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HEAVY-MINERAL ASSEMBLAGES IN NEOGENE MARINE AND NEAR-COASTAL DEPOSITS OF THE SOUTH-EASTERN NETHERLANDS

by

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Interdisciplinary investigations focused on the Venlo fault block and the southern part of the Central Graben in the south-eastern part of The Netherlands yielded a better understanding of the succession and the interrelation of Neogene deposits. The fact that a detailed mollusc biozonation is available now appeared to be especially advantageous.

A subdivision into eleven sedimentary petrological zones is presented, eight for the Miocene and three for the Pliocene deposits. Depositional hiatuses are encountered on top of the Oploo Sands (Late Miocene) and on top of the Venlo Clay (Early Pliocene), on the Venlo block.

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Contents:

SAMENVATTING

Met behulp van zware mineralen- en grindonderzoek wordt een onderverdeling gepresenteerd voor miocene en pliocene afzettingen op de Venlo schol en in het zuidelijk deel van de Centrale Slenk. De sedimentpetrologische zonering is voor een belangrijk deel gerelateerd aan de molluskenzonering. Het onderzoek werd beperkt tot een profielsectie tussen Venlo in het zuiden en Nijmegen in het noorden, gelegen op de Venlo schol, en de boring Broeksittard in het zuidelijk deel van de Centrale Slenk.

In het Mioceen kunnen acht zones worden onderscheiden tegen drie in het Plioceen. Zowel aan de top van de Zanden van Oploo (Laat Mioceen) als boven de Venlo Klei (Vroeg Plioceen) blijkt op de Venlo schol een belangrijk hiaat aanwezig.

INTRODUCTION

Publications on the heavy-mineral content of Neogene deposits in the south-eastern part of The Netherlands are scarce. In 1933, Edelman & Doeglas gave a first summary of results obtained in a series of systematically investigated locations, but they did not go into much detail in discussing their findings. Muller, who published in 1943 his important work on younger deposits in the southern part of the province of Limburg, went into more detail, especially in connection with his attempts to establish a correlation between continental and marine deposits on sedimentary petrological grounds. The Rijks Geologische Dienst published some very general notes in the explanations to the geological maps (Bisschops, 1973; Bisschops et al., 1985; Kuyl, 1980; van der Toorn, 1967). Most of these publications, however, suffered from the lack of a detailed biozonation. It was generally felt that heavy-mineral interpretation would allow little more than assignment to the Pliocene or Miocene and very often not even that, especially so for marine sediments.

The present discussion shows how a subdivision can be achieved with the help of heavy-mineral analysis by correlation with a detailed biozonation. The investigation reported here was restricted to a section on the Venlo fault block between Venlo in the South and Nijmegen in the North, and to the Broeksittard borehole, situated in the southern part of the Central Graben (Fig. 1). The heavy-mineral studies were performed in the usual way: counts were done in the non-opaque heavy fraction (s.g. > 2.87, size 63-500 μm) after pretreatment with hydrochloric acid 25% and nitric acid 50%, followed by separation with bromoform and mounting in Canada balsam, after which 200 grains were identified by line counting.

The fine-gravel analyses are based on counts of 300 grains in the fraction of 3-5 mm. For further information about the method, see Zandstra, 1959.

All deeper boreholes were additionally investigated with respect to organic remnants, which allowed a direct comparison between the results of the heavy-mineral analyses and biozonation.

ZONATION

The following succession is presented, where possible in relation to the mollusc zonation presented by Sliggers & van Leeuwen (1987).

Middle Miocene

Zone 1. The oldest investigated deposits, thought to be of Miocene age, occur in the lowermost meters of the Broeksittard borehole (60D/1033, 499.50-506.50 m) (Fig. 4). These are marine

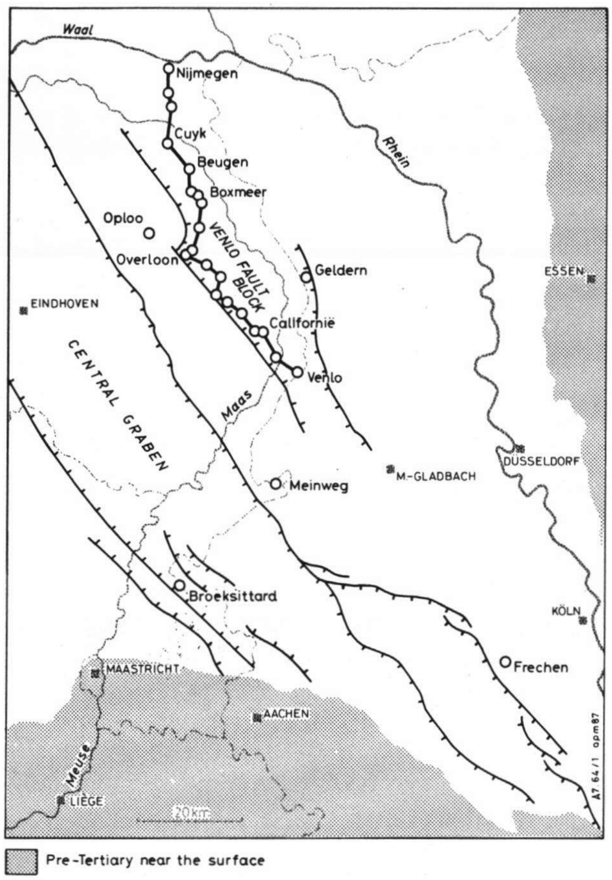


Fig. 1. Map showing tectonic setting of the area under study and localities mentioned in the text.

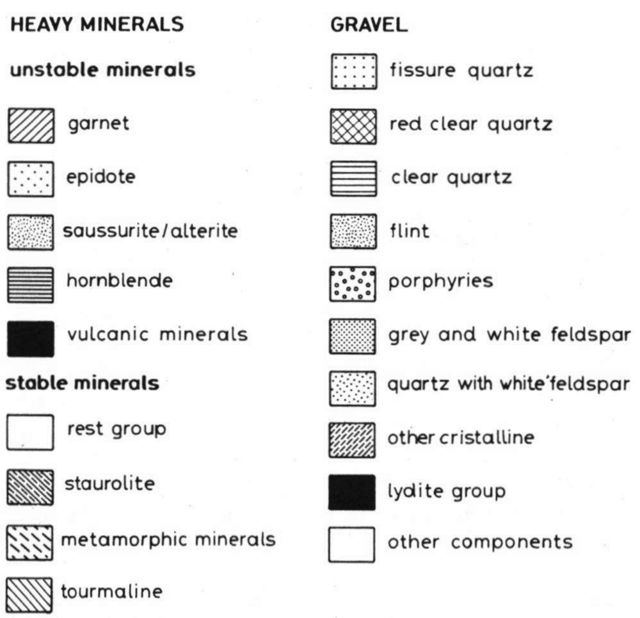


Fig. 2. Legend for heavy-mineral and gravel diagrams.

