

**STRATIGRAPHY, PALYNOLOGY AND RADIOCARBON DATING  
OF MIDDLE AND LATE WEICHSELIAN DEPOSITS  
IN THE DRENTSCHE AA VALLEY SYSTEM (DRENTE, THE NETHERLANDS)**

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ABSTRACT

De Gans, W. & P. Cleveringa 1981 Stratigraphy, palynology and radiocarbon dating of Middle and Late Weichselian deposits in the Drentsche Aa valley system (Drente, The Netherlands). *In*: A. J. van Loon (ed.): Quaternary geology: a farewell to A. J. Wiggers – Geol. Mijnbouw 60: 373-384.

A survey is given of the Middle Weichselian (Pleniglacial) and Late Weichselian (Late Glacial) deposits found in the Drentsche Aa valley system. The middle Pleniglacial succession consists of humic loam layers which are interpreted as thaw lake deposits. The upper Pleniglacial coarse fluvial sand is correlated with the lower part of the Beuningen Gravel Bed. Late Glacial aeolian and slope deposits cover these Pleniglacial deposits and relief. The tentative stratigraphic interpretation of these valley sediments is based on superposition and palynological data of pollen-bearing organic levels. However, the radiocarbon dates from the thaw lake deposits do not agree with this interpretation. Possible causes are discussed.

INTRODUCTION

The outlines of the Late Quaternary geology and geomorphology of the Aa area and the Eemian and early Weichselian fluvial deposits in the valley system were described by DE GANS (1980, 1981-a). This third paper deals with the Pleniglacial and Late Glacial deposits and stratigraphy in the valley. Organic layers interbedded within these valley deposits were found in two cross sections and in one exposure. They were investigated for their pollen content to establish the stratigraphic position of the deposits. The palynological data also provide information on the climate, vegetation and sedimentary environment. Radiocarbon dates obtained to establish the correlation and chronostratigraphic position of the organic layers may give too old data in Pleniglacial environments as will be discussed below.

OUTLINE OF THE AA VALLEY DEPOSITS

The Drentsche Aa valley is located at the eastern fringe of the Drente plateau which is situated in the north of The Netherlands (Fig. 1). The substratum of the valley sediments is composed of the Drente and Peelo Formations as described by TER WEE (1966, 1979) and ZAGWIJN & VAN STAALDUINEN (1975). The valley sediments are subdivided into (1) deposits of moderately sorted sand and gravel with mor-like levels or

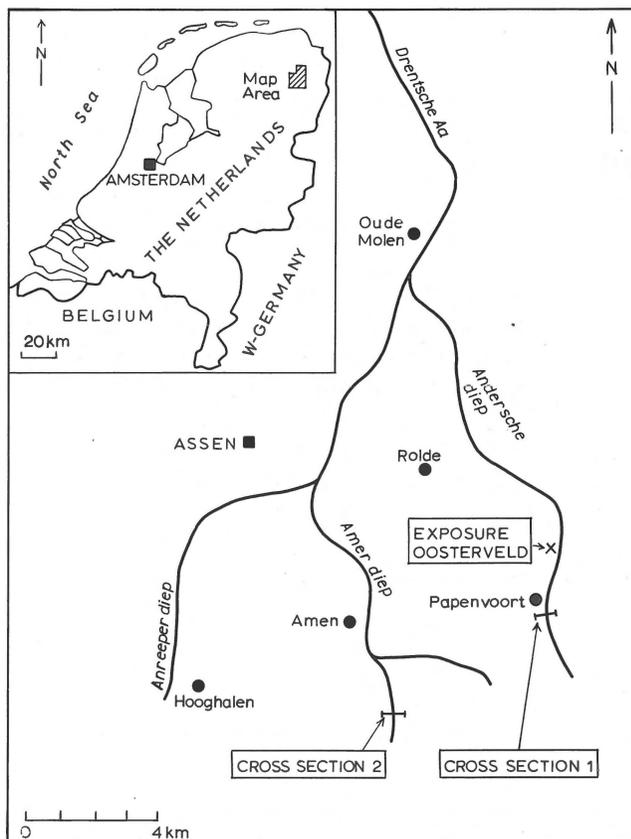


Fig. 1  
The Drentsche Aa area and the location of the exposure and the cross sections.

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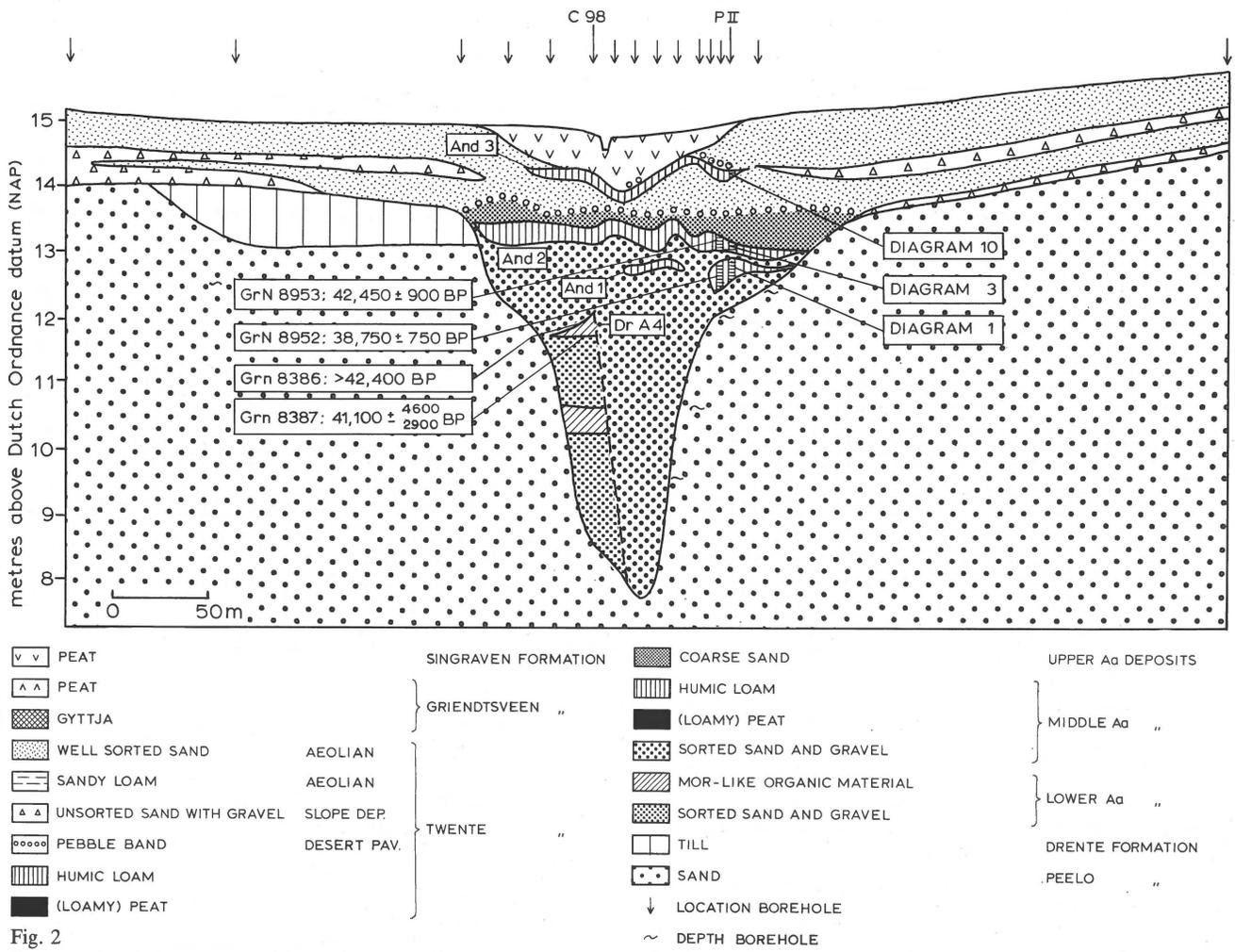


