Morphological studies on the eastern coast of Disko, West Greenland

By Niels Nielsen

Abstract

Description of a low coast in the island of Disko based on a detailed mapping of an offshore barrier system with lagoon and salt marsh areas. Preliminary investigations and measurements of tide, currents and beach drift, followed up by an analysis of the vegetation. Furthermore, some comments on the influence of ice on an arctic low coast.

In the summer of 1965 the author participated in a trip to West Greenland and worked as research assistant to *Dr. Kaj Hansen*. During this stay a short visit was paid to Mudderbugten at the island of Disko to reconnoitre a region which, from aerial photographs, looked very interesting from a coastal-morphological point of view. Of special interest was a sand barrier with a marsh formation behind; furthermore, the interaction between the forces working in the area, first and foremost the tide and the existing landforms, seemed to present very interesting aspects. Inspired by these first-hand observations stud. scient *Jørgen Nielsen* and the author were sent out the following year from the *Geographical Institute of the University of Copenhagen* with the purpose of analysing in greater details the geomorphology and the hydrography of the area. The investigations were concentrated around the eastern corner of Disko, called Nûk, located approximately at lat. 69°39′N and at long. 51°52′W, cf. fig. 1.

Geology

Together with Nûgssuaq and Svartenhuk, the island of Disko differs geologically from the rest of West Greenland by younger formations. The whole island of Disko is supposed to rest on Precambrian gneiss (the Agpatides); however, these lie open at a few places only, for example at Godhavn. The superstratum is the coal-bearing, cretaceous formation, which is dominated by a yellowish, easily friable sandstone. Strata of coal and clay slate are seen at several places along the SE-, E-, and NE-coast. During the Tertiary, the cretaceous deposits were overlain by enormous masses of eruptive material, viz. first submarine tuf and pillow lava followed by plateau basalt, which in certain places has a magnitude of nearly 1000 m. Quaternary occurrences are frequently seen as morainic deposits along the sides and in the bottom of the deeply eroded valleys that crisscross Disko.

Topography

The coastal plain presented here constitutes part of Flakkerhuk which is bounded to the northeast by a sandstone ridge called "Gule Ryg", to the north by the Mudderbugt estuary and to the southeast by Disko Bugt. Flakkerhuk is about 20 km long, 3-7 km wide and gently sloping towards the sea from Gule Ryg with a gradient of 20-50 metres per km. The surface consists largely of unconsolidated sand and gravel, but large, rounded stones and blocks are seen everywhere. Most of them are of basalt, but some of the blocks are of crystalline origin and were probably deposited by an ice tongue which has advanced from the bedrock area east of Disko Bugt. Many of the basalt blocks have been transported from the central part of Disko by the glaciers, others may originate from frost shattering and ice erosion of some of the basalt dykes intruding the Flakkerhuk plain. The topography of Flakkerhuk shows evidence of meltwater, rain, and frost erosion in postglacial time, but marine activity far above the present sea level must also have contributed.

During the Nûgssuaq Expedition in 1939 *D. Laursen* investigated changes in sea level in the Disko Bugt area. A comparison between these results and similar investigations elsewhere shows that the upper marine terrace lies at a higher level in North Greenland as compared with South Greenland. At the northern side of Nûgssuaq marine terraces are found 224 m a.s.l., at Asuk, North Disko, the top height is 200 m a.s.l. In the case of Flakkerhuk, *Steenstrup* (1881-82) states about 98 m, but it is very likely that still higher lying terraces have been formed, but levelling processes – primarily solifluction – have removed most traces of marine activity at the highest levels. Taken as a whole, the coasts of Greenland are at present subject to a relative subsidence, and both etnographical and direct measurements made by *Steenstrup* and *Froda* and repeated by *Laursen,* in South Greenland by *G. Holm,* prove this:

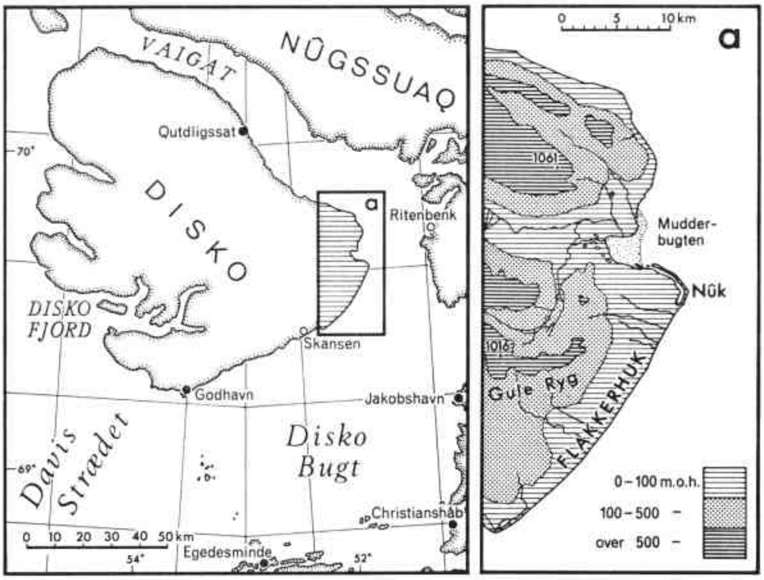

Fig. 1. The location of Flakkerhuk, Nûk, and Mudderbugten on the island of Disko, West Greenland. Section *a* is drawn after Geodetic Institute's map Greenland 1:250.000, measured in 1931 and 1933. Note the development of the offshore barrier.

Fig. 1. Nûk og Mudderbugtens beliggenhed på Disko. Kortudsnittet a er tegnet efter Geodætisk Instituts Grønland 1:250.000, opmålt i 1931 og 1933. Bemærk offshore barrierens udvikling.

	per 100 years
The relative subsistence at Umanak is indicated to be	1.67 m
– Ritenbenk	1.17
– Jakobshavn	1.17
– Godhavn	0.58
– Nanortalik	0.39

It is noteworthy that the greatest subsidence is found where the uplift was formerly the greatest.

The geomorphological development of Flakkerhuk is in brief outline: During the Ice Age the cretaceous sandstone formation was exposed to a heavy glacial erosion; subsequently the sea rose and covered the greater part of the Flakkerhuk plain at a certain time; during the transgression period the topography became levelled by waves and sedimentation. This was followed by an isostatic uplift of the land, river erosion influenced the relief and Flakkerhuk got its present appearance. Now, receding shorelines and formation of cliffs point at a relative subsidence. However, the subsidence does not proceed faster than accumulation of sediments takes place, as it may be seen for example at Nûk, Disko.

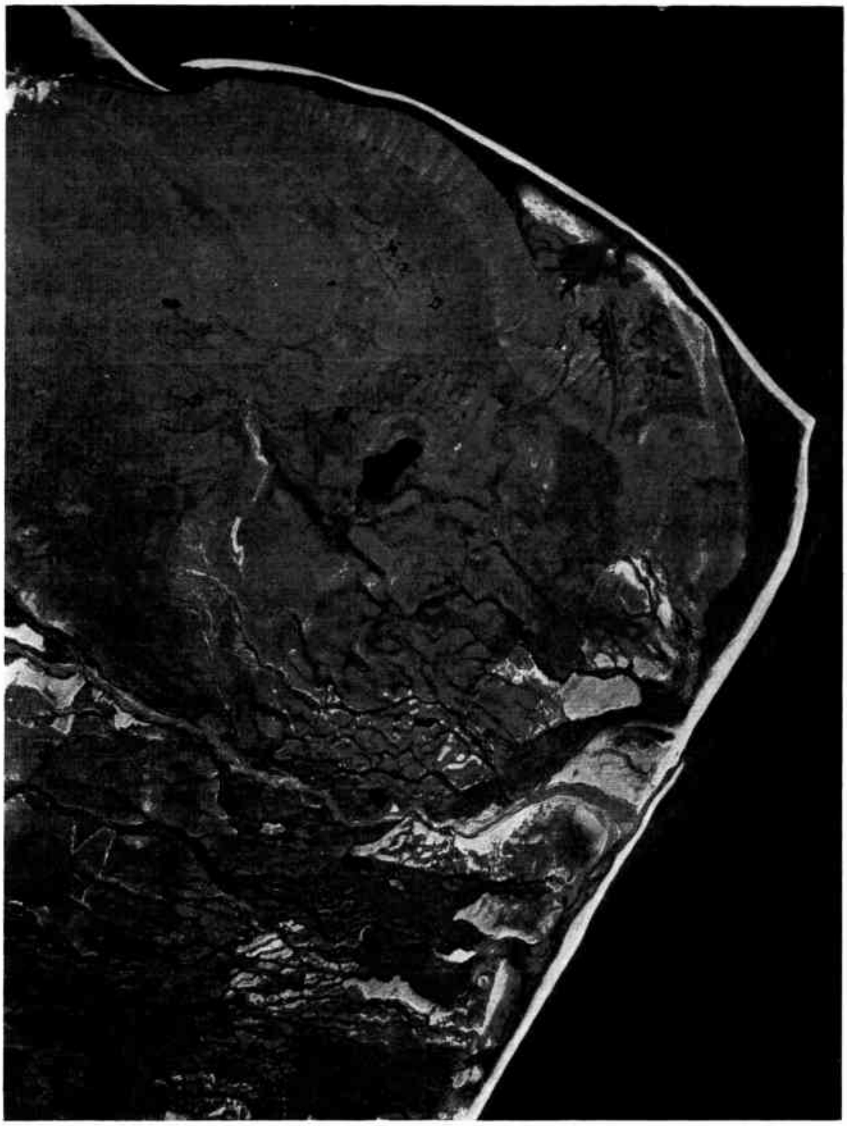

Fig. 2. Vertical aerial photograph of the northeastern part of Flakkerhuk, taken August 27, 1964. Height about 8687 m. Scale approximately 1:50.000.

Fig. 2. Lodret flyvebillede over den nordøstlige del af Flakkerhuk. Optaget 27. august 1964. Højde ca. 8687 m. Målestoksforhold ca. 1:50.000.

