Recent depositional conditions in Egens Vig, Denmark

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Sediment distribution in a low energy embayment, Egens Vig, depends both on topography and hydrography. There is a clear distinction between sediments in the shallow inshore water and that in the central basin. The distinction is shown both in a cluster analysis and in a Q_{da}-M_d diagram. The transport direction at the sediment surface differs from that 10 cm below. This difference, as well as lithological shifts at the depths of 7 cm and 17 cm, are correlated with diebacks in eel-grass.

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During the last two decades there has been great interest in the study of depositional conditions of marine sediments. However, the very varied conditions which have been found on shelves and in inland waters, make it desirable to collect information from a wide variety of environments.

The present study deals with a semi-enclosed, microtidal embayment on the Kattegat coast of Denmark. Most of the existing papers on marine sediments in Danish waters have dealt with the Wadden Sea on the exposed tidal North Sea coast (Gry, 1942; Hansen, 1951; Hansen, 1956; Olsen, 1958; Jacobsen, 1962; Bartholdy, 1980; Pejrup, 1980 and Pejrup, 1981). Work in the northeastern part of the North Sea has mainly been done by Dutch authors (Van Weering, 1975, 1981, 1982; Van Weering et al. 1973 and Wan Weering and Qvale, 1983). Only a few authors have dealt with conditions in inner Danish waters (e.g. Jørgensen, 1977; Christiansen and Lomholt, 1980; Christiansen et al., 1981 a and Chrstiansen et al. 1981 b).

EGENS VIG

The physical setting

Egens Vig is a small, semi-enclosed embayment on the north coast of Kalø Vig, Denmark. There are two inlets to the embayment with depths of 11 m and 6 m. (Fig. 1). They are separated by a moraine ridge. The area of the bay is about 4.0 km², the volume 15.7 × 10⁶ m³, with a mean depth of 3.9 m. On the basis of bottom topography, Egens Vig can be divided into two parts: 1) A basin area with depths exceeding 4 m, and 2) a shallow area (<2 m) near the coast. The slope between 2 and 4 metres depth occupies only a small area.

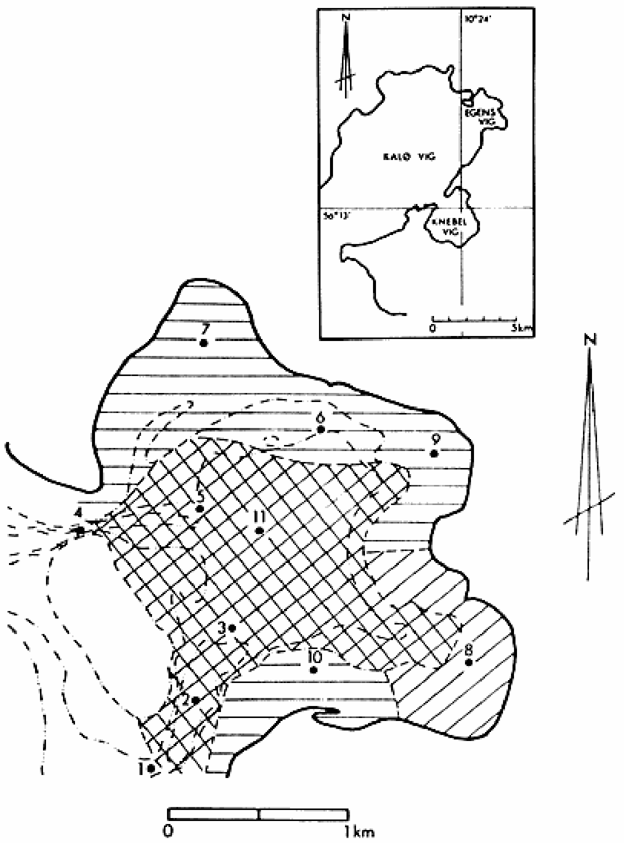

Fig. 1. Locational map showing sampling stations and mean grain size of surface sediments. ▤2-3 ø ▨3-4 ø ◇> 4 ø
Fig. 1. Oversigtskort visende prøvetagningsstationer samt bundsedimentets middelkornstørrelse.

Egens Vig is a micro-tidal environment with a tidal range of 0.40 m. The meteorological sea level fluctuations are much larger. Winds from the W and N give positive (up to + 1.5 m) deviations from DNN (Danish Ordnance Datum). Winds from the S and E give negative deviations (down to – 1.2 m). There is also a significant seasonal variation in mean sea level: it is lowest (– 0.18 m) in April and highest (+ 0.20 m) in November. The freshwater discharge to the bay is estimated to be only 250 l/s and is therefore not significant. Periodically the surface salinity in Egens Vig is inversed. This inversion is caused by a threelayer circulation (Christiansen et al., 1981 b).

There are seasonal fluctuations of redox potential (E_h) in the sediment in the basin. The O mV isoline is located deeper than 10 cm in spring, but is found near the se-

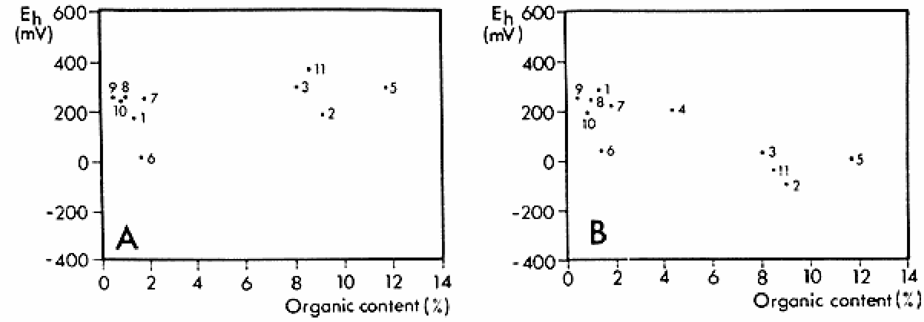

Fig. 2. E_h and organic content of the sediment. A) In the spring (790531). B) In the late summer (790831). From: Christiansen and Lomholt (1980).

