GEOLOGIE EN MIJNBOUW VOLUME 50 (3), p.417-424 1971

DEPOSITIONAL ENVIRONMENT AND WEATHERING PHENOMENA OF THE WHITE MIOCENE SANDS OF SOUTHERN LIMBURG (THE NETHERLANDS)

J.D. DE JONG [1)] and L. VAN DER WAALS [2)]

ABSTRACT

White Miocene sands occur in a block-faulted area near the southern limitation of the marine Miocene deposits in The Netherlands. Sedimentary structures, granulometric parameters, and the occurrence of fossil shells and burrows, point to shallow-marine tidal and littoral depositional environments. The mode of occurrence of silicifications in sand and lignite, the occurrence of red-yellow podzolic soils, and the absence of any unstable components among the heavy minerals point to a post-depositional strong chemical weathering in Tertiary times. The white colour of the sands should not be considered as an effect of bleaching by the lignites.

INTRODUCTION

Southern Limburg forms part of the transitional zone between the uplifted peneplaned Paleozoic-Mesozoic Ardennes and Eifel massif in the south and the subsiding fault trough of the Lower Rhine area in Germany in the northeast. This, and the fact that the coastline was situated somewhere in the transitional zone, resulted in transgressions and regressions in southern Limburg. The increasing thickness of the Tertiary sedimentary complex towards the north is due to the downward movement of tectonical blocks; these blocks are seperated by SE-NW-striking faults (fig. 1). From the distribution of marine deposits of Cretaceous, Oligocene, and Miocene times, it may be concluded that each successive major transgression covered a smaller area than the preceding one; the sea retreated northward step by step. The fault blocks dip to the northwest and the Miocene formations thin out south-eastward.

Among the Tertiary sediments the Miocene sediments may be distinguished by following characteristics in the field:

Pliocene: white sands, poorly sorted, angular, glauconite absent;

Miocene: white sands, well sorted, clear quartz grains dominant; parts of the sequence greenish; glauconite sometimes abundant. Paleosols may occur in outcrops of the Tertiary peneplain.

Oligocene: clayey, well-sorted quartz sands; rock fragments abundant; glauconite ubiquitous; in outcrops of the Tertiary peneplain paleosols are common.

Among the Miocene sedimentary complexes, two in particular have attracted the attention of geologists for several decades, i.e. the white quartz sands and the lignites (brown coal). The investigations carried out during recent years have concerned the sedimentary geology and the explanantion of the striking white colour and mineralogical composition of the sand layers occurring between the lignite layers. Is the composition of the sand layers directly or indirectly related to the presence of the lignites, or is the source area of these sands the conclusive factor, as held by M u l l e r (1943)?. The latter supposition in any case

[1)] Geology Department, Sedimentary Geology Section, University of Leiden, Leiden (The Netherlands).

[2)] Netherlands Geological Survey, Geologisch Bureau, Heerlen (The Netherlands).

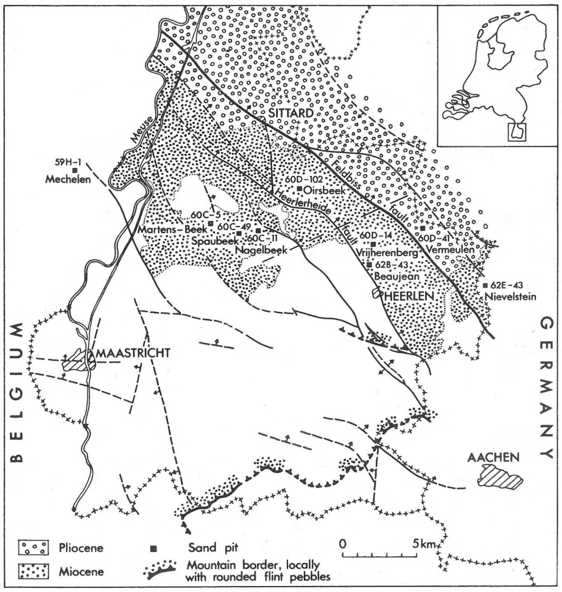

Fig. 1
Provisional geological map of southern Limburg, showing the distribution of Miocene and Pliocene formations; Quaternary is omitted.

implies that the juxtaposition of these contrasting formations must be attributed to a freak of nature.

