Cainozoic Research, **2**(1-2)(2002), pp. 129-134, October 2003

The late Middle Pleistocene non-marine molluscan fauna of borehole Noorderhoeve-19E117 (province of Noord-Holland, the Netherlands)

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Received: 28 March 2003; revised version accepted 17 April 2003

In borehole Noorderhoeve-19E117, molluscan assemblages from the lower portion of the marine Eemian deposits as well as from underlying fluvial deposits of Middle Pleistocene age, have been studied; separating these deposits is boulder clay of Saalian age. The pre-Saalian fluvial assemblages are predominated by *Corbicula fluminalis* (Müller) s. lat., and show the presence of *Borysthenia naticina* (Menke) and *Pisidium clessini* Neumayr. Based upon amino-acid racemization (AAR) analysis, these assemblages are assigned to the Oostermeer Interglacial, *i.e.* the last interglacial of the Middle Pleistocene. This means that the currently assumed Holsteinian age of this part of the Urk Formation is incorrect and that the local extinction of *B. naticina* and *P. clessini* occurred two interglacials later than hitherto thought.

KEY WORDS: late Middle Pleistocene, fluvial molluscs, AAR data

Introduction

Meijer & Preece (2000) have recently reviewed the stratigraphic occurrence of *Corbicula fluminalis* s. lat. in the Quaternary of England and the Netherlands, showing that in these countries this species is not present in the last interglacial (Eemian), and that in the Middle Pleistocene it is restricted to the last two or three interglacials. One of the Dutch sites mentioned was borehole Noorderhoeve (Figures 1, 2); however, no data on the molluscan assemblages encountered were provided. In the present note, the relevant faunal data are outlined and discussed. Samples taken between 29.90–53.90 metres below NAP (= 'Normaal Amsterdams Peil', Dutch ordnance level) were studied. The non-marine species have been analysed in full, while marine species have not been counted but analysed only qualitatively. The results of the first analysis are presented in Figure 3, those of the latter are mentioned in the text.
Borehole Noorderhoeve-19E117 (co-ordinates: x = 125.100, y = 513.099) was drilled in 1982 as a bailor well, reaching a depth of 50.50 m below surface (surface altitude: 3.40 m below NAP). Its position is close to section A-A' of the geological map of Alkmaar (Westerhoff *et al.*, 1987).

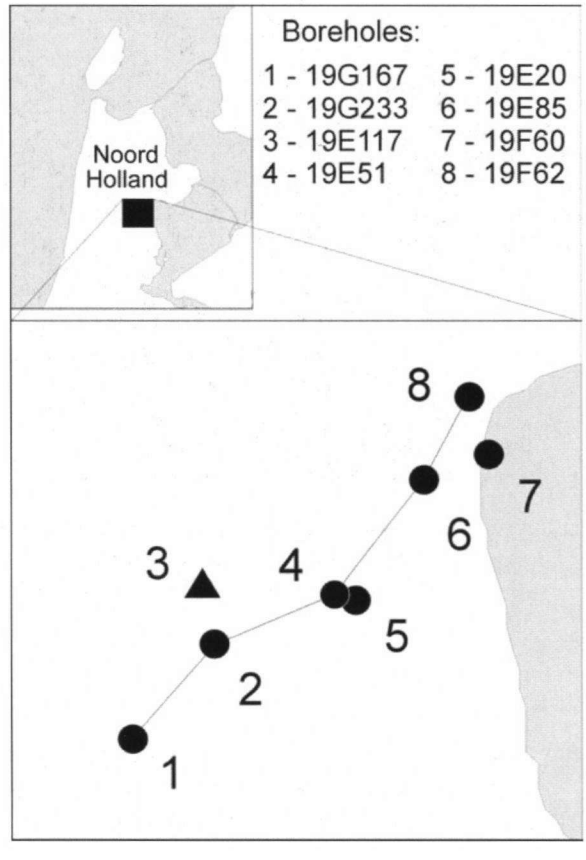

Figure 1. Map of the province of Noord-Holland (the Netherlands); part of section A-A' of geological map sheet Alkmaar and borehole Noorderhoeve-19E117 (triangle).