Fig. 2. Redoxpotentiale og organisk indhold i sedimentet A) Om foråret (790531) B) I sensommeren (790831).

diment surface in autumn. E_h depends on grain size and organic content in the sediment, as well as the oxygen saturation and stratification of the water. E_h is therefore high in the spring when there is plenty of oxygen in the water. In the autumn E_h is low in the central basin because of low oxygen content in the water. This in turn is due to a persistent pycnocline 2 m over the bottom so that the bottom water is stagnant (Fig. 2) (Christiansen and Lomholt, 1980).

Methods

Bottom sediments were collected from 11 stations in Egens Vig (Fig. 1) using a gravity corer with an inner diameter of 7.8 cm. Two samples at each station were taken at depths of 0-1.5 cm and 10-11.5 cm. The position of the vessel during sediment sampling and hydrographic measurements were plotted by means of Decca. The accuracy of the plots can be estimated to be within ± 10 m. Information on current velocitites and directions was collected by the direct reading current meter Braystroke MK II. Salinity and temperature were determined by the use of EIL MC-5 salinometers. Water density was calculated according to Wilmot (1976).

We used standard sieving (ASTM certificate sieves at 4√2 scale) and pipette analyses on samples from each of the stations. The sediments were classified according to Folk and Ward (1957) and Buller and McManus (1975). The QDa-Md system is usually based on graphical reading on the log-frequency curve (in mm). We have used readings from Ø probability curves, transformed back into mm. Our Q-type cluster analyses are in accordance with Parks (1966). We have used 1) mean grain size, 2) sorting, 3) skewness, 4) kurtosis, 5) % <37μ, 6) E_h and 7) organic content as components in the cluster analyses. (Table 1).

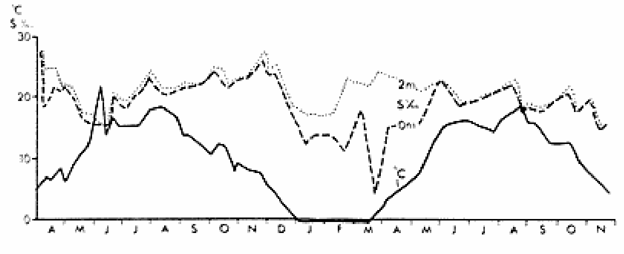

Fig. 3. Seasonal variation in A) Salinity in the surface and at the depth of 2 m. B) Temperature at the depth of 2 m.

Fig. 3. Sæsonmæssige variationer i A) Saltholdigheden i overfladen og i 2 m's dybde. B) Temperaturen i 2 m's dybde.

HYDROGRAPHIC CONDITIONS

Salinity and temperature

Salinity in Egens Vig depends strongly on the water exchange between the Balitc and the North Sea. Surface salinity is lowest in the spring due to freshwater runoff from the Baltic (Fig. 3). Normally, there is only a small difference in salinity between the surface and a depth of 2 m. An exception was the period from January to April 1978, when the embayment was covered with ice. During this

Cluster no.	Sample No.	Mean grain size (ϕ)	Sorting	Skewness	Kurtosis	%<37μ	E_h	Organic content (%)
1	1-0	2.35	0.95	-0.07	1.40	3.27	39	0.52
2	2-0	4.20	1.59	0.35	1.53	30.80	-97	8.57
3	3-0	4.90	2.82	0.42	1.41	47.49	-230	7.97
4	4-0	3.00	1.67	0.34	2.28	14.74	-38	3.00
5	5-0	5.35	2.60	0.36	0.89	65.95	-250	14.17
6	6-0	2.05	1.20	0.36	1.54	5.17	-209	0.28
7	7-0	2.35	0.95	0.01	1.26	4.60	-20	0.32
8	8-0	3.25	1.60	0.74	2.57	17.28	10	0.57
9	9-0	2.55	0.30	0.30	1.07	3.05	7	0.05
10	10-0	2.40	0.68	-0.20	1.43	1.47	-43	0.46
11	11-0	4.25	2.87	0.35	1.25	38.38	-303	8.33
12	2-10	2.95	0.97	0.27	1.81	12.64	-162	0.31
13	3-10	3.90	2.31	0.43	1.36	46.17	-398	6.55
14	5-10	5.35	2.57	0.24	1.05	77.97	-396	7.78
15	6-10	3.45	2.11	0.15	1.48	33.23	-369	0.52
16	7-10	2.60	0.60	-0.15	1.05	0.67	-110	0.54
17	8-10	2.75	0.49	-0.21	2.15	1.11	-140	0.01
18	9-10	2.45	0.62	0.11	1.20	3.90	-90	0.20
19	10-10	2.50	1.53	-0.50	1.06	3.94	-272	0.01
20	11-10	4.65	2.18	0.08	1.15	51.51	-398	7.44

Table 1. Data used in the cluster analysis.
Sample 2-0 = surface sample from station 2.
Sample 2-10 = sample from 10 cm's depth at station 2.