The present paper gives some of the results of the investigations up to this date. A more elaborate report will appear in due course. More detailed investigations still form part of our program.

GEOGRAPHICAL AND STRATIGRAPHICAL OCCURRENCE OF THE QUARTZ SAND

The lack of guide fossils or marker beds considerably hampers a stratigraphical interpretation and correlation of the Miocene deposits in southern Limburg. The present study represents a preliminary attempt to find lithological characteristics in the Miocene deposits of varying thicknesses in different tectonic blocks and to determine whether weathering has been decisive with respect to the heavy-mineral composition.

The Miocene formations in southern Limburg, which is a blockfaulted area, are more or less completely developed in the area north of the Feldbiss fault (stratigraphic throw about 300 m), where Miocene formations are overlain by Pliocene and Quaternary deposits. Miocene formations crop out between the SE-NW-striking Feldbiss and Heerlerheide faults; south of the latter, only isolated patches of Miocene deposits are found overlying Oligocene and Cretaceous formations.

The Miocene formations show greenish, glauconitic sands, white quartz sands, brown humic sands, occasionally bluish flint-pebble layers at different levels, and lignite layers up to 10 m thick. Attention will be concentrated here on some of the sedimentological and petrographical aspects of the white quartz sands.

White quartz sands are extracted from the sand pits indicated in fig. 1. The white quartz sands and the greenish glauconitic quartz sands show a gradual transition in several places. White sands are sometimes overlain by greenish sands, but the reverse also occurs. To determine the character of the boundaries between the white and the greenish sands, more field and laboratory work is required.

The Miocene complex situated north of the Feldbiss fault, forms part of a regressive sequence, coarsening upward from underlying fine-grained Oligocene sands – deposited in a shallow-marine environment – to coarse-grained gravel-bearing sands laid down in a fluvial environment of Pliocene age in the uppermost part of the sequence. The Miocene sequence itself shows minor transgressive and regressive sequences. Two shell horizons represent the bases of transgressive sequences; autochthonous lignite layers point to temporary emergence and the development of a vegetation cover. Glauconite, marine shells (not identified), and ghost structures point to a marine depositional environment. Lateritic profiles developed during periods of regression in Miocene times under continental conditions. Red-yellow podzolic soils have been formed in slightly clayey and glauconitic sands while precipitation of silica has taken place in sands, free of clay (S t e p h e n s, 1966).

Pollen analyses made by M a n t e n (1958) has confirmed Breddin's supposition that the two thickest lignite layers correspond with the Morken and Frimmersdorf layers, as exposed in the excavations in the Ville area between Aachen and Cologne. Therefore, the Dutch lignites in all likelihood correlate with the lower part of the German lignites, which implies a Middle Miocene age. Most probably the Lower Miocene is not present in this part of The Netherlands. The tentative stratigraphical profile gives information about the approximate correlation (fig. 3).

