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LITHO- AND BIOSTRATIGRAPHICAL STUDY OF QUATERNARY DEEP MARINE DEPOSITS OF THE WESTERN BELGIAN COASTAL PLAIN

by L. DENYS, L. LEBBE, B. C. SLIGGERS, G. SPAINK,

M. VAN STRIJDONCK & C. VERBRUGGEN.

SUMMARY. - Elaborate deep borings for hydrogeological purposes in the western part of the Belgian coastal plain revealed the presence of deep marine sediments with different facies.

A combined diatom-, mollusc- and pollen investigation procurred many new and interesting data about the diatom flora and the mollusc fauna as well as about the environment and the age of the sediments. The absence of direct reference investigations preventing uniform conclusions at this stage of the investigations. A radio-carbondating and the pollen analysis showed the presence of boreal sediments at the same depth of probably older (Eemian) deposits.

RESUME. - Une série de sondages dans le cadre d'une exploration hydrogéologique dans la région de De Panne (plaine maritime belge) a démontré la présence de sédiments marins quaternaires à des profondeurs de plus de 30 m. Une explication pour les grandes différences de facies de ces sédiments ne s'avérait possible que par des recherches paléontologiques détaillées.

Ainsi, les examens des diatomées, des mollusques et des pollens ont livré un grand nombre de données nouvelles sur les compositions paléontologiques, le milieu et l'âge des couches. A l'état actuel, l'absence de recherches de références directes n'a pas permis de réunir complètement les résultats des différentes disciplines dans une même conclusion. Néanmoins, une datation C_{14} et l'analyse pollinique ont prouvé la présence de sédiments boréals à la même profondeur que des sédiments plus anciens, probablement d'âge Eemien.

INTRODUCTION.

An hydrogeological study of an unconfined aquifer was conducted in the western part of the Belgian coastal plain. Twenty mechanical drill holes and sixty auger holes werd dug in order to place piezometers. The location of these holes is shown on fig. 1. The mechanical drill holes reach the Eocene clay substratum between 30 and 40 m depth; the augering only dug into the upper part of the unconfined aquifer with a depth ranging between 6 and 10 m. The main objective of the hydrogeological study was to identify the lithostratigraphical units, to determine their areal extend and to estimate their hydraulic conductivity. In this way the pervious and semi-pervious layers in the unconfined aquifer were recognised.

In order to obtain an accurate borehole log the macroscopic features of the obtained samples were described during the drillings. The elevation of the ground surface was measured by water levelling. Grain-size analyses were conducted on selected ground samples that were representative for the different layers. In this way a lithostratigraphical profile was constructed and some informal lithostratigraphical units werd described. A possible age and genesis was deduced from the existing literature on the quaternary deposits in the western coastal plain (L. LEBBE, 1980) although there still exist many problems on this subject. The lithostratigraphical profile shows a surface lying between the levels -16 and -18. Above this surface rather homogeneous sediments (layer 4) prevail while below this level the lithological composition can change laterally very abruptly (layer 2, layer 3.1 and layer 3.2). In this study this surface is called level -17. According to the present literature the sediments above level -17 correspond to Calais deposits. The age and the genesis of the sediments below level -17 are more difficult to determine. To obtain more insight in their age and genesis a palynological, diatomic and malacological study was carried out.

LITHO- AND BIOSTRATIGRAPHICAL STUDY OF QUATERNARY DEEP MARINE DEPOSITS OF THE WESTERN BELGIAN COASTAL PLAIN.

LITHOSTRATIGRAPHY

by L. LEBBE (*)

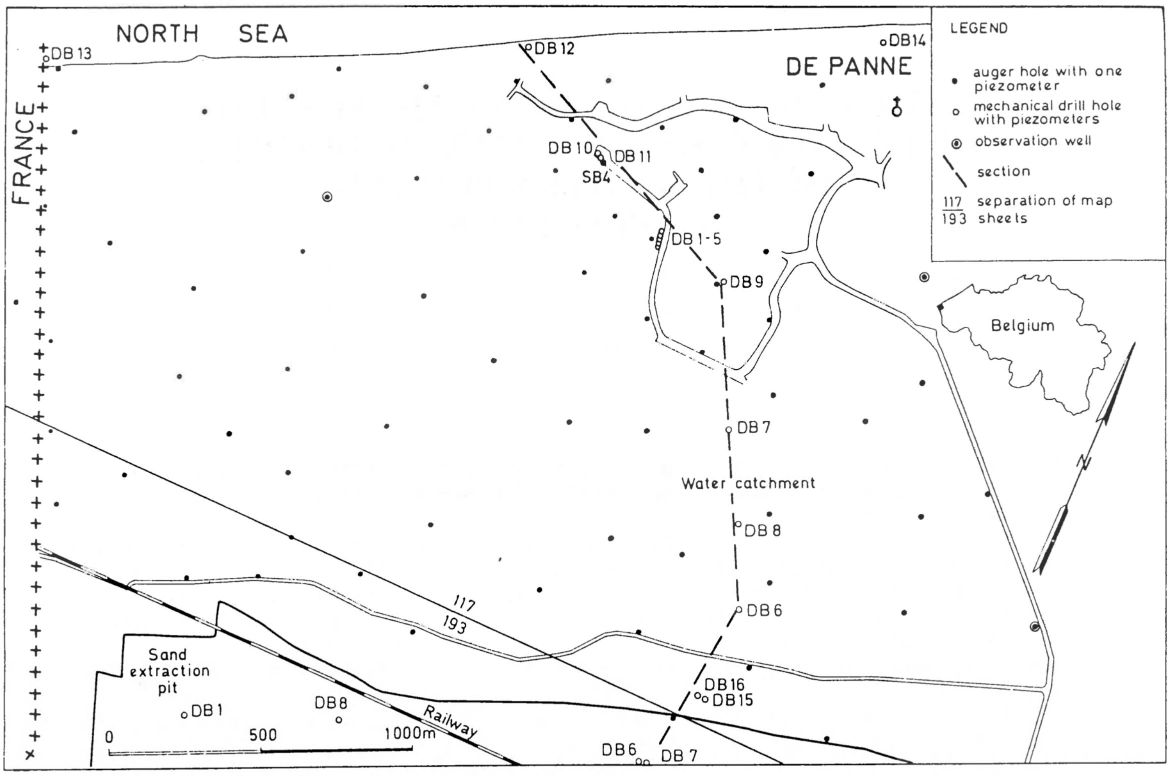

Fig. 1 - Localisation of holes and lithostratigraphical section.

This part is a summary of the lithostratigraphical study conducted in the scope of the hydrogeological study. Twinty mechanical drill holes were dug following the cable-tool method. The drilling was accomplished by regular lifting and dropping of a bailer while a casing was lowered to prevent caving of the borehole. The samples were taken at 50 cm interval. The level of the ground surface was accuratly measured by water-levelling so that we can construct a lithostratigraphical profile. All layer indicated by a number, were characterised by grain-size analyses. This gives us a first estimate of the hydraulic conductivity.

The grain-size analyses were made on samples without removal of $CaCO_3$ and organic matter. The gravel content was determined on the whole sample. They were done on 50 g of air-dry gravel-free samples (< 2 mm). The clay plus silt fraction (< 50 μm) was removed by wet sieving; when the clay plus silt fraction was larger than 5 % of the fine earth (< 2 mm), it was further separated into 50-20 μm, 20-10 μm and < 2 μm fractions by the pipette method of KÖHN. The air-dry sand fraction (2000-50 μm) was sieved on eighteen normalized TYLER-sieves with a darn ratio of $\sqrt[4]{2}$

From the results of the grain-size analyses, the mean grain-size (first moment) and the standard deviation (second moment) were calculated (S. GEETS & P. JACOBS, 1975). The specific surface (N. A. DE RIDDER & K. E. WIT, 1965) and the hydraulic conductivity were also derived from these date. For estimating the hydraulic conductivity two methods were applied : the first proposed by ERNST and the second by HAZEN. The first method was modified according to the method proposed by LEBBE (1978). The most important characteristics of the different layers are given in tabels 1 to 6.

TERTIARY SUBSTRATUM.

The top of the tertiary substratum occurs within the levels -24,5 (117 DB6) and -31,6 ☆ (117DB14). The upper boundary shows an undulating topography. The medium to coarse medium sand with shells rest on the tertiary substratum.

☆ TAW Datum level of the second general leveling (National Geographical Institute, Belgium)

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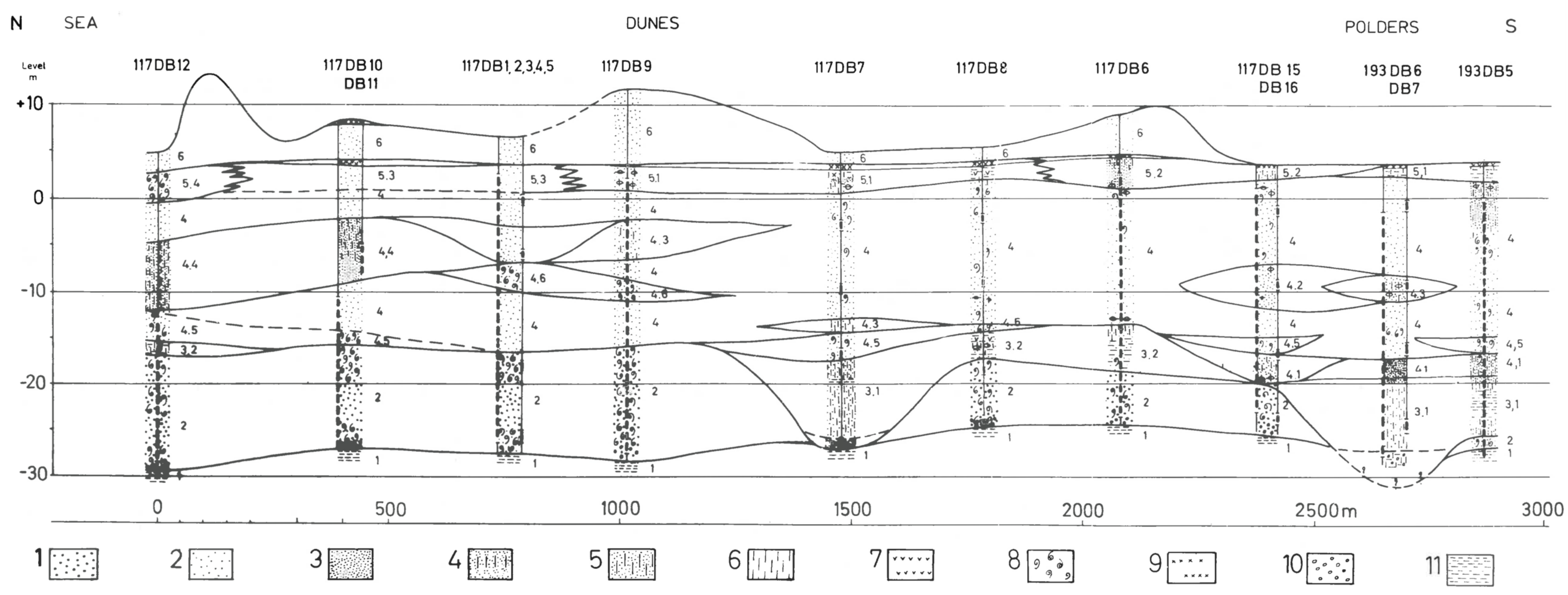

Fig. 2 _ LITHOSTRATIGRAPHICAL PROFILE

1 _ medium to coarse medium sands
2 _ medium sands
3 _ fine sands
4 _ slightly silt-bearing fine sands
5 _ silt-bearing fine sands
6 _ silt
7 _ peat
8 _ shells
9 _ humus
10 _ gravel
11 _ clay

Table 1 Characteristics of layer 2, medium to coarse medium sands (13 samples)		Mean value	Standard deviation	Max. value	Min. value
Mean grain size (first moment)	in Φ in µm	1,73 301	0,30 -	2,12 398	1,33 228
Standard deviation (second moment)	in Φ	0,68	0,22	1,01	0,30
Specific surface (2000-20 µm)		37,4	5,97	45,6	28,6
% gravel		10,7	9,6	35	0,11
Hydraulic conductivity in m/d (according to ERNST)		24,1	5,3	35,8	18,3
Hydraulic conductivity in m/d (according to HAZFN)		22,6	4,0	28,2	15,4

Table 2 Characteristics of layer 3, clay-silty complex (9 samples)		Mean value	Standard deviation	Max. value	Min. value
Mean grain size (first moment)	in Φ in µm	4,86 34,4	1,27 -	6,44 149	2,75 11,5
Standard deviation (second moment)	in Φ	3,40	0,56	4,28	2,76
Specific surface (2000-20 µm)		119	38	182	74,7
% silt (50-2 µm)		24,7	11,9	41,6	7,2
% clay (<2 µm)		13,9	7,0	25,7	5,5

Table 3 Characteristics of layer 4, medium to fine sands (24 samples)		Mean value	Standard deviation	Max. value	Min. value
Mean grain size (first moment)	in Φ in µm	2,56 170	0,14 -	2,76 221	2,18 148
Standard deviation (second moment)	in Φ	0,41	0,08	0,62	0,28
Specific surface (2000-20 µm)		63,5	5,7	70	50
Hydraulic conductivity in m/d (according to ERNST)		8,7	2,7	14,4	3,5
Hydraulic conductivity in m/d (according to HAZEN)		8,9	2,1	14,2	5,1

Lenses	4.1			4.2		4.3			4.4		4.5			4.6		
Number of examined samples	3			2		3			2		6			2		
Sample number or Statistic parameters	193DB6M28	193DB9M29	117DB7M38	117DB15M27	117DB15M35	193DB5M44	193DB6M45	117DB15M46	117DB12M33	117DB10M29	Mean value	Standard deviation	Maximum value	Minimum value	117DB1M32	117DB9M42
Mean graine size in Φ	3,14	2,99	3,05	2,76	2,86	3,01	3,02	2,81	3,41	3,65	2,06	0,20	2,31	1,87	2,00	1,91
(first moment) in µm	113	126	121	148	138	124	123	143	94	80	240	-	274	202	250	266
Standard deviation in Φ (second moment)	1,31	1,23	1,41	0,43	0,43	0,44	0,51	0,61	1,90	2,25	0,83	0,13	1,02	0,65	0,71	0,73
Specific surface (2000-20 µm)	83	78	87	73	78	87	120	80	93	96	50	8	62	39	45	42
% silt-clay (<50 µm)	4,3	4,1	7,5	3,1	2,4	4,3	8	4,3	11,6	14,9	-	-	-	-	-	-
% gravel (>2 mm)	-	-	-	-	-	-	-	-	-	-	10,1	9,1	27,6	2,0	2,7	4,0
Hydraulic conductivity in m/d according to ERNST	2,9	3,2	1,7	5,2	5,0	3,4	0,9	3,1	N.B.	N.B.	10,9	4,3	18,7	6,3	14,8	14,6
Hydraulic conductivity in m/d according to HAZEN	4,2	8,0	2,5	5,1	4,6	4,0	2,5	2,8	0,93	0,22	9,7	3,4	15,1	5,4	11,6	13,0

Table 4 - Characteristics of the lenses in layer 4.