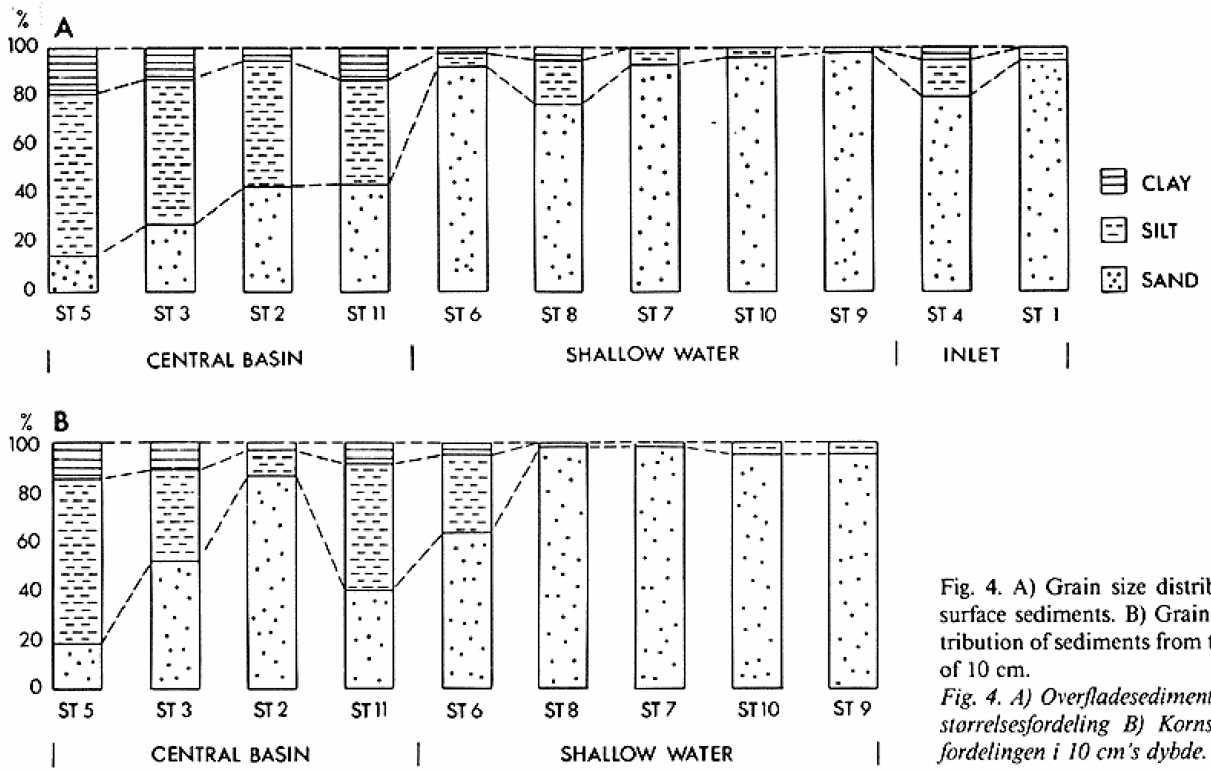

Fig. 4. A) Grain size distribution of surface sediments. B) Grain size distribution of sediments from the depth of 10 cm.
Fig. 4. A) Overfladesedimentets kornstørrelsesfordeling B) Kornstørrelsesfordelingen i 10 cm's dybde.

period the salinity was measured through holes in the ice. Most probably, therefore, the very low surface salinities in the period were due to meltwater in the holes. Our measurements of salinity in the central parts of the embayment were more sporadic. But, a persistent halocline existed in the central basin from 1.4. to 20.6.1978 and in June, August and October, 1979.

In order to eliminate diurnal fluctuations temperature was measured at the depth of 2 m. Seasonal variations were about 20°C. Greater variations can normally be expected as both the summers of 1978 and 1979 were windy and cold. We will not go into further details on the temperature, as the stratification of the water mass is more depended on the salinity. Within our range of salinity a change of 1‰ has the same effect on density as a change in temperature of 6°C.

Currents

Current velocities are highest in the two inlets to the embayment. In calm weather when currents are generated by the tide, the current velocities are 12-14 cm/s near the surface and 6-8 cm/s near the bottom. With winds from the W (10-12 m/s) current velocities can rise to respectively 40 cm/s and 25 cm/s.

In the central basin current velocities and directions were measured by following drift-buoys released at station 2 at depths of 2 and 4 m. In all cases the buoys stranded near station 8. Current velocities were always low (<5 cm/s).

Sediment distribution

The surface sediment distribution (Fig. 4) reflects the bottom topography. On the basis of grain size Egens Vig can be divided into two sedimentary provinces. According to the Shepard (1954) classification, sediments in the cental part (stations 2, 3, 5 and 11) can be grouped as silt-sandy silt, whereas sediments in the shallow parts near the coast (stations 7, 8, 9 and 10) are sand. Sediments in the two inlets (station 1 and 4) with relatively high current velocities resemble the shallow water sediments in spite of the greater depths.

Our data show that grain size at the sediment surface is almost everywhere very similar to that 10 cm below. The exceptions are stations 2 and 6. At station 6 the sand content rises from 63% at 10 cm's depth to 85% at the surface. This could be the result of the recent construction of a pleasure boat marina near this station. At station 2 the sand content changes from 86% at 10 cm's depth to 43% at the surface. The general similarity conceals intervening irregularities. In a description of the cores, Lomholt (1979) observed either a lithological shift or a layer of organic matter at the depth of 7 cm at stations 2, 6, 8 and 9. At station 1 and 4 coring depths were only a few cm.

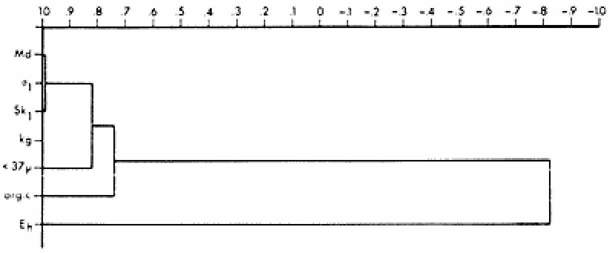

Fig. 5. R-type cluster analysis of sediment parameters (see table 1).
Fig. 5. Klynge-analyse af R-typen.

The R-type cluster analysis (Fig. 5) shows that Md, O_I, Sk_I and Kg can be grouped with a high (r = 0.987) correlation coefficient. The fraction $<37\mu$ and the organic content show poor correlations. E_h is negatively correlated with the other parameters (r = -0.821) and is an important environmental indicator in Egens Vig (Christiansen and Lomholt, 1980). The R-type cluster analysis shows that the elements in the analysis have their own characteristica. Therefore none of them have been eliminated in the Q-type cluster analysis as proposed by Parks (1966).

