig. 8 confirm that signals on the annual level can be observed (e.g. *Calluna*, Gramineae, Cerealia), but that clear monthly/seasonal patterns are absent.

Stomatal frequency analysis in the Mariapeel or the advantages of Big Betty

Friederike Wagner

The intensive work on the establishment of stomatal frequency analysis as a source for reliable palaeoatmospheric CO_2 proxy data evoked the need for naturally grown leaf material under well controlled conditions: without detailed information on the adaptation rates and manners of the potential "biosensor" species under present day conditions, no reconstructions of past conditions.
Classical approaches to quantify CO_2 related morphological adaptation in leaves are herbarium studies and / or controlled environment experiments. However, both methods suffer from certain deficiencies.

- Herbarium studies have the enormous advantage of precise dating of the leaf material, but the leaf material is usually collected over a wide geographical range. Local differences, and therefore possible scatter sources cannot be excluded.

- Growth experiments have the pro of perfect control on the environmental conditions, but are usually performed over only a very short time span and under absolute unnatural growth conditions.

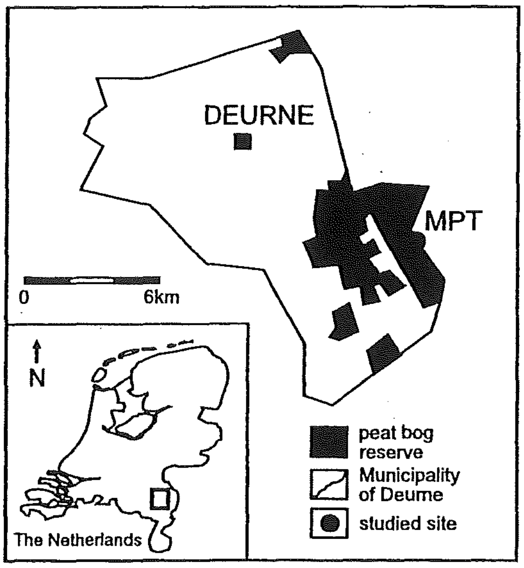
With the introduction of "natural archives" as the peasant peat pit in the Mariapeel, we were able to provide a well balanced compromise of dating, environmental control and covered time span.
In this fortunately actively refilling peat pit, the annual leaf shedding of the solitary *B. pendula* (Big Betty) growing on its margin is accumulated.
The taken Clymo core from this site delivered 17.5 cm *Sphagnum* peat with plenty of well preserved leaves in it. Hans Joosten and Pim de Klerk established a time scale for this site based on the comparison of the pollen data / sedimentology with historical land use data. The resolution and accuracy for the age assessments is ca 1 (!) year.
The age of Big Betty has been determined denrochronologically. Changes in habitat conditions at this site are reasonably to excellent known, since the Nature Conservation Area is monitored for numerous important factors such as nitrogen deposition, ground water levels and of course climate data.
Based on the analysis of the stomatal frequency of the preserved leaf material from Big Betty we were for the first time able to demonstrate that birch possesses the capacity of annual, lifetime adaptation to gradual CO_2 increase. Furthermore, the fact that the material is developed under natural conditions, allows the direct comparison with fossil material. "Chamber effects" are excluded. The results of the leaf record since 1952 are the main base of the calibration curve for tree birches currently used for palaeoatmospheric CO_2 concentrations (Wagner *et al.*, 1996; Wagner, 1998; Wagner *et al.*, 1999).
Big Betty is continuously monitored since five years now and serves as our "show horse". Field studies on sun / shade adaptation, leaf maturity and several other aspects are studied on material from this tree. And, of course, we annually add a data point to our CO_2 calibration curve.

F. Wagner, S.J.P. Bohncke, D.L. Dilcher, W.M. Kürschner, B. van Geel and H. Visscher (1999). Century-scale shifts in early Holocene atmospheric CO_2 concentrations. *Science* 284: 1971-1973.

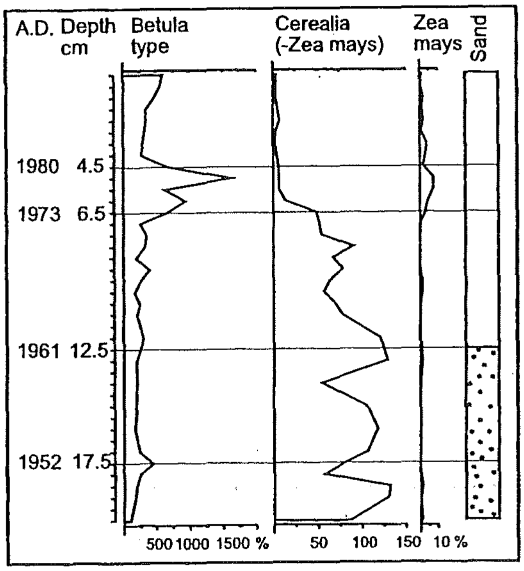
F. Wagner (1998). The Influence of environment on the stomatal frequency in *Betula*. Ph.D. thesis, LPP contributions series no.9, Utrecht, 124 pp.

F. Wagner, R. Below, P. de Klerk, D.L.Dilcher, H. Joosten, W.M. Kürschner and H. Visscher (1996). A natural experiment on plant acclimation: Lifetime stomatal frequency response of an individual tree to annual atmospheric CO_2 increase. *Proceedings of the National Academy of Science USA* 93: 11705-11708.

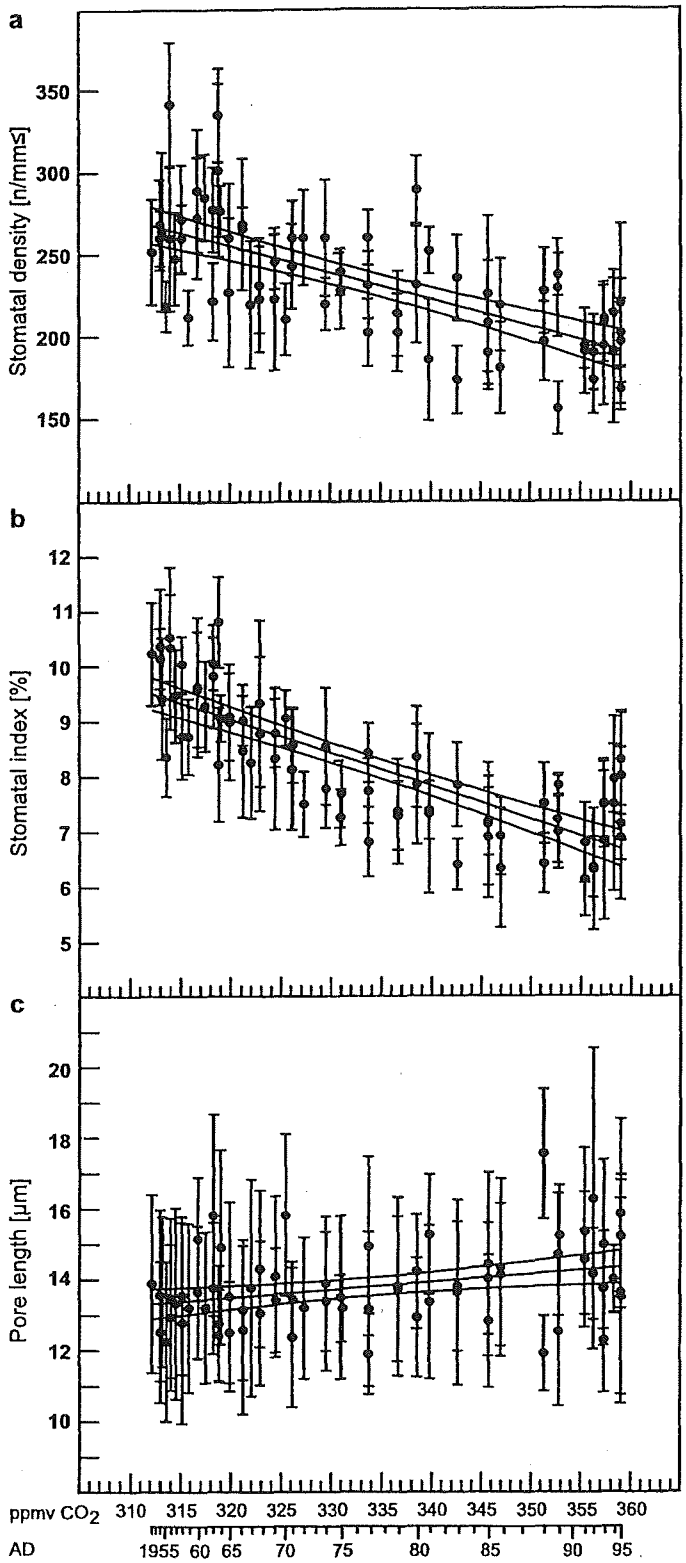
p. 65-67



Location map of site MPT in the Mariapeel nature reserve



Frequencies of selected pollen types (expressed relative to pine pollen numbers) and sand influx in the MPT core. Influx of wind-drifted sand ended in 1961 when arable fields in the surroundings had been converted to grasslands. The shift from *Secale* to *Zea* monoculture took place in 1973. Clearance of colonized *Betula*-dominant vegetation in 1980.



Response of stomatal parameters for *Betula pendula* to global atmospheric CO2 increase in the period 1952-1995.
Stomatal index = [stomatal density / (stomatal density + epidermal cell density)] x 100
Mean global atmospheric CO2 concentrations as measured at Mauna Loa, Hawaii.
For detailed information: see Wagner, 1998.

Moorexkursion 1999 in the Netherlands, tuesday 31st of August 1999

Location:	**The Dutch River Region (near Nijmegen)**
guides:	**Professor Daan Teunissen (University of Nijmegen)** **Dr. Sabine Karg (Universities of Leiden and Amsterdam)**
matter for discussion:	**oxbow lakes** **vegetation developments during the last 5500 years** **human impact reflected in the pollen diagrams**

Introduction

Today, the results of the palynological investigations that were performed by D. Teunissen and his wife some years ago will be discussed in new light and in terms of their value for the vegetation history of the Netherlands and of adjacent regions. Two pollen profiles dated by radiocarbon were chosen (see map). The site 'Horssen-Laagveld' still today is situated in meadow land, 15 km west of the city of Nijmegen between the rivers Maas and Waal. The second profile 'Kleefsche Beek' lies 20 km south of the city of Nijmegen east of the river Maas. This site was distroyed during the construction of a road junction.
The main questions are the continuity of the vegetation history reflected in the pollen diagrams and the question whether any activities of prehistoric and medieval men and of their domesticated animals are reflected in the pollen spectra.

Natural conditions

The Dutch Eastern River Region is situated in the Centre of the Netherlands near the city of Nijmegen and is not influenced by the tides of the Northern Sea. The landscape is characterized by three rivers: The river Rhine coming from the south divides into the Lower Rhine and into the river Waal, the Maas, also coming from the south bends to the west and parallels with the two Rhine branches. North of the Lower Rhine the landscape is hilly because of the presence of ice-pushed ridges. South of the Maas there is a slightly undulating landscape of Pleistocene sands. The river area itself (+/-10m a.s.l.) has for the greater part the character of a flat sedimentation plain transversed by several former river beds. In many cases, the latter are filled with peat. Many of the old and recent river courses are flanked by natural levees, and these, in their turn, enclose backswamp basins which often have peaty fillings as well. The location 'Kleefsche Beek' was an old river bed of the Maas that was cut off in the Boreal and covered by driftsand in Early Modern Times. 'Horssen-Laagveld' lies in the backswamp region between the rivers Maas and Waal.

Pollen sum and zonation of the diagrams

In order to avoid dominance of local plants, the following species were excluded from the pollen sum: alder (Alnus), willow (Salix), sedges (Cyperaceae) and grasses (Gramineae). Changes in the vegetation cover due to changing groundwater levels are, by this means, also eliminated (Janssen 1959). According to Firbas (1949, 1952) and Birks (1986) chronozones were defined, as well as local pollen assemblage zones. The subdivision into the local pollen assemblages is mainly based on changes in the AP/NAP ratio and obvious changes in the curves of the *Cerealia* and the cultural indicators.

Chronozone: SUBBOREAL

The Neolithic period

During the Neolithic period most parts of the landscape were covered with dense woodlands. On the higher parts of the landscape the climax forest was formed by a decidious mixed forest composed of oaks, lime trees and others. Hazel trees (bushes), as well as oaks were either elements of the alluvial forest (Hartholzaue after Ellenberg 1982), or might have bordered the edges of the mixed forest. First cereal pollen appear between 4317 and 3963 calBC. Indications for human activities in the river region are given by the presence of single pollen grains of barley, ribwort plantain, dock, Chenopodiaceae, mugwort and Compositae, all of them grow on cultivated or disturbed land. The anthropogenic signal (cereal pollen together with synanthropic herbs) means, that Neolithic man was present although archaeological finds are still rare.

The Bronze Age period

During the second millenium BC changes in the landscape are visible: the forested areas shrank and the human influence on the vegetation was gradually increasing. In the pollen diagrams the percentages of cultivated cereal grains and synanthropic herbs rose. Larger areas seem to have been under control.
The river area seems, from the frequency of archaeological findings, as well as from the pollen diagrams, to have been less densly inhabited during the Late Bronze Age period compared to the records dating to the Middle Bronze Age period.

Chronozone: SUBATLANTIKUM

The Iron Age period

The forest composition has changed and beech became a dominant tree. During the first millenium BC the NAP percentages increase most probabely because more land for agricultural purposes was needed.
Agricultural activities are detected in the pollen diagrams. Hordeum was an important food plant, which is not only shown by pollen analyses, but also by macroremain records. The rising number of archaeological records (settlements and grave yards) suggest that the population density increased at that time.

The Roman Age period

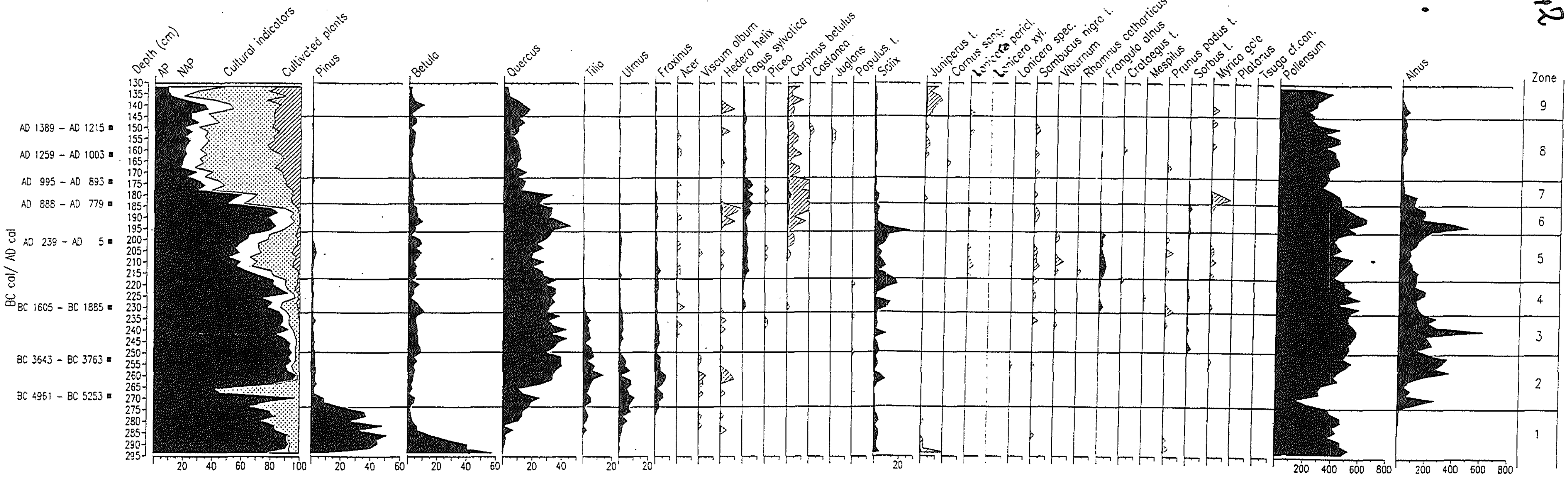
From the end of the 2nd decade BC until shortly after 400 AD, the region was under the influence of the Roman Empire. The northern border was fixed along the Rhine and the Lower Rhine. Large parts of the landscape must have been exploited in order to produce enough food for men and livestock. Rye was introduced as a crop in the River region during the Early Roman Age period.

At the end of the 3rd century AD, the migration of the Germanic tribes began and continued until the 6th century AD. These events left deep traces in the cultural, economic, and demographic development of the local population (Theuws 1991) and the decreased population density is clearly expressed in the pollen diagrams.

The Medieval Age period

The Early Medieval Age period was a time of reforestation in different parts of the landscape. The alluvial forests which were deforestated during earlier periods, as well as the forests on the dry soils became denser (darker). Noteworthy are the small scale evidences for agricultural activities present in the pollen diagrams.
A revival of man's activities can be seen in the palynological picture from at least the 7th century AD onwards.

Kleefsche Beek
Trees and shrubs
Pollensum ex. Alnus, Cyperaceae, Gramineae

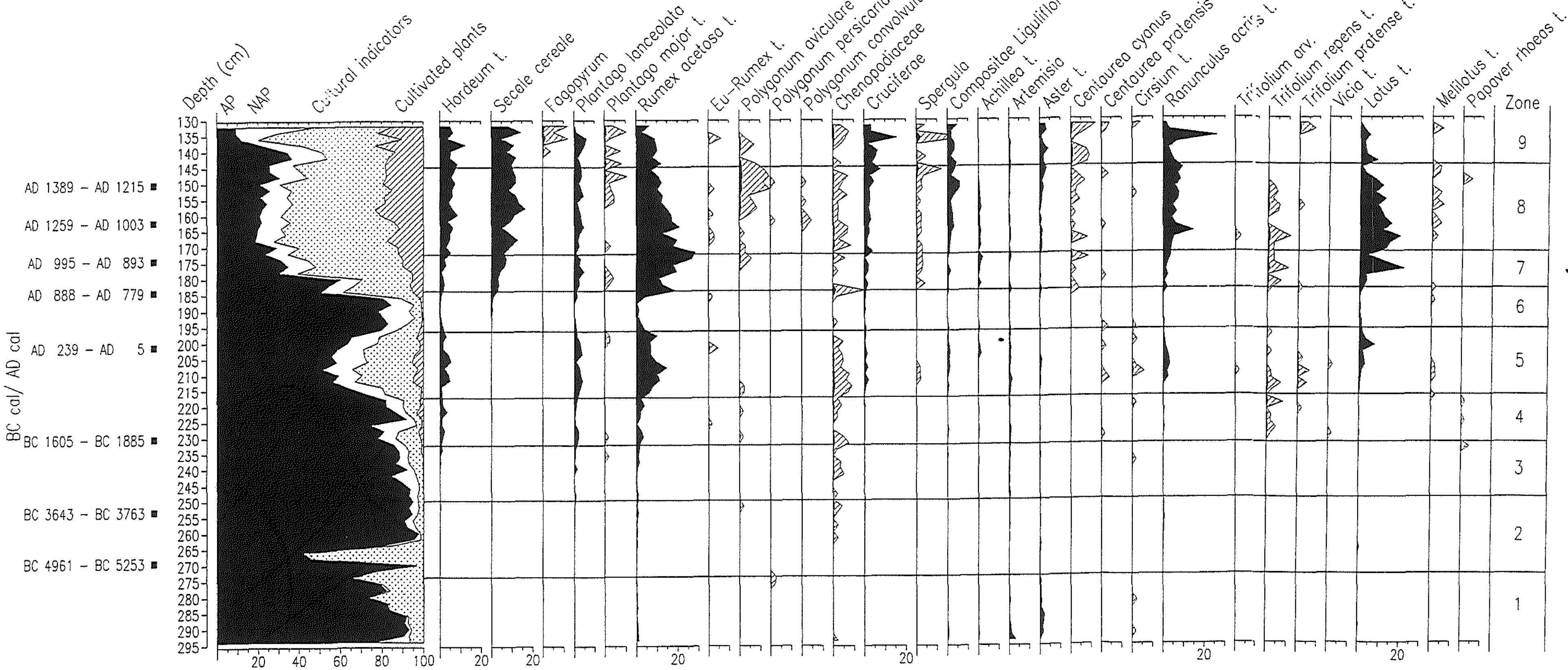


Analysis: H. Teunissen-v. Oorschot, R. de Man

Kleefsche Beek

Cultivated plants and cultural indicators

Pollensum ex. Alnus, Cyperaceae, Gramineae



Analysis: H. Teunissen-v. Oorschot, R. de Man

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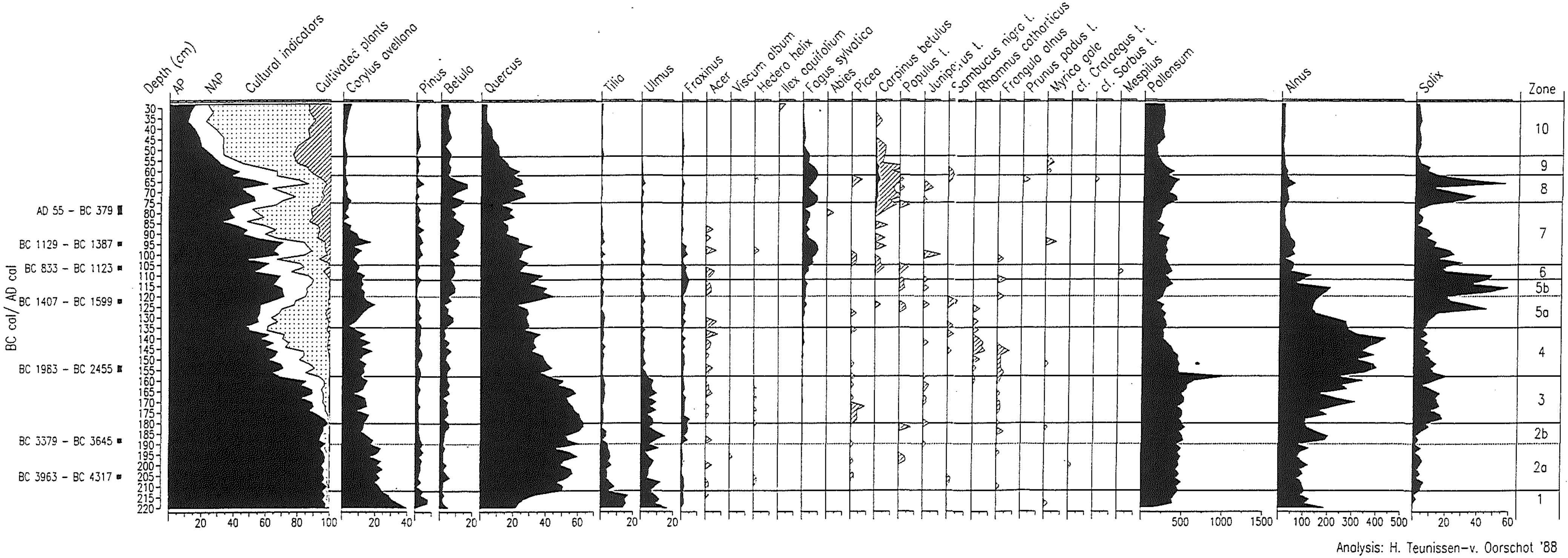
HORSSEN-LAAGVELD-b

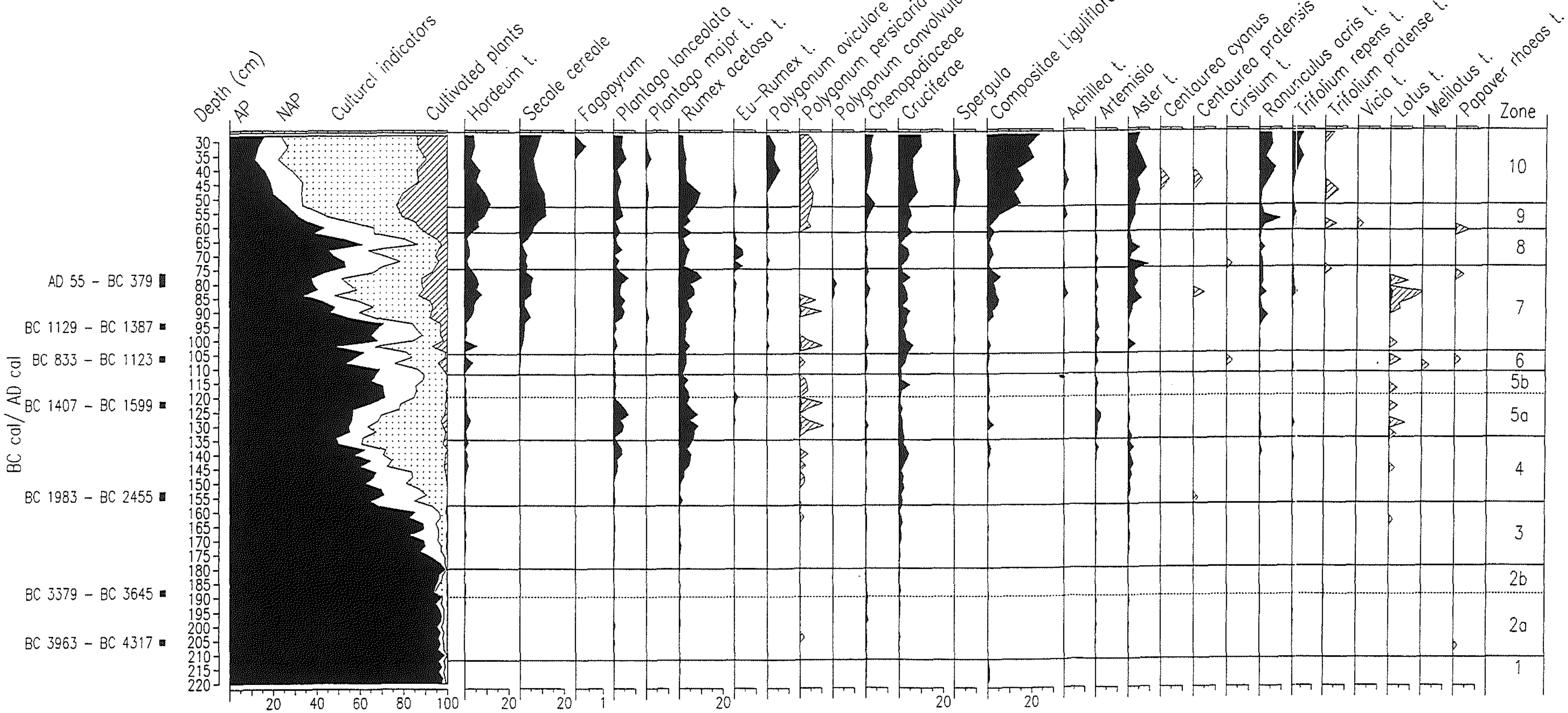
Trees and shrubs

Pollensum ex. Alnus, Salix, Cyperaceae, Gramineae



HORSSEN–LAAGVELD–b

Cultivated plants and cultural indicators
Pollensum ex. Alnus, Salix, Cyperaceae, Gramineae



Analysis: H. Teunissen–v. Oorschot '88

The gradual deforestation starting at that time led to the cultural landscape we are facing today. The period of the 11th to 13th century AD is known for the rising of the population and improvements in the economy. Macroremain studies and pollen analyses show that rye was cultivated from the first millenium AD onwards on a large scale.

The introduction of buckwheat (Fagopyrum esculentum) characterizes the beginning of the Modern Times. Well dated macroremains indicate the cultivation of buckwheat in Europe at the earliest from the 13th century AD onwards.

In general, the opening of the landscape seems to be a process of reclamation and reforestation during the last 5500 years, ending with a totally deforested scenery in the Late Medieval Period. The palynological picture in the river region reflect the continuous use of the landscape for agricultural activities with varying interests which probabely reflect changes in population density.
Human impact on a larger scale can be detected from the Late Neolithic period onwards. The impact is increasing in the Early and Middle Bronze Age period. During the Late Bronze Age period we can recognize a phase of forest regeneration in the river region. It seems likely that in the Iron Age period huge areas were under cultivation and surface erosion might have caused environmental problems. During the Roman period differences in the use of the landscape are obvious. The Early Medieval Age period is a time of forest regeneration although land was still under cultivation. Since the High Medieval Period every corner of the landscape is under human control.

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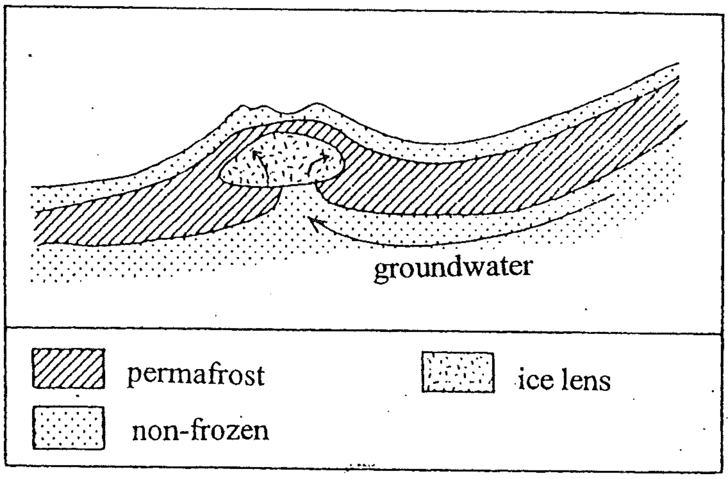
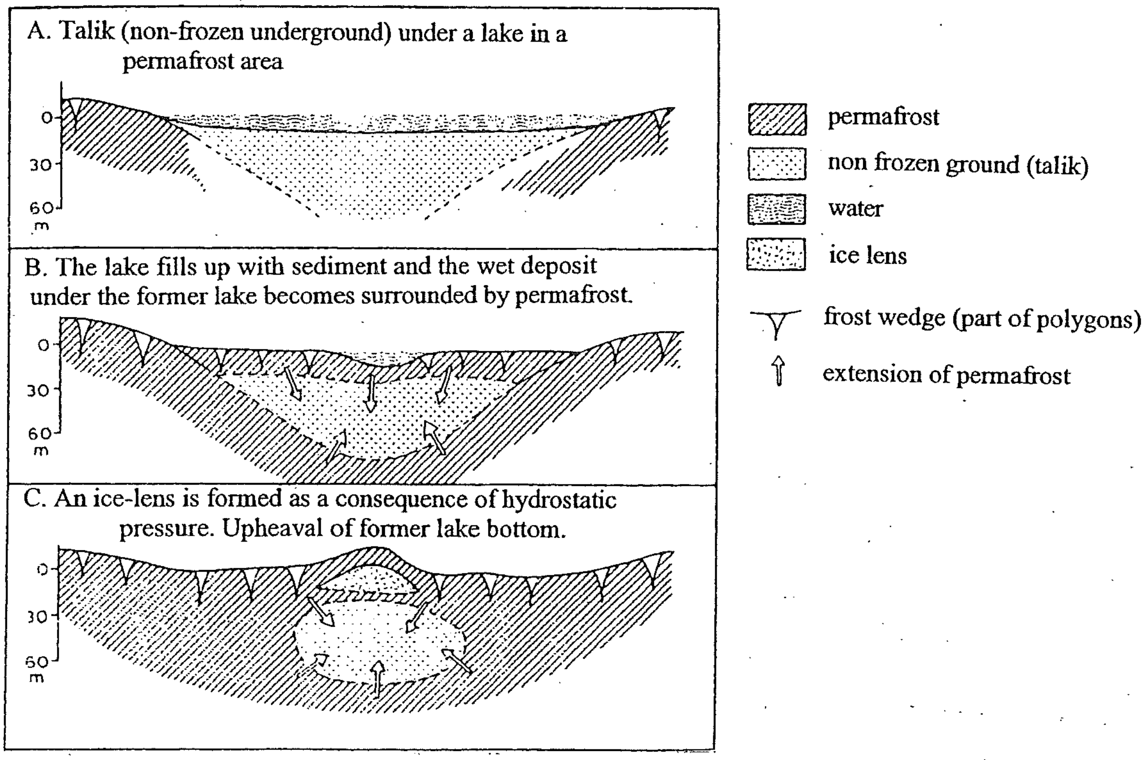
The Uddeler Meer (a shallow lake with a thick, endangered sediment layer, situated in a pingo scar) and the medieval ringfort **Hunneschans**

During the coldest part of the Weichselian a continuous permafrost layer was present in the Netherlands. At several places in the province of Gelderland and especially in Drenthe pingos (glacial ice lenses) were formed. Pingos came into existence between ca 30,000 and 20,000 BP (Upper Pleniglacial). Ice lenses of increasing thickness were formed when ground water from below the permafrost layer was pushed in upward direction (hydrostatic pressure). The maximum depth of pingo scars in Drenthe is 17 meters, which is indicative for the minimal thickness of the permafrost. Based on their development two types of pingos can be distinguished.