Facies	5.1				5.2		5.3			5.4
Number of examined samples	4				2		3			1
Sample number or Statictic parameters	193DB6M3	117DB8M5	117DB7M6	117DB7M9	117DB15M3	117DB6M11	117DB10M	117DB1M	117DB9M23	117DB12M8
Mean grain size in Φ	7,42	9,10	6,29	4,69	3,45	4,06	2,58	2,64	2,56	2,31
(first moment) in µm	5,8	1,8	12,8	38,7	92	60	167	160	170	202
Standard deviation in Φ (second moment)	3,56	3,45	3,61	3,15	2,04	2,70	0,33	0,31	0,32	0,58
Specific surface (2000-20 µm)	180	154	163	123	98	113	62	64	61	53
% silt	54,0	50,3	44,5	34,6	12,1	15,1	-	-	-	-
% clay	27,5	48,8	19,9	8,2	3,2	6,9	-	-	-	-
% gravel	-	-	-	-	-	-	-	-	-	17
Hydraulic conductivity in m/d according to ERNST	-	-	-	-	-	-	10,6	8,0	10,6	14,3
Hydraulic conductivity in m/d according to HAZEN	-	-	-	-	-	-	11,0	10,5	11,1	13,0

Table 5 - Characteristics of the facies in layer 5.

LAYER 2 : MEDIUM TO COARSE MEDIUM SANDS.

These sands occur almost everywhere in the study area, except at the borings 117DB7 and 193DB6. The thickness of these layers varies between 6 and 12 while their upper boundary is situated between levels -15,5 and -18,5. Table 1 gives the characteristics derived from the grain-size analyses.

LAYER 3 : CLAY-SILT COMPLEX.

A clay-silt complex (layer 3) overlies the medium to coarse medium sands (layer 2). The composition, the thickness and the level of this complex vary significantly from place to place. In the northern part of the area it is almost completely absent except in borings 117DB12 and 117DB14. These is a ca. 2 m thick silty sand layer in which shell waste and clay-silt lenses occur. The upper part consists of silts, 0,1 m to 0,5 m thick, with thin clay layers of a few centimeters. In the southern part of the area the clay-silt complex occurs more frequently and shows strong differences in thickness and facies. In boring 117DB7 layer 3 rests directly on the tertiary substratum. The deposit lies between the levels -17,3 and -26,8. The lower part of the sediment is sandy silt, 2,5 m thick, with shell waste, clay pieces and gravel at the base. The middle part is a 4,5 m thick silt layer covered by some clay. The upper part is a siltbearing sand to a sandy silt which becomes more granulated at the top. At this location, lenses of silt with organic matter and very small pale shell pieces are also present. In the south, in borings 117DB6 and 117DB8, the deposit is only 3 to 4 m thick and is located between levels -18 and -14. This layer consists of an alternation of silt and strongly silt-bearing sands. In the borings 117DB15 and 117DB16 this layer is reduced to lenses of silt at the level -16.

The thickness of the layer increases again in the southern part of the study area (193DB5, 193DB6 and 193DB7). It consists of heavier material and lies between the levels -19 and -27. In boring 193DB5 the layer changes gradually into the underlying layer 2. In boring 193DB6 layer 3 rests upon a very heterogeneous deposition of sand, clay and silt mixed with organic matter. The tertiary clay substratum was not reached at this location. In borings 193DB1 and 193DB8 layer 3 was not observed.

From a hydrogeological viewpoint it can be concluded that there are mainly two kinds of facies : a silty one (3.1), between the levels -14 and -18 with a maximum thickness of 4 m and a rather small hydraulic resistance, and a clayey one (3.2), between the levels -17 and -27 with a maximum thickness of 10 m and a large hydraulic resistance. The grain-size characteristics of layer 3 are given in table 2.

LAYER 4 : MEDIUM TO FINE SANDS.

This deposit rests on layer 2 or on layer 3. The basis is situated between the level -14,5 and -17,5; the top is found between +1 and +3. Layer 4 consists mainly of well sorted medium to fine sands (table 3). In the southern part of the study area this deposit tends to be slightly finer in grain-size. Lenses with slightly different composition occur : lenses 4.1 and 4.2 contains fine sand, lens 4.3 has small amounts of siltbearing fine sand, lens 4.4 contain siltbearing fine sand and finally lenses 4.5 and 4.6 with medium shell bearing sand (tabel 4).

LAYER 5 : CLAY-SILT-SAND COMPLEX.

This sediment overlies layer 4 throughout the study area. The top is located at about +4 and reaches the surface in the southern part of the region. This layer was found in the twenty borings which penetrate into the Eocene clay substratum and in the sixty handborings of the hydrogeological study (L. LEBBE & R. DE CEUNINCK, 1980).

Four facies can be distinguished. The first, 5.1, is a clay or a clay-silt layer with a thickness between 0,2 and 1,0 m which rests in strongly siltbearing sands, which become more sandy downwards. In some borings peat underlies the clay, in others a humusrich or a peaty soil layer is found on top of the clay.

The second facies, 5.2, is mainly a strongly siltbearing fine sand with silt- and clay lenses (less than 0,1 m thick). In most cases, a humusbearing or peaty soil layer is found on top.

The third facies, 5.3, occurs under the dunes in the northern part of the area and is formed by very well sorted fine sands. Finally, at the seaside under the fore-dunes and under the back-shore in the eastern part, the fourth facies 5.4 occurs. It is formed by a bank of pale, rubiginous shells and shellwaste. The characteristics of the four facies are given in tabel 5.

LAYER 6 : WELL SORTED FINE MEDIUM SANDS.

These sediments occur from the surface in the dunes to a depth corresponding with level +4. Within this layer different brown bands of light humus bearing sands can occur at several levels. The beach sands are less well sorted and slightly finer than the sands of the dunes (tabel 6).

Table 6
Characteristics of layer 6, well sorted fine medium sands

		underneath the dunes (7 samples)				underneath the beach
		Mean value	Standard deviation	Max. value	Min. value	
Mean grain size (first moment)	in Φ	2,34	0,07	2,44	2,25	2,49
	in μm	198	-	210	184	178
Standard deviation (sedond moment)	in Φ	0,31	0,04	0,39	0,28	0,40
Specific surface (2000-20 μm)		53	2	56	51	59
Hydraulic conductivity in m/d (according to ERNST)		13,5	3,2	16,7	7,2	11,9
Hydraulic conductivity in m/d (according to HAZEN)		13,8	1,8	15,8	11,1	11,6

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LITHO- AND BIOSTRATIGRAPHICAL STUDY OF QUATERNARY DEEP MARINE DEPOSITS OF THE WESTERN BELGIAN COASTAL PLAIN.

DIATOM ANALYSIS

55148

by L. DENYS (*)

INTRODUCTION AND METHODS.

Twenty-six samples from ten borings were placed at our disposal for diatom analysis. Only eleven of them were found to contain more or less well-preserved diatom frustules (tab. 1).

BORING	SAMPLE	DEPTH (m)	DIATOMS
117DB5	M56	28	
117DB6	M61	30.5	
117DB7	M40	20	+
"	M49	24.5	+
"	M58	29	+
"	M64	32	+
117DB8	M42	21	+
"	M61	30.5	
117DB9	M70	35	
"	M79	39.5	
117DB10	M68	34	
117DB12	M41	20.5	
"	M43	21.5	
"	M50	25	
"	M64	32	
117DB14	M28	14	+
"	M44	22	
"	M63	31.5	
"	M68	34	
193DB5	M51	25.5	+
"	M54	27	
"	M61	30.5	
193DB6	M24	12	+
"	M36	18	+
"	M60	30	+
"	M65	32.5	+

Table 1 - Examined samples.

Small amounts of sediment from these samples were treated with 30% H_2O_2 and $KMnO_4$ according to the method of VAN DER WERFF (1955) for removal of organic matter and with 0,1 N HCl for removal of lime particles. Only sand was removed by means of decantation. No attempts were made to get rid of smaller particles, since then small valves may be lost also. Slides of the residue were made using Cumaron (nD : 1.65) and examined qualitatively and quantitatively by means of a Leitz Orthoplan microscope equipped with Nomarski differential interference contrast optics.

Based on counts of at least 300 valves, relative percentages for the taxa were calculated (tab. 4) which were used to construct certain ecological spectra. The halobion system of VAN DER WERFF & HULS (1957-1974)(tab. 2) was applied for

	Cl^- (mg/l)	salinity (mg/l)
MARINE	>17000	>30000
MARINE-BRACKISH	10000-17000	18000-30000
BRACKISH-MARINE	5000-10000	9000-18000
BRACKISH	1000-5000	1800-9000
BRACKISH-FRESH	500-1000	900-1800
FRESH-BRACKISH	100-500	180-900
FRESH	<100	<180

Tab. 2 - The halobion system of VAN DER WERFF & HULS (1957-1974).

the salinity spectra (fig. 1). Benthonic, epontic (sessile) and planktonic taxa were distinguished in the habitat spectra (tab. 3). Aerophilous, pseudampotiphilous (tidal zone diatoms) and ampotixenous forms (diatoms preferring permanent inundation) were used to infer tidal flat conditions (tab. 3). The composition of the last two groups was based mainly on the work of SIMONSEN (1962). The ratio of allochtonous fresh water diatoms to autochtonous salt water taxa was calculated as in BEYENS & DENYS (1982) (tab. 3). The percentage of euryhaline forms was used as an indication of short term salinity variations during deposition (tab. 3).

RESULTS.

SALINITY (Fig. 1)

Sample 117DB14/M28 was found to be deposited in a typically marine environment where fresh water influence was very low (F : 0.05); Deposition of samples 193DB6/M36, 117DB7/M40/M58 and M64 occurred in a marine to marine-brackish milieu, with probably stronger salinity variations for 117DB7/M64 (58% euryhaline forms, tab. 3).

Somewhat lower palaeosalinities were found for 117DB7/M42 (marine-brackish to marine), 117 DB/M42 and 193DB6/M24 (both

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marine-brackish). Sample 193DB6/M24 contains a very high percentage of euryhaline taxa (69 %). However, salinity does not seem to have fluctuated much beyond the marine-brackish to marine region. Samples 193DB6/M60/M65 and 193 DB5/M51 show rather high percentages of fresh-brackish and brackish forms, probably due to a higher influx of allochtonous valves from less saline areas during sedimentation or coring technique.

WATERDEPTH AND TIDAL INFLUENCE (tab. 3).

Benthonic and epontic (especially epipsamnic) taxa dominate the habitat spectra. Percentages of planktonic forms are always low and generally less than ten percent. Ampotixenous forms are always scarce. Aerophilous and pseudampothiphilous forms are generally well represented. Together this points to rather undeep water and sedimentation between tidal limits. Typical tidal flat associations are found in samples 193DB6/M24/M36, 117DB7/M40/M49 and 117DB14/M28; this character is less pronounced in samples 117DB7/M58 and M64. Although 117DB/M42 scores low values for aerophilous (17%) and pseudampotiphilous forms (12%), tidal flat origin should not be excluded. *Nitzschia granulata* makes up more than 36 % of all diatoms in this sample. SIMONSEN (1962) does not classify this species in his system regarding tolerance of tidal zone conditions, but it is known to occur on shores, flats and salt marshes (GIFFEN, 1970; HENDEY, 1964; HUSTEDT, 1939; SULLIVAN, 1975, 1978). Samples 193DB6/M60/M65 and 193DB5/M51 may have been deposited in a slightly less shallow environment than the other samples.

FLORISTICS AND CHRONOLOGY.

Most diatoms found in the samples are normal constituents of the present-day littoral flora of the southern North Sea and are found more or less frequently in the Flandrian deposits at our coast. However, some exceptions have to be made. A number

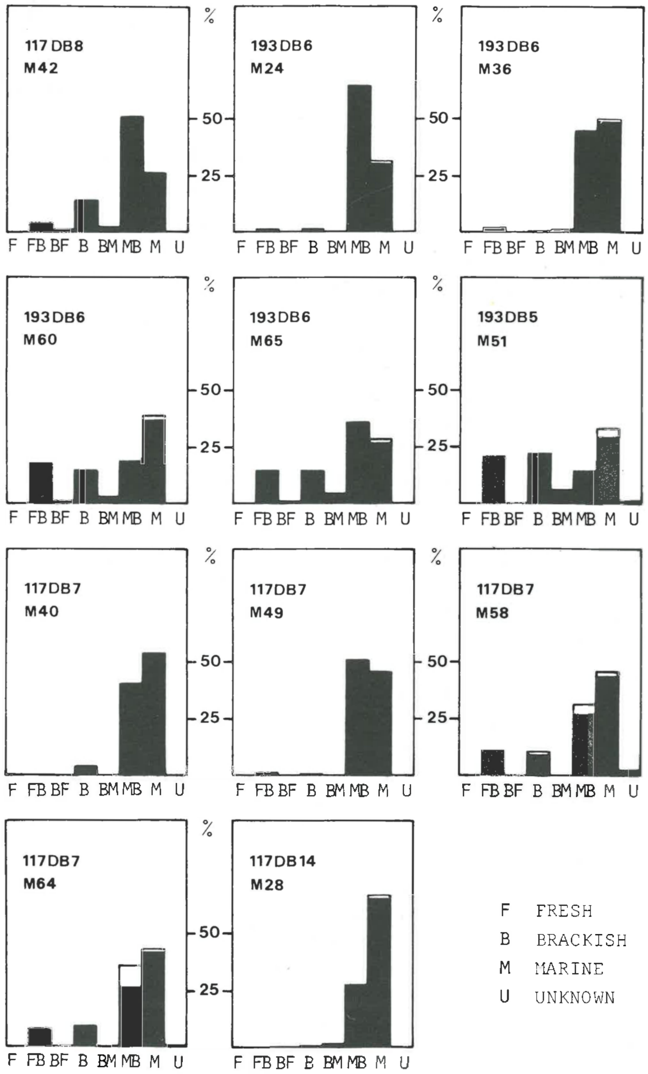

Fig. 1 – Salinity spectra. Blank sections of the colums represent uncertain entries.

	% Aerophilous	% Pseudampotiphilous	% Ampotixenous	% Euryhalinous	% Benthonic	% Epontic	% Planktonic	F-value
117DB8 M42	17	12	<1	33	80	16	4	0.26
193DB6 M24	84	66	2	69	28	69	2	0.03
193DB6 M36	77	42	3	47	44	48	8	0.05
193DB6 M60	37	10	3	37	62	25	13	0.72
193DB6 M65	32	17	2	51.	54	34	12	0.55
193DB5 M51	24	6	5	45	57	37	6	
117DB7 M40	54	39	1	46	52	42	6	0.05
117DB7 M49	49	47	1	49	46	52	2	0.02
117DB7 M58	35	23	3	39	64	32	4	0.27
117DB7 M64	34	23	1	58	65	30	5	0.22
117DB14M28	61	26	0	32	66	27	7	0.05

Table 3 – Percentages of several groups reflecting local ecological conditions during sedimentation and ratio of "allochtonous" freshwater taxa to "autochtonous" salt water taxa (F-value).

Tab. 4: Relative percentages of the observed diatoms (+: present but not counted) (continued).

