

## STRATIGRAPHY AND GENESIS OF PLEISTOCENE DEPOSITS AT ALPHEN (SOUTHERN NETHERLANDS)

J. VANDENBERGHE<sup>1</sup> & L. KROOK<sup>1</sup>

### ABSTRACT

Vandenberghē, J. & L. Krook 1981 Stratigraphy and genesis of Pleistocene deposits at Alphen (southern Netherlands). In: A. J. van Loon (ed.): Quaternary Geology: a farewell to A. J. Wiggers – Geol. Mijnbouw 60: 417-426.

A detailed study was carried out on a large outcrop at Alphen in the southern Netherlands. At the base fluvial, gravel-bearing sands were found with a stable heavy-mineral association. These deposits, referred to as 'Alphen Sands', are of Early or Middle Pleistocene age. They are overlain by Eemian peat and Weichselian aeolian deposits. Besides loamy coversands, the latter comprise a compact aeolian loam layer, fine dune sands and superficially reworked coversands. During two separate periods the sediments have been subject to periglacial deformations under permafrost conditions. Furthermore they show two gravel pavements. Mineralogically they are characterized by an association of both stable and unstable heavy minerals, probably indicating a mixture of allochthonous Rhine-derived sediments and more or less local deposits.

### INTRODUCTION

In the Campine border area between The Netherlands and Belgium – a region situated between Breda, Tilburg and Turnhout (Fig. 1)– geological and geomorphological fieldwork started in 1978. This area was chosen because the knowledge of the Quaternary geology was rather restricted here compared to several other regions. A detailed survey was necessary to obtain a refined picture of the stratigraphy and of the evolution of the landscape. A good opportunity presented itself in the extensive temporary excavations for the recreation centre at Alphen 't Zand (coord. 51°29'52" N, 4°57'30" E). This place is situated on a relatively elevated interfluvium between the Mark and the Donge river basins, both consequent on the cuesta of the Campine Clay (DE PLOEY, 1961) which comprises the Kedichem and Tegelen Formations, of Early Pleistocene age. The Campine Clay is overlain by Middle and Late Pleistocene deposits which form the subject of the fieldwork. The outcrops at Alphen 't Zand were studied in detail. This detailed analysis has to serve as a key to further studies in outcrops and drill holes in the surroundings. In total 20 sections were described from which the most relevant data have been combined in two schematized sections.

Some aspects of the deposits (e.g. periglacial structures, gravel analyses, morphoscopy of sand, etc.) will be treated in later publications.

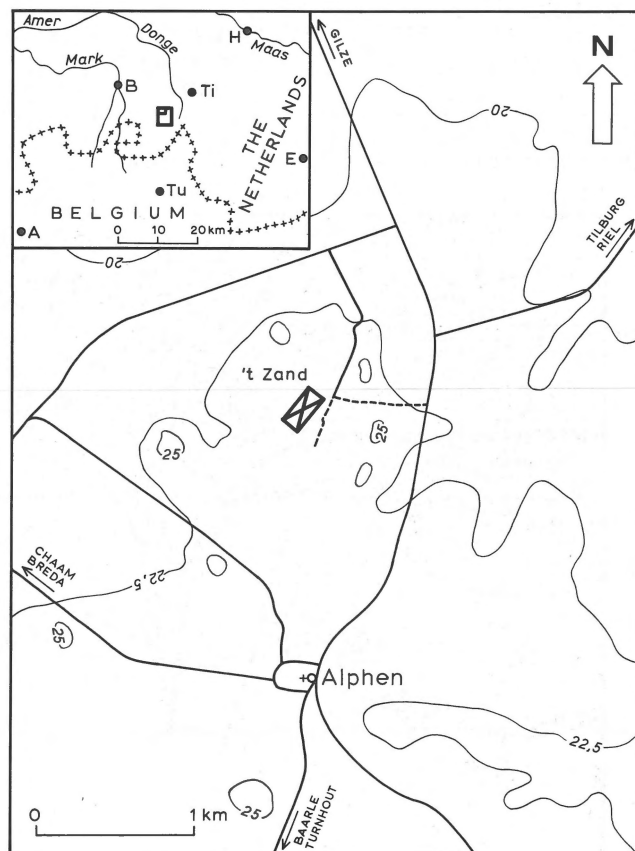


Fig. 1  
Localization map (B = Breda; Ti = Tilburg; H = 's Hertogenbosch; Tu = Turnhout; A = Antwerpen).

<sup>1</sup> Instituut voor Aardwetenschappen, Vrije Universiteit, Postbus 7161, 1007 MC AMSTERDAM, The Netherlands.

