COMPOSITE GRAINS IN HEAVY-MINERAL CONCENTRATES AND THEIR SIGNIFICANCE IN THE DIFFERENTIATION OF SURFACE DEPOSITS AT THE CONFLUENCE OF THE MAAS (MEUSE) AND ROER (RUR) RIVERS[1]

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ABSTRACT

E. B. A. Bisdom, A. Gerlofsma, J. N. B. Poelman & P. A. Riezebos (1978). Composite grains in heavy-mineral concentrates and their significance in the differentiation of surface deposits at the confluence of the Maas (Meuse) and Roer (Rur) rivers. Geol. Mijnbouw, 57, p. 407-416.

The varying content of composite grains in heavy-mineral concentrates was used for the differentiation of surface sediments in a geomorphologically and pedologically complicate landscape at the confluence of the Maas (Meuse) and the Roer (Rur). West of the Maas valley, these deposits contain quantities of minor importance (<10%), while to the east surface sediments with percentages ranging from 4 to 59 occur. In this latter area a decrease in an easterly direction is suggested from the data. The characteristic high composite content is also found in sediments from the present flood plain of the Maas as well as in an old fluvial deposit of this river (Caberg terrace).

It is suggested that the flood plain of the Maas is the source of the surface deposits being found to the east, and that similar deposits west of the Maas valley come from another source area.

Finally the possible use of composites as provenance indicators is discussed briefly.

INTRODUCTION

Soil mapping of the area south of the city of Roermond, The Netherlands, showed a large variety in soils and often a lack in relationship between soil type and topographic position. Hence the soils have been mapped as a separate association (Soil Map of The Netherlands 1:50,000, sheet 58 West, 1972). The landscape in this area has an undulating topography with differences in altitude not exceeding 10 m. According to the survey memoir of this soil map, the deposits in this area were formed by the river Roer and they were classed in the Kreftenheye Formation of Upper Pleistocene age (Soil Map of The Netherlands 1:50,000, sheet 58 West, 1972, survey memoir p. 124). The river subsequently eroded these sediments, which caused the main current topographical features (Fig. 1). Fine sands of aeolian origin also occur. The combination of erosional and depositional relief features make the morphogenesis of this landscape seem rather complicated. Also

sedimentary structures encountered in exposures were usually difficult to explain in terms of wind and/or water action.

Heavy-mineral analyses applied to sampled material from this area show that the mineral assemblages consist of tourmaline, epidote, saussurite, metamorphic minerals and garnet (about 80-90%) with subordinate amounts of amphibole, pyroxene and accessory minerals. During optical analysis, however, it was shown that many concentrates possess a considerable amount of aggregated grains, often composed of both opaque and translucent material. As it was impracticable to assess the nature of the opaque and translucent fine-grained substances with a petrological microscope, these grains are indicated as 'composites'. Other techniques had to be applied for their further characterisation. The results of this work form the subject of a separate paper (RIEZEBOS ET AL., 1978).

In order to determine whether these particular grains could be of any value in solving the problems in that complicated area, their number was established together with the individual mineral grains in the heavy concentrates. Initially this was carried out on concentrates (210-150 μm) from surface sediments in the area discussed above, but afterwards samples collected from similar deposits in the adjacent areas were included in the investigation.

APPEARANCE OF COMPOSITES IN HEAVY-MINE-RAL MOUNTS

Many composite grains seem to have a 'dirty' appearance. Surface staining with organic matter, iron or sulphide compounds, however, must be eliminated as a cause of this phenomenon, because the samples were subjected to a very thorough preparatory treatment with H_2O_2, HCl and HNO_3. Because the 'dirty' appearance still seems to be affected by opaque and/or semi-opaque material after the treatment, it must be intimately associated with the small crystalline translucent constituents of the composites, probably as cementing material, or finely dispersed between these microcrystalline translucent constituents.

Fig. 1
Hypsographic map, illustrating the relief features in the complicated area south of Roermond (according to Soil Map of The Netherlands 1:50 000, 1972). The position of this map is in the white area of Fig. 4, south of the city of Roermond and south of the confluence of Maas and Roer.

24 - 25 m	27 - 28 m
25 - 26 m	28 - 29 m
26 - 27 m	

A general description is greatly hampered by the large variety of the composites. They usually have one characteristic in common, i.e. they consist of opaque or semi-opaque and translucent substances, the latter being mostly microcrystalline or even cryptocrystalline. Their mutual description within the composites is variable. The most frequent types are illustrated in Fig. 2. Figure 2A displays a common type. Opaque or semi-opaque particles of varying shape and size are entirely or partially surrounded by microcrystalline and/or cryptocrystalline translucent material. One single composite of this type frequently contains one or two opaque particles or dots (Fig. 2B). The boundary between the two substances may be sharp or diffuse. In the translucent parts more or less parallel orientation of small individual particles may occur (Fig. 2C). In the case of cryptocrystalline grains this is sometimes recognizable by aggregate polarization. However, this orientation may also be lacking. There are peculiar, though not unusual, specimens with the opaque matter in the centre of the composite and with a surrounding translucent rim showing a somewhat radiated structure (Fig. 2D).

A second rather common type consists of fine-grained transparent matter with the opaque material irregularly distributed through it (Fig. 2D). As above, parallel orientation may or may not be present. The opaque and semi-opaque substances are often so crowded that they cannot be distinguished. In such composites, however, a considerably less dense accumulation of opaque spots is usually found in the boundary parts of the grains.

There is also a range of other aggregated grains which, owing to their similar appearances in the routine-analysis, have been assumed to be composites. These are shimmer aggregates originated by the decomposition of 'heavy' aluminous silicates, evident rock fragments with ore constituents, one or more translucent mineral particles firmly attached to opaque particles by a cementing substance not destroyed during the acid treatment, etc. In any case it seems evident that all these composites showed up in the heavy residues on account of the inclusion of opaque materials of a rather high specific density.

GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

Figure 3 gives a view of the Quaternary surface deposits in this region (VAN STAALDUINEN & VAN VEEN, 1975). The oldest sediments consisting of sands and gravels from the Sterksel Formation were deposited by the Rhine and the Maas during the Menapian and Cromerian complex (DOPPERT ET AL., 1975). The Veghel Formation, also consisting of river deposits, was laid down by the Maas in the upper part of the Cromerian complex, Elsterian, Holsteinian and Saalian. The Kreftenheye Formation, also comprising Maas and Rhine sediments, is Upper Pleistocene and occupies only a small part of
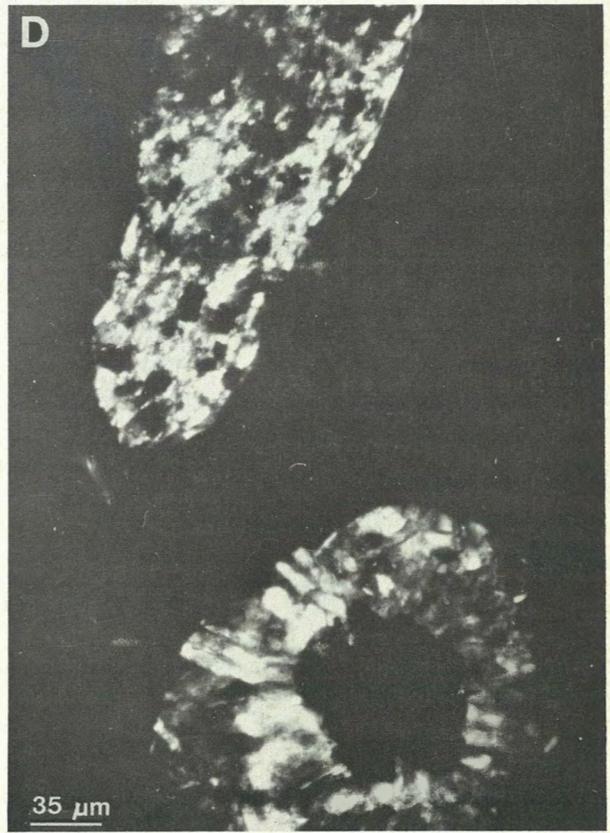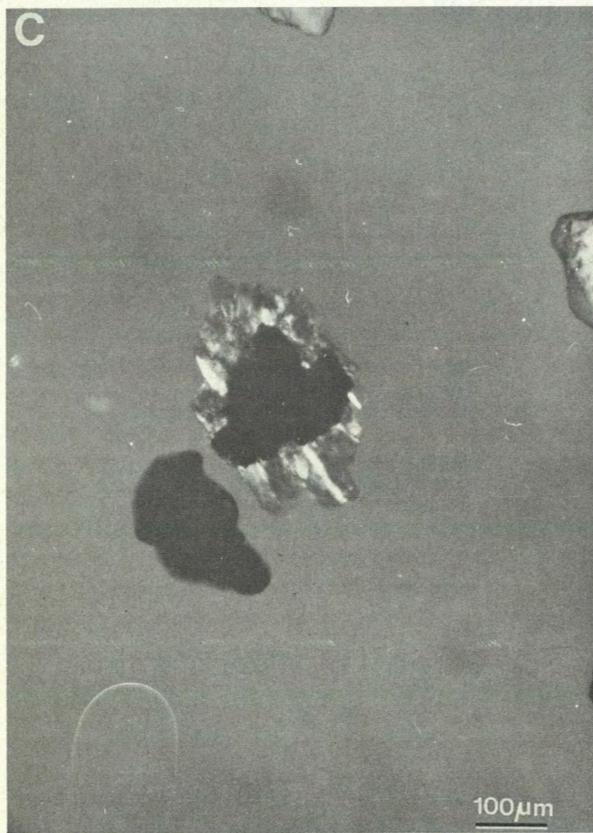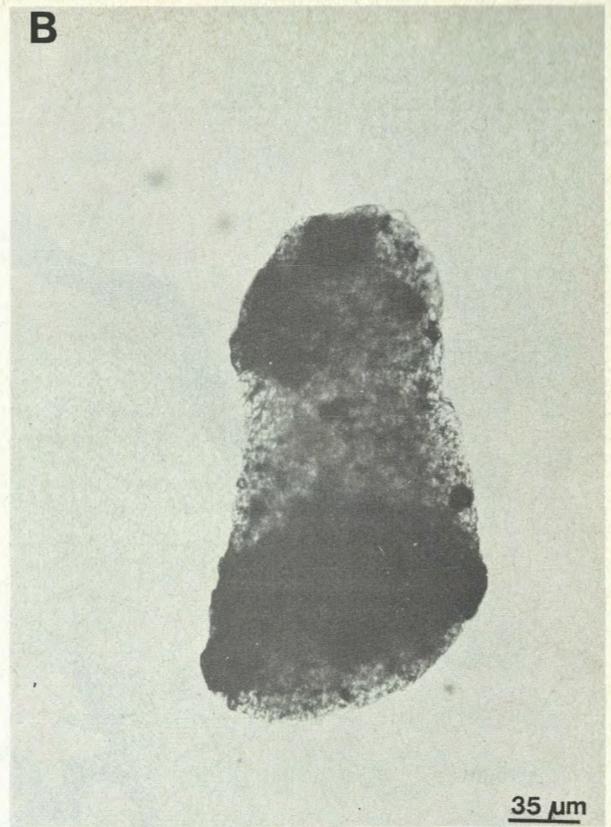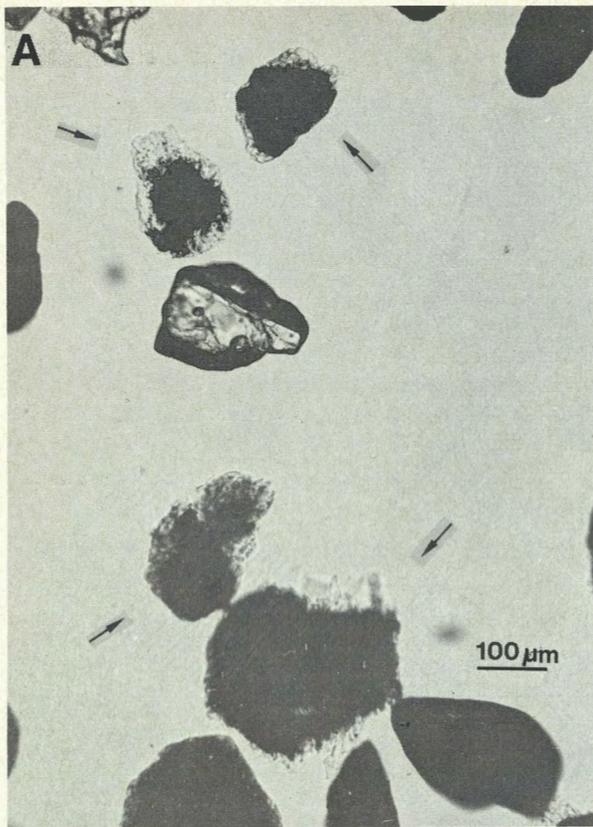