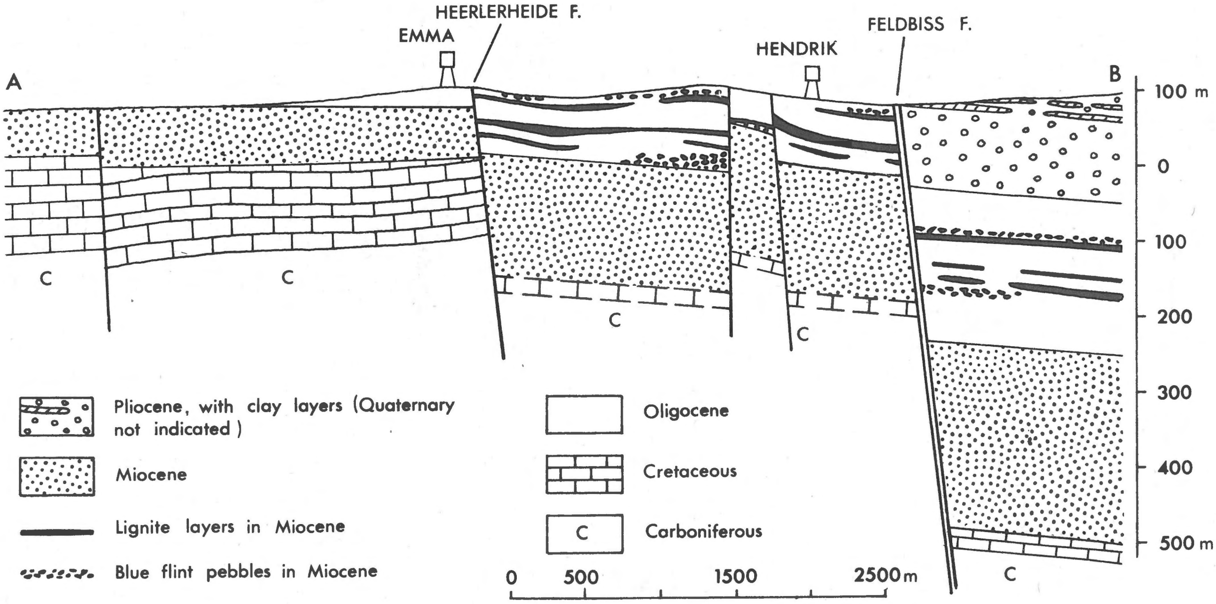

Fig. 2
Cross-section through the Tertiary of the northeastern part of southern Limburg (after Pannekoek et al., 1956).

The Miocene sequences very probably have stratigraphic hiatuses in several of the sand pits visited, because of the occurrence of silicified layers and silica concentrations in the sands as well as in the lignites.

The Miocene sands are predominantly without fossils. Indications of organic life are provided by ghost structures of lamellibranchs, Ophiomorpha burrowing structures, rootlet beds and the mottled character of some glauconitic sands, because of bioturbation, and perforations by knee roots.

Because of the sparseness of even non-diagnostic fossils, the absence of any marker beds, and the situation of pits in different tectonic blocks, the correlation from one sand pit to the other is generally uncertain. Moreover, in most cases it is not clear which part of the Miocene sequence is exposed in a given sand pit. The present state of our knowledge does not yet enable us to identify a given exposed profile as a stratigraphically continuous one or to conclude a hiatus is present – in which latter case its length may be unknown as well.

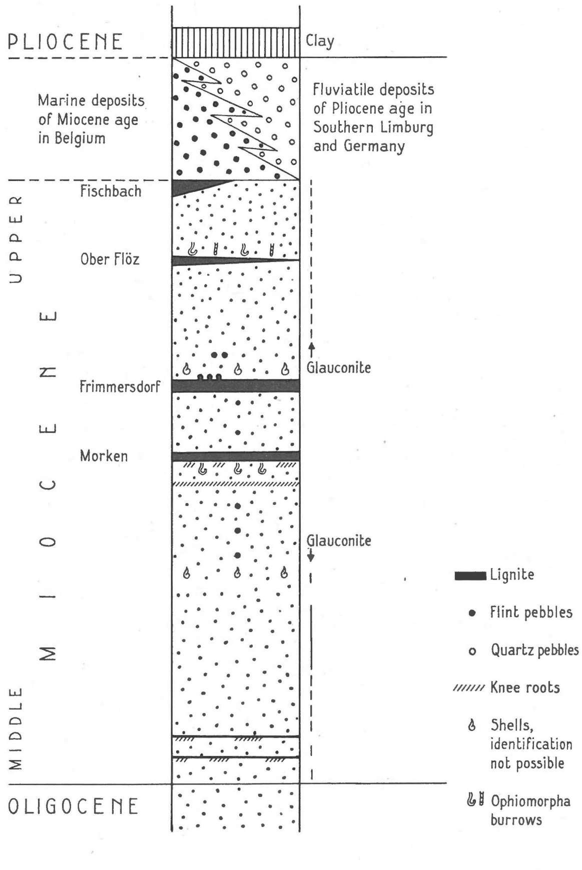

Fig. 3
Tentative section of Middle and Upper Miocene.

DEPOSITIONAL ENVIRONMENT OF THE QUARTZ SANDS

a. *Sedimentary structures*

Cursory investigations of several sand pits suggest that sedimentary structures differ within relatively narrow limits:

Low-angle inclined bedding, occasionally varying in direction which results in herring-bone structures (fig. 4), are often found in alternation with evenly laminated layers. Alternation with low-angle cross-bedding is found as well. Even lamination with 1 to 3 decimetre thick layers is common (fig. 5). When Ophiomorpha burrows are present, they are found in these layers.

