Meded. Werkgr. Tert. Kwart. Geol. | 25(1) | 49-60 | 4 figs. | Leiden, maart 1988

MOLLUSCA FROM THE BOREHOLE ZUURLAND-2 AT BRIELLE, THE NETHERLANDS (AN INTERIM REPORT)

by

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Meijer, T. Mollusca from the borehole Zuurland-2 at Brielle, The Netherlands (an interim report).—Meded. Werkgr. Tert. Kwart. Geol., 25(1): 49-60, 4 figs. Leiden, March 1988.

The malaco-stratigraphy of borehole Zuurland-2 at Brielle, The Netherlands, is briefly discussed. Holocene, Eemian, Waalian, and Late Tiglian deposits were found. The presence of Middle Pleistocene interglacial deposits is not excluded.

The climatological conditions under which the deposits between -50 m and -62 m were formed, are not clear and the age of this interval is uncertain. All mollusc-bearing sediments were laid down in a marine or at least in a strongly tidally influenced fluvial environment. Marine faunas of Waalian and Late Tiglian age in The Netherlands are reported for the first time.

The stratigraphical range of many species, among which are *Venerupis aurea* (Gmelin, 1791), *Macoma balthica* (Linné, 1758), *Barnea candida* (Linn, 1758) and *Mya arenaria lata* (Sowerby, 1815) appears to be longer than was assumed previously.

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CONTENTS

SAMENVATTING

Mollusca uit boring Zuurland-2 te Brielle (een tussentijds verslag).

De mollusken stratigrafie van boring Zuurland-2 ten zuiden van Brielle wordt kort besproken. Op enkele monsters na bevatten alle doorboorde sedimenten zowel mariene, zoetwater- als land-

mollusken. Tussen deze drie hoofdcomponenten van de associaties bestaat vrijwel nergens groot verschil in primaire conservatie. Dit is een argument voor het veronderstellen van een mariene of door getijden beïnvloedde fluviatiele (estuariene) facies voor de gehele sequentie. Er zijn alleen sedimenten uit interglacialen aanwezig. Daarop duidt, naast het optreden van een mariene fauna-component, ook de soortensamenstelling van de associaties. Vooral de aanwezigheid van een groot aandeel van zowel fluviatiele als bosbewonende soorten wijst op interglaciale omstandigheden. Met zekerheid kunnen vier interglacialen worden aangetoond: Holoceen, Eemien, Waalien en Laat Tiglien.

De mogelijkheid dat nog meer interglacialen in de sedimentaire sequentie zijn vertegenwoordigd, is niet uitgesloten: een of twee Midden Pleistocene interglacialen en een warme fase tussen het Waalien en het Laat Tiglien kunnen bij de huidige stand van het onderzoek niet definitief worden aangetoond. Naast onzekerheid over de ouderdom zijn ook de klimatologische omstandigheden waaronder de afzettingen tussen -50 m en -62 m zijn gevormd, niet duidelijk.

Het is de eerste keer dat in Nederland mariene mollusken fauna's uit het Waalien en het Laat Tiglien zijn aangetroffen. Het stratigrafische bereik van diverse soorten blijkt groter dan tot nu toe werd aangenomen. Dit betreft soorten die voor de mollusken stratigrafie van belang zijn. *Venerupis aurea* (Gmelin, 1791) blijkt reeds in het Waalien voor te komen en wijst dus niet meer eenduidig op Eemien. *Mya arenaria lata* (Sowerby, 1815) is in jongere afzettingen aangetroffen dan tot nu toe het geval was. Van deze soort werd verondersteld dat het laatste voorkomen aan het eind van het Midden Tiglien was. Dit blijkt nu Laat Tiglien te zijn. *Barnea candida* (Linné, 1758) en *Macoma balthica* (Linné, 1758) waren in Nederland niet bekend uit niveau's ouder dan het Vierde Cromerien Interglaciaal. Beide zijn nu gevonden in het Waalien en het Laat Tiglien. Vooral de laatste soort is van belang voor de correlatie van nederlandse mariene Kwartaire afzettingen met de Crags van East Anglia.

Van het molluskenonderzoek wordt slechts de aan- of afwezigheid van soorten besproken. Op de samenstelling van de associaties wordt hier nog niet ingegaan. Daarbij komt ook dat de boring nog niet is beindigd. Daarmee wordt hier alleen een tussenstand in het onderzoek weergegeven.

INTRODUCTION

The borehole Zuurland-2 at Brielle, situated about 3 km South of the Brielle borehole (Fig. 1) has been drilled since 1984 by Mr L.W. Hordijk (see Hordijk, 1985, 1986, 1988) as a one man private project. The Brielle borehole is an important reference in Quaternary stratigraphy of The Netherlands (Kuijper, 1973; van der Meulen & Zagwijn, 1974; van Voorthuysen, Toering & Zagwijn, 1972).

