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PALYNOLOGICAL INVESTIGATION OF THE ZUURLAND-2 BOREHOLE, THE NETHERLANDS (AN INTERIM REPORT)

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Palynological (pollen-analytical) data exclusively concerning clastic material from levels between -20.00 and -63.50 m were obtained. These levels cover the very basis of the Westland Formation (Holocene, to all probability Atlantic), part of the Kreftenheye Formation (Eemian), and sediments of the Kedichem/Tegelen Formation (Early Pleistocene). Considering the mollusc content of the Kreftenheye Formation, the pollen- analytical data must pertain to redeposited material. In the deposits of the Kedichem/Tegelen Formation, three pollen zones can be distinguished, from bottom to top: pollen zone 1, interglacial with marine influences; pollen zone 2, a cooler part of an interglacial; and pollen zone 3, interglacial. Pollen zones 2 and 3 lack clear indications of marine influences.

The pollen data from zones 1-3 do not permit a definite age determination, but they do suggest a pre-Bavelian age. They might represent substages of the Waalian interglacial (A, B and C) or (at least partially) substages of the Tiglian (TC 5, TC 6 ?). Investigation of the underlying sediments may yield a better determination of the chronostratigraphical position of the pollen zones under discussion.

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CONTENTS

SAMENVATTING

Palynologisch onderzoek van de boring Zuurland-2, Nederland (een tussentijds verslag).

De pollenanalytische gegevens werden uitsluitend verkregen van klastisch materiaal uit het traject van -20.00 tot -63.50 m. Het onderzoek betreft het onderste deel van de Westland Formatie (Holoceen, vermoedelijk Atlanticum), een deel van de Formatie van Kreftenheye (Eemien) en afzettingen van de Kedichem/Tegelen Formatie (Vroeg Pleistoceen). Op grond van de mollusken inhoud moet worden geconcludeerd, dat de spectra verkregen uit de afzettingen van de Kreftenheye Formatie afkomstig zijn van geremanieerd materiaal. In de afzettingen van de Kedichem/Tegelen Formatie kunnen drie pollenzones worden onderscheiden, t.w. van beneden naar boven: pollenzone 1, interglaciaal met mariene invloed; pollenzone 2, een koeler deel van een interglaciaal; pollenzone 3, interglaciaal. De pollenzones 2 en 3 bevatten geen duidelijke aanwijzingen voor mariene invloed.

De pollenzone's 1 tot en met 3 geven duidelijk delen weer van het Vroeg Pleistoceen en naar alle waarschijnlijkheid van het deel voor het Bavelien. Ze maken geen nadere datering mogelijk. Ze zouden zowel betrekking kunnen hebben op bepaalde delen van het Waalien Interglaciaal (Waalien A, B en C), als zeker voor een deel ook op het Tiglien (TC5, TC6 ?). Toekomstig onderzoek van de aansluitend dieper gelegen afzettingen zal mogelijk tot een beter inzicht in de chronostratigrafische positie van de onderzochte sedimenten kunnen leiden.

INTRODUCTION

The Zuurland-2 borehole is situated near to the town of Brielle on the island of Voorne in the western part of the Netherlands. For the location, the general geological position, literature on this subject and the applied lithostratigraphical and chronostratigraphical units one is referred to de Jong (1988a) in this volume.

The palynological investigation is part of a more extensive study, and the results obtained by specialists in various fields are also reported in this issue of 'Contributions to Tertiary and Quaternary Geology'. The conditions pertaining to the realization of the borehole are described in Hordijk (1985, 1986, 1988), the lithological description of the borehole is given in Burger *et al.* (1988); for the other studies reference is made to Burger (1988), Gaemers (1988), van Kolfschoten (1988), Kuijper (1988), Meijer (1988) and Vervoort-Kerkhoff & van Kolfschoten (1988) (all this volume). The pollen-analytical study was restricted to the Zuurland-2 borehole (37C/554).