Fig. 2
(A): Composites in a heavy-mineral mount (see arrows). Plane polarized light, objective P 10/0.25, ocular Periplan 10x.
(B): Composite showing two concentrations of opaque material. Plane polarized light, objective P 10/0.25, ocular Periplan 10x.
(C): Translucent rim displaying a rough parallel orientation of the mineral particles. Crossed nicols, objective P 10/0.25, ocular Periplan 10x.
(D): Composite showing a radialized translucent rim (at the left) and a specimen with irregular distribution of opaque material (at the right).
      Crossed nicols, objective P 10/0.25, ocular Periplan 10x.
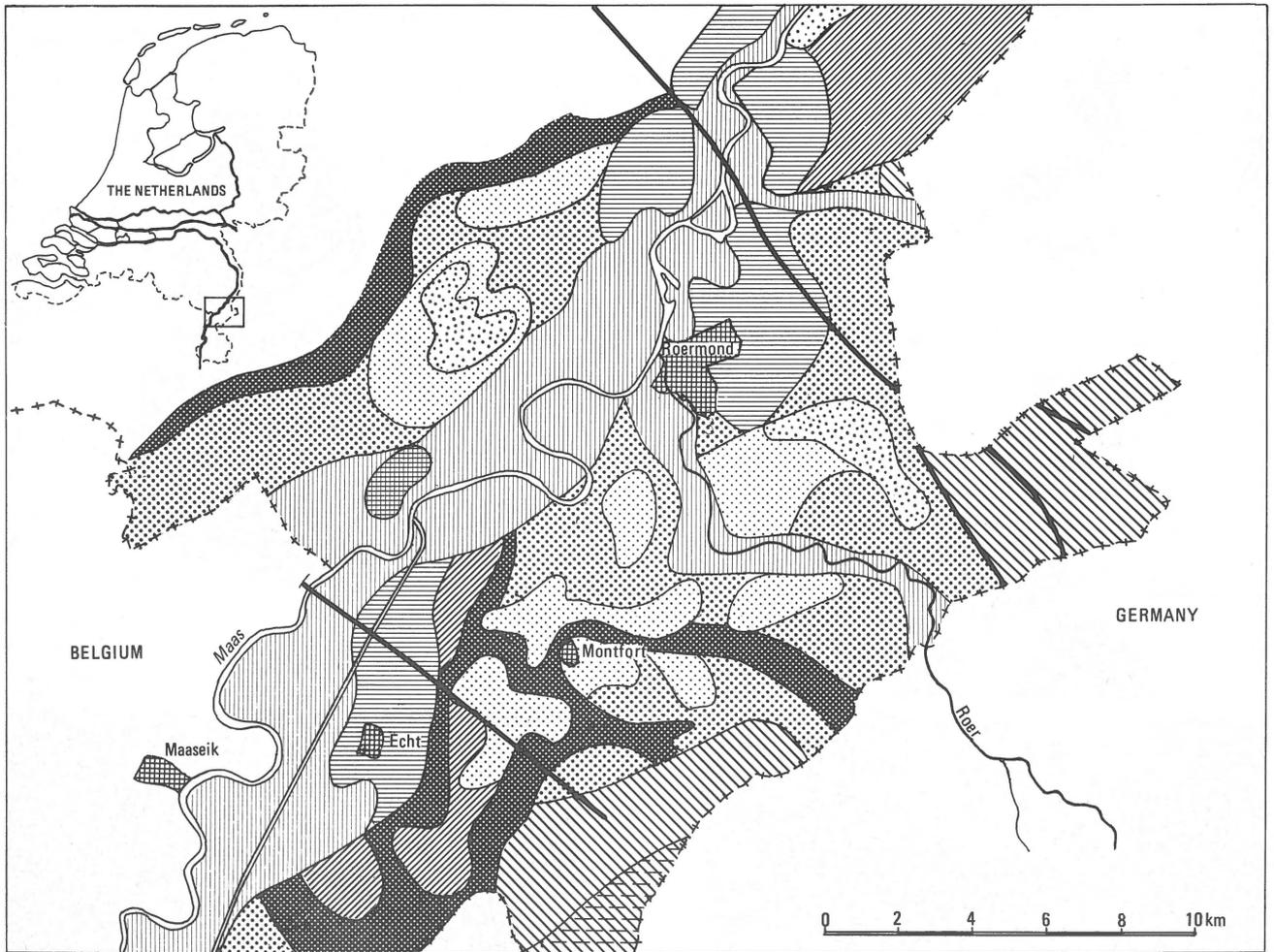
HOLOCENE

