Meded. Werkgr. Tert. Kwart. Geol.	vol. 18 (1)	pp. 11 - 28	6 tab., 7 figs	Rotterdam, maart 1981

CALAIS DEPOSITS (HOLOCENE) NEAR BENTHUIZEN (PROVINCE OF ZUID-HOLLAND, THE NETHERLANDS), WITH A PALEOECOLOGICAL RECONSTRUCTION

by

J. G. M. Raven
and
W. J. Kuijper

Raven, J. G. M. & W. J. Kuijper. Calais Deposits (Holocene) near Benthuizen (province of Zuid-Holland, The Netherlands), with a paleoecological reconstruction. - Meded. Werkgr. Tert. Kwart. Geol., 18(1): 11 - 28, 6 tab., 7 figs. Rotterdam, March 1981.

By means of a study of flora, fauna and sediment from a section through Calais Deposits (Calais III) near Benthuizen the geological history of the region (during late Atlantic and early Subboreal) is reconstructed. Initially a transgression reached only the lowermost parts of the area, forming irregular basins with a brackish environment. Later the transgression made marine influences more important and the area became covered by tidal flats. With the following regression peat formation started and continued until the area was reclaimed.

J. G. M. Raven, Pr. J. W. Frisolaan 229, 2263 CG Leidschendam, The Netherlands; W. J. Kuijper, Holbeekstraat 12, 2203 HB Noordwijk, The Netherlands.

Contents:
Samenvatting, p. 12
Introduction, p. 12
The section, p. 14
Fauna, p. 15
- Discussion of some mollusc species, p. 20
- The remaining fauna, p. 21

Flora, p. 21
- General remarks, p. 21
- Remarks on some plant species from the basal part of the Calais III Deposits, p. 23
- Ecological indications of the plant material, p. 23

Conclusions, p. 26
Acknowledgements, p. 27
References, p. 27

SAMENVATTING

In een tijdelijke ontsluiting ten oosten van Benthuizen (afb. 1) werd in mei 1978 een sektie opgemeten en gemonsterd (afb. 3). Het grootste deel daarvan wordt ingenomen door de Afzettingen van Calais III. Zowel met behulp van flora en fauna als het sediment werd het milieu gereconstrueerd. De plaats waar het profiel werd opgenomen werd door de eerste drie transgressiefasen van de Afzettingen van Calais bereikt. De eerste twee reikten niet ver landinwaarts zodat we daarvan in Benthuizen slechts perimariene afzettingen terugvinden (Afzettingen van Gorkum I en II, zie afb. 2). Het zoetwaterkarakter van deze afzettingen wordt bevestigd door de daarin aangetroffen plantenresten. Maar de derde fase reikte aanmerkelijk verder waarbij lagunaire- en wadafzettingen (Afzettingen van Calais III) werden gevormd. De ondergrond waarover de transgressie plaatsvond vertoonde een vrij sterk reliëf (enkele decimeters tot meters) door de verschillende mate van klink van de venige en kleiige sedimenten. Daardoor werden eerst de diepste plaatsen overstroomd zodat een grillig patroon van brakwaterplasjes en -geultjes ontstond. In dit zeer rustige milieu groeiden zeegras en ruppia (tabel 6) en leefden mosdiertjes (*Electra crustulenta*) en o.a. de mollusken *Hydrobia ventrosa, Littorina rudis* f. *tenebrosa* en *Cerastoderma glaucum* (tabel 1). De sedimentatie was zeer langzaam, slechts klei in suspensie (via de rivieren aangevoerd) bereikte het gebied en daardoor is de concentratie van de fossielen zeer hoog (ongeveer 9.000 schelpen per kilo droog sediment, tabel 1 en 3, afb. 4).

Door de voortschrijdende transgressie werd de zeespiegelstand hoger. De vrij geïsoleerde plasjes groeiden aaneen tot een groot brakwatergebied dat via twee grote geulen (een zuidelijke via Rijswijk, Nootdorp en Zoetermeer, een noordelijke via Katwijk, Leiden en Leiderdorp) in verbinding stond met de zee. De bestudeerde sektie lag ongeveer op de waterscheiding tussen de twee geulen. Door de geulen werd fijn zand aangevoerd. De waterbeweging werd sterker, het zoutgehalte werd iets hoger. Hierdoor verdween de karakteristieke *Ruppia maritima*, gingen de molluskensoorten die in de brakwaterplasjes leefden sterk achteruit en werden mariene molluskensoorten zoals *Scrobicularia plana* en *Peringia ulvae* wat algemener (tabel 1-3).

Met het aangevoerde sediment werd het gebied langzaam opgehoogd en doordat de zeespiegelstijging steeds trager ging werd het water ondieper en brakker zodat de mariene fauna weer verdween en tenslotte slechts brakwaterostracoden zich wisten te handhaven (tabel 1 en 5). De isolatie van het gebied nam verder toe doordat de strandwallen langs de kust zich verder uitbreidden en tenslotte was het water zover verzoet dat opnieuw veengroei begon waardoor een dik pakket Hollandveen werd gevormd, dat later is afgegraven.

INTRODUCTION

In 1978 a pipe-line for the transport of gas was constructed in the provinces of Noord- and Zuid-Holland. For that purpose an excavation with a length of many kilometers was made. Regrettably we could study only a small part of this excavation, a construction-pit 1,750 m East of Benthuizen, along the Hogeveense Weg (fig. 1, coordinates x = 98.800 y = 454.750, topographical map 1:25.000, sheet 30H Zoetermeer) on the boundary of the municipalities of Hazerswoude and Benthuizen. A section was measured by Mr A. W. Janssen (Rijksmuseum van Geologie en Mineralogie, Leiden) and the first author. Samples taken from the Calais Deposits in this section were studied in detail: the molluscs by the first author, the other animals and the plant remains by the second author.

