REPORT ON SYSTEMATIC STUDIES ON CORE SEDIMENTS FROM THE VLIETER CHANNEL. WADDEN SEA. THE NETHERLANDS - APPLICATION OF TECHNIQUES AND DIAGNOSIS OF DATA ON GRAIN SIZE. CALCIUM CARBONATE AND ORGANIC C.N.N CONTENT AND XRD - XRF - PB-210 ANALYSES

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1. INTRODUCTION

As a part of the research programme of the Indian scientists, a short cruise was organised by the Netherlands Institute for Sea Research (NIOZ) on board a research vessel 'M.S. Navicula' in parts of Wadden Sea at shallow depths from 12.10.83 to 13.10.83. Along with scientific and technical personnel of NIOZ, the authors and three other personnel from the Geological Survey of India, Government of India, participated in the cruise to collect samples. Dr. Doeke Eisma, Head of the Marine Geology Division, NIOZ, was the chief scientist of the cruise. In total three piston core and three box cores were collected. Detailed laboratory studies on the core sediments were carried out by the authors at the laboratories of NIOZ.

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2. DETAILS OF CRUISE

The vessel is fitted with an 'A' frame on aft side, through which a The cruise was undertaken on board the vessel 'M.S. Navicula', belonging to the Netherlands Institute for Sea Research, Texel. The vessel was equipped to work particularly in the shallow waters of the Wadden Sea. Specifications of the vessel are as follows:

Lenght:	21.25	meter
Breadth:	7.00	meter
Draft:	1.00	meter

Maximum Speed:	7	knots
Tonnage:	40,000	kg
Endurance:	10	days

The vessel has two DAF diesel engines of 135 HP each and the attached rubber boat (Zephyr) has two petrol engines of 25 HP. She is fitted with Furuno Radar (FR1011-N) and a gyro compass for navigational purpose. During the cruise, position fixations were done with the help of the buoys which mark the channels at various points in Wadden Sea. The launch has a echosounder (Lowrance 2460 MA, USA - display type) and radio telephone type RT4413. A removable multipurpose container can be fitted on board for laboratory studies. In this cruise, the container was used to split and process the cores. The vessel is fiited with an 'A' frame on aft side, through which a wire is lowered for sampling with the help of a small boom. There are two winches of 2.5 ton breaking strength, having a 70 meter long wire of 12 mm diameter to lower the geological samplers. There are two more winches on board for fishing nets. Besides, there is a hydrographic winch. All the winches are of the hydraulic type. Sampling operations were done by the two winches having 2.5 ton capacity.

The following geological samplers were used on board:

a) Piston corer (with trigger mechanism)

b) Boxcorer

Participants from Geological Survey of India were as follows:

1. B.K. Saha - Geologist
2. S. Majumdar - Geologist
3. M. Senthiappan - Geologist

4. M. Ramachandran - Mechanical Engineer

5. S.K. Mangla - Mechanical Engineer

The last three persons were engaged for the operation of the samplers.

The cruise was done in Texelstroom channel in the Wadden Sea (Fig. 1). The sampling was done in the Vlieter channel.

During this scientific exercise, altogether three piston cores and three box cores with bottom sediment were collected from two locations. Piston Core No. 1 got disturbed while hauling up the sampler. At station No. 2, the operation of piston corer was unsuccesful because of a negligible recovery of sediment. The core Nos. 3 and 3A were good and are from the same location. All the piston cores were split into two sections with an electrical saw and tightly sealed in plastic bags. The water depths of the sampling stations were measured by echosounder.

The details of the sampling stations are given in Table 1.

3. LABORATORY STUDIES

Storage of Cores.- The cores were tightly sealed in plastic bags with a Seal boy (Audison Electro make) and kept in the sample storage room at about 4°C. The core samples were brought in the laboratory whenever required for studies and were again kept in the storage room at the same conditions. The entire work on processing of samples and laboratory studies was carried out by the authors.

Megascopic Studies of Core Samples.- As mentioned above, all the core sections, covered with plastic liner, had been split longitudinally into equal halves with an electrical saw. In the laboratory both halves were photographed together with a meter tape on 1:1 scale. The megascopic descriptions of the sediments including colour etc were made from the freshly-split wet core after it was photographed and before sampling or any other determination. Determination of colour was done by direct visual comparison with the G.S.A. soil colour chart. Colour symbols along with names were used. An overall estimate of grain size was done comparing the sediment visually with the standard samples of different size fractions. Both halves of each core were compared with each other for megascopic studies. Descriptions of the core samples were done on the following parameters:

i) Colour
ii) Texture (Grain size)
iii) Physical character (relative compactness)
iv) Bedding (character of contact, bedding planes, markings surface, disturbances)
v) Organic/biogenic constituents
vi) Miscellaneous features

The descriptions were noted on graph paper (Fig. 1). The description of core No. vi83-1, being disturbed, could not be done properly.

X-ray Photographs (Radiographs) of Core Sections.- X-ray

photographs of core sections represent the physical character more truly and clearly than normal photographs as the former give the total features with penetration within the sediment. To suit the facilities of the equipment, one half of the core was cut into pieces with a maximum length of 40 cm. The X-ray films (maximum five at a time) were loaded in the X-ray equipment (43805N-X-ray system Faxitron Hewlett-Packard). Then the core sections were put on top of the X-ray films. In this system, at most five sections of not more than 40 cm length can be X-rayed at a time. Then the instrument was put on and with automatically controlled exposure time, X-ray films were exposed. The exposed films were developed in a dark room. Altogether 13 sections of cores No. 3 and 3A were photographed.

Sections photographed are as follows:

(a)

Top

	ii	i		
vi83 - 3A=2:	40cm	40cm		
	iv	iii	ii	i
vi83 - 3A=1:	28.7cm	40cm	40cm	40cm

vi83 - 3A=2 i & ii

five at a time

vi83-3A=1 i, ii,iii

100% exposure time = 16.4 minutes

vi83-3A=1

iv - one at one time

100% exposure time = 16 minutes

(b)

		Top			
		iii	ii	i	
vi83-3=2	:	11cm	40cm	40cm	
		iv	iii	ii	i
vi83-3=1		31cm	40cm	40cm	40cm

vi83-3=2 i, ii, iii
five at a time
100% exposure time = 22.1 minutes

vi83-3=1 i, ii

vi83-3=1 iii,iv two at a time
100% exposure time = 22.5 minutes

The films were studied visually on a transparent glass using light from below. The bands/layers of sediment and biogenic materials of various fractions are very distinct in the above radiographs. The sandy and clayey/silty zones are also clear showing dark and light colours respectively in the radiographs (photo-1). There are burrowing features which have been filled in some cases by finer sediments from above. The horizontal and random orientations of coarse shell fragments and whole shells indicate that those are not in situ but have been brought from elsewhere into the sediments. The fragments and whole shells are of species living on the surrounding tidal flats.

Studies of Smear Slides.- Based on the above observations, thirty and twenty-three points were chosen from cores No. 3

and 3a respectively at different depths within the sediments to prepare smear slides. A small amount of sediment was taken on a thin wooden peg, put on a glass slide and mixed with a few drops of demineralised water. The sediment on the slide was dried on a hot plate and Canada balsam was added to it putting a slide cover on the top to prepare the smear slide. The slides were studied under the petrographic microscope to get an estimate of sand/silt/clay, quartz, heavy minerals, biogenic materials, plant remains etc. It appears from the studies that the samples contain more sand/silt and less biogenic materials. Details of studies are given in the enclosed Table 2.

'nalytical studies.- The megasopic X-ray photographs and smear slide studies of the core sections were done to get a general idea of the composition, size and other physical characters of the core sections. Based on these observations, sampling points were chosen at different depths of the cores to carry out the following analyses:

i.)Grain size analysis, determination of total carbon, organic hydrogen and nitrogen, iii) determination of calcium carbonate/inorganic carbon, iv.) determination of the major oxides by X-ray fluorescence spectrometry, v) identification of clay and associated minerals by X-ray diffractometry and vi) determination of rate of sedimentation by the Pb-210 method.

The core No. 1, being disturbed, was not considered. As cores No. 3 and 3A from same station, one of them (3A) was choosen for laboratory studies. To do comparative studies, however, smear slides of both 3 and 3A were done.