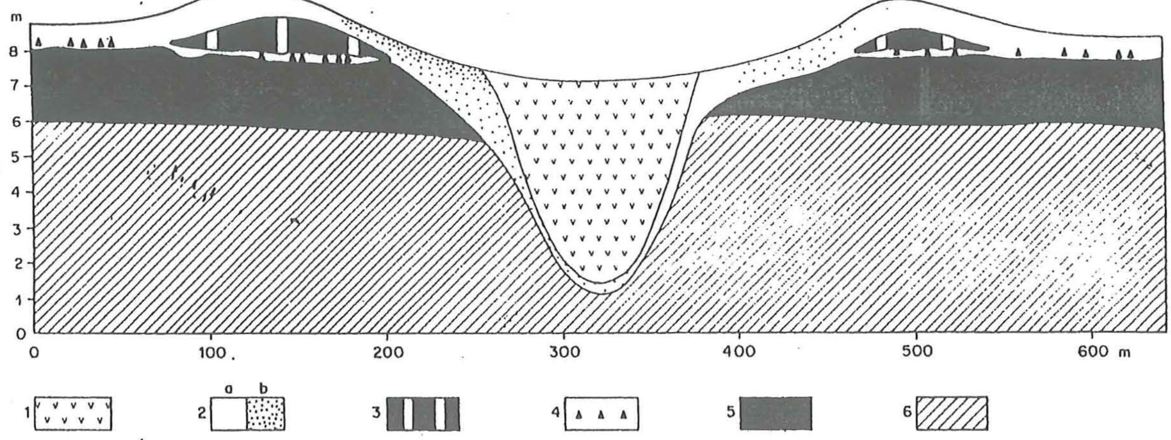
schematical development of an open-system-pingo (after French, 1976)

A different type of pingo starts as a lake in an area with permafrost (see illustration below). In first instance (A) the lake is so deep that in winter the water is not frozen untill the bottom layers. Under the lake a deep, non-frozen deposit (talik) is present. The lake fills up with sediment and when the winter ice reaches the bottom of the lake a permafrost layer is formed in the deposit under the lake water (B). Under hydrostatic pressure an ice lens is formed (C).



schematical development of a closed-system-pingo (after French, 1976)

Melting of pingos and the degradation to a pingo scar (with a central depression and a rampart) happened between ca 20,000 and 13,000 BP. At several former pingo sites the infills of the lakes were studied palynologically. At such sites the pollen record starts during the early Lateglacial.



Cross-section of a pingo scar in a Pleistocene landscape; the Siegerswoudstermeer in the Netherlands. 1: Lateglacial and Holocene lake and peat deposits. 2: Upper Pleniglacial (Weichselian) coversand (a), and gravelly sand (b). 3: Upper Pleniglacial redeposited boulder clay. 4: gravelly sand on boulder clay. 5: Boulder clay (Saalian deposit). 6: Saalian preglacial deposit.

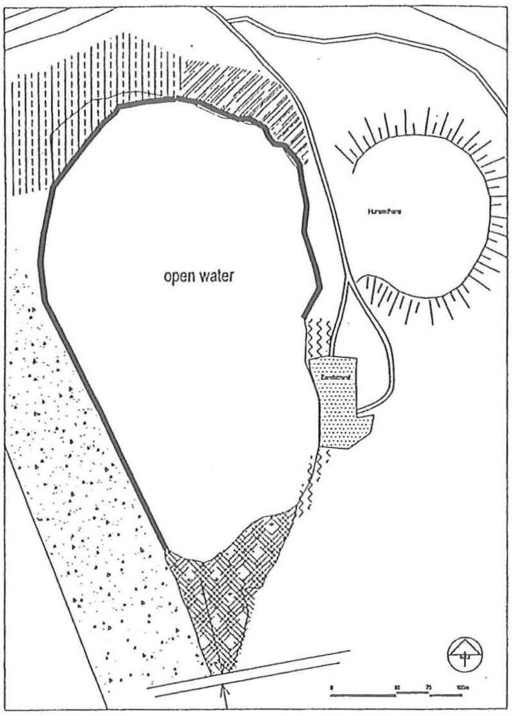
The planning of the Waterschap Veluwe concerning lake Uddel (Uddelermeer)

Until the beginning of the 20th century the Uddelermeer was poor in nutrients. From historical sources it is known that - until the start of the 20th century - a Littorellion was present in the area of the shallow lake border (a pollen diagram produced at the Free University also shows the evidence of a Littorellion; ask BvG in case you would like to see the diagram).

However, during the 20th century considerable eutrophication (especially P and N-components) took place. A consequence of a high level of phosphate enrichment (effluent and excreta) from the catchment area of the lake is that N-limited growth conditions occur. This is especially the case during summer, when a considerable part of the nitrogen components has been used by living algae. **Cyanobacteria** (formerly called Blue-green algae) can **fix nitrogen** from the atmosphere and that is the reason of blooms of these organisms (compare van Geel *et al.*, 1994 for medieval Lake Gosciaz). Many species of Cyanobacteria, for example *Microcystis*, produce toxic substances and therefore eutrophication can result in water that is too much polluted for swimming. The Cyanobacteria in the Uddelermeer are responsible for a pH>9.0.

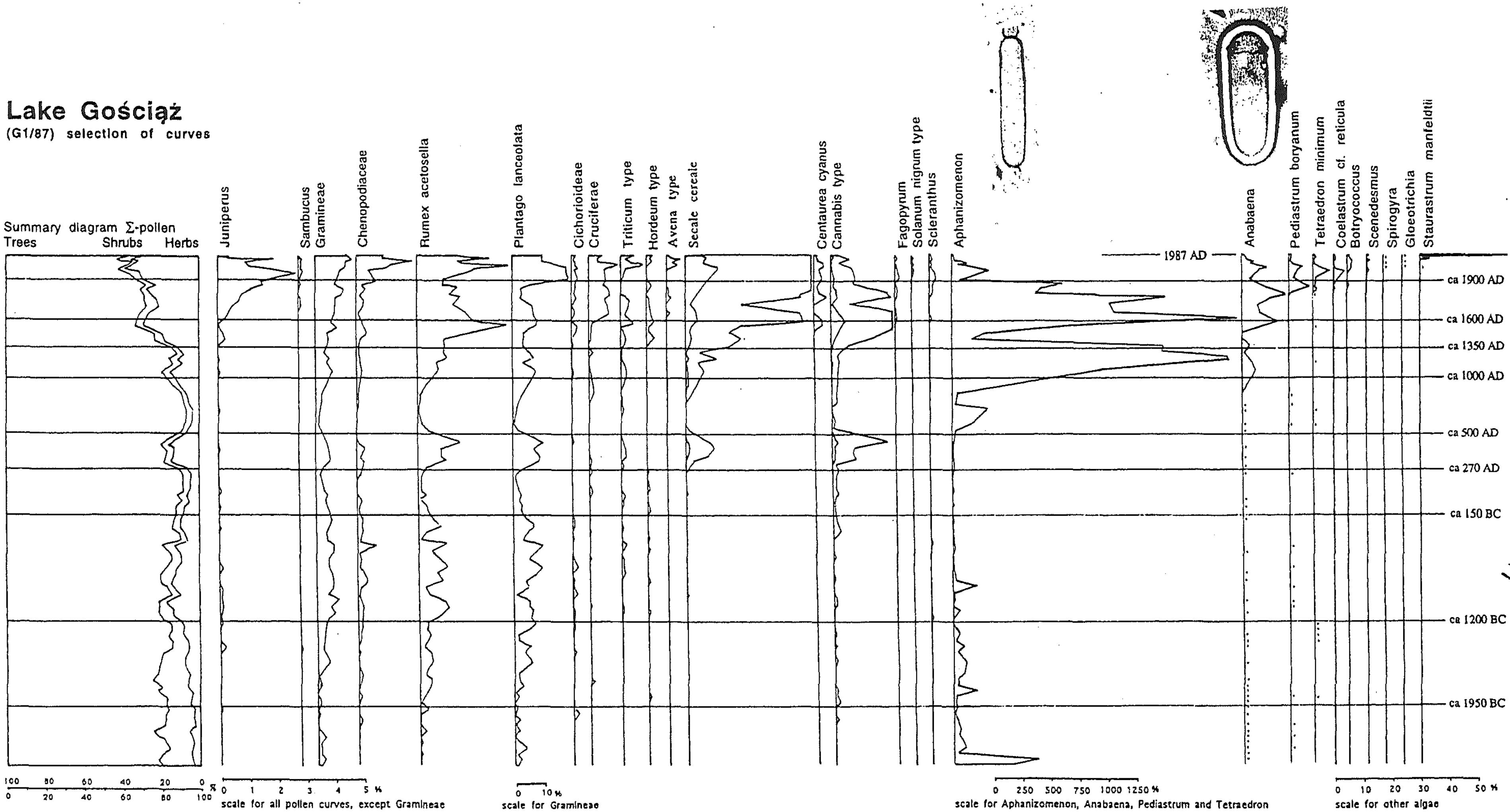
The staff of the **Waterschap Veluwe** (indeed we have, apart from the phenomenon 'Landschap', also 'Waterschap', which is the regional water management authority) found a brilliant solution: they planned to remove several meters of the phosphate-rich sediment (for 2.5 million guilders). The Uddelermeer is one of the very rare complete holocene paleo-archives in the Netherlands, and therefore we did not accept the ideas for 'restoration' of the lake. The responsible minister got questions from the Dutch parliament, and now (summer 1999) a paleoecological study of the upper meters of sediment is worked out at the Free University Amsterdam. The results will play a role in the final decisions about the Uddelermeer sediments. Note that there is a strong contrast between the targets of the biologists of the Waterschap and the Dutch paleobiologists.

p. 50-52



Overview present vegetation
(report Grontmij)

- Sphagnum
- Sphagnum (remains)
- Damp deciduous forest
- Damp meadows
- Damp deciduous forest
- Phragmites



Summary pollen diagram and selection of pollen curves of upper part of core G1/87 of Lake Gosciaz, in combination with curves of Cyanobacteria and algae.

Cyanobacteria and lake pollution in historical time; an example from Central Poland
Phosphate eutrophication, related N-limited growth conditions, and thus blooms of Cyanobacteria are not strictly modern phenomena. In the deposits of Lake Gosciaz we found that after ca 1000 AD enormous quantities of spores of Cyanobacteria (*Aphanizomenon* and *Anabaena*) parallel the high values of human impact indicators in the pollen diagram.

Research into the sub-recent sediments of the Uddelermeer

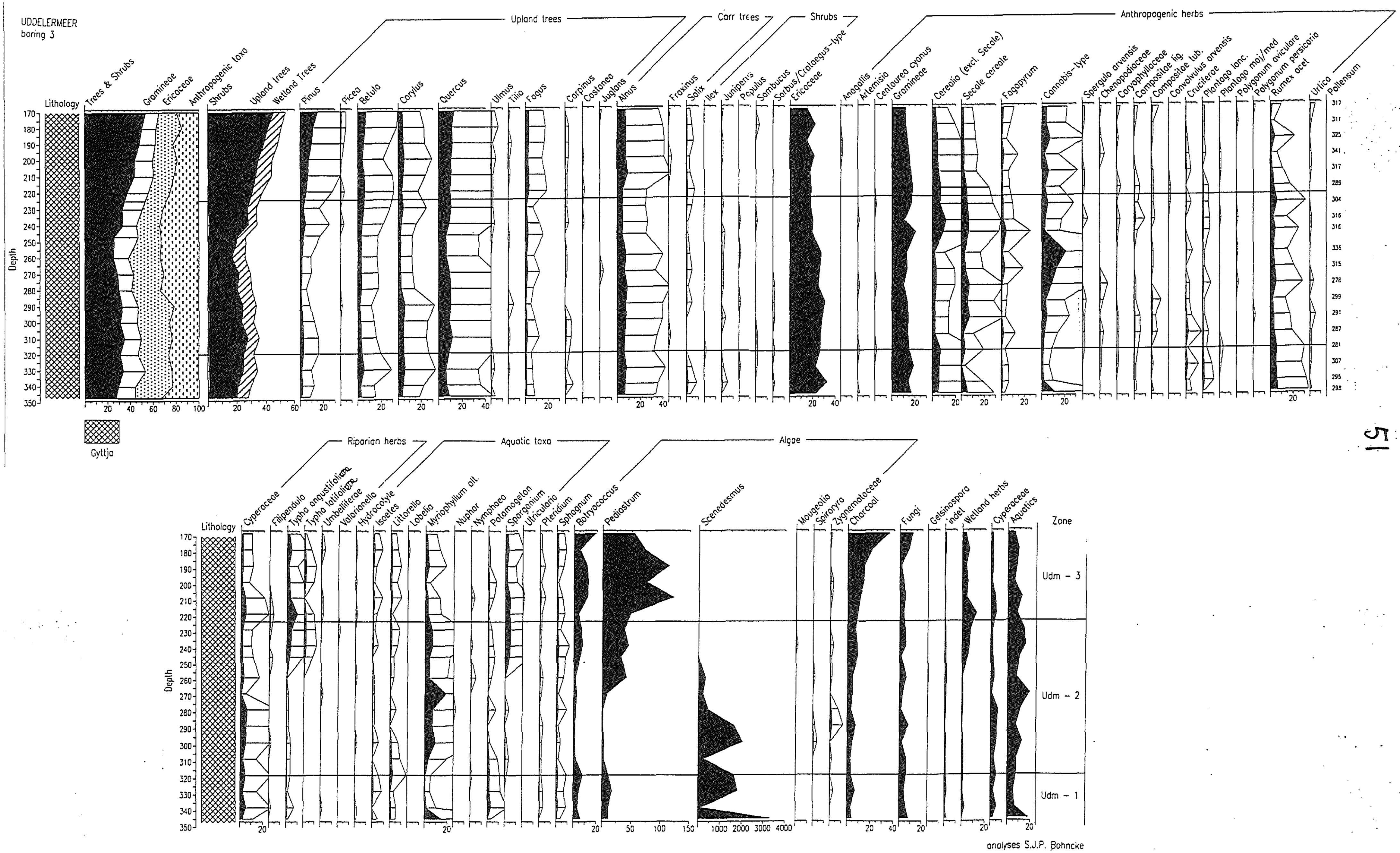
Sjoerd Bohncke, Instituut voor Aardwetenschappen, Vrije Universiteit Amsterdam

In spring 1999 the upper 2 meters of sediment of the Uddelermeer have been sampled in four cores. One of these, core 3 will be discussed here.
The topmost meter has been sampled with a Beeker sampler because of the water saturated nature of the sediments. The subsequent meter has been sampled with a piston corer. The perspex tube with the sample from the Beer sampler has been frozen with liquid nitrogen in an upright position in order to prevent mixing of the sediment during transport.

Core 3
Beeker sampler: 147 – 247 cm, effective core length 156 – 247 cm. The upper 9 cm were lost due to the sampling technique used. Piston corer: 247 – 347 cm
Based on the characteristics of human impact indicators the pollen diagram has been divided into 3 local pollen assemblage zones.

Zone Udm-1 (347 – 320 cm).
The AP amounts to around ± 30 % of the pollen sum, both *Fagus* and *Carpinus* are present in low values. A considerable percentage of pollen of cultivated plants is present. Cerealia, *Secale cereale*, *Fagopyrum* and *Cannabis* have been cultivated on the sandy soils around the Uddelermeer. *Secale* points to a mediaeval age, or younger. The presence of *Fagopyrum* in the Veluwe-area has been recorded in historical sources from about 1390 AD.

Zone Udm-2 (320 – 225 cm).
The pollen record demonstrates an increase in the cultivation of *Secale* and *Fagopyrum*, subsequently followed by a major rise in *Cannabis* pollen. In the historical records (e.g. Bieleman 1992) the widespread cultivation of *Fagopyrum* is recorded at 1566 next to the cultivation of *Secale* and the cultivation on a wide scale of barley (*Hordeum*). In this record it is also mentioned that the practice of using the cereal fields as a common grazing field after the harvest for the cattle was abandoned when *Fagopyrum* was cultivated on a large scale. Instead *Spergula arvensis* was used a fertilizer. This practice can be seen in the pollen record by the appearance of *Spergula arvensis*. Subsequently it disappears in favor of the cultivation of *Cannabis*. In the historical record there is no mention of the cultivation of *Cannabis* for the Veluwe but instead its wide scale increase is recorded for the western provinces of the Netherlands during the period between 1590 and 1660 AD. The cultivation of *Cannabis* was in principal meant for the production of fibers used in the shipping industry, which became a major industry during our Golden Age (16th century). Besides the fibres were used for the production of nets in the fishery. It cannot be excluded that


UDDELERMEER
boring 3
Lithology
Trees & Shrubs
Gramineae
Ericaceae
Anthropogenic taxa
Shrubs
Upland trees
Wetland Trees
Upland trees
Carr trees
Shrubs
Anthropogenic herbs
Pinus
Picea
Betula
Corylus
Quercus
Ulmus
Tilia
Fagus
Carpinus
Castanea
Juglans
Alnus
Fraxinus
Salix
Ilex
Juniperus
Populus
Sambucus
Sorbus/Crataegus-type
Ericaceae
Anagallis
Artemisia
Centaurea cyanus
Gramineae
Cerealia (excl. Secale)
Secale cereale
Fagopyrum
Cannabis-type
Spergula arvensis
Chenopodiaceae
Caryophyllaceae
Compositae lig.
Compositae tub.
Convolvulus arvensis
Cruciferae
Plantago lanc.
Plantago maj/med
Polygonum aviculare
Polygonum persicaria
Rumex acet
Urtica
Pollensum
Depth
Gyttja
Riparian herbs
Aquatic taxa
Algae
Cyperaceae
Filipendula
Typha angustifolia
Typha latifolia
Umbelliferae
Valeriana
Hydrocotyle
Isoetes
Littorella
Lobelia
Myriophyllum alt.
Nuphar
Nymphaea
Potamogeton
Sparganium
Utricularia
Pteridium
Sphagnum
Botryococcus
Pediastrum
Scenedesmus
Mougeotia
Spirogyra
Zygnemataceae
Charcoal
Fungi
Gelsinospora
indet
Wetland herbs
Cyperaceae
Aquatics
Zone
Udm - 3
Udm - 2
Udm - 1
analyses S.J.P. Bohncke

this later was the main purpose of the cultivation of *Cannabis* in the Veluwe area since there were several thriving fishery villages along the borders of the Zuiderzee (Harderwijk, Elburg).

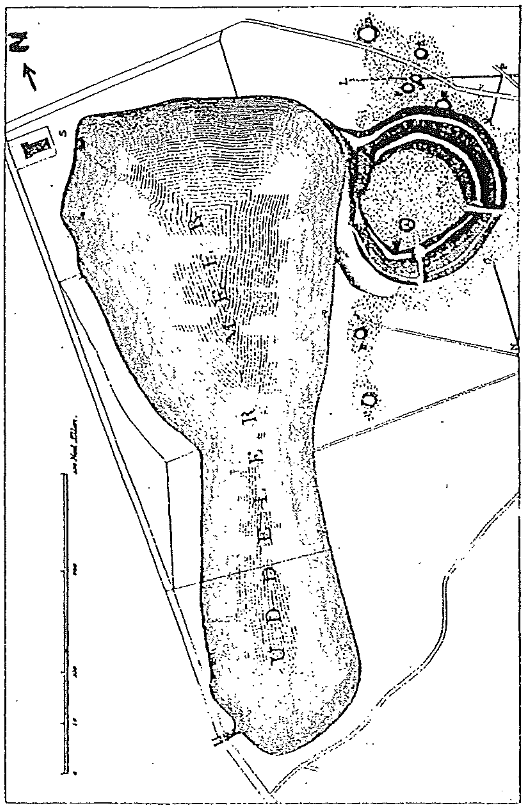
In other pollen records during the declining phase of the *Cannabis* cultivation, pollen of *Linum usitatissimum* was found and probably there was a shift from the cultivation of hemp towards flax. Towards the top the cultivation pressure on the landscape declines and trees and shrubs show an increase.

Zone Udm-3 (225 – 170 cm)
During this zone the cultivation pressure on the landscape declined and AP starts to increase. Remarkable is the quick return of *Fagus* and *Carpinus* to the pollen assemblage. Also *Castanea* seems to play a role. The increase of *Alnus* possibly means that also the border zone of the Uddelermeer got less anthropogenic pressure. The decline in the cultivation of cereals can probably be explained by the economic recession and the decline in the population, which is known to have occurred from the middle of the 17th century. This period of recession continued up to the middle of the 18th century after which reclamation of heath and of the wetter areas with *Alnus* and *Salix* took place. This event is not recorded in this sequence but it is recorded in core 4.

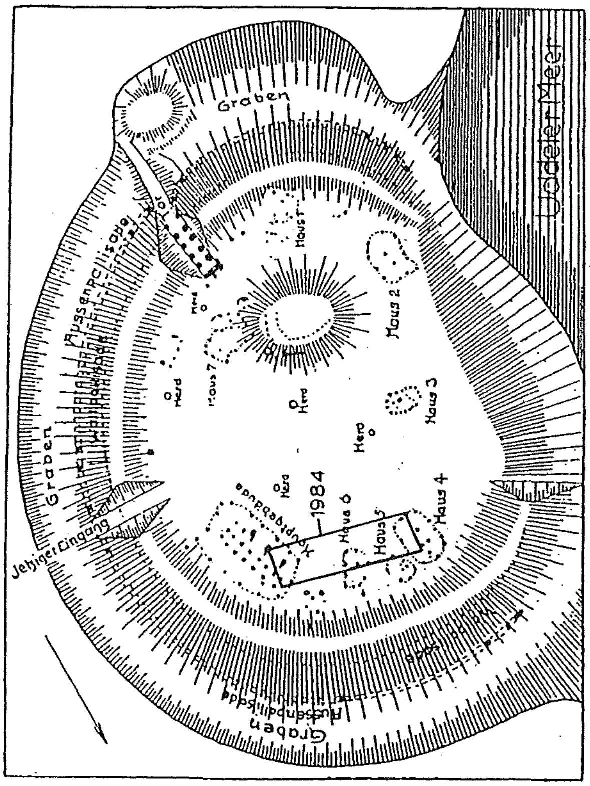
Local aquatics
The Littorellion with species like *Isoetes* and *Littorella* is present throughout the sequence as is *Myriophyllum alterniflorum*. This species increases where *Isoetes* declines, which is during the phase with maximum values of *Cannabis* pollen. Probably the water of the Uddelermeer was used to ret the hemp and due to this practice the water quality of the lake deteriorated and thus *Isoetes* temporarily declined. *Myriophyllum alterniflorum* instead reaches its maximum values in this zone probably taking advantage of the decline in *Isoetes*.

The medieval ring fort Hunneschans (the archaeologist Matthijs van Nie will be our guide)

The Hunneschans is one of the best preserved ring forts in the Netherlands. The fort consists of an approximately 4 m high, horseshoe-shaped earthwork surrounding an inner court of approximately 100 m in diameter. The earthwork is encircled by a dry ditch. The open side of the fort faces the lake Uddeler Meer. Matthijs van Nie will explain that the ditch around the medieval Hunneschans was filled with water, in direct connection with the lake Uddeler Meer.
Heidinga (1987) discussed the function of the Hunneschans, considering the date of construction, its use, the function of similar forts, its social and political context, its place in the regional system of settlement and the road system, and its position with regard to economic centres. The geographical position of the Hunneschans is related to an early medieval route on the Veluwe between the river Rhine and the Almere (predecessor of the present lake IJsselmeer).
The oldest pottery (Badorf-type material) related to the fort can be dated to somewhere in the second half of the 9th century and/or the first half of the 10th century. Nowadays the Hunneschans is situated in the economically insignificant central part of the Veluwe area (sandy, infertile soils). From archaeological excavations however, it is evident that the area was important and had a relatively high population density during the early medieval period. The economic potential of the Veluwe in the early Middle Ages was based on the **production and export of iron**. Ore in the form of lumps of iron hydroxide (which were called 'klapperstenen' = rattle stones) was found in the ice-pushed ridge, and it was exploited in open cast mines. The material was reduced to iron in furnaces with (oak) charcoal. For this purpose coppicing of oaks was practised. The charcoal was burned in *Grubenmeiler*. Enormous slag-heaps have been found in the Veluwe area. The material in those heaps is tap slag, scattered with charcoal and furnace remains. Heidinga (1987) mentions the possibility that the Hunneschans may even have been a transfer point for the iron trade, but according to van Nie the Hunneschans was built after the iron production had ceased.
In the course of the 9th century iron production finished, probably because (1) fuel (forests) became depleted, and (related?) sand drifts became a serious problem, and (2) large-scale iron production was started in Germany.
Van Nie is an expert in the study of prehistoric and medieval iron industry (van Nie, 1995, 1997). During our excursion he will speak about the Veluwe area as a centre of iron production in the period between the second half of the seventh and the tenth centuries AD.



The Hunneschans, the lake and some burial mounds around 1900 AD



Plan of the Hünneschans according to Holwerda. The part of the inner court re-excavated in 1984 is marked in heavy outlive.

Wednesday 1 September:

- In the north-western part of the province of Overijssel we will visit the fen area "Weerribben", which is interesting from historical ecological, hydrological and botanical points of view. Our guide will be Dr Geert van Wirdum. See p. 122-149

Thursday 2 September:
In the Twente area we will visit: (a) pushed moraine of Saalian age near Ootmarsum; (b) the Lutterzand in the Dinkel Valley where the deposits of the last ca 30,000 years of the Weichselian are exposed along the river Dinkel. These deposits were intensively studied by Thomas van der Hammen and colleagues (van der Hammen and Wymstra, 1971); (c) the Juniper stands in a former heath land; (d) the area Brecklenkamp where well developed "Plaggenboden" are present; (e) and the river forest along the Dinkel River near Beuningen.

Some remarks about the geology of the Twente area; the Lutterzand section
Major geomorphologic elements in the landscape are the ice-pushed ridges of Oldenzaal and Ootmarsum and the valleys beside these elevations. The pushed up deposits in the ridges mainly are Early to Middle Pleistocene river sediments and Tertiary marine clays. The ridges were formed during the penultimate glaciation (Saalian), when the border of the land-ice had reached its maximum southern extension until the Rhine area in the central Netherlands. At many places erratic blocks (Scandinavian and Baltic rock fragments, transported by the ice) can be observed.

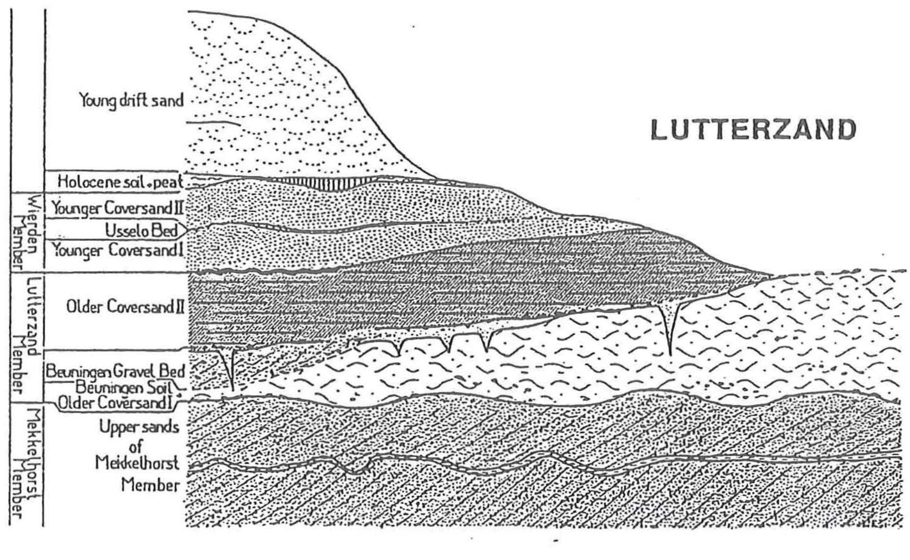
During the Eemian interglacial the valley was forested, with rivers and lakes (see reprint van Geel *et al.*, 1986). The Dinkel Valley was at many places more than 25 m deeper than today, whereas the ice-pushed ridges still were much higher than today because the erosion during the Weichselian had not yet taken place.

During the Weichselian (the ice cap did not pass eastern Denmark and northern Germany) erosion processes in the elevated areas of Twente resulted in very thick sediments in the valleys. The changing character of these sediments (fluvial; aeolian coversands; polar desert pavement, frost fissures and related periglacial features, peat deposits) reflects stages of different climatic regimes. Detailed geological and paleoecological studies were published in the double-thesis by van Huissteden(1990) and Ran (1990).
Some toponyms in the Twente area were used by van der Hammen to indicate various lithostratigraphic units: Hengelo, Denekamp, Beuningen, Rammelbeek. For an overview of the geology reference is made to Bateman and van Huissteden (1999; see ~~following pages~~). p. 150-156

The ice-pushed ridges also contain layers of Miocene marine clay. Ground water stagnating on these clay deposits appears in springs which are the sources of small brooks with a characteristic vegetation (a.o., *Chrysosplenium* species; *Cardamine amara*). The special temperature regime (the water is cool in summers but relatively warm in winters) is said to play a role.

We will walk along the naturally exposed **Lutterzand section** (a classical type site) and see and discuss the following phenomena:

- Middle Pleniglacial fluvial deposits (coarse, angular sands, often showing cross-bedding)
- Upper Pleniglacial aeolian coversands
- Beuningen gravel bed (pebble bed: polar desert pavement) and related phenomena (frost wedges as part of polygons) which were formed in an arctic environment.
- Lateglacial Younger Coversands with thin peat layer of Allerød age and its continuation in an Usselo soil.
- Holocene podzolised soil on top of Younger Dryas age sand dunes.
- Mediaeval sand dunes with young podzols.



The area Brecklenkamp

The north-eastern part of Twente escaped the re-allotment disaster and the landscape still shows several well developed 'essen' (German: Plaggenesch). During ca the last 1000 years poor sandy soils were improved by adding sods with manure. As a consequence the arable land was elevated with material from elsewhere (often more than 1 meter accumulation). This way of adding manure is strongly connected with cultivation on a large scale of *Secale cereale*. And for the continuous cultivation of *Secale* ('eternal rye cultivation') it was absolutely necessary to add nutrients to the soils on a regular basis. In historical time sods where taken from the heithlands, from forest and also from bogs.

In a preliminary study of one of the 'essen' from the Brecklenkamp area we found some oospores of Characeae as macrofossils in the accumulation layer of the es. This means that the farmers may have been aware of the advantage also to add some lime to the arable. According to Behre (1980) the practice of using sods with manure, in combination with *Secale* cultivation, started suddenly around 1000 years ago. The best dated example (10th century AD) is the Plaggenesch near Dunum (Germany), where the pollen record of the nearby Hilliges Moor shows a sharp increase of *Secale*, *Rumex acetosella*, *Sceranthus annuus* and various other 'Siedlungszeiger'.