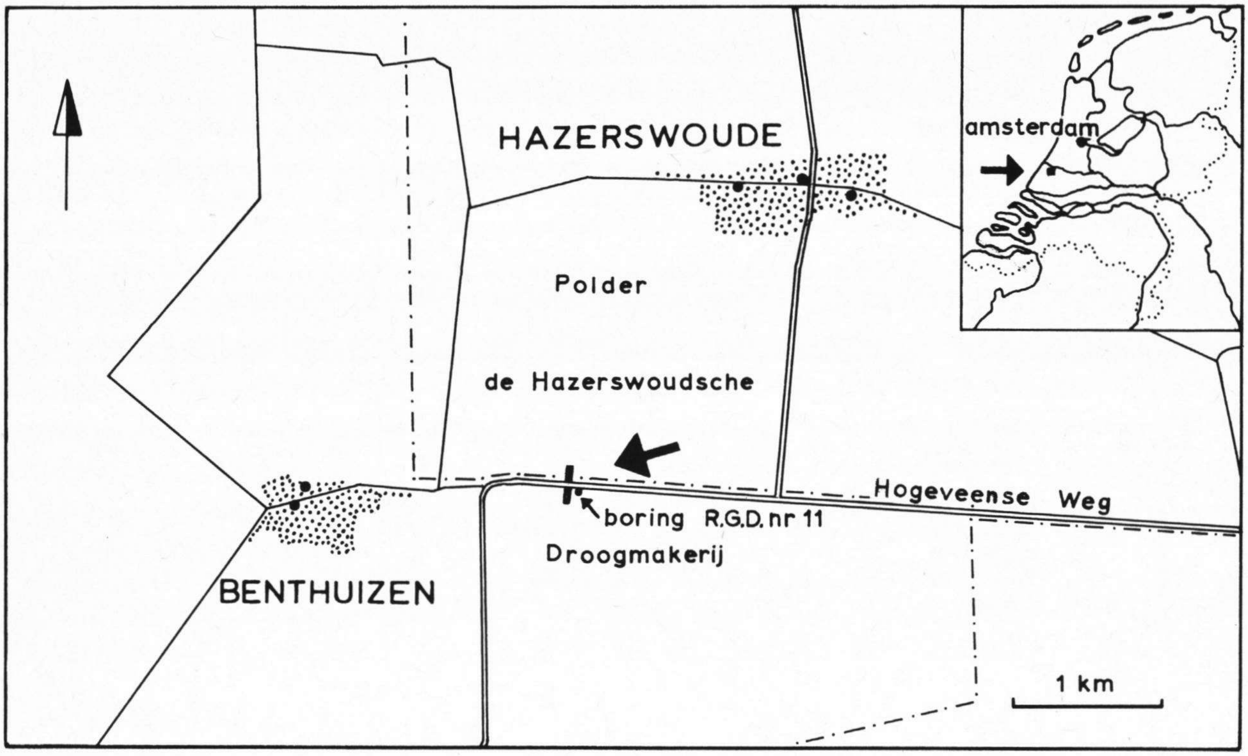

Fig. 1. Geographical position of the construction-pit (large arrow) and the boring.
Afb. 1. Geografische ligging van de ontsluiting (grote pijl) en de boring.

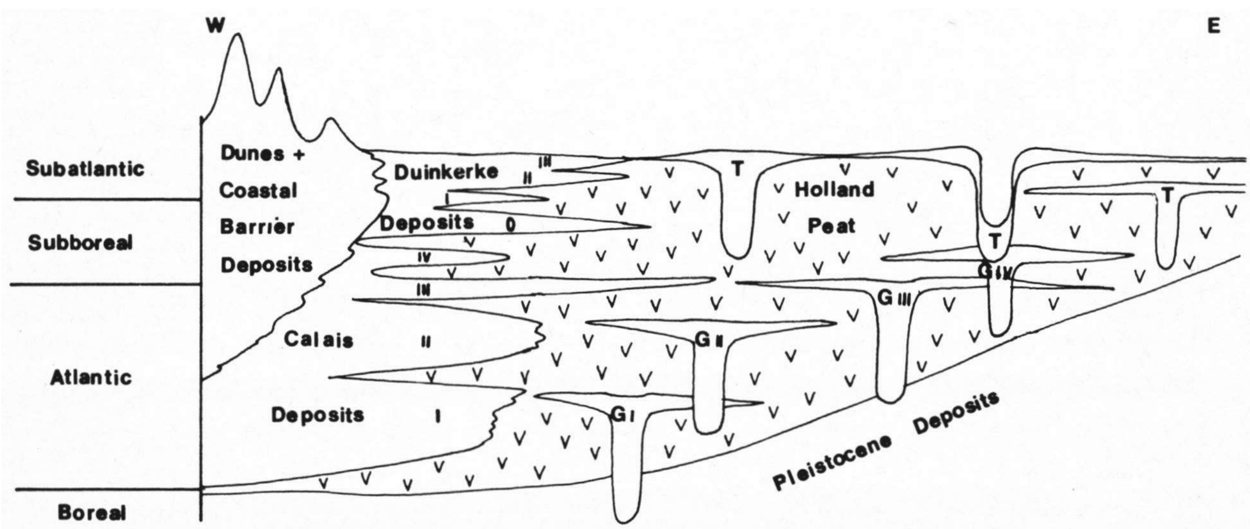

Fig. 2. Schematic cross-section of Holocene sediments in the western Netherlands (G = Gorkum Deposits, T = Tiel Deposits). Vertical scale strongly exaggerated.
Afb. 2. Schematisch profiel door de holocene afzettingen in West-Nederland (G = Afzettingen van Gorkum, T = Afzettingen van Tiel). De vertikale schaal is sterk overdreven.

First a summary will be given of the sedimentation in the western part of the Netherlands during the early Holocene. Because the ice-cap, reaching far South during the Weichselian, started to melt, the sea level rose quickly and at the same time also the ground water level. Along the landward moving coast line peat was formed (the so-called Lower Peat, the lowermost part of the Holland Peat). Because of the continued rise of the ground water level the peat was drowned and a freshwater lake came into existence. This lake developed through the stage of a brackish lagoon to a tidal flat (Calais Deposits, see fig. 2). This tidal flat was situated behind a coastal barrier lying West of the present coast line. During the transgression this entire complex of deposits moved landinward, synsedimentary erosion removed part of the deposits. Around 5,000 BP the rise in sea level diminished considerably and the coast became prograding. Each time a new coastal barrier was deposited on the sea side of the old one. Behind the barriers the water in the lagoon decreased in salinity to completely fresh water because of discharging large rivers. Therefore peat growth started soon (Holland Peat) (de Jong, 1971).

THE SECTION (fig. 3)

surface level 4.60 m –NAP (according to topographical map)

4.60 - 4.80 m	sandy clay, clayey sand and peat, with brick remains, disturbed.
4.80 - 5.26 m	very fine sandy clay, yellowish grey, particularly in its lower part with reddish brown oxidation spots around roots. Downwards passing into clayey sand. Few specimens of *Scrobicularia*.
5.26 - 5.43 m	slightly clayey, rather fine sand, greyish yellow, with reddish brown oxidation spots around roots. Somewhat below the middle three to five thin, dark brown detritus laminae with a single shell fragment. The upper and lower boundary-surfaces are sharp.
5.43 - 6.35 m	clay, with a very high content of fine sand, bluish grey. The upper 20 or 25 cm are horizontally laminated. Especially in the upper part, but also more to the base, roots are present. Many double-valved *Scrobicularia* in vertical position, few hydrobiids. In the laminated part small bivalves and some double-valved *Scrobicularia* shells in horizontal position.
6.35 - 7.90 m	clay, with a very high content of fine sand, bluish grey. Downwards passing into a heavy clay with more specimens of hydrobiids and *Cerastoderma*, in the lowermost part also *Macoma* and *Mytilus*. In the basal 5 cm pockets with high numbers of *Littorina, Hydrobia* and *Cerastoderma*.
7.90 - 7.95 m	dark brown *Phragmites*-peat.
7.95 - 8.15 m	yellowish grey, fine sandy clay with many peat remains, without fauna.
8.15 - 8.70 m	part of the section below water level.

This section was interpreted as follows (fig. 2):

4.60 - 7.90 m	Calais Deposits (Calais III)
7.90 - 7.95 m	Holland Peat
7.95 - 8.15 m	Gorkum Deposits (Gorkum II)

Close to this excavation a boring was made by the Rijks Geologische Dienst (file-number 454/98-11, see fig. 1 for location) reaching the top of the Pleistocene deposits:

0.00 - 4.65 m	below surface	Holocene:	Calais Deposits (Calais III)
4.65 - 4.70 m	„	„	Holland Peat
4.70 - 6.80 m	„	„	Gorkum Deposits (Gorkum II)
6.80 - 7.00 m	„	„	Holland Peat
7.00 - 7.30 m	„	„	Gorkum Deposits (Gorkum I)
7.30 - 7.70 m	„	„	Holland Peat (Lower Peat)
7.70 - (8.00m)	„	Pleistocene:	Kreftenheye Formation

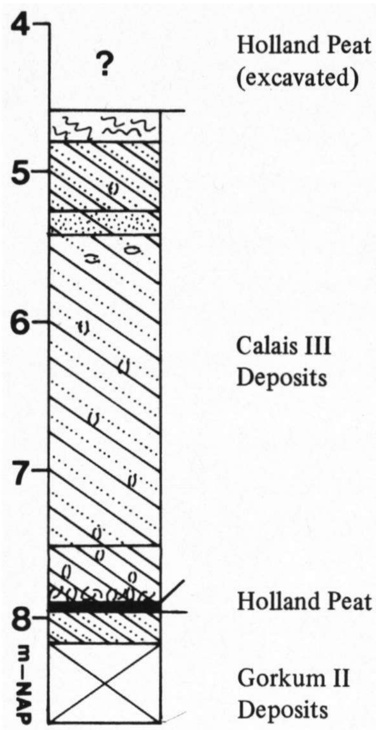

Fig. 3. The section measured at Benthuizen.
Afb. 3. De sektie die bij Benthuizen werd opgenomen.