Samples were taken from core No.3A at seventeen different depths to do the following laboratory studies:

Sample No.	Depth and section	Laboratory studies
1	3 - 4 cm = 2	Grain size $CaCO_3$ C,H,N
2	11 - 13.5 cm = 2	Grain size $CaCO_3$
3	32 - 33 cm = 2	Grain size $CaCO_3$ Pb-210, XRD
4	44 - 46.5 cm = 2	Grain size $CaCO_3$ XRD, XRF
5	56 - 57 cm = 2	Grain size $CaCO_3$ C, H, N
6	67 - 68 cm = 2	Grain size $CaCO_3$ XRD, Pb-210
7	16.5 - 18 cm = 1	Grain size $CaCO_3$ C,H,N
8	28.5 - 31 cm = 1	Grain size $CaCO_3$
9	40.5 - 41.5 cm = 1	Grain size $CaCO_3$ XRD, C, H, N
10	62.5 - 64 cm = 1	Grain size $CaCO_3$ Pb-210
11	68.5 - 71 cm = 1	Grain size $CaCO_3$
12	87.5 - 89 cm = 1	Grain size $CaCO_3$ XRD, C, H, N
13	109 - 111 cm = 1	Grain size $CaCO_3$ XRD. XRF
14	110 - 111 cm = 1	Pb-210
15	124 - 125.5 cm = 1	Grain size $CaCO_3$ C, H, N
16	136 - 137 cm = 1	Grain size $CaCO_3$ XRD, Pb-210
17	147.5 - 149 cm = 1	Grain size $CaCO_3$ XRD

Grain Size Analysis.- Sixteen samples were taken from different depths in the core to determine the distribution of

grain size. The samples were dried in an oven at 105°C and were treated with hydrogen peroxide of 30% strenght to remove organic matter, resulting in the disintegration of the sediment. The fraction <63μm size was separated by wet sieving. The dried fraction of >63μm size was sieved using 2000, 1000, 500, 250 and 125 micron sieves. The fraction <63μm size was mixed with 25 ml of sodium phosphate (concentration: 26.77 gm/l) as dispersing agent. The solution was made to 1000 ml by adding distilled water in a cylinder. Then pipetting was done to get the 32, 16, 8, 4, 2 and 1 μm size fractions, after shaking and settling for a definite period for a definite fraction. The percentages of the individual size fractions were calculated, out of the total weight for all fractions (Table 3). The percentages of sand-silt-clay were plotted on a ternary textural diagram (Fig. 2) to find out the nomenclature of the sediments after Shephard's Classification, 1954 (Table 4). The diagram indicates that the samples are mostly sandy with few silty/clayey samples at depth.

In order to deduce sedimentary environments, it is necessary to find out statistical parameters like average size, sorting and other frequency distribution properties. Cumulative percentages along the ordinate with grain size (Φ scale) along the abcissa were plotted on probability-linear graph paper (Fig. 3) to find out the frequency curve. In some cases, cumulative percents were plotted against grain size of mm scale on probability-log paper. In such cases mm scale is converted to phi-scale by formula,

ϕ = $-\log_2 d(mm)$, where d(mm) = grain size in mm. Phi-values corresponding to different cumulative percents were determined from the curve. The statistical parameters (Table-5) were calculated using the following formula (after Folk & Ward 1957):

$$\text{Mean size } (M_2) = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

$$\text{Graphic Standard Deviation } (\sigma_1) = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$$

$$\text{Inclusive Graphic Skewness } (SK_1) = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

$$\text{Kurtosis } (K_g) = \frac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$$

Mean size (M_z):

Mean size ranges 2.27 ϕ to 4.07 ϕ in case of sand. Silty sand/sandy silt samples show the values as 4.27 ϕ to 4.56 ϕ. The highest values of 5.60 ϕ 5.80 ϕ are from clay-sand-silt and sand-silt-clay respectively.

Standard Deviation (σ_1):

σ_1 values range from 0.55 ϕ to 2.85 ϕ. About 80% of the samples have a mean σ_1 of about 2.00 ϕ with mean M_z of about 4 ϕ. These samples have a clustering of σ_1 values at 1.46 ϕ to 2.00 ϕ (M_z = 2.89 to 4.56 ϕ), representing poorly sorted fine sand to sandy silt and at 2.32 ϕ to 2.85 ϕ (M_z = 4.50 to 5.80 ϕ), representing very poorly sorted silty sand to sand-silt-clay. Besides, there are a few samples which (M_z = 2.27 to 2.61 ϕ) are moderately well sorted to moderately sorted sand having σ_1 values of 0.55 ϕ to 0.82 ϕ. There is little opportunity for the sorting of sediments after deposition, as the sediments being deposited in the channel very recently from nearby sources, have been buried rapidly and no gentle reworking has taken place. Skewness (SK_1):

About half of the samples, grouped about a mean skewness of + 0.56 with a mean σ_1 of 1.87 (SK_1 ranges between + 0.50 to + 0.66) have a tail to the right (strong excess of fine material), resulting in poor sorting. Only few skewness

values occur in the range of - 0.14 to - 0.20 indicating a near symmetrical distribution around the median.

About two-thirds of the samples have a mean K_g of about 2 with a mean σ_1 of 1.45. This shows a non-normal distribution of kurtosis of a leptokurtic nature. This has a large clustering at about 1.13 to 1.67 and 2.26 to 3.32. A few samples are mesokurtic or platykurtic.

The cumulative curves show that in general there are three segments, limited by breaks at 250 µm and 63 µm. They represent three subpopulations of coarse to medium sand, fine sand and silt plus clay. The distribution of the standard deviation and the skewness values conform to this polymodality.

The high values of kurtosis indicate that part of the sediments might have achieved its sorting elsewhere in a high energy environment and was transported into the environment near the channel, where it was mixed with another type of sediment before or during deposition at the present location.

Determination of total carbon, hydrogen and nitrogen.- The analysis of six samples was done with an CHN-Autoanalyser (Model No. 240B - Perkin Elmer) to find out the weight percentages of carbon, hydrogen and nitrogen.

The Elemental Analyser accurately determines the carbon, hydrogen and nitrogen contents of organic compounds by detecting and measuring their combustion products CO_2, H_2O and N_2. Combustion occurs in pure oxygen under static conditions. The combustion products are then analysed automatically in a self-integrating, steady-state, thermal

conductivity analyser which eliminates the tedious calssical gravimetric-weighing of absorption traps. Results are recorded with the Perkin-Elmer Calculater system. Blanks, sensitivity factors and analytical results are computed directly in weight percents with the calculator. The samples are automatically processed without operator attention.

Three systems in the elemental analyser perform the determinations. These are the combustion train, the analytical system and the electronics. A pure oxygen supply is required for sample combustion. Helium is required to carry combustion products from the combustion train trhough the analytical system to the atmosphere. It was selected as a carrier because

1. It is chemically inert relative to tube packing materials.
2. It has a very high coefficient of thermal conductivity.

Before analysis, the samples were dried at 70°C in an oven and cooled at room temperature. While cooling, the samples were properly covered to avoid absorption of atmospheric humidity. The samples were powdered homogeneously in an agate mortar, then weighed in an automatic electrobalance CAHN25 of an accuracy of 0.01 mg and kept in an aluminium container (of about 3 mg weight). Normally about 30 mg of sample were taken.

To determine C, H and N by this system, acetanilid of about 3 to 4 mg of weight is used as standard. In this case 3.124 mg acetanilid (C_8H_9NO) was taken.

For analysis, the sample was loaded into the cool zone of the combustion train. Then the weight of the sample was fed to the computer and the analyzer was started. The entire system was flushed with helium at high flow rate and oxygen was introduced into the combustion train in order to promote sample combustion. This takes about 2.5 minutes. When the system is ready, the sample is moved magnetically into a high temperature (approx. 950°C) combustion zone. The weight percentages of C, H and N are then automatically recorded. It takes about eleven minutes to complete one sample.

The carbon (0.17 to 8.81%), hydrogen (0.03 to 6.8%) nitrogen (0.00 to 0.36%) contents were foundvary widely (Table 6). The weight percents of all the elements were plotted on graph against silt plus clay (<63 μm percents (Fig. 4,5,6). It shows that high values of these elements are associated with high contents of the finer fraction. To find out the relationship amongst different elements, regression lines were drawn for C versus H (Fig. 7), C versus N (Fig. 8) and H versus N (Fig. 9). Each element shows a linear relationship with another element, indicating that one element increases with the increase of an other element, especially in the case of nitrogen and hydrogen. The C-N ratio is between 15 to 30, which indicates that the organic matter is predominantly of continental origin (land vegetation).