The Q-type cluster analysis (Fig. 6) shows two distinct groups. Group A consists of samples from the relatively high energy areas near the shore and in the inlets. Group B represents samples from the low energy central basin. Fig. 5 also shows that group A can be divided into four subdivisions and group B into two subdivisions at the r = 0.7 level. The QDa-Md distribution both in the surface sediments (Fig. 7) and the -10 cm sediment also clearly divides Egens Vig into two regions.

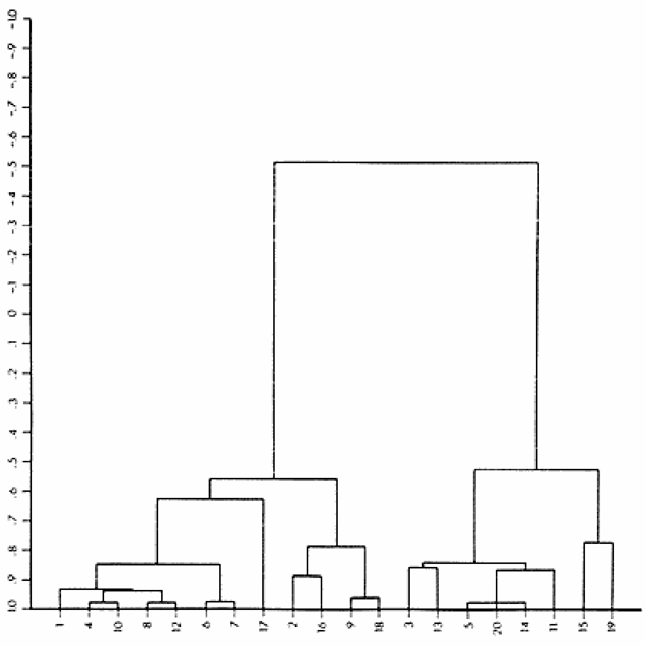

Fig. 6. Q-type cluster analysis of sediment parameters (see table 1).
Fig. 6. Klynge-analyse af Q-typen.

Following Buller and McManus (1975) the surface sediments in the central area at stations 2, 3, 5, and 11 are »fine quiet-water sediments (IF)«. In the Tay Estuary such sediments are deposited from suspension under conditions of very low current velocities and only slight surface wave activity (Table 2). The sediments at station 6 are »coarse quiet-water sediments (IC)«, i. e. lag sediment. This interpretation is not reasonable. The aberration is probably a result of recent engineering activity near station 6.

Environmental analogue	Key	Tay Estuary sub-environment	Egens Vig sub-environment	Egens Vig Station	Process analogues Tay
Fine 'quiet-water' sediments	1F	Marsh-edge	Basin	2_0	Very low current speeds, slight surface wave action; dominantly deposition of silt and clay from suspension.
	1F	- " -	- " -	3_0	
	1F	- " -	- " -	3_{10}	
	1F	- " -	- " -	5_0	
	1F	- " -	- " -	5_{10}	
	1F	- " -	- " -	6_{10}	
	1F	- " -	- " -	11_0	
	1F	- " -	- " -	11_{10}	
	1F	- " -	Inter-tidal flat	10_{10}	
Fine fluviatile sediments	3F	Upper inter-tidal-flat	- " -	7_0	Low current speeds, slight surface wave action; deposition of fine grains from suspension and coarser grains from graded suspension.
	3F	- " -	- " -	7_{10}	
	3F	- " -	- " -	8_0	
	3F	- " -	- " -	10_0	
	3F	- " -	Basin	2_{10}	
	3F	- " -	Inlet	1_0	
	3F	- " -	- " -	4_0	
Fine beach sediments	4F	Lower inter-tidal flat	Inter-tidal flat	8_{10}	Moderate current speeds; moderate wave action; deposition from suspension and bed-load.
Fine beach sediments	5F	- " -	- " -	9_0	Low current speeds, moderate wave action; deposition from suspension and bed-load.
	5F	- " -	- " -	9_{10}	
Coarse 'quiet-water' sediments	1C	Scoured channel	Basin	6_0	'Quiet-water' is a misnomer; very strong current flows; extreme turbulence; scouring; present-day coarse sediments mixed with older consolidated 'mud'; QDa-Md plots misplaced because of sediment heterogeneity.

Table 2. Relationships between QDa-Md environmental and process analogues.

Sediments on the intertidal flats at stations 7, 8, and 10, as well as those at stations 1 and 4 in the inlets, are characterized as »fine fluviatile sediments (3F)«. These sediments are deposited from suspension and graded suspension under conditions of low current velocities and only slight wave action. Sediments at station 9 are »fine beach sediments (5F)« deposited from both suspension and bed load.

A comparison of -10 cm and surface samples (Fig. 7) shows that sediments at station 2 and 8 change »key« from 1F to 3F. Sediments at station 10 change from 3F to 1F while at station 6 they change from 1C to 1F.

