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A CONTRIBUTION TO THE SEDIMENTARY-PETROLOGICAL DESCRIPTION OF THE MAAS DEPOSITS IN SOUTHERN LIMBURG (THE NETHERLANDS)

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ABSTRACT

From the Plio-Pleistocene series of sediments deposited by the river Maas on the Late Tertiary peneplain of southern Limburg (The Netherlands) three samples, one of Pliocene and two of Pleistocene age have been taken. From these samples the grains between 500 and 2 micron have been subjected to microscopic investigations. The acquired mineralogical data confirming in broad outline previous investigations, reveal that the Pleistocene materials deviate from the Pliocene especially on account of a very great content of goethite particles. It is suggested that the great amount of goethite may be of use to discern the Quaternary Maas deposits from other contemporary fluviatile sediments.

INTRODUCTION

The Late Tertiary peneplain in southern Limburg, presently the object of many-sided and extensive investigations (van der Waals e.a., 1962; van de Broek and van der Waals, 1967; van der Waals, 1967; de Jong & van der Waals, 1971), has been incised during Pleistocene times by the river Maas. This incision took place discontinuously and remnants of Pleistocene terrace deposits are found today covering western and eastern parts of this area at different heights.

These terrace deposits have been subjected to much investigation. Brueren (1945) measured the altitude of the base in exposed gravel-containing fluvial beds. The data obtained allowed a subdivision of the terraces according to their heights. Van Straaten (1946) investigated the gravel constituents by determining the content of certain rocks and rock-groups in some size grades. Zonneveld (1949) studied their heavy-mineral composition. The results of these sedimentary-petrological studies appeared to confirm the subdivision made by Brueren. Added to this, gravel and heavy-mineral composition both seemed to provide evidences for supply areas and the observed evolution in composition seemed to reflect important events in these areas

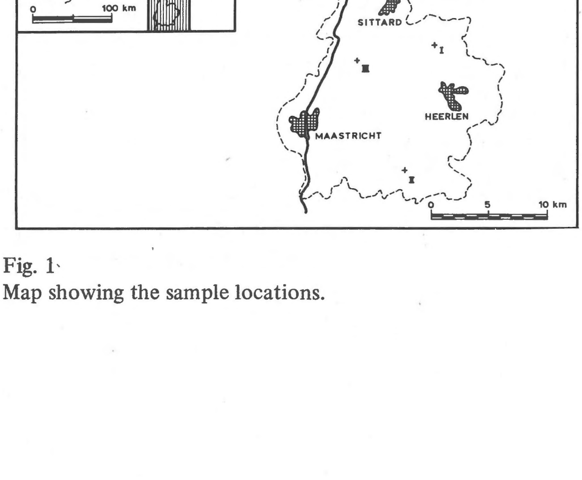

Fig. 1
Map showing the sample locations.

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during the deposition of the fluvial sediments in southern Limburg.

The present paper gives the outcomes of an optical analysis of fractioned samples from these Maas deposits. Sample I has been taken from sediments of Pliocene age, sample II from old Pleistocene and sample III from younger Pleistocene terrace deposits, being respectively Brueren's "Kosberg-niveau" and "St. Geertruidenbergniveau". The depth of sampling was several meters below surface in sand and gravel pits. Sample locations are indicated in figure 1.

METHODS

A. *Particle-size analysis*

Besides for common purposes in work like this a mechanical analysis is required to settle the amount to start from, in order to acquire a sufficient quantity in each size grade for optical study. The analysis was carried out in 20 grams of the less than 2 mm. material by a combination of sedimentation (< 32 micron particles) and sieving (> 32 micron particles). Before analysis eventual carbonates were removed by 0.2n. HC1 and possible organic matter by H_2O_2 6%.

B. *Gaining and mounting of size grades*

500 à 1000 gr. of the sample material were treated with 30% H_2O_2, 25% HCl and a dispersion agent. The sand and silt fractions were obtained from this material by sieving (> 32 micron) and sedimentation (< 32 micron) techniques. From the obtained size fractions between 32 and 420 micron, heavy minerals were separated by bromoform (s.g. 2.89). In 50 à 100 grams of the untreated sample material between 30 and 500 micron, specific-gravity separation was also made by bromoform in order to get a heavy concentrate for analysis of the opaque grains in incident light. Arguments for omitting size-fractioning of these constituents have been noted previously (R i e z e b o s, 1968). The concentrates were embedded in an artificial resin, that completely hardens without a due rise of temperature, and subsequently ground and polished. The translucent mineral grains of the light concentrates were immersed in several liquids and examined in temporary mounts; the translucent heavy-mineral grains were only studied in Canadabalsem.