Layers with a thickness of 1 to 4 decimetres and consisting of exclusively bluish, well-rounded flint pebbles were encountered in some sections. Laterally, these layers may peter out as one-pebble-thick layers. The pebbles show imbrication with a dip direction opposite to that of the underlying and overlying sand layers, which implies a similar current direction for pebbles and sand (fig. 6).

Other parts of the same sand pit show an alternation of well-rounded-pebble layers and sand layers with even lamination (fig. 7).

Silt and clay layers, found together with evenly laminated sand layers and on top of sand ripples, are common in some of the pits. Here, too, channel-shaped fills of clayey sand are found. Upwards, the complex shows a transition into sands with an indistinct flaser- and-linsen structure.

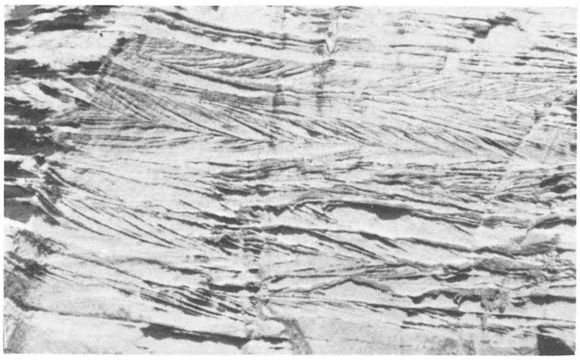

Fig. 4
Cross-bedding of variable direction; thickness of sets averages 20 centimetres. Nievelstein sand pit.

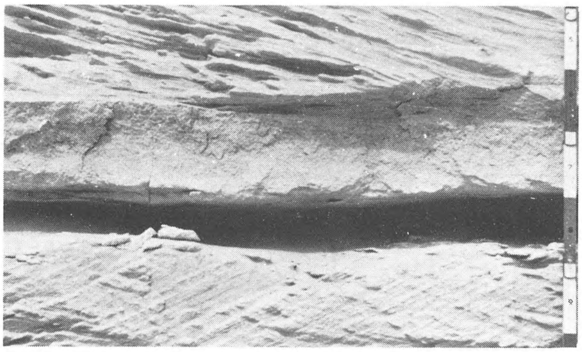

Fig. 5
Cross-bedding of variable direction and even laminated sandstone. Nievelstein sand pit.

Some sand pits, however, show sections in which field study revealed no sedimentary structures; homogeneous profiles sometimes occur, with a thickness of about 10 metres.

On the basis of these sedimentary structures, the occurrence of lamellibranchs, albeit as ghost structures (fig. 8), the layers of well-rounded pebbles, and the absence of clay and silt in most of the sections, a high-energy marine environment of deposition for the larger part of the exposed formations may be inferred. Because shell layers or heavy-mineral concentrations are lacking in the evenly laminated sand layers an interpretation as beaches is not immediately justified. Where well-rounded-pebble layers and intercalated horizontally laminated sand occurs a lag deposit in a shallow-marine environment seems obvious.

The herringbone structures are due to oppositely migrating megaripples, which may point to a tidal environment; the thickness of the sets gives a minimum value for the height of the ripples, in our case on an

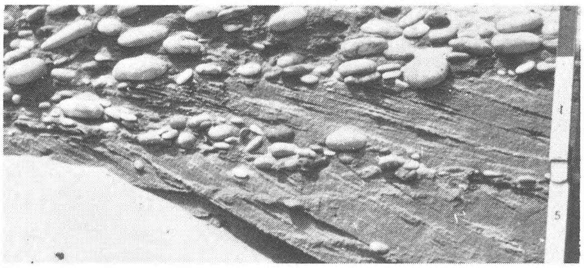

Fig. 6
Cross-bedding in white quartz sands; imbrication in bluish flint pebbles. Current from left to right. Scale at right in decimetres. Nievelstein sand pit.

