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Holocene palaeogeography and palaeoecology of the fluvial area near Maurik (Neder-Betuwe, The Netherlands)

J.L.A. Hofstede[1], H.J.A. Berendsen[2] & C.R. Janssen[3]
[1] *Institut für Geographie, T.U. Berlin, Budapesterstr. 44–46, 1000 Berlin 30, Bundesrepublik Deutschland;*
[2] *Geographical Institute, University of Utrecht, Heidelberglaan 2, 3508 TC Utrecht, The Netherlands;*
[3] *Laboratory of Palaeobotany and Palynology, University of Utrecht, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands*

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Abstract

In the Holocene river basin 'Het Broek' (Fig. 1) fluvial deposition of clay by six different river systems alternated with peat formation. The accumulation rate of peat in the backswamps between 8000 BP and 4000 BP was fairly constant; it averaged about 7,5 cm/century. Pollen analysis and radiocarbon dating were used to determine phases of fluvial activity. Both the lithostratigraphy and the pollen diagram reflect a number of flooding phases. Phases of fluvial deposition do not seem to be synchronous with those in the perimarine area, farther to the west. A clear decline of elm contemporaneously with a maximum in the ash values in the Early Neolithic is discussed in terms of changes in the water regime of the river and possible human interactions.

Introduction

The Holocene Rhine/Meuse delta in the Netherlands has been subdivided by Hageman (1969) into a marine, a perimarine and a fluvial area. Many aspects of the perimarine and fluvial parts of the delta have been studied in detail in the past 15 years.

Palaeogeographic research has been carried out by Verbraeck (1970) and Berendsen (1982) in the perimarine district, and by Havinga & Op 't Hof (1983) and Verbraeck (1984) in the fluvial district. Also, archaeological research was carried out in the perimarine district (Louwe Kooijmans, 1974) as well as in the fluvial district (Willems, 1986). Palaeoecological research was focused mainly on the perimarine district (Van der Woude, 1981); palaeoecological studies of the fluvial district have hardly been published.

This study focuses on the fluvial area near Maurik, the Netherlands (Fig. 1). Both the lithostratigraphy (Fig. 2) and the pollen diagram (Fig. 3) reflect a number of local (or regional) flooding phases. More pollen analysis in various river basins is necessary to verify the general trend. This study is part of a more extensive study, aimed at giving detailed reconstructions of both the palaeogeography and the palaeoecology of the fluvial area. Such reconstructions are used to help establish whether phases of fluvial deposition and peat formation can be correlated over wider areas, especially with those distinguished by Hageman (1969) for the western part of the Netherlands.

Methods

A new detailed geological map, scale 1:50,000 was prepared, based on 1300 handborings, 200 of which reached the Pleistocene subsoil. The map (Fig. 1) is more detailed than the geological map of the Netherlands, scale 1:50,000 published by Verbraeck (1984). Borings were carried out with the 'Edelman' hand auger, gauge, 'Van der Staay' suction corer and Livingstone corer, by students of Physical Geography at the State University of Utrecht.

A core from the river basin 'Het Broek' (Fig. 1) was selected for palynological research. Samples of the core were boiled in KOH (10%), sieved, and treated with HF (40%), before acetolysis. The identification of pollen in 33 spectra was based on Moore & Webb (1978). In the pollen sum only pollen types belonging to the regional vegetation were incorporated; at least 200 of these pollen grains were identified per pollen spectrum. Three samples of the core (Broek I, II, III) were radiocarbon dated (Table 1).

Fluvial deposits and Palaeogeography

During the Late Weichselian the investigated area was part of the Rhine/Meuse valley in which the Kreftenheye Formation was formed (Verbraeck, 1984). The top of this formation, which is at a depth of 0.2 to 2.4 m minus NAP (NAP = Dutch Ordnance Datum) that is 3.7 to 5.4 m below the surface (Fig. 2), consists of gravelly fluvial sands, generally covered with a layer of loam of approximately 0.2 to 0.4 m thick.

