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Late Weichselian and Holocene sedimentary history of the Leuvenumse beek valley (The Netherlands)

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Abstract

Lithostratigraphic and palynological research of the sediments in a small brook valley in the central part of the Netherlands demonstrates the existence of three sedimentary sequences. From the data four fluvial adjustments are derived and successively dated as 1) the end Pleniglacial-early late Weichselian, 2) the transition late Weichselian – Holocene, 3) the Boreal and 4) the Late Subatlantic. The fluvial adjustments are related to variations in water discharge due to climate and human impact. An attempt has been made to generalize the fluvial activity of the small drainage basins in the Netherlands since the Late Glacial.

Introduction

Brook valleys make up a remarkable feature of the Pleistocene landscape in the Netherlands. In the past many papers about brook valleys, dealing with changing fluvial regimes and phases of incision since the Eemian were published (e.g., Cnossen & Zandstra, 1965; Ter Wee, 1966, 1975, 1979; Polak, 1967; Buurman, 1970; Van der Hammen & Wijmstra, 1971; Bisschops, 1973; De Gans, 1981; Vandenberghe et al. 1984; Bisschops et al. 1985; Van Huissteden et al. 1986). Most of these studies are based on one or two cross sections.

The present study deals with the fluvial history since the Late Weichselian of a small valley in the central part of the Netherlands, viz., the Leuvenumse Beek (Leuvenum Brook). It is based on a three-dimensional framework of sections supported by pollen-analytical research and radiocarbon data. The Leuvenumse Beek Valley is situated in a small basin in the north–western part of a system of ice-pushed ridges in the central part of the Netherlands (Veluwe). The valley with a maximum width of 75 m is slightly meandering. Based on the present morphology of the valley it is possible to divide it into four segments. The upper part (segment 1; Fig. 1) comprises a dry valley system. In the field, segment 2 is hardly recognizable as a valley, for it is completely filled up with sediments and peat. Segment 3 is the most distinct valley part because the valley flood-plain lies about 2 m below the surrounding area. The lowest part of the valley (segment 4) is covered by aeolian deposits.

An outline of the investigated area

The central part of the basin is relatively flat and is surrounded by ice-pushed ridges: the Garderen Ridge, west of the basin, and the East Veluwe

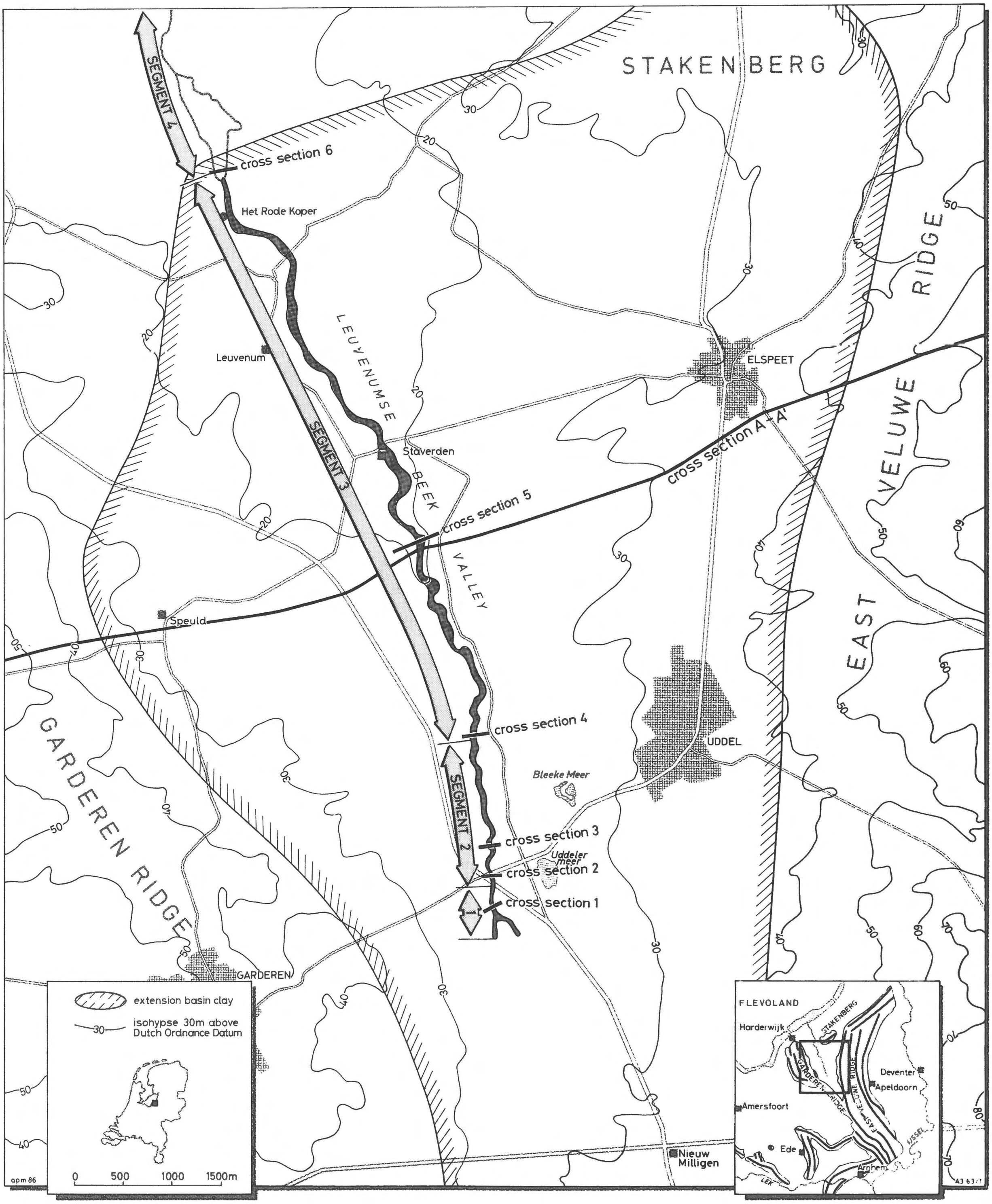

Fig. 1. The Leuvenum basin and the Leuvenumse Beek Valley.