Trends in grain size measures

In a theoretical investigation McLaren (1981) provides a

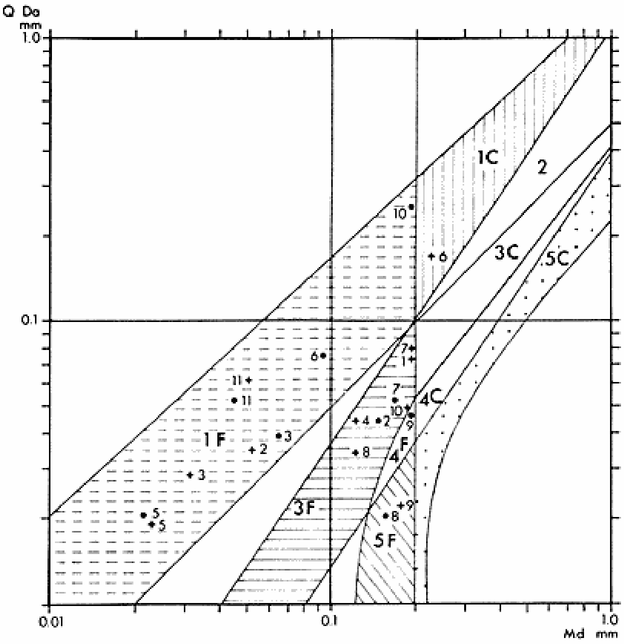

Fig. 7. QDa-Md diagram of the sediments.
Fig. 7. Egens Vig sedimenterne indplaceret i QDa-Md diagram.

method for a rapid determination of probable relationships between depositional environments and sediment transport directions. The theoretical background have been questioned by Bartholdy (in press).

Following McLaren (op. cit.) a sediment trend matrix was set up for Egens Vig (Fig. 8).

The grain size characteristics used to identify sediment trends are mean grain size, sorting and skewness. Kurtosis is not considered a measure that can provide further information, a view shared by several authors (e.g., Blatt et al., 1972; McLaren, 1981 and Christiansen and Miller, 1982).

Depending on the trend, the sediments at one station can be sources for the sediments at another, or they can not. The trends in the matrix (Fig. 8) suggest the following:

i) station 1 can be the source for stations 2, 3, 4, 5, 8 and 11.

ii) station 2 can be the source for stations 3, 5, 8 and 11.

iii) station 3 can not be a source.

iv) station 4 can be the source for stations 3, 5 and 11.

v) station 5 can be the source for station 3.

SOURCE

DEPOSIT

	1	2	3	4	5	6	7	8	9	10	11	
1		coarser poorer -	coarser poorer -	coarser poorer -	coarser poorer -	finer poorer -	= = -	coarser poorer -	coarser better -	coarser better +	coarser poorer -	Md σ_1 Sk_1
2	finer better +		coarser poorer -	finer poorer +	coarser poorer -	finer better -	finer better +	finer poorer -	finer better +	finer better -	coarser poorer =	Md σ_1 Sk_1
3	finer better +	finer better +		finer better +	coarser better +	finer better +	finer better +	finer better -	finer better +	finer better +	finer poorer +	Md σ_1 Sk_1
4	finer better +	coarser better -	coarser poorer -		coarser poorer -	finer better -	finer better +	coarser better -	finer better +	finer better +	coarser poorer -	Md σ_1 Sk_1
5	finer better +	finer better +	finer poorer -	finer better +		finer better =	finer better +	finer better -	finer better +	finer better +	finer poorer +	Md σ_1 Sk_1
6	coarser better +	coarser poorer +	coarser poorer -	coarser poorer +	coarser poorer =		coarser better +	coarser poorer -	coarser better +	coarser better +	coarser poorer +	Md σ_1 Sk_1
7	= = +	coarser poorer -	coarser poorer -	coarser poorer -	coarser poorer -	finer poorer -		coarser poorer -	coarser better -	coarser better +	coarser poorer -	Md σ_1 Sk_1
8	finer better +	coarser better +	coarser poorer +	finer poorer +	coarser poorer +	finer better +	finer better +		finer better +	finer better +	coarser poorer +	Md σ_1 Sk_1
9	finer poorer +	coarser poorer -	coarser poorer -	coarser poorer -	coarser poorer -	finer poorer -	finer poorer +	coarser poorer -		finer poorer +	coarser poorer -	Md σ_1 Sk_1
10	finer poorer -	coarser poorer -	coarser poorer -	finer poorer -	coarser poorer -	finer poorer -	finer poorer -	coarser poorer -	coarser better -		coarser poorer -	Md σ_1 Sk_1
11	finer better +	finer better =	coarser better -	finer better +	coarser better -	finer better -	finer better +	finer better -	finer better +	finer better +		Md σ_1 Sk_1

Fig. 8. Sediment trend matrix.

Fig. 8. Matrix over udgangssediment – aflejringssediment relationer.