On the basis of air photo (268 G No. 194 – 27. 8. 1964) from the *Geodetic Institute* in Copenhagen and field records a survey has been made of the north-eastern part of Flakkerhuk (see fig. 2-3). Looking at the shoreline the dominance of the accumulation forms is the

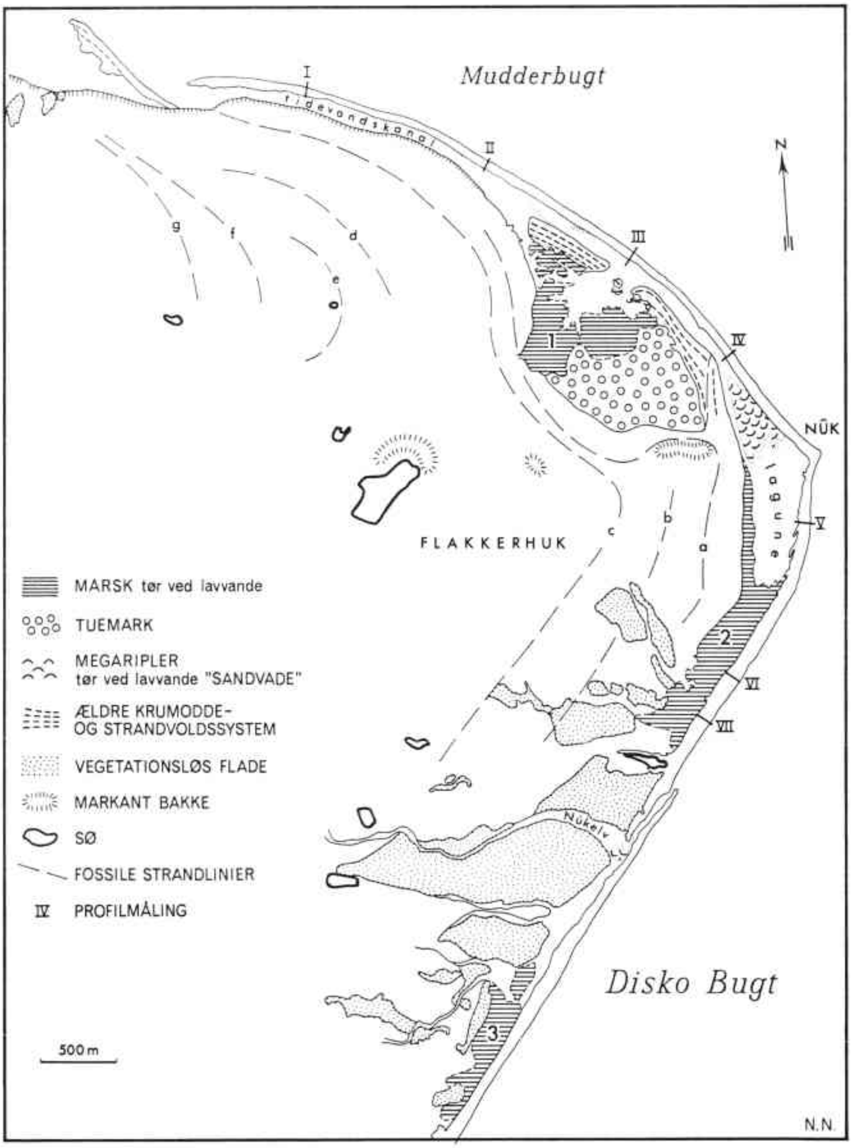

Fig. 3. Explanatory sketch map drawn on the basis of fig. 2 and field observations. 1. Salt marsh, dry at low tide. 2. Hummock field. 3. Megaripples, dry at low tide, "sand flat". 4. Older recurved spit and beach ridge systems. 5. Flat without vegetation. 6. Characteristic hill. 7. Lake. 8. Fossile shoreline. 9. Survey of cross profile.

Fig. 3. Forklarende kortskitse udtegnet efter lodret flyvebillede (fig. 2) samt feltobservationer.

most striking feature. The coastal area from the mouth of Nûkelv (not official name) to Nûk and about 5 km farther on towards the northwest makes up an unbroken marine formation, which can be characterized as an offshore barrier, *King* (1959).

Approximately 100 m from the end of the barrier another element of marine origin can be observed, namely a recurved spit complex whose form and location differ essentially from the barrier. Between the offshore barrier and the mainland a long channel is seen which enters the sea at the base of the recurved spit. The channel leads to a sand flat, 500-600 m NW of Nûk; then follows a lagoon area, about 1 km long, seen on the air photo in a low-tide situation. During moderate high-tides water covers the sand flat, whereas the hatched areas – the proper salt marshes – will de drowned only at significant high-tides. Salt marsh area 1 is partly barred to the NE by a recurved spit complex formed before the offshore barrier. The coast of the mainland between marsh 1 and the mouth of the channel is an abruptly sloping foreshore of a height of approx. 1 m at marsh 1 to about 30 m at the foot of the spit. After formation of the barrier, the erosion stopped and the cliff is now covered with vegetation (*Salix, Empetrum,* and *Cassiope* as the most common plants), whereas the littoral zone from the mouth of the tidal channel and some hundred metres farther on to the west is almost bare. The wave action is insignificant though there is no protecting bar, but the beach plain is rather high-lying (estuary deposits) and will therefore partly be drained at low-tide. The reason why there is no vegetation is primarily due to man's activities, as this part of the coast bears evidence of coal mining. The inhabitants of Ritenbenk have thus exploited this locality since time immemorial and up to the dissolution of the colony, according to a former Ritenbenker.

The aerial photography (fig. 2) shows a number of conspicuous, more or less conform lines which may be interpreted as fossil shorelines. They cannot be related to terrace or cliff forms, but must be weak traces left after the relative brief stay of the sea during the regression/transgression process. The lines d, e, f, and g, and the lines west of marsh 1 are the highest (g about 50 m a.s.l.), the oldest, and the most blurred ones, because here the levelling processes, primarily the solifluction, have been active for the longest span of time. The linies a, b, and c west of the lagoon and marsh 2, as well as the sides of the easternmost deposited hill clearly demonstrate marine activity, partly by erosion of the hill and partly by accumulation in the form of beach ridges (a and b), the latter are now subject to a strong, aeolian denudation.

The air photo shows some large, light areas with no vegetation at all. Where the colouring changes into light grey shades there is a tender vegetation of lichen and *Armeria maritima*. The surface topography is almost flat and consists of quartz sand, and gravel which at many places trend to develop a stone pavement. The plains seen everywhere at Flakkerhuk probably need a certain span of time to develop, as many of the white spots on the air photo are located west of, i.e. higher than, line c.

Finally, the three roughly outlined range of hills shown on the air photo due west of Nûk can briefly be described as follows: the easternmost of the hills is about 20 m high, and the top of it is covered with angular basalt boulders, whereas the hill sides consist predominantly of rust-coloured, unsorted, coarse sand. The intermediate hill is somewhat lower, but of the same type as the first one, whereas the westernmost hill is different both in form and in material. The boulders are few and the surface consists mostly of sand and silt/clay which by cryoturbation processes appear as a kind of patterned ground. The two hills nearest the coast are possibly a partially eroded dyke (basalt in situ was not found), whereas the westernmost crescent-shaped hill is a terminal moraine and the adjacent lake a central depression. Though Nûk lies in the continuation of the three ridges this location needs not be due to a partly disintegrated dyke, but may very well be explained on the basis of the general hydrography of the area.

Topographical Survey

For the purpose of a more detailed analysis of the morphological and hydrographical pattern in the coastal zone a survey was made of Nûk and its vicinity in order to have the offshore barrier – salt marsh – lagoon – tidal flat – mainland placed in relation to each other and to know the elevation pattern within the area. For this purpose a levelling on lines was used supplemented by tachymetric measurements, and a contour interval of 1 m was chosen. The submarine topography is mostly unknown, as soundings were impeded by the insufficient navigation facilities at our disposal; however, we succeeded in establishing one line at right angles to the coast and thus fix the –2 m level (fig. 4).

Upon arrival to the research field a water gauge was set up and records taken as often as possible. These gave us gradually an impression of the complicated tidal conditions prevailing (cf. p. 13); an approx. mean water level was calculated and used as local zero.

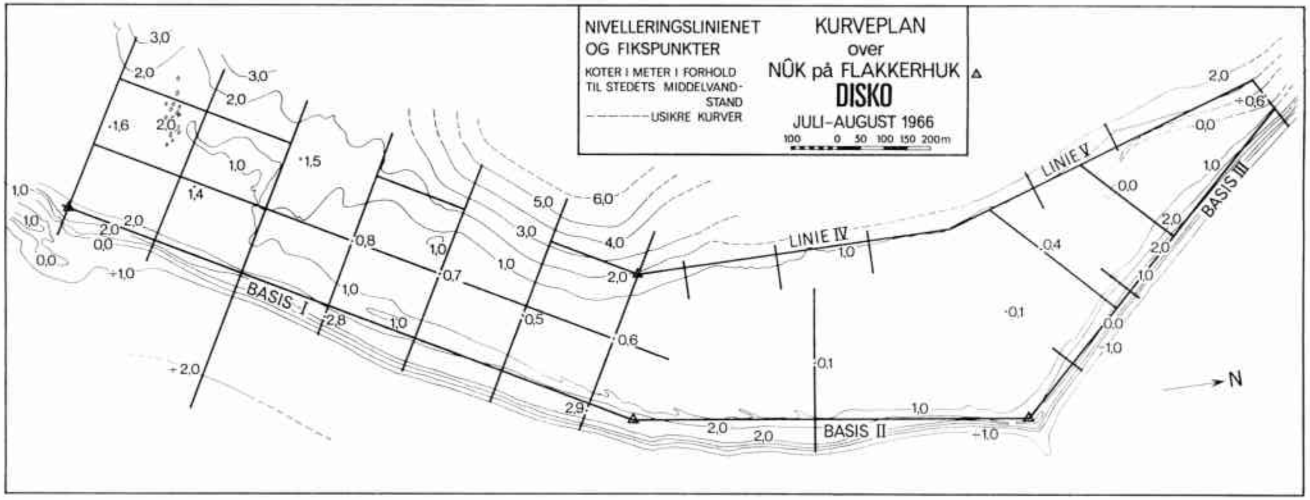

Fig. 4. Contour map of the coastline at Nûk with survey network. The triangles indicate fix points. Contour interval 1 m.

*Fig. 4. **Kurveplan over kystlandskabet ved Nûk med nivellementsnettet indtegnet. Trekanterne angiver fikspunkter. Ækvidistance 1 m.***

Heavy, 2 m long, galvanized 2″ iron pipes hammered into the ground were used as bench marks; their stability should be relatively good. A later re-establishment of the level grid should therefore be possible, as the pipes have been levelled and triangulated.

Besides the contour mapping, a geomorphological mapping was made based on the surveying lines already established (cf. plate). By means of different signatures we intended to map the location of the various morphological elements seen in relation to each other and thus get a tool for an interpretation of the topography and dynamics of the area.

The morphogenetic forces

The most important and also the most difficult task when trying to interprete the morphological development of any type of landscape is to realize the different forces working in the area. During our stay on Disko, it was beyond our possibilities to study all the factors involved and therefore only the most important ones will be discussed here, namely the wind, the tide, and the currents; finally, the influence of ice on arctic coasts will be discussed briefly.

