

SEDIMENTATION IN THE MID-NETHERLANDS RIVER AREA DURING THE LATE WEICHSELIAN

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ABSTRACT

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This paper is focussed on the distribution of river-dune deposits and characteristic overbank deposits, the so called 'Hochfluthlehm', in the central Netherlands river Rhine area. They are reckoned to the Lateglacial member of the Kreftenheye Formation. By means of pollen analyses and ¹⁴C-datings, the age of these deposits can be fixed. As a consequence of this lithological study a more precise picture can be presented of the changes from a Pleniglacial braided river system into a more channel-bound river system.

INTRODUCTION

Late Weichselian sediments of the mid-Netherlands river area form part of the Kreftenheye Formation. Originally, the name Kreftenheye zone was introduced by ZONNEVELD (1947) for gravels and sands deposited by the river Rhine during the maximum extension of the Saalian glaciation. Later the name was extended to Rhine deposits of Eemian and Weichselian age (ZONNEVELD, 1958), and to the deposits of the river Maas of this age range (VAN DER HEIDE & ZAGWIJN, 1967). The late Weichselian river-dune deposits, which closely associate the former Rhine and Maas river courses, were included into the Kreftenheye Formation by VERBRAECK (1970). The latter river-dune deposits are usually separated from the underlying fluvial deposits by a clay, sandy clay or loam bed of up to 1.50 m thickness (VERBRAECK ET AL., 1974; VAN DE MEENE, 1977). In this paper the relation between the fluvial sands and gravels of the Kreftenheye Formation and the overlying clay and river-dune sands will be discussed, mainly on the basis of the regional extension of these units in the mid-Netherlands river area (Fig. 1).

LATE WEICHSELIAN SEDIMENTS

River-dune deposits

The river dunes have been studied by, inter alia, PONS & SCHELLING (1951), VERBRAECK ET AL. (1974) and VAN DE MEENE

(1977), when respectively river dunes in the Land van Maas en Waal, 'donken' in the Alblasserwaard and eolian sands in the Liemers (eastern part of the river area) were described.

The eolian deposits can occur as distinct knolls in the terrain, protruding from the surrounding Holocene deposits or subsurface, covered by Holocene deposits. In the west of the river area, in the Alblasserwaard, the river dunes (called 'donken' in that area) constitute five, practically parallel series (VERBRAECK ET AL., 1974). In the Land van Maas en Waal the river dunes are concentrated in a single, extended strip, running practically southeast-northwest from the eastern part to the western part of this polder (PONS & SCHELLING, 1951). In the Liemers the eolian sands do not form distinct dunes, but instead extend as a fairly thin cover over older deposits.

VAN DE MEENE (1980) describes the eolian deposits in this area as a thin layer with a slightly undulating surface, which is almost entirely covered by Holocene flood-basin clay; one small river dune outcrops near Duiven.

In addition to these, river dunes of varying size are found scattered throughout the river area. The thickness of the eolian sands varies appreciably. According to VAN DE MEENE (1980) their thickness in the Liemers varies from 0.80 to 1.80 m. In the Land van Maas en Waal the thickness can be as much as several metres, while in the Alblasserwaard the thickness of these sands can amount to more than 12 m. The distribution of the river dunes in the mid-Netherlands river area is illustrated in figure 1. Outside this general map, but still within the mid-Netherlands river area, river dunes occur in the Bommelerwaard and to the east of the map in the area along the river Oude IJssel, which areas were not surveyed by us. As far as these areas are concerned reference may be made