Ridge, east of the basin. To the north the Stakenberg ridge, partly impedes the entrance of the basin (Fig. 1). According to Crommelin & Maarleveld (1952), Maarleveld (1955, 1960, 1981) and Jelgersma & Breeuwer (1975) the Leuvenum Basin is a glacial tongue basin formed during the Saalian glaciation. But Postma et al. (1983) suggested that the basin is a former ice-marginal lake. On the slopes of the basin terrace-like forms have been described as kame-terraces (Crommelin & Maarleveld, 1952; Maarleveld, 1955, 1960; Jelgersma & Breeuwer, 1975; Ten Houten De Lange, 1977).

The basin sediments are composed of (gravelly) sand and clay. Both deposits are assigned to the Drente Formation (Fig. 2). The sands are either interpreted as fluvioglacial deposits (Crommelin & Maarleveld, 1952; Maarleveld, 1955, 1960, 1981) or as mass-flow deposits (Postma et al., 1983). The laminated clay in the basin is after Crommelin & Maarleveld (1952) a warve-like deposit. Postma et al. (1983) described this deposit as a lacustroglacial rhythmite in an ice-marginal lake. So far, deposits of Eemian, Early or Middle Weichselian age have not been found in the basin. In the northwestern part of the basin, Koster (1978) described aeolian sands (coversands) from the Late Weichselian

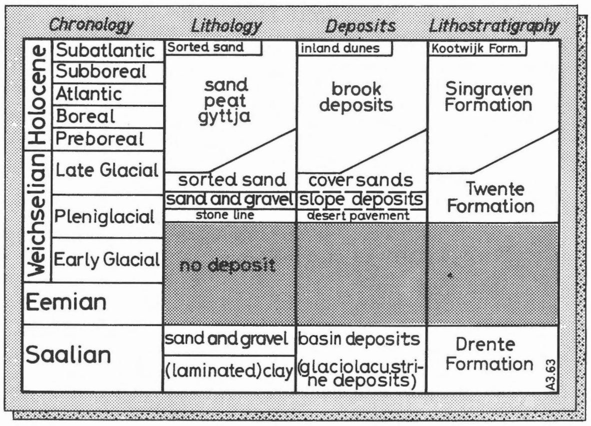

Fig. 2. Stratigraphy of the Leuvenum Basin and Leuvenumse Beek deposits.

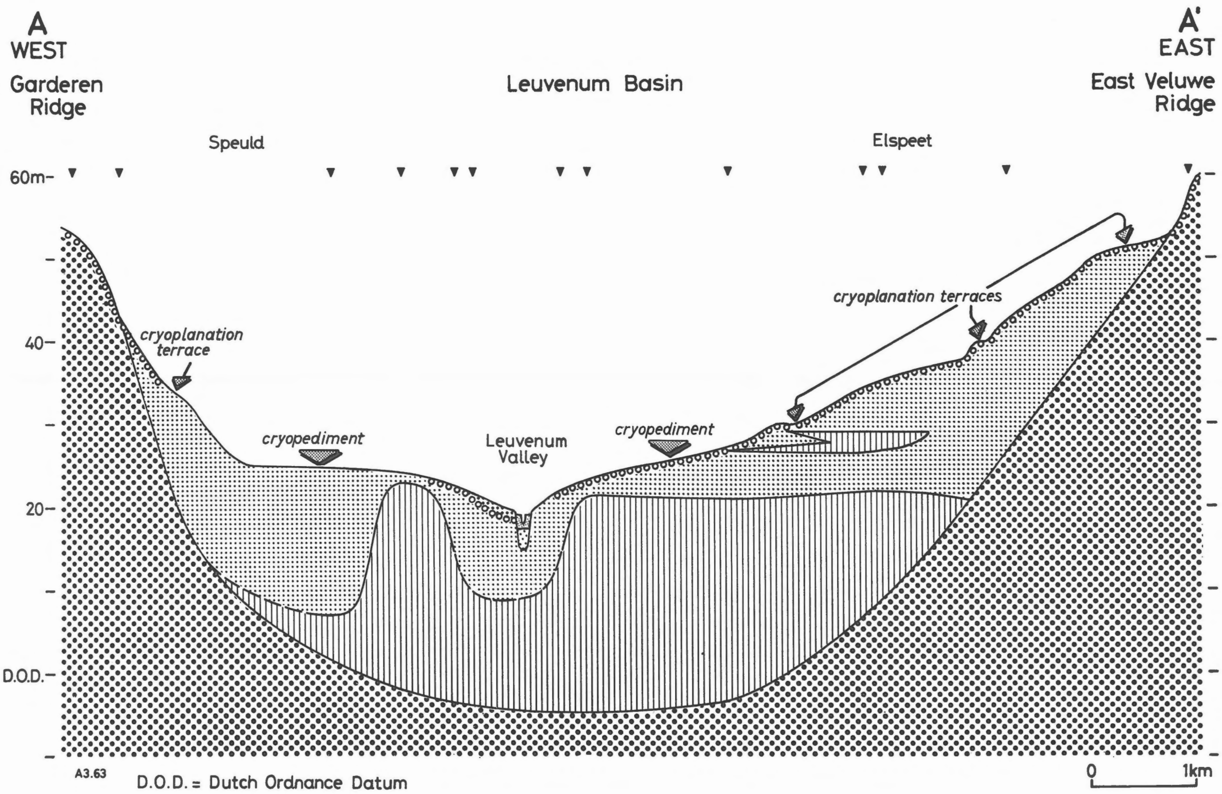

Fig. 3. Schematic cross section of the Leuvenum Basin (location see Fig. 1; legend Fig. 5).