Ecology	Boring...........................	117 DB8	193 DB6				193 DB5		117 DB7			117 DB14
	Sample...........................	M42	M24	M36	M60	M65	M51	M40	M49	M58	M64	M28
	Number of valves counted.........	420	386	348	330	345	382	356	404	385	459	433
5,2,e	*Achnantes brevipes* Ag.				+	1.5	+	+				+
4,1,e	*A. delicatula* (Kütz.) Grun. (1)	0.5	1.3	0.6	5.8	4.4	10.0		0.3	6.5	7.6	0.5
1,1	*A. exigua* Grun.						0.3			+		
7?,2	*A. groenlandica* (Cl.) Grun.										+	
2,2	*A. lanceolata* (Bréb.) Grun.			0.3	0.3		0.3					
7,1	*A. lilljeborgii* Grun.										+	0.2
4,1	*A. linkei* Hust.									+	+	
1,2	*A. minutissima* Kütz.										+	
7,3	*Actinocyclus ehrenbergii* Ralfs	+		+						+	+	+
7,3	*A. kützingii* (Schmidt) Sim.					0.3						
6,3,e	*Actinoptychus senarius* Ehr.	0.2	0.3	1.2	0.6	1.5	0.3	0.6	1.0	0.5	0.7	0.7
7,3	*A. splendens* (Shadb.) Ralfs		0.3	0.6		+		0.6	+		+	+
4,1,e	*Amphora coffaeiformis* (Ag.) Kütz. (2)			+	+	+	0.3		0.3	+	0.4	
7?,1,am	*A. crassa* Greg.										+	
7-6,1,a	*A. dubia* Greg.					0.3						
7-6,1,a	*A. exigua* Greg.				0.3		0.5					
2,1	*A. libyca* Ehr.				+						+	
2,1	*A. ovalis* Kütz.	0.2	+	+	0.6	1.7	0.8			1.8	1.3	
2,2	*A. pediculus* (Kütz.) Grun.		1.0	0.9		0.6	2.9					
7,1	*A. pusio* Cl.									+		
	A. sp.									+		
7,1	*A. turgida* Greg.									+	0.7	
2-3,1,e	*Anomoeoneis sphaerophora* (Kütz.) Pfitzer											+
7,1-3,e	*Aulacodiscus argus* (Ehr.) Schmidt	+	0.3	+	+	+	0.3	+				+
7,1	*Auliscus sculptus* (W. Sm.) Ralfs				+		+		0.3		+	+
2,3,e	*Bacillaria paradoxa* Gmelin						+					
7,3-2	*Biddulphia aurita* (Lyngb.) Bréb. & Godey			1.2	+	0.3		0.3	+			
7,1	*B. rhombus* (Ehr.) W. Sm.		0.5	0.6	+	0.6	0.3	+	0.3	0.5	0.2	0.5
3,1	*Caloneis permagna* (Bailey) Cl.				0.3							
4,1	*C. westii* (W. Sm.) Hendey	0.2		+				+				
4,1,a	*Campylodiscus clypeus* Ehr. var. *bicostatus* (W. Sm.) Hust.						0.3					
4,1,a	*C. echeneis* Ehr.	+		+	0.3	0.9	0.3					+
7,1-3,a	*Campylosira cymbelliformis* (Schmidt) Grun.		0.5	0.9	0.3	0.3		0.6				3.9
7,1-3	*Cerataulus smithii* Ralfs		+	+		+						0.5
7,1,am	*C. turgidus* Ehr.										+	
7?,1	*Cocconeis britannica* Naeg.										+	
7,1,am	*C. clandestina* Schmidt									+		
7?,1	*C. costata* Greg.				1.8	0.6	2.4			1.3	0.4	
7?,1	*C. debesi* Hust.		0.3	0.3				0.8		+	0.7	0.7
2,1-2	*C. diminuta* Pant.	0.2						0.3				
7,1,am	*C. distans* Greg.									0.3	0.2	
7?,1	*C. fluminensis* (Grun.) Perag.										+	
7?,2	*C. molesta* Kütz.										+	
3,2	*C. pediculus* Ehr.			+								
7?,2,am	*C. pelta* Schmidt		1.3	0.9		0.6	1.3			0.3	0.2	+
6,1,e	*C. peltoides* Hust.									+	0.4	
7?,1,am	*C. pinnata* Greg.										+	
2,2,e	*C. placentula* Ehr.	0.2		+	0.9	4.1	7.6			+	0.2	
2,2	*C. p.* var. *euglypta* (Ehr.) Cl.								0.3	0.3	0.2	+
7,1,am	*C. pseudomarginata* Greg.										+	
7,1,am	*C. quarnerensis* Grun.									+	+	
6,2,e	*C. scutellum* Ehr.	1.7		0.3	4.6	7.0	7.3		+	0.8	0.4	+
6,2,e	*C. s.* var. *parva* (Grun.) Cl.				+	0.3	1.3	0.3			+	
7?,1?	*C. s.* var. *speciosa* (Greg.) Cl.- E.									0.3	+	
	C. sp. 1									+	+	
	C. sp. 2						1.3					
2,2	*C. thumensis* Mayer										+	
7,3	*Coscinodiscus argus* Ehr.			+								
7,3	*C. centralis* Ehr.						0.3					

Ecology	Boring	117 DB8		193 DB6			193 DB5		117 DB7			117 DB14
	Sample	M42	M24	M36	M60	M65	M51	M40	M49	M58	M64	M28
	Number of valves counted	420	386	348	330	345	382	356	404	385	459	433
7,3	*C. cf. curvatulus* Grun.					0.3						
7,3	*C. lineatus* Ehr.			0.3								
7,1	*C. nitidus* Greg.									+	+	+
7,1-3	*C. oculus-iridis* Ehr.	+		0.3				0.8				+
7,3	*C. perforatus* Ehr. var. *cellulosa* Grun.											+
7,1-3	*C. radiatus* Ehr.			+								+
4,3,e	*C. rothii* (Ehr.) Grun. var. *subalsa* (Juhl.- Dannf.) Hust.	0.2			+	1.7		0.6		0.5	0.2	0.5
3,3	*Cyclotella menenghiniana* Kütz.									+	0.2	
4,3,e	*C. striata* (Kütz.) Grun.	0.2		+	1.2	1.5	+	1.7		+		+
7,4,a	*Cymatosira belgica* Grun.	2.1	16.8	31.6	16.7	6.4	12.0	11.5	1.0	8.8	7.6	29.3
2,1-2	*Cymbella aspera* (Ehr.) Cl.										+	
2,1	*C. caespitosa* (Kütz.) Brun				0.3							
2,1	*C. sinuata* Greg.										+	
2,1	*C. tumida* (Bréb.) V. Heurck									+		
2,1	*C. ventricosa* Ag. (incl. *C. turgida* Greg.)								0.3			
3,3	*Diatoma elongatum* (Lyngb.) Ag.										+	
7,1	*Dimerogramma marinum* (Greg.) Ralfs								+			+
7,1,a	*D. minor* (Greg.) Ralfs				+	0.6	0.3	0.6		+	+	+
7,1,a	*D. m.* var. *nana* (Greg.) V. Heurck			0.9			0.3					+
5,1,e,a	*Diploneis aestuarii* Hust.		0.5	0.9	0.3	+		0.3		+		1.8
7,1	*D. bombus* Ehr.	0.2	+	0.3	0.9	0.9	1.8					+
7?,1,am?	*D. coffaeiformis* (Schmidt) Cl.		0.3									
7,1	*D. crabro* Ehr.	+	+				+	+		+	+	
6,1,e	*D. didyma* (Ehr.) Cl.	1.2	0.5	+	+	1.5	+	1.1	+	+		0.2
7,1-3	*D. fusca* (Greg.) Cl.		+				0.3	0.3			+	+
7,1-3	*D. incurvata* (Greg.) Cl.								+			
4,1,e	*D. interrupta* (Kütz.) Cl.	0.5		+		+		0.3			+	
7,1	*D. lineata* (Donk.) Cl.										+	
7,1	*D. litoralis* (Donk.) Cl.			+							+	
6,1,e	*D. smithii* (Bréb.) Cl.	1.0	0.3			+		0.3		+		0.2
6,1,e	*D. s.* var. *pumila* (Grun.) Hust.									+		
7,1	*D. weisflogii* (Schmidt) Cl.		0.3	+				+				+
2,2	*Epithemia sorex* Kütz.									+		
2,2	*E. turgida* (Ehr.) Kütz.					0.3	+			+		
2,2	*E. zebra* (Ehr.) Kütz.										+	
7,1	*Eunotogramma dubium* Hust.			0.3						0.5	0.7	
2,1-3	*Fragilaria brevistriata* Grun.						0.3	+		+	+	
2,1-3	*F. b.* var. *inflata* (Pant.) Hust.				+							
2,1-2-3	*F. capitata* (Ehr.) Lange - Bert.									+		
2,1-3	*F. construens* (Ehr.) Grun.				3.6					0.3		
2,1-3	*F. c.* var. *binodis* (Ehr.) Grun.				0.3						0.2	
2,2	*F. c.* var. *subsalina* Hust.				+	0.3	1.3					
2,2-3	*F. c.* var. *venter* (Ehr.) Grun.	0.2		0.6	1.8	0.9	0.5		0.7	3.6	3.9	
2,1-3	*F. inflata* (Heid.) Hust.	0.2				+						
5?,2	*F. investiens* (W. Sm.) Cl. - E.									0.5		0.2
1,1	*F. leptostauron* (Ehr.) Hust.										+	
	F. cf. nitzschioides Grun.									+		
2,1-3	*F. pinnata* Ehr.				2.1	1.2	4.2			1.6	0.2	
3,2-3,e	*F. pulchella* (Ralfs) Lange - Bert.									+		+
5,2,e	*F. tabulata* (Ag.) Lange - Bert.	+			+	+		+			+	
5,2,e	*F. t.* var. *obtusa* (Pant.) Lange - Bert.						0.3				0.2	
4,2,e	*F. t.* var. *truncata* (Grev.) Lange - Bert.							+		0.3		
7,1	*Glyphodesmis distans* (Greg.) Grun.											+
2,2	*Gomphonema lanceolatum* Ag.									0.3		
2,2	*G. olivaceum* (Lyngb.) Desmazières									+	0.2	
7,2-3	*Grammatophora angulosa* Ehr.	0.2	+	0.3	0.6					+	+	0.9
7,2,am	*G. arcuata* Ehr.										+	
7,2,am?	*G. oceanica* (Ehr.) Grun.			+	2.1			0.3	+		0.2	+
7,2,am?	*G. o.* var. *macilenta* (W. Sm.) Grun.	0.2				1.7	2.6	0.3	0.5	0.3	+	+
7,2,am?	*G. o.* var. *m.* f. *nodosa* (Grun.) Hust.									+		

Ecology	Boring	117 DB8		193 DB6			193 DB5		117 DB7			117 DB14
	Sample	M42	M24	M36	M60	M65	M51	M40	M49	M58	M64	M28
	Number of valves counted	420	386	348	330	345	382	356	404	385	459	433
7,2-3	*G. serpentina* (Ralfs) Ehr.							+	0.5	+	+	
	G. sp.									+		
4,1,a,ps	*Gyrosigma balticum* (Ehr.) Rabenh.				+							
5,1	*Hantzschia virgata* (Roper) Grun.										+	
6,2,e	*Hyalodiscus scoticus* (Kütz.) Grun.								4.0	1.3	1.3	
7,2	*Isthmia enervis* Ehr.								+	+	+	
6,1,e	*Mastogloia pumila* (Grun.) Cl.						0.3					
2,3	*Melosira ambigua* (Grun.) Müll.	1.2			3.0	3.5	+					
2,3	*M. granulata* (Ehr.) Ralfs			+	+		1.1					
5,2-3	*M. moniliformis* (Müll.) Ag.						1.6					
7,3	*M. sol* (Ehr.) Kütz.									+		
7,4	*M. sulcata* (Ehr.) Kütz.	19.8	5.4	4.9	7.9	9.0	4.7	21.1	40.8	27.8	26.6	24.9
7,4	*M. westii* W. Sm.	0.2	1.6	0.9	0.3	1.2	0.3	12.6	1.0	+		1.8
2,3	*Meridion circulare* (Grev.) Ag.				+							
6,1,e,a	*Navicula abrupta* (Greg.) Donk.			+	+	0.3					+	
6,1,e	*N. arenaria* Donk.						1.1			1.3	0.7	
4,1,e,a	*N. avenacea* (Bréb.) Cl.				0.6	0.3						
7,1,a	*N. cancellata* Donk.											0.5
2,1	*N. capitata* Ehr. var. *hungarica* (Grun.) Ross									+		
2,1,e,a	*N. cari* Ehr. var. *cincta* (Ehr.) Lange - Bert.	1.0		0.6	3.0	1.2	0.3			0.5	0.9	0.5
4,1,e	*N. clementis* Grun.									+	+	
6?,1	*N. cluthensis* Greg.										+	
2-3,1	*N. costulata* Grun.				0.3	0.3						
7,1,a	*N. crucifera* Grun.									+	+	
2,1	*N. cryptocephala* Kütz.									+		
2,1	*N. dicephala* Ehr.				0.3		0.3			+		
4,1,e,a	*N. digitoradiata* (Greg.) Ralfs					0.6						
7?,1,am	*N. directa* (W. Sm.) Ralfs									+		
7,1	*N. distans* (W. Sm.) Ralfs										+	
7,1,a	*N. finmarchica* (Cl. & Grun.) Cl.										+	
6,1,a	*N. forcipata* Grev.				0.3	0.3	0.3			0.3		+
4,2,e	*N. gracilis* Ehr. var. *neglecta* (Thwaites) Grun.				2.1	0.3	2.6			1.3	1.3	
4,1	*N. gregaria* Donk.										+	
4,1	*N. halophila* (Grun.) Cl.			+								
7,1,a,am	*N. hennedyi* W. Sm.											+
6,1,e	*N. humerosa* Bréb.								+	+	+	
5?,1	*N. integra* (W. Sm.) Ralfs									+		
7?,1	*N. maculosa* Donk.											+
3,1,a	*N. mutica* Kütz.				0.3	+						+
3,1,a	*N. m.* var. *cohnii* (Hilse) Grun.									0.3		
2-3,1,a	*N. m.* var. *nivalis* (Ehr.) Hust.				+							
7,1,e	*N. palpebralis* Bréb.			+								+
6?,1	*N. diserta* Hust.									4.4	11.3	
4?,1,e	*N. cf. nolens* Sim.									1.6		
4,1,e	*N. peregrina* (Ehr.) Kütz.			+			0.3					
3,1	*N. protracta* (Grun.) Cl.										+	
2,1	*N. pseudolanceolata* Lange - Bert.						+			+	0.2	
2,1	*N. radiosa* Kütz.				0.3		0.3				+	
4,1	*N. rostellata* Kütz. (3)			+			0.3			0.5		
4,1,e	*N. salinarum* Grun.				0.3		0.3				+	
7,1	*N. scoliopleura* Schmidt										0.2	
2,1	*N. scutelloides* W. Sm.					+						
	N. sp.									2.1		
6?,1	*N. subforcipata* Hust.									+		
2,1	*N. viridula* (Kütz.) Ehr.						0.3			0.3		
6,1,e	*Nitzschia acuminata* (W. Sm.) Grun.			+	0.6	0.9	+				+	+
4,1	*N. commutata* Grun.				0.6		0.3					
5,1,e	*N. compressa* (Bailey) Boyer	1.4	+	+	2.1	3.2	3.9	0.3			+	+
2,1	*N. denticula* Grun.				+							
6,1	*N. granulata* Grun.	36.7			1.8	6.7	+				+	+