C. *Mineral analysis*

The material was examined only optically in transmitted and incident light. It has been aimed at to identify 300 grains in each mount. In the heavy fractions separated for translucent-species analysis, however, this was not always possible these species being very often insufficiently present. In one coarse size grade (sample I, 300-420 micron) no translucent grains could be detected at all, neither after preparing several mounts, whereas in others their total number did not exceed fifty.

Setting up a legend in work like this provides many difficulties, especially in the analysis of the light and the opaque mineral grains. If only grains consisting of one species with different appearences are concerned, these difficulties could be overcome rather easily. Composite grains, however, being the results of a great variety of causes a few known but many unknown, give the troubles which may be aggravated by the presence of rock fragments. From the latter constituents the parent rock could only occasionally be determined in the coarser size grades. In this connection the admirable initiative of B o g g s (1968) is certainly worth to be followed. This author studied artificial rock fragments with progressive diminuation, in order to determine whether the features preserved in the fragments are distinctive enough for identification.

In order to see the wood for the trees the legends have been given their present forms.

RESULTS

A. *Mechanical analysis* (fig. 2 and 3)

From the histograms in figure 3, it can already be inferred that the coarseness of the material seems to increase with decreasing age. The author thinks it wise to consider this result for the time being as a mere coincidence. The size-frequency curves in figure 2 show that the Md-values are growing accordingly. These curves have been drawn on arithmic-probability paper in order to compare the results with those obtained by D o e g l a s (1950) in his studies on grain-size distributions in various environments. The three curves, especially those of sample II and III, show at the coarse side a concave and at the fine side a somewhat more pronounced convex curvature,

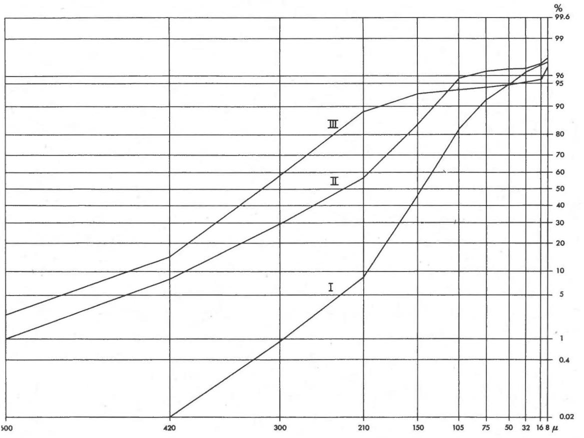

Fig. 2
Cumulative curves.

indicating that the material is a mixing of Doeglas' theoretically derived S and T fractions.

B. *Light minerals*

Under quartz 1 are taken together grains consisting of one single crystal. Clean or dirty surfaces, presence or absence of inclusions have not been considered. Grains composed of two or more intergrown, differently oriented crystals or particles being probably often rock fragments, have been grouped as quartz 2. Muscovites, biotites and chlorites are designated as micas. However, it is not excluded that very small slate fragments erroneously have been added to this as well as to the next group – weathered micas – comprising micaceous particles showing n_β and n_γ values under 1.580 and kaolinite minerals. Gibbsite includes mono- as well as polycrystalline grains.

Some conspicious points are displayed by the light mineral distribution. Firstly, the most abundant size grades seem to contain the greatest amount of quartz grains. Secondly, the contents of feldspar grains yield no variations worth speaking of. This refers to the size fractions within one sample as well as to the corresponding size fractions of the three samples considered. Further the amounts of weathered micas increasing with smaller size grades, seem to become more abundant as the sample material is older. Finally, the number of rock fragments almost to neglect in the sample I material, is growing in the coarser-silt and fine-sand fractions of sample II. In all the size grades of sample III, their numbers largely outdo those of sample I and II.