Fig. 2  
Cross section 1: Papenvoort (location: see Fig. 1).

humic loam layers; (2) well sorted sand occasionally containing loamy intercalations; and (3) unsorted sand mixed with gravel. These sediments were interpreted as fluvial, aeolian and slope deposits respectively (DE GANS, 1980, 1981-a). As no lithologic discrimination can be made between fluvial deposits of the Asten and Twente formations, the Weichselian and older fluvial sediments in the Aa valley are assigned to the Aa deposits (DE GANS, 1981-a). The aeolian and slope deposits are regarded as part of the Twente Formation (Table I). The slope deposits may pass laterally into a pebble band or have a pebble band on top. These pebble bands are, in accordance with KOLSTRUP (1980), VAN DER HAMMEN & WYMSTRA (1971), PAEPE & PISSART (1969) and VAN DER HAMMEN ET AL. (1967), interpreted as desert pavements. The aeolian deposits generally consist of sand (150-210 µm), loamy aeolian deposits being scarce in the Aa river area. The Singraven Formation overlies the Twente Formation in the valley and consists predominantly of eutrophic and mesotrophic peat (DE GANS, 1980; ZAGWIJN & VAN STAALDUINEN, 1975). Peat and gyttja located in topographic depressions in the Aa area are part of the Griendtsveen Formation (ZAGWIJN & VAN STAALDUINEN, 1975).

Table I  
Stratigraphy and lithology of the Middle Weichselian (Pleniglacial) and Late Weichselian (late Glacial) Drentsche Aa valley deposits.

CHRONO-STRATIGRAPHY	POLLEN DIAGRAM TYPES AND DESERT PAVEMENTS	LITHOSTRATIGRAPHY	LITHOLOGY	
HOLOCENE		GRIENDTSVEEN AND SINGRAVEN FORMATIONS	PEAT AND GYTTJA	
LATE GLACIAL (WEICHSELIAN)	PEBBLE BAND PB 3 LT 5 ALLERØD	TWENTE	WELL SORTED AEOLIAN SAND; UNSORTED SAND AND GRAVEL (SLOPE DEPOSIT); DESERT PAVEMENTS	
WEICHSELIAN (TUBANTIAN)	PEBBLE BAND PB 2		UPPER Aa DEPOSITS	COARSE SAND AND PEAT LAYERS
	LT 4		MIDDLE Aa DEPOSITS	SAND AND FINE GRAVEL INTERCALATED WITH HUMIC LOAM LAYERS (THAW LAKE DEPOSITS)
	LT 3			
MIDDLE	LT 2 LT 1	LOWER Aa DEPOSITS	SAND AND GRAVEL INTERCALATED WITH MOR-LIKE LEVELS	
LOWER	PEBBLE BAND PB 1 ET 3 "PAPENVOORT"			
EARLY GLACIAL (WEICHSELIAN)	ET 2 "ODDERADE" ET 1 "BRØRUP"			
EEMIAN	EM EEMIAN			
SAALIAN		DRENTE FORMATION	TILL	
HOLSTEINIAN				
ELSTERIAN		PEELO FORMATION	SAND AND CLAY (POTKLEI)	

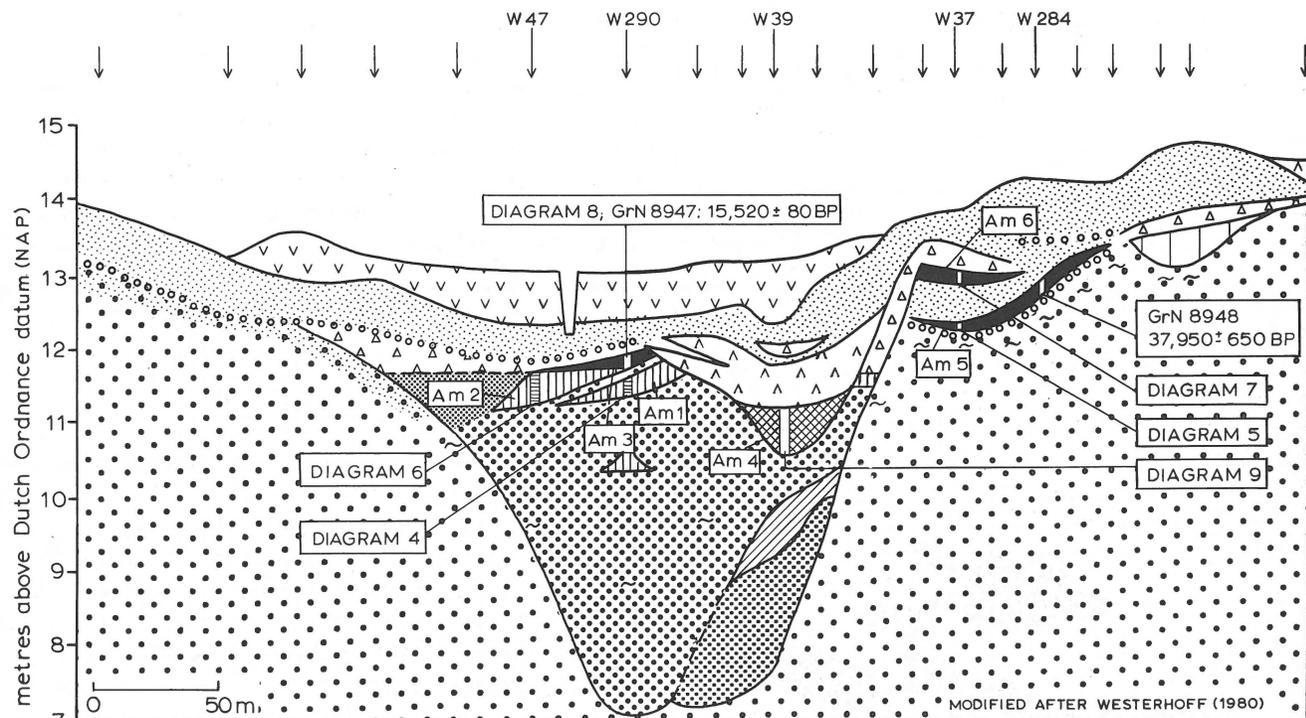


Fig. 3  
Cross section 2: Sterrenwacht (location: see Fig. 1; legend: see Fig. 2)

#### DESCRIPTION OF THE CROSS SECTIONS AND EXPOSURE

To facilitate the study of the Pleniglacial and Late Glacial Weichselian valley sediments, two subsurface cross sections were sampled and investigated, as well as one small exposure in the upstream Aa area. The locations of sections and exposure are given in figure 1.