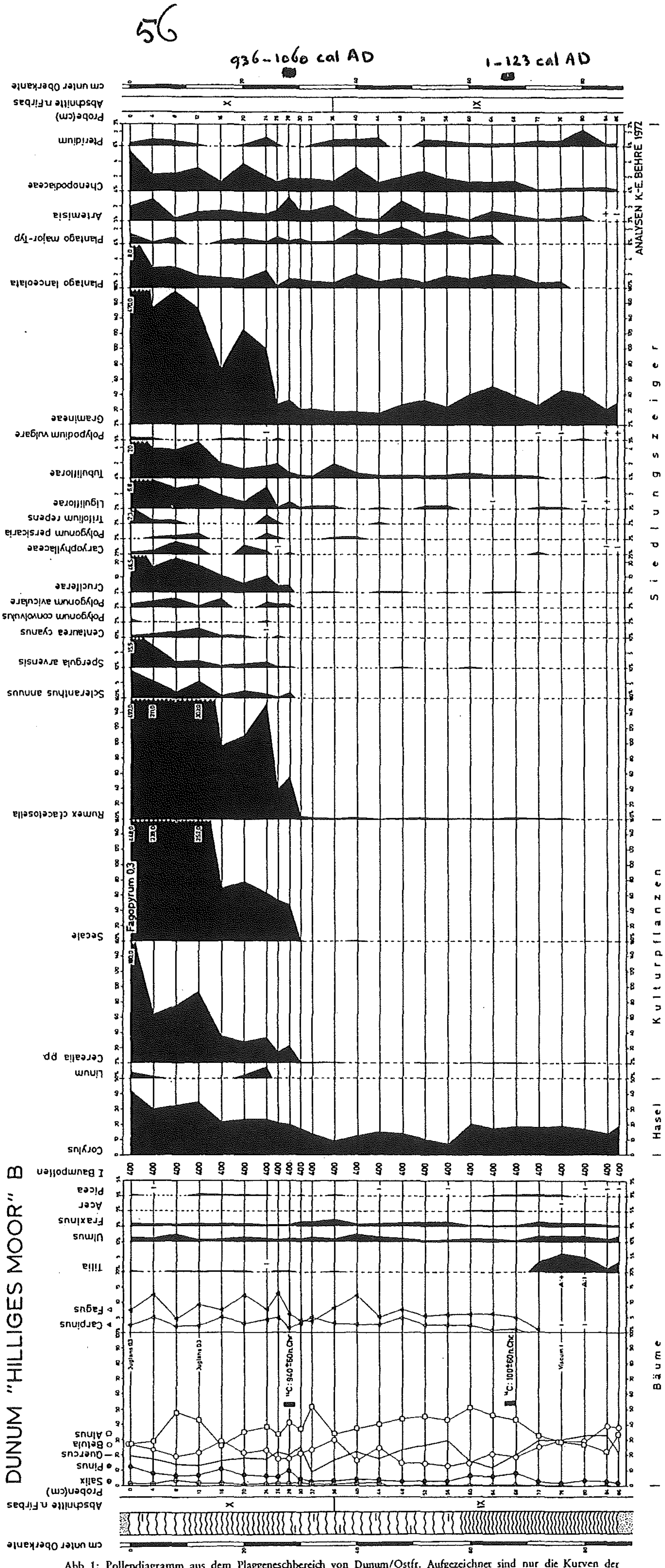
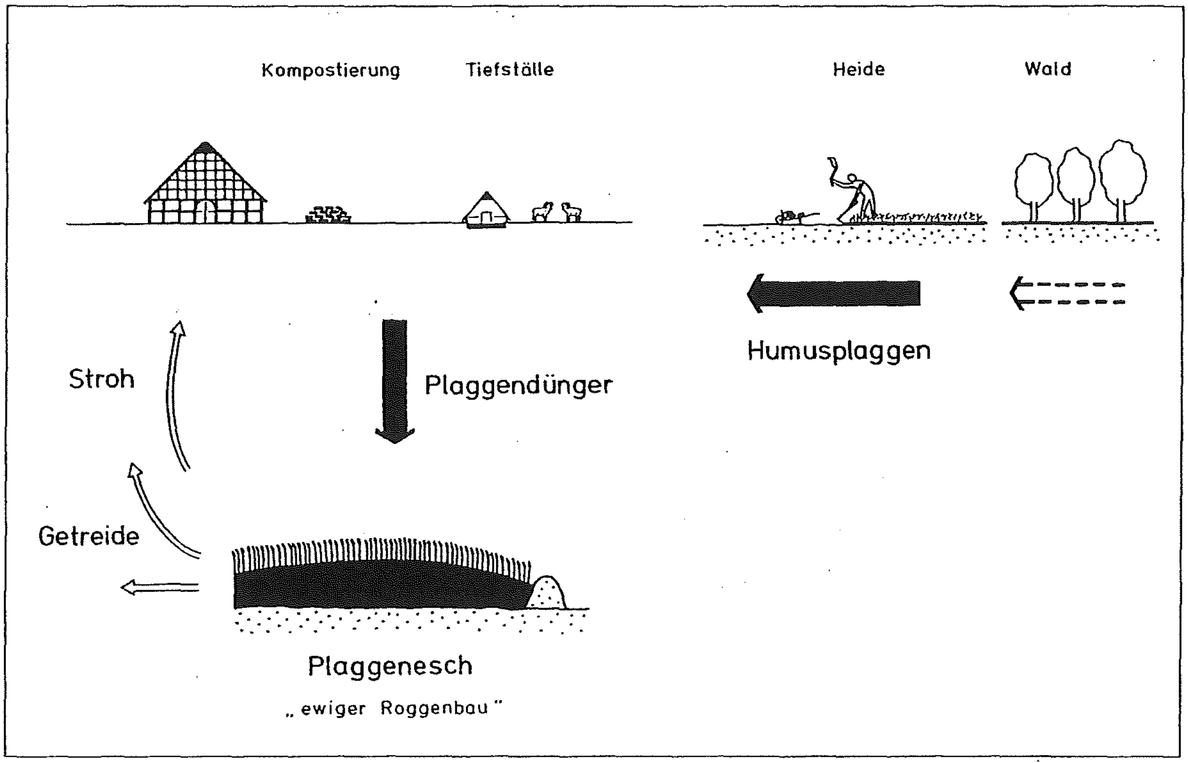


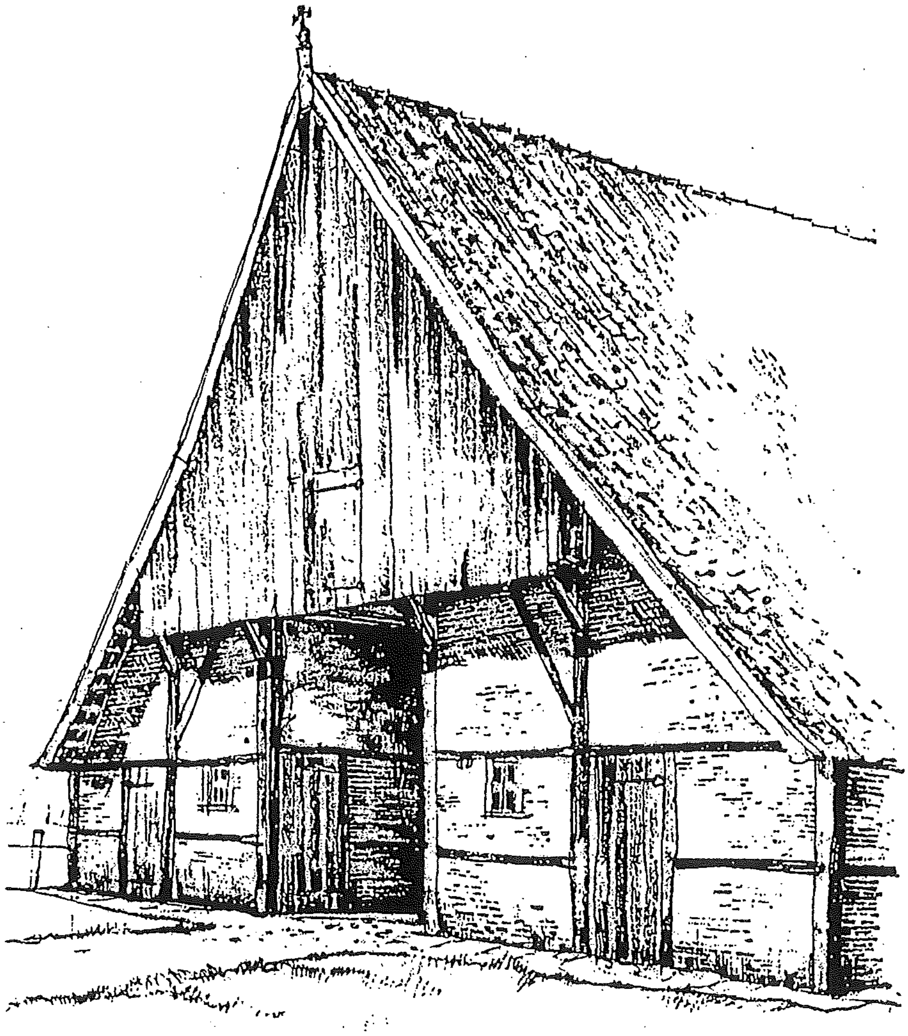
Abb. 1: Pollendiagramm aus dem Plaggeneschbereich von Dunum/Ostfr. Aufgezeichnet sind nur die Kurven der Baumpollen sowie (auf Baumpollen = 100 % bezogen) die der Kulturpflanzen und Siedlungszeiger. Bei cm 28 liegt die Einführung der Roggenkultur.



Scheme (Behre, 1994) showing the medieval and later 'Plaggenwirtschaft'

Hassinkhof

Along the river Dinkel, between the Beuningerbrug (brug = bridge) and the Kampbrug (south of Denekamp) there is a well developed wet forest, which the German-speaking colleagues may characterise as an 'Auenwald'. Inundations became rare since the regulation of the Dinkel in the sixties. In the relatively dry parts of the forest we find species of the Alno-Padion. The most wet places (former meanders of the Dinkel) are characterised by a Salicion.



Juniper stands, regeneration problems and an explanation based on paleorecords

In the man-made landscapes on Pleistocene sandy soils, heathlands and sand drift areas were present everywhere until artificial fertilizers became available. Like elsewhere in NW-Europe, most of the heathland could be transformed into arable land. In some of the remaining heathlands (nature reserves), stands of *Juniperus* are present. As a landscape element this is very much appreciated by the public, especially for aesthetic reasons. However, the Junipers are all of rather old age; the seeds do not germinate and sooner or later the old trees may die and the species will disappear.

During our excursion in the **Lutterzand** area (near the villages of Beuningen and Denekamp) we will see such a *Juniperus* stand. Its rejuvenation indeed is problematic. No young Junipers are present. And this is a general problem for *Juniperus* in the Netherlands.

One of the Juniper stands in the province of Drente is situated just besides a small boggy moorland pool, called Reigersplas (between municipalities Dwingeloo and Beilen). Two biology students Gerko Hopster and Roy Greeve (1999) have worked out (with the help of Bas van Geel) the paleoecological analysis of a one meter deep core from that site. We distinguished and interpreted the following zones (see diagrams and reconstruction of stages):

Zone I/A: strictly local occurrence of oligotrophic conditions (*Erica tetralix*, *Andromeda polifolia*, *Rhynchospora alba*, *Sphagnum*). Raised bog-like situation in open park-like landscape. Not earlier than Late mediaeval (presence of *Fagopyrum*).

Zones II, III/B: The sediment is sandy and was deposited in a moorland pool (*Potamogeton*, *Utricularia*, *Ceratophyllum*, Cladocera). We do not know yet if the bog became inundated after a rise of the water table (?effect of deforestation?) or if the moorland pool situation was created after peat cutting (in other words: hiatus or not?; ^{14}C dates not yet available). *Juncus* species were growing nearby or even local.
Grasses and other human impact indicators show relatively high percentages. Highly dynamic landscape (soil erosion in heathland). *Juniperus* still very low values. Ascospores of *Cercophora* indicate dung.

At the **transition between local zones II and III**, the input of sand shows a sharp decline and the pollen record shows that *Pinus* plantations (first plantations around 1875 AD) probably caused a decrease in erosion and sedimentation of sand. Decline of herbaceous human impact indicators. *Sphagnum* species start to play an important role again at the sample site. The terrestrialisation process (Verlandung) may have been accelerated by a lowering of the groundwater (more evapotranspiration in a forested area?).

Zone IV/C: Dominance of *S. cuspidatum* and later development towards the present oligotrophic *Sphagnum magellanicum* carpet. Only now Juniper shows an increase, indicating that the development of the Juniper stand is a rather late phenomenon in the landscape. For germination of its seeds this species needs a dynamic situation (open soils with erosion/deposition of sand; compare the early Lateglacial and early Holocene). On the other hand, the dynamic situation also hampered the full development of all individuals. When the dynamical situation came to an end (plantations of *Pinus sylvestris*; decrease of grazing by sheep) there was a temporary opportunity for many Juniper individuals to grow up to adult specimens. The further stabilization of soils (nowadays almost completely covered by mosses and herbaceous flowering plants) hampers the rejuvenation of the population.

Conclusion: Only artificial dynamics can help to avoid 'extinction'! The Lateglacial and early Holocene pollen record also shows that *Juniperus* only can play a temporary role as an early element in a succession towards forest.

Fig. 17

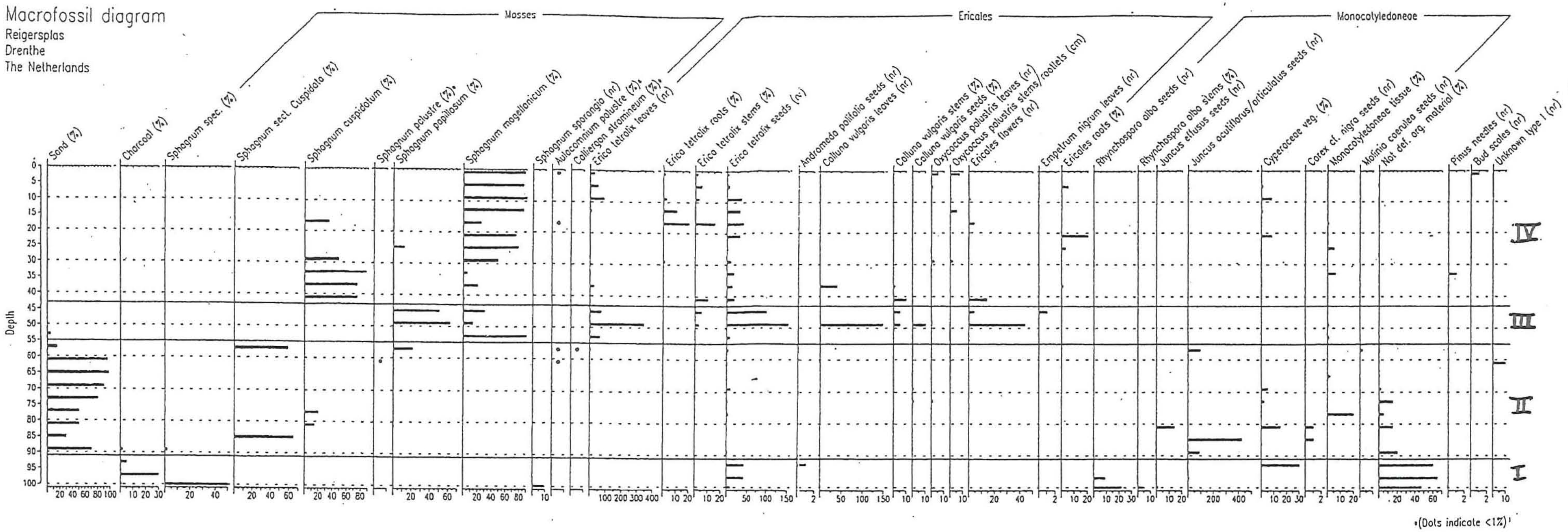
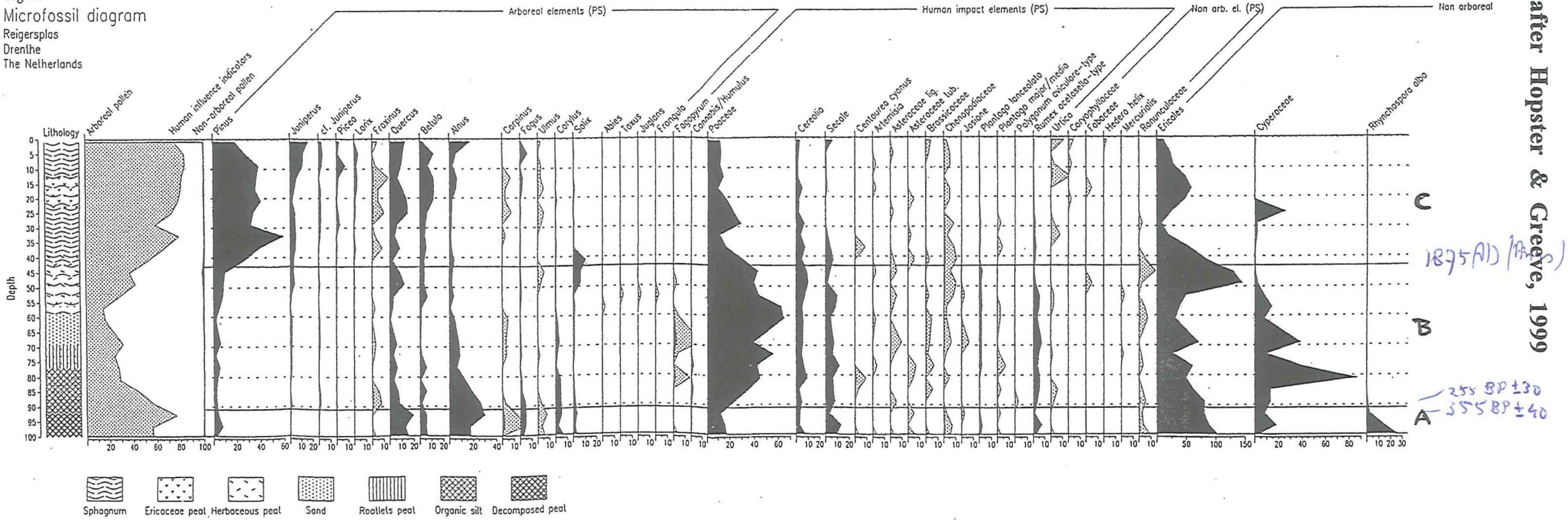


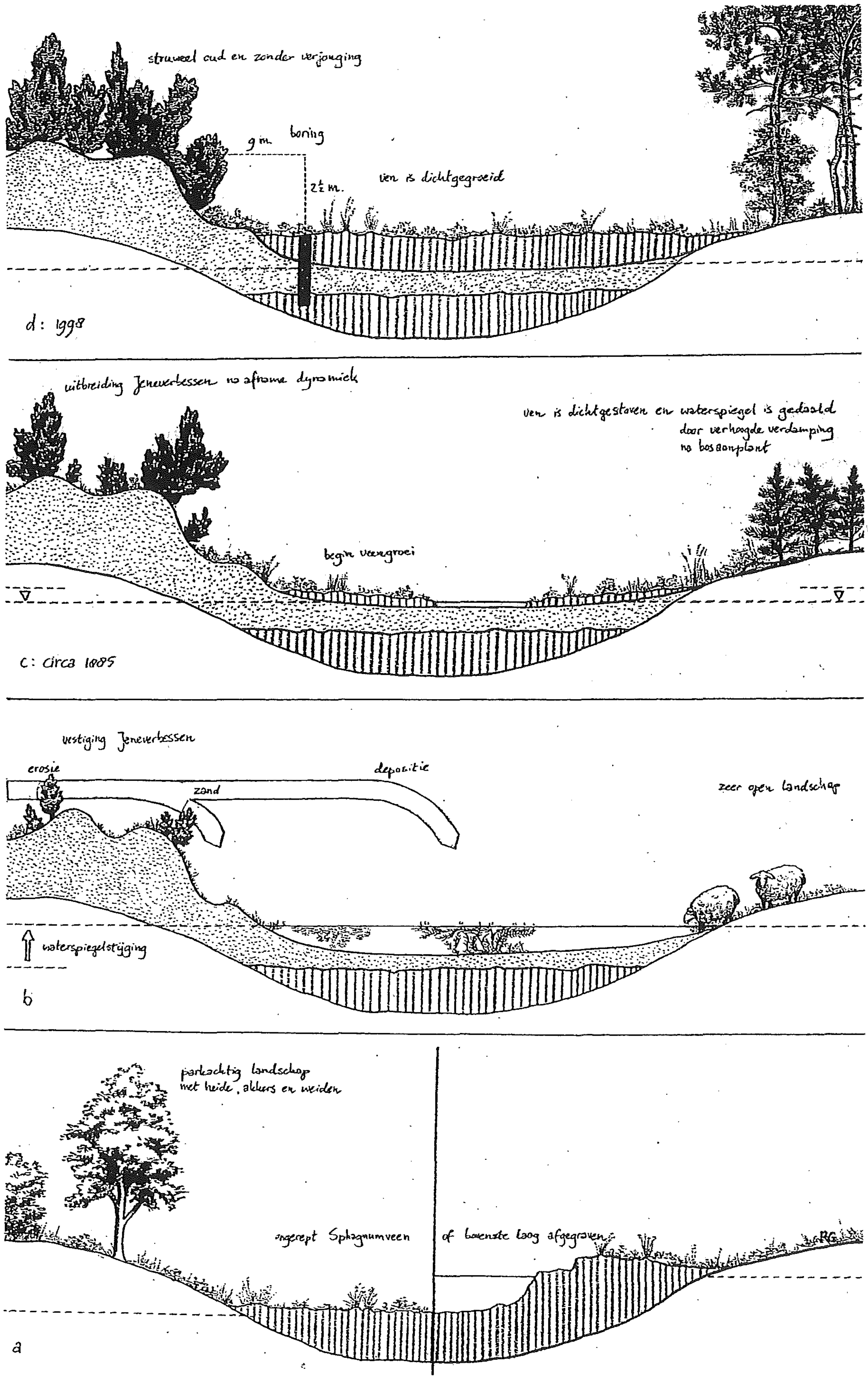
Fig. 18



Diagrams (partly) of Reigersplas, after Hopster & Greeve, 1999

Schematical reconstruction of stages in the development of the Reigersplas area (after Hopster & Greeve, 1999)

(try your Dutch or ask a Dutch colleague in case translation is a problem)



The paleo-record of the site 'Borchert' near Denekamp (Twente) and new details about the Younger Dryas/early Holocene transition

In November 1972 Thomas van der Hammen and Bas van Geel took a sample series at a rescue excavation (new housing development at the site 'De Borchert') in the municipality of Denekamp. A Roman Iron Age settlement was situated next to a narrow valley which was of Lateglacial origin. During the Iron Age the valley had been completely filled up with sandy sediments (including pottery fragments and charcoal) as a consequence of erosion by the farmers and their animal husbandry. Below those sandy sediments a Younger Dryas (minerogenic) to middle Holocene (peat) sequence was present. The preservation of the material was excellent and the complete core was studied (van Geel, Bohncke and Dee, 1981). On the next two pages the pollen diagram of the Borchert is shown. In another illustration a selection of taxa associated with the 'Verlandung' is shown.

The deepest samples of the Borchert sequence (upper part of Younger Dryas) still show pollen spectra of an open, sub-arctic landscape. As usual, the start of the Preboreal (Friesland Phase) is characterised by a sharp increase of the *Betula* pollen curve. But during the Preboreal there is a temporary decline (Rammelbeek-phase) of *Betula* and especially the pollen curve of grasses shows a sharp peak. In earlier publications such an increase of herbaceous pollen types, at the cost of *Betula*, had been interpreted as a very last cold phase ("Youngest Dryas", sensu Behre, 1978) of the last ice age. However, based on the presence of thermophilous taxa (*Nymphaea*, *Ceratophyllum*, *Typha latifolia*, *Mougeotia*), we concluded that a decline of the summer temperature could not have caused the changes in the pollen record which characterise the Rammelbeek Phase. Dryness or a temporary increase of the population of large herbivores seem to be more probable explanations.

In 1996 Friederike Wagner (Palaeobotany and Palynology, Utrecht University) presented a paper for the Dutch palynologists. She showed how birches react on changing atmospheric CO_2-levels by the formation of more, or less stomata in their leaves (for more details, see the Brabant part of this excursion guide, or see Wagner, 1999). p. 38,39 At the end of her presentation Wagner asked the audience about any studied cores where *Betula* leaves were still available. In Amsterdam we still had kept the Borchert material, so the decision was made to search the *Betula* leaf record at the Younger Dryas/Early Holocene transition. The results are fascinating: there is strong evidence for a sharp rise of CO_2 (to > 300 ppm!) where the pollen diagram shows the transition from YD to Early Holocene (see the following pages showing a copy of our publication in Science). p. 65-67 The *Betula*-CO_2 record of the Borchert site is quite different from the measurements of CO_2-concentrations in Antarctic and Greenland ice cores, and the following questions emerge:

- Did the temperature at the end of the Last Ice Age rise because the greenhouse gas CO_2 increased?

- Or was it the temperature rise which caused the sharp rise of the atmospheric CO_2-level?

If the last idea is right, then new questions arise about the present climate:

- Is it possible that the increase of solar activity during the last few decades is responsible for the present temperature rise (compare Svensmark and Friis-Christensen, 1997) and could that be **not the consequence of, but the reason for** the rising CO_2-level in the atmosphere?

- Is it true that oceans release more CO_2 in de atmosphere as a consequence of rising temperatures??

Compare Nigel Calder's ideas in his publication (1999) "The Carbon Dioxide Thermometer and the Cause of Global Warming"; see also:
http://www.sussex.ac.uk/spru/papers/Therm/thermometer.html

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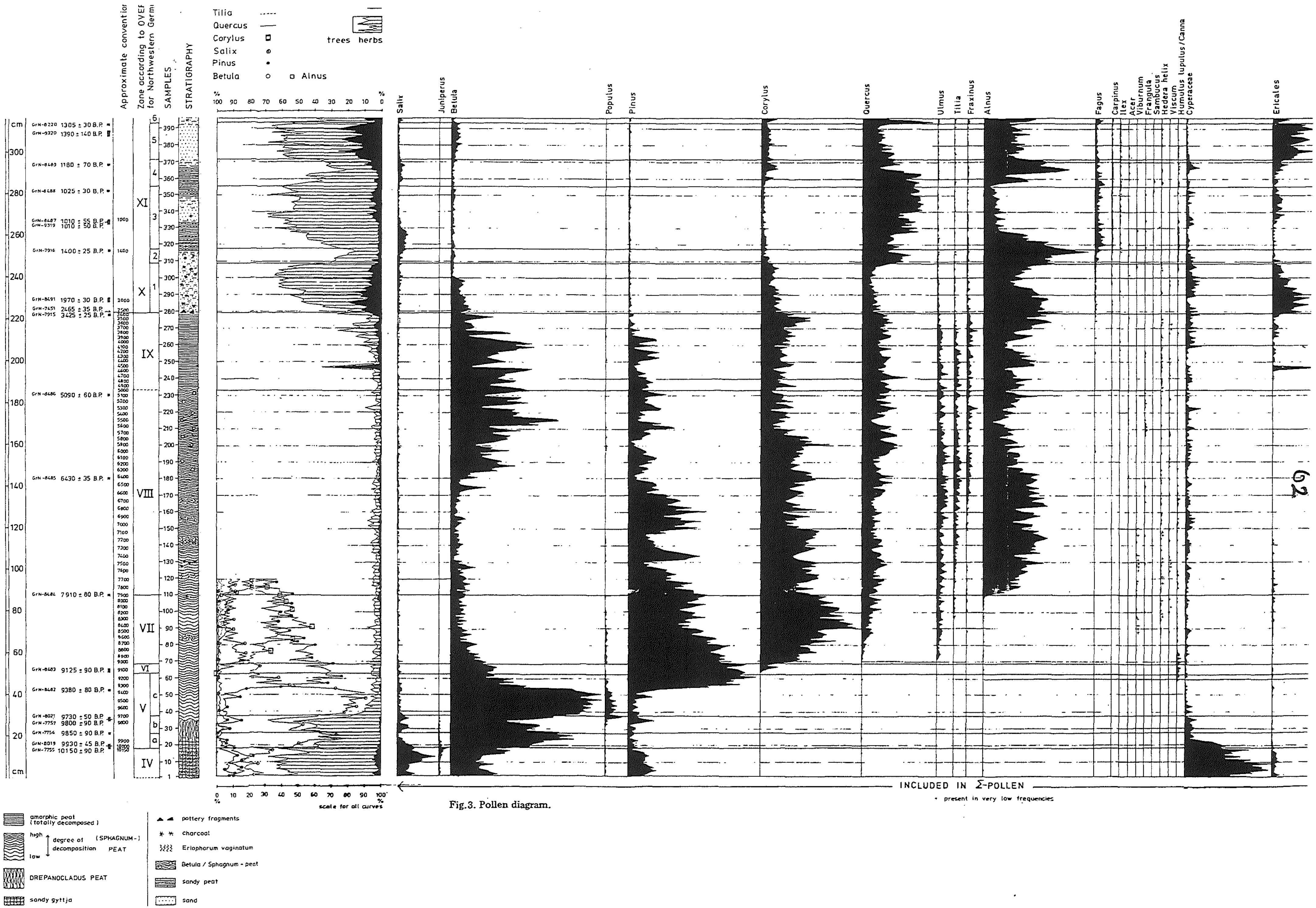
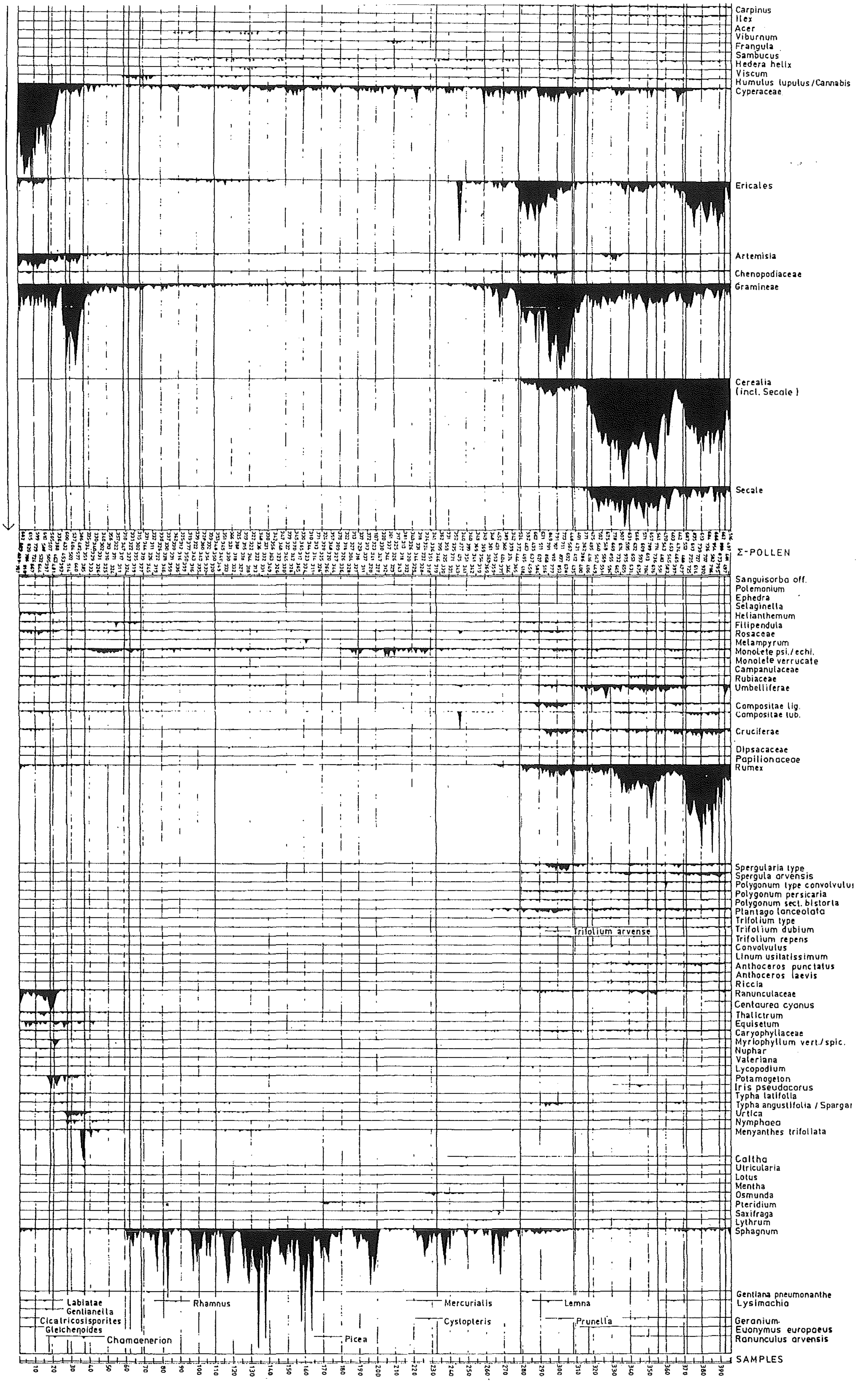


Fig.3. Pollen diagram.


