Meded. Werkgr. Tert. Kwart. Geol. | 25(1) | 23-30 | 5 figs. | Leiden, maart 1988

SEDIMENT-PETROLOGICAL INVESTIGATIONS OF SEDIMENTS FROM THE ZUURLAND BOREHOLE (AN INTERIM REPORT)

by

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Burger, A. W. Sediment-petrological investigations of sediments from the Zuurland borehole (an interim report).—Meded. Werkgr. Tert. Kwart. Geol., 25(1): 23-30, 5 figs. Leiden, March 1988.

Results of heavy-mineral and fine-gravel studies in the Zuurland borehole (37C/554) are presented. The results are compared with the findings in the Brielle borehole (37D/134), located some 3 km to the North. The occurrence of volcanic minerals points to a lower boundary of the Kreftenheye/Eem Formation at -36.20 m at Zuurland. This is not consistent with the results of the investigation of mammal remains. A possible solution based on the postulation of local erosion of Early Pleistocene deposits is put forward.

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CONTENTS

SAMENVATTING

Sediment-petrologische onderzoekingen aan sedimenten van boring Zuurland (een interim rapport).

De resultaten van zware mineralen- en fijn-grind analysen verricht aan monsters uit boring Zuurland worden gepresenteerd. Een vergelijking wordt gemaakt met het onderzoek van boring Brielle (37D/134), ongeveer 3 km noordelijker gelegen. Het voorkomen van vulkanische mineralen noodzaakt tot het plaatsen van de ondergrens van de Kreftenheye/Eem Formatie op 36.20 m onder maaiveld in Zuurland. Dit is niet in overeenstemming met de resultaten van het zoogdieronderzoek. Als mogelijke oplossing wordt locale erosie van de top van de vroeg-pleistocene afzettingen aangenomen.

INTRODUCTION

The island of Voorne-Putten (province of Zuid-Holland), on which the Zuurland borehole is located, has supplied many sediment-petrological data, but none of these results has been published as yet. This holds especially for deposits occurring at depths down to about 50 meters below N.A.P. (= Normal Amsterdam Ordnance Level).

Information on deeper levels has only been obtained from the well-known Brielle borehole, 37D/134, which is situated about 3 km North of the Zuurland location. From that borehole the results of pollen analysis, investigations of the non-marine mollusc and mammalian remains were published (van Voorthuysen et al., 1972; Kuijper, 1973; van der Meulen & Zagwijn, 1974). Here the results of heavy-mineral and fine-gravel analyses of the material from the Zuurland borehole are discussed in relation to the results obtained in the Brielle borehole.

The heavy-mineral studies were performed according to the method used by the Geological Survey: in brief, counts were done in the non-opaque heavy fraction (s.g. > 2.87, size 63-500 μ) 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 was studied by identifying 300 grains in the 3-5 mm fraction. For detailed information about the method one is referred to Zandstra (1959). The special upwelling method Mr L. W. Hordijk used to collect large samples provided sufficient material in the 3-5 mm grain-size fraction to study sediments which are almost devoid of such coarse elements.

Fig. 1. Map of the western part of the island of Voorne-Putten, showing the location of the Zuurland borehole and of the profile section given in Figure 4.

The Zuurland borehole is located in an area where the transitional zone between marine and continental deposition during the Pleistocene was located, in a period with a high sea-level. This is evident from the results of the study of the molluscs (Meijer, 1988). The clastic material originated mainly from the Rhine fluvial system, with possibly small admixtures of material from the rivers Meuse and/or Scheldt. The influence of the former Baltic river system (Bijlsma, 1981; Zandstra, 1971) was not detected in the part of the second Zuurland borehole from which the heavy-mineral assemblage was studied, but, rather surprisingly, this influence was recognized in the fine gravel at a much deeper level in the lowermost meters of the first Zuurland borehole. There, between -91 and -95 m, the amount of clear quartz increased, indicating some admixture of fine gravel from the Baltic river system. Essentially this association is restricted to the northern half of The Netherlands.