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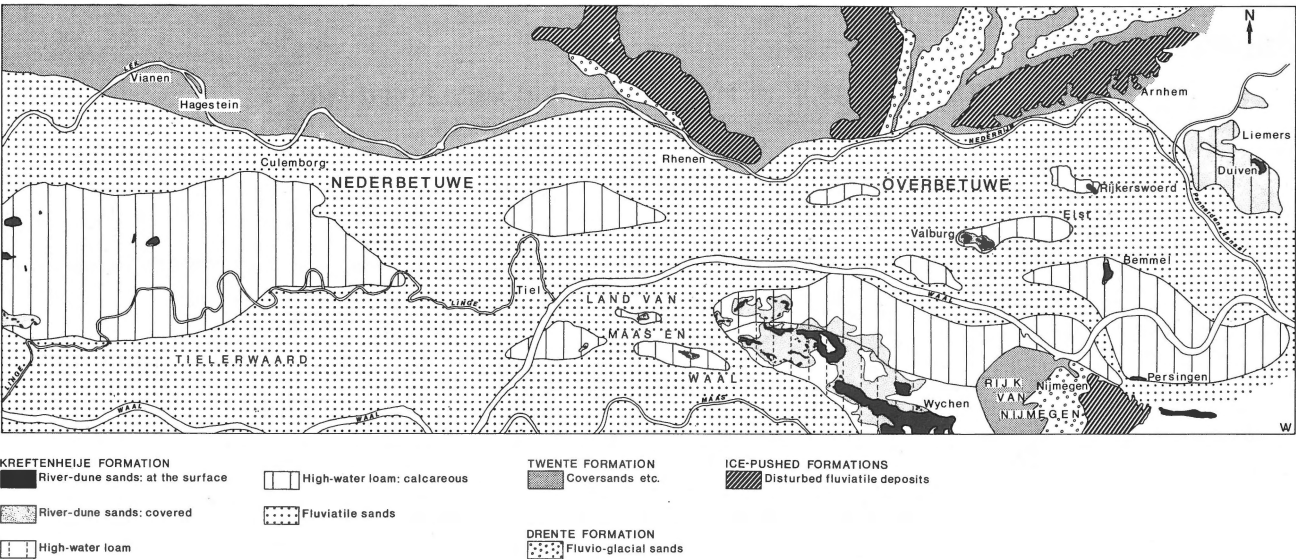


Fig. 1
Outline map of the loam and river occurrence in the central Netherlands river area.

to, inter alia, a soil survey of the Bommelerwaard by EDELMAN ET AL. (1950).

The river-dune deposits chiefly consist of fine grained to moderately coarse grained sands, the grain size ranging from 177 to 325 μm . Fine gravels hardly occur in these sands.

Table I shows the results of the grain-size analyses of river-dune sands from the Alblasserwaard and the eastern part of the river area. Clay or loam intercalations are not encountered in these eolian sand. The grain size of the river-dune sand is uniform. In the field these sands are defined as homogeneous, sharp sands; sharp pointing to the angularity of the river-sand grains. Compared to the cover sand, which likewise are eolian deposits of Weichselian age, river-dune sands are generally coarser grained and much sharper. Furthermore, the sand grains practically do not exhibit any sign of matting. The angularity of the grains and the absence of matting point to a short transport distance by the wind.

The heavy-mineral composition of the river-dune sands is characterized by a fairly high augite (averaging 28%) and alterite (averaging 23%) content with a relatively low garnet content (15%).

Loam deposits

The river-dune sands were for the greater part deposited on top of a loam layer of variable thickness. Hitherto the designation of this layer has given rise to some confusion. In the eastern part of the river area the Soil Survey Foundation refers to this deposit as clay (the clay content is too high for a loam; pers. comm. Poelman, 1983). In Germany this deposit is referred to by the term 'Hochflutlehm'. The loam layer is interpreted to be an overbank deposit, comparable to the Holocene flood-basin clay. However, the outward appearance enables a distinction between the loams and the

Holocene clays. The loams are tough and sticky and, when broken in half, exhibit a friable fracture surface. Flood-basin clays are less sticky and have a smoother fracture surface. It was especially this field characteristic that made us decide to speak of high-water loams in this case, although we are perfectly aware that analyses might well show this designation to be incorrect. However for convenience sake we will maintain the term loam for this particular deposit in this paper. The thickness of the loam layer can vary quite considerably. In the Liemers it varies from 0.50 to 1.00 m, (VAN DE MEENE, 1980). Elsewhere in the river area thicknesses of 50 cm are frequently encountered. In places the thickness can run to more than 1.50 m. It is quite possible, however, that in the case of great loam thickness the upper part of the loam is of Holocene age. The usually poor datability of the loam renders it impossible to give a decisive answer on this point. There are indications, however, in the northern part of the Liemers for instance, that the sedimentation of the Lateglacial loam continued into the early Holocene.

