

## GEOLOGY AND GEOMORPHOLOGY OF A FOSSIL AEOLIAN LANDSCAPE IN THE LIEMERS (EASTERN NETHERLANDS)<sup>1</sup>

E. A. VAN DE MEENE<sup>2</sup>

### ABSTRACT

Van de Meene, E.A. 1980 Geology and geomorphology of a fossil aeolian landscape in the Liemers (Eastern Netherlands) – *Geol. Mijnbouw* 59: 113-120.

A fossil aeolian landscape of 15 km<sup>2</sup> has been investigated with help of drillings and study of exposures. The sands show a gently undulating surface and an average thickness between 0.8 and 1.8 m. In one place they have a low dune morphology.

The sands are underlain by Late Weichselian floodplain deposits and overlain by Holocene floodplain deposits. Pollenanalytical dating limits the time of deposition to the interval Late Dryas Stadial/Atlanticum. As it is presumed that in this environment strong aeolian action is possible under periglacial circumstances only, the time of deposition must be restricted to the Late Dryas Stadial.

Stratigraphically the deposit represents an aeolian phase in the predominantly fluvatile Krefentehye Formation. It is closely associated with the Late Glacial river-dune deposits that are present along the major rivers in The Netherlands.

### INTRODUCTION

In the western part of the Rhine Valley in The Netherlands the generally flat landscape shows distinct natural mounds. The superficies of these mounds varies from less than one to a few tens of hectares. Their height above the surrounding flat lying river deposits varies from a few decimetres to a maximum of around 5 metres. They consist of sand.

These mounds offer very favourable sites for habitation, being high and dry places in a generally wet and clayey landscape. Locally they are known as 'donk' (plural: donken). It has become clear that they are outcropping tops of riverdunes, that are covered with fluvatile deposits in their lower reaches. VERBRAECK (1974) has studied the riverdunes of the Alblasserwaard in the Western Netherlands (Fig. 1). In cooperation with Kok and Van Meerkerk he investigated them with help of many drillings. The results of his investigations were published together with the history of the 'donken'.

During the mapping for the geological map at 1:50,000 scale in the Liemers (in the Eastern part of The Netherlands), aeolian sand was found lying in a position that is stratigraphically comparable with that of riverdune sand (VAN DE MEENE,