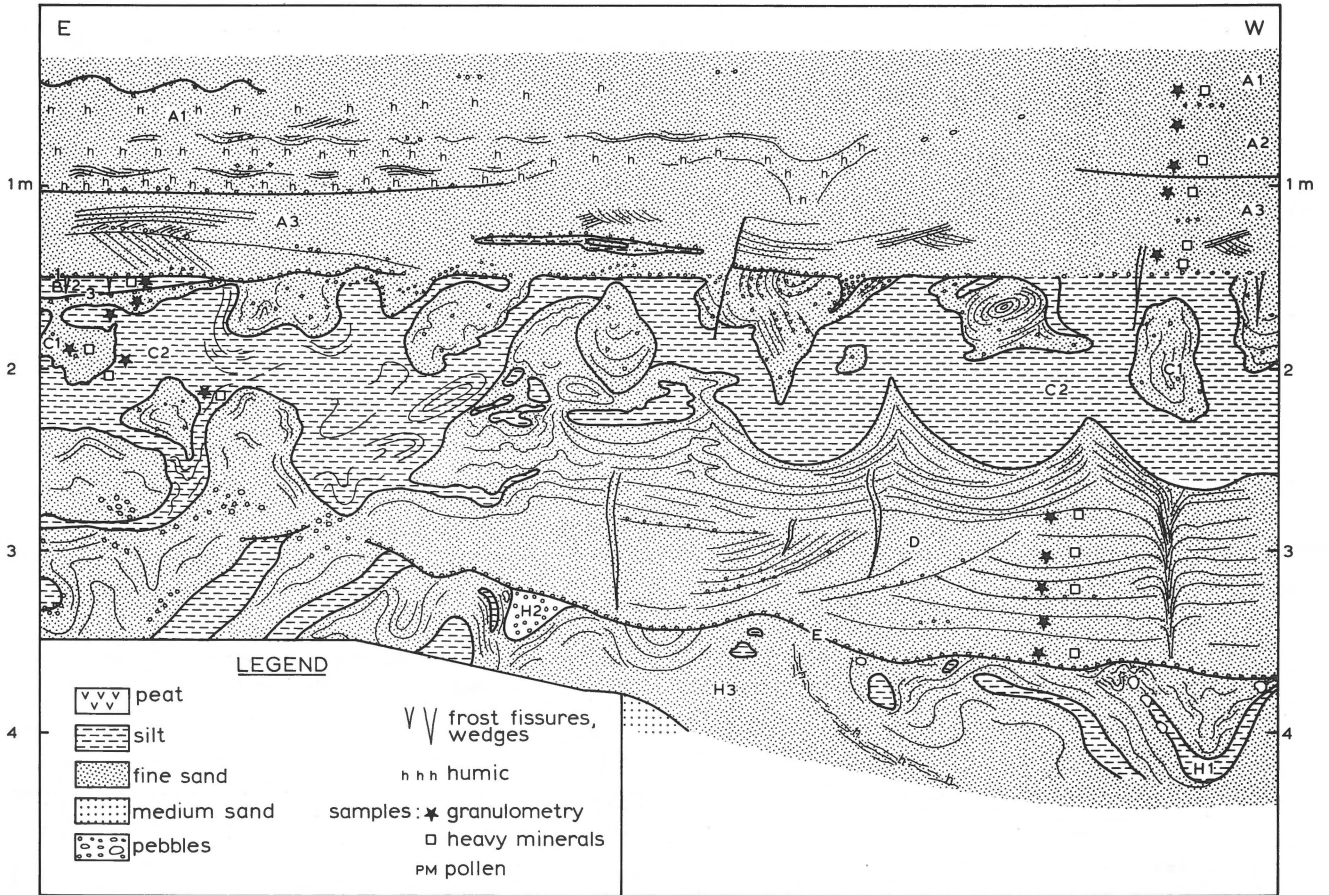


Fig. 2  
Combined section of the southern part of the excavation.

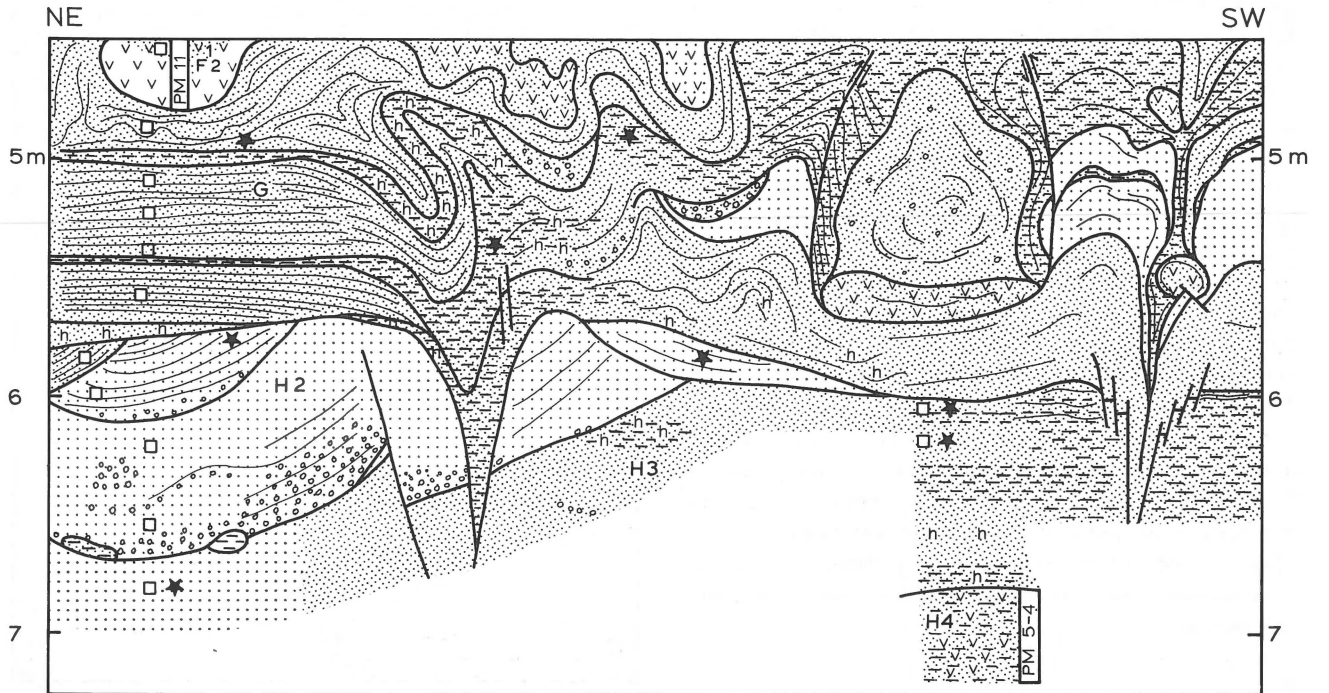


Fig. 3  
Combined section of the eastern part of the excavation (legend: see figure 2).

## DESCRIPTION AND ANALYSES

### *Description of two combined sections and grain-size analyses*

From top to bottom several lithologic units can be observed (Figs. 2-6). The granulometric distribution of a few samples is represented in Fig. 7, while in Fig. 8 some characteristic histograms are given.

Units A and C1 contain well-sorted, pale-yellowish, fine sands. They are homogeneous (A1), horizontally laminated (A2) or clearly cross-bedded (A3). The silt content is generally very low (< 4%), but > 10% in A2 and locally even higher at the base of A2. This basal part shows features of hydromorphic soil formation (Fig. 4). A3 and C1 contain a certain amount of coarse sand grains and small pebbles as a deflation residue (see e.g. A3-C1 (28) in Fig. 8). A few small undulations were observed in A2, while locally small frost fissures (max. 30 cm deep and 1 cm wide) start at the base of A3. All these deposits show the characteristics of typical coversands.

A continuous undisturbed pebble layer (B1) is sometimes underlain by a small horizontally laminated loamy bed (B2) and by convoluted pebble horizons (B3). The pebbles (< 5 mm) are wind-frosted and polished. Also some ventifacts were found. Consequently the pebble layers have been interpreted as desert pavements.

C2 is a very compact sandy loam which is characterized by a strong gleyification, showing brown and grey mottling. It is heavily cryoturbated together with the coversands of C1 and discontinuously overlain by unit B1-2 (Fig. 4). The grain-size distribution of the loam is characterized by a maximum in the coarse silt fraction as well as a second maximum at about 150  $\mu\text{m}$ . The low clay content (2-15%) is in contrast to the high silt content (30-60%). This loam has been called the 'Brabant Loam.'

The sands of unit D are significantly coarser than the overlying aeolian units and show locally broad, shallow, cross-laminated lenses. They represent mainly aeolian sediments reworked by superficial fluvial processes. Starting from the top rather narrow wedges penetrate into this unit to a maximum depth of 1.5 m. Very weakly developed collapse structures are found. The wedges have been interpreted as sand wedges or as the lower part of ice wedges from which the upper part has been disturbed by the strong cryoturbation mentioned under C.

The gravel pavement E, which contains pebbles up to 10 cm, is flat and rests unconformably on the underlying units. Sometimes broken parts of the original pebbles have been found together.

Below fine aeolian sands (F1) an organic layer (F2; Fig. 5) occurs which is replaced by a humic podzol on higher—originally dry—places. The peat has sunk in the underlying units by cryoturbation (Vandenberghé & Van de Broek, in prep.).