Today the wind and its effect on the rise of waves and their movement is generally considered of great importance in coastal processes. We tried to get an impression of wind direction and speed by placing a cup anemometre 2 m above the surface of the offshore barrier. Readings were taken with irregular intervals from mid-July to mid-August. The records are shown in fig. 5a. Northerly and southerly winds prevail and the latter coincide with the direction of the maximum fetch, whereas only 3 ENE winds from east and west were observed. In the literature a wind speed of 4 Beaufort ~ 8-9 m/sec. is often considered a threshold value for the ability of the wind to induce erosion and accumulation by wave action. When we relate this value to the collected data we only find 5 cases with wind speeds above 4 Beaufort. The strongest wind was recorded on July 21, namely 10 m/sec. ~ 5 Beaufort which resulted in wave heights of 30-40 cm.

It was attempted at to get a more overall picture of the wind pattern of Disko Bugt by studying the long-term observations from Godhavn, Egedesminde and Jakobshavn, cf. fig. 5b. The wind force formular V H F (V: velocity; H: frequency, F: fetch) has been modified to VH, as only the relative values of the stations are wanted. Scientists attach different degrees of importance to the factor V. Thus, the exponents 1, 2, 3 and 4 to V have been suggested.

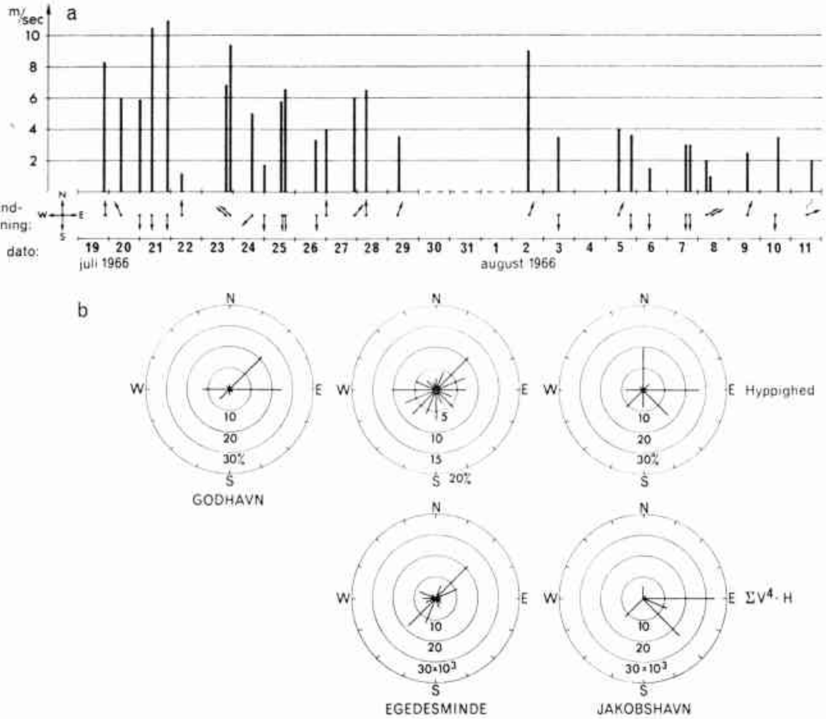

Fig. 5. a: wind observations from Nûk 19/7–11/8 1966. Though readings were aperiodic, the measurements show clearly the weak winds prevailing in the area (8–9 m/sec ~ 4 Beaufort). The arrows below the velocity diagram indicate the wind directions.

b: wind conditions in Disko Bugt illustrated by observations 1950–59 from Godhavn, Egedesminde and Jakobshavn. Uppermost: Wind frequency in per cent of all winds. Below: wind velocities (V) of 4 Beaufort and upwards, multiplied by the frequency percentage (H) for each compass direction. Because of a special presentation of the statistic data, the observations from Eegedesminde have been split up into 16 compass directions.

Fig. 5. a: vindobservationer fra Nûk 19/7–11/8 1966. Målingerne giver trods de aperiodiske observationer et billede af de gennemgående svage vindstyrker i området. (8–9 m/sec ~ 4 Beaufort). Pilene under hastighedssøjlerne angiver, hvorfra vinden kom.

b: vindforholdene i Disko Bugt repræsenteret ved vindobservationer fra Godhavn, Egedesminde og Jakobshavn. Talmateriale fra 1950–59. Øverst: vindhyppighed i procent af samtlige vinde. Nederst: Vindhastigheder på 4 Beaufort og derover multipliceret med hyppighedsprocenten (H) for de enkelte kompasretninger. På grund af de statistiske oplysningers udformning er Egedesminde-observationerne opdelt i 16 kompasretninger.

In the present work *P. Bruun's* value V^4H has been used, because this agrees fairly well with the true value according to my experience.

It must be presumed that the Godhavn measurements indicate the local wind conditions only, because of the sheltered location of the station behind the high basalt walls, whereas the Egedesminde station is situated in a low-lying archipelago, and the observations there will probably better reflect the wind conditions prevailing in Disko Bugt. The distance from Egedesminde to Nûk is about 105 km, which reduces the applicability of the records somewhat for the Nûk area. Also the records from Jakobshavn are to a great extent locally determined; especially, the chilly catabatic winds, the so-called glacier winds that are generally short, but strong easterly winds. As it appears from fig. 5, no strong winds were observed in the Nûk area during our stay, a trend that is apparently confirmed by a more extended material, viz. of 5400 wind observations in Jakobshavn the 8.8 % were $\geqq 4$ Beaufort and the 0.8 % gales, i.e. $\geqq 7$ Beaufort. When estimating the influence of the wind for the development of a coastline these percentages have to be reduced, however, as the impact of waves will be eliminated somewhat during the winter season. As a matter of course, the date when the sea freezes up and the extent of the ice-cover vary somewhat from year to year, but at any rate there will exist an ice foot along the shores for about 4 months from the middle of January till once at the end of April.

If the wind observations from Jakobshavn (nearest station to Nûk) are used when investigating the coastal development along Flakkerhuk, it is found that the direction resultant of wind power (the sum vector of the wind directions) is almost at right angles to the coastline Nûk-Skansen. This means that long-shore transport of sediment should be minimal, other things being equal. Observations show, however, that in reality there is a NE-directed drift of material along Flakkerhuk towards Nûk and farther on to the innermost part of Mudderbugten. According to Munch-Petersen's expression of the size of the transporting agent $M = S H \sqrt{F}$ (S = mean wind speed, H = frequency, F = fetch) F will be of the greatest importance since the maximum fetch goes S-SW. The direction of the actual drift is therefore comprehensible according to present day's theories of wind direction resultant and fetch, but to relate the available wind observations from surrounding stations directly to Flakkerhuk and Nûk cannot be recommended. Long-term measurements at Nûk is the only way to get exact knowledge of the influence of the winds in this area. The question of the sources of error in calculations of wind direction resultant shall not be touched upon here; only, that it is considered necessary to include the phenomenon swells when studying the orientation of wave power on a shoreline. In a few cases strong swells were observed from the SW i.e. from Davis Strait. High waves of this kind are able to transfer their energy over long stretches and will thus be a drift agent which the wind records do not reflect.

Apparently, the wind is not the only factor influencing the littoral drift here, as 1) the wind speeds are normally rather low in Disko Bugt and 2) the icebergs floating in the bay calm the waves, (*J. T. Møller,* 1958) and 3) observations of the offshore barrier at the mouth of Nûkelv showed that the shape of it changed considerably during a period with very faint winds.

The tide and the tidal currents seem to influence the littoral zone along Flakkerhuk definitely. The tidal wave propagates from the Atlantic through Baffin Bay and Davis Strait phase-displaced towards the north with the result that high-tide starts about one hour earlier at the entrance of Disko Bugt than at the entrance of Vaigat. The type of tide in the seas around Disko must be termed "mixed tides", which differ from the semi-diurnal tide by having great amplitude differences, see fig. 6. The form of the curve is astronomically determined, whereas the amplitude value is to some degree dependant on interfering waves in Disko Bugt; this is illustrated by the following figures showing the tidal range for some locations:

Egedesminde	2.2 m	
Jakobshavn	2.4 m	
Nûk	2.6 m	
Quervain Havn	3.0 m	(near Eqip Sermia)
Nûgssuaq	2.2 m	

At Nûk, there was a close interrelation between tide and current. As previously mentioned, measurements off the coast were unfortunately not possible to any greater extent. A single measurement showed a north-going along-shore current with speeds of 50-60 cm/sec. about 1 hour before a high high-tide; and subsequent, subjective observations confirmed this value. During low-tide the direction of the current showed SSW-going water movement about 1.5 km south of Nûk, but the current seemed to be weaker than during high-tide (no exact measurements available). Normally, the net value of the drifted material will be about zero, if the tidal range is not too great and if flood and ebb current are of the same order, and if other factors, as for example the wind, do not interfere (*King,* 1959). In this case there are many things indicating that

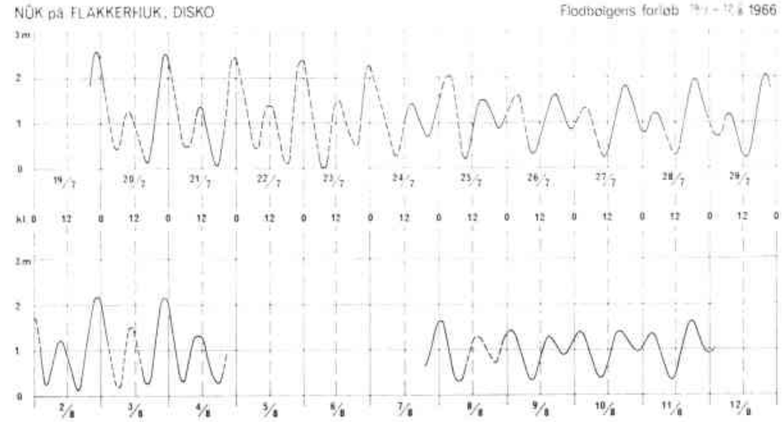

Fig. 6. Tide curve at Nûk 19/7–12/8 1966. The full-drawn part of the curve was directly measured, whereas the dashed part was recorded from bench marks on the foreshore. Culmination of new moon 18/7-1966 at 16.54 hrs. Culmination of full moon 1/8-1966 at 4.19 hrs.

Fig. 6. Flodbølgens forløb ved Nûk 19/7–12/8 1966. Den fuldt optrukne del af kurven er direkte målt, medens de stiplede dele er målt indirekte efter vandstandsmærker på forstranden. Nymånekulmination den 18/7-1966 kl. 16.54. Fuldmånekulmination den 1/8-1966 kl. 04.19.

the high-tide current is the dominating one and that different parts of the beach and offshore profile are influenced during flood and ebb period respectively because of the great amplitude.