Betuwe Formation

||||| river deposits, streambed

Kootwijk Formation

inland dune sands

Singraven Formation

brook deposits, clastic deposits

PLEISTOCENE

Twente Formation

coversands, locally loess

fluvio-periglacial deposits covered with a thin layer of coversands

loess

Kreftenheye Formation

river deposits, locally covered with younger Pleistocene deposits

Veghel Formation

river deposits covered with younger Pleistocene deposits

Sterksel Formation

river deposits covered with younger Pleistocene deposits

faults

Fig. 3
Quaternary formations in the area under investigation according to the General Geological Map of The Netherlands 1:600 000 by Van Staalduinen & Van Veen (Eds.), 1975.

the area discussed above, while the major part is covered by the Twente Formation possessing coversands, loess and fluvio-periglacial deposits (Upper Pleistocene). Brook and clastic deposits of the Singraven Formation are found in longitudinal depressions while the occurrence of the Betuwe Formation, containing modern fluvial sediments, is restricted to the Maas and Roer valleys.

VAN DEN BROEK & MAARLEVELD (1963) distinguished a number of terrace surfaces in this area (Fig. 4). Their map, representing the Late Pleistocene terraces of the river Maas, shows that Terrace I having a maximum elevation of 9 m above the alluvial plain, covers the major part of the area. Terrace II (6 m above the alluvial plain) is only found east of Roermond, terraces IIa, IIb to the north and terrace III north
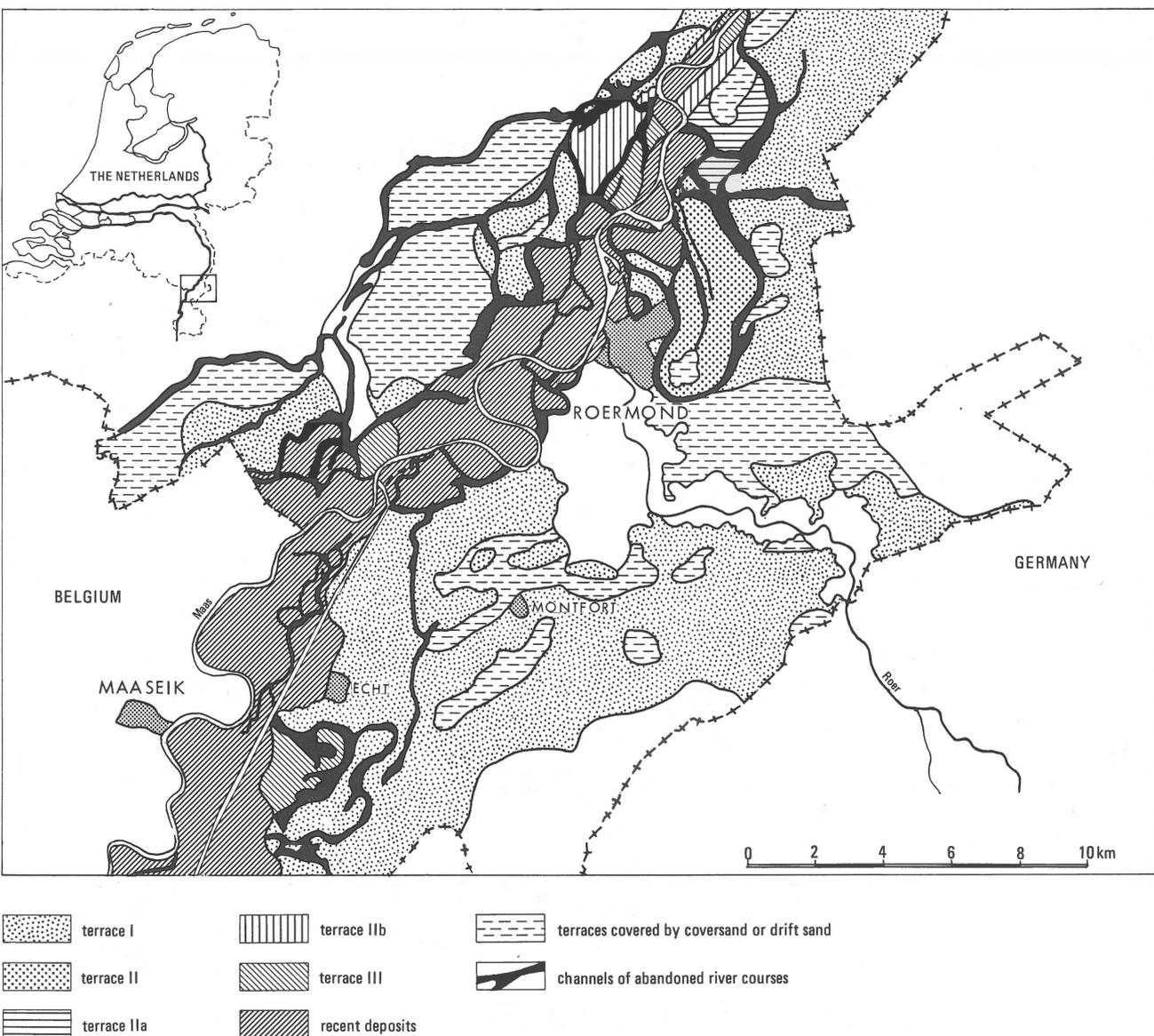
Fig. 4
Pleistocene terraces of the river Maas (after Van den Broek & Maarleveld, 1963).

Legend:
- terrace I
- terrace II
- terrace IIa
- terrace IIb
- terrace III
- recent deposits
- terraces covered by coversand or drift sand
- channels of abandoned river courses

and south of this town. No coversands or drift sands were found on terrace III. In the white areas (see Fig. 4), near the German border, the older Main Terrace is found (MAARLEVELD, 1956).

In view of the fact that the majority of the samples are derived from sediments at or near the surface (see 'depth' in Table I), they probably mainly represent materials from the Twente, Kootwijk and Betuwe Formations. The variability in depth of the samples is a consequence of human activity, soil development and the availability of exposures.

RESULTS AND DISCUSSION

In Table I the results have been arranged in five groups. The first group (A) comprises the samples derived from the area west of the Maas valley, where the Twente and Kootwijk Formations are found at the surface; group B contains the samples from the Betuwe Formation in this valley; the third group is made up of the sampled material from the area east of the Maas valley where the Sterksel, Veghel and Kreftenheye Formations are also present, while group D is composed of

Table I
Heavy-mineral compositions of the sampled Maas and Roer sediments.