The units G and H consist of beds of horizontally laminated (humic or loamy) fine sands and of coarse (gravelly) cross-bedded sands. Boulders measuring more than 0.5 m have



Fig. 4  
The top sediments of the sections: undisturbed aeolian deposits A and B1, a strongly cryoturbated unit C and rather homogeneous 'Alphen Sands' (H3).

been dug up in some places. These units occur in gullies of different sizes and were interpreted as being deposited in a very differentiated fluvial environment.

The three lower units have been penetrated by many large ice wedges, starting at the base of the involutions. Collapse structures can always be observed along the wedges. They originated in the permafrost below the active layer where the involutions were formed.

## HEAVY MINERALS

Figure 7 shows a graph representing the heavy-mineral composition of the sediments. The heavy minerals are theoretically from the fraction of 50-420  $\mu\text{m}$ . However, this has little practical meaning, firstly because the sands are fine grained

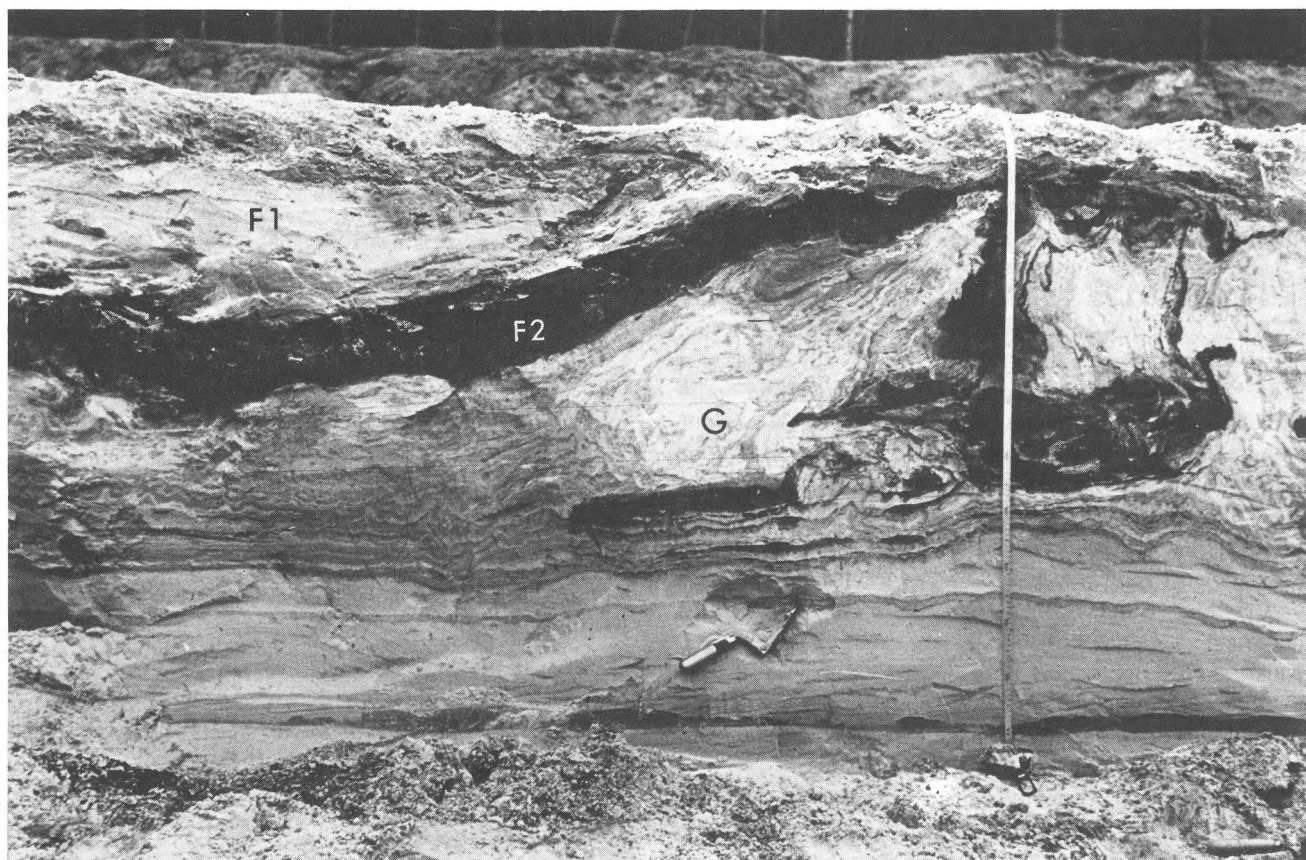


Fig. 5  
Involved late Eemian peat bed (F2) on top of the 'Alphen Sands' (G) and overlain by coversands (F1).

and secondly because the heavy minerals are of even finer grain size than the light minerals. In figure 8 this is illustrated (sample 30 from unit D). It shows the grain-size distribution of the heavy minerals of a coversand as compared to the distribution of the whole sample. In this sample, which represents an average coversand, less than 3% of the heavy fraction has a grain size above 150  $\mu\text{m}$ , while about 50% falls between 50 and 75  $\mu\text{m}$ . Consequently the fine fractions have a far higher heavy-minerals content than the coarse fractions.

The graph of figure 7 shows two different associations, viz. a lower, stable one and a higher one with a relatively high content of unstable minerals. The stable association, occurring in units G and H, consists mainly of the 'rest' group (zircon, rutile, some anatase and an occasional grain of brookite), a relatively high content of tourmaline, some staurolite and other metamorphic minerals and traces of chloritoid. In the greater part of the samples some unstable minerals are found, mostly epidote. From unit F upwards a different association occurs, about 40 or 50 percent of which consists of the same minerals as the underlying zone, while the other part comprises epidote, hornblende, garnet and alterite. Sphene and glaucophane are usually present in trace amounts.

## POLLEN ANALYSES

### *Alphen 5-4 (Fig. 3: PM 5-4; Fig. 9)*

The relatively small amount of arboreal pollen (AP), the low percentage of thermophilous species and the presence of some 'steppic' elements point to a kind of park-tundra and a cool climate. The small quantities of *Tsuga* are characteristic.

Similar assemblages were described by ZAGWIJN & ZONNEVELD (1956) and ZAGWIJN (1960, 1963) from the Kedichem Formation and dated as Menapian and Eburonian. In comparison the diagram at Alphen reflects warmer conditions than the coldest (subarctic) spectra of these two glacials where the AP content is only 20% and *Tsuga* is absent. Perhaps the most striking similarity can be found with the slightly warmer spectra from the Menapian. In conclusion the diagram can be interpreted as of late Early or early Middle Pleistocene age.

### *Alphen 11 (Fig. 3: PM 11; Fig. 10)*

This diagram represents clearly an interglacial flora. According to the absence of *Azolla* and 'Tertiary' elements, the

diagram can be interpreted as Eemian. The sharp rise of *Carpinus* and the Ericaceae indicates the start of the E5-zone (ZAGWIJN, 1961). The gyttja-rich sediments show larger quantities of *Betula* and *Sphagnum* while the more sandy sediments show considerably larger values of *Corylus* and *Bryophyta*. Corresponding diagrams reported by MENKE (1970) and by SPARKS & WEST (1970) are also characterized by a relatively high *Corylus* content. Apparently this feature is (partially) due to local circumstances. At Alphen the Quercetum mixtum and *Tilia* percentages are lower than in Zagwijn's corresponding E4b-E5 zones. Perhaps the edaphic conditions were unfavourable. Another possibility is to create a transition zone between E5 and E4, as was done in some cases by DE GROOTE (1977), with high *Corylus* values as in E4b, but with low values of the Quercetum mixtum and *Tilia* as in E5.