(Twente Formation) and Holocene inland dunes (Kootwijk Formation). Until now the brook deposits in the valley have not been investigated in detail. There is only one palynological study on this subject, published by Polak (1967).

Lithostratigraphy of the basin – and valley sediments

On the basis of bore-hole data from the Rijks Geologische Dienst (Geological Survey) and the Institute of Earth Sciences of the Free University, Amsterdam, a generalized section was constructed over the glacial basin (Fig. 3). Also the extension of the lacustroglacial clay of the Drente Formation has been investigated (Fig. 1). Finally detailed sections over the valley were constructed (Figs. 4 and 5). The basin sediments are composed of laminated clay beds which are covered and intercalated by another bed composed of (gravelly) sand (Fig. 3). All these beds are assigned to the Drente Formation. At many places the Drente Formation is capped by a stone-line which contains wind-facetted stones (Figs. 3 and 4). Hence this stone-line is interpreted as a desert pavement. In the southern part of the basin the stone-line is overlain by a bed composed of unsorted sand and gravel (Fig. 4.1–3). Because of its lithology and its downslope position in the basin this bed is interpreted as a slope deposit. In the northern part of the basin the slope deposit is absent. Instead the stone-line is overlain by well sorted fine sand which is interpreted as an aeolian deposit (coversand) as described by Koster (1978).

Stone-line, slope deposit and aeolian deposit are assigned to the Twente Formation (Fig. 2) and dated as Weichselian. From the sections of the Leuvenum Valley (Figs. 4 and 5) it is clear that the brook deposits in the valley comprise alternately clastic and organic beds. These brook deposits are confined to the Singraven Formation as described by Van der Hammen & Wijmstra (1971) and Doppert et al. (1975). The clastic beds are generally composed of sorted sand and gravel with plant fragments and fining upward sequences. Locally thin humic sand or loam layers may be intercalated.

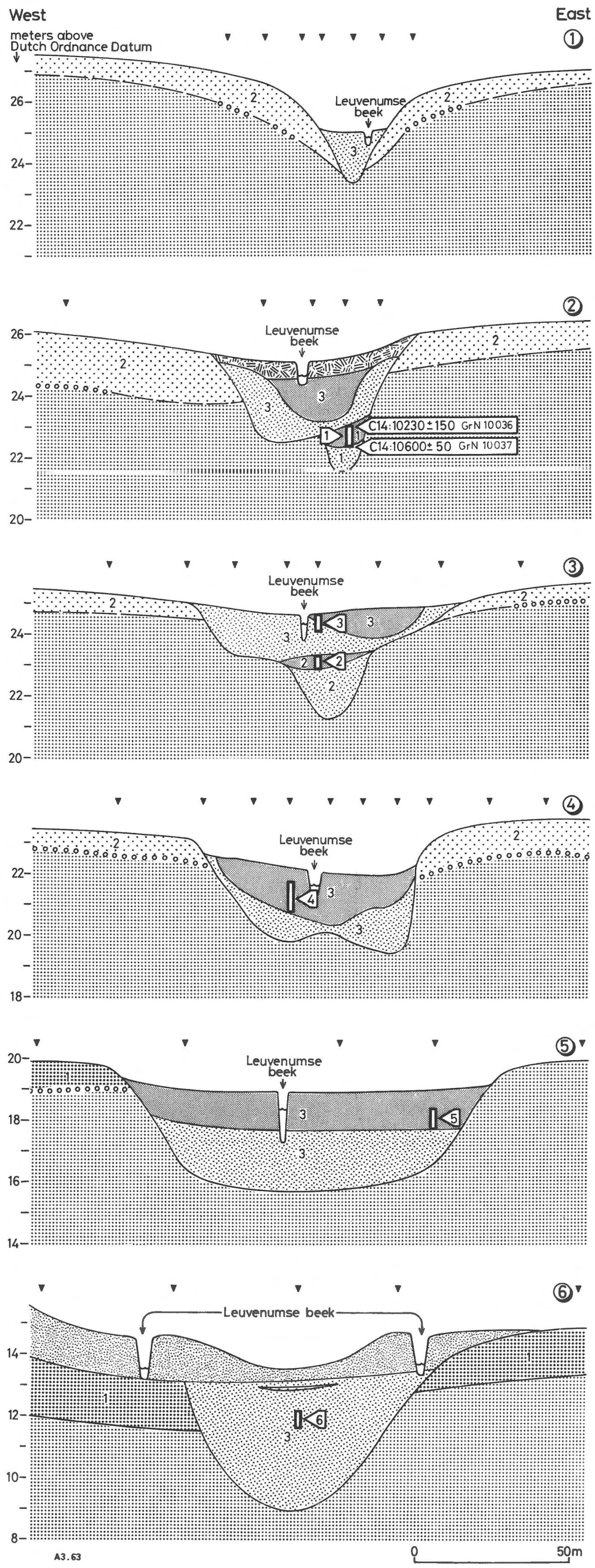

Fig. 4. Six cross sections of the Leuvenumse Beek Valley (location of the sections in Fig. 1; legend Fig. 5).