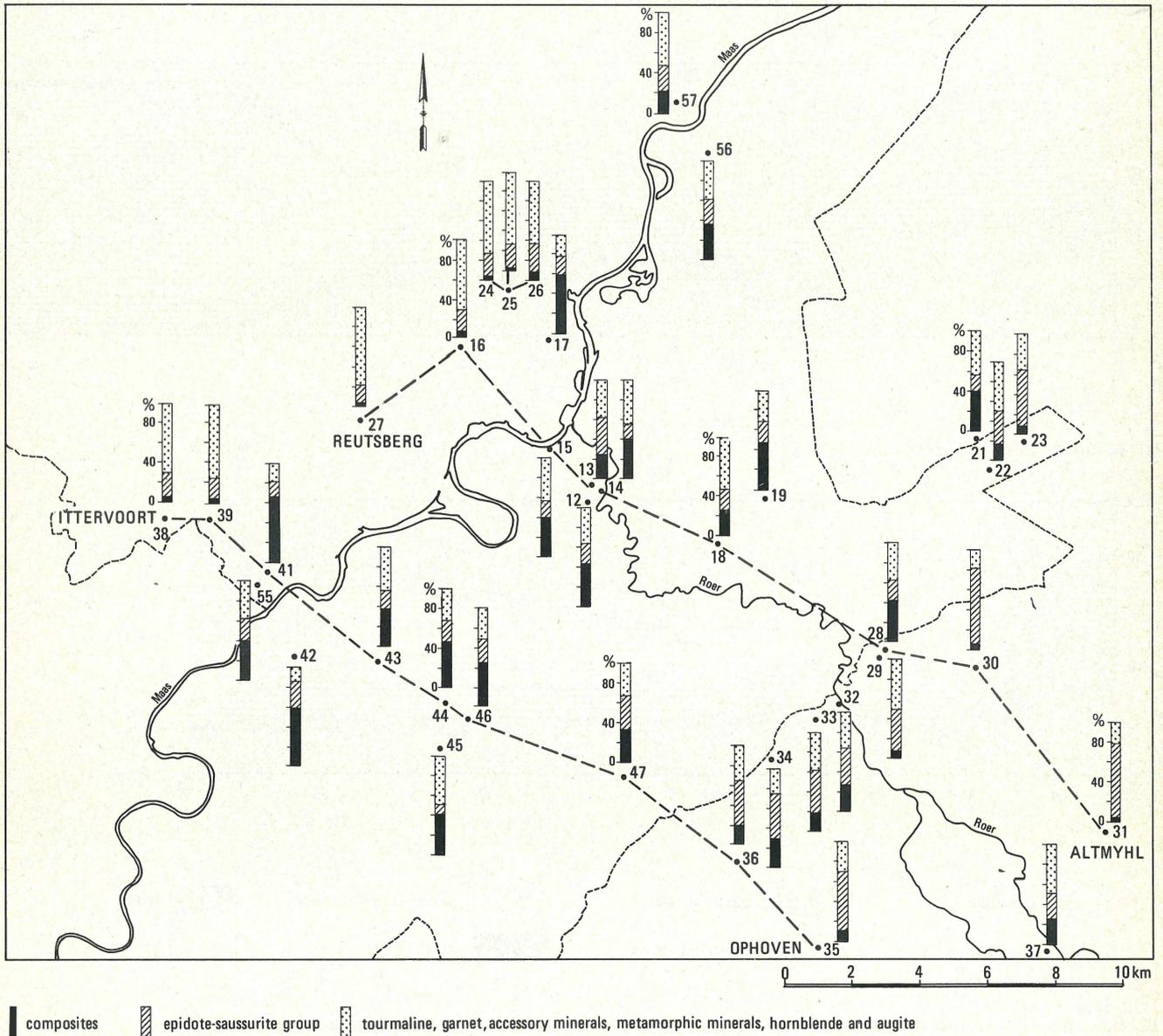| Number	Depth in cm	Material and Fraction	Tourmaline	Garnet	Rutile	Zircon	Anatase	Corundum	Sphene	Spinel	Total Accessory minerals	Staurolite	Kyanite	Andalusite	Sillimanite	Topaz	Bright Chloritoid	Total metamorphic minerals	Zoisite	Epidote	Saussurite	Pumpellyite	Total Epidote-Saussurite Group	Green Hornblende	Brown Hornblende	Glaucophane	Total Hornblende	Augite	Hypersthene	Total Augite	Composites	Opaque
A																																
16	50-60	loamy sand	21.0	18.7	1.3	0.7	0.3		0.3		2.6	11.0	5.0	6.0				22.0		14.0	13.7		27.7	1.0			1.0	0.3		0.3	6.7	17.7
24	40-50	fine sand	37.0	2.0		1.0					1.0	17.0	4.0	7.0	1.0			29.0		17.0	9.0		26.0	2.0			2.0				3.0	12.0
25	230-240	fine sand	29.0	6.0	2.0	1.0	3.0		1.0		7.0	10.0	6.0	11.0				27.0		15.0	11.0		26.0	4.0			4.0				1.0	19.0
26	350-360	fine sand	36.0	9.0		1.0	1.0				2.0	6.0	2.0	6.0			1.0	15.0		16.0	13.0		29.0	1.0			1.0				8.0	11.0
27	40-60	loamy sand	31.7	16.3	1.7	0.7	0.3		0.7		3.4	15.7	3.0	6.3	1.0			26.0		8.7	9.3		18.0	0.3			0.3				4.3	16.0
38	60-70	loamy sand	26.0	13.0	1.0	1.0			2.0		4.0	10.0	7.0	7.0		1.0		25.0		11.0	14.0		25.0		1.0		1.0				6.0	16.0
39	50-80	loamy sand	32.0	17.0	1.0	1.0	2.0		1.0		5.0	8.0	7.0	5.0				20.0		12.0	9.0		21.0								5.0	19.0
B																																
15	100-110	sandy gravel	15.3	15.0	0.7	0.3			1.7		2.7	7.0	3.3	1.0			0.4	11.7		5.3	10.3		15.6								39.7	19.3
17	30-50	loamy sand	14.0	3.0	1.0			1.0	1.0		3.0	1.0					1.0	2.0		12.0	6.0		18.0								60.0	19.0
41	150-160	sandy gravel	9.0	3.0			2.0		1.0		3.0	1.0	1.0				1.0	3.0		9.0	6.0		15.0								67.0	21.0
55	50-70	sandy gravel	14.0	8.0	1.0	1.0	1.0		3.0		6.0	7.0	1.0	1.0	1.0		4.0	14.0		10.0	8.0		18.0								40.0	16.0
57	50-60	loamy sand	31.5	5.0	0.5				0.5	0.5	1.5	6.5	2.5	3.5				12.5		11.0	13.5	0.5	25.0	0.5			0.5				24.0	16.0
56	60-70	loamy sand	19.3	5.5	0.3	0.3					0.6	4.4	1.0	2.3	0.3		1.3	9.3		15.0	13.0		28.0	1.0			1.0				36.3	15.7
C																																
1	16-28	loamy sand	19.8	6.0	0.3		0.3				0.6	4.0	2.0	1.7			0.3	8.0		13.3	8.3		21.6	0.3			0.3				43.7	7.0
13	60-100	loamy sand	14.0	5.0	2.0	1.0	1.0				4.0	4.0	3.0	5.0			4.0	16.0		17.0	19.0		36.0								25.0	37.0
14	60-100	sandy loam	22.0	2.0	2.0		2.0		2.0		6.0	5.0	2.0	1.0			2.0	10.0		12.0	5.0		17.0					2.0	1.0	3.0	40.0	26.0
18	60-70	loamy sand	21.3	12.3	1.3	0.3					1.6	8.7	4.3	2.3			1.2	16.5		11.0	8.7		19.7						0.3	0.3	28.3	13.7
19	40-60	loamy sand	20.0	5.0	1.0		1.0				2.0			1.0			1.0	3.0		9.0	12.0		21.0								49.0	14.0
21	40-50	loamy sand	20.0	10.0			2.0				2.0	3.0	2.0	5.0			2.0	12.0		6.0	10.0		16.0	1.0			1.0				39.0	19.0
22	30-50	sandy loess	22.0	9.0	1.0		2.0		1.0		4.0	7.0	2.0	1.8		1.0		11.8		20.0	14.0		34.0		0.2		0.2	1.0		1.0	18.0	21.0