RESULTS

Westland Formation (0.00 to -22.30 m)

Along the interval assigned to this formation only the fine gravel was investigated, starting at 9.00 m below the surface. The first analysis (-9.00 to -10.00 m) revealed a quartz content of 57.9%, rather low as compared to 71-78% in deeper levels of this formation. This difference can be explained by assuming the admixture of older fluviatile material (rich in quartz) in the deposits between -10.00 and -21.00 m, whereas the material in the -9.00 to -10.00 m sample represents an assemblage that was derived more directly from the hardrock source area. The composition of the lowermost gravel assemblage (-21.00 to -22.00 m) is identical to that of the upper part of the underlying Kreftenheye/Eem Formation.

Twente Formation (-22.30 to -23.80 m)

Although the depths of the samples used for the gravel analysis may suggest that the sand belonging to this formation contains gravel, this is not the case. Samples were taken at one-meter intervals, but gravel occurred only in the lowermost 20 cm of this trajectory, which actually lies below the base of the formation.

Kreftenheye/Eem Formation (-23.80 to -36.25 m)

The lower boundary of this unit is characterized by the presence of volcanic minerals: the sample taken at -35.00 m showed 10% augite, whereas the sample taken at -36.00 m, which belongs lithologically to the same deposit, has a content of heavy minerals which indicates considerable reworking of the underlying deposit. Deposits belonging to the Middle Pleistocene Urk Formation are unknown in this region (van Staalduinen, 1979). Therefore, the only possible assignment would be to the Kreftenheye/Eem Formation. A Late Pleistocene age is in contradiction with the mammal remains found between -27.00 m and -37.00 m. The latter indicate an earliest Middle Pleistocene or late Early Pleistocene age of this part of the section (van Kolfschoten, 1988).

Comparison of the heavy-mineral diagrams for Zuurland (Fig. 2) and Brielle (Fig. 3) seems to offer a solution to this problem. In Brielle, the base of the augite-rich deposit is found at -37.00 m. The underlying deposit (-37.00 m to -42.50 m), consisting of fine sand which is clayey at the base, shows an assemblage of heavy minerals with a very low content of volcanic minerals. The association is further characterized by a garnet maximum of about 30% and relatively high values for epidote.