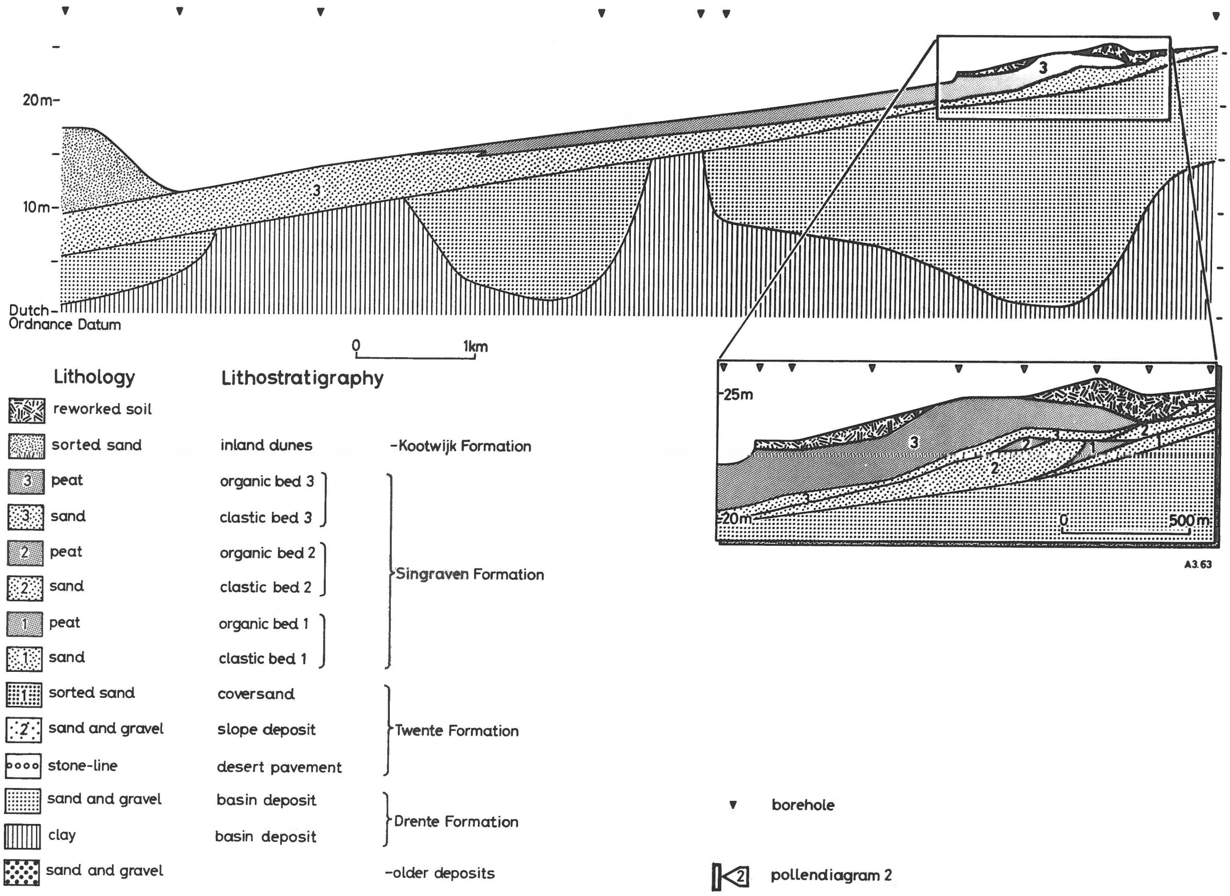

Fig. 5. Longitudinal section of the upper segments of the Leuvenumse Beek Valley.

The thickness of the clastic beds varies from a few decimetres to more than 4 m in the downstream sections. The interface between these clastic beds and the underlying organic beds is generally erosive. If the organic beds are absent, the discrimination between the clastic beds is arbitrary. The organic beds are composed of peat and detritic gyttja. On the basis of lithostratigraphic criteria they are subdivided into three separate beds:

- The lowest organic bed (Organic bed 1) consists of platy, compact, reddish to darkbrown peat with a maximum thickness of 1 m (Fig. 4.2).
- The middle organic bed (Organic bed 2) consists of sandy peat or alternate peat/sand laminae. It has a maximum thickness of 0,5 m (Fig. 4.3).
- The upper organic bed (Organic bed 3) constitutes the top of the valley deposits in most of the cross sections. It is composed of peat, sandy peat, amorphous peat or detritic gyttja. At the basal part it contains sand or sand intercalations. Organic bed 3 has a maximum thickness of 2 m (Fig. 4.3).

Pollenanalysis and radiocarbon datings

To establish the chronostratigraphic position of the valley sediments the organic beds were sampled for palynological investigation. All samples were treated with KOH and subsequently subjected to bromoform separation. Pollen slides were prepared from every 5 cm of the sampled cores. In the pollen diagrams (Figs. 7–12) the percentages were calculated on the basis of the sum of the arboreal pollen (AP), with the exception of pollen diagram 1 in which the sum of the arboreal pollen (AP) and