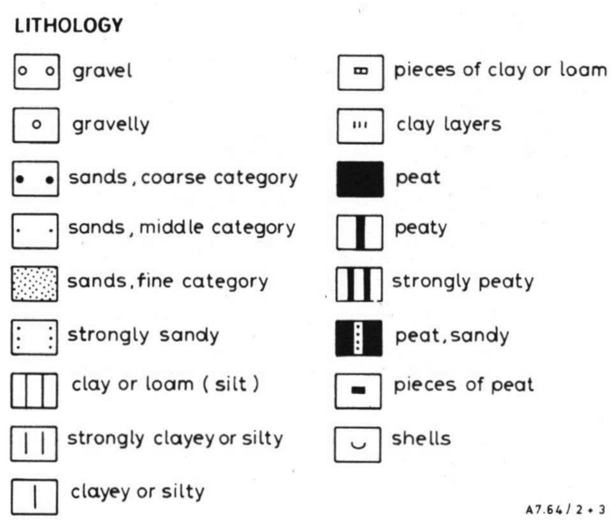


Fig. 3. Lithology legend.

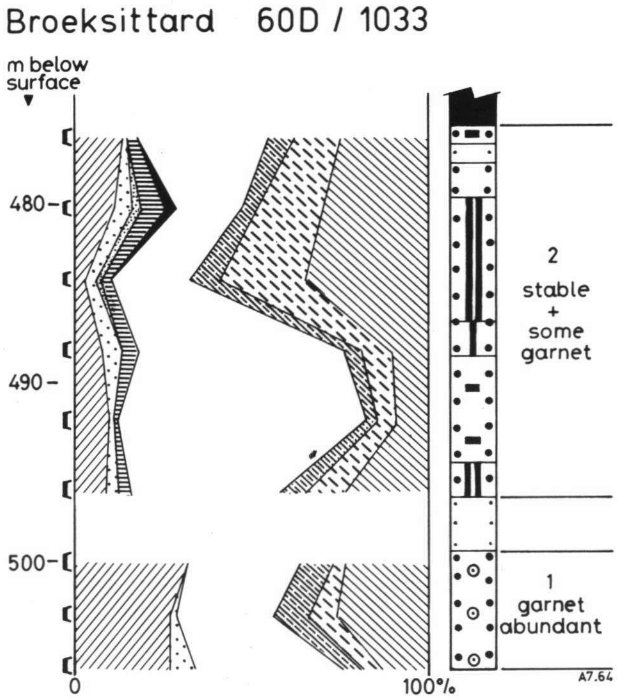


Fig. 4. Heavy-mineral diagram of Broeksittard borehole, 60D/1033 (472.0-507.5 m below surface).

deposits, characterized by an abundance of garnet with large amounts of tourmaline and metamorphic minerals. This is in accordance with Muller (1943). Boenigk (1981) published an identical occurrence in the Frechen pit in Germany, which is situated in a fluviatile/estuarine section just below the Main Brown-coal.

Zone 2. In upward direction in the Broeksittard well (475.50-496.50 m) (Fig. 4) the garnet content decreases to 10-15%. This association is found in a continental deposit overlain by a thick layer of brown-coal, thought to represent the Morken Seam. A small amount of hornblende is also present in the otherwise very stable assemblage. It is not yet clear whether the lowermost deposits in the Californie borehole (52G/198, 245.00-250.00 m) (Fig. 5), on the Venlo block, with a somewhat higher garnet content, can be correlative, although this is assumed by the present author.

Zone 3. In Zuid-Limburg and in the Meinweg region the zone 2 deposits are followed by an extremely stable mineral association. The lower boundary of these fluviatile deposits is mineralogically very sharp. In Broeksittard it is present in between the Morken Seam at its base and the overlying Frimmersdorf Seam (406.50-440.50 mm) (Fig. 6). The influence of the unstable group of heavy minerals is restricted to the occurrence of some garnet.

To the North-West these white sands merge into sandy marine deposits containing glauconite. In the latter deposits the influence of the stable minerals is still detectable until the Californie borehole (192.50-243.00 m) (Fig. 6). Tourmaline and the metamorphic minerals are substantially replaced by zircon, rutile and anatase. This is thought to be the result of differences in the grain sizes of the heavy fraction (Burger, 1970).

Fig. 6. Heavy-mineral diagrams of part of the Middle Miocene deposits of the boreholes of Oploo, 52A/22, Californie, 52G/198, and Broeksittard, 60D/1033, showing the interrelation of heavy-mineral assemblages.