The lithology of the Zuurland-2 borehole is described in Burger *et al.* (1988). A compilation of the results of various disciplines as presented in this volume is given in van Kolfschoten & de Boer (1988).

The drilling technique applied is a bailer sampler (Hordijk, 1988). Samples were washed on a 0.4 mm mesh and subsequently dried. The residue was analyzed under a binocular microscope by Mr Hordijk. Identifications of the molluscs were made by the present author, except for some of the Holocene marine molluscs which were identified by Mr A.C. Janse (Brielle). A quantitative analysis is still in progress. Therefore only the presence or absence of species is reported here.

Fig. 1. Location of the borehole at Zuurland

ECOLOGICAL CLASSIFICATION

The principles applied for ecological classification of non-marine species are given briefly in Meijer (1985a). Marine molluscs are subdivided according to the position of their habitat relative to sea level. Three main groups are distinguished: the upper part of the littoral zone (HLZ), the lower part of the littoral zone (LLZ), and the upper part of the sub-littoral zone (HSZ). Here, species are assigned to the highest one of the groups in which they occur. The ecological diagrams in this paper are based on absolute numbers of species (Fig. 2). Apart from the ecological presentation, the species were plotted according to their last appearance in distribution charts (Figs 3 and 4).

Sediments recovered belong to Quaternary lithostratigraphical units which, in this area, usually contain a large amount of reworked material from Tertiary deposits. Especially Eocene and Pliocene molluscs are quite common; sometimes they even outnumber the Quaternary fauna. In the Zuurland-2 borehole reworked Eocene, Pliocene, and Early Pleistocene molluscs were found indeed (Figs 2 and 3).

RESULTS

All samples, except those taken between -1 m and -5 m and between -61 m and -62 m, contain molluscan remains. Only mixed associations of marine, land, and freshwater species were