### GENETIC AND STRATIGRAPHIC INTERPRETATIONS (Fig. 11)

#### Unit A

The irregular sedimentary structures are indications of local circumstances of aeolian deposition (small homogeneous bodies), erosion (discontinuous deflation horizons) and stabilization (soil formation). These dune sands can be correlated with the Beerse Formation (DE PLOEY, 1961) and the 'Younger Coversands' in the Dutch terminology (NELSON & VAN DER HAMMEN, 1950). The local origin is in agreement with the opinion of several authors (a.o. CROMMELIN, 1964, 1965) that the Younger Coversands were formed mainly by the reworking of the Older Coversands. The enrichment of garnet in the Younger Coversands as has generally been recognized, seems to be confirmed here as well (see Fig. 7, unit A1).

In contrast to these dune sands, the regular horizontal lamination in A2 points to an equably deposited aeolian cover (coversands). In A3 the typical horizontal layering is absent and replaced by cross-lamination. The variability of the lamination may be explained by the local or temporary humidity of the surface: when the upper soil is dry and vegetation is scarce the circumstances are favourable to free saltation resulting in regular ripples and small dunes, characterized by typical cross-lamination (a.o. MACKEE, 1966); on the other hand, when the surface is wet and/or provided with a more or less dense mat of herbs or mosses the saltating movement is hampered by cohesive forces and by the mechanically hindering vegetation resulting in a sheet-like movement and deposition (see also DE PLOEY, 1977, 1980). The former conditions were rather rare during the Weichselian Pleniglacial: only at the highest interfluvia (e.g. at Alphen) and during dry periods. However, the latter conditions can be considered as more common because of the generally occurring horizontal layered sands whose humid mode of deposition is also confirmed by the higher loam content and the filling of the local depressions by loam deposition. The latter deposits were favourable to the

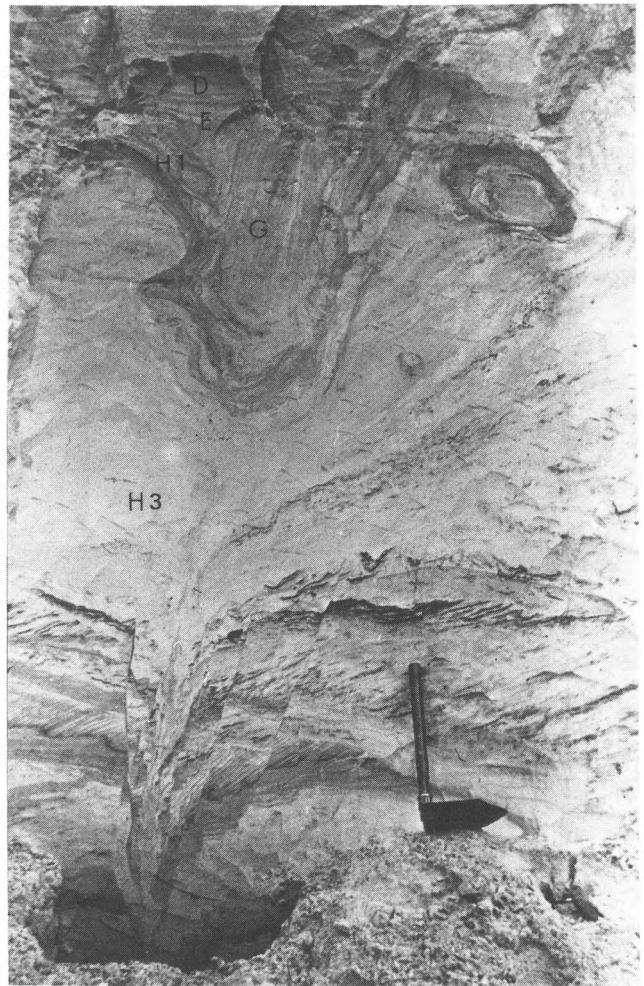


Fig. 6  
Large ice wedge associated with involution at the top and discontinuously overlain by desert pavement E and the 'reworked aeolian sands' D.

development of hydromorphic soils: at the base of A2 and in B2. They correspond to the Late-Würm 'Nass-bodens' in loess profiles (e.g. FINK, 1976). The presence of local swamps can be explained by the existence of frozen underground during a great part of the year.

Correlation of the A2 sands can be made with the 'Older Coversands 2' (VAN DER HAMMEN ET AL., 1967) and with the 'Coversands' (VANDENBERGHE & GULLENTOPS, 1977; VANDENBERGHE, 1980).

As to the grain-size characteristics the Late Glacial dune sands (A1) closely resemble the pleniglacial coversands at this place. Especially the almost loam-free sands (A3-C1) are difficult to distinguish from the upper dune sands (A1) on granulometric grounds. The coarse grain size or the better sorting of the Late Glacial sands (A1) have to be considered as insignificant, in contrast to results obtained by DE PLOEY (1961) in northern Belgium.

