Preliminary Report on the Sediments of the Danish Wadden Sea.

By

KAJ HANSEN.

Introduction.

In 1941 BØRGE JAKOBSEN, junior lecturer in the Geographical Laboratory of the University of Copenhagen, made a collection of sediment samples from the *wadden* (tidal flats), as a link in the investigations of the Skalling Laboratory. The samples were taken at 100 m. intervals along a number of profiles drawn out across the *wadden* from the coast. The samples were 10 cm. long and taken by means of a 2 cm. hand sampling tube; in all 1100 samples were collected.

The German occupation of Denmark caused further work with this material to be postponed, but in 1946 the author was entrusted with the task of undertaking a detailed analysis of the sediments not only of the flats, but also of the salt marsh. The material collected by JAKOBSEN, supplemented by the author's own sample collections and field studies formed the basis of this investigation.

The Danish "Wadden Sea" extends from Ho Bugt in the north to the German frontier in the south; it is thus the most northerly extension of the great tidal flat (*Wadden*) and salt-marsh region which extends along the coastline of the southerly North Sea as far as Calais.

The tidal fluctuation in the Danish part of the "Wadden Sea" decreases northward and, apart from a few divergent observations, lies between 120 and 200 cm. (LUNDBAK).

The "Wadden Sea" is separated from the North Sea by the peninsula Skallingen and the islands Fanø, Manø and Romø; its connection with the open sea is through the deeps Graadyb, Knudedyb, Juvre Dyb and Listerdyb (Fig. 10, p. 14).

The total area of the Danish "Wadden Sea" is 836 sq. kilometers, of which 589,82 sq. kilometers are true *wadden*. Distribution into the tidal areas of the deeps is thus (LUNDBAK):

Graadyb	76,37	sq. kilometers
Knudedyb	127,40	—
Juvre Dyb	111,62	—
Lister Dyb	274,62	—

The Terminology and Method of Investigation.

The collected material has been treated as follows. The fractions $< 62\,\mu$ (1/16 mm.) were determined by the pipette method given by KRUMBEIN and PETTIJOHN (1938). The fractions $>120\,\mu$ were determined by sieving, and the fraction 120–62 μ was determined by elutriation in a SCHÖNES rising current elutriator of the material deposited in the sedimentation cylinder.

The directions given by KRUMBEIN and PETTIJOHN were also followed in the graphic and statistical treatment of the material. The median diameter (Md) and quartiles (Q_3 and Q_1) were determined graphically. For the sake of clarity the coefficients of sorting and skewness are given in units of the WENTWORTH scale as QD_Φ and Skq_Φ. These figures thereby become directly proportional to the degree of sorting and skewness, and independent of the grain-size.

As is well known, there prevails a not inconsiderable confusion with regard to terminology because different authors use each their own designation for the different grain-size groups, and delimit these differently. In the present work WENTWORTH's terminology is used.

Φunits	÷ 1–0	2–1 mm.	Very coarse sand.
	1–0	1000–500 μ	Coarse sand.
	1–2	500–250–	Medium sand.
	2–3	250–125–	Fine sand.
	3–4	125– 62,5– (1/16 mm.)	Very fine sand.
	4–8	62,5– 4– (1/256 mm.)	Silt.
	> 8	< 4–	Clay.

Marsh Clay.

The sediments of the salt-marshes—both inside and outside the dikes—vary very strongly from place to place. Individual areas must therefore be subjected to thorough investigation before it is possible to give a more detailed explanation of the conditions of sedimentation. There is, however, so distinct a difference between marsh clay and the sediments of the *wadden*, that a brief summary of the grain-size features of the clay will be natural for comparison with the sediments of the *wadden*.

Marsh *klæg* and *slik* (Dutch: *Klei* and *Slik*) are the common names for the fine-grained sediment throughout the marsh areas of the North Sea coast.

This is generally referred to as mud or silt in the English literature, and as *Bou* or *Vase* in the French.

ERNST (1934) defined the relation between *slik* and *klæg* thus: *Klæg* is that clayey soil produced in the marshes by diagenesis, especially dehydration, of *slik*. The term *slik* is, however, differently defined by different authors.

WETZEL (1930) defines it as silt with copious admixture of both sand of medium grain-size, and clay. Most other authors mean a very fine-grained sediment approaching pure clay. ERNST (1934) describes it as a clayey semi-fluid deposit on the *wadden*. Both WARMING and WESENBERG LUND talk of fine muddy material (1904), and WESENBERG LUND states that *slik* is, for the greater part, composed of dead material and contains diatoms, cysts, Tintinnidae, Cyanophycea etc. In this case, as always when biologists describe deposists, too great an emphasis is laid on the biogenic components (KAJ HANSEN 1951), partly because clay particles cannot, or can only with difficulty be distinguished under an ordinary microscope, or even under a polarizing microscope. Other authors use the word *slik* without stating what they imply. KAMPS (1950) gives the grain-size of *slik* as less than 16 μ.

The diagram fig. 1, b, shows the median grain-size for 64 analyses of marsh clay, grain-size being indicated as class variants on the abcissa, and the number of analyses in each class on the ordinate. It is clearly seen that these samples are grouped about the average grain-sizes 15 μ and 75 μ or better in the classes 10–20 μ and 70–80 μ.

The last group is from stratified or sandy marsh, and is an average sample of sand and mud layers, for which reason it will not now be further discussed.

The first group, about the median grain-size 15 μ, is, on the other hand, homogeneous *klæg* and embraces samples collected partly from the newly-formed marsh on Skallingen, partly from the old marsh along the west and north sides of the bay Ho Bugt, and

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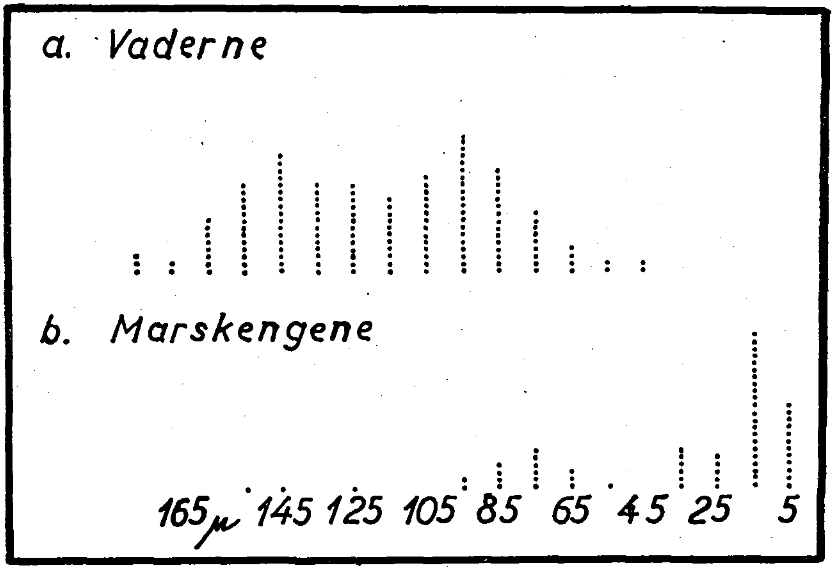


Fig. 1. Variation of median grain-size by a) sediments from the *wadden* sediment and b) sediments from the salt marsh.

Abcissa: median grain-size as class-variant.
Ordinate: number of samples in the class.

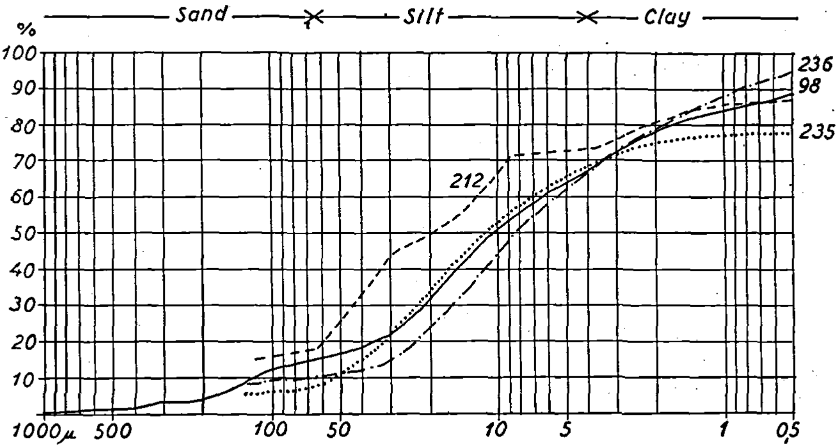


Fig. 2. Cumulative diagram of *klæg*.

near Novrup Bæk E. of Esbjerg, and partly from the dyked marsh near Ribe, Rejsby and Ballum.