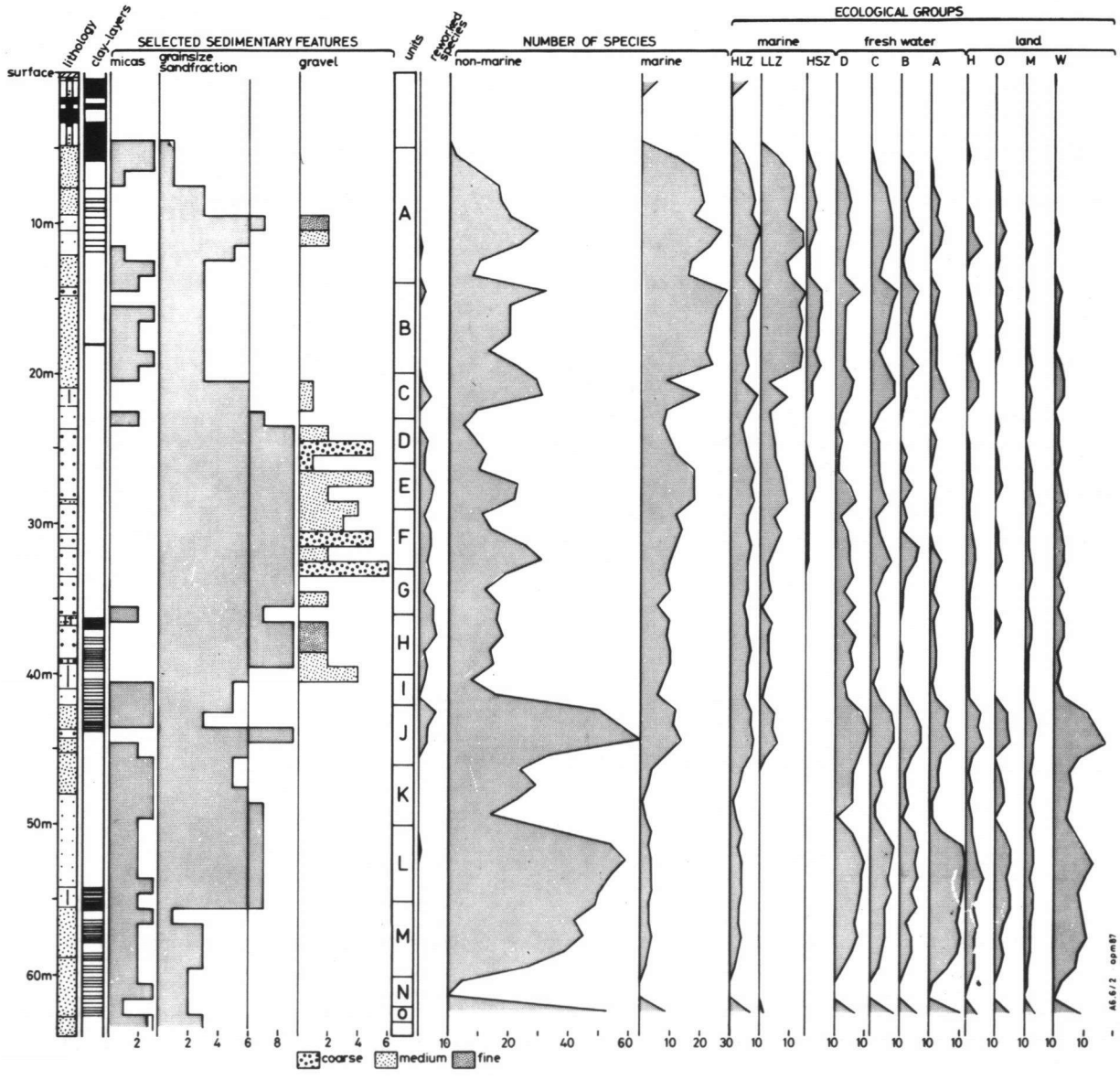
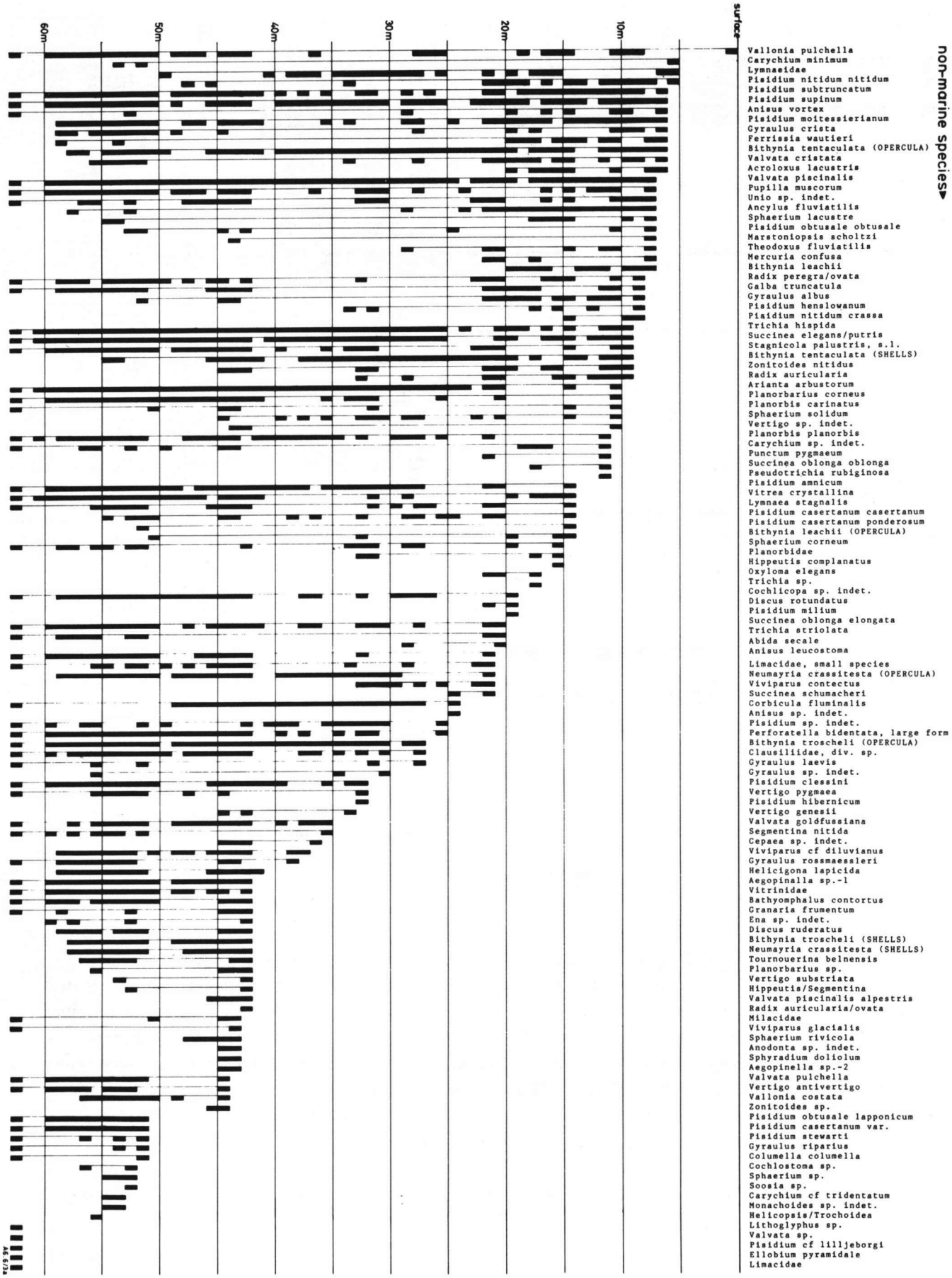