The composition of the loam varies. Fine grained sandy loams frequently occur, while loams in which the sand fraction is absent are also encountered. The latter is the case for instance in the Liemers, as a result of which VAN DE MEENE (1980) regarded the high-water deposit below the river-dune sands as flood-basin clay. The colour of the high-water loam can also vary. The loam frequently has a light-grey colour (in the field the loam is sometimes defined as whitish-grey loam), but brown and bluish-grey loams also occur. The high-water loams deposited by the river Rhine generally have a relatively high lime content. Those deposited by the Maas are largely free of lime. The distribution of high-water loam – a distinction being made between loams rich in lime and free of lime – is shown in figure 1.

On this general map the delimitations indicate the areas

Table 1
Grain-size analyses of river-dune sands in the mid-Netherlands river area.

Locality grain size in μm	<50	50	63	75	105	150	210	300	420	600	850	1200
		— 63	— 75	— 105	— 150	— 210	— 300	— 420	— 600	— 850	— 1200	— 1700
Duiven-de Ploen												
depth 1.30-1.50 m	2.1	0.2	0.2	0.9	4.6	23.1	29.9	22.4	10.1	4.4	1.6	0.5
depth 2.00 m	2.3	0.2	0.2	0.8	5.1	30.5	35.0	19.4	5.0	1.3	0.2	—
Duiven-Horsterstr.												
depth 1.00-1.20 m	3.2	0.2	0.2	0.8	5.3	29.4	32.5	19.6	6.3	2.1	0.4	
depth 2.00 m	2.2	0.2	—	0.4	3.6	27.6	37.2	24.2	4.3	0.3	—	
Bemmel												
depth 1.30-2.15 m	1.7	0.1	0.5	1.9	4.5	25.0	39.2	20.6	5.4	0.8	0.1	
Valburg												
depth 2.00-2.50 m	0.6	0.1	0.4	1.7	4.0	17.2	32.5	27.8	12.1	2.5	0.5	
Rijkerswoerd												
depth 1.40-2.50 m	0.9	0.1	0.6	2.3	5.1	22.8	37.3	22.6	6.4	1.4	0.3	
Duiven												
depth 1.80-2.40 m	0.1	—	0.1	0.5	2.1	16.9	34.2	26.2	13.5	4.7	1.1	
Persingen												
depth 1.40-190 m	0.6	—	0.3	1.4	5.8	18.8	37.0	26.6	7.8	1.3	0.2	
depth 4.00-4.40 m	0.6	0.1	0.3	1.0	3.7	20.0	48.7	20.7	3.0	0.6	0.2	
depth 4.50-5.00 m	0.1	—	0.1	0.3	2.6	9.8	31.2	32.6	16.7	3.9	0.8	
Alblasserwaard	2.0			0.8	2.9	17.5	27.7	30.1	15.0	4.6	0.5	0.3

where the loam described above is encountered. This means that this loam need not necessarily occur as a continuous layer. In the distribution areas the loam deposits are frequently intersected by narrow gullies, which are not shown on the map (Fig. 1) on account of their small width and erratic pattern. They probably represent the feeding channels for the overbank deposits.

As a rule, the above-mentioned loam is difficult to date. The loam is generally poor in pollen and even if pollen is present, part of it is reworked. It is only at a few points in the mid-Netherlands river area that the loam encountered was found to contain humic clay and gyttja intercalations. In the Rijk van Nijmegen area TEUNISSEN & DE MAN (1981) studied pollen in humic clay intercalations in the loam. They conclude that clay sedimentation started in the Older Dryas and continued throughout the Allerød period possibly into the beginning of the Younger Dryas.

Near Wychen in the Land van Maas en Waal area DE JONG (1981) investigated a gyttja layer at the top of this loam, which, at that location, is covered by river-dune sand. The loam below the gyttja is poor in pollen, and the spectra of this lower part contain a high percentage of reworked pollen.