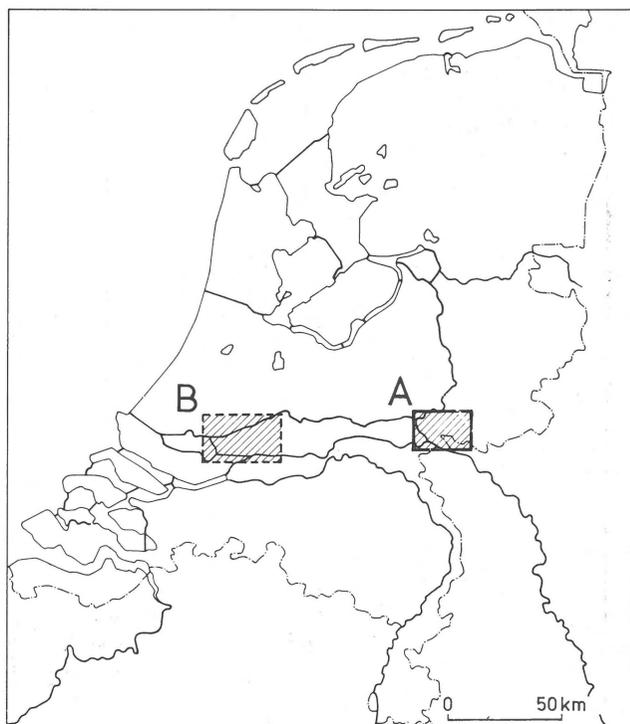
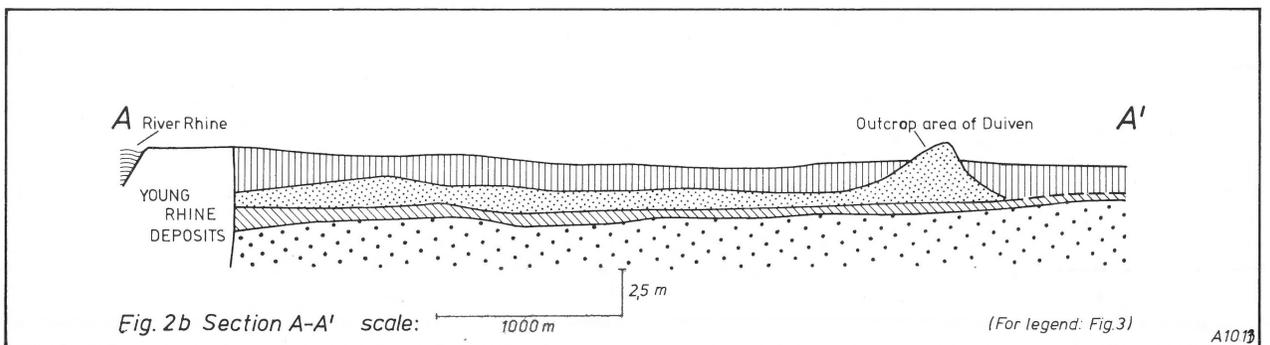
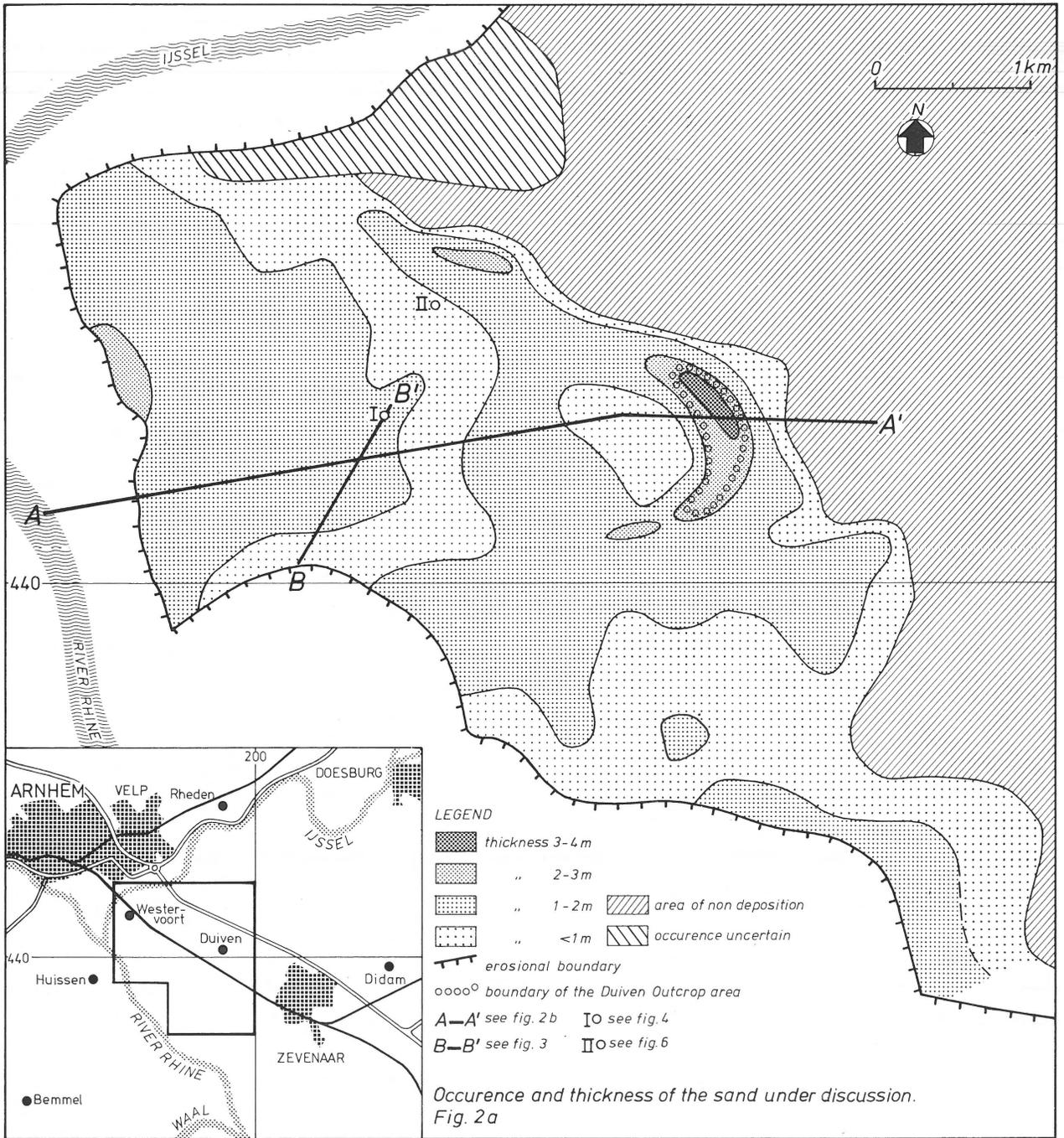


Fig. 1  
Map of The Netherlands showing the area of present investigations (A) and the area investigated by Verbraeck (1974) (B).

<sup>1</sup> Manuscript received: 1979-11-13.

Revised manuscript received and accepted: 1980-01-04.

<sup>2</sup> Geological Survey, P.O. Box 58, 7240 AB LOCHEM, The Netherlands.