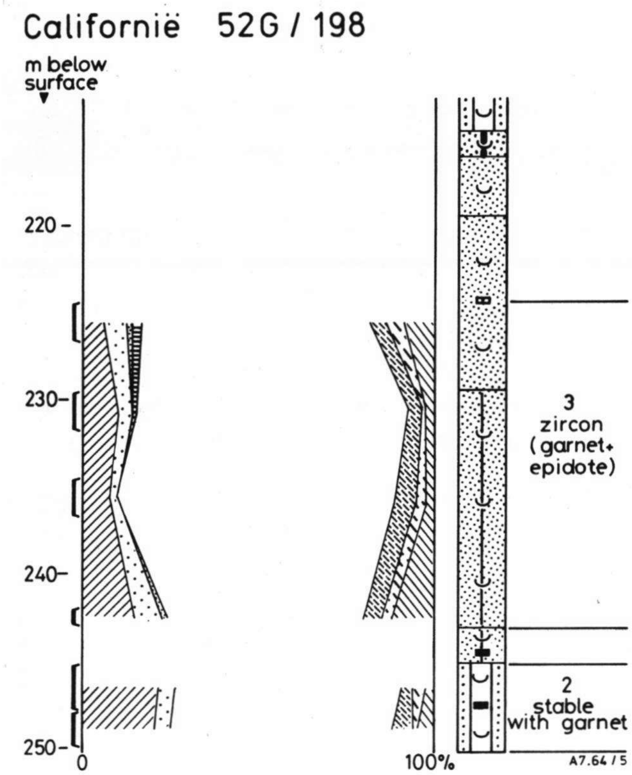
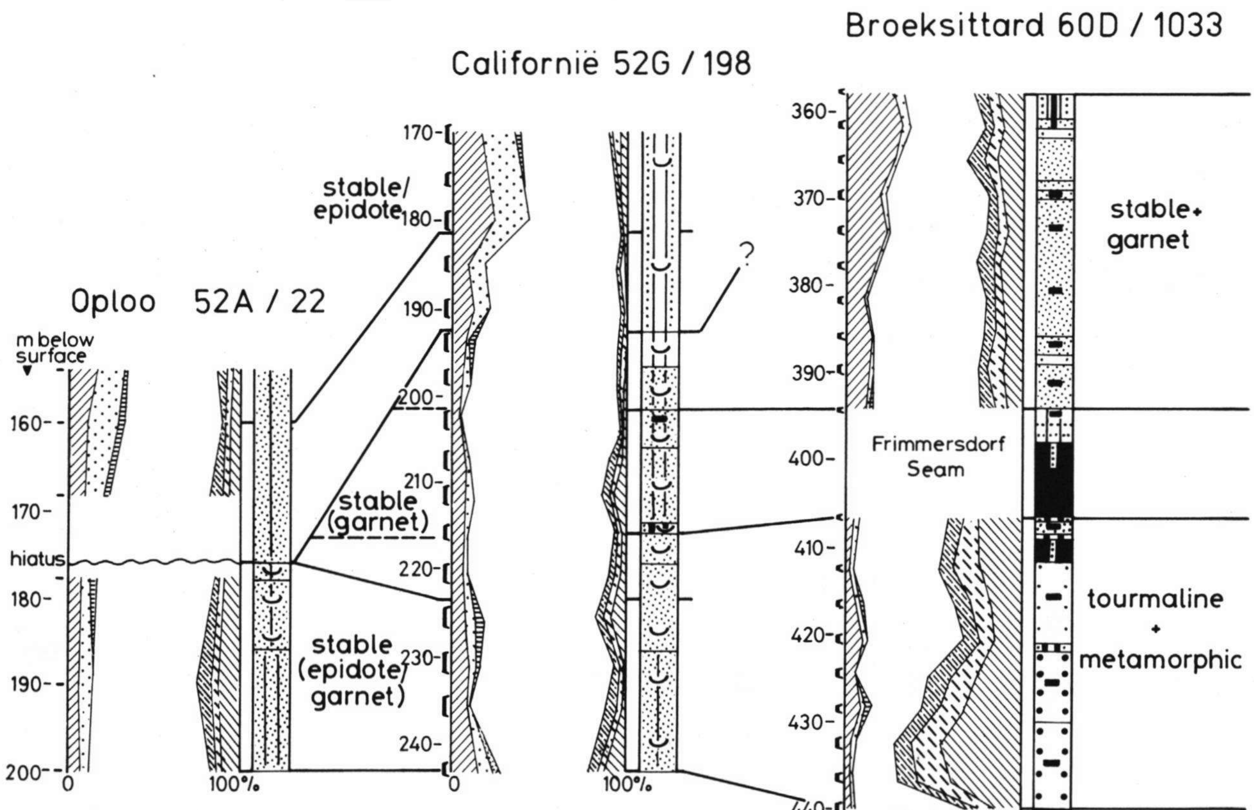


Fig. 5. Heavy-mineral diagram of Californie borehole, 52G/198 (222.0-250.0 m below surface).



The stratigraphic range of this Californie assemblage is wider than that of Broeksittard. In Broeksittard it is absent above the Frimmersdorf Seam, whereas in Californie it continues above this seam. The lower part differs from the upper part by the occurrence of some epidote. Since the Oploo borehole (52A/22) lacks this part without epidote, it may be assumed that the part above the Frimmersdorf Seam is absent in the Oploo well (Fig. 6).

Zone 4. The upper part of the Middle Miocene deposits on the Venlo block is composed mainly of a clayey sediment, often very poor in fossils. The mineral association found in these sediments is very characteristic due to a relatively high epidote content, occurring together with garnet in an otherwise zircon-rich assemblage (see e.g. Fig. 6, Californie, 52G/198, 168.50-181.00 m).

In deposits of about the same age in the Broeksittard borehole, the garnet percentage is maximally 30, occurring together with stable minerals. In the basal part epidote is virtually absent; it is only

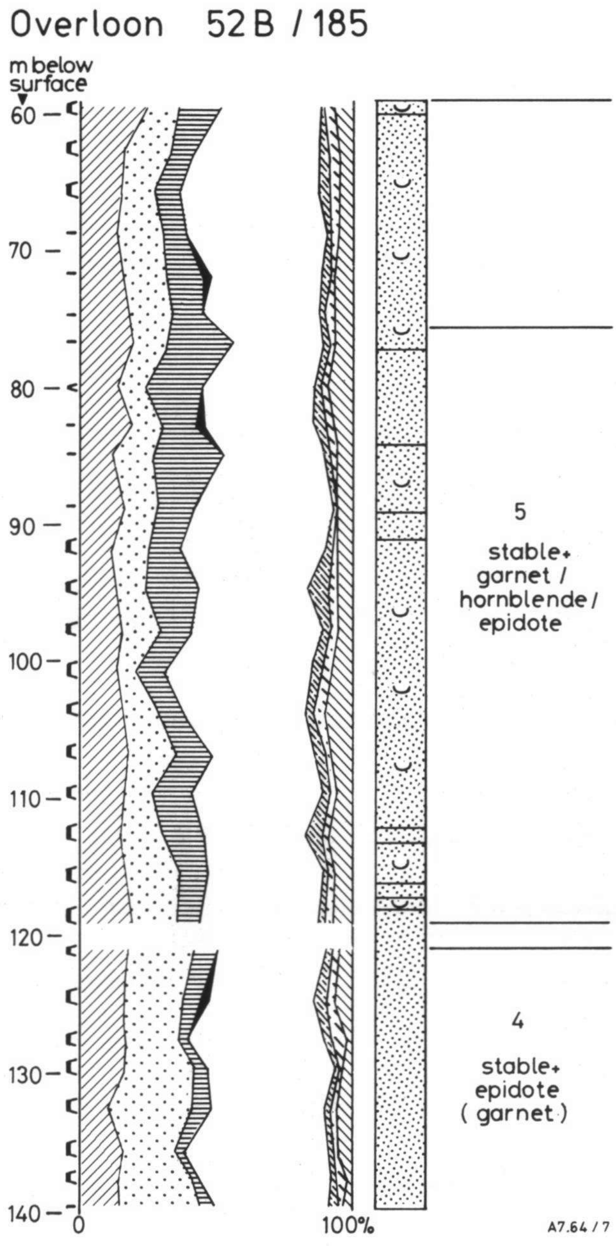


Fig. 7. Heavy-mineral diagram of the Overloon borehole, 52B/185 (75.0-140.0 m below surface).

much higher in the section that epidote reaches values of about 10% (Fig. 9). This coincides with a stronger influence of tourmaline and metamorphic minerals.