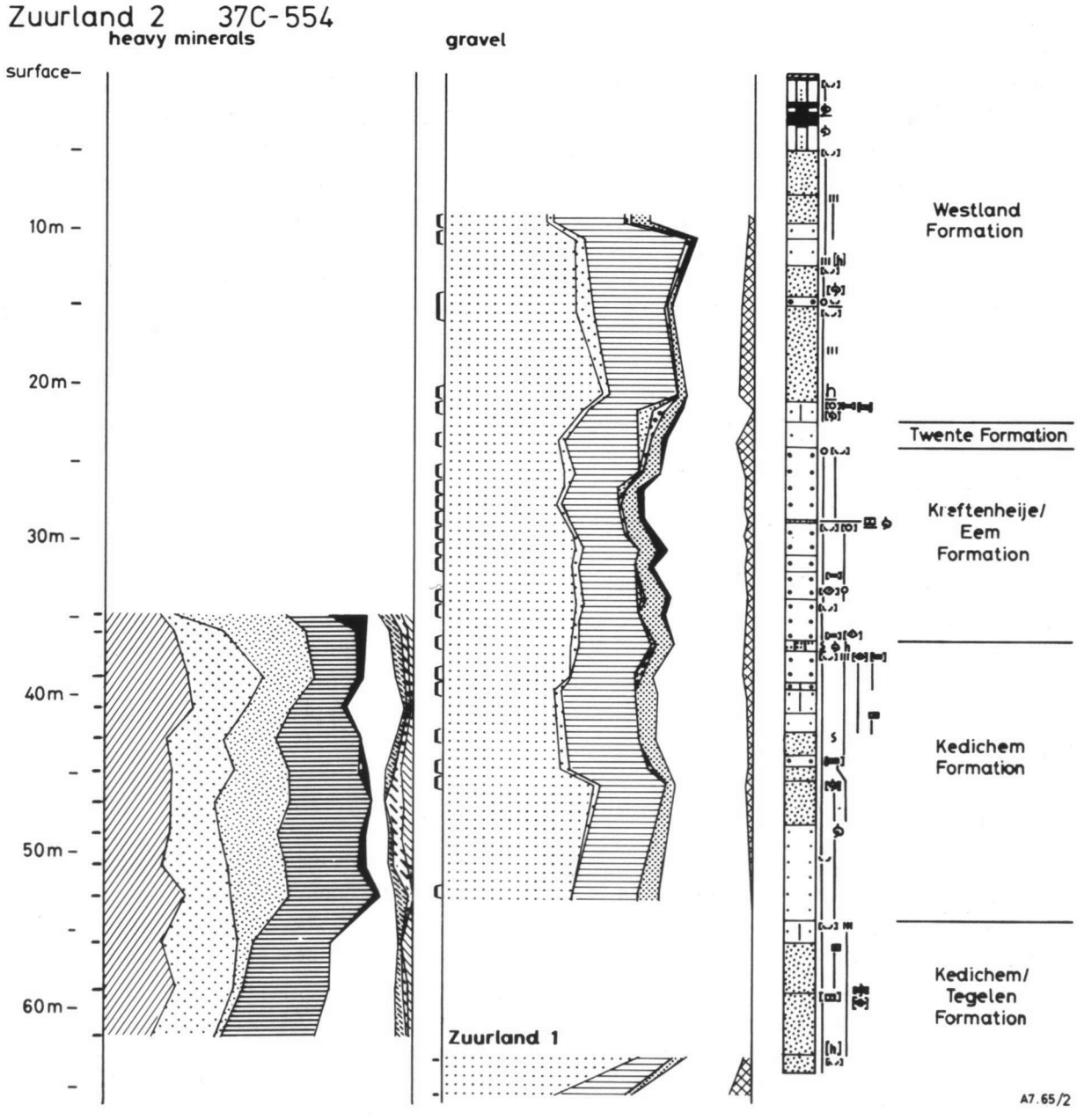

Fig. 2. Heavy-mineral and fine-gravel diagrams for the Zuurland borehole (for legend, see Figure 3).

This mineral assemblage is known in other areas from deposits assigned to the uppermost part of the Early Pleistocene (possibly Bavelian).

As is seen in the profile section (Fig. 4), the top of this deposit was partly eroded in the Zuurland area. This might explain the combination of an augite-rich sediment and much older mammalian remains. This hypothesis is supported by a comparison of all known bases of the sediments rich in augite (Fig. 5), which indeed shows a low position of this level in the area of the Zuurland borehole.