The section was measured in the southern part of the construction-pit, just at the edge of the road. The lowermost part of the section was below water level and could not be studied. The clay at the base of the section (8.15-7.95 m -NAP) contains remnants of freshwater plants and is interpreted therefore as Gorkum Deposits (Gorkum II). These were formed in a perimarine environment next to the lagoon in which the Calais Deposits were formed. The thin layer of reed peat on top of it belongs to the Holland Peat. It is a thin offshoot of the extensive peat area further landinward. The higher part of the section belongs to the Calais Deposits. A plough zone is present in the upper 20 cm.

Originally a thick layer of peat (Holland Peat, here about 2½ m) was present on top of the Calais Deposits, but was excavated in recent time. For a better understanding of the environmental circumstances of the Calais III Deposits, which were formed during the culmination of the Holocene transgression in the Netherlands, the botanical and faunistical remains present in our samples were studied.

FAUNA

Only in the Calais Deposits animal remains were found, mainly molluscs. The number of specimens was calculated from a standard of 1 kg dry sediment (the samples were slightly larger). The samples were washed on a 0.75 mm mesh, consequently most of the very juvenile shells were lost. They are represented in our countings in too low numbers.

Particularly the lower 0.50 m of the Calais Deposits is rich in fossils. They occur concentrated in pockets in the lowermost five cm (9,049 molluscs in a kg of sediment, see fig. 4). This basal layer increased considerably in thickness towards the northern part of the construction-pit. In this part of the section the small gastropods *Hydrobia ventrosa* and *Littorina rudis* f. *tenebrosa* dominate the

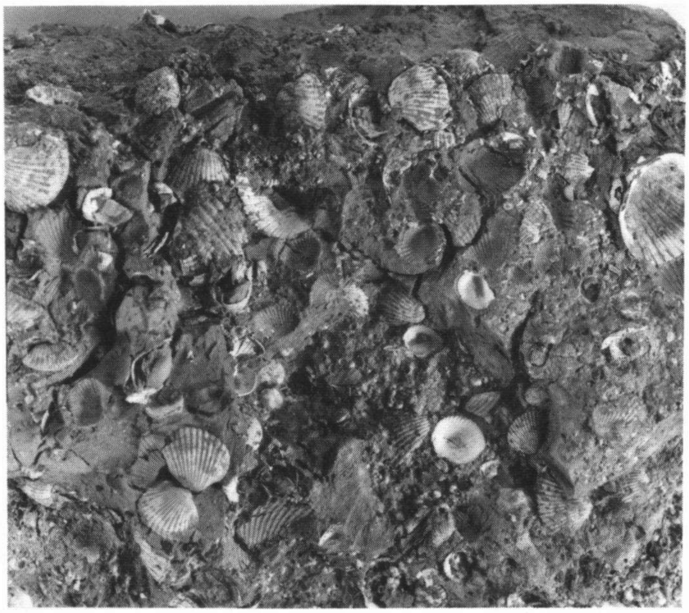

Fig. 4. Detail of a sample from the basal layer of the Calais III Deposits at Benthuizen.
Afb. 4. Detail van een monster van de basislaag van de Afzettingen van Calais III bij Benthuizen.

fauna (table 1). Also the bivalve *Cerastoderma glaucum* is present in high numbers. All these species prefer brackish water. Although the number of brackish water species is almost the same as the number of marine species, the number of specimens of the brackish water species is much higher (table 3). Gastropods strongly exceed the bivalves as is usual in brackish environments (table 2). The fauna is poor in species what is supposed to be caused by extreme life conditions (anually fluctuating salinity, temperature, etc.) but by a high supply of food. Species that agree with these extreme circumstances occur in high numbers.

The high concentration of fossil material (fig. 4) can be explained only by supposing a low sedimentation rate. Apparently both sources of sediment - open sea (through the inlets in the West) and rivers (Rhine in the North and Meuse in the South) - were so far away that only small quantities of fine-grained sediment reached the area under concern. The presence of *Cerastoderma glaucum* in high numbers and in large specimens and the absence of *C. edule* (Linné, 1758) indicate that water movement was minimal, as this species does not stand wave action or a long period of emersion (Koulman & Wolff, 1977). This is furthermore indicated by *Littorina rudis* f. *tenebrosa* which also lives in brackish water without strong currents. It lives on a firm substratum especially in dense vegetations of *Ruppia* or *Potamogeton* (Muus, 1967, p. 137). In Recent brackish water areas we found this form always accompanied by the bryozoan *Electra crustulenta* that also occurs in the basal layer (table 5). Also the fact that the entire thanatocoenosis exists of autochthonous specimens suggests a very quiet environment. The decrease in number of specimens, upwards in the basal 0.50 m, indicates an increasing rate of sedimentation.

In a sample taken from the basal layer in the northern part of the construction-pit a specimen of the gastropod *Ovatella myosotis* (Draparnaud, 1801) was found (fig. 5). This species lives in a salty or slightly brackish environment at moist locations under vegetation or under rocks on a firm bottom (Janssen & de Vogel, 1965), eg. marshes. As this shell shows no signs of transportation the coast may have been very close to the section studied.

In the interval between 7.35 and 6.35 m -NAP the composition of the fauna changes considerably: the number of specimens of brackish water species decreases strongly (tables 1 and 3). Especially the reduction of *Littorina* and *Cerastoderma*, already indicated in the upper part of the basal

depth in m below NAP	7.85–7.90	7.35–7.85	6.85–7.35	6.35–6.85	5.90–6.35	5.43–5.90	5.26–5.43	4.80–5.26	environment
Mytilus edulis Linné, 1758	1a, 2j	1a, 14j	4j	5j	½a, ½j	.	.	.	m
Pododesmus (Heteranomia) squamula (Linné, 1758)	.	.	.	1j	.	.	.	.	m
Mysella (Mysella) bidentata (Montagu, 1803)	.	.	½a	2/2a	.	.	.	.	m
Cerastoderma glaucum (Poiret, 1789)	30a, 539j	2a, 10j	1j	½a, 4j	.	.	.	.	b
Spisula (Spisula) subtruncata (Da Costa, 1778)	.	.	.	2j	.	.	.	.	m
Macoma (Macoma) balthica (Linné, 1758)	2a, 4j	2a, 28j	12j	4j	9j	6j	.	½j	m
Scrobicularia plana (Da Costa, 1778)	3a	4a	8a, 5j	7a, 11j	10a, 2j	5a, 1j	4j	+	m
Zirfaea crispata (Linné, 1758)	.	.	.	1j	.	.	.	.	m
Littorina (Littorinivaga) rudis f. *tenebrosa* (Montagu, 1803)	3869	284	1	2	.	.	.	.	b
Hydrobia neglecta Muus, 1963	+	.	.	.	.	.	.	.	b
Hydrobia stagnorum (Gmelin, 1791)	+	.	.	.	.	.	.	.	b
Hydrobia ventrosa (Montagu, 1803)	4450	1918	65	136	136	187	.	.	b
Peringia ulvae (Pennant, 1777)	49	27	90	41	9	34	.	.	m