The Holocene sequence in the river basin 'Het Broek' (Figs. 2 & 3) generally consists of an approximately 3 m thick layer of peat, clayey peat and peaty clay (belonging to the Broek Formation ac-

Table 1. Radiocarbon dates

name	GrN number	^{14}C age y BP	coördinates (x–y/z)	depth in m below surface	material
1. Eck en Wiel I[1]	6231	1635 ± 50	159.215 – 440.420/+5.6	4.62 – 4.75	base of humic clay in residual gully
2. Eck en Wiel II[1]	6232	5530 ± 55	158.540 – 440.460/+5.5	3.34 – 3.39	base of humic clay
3. Eck en Wiel II[1]	6233	4935 ± 60	158.540 – 440.460/+5.5	1.63 – 1.75	base of strongly humic clay
4. Lopikerstroom V[2]	7957	5350 ± 35	124.555 – 443.850/–0.8	4.85 – 4.90	base of strongly humic clay
5. Kromme Rijn I[2]	8706	3000 ± 35	144.382 – 449.450/+2.6	1.85 – 1.90	top of strongly humic clay
6. Zandberg 8	12.460	4235 ± 40	152.852 – 439.762/+2.8	1.45 – 1.50	top of clayey peat
7. Zandberg 9	12.461	5350 ± 40	152.852 – 439.762/+2.8	2.25 – 2.30	base of clayey peat
8. Broek I	12.468	7700 ± 110	156.490 – 439.540/+3.3	5.24	base of strongly humic clay
9. Broek II	12.469	5970 ± 70	156.490 – 439.540/+3.3	3.80	peat
10. Broek III	12.470	4390 ± 60	156.490 – 439.540/+3.3	2.40	top of peat
11. Ommeren stream ridge	12.458	2100 ± 35	158.430 – 439.552/+4.1	2.30 – 2.40	base of peat in residual gully

[1] published by DE JONG (1980) and BERENDSEN (1982)
[2] published by BERENDSEN (1982)

cording to Berendsen, 1982), overlain by a 2 m thick layer of fluvial clay (belonging to the Betuwe Formation). Peat alternates with clay and sandy clay (Fig. 2) near the margin of the river basin. The layers of clay were deposited successively by at least six different meandering river systems. The meander belts of these river systems consist of sandy channel deposits, overlain by an approximately 0.5 to 1.0 m thick cover of clayey bank deposits. The meander belts are 0.5 to 2.0 m higher than the flood basins. The zone where channel and bank deposits occur, is called a stream ridge. In Fig. 1 the stream ridges and their age are shown.

Peat formation in the swampy river basin 'Het Broek' started in a depression in the Pleistocene subsoil (Fig. 2) at a level of 2 m − NAP around 7700 ± 110 BP (GrN 12468). At this time sea level was at approximately 20 m − NAP (Jelgersma, 1979). This means that sea level rise cannot be held directly responsible for the onset of peat formation. Most likely seepage from the nearby Pleistocene ice-pushed ridges (Fig. 1) and river flooding stimulated the beginning of peat formation. This explanation agrees with the opinions of De Vries (1974) and Berendsen (1982). Peat formation ended around 4390 ± 60 BP (GrN 12470), because of increasing fluvial deposition (Fig. 2). This date is confirmed by a radiocarbon date of the top of the peat (Table 1: Zandberg 8), just west of the investigated area: 4235 ± 40 BP (GrN 12460).

The oldest stream ridge in the area (Fig. 1) is called the Maurik stream ridge after the nearby village of Maurik. This ridge is about 750 m wide. To the SW of the investigated area it is connected with the Tienhoven stream ridge (Berendsen, 1982, pp. 146–148, Verbraeck, 1984). The channel deposits consist mainly of fine to coarse sands. The slope of the top of the sand is 18 cm/km to the southwest, which is only slightly less than the slope of the Pleistocene subsoil (24 cm/km, according to Pons, 1957). According to De Boer & Pons (1960) the Tienhoven stream ridge is of Late Atlantic age. Their pollenanalytic dating is confirmed by radiocarbon datings of the overlying peat at two locations 30 km apart: in the Lopikerwaard (Berendsen, 1982): 5350 ± 35 BP (GrN 7957), and, just west of the investigated area, 5350 ± 40 BP (GrN 12461, Table 1: Zandberg 9).

The Zoelen stream ridge (Fig. 1) is a subsidiary branch of the Ommeren stream ridge. Both the Zoelen and the Ommeren stream ridges are 500 to 1000 m wide. The channel deposits consist of fine to very coarse sands with gravel. The Ommeren ridge contains much more gravel than the Zoelen ridge. The slope of the sand in the Zoelen stream ridge is about 20 cm/km to the west, that of the Ommeren ridge is about 12 cm/km to the north.