Carpinus
Ilex
Acer
Viburnum
Frangula
Sambucus
Hedera helix
Viscum
Humulus lupulus/Cannabis
Cyperaceae
Ericales
Artemisia
Chenopodiaceae
Gramineae
Cerealia (incl. Secale)
Secale
Σ-POLLEN
Sanguisorba off.
Polemonium
Ephedra
Selaginella
Helianthemum
Filipendula
Rosaceae
Melampyrum
Monolete psi./echi.
Monolete verrucate
Campanulaceae
Rubiaceae
Umbelliferae
Compositae lig.
Compositae tub.
Cruciferae
Dipsacaceae
Papilionaceae
Rumex
Spergularia type
Spergula arvensis
Polygonum type convolvulus
Polygonum persicaria
Polygonum sect. bistorta
Plantago lanceolata
Trifolium type
Trifolium dubium
Trifolium arvense
Trifolium repens
Convolvulus
Linum usitatissimum
Anthoceros punctatus
Anthoceros laevis
Riccia
Ranunculaceae
Centaurea cyanus
Thalictrum
Equisetum
Caryophyllaceae
Myriophyllum vert./spic.
Nuphar
Valeriana
Lycopodium
Potamogeton
Iris pseudacorus
Typha latifolia
Typha angustifolia / Spargar
Urtica
Nymphaea
Menyanthes trifoliata
Caltha
Utricularia
Lotus
Mentha
Osmunda
Pteridium
Saxifraga
Lythrum
Sphagnum
Labiatae
Gentianella
Cicatricosisporites
Gleichenoides
Chamaenerion
Rhamnus
Picea
Mercurialis
Cystopteris
Lemna
Prunella
Gentiana pneumonanthe
Lysimachia
Geranium
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Ranunculus arvensis
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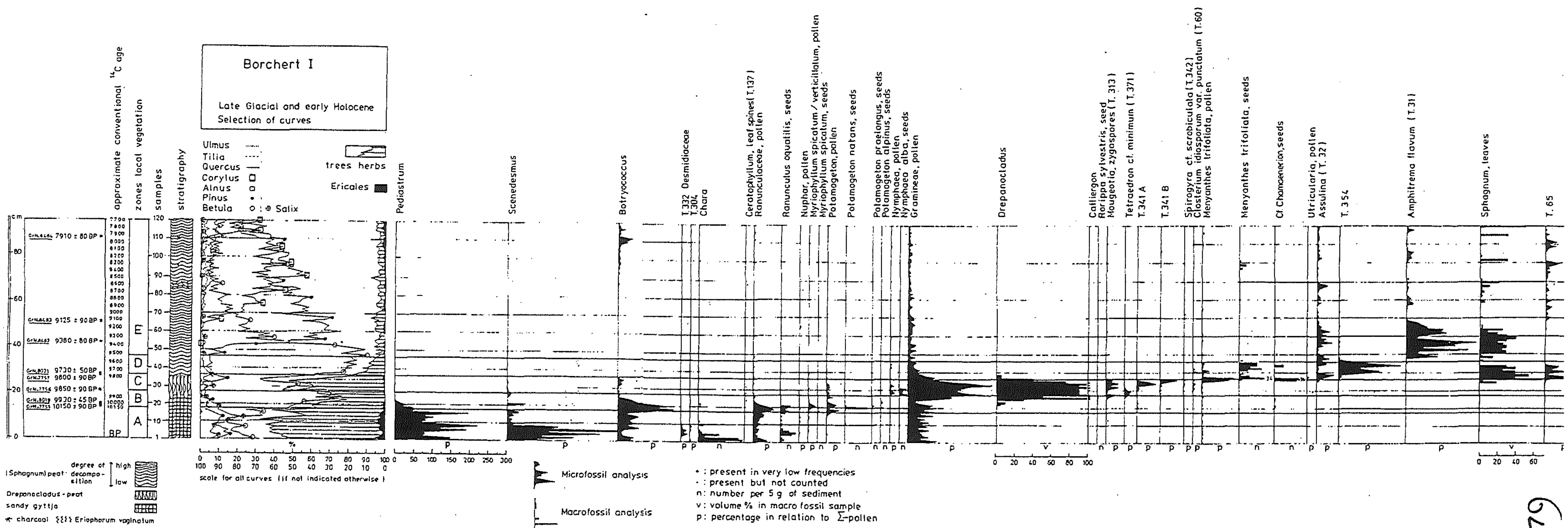

Fig.6. Selection of curves showing in a consecutive manner (from left to right) the taxa associated with the gradual filling-in of the depression during the Late Glacial and Early Holocene.

During the macrofossil analysis of the Borchert sequence it appeared that the high percentages of pollen of Gramineae which characterises the Rammelbeek-phase is not caused by a role of grasses in the strictly local succession. No fruits of grasses were encountered and no grass epidermis fragments were recorded. However, the maximum of grasses is synchronous with a special phase in the local succession: *Drepanocladus*-peat with various spore type of Zygnemataceae. In other words: the open water is filled in with vegetation. The process of 'Verlandung' may have been accelerated by temporary climatic dryness (grass maximum). At the end of the Rammelbeek-phase *Sphagna* take over the local vegetation succession.

Century-Scale Shifts in Early Holocene Atmospheric CO_2 Concentration

Friederike Wagner,[1] Sjoerd J. P. Bohncke,[2] David L. Dilcher,[3] Wolfram M. Kürschner,[1] Bas van Geel,[4] Henk Visscher[1]

The inverse relation between atmospheric carbon dioxide concentration and stomatal frequency in tree leaves provides an accurate method for detecting and quantifying century-scale carbon dioxide fluctuations. Stomatal frequency signatures of fossil birch leaves reflect an abrupt carbon dioxide increase at the beginning of the Holocene. A succeeding carbon dioxide decline matches the Preboreal Oscillation, a 150-year cooling pulse that occurred about 300 years after the onset of the Holocene. In contrast to conventional ice core estimates of 270 to 280 parts per million by volume (ppmv), the stomatal frequency signal suggests that early Holocene carbon dioxide concentrations were well above 300 ppmv.

The records of the relation of greenhouse gases to Quaternary climate change come largely from ice cores from Antarctica and Greenland. Trends in the atmospheric CO_2 amount parallel those of the temperature inferred from the isotopic compositions of oxygen ($\delta^{18}O$) and hydrogen (δD) during the past 250,000 years, showing that variation in greenhouse gas concentrations is an important factor in long-term glacial-interglacial climate evolution (*1*). Carbon dioxide data from ice cores also seem to correlate with millennial-scale temperature changes (*2*). However, a correlation of atmospheric CO_2 amounts to century-scale climate shifts in the Holocene (*3, 4*) is still unclear. Most of the Holocene ice core records from Antarctica do not have adequate temporal resolution (*5*). In Greenland ice, the Holocene CO_2 concentrations are generally considered to be influenced by postdepositional enrichment (*6*). Because of the apparent inadequacies and controversies in the CO_2 records derived from ice sheets, alternative methods have to be developed to improve the accuracy of detecting and quantifying possible short-term shifts in the Holocene atmospheric CO_2 regime. Here, we provide a century-scale record of early Holocene atmospheric CO_2 amounts, based on a stomatal frequency analysis of leaves that were buried in peat deposits.

An analysis of herbarium material collected over the past 200 years and controlled growth experiments under preindustrial CO_2 amounts (*7, 8*) has shown that, for Northern Hemisphere tree species, stomatal frequency decreases linearly as atmospheric CO_2 concentration increases. A near-annual analysis of a 40-year record of the buried leaves of a solitary growing birch (*Betula pendula*) has illustrated that deciduous trees are equipped with a plastic phenotype, capable of a lifetime adjustment of stomatal frequency to an increase in anthropogenic CO_2 (*9*).

Stomatal frequency is conventionally expressed in terms of stomatal density and stomatal index (SI) (*10*). In contrast to stomatal density, SI expresses frequency changes independently of variation in epidermal cell size and therefore is the more sensitive parameter for detecting stomatal frequency response to changes in CO_2 concentration (*11*). The effects of intrinsic variation in SI values within and among leaves of an individual tree species (*11, 12*) can be accounted for analytically, allowing the replication of temporal trends of mean SI values (*9, 13*). At least for European tree birches (*B. pendula* and *B. pubescens*), field studies and controlled-envi-

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ronment experiments show that CO_2-induced trends in mean SI values are not substantially disturbed by influences of environmental factors such as light, temperature, and nutrient supply (*14*). Calibrated against the Mauna Loa record of CO_2 increase (*15*), mean SI values for individual tree species may be empirically modeled as a function of changing atmospheric CO_2 concentrations (*16*). Response curves can be efficiently applied in the quantification of time-series data on stomatal frequency derived from fossil leaves of extant tree species. Long-term stomatal frequency changes in fossil leaves correlate with general glacial-interglacial CO_2 dynamics (*17*) and have been used to estimate atmospheric CO_2 concentrations in the late Miocene, Pliocene, and early Pleistocene (*8*).

We studied leaf material from a peat section that was temporarily exposed at the Borchert archaeological site near Denekamp, northeastern Netherlands (*18*). The sequence covers part of the Late Glacial (Younger Dryas) and the Holocene. We collected leaves of European tree birches (*B. pendula* and *B. pubescens*) from 16 horizons of the early Holocene (Preboreal) part of the section. Regionally, the Preboreal is subdivided into the Friesland phase, the Rammelbeek phase, and the Late Preboreal (Fig. 1A). Characterized by the spread of tree birches, the Friesland phase marks the rapid expansion of woodland at the beginning of the Holocene. Six ^{14}C dates suggest an average sampling resolution of 40 to 50 years.

Leaves of *B. pendula* and *B. pubescens* display essentially similar SI patterns (*16*). In stomatal frequency analysis, therefore, the mixed fossil assemblage of leaves of tree birches from the Borchert section can be treated as a single category (Fig. 1A). We used the rate of historical CO_2 responsiveness of tree birches (Fig. 2) to derive a Preboreal atmospheric CO_2 record based on the mean SI values for the fossil leaf remains. In the Friesland phase, inferred CO_2 concentrations of 265 ± 21 and 260 ± 25 parts per million by volume (ppmv) are followed by a rapid rise to 327 ± 10 ppmv and a more gradual increase to a maximum of 336 ± 8 ppmv in the early part of the Late Preboreal. Then, there is a continuous CO_2 decline to a minimum of 301 ± 21 ppmv, followed by a sharp increase to 348 ± 14 ppmv. In the uppermost part of the studied interval, CO_2 concentrations stabilize again to values between 333 ± 8 and 347 ± 11 ppmv.

The initial decrease of the SI in the Friesland phase suggests that atmospheric CO_2 concentrations rose by ~65 ppmv in less than a century. The CO_2 increase occurred during prominent environmental changes, which are reflected in the lithology and the palynological record (*18*). Basal gyttja formation is followed by a rapid hydroseral succession at the formerly open water site at this time. Regional woodland expansion is reflected by an increase in *Betula* pollen and the occurrence of *Betula* macrofossils. Both the CO_2 increase and the environmental changes at this site correlate with the global climate amelioration at the beginning of the Holocene.

Because of the lack of leaf material from the lowermost part of the section, the onset of the CO_2 rise could not be exactly determined. Yet, the general timing of the rise is in agreement with the CO_2 record from the Antarctic Byrd ice core (*19*), where the Younger Dryas–Holocene transition is defined by a sudden CO_2 increase from 260 to 280 ppmv. In our SI-based reconstruction, the magnitude of the rise is higher, resulting in CO_2 concentrations well above 300 ppmv. There is a clear covariation (Fig. 1B) between the reconstructed CO_2 increase and the rapid positive $\delta^{18}O$ shift that

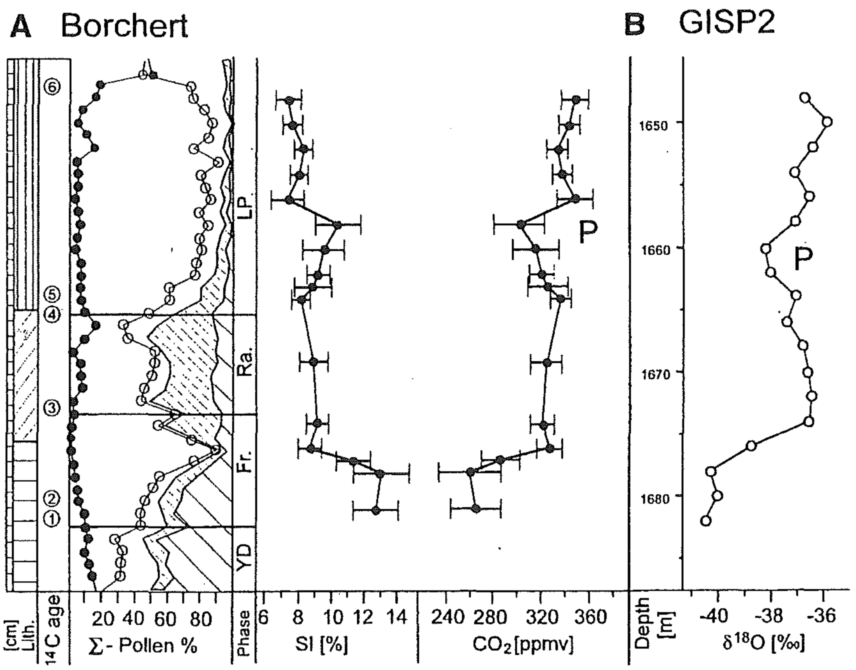

Fig. 1. **(A)** Mean SI values (±1σ) for *B. pendula* and *B. pubescens* from the early Holocene part of the Borchert section (Netherlands; 52.23°N, 7.00°E) and reconstructed CO_2 concentrations. The scale of the section is in centimeters. Three lithological (Lith.) units can be recognized (*18*): a basal gyttja (=), succeeded by *Drepanocladus* peat (//), which is subsequently overlain by *Sphagnum* peat (||). Six conventional ^{14}C dates (in years before the present) are available (indicated by circled numbers): 1, 10,070 ± 90; 2, 9930 ± 45; 3, 9685 ± 90; 4, 9770 ± 90; 5, 9730 ± 50; and 6, 9380 ± 80. Summary pollen diagram includes arboreal pollen (white area) with *Pinus* (●) and with *Betula* (○) and nonarboreal pollen with Gramineae (\\\) and with Cyperaceae, upland herbs, and Ericales (\ \). Regional climatic phases after (*18*): YD, Younger Dryas; Fr., Friesland phase; Ra., Rammelbeek phase; and LP, Late Preboreal. For analytical method, see (*13*). Quantification of CO_2 concentrations according to the rate of historical CO_2 responsiveness of European tree birches (Fig. 2). P indicates the reconstructed position of the Preboreal Oscillation. **(B)** $\delta^{18}O$ profile for the Younger Dryas–Holocene transition in the Greenland GISP2 ice core, after (*20*); P denotes the $\delta^{18}O$-inferred cooling of the Preboreal Oscillation, starting at ~11,300 calendar years before the present (*3*).

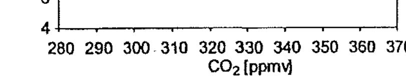

Fig. 2. Relation of mean SI for *B. pendula* (○) and *B. pubescens* (●) to the global atmospheric CO_2 increase in the period from 1896 to 1998. The historical training set for the European tree birches consists of 105 samples, originating from presently accumulating peat (*9*) supplemented by herbarium and field material. For analytical method, see (*13*). Mean historical CO_2 concentrations are derived from Mauna Loa monitoring (*15*) and Antarctic shallow ice core data (*24*). Mean SI values show a linear decrease from 11% at 290 ppmv to 6.4% at 360 ppmv CO_2 [n = 105; slope = −0.065; goodness-of-fit linear model: R^2 = 0.78, R^2_{adj} = 0.78; analysis of variance results $F(1, 103)$ = 384.97 (P < 0.000); statistics performed with SPSS 7.5 for Windows (Statistical Product and Service Solutions, Chicago, Illinois)].

characterizes the onset of Holocene warming in high-resolution isotope records from Greenland ice (*20*).

About three centuries after the initiation of Holocene warming, a $\delta^{18}O$ minimum in Greenland ice reflects a short cooling event (Fig. 1B). A 150-year climate deterioration has also been deduced from numerous terrestrial and marine biorecords (*21*). Although exact dating of the non–ice core records is hampered by the occurrence of ^{14}C-age plateaus during the early Holocene, multiproxy analysis suggests that all reported events collectively reflect the Preboreal Oscillation (*3*). In the Borchert section, the reconstructed CO_2 values drop from ~340 to ~300 ppmv at this time (Fig. 1A). A relation between CO_2 dynamics and the Preboreal Oscillation had been suspected on the basis of an abrupt rise in the early Holocene $\Delta^{14}C$ curve inferred from German pine dendrochronology (*3, 22*), but this could not be confirmed by ice core data.

Our results falsify the concept of relatively stabilized Holocene CO_2 concentrations of 270 to 280 ppmv until the industrial revolution. SI-based CO_2 reconstructions may even suggest that, during the early Holocene, atmospheric CO_2 concentrations that were >300 ppmv could have been the rule rather than the exception (*23*).

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25. We thank B. Aaby, R. Below, and P. J. C. Kuiper for stimulating discussions and for constructive comments on the topic. Supported by the Deutsche Forschungsgemeinschaft (DFG) and the Council for Earth and Life Sciences (ALW) of the Netherlands Organization for Scientific Research (NWO). This is contribution 990501 from the Netherlands Research School of Sedimentary Geology and contribution 510 from the University of Florida Contributions to Paleobiology.

5 March 1999; accepted 17 May 1999

Friday 3 September:
On our way from the hotel in Delden to Groningen we will make a stop for a bog-excursion in the south-eastern part of the province of Drenthe. There we will see how successful the raised bog ecosystem in the **Bargerveen nature reserve** was "resuscitated" by Staatsbosbeheer*. Before the exploitation of raised bog deposits, the Bargerveen area formed part of the Boertangerveen which was an enormous raised bog complex in the border area between Germany and the provinces of Drenthe and Groningen (Casparie, 1969, 1972). Nowadays the Bargerveen is only a relict of the raised bog ecosystems in the northern Netherlands. More than 15 *Sphagnum* species have been identified. Other plants that occur in this nature reserve are *Oxycoccus palustris, Andromeda polifolia, Erica tetralix, Empetrum nigrum, Calluna vulgaris, Eriophorum vaginatum, E. angustifolium, Narthecium ossifragum, Rhynchspora alba, Drosera rotundifolia, D. intermedia,* and *D. anglica.*
Some interesting occurrences from a zoological point of view: more than 30 dragon-fly species and butterflies, Adder (*Vipera berus*), Slow-worm (*Anguis fragilis*), Common Lizard (*Lacerta vivipara*) ; more than 220 bird species, among which Bluethroat (Blaukehlchen, *Cyanosylvia svecica*), Red-backed Shrike (Neuntöter, *Lanius collurio*) and Nightjar (Ziegenmelker, *Caprimulgus europaeus*).

In the remaining bog areas of the Pleistocene part of the Netherlands the original upper peat layers are always missing. The reason is that active burning and drainage of the bog surface was practised by poor people who cultivated *Fagopyrum* on the bog. And often the upper peat layers were removed for fuel. In the bog-'resuscitation'-activities the emphasis is on keeping the rainwater inside the nature reserve, so that *Sphagnum* species can settle again (and form an acrotelm). This was realised by making (peat)dikes around suitable areas. A well-developed acrotelm is responsible for a stable water table and a number of self-regulating mechanisms play a role:
- absorbtion of water by the *Sphagna*; this water is available during dry periods.
- a reduction of evaporation because under dry conditions the upper *Sphagnum* layer temporarily dries out and gets a white colour (empty hyaline cells) reflecting sun light.
- The bog surface rises during wet periods, whereas during dry periods the surface sinks somewhat. In that way the changing water table hardly fluctuates for the bog plants.

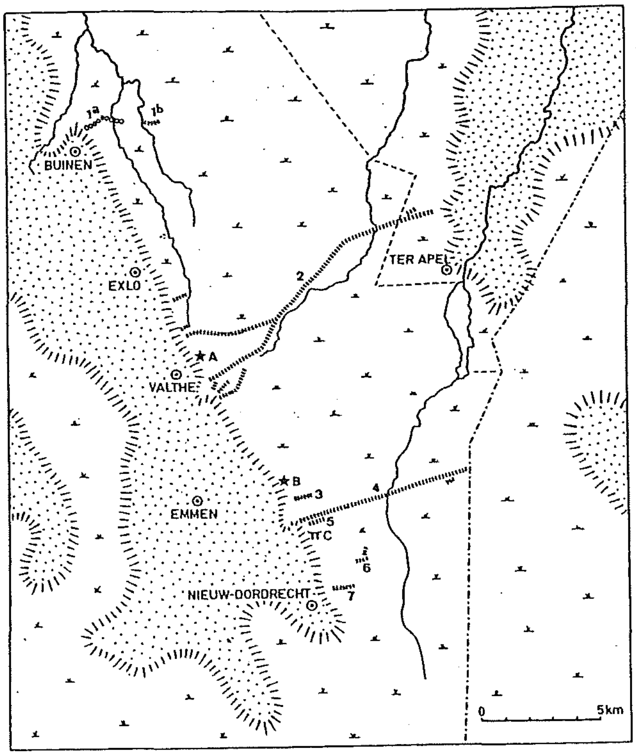
A living bog vegetation is able to keep enough rainwater, so that the water table rarely is lower than 30-40 cm below the vegetation surface. This is in sharp contrast with sites where old, decomposed peat deposits are at the surface: there the capacity to keep the rainwater is low. In such areas there are strongly fluctuating water tables, and during summers the water table may even be 70-80 cm below the surface. Evaporation is strong, especially when rooting plants like *Molinia caerulea* and *Betula* are present. *Sphagna* can hardly settle under such conditions of sharply fluctuating water tables.
For two different situations there are two strategies to get raised bog growth started again (Spieksma, 1999). Dikes - indeed we are in The Netherlands - play a crucial role in both cases:
- <u>Wetting the bare peaty surface</u>, so that the water table fluctuates between -30 and +10 cm.
- <u>Creating floating mats</u>: often the highly humified 'Older Sphagnum peat' was removed by the peat diggers, whereas the 'Younger Sphagnum peat' (mainly *S. imbricatum* and *S.papillosum*; bad quality as fuel) was thrown back in the pit. In such situations, when recently the water table was artificially brought up (< 50 cm above peat surface), the sods of 'Younger Sphagnum peat' together with new *S. cuspidatum*, started to form a floating mat. The role of CO_2 in the water is very important: high levels of CO_2 stimulate photosynthesis, and thus growth of *S. cuspidatum.* The escaping oxygen bubbles (product of photosynthesis) give buoyancy to the mat.

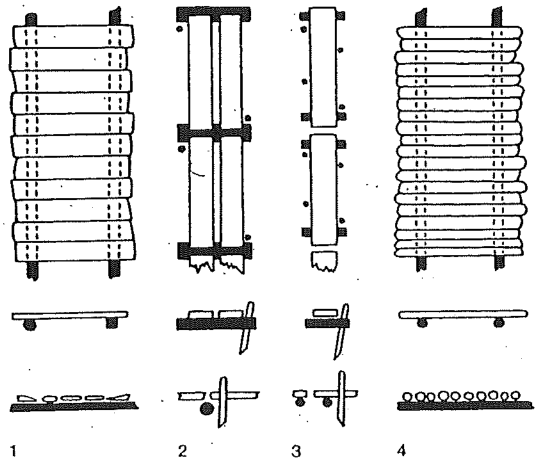
In some peat profiles of the Bargerveen we will see the shift (dark/light; also shift in *Sphagnum* species) at the transition of the Subboreal to the Subatlantic period and we will discuss the advantages of **14C-wiggle matching** and **'paleo-evidence for solar forcing of climate change'** as the cause behind this shift in bog development around 850 cal BC (see separate copies of papers by Kilian et al. (1995) by van Geel and Renssen (1998) and by van Geel et al. (1998).

* Staatsbosbeheer (State Forestry Service) is one of the organisations responsible for nature reserves. It was funded in 1899 as an organisation to start forest plantations in drift sand areas (over-exploited heathlands) and to produce wood, necessary for the coal mines in the province of Limburg (S-Netherlands).

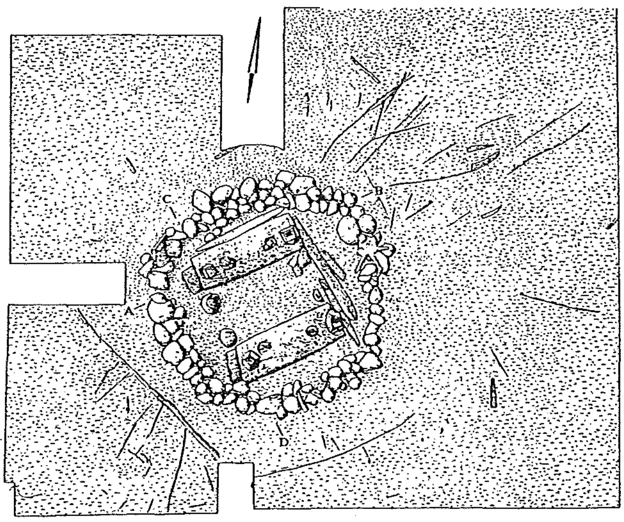
Raised bog complexes as natural barriers and wooden trackways to cross these

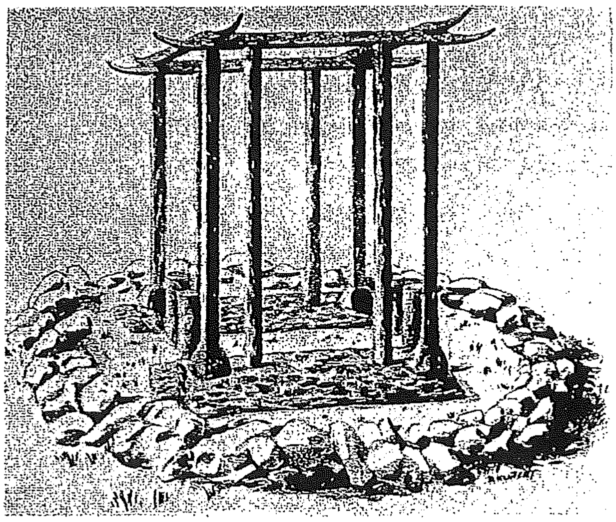
In SE-Drenthe several wooden trackways have been discovered, especially during the period of intense peat digging. Some of these clearly had been made to cross raised bogs, but some other trackways just ended in the middle of the bog.

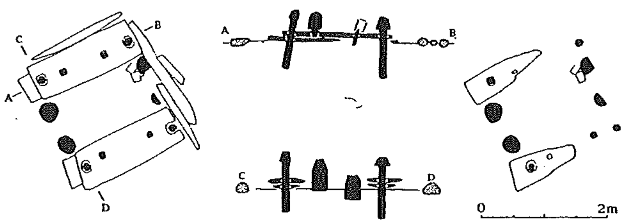


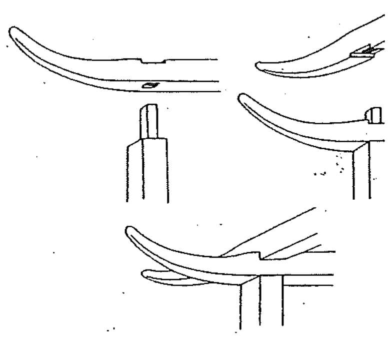


Near Bargeroosterveld a Middle Bronze Age cult construction ('temple') was recovered (Waterbolk and van Zeist, 1961).







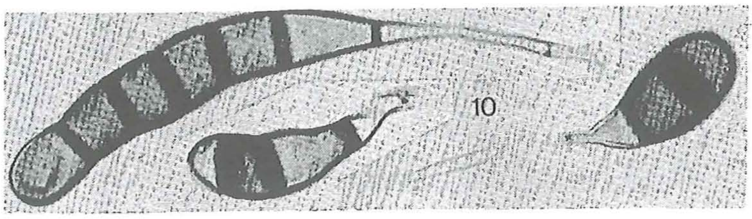


Microfossil 'Types' (fungal, algal, zoological and unknown remains)

From 1968 on, the bog research in Amsterdam had a 'fine resolution' character, which was strongly stimulated by the leader of the group (Thomas van der Hammen). Sample distances were short (often every cm; 'Lupendiagramme') and all fossils showing a characteristic morphology were recorded, described, illustrated, and ecological indicator values were explored. Some of the newly distinguished fossils appeared to be very useful paleo-environmental indicators.
It is impossible to give a complete overview. BvG hopes to make progress with his 'atlas of non-pollen palynomorphs' (as soon as there is no longer such interesting work to do in the field of solar forcing of climate change).

Only two examples of useful fungal remains from raised bog deposits are given here. Both have a close relationship with *Calluna vulgaris*.

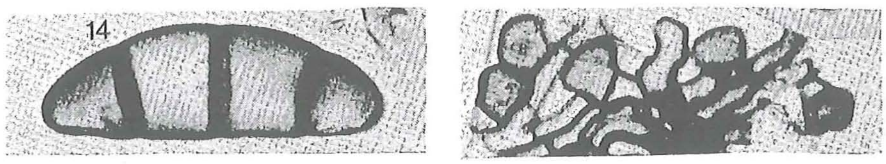
Type 10:



x 1000

In an early state of the raised bog research these spores appeared to be indicators for local dry conditions. During macrofossil analysis the observation was made that the spores are formed on mycelium which is in organic connection with rootlets of Ericales.
The next step was to study the living rootlets of the 5 species of Ericales which can occur in raised bogs (*Erica tetralix*, *Calluna vulgaris*, *Andromeda polifolia*, *Oxycoccus palustris* and *Empetrum nigrum*). The Type-10-fungus was observed on *Calluna* roots only.
Curve matching of Type 10 with the macrofossil record of Ericales in the raised bog core Engbertsdijksveen-I (see diagram on next page) also showed that there is a relation with *Calluna vulgaris*. It is highly probable that Type 10 plays a role as a mycorrhiza fungus.

Type 14:



x 1000

ascospore and mycelium of *Meliola niessleana*

Three-septate ascospores with a characteristic morphology were distinguished in an early stadium of our bog studies. A characteristic mycelium, originally recorded as Type 48, once was found in organic connection with a Type-14-ascospore (fossilised germinating spore). During the macrofossil analysis even the fungal fruit bodies of Type 14 were found. This was enough for a species identification: *Meliola niessleana*. Representatives of the genus *Meliola* are obligate and oligophagous parasites. Here also *Calluna* appeared to be the host plant. Fossil fruit-bodies and mycelium of *Meliola* were found, still in organic connection with *Calluna* stems and leaves. In the diagram on the following page the record of host and fungus are plotted next to each other.

What sort of information do these fossils bring us? Is it useful information?
During the analysis of a Late Eemian deposit from Twente (van Geel et al., 1995), the pollen curve of Ericales (mainly *Calluna*) showed relatively high values in the upper part of the core. The question was: is this the effect of the extension of heath land in the surroundings of the sample site or is it strictly local production of pollen of Ericales in a raised bog environment?
Macrofossil analysis showed that a local raised bog (with *Calluna vulgaris*) had developed.
But, even without macrofossil analysis we would have known that *Calluna* was of strictly local occurrence: Type 10 and also *Meliola niessleana* were present in the pollen slides of the levels showing high percentages of Ericales pollen.