When dealing with arctic regions, the ice as a coast-forming agent must also be taken into consideration. Rather many statements exist on ice-pressed ridges: from East Greenland (*I. P. Koch*, 1916), from Canada (*J. A. Peterson*, 1965 and *W. H. Ward*, 1959), and from Alaska (*R. G. McCarthy*, 1953), but all these coasts are formed by far coarser material, blocks and large stones, than the homogeneous sediment (sand fraction) found at Flakkerhuk. No ice-pressed ridges or disturbed strata in the offshore barrier were observed along the coast of Flakkerhuk, though the ice had been along the coast only 2-3 months before. *R. W. Rex* (1966) discusses the problem in a paper on the area around Point Barrow, Alaska, where a littoral zone of the same type as the one at Nûk was investigated during the winter 1952-53. Rex's investigations show that the ice is able to push sand and gravel upon the beach, and ridges were observed in more places along Barrow Beach during the winter season. Cross sections of the barrier at Pt. Barrow showed no deformation of the sand layers – the same as we observed at Nûk – and *Rex* explains it so that the ice-cover protects the barrier against pressure. Waves against the ice foot can throw sand and gravel upon it, and when the ice melts these deposits will be left on the foreshore. The ice foot may also be pushed upon the higher-lying parts of the ice-covered beach where material is left when the ice has melted away. Shortly after the disappearance of the ice at Barrow Beach all traces of ice activity disappeared as the waves levelled all accumulations not being elements in the dynamic equilibrium profile governed by the waves. From Barrow Beach it is concluded that generally, glaciation of the foreland and the existence of an ice foot will have a protective effect against variabality of profile and width of the barrier zone. Though in summertime the barrier does not show any traces of ice action it is still a question to what extent the ice acts as transporting agent of sediments; where do we find the material which as a matter of fact is added to the barrier in wintertime?

Finally, a wave phenomenon only found in arctic seas deserves notice. In Disko Bugt and in Vaigat a great number of icebergs are floating in summertime. Especially the glacier Jakobshavns Isbræ, but also Eqip Sermia, Kangilern Sermia and Sermeq Kujatdleq have a constant production of icebergs. The ice stream from Jakobshavn Isfjord culminates approximately every fortnight, a rythm corresponding to the occurrence of the spring tides (see fig. 6). Some of the icebergs wreck off the coast at Nûk and also farther in, near the shores of Mudderbugten. Occasionally, an iceberg starts rocking, capsizes, and large pieces of ice break off and fall down into the sea. This may produce heavy swells with a much longer than normal wave length. On July 20, about midnight, a capsize occurred that could be followed throghout all its phases. An enormous iceberg was floating about 5 km from the coast. Suddenly, it began to turn round while making a muffled sound with veritable thunderclap in between when larger parts of the iceberg broke off. Then, silence. The swells appeared after a few minutes and hit the coast at an angle of approx. 60 degrees. The interaction between the swells and the high-tide made the waves break near the top of the barrier and most of it was inundated. In all, five waves were registered, and these managed to level all the small relief on the leeside and on the top of the barrier and completely change the profile of the foreshore.

The offshore barrier is supposed to have started originally at the mouth of Nûkelv. The material drift has caused a growth towards the NNE and formation of a lagoon, because the mainland at the mouth of Nûkelv has a protruded position in relation to the present position of marsh 2. The change of direction of the barrier at Nûk is primarily due to the currents of the place which are influenced by the configuration of the former coastline, but, as previously mentioned, a submarine dyke might also have played a role. The growth of the barrier continues in northwesterly direction, and the tide is a dominating factor in its development. Without the influence of the tide, it is most probable that the lagoon would be barred and the beach drift continue along the original shoreline.

The growth of the offshore barrier amounts to approx. 27 m per year calculated on the basis of aerial photographs taken in 1953 and in 1964, i.e. a period of 11 years. If the rate of growth has been constant, the barrier was situated approx. around the present position of Nûk about 190 years ago and did not exist at all about 270 years ago. Of course this should not be taken too seriously, but older topographic maps show as a matter of fact – in spite of their inaccuracy and small scale – that these figures do not need to be absurd. The recurved spit is also constantly growing. On the 1:250.000 map (1931) made by the *Geodetic Institute,* Copenhagen, the position of the spit is nearly the same as today. Studies of air photos show that the base of the recurved spit has moved about 34 m farther in into the bay and the length of the spit has grown almost 20 m during the period 1953-64. During very low ebb tides the barrier point and the spit are surrounded by bare flats (see fig. 7); a vegetation of *Puccinellia sp.* has just got started but only between the cliff and the base of the spit. Formerly, the growth and development of the recurved spit were mainly dependant on the prevailing wave and current conditions, but the advancing barrier will now also be a factor influencing the growth of the spit, because the tidal inlet will come nearer; thus fig. 7 shows how the low-tide current has inundated the base of the spit. As mentioned, a rather large volumen of sediments is transported alongshore in spite of the fact that a migration can only take place during a few hours around high-tide. The fight between the morphological elements and the dynamic processes for opening or closing the tidal channel will enter upon an interesting phase in the years to come.

The displaced outlet of Nûkelv

Besides the offshore barrier, innumerable displaced and some completely barred river outlets along the coast of Flakkerhuk tell about a considerable drift of material. All of them indicated a NE-directed transportation. The outlet of Nûkelv was observed

Fig. 7. The inlet of the tidal channel between the barrier (right) and the recurved spit (left), photographed at high-tide, but the weak one, 5/8-1966. Note the high-water marks on the spit, left by the spring tide. The base of the recurved spit is partially broken through, presumably by the ebb current from the tidal channel. During low-water the whole spit and the outermost part of the barrier-end lie surrounded by mud-flats. To the right of the breakthrough lies an 11-feet boat.

Fig. 7. Tidevandskanalens indløb mellem barrieren (til h.) og krumodden (til v.). Billedet er taget omkring højvande under det „lille" højvande den 5/8. Bemærk højvandsmærkerne på krumodden, der er afsat under springflod. Krumoddens fod er delvis gennembrudt, formodentlig af ebbestrømmen fra tidevandskanalen. Ved lavvande er hele krumodden og det yderste af barrierespidsen omgivet af slikvader. Til højre for gennembruddet ligger en 11-fods jolle.

nearly daily and changes could be recognized from one day to the next.

The lower reaches of Nûkelv – the last 600 m before the outlet – are a braided river system, about 100 m wide. At the shore, the river meets a barrier connected with the mainland south of marsh 3 (cf. fig. 2-3). Barrier, salt marshes and lagoon are here to some degree analogous with the conditions at Nûk. The rate of flow is very low in summer, and during ebb it is possible in rubber boots to cross the river where it runs parallel with the barrier.

The dislocation of the outlet of the river is going on very rapidly. Unfortunately, the air photo from 1953 does not cover this spot, but photos from 1964 supplemented with own measurements (1966) show the development for these two years, for which period the advance has been calculated to be about 100 m. According to the morphology of the inner barrier, the growth of the outer one cannot exclusively be due to material coming from the south, but large amounts of sand must simply be transported from the inner to the outer barrier. Two detailed surveyings of the area were made in order to know about the processes working. Fig. 9 shows the situation on July 11, 1966, and fig. 10 on August 10. The location of the outlet in relation to base I appears from fig. 4. On the contour map for July 11, the following formations are noticed: east of the barrier tip a bank is under development and at low-tide it is seen to be connected with the barrier. Two depressions can be observed on the inner bar, and the southernmost is connected with the river outlet across a shallow entrance. This formation points towards river-morphology, but is influenced by the tide. Even if the flood and the ebb currents have the same velocity the first one does not show the same tendency to meander (*B. Jacobsen*, 1964); this also applies here although the environment differs essentially from the Danish Wadden Sea.

←

Fig. 8. The offshore barrier at profile V (cf. fig. 3) photographed towards the north about 1 hour after low-tide. To the left the lagoon and the easternmost of the hills shown in fig. 3. A_1 indicates an older barrier front edge with hummocky vegetation behind. Nearest A_1: *Honckenya and Mertensia*, towards the lagoon: *Elymus*. A indicates the new front edge. Note the stranded icebergs that reach far into the bay Mudderbugten.

Fig. 8. Offshore barrieren ved profil V (se fig. 3) set mod nord ca. 1 time efter lavvande. Til venstre ses lagunen og det østligste af de på fig. 3 afsatte højdedrag. A_1 viser en ældre barriereforkant, bag hvilke der ses tueformet vegetation. Nærmest A_1: Honckenya *og* Mertensia, *mod lagunen:* Elymus. *A angiver den nye forkant. Bemærk de strandede isbjerge, der når langt ind i Mudderbugten.*

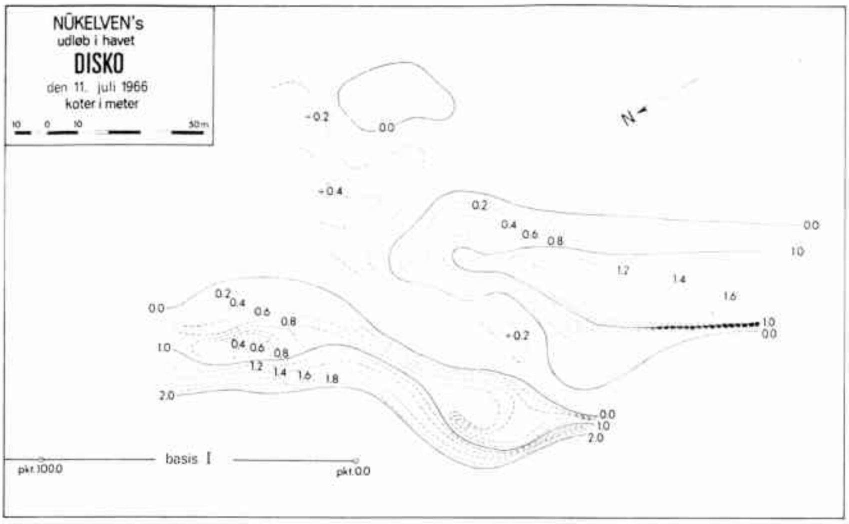

Fig. 9. Contour map of the outlet of Nûkelv, based on tachometry. Contour interval: 20 cm. The location of Base I appears from fig. 4.

Fig. 9. Kurveplan over Nûkelvens udløb udtegnet på grundlag af tachymetrisk opmåling. Kurveækvidistance: 20 cm. Beliggenheden af basis I fremgår af fig. 4.

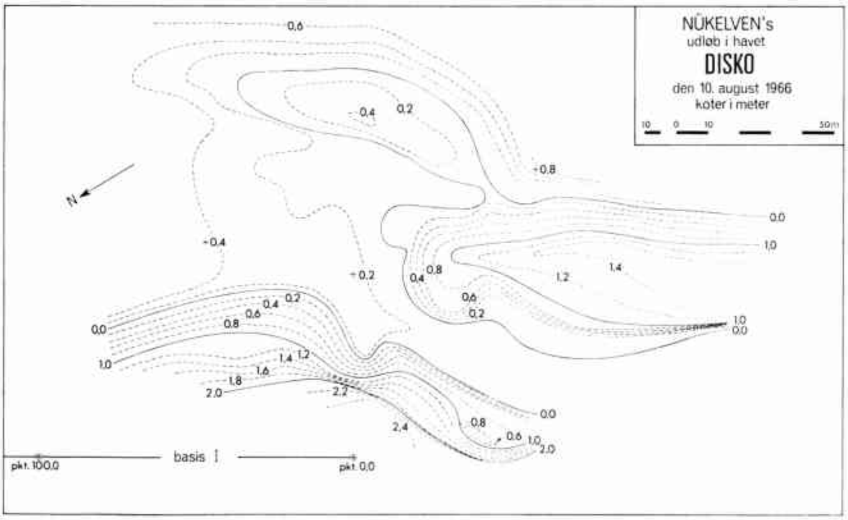

Fig. 10. Contour map of the outlet of Nûkelv, based on tachometry. Contour interval: 20 cm. The location of Base I appears from fig. 4.