Table 1. Molluscs (numbers of specimens) present in samples of 1 kg dried sediment. Two valves of Bivalvia were counted for one specimen, juvenile (j) and adult (a) shells were counted separately. In the last column is indicated whether the species is a brackish water (b) or marine species (m).
Tabel 1. Mollusken (aantallen exemplaren) aanwezig in de monsters van 1 kg gedroogd sediment. Boven de kolommen staat de diepte vermeld waarop de monsters werden genomen. Bij de tweekleppigen werd onderscheid gemaakt tussen juveniele (j) en volwassen (a) exemplaren, twee kleppen werden als één exemplaar geteld. In de laatste kolom staat aangegeven of de betreffende soort gewoonlijk in brak water (b) of in zee (m) leeft.

depth in m below NAP	7.85–7.90	7.35–7.85	6.85–7.35	6.35–6.85	5.90–6.35	5.43–5.90	5.26–5.43	4.80–5.26
Peringia : *Hydrobia* = 1:	92.9	71.0	0.72	3.32	15.1	5.5	-	-
Peringia : *Littorina* = 1:	79.0	10.5	0.01	0.05	0	0	-	-
bivalves : gastropods = 1:	14.6	36.5	5.0	5.3	6.3	18.4	0	0

Table 2. Ratio between numbers of specimens of different groups of molluscs.
Tabel 2. Verhoudingen tussen de aantallen exemplaren van de verschillende groepen mollusken.

depth in m below NAP	7.85-7.90	7.35-7.85	6.85-7.35	6.35-6.85	5.90-6.35	5.43-5.90	5.26-5.43	4.80-5.26
number of marine species	4	4	5	8	4	3	1	2
number of brackish water species	5	3	3	3	1	1	0	0
number of specimens (marine)	61	76	120	70	32	46	4	2
number of specimens (brackish water)	8988	2214	67	133	136	187	0	0

Table 3. Numbers of marine and brackish water species and numbers of specimens from both environments (molluscs).
Tabel 3. Aantallen mariene en brakwatersoorten en aantallen exemplaren uit beide milieu's (mollusken).

species	minimum	maximum	optimum	literature
Mytilus edulis	8-9			Wolff, 1973
Cerastoderma glaucum	4-5	13		Koulman & Wolff, 1977
Macoma balthica	1.7-2.1			Wolff, 1973
Scrobicularia plana	8-10	>16.5	10-15	Wolff, 1973
Littorina rudis f. *tenebrosa*	3.9-4.4		5.5-11	Muus, 1967
Hydrobia neglecta	5.5	13.3	5.5-8.3	Muus, 1967
Hydrobia ventrosa	3.3	11	3.9-10	Muus, 1967
Peringia ulvae			5.5-18.3	Muus, 1967

Table 4. Minima, maxima and optima of chlorinity (in $^0/_{00}$) endured by the molluscs species. The values of Muus (1967) were calculated from values of salinity.
Tabel 4. Minima, maxima en optima van chloriniteit (in $^0/_{00}$) die worden verdragen door de molluskensoorten. De waarden uit Muus (1967) werden berekend uit waarden van de saliniteit.

0.50 m (table 1), continued, indicating a higher energetic environment. At the same time, however, the number of specimens of marine species increased slightly and also the number of marine species. Specimens of *Mysella bidentata*, very juvenile shells of *Pododesmus squamula, Spisula subtruncata* and *Zirfaea crispata* were found. The number of spines of the heart urchin *Echinocardium cordatum* is much higher (table 5). These bivalves and spines are allochthonous faunal elements. Furthermore the sediment is more sandy. Together these data indicate an increase of marine influence, of salinity and water movement. The same conclusion can be drawn from the relative number of bivalves compared with that of the gastropods (table 2) and from the ratio between the marine species *Peringia ulvae* and the brackish water species *Hydrobia ventrosa* and *Littorina rudis* f. *tenebrosa* respectively (table 2). The increasing marine influences were caused by a transgression, shifting the whole complex of environments further landinwards (see introduction).

In the next interval, 6.35-5.43 m -NAP, the number of specimens of the latter group is higher again. Also the ratio between bivalves and gastropods has changed in favour of the gastropods (tables 2 and 3). The same is true for the ratio of *Peringia* and *Hydrobia* (table 2). This might indicate a decrease in salinity, but the brackish water species *Cerastoderma glaucum* and *Littorina rudis* f. *tenebrosa* remain absent because of the high energetic environment. This latter fact is demonstrated by the horizontal lamination in the upper part of this interval, caused by a sorting of the sediment. Also the horizontally embedded, but only slightly transported *Scrobicularia* shells (the valves are still connected in spite of a weak ligament tissue!) indicate a further increase in water movement. The upper part of this interval was deposited on an up-building tidal flat shoal.

The uppermost undisturbed interval (5.43-4.80 m -NAP) contains very few species and specimens of molluscs but the number of euryhaline ostracods [all *Cyprideis torosa* (Jones, 1850) which occurs mostly between 1.6 and 9.4 $^0/_{00}$ Cl$^-$] is very high (tables 1 and 3). Apparently it was depo-

	Crustacea, Cirripedia Balanidae sp.	Porifera spiculi of sponges	Echinodermata *Echinocardium cordatum*	Foraminifera	Crustacea Ostracoda	Bryozoa	Annelida, Polychaeta *Nereis* sp.	Vertebrata, Pisces skeleton parts	Vertebrata, Pisces *Pomatoschistus* sp.	Crustacea, Branchipoda Cladocera (ephippium)	Bryozoa *Cristatella mucedo*	Bryozoa *Plumatella* sp.	Insecta (fragments)	Arachnida Chelicerata (mites)
environment	m	(m)	m	mb	mb	mb	mb	(mb)	mb	f(b)	f	f	-	-
depth in m below NAP														
section South of road														
4.80 - 5.26	-	-	.	●	●	-	.	-	-	-	.	.	-	-
5.26 - 5.43	-	-	+	●	●	-	.	-	-	.	.	-	.	.
5.43 - 5.90	-	-	+	o	o	-	.	-	-	.	.	.	.	.
5.90 - 6.35	-	-	+	o	o	.	.	-	-	.	-	.	-	-
6.35 - 6.85	.	.	o	●	●	.	.	-	-	-	-	.	.	-
6.85 - 7.35	-	-	+	●	o	.	.	-	-	.	-	.	-	-
7.35 - 7.85	-	-	+	.	.	.	-	.	-	-	.	-	-	-
7.85 - 7.90	-	-	.	.	+	.	-	+	-	-	-	-	.	.
7.90 - 7.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7.95 - 8.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
section North of road														
circa 7.85	-	-	.	o	o	+	.	+	.	.	-	-	.	-

Table 5. Remnants of the other animals from the section at Benthuizen, arranged from marine (m) to freshwater (f). b = brackish, - = no fossils, . = 1 or some specimens, + = tens, o = hundreds, ● = thousands.
Tabel 5. Overblijfselen van de overige dieren uit de sektie bij Benthuizen, gerangschikt naar milieu van marien (m) naar zoetwater (f). b = brakwater, - = geen fossielen, . = één of enkele exemplaren, + = tientallen, o = honderden, ● = duizenden.

sited in very shallow, brackish water.