23	50-70	sandy gravel	16.0			1.0	1.0		4.0		6.0	2.0	3.0	1.0	4.0			10.0		49.0	8.0		57.0	1.0	1.0		2.0	1.0		1.0	8.0	15.0
42	260-280	sandy gravel	5.0	1.0			4.0				4.0	1.0		1.0			1.0	3.0		16.0	11.0		27.0	1.0			1.0				59.0	5.0
43	50-75	loamy sand	21.0	5.0								7.0	3.0	4.0			2.0	16.0		6.0	12.0		18.0								40.0	26.0
44	50-60	loamy sand	18.0	1.0			5.0				5.0	1.0	1.0	2.0			4.0	8.0		10.0	11.0		21.0								47.0	6.0
45	20-30	loamy sand	21.0	8.0	1.0	1.0	1.0				3.0	7.0	1.0	3.0			6.0	17.0		1.0	8.0		9.0								42.0	10.0
46	40-50	loamy sand	16.0	3.7	0.3						0.3	4.7	2.3	2.0			1.3	10.3		8.0	14.7		22.7								47.0	13.7
47	40-50	sandy gravel	14.3	6.0	1.0	0.3	0.3		0.3		1.9	6.0	1.0	2.0			1.3	10.3		11.0	22.9		33.9	0.3			0.3	0.3		0.3	33.0	9.7
D																																
28	110-120	loamy sand	19.0	3.0	1.0				0.3		1.3	6.0	3.0	2.3	0.4	0.3	1.7	13.7		10.7	10.7		21.4	0.3			0.3				41.3	19.0
29	100-110	sandy gravel	17.2	5.2	2.0	2.0	0.4		0.8		5.2	9.2	8.0	2.8	0.8		0.4	21.2	0.4	23.6	18.4		42.4	0.4			0.4	0.4		0.4	8.0	21.2
30	800-810	coarse sand	2.3	0.3	1.3				0.3		1.6	2.0	1.7	2.7	0.7		0.7	7.8	0.7	34.0	42.3		77.0	3.7	0.7		4.4		0.3	0.3	6.3	6.0
31	100-110	coarse sand	4.5	1.0	0.5		0.5				1.0	4.0	2.0	3.5			1.5	11.0	0.5	44.5	29.5		74.5	1.5			1.5	0.5	1.5	2.0	4.5	11.5
32	200-210	loamy sand	18.0	1.3	2.3		0.3		0.3	0.3	3.5	2.7	1.7	4.3				8.7		16.7	20.3	0.3	37.3	1.3	0.3	0.3	1.9	1.7	0.3	2.0	18.7	18.0
33	60-100	loamy sand	15.4	1.3	1.3	0.3					1.6	9.0	4.7	2.3			0.7	16.7		33.0	11.0		44.0	0.7	0.3		1.0	1.3	0.3	1.6	18.7	18.0
34	80-110	sandy loam	10.3	0.7	2.7	0.7			0.3	1.3	5.0	3.3	1.3	1.7	0.3			6.6	0.7	27.0	18.3		46.0	1.7			1.7		0.7	0.7	29.0	20.7
35	120-140	sandy gravel	15.3	0.7	1.0					1.0	2.0	3.0	2.0	3.0	1.0		0.7	9.7	0.3	42.7	15.7		58.7	2.7	0.3		3.0	0.3		0.3	10.3	21.3
36	30-50	clay loam/gravel	16.7	2.5	2.0	0.7	0.3		0.3		3.3	2.5	1.3	5.7			2.0	11.5		24.7	21.3		46.0	0.7	0.3		1.0	1.0		1.0	18.0	14.3
37	50-60	loamy sand	18.3	2.3	6.7	0.2			1.3	0.3	8.5	10.7	3.3	2.3				16.3		17.0	9.3		26.3	1.0			1.0	0.3	0.3	0.6	26.7	17.6
E																																
49	1200-1210	sand*	14.0	10.0	8.0	18.0	12.0				38.0	5.0	2.0		2.0		1.0	10.0		12.0	11.0		23.0						1.0	1.0	4.0	35.0
50	995-1005	gravel*	5.0	3.0	5.0	2.0	5.0				12.0	1.0	1.0	1.0			1.0	4.0		12.0	6.0		18.0	6.0	9.0		15.0		1.0	1.0	42.0	9.0
51	870-880	clay*	2.0	5.0	7.0	8.0	6.0	1.0	2.0		24.0	4.0	1.0				2.0	7.0		2.0	2.0		4.0	3.0	7.0		10.0				48.0	25.0
52	670-680	clay loam*	3.0	15.0	16.0	21.0	13.0		2.0		52.0	2.0	2.0	2.0		2.0		8.0		12.0			12.0	12.0			8.0			8.0	2.0	23.0
53	500-510	clay loam*	6.0	7.0	10.0	13.0	8.0		3.0		34.0	5.0	1.0					6.0		15.0	10.0		25.0	11.0	1.0		12.0				10.0	10.0
54	100-110	sandy loam*	7.0	2.3	1.0						0.7	1.7	2.7		1.0	0.3	2.7	8.4		10.0	10.7		20.7	3.0		0.3	3.3	0.3	0.3	0.6	56.0	11.7