C. *Heavy minerals* (fig. 4)

The heavy-mineral assemblages of the terrace deposits from which sample I has been taken, are characterized according to Z o n n e v e l d (1949) by metamorphic minerals and tourmaline, while those of the younger deposits represented here by sample II contain additionally some so-called turbid chloritoid. Brown green hornblende, tourmaline, turbid chloritoid and metamorphic minerals mark the composition of those still younger sediments from which sample III derives.

The present results seem to fit within the general framework given by Zonneveld. However, turbid chloritoid that according to Zonneveld's data usually may come to 13% in the youngest deposits, remains far below this value in the fractions analyzed of sample III. In the sample II material they have not been observed. In addition to the high amphibole content sample III contains also a considerable amount of epidote grains.

The most typical feature shown by the outcomes of this fractionated analysis is the connection between grain size and mineral species. Especially zircon and the minerals of the tourmaline group are plain examples. The results in figure 4 have been arranged according to decreasing specific-gravity values of the minerals observed. Comparison of these values with the distribution of the relating minerals all over the size grades shows unmistakebly that these distributions perceptibly are influenced by the density values. The lower the density, the more the displacement of the central tendency of the distribution towards coarser size grades seems to have taken place. Of course this general picture is occasionally disturbed, because sorting on account of shape and original ratios between the sizes in the load were decisive factors too.

The most serious interferences are shown by the epidote and amphibole minerals. Even if these mineral groups are supposed to have their highest possible density values, their distributions are still deviating. However, epidote and amphibole grains both, but especially the latter, exhibit a strongly attacked appearance already discussed by Z o n n e v e l d (1949). Nearly all amphibole grains are fragile and skelettal in such a degree that they cannot have been deposited in this form (fig. 5). Their appearance strongly suggests that these grains have been altered after their deposition at a depth which is now still