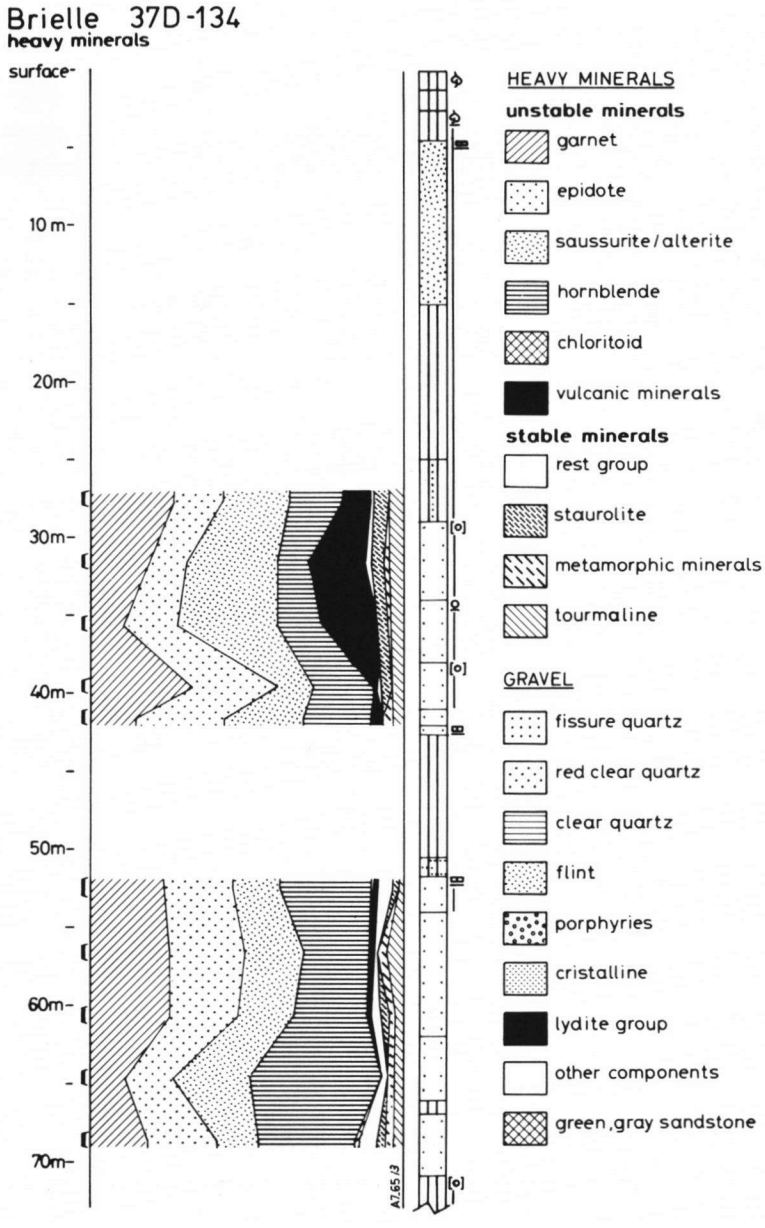

Fig. 3. Heavy-mineral diagram of the Brielle borehole.

The results of the fine-gravel analyses of the part of the section assigned to the Kreftenheye/Eem Formation at Zuurland allow to recognize an upper part with generally a few percent of flint (-23.80 m to -27.00 m), indicative of some influence of the Scheldt or Meuse rivers, and a lower part in which flint only occurs sporadically. The total quartz values range between 56% and 67%.

Kedichem Formation (-36.25 to -54.15 m)

The upper part of this formation is characterized by the occurrence of numerous thin layers of clay, intercalated with coarse and fine sands. Total quartz in the 3-5 mm fraction amounts to 62%. The heavy-mineral association is relatively poor in hornblende between -39.00 m and -41.00 m, where garnet accounts for 29%. The association has some resemblance to that of the -37.00 m to -42.50