It is striking that no freshwater molluscs were found because North as well as South of the present location large rivers discharged into the lagoon. Apparently the rate of freshwater supply was very low and marine influences could predominate. Of course the water was brackish because of a mixing of river water with sea water, but the absence of freshwater molluscs indicates that the main part of the sediment has a marine origin.

It is possible to estimate the chlorinity of the environment with the help of table 4. In the interval between 7.90 and 7.35 m and especially its lower part, the brackish water species lived in optimal life conditions (many and large specimens) whereas the marins species lived more or less near the lower limit of tolerance. So, from table 4 chlorinity can be estimated between 8 and 9 $^{o}/_{oo}$ Cl^{-}. In the interval between 7.35 and 6.35 m -NAP, chlorinity was slightly higher, about 10 to 15 $^{o}/_{oo}$ Cl^{-}. The upper interval, 6.35-5.43 m -NAP, was deposited in a more brackish environment with a chlorinity between 8 and 10 $^{o}/_{oo}$ Cl^{-}. The main cause of the differences in faunal composition, however, are not the slight changes in chlorinity, of more importance in this respect was the variable degree of water movement.

Discussion of some mollusc species

Littorina rudis f. *tenebrosa*

The systematical position of this taxon was discussed in Muus (1967) and Raven (1979). It is a typical brackish water form (or species). The shells are brown with white spots or have a reticulate pattern. One of the specimens is sinistral.

Hydrobia ventrosa, H. stagnorum and *H. neglecta* (fig. 5)

Only recently it was demonstrated that *H. ventrosa* and *stagnorum* are separate species. The morphological differences are given by Bank et al. (1979). A useful description of *H. neglecta* is to be found in Muus (1967). While *H. ventrosa* is abundant or even dominating in all fossiliferous samples only few specimens of both other species were found, all of them in the basal layer. Both prefer a very quiet environment. Important characteristics for the identification of the species are the first whorls (large in *stagnorum*, small in *ventrosa* and blunt in *neglecta*), the convexity of the whorls (very convex in *stagnorum*, less convex in *ventrosa* and flat in *neglecta*), the umbilicus (narrow in *stagnorum* and *neglecta*, wide in *ventrosa*) and the shape of the aperture.

Although recent investigations demonstrate important anatomical differences between the species traditionally grouped in the genus *Hydrobia*, the opinions of the different workers do not seem to be final and therefore a conservative nomenclature is used in this paper.

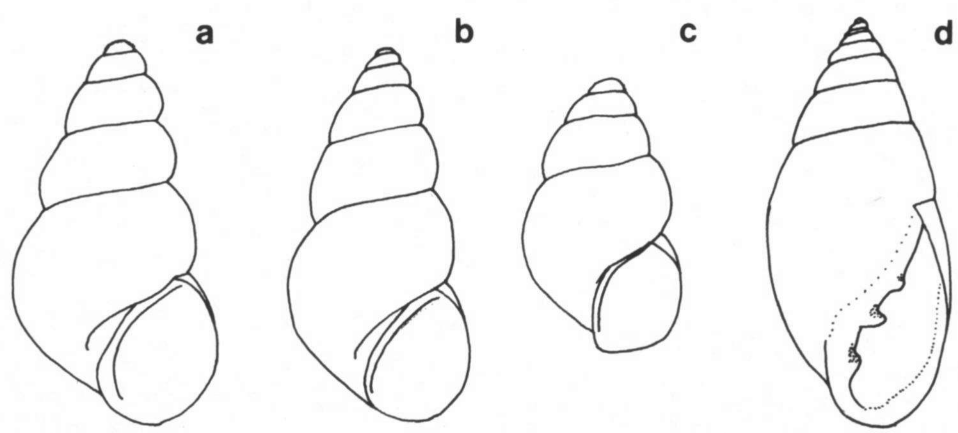

Fig. 5. Gastropods from the basal layer of the Calais III Deposits at Benthuizen.
Afb. 5. Gastropoden uit de basislaag van de Afzettingen van Calais III bij Benthuizen.
a. *Hydrobia ventrosa* (x14.5), b. *H. neglecta* (x14.5), c. *H. stagnorum* (x14.5), d. *Ovatella myosotis* (x6).

Cerastoderma glaucum

For a long time there has been much confusion about the status of this taxon, nowadays it is generally accepted as a separate species next to *C. edule*. The differences between the species are described, for example, by van Urk (1973). The specimens from Benthuizen are rather large (with a length up to 37.1 mm), indicating a favourable environment.

The remaining fauna

During the examination of the samples attention was paid also to the non-molluscs. Usually this material could not be identified to species level. Still it was possible to obtain supplementary information on the environments by these observations. Table 5 shows the results of our analyses with an indication of the specimen numbers. It appears that foraminifera and ostracodes are very common. The highest numbers are present above the basal part of the Calais III Deposits.

Spines of *Echinocardium cordatum* are common, except for the basal part, where they are very scarce. Because these animals live in open marine conditions their spines must have been washed in from such an environment. It is known that spines may be transported over long distances (Schäfer, 1962, p. 545).

The main part of the calcareous bryozoans was desintegrated during the washing procedure. In undisturbed samples, however, they were still visible. One of these colonies appears to be *Electra crustulenta.* This species is well-known from brackish environments. In general, Bryozoa indicate clear water, they live sublittorally on plants, shells and other solid substrates. Statoblasts were found of *Cristatella mucedo* and *Plumatella* sp. These resting stages of freshwater bryozoans are transported very easily over long distances.

Of *Nereis* sp., a ragworm, the jaws were found. Probably this is *N. diversicolor,* one of the few worms usually present in brackish waters.

Brown, well preserved, skeleton parts of a small fish were found in the basal part of the Calais III Deposits. Two otoliths from the same level appear to belong to a goby (*Pomatoschistus* sp.).

All fossils mentioned may have lived in or were transported into the environments as reconstructed with the help of the molluscs and plant remains.

FLORA

General remarks

The samples from the basal part of the Calais III Deposits (c. 7.85 m –NAP) yielded, apart from many molluscs, quite a lot of seeds and fruits. Sampling at various places in the same level gave a good impression of the contents of plant species preserved in the sediment. Alltogether 2.6 liters of clay from the basal part of the Calais III Deposits were washed on a 0.5 mm mesh, consequently it is possible that very small seeds were lost. Also eight smaller samples from the deposits below and on top of this layer were analysed for their seed content. The represented species are listed in table 6. All plant remains that were found agree very well with Recent seeds and fruits of the same species.