##### *Cross section 1: Papenvoort*

This section (Fig. 2) is located in the upstream part of the Andersche Diep valley which is eroded into glacial till and sand of the Drente and Peelo Formations. The fluvial deposits in this section consist of fining-upwards sequences of fine gravel and sand with organic levels locally occurring on top. Organic level DrA4 is the uppermost mor-like level and indicates the top of the lower Aa deposits (DE GANS, 1981-a). From this level two radiocarbon dates are available:  $> 42,400$  BP (GrN 8386) and  $41,400 \pm \frac{4600}{2900}$  BP (GrN 8387). The basal part of the overlying fluvial deposits occurs in a relatively narrow erosion valley which is incised, through organic level DrA4, into the lower Aa deposits and the Peelo Formation. These middle Aa deposits consist of moderately sorted fine gravel and sand containing debris of the mor-like levels up to 10 cm thick. The upper part of these deposits comprises two humic loam layers (And1 and And2) which locally show a thin lamination of fine sand and loam with organic detritus. From both levels a radiocarbon date is available. GrN 8952 from

level And1 gives  $38,750 \pm 750$  BP while GrN 8953 from the overlying level And2 gives, rather surprisingly,  $42,450 \pm 900$  BP. The undulating depth of these levels may indicate cryoturbation. The extension of level And2 indicates that during sedimentation of the top layers of the middle Aa deposits the valley floor was much wider than during sedimentation of the lower Aa deposits. Organic level And2 is overlain by a thin layer of moderately sorted coarse sand (300-400  $\mu\text{m}$ ). This sand is assigned to the upper Aa deposits. On top of this deposit a one stone thick pebble band with relatively coarse gravel occurs. The pebble band is in its turn overlain by well-sorted aeolian sand (150-210  $\mu\text{m}$ ) which contains thin intercalations of coarser sand in the basal part. In this aeolian sand an unstratified humic loam layer And3 is found, overlain by a second pebble band in its eastern part. This pebble band consists of relatively fine gravel and passes laterally into a slope deposit. In the upper part of the section a peat layer is found, which according to its position and lithology belongs to the Singraven Formation.

##### *Cross section 2: Radiosterrenwacht*

This section (Fig. 3) is situated in the upstream part of the Amer Diep valley near the radiotelescope at Westerbork. The substratum sediments of the valley are identical to those of section 1. In the fluvial sequence the lower, middle and upper Aa deposits can be distinguished. In the upper part of the middle Aa deposits two humic loam layers, called Am1 and Am2, are present. Organic level Am2 passes upwards into a

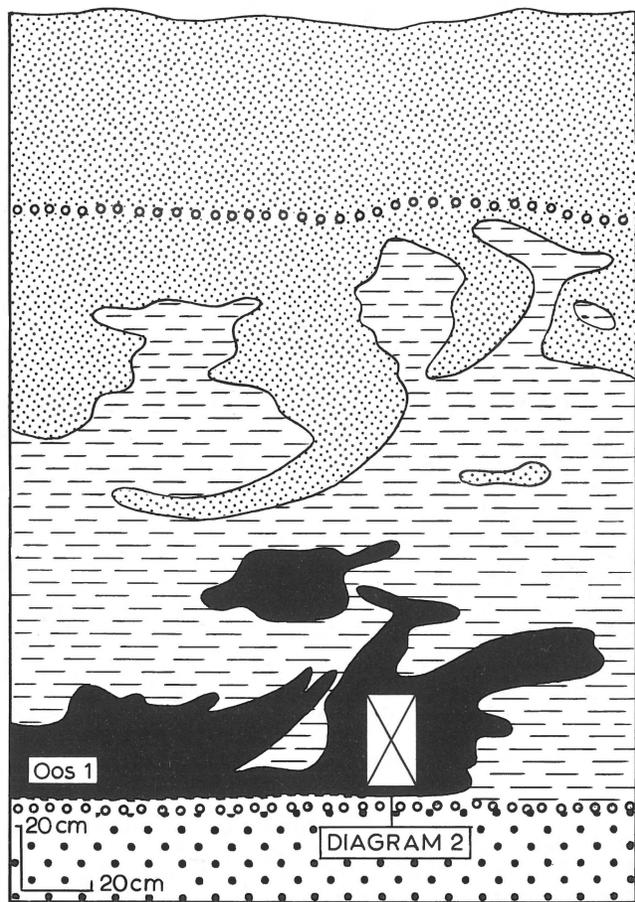


Fig. 4  
Exposure Oosterveld (location: see Fig. 1; legend: see Fig. 2)

thin peat layer called Am3. A radiocarbon date from this Am3 level gives  $15,520 \pm 80$  BP (GrN 8947). The upper Aa deposits are located in the western part of the former valley floor and are composed of moderately sorted coarse sand. They have a pebble band on top, which is correlated with the lowermost pebble band of section 1 (Fig. 2) because they both occur in similar lithologic sequences. A former depression in the eastern part of the valley floor was filled with gyttja and peat (organic level Am4) after deposition of this pebble band.

On the eastern valley slope two thin peat layers occur in deposits of the Twente Formation. These levels are called Am5 and Am6 respectively. Level Am5 overlies a pebble band with relatively coarse gravel and has a radiocarbon date of  $37,950 \pm 650$  BP (GrN 8948). A third pebble band is found between aeolian sand in the eastern part of the section. It contains relatively fine gravel and overlies level Am6. It is correlated with a thin slope deposit which overlies the organic deposits in the depression. In the upper part of the section peat layers occur, belonging to the Singraven or Griendtsveen Formations.

#### The Oosterveld exposure

This small exposure (Fig. 4) is located two kilometres north of

section 1 (Fig. 1) in the lowest part of the western slope of the Andersche Diep valley. The exposure shows two superposed pebble bands with a cryoturbated zone in between. The lower pebble band is composed of relatively coarse gravel and is situated in an erosive position upon the underlying coarse sand of the Peelo Formation. The cryoturbated zone has a thickness of 1.8 m and consists of a peaty loam layer (Oos1), aeolian loam and aeolian sand. The upper pebble band of relatively fine gravel is situated in aeolian sand and is located in an erosive position on the cryoturbated sediments.

## POLLEN ANALYSIS

### Method

Pollen samples were taken from the organic levels in between the Aa deposits and the Twente Formation to establish the palaeoenvironment and the correlation of these levels in the investigated sections. All samples were collected with a sampling auger type guts ( $\varnothing$  50 mm) with the exception of one sample taken from the Oosterveld exposure. The samples were treated with KOH and subsequently subjected to bromoform separation. Pollen slides were prepared in most cases from each centimetre of the cores. In the diagrams the percentages are calculated on the basis of the sum of the AP (arboreal pollen) and 'dry' NAP (non-arboreal pollen). In most cases a pollensum of 300 AP + NAP has been used. The pollen diagrams which were derived from these levels are tentatively classified on the basis of their palynological data as pollen diagram types LT1, LT2, LT3, LT4 and LT5 as they cannot as yet be correlated properly with the standard Weichselian biozonation as given by ZAGWIJN & VAN STAALDUINEN (1975). For the time being, since the diagram types are derived from superposed organic levels they can be regarded as indicating the relative age of these deposits.

### Pollen-diagram type LT1

This type is represented by pollen diagram 1 (Fig. 5) which is derived from organic level And1 in the Andersche Diep section (boring II, Fig. 2). The diagram is characterised by low percentages of AP with a continuous *Betula* curve which reaches up to 10%. The percentages of the NAP are high as Cyperaceae achieves up to 90%. The *Artemisia* curve is discontinuous and below 2%. The aquatics *Myriophyllum*, Ranunculaceae and the Algae *Botryococcus* and *Pediastrum* have low percentages and indicate an environment of shallow-water pools. Pollen-diagram type LT1 is indicative of a wet tundra vegetation similar to that described by GRAY & LOWE (1977) and WALTER & STRAKA (1970).