Fig. 10. Kurveplan over Nûkelvens udløb udtegnet på grundlag af tachymetrisk opmåling. Kurveækvidistance: 20 cm. Beliggenheden af basis I fremgår af fig. 4.

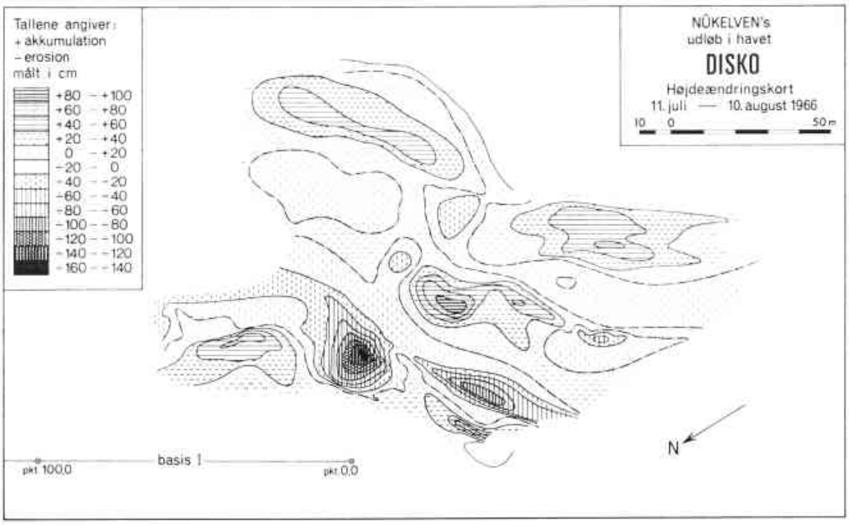

Fig. 11. Map of elevation changes observed in the outlet of Nûkelv 11/7–10/8 1966. The signatures show where accumulation and erosion take place. The isolines transverse points in fig. 9 and 10 of same elevation change values.

Fig. 11. Højdeændringskort over Nûkelvens udløb. Fladesignaturer angiver, hvor der henholdvis er akkumuleret og eroderet i udløbet. Isolinjerne går gennem punkter, hvor højdeændringen mellem fig. 9 og 10 er enslydende.

The depression can be considered a kind of ebb-channel, as the ebb-current is forced into this direction by the opposite lying bank. The material which the ebb-current takes from the inner barrier together with sediments from the river itself will be deposited at the outlet where the velocity decreases very suddenly. Turbulences occasioned by the meeting with the often simultaneously southgoing, alongshore current may explain the northernmost depression seen on the map. At the survey the depression was filled with remnants of *Laminaria sp.* The river outlet changed morphology during the 4 weeks after July 11, mostly the week prior to August 10. As seen on fig. 5, the period was very calm; erosion and transport of material due to wave action were therefore at a minimum; consequently, the tidal currents must be the principal forces acting on the shore profile. Fig. 10 shows that the small, isolated bank towards the east has grown considerably, and that the 0.0 m level now joins that of the outer barrier in a kind of minitombolo. Approx. in the middle of the inner barrier a marked notch can be observed; possibly, the flood-current is forced into this direction by the accretion bank on the outer barrier so that the notch is in reality a flood-channel. The northernmost depression from the situation on July 11 is almost filled up, while the contours at the presumed ebb-channel have approached each other; this means that a dislocation of sediment has taken place because of the changed position of the channel which again is the result of the movement of the bank towards the barrier point. In order to show the position of abrasion and accumulation a map of elevation changes was made (fig. 11). The isolines found connect points of the same elevation change values, and accordingly the map must not be taken as a topographic contour map but as an expression of the dynamics of the area. A planimetering of the areas of erosion and accumulation and calculations on the basis of hypsographic curves show that approx. 870 m^3 were removed and approx. 1760 m^3 were added, i.e. a net accumulation of 890 m^3.

Topography of the offshore barrier

The height of the barrier above local mean water level varies from nearly 2 to well 3 m. On top and leeside many smaller dunes have been formed. None of them being pure sand dunes, they have all grown up around some vegetation, primarily *Elymus*, but also *Honckenya* and *Mertensia* accumulate low heaps of sand (fig. 8). The *Elymus* vegetation dies out about 1 km NW of Nûk and with it the "high dunes"; the *Honckenya* and *Martensia* tufts continue far out on the distal part of the barrier and only for the last 100 m – where the barrier is low – there is no vegetation at all. The absence of *Elymus* the last few kilometres is presumably due to a slow rate of immigration of this plant as compared with the growth of the barrier. Variations in the cross profile of the barrier appear from fig. 12, and fig. 3 shows the approx. location of the measuring points. Profiles IV-VII have reference level to measured peg points, whereas an easily found high water mark was levelled and applied as basic level for the profiles I-III and VIII. The high water mark is subject to an uncertainty of max. 10 cm excl. possible fluctuations of amplitude along the shore. Based on table I the profiles can be divided into two main groups: 1) the barrier section from the outlet of Nûkelv to Nûk and 2) the barrier NW of Nûk. This is partly due to different impact of waves and partly to leeside erosion by outgoing tide together with the present stage of development of the barrier. All gradients of the windward side are of the same order and the same applies to the leeside. In consideration should be taken that the forces working on leeside and windward side respectively were of the same order during the measuring period,

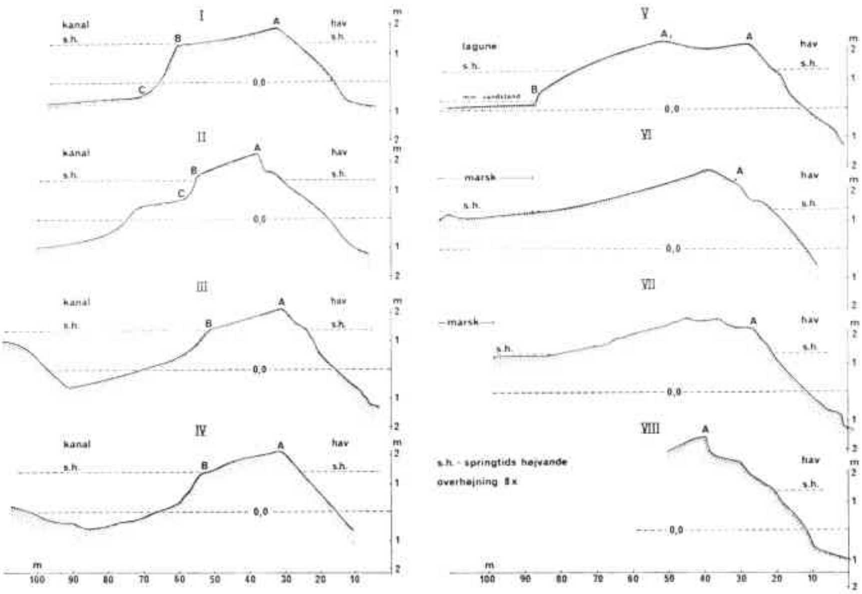

Fig. 12. Cross sections of the offshore barrier (cf. fig. 3). A: present front edge of the barrier. A_1: older front edge (cf. fig. 8) s. h.: spring tide level. Kanal: tidal channel. Exaggeration 8x.

Fig. 12. Tværprofiler af offshore barrieren (sml. fig. 3). A: barrierens aktuelle forkant. A_1: ældre forkant (sml. fig. 8).

and that the diametre of the mean grain size (Md = 0.6 mm) is practically the same all along the barrier. Profile VIII was measured about 13 km SW of Nûk, where a spit barred a river outlet. It is shown only to illustrate the approx. max. height which the accumulation forms reach at this coastline.

Table I. Characterization of the barrier

Parameters of the profiles

Profile No.	I	II	III	IV	V	VI	VII	VIII
Max. height in m above m.s.l.	1,9	2,3	2,2	2,4	2,4	2,8	2,6	3,3
Width in m at m.s.l.	50	58	56	53	75[1])	75[2])	87[2])	–
Width in m at m.h.s.t.	33	25	28	28	56	58	56	–
Gradient of windward side .	1:11	1:11	1:10	1:10	1:9	1:10	1:9	1:11
Gradient of leeside	1:48	1:24	1:29	1:29	1:26	1:30	1:28	–
Sq.m above m.s.l.	65	67	63	63	128	136	152	–
Sq.m above m.h.s.t.	6	12	10	11	35	38	40	–

[1]) to lagoon border [2]) to salt marsh border

Dynamics and morphology in the area between barrier and mainland

The area behind the barrier flooded during high high-tides can be divided into four main groups: a tidal channel, a sand flat, a lagoon, and an area covered with vegetation. Measurements were made of variations in water level and the hereof generating currents in order to study the individual development of these four morphological types. August 3, a station was established near profile IV. The channel is rather sharply defined at this place, and in respect of current it can still be considered a channel in spite of the vicinity of the sand flat. Two water gauges were set up, one in the sea and one in the channel and readings could be taken of both of them from the top of the barrier. In the channel, gauging was made from boat with an electric propeller of the type "Ott-lab". The velocity was measured at the surface, half a metre and one metre below the surface, and 10 cm above the bottom. The results appear from fig. 13. It is seen that the variations of water level in the channel is phase-displaced as to time and the curve does not show the symmetric shape seen on the curve indicating the variations in water level of the sea. Both factors are due to the braking effect of the channel. On this day the water level in the channel starts rising 20-30 min. after zero level in the sea when the water flows into the lagoon. The velocities increase gradually and reach maximum (91 cm/sec.) after 2 hours 45 min. Later on (1 hour 45 min.) the speed has dropped to 0 cm/sec., which, as normally, coincides with high tide in the channel. While the water level in the channel decreases gradually from 0.15 hrs. to 9.30 hrs. the velocities for the same period show a very irregular curve. Already 1 hour and 15 min. after reversion of the current it will reach its top value (47 m/sec.). The velocities now remain constant for about 3 hours and then decrease gradually till 9.30 hrs. Not till now, the sea will influence the water level in the tidal channel through the small flood wave. During the whole period the water level is higher in the channel than at the other side of the barrier, and a temporary delay of the water masses would therefore be likely as the current has still an outflowing tendency though the velocity is decreasing to zero. For the observation day the current regime in the channel can briefly be summed up as follows: the high high-tide in the sea brings about an inflowing, very strong current (5-6 hours). Because the water is temporarily delayed in the channel the clearing will last 18-19 hours. Consequently, outflowing