Fig. 2 and Table I show some examples of *klæg* obtained along the west side of Ho Bugt.

Analysis 98 is *klæg* from NIELS NIELSEN's measuring areas on Skallingen (NIELS NIELSEN 1935). No. 212 is *klæg* from Nyeng S. of Ho, no. 235 *klæg* from meadows between Ho and Bredmose and no. 236 *klæg* from Kirkeeng at the innermost end of Ho Bugt.

Table I.

Analysis No.	Md	Q_3	Q_1	QD_Φ	Skq_Φ
	μ	μ	μ		
98	11	27	2,6	1,7	0,39
212	20	50	3,0	2,1	0,71
235	11	27	2,0	1,9	0,58
236	8	20	2,6	1,5	0,16

These examples agree with other analyses of *klæg* and lead to the following definition of the *klæg*, and thereby also of *slik*.

Klæg is a fine-grained sediment with a median grain-size about 15μ, varying between 5–35μ. Sorting is rather poor with QD_Φ lying between 1.5–2.5. It corresponds most nearly to ATTERBERG's class Vesa (ESKOLA 1931) and to the term Schluff of German petrologists. In BOURCARTS outline (1947) it corresponds to the class Poudres (Vase) and possesses the other characteristics, too, which BOURCART assigns to this class. It corresponds most closely to the fraction silt of WENTWORTH's terminology, but contains from 22–34% clay; it may similarly contain from 6–22% fine and very fine sand. Single samples may contain as much as 46% clay.

The Sediments of the Tidal Flats (Wadden).

From older times one has distinguished between sand *wadden* and *slik wadden*. Sand *wadden* are clearly composed of sand and are firm, and hard to walk upon. *Slik wadden* are soft to walk upon and one sinks more or less deeply into them. In the fresh, wet state the sediment is soft and clayey to the touch, but the designation *slik wadden* is, as will be apparent from the following, sometimes un-

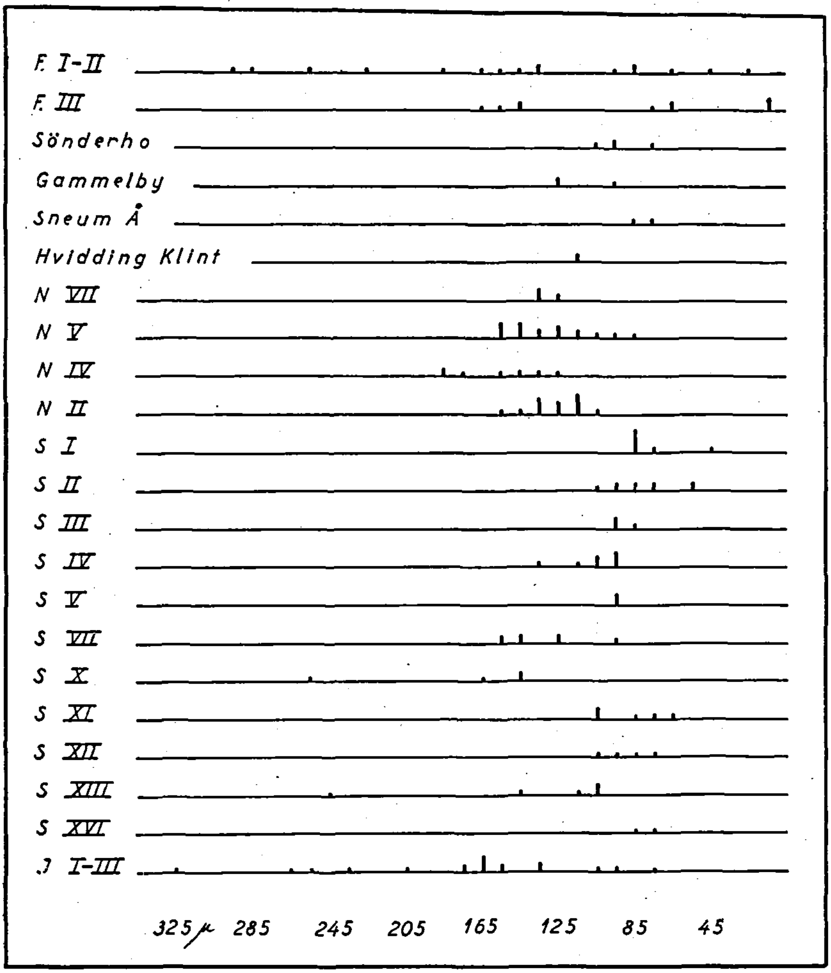


Fig. 3. Distribution of the median grain-size in different parts of the Wadden Sea.
Abcissa: medium grain-size as class-variants.
Ordinate: numbers of samples in the class.

fortunately chosen since the greater part of the sediment generally consists of sand. One should therefore rather distinguish between hard and soft *wadden*.

The Hard Wadden.

Fig. 1, a, shows the variation and average grain-size of the sediments of the *wadden*. Here also, the grain-size is marked off as class variants on the abcissa, while the number of analyses within each class are given on the ordinate.

The class interval is also here 10μ. Apart from the analyses shown in the diagram there are nine whose average grain-size reaches up to 300μ.

It is clearly seen that there is an essential difference between these sediments and the *slik,* and that the median grain-size of the sediments of the flats are grouped about the median grain-sizes 95μ and 145μ. The median grain-sizes from each of the different sample profiles are similarly shown in fig. 3 in order to indicate the regional distribution. The profiles N. II, N. III, etc., extend from the Rømø Dam northward to the low-tide route (Ebbevejen) to Mandø, fig. 10. The profiles S. II, S. III, etc., extend from the Rømø Dam southward to the German frontier. It is clearly to be seen from the diagram that the samples from the northern portion of the "Wadden Sea" are slightly coarser than those from the southern portion.

Four profiles, namely F. I, FII, F. III and J. I–III, are conspicuously divergent from the remainder. The first three lie on the east side of Fanø, while J. I–III go from Hjerpsted out to, and around Jordsand. These analyses will be treated more thoroughly in the following.

Some examples will serve to illustrate the sediments of the hard *wadden.*

Fig. 4 and Table II show four average samples of the sediments of the hard *wadden.* The four samples are chosen so that by far the greater part of all the analyses have cumulation curves which expire in the area between analyses 202–226. Divergencies will be treated in greater detail in the following.

Table II.