Fig. 2. Ecological diagrams of molluscan species.
Explanation: micas and gravel: 1-some, 2-a trace, 3-very few, 4-few, 5-rather few, 6-rather much.
Grainsize sandfraction: 1-extremely fine, 2-extremely to very fine, 3-very fine, 4-moderately to very fine, 5-moderately fine, 6-moderately fine to moderately coarse, 7-moderately coarse, 8-moderately coarse to very coarse, 9-very coarse.
The line in fraction 6 indicates a grainsize of 210 μ.
Marine ecological groups: HLZ-upper part of the littoral zone, LLZ-lower part of the littoral zone, HSZ-upper part of the sublittoral zone.
Freshwater ecological groups: D-species living in moving waters, C-species of stagnant and moving waters, B-stagnant waters, A-marches, banks and periodic waters.
Land ecological groups: H-hygrophile species, O-species living on open ground, M-mesophile species, W-species living in woodland.

Fig. 3. Distribution chart of molluscan species according to their last occurrences. Non-marine species.


60m
50m
40m
30m
20m
10m
surface
non-marine species
Vallonia pulchella
Carychium minimum
Lymnaeidae
Pisidium nitidum nitidum
Pisidium subtruncatum
Pisidium supinum
Anisus vortex
Pisidium moitessierianum
Gyraulus crista
Ferrissia wautieri
Bithynia tentaculata (OPERCULA)
Valvata cristata
Acroloxus lacustris
Valvata piscinalis
Pupilla muscorum
Unio sp. indet.
Ancylus fluviatilis
Sphaerium lacustre
Pisidium obtusale obtusale
Marstoniopsis scholtzi
Theodoxus fluviatilis
Mercuria confusa
Bithynia leachii
Radix peregra/ovata
Galba truncatula
Gyraulus albus
Pisidium henslowanum
Pisidium nitidum crassa
Trichia hispida
Succinea elegans/putris
Stagnicola palustris, s.l.
Bithynia tentaculata (SHELLS)
Zonitoides nitidus
Radix auricularia
Arianta arbustorum
Planorbarius corneus
Planorbis carinatus
Sphaerium solidum
Vertigo sp. indet.
Planorbis planorbis
Carychium sp. indet.
Punctum pygmaeum
Succinea oblonga oblonga
Pseudotrichia rubiginosa
Pisidium amnicum
Vitrea crystallina
Lymnaea stagnalis
Pisidium casertanum casertanum
Pisidium casertanum ponderosum
Bithynia leachii (OPERCULA)
Sphaerium corneum
Planorbidae
Hippeutis complanatus
Oxyloma elegans
Trichia sp.
Cochlicopa sp. indet.
Discus rotundatus
Pisidium milium
Succinea oblonga elongata
Trichia striolata
Abida secale
Anisus leucostoma
Limacidae, small species
Neumayria crassitesta (OPERCULA)
Viviparus contectus
Succinea schumacheri
Corbicula fluminalis
Anisus sp. indet.
Pisidium sp. indet.
Perforatella bidentata, large form
Bithynia troscheli (OPERCULA)
Clausiliidae, div. sp.
Gyraulus laevis
Gyraulus sp. indet.
Pisidium clessini
Vertigo pygmaea
Pisidium hibernicum
Vertigo genesii
Valvata goldfussiana
Segmentina nitida
Cepaea sp. indet.
Viviparus cf diluvianus
Gyraulus rossmaessleri
Helicigona lapicida
Aegopinalla sp.-1
Vitrinidae
Bathyomphalus contortus
Granaria frumentum
Ena sp. indet.
Discus ruderatus
Bithynia troscheli (SHELLS)
Neumayria crassitesta (SHELLS)
Tournouerina belnensis
Planorbarius sp.
Vertigo substriata
Hippeutis/Segmentina
Valvata piscinalis alpestris
Radix auricularia/ovata
Milacidae
Viviparus glacialis
Sphaerium rivicola
Anodonta sp. indet.
Sphyradium doliolum
Aegopinella sp.-2
Valvata pulchella
Vertigo antivertigo
Vallonia costata
Zonitoides sp.
Pisidium obtusale lapponicum
Pisidium casertanum var.
Pisidium stewarti
Gyraulus riparius
Columella columella
Cochlostoma sp.
Sphaerium sp.
Soosia sp.
Carychium cf tridentatum
Monachoides sp. indet.
Helicopsis/Trochoidea
Lithoglyphus sp.
Valvata sp.
Pisidium cf lilljeborgi
Ellobium pyramidale
Limacidae