The principle aim of the palynological study was to contribute to the determination of the age of the deposits of the Kreftenheye and the Kedichem/ Tegelen Formations, especially in relation to the faunal assemblages of molluscs and vertebrates. Mention must be made here of the Brielle borehole 37D/134, located about three kilometers from the Zuurland-2 borehole (de Jong, 1988a, Fig. 1; this volume). In the study reported here, frequent reference is made to the lithological composition of the material from this borehole and the results of other paleontological investigations (van der Meulen & Zagwijn, 1974; van Voorthuysen *et al.*, 1972; Kuijper, 1973).

PALYNOLOGICAL RESULTS

The interval from about -20.00 m to -63.50 m was studied for its pollen content. The study was confined to the basis of the Holocene deposits and the underlying sequence. This part of the section consists entirely of clastic material, mainly sand; a description of the whole section is given by Burger, Hordijk & Meijer (1988, this volume); for the lithological composition of the part of the sequence investigated by means of pollen analysis, see column in Fig. 1. The spectra were determined only in clay or clayey sands; some of the sedimentary material covering the Kreftenheye Formation does not contain any material suitable for pollen analysis.

Chemical treatment of the samples was performed according to the standard method used by the Department of Cenozoic Palaeobotany of the Geological Survey of The Netherlands (HF, KOH, acetolysis, specific weight separation with bromoform). The results are shown in a pollen diagram (Fig. 1), arranged according to Zagwijn (1963), with a slight modification (see legend in Fig. 1). The diagram only concerns selected taxa.

POLLEN-ANALYTICAL RECORDS

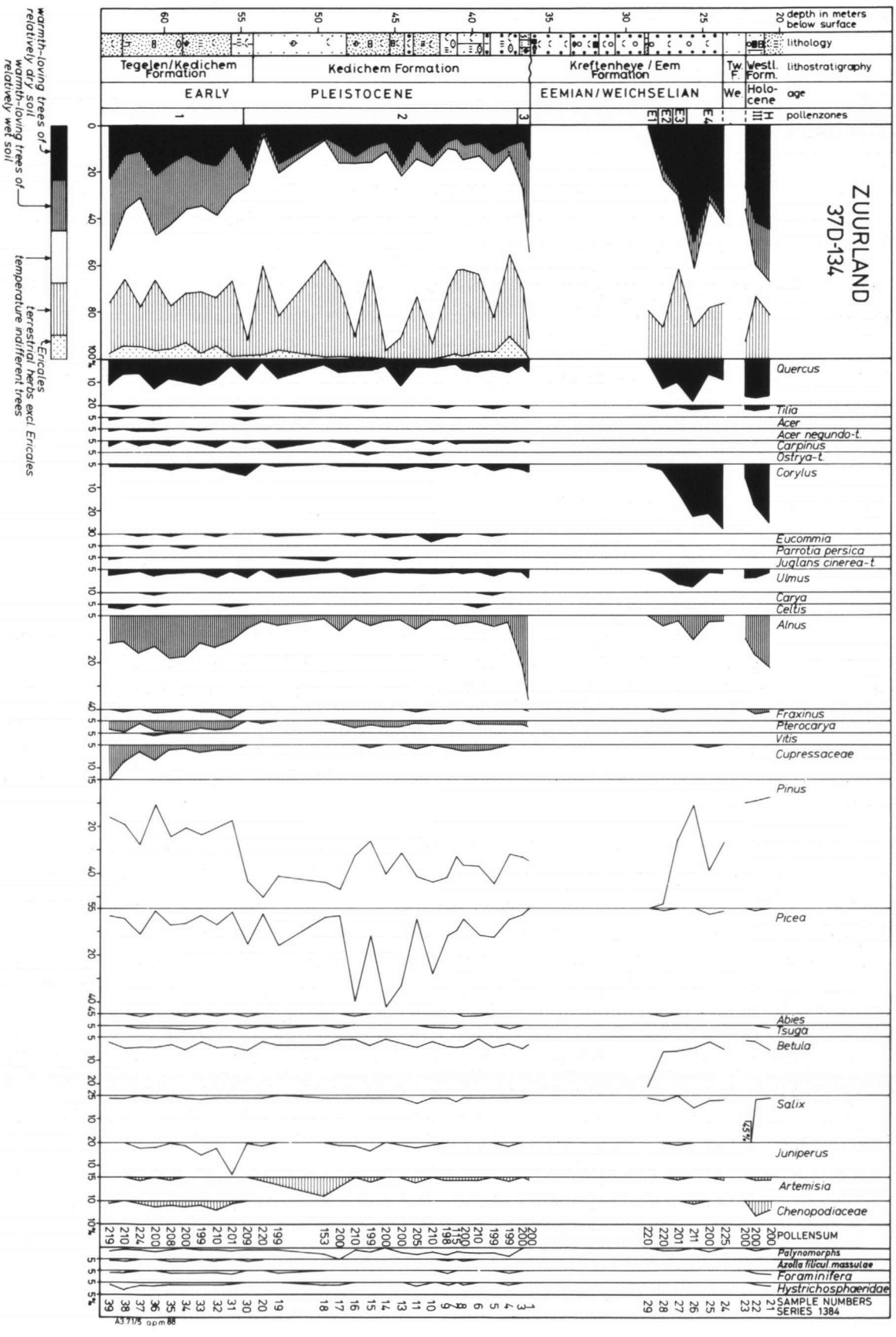
In this section the pollen zones and their age determination are described. The stratigraphical implications are dealt with in the general discussion.