Determination of Calcium Carbonate. Inorganic and Organic Carbon.- Calcium contents of sixteen samples were determined with a Corning Calcium Analyzer - 940 (Complexometric-

Fluorometric titration). The weight percentages of inorganic carbon were obtained from the percentages of $CaCO_3$ which were calculated from the percentages of calcium. The dried and homogeneously powdered samples were weighed in an automatic Electrobalance. Normally about 500 mg of samples are required. Samples were mixed with demineralised water and shaked by a mechanical shaker. The solutions were centrifuged for ten minutes at 3000 R.P.M. to remove free calcium chloride (from sea salts). After decanting the water, 20 ml of hydrochloric acid (diluted to 1:3) was added to samples and these were shaked in mechanical shaker for at least one hour to dissolve $CaCo_3$ into $2Ca^{+} + CO^{-}_{3} + Cl^{-} + (H_2O)\ H^{+} . OH^{-}$. Then the solution was brought to 75 ml by adding more demineralised water and was shake to make it homogeneous. For analysis, a standard quantity of KOH-1N solution was taken in a Cuvette bottle of 240 ml size; 100 microlitre of Calcium Indicator was added to this with a Corning hundred microlitre T.C. disposable pipette. The bottle was loaded to the analyser. Then 50 microlitre of 1N calcium standard solution was put in the bottle by pipette. The 'titration switch' of the equipment was put on and after some time when the 'Ready Indicator' of the equipment glued, another 50 microlitre of standard solution was added. With the 'titration switch' on, a reading is displayed on the system. The adding of 50 microlitre of standard solution was repeated untill a constant value was obtained for at least three consecutive additions. Then calibration of the system was done by adding 50 microlitre of some standard solution for number of times untill the display figure became 5 (standard solution = 2.5 m

mol/l of Ca).
After calibration of the system, 50 microlitre of sample solution was brought into the above cuvette bottle by pipette. The calcium content in m.eq./l of the samples is then automatically recorded in the system. This was repeated for three times and the average results were taken.

The calcium contents in m.eq./l were computed into m.mol/l, from which the Ca contents in m.mol per 75 ml were calculated. This was converted to Ca contents in mg by multiplying it with its atomic weight 40. Then the total $CaCO_3$ contents were calculated and weight percents were determined from the weight of respective dry sediment samples. The content of organic carbon was calculated by subtracting inorganic carbon from the total carbon. In total, sixteen samples were analysed for $CaCO_3$ and inorganic carbon and organic carbon contents were determined in six out of above sixteen samples.

Calcium carbonate contents were found to range widely from 1% to 23% and are related to the <63µm fractions, though not very well. The carbonate percent versus silt plus clay percent (<63µm) was plotted on linear graph paper (fig. 10). The regression line has s small angle of inclination. The carbonate content which increases with the increase of silt plus clay content, is attributed to finely divided calcium carbonate that has been deposited in association with silt and clay fraction. A few samples with small amounts of silt and clay, from or near the seafloor surface, contain high values of $CaCO_3$ due to the presence of large shell fragments.

Comparing the depth within the sediment with the corresponding $CaCO_3$ content, it is seen that there is no relationship between depth within the sediment and the carbonate content.

Organic carbon content also varies widely from 0.03% to 6.62%. It appears that sediments at depth show higher values of organic carbon compared to those from or near the seabottom surface. The organic carbon weight percentages and silt plus clay percentages were plotted on a linear graph paper (Fig. 11) to find out their relation. The regression line shows that the relation is not very sharp. But it is noticed that the high values of organic carbon are sometimes associated with higher percents of silt plus clay. This illustrates that the organic material of the sediment is most probably absorbed to the finer fractions.

The ratio of organic and inorganic carbon varies from 0.21 to 2.55 the finer sediments give a higher ratio.

Determination of major oxides in the sediments.- The weight percentages of major oxides in two sediment samples were determined by X-ray fluorescence spectrometer (PW1410).

After taking the sediment samples from the core sections, these were mixed with distilled water and were preserved in a cooler at 10°C. For analysis, about 3 gm of sample were taken and mixed with distilled water, which was centrifuged, for three times, at 3000 R.P.M. for ten minutes to remove sea salt (mostly NaCl) completely. After decanting the water, the samples were dried in an oven for about six hours at 105°C. The dried samples were powdered homogeneously in an agate

mortar on an electrical rotator (FRITSCH) for about ten minutes. Then the samples were melted with lithium tetraborate in a platinum crucible. The melted material was allowed to cool down at room temperature to form a bead (normally it takes about 15 minutes for complete melting). In this case, the weight of each sample was 1/5th of the weight of the tetraborate. The weight of the samples plus the tetraborate was noted before melting and also after melting to find out the loss of weight due to evaporation during melting. This is called 'loss on ignition'. For accuracy each samnple was taken in duplicate and out of each two beads were made.

For analysis, a bead contained in a sample holder was loaded in the spectrometer. After putting on the system programme, the results in weight percents were automatically recorded and come out in print. The analysis of sample No. 4 (two beads) and sample No. 13 (two beads) were carried out for three and two times respectively. The average results were taken. Necessary correction for 'loss of ignition' was done on the printed data to get the actual results as below (Table 8)

Results.- The sample No. 4, which is sand in size, contains 92.66% SiO_2, whereas the sample No. 13, which is sand-silt-clay in size, contains only 41.60% SiO_2. Although the term 'size fraction' (e.g. sand) refers strictly to size and has nothing to do with composition, the above results show that in the present case the composition of the sand fraction is largely SiO_2 which may be attributed to quartz. It may not be

proper to draw any inference on only two samples, but it is apparent that higher values of all non-silicon oxides are associated with the finer sediment. The high values of iron in finer sediments may be due to presence of iron as coating on the surface of the grains. Al, K and Na might have been derived from feldspar and clay minerals. Ca and Mg are associated with finely divided carbonates that probably have been deposited with the finer fraction.

X-ray diffraction studies.- X-ray diffraction studies were carried out on eight bulk samples mainly for identification of the constituent minerals and also on the <2μm fractions of two samples for identification of the clay-size contents. The bulk samples were scanned from 2 to 50° at 1°2θ/min at 50% relative humidity and the fine fractions from 0.8 to 16° to 1°2θ/min at relative humidity of 0%, 50% and 100%. XRD analyses were carried out using CoK radiation in a combination of a PW1730 Philips generator, PW1300 channel control, PW1394 motor control and PW1050/25 goniometer equipped with a curved graphite monochrometer AMR and a helium-vacuum attachment.

For studying the bulk constituents the samples were powdered in a porcelain mortar to homogeneous size and were treated for Ca exchange before preparing randomly oriented mounts in brass sample holders. For separation of the clay-size fractions, 10 to 15 gm of each sample was mixed thoroughly with demineralised water in a 200 ml glass bottle and was run in the centrifuge at 1500 R.P.M. for 1 min 55 sec. The procedure was repeated 15 times to ensure complete

separation of the clay fraction. The clay suspension, in turn, was treated with 2/3 spoon $CaCl_2$ powder for flocculation and complete separation of the clay material. About 5 mg of the clay sample was mixed with 2/3 ml 1N$CaCl_2$ and few drops of demineralised water in a 15 ml test tube. The contents were centrifuged at 2000 to 2500 R.P.M. for about 5 minutes. The procedure was repeated three times with 1N $CaCl_2$ and water and two or three times with only water until a proper suspension of clay in water was obtained. Similar Ca exchange was also done for the bulk samples. For the clay minerals study, however, mounts were made by suction on porous ceramic tiles.