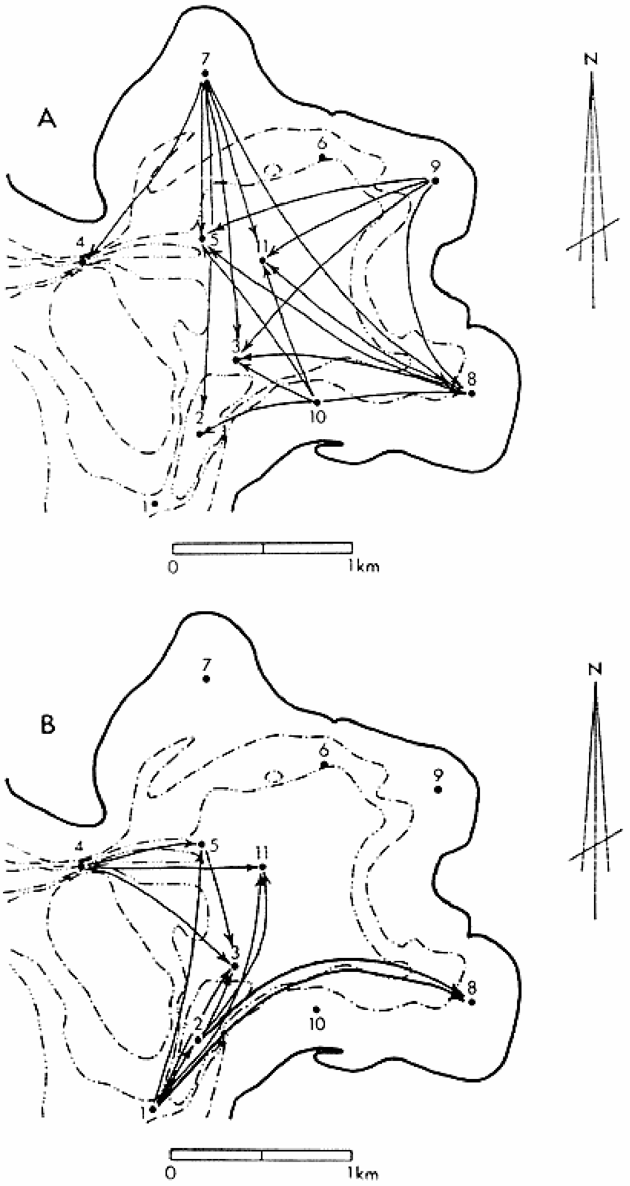

Fig. 9. Possible sediment transport directions. A) From shallow water stations. B) From deep water stations.
Fig. 9. Mulige sedimenttransportretninger A) For stationerne på lavt vand. B) For stationer på dybere vand.

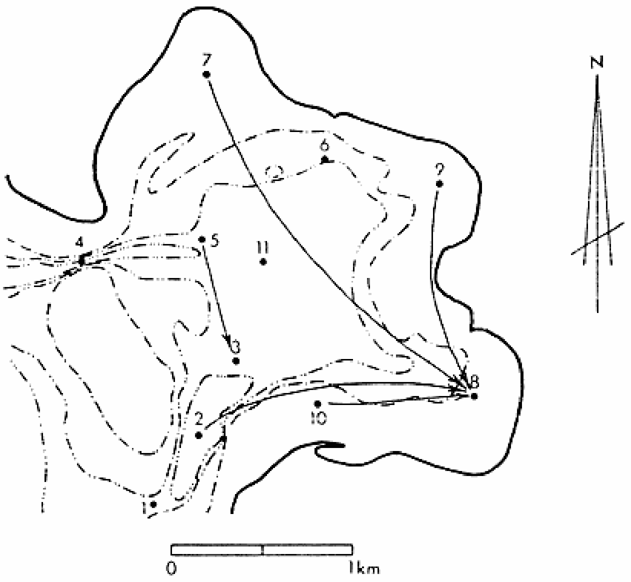

Fig. 10. Changes in sediment transport directions between the surface and 10 cm's depth.
Fig. 10. Ændringer i mulige transportretninger fra 10 cm's dybde til overfladen.

vi) station 7 can be the source for stations 2, 3, 4, 5, 8 and 11.

vii) station 8 can be the source for stations 3, 5 and 11.

viii) station 9 can be the source for stations 2, 3, 4, 5, 8 and 11.

ix) station 10 can be the source for stations 1, 2, 3, 4, 5, 7, 8 and 11.

x) station 11 can not be a source.

Because of engineering activity near station 6, this section has been omitted in the above relationships. From the above we can conclude that the two stations in the inlets, as well as the stations in shallow water, can be sources for stations in the central basin (Fig. 9). Shallow water stations as possible sources for central basin stations are also observed in Knebel Vig a few kilometers to the South (Christiansen et al., 1981 c).

The sediments from 10 cm below the surface show very similar trends. The differences in trends are shown in Fig. 10. The most pronounced difference is that at the depth of 10 cm station 8 could not be a deposit from the sources 2, 7, 9 and 10.

DISCUSSION

Within this low-energy embayment there is a clear difference in depositional conditions between the shallow nearshore water and the central basin (see Fig. 6 and Fig. 7). The difference is reflected in grain size parameters as well as in organic content and redox potential. In the QDa-Md diagram the two stations in the inlets to the embayment (stations 1 and 4) are classified with the shallow water stations. It is therefore tempting to ascribe the above differences in depositional conditions by hydrodynamics: The relatively high current velocities in the inlets produce the same depositional conditions as wave activity does in shallow water. In these relatively high-energy areas the sediments are coarser, better sorted, more negatively skewed, with a high redox potential and a low organic content. In the low-energy areas in the central basin the sediments are finer, poorly sorted, more positively skewed, with a low redox potential and a high organic content.

However, hydrodynamics is not the only governing factor for deposition. for example, the content of material

$<37\mu$ at stations 4 and 8 is comparable with a ratio of 0.85 (Table 1). Yet the organic content at station 4 is more than 5 times that at station 8, and redox potential at 4 is negative as against the positive redox potential at station 8. This suggests that the position of stations either above (station 4) or below (station 8) a pycnocline (Fig. 3) is also a governing factor.

Both the difference in possible source-deposit relationships between surface sediments and sediments from the depth of 10 cm, and the lithological shift or layer of organic matter at the depth of both 7 cm and 17 cm, could have the same cause. Using the highest rates of sedimentation (4 mm/year) from the more protected Knebel Vig nearby (Christiansen et al., 1981 c) the -7 cm level corresponds to 1961 and the -17 cm level corresponds to 1934. This is in good agreement with data from the more exposed parts of Kalø Vig where the -20 cm level corresponds to 1934 (Vandkvalitetsinstituttet, 1980). Both in the sixties and in the thirties die-backs in eel-grass produced similar near-shore changes at Kyholm (Christiansen et al. 1981 a). The observed differences in source-deposit relationships in Egens Vig could therefore also be a result of the disappearance of eel-grass. This hypothesis is corobborated by the presence of high-organic horizons in most of the cores, and in the majority of these there are eel-grass fragments. The eelgrass hypothesis could also explain an anomaly in the Pb-210 activity profile at depths of 20 to 25 cm in Kalø Vig (Vandkvalitetsinstituttet, 1980). This anomaly, with signs of sediments-mixing, could be the result of the disappearance of eel-grass which acts as sediment stabilizer.

To-day there is no vegetation below the depth of 5 m in Egens Vig and alomst none in other parts of Kalø Vig (Mathiesen and Mathiesen, 1977). We therefore conclude that vegetation can be a major sedimentational parameter even in areas where no vegetation is found to-day.