* = 150-50 μm; other samples 210-150 μm.

Fig. 5
Sample localities and simplified heavy-mineral compositions in the size-fraction 210-150 μm. Broken-lines indicate the positions of the two diagrams in figure 6.

samples from the adjacent German areas. The last group (E) represents some samples from an exposure in the Caberg terrace and one sample from the Maas valley near Grevenbricht.

The mineral assemblages, which have been graphically represented on the location map in Fig. 5, show a distribution pattern when the composite contents are considered. West of the Maas valley (group A), the amount of composites is never larger than 10%. Their contents in the Maas valley samples (group B), however, vary between 24 and 67%. Also the samples collected east of the Maas (group C) generally have mineral compositions showing a rather high number of com-

posites, though within this group assemblages with low composite contents also occur. In group D (adjacent German areas) low, intermediate and high contents were found, but values of more than 40% are rare.

The epidote-saussurite group also contributes somewhat to a recognition of this pattern. The highest percentages were obtained in group D with values varying between 22 and 77%. The values in group C range from 9 to 57%, in B from 15 to 25% and in A from 21 to 29%.

It can be argued that the increase in epidote-saussurite towards the east is very probably related to the occurrence of the older Sterksel and Veghel Formations at the surface and
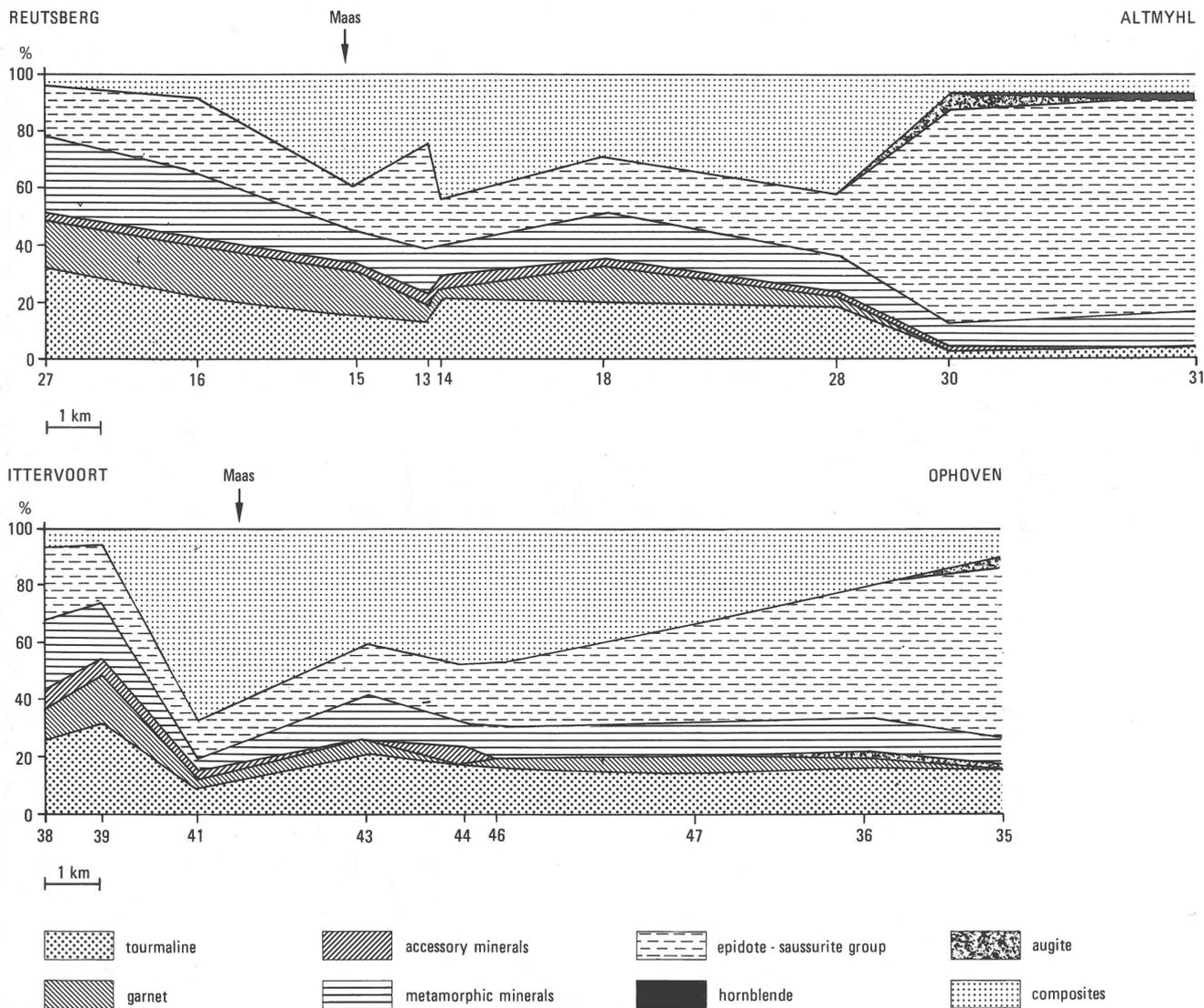
Fig. 6
Changes in heavy-mineral composition between Reutsberg and Altmyhl and between Ittervoort and Ophoven.

that the high composite contents are more related to the Kreftenheye, Twente and Betuwe Formations. However, this contention is only partly supported by the present findings. The relationship of the composites with the Betuwe Formation is obvious, but apparently does not exist with the Twente Formation in view of the large differences shown by the samples east and west of the Maas valley.

Figure 6 gives an impression of how the mineral compositions in a number of samples are related to their positions in the area. We acknowledge that these representations are highly suggestive but they do illustrate the distribution pattern distinguished on the basis of the composite contents. A close connection is suggested between the sediments of the Maas valley and the surface deposits east of this river while

such a connection with these deposits west of the Maas is lacking.