The 2θ values for all recognisable peaks on the diffractograms were measured and converted into Angstrom values using the standard chart. For identification of the concerned minerals, the Angstrom values were compared with the ASTM Cards, taking initial guidance from Thorez (1975), Carroll(1970) and from X-ray patterns from a collection of standard minerals present in the laboratory. On the diffractograms of bulk samples, the minerals identified are quartz (5 peaks), feldspar (unclassified, 6 to 9 peaks), chlorite (4 peaks), muscovite/illite (2 peaks), kaolinite (1 to 3 peaks), combined clays (unclassified, 2 peaks), calcite (3 peaks), dolomite (1 to 3 peaks) and pyrite (2 to 3 peaks). Besides, amphibole (unclassified), gypsum and sea salt (NaCl) are represented by distinctive peaks in some samples. A combination of clay minerals with peaks at 4.47 Å are called combined clays. Table 9 outlines the minerals identified and their characteristic d-spacings.

Although no internal standard was used in the present case, on the basis of heights of the characteristic peaks from the base an attempt has been made to picturise tentatively the relative proportions of the minerals present in the different samples (Fig. 12). Thus quartz appears to be 3 to 4 times more in the samples Nos. 4, 16 and 17 compared to the rest. For calcite highest and lowest values, 6: 1 in proportion, are shown by sample 13 and 4 respectively. Sample 16 shows much higher enrichment compared to the others in dolomite and also dominates over the rest in content of quartz, muscovite/illite and gypsum. Sample 4, on the other hand, is unique in being impoverished in most minerals excepting quartz for which it contains the second highest peak. The highest peaks for combined clays, amphibole and pyrite are recorded in sample 13, 3 and 6 respectively. The relative proportions of the minerals thus estimated compare quite well with those noted in the corresponding smear slides.

The quantity of calcite and also calcite + 1/ 2 dolomite estimated on diffractograms of the bulk samples the $CaCo_3$ % determined directly, were plotted in Fig. 13, taking the lowest quantity as unit and converting other figures accordingly in both the cases. Similar plots were also made for combined clays to compare the XRD data with the directly-measured 1μm and 2μm size fractions (fig. 14). In case of calcite (or $CaCo_3$), the graphs behave similarly for samples 3, 4 & 6, but do not match for others. Consideration of 1/2 dolomite does not change the relation between XRD and directly-determined patterns. The discrepancy may be due to

the possible influence of feldspar (fresh or altered) or other minerals, in variable quantities, on the concerned peak and/or base of calcite. For combined clays, on the other hand, the quantitative patterns obtained by size-fraction analysis match quite perfectly with the patterns deduced from peak heights. While for the 1 μm fraction the patterns are identical, only samnple 12 and 16 for the 2μm fraction behave somewhat differently.

In the diffractograms (fig. 15) for the clay fractions of sample Nos. 4 and 13 at 50% relative humidity the swelling mineral smectite (14.48 Å), muscovite/illite (10.08 Å) and kaolinite (7.19 Å) are recorded. Chlorite which is common in the corresponding bulk samples is present in minor amounts in the - 2μ fractions, shown in the 0% relative humidity pattern at 14,28 Å. At 0% relative humidity in both the samples the smectite totally collapses while its diffused peak shifts towards the high-angle muscovite-illite peak. On the contrary, at 100% relative humidity the smectite peak broadens and shifts to low angle ($2\theta = 5.32°$ 19.29 Å) for both the samples. Moreover, at 100% relative humidity the sample 4 shows distinct lowering of peak height, which is possibly due to the fact that under complete wet conditions the mineral not only swells but also undulates to such extent so as not to enable the X-ray to account for all the concerned grains. This phenomenon is, however, not displayed by the other sample which more or less maintains the same peak height as at 50% relative humidity.

Determination of sedimentation rate/age by ^{210}pb.- In the

atmosphere there is ^{222}Rn, a gas that continuously escapes from the earth crust. The Rn decays to ^{210}Pb which is transported back to the continent and ocean by rain etc. In the ocean it is adsorbed by particles and sinks to the bottom. In the sediment there is alsways a certain amount of ^{226}Ra which decays through ^{222}Rn to ^{210}Pb. The concentration of ^{210}Pb which is absorbed in the sediment through the first process will tell about the sedimentation rate. The total ^{210}Pb concentration in the sediment is the measure of ^{210}Pb, produced by both ways. So it is required to know how much ^{210}Pb is produced in the sediment by decaying $^{226}Ra/^{222}Rn$. This is possible by measuring the concentration of ^{226}Ra which is in equilibrium with ^{210}Pb and has the same concentration (measured in disintegration per minute per gram). After subtracting this from total ^{210}Pb concentration, the amount of ^{210}Pb that is introduced to the sediment via the atmosphere is obtained.

The sedimentation rate is calculated by the following formula:

$$S = \frac{\lambda \times h}{\ln \frac{A_1}{A_0}}$$ where:

S = Sedimentation rate in cm/year

λ = decay constant of ^{210}Pb(0.031)

A_1 = activity (dpm) on level A_1

A_o = activity (dpm) on level A_o

h = difference in level in cm $(A_o - A_1)$

In the core total five samples at different depths were taken to find out the sedimentation rate from which the age of the core samples was determined.

Sample No.	Depth in cm
3	32 - 33
6	67 - 68
10	142.5 - 144
14	190 - 191
16	216 - 217

The measurement of ^{210}Pb was done using the following scheme :

$$^{210}Pb \xrightarrow[22\ yr]{\beta} {}^{210}Bl \xrightarrow[5\ days]{\beta} {}^{210}Po \xrightarrow[138\ days]{\alpha} {}^{206}Pb \quad Stable$$

The energy of βradiation is of several scales, whereas the energy αradiation is fixed (energy of ^{210}Po = 5.30 Me Vo). So it is advantageous to measure αradiation. The ^{210}Pb concentration will be same as ^{210}Po concentration. In this case ^{210}Po concentrations were measured with a Philips PW4470 αSpectrometer equipped with a Si(Li) surface barrier detector and a 400 channel analyser. The results are given in Table No. 10. Data on sample Nos. 3 and 10 are not considered, as these appear to be erratic. The other results indicate that the average sedimentation rate of the core is 5.21 cm/year. The length of the core is 230 cm. Hence the age of oldest

point of the core (bottommost part) is about 44 years i.e. just after eight years of construction of the 'Afsluit Dyke' which caused the silting of the channel. The geological information, obtained from the core, covers more than 75% of the period of silting of the channel.

4. DISCUSSION

The Wadden sea is a shallow coastal sea along the western and northern coasts of Denmark, F.R.G. and the Netherlands. Towards the North sea, it is bound by 17 large inhabitated barrier islands as well as numerous small uninhabitated sand banks and tiny islands. the boundary towards the mainland is characterised by the presence of salt marshes, sea walls and some Pleistocene cliffs. Three large rivers namely Ems, Weser and Elbe as well as a number of small rivers have estuaries opening into the Wadden sea. The natural forces that influence the geomorphology of the Wadden sea are wind and other climatic factors, the tide and the biological conditions. Wave directions in Wadden sea and adjacent North sea generally correspond to wind directions and are mostly westerly.

The Vlieter channel in the Wadden sea was the main channel of 10 m deep from Texel stroom to the Zuider sea, a bay within the mainland (now named the IJssel lake). During the year of 1932, a long dyke (Afsluitdyke) was built at the southwest face of the Vlieter channel to enclose the Zuider sea.

This caused silting of the channel with a high rate of sedimentation, starting mainly after 5 years i.e. from 1937. Previous work indicates that the silt/clay and sand deposits are layered. Actually in the channels clay/silt is found in suspension and sand is found along the bottom. Tide causes a regular movement whereas waves/wind generate irregular movement in a certain direction. The wind stirs up the bottom sediments and increases the silt/clay transportation in suspension. The suspended matter content in Wadden sea is 10-50 mg/l. Clay/silt in suspension comes from southern part of Dutch-Belgian coast and the Channel, due to erosion of the bottom and river supply. The Rhine itself contributes about 10-20 % of total inputs. Sand comes in the tidal channels from the coast and the seabottom of the adjacent North sea (down to a depth of 20m). It is difficult to measure the actual rate of flow, because bottom transportation of sand is strongly influenced by the measuring instrument.