In the three uppermost spectra (above -23.50 m), trees characteristic of a temperate forest dominate (e.g. *Quercus*, *Corylus*, *Alnus*). The spectra indicate a Holocene age and in all probability belong to pollen zone H III (*Ulmus*), Atlantic. This is consistent with the lithostratigraphical position. The presence of Chenopodiaceae in the two uppermost spectra indicates a halophyte vegetation, which points to a coastal environment. The occurrence of Foraminifera and Hystrichosphaeridae (dinoflagellates), points to a direct marine influence, which is consistent with the shell content of these deposits.

The spectra of the underlying interval (-23.50 m to -28.50 m) are also characterized by temperate forest elements such as *Quercus*, *Corylus*, and *Alnus*, except for the two lowermost spectra, in which *Pinus* takes a substantial share. The spectra show a sequence reflecting the beginning of an interglacial, in fact the Eemian. The spectra show neither signs indicating proximity of the sea nor evidence of a direct marine influence (scarcity of Chenopodiaceae and *Artemisia*; absence of Foraminifera and Hystrichosphaeridae). The character of the mollusc fauna in this stretch of the sequence points to redeposition of the material under study (see paragraph Discussion).

The composition of the spectra obtained from clay and clayey sediments belonging to the lower part of the sequence of the borehole (between -36.20 m and -63.50 m) differs from the spectral composition in the upper part. The majority of the spectra show moderate frequencies of thermophilous trees (e.g. *Quercus*, *Carpinus*, *Corylus*, *Ulmus*, and in places *Alnus*), the values for anemophilous herbs are slightly higher. The considerable frequencies of conifers (*Pinus* and *Picea*) in the middle part of the sequence are striking and the presence of *Pterocarya* and *Tsuga* throughout the entire sequence is noteworthy. The latter occurrences indicate an Early Pleistocene age, which is confirmed by the occurrence of *Eucommia*, *Ostrya*-t., *Parrotia persica* C.A.M. and *Juglans cinerea*-t.

Three pollen zones can be distinguished in this sequence:


warmth-loving trees of relatively dry soil
warmth-loving trees of relatively wet soil
Ericales
terrestrial herbs excl Ericales
temperature indifferent trees
depth in meters below surface
lithology
lithostratigraphy
Tegelen/Kedichem Formation
Kedichem Formation
Kreftenheye / Eem Formation
Tw. F.
Westl. Form.
age
EARLY
PLEISTOCENE
EEMIAN/WEICHSELIAN
We.
Holo-cene
pollenzones
ZUURLAND
37D-134
Quercus
Tilia
Acer
Acer negundo-t.
Carpinus
Ostrya-t.
Corylus
Eucommia
Parrotia persica
Juglans cinerea-t.
Ulmus
Carya
Celtis
Alnus
Fraxinus
Pterocarya
Vitis
Cupressaceae
Pinus
Picea
Abies
Tsuga
Betula
Salix
Juniperus
Artemisia
Chenopodiaceae
POLLENSUM
Palynomorphs
Azolla filicul. massulae
Foraminifera
Hystrichosphaeridae
SAMPLE NUMBERS SERIES 1384
A3 71/5 apm 88

Pollen zone 1.