The spectra of the upper part of the loam layer, including the gyttja, are practically all characterized by high herbal values and the occurrence of *Artemisia*, *Chenopodiaceae* and

Juniperus. According to DE JONG the upper part of the loam dates from the Lateglacial. In view of the occurrence of *Ericales* zone LW III (Late Dryas Stadial) would seem quite likely. In that case lower part of the loam could well date back to the Allerød Interstadial on pollen-analytical grounds.

In the eastern part of the river area, in the Liemers, samples were obtained of 'high-water loam' encountered below eolian sands. The results of the pollen-analytical investigation point to a Late Weichselian age. Frost phenomena occur in the upper part of the loam and according to VAN DE MEENE (1980) it may be assumed that this upper part may well have been deposited in the Late Dryas stadial. A similar age range for the loam – Early Dryas to Young Dryas – was found below a buried river dune near Groot Ammers in the Alblasserwaard (VERBRAECK ET AL., 1974).

Fluvialite sands and gravel deposits

The Lateglacial loam in the mid-Netherlands river area was deposited on fluvialite sands and gravels of the Kreftenheye Formation. Mainly on the basis of the composition of the gravels and sand and the depth of the channel base VERBRAECK & VAN DER STAAY (in preparation) subdivide the fluvialite Kreftenheye deposits into 6 members, each representing different river courses of the Rhine and Maas in the time span Saalian

to late Weichselian. The late Weichselian loam layer overlies several of these Kreftenheye units. Mostly, the loams occur on top of the Pleniglacial (Weichselian) Kreftenheye deposits, as for instance in the Liemers (VAN DE MEENE & ZAGWIJN, 1978), but locally, they occur on even older Kreftenheye sands. In contrast, loam deposits are never found on fluvial Kreftenheye sands of Lateglacial (Weichselian) age, which suggests that the loams are the overbank deposits of the Lateglacial river system.

One of the most characteristic features of the Lateglacial Kreftenheye member is the occurrence of pumice fragments from about 2.50 m above its base inward. Moderately coarse grained sands were deposited at the base of these youngest Kreftenheye deposits. The gravel content is usually low. About 2.50 m above the base the sands deposited by the Rhine courses become fine grained. These sands form a layer of 30 to 40 cm thick, in which frequently fine pumice granules – concentrated in a layer of 20 to 30 cm – are encountered. This pumice horizon contains remnants of plants and wood, with a ^{14}C -age of 11770 ± 120 B.P. (DE JONG, 1980). The pumice granules, which usually are from 1 to 1.5 mm in diameter, but can in places south of Arnhem reach a size of 2 or 3 cm, originated from the Laacher See volcanic area, where strong volcanic activity occurred during the Allerød.

The fine grained sand sedimentation was accompanied by clay sedimentation. Later the grain size of the material deposited by the Rhine courses once more increased.

A moderately coarse grained sand (210–300 μm) covers the fine sand/pumice horizon. In addition to fine gravels this top part also contains some pumice in irregularly shaped lenses. The erratic pattern of this pumice deposit suggests reworking.

The fine grained and moderately coarse grained sands are generally rich in lime. They were deposited by Rhine courses, which from the Netherlands-German frontier at Lobith flowed in a northwesterly direction and at the point of Arnhem-Nijmegen assumed a more westerly course. These Lateglacial Rhine courses had a drainage area north of the present-day River Waal and via the Betuwe flowed in a westerly direction. This explains why in the Land van Maas en Waal no pumice granules are found in the Lateglacial fluvial deposits, to which PONS drew attention as early as in 1957. The Lateglacial deposits in the Land van Maas en Waal originated exclusively from Maas courses, which deposited sands there free of lime and pumice. In the course of time the Lateglacial Kreftenheye sands became somewhat coarser, but they generally remained moderately coarse grained (250–300 μm). Another characteristic feature of these Kreftenheye sands is the low gravel content, which as a rule is less than 10%. The gravel is largely fine (fraction from 2 to 20 mm). Practically no gravel in the fraction of from 20 to 64 mm is found in these Kreftenheye sands. The low gravel content is a good contrast with the older Weichselian Kreftenheye sands, which usually contain much more gravel; as much as 25 to 30%. Moreover the gravels in the older Kreftenheye deposits can be both fine (2–16 mm) and coarse (up to 60 mm).