Coversands from this area have been studied previously. MAARLEVELD (1968) examined these sands with the 'adhesive tape' method. No difference was found between the sands west and east of the Maas valley (Maarleveld's sub-area 14), but those occurring east of the Maas and north of the Roer valley (Maarleveld's sub-area 13) were different. CROMMELIN & DE GRUIJTER (1973) applied cluster analysis to a number of the same samples. When a sub-division into 11 clusters is used for a number of 465 samples with 22 variables including 8 mineralogical characteristics, the results indicate that two clusters (2 and 4) coincide with Maarleveld's sub-area 13. Maarleveld's sub-area 14 is also covered by the same clus-

ters, but cluster 2 is confined exclusively to the coversands west, and cluster 4 to those sands east of the Maas valley. ZONNEVELD (1974-b) noted that a turbid type of chloritoid occurred in the coversands east of the Maas and that this mineral was virtually absent in coversands west of the river.

The close agreement, as shown by their composite contents, between the sediments from the Maas valley (Betuwe Formation) and the surface deposits to the east, strongly suggests a common source. MAARLEVELD (1968) and ZONNEVELD (1974-b), in discussing the origin of Pleistocene coversands, pointed out the importance of river valleys in supplying this material. During dry conditions sandy and fine materials may be highly susceptible to erosion and subsequent displacement by wind. This process possibly also provides an adequate mechanism to account for the present data. Westerly winds take up the materials from the river plain and transport them in an easterly direction. The rather rapid decrease in the composite percentages together with the increase in epidote-saussurite in easterly directions, suggests limited distances of transport. Coversands found west of the Maas valley must have had a different source.

The time at which the river Maas started to carry and supply materials characterized by a high number of composites in the heavy concentrates, or whether these particular Maas sediments are of local or more regional significance cannot be deduced from the data discussed so far. Table I(E) gives the heavy-mineral assemblages from samples collected upstream from the Maas. Sample 54, which is derived from the Betuwe Formation in the floodplain near Grevenbricht, contains 56% composites. The samples 49-53 come from an exposure in the Caberg terrace situated west of the city of Maastricht (Fig. 7). From the bottom to the top of the section the following materials are found: Tertiary sand (sample 49) covered by gravel (sample 50) and a clay layer (sample 51) which is covered by loess (samples 52 and 53). The high percentage of composites in samples 50 and 51, which are very likely fluviatile Maas deposits, are in the same order of magnitude as those found in the samples discussed above. The Caberg terrace is thought to be Elsterian (ZONNEVELD, 1974-a). The findings summarized in Table I(E) suggest that the occurrence of composites is not very restricted in space and time.

CONCLUDING REMARKS

The consideration and quantitative evaluation of composite grain contents allow us to hypothesize on the origin of surface sediments in a landscape that appeared to be rather complicated with respect to its morphogenesis and pedogenesis. According to the hypothesis, the uppermost deposits mainly consist of sands coming from the Maas flood plain and constituting a system of dunes on the eastern bank of this river. On the basis of the present data it cannot be said how far sediments already deposited by the Roer are related to these
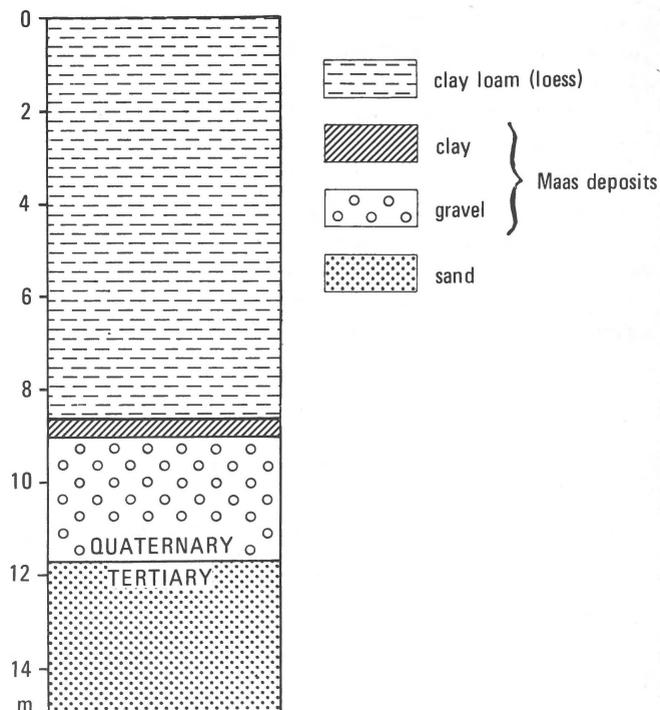

Fig. 7
Exposure in the Caberg terrace near Maastricht.

aeolian deposits. Some compositions from alluvial Roer samples (32 and 37) show a relatively high composite content but it is difficult to decide whether this is due to contamination with Maas sands blown into the Roer depression or to the presence of source material with a similar characteristic component somewhere in the drainage area of this river. It is conceivable that the lower course of the Roer was affected by this aeolian deposition at that time. The system of braided depressions and hillocks (Fig. 1) probably reflects the continuous displacement of its stream bed by the shifting dunes and other aeolian deposits. Also the present position and the strongly meandering character of the lower course of the Roer may in fact have been affected by this, though it is obvious that tectonic influences in this area cannot be excluded.

In a previous investigation there was evidence that the opaque components in the heavy concentrates from some Pleistocene Maas deposits are characterized by the predominance of the mineral goethite (RIEZEBOS, 1971). An ore microscope, however, is needed for this identification and the application of ore microscopy in sedimentary petrography is still rather unusual. Therefore, it would be more convenient if the criterion for differentiation could be found in the transparent part of the heavy concentrates. Translucent constituents are generally easier to determine and their evaluation occurs within the routine procedure of heavy-mineral analysis.

It is realized that composite grains do not generally survive

re-cycling as well as individual mineral fragments and that, in addition, their survival is highly dependent upon their nature. Intergrown mixtures of different mineral species, due to weathering or diagenetic processes, are probably less resistent to forces operating during transport than rock fragments, though various stabilities will also occur within this category. However, the presence or relative abundance of composite grains may serve for marking off purposes as has been shown by the present study. Further petrographic investigation, however, is needed to determine, amongst other things, whether the composite grains are relatable to distinct rock types (cf. RIEZEBOS ET AL., 1978).

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