According to Verbraeck (1984) the main period of sedimentation of the Ommeren as well as the Zoelen streams was from 5530 ± 50 BP (GrN 6232) to 4935 ± 60 BP (GrN 6233). Palynological data (Fig. 3) correspond well with these dates. Based on archaeological evidence Havinga & Op 't Hof (1983) concluded that the Ommeren stream had a second phase of sedimentation, namely between 3000 and 2050 BP. They assumed that sediments of this age occur also along the Zoelen stream ridge. This, however, was not confirmed by our field study. Lithostratigraphy suggests that sediments of this age are present only along the Ommeren ridge and to the east of the area investigated (Offerein, 1987). In the residual gully of the Ommeren ridge (Fig. 1), at a depth of 2.35 m below the surface, the base of a layer of peat, directly overlying coarse fluvial sands, has been radiocarbon dated (Table 1: Ommeren stream ridge): 2100 ± 35 BP (GrN 12458). The residual gully therefore seems to belong to the younger phase of sedimentation.

A fragment of the younger Houten stream ridge is present in the northwestern part of Fig. 1. Detailed information on this stream ridge has been published by Berendsen (1982), Havinga & Op 't Hof (1983) and Verbraeck (1984). The channel deposits consist of medium coarse to very coarse sands with some gravel. The local slope of the top of the sand is 14 cm/km to the west. According to Berendsen (1982) the main sedimentation phase lies between 4000 and 2225 BP, according to Havinga & Op 't Hof (1983) between 3800 and 2050 BP.

To the west of the village of Maurik (Fig. 1) channel deposits of the Kromme Rijn stream ridge occur. They consist of medium coarse to coarse