Analysis No.	Md µ	Q_3 µ	Q_1 µ	QD_Φ	Skq_Φ
87	130	160	105	0,3	0,04
185	110	145	86	0,4	÷0,04
202	90	102	80	0,2	÷0,04
226	140	170	105	0,3	÷0,07

Analysis 87 is taken 4 km. due west of the mouth of Rejsby Aa; analysis 185 is taken 2 km. to the north, and 500 m from land. Analysis 202 is taken 1 km. south of the Rømø Dam and 350 m from

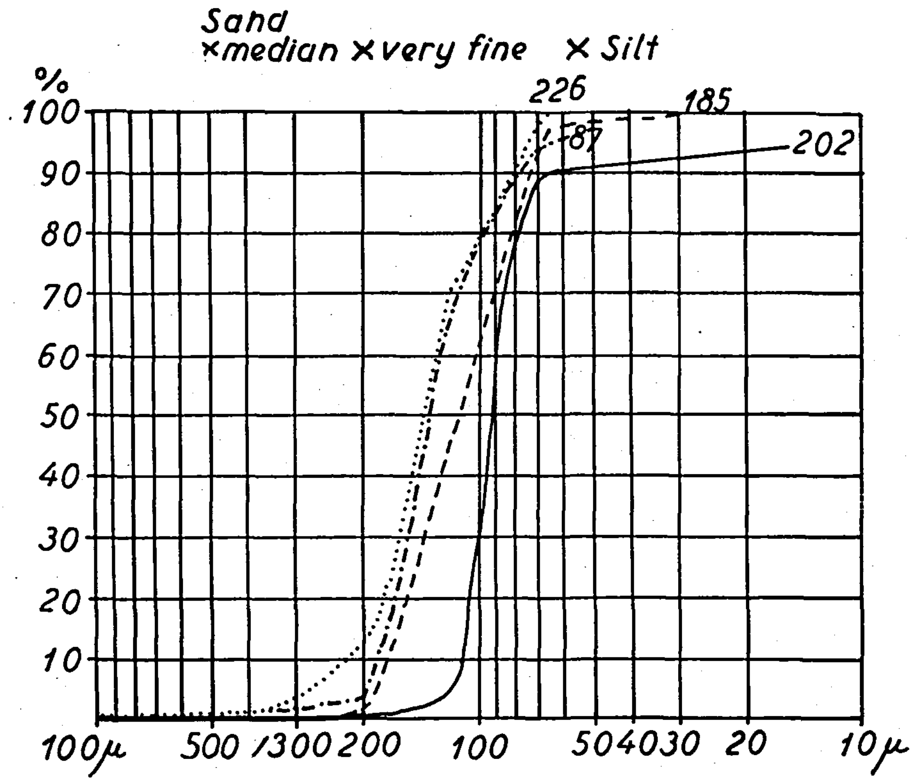


Fig. 4. Cumulation diagram of *wadden* sediments of the average type.

land, while analysis 226 is taken 400 m north of Baadsbøl (fig. 10). JAKOBSEN states that the *wadden* are everywhere hard sand-*wadden* without vegetation. Only at point 202 there is scattered growth of *Salicornia herbacea*.

As is to be seen from the diagram, all the samples are composed of extremely well-sorted fine and very fine sand with an average grain-size varying between 90–140μ. The sorting is particularly good since QD_{Φ} lies between 0.2–0.4, in contrast to the *klæg* where it is 2–5 times as large. Skq_{Φ} shows that the corresponding distribution curves are very nearly symmetrical. The fraction $>750\mu$ is in all samples composed exclusively of shell fragments. All grains larger than 200μ are rolled and worn, while grains $<200\mu$ are in the majority of cases angular. Only in analysis 226 are angular grains found up to 250μ in size.

The normal sediment of the hard *wadden* corresponds rather closely

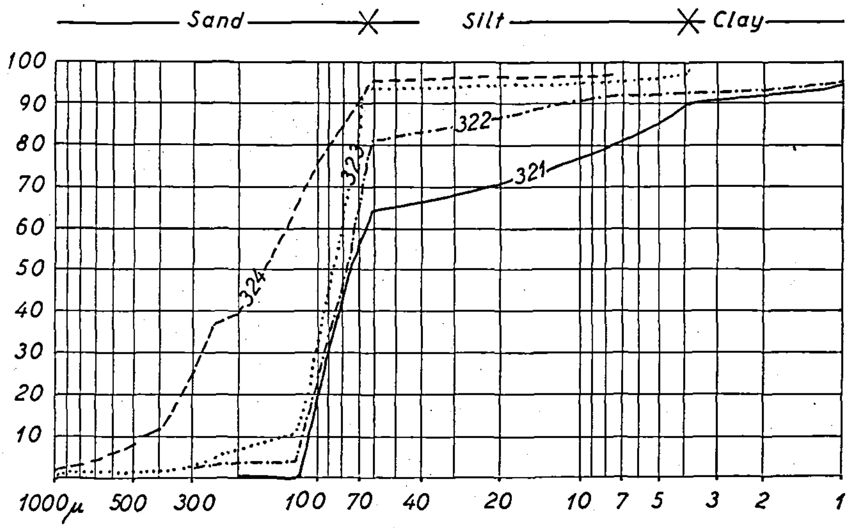


Fig. 5. Cumulation diagram of samples from the hard *wadden* by Lilho to the north of Esbjerg.

Table III.

Analysis No.	Md μ	Q_3 μ	Q_1 μ	QD_{Φ}	Skq_{Φ}
321	75	87	12	1,5	1,17
322	77	100	65	0,3	÷0,06
323	87	105	75	0,2	÷0,02
324	160	300	100	0,8	÷0,1
321a	77	95	63	0,3	÷0,2
321b	6,5	16	3	1,2	0,45
324a	320	470	285	0,35	÷0,18
324b	130	160	95	0,4	÷0,08

to ATTERBERG's class "Finmo". The content of coarser components can reach 15%. There may also be a small amount of *slik* mixed in the sand but not, however, more than 10% of the total sediment.

Fig. 5 and Table III show some samples taken on the *wadden* inside Lilho, NW. of Esbjerg. GRY (1942) describes this sediment as a mixture of sand and *slik*.

The *wadden* is a firm and hard sand flat, on the outer margin of which is found an about 200 m. wide belt with *Mytilus* in such large numbers that they form shell-banks.

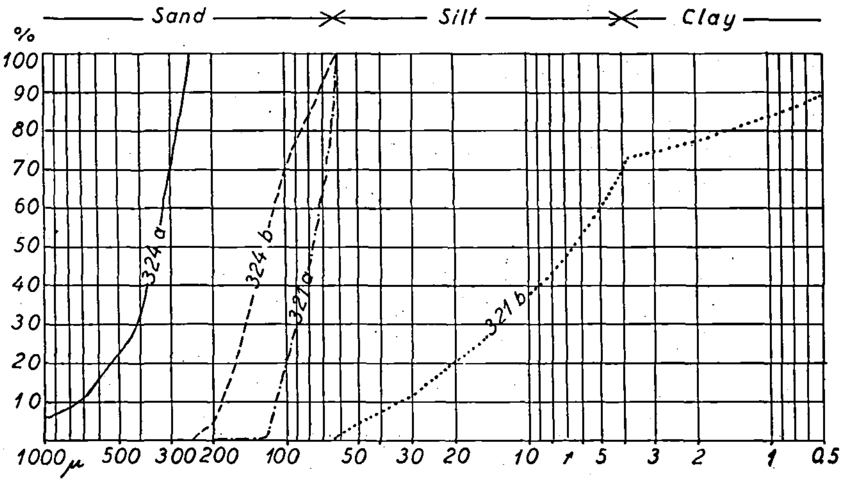


Fig. 6. The samples from fig. 5 divided into their components.

Analysis 321 is taken on the Mytilus bank among the shells. Nos. 322 and 323 are from the *wadden* between the banks, and no. 324 is taken half-way in to land, where the *wad* is covered by a scattered growth of *Zostera*.

No. 323 is a normal *wadden* sand with median grain-size 87μ, and QD_{Φ} 0.2: a well sorted fine-sand. Nos. 321 and 322 are, on the other hand, clearly mixed sediments. In order more closely to study their composition they are in fig. 6 divided into their components respectively larger and smaller than 1/16 mm. The sandy portion shows itself to be normal *wadden* sand with a median grain-size of 77μ, and QD_{Φ} of 0.3. The finer components are pure mud with an average grain-size of 6.5μ and QD_{Φ} of 1.2. The amount of *slik* reaches 36% in analysis 321 and 18% in analysis 322. It is thus only in the Mytilus banks themselves that the deposits are mixed with *slik*, while outside these there is a pure hard sand flat.