See p. 72

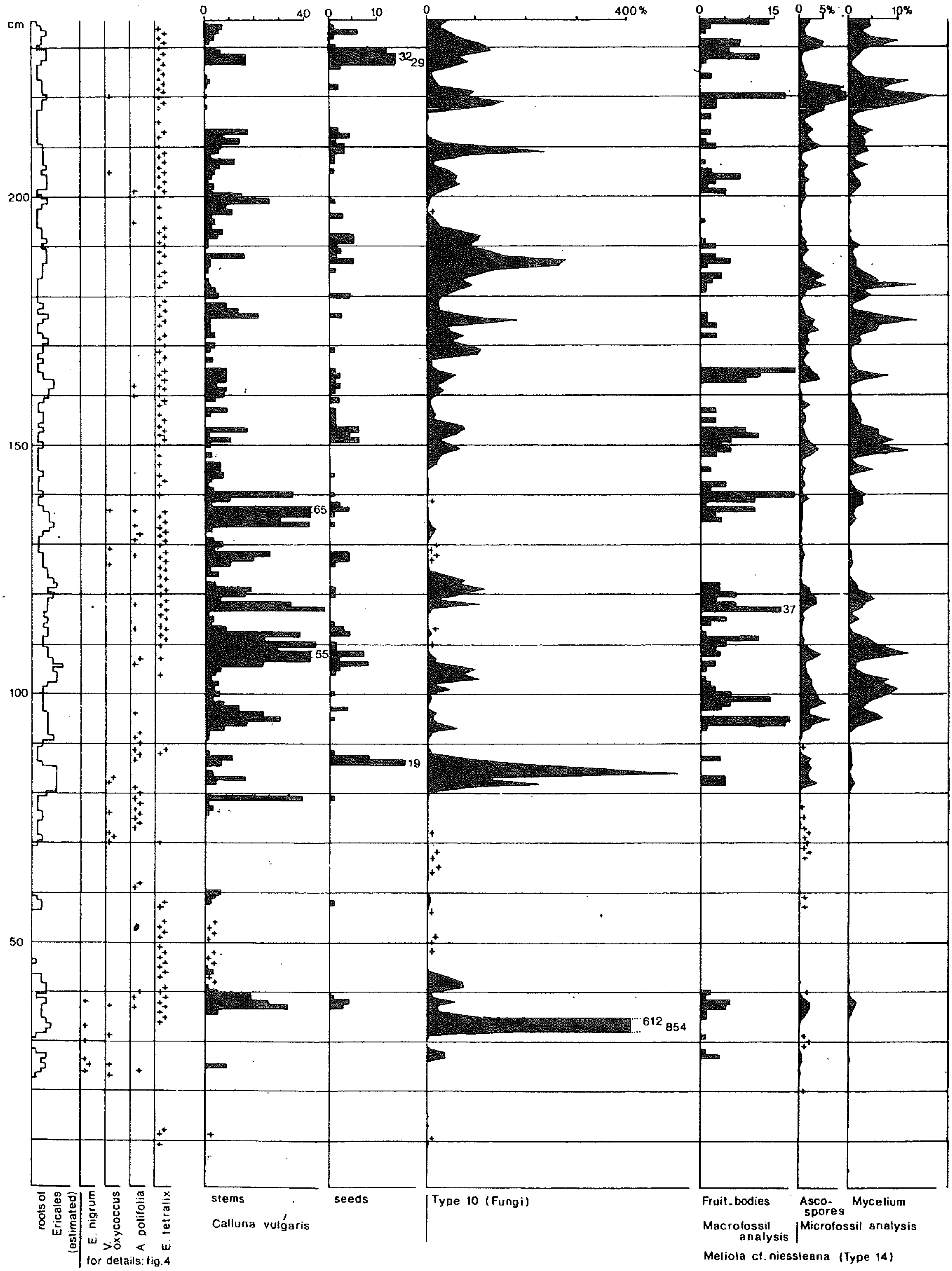
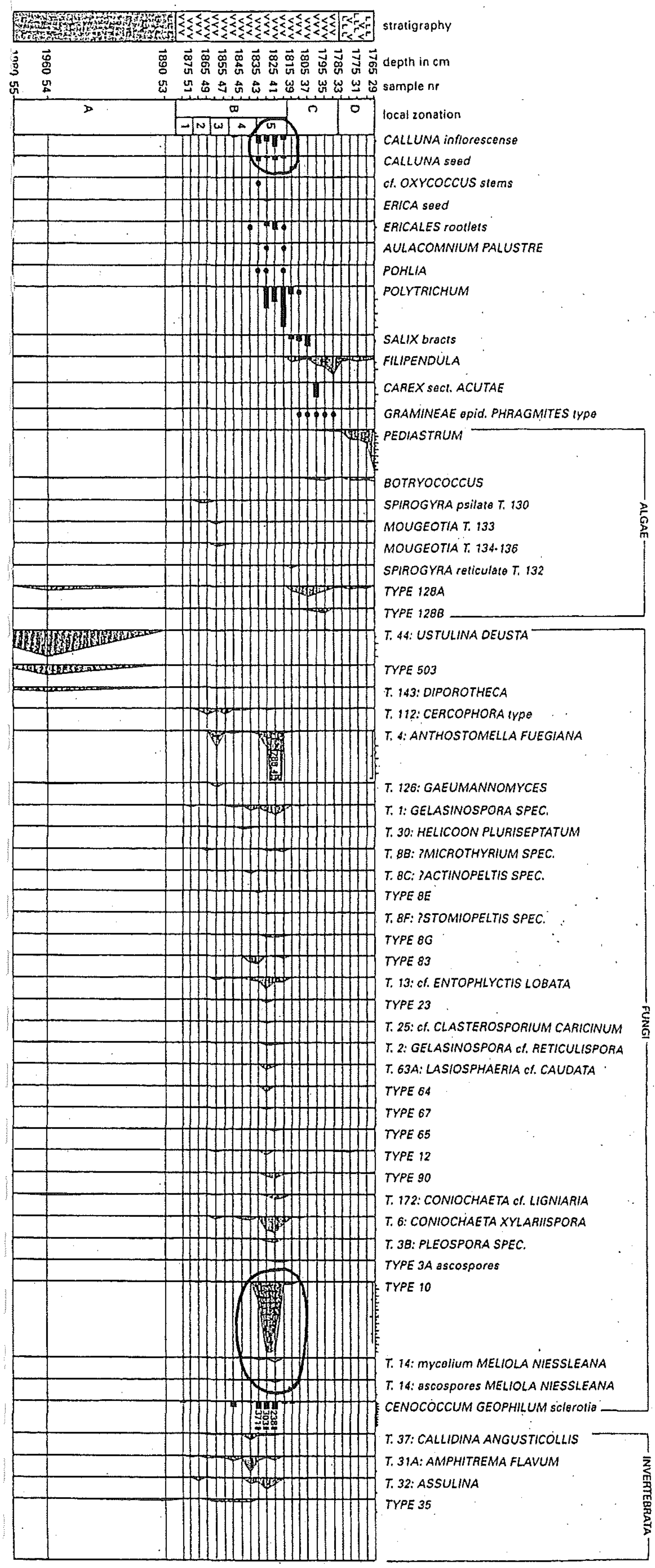


Diagram of *Calluna vulgaris* and associated fungi, Engbertsdijksveen I.

Noord-Deurningen

Samples 29 - 55 Micro- and macrofossils

Late Eemian

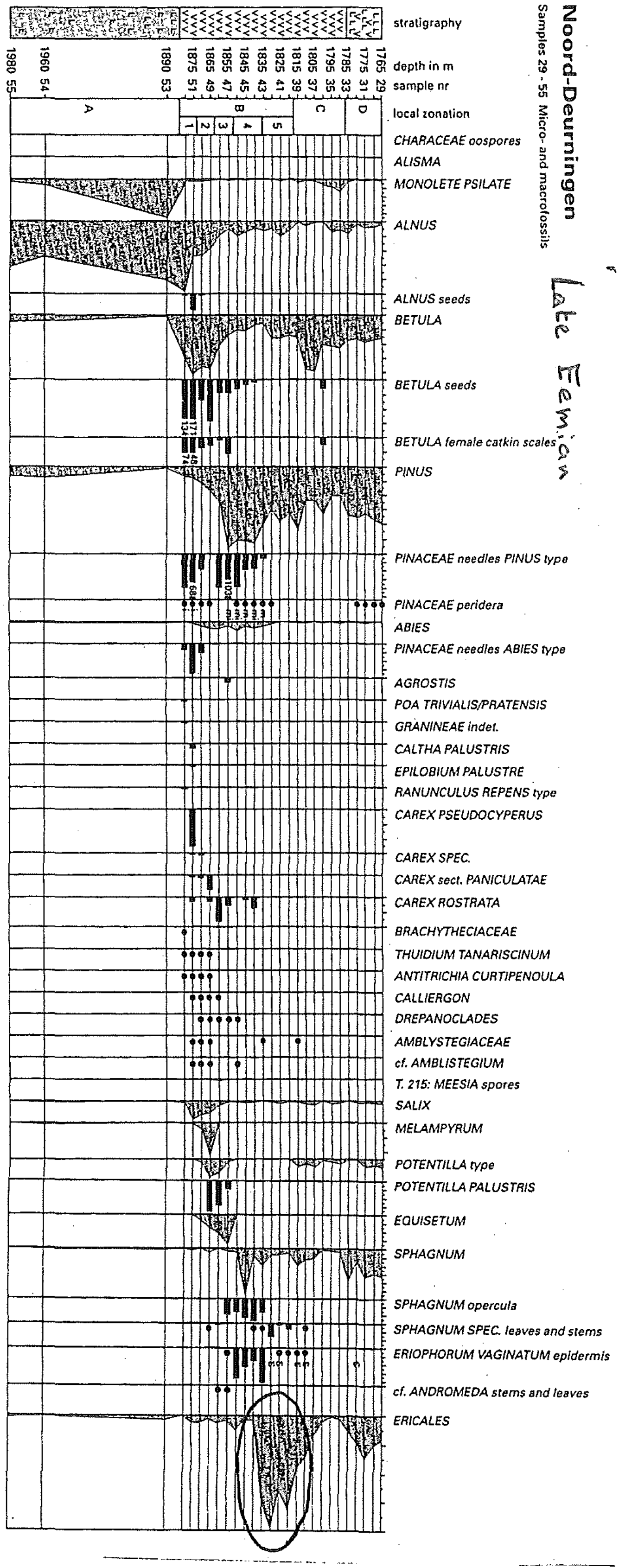


clay · peat · sand

0 10 20 30 40 50% Scale, unless otherwise indicated

microfossils (%) · macrofossils (number or volume %) · ● less than 1%

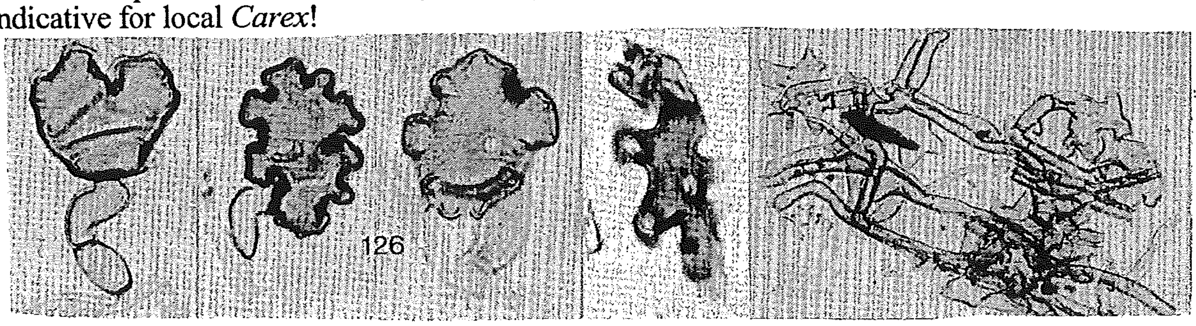
m: mycorrhizal roots · i: male cone · s: sclerenchymatic bodies

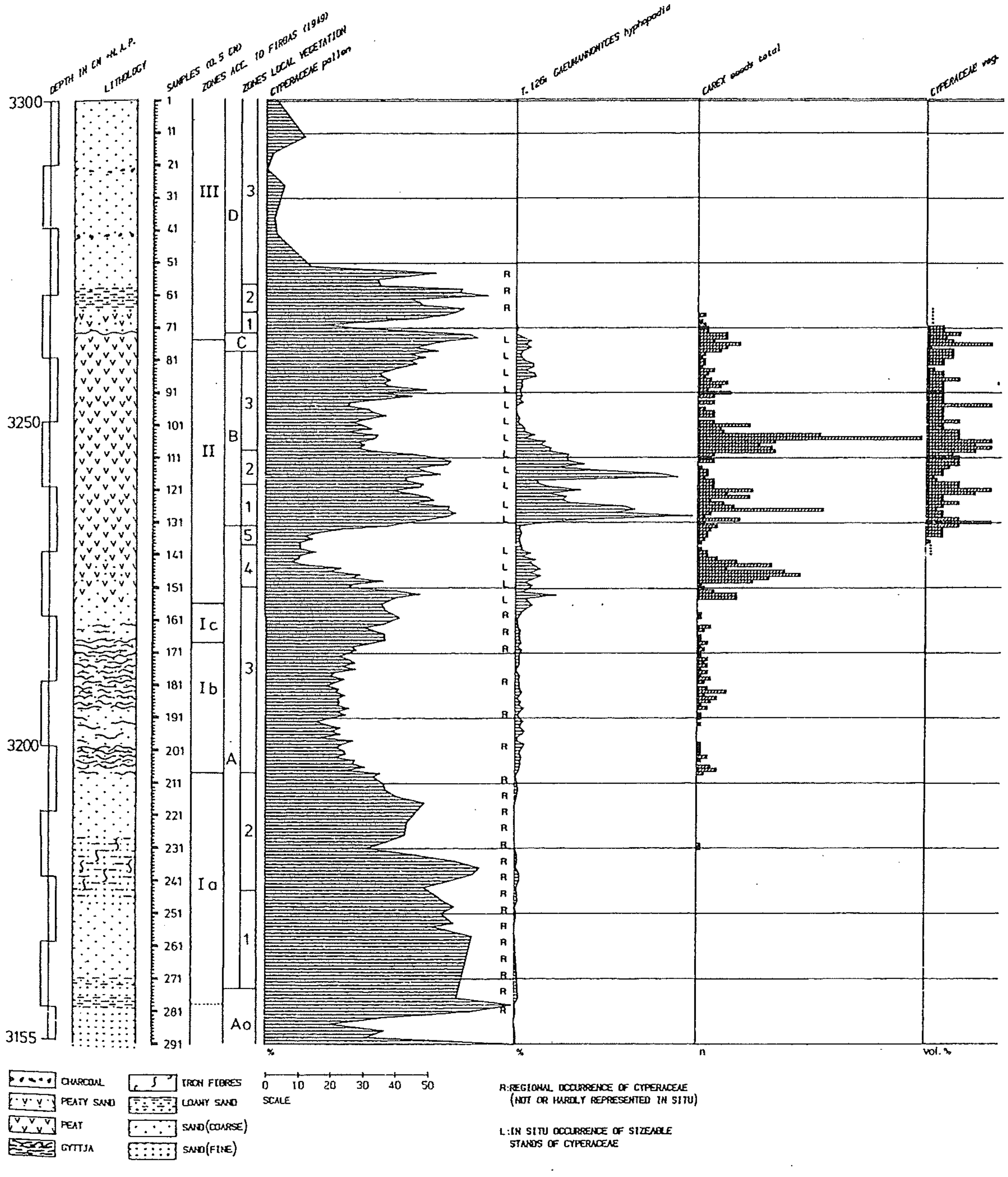


Gaeumannomyces: an indicator for local *Carex*

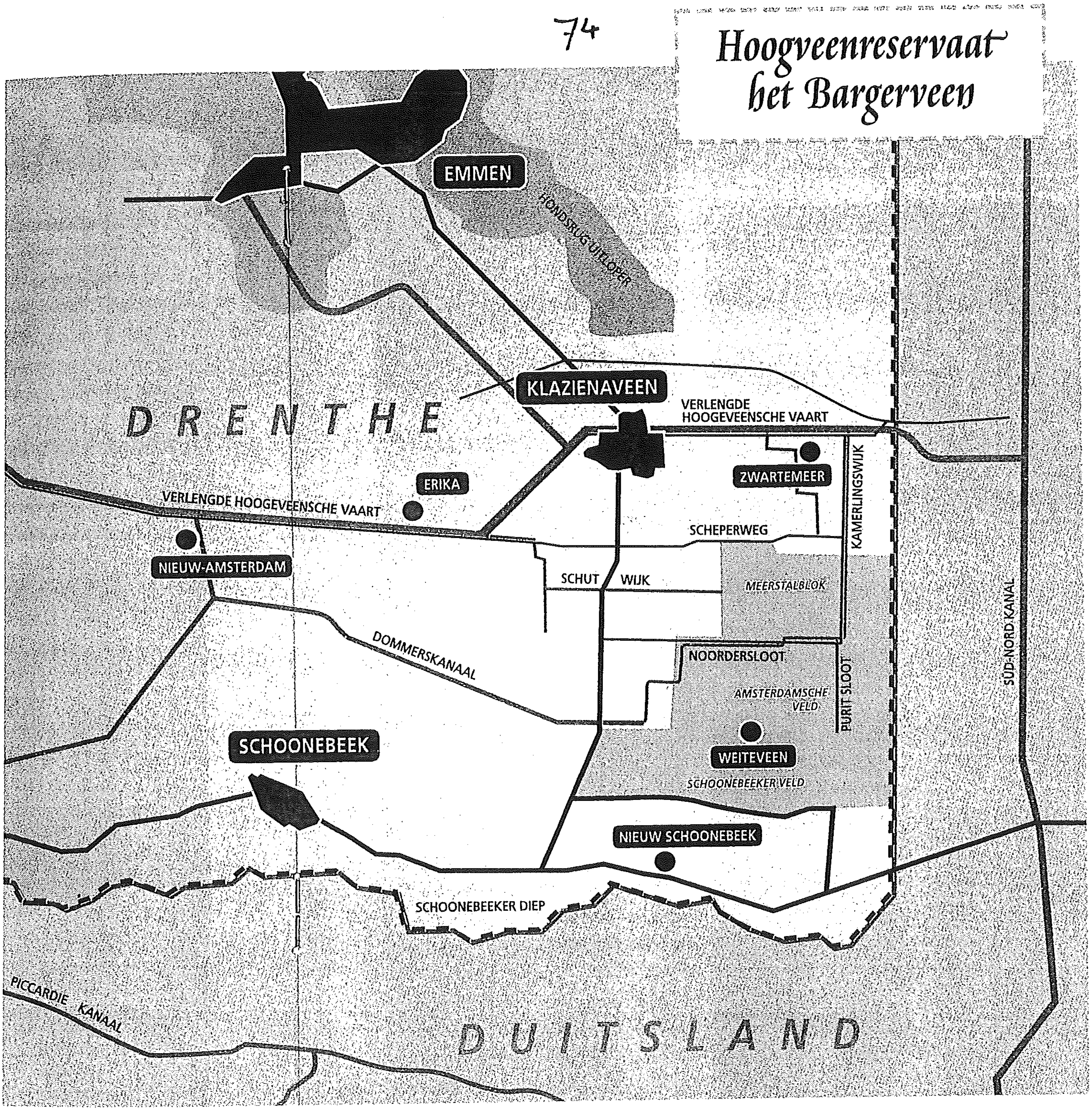
In wetlands under eutrophic to mesotrophic conditions often Cyperaceae play an important role in the peat-forming vegetation. The characteristic hyphopodia of the fungus *Gaeumannomyces* (originally recorded as an unknown Type 126) appeared to be indicative for local *Carex* species. This is not only the case in NW-Europe but also elsewhere in the world. In case no macrofossil analysis is worked out, *Gaeumannomyces* still shows us the levels with local sedges.

In the diagram below (Lateglacial site Usselo; van Geel *et al.*, 1989) we observe that Cyperaceae (*Carex*) were important in the regional vegetation of zones A1, A2, A3 (partly) and D1 and D2. The zones A4, A5 and B1-3 (peat deposit) show macrofossil evidence for strictly local *Carex*. The Carex-parasite *Gaeumannomyces* (expressed as percentage related to Σ-pollen) appears to be indicative for local *Carex*!





Frequency curve of hyphopodia of the fungus *Gaeumannomyces* next to the curves of pollen and vegetative remains of Cyperaceae and *Carex* fruits.



In the afternoon of Friday 3 September we arrive in **Hotel Weeva** in the centre of the town of Groningen. We will stay for four nights in this hotel.

NB: **After dinner** ('on your own'; not organised; there is a variety of restaurants in Groningen) we will come together near the front door of our hotel for a **visit** of the **Laboratory for Isotope Physics** (in northern part of Groningen town; we will travel by bus). Dr **Hans van der Plicht** will show us the lab with conventional radiocarbon equipment and **AMS** and he will tell us the last news about the **extension of the ^{14}C calibration curve (last ca 50,000 years!) based on AMS-dates of macrofossils from the laminated sediments of a lake in Japan**.

Saturday 4 September: optional excursion

Those of you who prefer to stay in Groningen city (for shopping, visiting the museum, extra sleep, etc.) will miss the opportunity to see, among others, the interesting sand dune and salt marsh vegetation types.

NB: early breakfast because we start to drive at 8.00 to arrive in time (9.00) for the ferry to the **Wadden-island Schiermonnikoog** (departure of the boat at 9.30).

We will park the buses on the parking place of Lauwersoog before entering the ferry. On Schiermonnikoog we will rent bikes, but alternatively you can make a walk. Be in time for the boat back to the mainland please. The boat does not wait and travelling back on your own is complicated.

Some remarks about the Waddenzee and the Wadden Zeedijk

(we will cross the Waddenzee on our way to the Frisian island of Schiermonnikoog)

The northern coast of the provinces of Groningen and Friesland is protected by a more than 165 km long dike. The shallow sea to the north of the dike is called Waddenzee. Nowadays the area with its gullies, mud flats and salt marshes is an important nature reserve, providing food to many birds during their yearly migrations. It is also an area used for recreation and, (a more serious problem) there are natural gas reserves. For many years there is a public discussion about starting to use these reserves. Up to now the vulnarability of the Wadden ecosystems was an argument to keep the oil and gas industry away from the Wadden area. But the discussion continues and the gas reserves under the mainland of the province of Groningen are diminishing .....

The oldest dikes in Groningen and Friesland date from the end of the 12th century and monks organised the building of these dikes. Later also farmers (=boeren) organised dike-building, because they could automatically become the owners of the new land (note the name "Zevenboerenpolder", which was created by seven farmers). In due course the main (most northern) dike has been heightened more than 9 meters above NAP (Dutch ordnance level). Older dikes, now not in function any more, had special entrances for roads crossing the dikes. These openings could be closed with wooden beams during floods. From 1930 on the State is responsible for maitenance and security.

Landscape aspects of a Wadden island

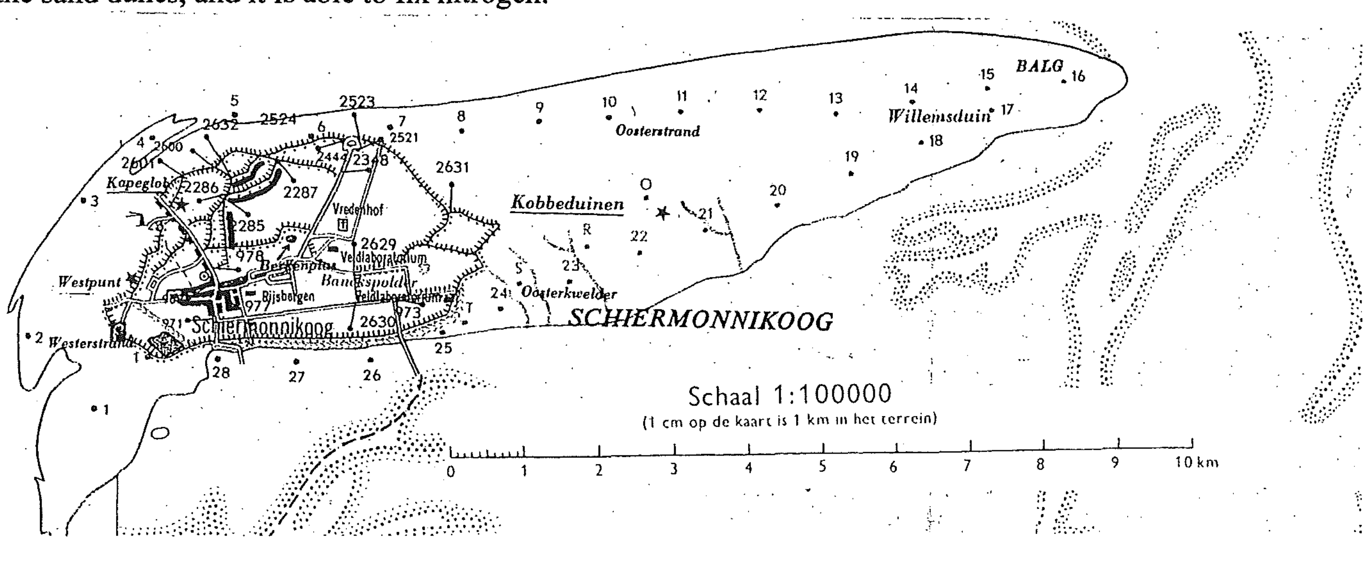
Apart from the cultural landscape (village with meadows) we will also see a semi-natural to natural situation (which is rare in The Netherlands):

- in the western and northern part of the isle: the beach and the characteristic vegetation of dunes and dune valleys .
- in the southern and eastern part: halophytic communities on the salt marshes, 'schorren' and 'slikken'. The different plant communities and the vegetation dynamics depend on local topography and thus mainly on inundation frequency and sedimentation.

Generally speaking erosion and accumulation are important geological processes for the Frisian Islands. There are three main factors: (1) The Gulfstream is responsible for a constant transport of sand along the coast. (2) The dominating western to nw-wind (eolian sand transport and dune formation). The grasses *Elymus farctus*, *Ammophila arenaria* and *Leymus arenarius* play an important role in primary dune formation.

(3) The presence of the Waddenzee as a quiet area of sedimentation so that mud is deposited at the southern coast of the islands.

Worth mentioning here is the abundant *Hippophae rhamnoides in* the lime-rich sand dunes. As paleoecologists we know this pioneer species from inland sites (far from the sea) directly after the temperature rise during the Lateglacial (early Bølling). It is its pioneer strategy that gives this species the advantage in the competition with other plants. It can stand the dynamic conditions of the sand dunes, and it is able to fix nitrogen.



Sunday 5 September:
Aspects of archaeology and cultural landscape in Northern Drenthe
(uplands of pleistocene boulder clay with cover sands, pingo remnants and brook valleys)

We will be guided by Professor Tjalling Waterbolk. He started in palynology, long ago, and has been active during many years as a leading archaeologist and director of the Biological-Archaeological Institute of Groningen University.

(For an overview of the archaeology of the northern provinces: see the copy of Waterbolk's 1995 paper "Patterns of the peasant landscape" in PPS 61: 1-36; appendix of this excursion guide book). p. 157 - 192

Via A28, N34, Anloo (medieval church) Gasteren, Anderen, Rolde to **Balloo.**

Kampsheide: barrow cemetery, megalithic tomb, brook valley Drentsche A, old farm Kamps, deserted farm Lantinge, *Juniperus communis, Gentiana pneumonanthe, Lycopodium inundatum.*

Ballooërveld: Celtic fields, barrows, medieval road tracks, anti-tank ditches (WW-II), pingo remnants, aeolic depressions.

Via Loon (megalithic tomb), Taarlo, Ubbena to **Zeijen**: village with 'brink' and 'es'.

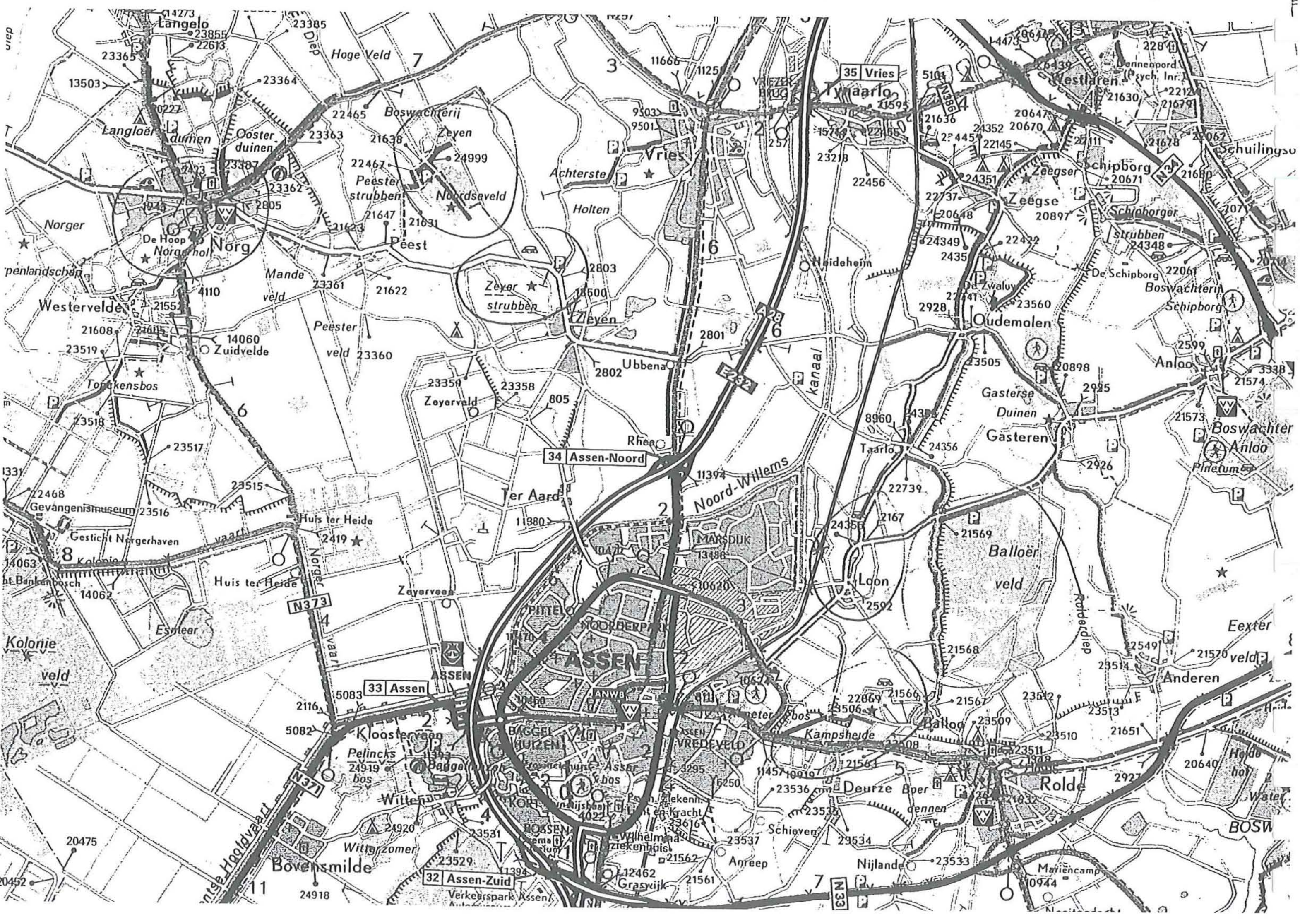
Bolleveen: pingo remnant.

Zeijerstrubben: woodland between 'es' and former heathland, with barrows, *Ilex europaea, Trientalis europaea, Cornus suecica.*

Noordscheveld: barrows, Celtic fields, megalithic tomb, pingo remnant Witteveen.

Via Peest and Zuidvelde (megalithic tomb) to **Norg**.

Norgerholt: old 'marke' forest with *Ilex*. Via Donderen, Yde and A28 back to Groningen.



THE CELTIC FIELD ON "HET NOORDSEVELD" NEAR ZEYEN, PROV. OF DRENTE: PALYNOLOGICAL ANALYSIS OF A SECTION THROUGH WALL AND FIELD

W. Groenman-van Waateringe

Introduction

This analysis is part of a project initiated by Ir. Th. Spek (landscape development and soil geographical aspects) and carried out in cooperation with Dr. M.J. Kooistra (micromorphological analysis). The aim of the project is to get a better insight into the meaning of Celtic Fields for the agricultural development of the landscape, location, dating, soil development, wall construction and agricultural use.

Celtic Fields (CF), still widespread on the Pleistocene sandy soils of NW Europe, consist of small (diameter ca. 30 m), more or less square plots surrounded by low walls, made of earth and/or stones, with a width of 6-16 m. They are dated between the late Bronze Age (1100 BC) to the late Iron Age/Roman period.

In 1993 a trench (18 m long, 1 m wide and 1.5 m deep) through a CF wall and adjacent field was dug and samples taken for a.o. Carbon 14 dating, phosphate, micromorphological and pollen analyses. For these last two adjacent sections were sampled.

The following is a preliminary report of the pollen analytical work. The final report will be written by Spek, Kooistra & Groenman-van Waateringe. It will be submitted for publication to Environmental Archaeology, The Journal of Human Palaeoecology.

Material and methods

Two sections were sampled for pollen analysis: section 1, samples 1-10 through subsoil and arable field and section 2, samples 1-17 through the wall adjacent to the arable field of section 1. Samples were taken in plastic tubes in distances ranging from 3-5 cm, save for the two subsoil samples of section 1, taken at 7 and 9 cm intervals. The samples were prepared according to the acetolysis method of Erdtmann (1960), following HF treatment. Pollen preservation was rather bad, resulting in a high number of unidentifiable pollen.