For some of the fossil species measurements are given. Dimensions (wet seed material) are measured with a Wild M7 binocular microscope with a micrometer. For the identifications mainly Beijerinck (1947), Knörzer (1970) and Körber-Grohne (1964, 1967) were used, as well as the reference-collection of Recent seeds and fruits of the Instituut voor Prehistorie (Rijksuniversiteit Leiden).

depth in meters below NAP	sample size in liters	group 1			group 2			group 3									
		a	e	e	a	b	b	a	b	b	b	b	b	b	c	c	c
		Chenopodium polyspermum L.	*Atriplex hastata* L./*patula* L.	*Polygonum lapathifolium* L.	*Mentha arvensis* L./*aquatica* L.	*Juncus bufonius* L.	*Ranunculus sceleratus* L.	*Atriplex littoralis* L.	*Zostera marina* L.	*Ruppia maritima* L.	*Salicornia europaea* L.	*Suaeda maritima* (L.) Dum.	*Triglochin maritima* L.	*Aster tripolium* L.	*Armeria maritima* (Mill.) Willd.	*Juncus gerardii* Loisl.	*Juncus buforius* L.
section South of road																	
4.80 - 5.26	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
5.26 - 5.43	0.2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
5.43 - 5.90	0.2	-	-	-	-	-	1	-	-	-	1	-	-	1	-	2	-
5.90 - 6.35	0.2	-	-	-	2	-	-	-	-	2	-	-	-	-	-	6	-
6.35 - 6.85	0.2	1	-	-	2	-	-	-	-	1	2	-	-	-	-	3	-
6.85 - 7.35	0.2	-	-	-	2	1	-	-	-	-	1	-	-	-	-	2	1
7.35 - 7.85	0.2	-	1	-	-	-	-	-	6	21	2	1	1	4	-	-	-
7.85 - 7.90	0.2	-	34	-	1	-	-	2	70	39	2	8	-	14	-	-	-
7.90 - 7.95	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7.95 - 8.15	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
samples North of road																	
circa 7.85	0.2	-	14	-	2	-	-	1	-	6	6	11	-	4	-	2	-
circa 7.85	1.0	-	82	1	3	-	-	13	22	169	5	24	-	63	-	-	-
circa 7.85	1,0	-	62	-	4	-	-	4	8	171	5	23	-	31	1	-	-

depth in meters below NAP	sample size in liters	group 4																		group 8			9	various		
		a	a	a	a	a	a	c	c	c	c	c	c	c	c	c	d	d	d	b	d	d	a			
		Potamogeton pectinatus L.	*Potamogeton* sp.	*Zannichellia palustris* L.	*Chara* sp.	*Ranunculus* (*Bartachium*) sp.	*Lemna* sp.	*Alisma plantago-aquatica* L.	*Mentha aquatica* L./*arvensis* L.	*Phragmites australis* (Cav.) Trin. ex Steud.	*Scirpus maritimus* L.	*Scirpus lacustris* L.	*Typha latifolia* L./*angustifolia* L.	*Carex acutiformis* Ehrh.	*Cladium mariscus* (L.) Pohl.	*Lycopus europaeus* L.	*Eupatorium cannibinum* L.	*Lythrum salicaria* L.	*Solanum dulcamara* L.	*Urtica dioica* L.	*Sambucus nigra* L.	*Humulus lupulus* L.	*Alnus glutinosa* (L.) Vill.	*Carex* sp.	*Juncus* sp.	*Sphagnum* sp.
section South of road																										
4.80 - 5.26	0.2	-	-	-	-	-	-	1	-	1	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-
5.26 - 5.43	0.2	-	2	1	2	-	-	-	-	-	-	1	3	-	-	1	1	-	-	-	-	-	-	1	-	-
5.43 - 5.90	0.2	-	-	-	2	-	-	-	-	-	-	-	6	-	-	-	1	-	-	-	-	-	-	-	-	-
5.90 - 6.35	0.2	-	-	-	-	-	-	-	2	1	-	-	9	-	-	-	-	-	-	1	-	-	-	-	-	-
6.35 - 6.85	0.2	-	-	-	3	-	1	-	2	-	-	3	4	-	-	1	-	1	1	1	1	-	2	1	-	-
6.85 - 7.35	0.2	-	2	-	3	1	-	-	2	2	-	2	5	-	1	1	-	-	-	1	-	-	1	3	2	+
7.35 - 7.85	0.2	-	1	1	5	-	-	4	-	-	1	-	-	-	-	-	-	-	-	-	-	1	5	2	-	+
7.85 - 7.90	0.2	-	-	-	4	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
7.90 - 7.95	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7.95 - 8.15	0.2	-	-	-	-	-	-	1	-	-	-	1	-	3	-	8	-	-	-	-	-	-	-	-	-	-
samples North of road																										
circa 7.85	0.2	1	-	-	54	-	-	-	2	2	1	1	8	-	-	-	-	1	-	-	-	-	-	-	-	-
circa 7.85	1.0	5	10	1	40	-	-	5	3	1	1	4	1	-	-	-	1	-	-	1	-	-	-	-	-	+
circa 7.85	1,0	4	11	-	50	-	-	4	4	3	2	2	-	-	-	-	1	-	-	-	-	-	1	-	-	-

Table 6. Plant remains in samples from the section near Benthuizen and from the basal part of the Calais III Deposits North of the road. The species are arranged in groups according to Arnolds & van der Meyden (1976).

Tabel 6. Plantenresten uit monsters van de sektie nabij Benthuizen en van de basis van de Afzettingen van Calais III ten noorden van de weg. De soorten zijn gerangschikt in groepen volgens de indeling van Arnolds & Van der Meyden (1976).

Remarks on some plant species from the basal part of the Calais III Deposits

Bryophyta
Sphagnum sp. – Isolated leaves of bog moss were observed (not counted).

Charophyta
Chara sp. – Oögonia with and without (broken?) calcareous layer.

Spermatophyta
Atriplex hastata and/or *Atriplex patula* – Well-preserved seeds, roundish or angular in outline, diameter 0.8-1.8 mm. Some specimens show remains of the perianth on the seed surface.
Salicornia europaea – Well-preserved seeds, with short hairs.
Suaeda maritima – Well-preserved seeds, some of them still have a part of the perianth on the seed surface.
Armeria maritima – A damaged and corroded calyce.
Aster tripolium – Some of the fruits still have hairs on the surface and a pappus. Length, width and thickness of 50 fruits: 2.75 (1.9-4.1) x 0.94 (0.7-1.3) x 0.48 (0.35-0.7) mm.
Zostera marina – The ribbed seeds are crushed and partly corroded. Originally they had a circular transverse section, which is still visible at the top and the base of some specimens. Length and width of 14 seeds: 2.71 (2.2-3.2) x 1.33 (0.9-1.8) mm.
Potamogeton pectinatus – Rather well-preserved fruits. Some of these have remnants of the thin outer fruit coat. Dimensions of four fruits: all 3.9 x 3.1 x 2.0 mm.
Potamogeton sp. – This material belongs probably (at least partly) to *P. pectinatus*. Because of the unfavourable state of preservation identification to species level was not possible.
Ruppia maritima s. lat. – Black, solid, rather smooth fruits, very well-preserved. In spite of sampling and washing (a part of) the fruit-stalk is still present on many specimens. The fruits are variable in shape, fig. 6 gives a general idea of the variability. Some of the fruits have partly a rough surface which is caused by the presence of small spines. Length, width (incl. carina) and thickness of 100 fruits: 2.42 (1.8-2.8) x 1.67 (1.0-2.2) x 1.26 (0.8-1.9) mm. The scatter diagram of fig. 7 shows the length/width-ratio of these fruits.

The nomenclature within the genus *Ruppia* is complex (Verhoeven, 1980). The European material was considered to belong to one species: *Ruppia maritima* with subspecies and varieties. Some authors, however, distinguished *R. cirrhosa* (Petagna) Grande and *R. maritima* as separate species, the latter with the var. *maritima* (with fruit-stalks 2-5 cm) and var. *brevirostris* (Agard) (with fruit-stalks less than 0.5 cm). Our material probably belongs to *R. cirrhosa* or (and?) *R. maritima* var. *maritima*.