Rather high proportion of thermophilous trees, including *Alnus*; prominence of *Pterocarya*; presence of Chenopodiaceae in almost all spectra, and presence of *Azolla filiculoides* Lamk, Foraminifera, and Hystrichosphaeridae. The components of this pollen zone indicate a rather warm period in an interglacial of the Early Pleistocene. Deposition took place in an environment exposed to a marine influence.

Pollen zone 2.

The representation of thermophilous trees characteristic of dry soils is slightly lower than in pollen zone 1; *Alnus* is very scarce; frequencies of anemophilous herbs vary; there is a substantial representation of *Pinus* and *Picea*, the values of the latter fluctuating widely. *Pterocarya* and *Tsuga* are present, Chenopodiaceae almost absent, *Artemisia* is very well represented, and there is a scattered occurrence of *Azolla filiculoides* and Foraminifera.

This pollen zone reflects a cool interval of an interglacial in the Early Pleistocene. Compared with pollen zone 1 it represents a period with a more boreal and probably more continental climate. There are no clear indications of a marine influence on the environment.

On the basis of high frequencies of *Picea* three subzones can be distinguished. Because of the fluctuating values, these subzones cannot be sharply delimited; therefore they are not indicated in Fig. 1.

Pollen zone 3.

This pollen zone has only two spectra, both of which are rather similar to those of pollen zone 1, the main exceptions being lower values of *Pterocarya* and an abundance of spores of the ferns *Dryopteris* and *Osmunda*. Pollenzone 3 reflects an interval in an Early Pleistocene interglacial. There is no evidence of a marine influence.

DISCUSSION

Kreftenheye Formation

The Eemian dating (pollen zones E1-E4) as well as the non-marine character of the spectra for the upper part of the deposits of the Kreftenheye Formation are in conflict with the occurrence of marine shells in the deposits under discussion.

Furthermore, below this level (-28.30 m) the shell content indicates interglacial marine conditions, which to all probability cannot be found earlier than pollen zone E3, according to the estimated sea-level at that time (Zagwijn, 1983). The general stratigraphical position and the faunistic composition (Meijer, 1988, this volume) point to an Eemian age of these deposits. This leads to the conclusion

Fig. 1. Pollen diagram for the Zuurland-2 borehole.
Pollen zones: H III (Holocene, Atlantic); E1-E4, (Eemian, redeposited); 1, 2 and 3 interglacial(s) of the Early Pleistocene.
Abbreviations: TwF = Twente Formation, We = Westland Formation.

that the pollen spectra are derived from redeposited material and that the sequence observed in the vegetational succession is a coincidence.

The sedimentary composition of the deposits of the Kreftenheye Formation in this area is rather well known from continuously cored boreholes from many localities in the area (Ministry of Transport and Public Works). The findings indicate that the material is heterogenous, with scattered occurrences of shells and clay fragments and more incidentally of organic matter. Pollen-analytical data point to various pollen zones of the Eemian (E4, E5), to a pleniglacial period (probably of the Weichselian), and some of the spectra suggest an Early Weichselian age. This points to the presence of gully-fills differing in age and to erosion and redeposition of sediments, possibly during the later part of the Eemian and in Weichselian times. In most cases it is impossible to decide which material is autochthonous in a given place.

In one locality, however, pollen spectra of pollen zone E4, at a depth of approximately -25 m, supplied an age, obtained from the clayey filling of a cluster of specimens of the bivalve *Ostrea edulis* Linn, 1758, that fits with the inferred age of the marine deposit, indicating the in situ presence of an oyster bed. On these grounds it is concluded that the deeper parts of the Kreftenheye Formation contain marine shells of Eemian age. The marine shells in the upper part may have been redeposited. A proportion of the enclosed lumps of clay and organic material, whether or not contemporaneous with the main deposits of the Kreftenheye Formation, may have been derived from upstream areas.