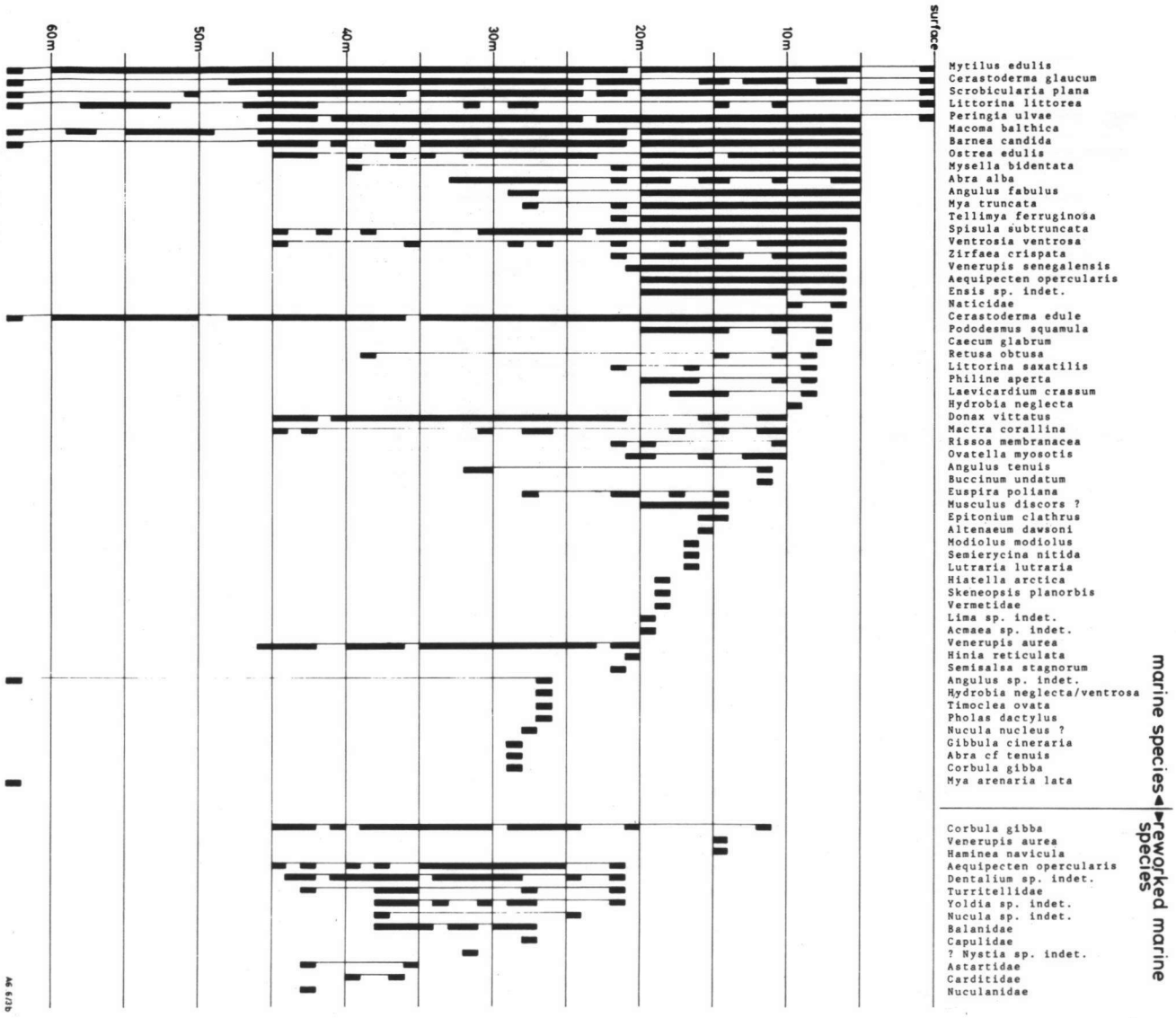


Fig. 4. Distribution chart of molluscan species according to their last occurrences. Marine species and reworked marine species.

encountered. The main faunal components in the various samples usually show hardly any difference in the quality of preservation. For the Quaternary associations hardly any evidence of long-distance transport of shell material was found. This suggests that deposition took place in a marine or in a tidally influenced fluvial environment (see e.g.: Noordhoorn van der Kruyff & Lagaay, 1960). The effect of post-depositional leaching is important in the levels below -23 m and is even stronger between -33 m and -48 m. Below -23 m, the absence of molluscan spatfall and tiny chalky remains of other invertebrates, both present above that level, might be directly related to leaching, but could also be primarily due to the prevailing sedimentary regime. Below -23 m the grain size of the sediments (Fig. 2) is considerably larger than higher in the sequence, indicating a higher energetic depositional environment, which could have prevented sedimentation of these small remains.