References

Bartholdy, J., 1980: Sediments and dynamics in the Varde Å estuary. Geografisk Tidsskrift 80, 64-71.

Bartholdy, J. (in press): Recent sedimentologi i Ho Dyb's tidevandsområde. Meddelelser fra Skalling-Laboratoriet. Bd. XXX.

Blatt, H., Midddleton, G., and Murray, R., 1972: Origin of sedimentary rocks. Englewood Cliffs, J. J., Prentice Hall, 634 pp.

Buller, A. T. and McManus, J., 1975: Sediments of the Tay Estuary 1. Bottom sediments of the upper and upper middle reaches. Proc. Roy. Soc. Edinburgh 75, 41-63.

Christiansen, C., Christoffersen, H., Dalsgaard, J. and Nørnberg, P., 1981 a: Coastal and near-shore changes correlated with die-back in Eel-grass (Zostera marina, L.). Sediment. Geol. 28, 163-173.

Christiansen, C., Christoffersen, H. and Lomholt, S., 1981 b: Characteristics of three-layer circulation and inverse surface salinity gradients in two small semi-enclosed embayments. Nordic Hydrology 12, 119-128.

Christiansen, C., Christoffersen, H. and Schultz, K. E., 1981 c: Hydrography, sediments and sedimentation in a low energy embayment, Knebel Vig, Denmark. Geogr. Ann. 63 (A), 95-103.

Christiansen, C. and Lomholt, S., 1980: On non-biological changes in E_h in a marine sediment. Vatten 36, 295-300.

Christiansen, C. and Miller, P., 1983: Spartina in Mariager Fjord, Denmark. The effect on sediment parameters. Earth surface Processes and Landforms. 8, 55-62.

Folk, R. L. and Ward, W. C., 1957: Brazos River bar, a study in the significance of grain-size parameters. J. Sediment. Petrol. 27, 3-27.

Gry, H., 1942: Das Wattenmeer bei Skallingen. Folia Geographica Danica 11, 1.

Hansen, K., 1951: Preliminary report on the sediments of the Danish Wadden Sea. Medd. fra Geol. Foren. 12, 1.

Hansen, K., 1956: The sedimentation along the Rømø-dam. Medd. fra Geol. Foren. 13, 2.

Jacobsen, B., 1962: Morfologiske og hydrografiske undersøgelser af flod- og ebbeskår i tidevandsrender. Geografisk Tidsskrift, 61, 119-142.

Jørgensen, B. B., 1977: The sulfur cycle of a coastal marine sediment. Limnol. Oceangr. 22, 814-832.

Lomholt, S., 1979: Undersøgelser i Egens Vig. Unpublished. M. Sc. report. Geol. Inst. Aarhus Universitet.

McLaren, P., 1981: An interpretation of trends in grain size measures. J. Sediment. Petrol. 51, 611-624.

Olsen, H. A., 1958: The influence of the Rømø Dam on the sedimentation in the adjacent part of the Danish Wadden Sea. Geografisk Tidsskrift 58, 119-140.

Parks, J. M., 1966: Cluster analysis applied to multivariate geologic problems. J. Geol. 74, 703-715.

Pejrup, M., 1980: The turbidity maximum in the northern part of Ho Bugt. Geografisk Tidsskrift 80, 72-77.

Pejrup, M., 1981: Bottom sediments in Ho Bugt – a wadden sea environment. Geografisk Tidsskrift 81, 11-16.

Pejrup, M., 1983: Et metodestudium af den suspenderede sedimenttransport i et vadehavsmiljø. Meddelelser fra Skalling-Laboratoriet. Bd. XXIX.

Shepard, F. P., 1954: Nomenclature based on sand-silty-clay ratios. J. Sediment. Petrol. 24, 151-158.

Vandkvalitetsinstituttet, 1980: Aarhus Bugt-Kaløvig 1978-1979, Sediment. Report Nr. 10.

Van Weering, T. C. E., 1975. Late quarternary history of the Skagerak; an interpretation of acoustical profiles. Geol. Mijnbouw., 54, 130-145.

Van Weering, T. C. E., 1981: Recent sediments and sediment transport in the North Sea; surface sediments of the Skagerak. In: Nio, S. D., Schütterhelm, R. T. E. and Van Weering, T. C. E. (eds.), Holocene marine sedimentation in the North Sea basin. Spec. Publ. Int. Assoc. Sedimentol. 5, 335-359.

Van Weering, T. C. E., 1982: Recent sediments and sediment transport in the northeastern North Sea; pistoncores from the Skagerak. Proc. KNAW, Ser. B, 85, 155-201.

Van Weering, T. C. E. and Qvale, G., 1983: Recent sediments and foraminiferal distribution in the Skagerak, Northeastern North Sea. Mar. Geol., 52, 75-99.

Wilmot, W., 1976: A nummerical model of the effect of reactor cooling on fjord circulation. SMHI. Nr. RHO 6.

$<37\mu$ at stations 4 and 8 is comparable with a ratio of 0.85 (Table 1). Yet the organic content at station 4 is more than 5 times that at station 8, and redox potential at 4 is negative as against the positive redox potential at station 8. This suggests that the position of stations either above (station 4) or below (station 8) a pycnocline (Fig. 3) is also a governing factor.