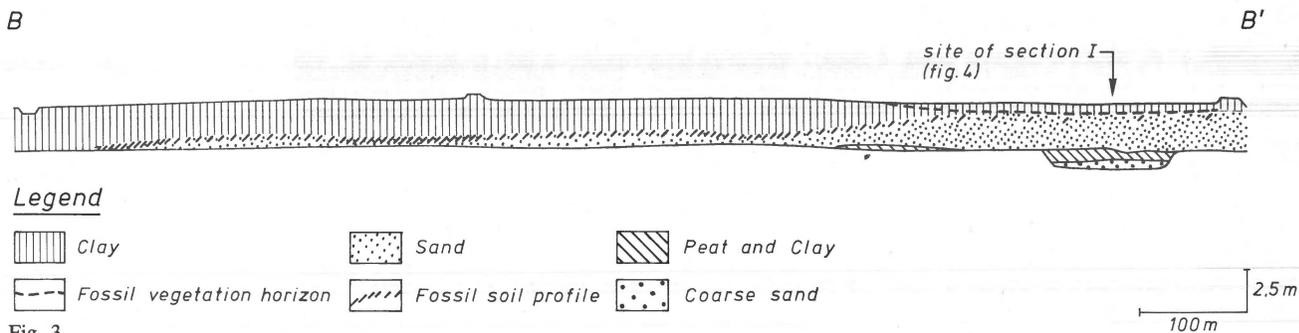


Fig. 3

Section B-B', as seen in a pipeline trench. At the right hand side the complete sequence has been exposed, showing Holocene floodbasin clay at the top, followed by the aeolian sandbody, the Late Weichselian floodbasin deposits and at the bottom coarse fluviatile sand. Towards the left the trench was less deep showing only the gently undulating top of the aeolian sand and the clay cover. (Surveyed by T. Bruins)

1977). Whereas in the Liemers the thickness of the overlying river deposits is much less than in the Alblasterwaard (about 1-2 m versus 5-10 m), the aeolian sand could be studied in temporary exposures. Especially those offered during the excavation of a pipeline trench proved to be highly useful in understanding the character of the sands and their stratigraphic position.

The present study describes the aeolian sand body in the Liemers. Its stratigraphic position and relation to the riverdunes in the Alblasterwaard are discussed.

#### FIELD OBSERVATIONS AND INTERPRETATION

The aeolian sand area in the Liemers covers around 15 km<sup>2</sup> (Fig. 2A). For the greater part it is overlain by fluviatile clay (Figs. 2B and 3). In the eastern part only a small outcrop occurs on which the village of Duiven is situated. Being a natural mound in a flat floodbasin, this outcrop may be called a 'donk'. The aeolian sand is underlain by clay and peat of a fluviatile origin. Overlying and underlying units will be discussed in so far as they are of relevance to the present study. For additional information concerning these units reference can be made to VAN DE MEENE (1977).

#### the underlying deposits

The majority of the underlying deposits are distinctly of fluviatile origin. These are coarse-grained braided-river deposits consisting of sand and gravel, overlain by clayey, silty and peaty floodbasin deposits. There is a distinct timelag between them. On section I (Figs. 4 and 5) these units are shown in some detail.

The coarse-grained material at the base was laid down by the river Rhine and is dated as Middle Weichselian (= Pleniglacial) (VAN DE MEENE & ZAGWIJN, 1978). In its upper part signs of strong frost action are often visible: cryoturbation, frost-wedges, polygons. Usually a desert pavement is present at its top.

Locally this deposit is overlain by a few decimetres of

fluvioperiglacial fine loamy sand (not indicated on sections). On top of it floodbasin deposits occur. They were formed in an extensive floodbasin on the right bank (Northside) of the Rhine. They consist of clay, silt and peat with a thickness of ½-1 m. On two spots in the vicinity of section I, this material was sampled and dated palynologically. From both datings it was inferred that the unit was formed during the Late Weichselian. In some places the unit has been affected by frost action, as can be seen on section II (Figs. 6, 7 and 8). It is not clear if and to what extent the overlying aeolian sand was also affected by frost action. As a Late Dryas age for the frost action seems very logical, the deposition of the sand and the frost action may very well have been contemporaneous (see below).

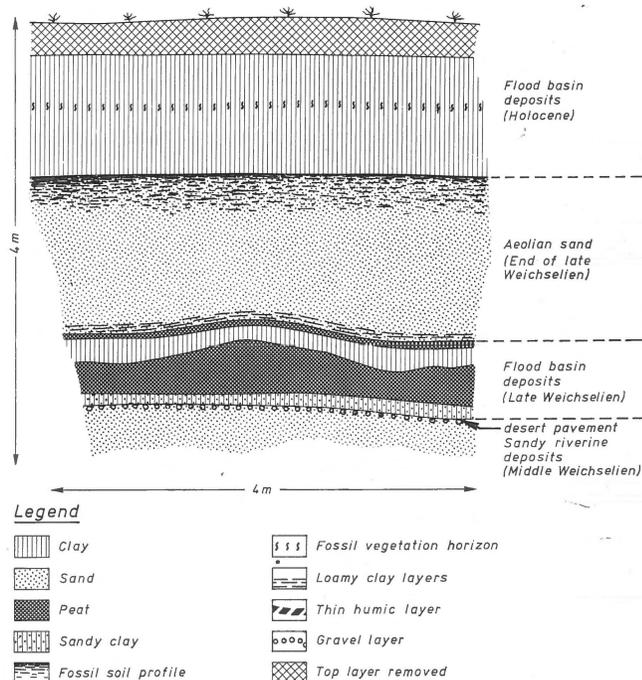


Fig. 4

Section I, showing the aeolian sand and the overlying and underlying deposits. Compare with figure 5. (Surveyed by T. Bruins)