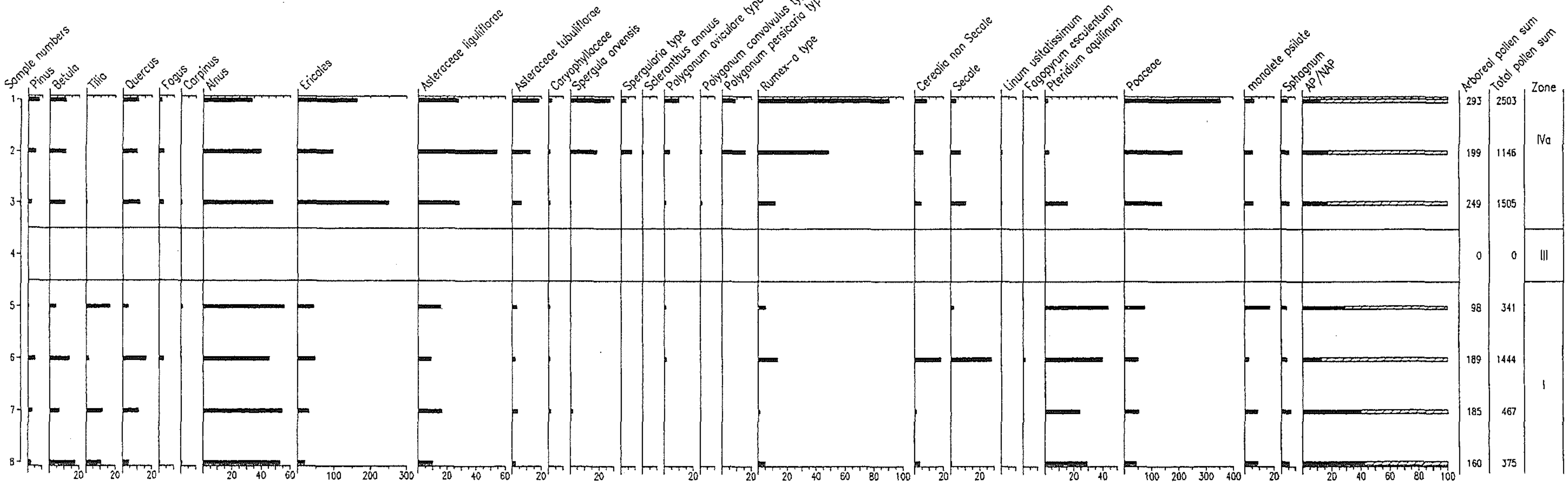
Interpretation

The arable field (fig.: CF Zeyen, pollen diagram of section 1)

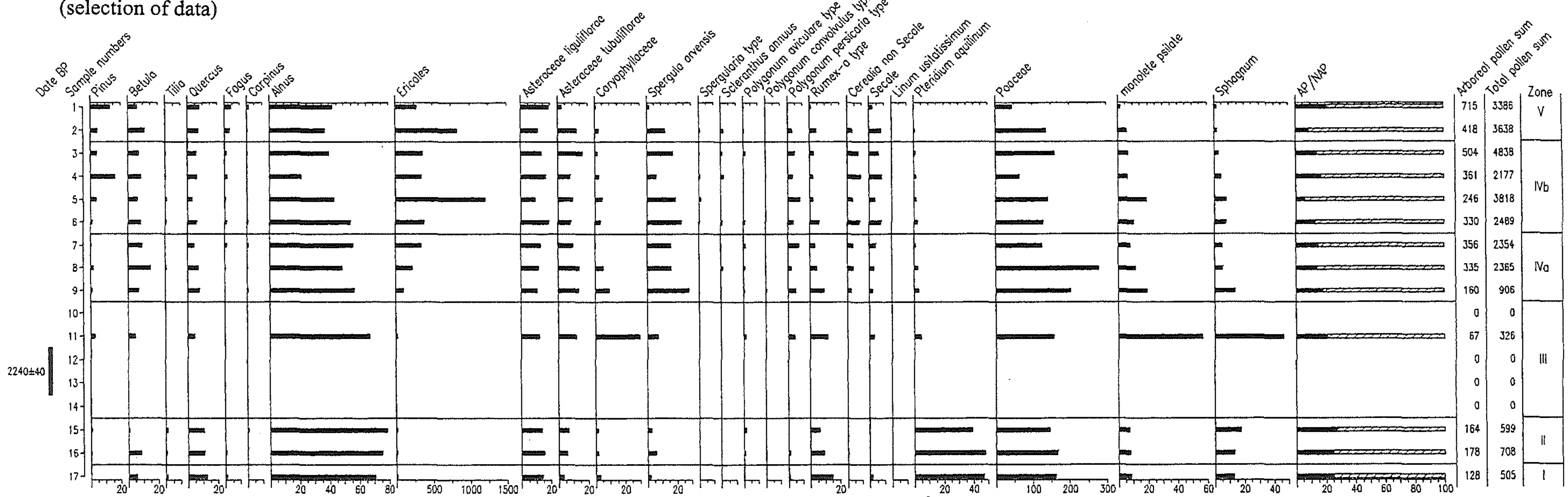
The subsoil samples 9-10 did not contain pollen. Sample 6 with a low tree pollen percentage, high percentages for cereal pollen and the presence of *Fagopyrum* is obviously contaminated and will thus be left aside. Sample 5 seems also slightly contaminated because of the presence of *Secale*, but otherwise fits quite well into the pattern of samples 7-8. Samples 7-8 and 5 are characterised by AP percentages around 40% and high *Alnus* values (55-60%). The percentages for *Pteridium aquilinum* and Poaceae are rather high, for Ericales low. The high *Tilia* percentages are probably caused by selective corrosion. Taken together, man's influence on the landscape is obvious. It was already rather open, dominated by a secondary, open birch-oak wood with a grassy undergrowth. The absence in two samples and the low value in sample 8 for *Fagus* point to a dating of this part of section 1 in the pre-CF period, thus somewhere in the Bronze Age. Because of the low values for herbs indicative for either cereal cultivation or pastoral activities (Behre 1981, 1986) local pre-CF agriculture seems not to have taken place in that period.

The beginning of the CF arable cultivation is not traceable. If this had to be placed around sample 4 the presence of a rather high amount of charcoal points to burning of the forest

CF Zeyen: pollen diagram of section 1 in the arable field.
(selection of data)



CF Zeyen: pollen diagram of section 2 in the wall.
(selection of data)



vegetation prior to cultivation and the regular burning of the weed vegetation resulting from cultivation. The pollen will not have survived this burning.
Neither do the samples 1-3 present the CF arable activities. With the continuous presence of *Secale*, with percentages between 5-10%, this part of the diagram can not be dated to the pre-Roman Iron Age, or even, according to the one C14 dating available, to the 4th C BC, the middle Iron Age. Cultivation of *Secale*, resulting in a continuous pollen curve, starts in the northern part of The Netherlands not before the Roman and Migration periods (Behre 1992, 148). Thus the earliest dating of this part of the diagram is the Roman period.
The samples 1-3 are characterised by low AP values (less than 20%), the presence of other cereals besides *Secale*, of *Linum* pollen, *Scleranthus annuus*, *Polygonum convolvulus* and high percentages for Asteraceae, *Spergula arvensis*, *Spergularia* type, *Rumex*-a type, *Polygonum aviculare*, *P. persicaria* and many other herbs. Together with the high values for Ericales this combination of pollen types recalls strongly the pollen assemblages of medieval plaggen soils (Bakels 1988; Groenman-van Waateringe 1992, Groenman-van Waateringe & Luijten 1995; van Smeerdijk, Spek & Kooistra 1995), be it that the values for *Secale* are much less in the samples from Zeyen. The resemblance, however, with the pre- plaggen soil agriculture as shown in diagrams from Dommelen and Geldrop (Groenman-van Waateringe & Luijten 1995) is striking.
The high percentages for *Rumex*-a type and Poaceae may point to pastoral activities in between the walls.

The wall (fig.: CF Zeyen, pollen diagram of section 2)

Sample 11 can not be compared to any of the samples above or below it. It shows higher values for Caryophyllaceae, monolete psilate spores and *Sphagnum* than any of the other samples. Contamination or bringing-in of material from elsewhere must be considered.
Samples 15-17 can be compared with samples 7-8: higher AP percentages than in samples 1-9 (although a bit less than in the section of the arable field), high values for *Alnus*, *Pteridium aquilinum* and Poaceae (the latter much higher than in the arable field section), low values for *Fagus*.
Again one gets the impression of a secondary, open birch-oak forest with grassy undergrowth. The dating of the samples could be somewhat younger than those of samples 7-8 of the arable field section, but still pre-CF.
Samples 12-14 and 10 do not contain pollen. A high charcoal content in the layers from which these samples were taken makes comparison with sample 4 of the field section obvious. The lack of pollen may be caused by the same reason given for the field section.
Samples 1-9 with their continuous curve for *Secale* and indeed the presence and percentages of all the other pollen types match samples 1-3 of the field section well. Thus again there is evidence for agricultural activities from the post-CF period, at its youngest from the Roman period.

The Cerealia-non *Secale* consisted mainly of pollen of *Triticum* type, both in wall and field samples, with a few *Panicum*, *Hordeum* and *Avena* type pollen.

Comparison with other pollen data and conclusion

Both pollen sections, either from the arable field or from the wall beside it do not give any botanical information on the CF agricultural activities, because regular burning obviously has destroyed all pollen grains. The beginning of the CF agriculture, and in fact the whole CF period is shrouded by lack of pollen. Only charcoal particles are left behind as remains of the vegetation contemporaneous with the CF period. However, some information may be gathered from this, burning was apparently a regular practice, pointing to a long period of fallow, in which bushes could develop.
In a later period, at the earliest in Roman times, but before the general increase of *Fagus* and *Carpinus* in the post-Roman/early Medieval period, the CF was again taken into cultivation,

Monday 6 September

Aspects of archaeology and cultural landscape in the province of Groningen
(marine clay deposits within dykes, artificial dwelling mounds ('terpen' or 'wierden'), locks, Waddenzee area with salt marshes, medieval 'streek' villages in former raised bog areas).

Via 'terp' villages Dorkwerd, Oostum, Garnwerd and lock village Aduarderzijl to **Ezinge**.

Ezinge: 'terp', excavation site, museum Wierdenland.

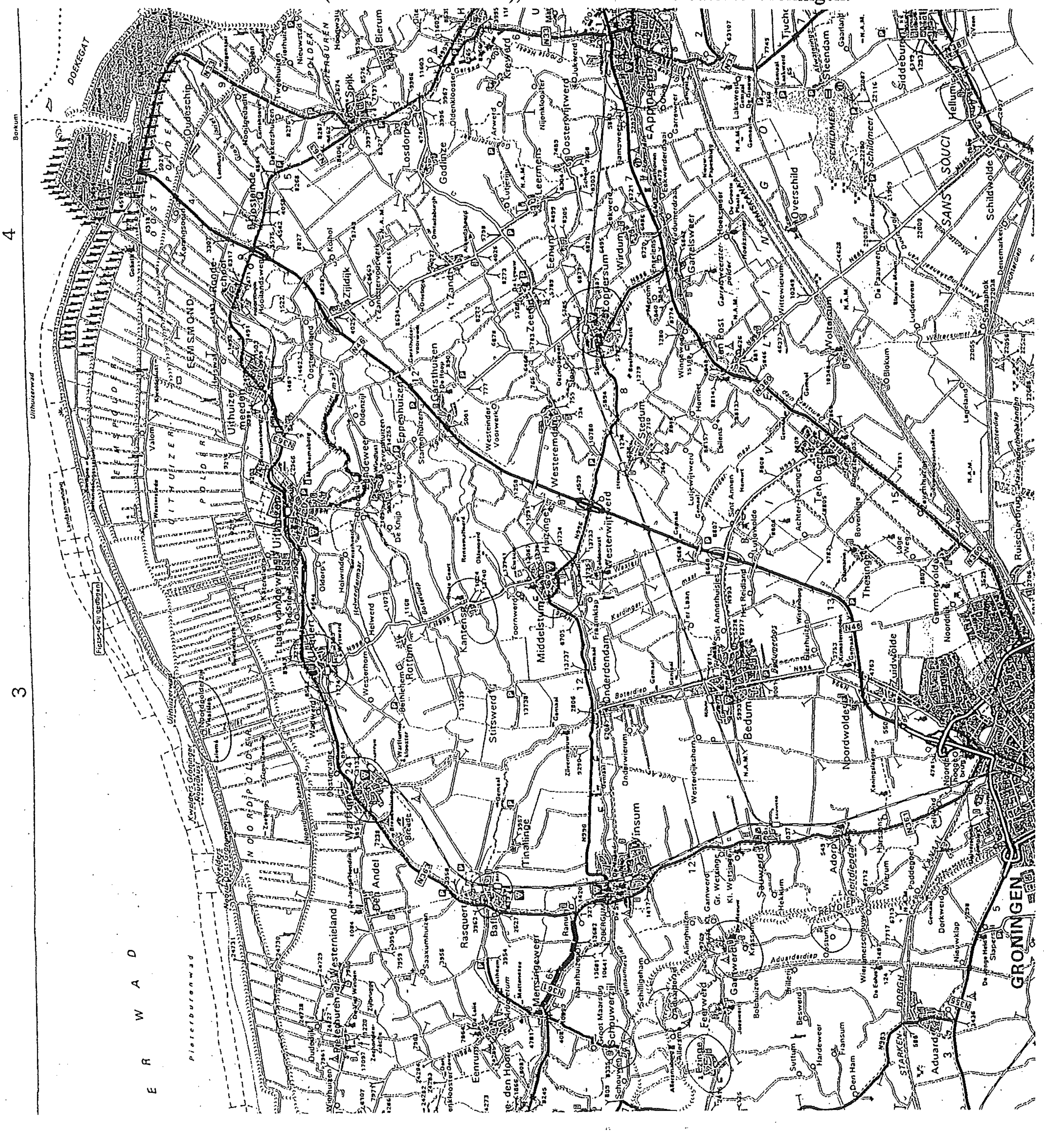
Via Saaksum (terp), Roodehaan (crossing the Reitdiep), Schouwen (terp), Schouwerzijl (lock), Groot Maarslag (terp), Mensingeweer, Baflo, Rasquert, Breede, Warffum to **Noordpolderzijl.**

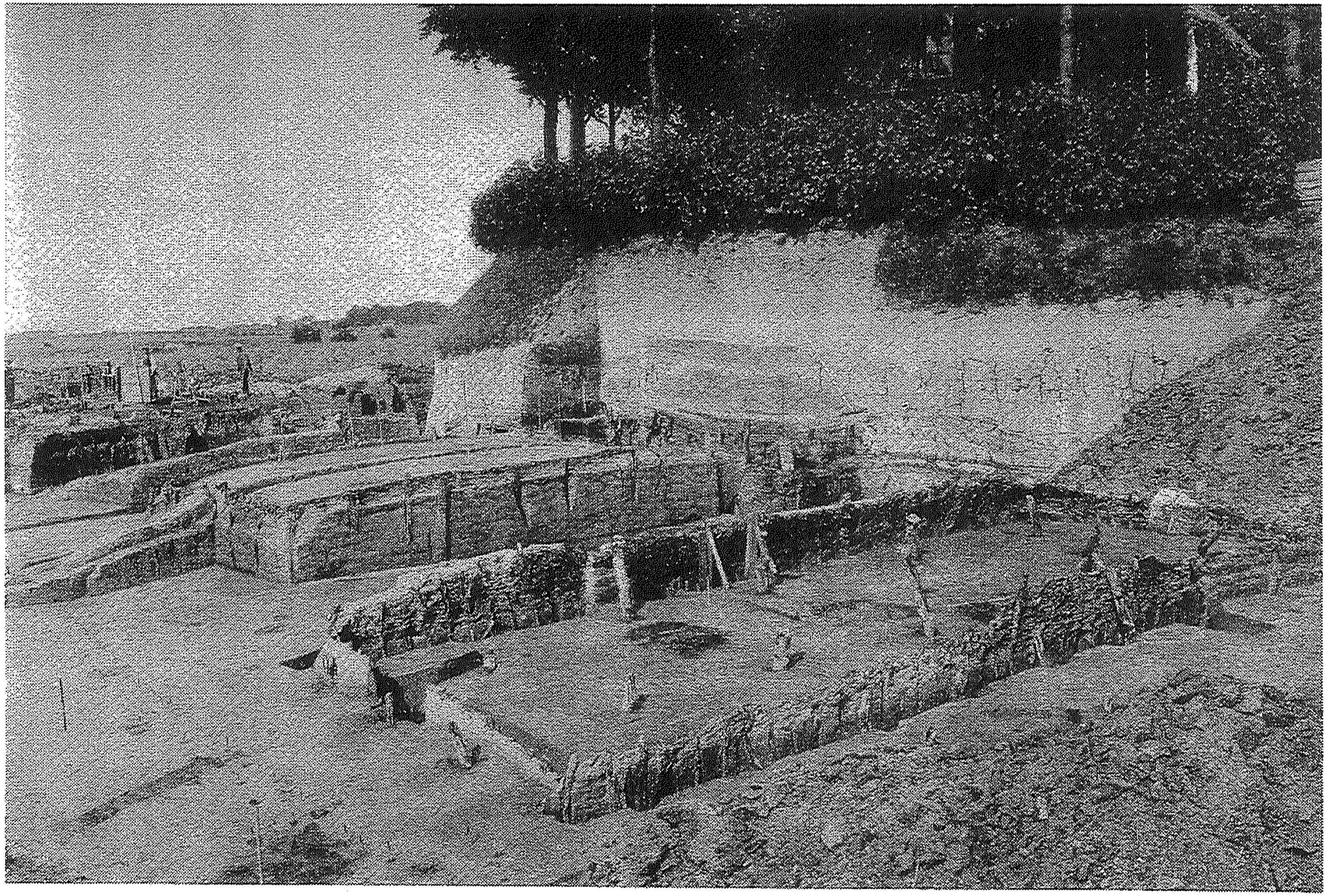
Noordpolderzijl : old and modern lock, small harbour, Waddensea, salt marshes, land reclamation works, coffee stop.

Via Usquert, Uithuizen (Menkemaborg manor), Zandeweer, Westeremden (terp), Loppersum, Garrelsweer, ten Post and Wittewierum to the 'streek' villages Schildwolde and **Slochteren.**

Slochteren: Fraeylemaborg manor

Via Noordbroek (late medieval church), Zuidbroek and N7 back to Groningen.



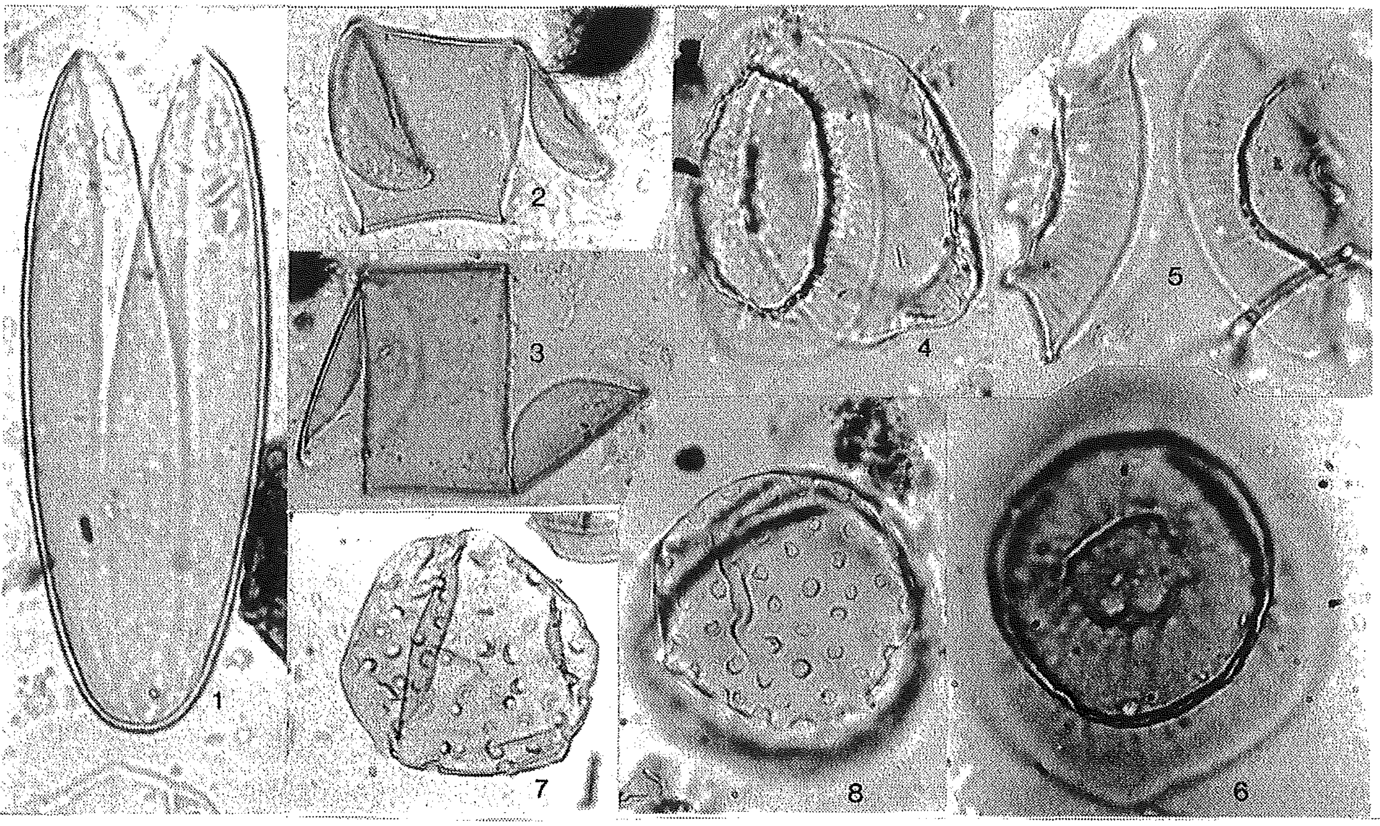


In the period 1930-1934 the terp of Ezinge was excavated by prof. A.E. van Giffen.

Tuesday 7 September:
We will leave the Weeva hotel in Groningen. We cross the beautiful province of Friesland, with its eleven towns (some of them with the size of a village). We pass the **'Afsluitdijk'**, which is a 32 km long dike between Friesland and the province of Noord-Holland. This dike was finished in 1932 and it was made to protect the area around the former Zuyderzee against storm surges. The new lake was called IJsselmeer, and after ca 8 years it was filled with fresh water. Later, enormous polders (total surface more than 1400 km^2) were made in the IJsselmeer, so that nowadays only part of the original freshwater lake area is left. It is of crucial imprtance for the fresh water supply in The Netherlands. The new polders play an important role in food production, but also - especially in the southern part - as 'overflow' for the dense human population in the western and central Netherlands.

Soon after passing the **Afsluitdijk** we will arrive in the area called **West-Friesland** (part of the province of Noord-Holland; formerly connected with **Friesland** when peat deposits in between were not yet eroded by the sea).
Several paleoecological studies were worked out in relation to the archaeology of West-Friesland. There are no sites interesting enough to make stops on our way to the hotel, but worth mentioning are:
In former ditches in a Bronze Age settlement near Hoogkarspel the spores of Zygnemataceae (clean, oxygen-rich, shallow, stagnant freshwater) were recognised for the first time (van Geel, 1976). Zygnemataceae have an old history, going back to the Carboniferous (more than 300 million years ago), when spores with the same morphology (see below) already occurred (van Geel and Grenfell, 1996).

SPORES OF ZYGNEMATACEAE Plate I



1 Psilate zygospore or aplanospore of *Spirogyra* sp.; ca. 25 000 BP; 1000x.

2, 3 Zygospores of *Mougeotia* sp. cf. *M. laetevirens*; ca. 26 000 BP; 500x.

4, 5 Zygospores of *Debarya* sp. cf. *D. glyptosperma*; ca. 23 000 BP; 1000x.

6 Zygospore of *Debarya* sp.; ca. 12 000 BP; 1000x.

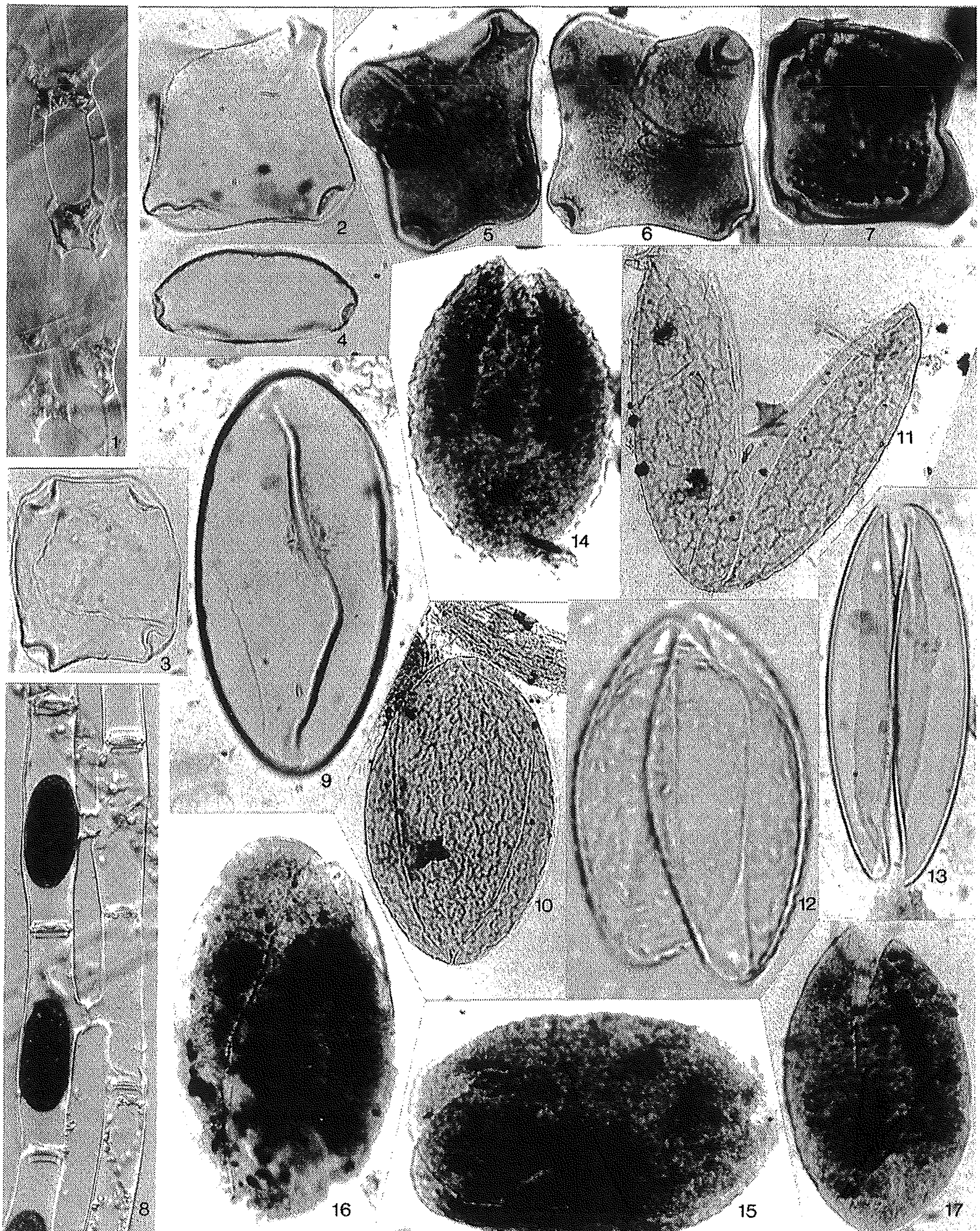
7 Zygospore or aplanospore of *Zygnema*-type; ca. 9900 BP; 500x.

9 Zygospore or aplanospore of *Zygnema*-type; ca. 18 000 BP; 1000x.

Material: 1, 2, 3, 4, 5, 8, from a Colombian lake deposit (van Geel & van der Hammen 1978); 6, from a Late Glacial lake deposit in the Netherlands (unpublished); 7, from a Late Glacial/Holocene shallow pool deposit in the Netherlands (van Geel *et al.* 1981).

SPORES OF ZYGNEMATACEAE

Plate II



For caption see next page

1 Conjugating filaments of *Mougeotia viridis* (Recent), with zygospores; ca. 500x.
2 Zygospore of *Mougeotia* sp.; ca. 3000 BP; 1000x.
3 Zygospore of *Mougeotia* sp.; ca. 30 000 BP; 870x.
4 Aplanospore of *Mougeotia* sp.; ca. 9800 BP; 1000x.
5, 6, 7 *Tetraporina*; Lower Carboniferous; 750x.
8 Conjugating filaments of *Spirogyra hassallii* (Recent), with zygospores; ca. 300x.
9 Psilate zygospore or aplanospore of *Spirogyra* sp.; ca. 10 300 BP; 1000x.
10, 11 Reticulate zygospores or aplanospores of *Spirogyra* sp.; ca. 2800 BP; 500x.
12 Foveolate/fossulate zygospore or aplanospore of *Spirogyra* sp.; ca. 12 300 BP; 1000x.
13 Psilate zygospore or aplanospore of *Spirogyra* sp.; ca. 10 300 BP; 1000x.
14, 15 Reticulate *Spirogyra*-like spores; Lower Carboniferous; 750x.
16, 17 Psilate *Spirogyra*-like spores; Lower Carboniferous; 750x.

Material: 1 and 8, collected and provided by J. Simons, Free University, Amsterdam; 2, from ditches in a prehistoric settlement (van Geel 1976); 3, from a Colombian lake deposit (van Geel & van der Hammen 1978); 4, 9 and 13, from a Late Glacial/Holocene shallow pool deposit in the Netherlands (van Geel *et al.* 1981); 5-7 and 14-17, Lower Carboniferous sample from a site near Moscow, provided by H. Visscher, State University Utrecht; 10 and 11, from a Holocene peat deposit in the Netherlands (Pals *et al.* 1980); 12, from a Late Glacial pool deposit in the Netherlands (van Geel *et al.* 1989).

The end of settlement sites in the N. Netherlands in hydrologically marginal areas at the Bronze Age - Iron Age transition

Referring to van Geel et al. (1983), Buurman et al. (1995) and van Geel et al. (1996, 1998) the end of Bronze Age occupation in West-Friesland is worth mentioning in relation to what we have seen in the raised bogs at the Subboreal/Subatlantic transition:

In West-Friesland we found archaeological and paleoecological evidence that climate change around 850 cal BC must have had dramatic effects for prehistoric farmers. Based on excavations in the West-Friesland area it was concluded that the settlement phase (which had started around 3350 BP) suddenly stopped during the Late Bronze Age, and no settlements were present until Medieval time. The period of the last circa 140 "radiocarbon years" of the Bronze Age settlements (between 2760 ± 35 BP and 2620 ± 20 BP, and corresponding to only circa 50 calendar years) was characterised by houses that were built on small 'terpen' (artificial mounds). These 'terpen' were needed due to the ground water level being suddenly too high. All the radiocarbon dates of that last wet phase of the settlements correspond with the first circa 50 years of the period of sharply rising ^{14}C content of the atmosphere. The very last date of the settlement phase in West-Friesland corresponds to the steepest rise of $\Delta^{14}C$, when *Sphagnum imbricatum* starts to be an important peat former in the raised bogs elsewhere in NW-Europe. In West-Friesland the highest, driest, parts (the farming areas) disappeared and the human population could not stay there because the area became too wet. Apart from the archaeological information also the study of preserved organic deposits under the West-Frisian Medieval dike near Enkhuizen experienced a rise in the water table (for details see van Geel et al., 1998, in Radiocarbon). At that site 'Enkhuizen-dijk' a sandy soil that formed during the Bronze Age habitation phase was covered by an organic deposit representing a shallow fresh water pool, formed after a rising water table. AMS-radiocarbon dating of the start of the formation of the organic deposit showed that the sudden rise of the water table occurred somewhere between 906 and 820 calendar years BC, which means - in combination with the archaeological radiocarbon dates from the area - that the area became inundated (with fresh water) during the period of that sudden increase of ^{14}C.