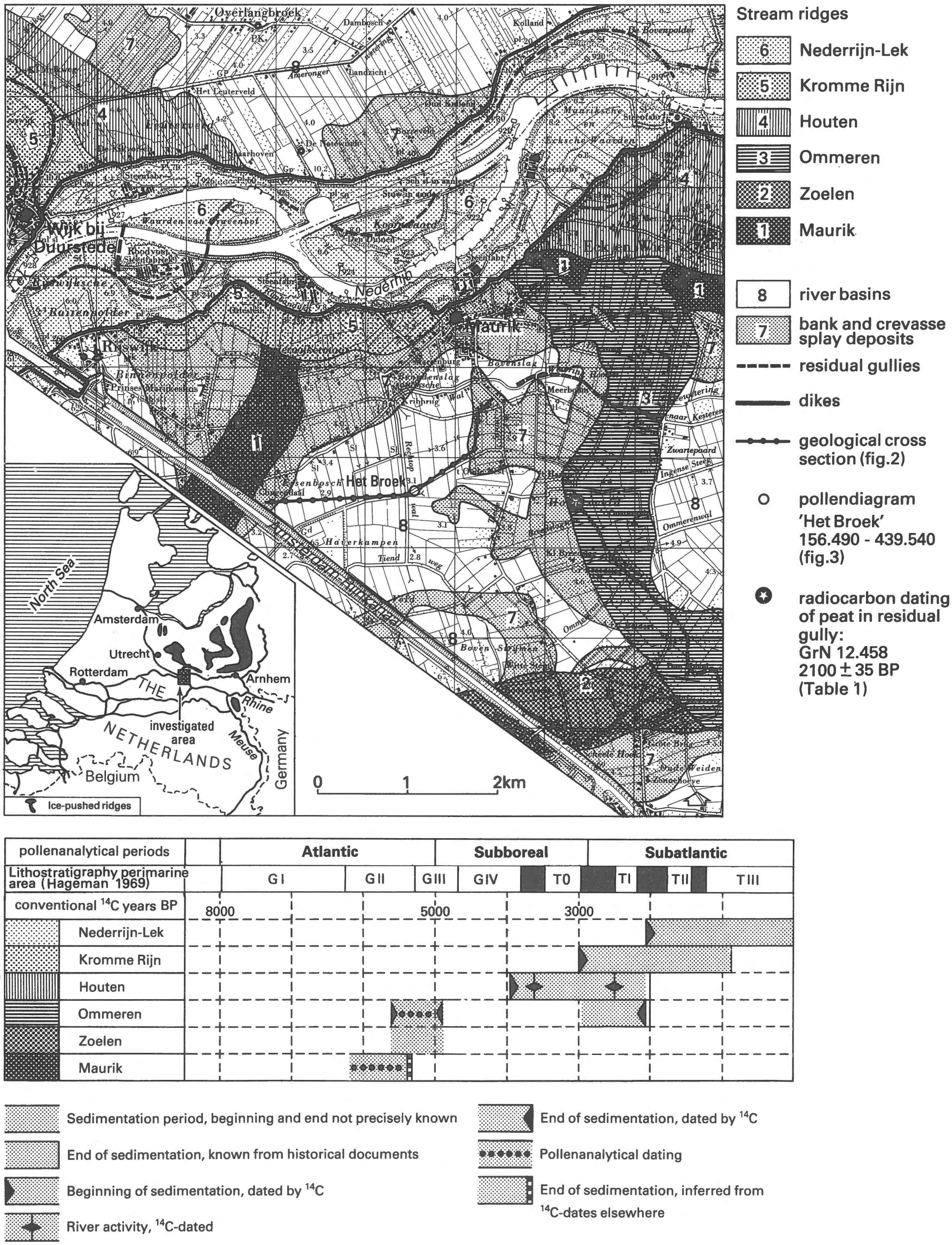

Fig. 1. Geological map of the investigated area, and age of the stream ridges.

sands. Bank deposits are found overlying a vegetation horizon, that was dated between 3800 and 3000 BP, based on archaeological evidence (Havinga & Op 't Hof, 1975). This corresponds well with a radiocarbon date of peat, underlying fluvial clay deposited by the Kromme Rijn (Berendsen, 1982): 3000 ± 35 BP (GrN 8706). In 1122 AD the river was dammed at Wijk bij Duurstede (Dekker, 1980).

The present meander belt of the river Nederrijn-Lek consists of two distinctly different parts. East of Wijk bij Duurstede the meander belt of the Nederrijn is much wider, because it includes also a large part of the former meander belt of the Kromme Rijn. West of Wijk bij Duurstede sedimentation of the river Lek started only after 2000 BP (Berendsen 1982), probably at the end of the Roman period.

The period of sedimentation of the various river systems is also indicated in Fig. 1. It seems that river sedimentation in this area was restricted only during the Early Subboreal. Sedimentation phases as described by Hageman (1969) for the perimarine area in the western Netherlands obviously cannot be corroborated with those in Fig. 1.

Peat

Fig. 2 is a geological cross section of the river basin 'Het Broek', showing the main types of peat. The basal peat layers generally are composed of reed peat. In the middle and western part of the section reed peat is overlain by wood peat (with alder as its main constituent). At a level of about 0 m NAP in many boreholes reed is again the main constituent of the peat. This means that the ground water level in the swamp was relatively higher, probably as a result of inundations by the rivers of the Ommeren and Zoelen stream ridges. At a level between 0 and 1 m + NAP in the cross section wood (alder) peat is more abundant again. At the top of the Broek Formation reed is the main component, as a result of increased flooding of the river of the Houten stream ridge. The overlying flood basin deposits are deposited by the Houten, Kromme Rijn and Nederrijn-Lek rivers.

In the Alblasserwaard, approximately 40 km to the west of this area, Van der Woude (1981) found thick layers of gyttja intercalated with peat. The gyttja layers were considered to indicate a fluvio-lacustrine or fluvio-lagoonal origin. In the area near Maurik, however, gyttja has not been found. This means that large lakes of a fluvio-lagoonal origin probably never existed here. It seems reasonable to conclude, that during the Holocene the area was always located well east of the region with tidal influence and the environment must be considered to have been strictly fluviatile.

From the middle of the river basin (Figs. 1 & 2) a core was selected for pollenanalytic investigation, in order to study the relationship between river activity and peat formation.

Pollen analytical studies and radiocarbon dating

In the pollen diagram the regional pollenzones (based on Zagwijn & Van Staalduinen, 1975, and De Jong, 1971) are indicated on the left. The boundary between subzones II and III is based on the *Pinus*/*Alnus* intersection, at a depth of 5.2 m below the surface. However, since *Alnus* values are already high, the lower part of the diagram might also belong to pollen zone III. The radiocarbon date of the level of the *Pinus*/*Alnus* intersection GrN 12.468: 7700 ± 110 BP indicates an Early Atlantic age in the sense of Mangerud et al., 1974. The boundary between subzones III and IVa (the beginning of the Subboreal) is based on a small fluctuation in the *Ulmus* curve at a depth of 3 m below the surface. This level lies in between the radiocarbon dates GrN 12.469 and GrN 12.470 (Fig. 3), and corresponds with an age of 5000 BP (Zagwijn & van Staalduinen, 1975). The boundary between subzones IVa and IVb (3700 BP) is based on the occurrence of *Fagus* in the diagram.