### Pollen-diagram type LT2

Type LT2 is represented by pollen diagram 2 (Fig. 6) which is

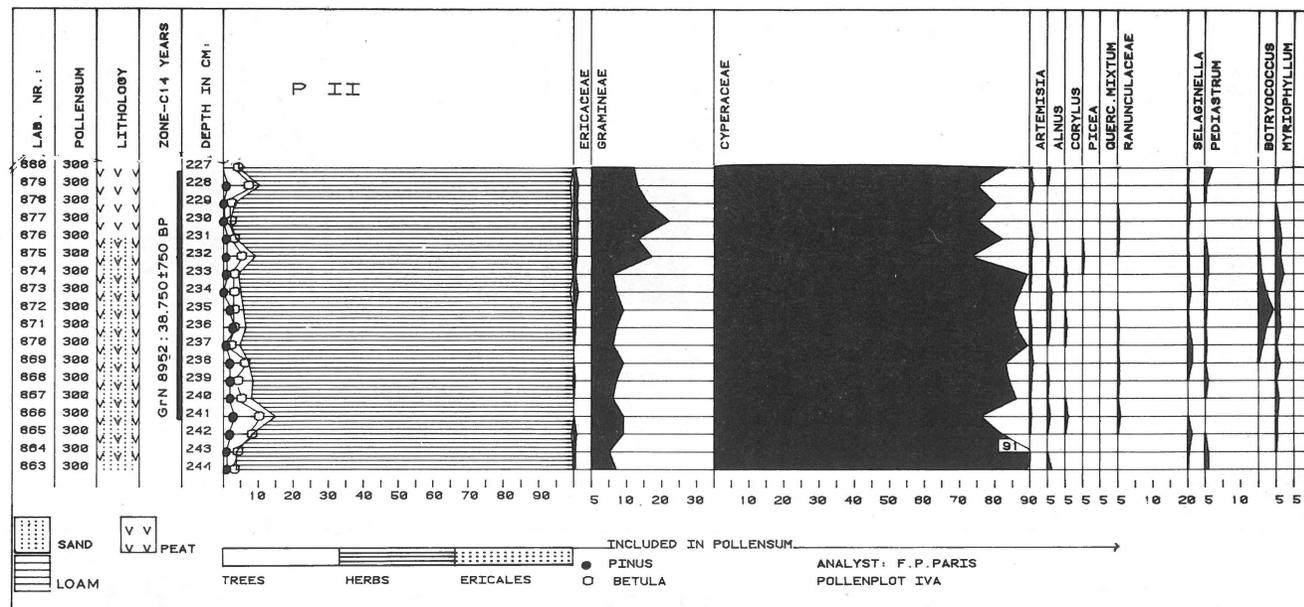


Fig. 5  
 Pollen diagram 1.

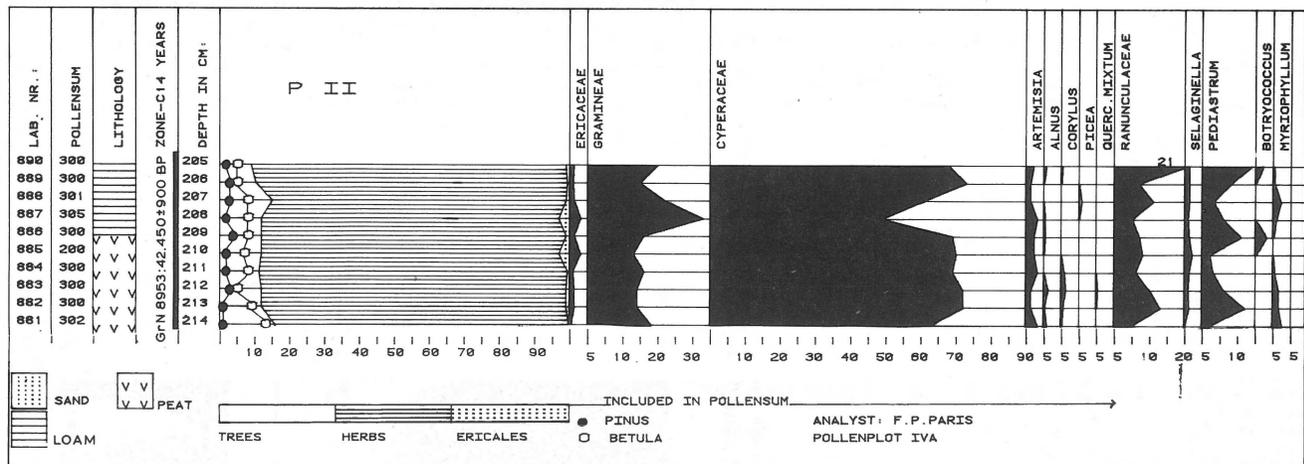


Fig. 6  
 Pollen diagram 2.

derived from organic level And2 (boring II, Fig. 2). As level And2 overlies level And1 from which type LT1 is derived type LT2 is younger than type LT1. In type LT2 *Pinus* has percentages up to 3% and *Betula*, which has a fluctuating curve, reaches 15%. *Artemisia* is continuously present with percentages up to 5%. *Ranunculaceae* (up to 21%) and *Myriophyllum* (3%) have higher percentages than type LT1. This also applies to the Algae *Pediastrum* and *Botryococcus*. Again, this type of diagram represents a wet tundra vegetation, but possibly in an environment of deeper and more open water.

The pollen diagrams 3 (Fig. 7), 4 (Fig. 8), and 5 (Fig. 9) which are respectively derived from organic level Oos1 (Fig. 4), Am1 (boring W290, Fig. 3) and Am5 (boring W37, Fig. 3) are comparable with diagram 2 as the small differences between these diagrams are mutually thought to be the result of local environmental variations. Consequently, they are all classified as pollendiagram types LT2.

It should be noted, however, that the differences between pollen diagram type LT1 and LT2 are small, and may be caused by facies as well as by climatic changes.

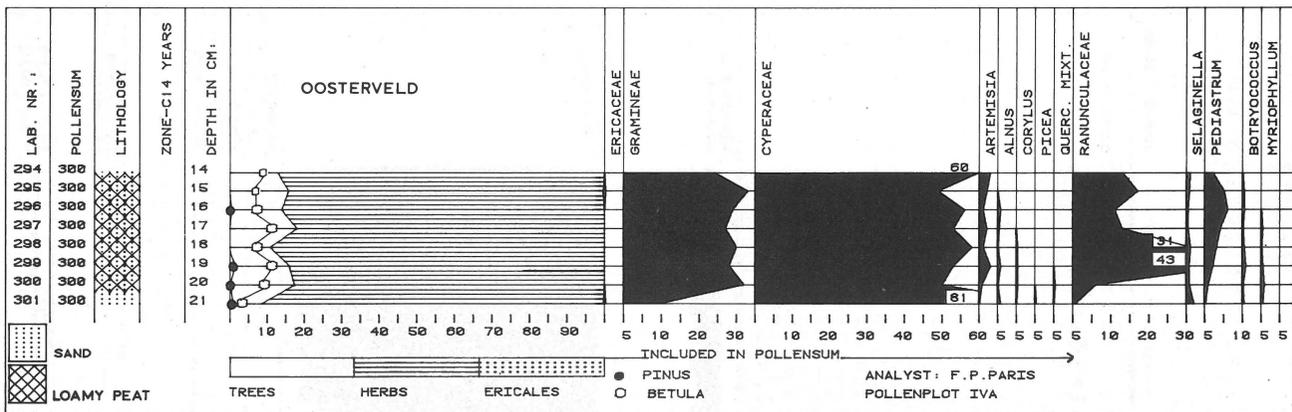


Fig. 7  
Pollen diagram 3.