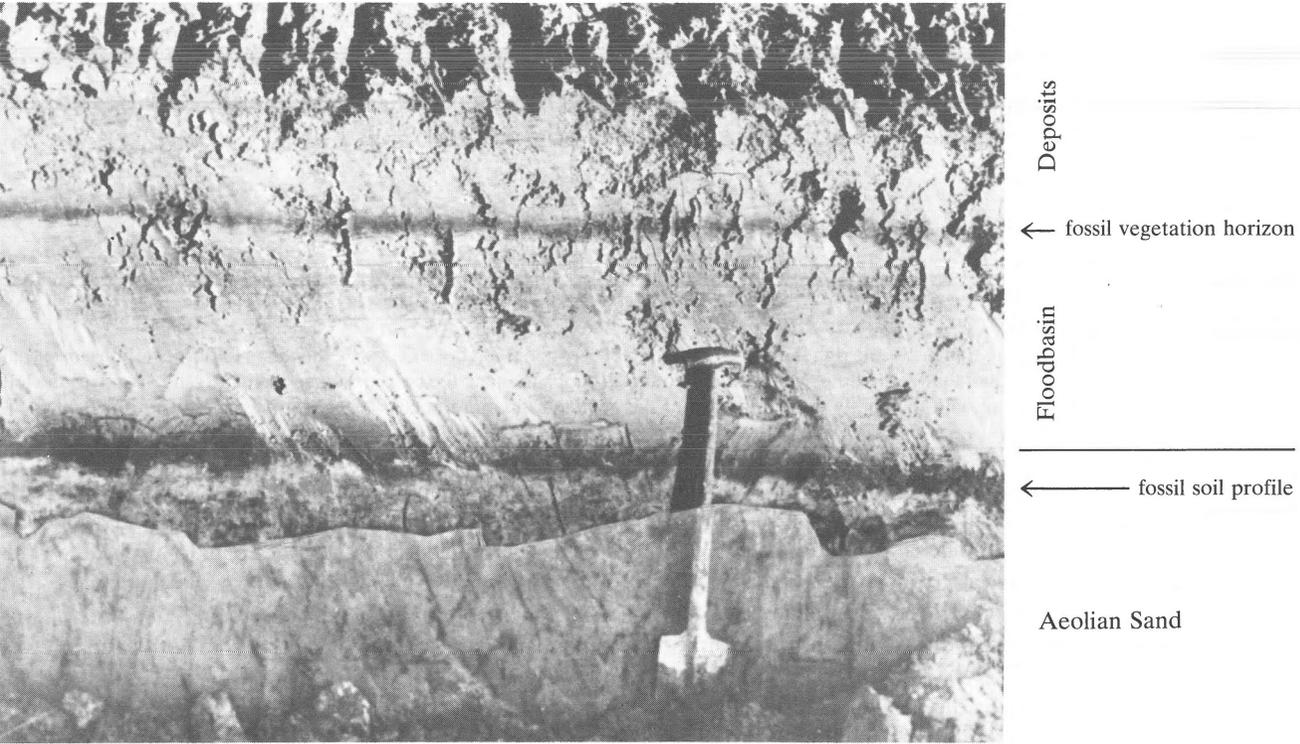


Fig. 5  
Upper part of aeolian sand with well-developed fossil soil profile. Compare with figure 4. (This picture is a composite made of two photographs. Note the undulating dividing line)

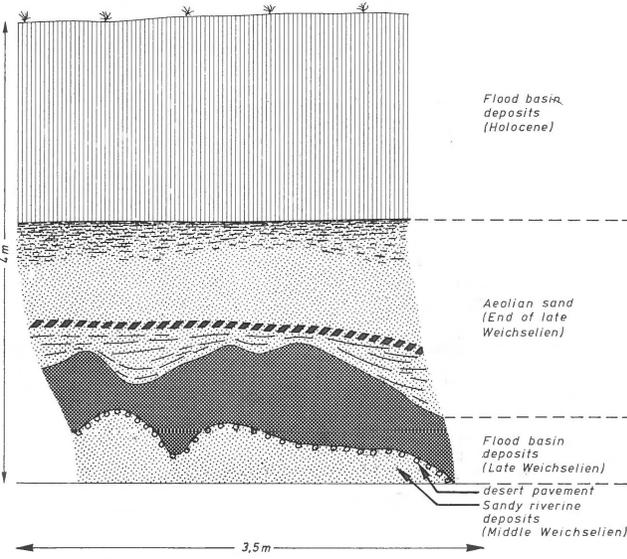


Fig. 6  
Section II.  
The aeolian sand here contains some waterlaid layers at its base. The underlying peat and sand are affected by frost action. Compare with figures 7 and 8. (Surveyed by T. Bruins)

*the overlying deposits*

On top of the aeolian sand Holocene floodbasin deposits are to be found. They consist of clay with peat layers intercalated

locally. These deposits were formed under the influence of the river Rhine as well. Their thickness varies between ½ and 2 metres. Sedimentation started in the Subboreal as can be inferred from palynological datings. The present landsurface of the Western Liemers is made up of these Holocene floodbasin deposits.

*the aeolian sand deposits*

The area in which the aeolian sands are located is indicated on the map of figure 2A. They form a continuous blanket of varying thickness which covers the underlying floodbasin deposits. The greatest thickness was measured in the outcrop area in Duiven, where slightly over 3 m of sand are present. Normally, however, the thickness varies between 0.8 and 1.8 m. This points towards a quite flat landscape, showing distinct dune features in a limited area only, viz. Duiven. As the map presented in figure 2A is based on a systematic grid of 9 borings per square kilometre, it presents only a generalised picture. The soil map of the area that is based on 12-25 drillings per km<sup>2</sup>, shows no other sand outcrops than the one in Duiven (STICHTING VOOR BODEMKARTERING, 1975).