In addition to these regional pollen zones, the pollen diagram has been subdivided arbitrarily and informally in ten site zones on the basis of major changes in the pollen assemblages. These site zones (indicated on the right in Fig. 3) are based on combinations of fluctuations in the individual pol-

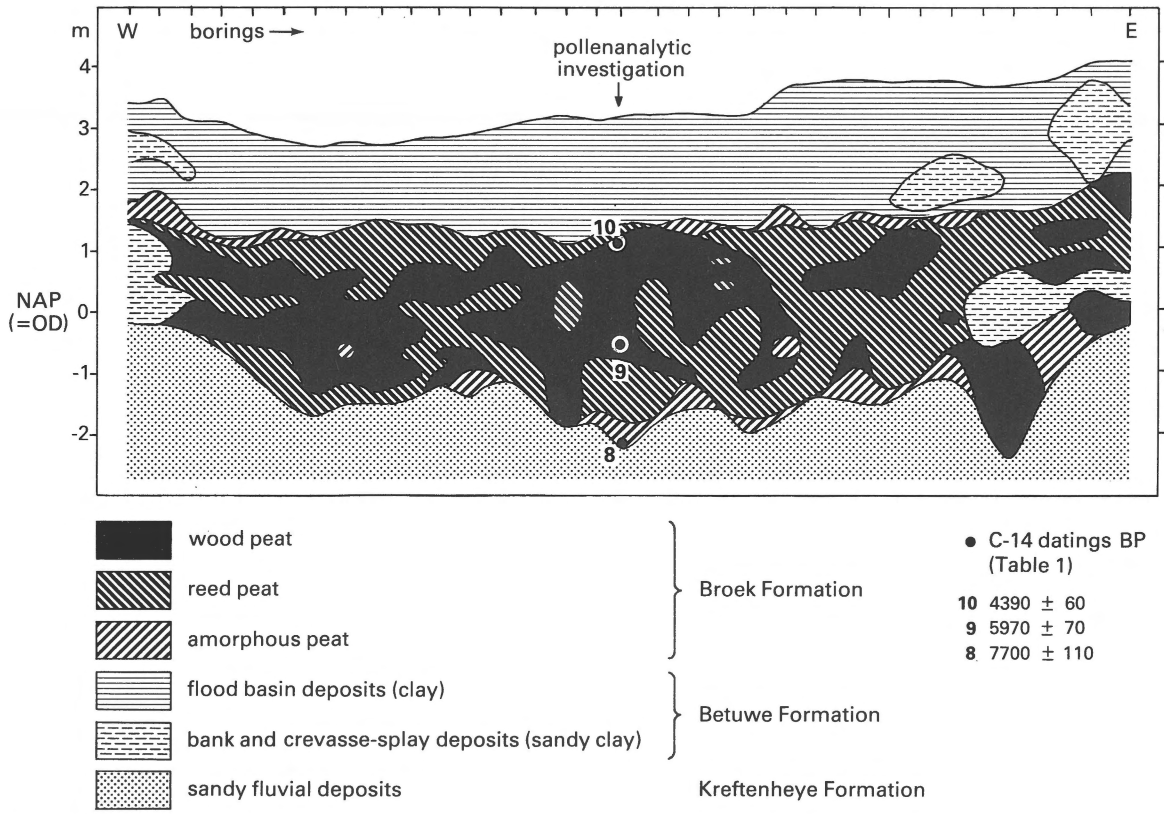

Fig. 2. Geological cross section.

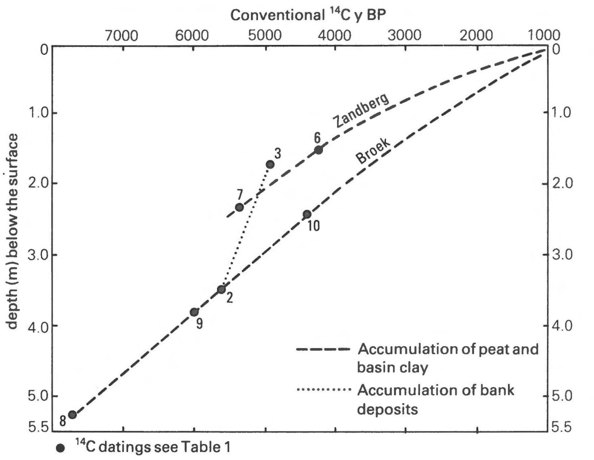

Fig. 4. Time-depth diagram of peat formation in the river basin 'Het Broek'.

len curves. More pollen diagrams are necessary to test the general applicability of the site zones.