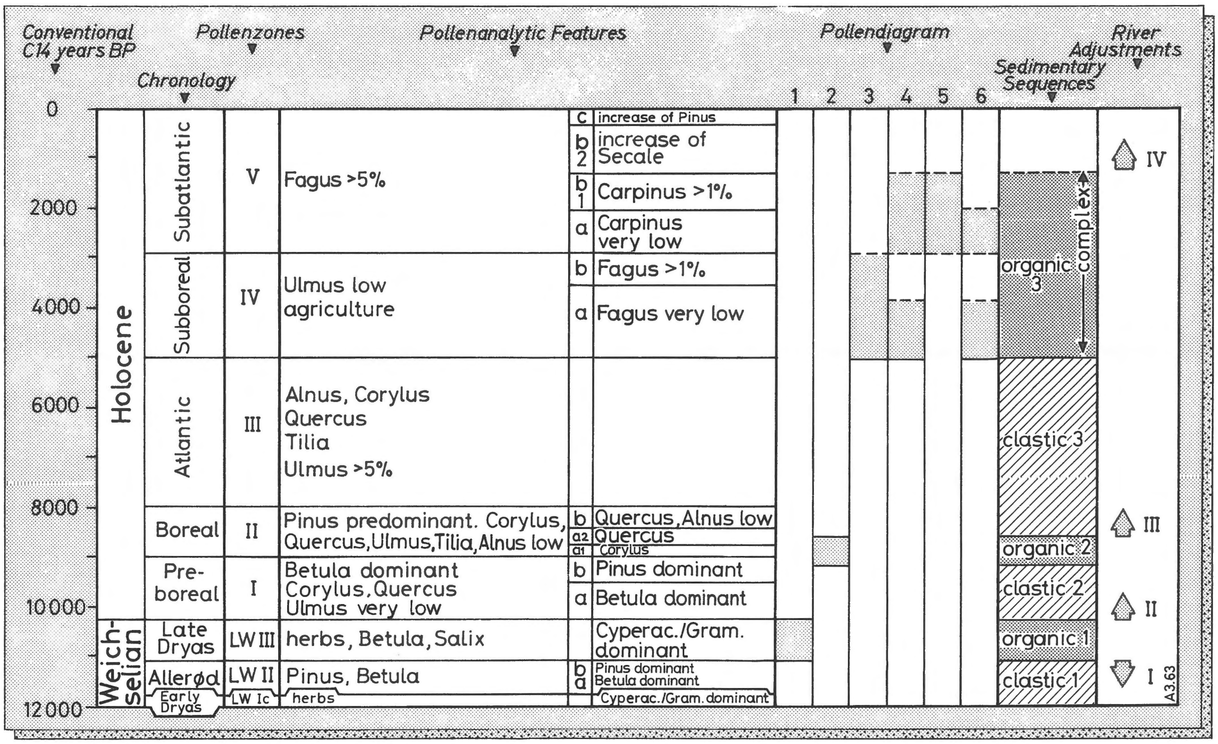

Fig. 6. Palynological data of the Leuvenumse Beek samples.

non arboreal pollen (NAP) has also been used. In general, the total pollen count amounts to 300 pollen grains. To establish the age of the periods represented by the diagrams, they have been compared and then fitted into the scheme of chronostratigraphic subdivision and main features of the pollenzones of the Holocene as presented by De Jong (1982). The established age is presented in Fig. 6. The organic beds cover three periods: the Younger Dryas (diagram 1, Fig. 7), the transition Preboreal/Boreal (diagram 2, Fig. 8), and the Subboreal – Early Subatlantic (diagrams 3, 4, 5 and 6 i.e. Figs. 9, 10. 11 and 12, respectively). The early Preboreal, the upper Boreal, the Atlantic and the late Subatlantic are not covered by the diagrams. In these periods clastic sedimentation, non-deposition or erosion took place. In diagram 5 the upper Subboreal is represented by a hiatus. From Organic bed 1 two radiocarbon data have been derived. The datum from the top (GrN 10036: 10230 + 150 BP) and the bottom of this bed (GrN 10037: 10.600 + 50 BP) both support the presumption that it could represent the Younger Dryas period (Fig. 4.2).

Discussion

Before the fluvial history of the valley will be discussed one remark must be made about the basin morphology. The basin morphology is characterized by a flat central area surrounded by step-like slopes (Fig. 3). This surface is almost entirely covered by a desert pavement, which, because of its stratigraphic position below upper Weichselian coversands, is correlated with the Beuningen Gravel Bed. This gravel bed is described by Van der Hammen & Wijmstra (1971), Kolstrup (1980) and De Gans (1981) and is dated as 19.000 – 14.000 BP.

The absence of Eemian and lower Weichselian deposits and the existence of a large Weichselian outwash plain in front of the basin entrance (Haans & Maarleveld, 1957) indicate a substantial Middle Weichselian erosion in the basin before the formation of the desert pavement. For this reason the basin morphology is erosional rather than depositional. This erosion represents the end of the Middle Weichselian, a period in which the basin was affected by permafrost (Sohl, 1983). Therefore, the flat central part of the basin can be explained as a valley cryopediment as described by Czudek (1985). Tentatively the step-like features on the slopes of the basin are explained as cryoplanation terraces (Czudek & Demek, 1970; Demek, 1968, 1969 and French, 1976).

The initial Leuvenumse Beek cut its valley into this cryopediment and the valley is therefore younger or of the same age. The sediments of the valley are composed of three sequences, each composed of a clastic sand bed with an organic bed on top; the palynological and radiocarbon data permit the age-assessment of these fluvial sequences in the valley (Figs. 5 and 6):

- Sequence 1 starts before the beginning of the Younger Dryas (10.230 BP) and terminates at the end of the Younger Dryas period;
- Sequence 2 begins at the transition of the Weichselian to the Holocene and terminates at the end of the Preboreal or just at the beginning of the Boreal;
- Sequence 3 starts in the Boreal and ends in the Subatlantic. All the sediments of the preceding sequences were eroded by this sequence, downstream section 4 (Fig. 4.3). The presence of a hiatus in the pollen sequences indicates a rather complex character of this sequence.