Ecology	Boring	117 DB8		193 DB6			193 DB5		117 DB7			117 DB14
	Sample	M42	M24	M36	M60	M65	M51	M40	M49	M58	M64	M28
	Number of valves counted	420	386	348	330	345	382	356	404	385	459	433
4,1	*N. hustedtiana* Salah				2.7	1.7	6.0					
4,1,e	*N. navicularis* (Brêb.) Grun.	14.3	+	+	0.6	2.0	0.3	1.4		+	+	+
5,1,a	*N. obtusa* W. Sm.				+							
7,1,e,a	*N. panduriformis* Greg.	0.2	+	0.6	3.0	1.2	1.6	0.3			0.4	0.5
3,1,e,a	*N. sigma* (Kütz.) W. Sm.	+	+	+	+	+				+		+
2,1	*N. sociabilis* Hust.				0.6							
3,1,e	*N. tryblionella* Hantzsch	0.5		0.3	0.6	1.2						
7,1	*Opephora marina* (Greg.) Petit									+		
2,1	*O. martyi* Hérib.	1.0			0.6	1.2	0.3		0.3	1.0	1.1	
7,1,a	*O. pacifica* (Grun.) Petit	+			1.2	0.3	0.8		0.5	1.8	1.5	
7,1,a	*Pinnularia cruciformis* (Donk.) Cl.			+								
7,1	*Plagiogramma laevis* (Greg.) Ralfs				0.6						+	
7,1,a	*P. staurophorum* (Greg.) Heib.	0.2				0.3	0.3		0.7	0.5	0.9	+
7,1	*P. vanheurckii* Grun.			0.6	0.9	1.2				1.0	0.4	
7,1	*Pleurosigma affine* Grun.											0.2
7?,2	*Podosira hormoides* (Mont.) Kütz.					0.3						
7,2-3	*P. steliger* (Bailey) Mann	2.6	1.6	1.2	+	0.9	1.1	3.1	+	+	1.2	
7,2,am	*Rhabdonema adriaticum* Kütz.				+	+	+		+		+	
7,2,am	*R. arcuatum* (Lyngb.? Ag.) Kütz.									+	+	
7,2,am	*R. minutum* Kütz.		0.5	1.7	0.9		1.3	0.3				+
6,2,e,a,ps	*Rhaphoneis amphiceros* Ehr.	4.3	21.8	18.7	4.6	5.5	0.5	12.9	7.4	2.1	2.4	7.9
6,2,e,a,ps	*R. minutissima* Hust.	0.5	0.5	3.2	4.6	5.5	5.0	0.3				2.5
7?,2	*R. nitida* (Greg.) Grun.										+	
6,2,e,a,ps	*R. surirella* (Ehr.) Grun.	5.5	43.3	20.1		5.5	0.5	25.0	39.1	20.5	20.7	14.6
7,3	*Rhizosolenia setigera* Brightwell			+						+	+	+
2,2	*Rhoicosphenia curvata* (Kütz.) Grun.				0.3		+			+		+
2,1	*Rhopalodia gibba* (Ehr.) Müll.										+	
4,1	*R. gibberula* (Ehr.) Müll.	+		+	0.3	2.0	1.3			+		
4,1,e	*R. musculus* (Kütz.) Müll.				0.3					+		
5,1,a,ps	*Scoliopleura tumida* (Brêb.) Rabenh.	0.7	+	+	0.3	+						+
7,1	*Scoliotropis latestriata* (Brêb.) Cl.									+		
5,1,e	*Stauroneis amphioxys* Greg.				0.6	0.3	0.5					+
2,3	*Stephanodiscus astraea* (Ehr.) Grun. var. *minutula* (Kütz.) Grun.										+	
7,2-3,e,am	*Striatella delicatula* (Kütz.) Grun.									2.1	0.7	
7,1	*Surirella fastuosa* Ehr.				+		0.3		+	+		
5,1,a	*S. gemma* Ehr.				+							
5,1	*S. ovalis* Brêb.				+							
2,1,a	*S. ovata* Kütz.						0.3					
2,1,a	*S. o.* var. *crumena* (Brêb.) Hust.				+							
6,1,am	*Synedra crystallina* (Ag.) Kütz.	+			+	+	+				+	
2,1-3	*Tabellaria fenestrata* (Lyngb.) Kütz.										+	
7,3,e	*Thalassionema nitzschioides* Grun.		+		+	0.3		0.3	0.5	+	0.2	2.3
7-6,3	*Thalassiosira decipiens* (Grun.) Jørg.	0.2	0.3	2.9	3.3	0.9	0.3			0.3	0.4	+
6,1-3	*T. excentrica* (Ehr.) Cl.	+	0.5	0.3		0.3		+				1.6
7,3	*T. nordenskioeldii* Cl.			0.3						+	0.2	
7,1,a	*Trachyneis aspera* (Ehr.) Cl.	+			0.3	0.6	0.5	+		+	+	0.5
7,2-3	*Triceratium alternans* Bailey				+	0.3	+					0.2
7,1	*T. antediluvianum* (Ehr.) Grun.	+			+	+	+	+			+	
7,1-3	*T. favus* Ehr.		+	+	+			+			+	+
7,2-3	*T. reticulum* Ehr.											+
	Indeterminata (*Centrales*)											0.5
	Indeterminata (*Pennales*)										1.1	

(1) sensu LANGE-BERTALOT & RUPPEL (1980)
(2) sensu VAN LANDINGHAM (1967)
(3) sensu BROCKMANN (1950)

Ecology: 1st number (salinity group):
1 fresh
2 fresh-brackish
3 brackish-fresh
4 brackish
5 brackish-marine
6 marine-brackish
7 marine

2nd number (habitat):
1 benthonic
2 epontic
3 planktonic
4 generally benthonic, facultatively planktonic

e: euryhaline
a: aerophilous
am: ampotixenous
ps: pseudampotiphilous

of taxa, especially from samples 117DB7/M58 and M64, have not yet or only very rarely been met with in Holocene Belgian coastal deposits. This is the case for *Achnantes groenlandica, Cerataulus turgidus, Cocconeis brittanica, C. clandestina, C. fluminensis, C. molesta, C. scutellum* var. *speciosa, C. quarnerensis, Grammatophora arcuata, Isthmia enervis, Melosira sol* and *Rhaphoneis nitida*. *Achnantes groenlandica* and *Grammatophora arcuata* are considered to be arctic species (CLEVE-EULER) 1951-1955; HUSTEDT, 1931-1959). According to HENDEY (1964), *Cocconeis scutellum* var. *speciosa* is probably also a cold water form. *Cocconeis brittanica, C. fluminensis, C. molesta, C. quarnerensis, Cerataulus turgidus, Melosira sol* and *Rhaphoneis nitida* are recorded to prefer warmer water (CLEVE-EULER, 1951-1955; HUSTEDT, 1927-1930, 1931-1959). Nevertheless most of the diatoms mentioned may be found on recent southern North Sea coasts.

BROCKMANN (1928, 1930, 1934, 1940) studied Dutch and German Quaternary coastal deposits and concluded that Eemian sediments could be distinguished from younger deposits mainly by the absence of *Aulacodiscus argus* and the presence of *Cocconeis debesi, C. quarnerensis, Endictya oceanica, Stephanopyxis turris* and *Terpsinoe americana*. According to KONIG (1953) however *Aulacodiscus argus* is not completely absent from all German Eemian deposits. So far the diatoms of only a very limited number of marine Eemian samples from Belgium have been examined. CLARYSSE (1974) examined eight samples of the Steenbrugge clay. In these samples *Aulacodiscus argus*, a conspicuous species present in almost all Holocene North Sea sediments, is lacking, however none of the other species mentioned above are reported to be present. *Aulacodiscus argus* is also absent in our samples 117DB7/M49/M58 and M64. Of BROCKMANN's "Characterformen" for the Eemian, *Cocconeis quarnerensis* was found in samples M58 and M64. *Cocconeis debesi* was found to occur fairly frequently in Belgian Calais- and Dunkerque deposits (DENYS, 1982) and was thus not considered. From this it can be concluded that the lower samples of 117DB7 show a certain similarity to known Eemian deposits with respect of their diatom flora. Possibly, the floristic differences between these samples and normal Fladrian deposits discussed above, may also indicate a pre-Holocene age. A conclusion on the chronology of these samples based on diatoms alone however seems as yet premature.

NOTE ON THE STRATIGRAPHIC RANGE OF *Rhaphoneis nitida* (GREG.) GRUN.

Until recently *R. nitida* was not known to occur as a fossil (ANDREWS, 1975). Nowadays the species is know from the marine littoral of the Mediterranean and the southern North Sea. VAN HEURCK (1896) observed one specimen at Blankenberge, probably the only recent finding on our coast as yet. In the last few years this species was found to occur sporadically in deposits from Holocene (DENYS, 1981) to Eemian age (NIEMELA & TYNNI, 1979). It was also found in sample 117DB7/M64.

ACKNOWLEDGEMENTS.

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LITHO- AND BIOSTRATIGRAPHICAL STUDY OF QUATERNARY DEEP MARINE DEPOSITS OF THE WESTERN BELGIAN COASTAL PLAIN.

MOLLUSC INVESTIGATION

55251

by G. SPAINK en B. C. SLIGGERS (*)

INTRODUCTION.

The following shell-bearing samples were examined.

193DB5	M61	-	25,7 to	-	26,2	m TAW
117DB7	M64	-	26,3 to	-	26,8	m
117DB9	M77	-	27,2 to	-	27,7	m
117DB12	M66	-	27,6 to	-	28,1	m
117DB13	M49	-	18,9 to	-	19,4	m

From a faunistical viewpoint all samples are very similar. Therefore they are considered to belong to one single fauna, which is compared with known accurately dated faunas of Eemian- and Holocene times.

MOLLUSCS IN EEMIAN DEPOSITS IN BELGIUM.

Eemian-deposits in Belgium occur around Ghent in the so called "Flemish Valley" and in the actual coastal plain. The fauna of the Flemish Valley is rather poor; it is characterized by *Corbicula fluminalis* and *Venerupis aurea senescens*, as well as *Cerastoderma edule, Macoma balthica, Mytilus edulis, Hydrobia ulvae, Nassarius reticulatus, Littorina littorea* and *Natica* (PAEPE, 1965). These species are typical for coastal and estuarine environments. *Corbicula fluminalis* is a fresh water species of large rivers, in this case the Scheldt. However, a number of these species have recently been found in marine sediments of Holsteinian age (PAEPE *et al.*, 1981). There is practically no published information on mollusc faunas in the coastal plain. NORDMANN (1908), compared molluscs from 4 borings with known Eemian faunas of Europe. His findings in borings of Ostend, Leffinghe and Petit Crocodile (Nieuwport) contain 88 marine and 6 continental molluscs.

This fauna from about the same depth shows a large similarity with the De Panne borings (see appendix). Stratigraphically NORDMANN situated this fauna in the "système flandrien". After comparison he came to the conclusion that there are some significant differences between the faunas of the Holocene deposits of the "Mer-flandrienne" and those of the Eemian sea. For the De Panne borings we will make the same comparison.

COMPARISON WITH THE DUTCH EEMIAN FAUNAS.

Since the investigations on Belgian Eemian-faunas are still incomplete, it seems appropriate to compare them with Dutch faunas. The five samples of the De Panne borings contain 113 marine and 11 continental molluscs species.

The following points are of special interest :

1. 21 species are unknown from Dutch Eemian faunas.

(*Acmaea virginea, Alvania crassa, Calliostoma zyzyphinum, Chauvetia minima, Cingula semistriata, Emarginula reticulata, Gibbula tumida, Parastrophia asturiana, Phasianella pullus picta, Skenea nitens, Skeneopsis planorbis, Velutina velutina, Astarte digitaria, Chlamys cf distortus, Gari fervensis, Kellia suborbicularis, Limopsis aurita, Musculus niger, Phacoides borealis, Parvicardium scabrum and Venus casina*).

Most of these species have been recorded at other places and in deposits which are older than Eemian; viz. in Pliocene sediments in Italy and England and in several sites of Pleistocene age in Europe. The stratigraphical position is not clear in all the cases, because the conformity between the recent forms and the fossil ones is still uncertain.

There are no records in the literature (WOOD, 1848-1879; HARMER, 1914-1925 and GLIBERT, 1957-1959) on fossil specimens of the following species : *Musculus niger, Chauvetia minima, Parastrophia asturiana and Skeneopsis planorbis*.

For some other species (*Phasianella pullus picta* and *Alvania crassa*), there are only records of fossils in the Mediterranean basin but not from the North Sea.

2. Typical Dutch Eemian species are missing.

The absence of *Venerupis aurea senescens* and *Abra ovata* has been observed already by NORDMANN (1908). Other species such as *Angulus distortus, Cardium paucicostatum, Divaricella divaricata, Turbonilla*-species and *Rissoa radiata balkei* are also absent. *Bittium reticulatum* which is often dominant in Dutch Eemian faunas, has been found only four times in samples of the De Panne borings. It is probable that differences in facies between the Dutch Eemian inland sea and the more open character of the Belgian coastal sea may explain the differences between the two faunas.

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COMPARISON WITH THE FAUNA OF *Angulus pygmaeus*.

The De Panne fauna is closely related to the mollusc-fauna with a lusitanic character found in Holocene sediments of the southern North Sea. This fauna, which original from the Channel and is typified by *Angulus pygmaeus*, was described under this name by SPAINK in 1973. In spite of the absence of *Angulus pygmaeus* in the samples of De Panne, the remaining part of the fauna is typical for this *Angulus pygmaeus* fauna. It is assumed that this fauna immigrated to the Southern North Sea in the Boreal or the early Atlantic period and spread along the Belgian and Dutch coasts as far as the Wadden Islands.

Most species have never been found alife along the Dutch coast. However, a number of them are presently found more to the south along the Belgian coast, in the Channel, close to the southern coast of England, along the French West-coast as far as the Gulf of Biscay and also at the Norvegian coast probably due to the warm Gulfstream (SPAINK, 1973). The De Panne fauna is also in good agreement with faunas from seacores in front of the Belgian coast near Ostend, where the *Angulus pygmaeus* fauna has also been found (SPAINK, 1979). An interesting site was the open excavation of Loon Plage (Dep. du Nord, France). In the exposures during construction works in the Port Rapide of Dunkerque, marine sediments could be studied *in situ*. The *Angulus pygmaeus* fauna was found at a depth of 20 m. Though *Angulus pygmaeus* itself was absent throughout, the fauna could be very well correlated with faunas from sea borings that were made in front of the same spot.

LAND MOLLUSCS.

Except for sample 117DB7, all samples contain some continental molluscs. Landmolluscs only occur in 117DB13 : *Pupilla muscorum*, *Succinea elegans/putris*, *Succinea oblonga* and *Trichia hispida*. They point to wet as well as to dry conditions in the neighbourhood of fresh water. All species are still living at the places of the borings. *Pupilla muscorum*, *Succinea oblonga* and *Trichia hispida* are known in the Netherlands ever since the Tiglian.

FRESH WATER MOLLUSCS.

They are present in all samples. Their ecological conditions vary from brackish water to stagnant fresh and running water. *Bithynia tentaculata*, *Lymnaea palustris* and *Planorbis leucostoma* occur in W. Europe since the Tiglian.

Pisidium clessini occurs since the Tiglian and disappears in the Saalian. *Corbicula fluminalis* belonged to the Pleistocene fauna from the Tiglian up to and including the Eemian. After that period this species withdrew to the eastern Mediterranean and Asia Minor.

Recently *Corbicula fluminalis* was recorded again in Spain and Portugal.

Summarizing, it can be concluded that only one pre-Saalian continental species is present, and that is was probably introduced into the system. Given the presence of middle Pleistocene sediments in the studied area it can be accepted that the original fauna has been reworked.

TERTIARY MOLLUSCS.

The sediments examined during this study are underlain by Eocene Ieperian clay. This clay is the most probable source of nummuliths and fragments of *Turritella solanderi* which occur in all samples. A top-fragment of *Neptunea contraria* is also of tertiary age. This species is commonly present in the Pliocene deposits of Belgium. Also the sharkteeth, found in some samples, are considered to belong to the Tertiary age.

CONCLUSIONS.

The five samples contain a rich marine mollusc fauna.

An Eemian age for the sediments is difficult to accept for the following reasons :

1. The typical Dutch Eemian species are missing.
2. Some fossil species are unknown in the fossilrecord from the North Sea-basin, including the southern part.
3. Some species are completely unknown in the fossilrecord.

Given the close similarity with the *Angulus pygmaeus* fauna, a Holocene Subboreal age appears to be most probable. This Holocene dating implies that during this period the sea cut deeply into the Eocene clay, and removed Holsteinian and Eemian deposits. The Eemian age for sample 117DB7, found on the basis of pollen and diatomic analysis, could not be confirmed by the mollusc fauna.