The study of exposures provided more detailed information. The longest continuous section available had a length of slightly over 1200 m and an average depth of 2½ m (Fig. 3). At one or two spots the trench was 4 m deep. Due to difficult working conditions no exact measuring could be performed

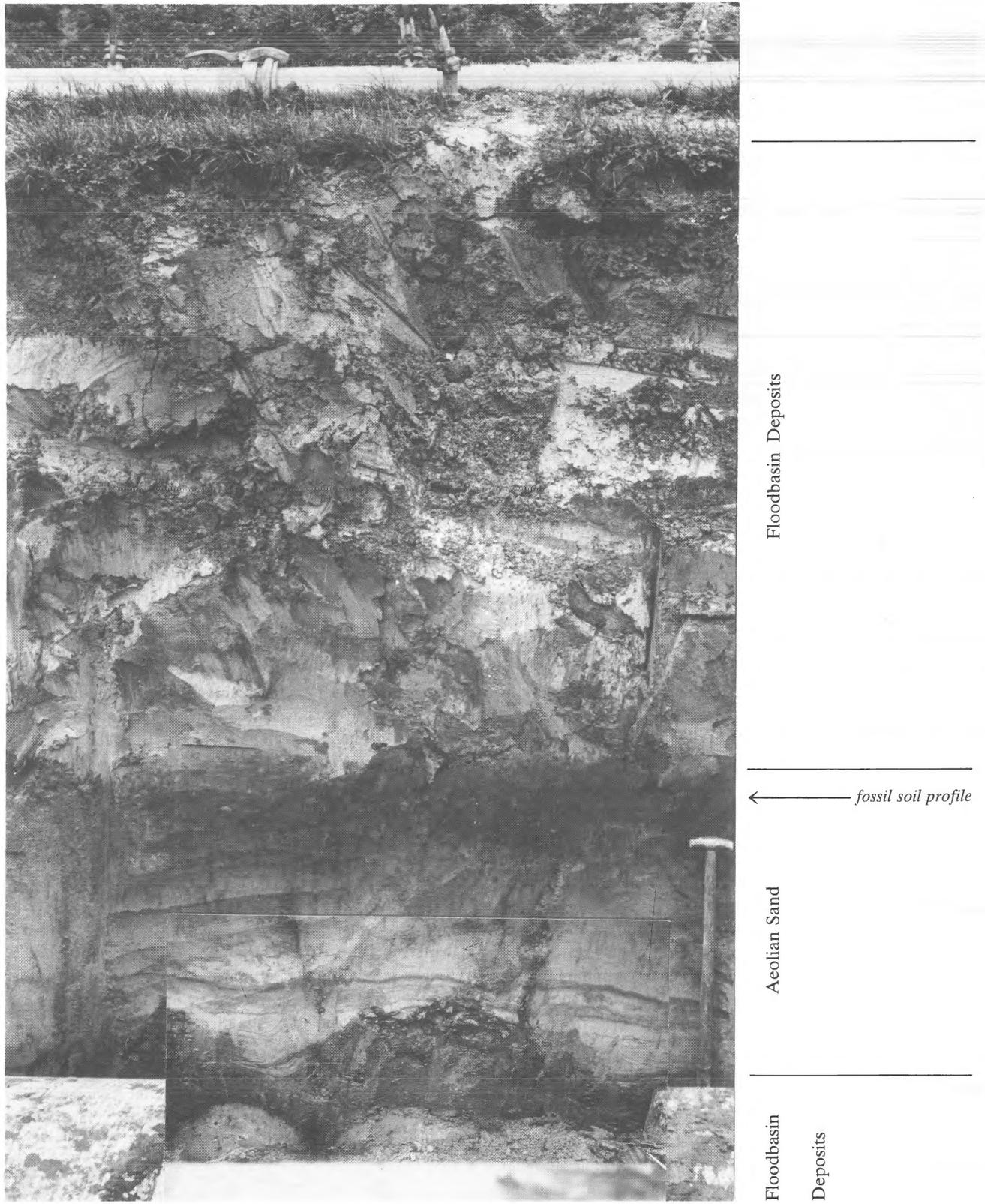


Fig. 7  
Complete sequence showing aeolian sand with over- and underlying deposits, the latter being strongly affected by frost action. Compare with figure 6. (This picture is a composite made of two photographs)