A lot of species of stratigraphical importance were found. They are significant with respect to the age of their first and last appearance in Quaternary deposits of The Netherlands. The following First and Last Appearance Data (FAD and LAD) are of special interest:

FAD in the Eemian: *Theodoxus fluviatilis* (Linné, 1758) and *Venerupis senegalensis* (Gmelin, 1791).

FAD in the Fourth Cromerian Interglacial: *Macoma balthica* (Linné, 1758), *Barnea candida* (Linné, 1758) (NB: The former species is known from the youngest parts of the Norwich Crag in the U.K.).

LAD in the Eemian: *Perforatella bidentata* (Gmelin, 1791) (small form) and *Corbicula fluminalis* (Müller, 1774). *Venerupis aurea* (Gmelin, 1791) is only known from the Eemian. Moreover, several species occur at present in the North Sea, but have never been encountered in Dutch Holocene deposits: *Gibbula cineraria* (Linné, 1758), *Ostrea edulis* Linné, 1758 (adults), *Timoclea ovata* (Pennant, 1777), *Pholas dactylus* Linné, 1758 and *Corbula gibba* (Olivi, 1792). With caution, these species can be considered more or less characteristic for the Eemian as well. *Gibbula cineraria* (Linné, 1758) is not known from older deposits; the other species occur in Middle Tiglian marine deposits.

LAD in the intra-Saalian warm stage: *Bithynia troscheli* Paasch, 1842 (NB: In the U.K. still occurring in the Ipswichian).

LAD in the Holsteinian: *Viviparus diluvianus* (Kunth, 1865), *Neumayria crassitesta* (Brömme, 1865), *Pisidium clessini* Neumayr, 1875.

LAD in the Second Cromerian Interglacial: *Valvata goldfussiana* Wüst, 1900 [NB: Also known from the Cromerian of West Runton (U.K.) and the first interglacial in Voigtstedt (G.D.R.). These interglacials are currently correlated with the Fourth Cromerian Interglacial].

LAD in the Interglacial of Leerdam: *Lithoglyphus* sp.

LAD in the Interglacial of Bavel: *Perforatella bidentata* (Gmelin, 1788) (large form); until now *Planorbarius* sp. was only known from this stage.

LAD in the Waalian: *Tournouerina belnensis* (Delafond & Dperet, 1893).

LAD in the Eburonian: *Cochlostoma* sp. and *Granaria frumentum* (Draparnaud, 1801).

LAD in the Late Tiglian: *Viviparus glacialis* (Wood, 1872), *Sphaerium* sp., and *Soosia* sp.

LAD in the Middle Tiglian: *Ellobium pyramidale* (Sowerby, 1824) and *Mya arenaria lata* (Sowerby, 1815).

The indicators of a cold climate, being of less direct stratigraphical importance, include: *Succinea elegans schumacheri* (Andreae, 1884), *Columella columella* (Martens, 1830), *Vertigo genesii* (Gredler, 1856), *Gyraulus rossmaessleri* (Schmidt, 1851), *Pisidium stewarti* Preston, 1909 and *Pisidium obtusale lapponicum* (Clessin, 1877). Especially *Columella columella* (Martens, 1830) is a significant indicator of a tundra environment.

The results of the present research force to modify the level of certain first and last occurrences presently used in Dutch Quaternary malaco-stratigraphy. It appears that the stratigraphical distribution of many species is considerably larger than has been assumed. A noteworthy discovery is the presence of marine faunas in Early Pleistocene deposits with a Waalian and Late Tiglian age. Previously only non-marine faunas were known from these mild periods (Freudenthal, Meijer & van der Meulen, 1976; Kuijper, 1973; Meijer, 1986, 1987). On the basis of molluscan evidence, units A-O are distinguished (Fig. 2).

DISCUSSION

Units A-C (0 m to -23 m)

The mollusc faunas indicate a Holocene age. The change in preservation at -23 m is considered to indicate the base of the Holocene deposits. Immediately below this level *Venerupis aurea* (Gmelin, 1791) has its latest occurrence, indicating a Pleistocene age.

Units D-E (-23 m to -29 m)

Both units have similar faunas, those in unit D being less diverse than in E. An Eemian age is indicated by the occurrence of *Theodoxus fluviatilis* (Linné, 1758) and several warm marine species [*Gibbula cineraria* (Linné, 1758), *Nucula nucleus* (Linné, 1767), *Timoclea ovata* (Pennant, 1777) and *Pholas dactylus* Linné, 1758] unknown in the Dutch Holocene and Middle Quaternary deposits. These species are indicative for the climatic optimum of the Eemian, which means that unit E could represent the middle phase of this interglacial. However, only a very limited number of worn specimens was found among large quantities of better preserved material of less demanding species. Therefore, reworking of the warm species during the late phase of the same interglacial is assumed. Such reworking of Middle Eemian deposits during the late phase is commonly observed in The Netherlands. This implies a Late Eemian age for both units D and E.