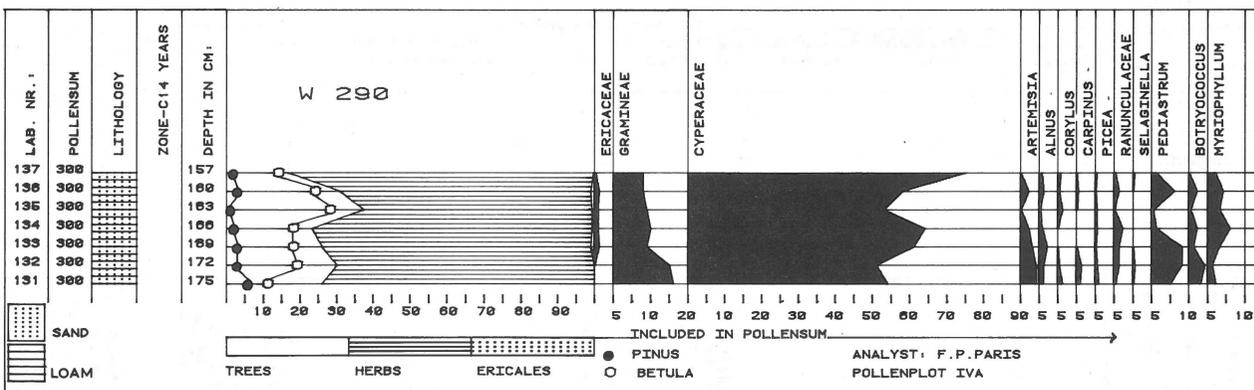


Fig. 8  
Pollen diagram 4.

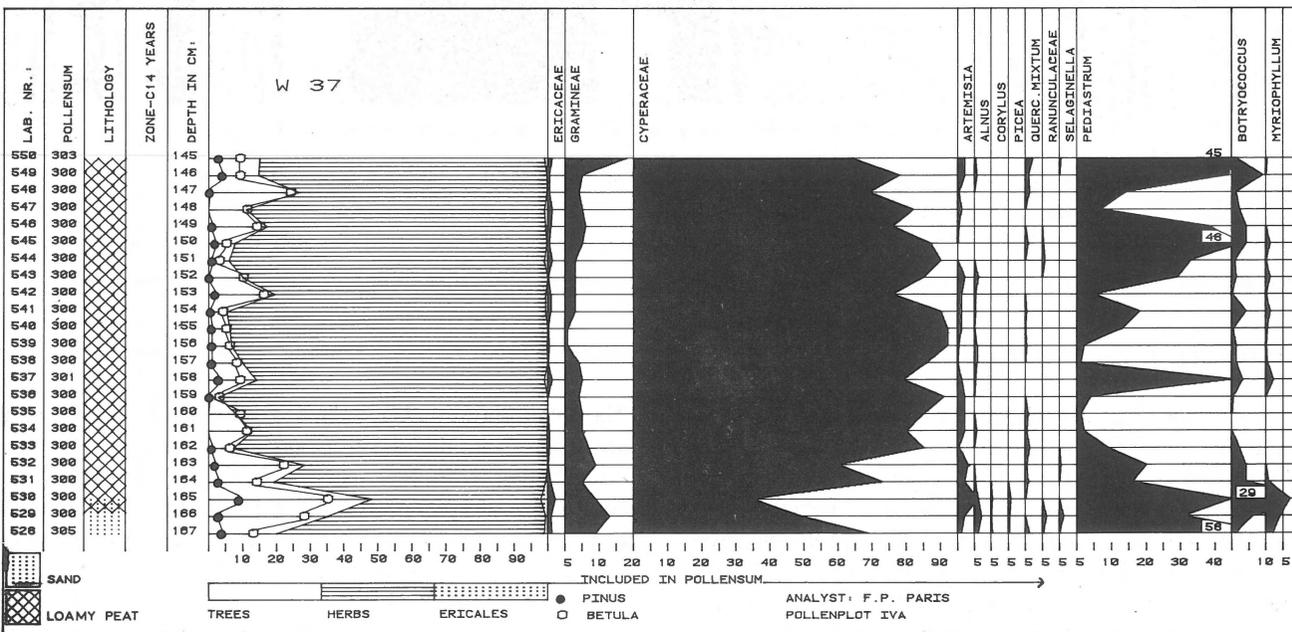


Fig. 9  
Pollen diagram 5.

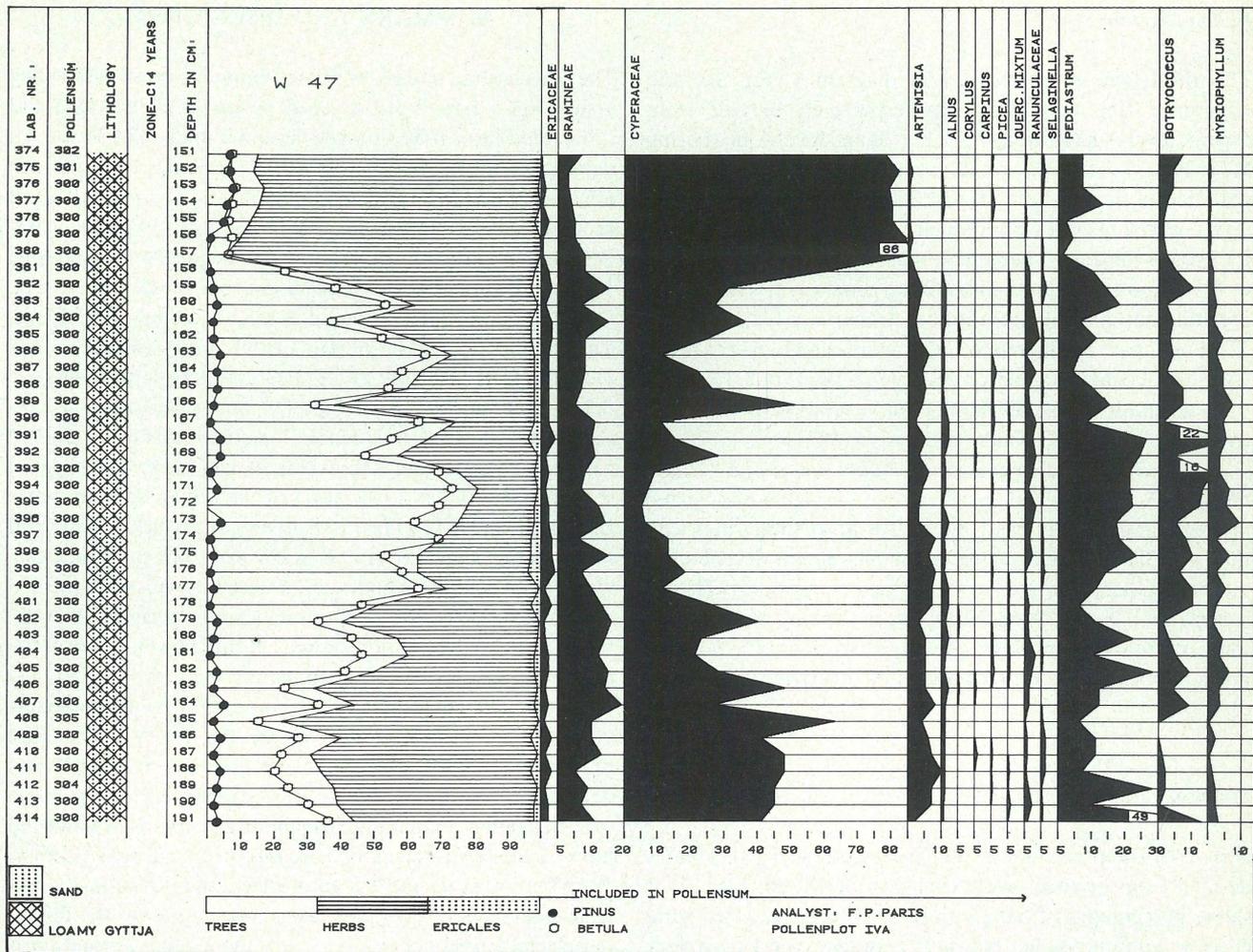


Fig. 10  
 Pollen diagram 6.