The sample, analysis 324, is rather coarse sand, but the curve is characterized by a hump at 250μ. This shows that also in this case we are dealing with a mixed sediment; the components are represented by the curves 324 a and b in fig. 6. It is to be seen that it is partly normal *wadden* sand of average grain-size 130μ, but also a somewhat coarser sand of average grain-size 320μ which is present. The most natural explanation of this mixture would be that the coarse material was derived from the coast, which here is a cliff, facing the *wadden*. The greater part of the cliff is composed of fine

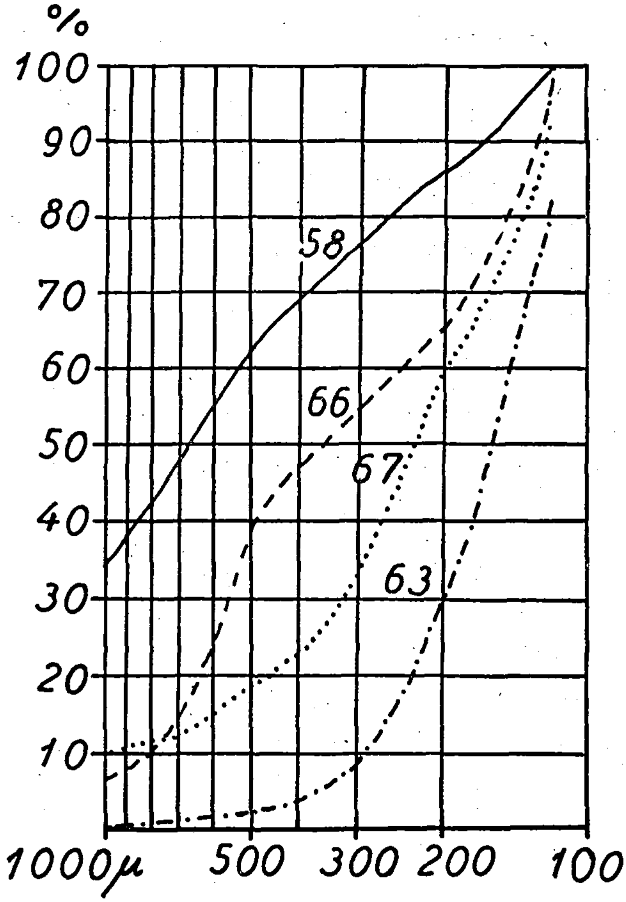


Fig. 7. Cumulation diagram of samples from the *wadden* around Jordsand.

Table IV.

Analysis No.	Md μ	Q_3 μ	Q_1 μ	QD_Φ	Skq_Φ
58	675	1200?	320		
63	160	220	130	0,4	÷0,07
66	360	600	160	1,0	÷1,43
67	230	390	150	0,7	÷0,07

Miocene mica-sand, covered by about 1–2 m. of boulder clay. As will become apparent from the following, there is reason to assume that glacial or early post-glacial deposits are present in the *wadden* or are only covered by a thin layer of recent *wadden* sand.

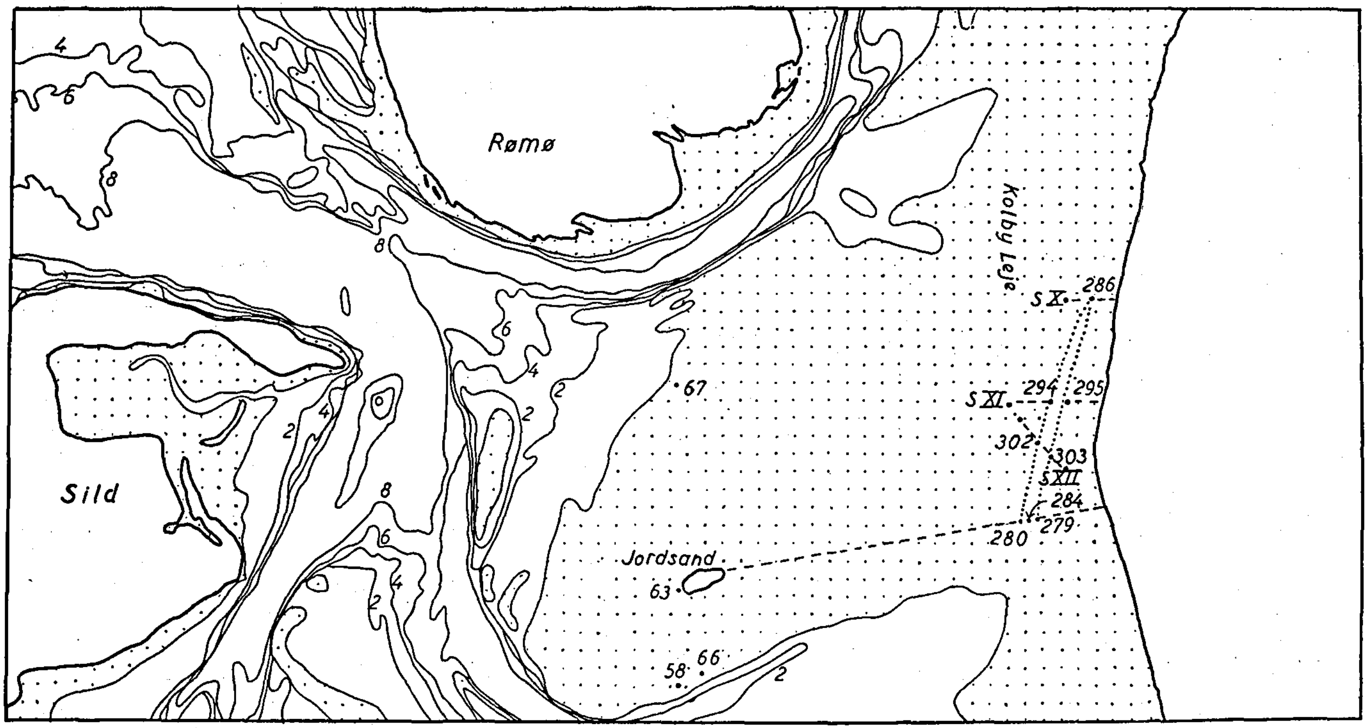
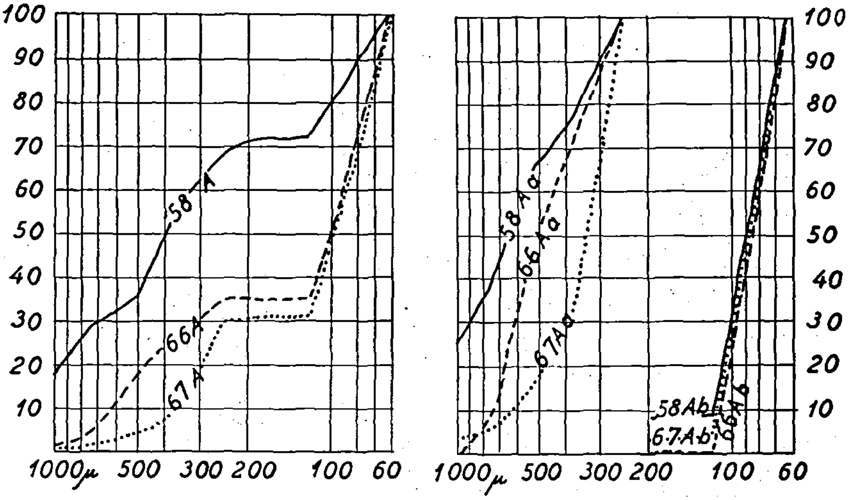


Fig. 8. The *wadden* around Jordsand. Curves for each 2 m in Listerdyb between Rømø and Sild.



a Fig. 9. b

The same samples as in fig. 8 but free of calcium carbonate.

Table V.

Analysis No.	Md μ	Q_3 μ	Q_1 μ	QD_Φ	Skq_Φ
58.A	420	920	110	1,8	0,67
66.A	105	380	85	1,0	÷0,99
67.A	90	270	80	2,6	÷0,64
58.A.a	650	1000	390	0,7	0,16
58.A.b	87	110	75	0,2	0,0
66.A.a	500	625	340	0,4	0,11
66.A.b	87	102	73	0,2	0,0
67.A.a	340	440	270	0,3	0,06
67.A.b	87	105	75	0,2	0,0

Fig. 7 and Table IV show some analyses from the *wadden* around Jordsand, profiles J. I–III in fig. 3. The positions of the sampling stations are seen in fig. 8. The cumulation curves are, with the exception of analysis 63, sharply divergent from the typical diagram. The median grain-size is distinctly larger, lying between 160 and 675μ, and sorting is recognizably poorer, with QD_Φ between 0,4–1. The skewness is also greater in the direction of the coarser part of the distribution curve.