The gravels in the fraction of from 5 to 20 mm have quartz contents of from 47 to 56%. Near the Netherlands-German frontier the quartz contents are about 47%. Downstream in the western part of the river area this quartz content has risen to 56%, which amounts to a rise in quartz content of about 1% per 10 km. In the gravel analysis the Lateglacial gravels are also characterized by a high percentage of well-rounded Palaeozoic sandstone fragments, grey to greenish-grey, characteristic of young (i.e. Lateglacial and Holocene) Rhine sands.

The Lateglacial Kreftenheye fluvial sands exhibit a heavy-mineral composition, which closely corresponds to that of the river-dune sands. A high augite content (about 28%), a fairly high alterite content and again a relatively low garnet content, averaging about 11%. The older Weichselian Kreftenheye sands, on the other hand generally have a higher garnet content, while the augite content is usually somewhat lower than that of the Lateglacial Kreftenheye sands.

CONCLUSION

Although more age data on the Lateglacial Kreftenheye deposits are still needed, the evidence at hand strongly suggests that the loam layer overlying Pleniglacial and older Kreftenheye fluvial sediments is the overbank deposit of the youngest, mainly Allerød Kreftenheye river system. Both the age data and the distribution of these units (Fig. 1) favour this view. However, whereas the overbank deposits of the Holocene rivers – the flood-basin clays – in general are deposited at about the same level as the river bed, the base of the Lateglacial loam sometimes lies a few metres higher than the associated river bed, suggesting that the seasonal variation in discharge was considerable greater than that for the Holocene rivers.

As shown in figure 1, a close relationship exists between the Lateglacial high-water loams and the river dunes. The latter frequently occur in parts of the distribution areas of the Lateglacial loams. These river dunes are concentrated in the peripheral parts of the loam areas, where these border the Lateglacial river courses.

Considering the age of the loam it seems likely that deposition of the dunes took place in the late Dryas when climate deteriorated again. The similarity in heavy-mineral composition shows that the sand of the dunes was deflated from the seasonally dry beds of the Lateglacial Kreftenheye rivers by southwestern winds (VERBRAECK ET AL., 1974).

The more or less limited distribution of these eolian sands along the peripheries of the loam, as well as the angularity of the grains indicate that the sand carried off by the wind was transported over a short distance.

It is possible that the vegetation on the loam surface was responsible for the stabilization of the dunes. In view of the frequent absence of river-dune sand grains in the deposits surrounding the dunes a fast growth of vegetation from the

beginning of river-dune formation in the Late Dryas interstadial would seem quite likely. An exception as regards sand drift from the river dunes is a basin in the Land van Maas en Waal, where driftsand grains from river dunes are encountered in the Holocene flood-basin clays on a fairly large scale.*

A question which arises from the distribution pattern of the river dunes throughout the mid-Netherlands river area is why the pattern of these dunes is so irregular. There are parts of the river area where river-dune formation took place on a large scale, whereas in other areas there are no river dunes at all. This erratic pattern may be partly due to the following causes:

1. During the young Dryas and the period following this era the major river activity was concentrated in the Betuwe and in the Tielerwaard. Dunes would have been destroyed in these areas because of repeatedly changing river beds. Elsewhere in the mid-Netherlands river area such river-dune formation would seem to have been quite possible, but the presence or absence of river dunes must have been greatly dependent on the measure of river activity during the Holocene.

2. The undisturbed existence of the many river dunes in the Land van Maas en Waal, the Alblasserwaard and the area adjoining this polder to the east is due to low river activity in these areas during a large part of the Holocene. The 'solitary' river dunes found here and there in the east Betuwe between Arnhem and Nijmegen and east of Nijmegen, were probably saved from river erosion because of the fixation of river courses in permanently formed, wide river belts.

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* Het oeden niet in het rivierduningsgebied. Het is het Holocene verstuiverings-eoal, niet onwaarschijnlijk aan het begin (Huibert)