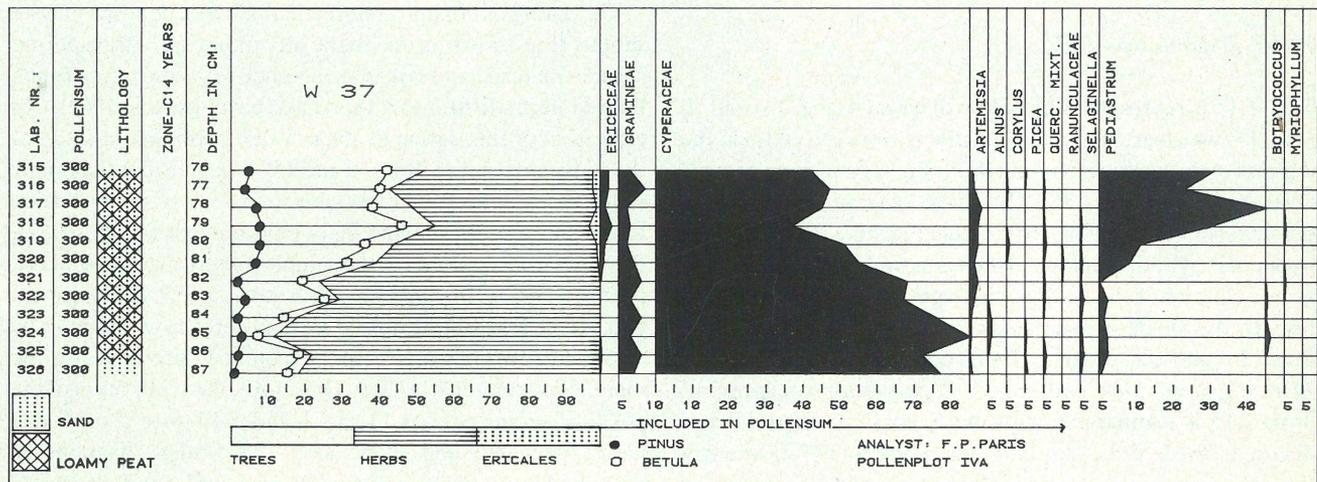


Fig. 11  
 Pollen diagram 7.

### Pollen-diagram type LT3

This third type is represented by diagram 6 (Fig. 10) and diagram 7 (Fig. 11) which are respectively derived from organic level Am2 (boring W47, Fig. 3) and level Am6 (boring W37, Fig. 3). These diagrams represent a younger timespan than that of the preceding type LT2 as they are derived from levels overlying layers from which type LT2 is obtained. Type LT3 shows increasing percentages of AP as *Betula* reaches up to 70%. The percentages of NAP are generally low. Aquatics are still continuously present and *Artemisia* reaches 5-10%. The upper part of diagram 6 shows increasing percentages of Cyperaceae and is correlated with type LT4. Type LT3 represents a wet arctic shrub/lichen heath vegetation as described by GRAY & LOWE (1977) and IVES & BARRY (1974).

As the *Betula* pollen represent *Betula nana*, and *Helianthemum*, *Selaginella* and Saxifragaceae, though not indicated in the diagram, are present, type LT3 shows similarities with the Late Glacial Bølling Interstadial diagrams as described by VAN DER HAMMEN (1951), VAN DER HAMMEN & WYMSTRA (1971) and CASPARI & VAN ZEIST (1960). However, in the case of diagram 6 this represents a contradiction with its stratigraphic position and a radiocarbon datum for one of the overlying levels (Fig. 3).

### Pollen-diagram type LT4

Type LT4 is represented by pollen diagram 8 (Fig. 12) and is derived from organic level Am3 (boring W290, Fig. 3). It shows percentages of *Betula* up to 19%, while the *Artemisia* curve is continuous, but below 2%. In fact type LT4 is very similar to type LT2, although the amount of aquatics is noticeably lower than in the preceding types. This may indicate a colder as well as a drier environment. Type LT4 represents a grassland community as described by GRAY & LOWE (1977).

### Pollen-diagram type LT5

Type LT5 is represented by pollen diagram 9 (Fig. 13) and 10 (Fig. 14) which are derived respectively from the gyttja in the depression in section 2 (boring W39, Fig. 3) and from organic level And3 (boring II, Fig. 2). These diagrams show higher percentages of AP again, with *Betula* reaching > 30%. In the upper part of both diagrams *Betula* is as high as 60-80%, *Pinus* is over 20% while the NAP percentages (e.g. Cyperaceae) are low. In this diagram type *Empetrum* is present for the first time. In the lower parts of the diagram aquatics such as *Myriophyllum*, *Menyanthes* and *Potamogeton* are present. Type LT5 is comparable with the Early Dryas and Allerød diagrams as described by VAN DER HAMMEN (1951), VAN DER HAMMEN & WYMSTRA (1971) and CASPARI & VAN ZEIST (1960) and represent the initial stages of a boreal vegetation as indicated by HULTÈN (1971) and WALTER & STRAKA (1970).

## SUMMARY AND DISCUSSION

The Weichselian and older fluvial sediments in the Aa valley system are assigned to the Aa deposits (DE GANS, 1981) and subdivided into three lithostratigraphic units. The lower Aa deposits comprise moderately sorted sand and gravel and are intercalated with mor-like organic levels. On palynological grounds, these levels are dated as late Eemian, early Weichselian and lower Pleniglacial respectively (DE GANS, 1981-a). The middle Aa deposits were formed after a deep fluvial incision which occurred at the beginning of the Pleniglacial (Fig. 2). The basal part of this succession consists of moderately sorted sand and gravel and may contain organic debris from the mor-like levels. The upper part of the succession is intercalated with humic loam layers (Figs. 2 and 3) which have a maximum thickness of 1 m in the investigated sections. The pollen association of the pollen diagram types LT1, LT2 and LT3 (Figs. 5, 6, 8 and 10) which are derived from organic levels separated by clastic sediments indicates a wet tundra vegetation and suggest that the levels were formed in a shallow lacustrine environment under periglacial conditions. The thin laminations in part of these levels confirm the idea of sedimentation in open water pools. It is tentatively concluded from the occurrence of ramparts of pingo remnants on these humic loam layers in the Aa valley system that permafrost may have been present (DE GANS, in prep.). The depression in section 2 (Fig. 3) may be regarded as an example of such a pingo remnant. Consequently the pools in which the humic loam levels developed are interpreted as thaw lakes as described by BLACK (1969). In our view the fluvial and lacustrine sediments of this thaw lake phase represent the fluvio-periglacial sediments *sensu stricto* of the Twente Formation as described by ZAGWIJN & VAN STAALDUINEN (1975) and TER WEE (1966, 1979) and the 'niveo-fluviatile' sediments as described by VAN DER HAMMEN (1951). This sedimentary succession is described by VAN DER HAMMEN ET AL. (1967) as 'loamy beds and peat' and dated as middle Pleniglacial.

The dating of organic material in thaw lake deposits may be subject to gross errors due to the incorporation of transported organic material and collapse together with reworking of the thawed permafrost into a thaw lake basin (BLACK, 1969). An indication of this dating problem is the reversion of some of the radiocarbon data (Figs. 2 and 15). We consider that many radiocarbon dates from thaw lake deposits may be too old due to the nature of the sedimentary environment (BLACK, 1969), the low carbon content of the sample material (OLSSON, 1979), the presence of *Drepanoclades* (SHOTTON, 1972), and the reservoir effect resulting from old groundwater as mentioned by OLSSON (1979) and Mook (pers. comm.), provided by the melting of groundice bodies. Therefore, the correlation of the pollen-diagram types LT1, LT2 and LT3 with the Moershoofd, Hengelo and Denekamp Interstadial diagrams as described by VAN DER HAMMEN & WYMSTRA (1971) and KOLSTRUP & WYMSTRA (1977), which is for a substantial part based on radiocarbon datings, cannot be substantiated in the Aa area.