Eemian deposits are known to occur in the area at depths comparable to those found in the Zuurland-2 borehole (e.g. Burger, 1988; de Jong, 1988a, 1988b; de Jong & Zagwijn, 1983; van Staalduinen, 1979). Data on molluscs were published by Kuijper (1973) and Hordijk & Janse (1987). Almost all of the species occurring in units D and E, including those indicating an Eemian age, were mentioned by these authors.

Here, the significance of *Theodoxus fluviatilis* (Linné, 1758) must be stressed. In Western Europe this species did not occur before the Eemian interglacial. References to its occurrence in Middle Pleistocene deposits (e.g. Tavernier & de Heinzelin, 1962) are erroneous (Meijer, in prep.).

Unit F (-29 m to -33 m)

The occurrence of *Viviparus contectus* (Millet, 1813) and *Abra alba* (Wood, 1802) (both appearing for the first time in this unit and persisting in subsequent deposits) is suggestive of an Eemian age. If this assumption is correct the gravel at -33 m may represent the base of the Eemian sedimentary cycle. Other fossil remains indicate a higher age for this and the overlying units (van Kolfschoten, 1988). An Eemian age should imply reworking of these remains.

Unit G (-33 m to -36 m)

The change in preservation at -33 m, the absence of typical Eemian species, and the occurrence of *Pisidium clessini* Neumayr, 1875 might point to a pre-Eemian interglacial, although an Eemian age cannot be fully excluded. In that case, the specimen of *Pisidium clessini* Neumayr, 1875, which is poorly preserved, must have been reworked from older strata. Considering also the heavy mineral analyses by Burger (1988), the age would be in the range of the Eemian- Holsteinian-Fourth Cromerian Interglacial.

Unit H (-36 m to -40 m)

Data on the stratigraphical range of *Valvata goldfussiana* Wüst, 1900 in The Netherlands, indicate the Second Cromerian Interglacial as the upper age limit for this unit.

Unit I (-40 m to -42 m)

Pisidium clessini Neumayr, 1875 points to an age predating the Intra Saalian Warm Stage (Meijer, 1985a). In all probability, units H and I belong to parts of the same interglacial.

Unit J (-42 m -46 m)

This unit shows by far the richest fauna encountered in the borehole. The associations are marked by a predominance of forest species. Some cool-climate non-marine species [*Vertigo genesii* (Gredler, 1856), *Gyraulus rossmaessleri* (Schmidt, 1851), *Valvata piscinalis alpestris* (Küster, 1852)] not necessarily contradict the temperate conditions indicated by most of the other species. Their presence is perhaps comparable to that of the norway lemming, also occurring in this unit (van Kolfschoten, 1988). The first appearance of marine molluscs from the lower littoral zone is accompanied by the first appearance of reworked Tertiary marine species and an important change in the sedimentary regime (Fig. 2). The occurrence of *Tournouerina belnensis* (Delafond & Dperet, 1893) (= *Nematurella minima* Tesch, 1939) points to Waalian as the minimal age (Meijer, 1987). Despite the considerable numbers of fluvial species, no well-preserved, unreworked material of *Viviparus glacialis* (Wood, 1872) was found. This absence and the occurrence of *T. belnensis* (Delafond & Dperet, 1893) point to a Waalian age.

Because *Venerupis aurea* (Gmelin, 1791) occurs in this unit, this species is no longer conclusive for dating the Eemian as was assumed previously (Spaink, 1958).

Unit K (-46 m to -50 m)

The number of species is considerably smaller than in the overlying unit. Lower littoral species are missing. The occurrence of *Sphaerium rivicola* (Lamarck, 1818), otherwise only present in unit J, suggests a similar age for both units J and K.

Unit L (-50 m to -55 m)

The number of species almost equals that in unit J. The sediments were deposited under predominantly temperate conditions, as is indicated by the occurrence of a low-boreal intertidal marine fauna accompanied by large numbers of both fluvial and forest species. There is, however, a minor but nevertheless pronounced occurrence of non-marine high-boreal to arctic species [*Pisidium stewarti* Preston, 1909; *P. obtusale lapponicum* (Clessin, 1877); *Columella columella* (Martens, 1830)]; together with some species with great climatic tolerance [*Valvata pulchella* Studer, 1820; *Gyraulus rossmaessleri* (Schmidt, 1851); *Gyraulus riparius* (Westerlund, 1865); *Helicopsis*/*Trochoidea*). *Columella columella* (Martens, 1830) indicates a tundra environment, whereas *Helicopsis* points to steppe conditions.