Late Miocene

In the Venlo fault block the epidote-rich association continues into deposits of Late Miocene age consisting of clay and extremely fine, mostly greenish-grey sands with a grain size of about 70 µm and a low content of glauconite in the sand size range (fig. 7, Overloon, 52B/185, 121.00-140.00 m). The upper boundary of this assemblage is found within mollusc zone Mol F 5 (Sliggers & van Leeuwen, 1987).

A similar situation was recently described for the Geldern borehole T1 (van Rooyen et al., 1984). The beds with this mineral assemblage also date from the transition of the Middle to the Late Miocene (100.00-135.00 m).

Zone 5. The transition to the overlying assemblage, which is richer in hornblende, is frequently gradual over a trajectory in which the grain size does not change. The glauconite content too remains noticeably low (Fig. 7). Where a hornblende value of over 10% occurs, however, the sand is generally rich in glauconite and the mean grain size is about 120-130 µm. Hornblende can account for up to 30% of the transparent heavy fraction. The values for epidote remain consistently lower than in the preceding deposit.

This assemblage with garnet/hornblende/epidote is found in the Venlo block in deposits with mollusc associations Mol F 5 and Mol F 4. The Broeksittard well (60D/1033) shows a different development again. Hornblende is still virtually absent in time-equivalent sediments. The mineralogical picture of the earlier deposits persists up to the top of a shell-bearing clay deposit.

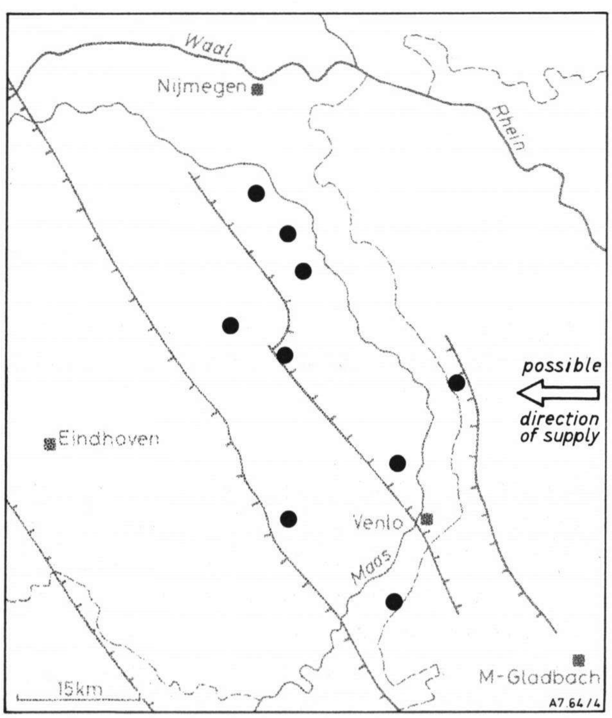


Fig. 8. Known occurrence of epidote-rich assemblage in the transitional zone between mollusc zones Mol G and Mol F 5.

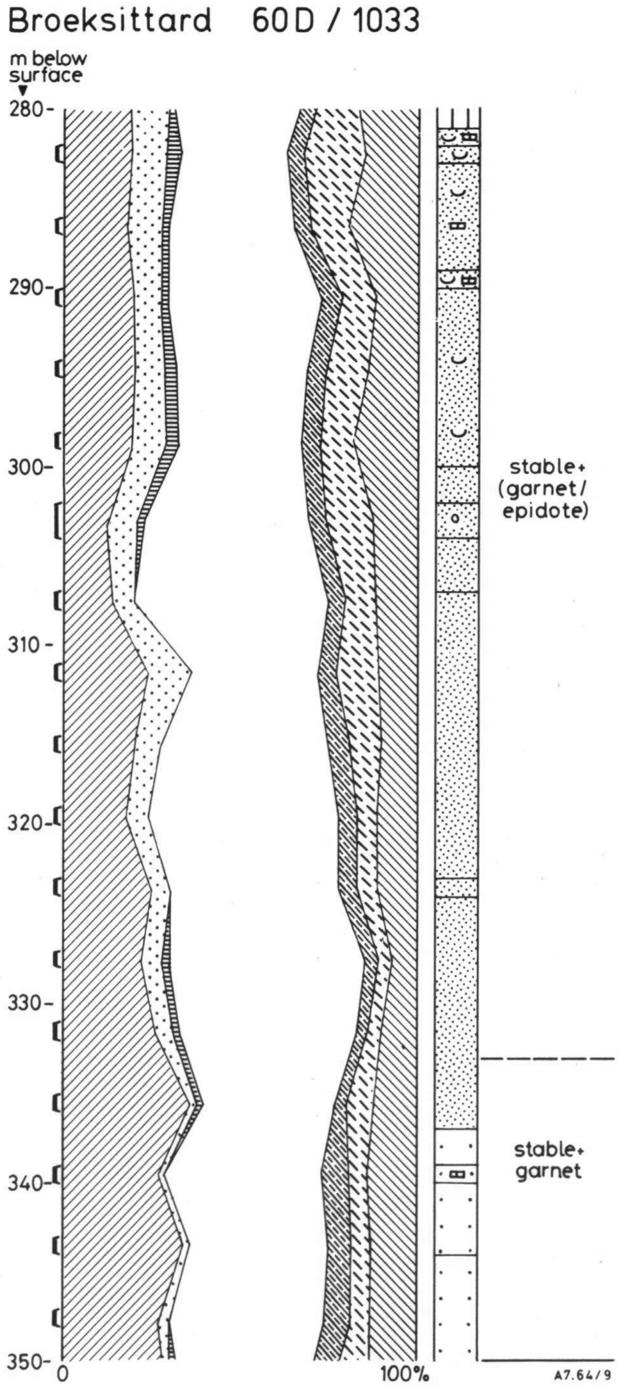


Fig. 9. Heavy-mineral diagram of Broeksittard borehole, 60D/1033 (280.0-350.0 m below surface).