In these analyses an essential part of the fraction greater than

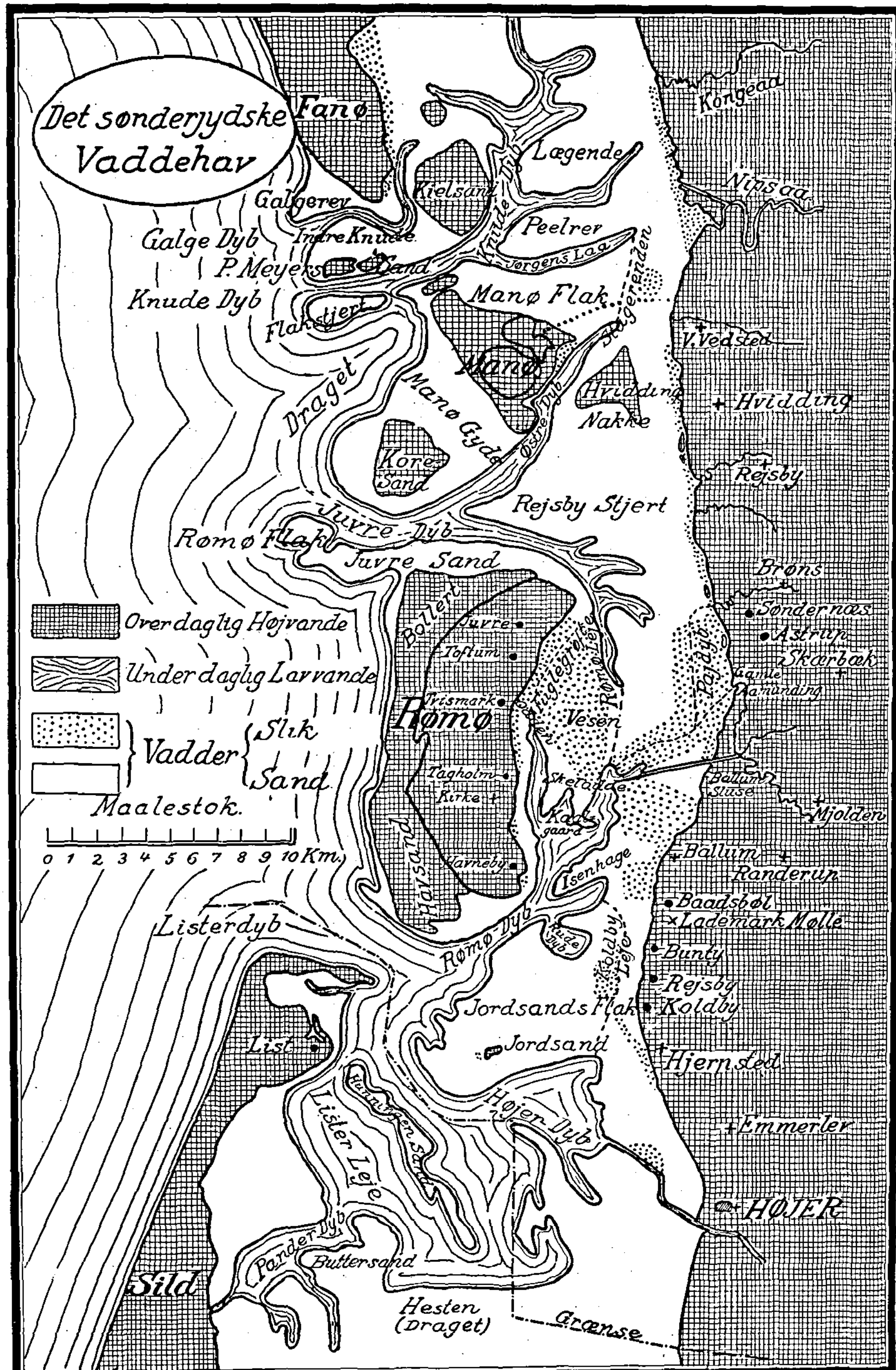


Fig. 10. The Danish Wadden Sea (Thade Petersen 1926).
The later-build Rømø Dam runs from Skærbæk to Toftum.

200μ is made up of shell-fragments; this rather alters the picture of grain-size distribution. In order the more clearly to show this, a further granulometric analysis has been carried out on the same samples after digestion with dilute HCl to remove calcium carbonate. Fig. 9 a. and Table V show the result of this treatment.

The picture is now completely changed; it is now evident that we are here concerned with a mixed sediment as at Lilho, and in order to show this more clearly the diagram, fig. 9 b, is arranged as previously.

Normal *wadden* sand with median grain-size 87μ and coarser sand with median grain-size varying from $340–650\mu$ also occur here. The coarse sand is hardly transported out from the coast. Certainly a more or less steep coastal cliff capped with boulder clay is also present here, extending from Ballum in the north to Emmerlev in the south, and the same coarse sand is also found on the more landward part of the profile. But all the samples from close in-shore, both to the north and the south of this line, have the same granulometric composition as normal *wadden* sand, with average grain-size less than 200μ. There can be no doubt that the coarse sand found here, just as by Lilho, must originate from re-worked coarser sediments present beneath the *wadden* sand along the margin of Lister Dyb. The Lilho *wadden* lies opposite Graadyb, and the Jordsand *wadden* lies opposite the broad, deep Lister Dyb. There is reason to assume that the stronger wave and tidal movement in these places could be the reason for the presence of these coarse sediments. However, as will be apparent from the following, this is in any case not the only reason.

The Soft Wadden.

THADE PETERSEN's map of the Danish "Wadden Sea" (1926) is shown in fig. 10 and it will be seen that there is marked on this a large area of *slik wadden* between Rømø and the mainland. There is in the text an account of the extent and character of these *slik wadden*, and of the thickness of the *slik*. The only criterion which PETERSEN has used is, however, how far one sinks down into these flats.

Eleven of the sample profiles of the Skalling Laboratory extend from the coast out into this region of *slik wadden* and there have been collected 229 samples from the area. With the exception of a few samples, which will be more closely discussed in the following, all the others consist of normal *wadden* sand.

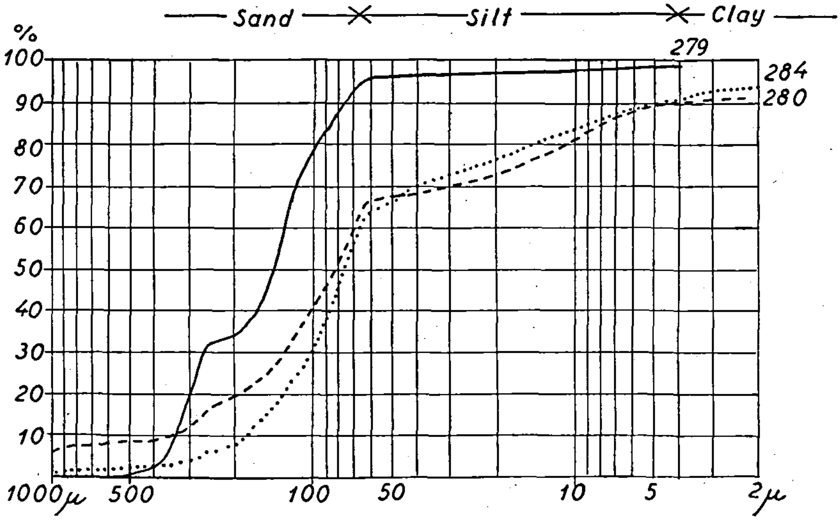


Fig. 11. Culmulation diagram of samples from Koldby Leje.