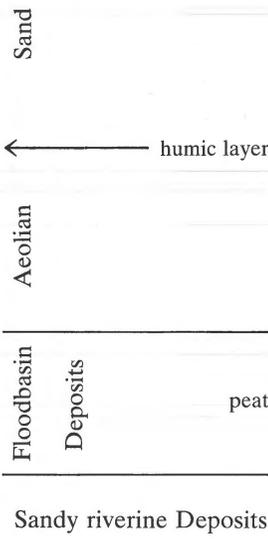
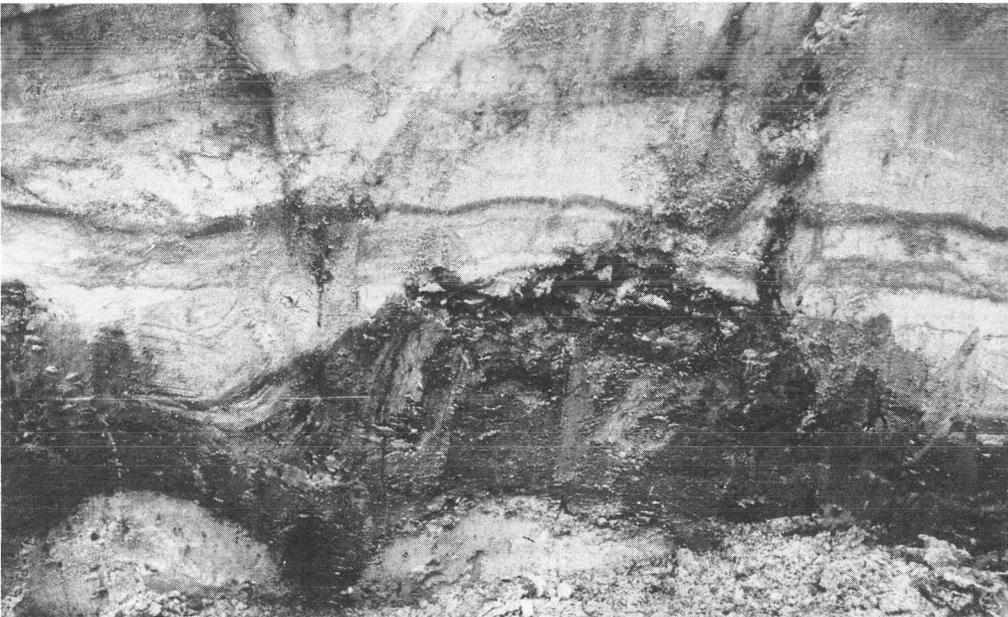


Fig. 8  
Detail of lower part of the sequence. The thin layers ascribed to aquatic influence are clearly visible. Compare with figures 6 and 7.

along this section. Nevertheless it has become clear that the surface of the sand is rather flat and only gently undulating. Over the full length of the exposure a fossil soil profile is present in the top layer of the sandbody (Figs. 5 and 7). In the higher parts of the sands the soil has a grey colour, being less distinctly dark and humic than in the lower parts. The development of the soil must have taken place after the deposition of the sand and before the subsequent overflowing by the river Rhine started. The presence of this soil in all exposures indicates that the latter exerted no erosion on this landscape before depositing its floodbasin clays.

The aeolian sand deposit mainly consists of brown coloured moderately coarse sand. Table I shows the characteristics of four samples of the Liemers compared with an average granulometric analysis from the Alblasserwaard as given by VERBRAECK (1974). The sand in the Liemers has a median of 250  $\mu\text{m}$  and a mode in the class 210-300  $\mu\text{m}$ , whereas the Alblasserwaard sand has a median of 300  $\mu\text{m}$  and a mode in class 300-420  $\mu\text{m}$ . As one of the samples analysed by Verbraeck shows the same characteristics as those of the Liemers and whereas only four samples of the latter area were analysed, it is not possible to say whether or not these differences have any implications.

At its base the sand is often somewhat clayey or contains thin loamy layers of a waterlaid origin e.g. section II (Figs. 6 and 8). Whereas the underlying clay-peat deposit is present everywhere in the area and never shows clear signs of erosion at its top, this basal sand is considered to be aeolian sand that is mixed and intercalated with clay washed out from the slightly higher parts of the Pleistocene floodbasin deposits. This washing out must have taken place under influence of local precipitation, causing only superficial run-off and very limited erosion. The basal layer can be seen clearly on section

II (Fig. 6) and in figures 7 and 8. Its thickness varies from 1-4 dm. Its topmost layer is very humic, probably due to washed out peat particles. However, this is a very local feature.

DATING OF THE AEOLIAN SAND

In the previous section the results of the age dating of the underlying deposits have already been mentioned. Dating was done with help of pollen analysis on two sections with a horizontal distance of 600 m between them. In both sections the pollenzones LWI, LWII and LWIII could be recognised. Zone LW I, covering the Bølling Interstadial and Early Dryas Stadial has a thickness of 10-20 cm and consists mainly of gyttja. Zone LW II, the Allerød Interstadial, consists of peat with very little clay and gyttja and has a thickness of 10-20 cm. In the Late Dryas Stadial (zone LW III) 20-40 cm clay with some gyttja was deposited.

In one place the overlying floodbasin deposits were dated as well. The sedimentation of the clay started in the Subboreal (pollen zone H IV-a). The soil developed at the top of the aeolian sand indicates an Atlantic age (pollen zone H III).

These datings restrict the span of time in which the deposit was formed to Late Dryas Stadial-Atlanticum. This is in accordance with the datings performed in the Alblasserwaard (VERBRAECK, 1974). In the following section the genesis of the aeolian landscape will be more precisely dated.

DISCUSSION

When the area was mapped there was some doubt about the agent that deposited the sand. The coarseness of the sand, and

the thin clay layers that are sometimes present at the base of the deposit suggest a water-laid origin. As the grain size of the sand is comparable with that of the dune sand in the Alblasserwaard, and as the origin of the clay layers can be explained satisfactorily as well (see above) there are no longer any strong reasons to reject an aeolian origin. A point for an aeolian origin is the lack of erosion of the underlying deposits. In all sections studied this clay and peat layer was present without any appreciable erosion. In all drillings the unit was

also present.