The absence of peat in the downstream cross sections, the low position of the top of the floodplain in sections 3 (Fig. 4.3) and 4 (Fig. 4.4), and the absence of the late Subatlantic pollen records, may indicate a substantial erosion and deposition of clastic sediments since the Roman period (late Subatlantic). The presence of the three fluvial sequences, together with the presumed late Subatlantic erosion suggest that four periods of fluvial adjustments are registered in the valley drainage basin. These periods of adjustment are: (1) end Pleniglacial – Early late Weichselian, (2) transition late Weichselian/early Holocene, (3) Boreal and (4) late Subatlantic (Roman or post-Roman). The term adjustment is applied after Gregory (1977),

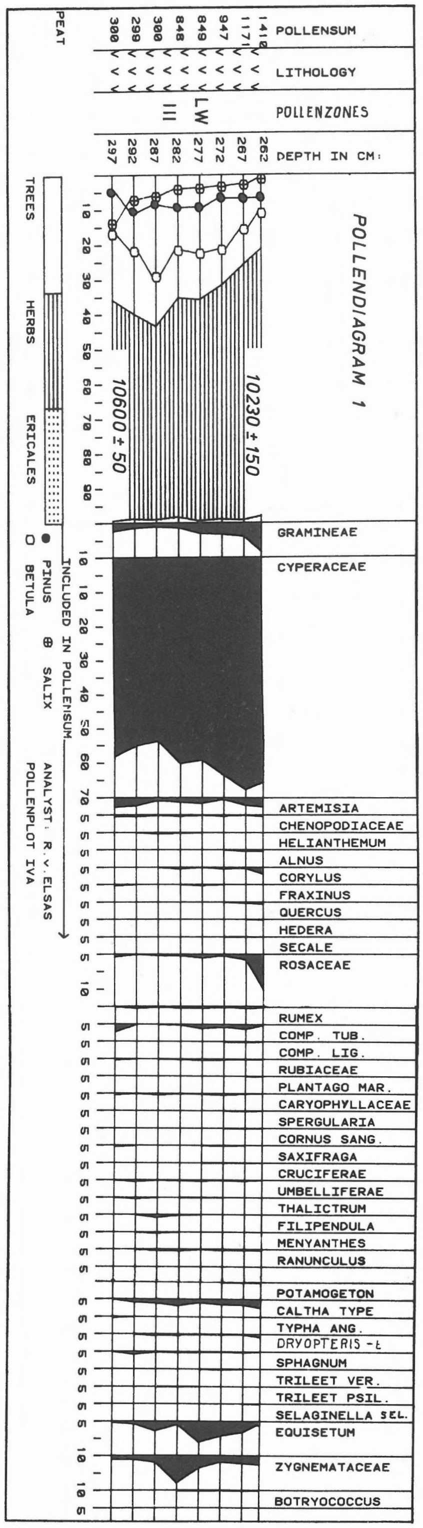

Fig. 7. Pollen diagram 1.

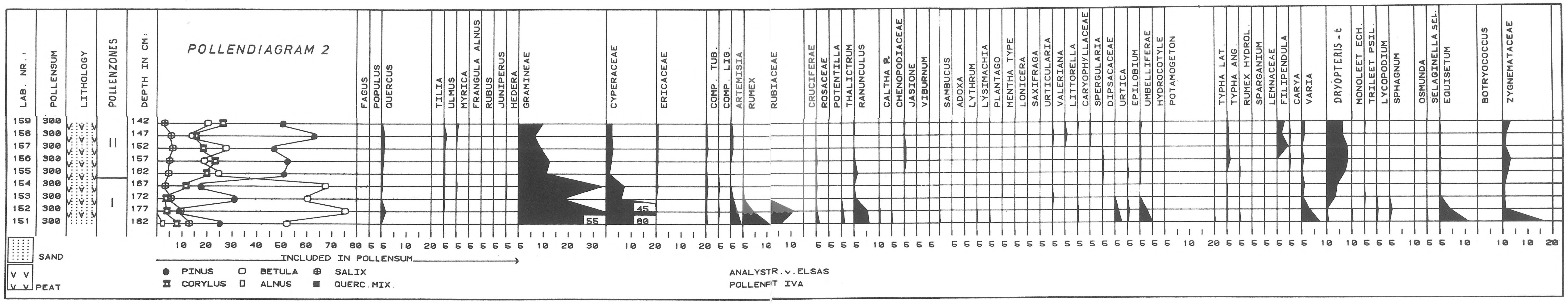

Fig. 8. Pollen diagram 2.

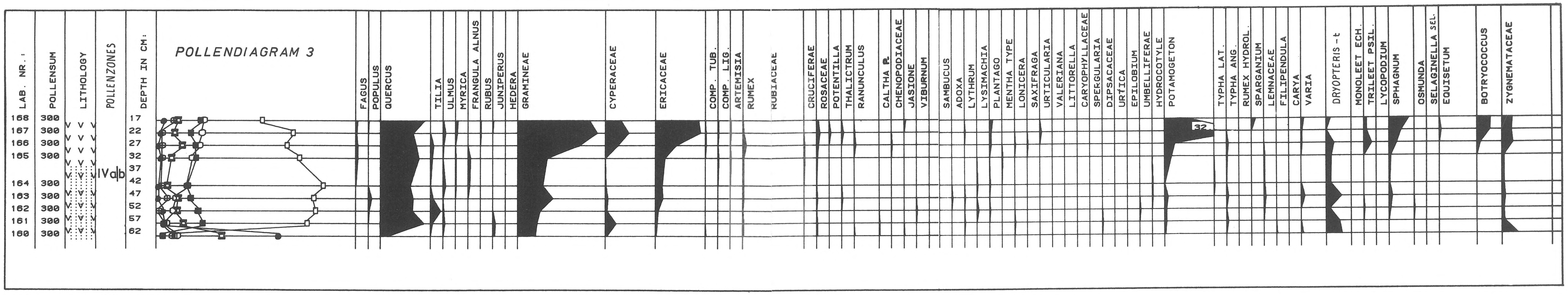

Fig. 9. Pollen diagram 3.