Lithology and lithostratigraphy

The lithology of the samples studied is as follows (depths in metres below NAP):

29.90-32.40 medium-coarse, dark brown grey sand with shells and shell fragments;
32.40-37.90 dark grey sandy loam with gravel;
37.90-44.40 medium-coarse, grey brown sand with few shells;
44.40-46.40 very coarse, dark grey brown sand with few shells;
46.40-48.40 medium-coarse, grey brown sand with few shells;
48.40-48.90 fine layering of dark grey to light grey brown silty loam and silt bands; fine plant debris;
48.90-51.90 very coarse dark grey brown sand with few shells;
51.90-53.90 medium-coarse, grey brown sand with few shells.

The lithostratigraphic interpretation of these beds is as follows:

29.90-32.40 Eem Formation;
32.40-37.90 Drenthe Formation (boulder clay);
37.90-53.90 Urk Formation.

The Eem Formation essentially consists of marine shell-bearing deposits dating from the Last Interglacial, the Eemian. The boulder clay in the Drenthe Formation is of Saalian age, whereas the Urk Formation consists mostly of fluvial deposits of the River Rhine, characterised by the relatively common occurrence of the volcanic mineral augite in the sand fraction and by the absence of northern erratic components in the gravel fraction. The Urk Formation is of a broadly late Middle Pleistocene age.

In Figure 2 the borehole column is projected on part of the section A-A' of Westerhoff *et al.* (1987). The samples studied from the Eem and Urk formations are indicated 'A' and 'B', respectively. In Figure 1 the position of the section is indicated.

Molluscan assemblages

Most of the non-marine molluscs (Figure 3) above the boulder clay are well preserved and co-occur with numerous marine species in varying states of preservation.