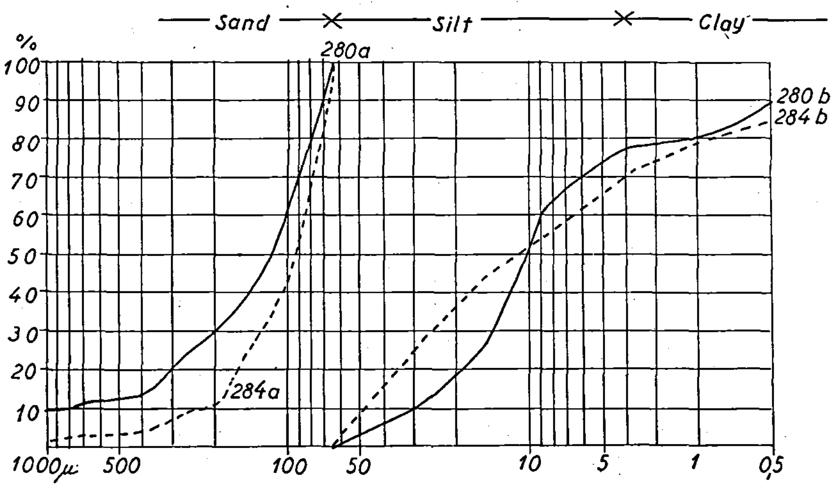


Fig. 12. The samples as in fig. 11 divided into their components.

Analyses of some samples taken on the profile from Hjerpsted to Jordsand are shown in fig. 11 and table VI, and their location is seen on fig. 8. Altogether 50 samples were taken on this profile at intervals of 100 m. With the exception of analyses 280 and 284 they all showed cumulation curves similar to that of analysis 279, fig. 11. This curve agrees on the whole with the normal type curve, and the median grain-size lies just at the upper boundary of the normal type. Sorting is poorer since QD_Φ is 0.7. Also in this case the cumulation curve shows a marked hump in the sand fraction 200–250μ, suggesting that older sediments reach nearly up to the surface of the flat.

Table VI.

Analysis No.	Md µ	Q_3 µ	Q_1 µ	QD_Φ	Skq_Φ
279	140	280	110	0.7	÷0.32
280	80	150	16	1.6	0.71
284	75	110	24	1.6	0.55
280.a	115	250	85	0.8	÷0.33
280.b	10	30	5	1.3	÷0.28
284.a	95	150	75	0.4	0.0
284.b	11	15	3	1.2	÷0.05

The samples 280 and 284 diverge from the normal type by being more fine-grained. The median grain-size is somewhat under the lower boundary for normal *wadden* sediments, and sorting is markedly poorer, QD_Φ being respectively 1.1 and 1.6. The curve alone shows that one is concerned with fine sand with admixture of fine material. The two samples are divided into their components in fig. 12.

The sand fraction now gives a curve of the same type as the normal *wadden* sand from fig. 4 and with the same median grain-size. Sorting is, however, somewhat poorer as QD_Φ is greater than 0.4. Skewness is also somewhat greater, particularly in analysis 280.a. The *slik* content has the normal character with a median grain-size of 10μ. Both these samples are from Koldby Leje, an old watercourse connecting the inner part of Højer Dyb with Rømø Dyb. The water depth at low tide is about 35 cm. and at high tide about 2 m. Koldby Leje also shows itself in the same way further to the north where, in the sediments from profiles S.X, S. XI and S. XII, the analyses 286, 294, 295, 302 and 303 show a composition similar to 280 and 284 (see fig. 8). The remaining samples from these two profiles are on the other hand composed of *wadden* sand.

As there is ordinarily a very strong current through Koldby Leje it is surprising that the sediments here contain such large amounts of mud, and that the bottom is so soft that one sinks in nearly up to the knees.

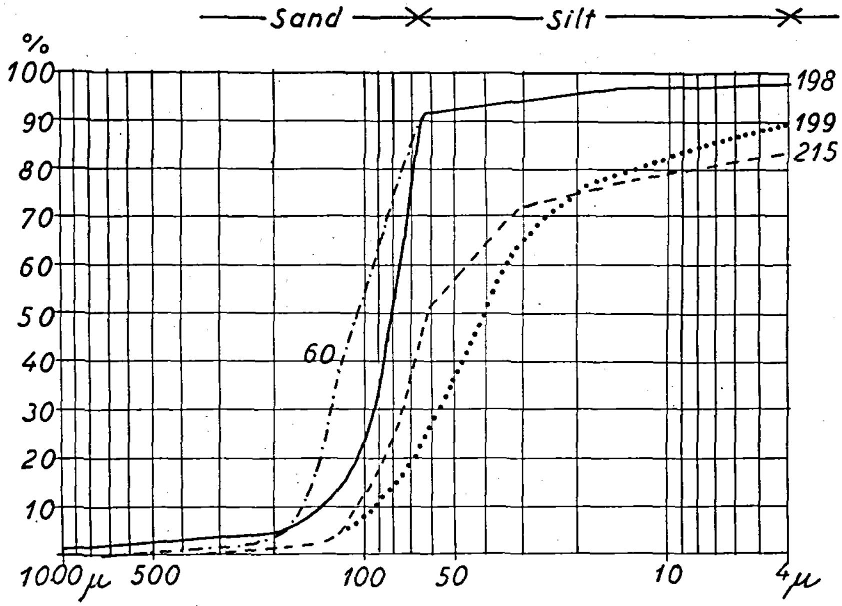


Fig. 13. Cumulation diagram of samples from the silting-up old Bredeaa course.

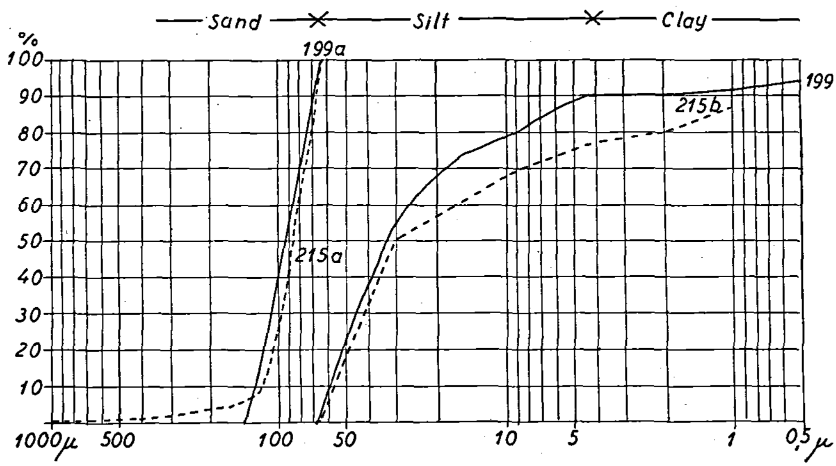


Fig. 14. The samples from fig. 13 divided into their components.

Figs. 13 and 14 together with Table VII show another example of the same. In this case it is the old course of Brede Aa to the south of Pajdyb (fig. 10) through the *wadden* which shows itself in the same way in the composition of the sediments. The analyses 60 and 198 are taken on the *wadden* and have the same granulometric composition as the normal type of *wadden* sand. The parameters also fall within these limits.

The analyses 199 and 215, on the other hand, have the same character as those from Koldby Leje.

They are taken in the old course. Both have a median grain-size distinctly below that which is normal for *wadden* sediments, and both have poorer sorting. QD_{Φ} lies between 0.8 and 1. The skewness also shows, particularly in analysis 215, a marked excess on the fine-grained side in the same way as analysis 280 from Koldby Leje.

Table VII.

Analysis No.	Md µ	Q_3 µ	Q_1 µ	QD_{Φ}	Skq_{Φ}
60	107	130	80	0.3	0.08
198	82	100	72	0.2	÷0.01
199	40	60	20	0.8	0.22
215	65	80	20	1.0	0.71
199.a	95	120	75	0.3	0.3
199.b	33	55	14	1.0	0.25
215.a	85	110	75	0.2	÷0.9
215.b	30	52	5	1.9	0.91

Fig. 14 shows the division into component parts. Analysis 199.a has the same composition as *wadden* sand, whereas analysis 215 is slightly more fine grained with a median grain size of 80μ. Sorting and skewness are, on the other hand, the same.