Zone 6. The overlying deposit in the Venlo block shows a transition from grey near-coastal barren sands in the South-East, poor in glauconite, to dark-green glauconitic sands rich in molluscs in the north-western part. In the Californie borehole (52G/198, 59.00-83.50 m) (Fig. 10), these sediments show a very stable mineral assemblage dominated by zircon; garnet is present in values of about 10%. The basal deposits, with their low content of hornblende, already reflect the transition to the mineralogy of the glauconite sands in the North, known as Oploo Sands. In a more near-coastal development these deposits remain distinguishable by their relatively hornblende poverty.

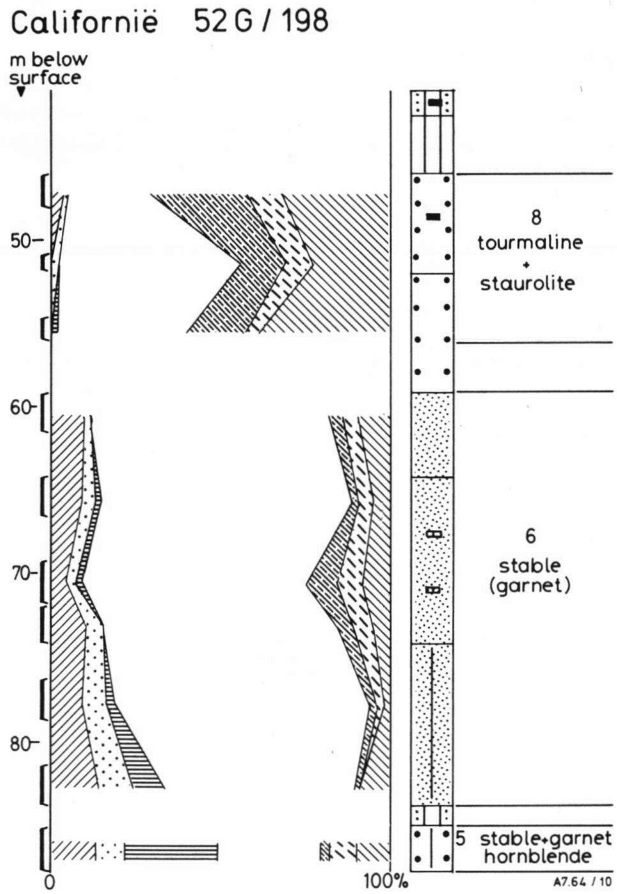


Fig. 10. Heavy-mineral diagram of Californie borehole, 52G/198 (43.0-88.0 m below surface).

Zone 7. Starting approximately in the Overloon well (52B/185), a zone richer in hornblende is found in the top layers. Both associations are found in sediments with mollusc zones Mol F 3 to F 1. In the North the assemblage with more hornblende reaches into mollusc zone Mol E.

The composition of the section in fig. 19 strongly suggests an interruption of the sedimentation at the top of these deposits. The hiatus is indicated in the figure.

Zone 6a. A probably corresponding deposit is also found in Broeksittard (60D/1033, 191.00-251.00 m) (Fig. 11). It consists of an alternation of coarse and fine sands with gravel. On mineralogical grounds it is not possible to differentiate between this unit and the underlying deposits. In the investigated 3-5 mm fraction, however, the gravel content is characteristic. As a rule this gravel is rather rounded (Fig. 12) and it generally contains more clear quartz than is usual for river deposits of southern origin. Furthermore the amount of flint is conspicuous, in two intervals even reaching more than 40%.

The roundness, as well as the amount of clear quartz militate against a direct relation with the observations made in the Inden Beds in German brown-coal pits. The gravel in these beds is described as very angular (Boenigk, 1981) and showing a specific type of grey fissure quartz, not found in Broeksittard.

There probably was no direct influence of an important river system (the "proto-Rhine"), but material was transported along the coast toward the area of Broeksittard.