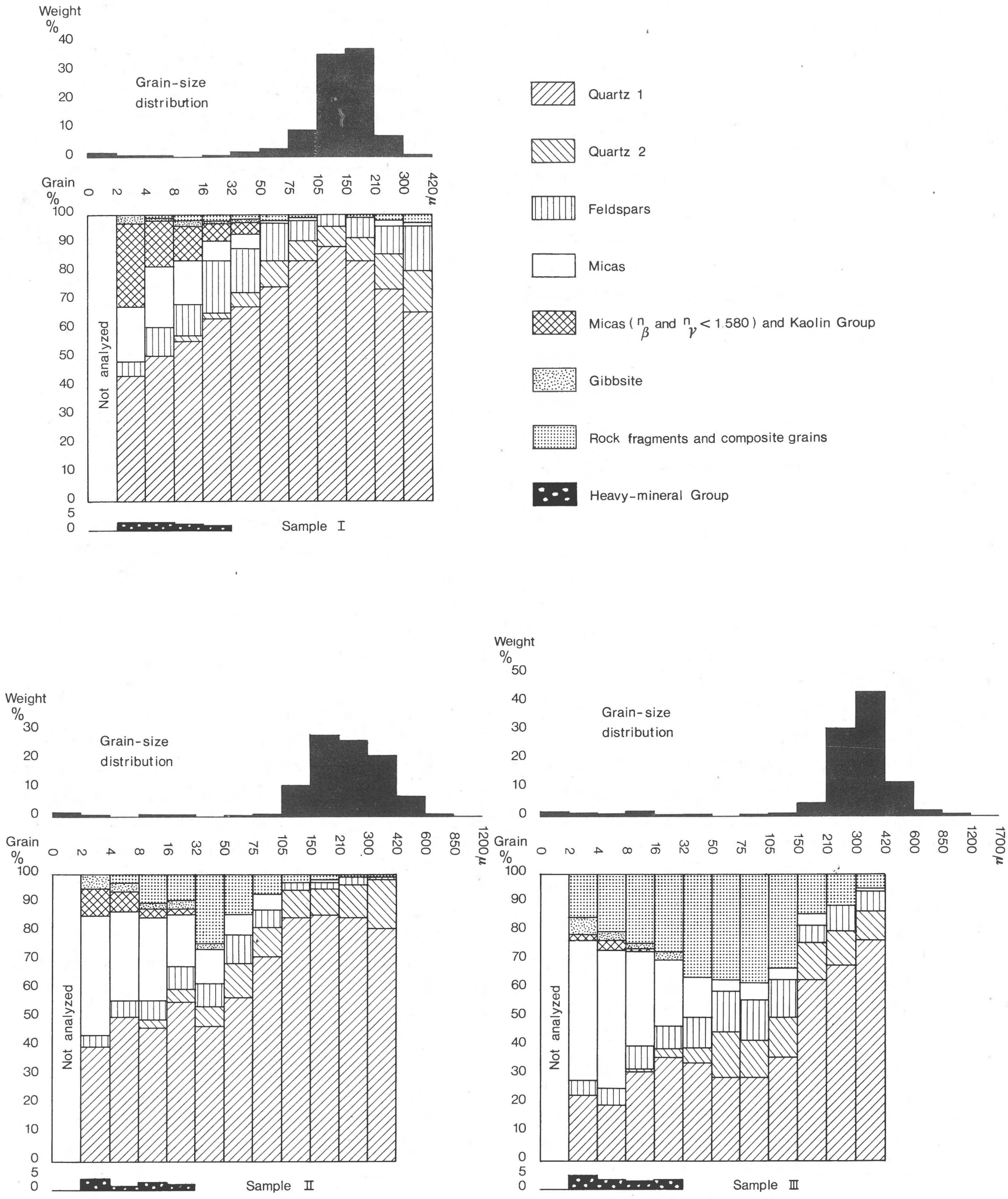

Fig. 3
Histograms and light-mineral diagrams

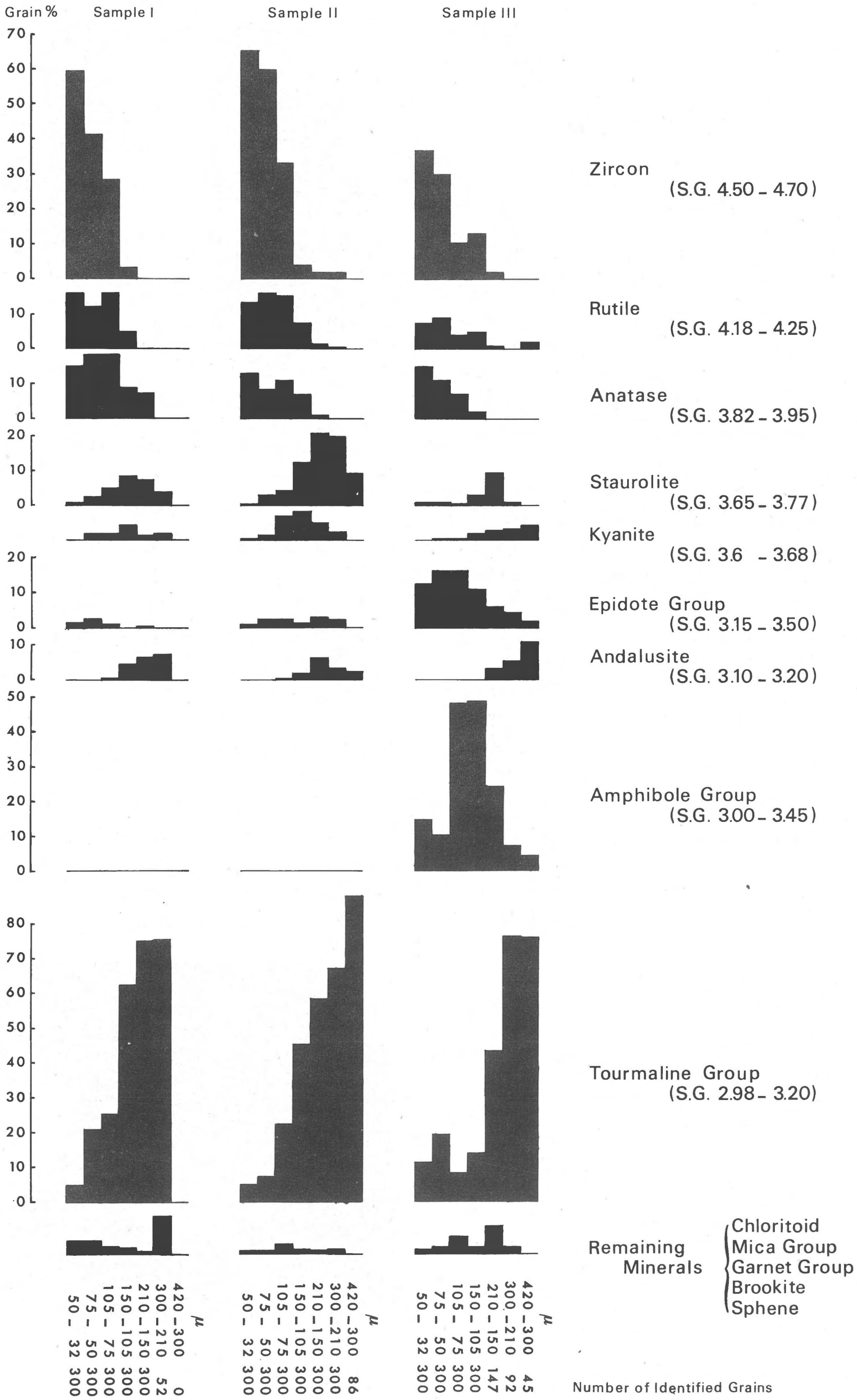

Fig. 4
Data from fractionated heavy-mineral analysis arranged according to specific-gravity values.

several meters below the present surface. If this interpretation of the optical observations is right, the pronounced deviations from the general trend shown by these mineral grains are in any case partly due to size diminishing after deposition.

D. *Opaque minerals* (table 1)

The opaque grains in the present materials consist of mineral species belonging to the FeO-Fe_2O_3-TiO_2-system just like those described from some other Dutch deposits (N e l s o n and N i g g l i, 1950; R i e z e b o s, 1968).

In sample I the opaque grains have a common feature: only small parts of the total surface areas of the grain sections appear to be polished (fig. 6). A great amount of holes, veins, pits, cracks and numerous other irregularly formed intervening spaces occur bearing only occasionally upon crystallographic directions. The empty spaces between the polished parts are thought to be due partly to dissolution of other intergrown species, partly to accentuation of inherited cataclastic textures.