A possible explanation could be found in the differences in facies and the geographical position between the Dutch and Belgian Eemian sea. On the other hand, if an Eemian age should be admitted, the stratigraphical distribution of a number of molluscs would have to be revised.

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LITHO- AND BIOSTRATIGRAPHICAL STUDY OF QUATERNARY DEEP MARINE DEPOSITS IN THE WESTERN BELGIAN COASTAL PLAIN.

RADIOCARBON DATING 55254

by M. VAN STRIJDONCK (*)

The weight of the peaty-clay sample 193 DB 5/M53 from Adinkerke-Lebbe was 1035 g. It contained a lot of small shells. Most of the organic fraction was separated from the peat by decantation and sieving of the sample deluted with water.

Since the organic particles were inbedded in a calcareous clay (shells) a severe impregnation of younger humic acids was not feared.

Nevertheless the sample was washed with a hot solution of 1 % NaOH. Since shell carbonate can have a bad influence on the date a severe washing with a hot HCl-solution was necessary to eliminate all the carbonate.

After washing with distillated water and drying, 35 g of the sample was combusted. The combustion yield only 0.27 mol CO_2, meaning that most of the combusted material was still inorganic.

The CO_2 was converted into CH_4 and counted in a proportional counter. The activity of the sample was compared with the activity of a N. B. S. modern standard which resulted in a conventional radiocarbon date of 7795 ± 130 BP (lab. n° IRPA/439).

At present there is no calibration curve available to convert conventional radiocarbon dates into calendar dates for samples older than 7240 BP. The only correction that can be made is the 3% increasement of the sample age due to the convertion from the Libby Half-life (commonly used in radiocarbon dating) to the real ^{14}C half-life. This gives us a date of 6080 ± 130 years BC.

(*) C_{14} - laboratory : Koninklijk Instituut voor het Kunstpatrimonium (IRPA), Brussel.

TABLE.

GASTROPODA	193DB5 25,7 - 26,2 m TAW	117DB7 26,3 - 26,8 m TAW	117DB9 27,2 - 27,7 m TAW	117DB12 27,6 - 28,1 m TAW	117DB13 18,9 - 19,4 m TAW	Dutch Eemian fauna	Fauna of Angulus pygmaeus	Nordmann, 1908
Lepidochitona cinerea (Linné)				e̲	e̲	x	x	
Acanthochiton spec.			e̲		e̲	x	x	
Chiton spec.		l̲	e̲	l̲				
Scisurella crispata Fleming					l̲		x	
Emarginula reticulata Sowerby	e-	l̲			e-		x	x
Diodora apertura (Montagu)		l-d	l̲			x	x	
Acmaea virginea (Müller)	e-	e-	zw	vw	zw-		x	x
Calliostoma zyzyphinum Linné	e̲	e̲	zw-	e-,e̲	zw-		x	x
Gibbula cineraria (Linné)	e-,e̲	e,z̲w̲	zw,e̲	v,v̲	zw	x	x	x
Gibbula tumida (Montagu)	e	e,e̲	zw,e̲	zw	zw		x	
Phasianella pullus picta (Da Costa)	e	ld,l̲	w	e̲	zw		x	x
Lacuna crassior (Montagu)		w	e̲			x	x	
Lacuna vincta (Montagu)		e-	l			x	x	
Littorina littorea (Linné)				e̲	e-	x		x
Littorina saxatilis (Olivi)		l			e-	x		
Hydrobia ulvae (Pennant)	zw	ed	zw		w	x		x
Hydrobia ventrosa (Montagu)	e			zw		x		
Cingula alderi (Jeffreys)			e	l	e		x	
Cingula semicostata aculeus Gould			e	l	e		x	
Cingula semistriata (Montagu)	e		zw	l	e		x	
Alvania crassa (Kanmacher)					l		x	
Rissoa inconspicua (Alder)	e	l				x	x	x
Rissoa parva parva (Da Costa)	l̲				e	x	x	x
Rissoa parva interrupta (Adams)	zw	vw	vv	w	zw	x	x	x
Tornus subcarinatus (Montagu)			l		e	x	x	x
Skeneopsis planorbis (Fabricius)	e						x	x
Turritella solanderi (Mayer-Eymar)	e̲	l̲vs	e̲	l̲	e̲			
Turritella tricarinata communis Risso		l̲			l-	x		x
Caecum glabrum (Montagu)			e		zw	x	x	x
Parastrophia asturiana de Folin		lt						
Bittium reticulatum (Da Costa)	l-	l		l	l	x	x	x
Cerithiopsis tubercularis (Montagu)	l̲	ed	z̲w̲	l,l̲	e̲	x	x	
Triphora perversa adversa (Montagu)			l̲			x	x	x
Epitonium clathratulum (Kanmacher)					e	x	x	x
Epitonium clathrus (Linné)			l̲		e̲	x	x	x
Graphis albida (Kanmacher)					e	x	x	
Polinices polianus (Della Chiaje)		zw	e-	zw-,z̲w̲	e-	x		x
Velutina velutina (Müller)			l-	l-		x	x	x
Trivia spec.	l̲		e̲	e̲	e̲	x	x	x
Trophon truncatus (Ström)	e̲	e,e̲	zw	zw	zw-	x	x	x
Nucella lapillus (Linné)		l̲	e-,e̲	e,e̲,e-	e-	x	x	x
Ocenebra erinacea (Linné)		l̲	e-	z̲w̲,e-		x	x	x
Neptunae contraria (Linné)			l̲t					
Buccinum undatum Linné	l̲	e̲	e-,z̲w̲	vv-,v̲v̲	e-	x	x	x
Chauvetia minima (Montagu)			e̲,ed	l,l̲			x	
Nassarius incrassatus (Ström)					ld,l̲	x	x	x
Nassarius reticulatus (Linné)		e̲		e̲	e̲	x	x	x
Nassarius spec.			lt					
Mangelia nebula (Montagu)	lvs					x	x	
Oenopota turricula (Montagu)	e-			e,e̲	e̲	x	x	x
Chrysallida indistincta (Montagu)					lvs	x	x	
Chrysallida obtusa (Brown)	e					x	x	x
Chrysallida spiralis (Montagu)		ld	evs	evs	zw	x	x	x
Odostomia conoidea (Brocchi)					l	x	x	
Odostomia eulimoides Hanley	l	ld	l	l,l̲	ed	x	x	
Odostomia plicata (Montagu)		ld				x	x	
Odostomia turrita Hanley	e		zw		e	x	x	
Turbonilla crenata (Brown)		e,e̲				x	x	
Retusa obtusa (Montagu)		l-	l̲		e,e̲	x	x	
Philine aperta quadripartita Ascanius					e-,z̲w̲	x	x	

SCAPHOPODA

Dentalium vulgara (Da Costa)	l	e	l		l	x	x	
Dentalium spec.	lvs			l				
BIVALVIA								
Nucula nucleus (Linné)	e	e	e,e	e	zw	x	x	x
Arca lactea Linné	l,e	e	e-		e	x	x	x
Limopsis aurita (Brocchi)	e-	e	e		zw		x	x
Modiolus modiolus (Linné)		evs	w	zw		x	x	
Musculus discors (Linné)	zw-d	l	e-,e	zw-	w-	x	x	
Musculus niger (Gray)				l			x	
Mytilus edulis Linné	vw	v	zw	e	e-,zw	x		x
Chlamys cf distortus (Da Costa)			l				x	
Chlamys flexuosa (Poli)	l				l	x	x	x
Chlamys opercularis (Linné)	e				e	x	x	x
Chlamys varia (Linné)	e	evs	l,e-	e	e-,e	x	x	x
Anomia ephippium Linné					e	x	x	x
Ostrea edulis Linné	l-	l-	w	e	zw,e-	x		x
Astarte digitaria Linné	e	e	e-	l-,l	l-		x	x
Astarte montagui (Dillwyn)		e	zw-	e-	zw-	x	x	
Astarte triangularis (Montagu)	zw	e,e	vw	e,e	e	x	x	x
Altenaeum dawsoni (Jeffreys)		l			l	x	x	
Phacoides borealis (Linné)		ld	l-d	e			x	x
Erycina nitida (Turton)			l	l	l	x	x	
Montacuta ferruginosa (Montagu)					l	x	x	
Kellia suborbicularis (Montagu)					l,l/l-		x	
Mysella bidentata (Montagu)		l	e-	e	e	x	x	x
Cerastoderma edule (Linné)	e,vw	vw	e-,e	vw	w-	x		x
Cerastoderma glaucum (Poiret)		e			ld	x		
Parvicardium exiguum (Gmelin)			e			x	x	x
Parvicardium scabrum (Philippi)	l	l-					x	
Plagiocardium papillosum (Poli)		l,e				x		x
Venus casina Linné			e	e			x	
Venus gallina striatula (Da Costa)		l-	e-,e	zw-,e	e-	x		x
Venus ovata Pennant	zw	zw	e	e	e,e	x	x	x
Venerupis decussata (Linné)			l-			x	x	
Venerupis senegalensis (Gmelin)				l		x		x
Venerupis rhomboides (Pennant)			e			x	x	
Spisula elliptica (Brown)	e	zw	zw,e	zw-,e	ed,e-	x	x	
Spisula subtruncata (Da Costa)	e-	e	l		e-	x		x
Mactra corallina cinerea Montagu					l	x		x
Donax vittatus (Da Costa)	l,e	e	evs	e	e-	x		x
Gari fervensis (Gmelin)		lvs					x	
Abra alba (Wood)		w	e	e	zw,zw-	x		x
Abra prismatica (Montagu)		e				x	x	
Scrobicularia plana (Da Costa)	e		e	l	l	x		x
Macoma balthica (Linné)	ed,zw	l	e		e-,l	x		x
Angulus fabulus (Gmelin)		e		e	e-,e	x		x
Tellina tenuis Da Costa			l			x		x
Ensis arcuatus (Jeffreys)		l	e	e	l	x		
Solen marginatus Pulteney			l			x	x	
Hiatella arctica (Linné)	e	e	vv	zw,zw	w-	x	x	x
Mya truncata Linné		e-	vw	zw	e	x	x	x
Barnea candida (Linné)	vv	w	v	w	vw	x		x
Zirfea crispata (Linné)	e	e	e	zw		x	x	x
Thracia papyracea (Poli)					e,e/l-	x	x	

CONTINENTAL MOLLUSCS

Bithynia tentaculata (Linné)			1^{op}		
Lymnaea palustris (Müller)					1̲
Lymnaea spec.	1̲				
Planorbis leucostoma Millet					1̲
Succinea elegans/putris					e̲
Succinea oblonga Draparnaud					1d
Succinea spec.					e̲
Pupilla muscorum (Linné)					1̲
Trichia hispida (Linné)					e̲
Corbicula fluminalis (Müller)	1-			e	
Pisidium clessini Neumayr	1̲				
NON MOLLUSCS					
Pisces - vertebra	1̲				1̲
- otolith		1,1̲			
- shark tooth		1-	1	1	
Serpula			z̲w̲	z̲w̲	
Spirorbis		1			
Balanus spec.	v̲w̲	z̲v̲	dom.	dom.	dom.
Verruca strömia Müller	e̲	e̲	e̲	e̲	z̲w̲
Decapoda			e̲	e̲	z̲w̲
Ophiuridae			v̲w̲	e̲	v̲
Echinocardium cordatum (Pennant)	e̲st	e̲st	e̲st		e̲,zwst
Psammechinus miliaris (Gmelin)	z̲w̲st	e̲,est	zw,z̲w̲st	e̲,est	wst,z̲w̲
Echinocyamus pusillus (O.F. Müller)			e̲	e,e̲	
Ostracoda			zw	zw	zw
Corals	e			e-	e
Bryozoa div. spec.	v̲w̲	e	v̲v̲	v̲v̲	z̲v̲
Cellaria	zw	e	vv	w	w
Foraminifera	w	w	vv	vv	vw
Nummulites		e	e̲	e	e
Sponge spicula					zw

EXPLANATION OF SYMBOLS AND ADDITIONS

1 = one single specimen

e = some specimens

zw = very few specimens

w = few specimens

vw = rather few specimens

vv = rather much specimens

v = many specimens

zv = very much specimens

dom. = dominant

1- = one juvenile specimen

1= = one very juvenile specimen

1̲ = one fragment

1̳ = one little fragment

1/1 = one paired valve

1t = one topfragment

1d = one defective specimen

1vs = one worn specimen

1st = one spine

1op = one operculum

LITHO- AND BIOSTRATIGRAPHICAL STUDY OF QUATERNARY DEEP MARINE DEPOSITS OF THE WESTERN BELGIAN COASTAL PLAIN.

POLLEN ANALYSIS

55255

by C. VERBRUGGEN (★)

Samples have been taken from the borings 193DB5, DB6, 117DB15, DB6, DB8, DB7, DB9, DB12, DB13, DB14.

The total number of samples is about 650. Since only the lower part of the sediments below -17 m relates to the main question of this study, the number of samples was reduced to 250. For comparison 15 pollenslides of samples above -17 m were made. The samples below the -17 m level that have been investigated palynologically represent nearly 40 % of the available stock.

To determine the palynological character of the sediments, initially only organic and/or clayey samples were treated. The good preservation of the pollengrains, the undisturbed character of the spectra and the interesting results lead to a taking into consideration of the predominant number of coarse sandy samples. By using samples of 50 gr. or more, most levels yielded good pollenslides. Some were extremely poor even pollenless. They are indicated on the pollenplots by a sign (-) together with the number of pollengrains that have been found.

The pollensum represents the A. P. Contamination caused by the coring method where small quantities of the overlaying levels may have been mixed with the underlying material, did not seem to have altered the pollenspectra significantly.

The pollengrains which showed the most striking differences were those of *Hippophae*. Their generally excellent state of preservation distinguished them from other pollen. They were found in corings which were carried out in April and may, the flourishing time of the sea buckthorn which actually covers the dunes in the study area. For this reason *Hippophae* was given a particular place in the pollendiagrams. In spite of these limitations and in the absence of reference investigations the following conclusions seem to be valid :

- there is a perfect agreement between the pollenspectra of the peaty-clay of 193DB5 and the C14 dating of this layer;
- the results of the analysis of sandy samples fit closely with those obtained for the clayey sequences.

A systematical description and interpretation of the pollendiagrams following the rank of the geological transect is given below. The samples are numbered beginning from the base.

193DB5

Under the -17 m level, the pollenspectra show a typical "boreal" composition with a dominance of *Corylus*. The relative abundance of *Ulmus* and the absence of *Alnus* and *Tilia* is also characteristic; there is a continuous curve for *Hedera*. Fresh water plants occur together with *Chenopodiaceae*. Certain samples show a clear evidence of Tertiary remaniation. The sediments of this sequence are generally clayey, sometimes rather organic. In sample 3 the high percentages of *Cyperaceae* point to marshy conditions. The C14 dating of the sample : 7795 ± 130 BP. is in perfect agreement with the Late Boreal pollenspectra.

The uppermost sample, above the -17 m level, seems to be much younger with *Alnus, Tilia* and especially *Fagus*.

195BB6.

This diagram is similar to that of 193DB5. There is again the clear difference between the "boreal" lower part and the post atlantic upper part, above the -17 m level.

117DB15.

The sediments under the -17 m level are poor in pollen. Only the spectrum of sample 3 is shown. *Chenopodiaceae* are relatively abundant. From sample 3 onwards the pollencontent points to post-atlantic conditions.

117DB6.

The diagram can be subdivided in three parts.