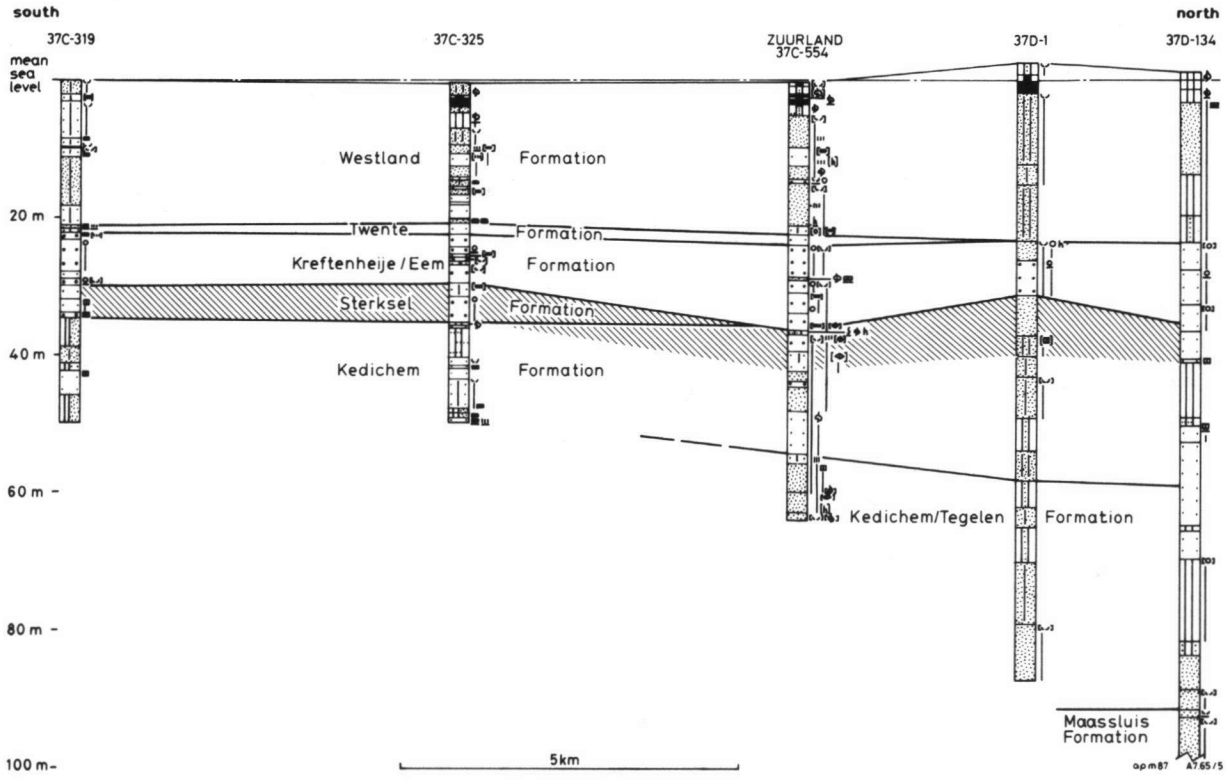

Fig. 4. Profile section along the line indicated in Fig. 1. Hatched areas represent sediments with a mineral assemblage suggesting bavelian age. Note that these sediments belong to two different lithostratigraphical units: the Sterksel Formation and the Kedichem Formation.

m interval in the Brielle borehole. As mentioned above it is assumed that the -36.25 m to -41.00 m interval in the Zuurland borehole represents the lower part of a deposit of Bavelian age. Its top, which is present in Brielle, was eroded here during the Late-Pleistocene.

The sediments between -43.00 m and -53.00 m, assigned to the Kedichem Formation yielded a rather monotonous assemblage with hornblende accounting for about 25% and garnet averaging about 20%. Alterite is of importance throughout this part of the section, values generally lying between 15% and 20%.

The sediment consists of moderately fine to very coarse, moderately sorted sands without clay layers. In the Brielle borehole 37D/134, the -51.80 m to -61.00 m interval ismineralogically identical to that from -43.00 m to -53.00 m in the Zuurland borehole. Both the fine-gravel and the heavy-mineral counts indicate a strong influence of the system of the Rhine during the deposition of the Kedichem Formation. The sediment-petrological data do not permit a dating more accurate than Early Pleistocene.

Kedichem/Tegelen Formation (-54.15 m to -64.00 m)

The sediment between -54.15 m and -62.80 m is again characterized by the occurrence of thin layers of clay. The intercalated sand is moderately coarse down to -55.60 m. At greater depths the sand has a very characteristic olive-greenish grey colour and is extremely fine. The heavy-mineral associa-