The sediment of the core studied, the bottom-most part of which is 44 years old, covers more than three-fourth of the period of silting of the channel. The cores are mostly sandy with clay/silt layers and less biogenic materials. The coarse shell fragments were brought from elsewhere into the sediment. Amongst the microfossils foraminifera, diatoms, radiolarians and coccoliths are present. Plant remains of land vegetation are always present. The grain size of sediment comprises three subpopulations of coarse to medium sand, fine sand and silt plus clay. The sediments are poorly sorted with a few well sorted fine sands. These are mostly strongly fine skewed with few samples having a near

symmetrical distribution around the median. About two-third of the samples show a non-normal distribution of kurtosis of leptokurtic nature. The poor sorting of sediments is due to the nearby source and the lack of gentle reworking of the sediments. The polymodality and variations of sorting are due to the different sources of sediments with different distances through which the sediments travelled before reaching this channel, as discussed earlier. The high C-N ratios indicate that organic matter is predominantly of continental origin. The carbonate content is mainly attributed to finely divided calcium carbonate that has been deposited in association with silt and clay fractions. The organic matter of the sediment is most probably adsorbed to the finer fractions. The Wadden sea sands consist mainly quartz (80%), feldspar, mica, carbonate, opaque and heavy minerals of (Van Straaten, 1964). The smear slide studies and results of XRD-XRF analyses conform to this observation. The high concentration of iron in the finer fraction may be due to the presence of iron as coating on grains. The high values of Ca and Mg in finer fractions (XRF data) are conformable to the carbonate content of the samples, measured directly. The high contents of Al, K and Na in finer fraction are attributed to the clay minerals and feldspars. The Wadden sea silt fraction contains little kaolinite (Gadow, 1970) while the clay fraction contains clay minerals like illite, kaolinite and montmorillonite (Van Straaten, 1964). The present XRD studies of bulk samples indicate the presence of illite, kaolinite and combined clays (combination of unclassified clays) and 2μm fractions show the presence of

smectite, illite, kaolinite and chlorite. The average sedimentation in the channel is at the rate of 5.21 cm/year.

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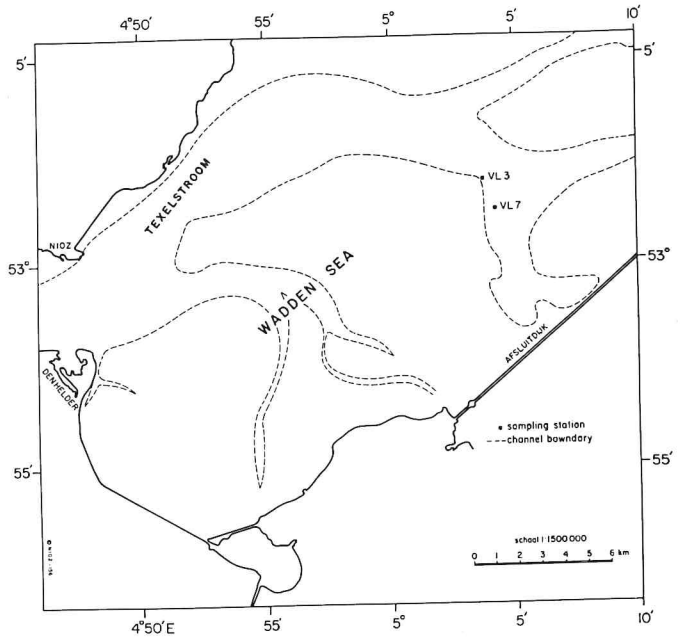

Fig. 1. Map showing sampling stations in Texelstroom, Wadden Sea, The Netherlands in October 1983.

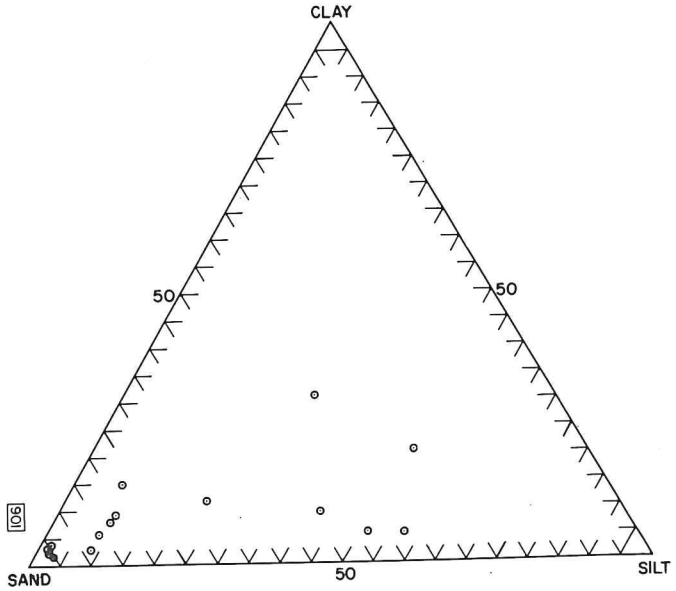

Fig. 2. Ternary textual diagram of sediments.

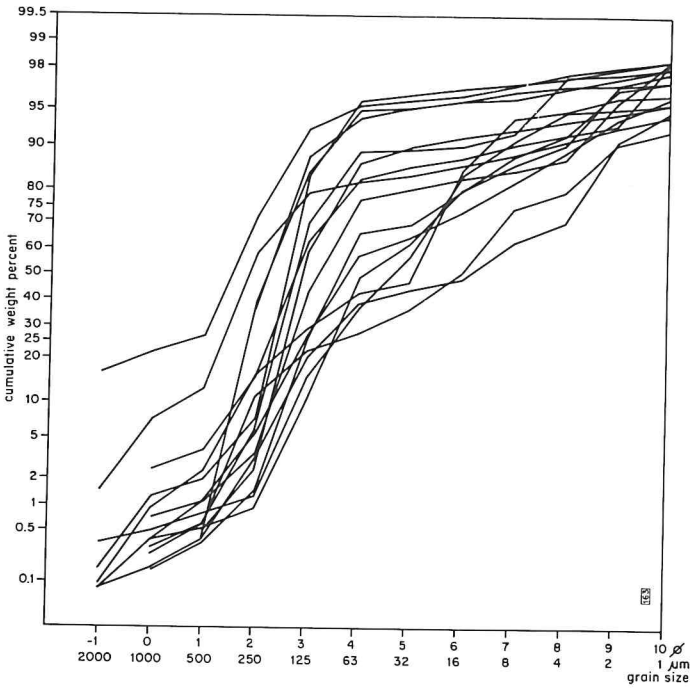

Fig. 3. Cumulative grain size curves.

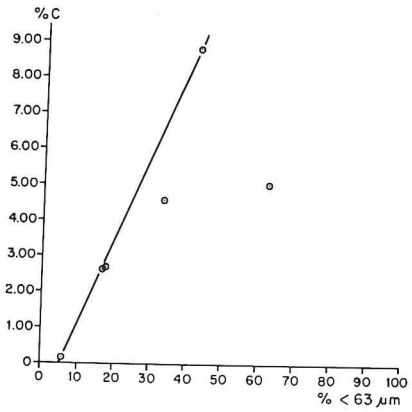

Fig. 4. Relationship between total carbon (%C) and silt plus clay percentage (% 63µm).

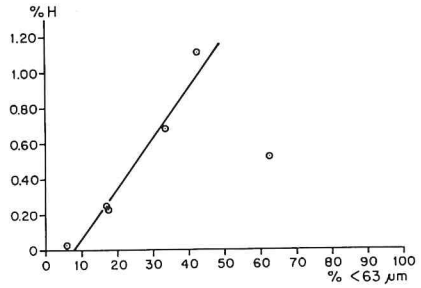

Fig. 5. Relationship between hydrogen content (%H) and silt plus clay percentage (%<63µm).

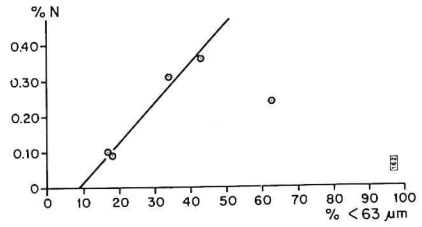

Fig. 6. Relationship between nitrogen content (%N) and silt plus clau percentages (%<63µm).