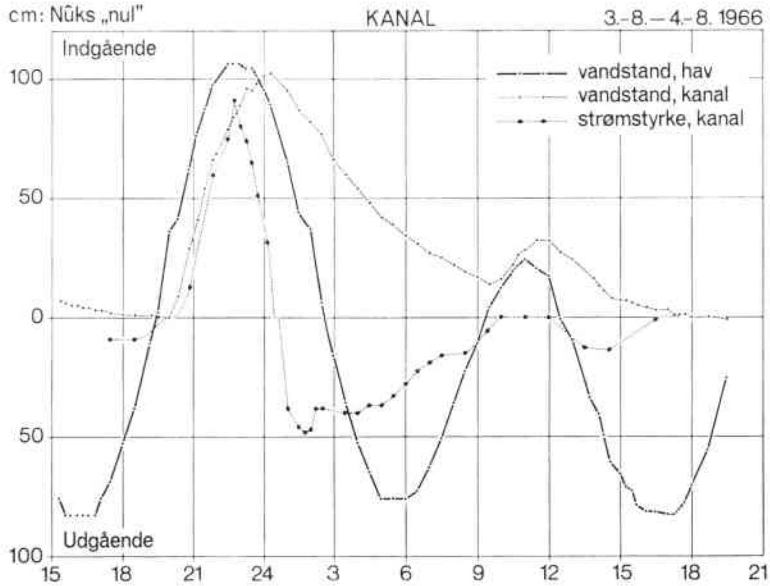

Fig. 13. Curves showing changes in water level and current velocity in the channel at profile IV (see fig. 3). Thick line: water level in the sea. Thin line = water level in the channel. Dashed line = current velocity in the channel, measured in cm/sec. Indgående = flood period. Udgående = ebb period.

Fig. 13. Kurver over vandstandsændringerne og strømhastighederne i kanalen ved profil IV (se fig. 3). Kraftigt optrukket kurve = vandstand i hav, tyndt optrukket = vand i kanal, punkteret linje = strømhastighed i kanal, målt i cm/sec.

currents have much lower velocities (max. 47 cm/sec.) than the inflowing ones.

There was a marked difference in grain size of sediments taken from the tidal flat and from the lagoon floor. The sudden widening of the channel into tidal flat and lagoon involved a fall in velocities which the measurements seen in fig. 14 reflect very well. Unfortunately, this measuring was in some respects made under unfavourable circumstances, the tidal range was not very high, simultaneous measurements in the sea could not be made, and only surface velocities were measured as we only had a propeller gauge at our disposal. The results in fig. 13 and 14 are to some extent recognizable in the morphological complex of elements that is basically dependant upon the hydrography and, consequently, upon the sedimentary conditions. Current velocities of 1 m/sec. are able to transport all present grain sizes of which the greater part are delta deposits from Mudderbugten (clay-fine sand) and abrasion material from Flakkerhuk (medium-coarse sand). The sudden drop in velocity over the tidal flat (fig. 14), has the effect that the sediment transported through the channel will again be divided into a coarse and a fine fraction. Thus, the material of the tidal flat consists of well-sorted sand with a $M_d = 0.6$ mm. Gradually this deposit has grown so high (+ 0.3 to 0.4 m) that it is left dry at low tide and thus makes up a shallow entrance between channel and lagoon (mean level + 0.1 m). This can also be recognized in fig. 13; on August 4, at 5 hrs., the velocities decrease gradually after having been constant for some hours. The reason is the drainage of the tidal flat and the subsequent sudden reduction of the basin feeding the outflowing current. The fine material suspended in the flood current is transported across the tidal flat into the lagoon and over the marsh. Here, part of the finest material (the clay-silt fraction) is detained by the vegetation, whereas a decantation will take place in the lagoon because the water body becomes stagnant when the water level has dropped to a point below the level of the tidal flat. Besides the sedimentary differentiation, the high velocities of the flood current cause megaripples to be formed on the tidal flat. The ripples are asymmetric, the steep side is facing the lagoon and they are about 50 cm high (fig. 15) in the transition zone between channel and flat.

With rising water level the direction of the current goes from the channel, across the tidal flat, straight-lined across the lagoon and will be rejected from the innerside of the barrier and build some well-shaped recurved spits. The flood current continues along the barrier and will at first inundate the part of the salt marsh located between the large central creek and the barrier. The notch visible in the vegetation between mud flat and marsh, cf. plate 1, may therefore be interpreted as a weakly developed flood-channel. During the retreat of the water masses it was observed that the current concentrated mostly in the center of the marsh, then it continued along the western bank of the lagoon and the tidal flat.

The salt marsh

(Plate 1 and fig. 4 and 16)

About in the middle of the marsh-covered area there is a larger stream that primarily functions as main creek during the summer months, but also as outflow gully for the 4 small river outlets in the southern part of the adjoining mainland. The three northernmost outlets show traces of a heavy, temporary rate of flow, in the shape of flat deposit cones of a coarse-medium-grained sand from the mainland. The boundary between these cones and the marsh

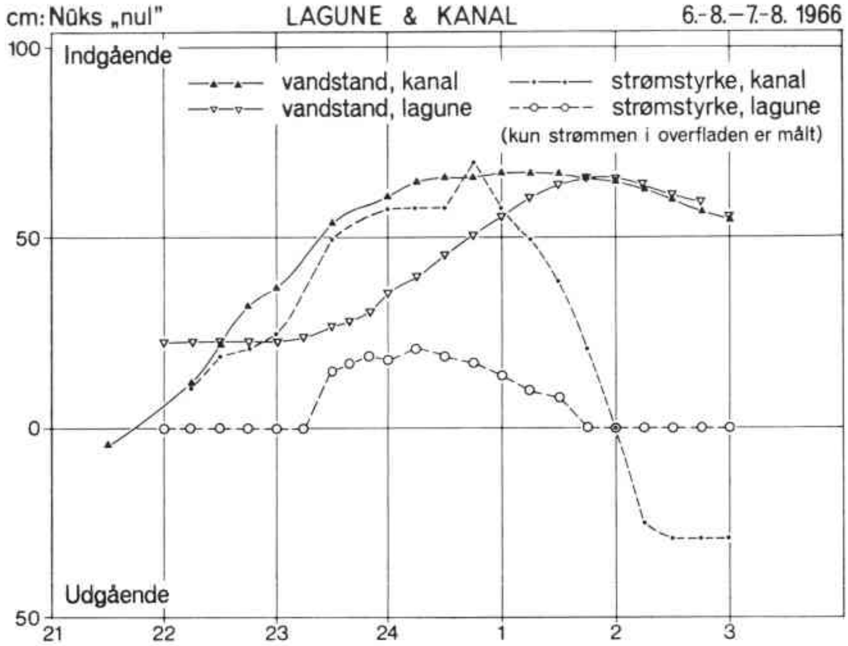

Fig. 14. Curves showing water level and current velocity in the lagoon and channel. The curve illustrates very clearly the decline of current velocity over the sand flat. Inflow of current into the lagoon does not take place until the shallow entrance, + 0.4 m, between flat and lagoon can be passed. Velocity measured in cm/sec.

Fig. 14. Vandstands- og strømkurver fra lagune og kanal. Strømhastighedsfaldet over sandvaden fremgår tydeligt af kurverne. Indgående strøm i lagunen viser sig først, når sandvadens tærskelværdi, ca. + 0.4 m, overskrides. Strømhastigheden målt i cm/sec.

is diffuse as to level though evident enough because of a sudden change in vegetation. This minor outwash of sand must take place during springtime, as outflow of fresh water only takes place in the southernmost outlet in summer.

The morphological map shows some larger and smaller water holes with no outlet, which owe their existence to two different processes brought about when the tidal currents overflow the marsh. West of the main creek the development of the holes could be explained in several cases by washed-up *Laminaria* causing a dead salt-marsh vegetation, *Puccinellia phryganodes*, and the bare spots will be more exposed to erosion than the surroundings ("rotten spots", *Chapman* 1960). At more places it was observed that the bottom of a hole was covered with algae, 2-3 mm thick, under which there was a black, evil smelling sulphurous sediment. At the eastern side of the main creek such holes were not found, those observed looked like old creek systems being overgrown, judging from pattern and orientation.

Besides the normal depositation of material by high tide another agent can be observed. Presumably in spring, during high high-floods it happens that icefloes are beached on the marsh. As mentioned earlier, the flood current goes mainly along the innerside of the barrier. This means that the floes do strand somewhere between the barrier and the main tidal creek dependant on the thickness of the icefloe and the range of the tide. Often a very homogeneous, fine-grained sediment is frozen solid to the underside of the icefloes and this layer will be left as clay flakes when the ice has melted away. The size varies between 3-7 cm in thickness and with a diametre of 10-20 m; their form is often edged. It was possible to see that the clay flakes were of different age. The last deposited, from the winter of 1965-66, were without vegetation, but below there was a dense vegetation of *Puccinellia maritima*. Other flakes could be referred to the previous year, as a young Puccinellia vegetation was seen and even another layer under decomposition could be observed below. This type of accumulation was characteristic for the area between the barrier and the main creek, whereas clay flakes were lacking in the western salt-marsh area. A causality may be found in the many holes on the one side of the main tidal creek and none at all at the other side. If a hole is developing in the salt-marsh facing the barrier, this will in all probability be obstructed by sediments deposited by the ice the following spring. The morphological map shows a 50-70 m wide salt-marsh border between lagoon and mainland, and the nip of it makes a steep, 30-50 cm high cliff towards the lagoon. Abrasion by wave action and the dominance of the ebb-current in the western part of the lagoon must be considered the most important agents in the formation of this cliff. In the transition zone between the lagoon and the southern part of the salt-marsh there are no cliff formations. From the floor of the lagoon (level + 0.1 m) the relief is gently rising and when it passes level + 0.4 m the vegetation starts. Between the coherent cover of vegetation and the lagoon there are many larger and smaller hummocks of *Puccinellia*. The topography survey showed that the hummocks are about 10 cm higher than the surrounding flat, the level of which is very close to + 0.3 m. It is therefore reasonable to suppose that the level + 0.4 m is a critical, decisive limit for the vegetation. It is beyond my ability to discuss how resistent to cold and drowning the Puccinellia type

Fig. 15. The sand flat with megaripples. The barrier lies just to the left of the rippled area, the photograph is taken towards the southeast. The surveyor's pin has 20 cm's intervals.

Fig. 15. Sandvaden med megarippler fotograferet mod SØ. Barrieren ligger umiddelbart til venstre for ripple-området. Landmålerstokken er inddelt i felter på 20 cm.