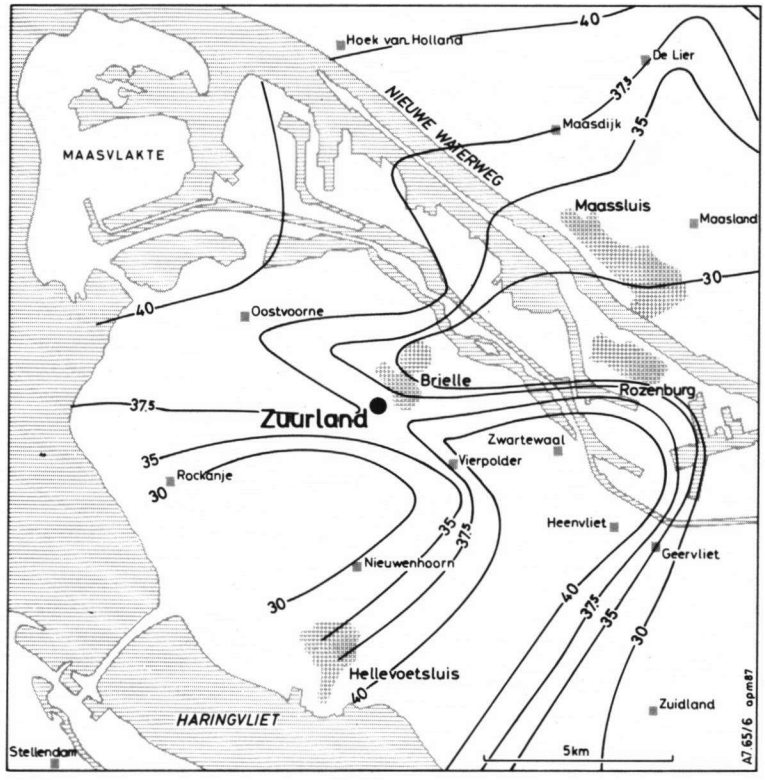

Fig. 5. Map showing contours of the base of the Kreftenheye/Eem Formation. Depth is given in meters below Dutch Ordnance Level (NAP).

tion is very poor in alterite. This can be due to grain-size effects of the heavy fraction (Burger, 1970), but it is more probably related to a different source of the material. This hornblende-epidote-garnet association is relatively rich in fine stable minerals, especially zircon, and it is easy to recognize. In the Brielle borehole this association was not found, although an assemblage relatively rich in hornblende is present below -61.00 m. It is assumed that these two associations do not represent the same deposit, because the differences in the alterite and especially the zircon content are sufficient to permit differentiation. It is supposed that the Brielle borehole (37D/134) has a gap at -61.00 m corresponding to the -54.15 m to -62.80 m trajectory in the Zuurland borehole.

Information about the heavy-mineral content at deeper levels is not available for the Zuurland location as yet, but the analysis of two samples of fine-gravel from the directly underlying deposit in the first borehole, at -63.10 m and from the -65.25 m to -65.45 m interval, indicates a dominant influence of the river Rhine.

DISCUSSION

Although the analysis of heavy minerals and gravel does not allow an exact dating of the sediments, some conclusions can be drawn from the research on the Zuurland borehole. The coarse deposit down to -36.20 m belongs to an augite-rich sediment known to occur in several localities in the surroun-

dings. So far, evidence favouring a Middle Pleistocene age of any of the Voorne-Putten deposits has not been obtained. The oldest known deposits containing fair amounts of augite in The Netherlands are thought to be of Cromerian C age (Doppert et al., 1975). Because the vertebrate remains point to an Early Pleistocene age, reworking offers the only acceptable explanation.

The results of the analyses of heavy minerals in the Early Pleistocene part of the section show, between -56.00 m and -62.00 m, an assemblage that is easy to recognize and that can be traced to other localities in the neighbourhood. The inferred stratigraphic position is above a clay-layer, which was dated on the basis of pollen analysis as Late Tiglian (pollen zone TC6). Therefore, Late Tiglian (TC6) is the oldest possible age of the sediments with the zircon-rich hornblende-epidote-garnet heavy-mineral assemblage.

ACKNOWLEDGMENTS

The author is greatly indebted to Mr L. W. Hordijk, who provided the samples and stimulated the studies by his enormousenthusiasm, to the many colleagues whose cooperation was invaluable and to Mr T. Meijer for the many discussions. The director of the Geological Survey of The Netherlands is thanked for his permission to publish the results of this study. Mr P. Marselje prepared the drawings and Mrs I. Seeger-Wolf read the English manuscript.

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Manuscript received 9 february 1988