In zone 1 pollen of *Pinus* dominates but *Alnus* reaches already 30%. Pollen of marsh and aquatic plants is hardly present.

In zone 2 the *Pinus* values decrease considerably, while those of *Quercus* and marsh plants increase. The area obviously became increasingly wet, probably as a result of seepage and river flooding, resulting in clay sedimentation.

In zone 3 the pollen values of *Corylus* and *Ulmus* reach a maximum. The vegetation of the lower parts of the swamp consisted of Poaceae and Cyperaceae.

In zone 4 the Cyperaceae values reach a maximum, while those of the Poaeceae and of *Salix* are relatively high. *Ulmus* and *Quercus* values decrease, while *Alnus* and *Fraxinus* values increase.

In zone 5 the Poaceae and Cyperaceae values decrease considerably, while those of *Alnus* increase and reach a maximum. This is probably a reflection of dryer conditions, with average water levels near or just above the surface (terrestrialisation).

Pollen of aquatic plants (*Nuphar, Alisma, Myriophyllum*, and *Typha latifolia*) is also present. This reflects the presence of open water at low-lying places in the swamp.

In zone 6 the *Alnus* values decrease (this is also the case if *Alnus* is excluded from the pollen sum), while those of the Poaceae increase again. Near the base of this zone the *Ulmus* values decrease below 5%. This level has been radiocarbon dated: 5970 ± 70 BP (GrN 12469). The *Ulmus* decrease is followed by an increase in the *Fraxinus* values. This phenomenon deserves some attention. The elm decline has been discussed extensively in the literature. It has been explained by climatic change, competition, soil deterioration, selective collection of leaf-fodder following pollarding, and disease, or a combination of Neolithic agriculture and disease (Berglund, 1986).

In this case, the elm (*Ulmus*) decline is followed by an increase in the values of ash (*Fraxinus*). This may be explained by assuming changes in the water regime of the river i.e. the frequency of inundations. If we consider that the original forest on the levees was a forest of mostly *Ulmus* and *Quercus* with some *Fraxinus* and that a general rise of the water level occurred, then *Fraxinus* would have been favoured at the expense of *Ulmus*.

We doubt however that a rise in water level took place. The decline in the *Alnus* values and the low values of Poaceae and Cyperaceae in zone 6 rather indicate a possible lowering of the water level. Moreover the type of deposit is pure peat without any admixture of inorganic material. Another argument against a rise of the water level is the absence of pollen of *Picea* and *Fagus*. *Picea* has never been indigenous in the Netherlands, whereas *Fagus* had barely migrated into this area around 6000 BP. These pollen types can be transported by the river Rhine during times of frequent inundations, as is demonstrated in the pollen diagram by the presence of these pollen types in the clayey peats and peaty clays of zones 5 and 8 and in the humic clay of zone 10. An other explanation of the disturbance in zone 6 would be to accept some human influence. Troels-Smith (1960) postulated that pollarding trees by Neolithic man in order to feed their cattle, leads to a reduction of the flowering capacity of the elm for 7 to 8 years, whereas the ash starts flowering again after a few years with an increased flowering capacity. Van Zeist (1959, pp. 160–166) showed this phenomenon for the Late Neolithic in the northern Netherlands.

In the perimarine area, about 40 km to the west of Maurik a decline of *Ulmus* around 5300 BP has been attributed to the Swifterband occupation phase (Louwe Kooijmans, 1974, 1985). However, the elm decline in our study is 700 years older, much too early to accept beginning cultivation ('landnam' in the sense of Iversen, 1949). Pollen of *Plantago lanceolata*, often considered an indicator of anthropogenic activities, is absent during the phase of the *Fraxinus* (ash) maximum. This pollen type appears (3 grains) in the deposits only at the top of zone 6, where elm reaches minimum values. Kalis (1988) demonstrated an *Ulmus* (elm) fall plus maxima of *Fraxinus* (ash) in the absence of *Plantago lanceolata* in the river valley of the Roer 16 km to the east of the Dutch/German border, at the time when these areas were densily populated during the Rössen phase in the Middle Neolithic (5900-5700 BP: Lüning, 1983).