Fig. 16. Section of the salt marsh located behind the offshore barrier, seen in the background. Dry cracks in the silt can be observed in the lower part of the picture. These were a very significant feature over large parts of the salt marsh during the period of neap tide.

Fig. 16. Udsnit af marsken bag offshore barrieren, der ses i baggrunden. Nederst i billedet ses nogle tørsprækker i silten. Disse var karakteristiske over store dele af marsken i perioden omkring nip-flod.

growing here is; apparently, however, the vegetation only endures inundation once a day, as it is remarkable that the + 0.4 m level is only passed by half of the month's approximately 60 high-tides, cf. fig. 6. The highest recorded flood occurred the night between July 19-20, when the water level in the salt-marsh reached + 1.5 m. The maximum extent of water behind the barrier is shown by a dashed line on the morphological map, but the border line between salt-marsh and the surrounding area is indistinct; the area south of the dashed line is placed only 10 cm above high-water level of July 19. By and large, however, this line coincides with a vegetation limit south of which *Puccinellia* is not found. The fluctuations of high-tide level throughout the month cause a decreasing frequency of inundations by high tides the farther south one goes. Apart from the vegetation, this shows clearly in the thickness of the sediment layers which continue under perma-frost level at the lagoon, here at level ÷ 1.0 m, whereas only a few centimetres of fine-grained material were measured in the transition zone between salt-marsh and meadow.

Within the area the vegetation groups reflected the morphology of the spot and the influence of the tide. The vegetation limits seen in fig. 17 were surveyed on the basis of the levelling grid so that, at possible later visits, changes in vegetation pattern might easily be entered. Thick lines indicate sudden transitions in the vegetation and the dashed lines show a more indistinct change-over from one plant community to the next. The salt-marsh areas inundated regularly have a homogeneous vegetation (area 1 in fig. 17) and only two species do well here, viz. *Puccinellia phryg.* and *Stellaria humifusa*. The latter grows sparsely in the whole *Puccinellia* zone. Nearest to the lagoon only *Puccinellia* grows, and thus this is the first plant invading the silt-covered area that has grown up to level + 0.4 m. *Puccinellia phryg.* propagates by means of long offshoots, though also flowering specimen were observed. However, these are presumably barren as the plant is triploide. *M. P. Porsild* (1898) mentions that he has never seen flowering *Puccinellia* in Disko; *Porsild* must then either have overlooked the occurrence here or the plant has started flowering after that time. In the transition zone between salt-marsh and barrier (area 2) the *Puccinellia* gradually gives ground for a 2-3 cm high sedge, the *Carex ursina*. At places it is very dense and at some distance it may be difficult to distinguish it from the *Puccinellia*. *Carex ursina* is common in arctic marshes (*Chapman*, 1960). *Porsild* characterized

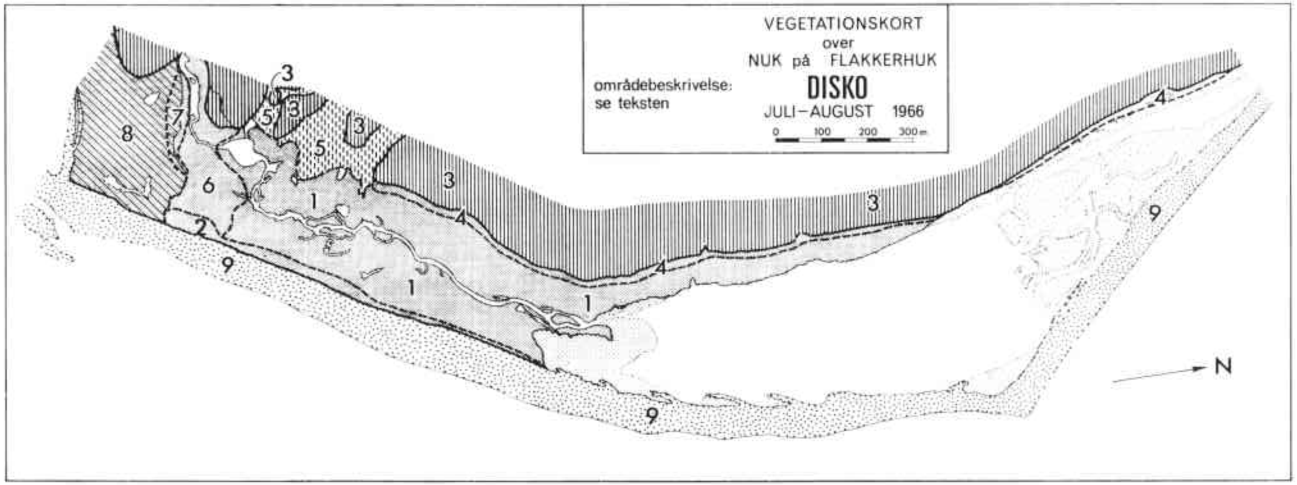

Fig. 17. Vegetation map: the numbers refer to areas with a homogeneous, dominating vegetation. Thick lines indicate a clear border between plant communities, whereas dashed lines are evidence of more slurred borders.

Fig. 17. Vegetationskort: tallene angiver områder, hvor vegetationen m. h. t. dominerende arter er homogen. Fuldt optrukne linjer viser en klar overgang fra et plantesamfund til et andet, medens stiplede linjer angiver mere flydende grænser. 1: Puccinellia phryganodes, Stellaria humifusa. – *2:* Carex ursina. – *3:* Cassiope tetragona, Empetrum, Vaccinium, Betula nana. – *4:* Carex rariflora, C. stans, Puccinellia phryganodes. – *5:* Carex stans, C. rariflora. – *6:* Puccinellia phryganodes, Carex ursina, C. glareosa, C. subspathacea. – *7:* Carex stans, Empetrum, Poa arctica, Polygonum viviparum, Calamagrostis neglecta. *Between the pals mainly* Carex stans, C. rariflora. *8:* Carex stans, C. rariflora, C. glareosa, Juncus arctia. J. castaneus, Eriophorum scheuchzeri. *9:* Elymus, Mertensia, Honckenza.

the mainland, area 3, as a heath with *Cassiope tetragona, Empetrum, Vaccinium, Betula nana* and various lichens as the dominating vegetation. In the marginal zone, towards the salt-marsh area, the mainland has large, flat-domed areas lying as small isles during high-tide; the heather vegetation becomes here saltlogged and has a reddish appearance, and in this zone *Carex rariflora* and *Carex stans* are growing. Between the isolated heather areas fine-grained sediments will be deposited whereupon *Puccinellia* and sedge can get a foothold (area 4). The vegetation brought about by the spring flood is solely *Carex stans* and *Carex rariflora* (area 5). The southernmost part of the marsh is only covered by water a few times during a month's tides. Sedges as *Carex ursina, Carex glareosa* and *Carex subspathacea* become more frequent and outplay the *Puccinellia* at high-lying parts (area 6). The pals[1]) area differs in vegetation from the surroundings, because many of the pals lie above level + 2.0 m and will thus only seldom be touched by salt water. The ground is consequently not so moist and besides *Carex stans,* plants as *Empetrum, Salix glauca, Polygonum viviparum, Poa arctica* and *Calamagrostis neglecta* have immigrated.

The ground between the pals was more moist and had a thick and abundant vegetation of *Carex stans* and *Carex rariflora* and only these two were found. Area 8 must be characterized as a moist meadow completely covered by *Carex stans, Carex rariflora, Carex glareosa* and, in especially waterlogged parts of the area, by *Juncus arcticus, Juncus castaneus* and *Eriophorum scheuchzeri.* On weakly developed, isolated pals a few specimen of *Salix glauca* had gained a foothold. The vegetation of the offshore barrier (area 9) has already been described.

Final remarks

This paper is a preliminary report and part of a M.Sc. dissertation. The field records have been dealt with in a descriptive way. It has been intended to give an introduction to later, more detailed investigations of the area, which, it is hoped, will be rendered possible. Shortage of time made it necessary to limit the collection of data. We found it most fruitful first to make a very detailed mapping of a restricted area and in this way to obtain a thorough knowledge of the various elements. Afterwards, the interaction between forces

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[1]) Pals (Swedish: palsar) is an arctic-subarctic phenomenon, appearing as an uplift in the ground caused by ice pressure from below. The pals observed at Nûk will be discussed in a forthcoming paper.

and morphology has been analysed. Measurements of current, water level, wind speed, and sedimentation could only be short-termed and sporadic; especially here, future investigations would be fruitful. Furthermore, the mapping must be extended to comprise the nearshore part of the beach plane and the stretch from the already mapped area up to and including the distal part of the barrier. Only in this way it will be possible to give a satisfactory explanation of the development of a coast of this type. The littoral stretch from Nûkelv to the Mudderbugt-delta is an excellent research field, especially with a view to material drift, and calculations of the sedimentation budget in the closed basin between barrier and mainland. In the salt-marsh area, sample plots have been covered with an alien material so that exact measurements of the accumulation can be made after a few years, and finally there is here a tidal inlet of very "handy" dimensions, the development of which might change the nearshore zone fundamentally within a rather short span of time.

RESUMÉ

Artiklen beskriver en række iagttagelser og enkelte foreløbige målinger fra en kyststrækning omkring Diskos østlige hjørne, kaldet Nûk, beliggende: 69°39′ n.b. og 51°52′ v. l. (fig. 1).

Geologisk består denne del af Disko først og fremmest af kretasisk, løst sammenhængende sandsten med enkelte kul- og lerskiferlag. Nord for Nûk ligger Mudderbugten, i hvilken et større delta skyder sig frem, dannet af materiale eroderet fra den tertiære plateaubasalt, der overlejrer sandstensformationen vest for Flakkerhuk.

Flakkerhuk er en 20 km lang og 3-7 km bred flade, der falder mod Disko Bugt med 20-50 m pr. km. Topografien her præges af smeltevands- og normalerosion, men marin virksomhed langt over det nuværende havniveau har også gjort sig gældende. Postglaciale marine terrasser 98 m o. h. er fundet på Flakkerhuk (Steenstrup 1881-82); dog er højere havniveauer sandsynlige, idet den øverste marine grænse på Norddisko er ca. 200 m o. h. (Laursen 1944). Flakkerhuks kyst er nu under relativ sænkning med omkring 1 m pr. 100 år (Laursen 1944) med vigende kystlinier og klintdannelser til følge. Grundet den kraftige materialvandring langs Flakkerhuk mod NEE, præges kystformerne omkring Nûk imidlertid af materialakkumulation i form af offshore barriere- og krumoddedannelse. Fig. 2-3 viser Flakkerhuks nordøstlige del med vigtigste terænelementer indtegnet.

Med henblik på en yderligere analyse af det morfologiske og hydrografiske mønster bag Nûk er der udarbejdet et kurvekort og et geomorfologisk kort over området (fig. 4 og planche bagi).*)

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*) Stedets middelvandstand er anvendt som 0,0 m kote „Nûks nul" udarbejdet efter tidevandsvariationen ved Nûk.