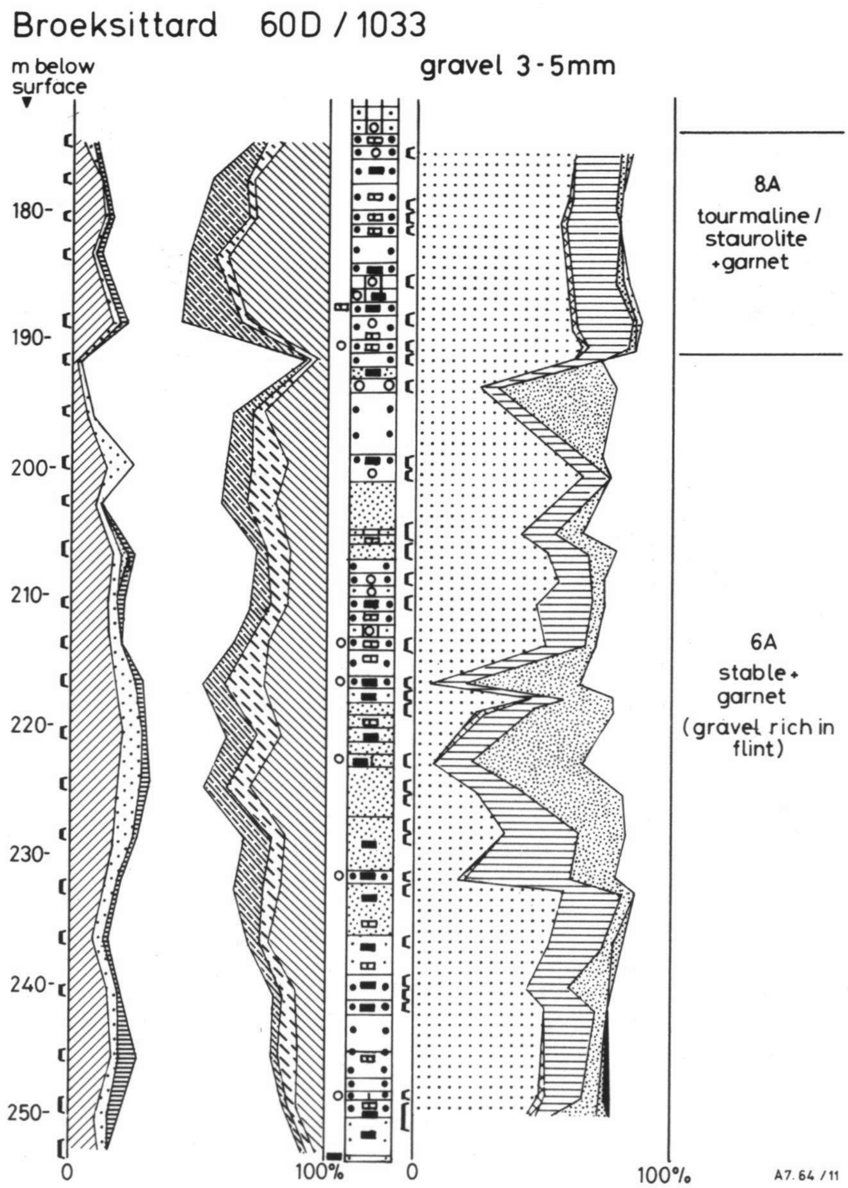


Fig. 11. Heavy-mineral and fine-gravel diagrams of Broeksittard borehole, 60D/1033 (172.0-252.0 m below surface).

Zone 8a. In the Central Graben the deposit of zone 6a is capped erosively by the coarse Waubach Deposits of the Kieseloölite Formation (Fig. 11). These deposits show a continuous occurrence of garnet. Among the metamorphic minerals, staurolite is strongly dominant. In this formation the Gravel in the 3-5 mm fraction is considerably more angular and has a lower content of clear quartz compared with the underlying deposit (Fig. 13). The flint content is very low and can be neglected.

Zone 8. In the Venlo fault block a rather complex series of deposits occurs on top of the Oploo Sands. In the South these are coarse fluviatile sands, named Venlo Sand (Zagwijn, 1960). The lower part of these sands shows an extremely stable mineralogy, dominated by tourmaline and with a strong influence of staurolite (Venlo, 58F/15, 76.50-94.00) (Fig. 14).

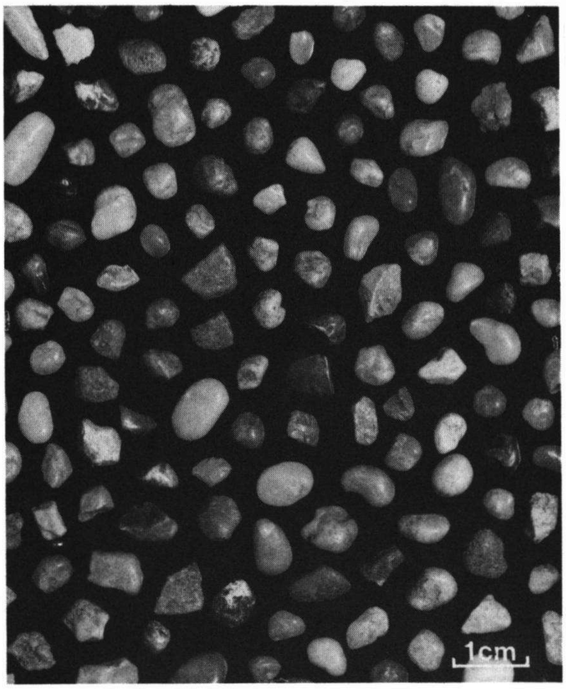


Fig. 12. Fine gravel from the Broeksittard borehole 60D/1033; cf. Inden Beds (sample from 231.00-232.00 m below surface). Note the roundness of the grains.

Fig. 13. Fine gravel from the Broeksittard borehole 60D/1033; Waubach Beds (sample from 165.00-166.00 m below surface). The gravel is rather angular.

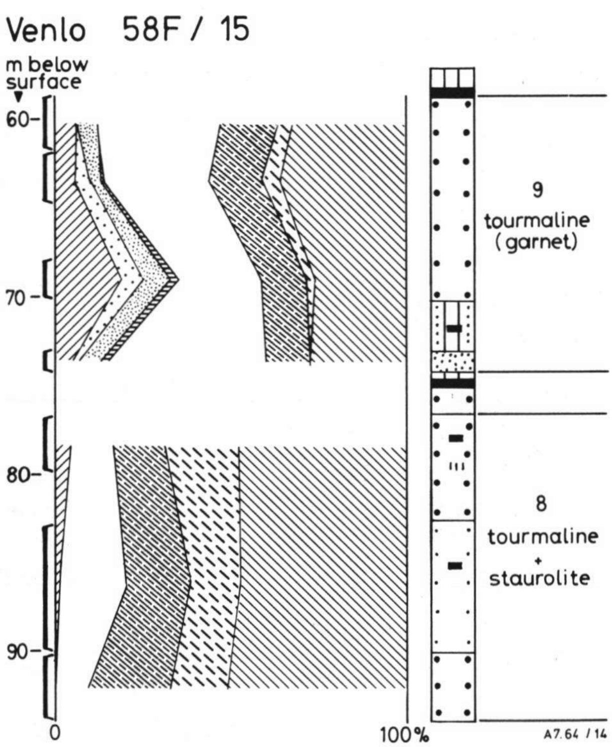


Fig. 14. Heavy-mineral diagram of Venlo borehole, 58F/15 (58.0-94.0 m below surface).

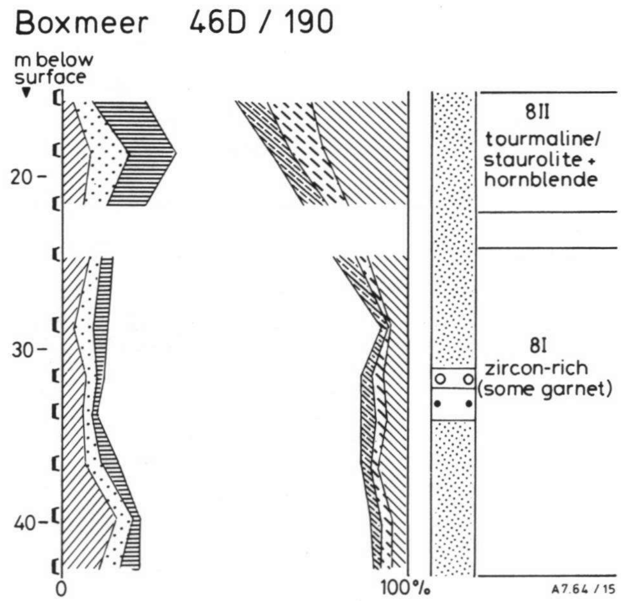


Fig. 15. Heavy-mineral diagram of Boxmeer borehole 46D/190 (15.0-43.0 m below surface).