Kedichem/Tegelen Formation

The whole sequence below -36.20 m was deposited during the Early Pleistocene. In Early Pleistocene pollen diagrams covering, for instance, the Tiglian and the Waalian interglacials, various pollen zones can be recognized, but these zones cannot be sharply defined on the basis of successive immigrations of the taxa concerned. This is in contrast with the interglacials of the Middle and Late Pleistocene (including the Holocene), which show a systematical pattern with respect to the appearance of various taxa: increase, culmination, and decrease (de Jong, 1988b). From the pollen zones of this type of interglacial, a specific stage in the vegetation development of an interglacial can often be identified or at least significant features of a specific interglacial can be distinguished. Such features are already detectable in the youngest Early Pleistocene interglacials in the Bavelian (Bavel Interglacial, Leerdam Interglacial) (Zagwijn & de Jong, 1984). The pollen spectra obtained in the Zuurland-2 samples, lack such characteristic features of later interglacials, and in all likelihood they precede the Bavelian stage. In this part of the Early Pleistocene the pollen zones are often less informative, and in many cases a more exact age determination is hardly possible, especially where the lithostratigraphic units are short, as in Zuurland.

The spectra of pollen zone 1 have a rather constant composition reflecting part of an interglacial. They show some similarity to Brielle borehole 37D/134 spectra for the interval of -42.50 m to -51.70 m (clay layer; van der Meulen & Zagwijn, 1974), but are not identical to the latter, which have a more thermophilous character. However, the Zuurland spectra might represent a slightly later part of the same stage, *i.e.* the Waalian (A) Interglacial.

Because pollen zone 1 in the Zuurland-2 borehole lies below the level of the above-mentioned clay layer in the Brielle borehole (below about -55 m) it is also possible that a substage of the Tiglian Interglacial is present, *i.e.* pollen zone TC 5. Such age is not contradicted by the pollen record.

Pollen zone 2 indicates a quite cool interval in which the high frequencies of *Picea* are striking. The presence of the latter together with *Pinus* and *Artemisia* might indicate a more continental character of the vegetation. The substantial proportion of thermophilous trees and the relatively low frequencies of non-tree pollen, do not point to a true glacial stage such as the Eburonian and the Menapian. If we accept the postulated Waalian A age for pollen zone 1, pollen zone 2 could represent the Waalian B cool interval. The high frequencies of *Picea* are not restricted to this part of the interglacial, but little information is available on this point. The pollen-analytical data would even permit a position in a late part of the Tiglian, *i.e.* TC 6.

Pollen zone 3 represents an interglacial of the Early Pleistocene, but the data do not indicate which one. A Waalian C age would be possible.

As shown, the pollen-analytical data do not permit a definite dating. Investigation of the underlying strata may provide a better stratigraphic orientation, especially as to the position of the substages of the Tiglian. In my opinion, it is no use attempting to draw detailed conclusions from all changes in the composition of the spectra or to relate such changes to large-scale chronostratigraphic units. The sedimentary character of the material does not permit this, and, furthermore there may be gaps in the sedimentary record, for example at -55 m, where a transition from fine-grained to coarse deposits occurs. It should also be kept in mind that, despite all the emphasis put on careful sampling, contamination cannot be avoided with this kind of drilling (bailer sampling). This may explain the extreme fluctuations in the frequencies of *Picea* in pollen zone 1.

CONCLUSIONS

1. At the borehole site, the oldest deposits of the Westland Formation are to all probability of Atlantic age.

2. The spectra of the upper part of the deposits of the Kreftenheye Formation, indicating an early part of an interglacial (*i.e.*, the Eemian), must be the result of redeposition considering the mollusc content. The molluscs too indicate an Eemian age, albeit a later part of the interglacial.

3. In the spectra obtained from the deposits of the Kedichem/Tegelen Formation, three pollen zones can be distinguished, the lowermost of which reflects a marine influence. All zones are related to intervals in one or more interglacial(s) of the Early Pleistocene, *i.e.*, in all probability of pre-Bavelian age. The pollen-analytical data do not permit a more exact dating, but suggest substages of the Waalian Interglacial, or (at least part of) the Late Tiglian.

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