No marked differences in preservation are noted between the different faunal components. The associations are consistent with a climate dominated by a strong continental influence (mild summers, cold winters). *Columella columella* (Martens, 1830) is present just before the strong decline in the number of species in the interval of -51 m to -52 m. This occurrence and the numerical decline

might be signs of climatic detoriation leading to arctic conditions. This is, however, in conflict with the overall temperate climatic conditions reflected by most of the species. Although several hypotheses are possible , none of them offers a satisfying explanation. Reworking of the delicate specimens is highly improbable. Thus the question of the climatic conditions prevailing in unit L remains open as yet.

Except for the cold-climate non-marine species, the majority of the associations are very similar to those in unit J. Three species, however, are suggestive of a pre-Waalian age. These are: *Cochlostoma* sp., not known from post-Eburonian deposits and *Soosia* sp., and *Sphaerium* sp., which are found only in Tiglian deposits. These species are represented only by a few fragments, the state of preservation being comparably good compared to that of the other material. In spite of the excellent preservation, reworking of molluscan remains from pre-Waalian deposits cannot be completely excluded.

Unit M (-55 m to -60 m)

Very similar to unit L, but differing by the lack of species indicating a pre-Waalian age. Because the unit is preceded by a non-fossiliferous deposit and the faunas of units L and M are very similar, I presume the age of unit M to be close to that of unit L.

Unit N (-60 m to -62 m)

The lower sample is devoid of molluscs, the upper sample only contains a very small number of indifferent species. No conclusions can be drawn from this limited evidence.

Unit O (-62 m to -63 m)

The deepest sample reported here must be assigned to the Tiglian, because of the presence of *Viviparus glacialis* (Wood, 1872) and *Mya arenaria lata* (Sowerby, 1815). Recent results of further drilling shows that this unit extends at least several meters further down. Comparisons with the Brielle borehole (Kuijper, 1973; Meijer, 1985b) indicate that this unit represents the Late Tiglian. This is confirmed by vertebrate evidence, indicating the Late Villanyian (van Kolfschoten, 1988). The deposits show a marine molluscan fauna, which means that a marine deposit of this age is recognized for the first time in The Netherlands on the basis of the molluscan fauna.

Tiglian marine faunas are known especially from the Middle Tiglian. The marine faunas of this stage differ from those of the Late Tiglian of Zuurland. The latter shows a lower diversity and includes (among other species) *Macoma balthica* (Linné, 1758) and *Barnea candida* (Linné, 1758), neither of which was previously known to have occurred in The Netherlands before the Fourth Cromerian Interglacial (Spaink & Norton, 1967; ter Wee, 1976). These species have not been found in the Middle Tiglian. In marine deposits of this age (Maassluis Formation) the related *Macoma praetenuis* (Leathes in Woodward, 1830) is not yet replaced by the newcomer *Macoma balthica* (Linné, 1758). These findings open new possibilities for correlation between Early Pleistocene marine strata in The Netherlands and the Quaternary Crag deposits of East Anglia (U.K.).

Unit O shows relatively many non-marine cold-climate indicators, including *Columella columella* (Martens, 1830). For the uppermost part of the unit and perhaps also for unit N, which is almost barren, the possibility of a period with an arctic climate must be considered.

CONCLUSIONS

All mollusc-bearing deposits were formed in a marine or a strongly tidally influenced fluvial environment.

Interglacial deposits belonging to at least four and possibly seven climatic cycles are present. No indications for glacigene deposits were found. The presence of non-marine cold-climate indicators, among them a tundra species, between -50 m and -62 m is difficult to explain, but further studies in comparable strata may solve this problem.

The stratigraphy at Zuurland, based on the malacological evidence, is summarized as follows:

0 m to -23 m	Holocene
-23 m to -33 m	Eemian, Late or Middle phase
-33 m to -36 m	Interglacial, possibly Eemian, Holsteinian or Fourth Cromerian Interglacial
-36 m to -42 m	Interglacial, predating the Fourth Cromerian Interglacial, not necessarily differing in age from the next interval
-42 m to -50 m	Waalian
-50 m to -62 m	Interglacial with a Waalian age or older
-62 m to -63 m	Late Tiglian

ACKNOWLEDGMENTS

For permission to publish the results of this research, I wish to express my gratitude to the Director of the Geological Survey of The Netherlands. The generosity of Mr L.W. Hordijk in permitting to study his material and to publish the results is greatly appreciated. For discussions on stratigraphic and other problems I wish to thank all my co-researchers. I am also indebted to Mr A.C. Janse, for identifications of marine Holocene species, to Dr W.H. Zagwijn, for discussions and his critical reading of the manuscript, to Mrs I. Seeger and Dr P.L. de Boer, for reading of the English text, and Mr P. Marselje, for the preparation of the illustrations in this paper.

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Manuscript received 9 February 1988