1. Sample 1 and 2.

The characterizing elements are *Pinus, Picea, Carpinus* and *Ericaceae*. They occur together with the trees of the atlantic forest; *Betula* is rather important. Such a composition prevailed at the end of the Eemian.

2. Samples 3, 4 and 5.

A late Boreal or early Atlantic composition is recognized on the basis

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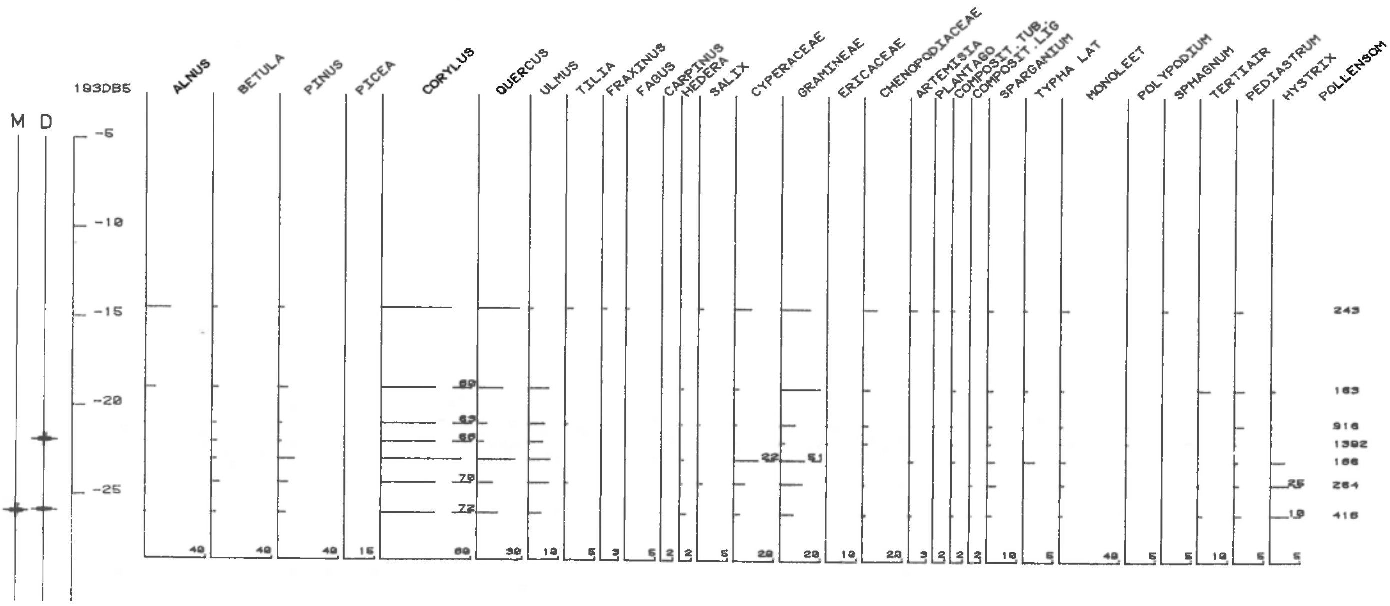
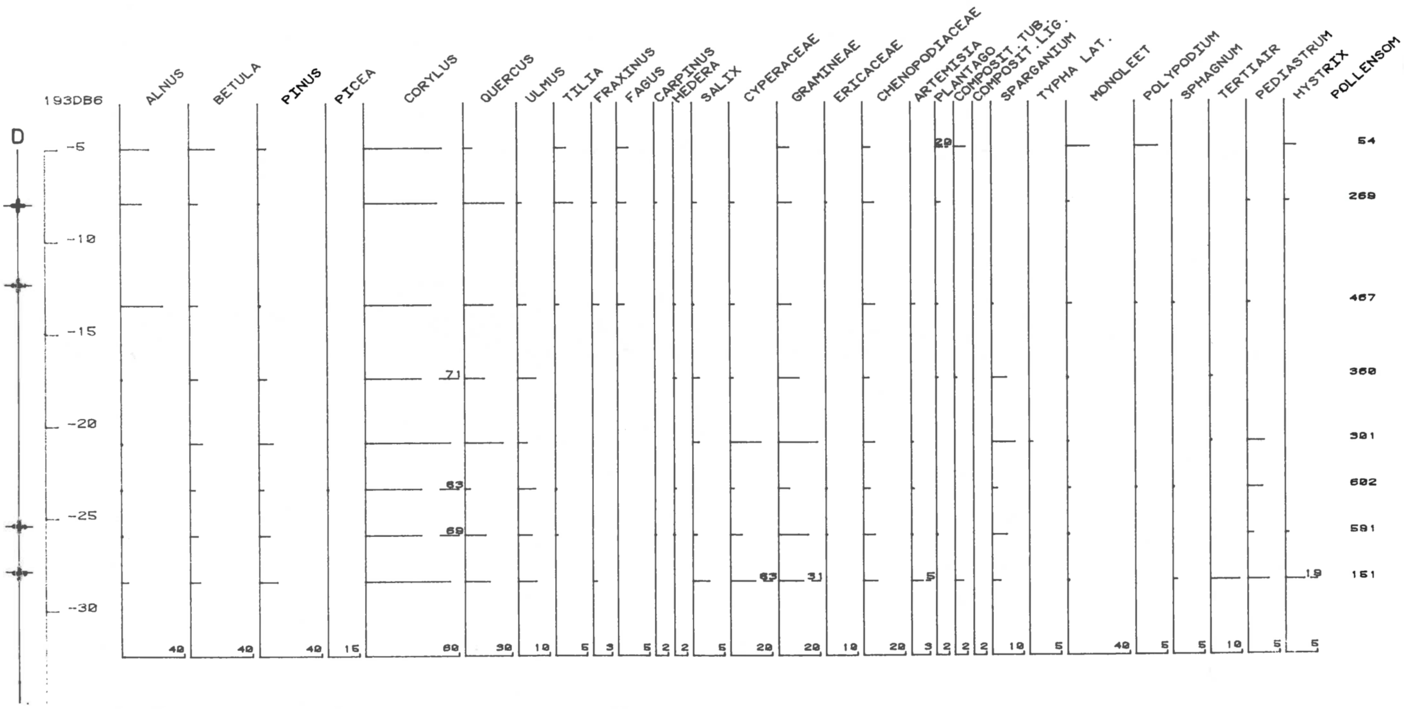
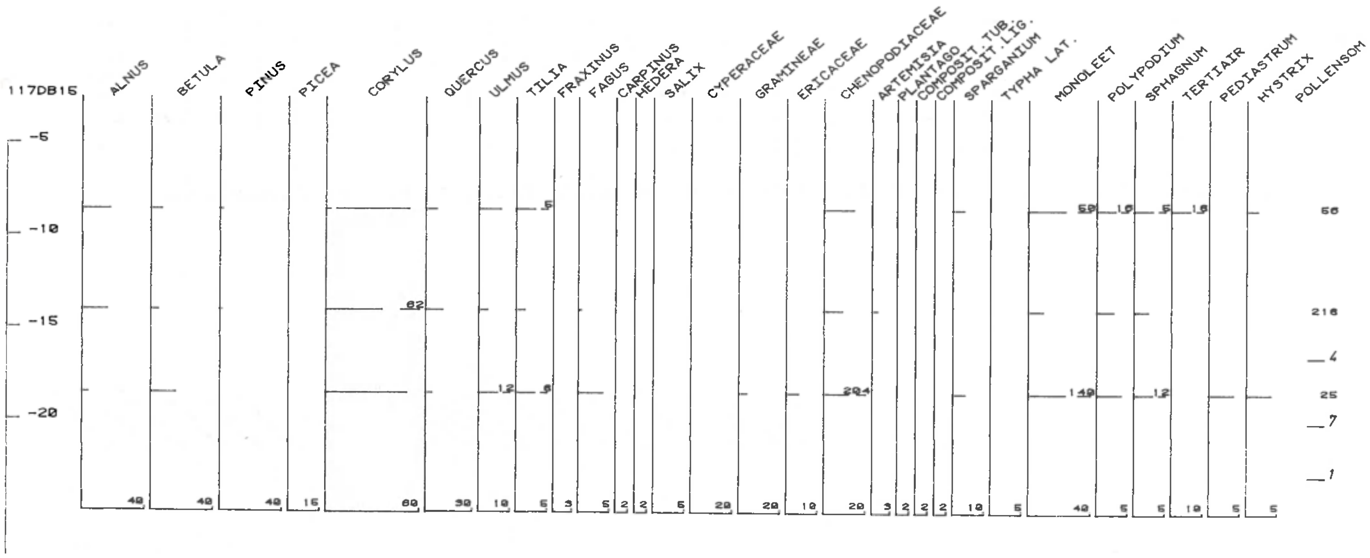
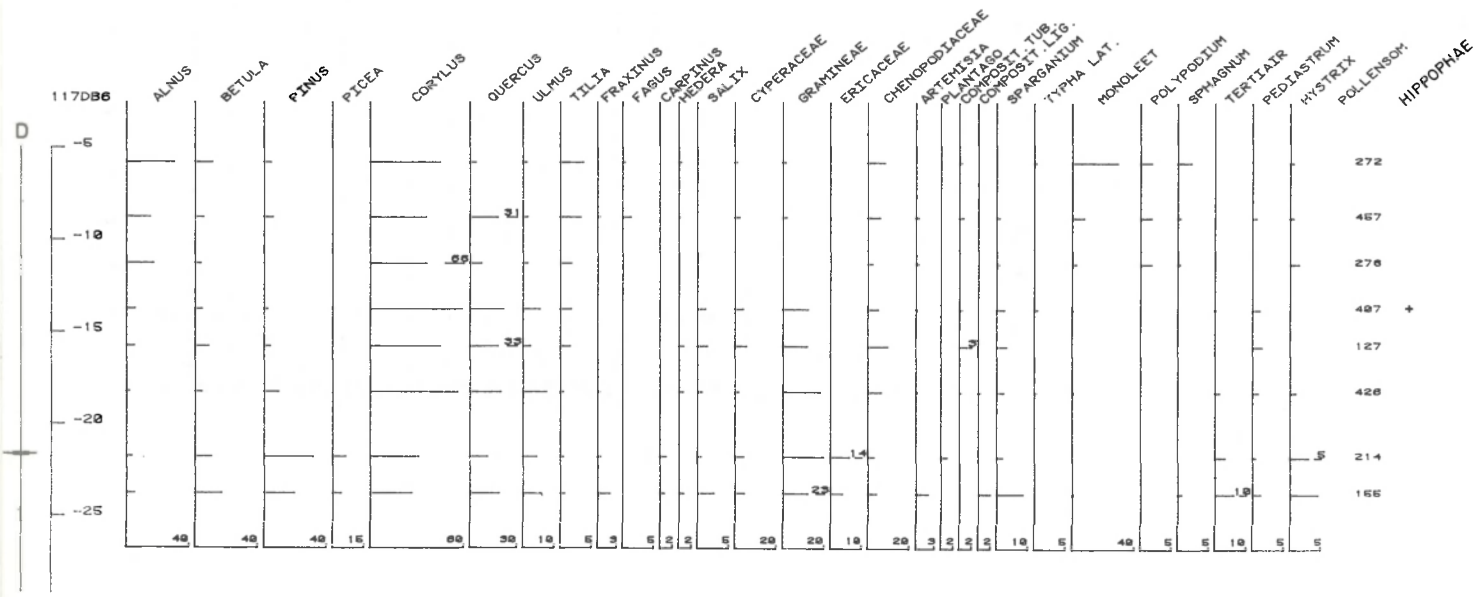


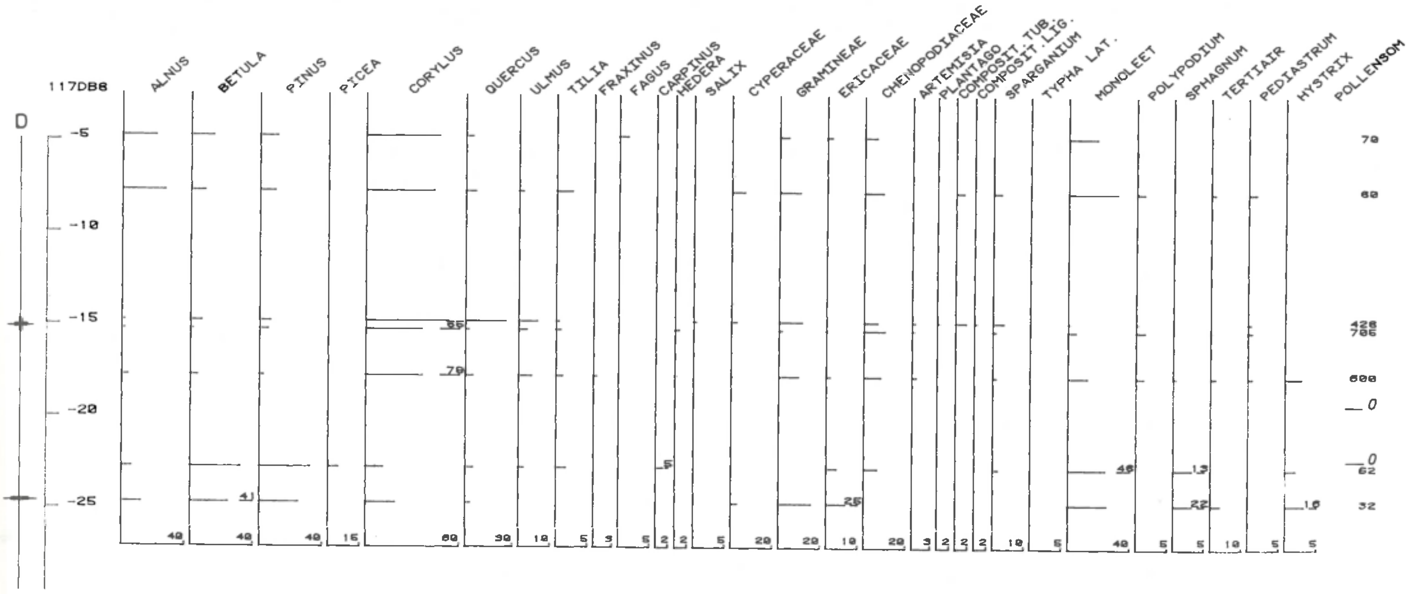


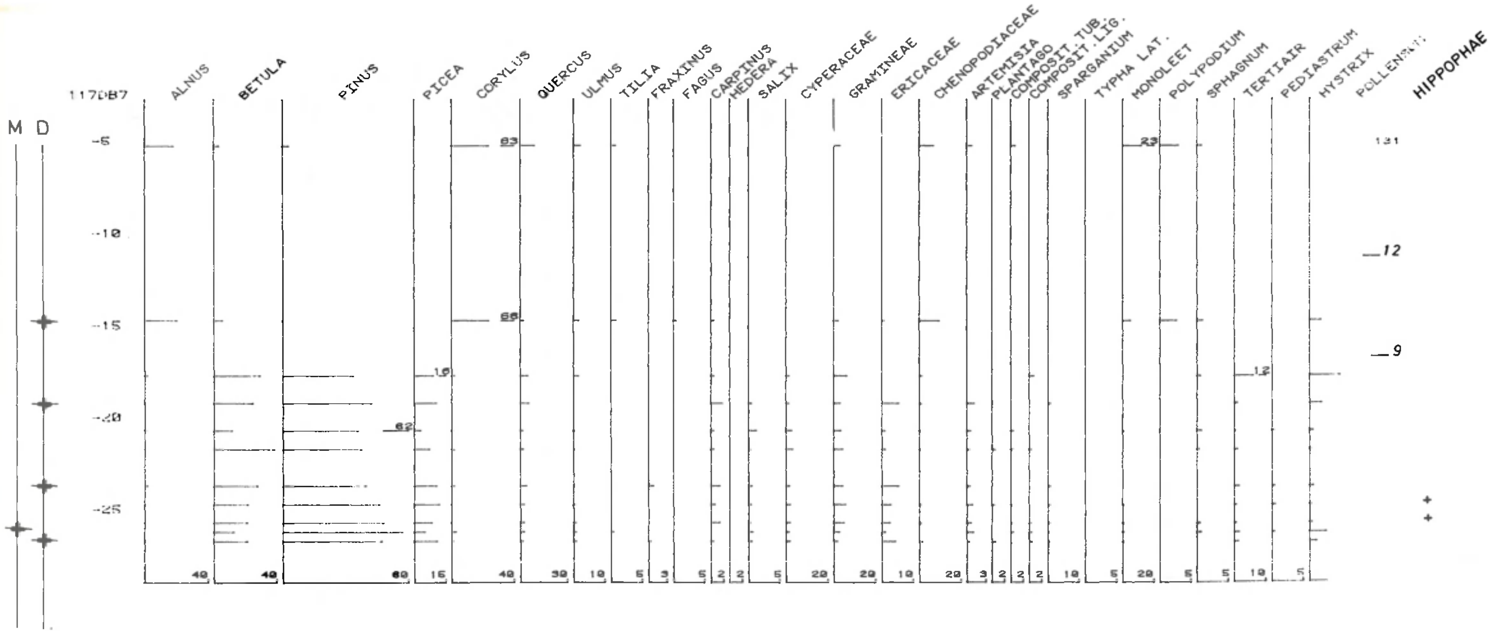
D : Diatom sample   + positive
- negative