The sand must have originated from a source west or southwest of the area under discussion. The reason for this is the wedging out of the sandbody towards the east and northeast (Fig. 2B) and the lack of a suitable source area at that side. Also the parabolic shape as suggested by the contours of the outcrop in Duiven is in accordance with a western to southwestern wind direction. Besides, in The Netherlands westerly winds are thought to be responsible for Late Weichselian and

Table I  
Grainsize analyses of 4 samples in the Liemers, compared with an average granulometric distribution in the Alblasserwaard.

Locality	grain size in $\mu\text{m}$													
		<50	50 63	63 50	75 105	105 150	150 210	210 300	300 420	420 600	600 850	800 1200	1200 1700	1700 2000
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-Horsterstraat														
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	—	—	—
Alblasserwaard		2.0	(0.2)	0.8	2.9	17.5	27.7	30.1	15.0	4.6	0.5	0.3	—	—

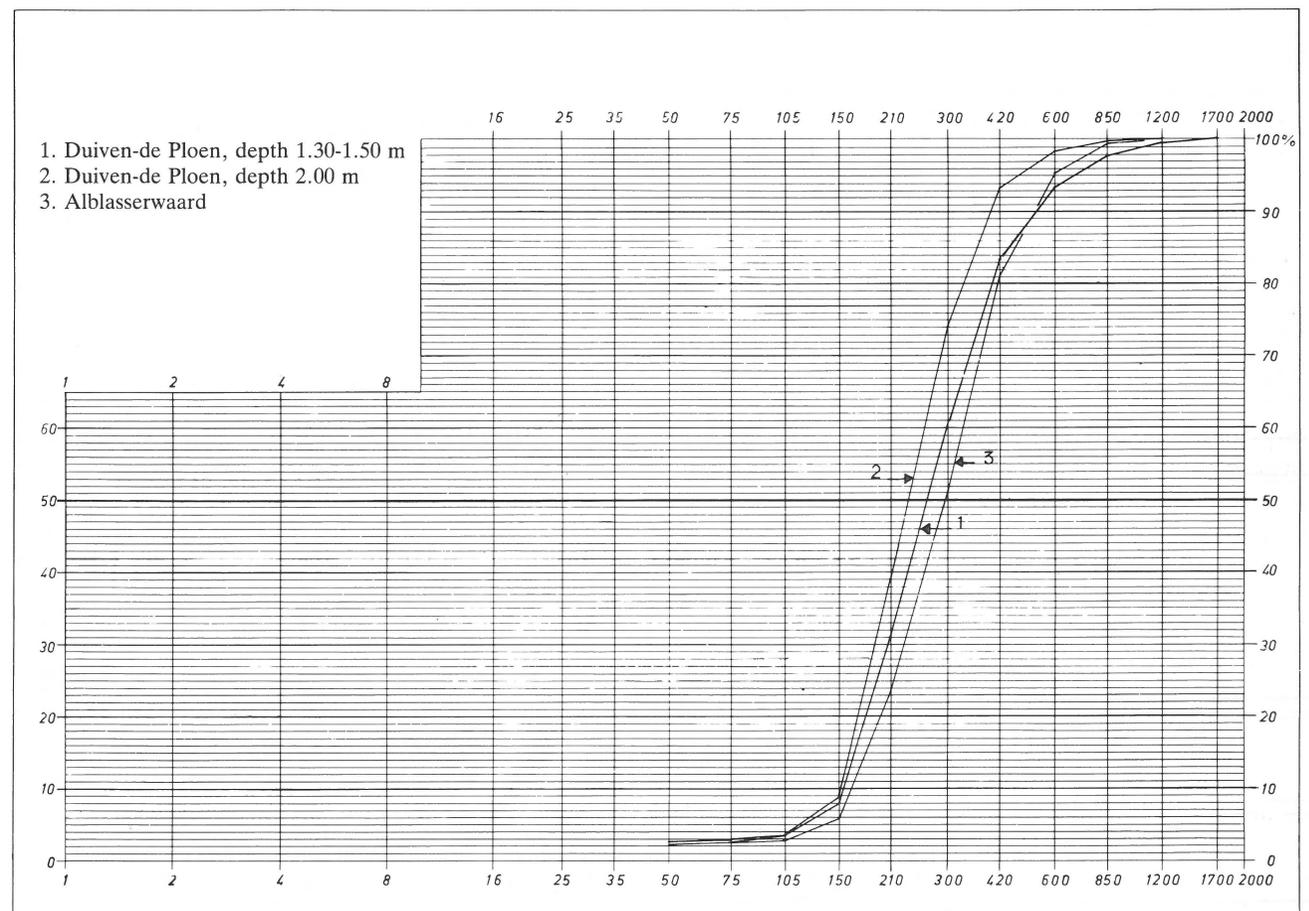


Fig. 9  
Cumulative curves of three characteristic samples (see Table I)

Early Holocene aeolian deposits (VAN DEN AKKER ET AL., 1964). The mineralogical composition of the sand points towards the Rhine as the only possible source area.