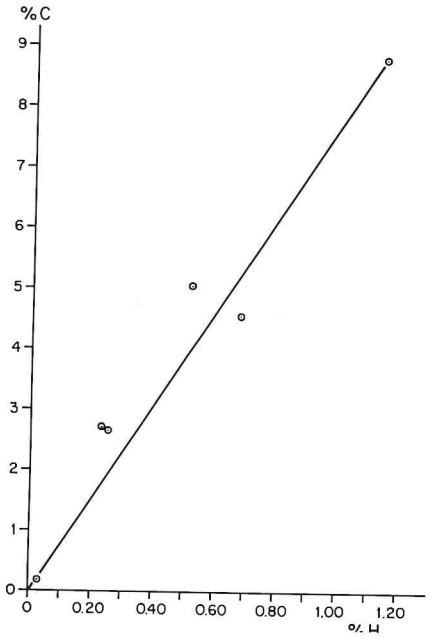

Fig. 7. Relationship between total carbon (%C) and hydrogen %H) content.

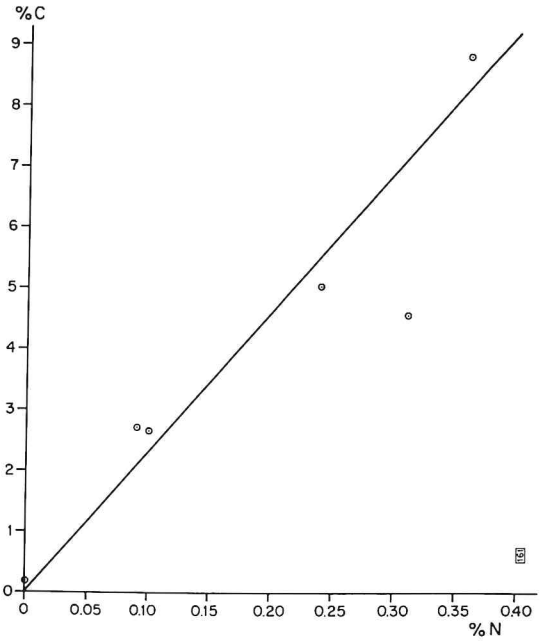

Fig. 8. Relationship between total carbon %C) and nitrogen (%N) content.

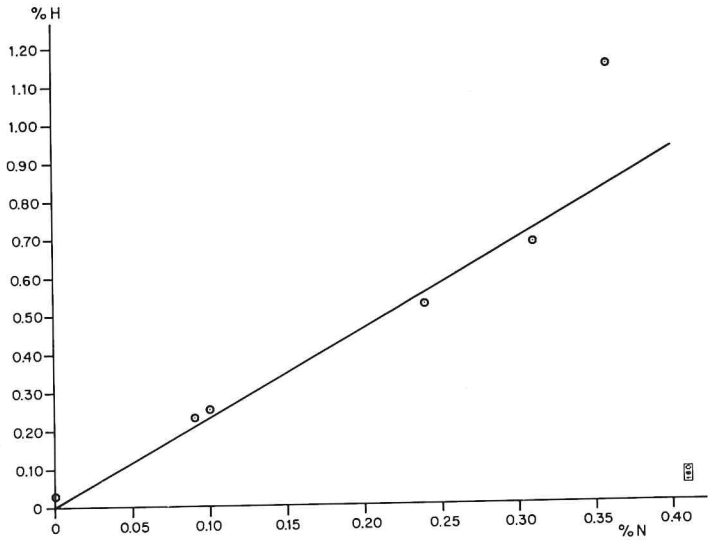

Fig. 9. Relationship between (%H) and nitrogen (%N) content.

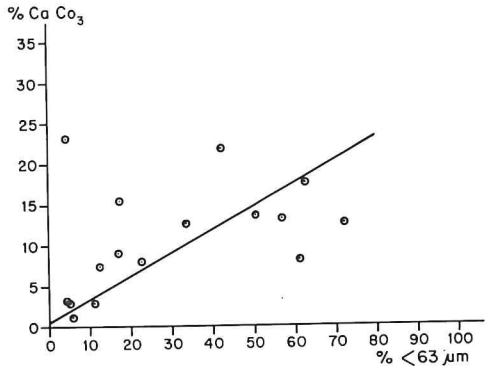

Fig. 10. Relationship between carbonate content (%C) and silt plus clay percentage (%<63µm).

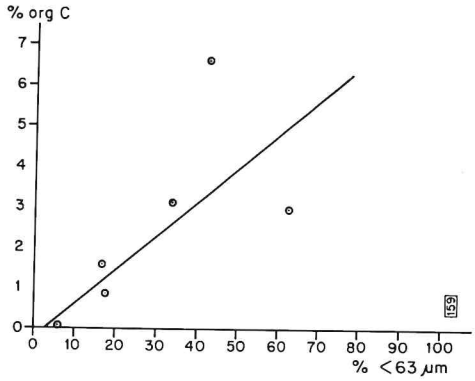

Fig. 11. Relationship between organic carbon content (%Org.) and silt plus clay (%<63µm).

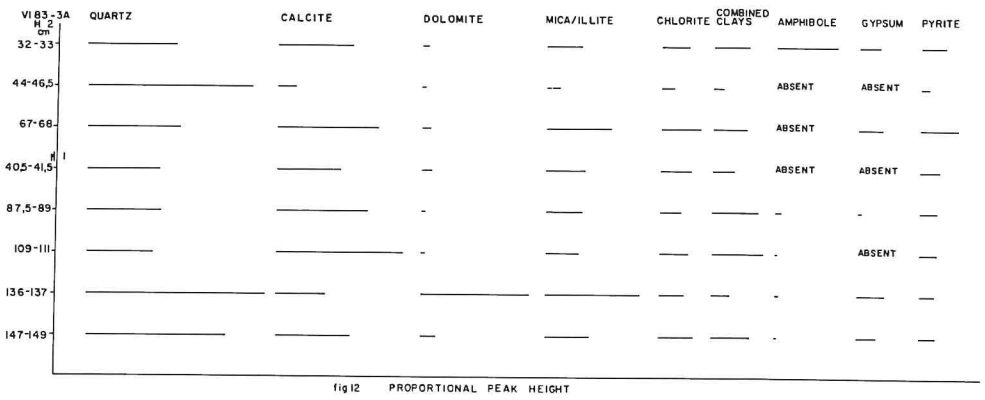

Fig. 12. Plots showing proportional peak heights of individual minerals in the bulk samples, measured in diffractograms at 50% relative humidity. Scale used is different for different minerals.

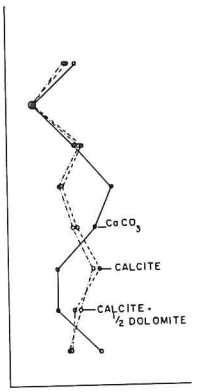

Fig. 13. Plots showing relation between $CaCO_3$ % determined directly and relative quantities measured as peak heights of calcite and calcite plus 1/2 dolomite. Lowest value in all the cases was taken as unity and the other values were converted proportionately. Scale is same in all cases.

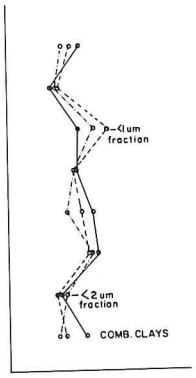

Fig. 14. Plots showing relation between directly-measured <1 μm and <2μm size fractions and peak heights of COMB. CLAYS (combined clays). Lowest value in all cases was taken as unity and the other values were converted proportionately. Scale is same in all cases.