A similar phenomenon can be observed in pollen diagrams from the northern limit of the areal distribution of the Rössen Culture (Wiermann & Schulze, 1986). According to the radiocarbon dates such a landnam occurred also during the Rössen phase. Kalis & Meurers-Balke (1988) also discussed the influence of the Rössen Culture on pollen diagrams.

Obviously pollen diagrams from adjacent Germany from the Early Neolithic seem to indicate the possibility of human influence. Although archaeological remains from the period 5000 to 6000 BP have not yet been found in the area, migration of people and cattle (transhumance) from arable

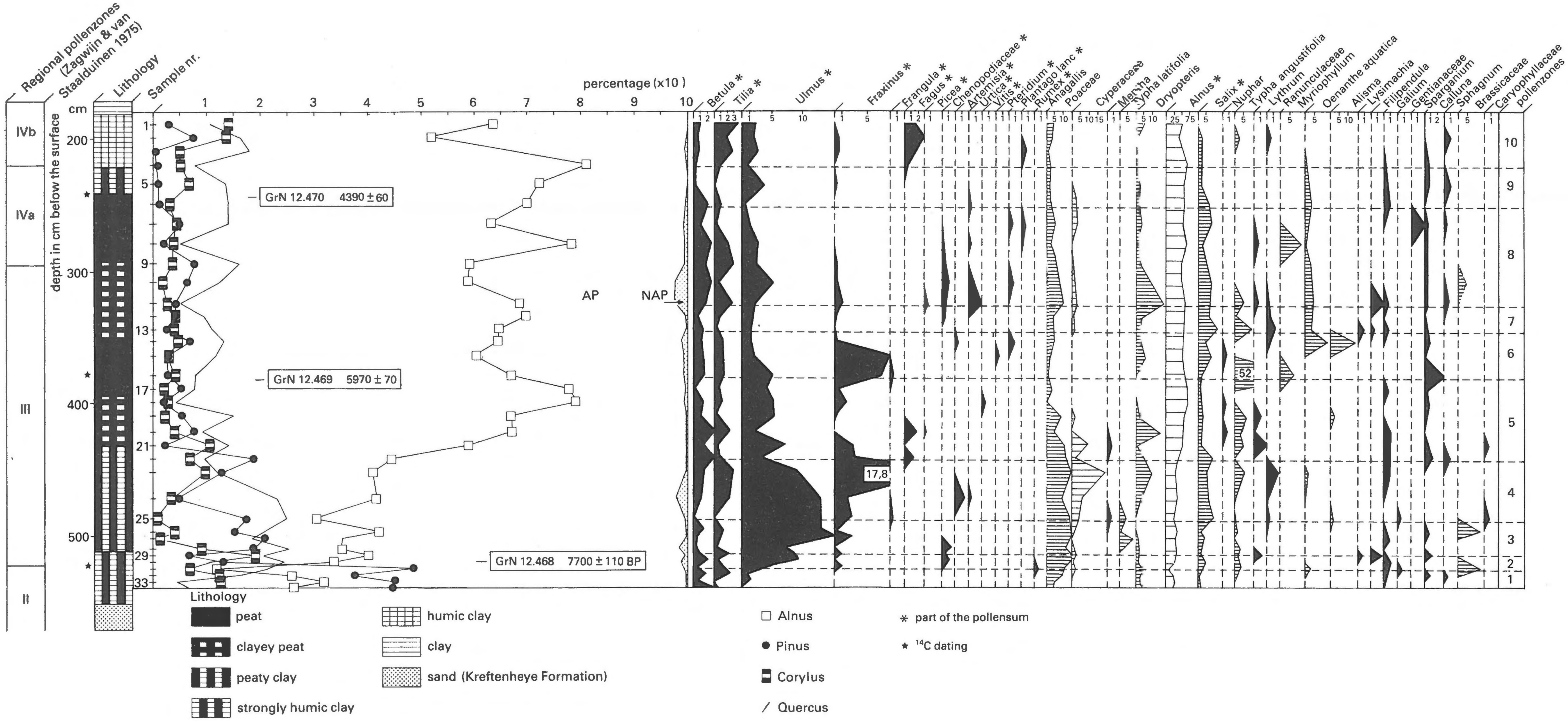

Fig. 3. Pollen diagram of river basin 'Het Broek'.

fields in the south (Bakels, 1983) is considered possible northward along the levees of the rivers. To confirm this hypothesis additional levels and sites must be analysed pollen analytically accompanied by radiocarbon dating of critical levels.