Kozarsky & Rotnicki (1977), Kozarsky (1983), Starkel (1983) and Cleveringa et al. (1988) to indicate changes in fluvial behaviour in a valley system. The compositional development of the sequences (clastic -> organic) indicates a decrease of water discharge in the valley during each sequence followed by an increase in discharge at the beginning of a new sequence. The fluvial adjustments are correlated with the interface between clastic bed and underlying organic bed, but they can also be estimated as a terminus ante quem for the adjustment causing the initial incision of the valley before the Younger Dryas. The dates of the fluvial adjustments are estimations because the top level of the organic beds has been eroded, giving a terminus post quem dating. Furthermore, it should be noted that one specific fluvial adjustment does not need to be time-equivalent all over the valley system (De Gans, 1981). Downstream section 4 (Fig. 4.4), for instance, the upper organic bed (3) both decreases in thickness and is progressively younger at its basal part. The pollen data (diagram 6) also indicate that in section 6 (Fig. 4.6) the sand was deposited while at the same time upstream in the valley peat was growing. Nevertheless, it is thought that the adjustments in the Leuvenum Valley are not local events since the dating of the first three adjustments is supported by data from other valleys presented by, e.g., De Gans (1981), Vandenberghe et al. (1984) and Cleveringa et al. (1988). Therefore it is suggested that they represent a more general trend in the behaviour of small rivers. The nature of the events that caused the changes in the fluvial behaviour remains questionable. The first three adjustments probably took place as a result of climatic induced changes in the vegetation giving rise to variable water discharge in the valley. The last adjustment may primarily be caused by human interference in the landscape, mainly the cutting of wood resulting in an increased surface runoff. This adjustment can be dated more precisely because it occurred before the deposition of the inland dunes of the Kootwijk Formation which are dated to the Middle Ages (ca. 1000 BP) by Koster (1978). This

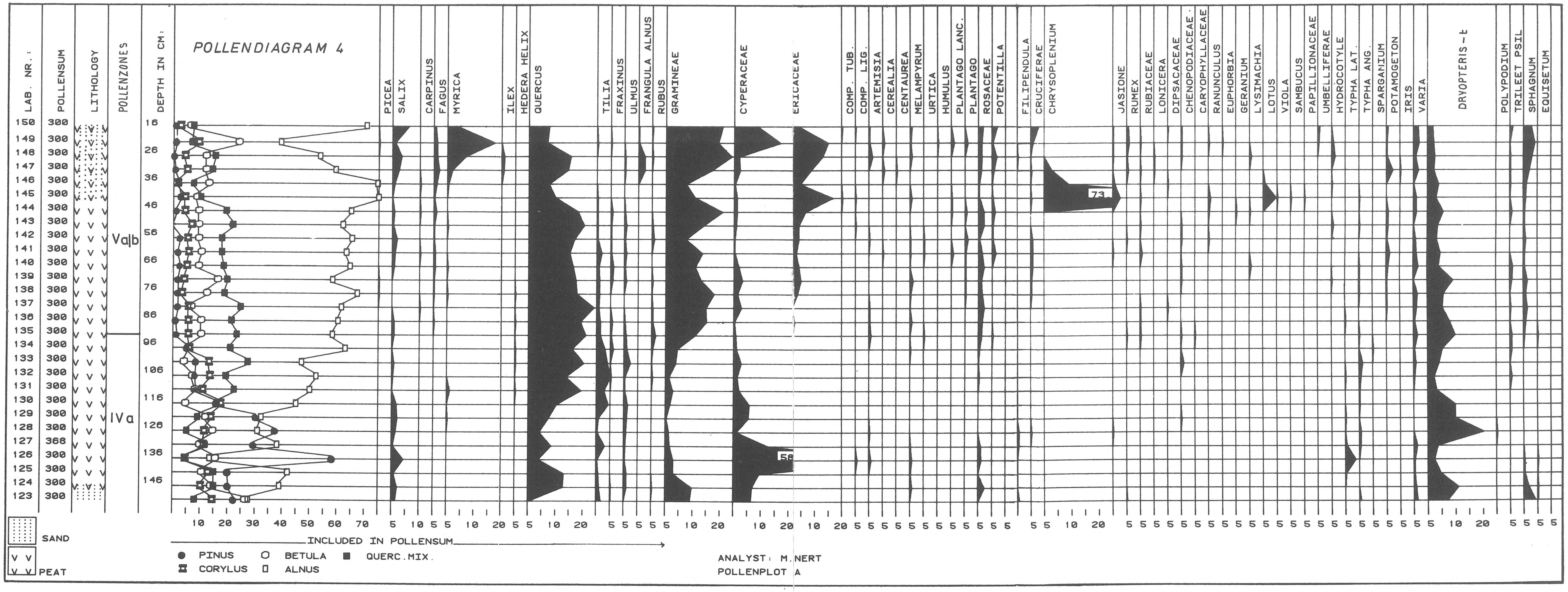

Fig. 10. Pollen diagram 4.

is supported by data of Teunissen (1961). The archeological investigations in the Veluwe area by Brongers (1976), Heidinga (1984), Modderman (1963) and Modderman et al. (1976) indicate a gradual increase of human activity since the beginning of the Subboreal. To what extent the influence of men on vegetation and morphology affected the fluvial activity of the Leuvenumse Beek during the Subboreal till the Middle Ages depended, however, on local factors.