The opaque-mineral composition is predominated by rutile in a degree not presumed from the outcomes of the translucent heavy-mineral analysis. As "leucoxene" according to B a i l y e.a. (1956) commonly consists of rutile, the opaque assemblage can be said to be composed of rutile only.

From these observations it is evident that the majority of rutile grains are remnants of previous graphic and mottled textured intergrowths from which all intergrown species but rutile have disappeared by dissolution. Thouth the present rutile patterns occasionally provide obvious pseudomorphs, the author thinks them to be of secondary origin. Arguments in favour of this view are the lack of twinning, the irregular grain boundaries and the prevalence of light-coloured internal reflections. These features are different from those shown by the other rutile grains. The latter exhibit very ofter recognizable idiomorphic boundaries, proportionally large polished surface areas, the frequent presence of polysynthetic twinning and more dark-coloured internal reflections. Very probably these grains correspond with those recognized in the analysis of the translucent heavy fraction and may be considered as the

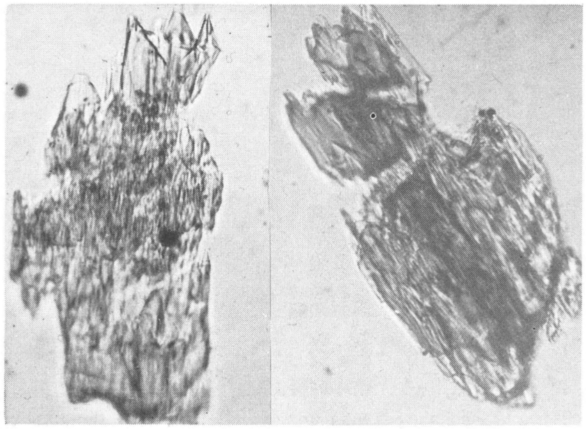

Fig. 5
Amphibole grains from the 75-105 micron size grade of sample III in plane polarized light. Objective P.25/0.50, Ocular Periplan 10 x.