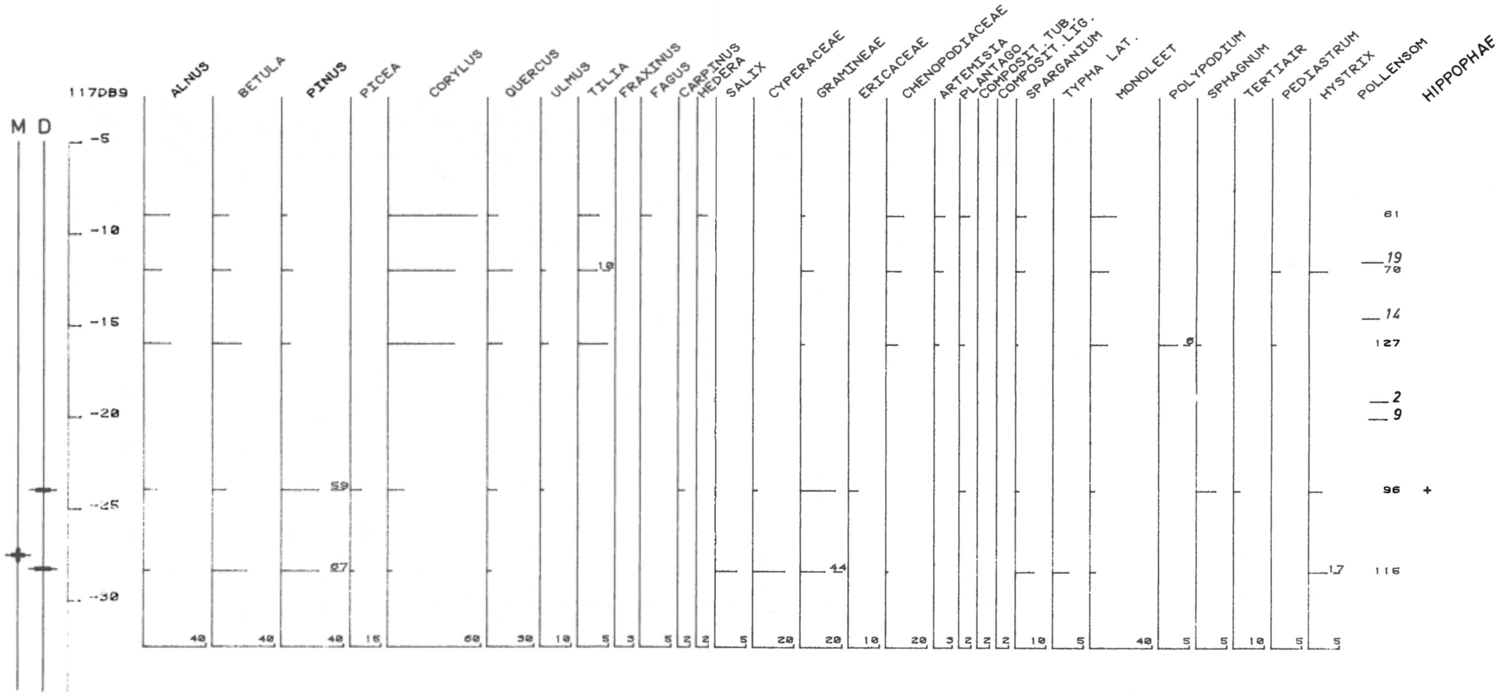
M : Mollusc sample

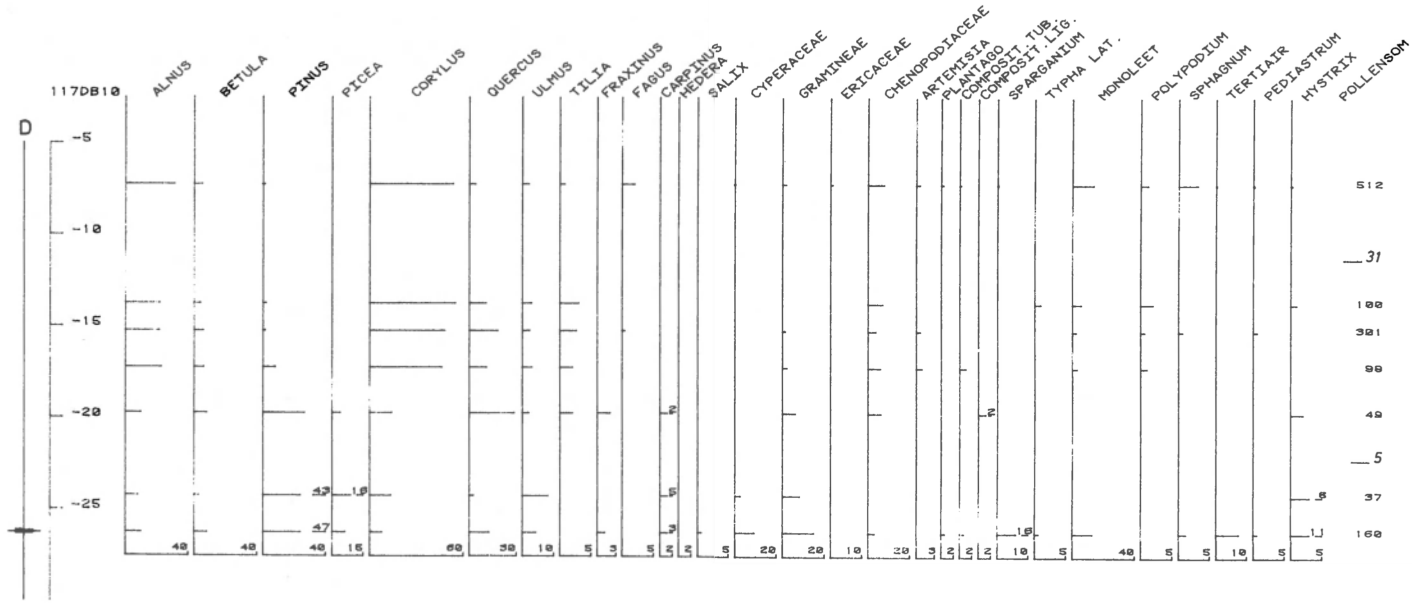

117DB15
ALNUS
BETULA
PINUS
PICEA
CORYLUS
QUERCUS
ULMUS
TILIA
FRAXINUS
FAGUS
CARPINUS
HEDERA
SALIX
CYPERACEAE
GRAMINEAE
ERICACEAE
CHENOPODIACEAE
ARTEMISIA
PLANTAGO
COMPOSIT.TUB.
COMPOSIT.LIG.
SPARGANIUM
TYPHA LAT.
MONOLEET
POLYPODIUM
SPHAGNUM
TERTIAIR
PEDIASTRUM
HYSTRIX
POLLENSOM
-5
-10
-15
-20
56
216
25
4
7
1

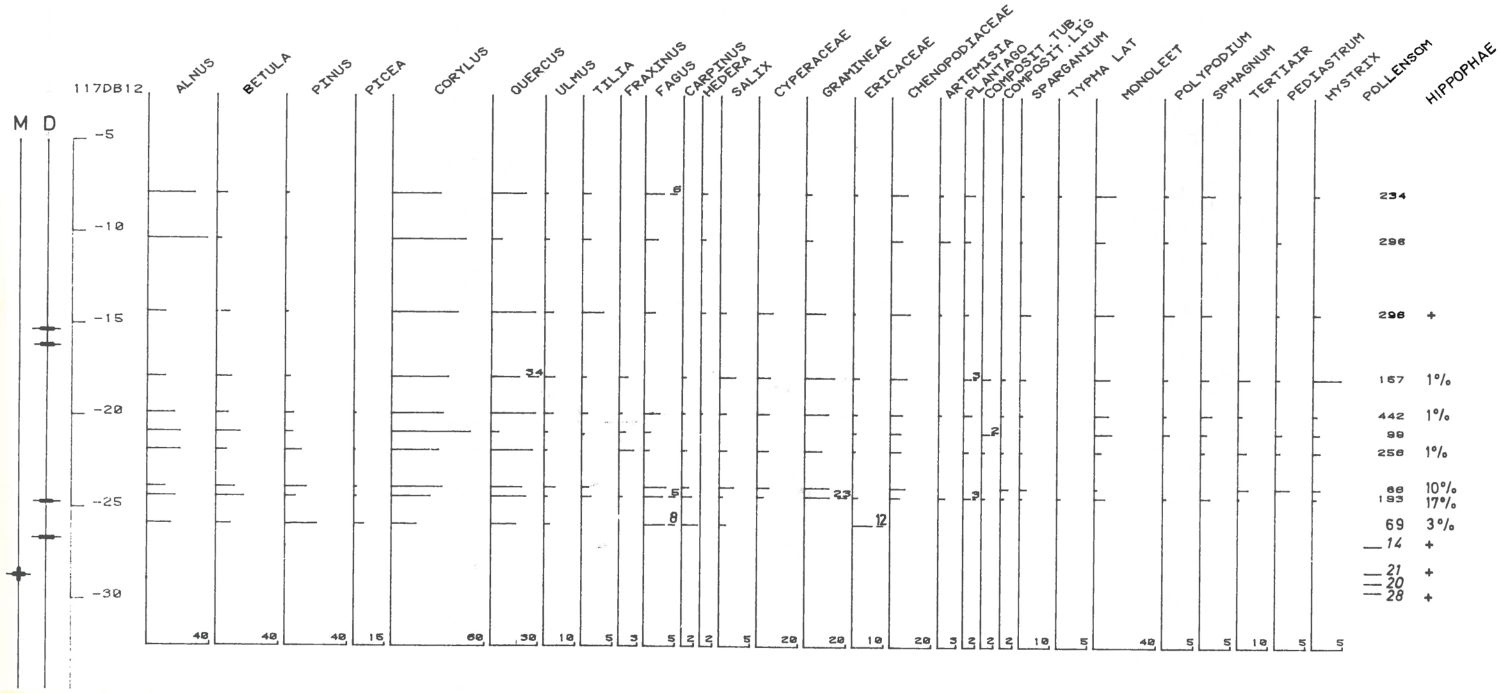

117DB6
D
ALNUS
BETULA
PINUS
PICEA
CORYLUS
QUERCUS
ULMUS
TILIA
FRAXINUS
FAGUS
CARPINUS
HEDERA
SALIX
CYPERACEAE
GRAMINEAE
ERICACEAE
CHENOPODIACEAE
ARTEMISIA
PLANTAGO
COMPOSIT.TUB.
COMPOSIT.LIG.
SPARGANIUM
TYPHA LAT.
MONOLEET
POLYPODIUM
SPHAGNUM
TERTIAIR
PEDIASTRUM
HYSTRIX
POLLENSOM.
HIPPOPHAE
-5
-10
-15
-20
-25
272
467
276
407
127
426
214
166
+

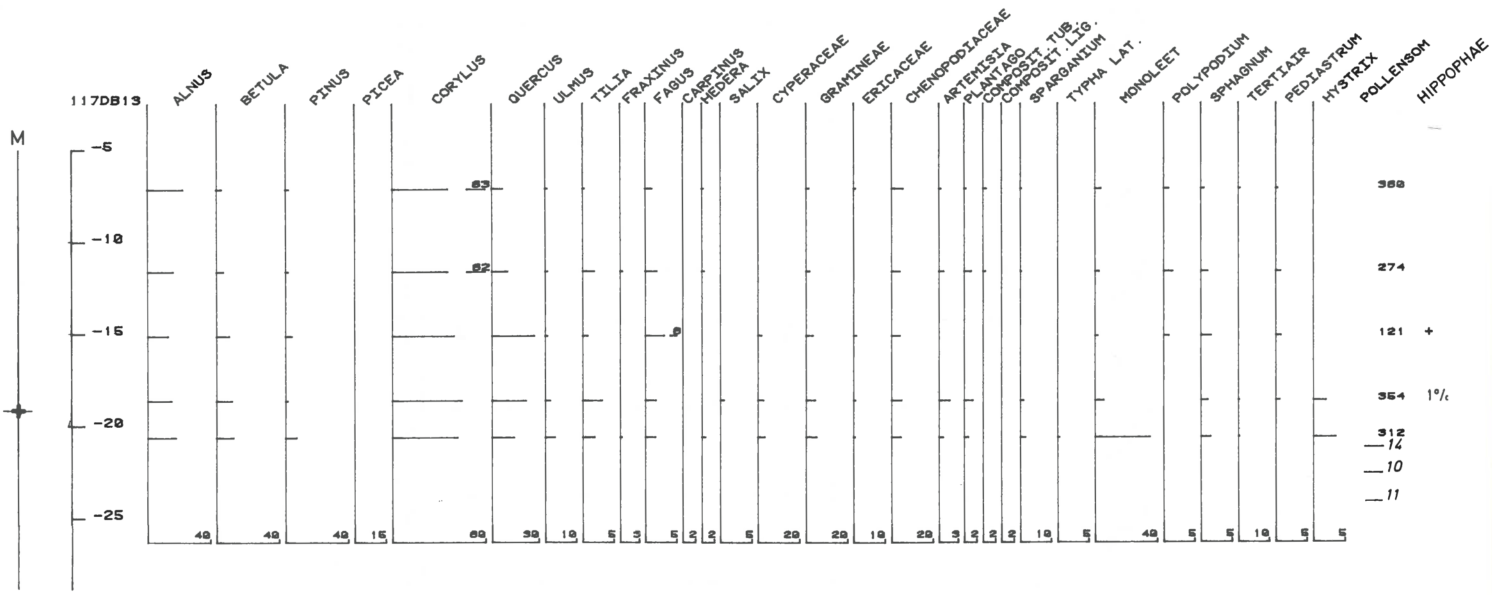

117DB8
D
ALNUS
BETULA
PINUS
PICEA
CORYLUS
QUERCUS
ULMUS
TILIA
FRAXINUS
FAGUS
CARPINUS
HEDERA
SALIX
CYPERACEAE
GRAMINEAE
ERICACEAE
CHENOPODIACEAE
ARTEMISIA
PLANTAGO
COMPOSIT.TUB.
COMPOSIT.LIG.
SPARGANIUM
TYPHA LAT.
MONOLEET
POLYPODIUM
SPHAGNUM
TERTIAIR
PEDIASTRUM
HYSTRIX
POLLENSOM
-5
-10
-15
-20
-25
70
60
428
706
600
0
0
62
32