The *slik* is, however, coarser here than at Koldby Leje with median grain-size 30–33μ as against 10–15μ for pure *slik*. The sediment is here muddy sand or sandy mud, but the mud is distinctly more coarse grained than normally.

It is a general feature, that the first samples of the profiles nearest to the coast have a larger or smaller mud content, not, however, more than 20%. The reason for this is that there is very often a broad, shallow channel (Slund) parallel with the coast; this contains water even at low tide, and the bottom here is softer than normal on the *wadden*.

Soft *wadden* are also found on the east side of the islands. Figs. 15, 16 and 17 show a series of analyses from profile F. 1. across the bay by Nordby on Fanø (Fig. 18), the corresponding parameters are given in Table VIII.

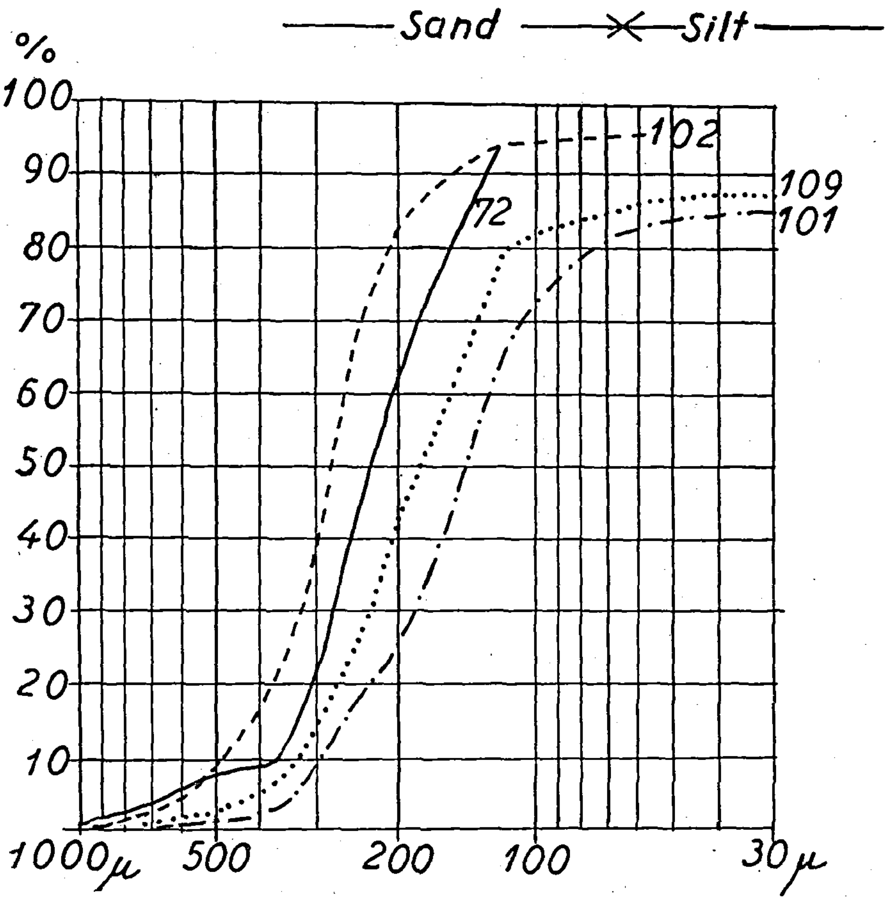


Fig. 15. Cumulation diagram from the southern part of the bay by Nordby on Fanø.

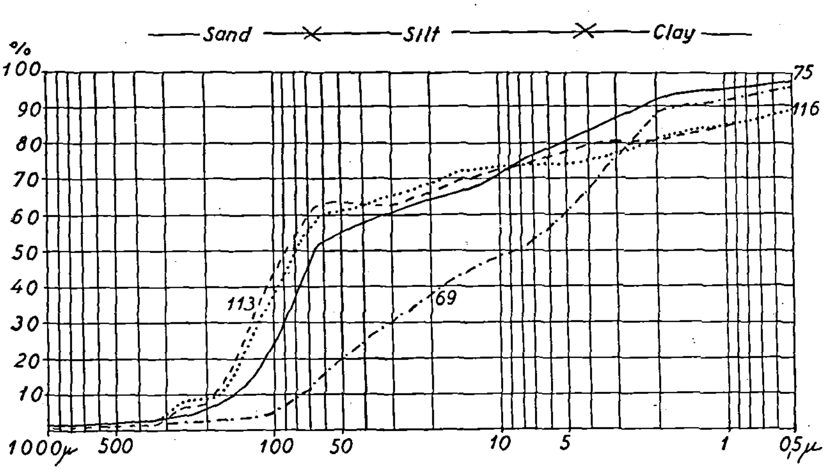


Fig. 16. Cumulation diagram from the nw-part of the bay by Nordby on Fanø.

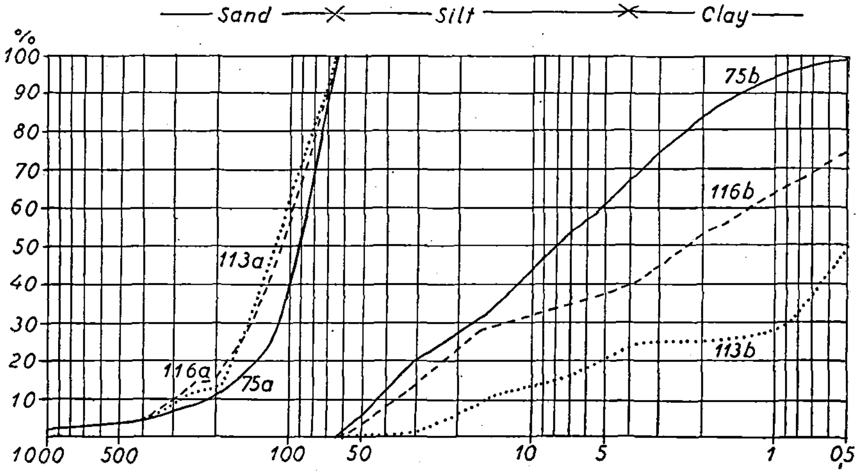


Fig. 17. Cumulation diagram from the nw-part of the bay by Nordby divided into their components.

Table VIII.

Analysis No.	Md μ	Q_3 μ	Q_1 μ	QD_Φ	Skq_Φ
72	230	290	170	0.4	0.06
101	140	200	90	0.6	0.03
102	280	350	230	0.1	0.0
109	180	250	125	0.5	0.03
69	8,5	40	3	1.9	÷0.36
75	65	100	8	1.8	1.04
113	90	130	6	2.2	1.63
116	80	125	5.5	2.6	1.94
75.a	92	120	75	0.3	÷0.03
75.b	8	23	3	1.5	÷0.03
113.a	115	160	87	0.4	÷0.03
113.b	0.5	3			
116.a	110	160	82	0.1	÷0.05
116.b	2.3	19	0.5	2.7	÷0.33

Analyses 72 and 102 are from the south-eastern part of the profile, and it is to be seen that the sediment here is somewhat coarser than is normal for *wadden* sediments, but that there is no hump of the curve as is seen at Lilho and Jordsand. Other samples from the bay by Nordby, however, show this hump. Sorting is also rather poorer than in normal flat sediments.