TABLE 1
Reflected light analysis of 300 opaque grains from the 30-500 micron size range.

	sample I	sample II	sample III
Rutile	215	18	10
Ilmenite	8	2	–
Ilmenite altering in leucoxene	7	3	2
Leucoxene	64	3	2
Chromite	6	–	1
Magnetite	–	1	–
Magnetite altering in martite	–	3	–
Martite	–	2	1
Hematite	–	8	12
Goethite including lepidocrocite	–	260	272

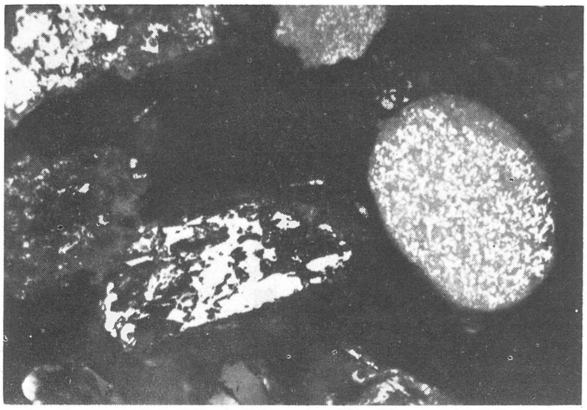

Fig. 6
Some opaque constituents from sample I in reflected light. Objective P.25/0.65 (oil immersion), ocular Periplan 10 x.

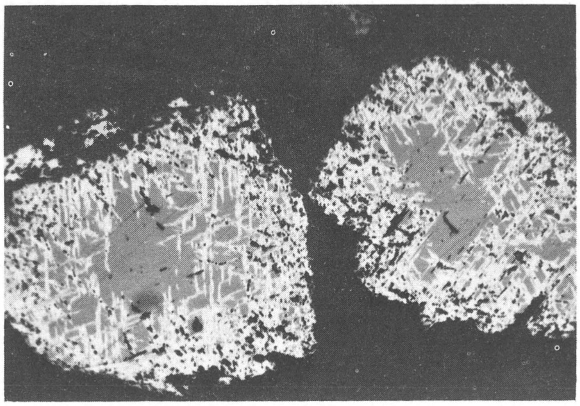

Fig. 7
Magnetite grains altering in martite. Reflected light, objective P.25/0.65 (oil immersion), ocular Periplan 10 x.

original high-temperature TiO_2 polymorphs. Leucoxene is assumed to be the alternation product of ilmenite under atmospheric conditions (B a i l e y e.a., 1956). The textural characteristics pertinent to this alteration seldom fail to be present in the grains.

The opaque fractions of sample II and III principally consist of goethite grains and the number of rutile grains is considerably decreased. The great abundance of goethite particles affords a good opportunity to observe the texture of goethite. The observations learn that this mineral, though being of supergene origin, here is present as detrital particles. It is true, there are some spherical or ellipsoidal grains showing a series of concentric goethite laminations built around a nucleus that may be a goethite fragment itself. However, the majority of the grains is made up of irregularly bounded, fine crystalline aggregates of varied porosity and texture, containing additionally numerous inclusions; fragments of öoliths and pisoliths; grains showing banding and even colloform textures; pseudomorphs after organic structure; etc.

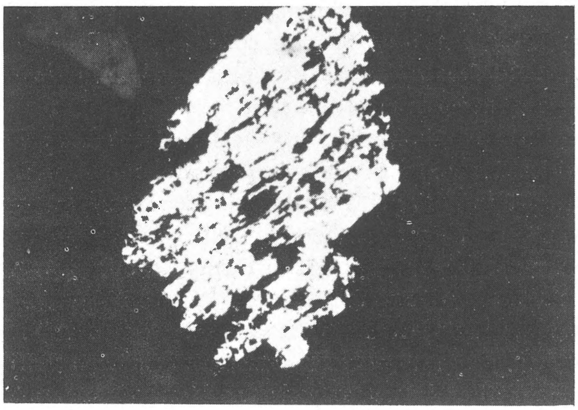

Fig. 8
Porous hematite grain in reflected light. Objective P.25/0.65 (oil immersion), ocular Periplan 10 x.

In magnetite grains the replacement of Fe_3O_4 by Fe_2O_3 as a result of oxidation, is present in intermediate and final stages. During the former, the alteration proceeds with decreasing effect from the grain boundaries inwardly along well-defined crystallographic planes (fig. 7). This may point to an alteration in already disintegrated, single magnetite particles. No magnetite of importance is left in the grains which have attained to the final stage, characterized by a Widmanstetten texture. Transformation of this martite into goethite has not been observed. However, the martite rims are characterized by a great porosity which may point to solution of the hematite or of the enclosed, still unaltered magnetite. This phenomenon, but much more intensified, is displayed too by single hematite grains originally undoubtedly martites or hematite remnants from former intergrowths (fig. 8).