TABLE 1

Location, water depths, lengths of the sediment cores

Sl. No.	Station and Core no	Date	Location	Nature of core	water depths	Remarks
1	vi83-1	12.10.83	53°1.4'N 5°4.4'E (VL7)	Piston core of 244.5cm ≠ 1; 150 cm ≠ 2; 94.5 cm	6.5 m	Grab lowere no sample; 5 cm core catcher sam trip core empty; core sample is disturbed
2	vi83-2	12.10.83	53°2.1'N 5°3.9'N (VL3)	Piston core lowered	19 m	No sample
3	vi83-3	13.10.83 Do		Piston core of 241.0cm ≠1 : 150 cm ≠2 : 91 cm	19 m	Trip core empty; no core catche. sample
4	vi83-3A	13.10.83 Do		Piston core of 230 cm ≠1 150 cm ≠2 80 cm	19 m	Trip core empty; no core catcher sam
5	vi83-3 (Box-A)	13.10.83 Do		Box core	19 m	Some sample lost from tl bottom
6	vi83-3 (Box-B)	13.10.83 Do		Box core	19 m	
7	vi83-4	13.10.83	53°1.4'N 5°4.4'E (VL7)	Box core	6.5 m	

TABLE 2 A

N=nil, T=<2%, F=<10%
C=<20%, A=>20%

CORE VI83-3 ≠ 1	clay	silt	sand	mica	quartz	heavy mineral	pyrite	volcanic ash	biogenic material	diatoms	radiolaria	forams	coccoliths	bio-material /minerals	plant remains	remarks
2 cm	C	A	T	F	T	F	N	N	F	F	F	T	T	M	T	Opaque minerals
11 cm	F	C	A	F	A	T	N	N	T	N	T	T	T	M	T	Less no. of grains, opaque minerals, Spene
16 cm	C	A	C	F	C	F	N	N	C	F	F	F	T	M	T	Opaque minerals, epidot e
25 cm	F	C	A	T	A	T	N	N	T	N	N	T	N	M	T	Opaque minerals
45.5 cm	C	A	C	C	F	F	N	N	T	T	T	T	T	M	C	Opaque minerals
54 cm	C	A	A	A	C	T	N	N	T	T	T	T	T	M	T	Opaque minerals, orthoclase microcline, plagioclase, calcite
67 cm	A	A	C	F	F	F	N	N	T	T	N	T	T	M	T	Opaque minerals, microcline, plagioclase, shell fragments
76 cm	A	A	F	C	F	F	N	N	F	T	T	T	T	M	F	Opaque minerals, garnet
83.5 cm	F	A	C	T	F	F	N	N	T	T	T	T	T	M	C	Opaque minerals
97 cm	C	A	A	A	F	T	N	N	F	T	T	T	T	M	F	Microcline, shell fragments
107 cm	A	A	T	A	T	C	N	N	F	T	F	T	T	M	T	Shell fragments, opaque min.
116 cm	T	F	A	T	A	T	N	N	T	T	N	T	T	M	T	Opaque minerals
121 cm	A	A	C	F	C	T	N	N	C	C	T	T	T	M	T	Opaque minerals
129 cm	T	F	A	T	A	T	N	N	T	T	N	N	N	M	T	Opaque minerals
145 cm	T	F	A	T	A	T	N	N	T	T	N	N	N	M	T	Opaque minerals

Results of smear-slide studies of the sediment cores.

TABLE 2 A (continued)

CORE VI83-3 ≠ 2	clay	silt	sand	mica	quartz	heavy mineral	pyrite	volcanic ash	biogenic material	diatoms	radiolaria	forams	coccoliths	bio-material /minerals	plant remains	remarks
5 cm	T	A	A	T	C	-	-	-	-	-	T	-	T	-	T	Opaque minerals, section could not be identified, due to air bubles and thick c.b.
17 cm	T	C	A	F	C	T	N	-	-	-	-	-	-	-	-	Pyroxene, microcline, -full of air bubles
31 cm	C	A	F	F	F	-	-	-	-	-	-	-	-	-	F	Leave features, -grains are less
40 cm	C	A	C	F	C	F	N	N	C	F	F	F	TF	M	F	Opaque minerals
49 cm	F	F	A	F	A	F	N	N	F	T	T	T	T	M	T	Calcite, opaque minerals
50.8 cm	C	A	C	F	C	C	N	N	T	T	T	T	T	M	T	Opaque minerals
78 cm	A	A	T	C	T	C	N	N	C	F	F	T	T	M	T	Opaque minerals
88 cm	T	C	A	T	A	T	N	N	T	T	N	N	T	M	T	Opaque minerals

TABLE 2 B

CORE VI83-3A ≠ 1	clay	silt	sand	mica	quartz	heavy mineral	pyrite	volcanic ash	biogenic material	diatoms	radiolaria	forams	coccoliths	bio-material /minerals	plant remains	remarks
2.5 cm	A	C	C	C	C	F	N	N	F	F	N	N	N	M	F	
3 cm	A	C	C	C	F	F	N	N	F	C	N	T	T	M	F	Garnet, opaque minerals
6 cm	A	C	F	F	C	T	N	N	F	F	N	N	T	M	F	Shell fragments
8 cm	A	C	F	C	T	T	N	N	C	F	F	T	F	M	F	Opaque minerals, shell fragments common
26 cm	A	C	A	F	F	F	N	N	C	F	F	F	F	M	F	Augite, garnet, opaque minerals
39 cm	A	C	A	F	A	F	N	N	E	F	T	N	T	M	F	Opaque minerals, discoaster (?) O
40 cm	F	A	C	C	C	F	N	N	C	F	F	T	T	M	F	Opaque minerals
47 cm	C	C	A	C	C	F	N	N	F	T	T	N	N	M	F	Augite, garnet, opaque minerals
57 cm	A	C	C	F	C	F	N	N	C	F	F	T	F	M	F	Garnet, opaque minerals, discoaster (?)
65 cm	F	C	A	C	C	T	N	N	T	T	T	N	T	M	T	Opaque minerals
67 cm	A	A	F	F	F	C	N	N	C	F	F	T	T	M	F	Opaque minerals
73 cm	A	A	C	T	A	F	N	N	F	T	T	N	N	M	F	Augite, garnet
84 cm	C	F	C	T	T	F	F	N	F	T	T	N	T	M	T	Opaque minerals
88 cm	A	A	C	C	C	T	N	N	C	F	F	T	T	M	T	Altered epidote, discoaster (?)
97 cm	F	C	F	F	F	T	N	N	N	N	N	N	N	M	T	Opaque minerals
99 cm	C	C	T	A	T	T	N	N	F	T	F	T	T	M	C	Opaque minerals
125 cm	A	A	F	C	C	F	N	N	F	F	T	T	T	M	T	Opaque minerals, discoaster (?)
146 cm	A	A	F	C	C	F	N	N	F	F	T	T	N	M	F	Opaque minerals, hyaloylix

TABLE 2 B (continued)

CORE VI83-3A ≠ 2	clay	silt	sand	mica	quartz	heavy mineral	pyrite	volcanic ash	biogenic material	diatoms	radiolaria	forams	coccoliths	bio-material /minerals	plant remains	remarks
3 cm	C	A	C	C	C	T	N	N	F	T	C	T	F	M	F	Opaque minerals, discoaster, Mollusca
17 cm	C	A	A	F	A	F	N	N	C	F	C	F	F	M	F	Opaque minerals
23 cm	F	A	A	C	A	T	N	N	F	T	T	T	T	M	T	Rock fragments, opaque minerals, ostracoda
32 cm	C	A	T	F	F	F	N	N	F	F	F	N	T	M	F	Calcite, garnet, opaque minerals
42 cm	F	C	A	F	A	F	N	N	F	T	T	T	T	M	T	Opaque minerals, discoaster, less no. of grains
48 cm	A	A	F	C	C	C	N	N	F	F	F	F	F	M	F	Opaque minerals, discoaster
53 cm	A	C	A	C	A	F	N	N	A	F	F	T	F	M	F	Opaque minerals, mollusca
56 cm	F	F	A	F	A	F	N	N	F	T	T	T	T	M	T	Perthite, opaque minerals
63 cm	A	A	C	C	C	C	N	N	C	T	C	F	T	M	T	mollusca, petrepoda Opaque minerals, calcite, pyroxene, sphene(?)
66 cm	A	A	C	C	F	C	N	N	F	F	F	T	T	M	F	Opaque minerals
72 cm	A	A	A	T	A	F	N	N	F	T	T	N	T	M	T	Calcite, opaque minerals
76 cm	A	A	F	C	F	C	N	N	C	F	F	F	T	M	F	Opaque minerals