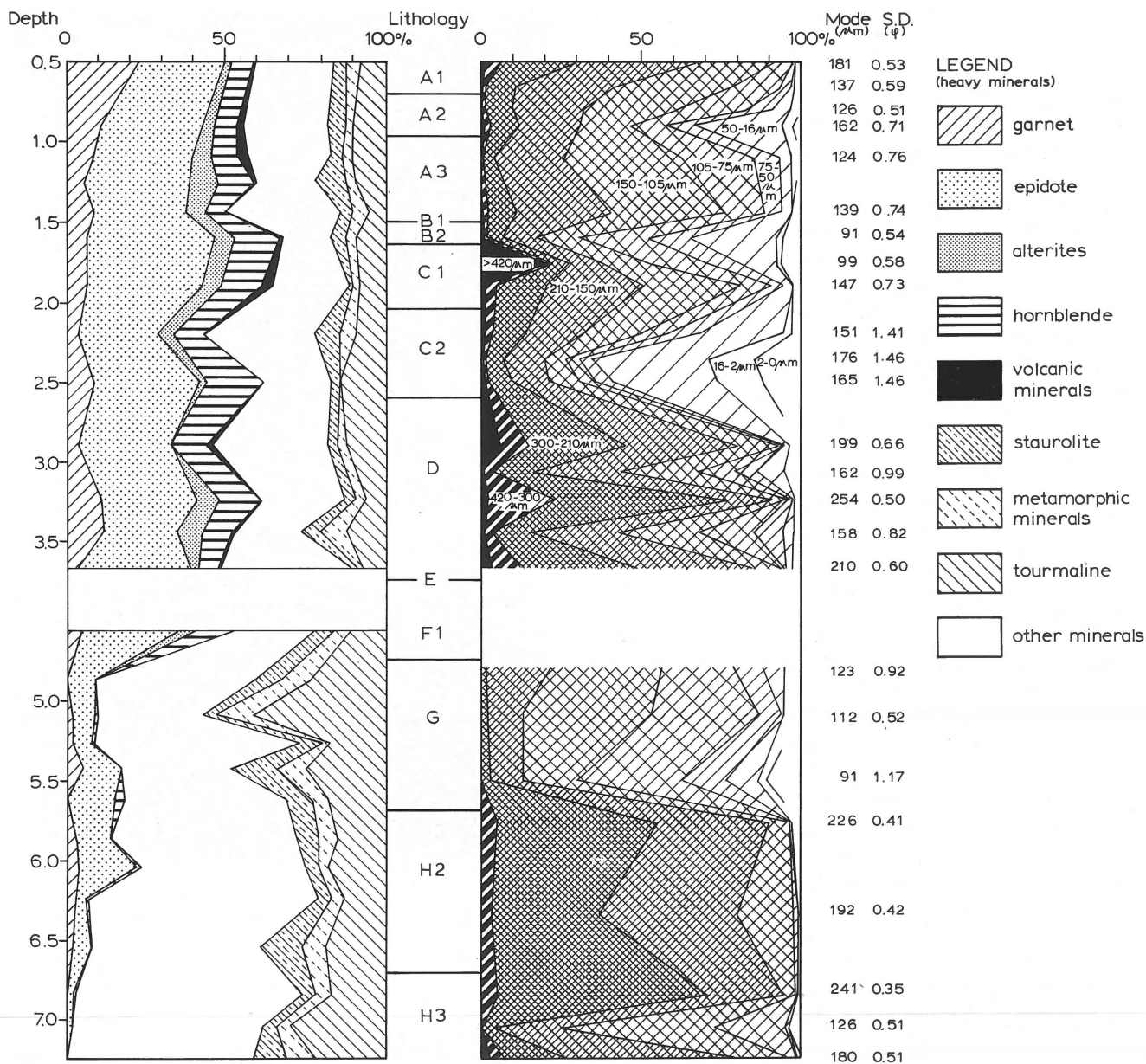


Fig. 7 Heavy-mineral (left) and granulometric (right) diagrams compiled from samples of the various sections. Localization of the samples is indicated on figures 2 and 3.

### Unit B

The desert pavement is a very characteristic horizon between the undisturbed 'coversands' and the highly cryoturbated 'Loams and Coversands' (unit C). Moreover its widespread occurrence makes it a valuable stratigraphic marker (Beuningen gravel of VAN DER HAMMEN ET AL., 1967; desert pavement 3 of PAEPE & VAN HOORNE, 1967; VANDENBERGHE, 1977; KOLSTRUP, 1980). However, it follows from our observations in this region that this gravel may consist of several deflation pavements interrupted by periods of sedimentation. In this pit

at least two thin gravel pavements have been found, a cryoturbated one and an undisturbed younger one. Apparently the formation of the desert pavements has lasted during a rather long period at some places. The unconformable position of the pebble layer on the cryoturbated units (B3 and C1-2) and the stratigraphically corresponding gullies in the neighbourhood suggest that in a first phase the gravels were enriched by superficial and concentrated run-off. The typical aeolian diagnostic characteristics of the pebbles, on the other hand, prove the activity of aeolian processes in a later phase.

## Unit C

Below the pebble layers, loam beds (C2) again alternate with dry aeolian sands (C1). However, here the loams are dominant. Their low clay content and occurrence of one of their grain-size maxima in the coarse silt fraction are typical characteristics of loess deposits (a.o. GULLENTOPS, 1954; SOMMÉ, 1967; PISSART ET AL., 1969). However, the fraction between 10 and 50  $\mu\text{m}$  of a typical loess represents more than 60% according to VINK (1949) and more than 50% according to FINK & NESTROI (1967). It is clear that generally the sand fraction at Alphen is too high for a typical loess. This can readily be explained by the fact that in transitional regions between coversand and loess areas pure loess is not common but is usually mixed with coversand. In this respect the northern boundary of the loam belt at this time should have been situated more to the north than during the deposition of the overlying coversands A2-3 (= the actual boundary between loam and coversand belts). Thus it is obvious that the sorting here is poor in comparison with the sorting of a typical loess. Although more sandy the loams at Alphen resemble the deposits of typical loess regions. The loam layers occur here as continuous layers deposited on the dry interfluvies by pure wind action without any traces of displacement by water.

Toward the end of the deposition of the 'loams and coversands' deflation became more important. Probably cryoturbation took place during the deposition; in any case at the end the sediments were extensively convoluted. The lithology of the sediments makes us assume that this could only occur under permafrost conditions. As explained in the first paragraph at this level only doubtful remnants of ice wedges were found. In other excavations well-developed ice wedges occur in the same stratigraphic position. This cold period of strong cryoturbation at Alphen has previously been found in the same stratigraphical position below the Beuningen gravel (VANDENBERGHE ET AL., 1974) and dated slightly younger than 24,700 BP (VANDENBERGHE & GULLENTOPS, 1977).

## Units D-E-F1

The gravel layer E may be considered as a kind of lag deposit and is the witness of an important erosion phase. Aeolian

<sup>2</sup> The average composition of the associations mentioned in this text is as follows:

	garnet	epidote	alterite	hornblende	chloritoid	volc. min.	rest	staurolite	met. min.	tourmaline
A-association	31	27	1	24	2	10	2	1	2	
H-association	30	26	15	14	3	2	4	3	3	(Edelman, 1933, 1938)
Limburg-ass.			1		38	15	16	30		(Baak, 1936)
										(Edelman, 1933, 1938)

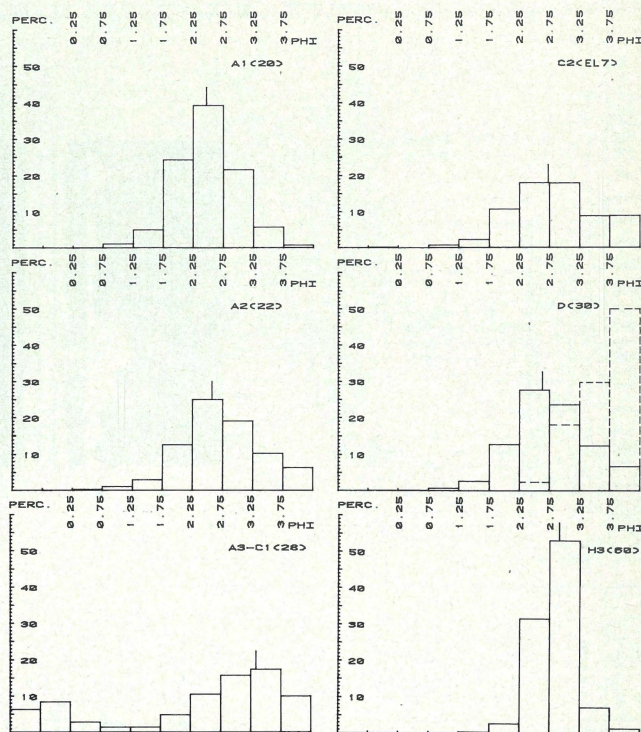


Fig. 8

Some characteristic granulometric histograms (sand fraction). The vertical line indicates the modal value. Sample D(30) shows also the histogram of the heavy minerals (dashed lines).

activity afterwards is not so clearly expressed as in the upper desert pavement (B1-3). From the mineralogy, the sedimentary structures and the granulometric distribution the deposits of D can be interpreted as reworked aeolian sands.