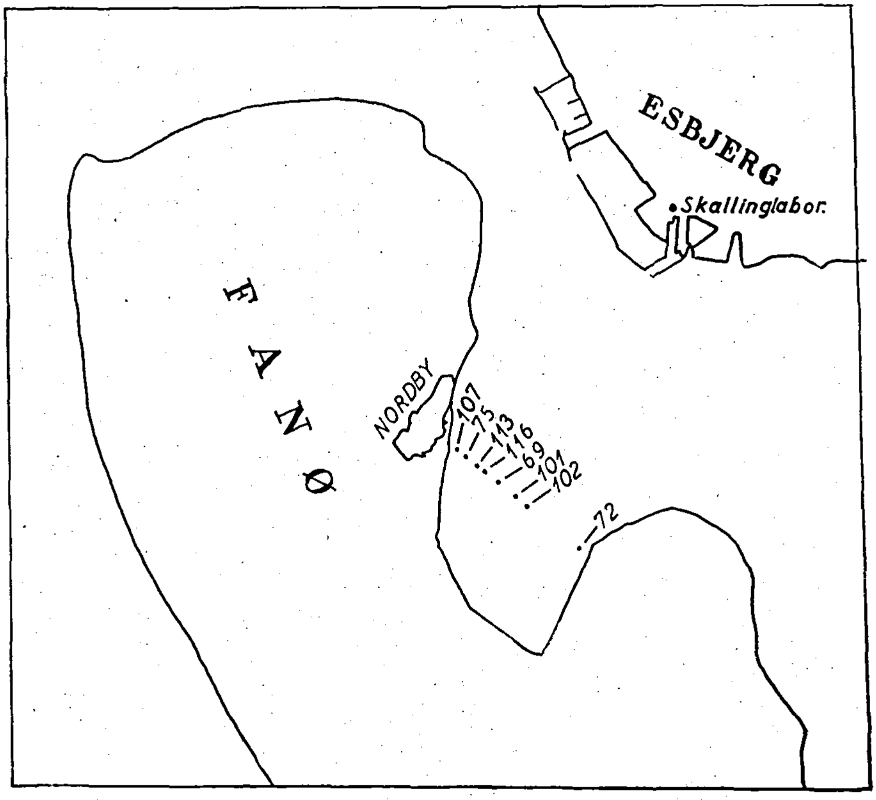


Fig. 18. The profile in the bay by Nordby on Fanø.

Analyses 75, 113 and 116, from the north-western part of the profile, show a marked admixture of mud, especially in analysis 69 which has 12% sand and 88% *slik*. Fig. 17 and Table VIII show that the fine-grained components have the same composition in analysis 69 as in analyses 75, 113 and 116, and that they are distinctly more fine grained than the *slik* components both of Koldby Leje and in the old channel of Bredeaa.

A comparison of the map, fig. 18, and the aerial photograph, fig. 19, shows that the muddy area lies in the innermost, silted-up part of the channel Fanø Lo. The innermost part of the bay is, furthermore, surrounded by old salt-marsh undergoing erosion. From this, large amounts of *klæg* are transported to the *wadden* through ditches and directly from the edge of the marsh. This explains that the *slik* content of this flat is greater and more fine-grained than in Koldby Leje and Bredaa Leje.

Fig. 19. Air photo of the northern part of Fanø at low tide with the *wadden* and the deep Fanø Lo in the bay by Nordby. To the the right, city of Esbjerg.

Similar conditions are also met with in Albuebugten further south along the east coast of Fanø (profile F. III in fig. 3) where the high mud content of some of the samples is referred to the break-up of old marsh inside the *wadden*.

Fig. 20 and Table IX show, lastly, some examples of soft *wadden* along the east coast of Rømø.

The samples were collected in 1933, before the Rømø Dam was built, but after the completion of the Hindenburg Dam between Sild and the mainland. Analysis 352 is from a soft *wad* just north of the old jetty by Kongsmark. Fresh, it is a soft black humic mud with a brown surface layer 3–4 m. thick. It contains numerous *Corophies* and *Mytilus* attached to the leaves of *Zostera*.

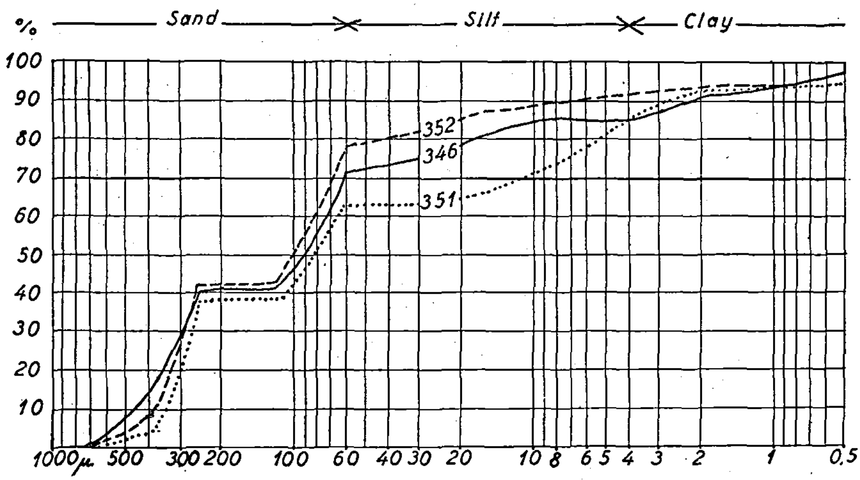


Fig. 20. Cumulation diagram of samples from a soft *wadden* by Rømø.

Table IX.

Analysis No.	Md μ	Q_3 μ	Q_1 μ	QD_{Φ}	Skq_{Φ}
346	95	320	28	1.8	0.0
351	80	280	70	1.0	÷0.78
352	100	300	65	1.1	÷0.48

Analysis 346 is taken more to the north, where the brown surface layer is only a few millimeters thick. Analysis 351 is taken opposite Bolilmark almost where the Rømø Dam now reaches the island. It is the innermost edge of a Zostera *wadden* and the sample is riddled by plant roots. The analyses show that these soft *wadden*, into which one sinks deeply, are all composed of sand with up to 38% mud. Here, also, there is old marsh undergoing erosion and in some places the marsh clay is subject to erosion from the seaward side (Fig. 21).

The diagram shows that also here the sand in the flat is the same mixture of older coarser sand and recent *wadden* sand.

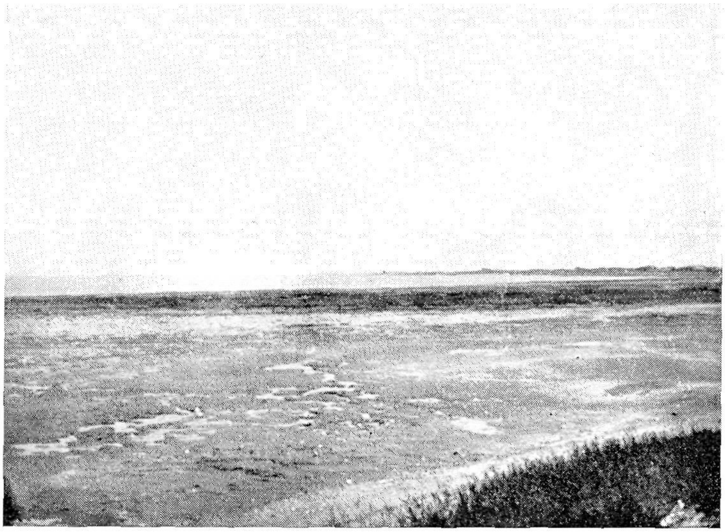


Fig. 21. Eroded old salt marsh *klæg* on the *wadden* along the east side of Rømø by Bolilmark 1933.

Summary.

The result of these preliminary investigations is that the normal sediment on the *wadden* in the Danish Wadden Sea is the sand. *Slik* deposition may on a smaller or larger scale take place during very special conditions, as for instance in the old silted-up channels or along the eastern side of the islands and into Ho Bugt where old salt marshes are being eroded.

The very restricted areas with *slik wadden* situated here are not real *slik wadden* but rather old salt marsh from which the upper layer is eroded so that the surface now lies so low, that it can only dry up by low tide.

The proper area for deposition of *slik* in the Danish Wadden Sea is not the *wadden* but the salt marsh, i. l., the areas covered with vegetation.

The measurements by NIELS NIELSEN on Skallingen (NIELS NIELSEN 1935) and the still unpublished investigations by BØRGE JAKOBSEN along the whole Danish Wadden Sea and salt marsh area show that only when the vegetation, especially the *Puccinellia* vegetation, get foothold on the sand *wadden*, a deposition of *slik* will take place on a larger scale and then the *wadden* will be transformed into salt marsh.

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