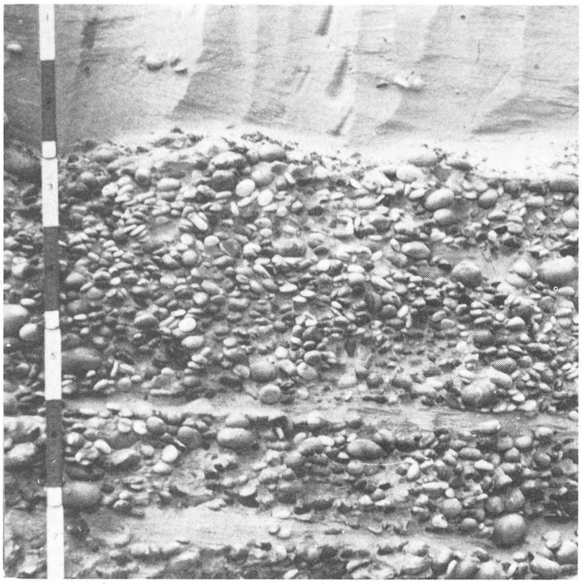

Fig. 7
Sand with even lamination and layers of flint pebbles with imbrication in variable directions. Nievelstein sand pit.

average of 20 centimetres high. The simultaneous occurrence of layers of imbricated pebbles might indicate longshore currents with a transport capacity capable of carrying pebbles to the locality under consideration. The flint pebbles may have resulted from abrasion of near-by cliffs of Cretaceous flint-bearing chalks generally underlying the Tertiary deposits. An escarpment in the Cretaceous chalk with concentrations of well-rounded flint pebbles at its base may be interpreted as a marine cliff in Miocene times. This escarpment could be the southernmost limit of the Miocene transgressions (fig. 1).

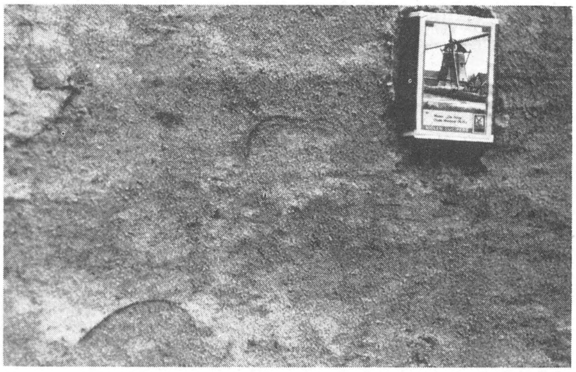

Fig. 8
Ghost structures in mottled, bioturbate glauconite sands. Oirsbeek sand pit.

The Ophiomorpha burrows are most likely produced by the decapod *Calianassa major* Say. These burrows when found in well-sorted massive bedded sands point to a wave-agitated littoral to shallow-neritic environment (W e i m e r and H o y t, 1964).

The occurrence of clay in ripple troughs and of some flaser-and-linsen structures points to conditions under which the current fell off now and then.

Trough-shaped fillings of clay and sand point to scour-and-fill processes. Compared with the sand deposits free of clay, these structures indicate a change in environmental conditions. Cross-bedding, very well-sorted sands overlying these variegated sand-clay sediments, as seen in one of the pits, may be interpreted as eolian dune deposits.

b. *Grain-size distribution*

Grain-size analyses were made of samples from different layers in the sand pits. The median-values range from 134-323 micron. Some pits show relatively low values throughout the exposed layers, e.g. 134-156 micron in one pit, whereas relatively high values, i.e. 200-311 micron, were found in another. The samples from another pit show a rather large spread of median-values, between 155 and 323 micron.

The clay + silt content (total content of particles < 50 micron) is very low in several cases. The evenly laminated and low-angle cross-bedded complex in one of the pits show nil percent, whereas in other parts of the excavation these percentages are lower than 2. Percentages up to 12 occur as well. Clay flakes may reach percentages of more than 80.