Before the erosion phase just mentioned a second very cold period with permafrost conditions caused the formation of strong cryoturbations associated with large ice wedges. The presence of 'frost wedges' between Brørup and Hengelo was mentioned earlier by ZAGWIJN (1961) and VANDERHAMMEN ET AL. (1967). This period was preceded by aeolian deposition, only locally preserved (F1), dating from the first cold phases of the Weichselian.

The determination of the age of the peat layer (F2) as late Eemian put all the overlying deposits in the Twente Formation. Informal names were given to the members until the stratigraphic study of this region is finished.

In the upper part of the section (units A-F) all sediments show the same heavy-mineral association (Fig. 7), as has been mentioned in the paragraph concerned. This association might well be a mixture of the underlying stable suite and a garnet-epidote-hornblende association of either A- or H-composition.<sup>2</sup> This opinion has already been forwarded by VINK (1949), who explained the composition of nearby coversands as a mixture of local, stable, sands and A-sands of the North Sea or the Rhine delta. On the other hand, neighbouring Belgian coversands with a similar heavy-mineral composition were described as A-province sediments by TAVERNIER

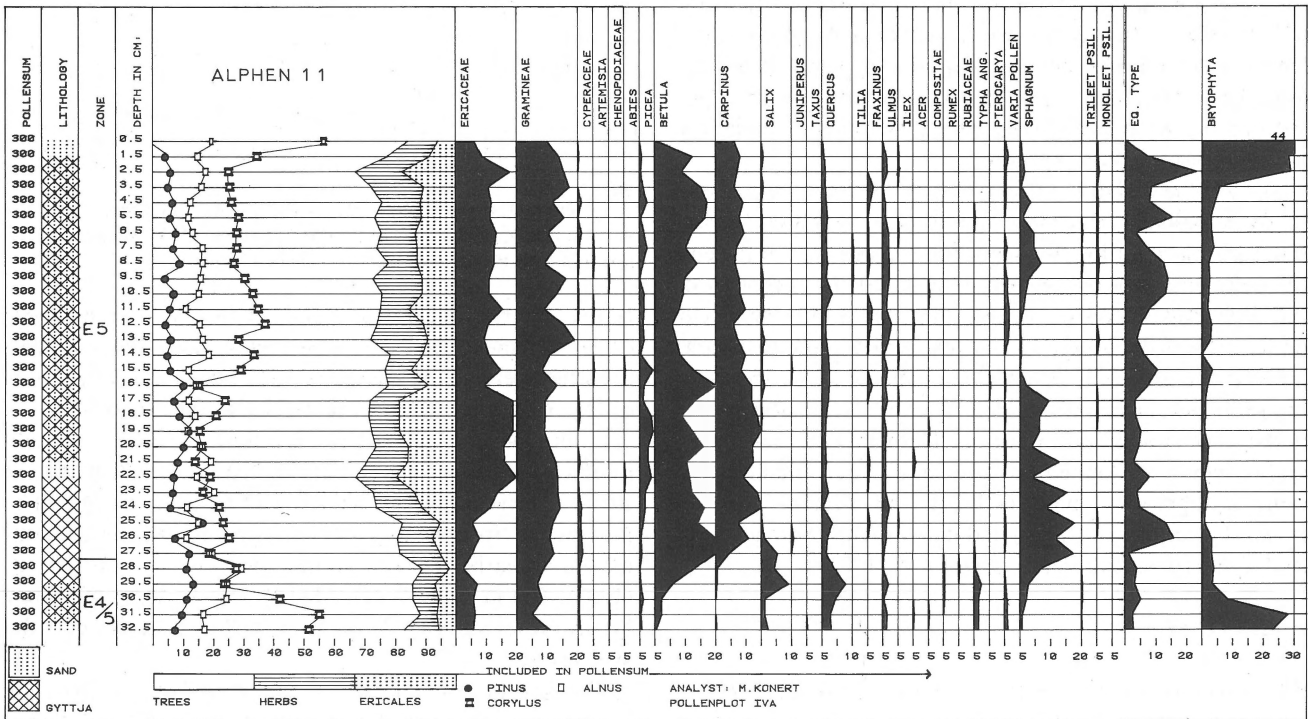
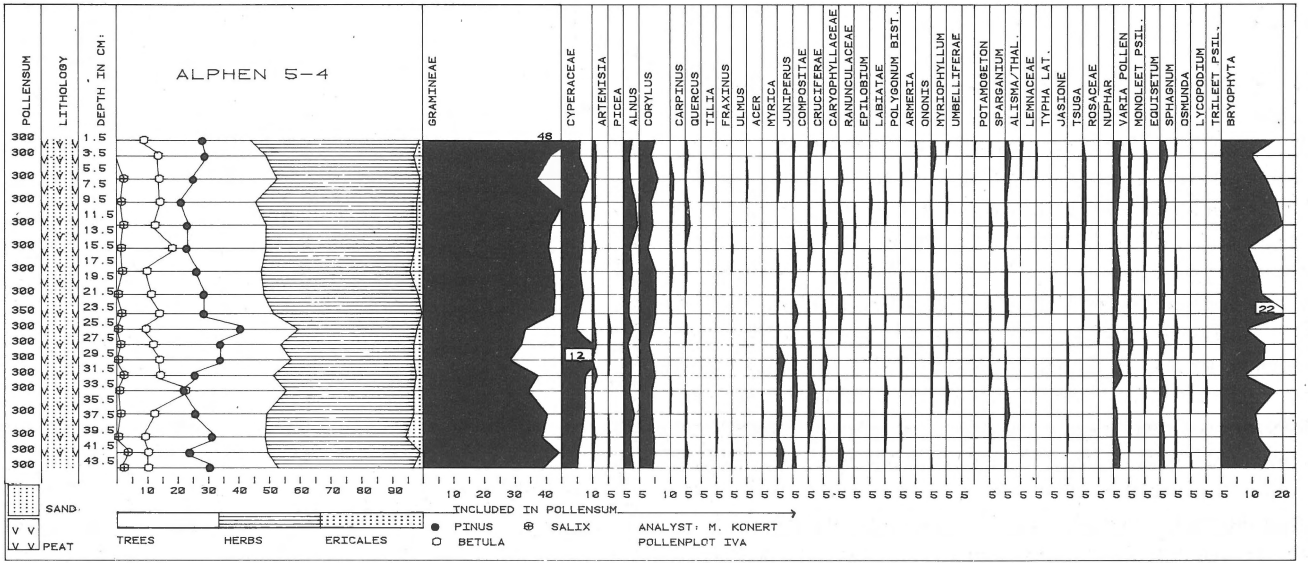


Fig. 9-10  
Pollen diagrams PM 5-4 and PM 11 (localization: see figure 3).