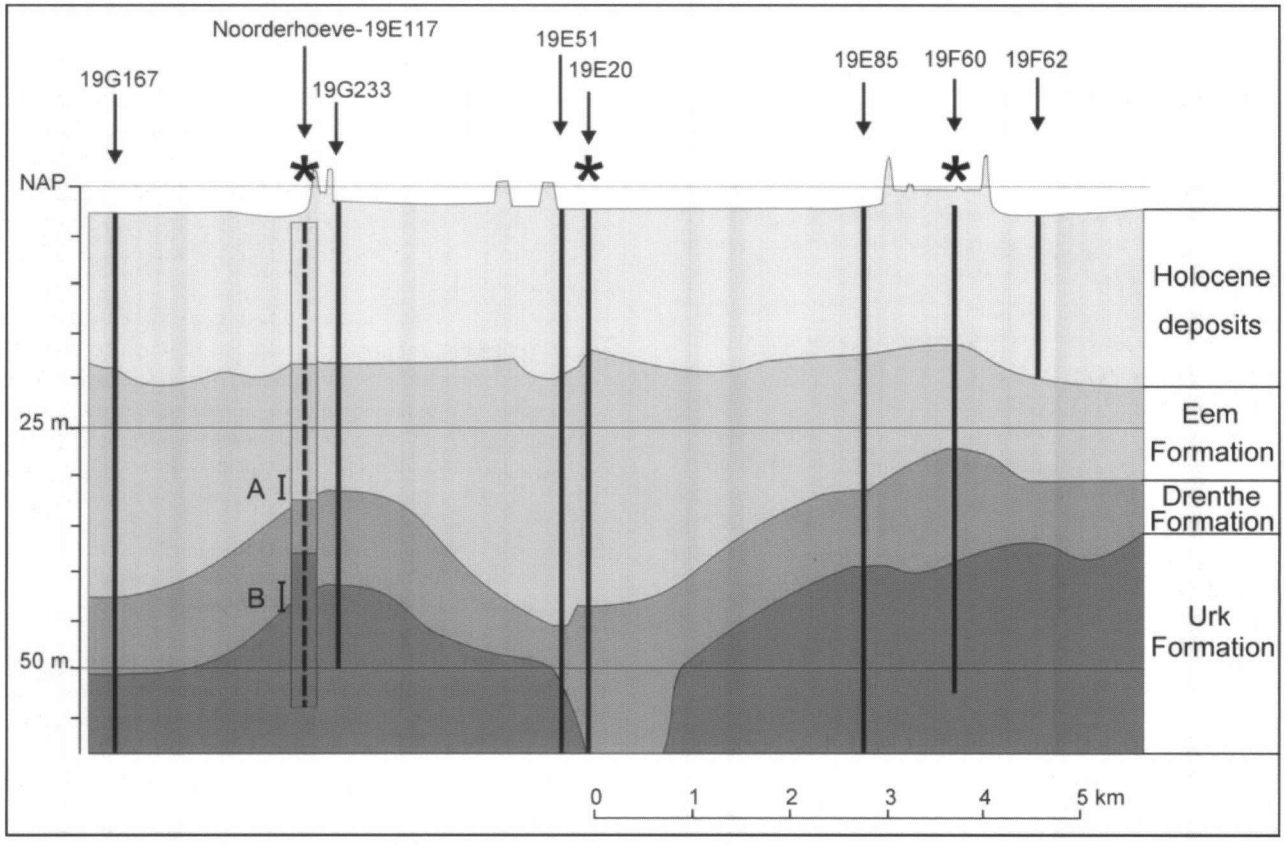

Figure 2. Borehole Noorderhoeve-19E117 projected on part of section A-A' (modified after Westerhoff *et al.*, 1987); only the upper 65 metres are shown. Asterisks: projected boreholes. A = marine Eemian samples studied, B = samples from the Oostermeer Interglacial studied.