To check the interpretation of the cursory observations on sedimentary structures in the field, K o l d i j k's (1968) computer program was followed for the calculation of several statistical parameters. Friedman's second (σ_φ), third ($\alpha_{3\varphi}$), and fourth ($\alpha_{4\varphi}$) moment measures were plotted graphically. The samples from the Beaujean sand pit gave values concentrated in three clusters in the $\alpha_{3\varphi}$-σ_φ graph (fig. 9). Comparison on this graph with a similar graph of the Nievelstein samples (fig. 10) reveals that the values of the latter are scattered over the area covered by Beaujean groups II and III, as well as the area in between. A cluster of points with low $\alpha_{3\varphi}$ and relatively low σ_φ values, so distinct in the Beaujean samples, was not found for Nievelstein. Similar graphs from samples of other sand pits show that all samples

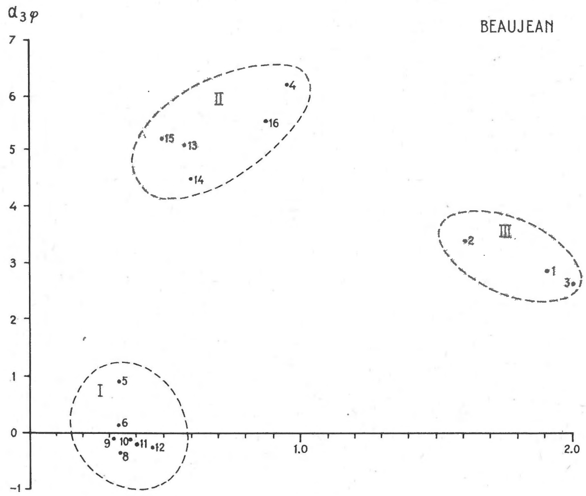

Fig. 9
Friedman's standard deviation plotted against skewness (second against third moment) of some Beaujean samples.

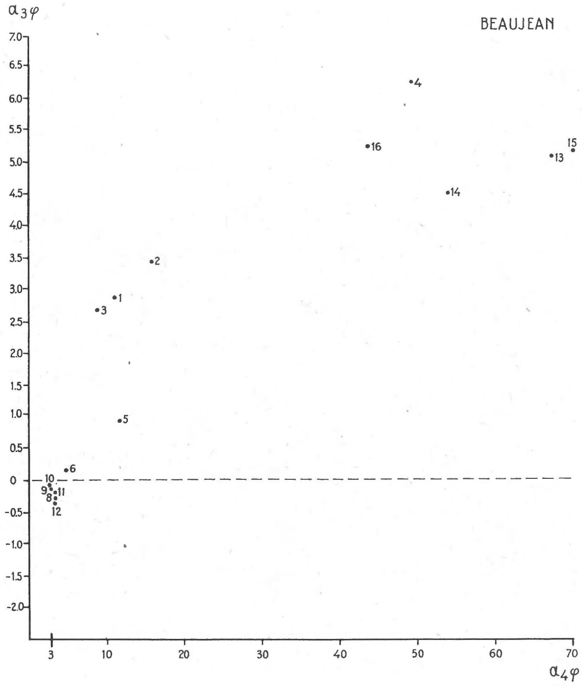

Fig. 11
Friedman's kurtosis plotted against skewness (fourth against third moment) of some Beaujean samples.

fall within the area covered by cluster I or cluster II + III. The samples clustered in one group in the graph proved to occur in a particular part of the section, but they may also occur in alternation with the samples of the other group. Therefore, two granulometric facies seem to be present.

The samples with low, positive to negative $\alpha_{3\varphi}$ (skewness) values, clustered in group I, point to a coarse tail of the grain-size distribution. This may have been caused by winnowing of the silt and fine-grained sand particles, a process very common in littoral to shallow-marine environments, shallow in this case meaning within wave base. Along a sandy coast such sediments are found offshore at the barrier face and on the beach. The other group with higher $\alpha_{3\varphi}$, $\alpha_{4\varphi}$, and σ_φ values, as groups II + III is labelled as shallow-marine tidal but not yet on granulometric criteria. Field observations, such as the occurrence of glauconite, burrows, and herring-bone structures have to be borrowed here from the conventional criteria.

The picture displayed by the $\alpha_{3\varphi}$-$\alpha_{4\varphi}$ graphs of the Beaujean (fig. 11) and Nievelstein (fig. 12) pits appears to be shared by the samples of other pits: a slightly curved or a straight bend representing a rectilinear relation between the $\alpha_{3\varphi}$ and $\alpha_{4\varphi}$ values.

Little is known as yet about the influences of weathering on the grain-size distribution and the degree of sorting.