(1947) and H-province deposits by DE PLOEY (1961). Neither explained the relatively high content of stable minerals.

CROMMELIN (1964, 1965) took a different stand. He opposed the general usage of carrying out unfractionated analyses. Instead, to eliminate the influence of grain size, he chose the fraction of 150-210  $\mu\text{m}$ , being the modal fraction of most of the coversands. By this practice, however, he overlooked the fact that the modal fraction of the combined light and heavy minerals is considerably coarser than the modal fraction of the

heavy minerals alone, as has been explained above. Crommelin's results were, naturally, very different from those of all previous authors. Notably the combined group of tourmaline and the metamorphic minerals (including staurolite) showed high values due to the relatively coarse nature of these minerals. They averaged 50% at a place 10 km north of Alphen versus 18% in the present study. A count of the 150-210  $\mu\text{m}$  fraction of a few of our coversand samples showed a remarkable likeness to Crommelin's data. However, even in this

fraction there was a great difference in composition with the underlying stable suite. Crommelin concluded that the coversands were of mainly local origin. We do not agree with this. The coversands have a definitely unstable element which does not occur in our underlying sands. This element, comprising garnet, epidote, hornblende and alterite, must have been derived elsewhere. Unconsolidated sands which were outcropping during the supply of the coversands are the local sands of the G- and H-units, the Sterksel Formation and the Kreftenheye Formation. Most material has probably been supplied by the Kreftenheye Formation, the sediments of which were deposited at regular intervals which made them pre-eminently suitable to provide fresh material. Samples of the Kreftenheye Formation, taken from drill holes in the Alblasserwaard in the lower Rhine area, showed a Rhine composition which was an almost exact copy of the H-association as defined by BAAK (1936)<sup>2</sup> (Suprpto, 1980, pers. comm.). Furthermore, these sands contained some chlorite (not generally noted in heavy-mineral counts) and traces of glaucophane which are both highly characteristic of the Brabant coversands as well. In view of the above we assume that the NW winds transported the fine fractions from the sands mainly supplied by the Rhine, to Noord-Brabant and northern Belgium where they were mixed with sands blown up from local outcropping formations, thus reconfirming VINK's (1949) conclusions.

#### Units G-H

There is some difficulty in placing the fluvial sands of units G and H in the existing chronostratigraphic and lithostratigraphic system. The stable heavy-mineral association shows a great resemblance with the Limburg province<sup>2</sup> which is of Meuse origin. The sands are mineralogically similar to the upper part of the Kedichem Formation, but, on the whole, they are far too coarse (DOPPERS ET AL., 1975). They are underlain by the Campine Clay, the top of which corresponds with the Kedichem Formation. From a textural point of view they might fit in the Sterksel Formation, but they do not match mineralogically. East of Alphen we find the same sands below the Sterksel Formation. Since they obviously do not belong to these formations as they are now defined, we will refer to them as 'Alphen Sands.'

### CONCLUSIONS

The outcrop at Alphen revealed much new information on the geological history of the area in relation to climate and environment.

At the base fine to very coarse fluvial deposits are found with a stable heavy-mineral composition. These 'Alphen Sands' have not been described earlier. Pollen analysis and stratigraphical position point to deposition in a glacial of late Early or early Middle Pleistocene age.

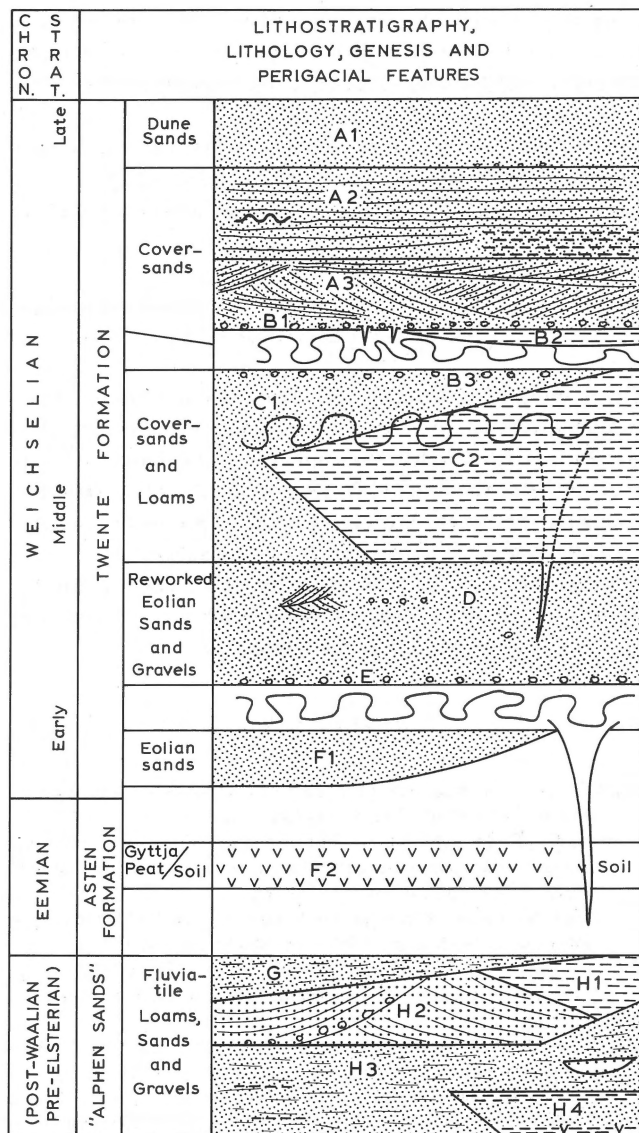


Fig. 11  
Schematic sequence of lithology, periglacial phenomena, stratigraphy and genetic interpretations (legend: see figure 2).

The overlying Weichselian sands and loams are of aeolian origin. They show a heavy-mineral association of mixed stable and unstable composition which suggests mixing of sands from the Rhine delta and local sands of the stable suite.

The characteristic compact loam layer, locally known as 'Brabant Loam', is typically windblown and deposited in a dry environment. There are no indications for subsequent water transport. Its occurrence indicates a temporary shift of the coversand-loess boundary to the north.

Two types of Weichselian pleniglacial coversands have been found: an almost loamless, slightly cross-bedded, coversand deposited in a very dry environment and a completely horizontally finely laminated type deposited in more humid conditions.

The pebble bed corresponding to the 'Beuningen Gravel'

consists of at least two desert pavements. The lowermost of these is cryoturbated while the upper one is horizontal and covers the underlying sediments unconformably. Frost fissures locally start from the upper level.

During the Weichselian two periods of permafrost existed, characterized by strong cryoturbations and ice wedges: one at the beginning of the Weichselian and one during the middle of the Pleniglacial.

#### ACKNOWLEDGEMENTS

The authors wish to thank Drs. Huisman and Messrs. Brus and Pinkster for their contribution to the fieldwork. We gratefully acknowledge the numerous laboratory analyses made by Mrs. Meyer and Mr. Konert and the counting of the pollen by the latter. We are grateful to professor Van der Hammen and Drs. Cleveringa for useful suggestions.