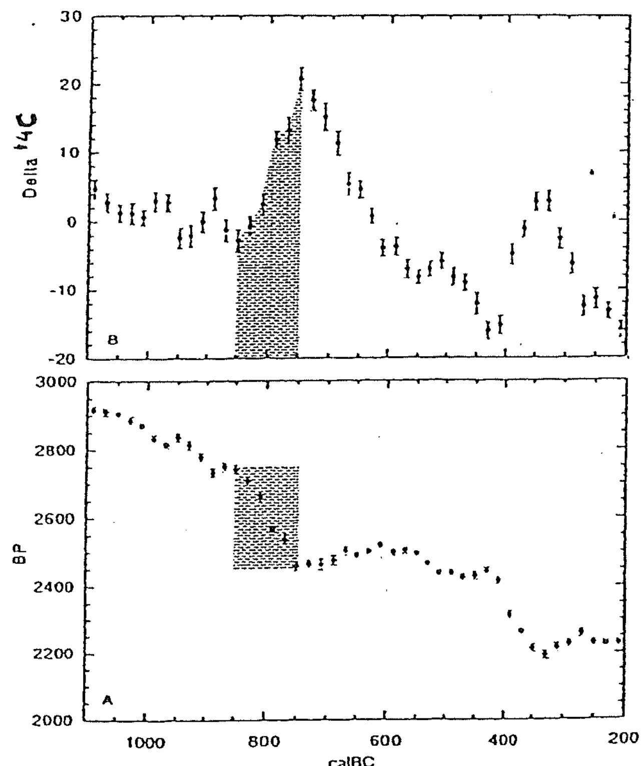
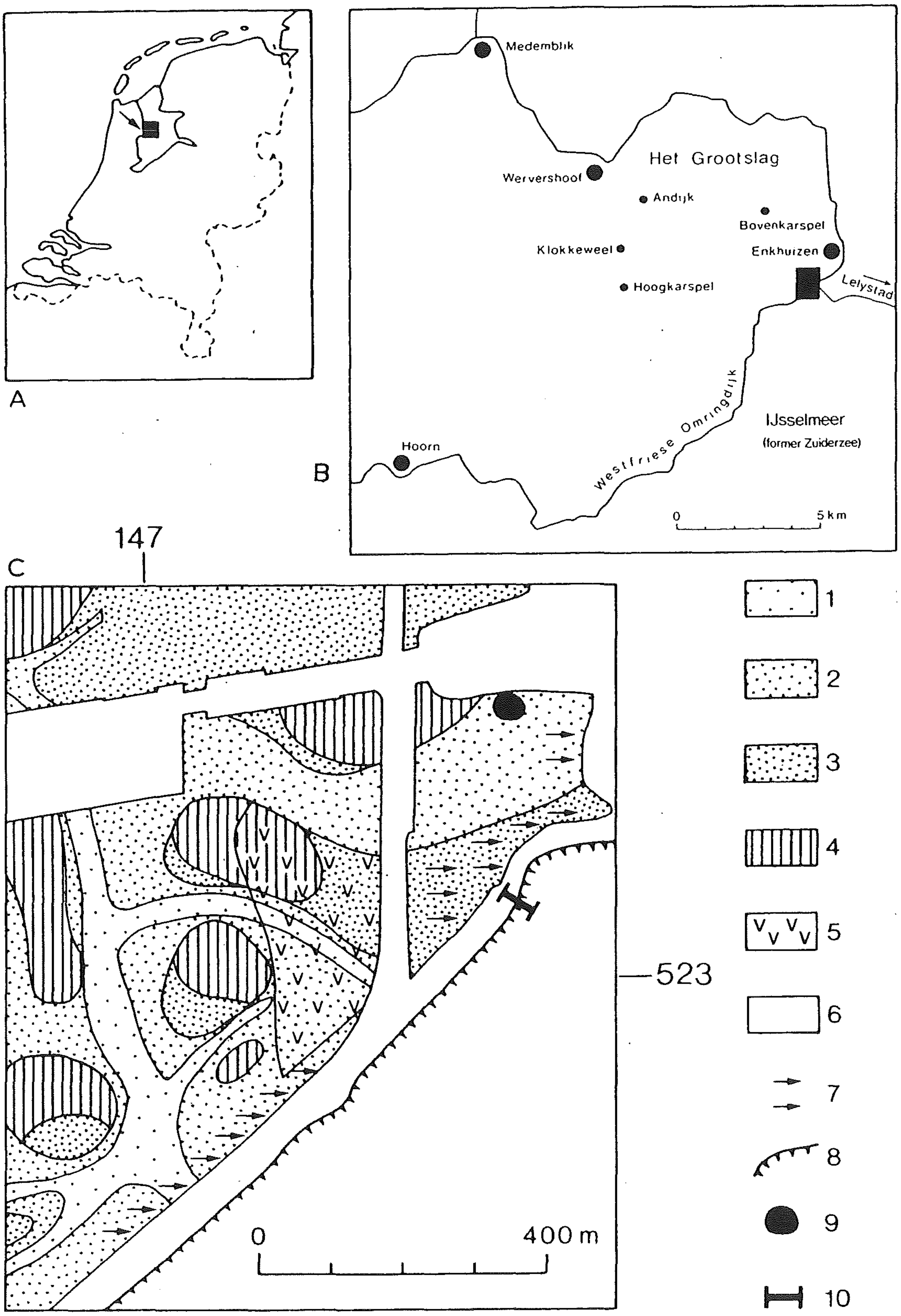


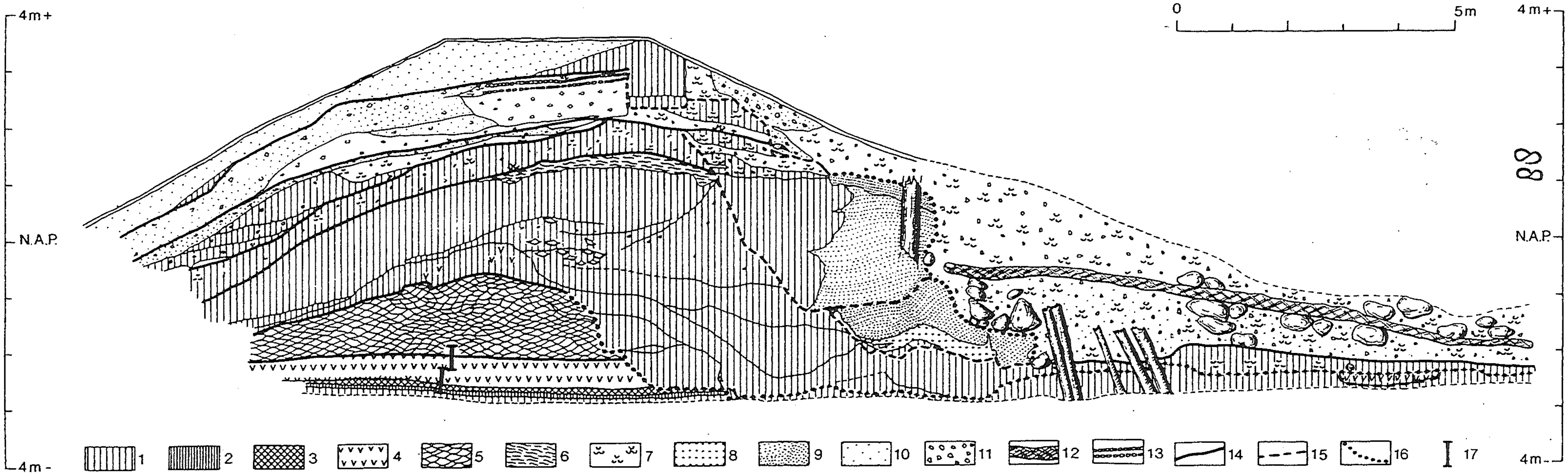
Fig. A: The ^{14}C calibration curve between 1100 and 200 calendar years BC, and **Fig. B:** the corresponding former changes of the atmospheric radiocarbon content (detrended $\Delta^{14}C$). The phase of palaeoecological, geological and archaeological evidence for climate change is shown by vertical hatching. It is characterised by a sharp rise in the ^{14}C-content of the atmosphere. The actual increase of cosmic rays and related climate change may have started 10-20 years earlier than the start of the rise in $\Delta^{14}C$ (Bard *et al.*, 1997). For the period 8100 to 5100 calendar years BP Finkel and Nishiizumi (1997) showed that peaks of the cosmogenic isotope ^{10}Be precede $\Delta^{14}C$ peaks even by circa 100 years.

Bard, E., Raisbeck, G.M., Yiou, F. and Jouzel, J., 1997, Solar modulation of cosmogenic nuclide production over the last millennium: comparison between ^{14}C and ^{10}Be records, Earth and Planetary Science Letters, 150, 453-462.

Finkel, R.C. and Nishiizumi, K., 1997, Beryllium 10 concentrations in the Greenland Ice Sheet Project 2 ice core from 3-40 ka, Journal of Geophysical Research, 102; C12, 26,699-26,706.

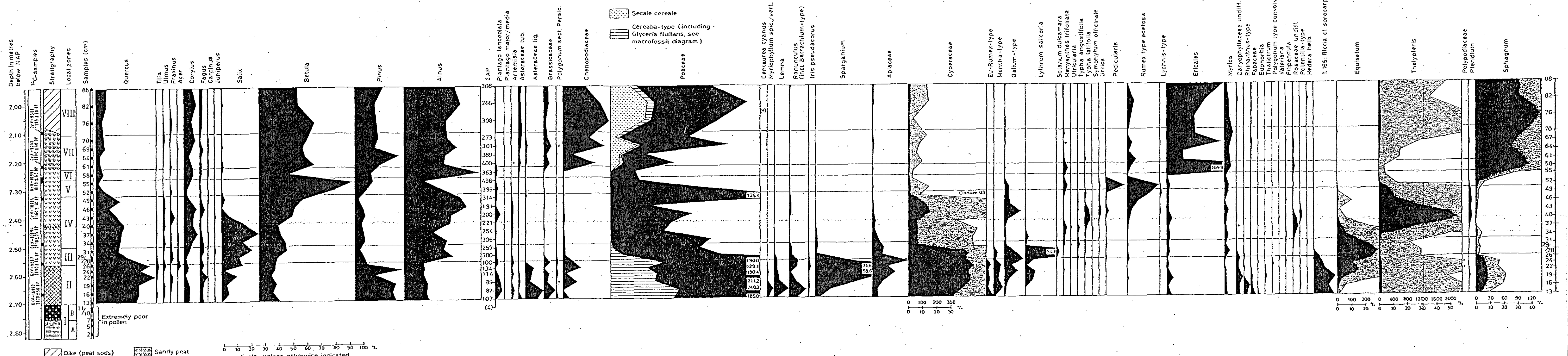


Location map of the section Enkhuizen dike. A. The Netherlands and location of B. B. Eastern West-Friesland, places mentioned in text, and location of C. C. Location and geology of the surroundings of the dike section. Legend: *1* = sand; *2* = sandy clay; *3* = sandy clay on clay; *4* = clay; *5* = peaty layer on top of *1—4*; *6* = not mapped or open water; *7* = reworked; *8* = dike; *9* = Bronze Age settlement; *10* = location of dike section.



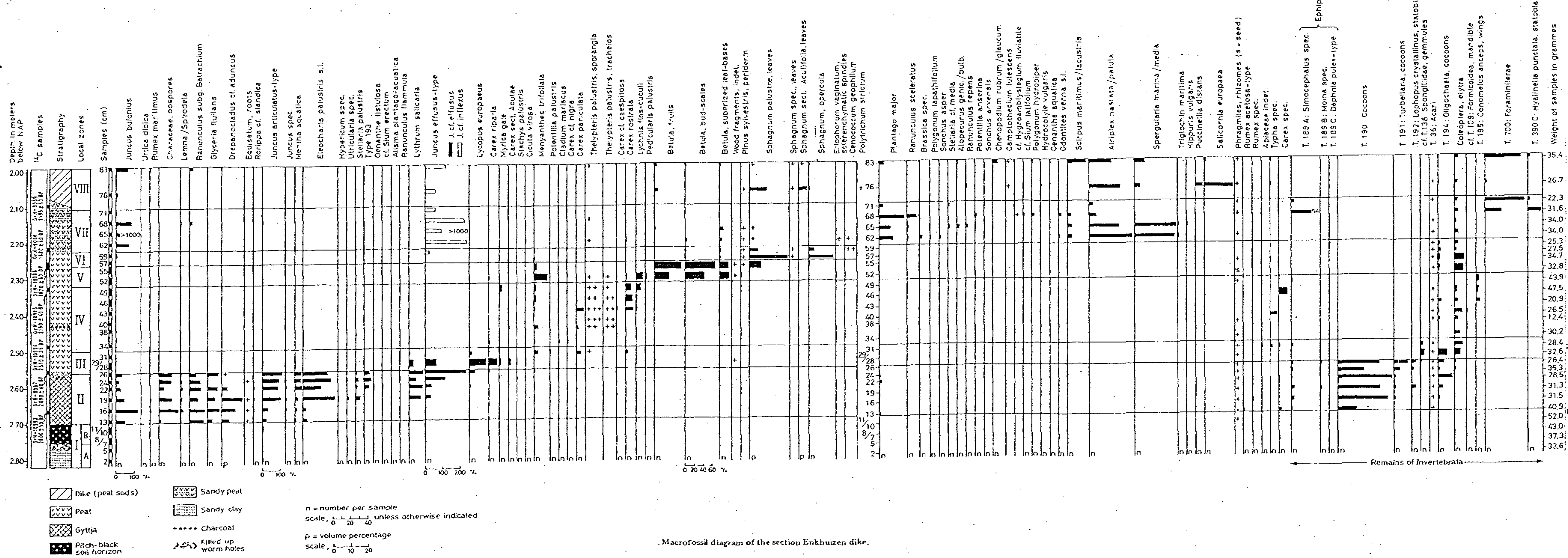
Section through dike. Legend: *1* = clay/sandy clay; *2* = black soil horizon at the top of Calais deposits; *3* = gyttja; *4* = peat; *5* = peat lumps; *6* = strongly rooted layer; *7* = shells; *8* = reed and twigs; *9* = sea weed; *10* = sand; *11* = rubble; *12* = willow mattress; *13* = bricks; *14* = old surface; *15* = extension of digging in older strata; *16* = extension of erosion by the sea; *17* = location of samples.

ENKHUIZEN-DIJK, POLLEN AND SPORES



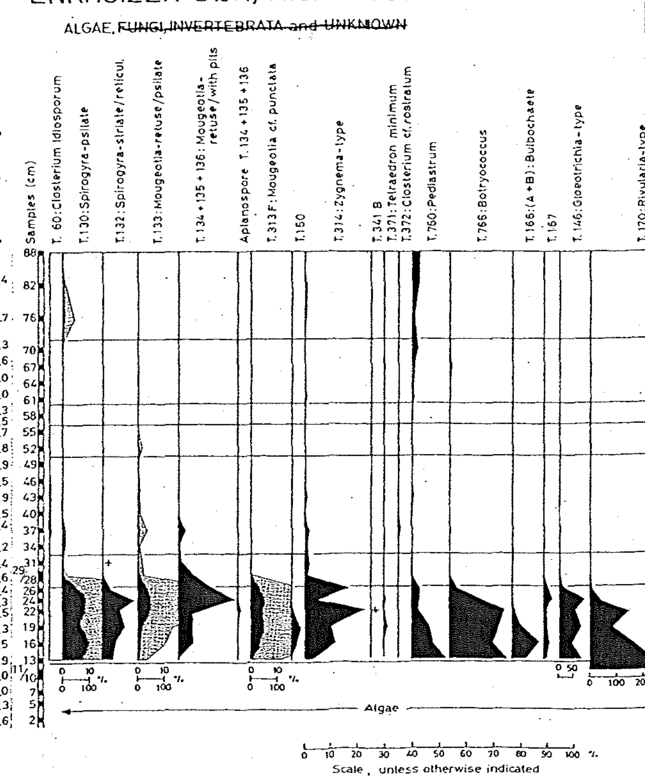
Pollen diagram of the section Enkhuizen dike. 88 cm: *Potamogeton* 0.3%; 82 cm: *Potamogeton* 0.4%; 70 cm: *Nymphaea* 0.3%; 64 cm: *Hydrocotyle* 0.3%; 61 cm: *Hypericum* 0.2%, *Drosera* 0.2%; 49 cm: *Humulus/Cannabis* 0.3%; 37 cm: *Melampyrum* 0.4%; 28/29 cm: *Lysimachia* 0.3%, *Picea* 0.7%; 26 cm: Oenotheraceae 0.4%; 16 cm: *Picea* 1.2%; 13 cm: *Picea* 0.9%, Convolulaceae 0.6%.

ENKHUIZEN-DIJK, MACROFOSSILS

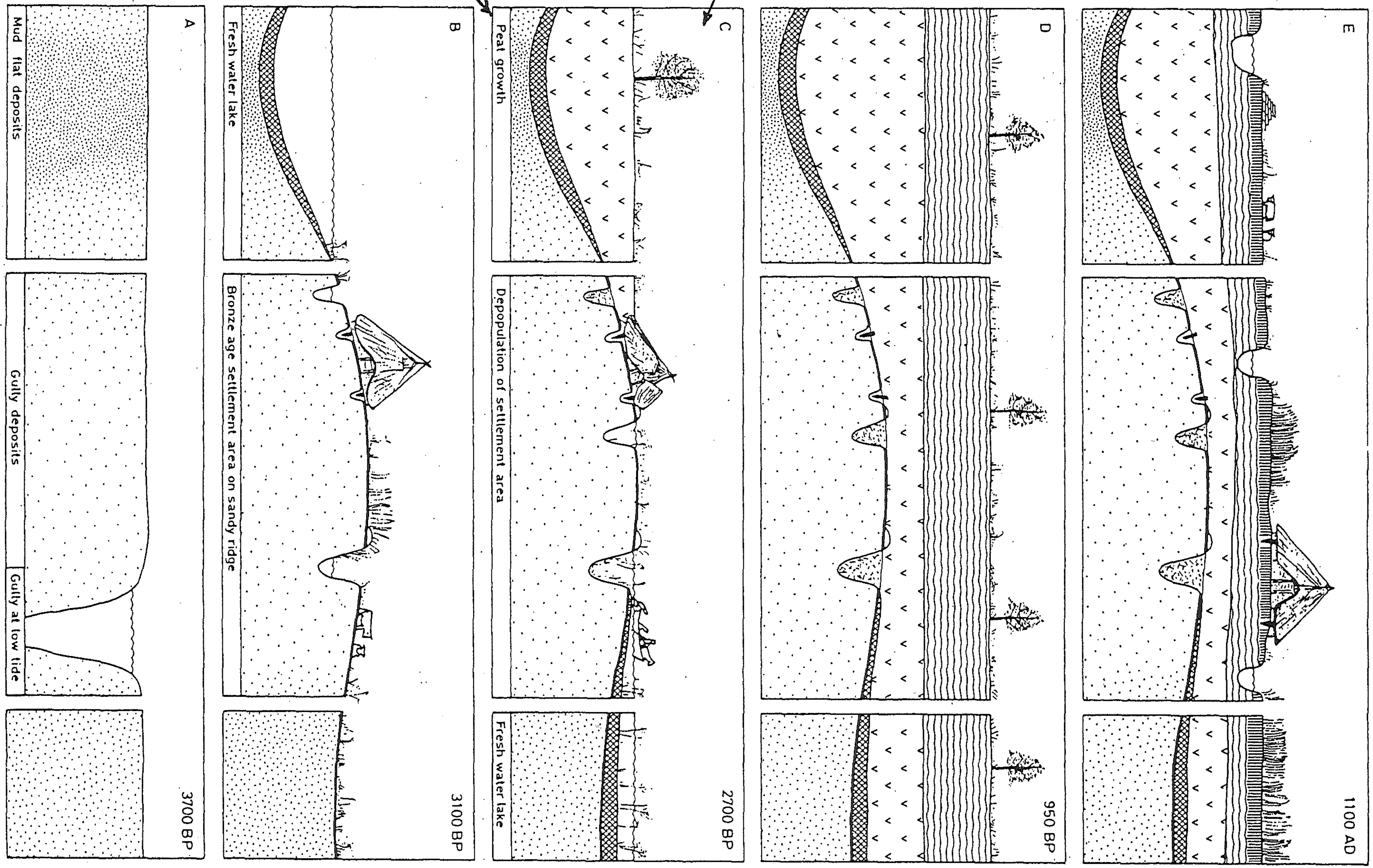


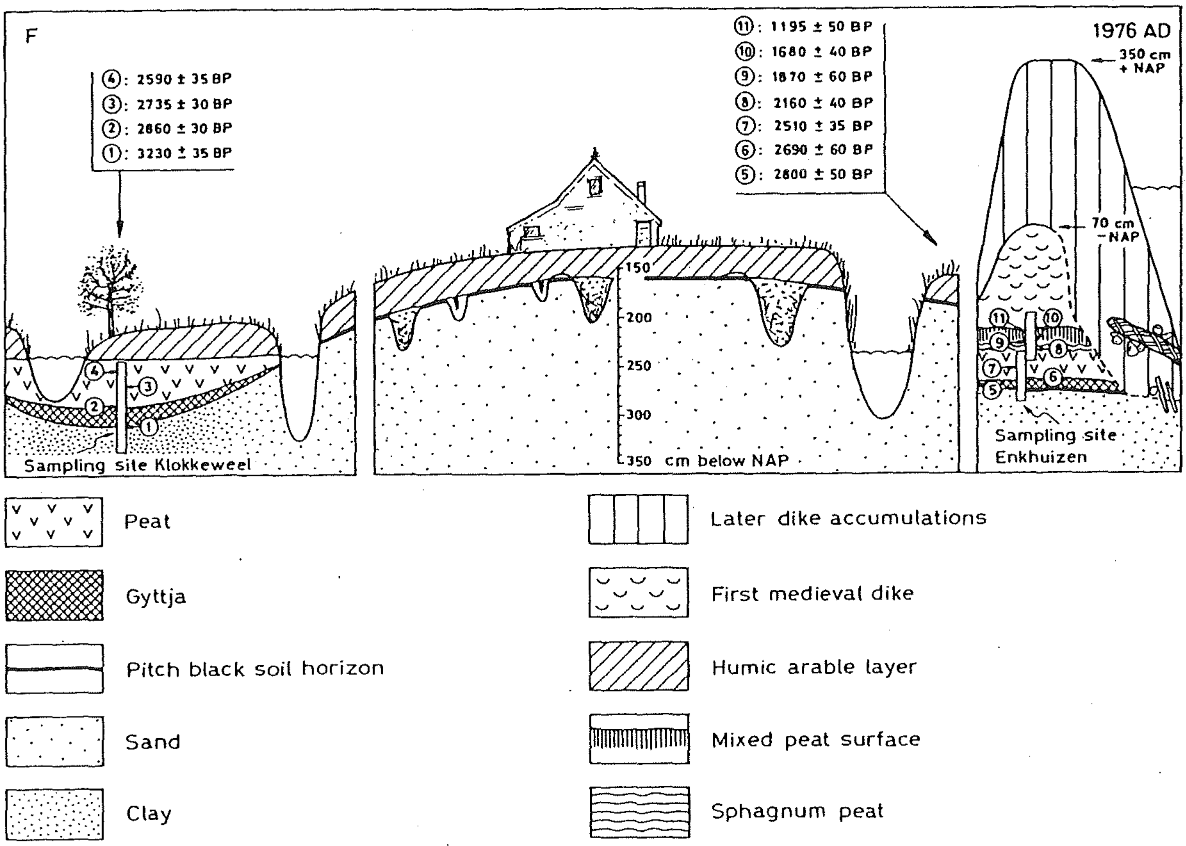
Macrofossil diagram of the section Enkhuizen dike.

ENKHUIZEN-DIJK, MICROFOSSILS



See van Geel et al. (1998, in Radiocarbon) for a climatological interpretation of the sharp rise of the water table around 2700 BP and a link with the raised bog records: decrease of solar activity; sharp increase of cosmic ray intensity; more clouds and precipitation, sharp rise of delta ^{14}C !!





Sketches of six successive stadia in the genesis of the eastern part of West-Friesland during the Late Holocene (a tentative over-simplified reconstruction). The left, central and right parts of the sketches represent our ideas concerning the development in:

a. The Klokkeweel area near Hoogkarspel as an example of a development of a clayey deposit in a marine environment which became a fresh-water lake, that gradually became filled up by lake deposits and peat (see Pals et al., 1980).

b. One of the gullies in the area that became a sandy ridge after subsidence of the neighbouring flats. During the Middle and Late Bronze Age, settlements were situated on many of these ridges.

c. The sampling site of the section Enkhuizen dike.

In the lower part of F a vertical scale in cm below N.A.P. (Dutch Ordnance Level) is indicated. Important differential subsidence of the area has taken place in modern times. For practical reasons (because the rate of such a differential subsidence is largely unknown), possible relative differences in the surface level of the Calais deposits in the different stadia could not be taken into consideration. We only assume (see p. 273) that the top level of the Calais deposits underneath the dike originally had about the same elevation as the top level of similar deposits in the vicinity of the dike (compare F with figs.B—E). A. The area formed part of a tidal flat with sandy material being deposited in and near gullies and clay on the flats. B. When the sea had lost its influence, subsidence of especially the clayey deposits resulted in depressions, so that the lowermost ones became fresh-water lakes. Former gullies became meandering sandy ridges. During the Middle and Late Bronze Age an intensive occupation of the area took place; settlements were located on sandy ridges. C. A rise of the water table finally resulted in the abandonment of the settlements in the area. D. The area was covered with peat deposits. The upper peat layer was formed under oligotrophic conditions, at least at the Enkhuizen dike sampling site. E. Reclamation of the area took place, resulting in subsidence of the peat surface because of drainage and oxidation of the upper peat layer. In these circumstances the area was inundated during storm surges and a dike was constructed to protect the area. F. Present situation: the peat has disappeared almost everywhere owing to drainage, oxidation and probably also peat cutting for fuel. Some peat deposits are still present under the sea dike and also in depressions in the landscape.

Evidence for medieval salt making in Noord-Holland by using *Zostera marina* as the raw material

(based on: van Geel, B., van den Broeke, P. and Borger, G.J., in prep. Evidence for the use of *Zostera marina* for salt production in medieval Holland.)

In medieval time raised bog peat that had been exposed to sea water was generally used as the raw material for salt making. Salt used to be one of the important products of the extensive 'Frisian' trade (Borger, 1992). Enormous quantities of raised bog peat disappeared with this 'selbernen' (salt burning) by 'pannemannen'. After burning the salt was concentrated in the ashes. Subsequently the salt was washes out and filtered and dried (cristallized) in pans above fires. It is noteworthy that the word potassium is derived from the word 'potas' (K_2CO_3).
At many places along the coast the evidence for peat cutting is present in the form of clay-filled pits in peat deposits. No doubt that submerged raised bog peat was used for salt making, but less well known is salt making starting with *Zostera marina*, a species which was very common in the Wadden area until it almost died out after the outbreak of an illness in 1933.
Historical sources mention *Zostera* as the raw material for salt production. Linnaeus, translated in Dutch by Houttuyn (1783) mentions the use of *Zostera* as material for, a.o., dike building and for salt making (for those of you who want to try to understand the Dutch language):

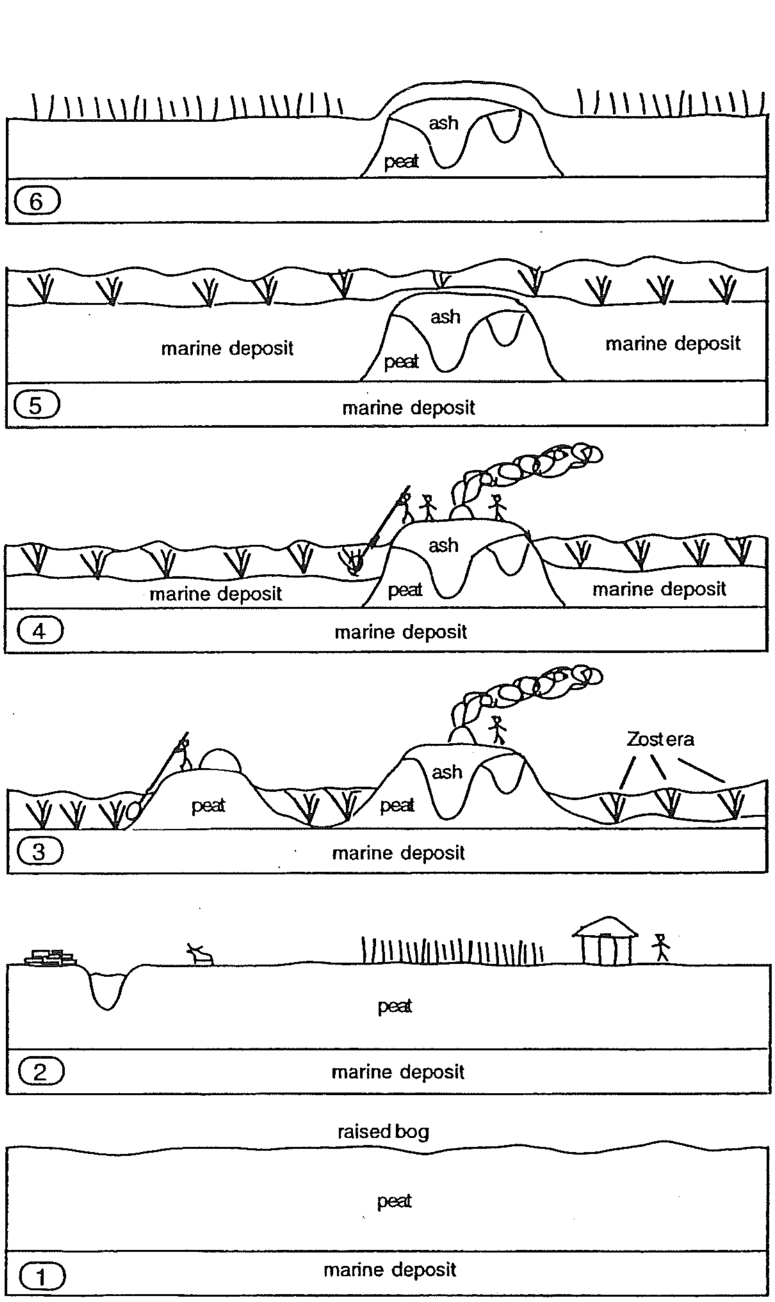
> "De Asch van 't Zee-Wier levert, door uitlooging, een Zout, dat niet alleen dienen kan om 't Vleesch voor bederf te bewaaren, maar ook dikwils in de Glasblaazeryën van Engeland, als ook tot het maken van Aluin en Zeep in plaats van Potasch, onder den naam van Kelp gebruikt wordt. Dus moet dit Zout dan aanmerkelyk verschillen van dat Zout van Wier, 't welk men uit verscheide soorten van Zee-Ruy, aan 't strand der Noordzee opgeworpen, heeft bekomen'. Houttuyn also mentions that the Jutlanders 'daar een Zout van maaken, waarmede zij den Visch, die er echter zwartachtig van wordt, ter bewaaringe inzouten".

More recent data about salt making in Denmark is given by Brøndegaard (1987) in his impressive historical etnobotanical study (how is your Danish?):

> "Langs den jyske østkyst .. blev 'fra de aeldste tider' og ind i 1800-t braendt store maengder baendeltang (Zostera marina) på åben mark og af asken kogt salt eller lage til nedsaltning af fisk samt kød og flaesk til røgning (men sjaeldent anvendt som smørsalt). Af 18 bønderlaes tørret tang fik man ca. 8 tønder aske, der gav 1 td. salt. Når luden var inkogt i kedler og gryder, skulle den klares med okse- eller lammeblod. For kystboerne og navnlig fattigfolk var denne tilvirkning en meget vigtig hjemmeindustri, men 'egentlig en syssel for kvindekønnet i ledige timer'; en bondekone kunne på fire dage braende 8 tdr. aske. Man solgte de faste blokke (stensalt) på torve og markeder, men det kunne dårligt konkurrere med udenlandsk salt. Af asken kunne fremstilles potaske og glaubersalt (natriumsulfat); den skulle vaere bedre til vask end bøgeaske og var anvendelig til saebe " (Brøndegaard, 1987).

In 1995 Bas van Geel was asked to take peat samples at an archaeological excavation in the Waardpolder near Kolhorn, just to the north of the Westfriese Omringdijk. In the excavation (two cross sections through marine deposits and also cutting an *in situ* strip of raised bog peat, the following observations were made:
Many pits had been made in the peat, and these had been filled up with enormous quantities of ash. Like in many similar archeological sites in Noord-Holland and Friesland (Griede, 1978; Borger, 1992) the ash was interpreted as the result of medieval salt industry. However, in the ashes no raised bog plants could be recognised. But many remains of *Zostera marina* were present (see Plates). There is strong circumstancial evidence that during the late medieval period *Zostera* was burned for economical reasons. Salt (NaCl) was very important for the conservation of food and potassium was used in the process of dying of wool, for soap production and for glass production. In the following figure the different stadia of the landscape around the site of (interpreted) medieval salt industry are shown.