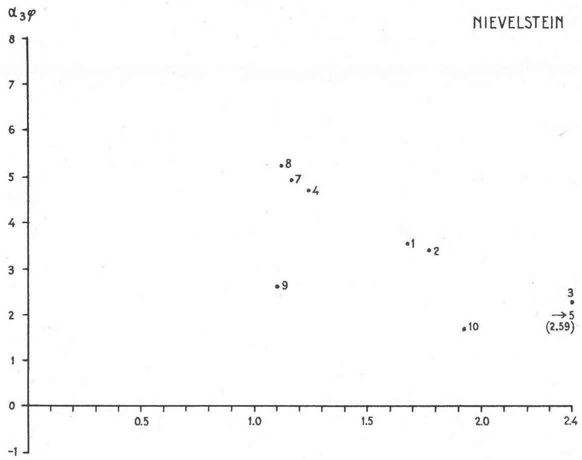

Fig. 10
Standard deviation plotted against skewness of some Nievelstein samples.

c. *Mineralogical composition*

Under this heading the presence of glauconite, only, will be mentioned here. This mineral, considered as a marine clay mineral is abundant in layers, merging into white sands, in the Miocene complex.

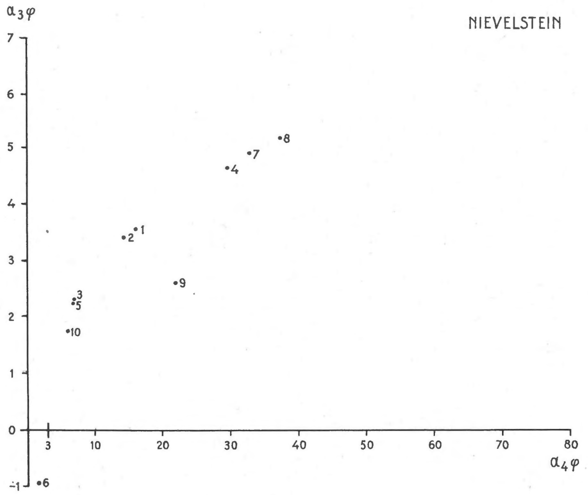

Fig. 12
Kurtosis plotted against skewness of some Nievelstein samples.

That temperatures lower than about 15 centigrades tend to be favourable for the formation of authigenic glauconite, and this mineral develops generally between 30 and 2000 m (P o r r e n g a, 1967) imply a shallow-marine to neritic depositional environment, for the Miocene glauconitic sands of the present area.

POST-DEPOSITIONAL CHANGES OF THE MIOCENE CLASTIC SEDIMENTS

The Miocene quartz sands belong to the formations occurring along the surface of the former peneplain. This conclusion is based on the fact that red-yellow podzolic soils developed, that the quartz sands are almost pure in several cases, that some rock fragments and potash-feldspar are found only subordinately along with quartz among the light minerals, and that the heavy-mineral assemblage consists exclusively of stable minerals. Furthermore, silicifications are a common occurrence in the quartz sands.

a. *Silicifications*

Several pits show layers of silicified sand, sometimes as subordinate layers with a thickness of one to two decimetres, in other cases as boulders with a diameter of several metres. The silicified layers sometimes occur in the top parts of the exposed Miocene sands near the boundary with the overlying Quaternary terrace-gravel deposits. In the sandstones, root tubes are common. Silicifications are found in outcrops of various stratigraphical levels, with predominantly clean white sands containing only little or no clay. The sandstones made part of a lateritic soil horizon in Tertiary times.

Cretaceous formations also show silicifications along the surface, and concentrations of flint and silicified fossils occur sporadically (v a n d e n B r o e k and v a n d e r W a a l s, 1967).

b. *Mineralogical composition*

Light minerals (specific gravity, below 2.9): The average mineralogical composition of the light-mineral fraction of some samples from the Beaujean sand pit shows a predominance of quartz (85%) with some rock fragments (9%) and potash-feldspar (6%). Samples from other pits showed even higher quartz percentages (90-99), with 1-6.5% rock fragments and 0-1.5% potash-feldspar.

Heavy minerals: The total percentages of heavy minerals, both opaque and translucent, are generally very low, ranging from 0.003 to occasional, relatively high values (1.48%).

Titaniferous minerals i.e. rutile, leucoxene with a minor amount of ilmenite, dominate among the opaque minerals.