Thanks are also due to Messrs. Heine and Sion for drawing the figures, Mr. Van der Bliek for the photographic work and Mrs. Snijder for typing the manuscript.

#### REFERENCES

- Baak, J. A. 1936 Regional petrology of the southern North Sea – Ph. D thesis Univ. Leiden: 128 pp.
- Crommelin, R. D. 1964 A contribution to the sedimentary petrology and provenance of young Pleistocene coversand in The Netherlands – *Geol. Mijnbouw* 43: 389-402.
- 1965 Sediment-petrologie en herkomst van Jong-Pleistoecen dekzand in Nederland – *Boor en Spade* 14: 138-150.
- De Groot, V. 1977 Pollenanalytisch onderzoek van Midden- en Boven-Pleistocene afzettingen in Vlaanderen – *Doctoraatsverhand. Univ. Gent*: 98 pp.
- De Ploey, J. 1961 Morphologie en kwartairstratigrafie van de Antwerpse Noorderkempen – *Acta Geogr. Lovan.* 1: 130 pp.
- 1977 Some experimental data on slopewash and wind action with reference to Quaternary morphogenesis in Belgium – *Earth Surface Processes* 2: 101-115.
- 1980 Some field measurements and experimental data on wind-blown sands – *Proc. Workshop 'Assessment of erosion in USA and Europe'* (Gent, 1978): 541-552.
- Doppert, J. W. Chr., G. J. H. Ruegg, C. J. van Staalduin, W. H. Zagwijn & J. G. Zandstra 1975 Formaties van het Kwartair en Boven-Tertiair in Nederland. In: W. H. Zagwijn & C. J. van Staalduin (eds.): *Toelichting bij geologische overzichtskarten van Nederland – Rijks Geol. Dienst (Haarlem)*: 11-56.
- Dricot, E. M. 1961 *Microstratigraphie des Argiles de Campine* – *Bull. Soc. belge Géol.* 70: 113-141.
- Edelman, C. H. 1933 *Petrologische provincies in het Nederlandsche Kwartair* – Ph. D. thesis Univ. Amsterdam: 104 pp.
- 1938 *Samenvatting van de resultaten van vijf jaar sediment-petrologisch onderzoek in Nederland en aangrenzende gebieden* – *Tijdschr. Kon. Ned. Aardr. Gen.* 55: 397-431.
- Fink, J. 1976 *Internationale Lössforschungen – Eiszeitalter u. Gegenwart* 27: 220-235.
- Fink, J. & O. Nestroi 1967 *Communication no. 14 de la sous-commission INQUA pour l'étude des loess – Doc. travail de cette commission.*
- Gullentops, F. 1954 *Contribution à la chronologie du Pleistocène et des formes du relief en Belgique – Mém. Inst. Géol. Univ. Louvain* 18: 123-252.
- Kolstrup, E. 1980 *Climate and stratigraphy in northwestern Europe between 30.000 BP and 13.000 BP, with special reference to The Netherlands* – *Meded. Rijks Geol. Dienst* 32-15: 181-253.
- McKee, E. D. 1966 *Structures of dunes at White Sands National Monument, New Mexico (and a comparison with structures of dunes from other selected areas)* – *Sedimentology* 7: 1-69.
- Menke, B. 1970 *Ergebnisse der Pollenanalyse zur Pleistozän-Stratigraphie und zur Pliozän-Pleistozän-Grenze in Schleswig-Holstein – Eiszeitalter u. Gegenwart* 21: 5-21.
- Nelson, H. W. & T. van der Hammen 1950 *Een kwartairgeologisch onderzoek van het zuidwestelijk deel van Noord-Brabant* – *Geol. Mijnbouw N.S.* 12: 241-254, 272-278.
- Paepe, R. & R. Vanhoorne 1967 *The stratigraphy and paleobotany of the Late Pleistocene in Belgium* – *Toelicht. Verhand. Geol. Kaart en Mijnskaart België* 8: 95 pp.
- Pissart, A., R. Paepe & P. Bourguignon 1969 *Dépôts fluviatiles, éoliens et paléosols sur la terrasse de Hermée* – *Ann. Soc. géol. Belgique* 92: 429-445.
- Sommé, J. 1967 *Quelques coupes dans la région loessique du Nord de la France – Discussions: Meeting Sub-Comm. Loess-Stratigraphy (Belgium, 1967)*: 30-41.
- Sparks, B. W. & R. G. West 1970 *Late Pleistocene deposits at Wretton, Norfolk. I. Ipswichian interglacial deposits* – *Philos. Trans. Royal Soc. London B-258 (818)*: 1-30.
- Tavernier, R. 1947 *Aperçu sur la pétrologie des terrains postpaléozoïques de la Belgique. La Géologie des Terrains Récents dans l'Ouest de l'Europe* – *Sess. extraord. Soc. belge Géol.* 1946: 69-90.
- Vandenbergh, J. 1977 *Geomorfologie van de Zuiderkempen* – *Verhand. Kon. Acad. Wet., Lett. Sch. Kunsten België, Kl. Wet.* 140: 166 pp.
- 1980 *Weichselian stratigraphy in the Southern Netherlands and Northern Belgium* – *Quaternary Studies in Poland (Polish Acad. Sci., Comm. Quat. Res.)* 3: in press.
- Vandenbergh, J. & F. Gullentops 1977 *Contribution to the stratigraphy of the Weichsel pleniglacial in the Belgian coversand area* – *Geol. Mijnbouw* 56: 123-128.
- Vandenbergh, J., N. Vandenbergh & F. Gullentops 1974 *Late Pleistocene and Holocene in the neighbourhood of Brugge* – *Meded. Kon. Acad. Wet., Lett. Sch. Kunsten België, Kl. Wet.* 36 (3): 77 pp.
- Van der Hammen, T., G. C. Maarleveld, J. C. Vogel & W. H. Zagwijn 1967 *Stratigraphy, climatic succession and radiocarbon dating of the last glacial in The Netherlands* – *Geol. Mijnbouw* 46: 79-95.
- Vink, A. P. A. 1949 *Bijdrage tot de kennis van loess en dekzanden, in het bijzonder van de Zuidoostelijke Veluwe* – Ph. D. thesis *Agricult. Univ. Wageningen*: 147 pp.
- Zagwijn, W. H. 1960 *Aspects of the Pliocene and Early Pleistocene vegetation in The Netherlands* – *Meded. Geol. Sticht. C-III-1 (5)*: 78 pp.
- 1961 *Vegetation, climate and radiocarbon datings in the Late Pleistocene of The Netherlands I: Eemian and Early Weichselian* – *Meded. Geol. Sticht. N.S.* 14: 15-45.
- 1963 *Pollen-analytic investigations in the Tiglian of The Netherlands* – *Meded. Geol. Sticht. N.S.* 16: 49-69.
- Zagwijn, W. H. & J. I. S. Zonneveld 1956 *The interglacial of Westervolgen* – *Geol. Mijnbouw N.S.* 18: 37-46.