Simplified, preliminary reconstruction in six stages of landscape development and human activities in the Waardpolder area near Kolhorn.



(1) Before the arrival of medieval pioniers the marine deposits of West-Friesland were covered with peat deposits (Borger, 1975; van Geel et al., 1983).

(2) Around 1000 AD pioniers reclaimed the bog by digging ditches and canals. The bog stopped to grow and subsidence and oxidation of the upper peat layers started. Rye was cultivated on top of the peat. There was plenty of fuel in the form of peat deposits.

(3) The lowering of the soil surface, in combination with the constant rise of the sea level resulted in inundations during floods. West-Friesland was protected by building the Westfriese Omringdijk, but the Waardpolder-area was not protected. The regularly inundated peat layers could be used for salt making. The areas where the peat had been taken away formed a suitable habitat for *Zostera*. This plant thus formed a good alternative for the salt peat. The area - not protected by dikes - could not longer be used for living, but was still suitable for the salt industry.

(4) A strip of peat was left and it formed a ridge in the mud flat area where salt making by using *Zostera* was continued.

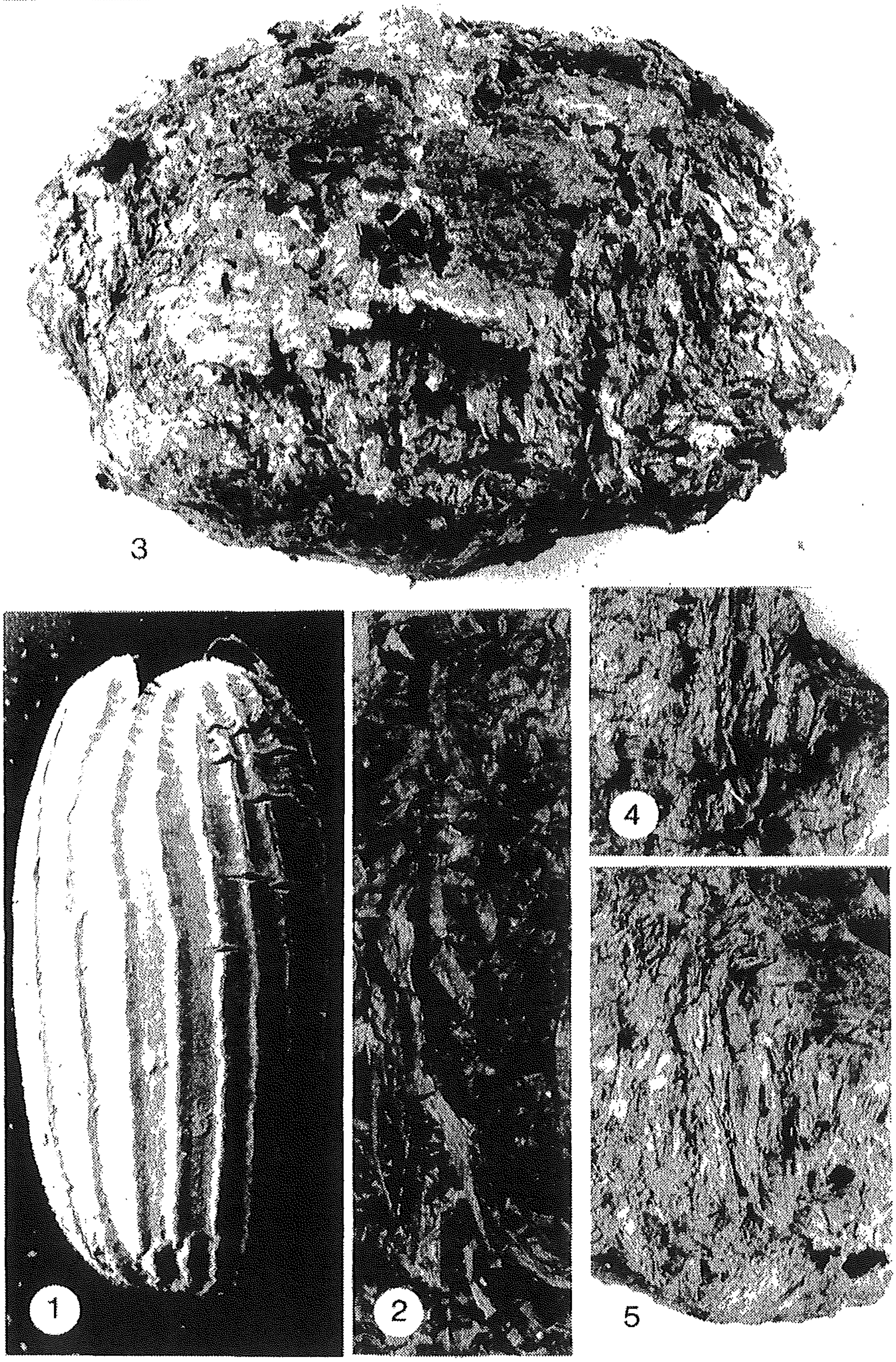
(5) The salt making activities had to be finished as a consequence of the rising sea level. The complete area was covered by the marine deposits.

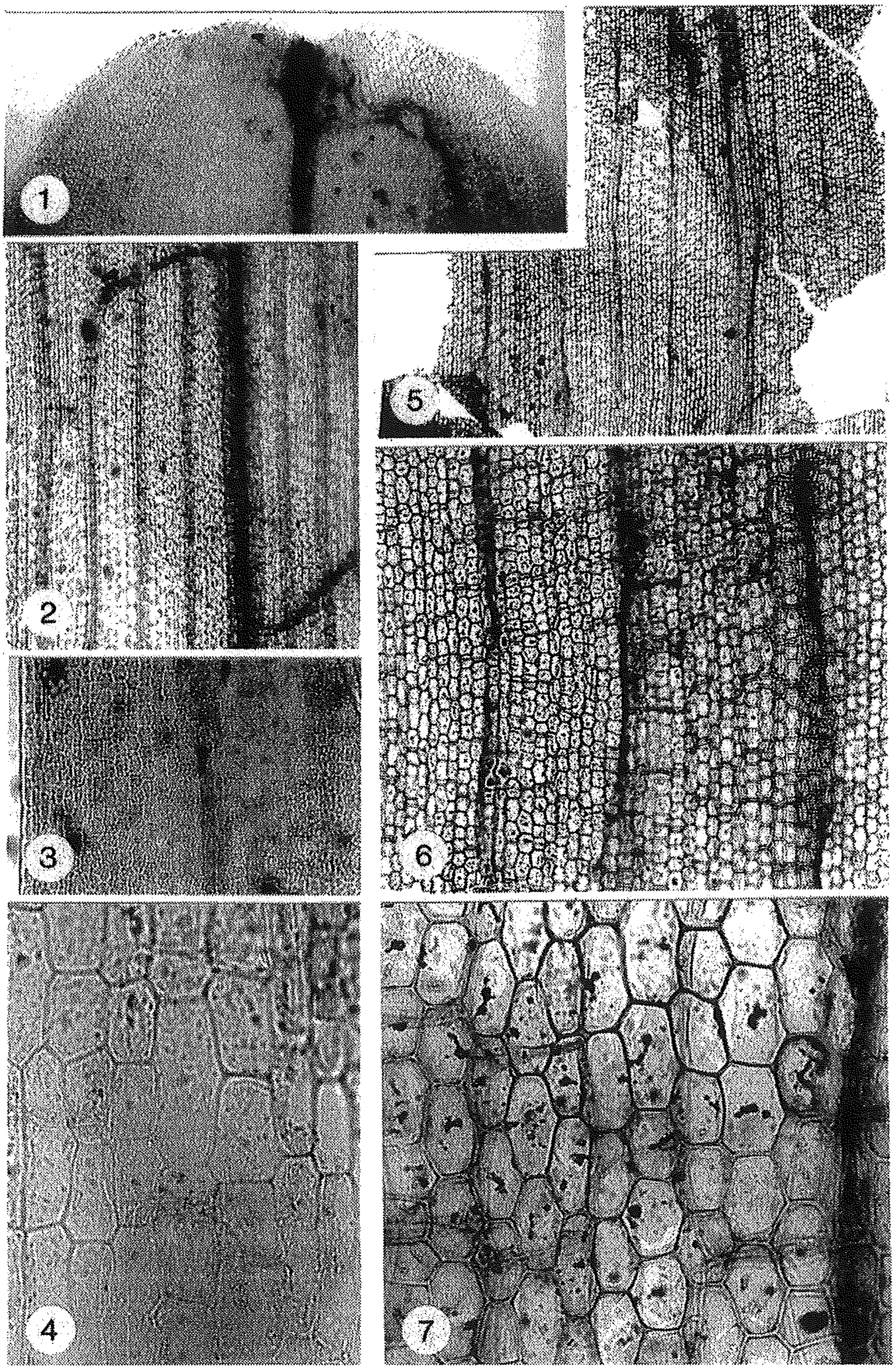
(6) When the Waardpolder was created, the peat strip in the subsoil became visible after plowing of the land (bringing up peat and ash).

Plates showing *Zostera* remains from excavation Waardpolder: see next two pages.

Plate I: Subfossil and incinerated remains of *Zostera marina* from the excavation near Kolhorn.
1. Seed of Zostera (x 32) found in compact layers of subfossil *Zostera*.
2. Subfossil vegetative remains (x 1,6).
3. Grey ash-lumb with recognisable remains of *Zostera*.
4 and 5: Ash with *Zostera* remains.

Plate II: Microscopical leaf structures (various magnifications) of subfossil and incinerated remains of *Zostera marina* from the Kolhorn excavation.




1
2
3
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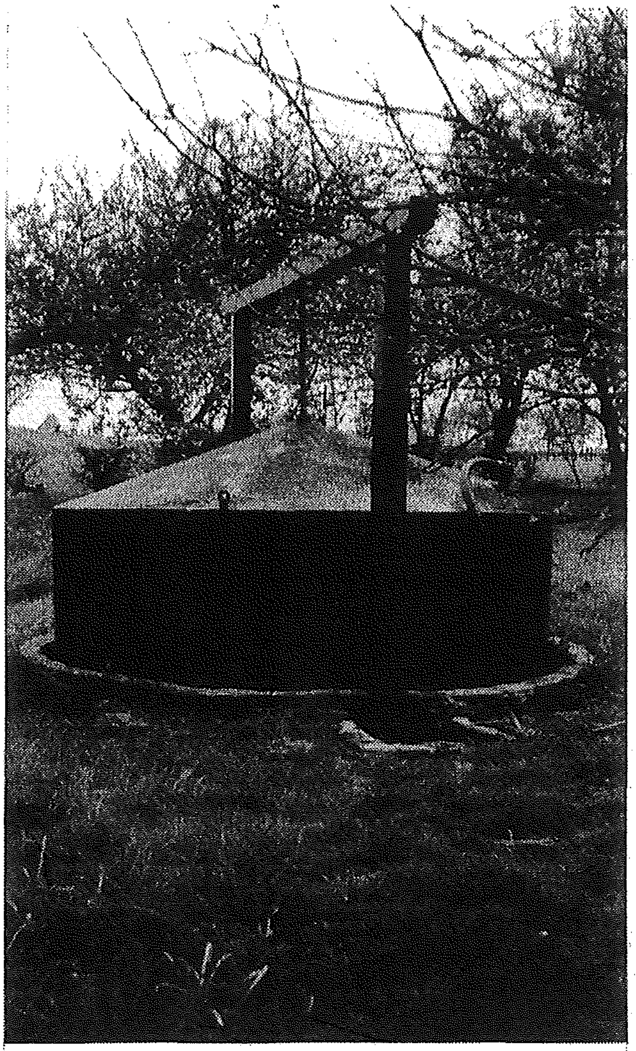
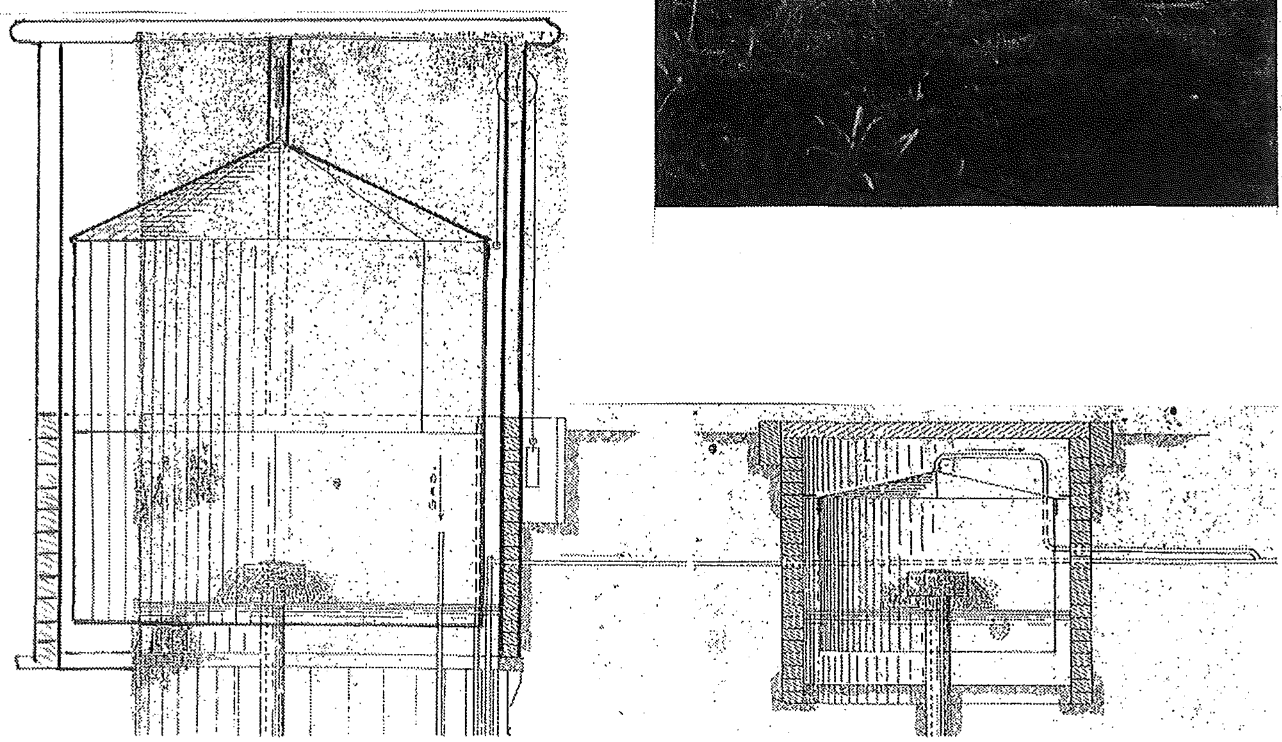
6
7

Marshgas wells (Sumpfgasbrunnen) in the polders of Noord-Holland
At 40 - 60 m deep marshgas is present in several areas in Noord-Holland. It is the decomposition product of early Holocene peat layers. The gas is under pressure because it cannot escape (overlying, impermeable marine clay layers and heavy sand and peat deposits). The gas is dissolved in water. It is a mixture and the main components are methane (57-92%), carbondioxide (3-20%) and nitrogen (4-36%). Reference: Overbeck, 1975, p.119.

In the provinces of Holland and Friesland marshgas was used as a fuel from ca 1895 on. Wells were made by coring, and pipes were installed that ended in a floating gas tank. Water with gas streams upwards through the pipe.



The pressure diminishes when the water flows out and the escaping gas is trapped under the heavy tank. This tank is floating on water in a cylindrical tankholder. The tank has a pipe connection with the house, where the gas is used for heating, cooking and making light. Around 1950 thousands of wells were still in use, but nowadays this has become a rare and old-fashioned way of using fossil fuel. Objections are made by the authorities because the brackish upwelling water is discharged into the ditches, which is bad for crop plants, cows, etc.
We will see a marshgas installation in the Beemsterpolder near Schermerhorn (J. van der Hoek; Westdijk nr 8). Such installations are only effective in the deep polders (former lakes). In the area of the adjacent 'old land', where the upper peat deposits are still present, the soil surface is too high (pressure from below is not sufficient for pushing up the water with gas from the deep layers to the surface). The weather is playing a role in the whole process: the lower the air pressure is, the more water and gas can escape from below!



Outline (1917) of two coupled marsgas wells as they were constructed in the Beemster polder

About the present landscape of Noord-Holland and its history

See also p. 193-203

On our way to **Waterland** (the area just to the north of Amsterdam) we will get an impression of a characteristic landscape of Holland: meadows on top of several meters of raised bog deposits, but also polders, which are former lakes that were reclaimed by using windmills, more than 300 years ago. We will enjoy the area of Waterland on bikes. Our start and finish is in the village of Broek-in-Waterland (Broek = Bruch(wald) = wet forest). We will discuss the reclamation activities of mediaeval pioneers. We will see the traces of disastrous floods: lakes which were formed after peat erosion where dikes had broken during storm surges. Also the effects of peat cutting and dredging are evident.

In the southern and eastern Netherlands the holocene raised bogs on top of Pleistocene deposits could be drained efficiently and subsequently cut away and used as fuel. However, in the western Netherlands most of the peat deposits are situated under the ground water table (nowadays below mean sea level). Also in the western Netherlands enormous quantities of peat were removed (cutting, and later dredging). Using the remaining archives of peat deposits and lake sediments in Noord-Holland we tried to reconstruct the developments of the landscape (Pals et al., 1980; Bakker and van Smeerdijk, 1982; van Geel et al., 1983a, 1983b; Witte and van Geel, 1985; Willemsen et al., 1996). We studied changing trophic conditions, based on the record of successive local stands of vegetation, and also human impact and the effects of storm surges.
In most cases peat growth started in eutrophic conditions and the increasingly thick peat layers formed a barrier for nutrients from the mineral subsoil and the ground water, so that after a mesotrophic phase, ombrotrophic raised bog growth started. The Ilperveld sequence (Bakker and van Smeerdijk, 1982) shows the most complete, longest record. p. 105-106

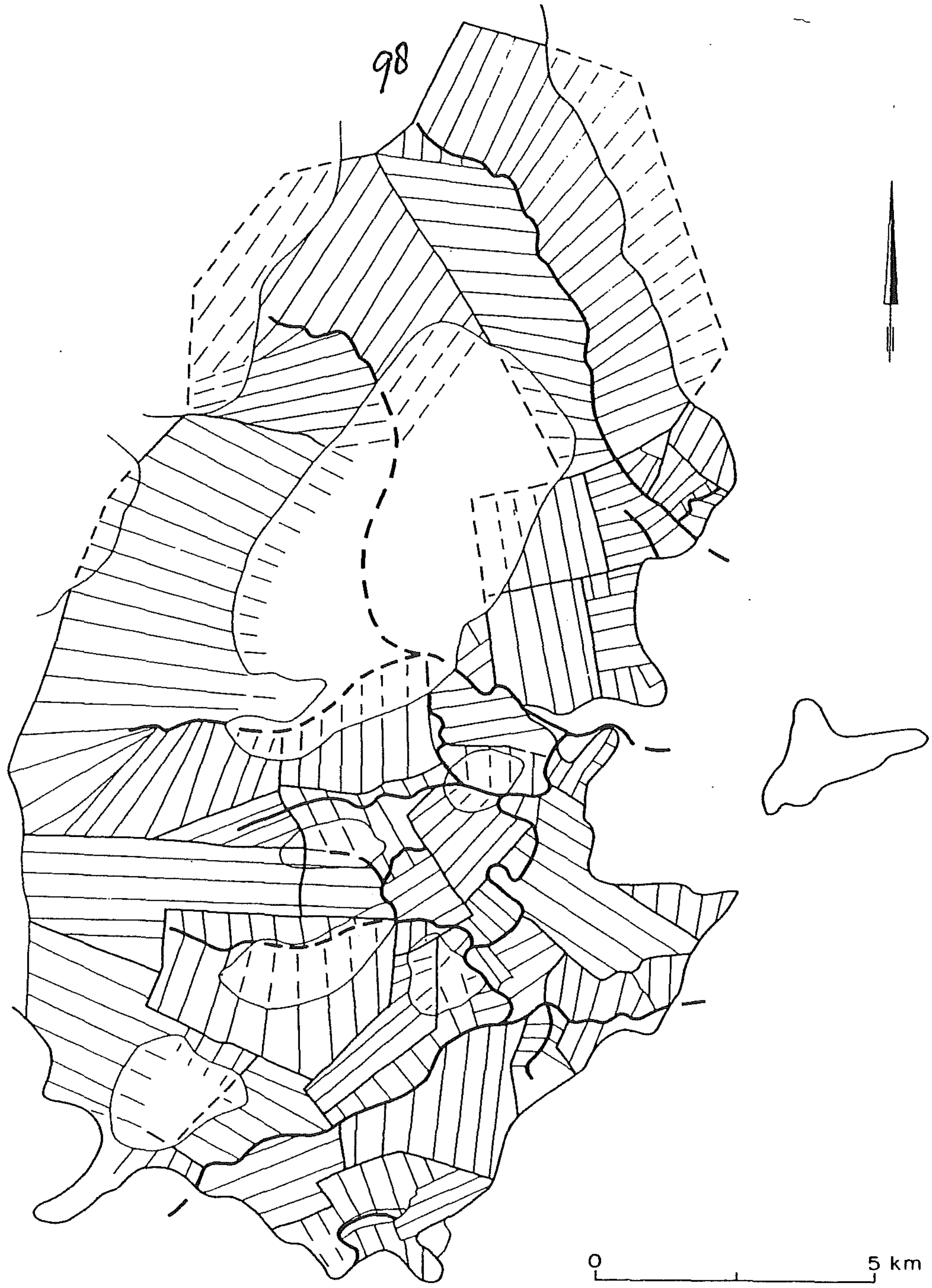
From the 10th century AD on, farmers invaded the raised bog areas: pioneers started drainage by making ditches and farming became important. The original, mediaeval pattern of main ditches (see illustration) shows that the direction of the water in natural bog rivulets played a role in the planning: the direction of ditches often is related to the downstream direction of the rivulets.
Local field-names of meadow parcels, and also the shape of parcels give information about mediaeval habitation: based on archaeological data (pottery fragments, etc.), the parcels with 'laan'-names often appeared to be sites where mediaeval houses had been present (see illustrations).

Palaeoecological records provide a unique insight into the fragility of bog ecosystems in response to human activity. Most of the peat studies in the western Netherlands were worked out to solve archaeological questions. However, the reconstruction of the vegetation successions may be detailed enough (information about duration and direction of stages) so that the data might be useful in the planning, restoration and management of wetland nature reserves.

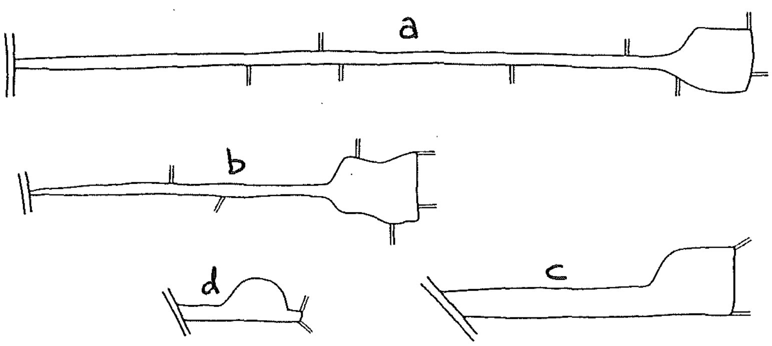
In the meadow area on top of peat deposits ('veenweidegebied') in Noord-Holland there are sites where, as a relict, or after recent vegetation succession, oligotrophic vegetation types are present. The species composition of these sites is not very different from the taxa of the raised bog ecosystems which once dominated the landscape. However, in many cases the continuity of these oligotrophic sites depends on management (mowing and removing of the mowed vegetation). Without mowing *Betula* carr would start to dominate.
In Noord-Holland there is an extra factor which works out in a positive way for plants preferring ombrotrophic conditions: the ground water for a long time was, and still is brackish because of the many inundations by the sea, and also because of connections with the sea through canals.
Brackish water is heavier than rainwater, so in the wetland vegetation types a lens of rainwater is formed on top of the brackish ground water. This phenomenon accelerates oligotrophication and thus stimulates the growth of *Sphagna* and other raised bog plants.

We still are not sure about the question if the pioneer-farmers settled on undisturbed raised bog (because of dry 10th century?) or if these areas had already been drained and eutrofied by natural processes. From the study of the mediaeval site Poppendam (Willemsen et al., 1996) it became clear that at least some (marginal?) raised bog areas were already eutrophied for natural reasons long before the arrival of the pioneer-farmers.

See p. 101



Patterns of ditches in relation to former natural rivulets in the raised bog complexes of Waterland (Bos, 1988, based on Pons and van Oosten, 1974)

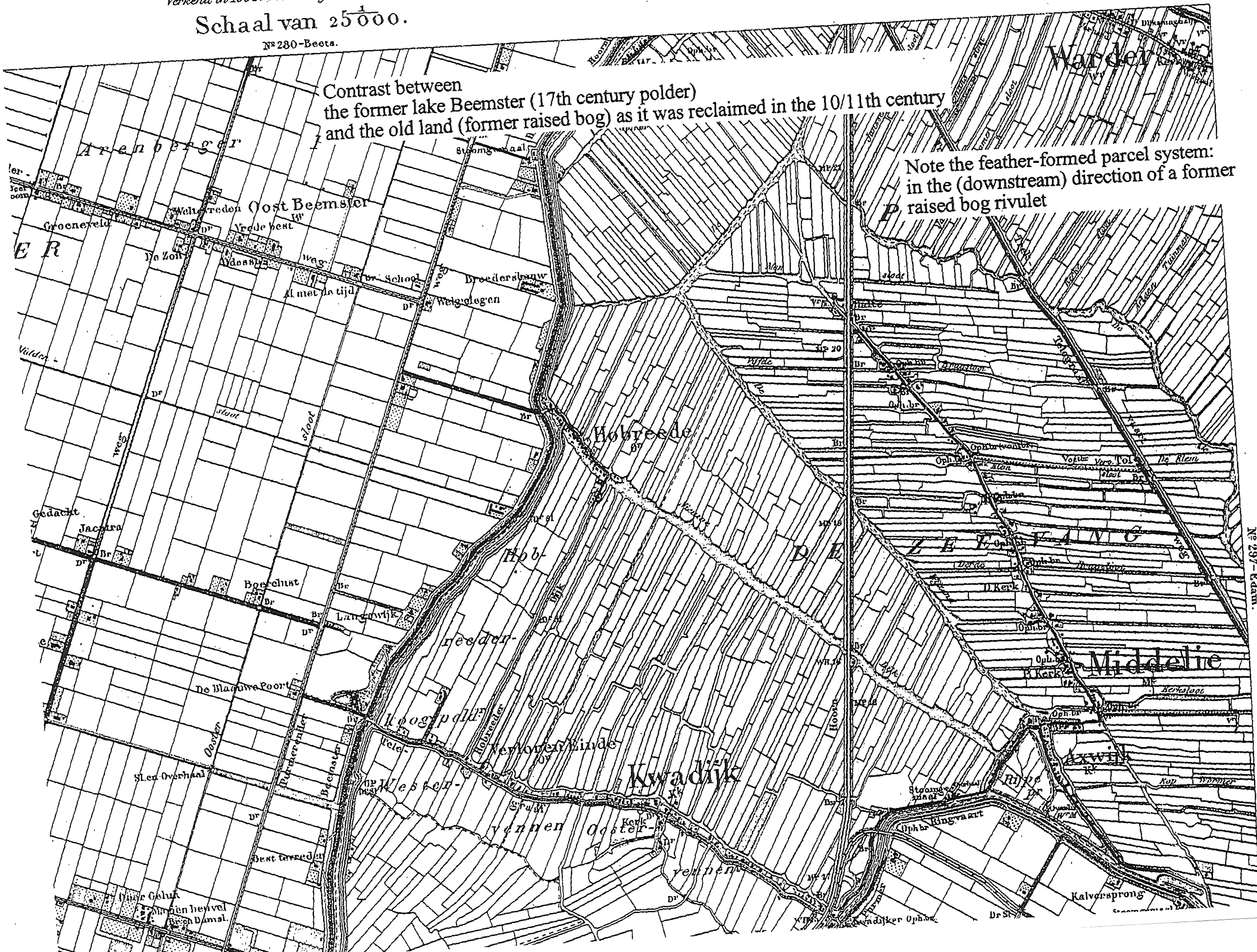


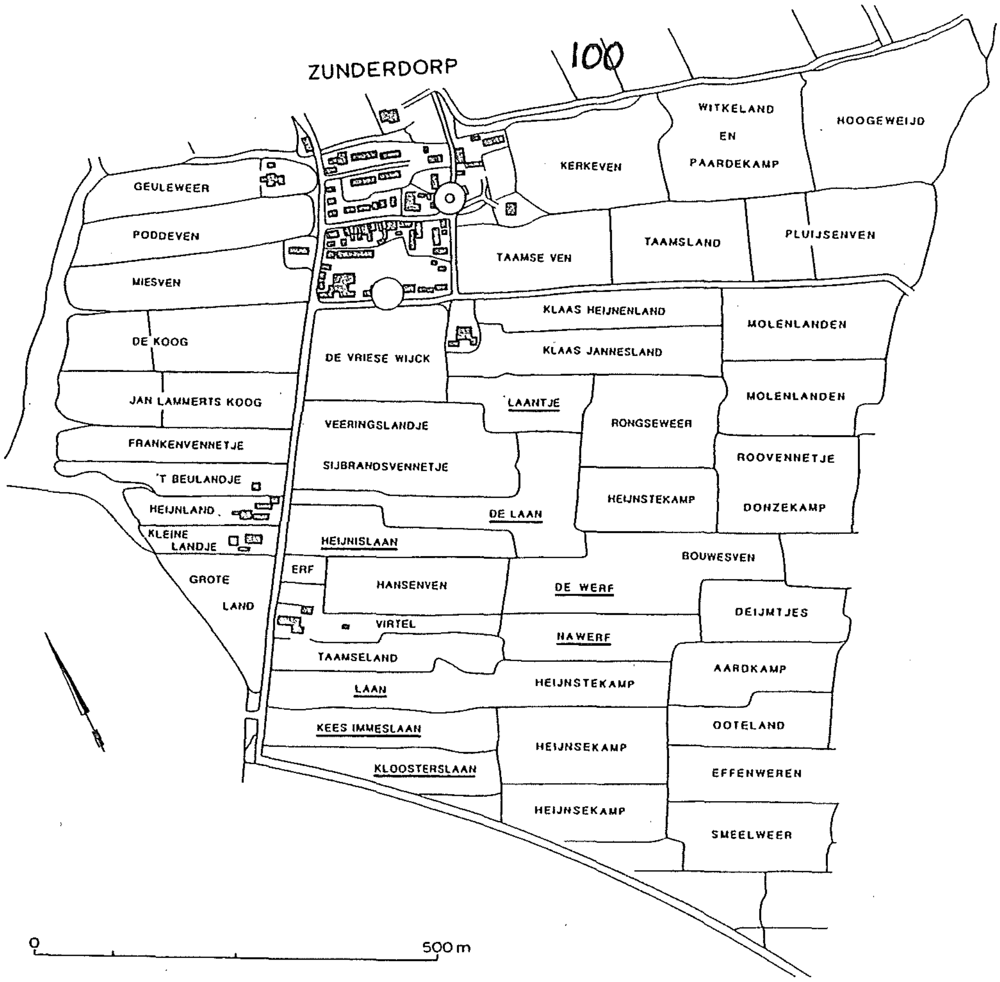
Examples of parcels with 'laan'-names
(cf. 'lane' in English)
a: **Lange Laan**, near Schellingwoude
b: **Matthijslaan**, near Schellingwoude
c: **'t Laantje** near Zunderdorp
d: **Kees Immeslaan** near Zunderdorp

Verkend in 1892. Gedeeltelijk herzien in 1906.

Schaal van $\frac{1}{25000}$.

No 280-Beets.





18th century field names near Zunderdorp. Names of parcels (nowadays all pasture land) indicating early settlements ('laan', 'werf') have been underlined. Compare the illustration below (Bos, 1988).

Medieval house sites near Zunderdorp. (based on pottery fragments from dredged ditches and other archaeological observations; Bos, 1988).