Both the difference in possible source-deposit relationships between surface sediments and sediments from the depth of 10 cm, and the lithological shift or layer of organic matter at the depth of both 7 cm and 17 cm, could have the same cause. Using the highest rates of sedimentation (4 mm/year) from the more protected Knebel Vig nearby (Christiansen et al., 1981 c) the -7 cm level corresponds to 1961 and the -17 cm level corresponds to 1934. This is in good agreement with data from the more exposed parts of Kalø Vig where the -20 cm level corresponds to 1934 (Vandkvalitetsinstituttet, 1980). Both in the sixties and in the thirties die-backs in eel-grass produced similar near-shore changes at Kyholm (Christiansen et al. 1981 a). The observed differences in source-deposit relationships in Egens Vig could therefore also be a result of the disappearance of eel-grass. This hypothesis is corobborated by the presence of high-organic horizons in most of the cores, and in the majority of these there are eel-grass fragments. The eelgrass hypothesis could also explain an anomaly in the Pb-210 activity profile at depths of 20 to 25 cm in Kalø Vig (Vandkvalitetsinstituttet, 1980). This anomaly, with signs of sediments-mixing, could be the result of the disappearance of eel-grass which acts as sediment stabilizer.

To-day there is no vegetation below the depth of 5 m in Egens Vig and alomst none in other parts of Kalø Vig (Mathiesen and Mathiesen, 1977). We therefore conclude that vegetation can be a major sedimentational parameter even in areas where no vegetation is found to-day.

References

Bartholdy, J., 1980: Sediments and dynamics in the Varde Å estuary. Geografisk Tidsskrift 80, 64-71.

Bartholdy, J. (in press): Recent sedimentologi i Ho Dyb's tidevandsområde. Meddelelser fra Skalling-Laboratoriet. Bd. XXX.

Blatt, H., Midddleton, G., and Murray, R., 1972: Origin of sedimentary rocks. Englewood Cliffs, J. J., Prentice Hall, 634 pp.

Buller, A. T. and McManus, J., 1975: Sediments of the Tay Estuary 1. Bottom sediments of the upper and upper middle reaches. Proc. Roy. Soc. Edinburgh 75, 41-63.

Christiansen, C., Christoffersen, H., Dalsgaard, J. and Nørnberg, P., 1981 a: Coastal and near-shore changes correlated with die-back in Eel-grass (Zostera marina, L.). Sediment. Geol. 28, 163-173.

Christiansen, C., Christoffersen, H. and Lomholt, S., 1981 b: Characteristics of three-layer circulation and inverse surface salinity gradients in two small semi-enclosed embayments. Nordic Hydrology 12, 119-128.

Christiansen, C., Christoffersen, H. and Schultz, K. E., 1981 c: Hydrography, sediments and sedimentation in a low energy embayment, Knebel Vig, Denmark. Geogr. Ann. 63 (A), 95-103.

Christiansen, C. and Lomholt, S., 1980: On non-biological changes in E_h in a marine sediment. Vatten 36, 295-300.

Christiansen, C. and Miller, P., 1983: Spartina in Mariager Fjord, Denmark. The effect on sediment parameters. Earth surface Processes and Landforms. 8, 55-62.

Folk, R. L. and Ward, W. C., 1957: Brazos River bar, a study in the significance of grain-size parameters. J. Sediment. Petrol. 27, 3-27.

Gry, H., 1942: Das Wattenmeer bei Skallingen. Folia Geographica Danica 11, 1.

Hansen, K., 1951: Preliminary report on the sediments of the Danish Wadden Sea. Medd. fra Geol. Foren. 12, 1.

Hansen, K., 1956: The sedimentation along the Rømø-dam. Medd. fra Geol. Foren. 13, 2.

Jacobsen, B., 1962: Morfologiske og hydrografiske undersøgelser af flod- og ebbeskår i tidevandsrender. Geografisk Tidsskrift, 61, 119-142.

Jørgensen, B. B., 1977: The sulfur cycle of a coastal marine sediment. Limnol. Oceangr. 22, 814-832.

Lomholt, S., 1979: Undersøgelser i Egens Vig. Unpublished. M. Sc. report. Geol. Inst. Aarhus Universitet.

McLaren, P., 1981: An interpretation of trends in grain size measures. J. Sediment. Petrol. 51, 611-624.

Olsen, H. A., 1958: The influence of the Rømø Dam on the sedimentation in the adjacent part of the Danish Wadden Sea. Geografisk Tidsskrift 58, 119-140.

Parks, J. M., 1966: Cluster analysis applied to multivariate geologic problems. J. Geol. 74, 703-715.

Pejrup, M., 1980: The turbidity maximum in the northern part of Ho Bugt. Geografisk Tidsskrift 80, 72-77.

Pejrup, M., 1981: Bottom sediments in Ho Bugt – a wadden sea environment. Geografisk Tidsskrift 81, 11-16.

Pejrup, M., 1983: Et metodestudium af den suspenderede sedimenttransport i et vadehavsmiljø. Meddelelser fra Skalling-Laboratoriet. Bd. XXIX.

Shepard, F. P., 1954: Nomenclature based on sand-silty-clay ratios. J. Sediment. Petrol. 24, 151-158.

Vandkvalitetsinstituttet, 1980: Aarhus Bugt-Kaløvig 1978-1979, Sediment. Report Nr. 10.

Van Weering, T. C. E., 1975. Late quarternary history of the Skagerak; an interpretation of acoustical profiles. Geol. Mijnbouw., 54, 130-145.

Van Weering, T. C. E., 1981: Recent sediments and sediment transport in the North Sea; surface sediments of the Skagerak. In: Nio, S. D., Schütterhelm, R. T. E. and Van Weering, T. C. E. (eds.), Holocene marine sedimentation in the North Sea basin. Spec. Publ. Int. Assoc. Sedimentol. 5, 335-359.

Van Weering, T. C. E., 1982: Recent sediments and sediment transport in the northeastern North Sea; pistoncores from the Skagerak. Proc. KNAW, Ser. B, 85, 155-201.

Van Weering, T. C. E. and Qvale, G., 1983: Recent sediments and foraminiferal distribution in the Skagerak, Northeastern North Sea. Mar. Geol., 52, 75-99.

Wilmot, W., 1976: A nummerical model of the effect of reactor cooling on fjord circulation. SMHI. Nr. RHO 6.