Most of the material not discussed in detail here is rather well to excellently preserved. Some species, however, are represented by corroded or damaged seeds. This bad preservation is mainly the case for *Alnus glutinosa* (fruits, also a part of a fruitcone), *Humulus lupulus, Polygonum lapathifolium* (rest perigon), *Lythrum salicaria, Eupatorium cannabinum* and *Carex* sp.

Ecological indications of the plant material

The species found in the basal part of the Calais III Deposits were united into a number of ecological groups according to Arnolds & van der Meyden (1976, see also table 6):

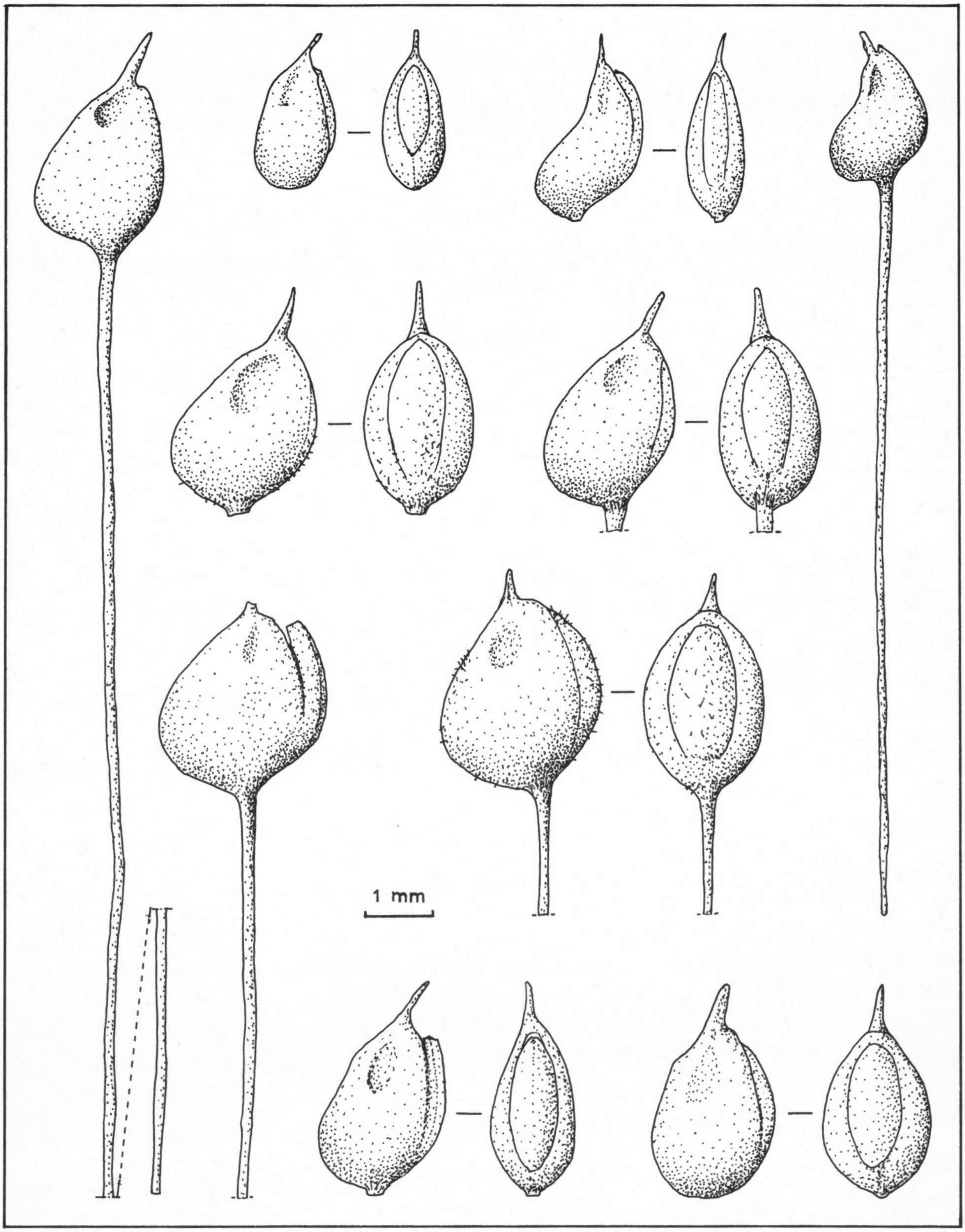

Fig. 6. Fruits of *Ruppia maritima* s. lat. from the basal part of the Calais III Deposits at Benthuizen (depth c. 7.85 m -NAP).

Afb. 6. Vruchten van *Ruppia maritima* s. lat. van de basis van de Afzettingen van Calais III te Benthuizen (diepte ca. 7.85 m -NAP).

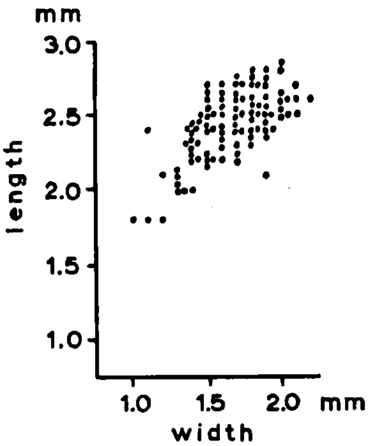

Fig. 7. Dimensions of 100 fruits of *Ruppia maritima* s. lat. from the basal part of the Calais III Deposits at Benthuizen.
Afb. 7. Afmetingen van 100 vruchten van *Ruppia maritima* s. lat. van de basis van de Afzettingen van Calais III te Benthuizen.

Group 1. Fields and dry waste places.
 e. waste places on little trodden, rich in nutrient, non-humous and non-calcareous, dry soil.
Group 2. Disturbed places or an exposed, moist to wet soil with a low humous content.
 a. places rich in nutrient with fluctuating water level or otherwise strongly fluctuating environmental circumstances.
Group 3. Seadunes, saltish waters and salt-marshes.
 a. beaches, seadunes and sandy tide marks.
 b. saltish and strongly brackish waters, mud flats and low salt-marshes.
 c. high salt-marshes and contact situations between marine and freshwater environments.
Group 4. Freshwater and banks.
 a. moderately brackish to freshwater, rich in nutrient.
 c. nutrient-rich watersides and swamps.
 d. driftzones, wet waste places and river-accompanying willow bushes.
Group 8. Forest cleanings, borders and bushes.
 b. borders on nutrient- (especially nitrogen-)rich soil, poor in carbonate, humous, moderately moist.
 d. bushes on moderately moist to dry soil, rich in nutrient.
Group 9. Woods.
 a. woods on rich in nutrient, moist to wet soils and of source levels.

Our material indicates that the group 'seadunes, saltish waters and salt-marshes' was the most important contributer to the fossil plant record. Especially *Ruppia maritima* is characteristic.

The composition of the plant material gives an idea of the communities that were present. On the site itself this was the Ruppion maritimae. Next to or mixed with it, in the same water or at a very short distance, vegetations existed, belonging to the Zosterion and the Charion. Along shores and banks the Thero-salicornion, the Thero-suaedion, the Atriplicion littoralis and the Astereta tripolii may have been present and also remote vegetations of the Potametea and the Phragmitetea.