DISCUSSION

In earth sciences a growing need is felt to improve the understanding of relationships between processes and their effects. Now the question may arise as to whether detailed, descriptive investigations as offered here should lead to this result. Present-day observations reveal that different processes may produce a similar effect, whereas the same process may cause different results. It should therefore be unwise to state that by this sort of work the actual relationships between process and product will be given. However, apart from the considerations that descriptions are never exhausting enough, the existing approaches could be broadened and possibly new ones could be opened.

It must be borne in mind that in each of the samples studied the obtained data may carry informations on a range of subsequent environments. Usually, however, only the final ones are of interest, namely the environmental conditions in the supply area, those reigning during transfer and deposition of the supplied materials and those affecting them after their deposition.

Significant features originated during and after deposition are scarcely traceable in the sample material. This is due to the way of sampling that completely destroys sedimentary features arosen after deposition just as the remnants of those produced by the sedimentation itself. Moreover, the pretreatment of the sample material involves very often partial or entire destruction of mineral phases that have been generated by these environments. Only undisturbed samples impregnated in the field may yield more information, so merely features preserved at the single mineral grains having escaped destruction, can be used.

The changes in the quantitative composition of the light minerals point to a lesser degree of weathering as the sample materials are younger. From this two things may be inferred: a supply of progressively lesser weathered material and/or a declining post-depositional alteration in the course of Pliocene and Pleistocene times.

The translucent heavy-mineral data suggest an additional supply of material characterized by amphibole mineral grains and a greater amount of epidote minerals, at some time after the deposition of the sediments from which sample II has been taken. However, as already mentioned, these characteristic components in the sample III material have been subjected to a post-depositional chemical solution. This implies their former presence in older material too, so the observed changes probably must be attributed to a diminishing result of this chemical attack.

The results of the opaque-mineral analysis show a considerable compositional difference between the first and the remaining samples. Whether this can be considered as a convincing proof for an additional supply after deposition of the sample I material, depends upon the stability of the mineral species causing this change. According to the most recent experimental study concerning the thermodynamical stability of fine-grained goethite (Berner, 1969), this mineral is unstable with respect to hematite and water under earth's surface conditions. However, the complete lack of hematite in sample I proofs that the present absence of goethite can not be the result of the transformation of goethite into hematite. Only a complete post-depositional dissolution of goethite would be able to account for this.

The conditions necessary for this process, however, are highly uncommon in the sedimentary environment of this material; so, in the opinion of the present writer, this change has to be considered as a conclusive evidence for additional supply.

Whether this supply characterized by goethite has resulted from a reinforced incision or from an enlargement of the drainage area is a point of interest. The acquired data provide arguments in favour of both causes. Since a renewed incision has been well documented previously, this aspect of the present data needs no emphasis.

Enlargement of the drainage area, however, seems still to be a point of controversy. Van Straaten (1946) has shown that the content of "cement kwartsiet", a constituent of Pliocene and Pleistocene Maas gravels, is considerably higher in the latter deposits. According to this author, this is in agreement with Stevens's idea of a capture of the Lotharingen Maas by the Maas of Dinant in the early part of the Quaternary Period (Stevens, 1938). Hol (1948), however, argued that this gravel constutuent is not restricted to Lotharingen and Zonneveld (1955) reported that against the idea of Stevens objections can be made from a geomorphological point of view. More recent geomorphol gical work, however, (Pissart, 1960-1961) adduces new data confirming in broad outline Stevens's idea.

Being a mineral of supergene origin, goethite might be considered as a detrital erosion product of a laterized landscape. Unfortunately the present writer is completely unacquainted with the textural features common in a lateritic weathering crust nor could he find in literature any ore microscopic descriptions of this type of rock. So it is dangerous to infer from the textures of these goethite grains a formerly stripped of lateritic mantle. Perhaps colloform textures and goethite pseudomorphic after organic structures may be considered as some clue to it.