Zone 8-I. North-West of Overloon the coarse Venlo Sand changes into usually fine or medium-sized sands with an extremely zircon-rich association. The percentage of garnet increases gradually to the North-West (Boxmeer well, 46D/190, 24.00-43.00 m) (Fig. 15). This assemblage is found mainly in what are called the Haps Sands of the Breda Formation. These usually slightly glauconitic sands sometimes contain gravel rich in fissure quartz, differing from the flint-rich gravel sometimes found in the Oploo Sands.

Zone 8-II. In a somewhat higher position, but still related to the staurolite-rich sands and running from Venray to the North-West, an association is found with hornblende added to an otherwise unchanged tourmaline- and staurolite-rich assemblage (Overloon, 46D/143, 17.00-33.00 m) (Fig. 16). As far as it is known, the distribution of these staurolite-rich assemblages, with and without hornblende, is plotted on a provisional map (Fig. 17).

The combination of a relatively high percentage of "coarse-stable" minerals with a maximum of hornblende continues northward into shell-bearing marine deposits with mollusc association Mol D.

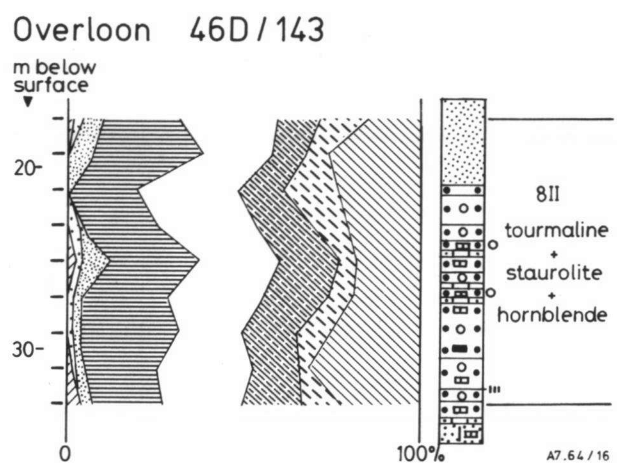


Fig. 16. Heavy-mineral diagram of the Overloon borehole, 46D/143 (17.0-33.0 m below surface).

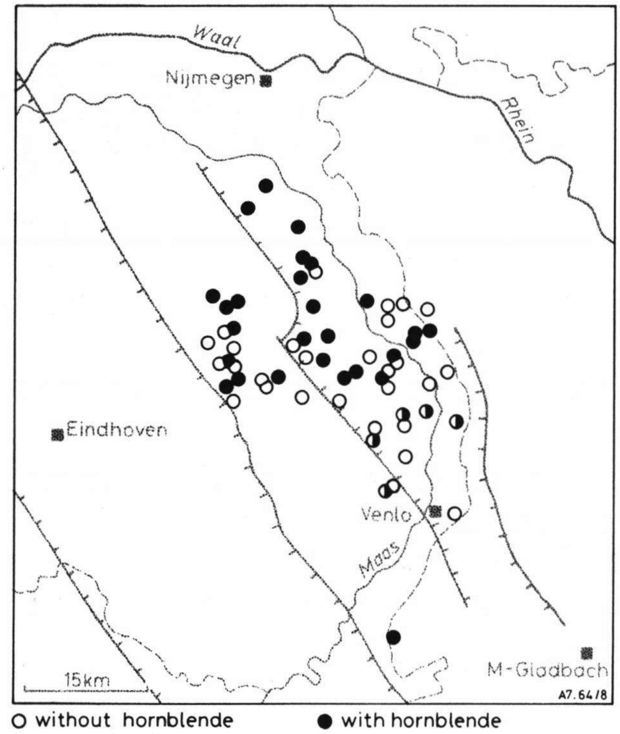


Fig. 17. Distribution of staurolite-rich assemblages in the lower part of the Venlo Sands.

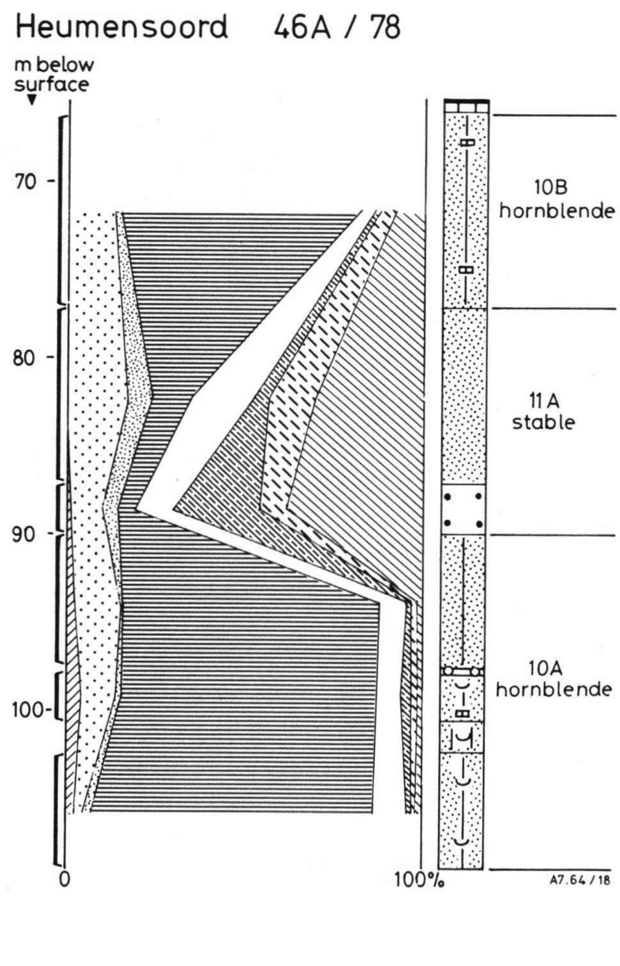


Fig. 18. Heavy-mineral diagram of the Heumensoord borehole 46A/78 (66.0-109.0 m below surface).