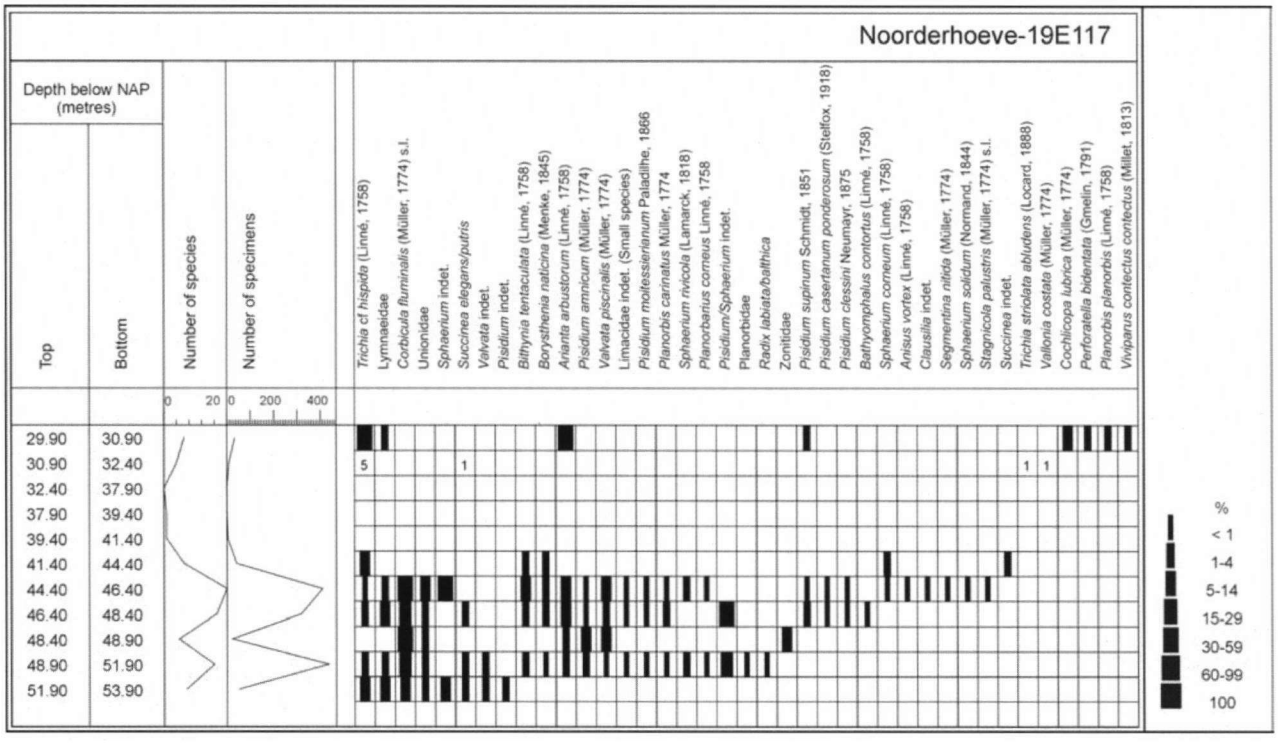

Figure 3. Molluscan assemblages of the Oostermeer Interglacial in borehole Noorderhoeve-19E117.

Among the well-preserved marine species the following are worth mentioning:

Abra alba (Wood)
Acanthocardia paucicostata (Sowerby)
Angulus distortus (Poli)
Anomia ephippium (Linné)
Bittium reticulatum (Da Costa)
Cerithiopsis nana (Jeffreys)
Cerithiopsis tubercularis (Montagu)
Corbula gibba (Olivi)
Gastrana fragilis (Linné)
Hiatella arctica (Linné)
Hinia reticulata (Linné)
Lucinella divaricata (Linné)
Thracia papyracea (Poli)
Timoclea ovata (Pennant)
Turbonilla lactea (Linné)
Paphia aurea senescens (Cocconi).

Corbula gibba is the predominant species in the assemblages.The marine species are characteristic of the Eemian interglacial and the assemblages point to a rather warm, shallow-marine, subtidal sheltered environment, probably situated in a lagoon. Only a few non-marine species are present, which are considered to have been washed in by fluvial activity. Of these, *Viviparus contectus* (Millet) and *Trichia striolata abludens* (Locard) may be mentioned; these are frequently found in similar deposits of Eemian age in the central part of the Netherlands.

Below the boulder clay, the molluscan assemblages are essentially non marine. Only a few temperate shallow-marine species (*Mytilus edulis* Linné, *Cerastoderma* indet., *Ostrea edulis* Linné) occur in very low frequencies. These marine species are stratigraphically insignificant and their occurrence is interpreted merely as an indication of the proximity of the sea.

In the non-marine assemblages, *Viviparus contectus* and *Trichia striolata abludens* are absent, whereas commonly occurring taxa are *Corbicula fluminalis* s. lat., *Pisidium,* and species of *Sphaerium*. In addition to *Corbicula,* significant stratigraphical markers are *Borysthenia naticina* and *Pisidium clessini.* All three are (locally) extinct prior to the Eemian. The assemblages point to a fluvial environment in a temperate climate.

Amino-acid racemization (AAR)

Mean D/L ratios from shells of *Corbicula* of this site were presented by Meijer & Preece (2000). A brief introduction to Dutch AAR stratigraphy was provided by Meijer & Cleveringa (2003); their zonation is here shown in Figure 4.

The analyses of the shells were performed in the AAR laboratory of the University of Wales at Cardiff (UK) in 1996. The sample set, consisting of four shells, was submitted without providing stratigraphic data. The resulting D/L ratios (only from the total -hydrolysed- fraction) were:

A - 0.323, B - 0.340, C - 0.135, and D - 0.289 (Cardiff ID: UKAL-248). The comment of the laboratory to these D/L ratios was, 'The ratio for sample C is considered unreliable.