There are, however, a few facts hardly to reconcile with the presence of a laterized surface before, and its stripping of during and after the deposition of the sample II material as the only cause of the abundant goethite supply. The first difficulty arises from the goethite's persistent presence. Its percentages in samples II and III are in the same order of magnitude though the light-mineral composition in sample III points to a considerably lower degree of alteration than that in sample II. Superficial inspection of the opaque constituents in an Holocene Maas deposit revealed a similar high content. The erosion and denudation of a laterized surface as the only cause of the goethite's appearance in the terrace deposits concerned, harldy tallies with this, as in that case it has to be assumed that the destruction of fully developed Tertiary weathering crusts should yield the same results as the present-day attack of their poor remnants.

The composition of the opaque constituents im sample I provides another difficulty in this connection. It is completely devoid of goethite, which seems irreconcilable with the occurrence of surfaces formed in the course of the Tertiary period and covered by iron caps, unless there is a very great interval of time between the deposition of sample I and II. The results of the translucent minerals analysis, however, suggest a close affinity between sample I and II.

To elucidate these discrepant facts a goethite supply, partially originating from a continuous incision of goethite bearing rocks has to be assumed. Such Jurassic rocks abound in Lotharingen, so the idea of Stevens seems to be very well workable in explaining the present observations too.

If the opaque fractions of the Quaternary Maas deposits are indeed characterized by high goethite contents, then the analysis of their opaque constituents may be an additional useful tool in distinguishing them from other synchronous fluviatile sediments.

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REFERENCES

Bailey, S.W., E.N. Cameron, H.R. Speddon and Randall J. Weege, (1956) – The alteration of ilmenite in beach sands. Economic Geology, 51 p. 263-279.

Berner, A. (1969) – Goethite stability and the origin of red beds. Geochimica and Cosmochimica Acta, 33, p. 267-273.

Boggs, S. Jr. (1968) – Experimental study of Rock Fragments. Journ. Sedimentary Petrology, 38, p. 1326-1340.

Broek, J.M.M. van den and L. van der Waals (1967) – The Late Tertiary peneplain of South Limburg (The Netherlands). Geologie en Mijnbouw, 46, p. 318-332.

Brueren, J.W.R. (1945) – Het terrassenlandschap van Zuid-Limburg. Med. Geol. Stichting, Series C-VI, nr. 1.

Doeglas, D.J. (1950) – De interpretatie van korrelgrootte-analysen. Verh. Ned. Geol. Mijnb. Genootschap, Dl. XV, p. 247-328.

Hol, J.B.L. (1948) – Geomorfologie. Handboek der Geografie van Nederland, Dl. 1.

Jong, J.D. de, L. van der Waals (1971) – Depositional environment and weathering phenomena of the white pliocene sands of southern Limburg Geologie en Mijnbouw, 50. p. 417.

Nelson, H.W. en E. Niggli (1950) – Röntgenologisch onderzoek van de ondoorzichtige zware fractie van enkele Nederlandse zanden. Proc. Kon. Ned. Ak. van Wetenschappen. L III, nr. 8.

Pissart, A. (1960-1961) – Les terrasses de la Meuse et la Semois. La capture de la Meuse Lorraine par la Meuse de Dinant. Ann. Soc. Géol. Belg, 84, Mémoires, p. 1-104.

Riezebos, P.A. (1968) – Mineralogical composition of material less than 500 micron from a red and a grey boulder clay sample in the Netherlands. Geol. en Mijnbouw, 47, p. 98-101.

Stevens, Ch. (1938) – Le relief de la Belgique. Mém. Inst. Géol. Univ. Louvain, 12.

Straaten, L.M.J.U. van (1946) – Grindonderzoek in Zuid-Limburg. Med. Geol. Stichting, Serie C.VI, nr. 2.

Waals, L van der, J.M.M. van den Broek, J.P. Bakker and E.A. Kummer (1962) – The Beaujean sand-pit on the Heerenweg at Heerlen, South Limburg. Med. Geol. Stichting, N.S. 15, 45-48.

Waals, L. van der (1967) – Morphological phenomena on quartz grains in unconsolidated sands, due to migration of quartz near the earth's surface. Med. Geol. Stichting, N.S. 18, p. 47-52.

Zonneveld, J.I.S. (1949) – Zand-petrologische onderzoekingen in de terrassen van Zuid-Limburg. Med. Geol. Stichting. N.S. 3, p. 103-123.

—— (1955) – De kwartaire rivierterrassen van Zuid-Limburg. T. Kon. Ned. Aardrijks. Gen., 72, p. 329-343.