Pliocene

Zone 9. The Pliocene sedimentation in the Venlo fault block reflects a further retreat of marine conditions to the North-West. Fluviatile deposition continued, forming the upper part of the Venlo Sand, which are coarse-grained sands covered by an occasionally lignitic clay, named Venlo Clay (Zagwijn, 1960). The mineralogical picture differs somewhat from that of the underlying deposits (Venlo, 58F/15, 58.50-74.10 m) (Fig. 14). The values for staurolite are generally lower. A small amount of garnet is always present, together with some epidote and sometimes a little hornblende. This unit is easily traced from Venlo to Venray, where it constitutes the youngest Tertiary cover (Fig. 19). Near Overloon the same deposit is encountered.

Northward from Boxmeer, marine deposits of Brunssumian age occur, recognizable by their low hornblende content.

Zone 10. Deposits of Late Pliocene age are only found from Cuyk northwards in the section represented in Fig. 19 to Nijmegen. Where they are marine deposits they are characterized by extremely high percentages of hornblende (Heumensoord, 46A/78) (Fig. 18).

Zone 11. The continental influence is marked by stable influxes. The youngest of these reaches farthest North, reflecting the progressive continental influence.

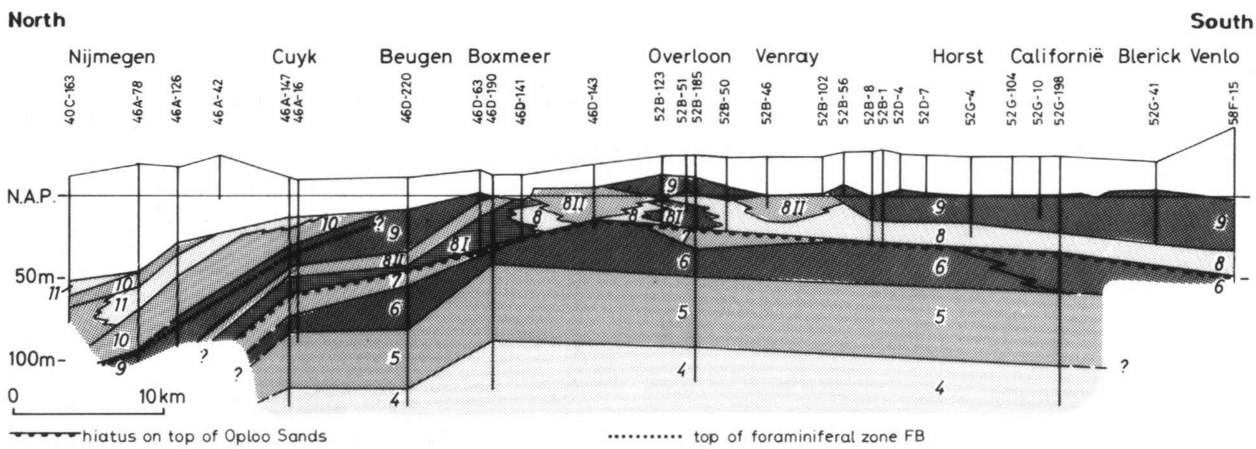


Fig. 19. Profile section through the Venlo fault block between Nijmegen and Venlo, showing the heavy-mineral succession. The hiatus on top of the Oploo Sands is indicated.

FINAL OBSERVATIONS

For the Venlo fault block between Venlo and Nijmegen the subdivision based on heavy-mineral analyses resulted in the profile reconstruction presented in Fig. 19. Starting at Cuyk the strata show a strong northward dip which explains the lack of information on older deposits in this area. The hiatus on top of the Oploo Sands is also indicated in Fig. 19, as is the top of foraminiferal zone FB, the latter reflecting the transition from the Early to the Late Pliocene. In Fig. 20, the same section—but drawn schematically and related to the mollusc zonation—clearly shows a hiatus on top of the Oploo Sands, as well as on top of the Venlo Sands, both gaps probably caused by tectonic movements.

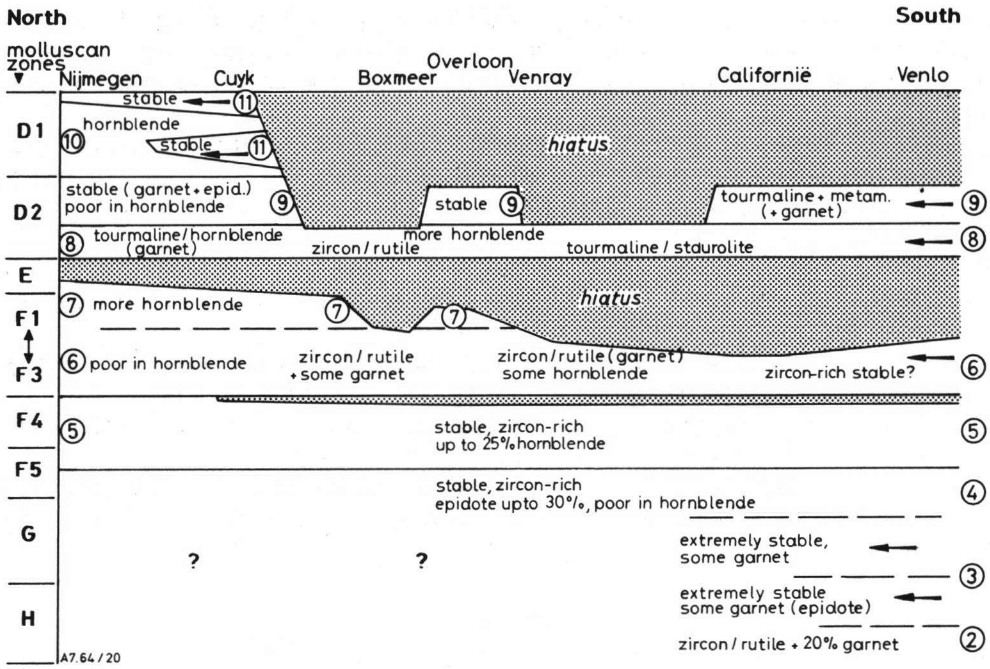


Fig. 20. Postulated succession and interrelation of heavy-mineral assemblages of the Venlo fault block in relation to the mollusc zonation.

I am aware of the fact that this scheme can only be applied successfully in a restricted area. The relations with other regions are not yet fully understood, but further investigations of long vertical sections combined with dating of the organic remnants may solve these problems in the near future.

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The author wishes to thank the Director of the Geological Survey of The Netherlands for permission to publish the results and furthermore the following colleagues: Mr J.G. Zandstra, for numerous fruitful discussions; Dr W.H. Zagwijn, for valuable opinions and many discussions on stratigraphy; Mr A.P. Marselje, for the preparation of the figures and Mrs I. Seeger for reading the English text.

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