TABLE 3 Weight percentages of different size fraction of sediments

Size	sample no 1	sample no 2	sample no 3	sample no 4	sample no 5	sample no 6	sample no 7	sample no 8	sample no 9	sample no 10	sample no 11	sample no 12	sample no 13	sample no 15	sample no 16	sample no 17
+2000 μ (−1ø)	1.52	16.02	0.09	0.08	0.00	0.00	0.00	-	0.00	0.15	-	0.00	0.00	0.00	0.00	0.08
+1000 μ (0.00ø)	5.80	5.61	0.83	0.08	0.25	0.30	2.50	-	0.38	1.13	-	0.35	0.00	0.14	0.74	0.31
+500 μ (1.00ø)	5.35	4.85	1.48	0.23	0.34	0.30	1.40	0.60	0.76	0.68	0.50	0.17	0.40	0.21	0.41	0.16
+250 μ (2.00ø)	45.32	45.17	13.38	38.41	36.61	10.41	11.31	5.31	4.30	5.35	2.01	0.78	2.78	1.12	2.54	0.39
+125 μ (3.00ø)	21.05	21.13	13.84	46.14	50.93	11.03	42.57	63.50	21.41	76.28	56.82	14.17	17.22	24.55	39.18	9.65
+63 μ (4.00ø)	3.30	2.54	13.28	10.05	5.93	5.67	25.27	19.60	30.60	12.12	27.23	21.74	18.15	40.28	34.51	38.67
+32 μ (5.00ø)	1.62	0.50	3.90	0.18	1.16	8.91	2.94	0.30	7.10	1.07	3.36	20.32	5.58	2.70	3.01	13.05
+16 μ (6.00ø)	2.39	0.38	38.50	0.76	0.66	13.10	1.79	0.75	8.91	-	1.52	26.49	4.13	10.91	2.96	18.24
+8 μ (7.00ø)	2.09	0.86	8.78	0 13	0.81	24.46	2.44	2.12	8.87	0.38	1.08	7.60	14.23	8.33	1.77	6.14
+4 μ (8.00ø)	2.64	0.58	0.86	0.74	0.38	5.25	1.69	5.28	6.44	0.38	1.26	3.19	7.33	3.50	2.31	3.55
+2 μ (9.00ø)	1.84	0.42	1.16	0.67	0.07	10.94	1.22	0.23	5.00	0.38	0.68	0.47	21.06	5.04	8.29	6.71
+1 μ (10.00ø)	1.45	0.79	0.34	0.52	0.64	1.87	5.16	0.33	2.36	0.48	1.06	0.004	3.83	0.54	2.57	0.38
−1 μ (−10.00ø)	5.62	1.13	3.55	2.09	2.18	7.69	1.68	1.92	3.83	1.51	3.82	4.66	5.34	2.67	1.68	2.67
Total	99.99	100.43	99.99	100.08	99.96	99.93	99.99	99.94	100.00	99.91	100.36	99.90	100.05	99.99	99.97	100.00

TABLE 4

The weight percentage of sand, silt and clay of sediments

Sample no.	Sand % + 4ø	Silty % + 8ø - 4ø	Clay % - 8ø	Remarks
1	82.34	8.74	8.91	sand
2	95.32	2.32	2.34	sand
3	42.90	52.04	5.05	sandy-silt
4	94.99	1.81	3.20	sand
5	94.06	3.01	2.89	sand
6	27.71	51.72	20.50	clay-sand-silt
7	83.07	8.86	8.06	sand
8	89.01	8.45	2.48	sand
9	57.45	31.36	11.19	silty-sand
10	95.71	1.83	2.37	sand
11	86.56	7.20	5.58	sand
12	37.21	57.56	5.13	sandy-silt
13	38.55	31.27	30.18	sand-silt-clay
15	66.30	21.94	11.75	silty-sand
16	77.38	7.74	14.85	sand
17	49.26	40.98	9.76	silty-sand

TABLE 5

Values of statistical parameters

Sample no	Mean (M_z) ϕ values	Inclusive standard deviation (τ_1) ϕ values	Inclusive graphic Skewness (SK_1)	Kurtosis (kg)
1	2.66	2.59	0.61	3.03
2	1.00	1.61	-0.225	1.31
3	4.35	1.99	0.08	0.94
4	2.28	0.74	0.20	1.15
5	2.27	0.82	0.32	1.67
6	5.60	2.85	-0.14	1.06
7	3.05	1.80	0.50	2.54
8	2.89	1.19	0.50	2.76
9	4.50	2.32	0.50	0.96
10	2.61	0.55	0.12	1.64
11	3.08	1.46	0.59	3.32
12	4.56	1.66	0.10	1.20
13	5.8	2.66	-0.07	0.66
15	4.27	1.87	0.57	1.00
16	4.07	2.02	0.66	2.26
17	4.64	1.75	0.56	1.13

TABLE 6 (Weight percentage of total carbon, hydrogen, nitrogen and carbon-nitrogen ratio)

Sample no.	Wt.% of total carbon	Wt.% of total hydrogen	Wt.% of total nitrogen	C-N ratio
1	2.71	0.23	0.09	30.11
5	0.17	0.03	0.00	-
7	2.64	0.25	0.10	26.40
9	8.81	1.14	0.36	24.47
12	5.03	0.52	0.24	20.96
15	4.56	0.68	0.31	14.71

TABLE 7
(Weight percentages of calcium carbonate, inorganic carbon, organic carbon and org./inorg. carbon ratio)

Sample No.	Wt%of $CaCO_3$	Wt% of Inorg.C	Wt% of Org. C	Org./Inorg. C
1	15.51	1.86	0.85	0.46
2	23.26	2.79	-	-
3	13.11	3.05	-	-
4	2.56	0.30	-	-
5	1.18	0.14	0.03	0.21
6	12.67	1.52	-	-
7	9.13	1.10	1.54	1.40
8	2.96	0.36	-	-
9	21.61	2.59	6.62	2.55
10	3.34	0.41	-	-
11	7.32	0.88	-	-
12	17.46	2.09	2.94	1.40
13	7.98	0.96	-	-
15	12.52	1.44	3.12	2.16
16	8.07	0.97	-	-
17	13.47	1.62	-	-

TABLE 8

The weight percentages of major oxides in two sediment samples

Sample	SiO_2%	Al_2O_3%	TiO_2%	Fe_2O_3%	CaO%	K_2O%	Na_2O%	MgO%	MnO%	Total
4	92.66	1.82	0.10	0.37	1.74	0.76	0.35	0.27	0.03	98.10
13	41.60	8.83	0.39	3.66	7.99	1.82	1.01	1.70	0.09	67.09

TABLE 9
Characteristic d-spacings of the minerals in bulk samples

	No.3	No. 4	No. 6	No. 9	No. 12	No. 13	No. 16	No. 17
Quartz	4.25 *3.34	4.25 3.34	4.27 3.34	4.25 3.33	4.25 3.35	4.24 3.34	4.25 3.35	4.26 3.35
Feldspar (unclassified)	3.24 3.19	3.24 3.18	3.25 3.19	3.24 3.18	3.25 3.19	3.24 3.18	3.25 3.19	3.25 3.19
Chlorite	*14.02 7.05	14.06 7.04	14.22 7.09	13.98 7.04	14.06 7.08	13.97 7.04	13.97 7.03	14.10 7.07
Muscovite Illite	*9.92 4.97	9.90 4.96	9.99 4.99	9.89 4.96	9.95 4.99	9.88 4.96	9.93 4.96	9.93 4.98
Combined Clays	*4.47 2.56	4.48 2.59	4.49 2.57	4.45 2.57	4.48 2.56	4.47 2.56	4.46 2.56	4.45 2.56
Kaolinite	7.12 3.56	7.20 absent	indistinct 3.58	7.19 3.56	7.18 3.58	indistinct 3.56	indistinct indistinct	indistinct 3.57
Calcite	*3.03 2.49	3.03 2.49	3.03 2.50	3.02 2.49	3.04 2.49	3.03 2.49	3.03 2.49	3.03 2.50
Dolomite	*2.89 indistinct	2,89 absent	2.90 2.20	2.88 2.19	2.89 2.19	2.88 2.18	2.88 2.19	2.89 2.19
Pyrite	*2.71 2.43	2.70 2.40	2.71 2.43	2.71 2.42	2.71 2.42	2.70 2.42	2.70 absent	2.72 2.43
Amphibole (unclassified)	*8.47	8.37	absent	absent	absent	absent	8.34	indistinct
Gypsum	*7.60	absent	7.63	absent	7.60	absent	7.56	7.61
Sea salt (NaCl)	2.82	absent	2.83	2.82	2.82	2.79	2.82	2.82

* Peaks considered for estimation of relative proportions of minerals.

TABLE 10

Concentration of ^{210}Pb, ^{226}Ra, and corrected concentration of ^{210}Pb in three sediment samples.

Depth in cm	Conc. of 210 Pb, disintegration per minute/gm	Conc. of 226 Ra dpm/gm	Corrected value for 210 Pb
67.5	2.24	0.80	1.44
190.5	1.74	0.80	0.94
216.5	0.94	0.80	0.14