AAR zone	M.I.S.	STAGE
A	1	Holocene
	2-5d	Weichselian
B	5e	Eemian
	6	Saalian
C	7	Oostermeer
	8	(unnamed)
D	9	Belvédère
	10	(unnamed)
E	11	Holsteinian
	12	Elsterian

Figure 4. AAR stratigraphy of the Netherlands (modified after Meijer & Cleveringa, 2003); M.I.S. = Marine Isotope Stage.

The quantity of most amino-acids was similar to those in the other samples, but the quantity of D-alloisoleucine was much less, resulting in a lower D/L ratio. Because this ratio is much lower than the others, it is not used in the calculation of the mean ratio. The chromatograms of the other samples were all of good quality. The ratio for sample D is slightly low, but the ratio is included in the calculation of the mean value. The chromatograms for samples A and B were of the best quality, and the ratios for (0,323 and 0,340) are considered to be the more reliable for this set of samples'.

Meijer & Cleveringa (2003) accepted only the most reliable and highest D/L ratios within a sample set, which in this case means only the ratios of samples A and B. These provide a mean D/L ratio of 0.332 (± 0.009), which matches their AAR-zone C.

Discussion

Fluvial species show the highest rate of (local) extinction among northwest European freshwater molluscs and are therefore stratigraphically significant (Meijer, 1990; Meijer & Preece, 1995; Keen, 2001). In borehole Noorderhoeve three species belong to this group, namely *Borysthenia naticina*, *Pisidium clessini* and *Corbicula fluminalis* s. lat. In the Netherlands, the last-named species was long thought to be characteristic of the Eemian. However, Meijer & Preece (2000) have recently shown that its local extinction already occurred prior to this interglacial. The other two species were considered to have become locally extinct immediately following the Holsteinian (Meijer, 1990).

In Table 1, AAR data of several critical sites are listed. The *Corbicula* D/L ratio of Noorderhoeve-19E117 is comparable to that of Zuurland-37C554 and clearly lower than the Belvédère ratio. Comparison with the Holsteinian can only be made using D/L ratios of *Valvata piscinalis* (Müller) and *Borysthenia naticina* from locality Neede. *Valvata* D/L ratios of the Belvédère and Rhenen-Leccius de Ridder sites are added for that reason.

SITE	MEAN D/L RATIOS		AGE	AAR zone
	Corbicula fluminalis	*Valvata & Borysthenia*		
Rhenen, Leccius de Ridder pit	-	0.172 ± 0.021 [4] (UKAL-239) *Vp*	O	C
Zuurland-37C554, 30-32 m.	0.301 ± 0.012 [4] (UKAL-251)	-	O	C
Noorderhoeve-19E117, 43-45 m.	0.332 ± 0.009 [2] (UKAL-248)	-	O	C
Belvédère	0.408 ± 0.033 [5] (UKAL-255)	0.216 ± 0.020 [4] (UKAL-226) *Vp*	B	D
Neede	-	0.284 ± 0.010 [3] (UKAL-235) *Vp*	H	E
Neede	-	0.311 ± 0.034 [5] (UKAL-236) *Bn*	H	E
Noordbergum-6D38, 58.45-60.20 m.	-	0.336 ± 0.019 [3] (UKAL-237) *Bn*	H	E

Table 1. Amino-acid analyses; means of accepted D/L ratios of Noorderhoeve-19E117 and several critical sites in the Netherlands. **First column:** locality names with NITG borehole ID and depth in metres below NAP; **second and third columns:** mean D/L ratios with standard deviation, number of analyses and laboratory code. UKAL = amino-acid laboratory of the University of Wales at Cardiff (UK).
Bn = Borysthenia naticina, Vp = Valvata piscinalis; **fourth column:** O = Oostermeer Interglacial; B = Belvédère Interglacial; H = Holsteinian.