The translucent heavy minerals generally show relatively high percentages of tourmaline (20-55), whereas zircon + rutile + anatase were found in different amounts (0-32%) the other metamorphic minerals (kyanite, andalusite, sillimanite) showing 2-64%. Less stable minerals such as epidote, hornblende, and garnet, occasionally occur in very subordinate amounts but are generally absent.

M u l l e r (1943) distinguished between Miocene sands with a relatively high garnet content (up to more than 40 percent) and with almost none in samples from borings and colliery shafts. He always found the lignite layers in the sands without garnet. Some borings show a garnet-free upper part overlying the garnet-bearing part of the Miocene sequence. However, in some borings there is an alternation of the garnet-free and garnet-bearing heavy-mineral assemblages. Muller explained these differences in heavy-mineral composition by assuming different source areas for the sands laid down in different depositional environments.

The present paper confines the inquiries to the Miocene sediments as exposed in the sand pits. A future paper will also deal with the Miocene formations from the borings.

CONCLUSIONS

The present area displays a magnificent interplay of sedimentation and non-deposition; during the latter periods, the appearence of the formations was changed considerably by very strong weathering.

The tectonic structure of southern Limburg, with deep-lying blocks in the northeast and high-lying blocks in the southwest, is responsible for the decrease of the Tertiary cover from several hundreds of metres in the northeast to a cover of isolated relics wedging out to the southwest. White sands are found on blocks where the Miocene cover is relatively thin; their presence is accentuated by large-scale excavation of sand for industrial purposes. Greenish, glauconitic sands predominate in sections of the deeper blocks. White sands of high industrial quality are found only where an impermeable covering layer including lignite is present; this layer is thought to prevent the infiltration of iron-bearing solutions from overlying Pleistocene terrace gravels.

The Miocene white quartz sands represent a littoral to very shallow-marine tidal-environment in which sedimentation kept abreast of weathering. Therefore, it is virtually impossible to separate the effects of synsedimentary and postsedimentary processes. In areas farther to the northwest with a more continuous subsidence the Miocene formations are thicker. Here, away from the near-shore environment, where lignite layers are no longer found, weathering of recently deposited sediments could not take place and they were covered directly by other sediments.

Summarizing the foregoing, it may be stated that the position of a littoral environment and the subsidence and emergence of different blocks in the present block-faulted area, together with the occurrence of red-yellow and yellow podzolic soils, point to sedimentation and weathering under a subtropical climate with dry seasons. According to Manten (1958) the composition of the flora makes it likely that the Miocene climate was moderately subtropical. Solarization (dehydration) of flint pebbles and solution and leaching of the Upper Cretaceous formations point in the same direction. The final result has been strong chemical weathering. Apart from one or two per cent in a few samples, garnet is absent in the material from the sand pits. We were also unable to detect it in samples given a greenish colour by a considerable percentage of glauconite.

Too little is known yet about the relative stability of minerals like garnet and glauconite under the conditions prevailing in the area since the deposition during the Miocene.

REFERENCES

Breddin, H. (1950) – Die Hauptflözgruppe im niederrheinischen Braunkohlenrevier. Braunkohle, Wärme und Energie, Jahrg. 1960, p. 312-320 and p. 378-385.

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

Manten, A.A. (1958) – Palynology of the Miocene Browncoal mines at Haanrade (Limburg, Netherlands). Acta bot. neerl., 7, p. 445-488.

Muller, J.E. (1943) – Sedimentpetrologie van het dekgebergte in Limburg. Med. Geol. Sticht., Serie C-II-2-No. 2, 78 p.

Pannekoek, A.J. (ed.) (1956 – Geological History of The Netherlands. Gouvernment Printing and Publishing Office, 's Gravenhage, 147 p.

Porrenga, D.H. (1967) – Glauconite and chamosite as depth indicators in the marine environment. Marine Geology, 5, p. 495-501.

Stephens, C.G. (1966) – The origin of silcretes of Central Australia. Nature, 209, p. 496, London.

Weimer, R.J. and J.H. Hoyt (1964) – Burrows of *Calianassa major* Say, geologic indicators of littoral and shallow neritic environment. Journ. Pal., 38, p. 761-767.