Conclusions

By studying the Leuvenumse Beek valley as an integral unit by means of many cross sections and datings it is possible to construct a three-dimensional framework of the lithostratigraphic units (clastic and organic beds) in the valley and to recognize three fluvial sedimentary sequences. From these sequences four periods of fluvial adjustments are derived:

- the Late Subatlantic (Roman or post Roman);
- the Boreal;
- the transition Late Weichselian/early Holocene;
- the end Middle Weichselian/early Late Weichselian.

A comparison of these data with adjustments known from other valley systems suggests that they took place more or less simultaneously in different valleys (Cleveringa et al., 1988). The oldest fluvial adjustment (initial valley incision) is possibly synchronous with the origin of the valley cryopediment. The origin of the fluvial adjustments, which becomes visible in a headward erosion in the valley, is probably related to variations in run-off and river discharge. These quantities depend either on changes in climate and vegetation or on the human impact on the vegetation and landscape. From the fluvial history of the Leuvenum Valley and the available data of the basin morphology it is possible to establish the geomorphological evolution of the valley:

– Middle Weichselian	– cryoplanation of the basin (Fig. 3)
– Upper Weichselian/Early Holocene	– vertical incision of the valley (Fig. 4.1, 4.2, 4.3)
– Middle and Late Holocene	– lateral erosion in the valley (Fig. 4.4, 4.5)

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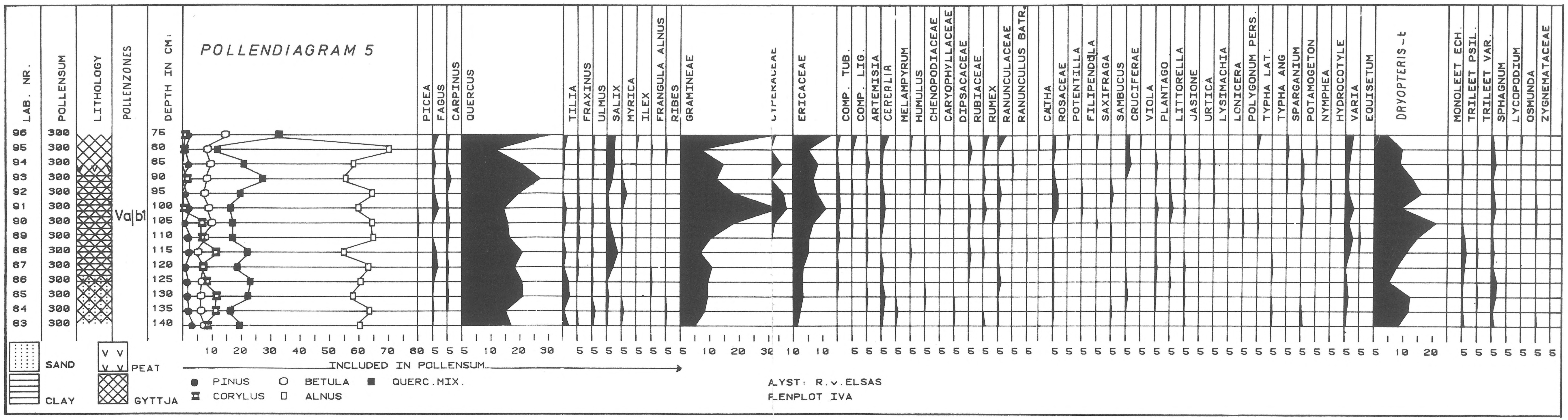

Fig. 11. Pollen diagram 5.

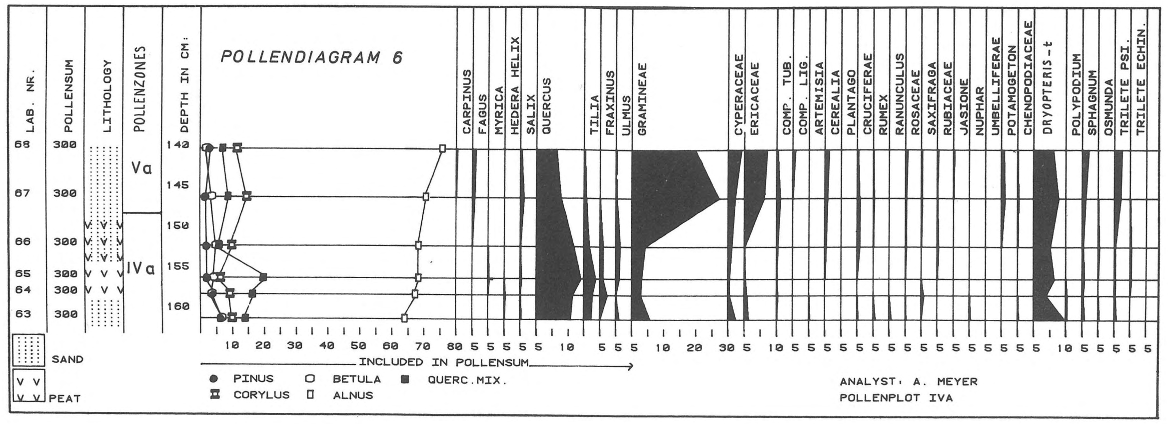

Fig. 12. Pollen diagram 6.

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