The following reconstruction can be made now of the environmental circumstances. The basal layer was deposited in a sheltered, permanent, low-energetic water body with clear, brackish water and only minor fluctuations in the surface level. Therefore, daily fluctuations in salinity were insignificant, but annual fluctuations occurred, with a high chloride content (euhaline) during dry periods and a low chloride content (β-mesohaline) in periods with a high precipitation. Generally polyhaline or a-mesohaline circumstances may have been dominating, estimated at a chlorinity of $10^{o}/_{oo}$ with fluctuations between 5 and $15^{o}/_{oo}$. Water depth may have been some decimeters to maximally one meter. Along the shores minor changes in water level caused a marshy, saltish zone. The water-side was marked by plant remains washed ashore and here nitrogen-rich circumstances prevailed. Not far from the sampling site salinity decreased and in the hinterland probably nutrient-rich, stagnant to streaming, freshwater with marshy banks was present.

The reconstructed general picture is that of a sheltered shallow brackish lagoon in a coastal area indirectly connected with open sea. The lagoon was surrounded by an open saline landscape.

Except for the samples of the level around 7.85 m -NAP, discussed above, some further samples from the same section (fig. 2) were analysed, showing that the characteristic flora with *Ruppia maritima* is restricted to the basal part of the Calais III Deposits. Indeed many identical species are present in the higher deposits as well, but numbers and species combinations indicate different environments.

The plant remains in the samples of 7.35-4.80 m -NAP indicate a marine or brackish environment. Again species from places strongly influenced by marine circumstances, freshwater and borders. The material was undoubtedly transported by water and reworking from older deposits is possible.

The two lowermost samples indicate different conditions. Between the plant remains of the peat layer (7.95-7.90 m -NAP) no seeds were found. The sample of 8.15-7.95 m -NAP yielded some small plant remains and the seeds of four plant species from freshwater environments. This deposit (Gorkum II) originated in fresh water.

CONCLUSIONS

In the preceding chapters on flora and fauna a general reconstruction of the environment was composed. To check this picture the information was compared with the results obtained by the Rijks Geologische Dienst (J. H. A. Bosch and A. P. Pruissers, pers. comm.). These agreed well with our results and together the information lead to the following general reconstruction.

During the Atlantic the studied section was lying East of a tidal flat area, in a region with freshwater where clay and peat were deposited. In the early Subboreal a transgression reached this area. At that time the land had a relief as a result of the early Holocene peat and clay settlement. Thus, the lowest parts of the area were inundated by this Calais III transgression, forming an irregular pattern of brackish water basins. The water in each part of this area was low-energetic and sedimentation was very slow. Because of the continuing sea level rise an increasingly large area was reached and separate basins were connected resulting in a tidal flat area with some large channels and many gullies. The increasing influence of marine conditions is demonstrated by the higher salinity and the supply of sediment with marine shells. From the inlets (through the coastal barrier) to the landside of the lagoon marine influences diminished rapidly. One large tidal channel was situated at Rijswijk, Nootdorp and Zoetermeer, another one at Katwijk, Leiden and Leiderdorp. The position of the studied section was near the watershed between both channels what is reflected in the very quiet conditions of sedimentation. When sea level rise decreased the up-building of the tidal flat area went on rapidly, water depth decreased and again the water became more brackish. Finally the chloride content was so low that reed growth and peat formation started again.

ACKNOWLEDGEMENTS

We are grateful to all persons who helped us with the preparation of this paper: Mr J. H. A. Bosch (R.G.D., Alkmaar) and Mr A. P. Pruissers (R.G.D., Haarlem) for the valuable discussion and the information they provided; Mr A. W. Janssen (R.G.M., Leiden) discovered the excavation, assisted in the fieldwork and critically read the manuscript; Mr T. Meijer (R.G.D., Haarlem) identified the *Hydrobia* species and Dr P. A. M. Gaemers (Leiden) identified the otoliths.

The material described here is kept in the private collections of the authors, furthermore material from the same location is present in private collections of Mr T. Meijer and Mr M. C. Cadée (Leiden) and in the collection of the Rijksmuseum van Geologie en Mineralogie, Leiden. The drawings of the molluscs were made with a Wild M5 binocular microscope with camera lucida device.

REFERENCES

Arnolds, E. J. M. & R. van der Meijden, 1976. Standaardlijst van de Nederlandse flora 1975. Leiden (Rijksherbarium), 26 pp.

Bank, R. A., L. J. M. Butot & E. Gittenberger, 1979. On the identity of Helix stagnorum Gmelin, 1791 and Turbo ventrosus Montagu, 1803 (Prosobranchia, Hydrobiidae). - Basteria, 43: 51-60.

Beijerinck, W., 1947. Zadenatlas der nederlandse flora ten behoeve van de botanie, palaeontologie, bodemcultuur en warenkennis. - Meded. Biol. Station Wijster, 30, 316 pp.

Flora Neerlandica, 1964. Deel 1, Afl. 6: 1. Alismataceae - 15. Typhaceae.

Heukels, H. & S. J. van Ooststroom, 1975. Flora van Nederland. Groningen (Wolters-Noordhoff), 913 pp., 1038 fig.

Janssen, A. W. & E. F. de Vogel, 1965. Zoetwatermollusken van Nederland. Den Haag (Ned. Jeugdb. Natuurst.), 160 pp.

Jong, J. D. de, 1971. The scenery of the Netherlands against the background of Holocene geology; a review of the recent literature. - Revue géogr. phys. géol. dynamique, (2)13(2): 143-162.

Knörzer, K.-H., 1970. Römerzeitliche Pflanzenfunde aus Neuss. - Novaesium IV, (Limesforschungen 10), 162 pp., 23 pl.

Körber-Grohne, U., 1964. Bestimmungsschlüssel für subfossile Juncus-Samen und Gramineen-Früchte. - Probl. Küstenforsch. Südl. Nordseegebiet, 7, 47 pp., 21 pl.

Körber-Grohne, U., 1967. Geobotanische Untersuchungen auf der Feddersen Wierde. - Feddersen Wierde, I, 357 pp., 84 pl.

Koulman, J. G. & W. J. Wolff, 1977. The Mollusca of the estuarine region of the rivers Rhine, Meuse, and Scheldt in relation to the hydrography of the area. V. The Cardiidae. - Basteria, 41: 21-32.

Muus, B. J., 1967. The fauna of Danish estuaries and lagoons. - Medd. Danm. Fiskeri.-og Havundersøgelser, (N.S.)5(1): 316 pp.

Raven, J. G. M., 1979. The Subboreal coastal barriers at Leidschendam, with a description of the faunas (province of Zuid-Holland, The Netherlands). - Meded. Werkgr. Tert. Kwart. Geol., 16(1): 17-54, 6 tab., 4 fig., 5 pl.

Schäfer, W., 1962. Aktuo-paläontologie nach Studien in der Nordsee. Frankfurt a. M. (Kramer), 666 pp.

Urk, R. M. van, 1973. Systematical notes on Cardium edule L. and Cardium glaucum Brug. in the Netherlands I. - Basteria, 37: 95-112.

Verhoeven, J. T. A., 1980. The ecology of Ruppia-dominated communities in western Europe. Thesis (Kath. Univ. Nijmegen), 222 pp.

Westhoff, V. & A. J. den Held, 1975. Plantengemeenschappen van Nederland. Zutphen (Thieme), 324 pp.

Wolff, W. J., 1973. The estuary as a habitat. An analysis of data on the soft-bottom macrofauna of the estuarine area of the rivers Rhine, Meuse and Scheldt. - Zool. Verh. Leiden, 126: 1-242.

Zeist, W. van, 1974. Palaeobotanical studies of settlement sites in the coastal area of the Netherlands. - Palaeohistoria, 16: 223-371.