At both these localities *Corbicula* occurs, although only at the Belvédère site has this species provided enough material for an AAR analysis. On the basis of faunal data, the Rhenen-Leccius de Ridder site may correlate with the Oostermeer Interglacial, whereas the age of the Belvédère site is between this site and the Holsteinian of Neede.

The D/L ratios presented may be assigned to AAR zones C, D, and E and clearly show that the last appearance datums

of *Borysthenia naticina* and *Pisidium clessini* are two interglacials later than previously assumed, and as a matter of fact, are coeveal with *Corbicula fluminalis* s. lat. At Neede, *B. naticina* and *P. clessini* co-occur with *Viviparus diluvianus* (Kunth) and *Parafossarulus crassitesta* (Brömme), while *Corbicula fluminalis* s. lat. is absent (Oostingh & Florschütz, 1928; Meijer, 1972). In Noorderhoeve-19E117, as well as at Neede, the fluvial assemblages occur in the Urk Formation which was deposited by the River Rhine. As both assemblages lived in the same river system, the difference in species composition may have stratigraphic significance. For both assemblages other examples from Rhenish deposits may be mentioned: the Neede assemblage is also known from the Noordbergum-6D38 borehole at a depth of 58.45-60.20 m (Tesch, 1939, 1942; Meijer & Preece, 1996), which is assigned to AAR-zone E, whereas the Noorderhoeve assemblage is also known from borehole Zuurland-37C554 at a depth of 33-36 m (Meijer, 1988) assigned to AAR-zone C (Table 1). Although the Noordbergum-6D38 deposits were considered to represent the fourth interglacial of the Cromerian Complex (Zagwijn, 1996), Meijer & Cleveringa (2003) argued that this assignment could be questioned on the basis of faunal and AAR data. These authors preferred to correlate the estuarine deposits of this site with the Holsteinian, an opinion also expressed earlier by Tesch (1939, 1942).

Of the species mentioned, only *Corbicula fluminalis* s. lat. occurs in the Belvédère Interglacial. The observed pattern of co-occurrences may have stratigraphic significance; it is here summarised in Table 2.

	O	B	H
Viviparus diluvianus (Kunth)	–	–	X
Parafossarulus crassitesta (Brömme)	–	–	X
Borysthenia naticina (Menke)	X	–	X
Pisidium clessini Neumayr	X	–	X
Corbicula fluminalis (Müller) s. lat.	X	X	–

Table 2. Stratigraphic occurrence of fluvial molluscs in the Netherlands; O = Oostermeer Interglacial, B = Belvédère Interglacial, H = Holsteinian.

Conclusions

In borehole Noorderhoeve-19E117, a Saalian boulder clay separates Eemian deposits with characteristic warm-temperate, marine molluscan assemblages from underlying fluvial deposits with a *Corbicula* assemblage. In these fluvial deposits a few marine species indicate the proximity of the sea. AAR analyses point to deposition of the fluvial deposits during the Oostermeer Interglacial (AAR-zone C). Consequently, their age is much younger than the Holsteinian interglacial with which it had been correlated (= upper part of the Urk Formation). The presence of the stratigraphically significant fluvial species *Borysthenia naticina* and *Pisidium clessini*, held to have become (locally) extinct immediately following the Holsteinian, indicates that their extinction occurred two interglacials later, *i.e.* following the Oostermeer Interglacial. Possibly, the co-occurrence of *B. naticina*, *C. fluminalis* s. lat., and *P. clessini* and the absence of *Viviparus diluvianus* and *Parafossarulus crassitesta* characterises fluvial molluscan assemblages of this interglacial.

Acknowledgements

I thank Piet Cleveringa (TNO-NITG, Utrecht) for numerous discussions on the stratigraphy of the Dutch Middle Pleistocene and for critical reading of the typescript.

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