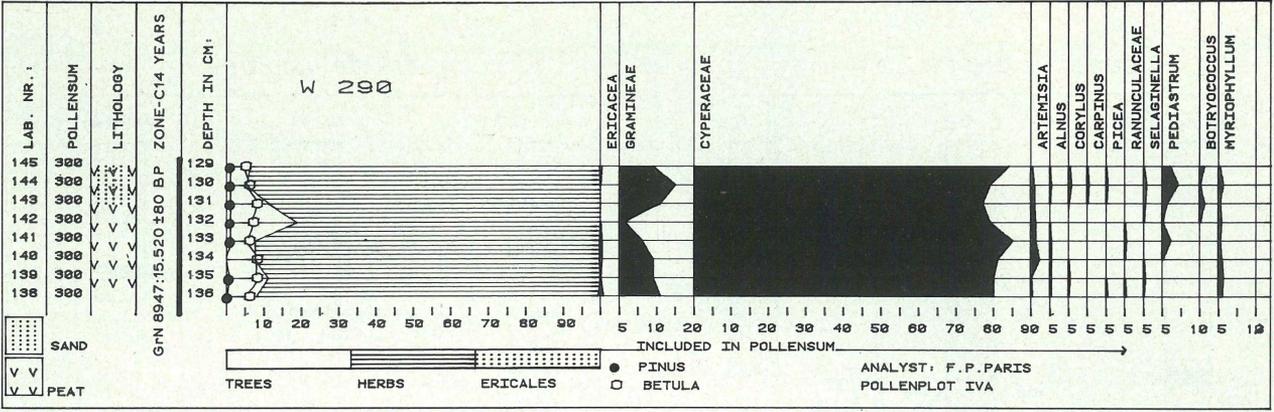


Fig. 12  
Pollen diagram 8.

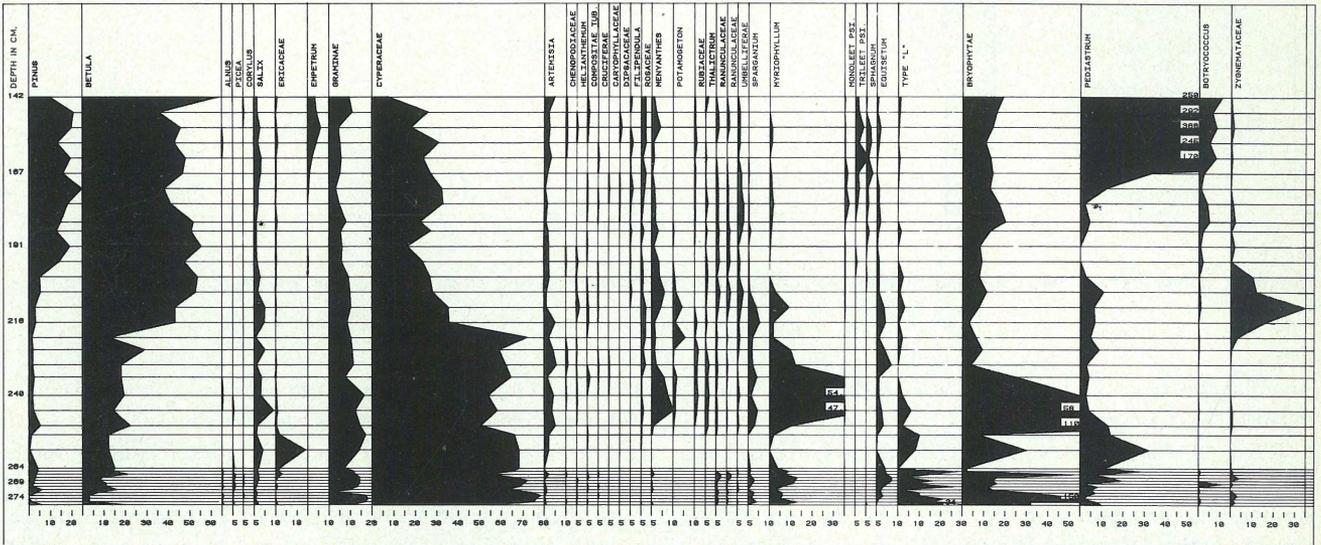


Fig. 13  
Pollen diagram 9.

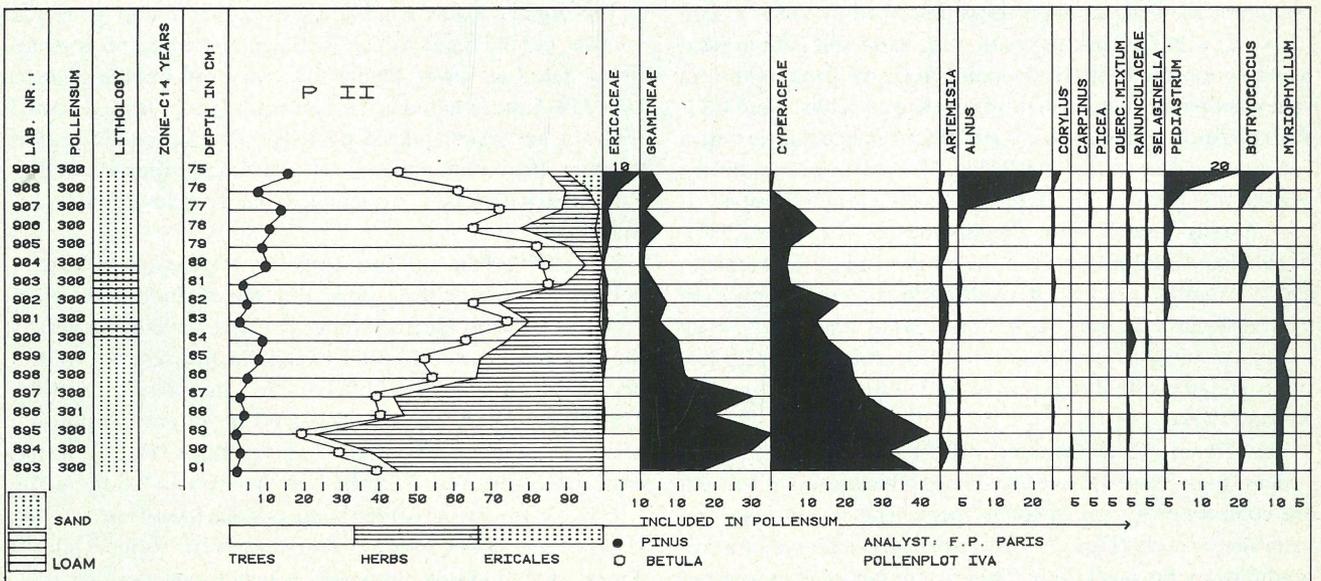


Fig. 14  
Pollen diagram 10.