De vigtigste kystformende faktorer er: vind (bølger), tidevand, tidevandsstrøm og is.

Vindstyrkerne på lokaliteten var under opholdet ringe, hvilket de sporadiske skålkorsanemometermålinger viser (fig. 5a). Højeste bølgehøjde, ca. 35 cm, målt under den størst registrerede vindhastighed, 10 m/sec, havde ingen synlig indflydelse på kystprofilet. – De generelle vindforhold i Disko Bugt er belyst gennem observationer fra Godhavn, Egedesminde og Jakobshavn (fig. 5b). På grund af afstandsfaktoren kan kun Jakobshavnsmålingerne anvendes til en tilnærmelsesvis vurdering af vindforholdene omkring Nûk, når det samtidigt bemærkes, at vindene også ved Jakobshavn er lokalt influeret (især må de katabatiske vinde, kortvarige kraftige østenvinde nævnes). Anvendes vindvirkeresultanten fra Jakobshavn, står denne næsten vinkelret på kysten Nûk-Skansen, hvilket skulle give minimal materialvandring. En betydelig materialvandring mod NE til Nûk og videre ind i Mudderbugten finder imidlertid sted. Indkorporeres „det frie stræk", som i Munch-Petersens formel for den materialførende kraft $M = SH\sqrt{F}$ (S = middelvindstyrke, H = hyppighed, F = frit stræk), er materialtransportens retning forståelig (*A. Schou,* 1945). Derimod kan materialtransportens størrelse næppe forklares alene ud fra vindhastighederne, der gennemgående er små. Af 5400 vindobservationer i Jakobshavn er 8,8 % $>$ 4 Beaufort, og kun 0,8 % er $\geqq$ 7 Beaufort, tal der yderligere skal reduceres, da Disko Bugt er isdækket gennemsnitlig i 4 måneder om året. – Dønninger fra SW, dvs. fra Davis Strædet, blev iagttaget og må medtages i betragtningerne over bølgekraftens orientering; men eksakte mål mangler.

Tidevandet ved Nûk, dets karakteristika og størrelsen fremgår af fig. 6. Strømskift, som fulgte tidevandsrytmen, forekom, således at der under flod, ca. 1 time før højvande, var NNE-gående strøm med hastigheder på ca. 50 cm/sec, hvorimod ebbestrømmen var tydelig mindre (ingen nøjagtige mål) med SSW-gående retning. Materialvandringen mod nord langs Flakkerhuk finder derfor en del af sin forklaring i tidsvandsstrømmens orientering.

Ifølge rekognosceringer langs kysten synes isen ikke at påvirke denne, hverken i form af ispressede volde eller forstyrrelser i barrierens lagstruktur. *R. W. Rex* viser ved Point Barrow, Alaska, hvor en kyststrækning af samme type som ved Nûk undersøgtes i vinteren 1952-53, at isen presser sand og grusvolde op på forstranden, men at denne forinden ved bølgesprøjt har opnået en fast tilfrosset overflade. Lagstrukturen beskyttes og evt. oppressede volde fjernes hurtigt ved forårets første større bølgepåvirkning. Skønt barrieren om sommeren derfor ikke bærer spor af isens indflydelse, er det stadig et uløst problem, i hvor høj grad havisen er en sedimenttransporterende faktor.

Jakobshavn-gletscheren, og gletschere fra Eqip Sermia, Kangilern Sermia og Sermeq Kujatdleq sender til stadighed isbjerge ud i Disko Bugt og i Vaigat. Kæntringsbølger fra isbjergene, når disse kommer ud af ligevægt og vælter, er hyppige. Sammentræf mellem et stort isbjergs kæntring og højvande ved springtid (hvilket skete den 20.-7. omkring midnat) bevirker bølgebrydning nær barrierens top. I nævnte tilfælde kom kun 5 dønninger, men disse nåede til gengæld at udjævne smårelieffet på den øverste del af barrieren samt på dennes læside og fuldstændig ændre forstrandens profil.

Flere mindre, forskudte elvudløb langs Flakkerhuks kyst vidnede om en N-gående materialtransport. Forskydningen af Nûkelvens udløb mod NNE er beregnet til ca. 50 m pr. år på grundlag af et flyvebillede fra august 1964 og kortlægningen i august 1966. Denne vækst skyldes dog ikke alene materiale transporteret langs kysten fra syd, men er også et resultat af en omplacering af sandmasserne fra den „indre" til den „ydre" barriere, hvilket tydelig fremgår af to opmålinger med en måneds interval (fig. 9, 10 og 11).

Offshore barrieren er landfast ved Nûkelvens udløb og fortsætter herfra ubrudt ca. 7,5 km. Længden øges med ca. 27 m pr. år (opmålt på flyvebilleder fra 1953 og 1964). En større krumodde "mid-bay recurved spit" (fig. 7) er dannet vest for barrierens distale afslutning og vandrer ligeledes ind mod deltaet i Mudderbugten, dog med ringe hastighed. Krumoddebasis er forskudt ialt ca. 34 m mod vest på 11 år. Tidevandskanalens mundingsområde indsnævres derfor, og ebbestrømmen er begyndt at erodere i krumoddens fod (fig. 7). Hvorvidt dette "tidal inlet" lukkes inden for få år, eller det til stadighed kan holdes åbent trods de tilvandrende sedimentmængder, er et morfologisk og dynamisk interessant problem, ikke mindst fordi barrierespids og krumodde nu er så langt inde mod deltaet, at de er omgivet af deltaaflejringer (silt i modsætning til barrierens sand med en $M_d = 0{,}6$ mm), der er tørlagt ved lavvande.

Variationer i barrierens tværprofil ses på fig. 12; opmålingsstederne ses fig. 3. Profilernes karakteristika fremgår af tabel I. Der sker et tydeligt spring i profilformen ved Nûk, hvilket først og fremmest skyldes den forskellige eksponering m. h. t. bølgepåvirkning samt tidevandskanalens strømerosion på barrierens læside. Ligheden i gradientmålene skal delvis ses på baggrund af barrierematerialets overordentlige store homogenitet i hele barrierens længde.

Tidevandskanalen, sandvaden, lagunen og marskområdet er under stadig udvikling som følge af tidevandet og materialvandringen. Uden tidevand ville lagunen på et tidligt tidspunkt formentlig være aflukket omkring profil IV. For at finde årsagen til den skarpe differentiering mellem sedimenterne på henholdsvis sandvade, lagune og marsk samt tidevandskanalens fortsatte eksistens gennemførtes nogle orienterende strømhastighedsmålinger i forbindelse med vandstandsvariationen inden og uden for barrieren (fig. 13 og 14). Et stort højvande i havet omkring springtid bevirker en indadgående kraftig vandstrøm (max. 91 cm/sec.) af 5-6 timers varighed. Udstrømningen sker over en 18-19 timers periode som følge af opstuvning p. gr. a. det lille højvande og kanalens bremsevirkning, hvorfor udgående strømhastigheder bliver relativ små (max. 47 cm/sec, fig. 13). Kanalens tragtformede udvidelse i sandvade og lagune forårsager et markant fald i flodstrømshastigheden (fig. 14, tidevandsamplituden er aftagende, jf. dato og fig. 6). Under den kraftige flodstrøm transporteres materiale, dels deltaaflejringer (ler-silt-finsand, (Wentworth skala)), og dels nedbrydningsprodukter fra Flakkerhuk (mellem-grovsand) ind i bassinet. Strømhastighedsfaldet over sandvaden opdeler disse sedimenter i en grov fraktion, der afsættes på sandvaden, mens det finere materiale føres i suspenderet tilstand ind over lagune og marsk. Vegetationen på marsken tilbageholder en del af de fineste kornstørrelser (ler-silt), og i lagunen dekanteres silt og finsand i det stillestående vandlegeme, der opstår, efter at vandstanden er faldet til et niveau under sandvadens (sml. fig. 4, 13 og 14). De store flodstrømshastigheder afspejles også i megaripple-dannelse på sandvaden (fig. 15). Krumodderne på barrierens inderside er ligeledes et resultat af flodstrømmen, der retlinjet fra kanalen går over sandvade og lagune, hvorefter den følger barrieren. Under faldende vande koncentreres strømmen langs bassinets vestlige bred.

Marsken drænes af en hovedlo med flere mindre tilløb. Tilstrømning af ferskvand er minimal om sommeren, men flade aflejringskegler af groft-mellemkornet sand viser, at en kraftig temporær vandføring finder sted, formentlig under vårflommen. – Vandhullernes fordeling på marskfladen er delvis bestemt af tidevandets strømretninger. Udviklingen af huller mellem barriere og hovedlo hæmmes, idet flodstrømmen, der koncentreres langs barrierens inderside (bemærk indskæringen i vegetationskanten øst for hovedloens udløb i lagunen, se planche), om foråret medfører isflager fra lagunen og måske helt fra Mudderbugt-deltaet. Finkornet, homogent materiale er fastfrosset på isflagernes underside og efterlades, når isen smelter. Klægkagerne er 3-7 cm tykke og 10-20 m i diameter med kantet omrids. Der kunne skelnes mellem flere „årgange" af disse flager. Således var de i foråret 1966 afsatte flager vegetationsløse, men overlejrede ofte flager fra året før med vegetation under nedbrydning. I den 50-70 m brede marskbræmme mellem lagune og bagland er en 30-50 cm lodret klint udformet (the nip). Derimod går lagunebunden jævnt over i marsken mod syd. Ved kote + 0,4 m indfinder vegetationen sig, først i form af tuedannelser med *Puccinellia phryganodes* som pionerplante. Kote + 0,4 m er en kritisk grænse for vegetationen, og sammenholdes denne med tidevandskurven (fig. 6), bemærkes det, at niveauer over kote + 0,4 m kun udsættes for kortvarig vanddækning og max. 1 gang i døgnet. – Natten mellem d. 19. og 20. juli nåede vandstanden i marsken op til kote + 1,5 m (markeret på planchen som grænsen mellem marsk og strandeng). Skønt strandengsniveauet kun er ca. 10 cm højere end størst observerede vandstand, falder omtalte grænse sammen med en vegetationsændring, og i dette område ophører de tidevandsaflejrede sedimenter (ved lagunen fortsætter disse under perma-frostniveauet, som ligger i ca. 1 meters dybde).

Resultatet af vegetationsanalysen fremgår af fig. 17. Vegetationsgrænserne er indmålt med nivellementsnettet som grundlag, hvorved ændringer i vegetationen kan fastlægges ved rekartering af området.

I område 7 (fig. 17) findes en række palser (sml. fig. 4 og planche) Pals (svensk: palsar) er et arktisk-subarktisk frostfænomen, der giver sig til kende i en opbulning af jorden forårsaget af ispres nedefra. I modsætning til andre beskrevne formationer af denne type, indgår der så godt som ingen tørvelag i den her forekommende oppressede sedimentære lagfølge.

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