At the top of zone 6 maxima in the values of *Alnus, Alisma* and *Oenanthe aquatica* attest to flooding of the low-lying river basins. On the levees *Quercus* persisted.

In zone 7 pollen values of *Alnus* reach a relative maximum, while those of *Nuphar* and *Oenanthe aquatica* remain high. Near the top relative maxima of Poaceae, Cyperaceae and Typhaceae are found. This indicates that the area became increasingly wet. Also some pollen of *Picea* is found here, suggesting river activity (Van der Woude, 1981). The lithology (clayey peat) between 3.45 and 2.90 m below the surface also indicates increased river flooding, probably by the channels of the Ommeren and Zoelen stream ridges.

In zone 8 pollen values of *Alnus, Salix* and marsh and aquatic plants decrease, while those of *Corylus* and *Quercus* increase, indicating a relatively lower ground water table.

In zone 9 pollen values of *Alnus, Quercus* and *Corylus* are high; those of marsh and aquatic plants continue to decrease. The area obviously became relatively dry. Near the base of this zone peat formation ended as a result of sedimentation by the Houten river system: the peat became covered by a thick layer of clay. In zone 10 the pollen values of *Alnus* continue to decrease, while those of *Corylus* continue to increase, possibly as a result of migration of *Corylus* into the river basin.

The accumulation rate of both clay and peat in the backswamp can be calculated, based on the available radiocarbon datings (Table 1), and the assumption that sedimentation in the backswamp ended around 1100 AD (850 BP) when the rivers were embanked. The results are shown in Fig. 4. The average accumulation rate in the backswamp is about 9 cm per 100 C-14 years, or 7,5 cm/century if dendrochronologically calibrated dates are used. The accumulation rate of bank deposits, that occur in between samples 2 and 3 (Table 1) is about 24 cm/century. This corresponds with data given by Berendsen (1984) from the adjoining river clay area near Utrecht.

Summary of main palaeoecological and geomorphological events

In the Early Holocene the vegetation in the depression in the Pleistocene subsurface at the location of the present river basin 'Het Broek' (Fig. 2) was a forest with willow (*Salix*), hazel (*Corylus* and later alder (*Alnus*), with an undergrowth of ferns. At wet spots reed (Poaceae) and sedges (Cyperaceae) were found. On the higher and dryer grounds a forest with pine (*Pinus*) and hazel (*Corylus*) existed.

At the beginning of the Atlantic this forest was replaced by a forest in which oak (*Quercus*) dominated, together with genera like elm (*Ulmus*), linden (*Tilia*), hazel (*Corylus*) and some birch (*Betula*) and ash *(Fraxinus)* trees. At the same time peat formation started. In the marsh reed and sedge dominated, alder and willow probably grew near the margin.

During the Atlantic the marsh turned into a swamp: reed and sedge were gradually replaced by alder. This is the normal succession if water levels drop relatively due to the accumulation of peat (autogenic succession). During the second half of the Atlantic sedimentation of the Maurik stream began to influence the area, while peat formation in the swamp continued. Oak forest, mixed with elm, linden, hazel and some birch spread to the natural levees of the Maurik stream. Sedimentation of the Maurik stream ended around 5350 BP. Human influence on the vegetation may have started on the Maurik stream ridge. Between 5600 BP and 4950 BP the rivers of the Ommeren and Zoelen stream ridges deposited clay in the swamp. The inundations led to an expansion of reed, sedge and aquatic plants like fine-leaved water dropwort (*Oenanthe aquatica*), water plantain (*Alisma plantago-aquatica*) and yellow water lily (*Nuphar*). On the natural levees oak forest with hazel and linden persisted. Around 4400 BP peat formation ended as a result of sedimentation of clay by the Houten river system. This caused a relative drop in ground water level, and a migration of hazel trees into the swamp. On the natural levees beech migrated into the oak forest.

Sediments of the Houten, Kromme Rijn and Nederrijn-Lek river systems occur in the back-swamp as an approximately 2 m thick layer of clay, that cannot be differentiated into layers deposited by the individual river systems.

Phases of fluvial deposition in this area do not seem to be synchronous with phases of fluvial deposition that are supposed to exist (Hageman, 1969) in the perimarine area of the Netherlands.

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