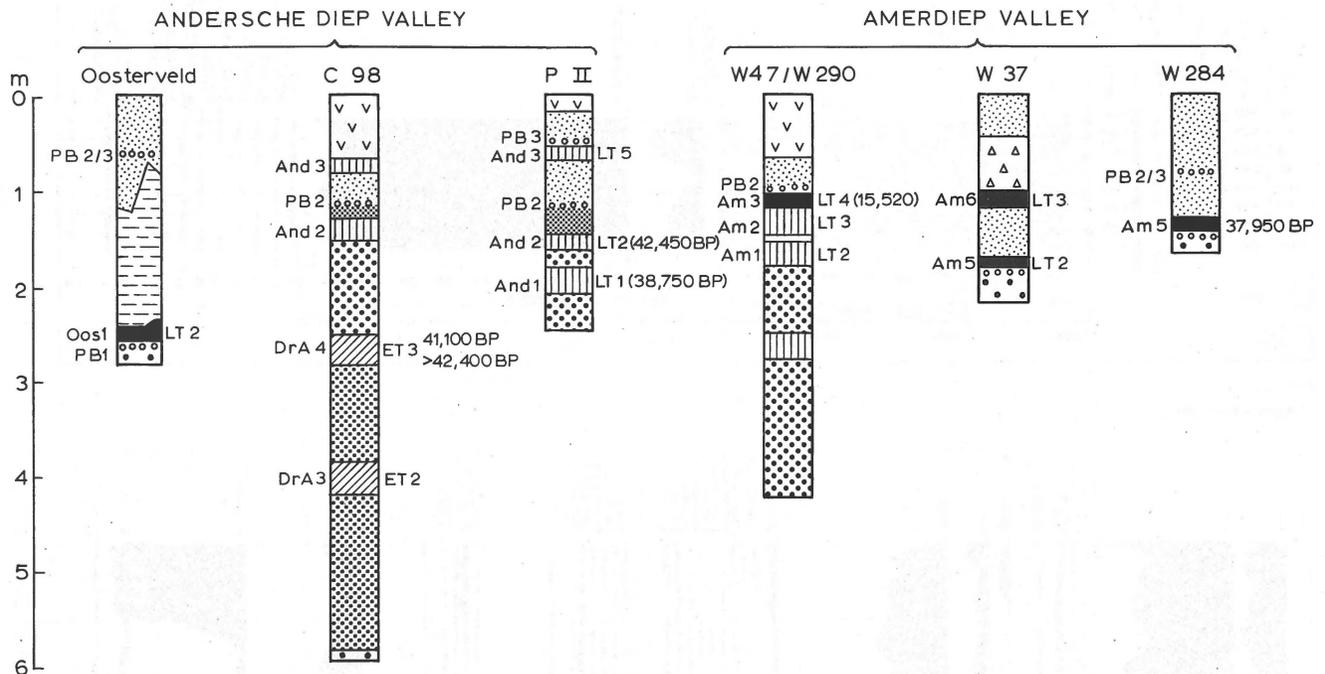


Fig. 15  
Lithology, palynology and radiocarbon data of the Andersche Diep and Amer Diep valley deposits (location: see Figs. 2, 3 and 4; legend: see Fig. 2).

The diagram types LT1 and LT2 will be discussed in more detail by DE GANS (in prep.).

The upper Aa deposits consist of coarse sand, overlain by a pebble band which marks the top of the Aa deposits. The stratigraphic gap between the upper Aa and middle Aa deposits in the Andersche Diep valley is far more substantial than in the Amer Diep valley (Figs. 2 and 3). The upper Aa deposits correspond in stratigraphic position and facies with the upper Pleniglacial deposits as described by VAN DER HAMMEN ET AL. (1967). This means that the sand and pebble band may be correlated with the Beuningen Gravel Bed. In the Aa valley this pebble band will be referred to as pebble band PB2. The superposition of pebble band PB2 over a peat layer with a radiocarbon date of 15,520 BP (Fig. 3) gives it a maximum age but the reliability of this date itself is uncertain. However, it corresponds roughly with the findings of KOLSTRUP (1980). Pebble band PB2 probably indicates the end of the Pleniglacial permafrost because it overlies in an erosive position icewedge casts as may be deduced from data by VAN DER HAMMEN ET AL. (1967), MAARLEVELD (1976) and KOLSTRUP (1980). It is correlated with desert pavement 3 as described by PAEPE & PISSART (1969).

The organic levels situated on the slopes of the valley system (Figs. 3 and 4) have a maximum thickness of 0.5 m and are composed of peat or loamy peat. The pollen diagrams from these levels (Figs. 7, 9, 11) are representative of a wet tundra or arctic vegetation. They are tentatively interpreted

as fossil A1 horizons of former organic cryosols formed under wet environmental conditions as described by TARNOCAI (1978). The palynological and radiocarbon data of these organic levels in the middle Aa deposits and in the Twente Formation are summarized in figure 15. The radiocarbon date of level Am5 (Fig. 15) would suggest a Hengelo Interstadial age but, as stated before, care must be taken with its reliability.

The organic levels Am5 and Oos1 (Figs. 3 and 4) overlie another pebble band, which is designated PB1 and is tentatively dated as lower Pleniglacial. A third pebble band is called PB3 and situated in aeolian sand. It overlies level And3 (Fig. 2) and Am6 and Am4 (Fig. 3). Consequently it is younger than pollen diagram type LT5 (Allerød) and is correlated with Late Glacial pebble bands as described by TER WEE (1979).

The pebble bands in the Aa valley system are formed by deflation of pre-existing slope deposits as indicated by the presence of wind-faceted stones (DE GANS, 1980). Generally the gravel in the lowest pebble band is the most coarse, while it becomes finer in each pebble band in a downslope direction. The pebble bands are often located in an erosive position upon the underlying cryoturbated structures (Fig. 4), as has been observed and described by KOLSTRUP (1980), RUEGG (1975), PAEPE & PISSART (1969) and VAN DER HAMMEN & WYMSTRA (1971). This might indicate that they were formed after a period of cold climate under drier conditions.

## CONCLUSIONS

The Weichselian and older fluvial deposits in the Drentsche Aa valley system are subdivided in three lithostratigraphic units: the lower, middle and upper Aa deposits. In their upper part the middle Aa deposits contain humic loam layers which can be compared with the middle Pleniglacial sequence as described by VAN DER HAMMEN ET AL. (1967). The humic loam layers are interpreted as thaw lake deposits on lithological and palynological arguments. The upper Aa deposits consist of coarse sand and are of late Pleniglacial age. They are overlain by a pebble band which is correlated with the uppermost part of the Beuningen Gravel Bed. As two more pebble bands are found in the Aa valley system provisionally dated as early Pleniglacial and Late Glacial respectively, care must be taken with the chronostratigraphic interpretation of individual bands, since they may be located in similar lithologic successions on the slopes of the valley system. The formation of these pebble bands was preceded by periglacial slope processes which are apparently responsible for the asymmetry of the Aa valley slopes (DE GANS, 1980, 1981-b) and the planation of the Aa area. Consequently the pebble bands in the Aa area are interpreted as subsequent planation surfaces formed under periglacial conditions.

The pollen diagrams which are derived from organic levels in the middle Aa deposits and Twente Formation are classified into five successive pollendiagram types respectively called LT1-LT5. The tentative chronologic succession of these types is based on their superposition. The palynological data suggest a more or less progressively higher percentage of tree pollen in the subsequent pollen diagram types. The pollen-diagram types cannot be correlated with certainty with known middle Pleniglacial Interstadial diagrams due to the impaired reliability of the radiocarbon data. However, the pollen association of the types LT1 and LT2 is comparable with those of the Moershoofd, Hengelo and Denekamp Interstadial diagrams.

## ACKNOWLEDGEMENTS

Mr. Konert and Mrs. Meyer prepared the pollen samples which were counted by Drs. Paris. Mr. Konert drafted the computer program pollen plot IVA and Mr. Jagerman typed the pollen data out on the computer. Mr. Heine and Mr. Sion made the line drawings which were photographed by Mr. Van der Blik. Mrs. Snijder typed the manuscript. Professor Van der Hammen and Professor Wiggers kindly read the text critically while Dr. Bryant improved the English. Professor Mook provided the radiocarbon data.

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