The sand has been transported over several kilometres and forms a thin blanket over most of the area. This indicates that in that period the area must have been barren. Taking into account what has been said about the age of the underlying deposits the time of accumulation of the sand must have been the Late Dryas Stadial. Whereas both the sand area and the surrounding floodplain offer favourable conditions for plant-growth, it is likely that they were covered with vegetation as soon as the climate improved at the end of the Weichselian. Therefore the genesis of the aeolian landscape is thought to be limited to the upper part of the Late Dryas Stadial only. VERBRAECK (1974) has come to the same conclusion for the riverdunes of the Alblasserwaard.

As it has been shown above the sand deposit of the Liemers has a limited variation in thickness and a softly undulating surface. Dunes are to be found around the village of Duiven only. At present the height of these dunes is less than 2 m above the adjoining buried sand surface. This doesn't indicate a very pronounced dune morphology, although it is likely that the outcrop was strongly lowered by human activities. The source of the aeolian sand must be found in the highwater-bed of the river course that was used by the Rhine during the Late Dryas Stadial/Praeboreal. The W and SW winds must have concentrated it on the right hand bank and transported it gradually further inland. As is shown by the small variations in thickness of the sandbody sand supply and transportation must have been quite balanced for a time. It also shows, that vegetation must have covered the area after the amelioration of the climate and that no parts were left barren. The only area where further aeolian sedimentation might have taken place much longer is the bank of the Rhine. Sand could have been blown out of the riverbed and concentrated into real dunes on the already vegetated bank. Whereas in the Liemers the Western and Southwestern edge of the sand area are strongly eroded by Rhine and IJssel (indicated on Fig. 2A and 2B) it is quite possible that the riverdunes *sensu stricto* have disappeared and that the present area is the less typical remainder of a once well-developed riverdune landscape. The discontinuation of blowing-out sand from the Late Glacial Rhine beds before the Praeboreal, that was assumed for the Alblasserwaard (VERBRAECK 1974), pleads against this theory.

The position of the described aeolian sand in the lithostratigraphic classification as developed by the Geological Survey of The Netherlands for its 1:50,000 and 1:600,000 scale geological maps, requires some discussion (ZAGWIJN & VAN STAALDUINEN, 1975). The age of Late Dryas Stadial and the character of an extensive sand sheet with a softly undulating surface directs towards an interpretation as Younger Coversand II (Twente Formation). On the other hand this very dating and the close association with the river Rhine makes the interpretation of an aeolian phase of the Kreftenheye Formation also acceptable.

In the explanatory note of the geological map 1:50,000 scale Arnhem Oost the aeolian sand is classified as part of the Kreftenheye Formation (VAN DE MEENE, 1977). This is mainly based on the good stratigraphic, genetic and lithologic agreement with the riverdune deposits in the Alblasserwaard (VERBRAECK, 1970, 1974). However, the lack of a distinct dune morphology in the aeolian landscape of the Liemers renders it less correct to call it a riverdune landscape.

## CONCLUSIONS

The fossil aeolian sand landscape came into being during the last part of the Late Dryas Stadial. In its origins it is comparable with the riverdune landscapes that are present in other parts of The Netherlands. From a morphological point of view it resembles a coversand landscape.

Stratigraphically the deposits should be described as an aeolian phase of the predominantly fluvial Kreftenheye Formation.

## ACKNOWLEDGEMENTS

The author is grateful to the director of the Netherlands Geological Survey for his permission to publish this paper and to his colleagues and collaborators for their support. Mr. J. de Jong did the palynological age datings and Mr. T. Bruins most of the study of exposures. Dr. C. J. van Staaldunin and Drs. A. Verbraeck read the manuscript critically and made many useful remarks. Drawings were made by Mr. A. Koers and Mr. J. A. M. Bruinenberg and photographic reproduction work was done by Mr. F. Willemsen.

## REFERENCES

- Stichting voor Bodemkartering 1975 Bodemkaart van Nederland, schaal 1:50 000. Toelichting bij kaartbladen 40 West Arnhem en 40 Oost Arnhem – Stiboka (Wageningen).
- Van de Meene, E. A. 1977 Toelichtingen bij de geologische kaart van Nederland 1:50 000. Blad Arnhem Oost (40 0) – Rijks Geol. Dienst (Haarlem).
- Van de Meene, E. A. & W. H. Zagwijn 1978 Die Rheinläufe im deutsch-niederländischen Grenzgebiet seit der Saale-Kaltzeit. Ueberblick neuer geologischer und pollenanalytischer Untersuchungen – Fortschr. Geol. Rheinld. Westf. 28: 345-359.
- Van den Akker, A. M., M. Knibbe & G. C. Maarleveld 1964 Het Sallandse dekzandlandschap – Tijdschr. Aardr. Gen., 2e reeks, 81: 287-296.
- Verbraeck, A. 1970 Toelichtingen bij de geologische kaart van Nederland 1:50 000. Blad Gorinchem (Gorkum) Oost (38 0) – Rijks Geol. Dienst (Haarlem).
- 1974 The genesis and age of the riverdunes (donken) in the Alblasserwaard – Meded. Rijks Geol. Dienst NS 25: 1-8.
- Zagwijn, W. H. & C. J. van Staaldunin (eds.) 1975 Toelichtingen bij de geologische overzichtskaarten van Nederland – Rijks Geol. Dienst (Haarlem).