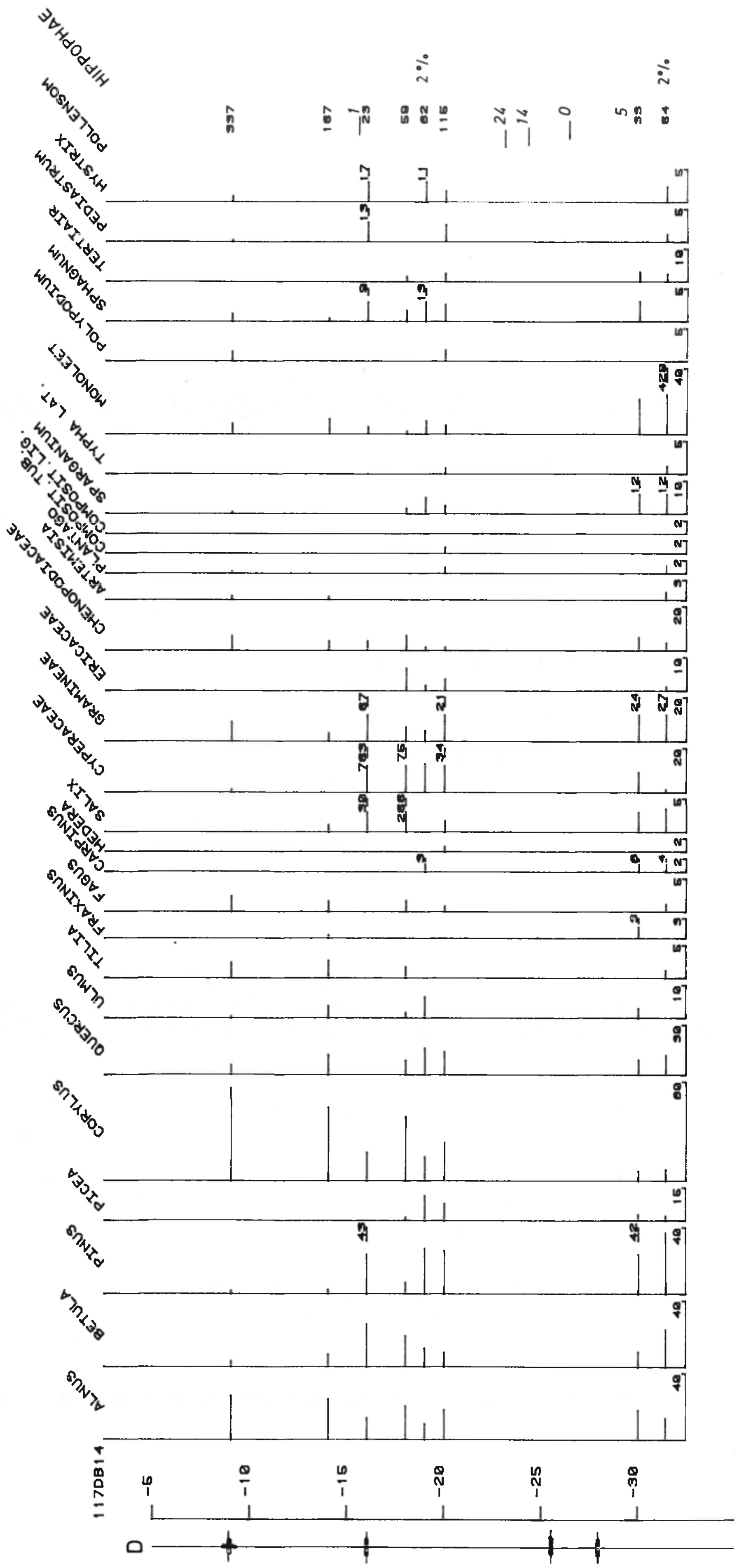

117DB7
M D
ALNUS
BETULA
PINUS
PICEA
CORYLUS
QUERCUS
ULMUS
TILIA
FRAXINUS
FAGUS
CARPINUS
HEDERA
SALIX
CYPERACEAE
GRAMINEAE
ERICACEAE
CHENOPODIACEAE
ARTEMISIA
PLANTAGO
COMPOSIT.TUB.
COMPOSIT.LIG.
SPARGANIUM
TYPHA LAT.
MONOLEET
POLYPODIUM
SPHAGNUM
TERTIAIR
PEDIASTRUM
HYSTRIX
HIPPOPHAE
-5
-10
-15
-20
-25
131
12
9


117DB9
M D
ALNUS BETULA PINUS PICEA CORYLUS QUERCUS ULMUS TILIA FRAXINUS FAGUS CARPINUS HEDERA SALIX CYPERACEAE GRAMINEAE ERICACEAE CHENOPODIACEAE ARTEMISIA PLANTAGO COMPOSIT.TUB. COMPOSIT.LIG. SPARGANIUM TYPHA LAT. MONOLEET POLYPODIUM SPHAGNUM TERTIAIR PEDIASTRUM HYSTRIX POLLENSOM HIPPOPHAE


117DB10
D
ALNUS BETULA PINUS PICEA CORYLUS QUERCUS ULMUS TILIA FRAXINUS FAGUS CARPINUS HEDERA SALIX CYPERACEAE GRAMINEAE ERICACEAE CHENOPODIACEAE ARTEMISIA PLANTAGO COMPOSIT.TUB. COMPOSIT.LIG. SPARGANIUM TYPHA LAT. MONOLEET POLYPODIUM SPHAGNUM TERTIAIR PEDIASTRUM HYSTRIX POLLENSOM


117DB12
M D
ALNUS
BETULA
PINUS
PICEA
CORYLUS
QUERCUS
ULMUS
TILIA
FRAXINUS
FAGUS
CARPINUS
HEDERA
SALIX
CYPERACEAE
GRAMINEAE
ERICACEAE
CHENOPODIACEAE
ARTEMISIA
PLANTAGO
COMPOSIT. TUB.
COMPOSIT. LIG
SPARGANIUM
TYPHA LAT
MONOLEET
POLYPODIUM
SPHAGNUM
TERTIAIR
PEDIASTRUM
HYSTRIX
POLLENSOM
HIPPOPHAE
-5
-10
-15
-20
-25
-30
234
296
298 +
167 1%
442 1%
99
258 1%
88 10%
193 17%
69 3%
14 +
21 +
20
28 +


117DB13
M
ALNUS
BETULA
PINUS
PICEA
CORYLUS
QUERCUS
ULMUS
TILIA
FRAXINUS
FAGUS
CARPINUS
HEDERA
SALIX
CYPERACEAE
GRAMINEAE
ERICACEAE
CHENOPODIACEAE
ARTEMISIA
PLANTAGO
COMPOSIT. TUB.
COMPOSIT. LIG.
SPARGANIUM
TYPHA LAT.
MONOLEET
POLYPODIUM
SPHAGNUM
TERTIAIR
PEDIASTRUM
HYSTRIX
POLLENSOM
HIPPOPHAE
-5
-10
-15
-20
-25
380
274
121 +
354 1%
312
14
10
11


HIPPOPHAE
POLLENSOM
HYSTRIX
PEDIASTRUM
TERTIAIR
SPHAGNUM
POLYPODIUM
MONOLEET
TYPHA LAT.
SPARGANIUM
COMPOSIT. LIG.
COMPOSIT. TUB.
PLANTAGO
ARTEMISIA
CHENOPODIACEAE
ERICACEAE
GRAMINEAE
CYPERACEAE
SALIX
HEDERA
CARPINUS
FAGUS
FRAXINUS
TILIA
ULMUS
QUERCUS
CORYLUS
PICEA
PINUS
BETULA
ALNUS
117DB14
D
-5
-10
-15
-20
-25
-30
2 %
2 %

of the high values of *Corylus* and *Ulmus* and the low values of *Alnus* and *Tilia*.

3. Sample 6, 7 and 8.

Alnus and *Fagus* as well as the QM-components indicate a post-atlantic time.

117DB8.

In spite of the low pollenfrequencies in the lower part of the sequence, a subdivision similar to that of coring 117DB6 may be recognized.

1. Sample 1 and 2 : Late Eemian composition.

2. Sample 3 , 4 and 5 : Late-Boreal, early Atlantic composition.

3. Sample 6 and 7 : Post-Atlantic composition.

117DB7.

Under the -17 m level all the pollenspectra have a similar composition : *Pinus, Betula* and *Picea* are the dominant elements. Thermophilous trees are scarcely represented. Other characteristics are the continuous curves for *Carpinus, Salix, Ericaceae* and *Artemisia* as well as the very low values of *Chenopodiaceae*. Such a vegetation belongs to cold temperate conditions such as at the end of the Eemian or in the Early Weichselian.

The two spectra on top of the -17 m level have a post-Atlantic composition.

117DB9.

Samples 1 and 2 have a late Eemian composition.

The three plotted samples up to the -17 m level reflect an atlantic to post-atlantic age.

117DB10.

Samples 1 to 4 are late Eemian.

The higher samples are atlantic to postatlantic.

117DB12.

The lowermost samples are poor in pollen. However the few pollen that are present, point to a similar composition as this of the overlaying samples. The nearly continuous curve of *Fagus* indicates a Subatlantic age for the whole sequence. In the samples below -20 m *Picea* is present in noticeable numbers.

117DB13.

This sequence shows great similarity with 117DB12.

117DB14.

This sequence too may be compared with the two preceeding-ones. An uncommon zone of clayey-sediment with high percentage for *Salix, Cyperaceae* and *Gramineae* occurs between -20 m and -16 m. Under that zone the pollencontent is generally low. *Fagus* is only present in some samples, but the *Picea* curve is continuous.

CONCLUSIONS (see fig. 1).

The pollendiagrams allow to distinguish four different pollen assemblages. The presence of a considerable number of *Chenopodiaceae* all over the sequences proves that all the sediments are from marine origin.

1. An Atlantic to Postatlantic assemblage for all the samples up to the -17 m. It is evident that we are dealing here with the Calais-deposits. It is remarkable that *Fagus* is often present in the deepest layers of these deposits. If the dating of this deep presence of *Fagus* is comparable with the dating of the appearance of *Fagus* in coastal peat sequences, a sedimentological gap between early atlantic times and late subboreal ones has to be supposed. This pollen assemblage also occurs in the borings 117DB12, 117DB13 and 117DB14, at depths well below the -17 m level. Together with the relative high percentages of *Fagus*, high numbers of *Hippophae* have been found. The fact that these findings were made closest to the sea (they are on the beach) lead to the supposition that deep marine erosion has taken place there during the Subatlantic. In the light of this, the explanation about the strange behaviour of the *Hippophae* pollengrains, as given in the introduction has to be revised. (see also the stratigraphical conclusions).

2. A Boreal assemblage.
   It is very characterized by its botanical composition, and confirmed by the radiacarbon date. An extrapolation to the base of boring 193DB5 results in an age of 8500 BP for the sealevel at -26 m TAW (± -28 m NAP). Early atlantic sediments are probably present in the top samples under the -17 m level in the borings 117DB8 and 117DB6.

3. A late Eemian or early Weichselian assemblage.
   It is only present in boring 117DB7. It is very pronounced too over the total length of the sequence. It points to sediments of the regressing Eemian Sea.

4. A late Eemian assemblage.
   In all the borings, with exception for assemblages 2 and 3 the deepest sediments are generally poor in pollen. Nevertheless sufficiently data could be collected to conclude that these sediments are of an older origin than Holocene. The fact that together with the late Eemian pollenflora some grains of typical cold plants like *Selaginella* were found, could indicate that these marine late Eemian sediments have been reworked in Weichselian times.

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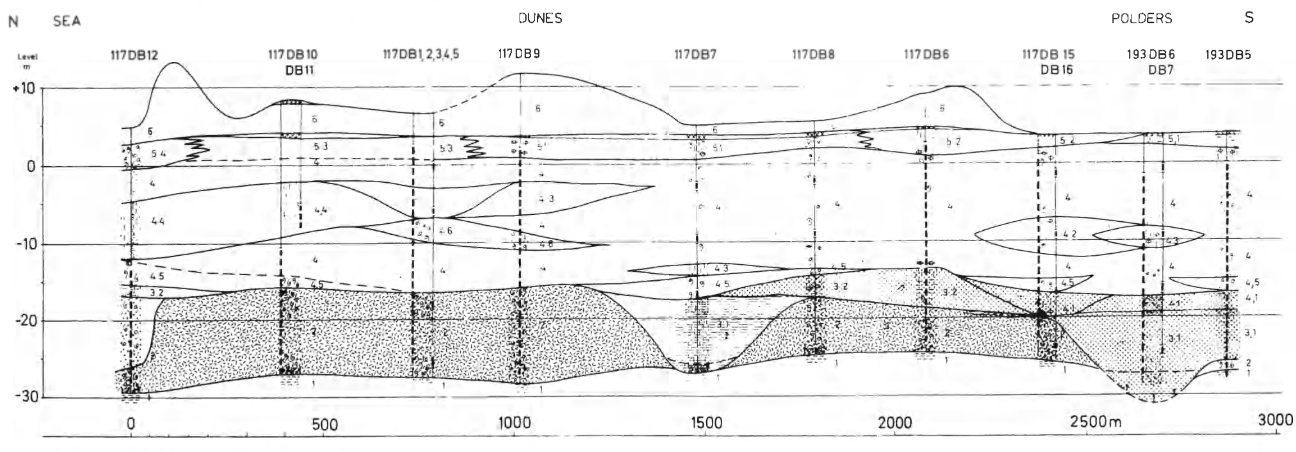

Fig. 1 POLLEN ASSEMBLAGE-ZONES

1 2 3 4

GENERAL CONCLUSIONS.

The biostratigraphical study, comprising pollen, diatom and mollusc investigations, sheds more light on the age and the genesis of the deposits below level -17.

The pollen analysis gives the most accurate geochronological order for the sediments. The medium to coarse medium sand (layer 2) corresponds with the Late Eemian assemblage. The clay-silt complex (layer 3) not only varies in grain-size distribution, thickness and level of occurrence but also contains three different pollen assemblages :

- a Late Eemian or Early Weichselian assemblage in boring 117DB7 between the levels -17 and -27;
- a Boreal assemblage in borings 193DB5 and 193DB7 between the levels -19 and -27;
- an Early Atlantic assemblage in the borings 117DB8 and 117 DB6 between the levels -14 and -18.

It is difficult to interpret the presence of *Fagus* and *Hippophae* in the medium to coarse medium sands (layer 2) in the borings on the back-shore. One explanation may be that this few pollen are present because of stronger vertical groundwaterflow in the Belgian coastal plain (L. LEBBE, 1981).

The diatom analyses indicates the presence of four kinds of sediments :

- marine-brackish to marine Calais deposits of tidal flat origin above the level -17.
- sediments of possible Eemian age with a somewhat different diatom flora, laid down under similar conditions (the deeper sediments of 117DB7);
- Calais sediments with a marked fresh water influence below the -17 level (193DB5 and 193DB6);
- diatom-free sediments (also containing very few pollen grains).

These interpretations are still considered tentative due to the limited amount of material examined.

The mollusc investigation did not lead to similar results. Besides the reasons that were put forward previously our limited knowledge of Belgian mollusc faunas does not allow more precise conclusions. Indeed when out of a total amount of 113 marine species, 21 i. e. nearly 20 %, have never been recorded before, obviously further investigations are necessary to classify the problems left by this study.

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