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REMARKS ON *MYTILUS EDULIS* L. IN RAISED BEACHES IN EAST GREENLAND

BY

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WITH 5 FIGURES IN THE TEXT AND 1 PLATE

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PREFACE

The geological investigations recorded here have the character of more or less casual observations, having accompanied another series of geological field work.

Nevertheless I have decided to publish these observations, because they have revealed some fresh data concerning the sub-fossil fauna of East-Greenland. If the observations might be of some use until a coming detailed investigation has thrown light upon the main features of these highly interesting problems, the object of this brief paper has been fulfilled.

Owing to the fact that part of the fossil-collections mentioned in the following pages were not confined to marked terraces and clearly raised beaches, a great deal of the numbers are given in brackets; thus only numbers not enclosed in brackets mark marine limits in the proper sense of the word.

May I here express my sincere thanks to Dr. Lauge Koch, the chief of the expedition, for various help during the survey in the field and during the preparation of this paper. Further I should like to express my best thanks to Magister Thorson, of the Zoological Museum of Copenhagen, for having gone through part of the mussels, determined some fragmentary shells, and given valuable information concerning the conditions in the East Greenland fjords at the present day.

Copenhagen, 3rd November, 1932.

Arne Noe-Nygaard.

PREVIOUS INVESTIGATIONS

In the literature concerning East Greenland information about raised beaches of post-Glacial age and their fauna is rather sparse. Part of these data are derived from the Scoresby Sound district. In the Franz Joseph Fjord—King Oscar Fjord district, the only observations prior to those of the last years have been made by NATHORST (12), who mentions raised beaches from the following localities: the south coast of Suess Land, Eleonore Bay, the mouth of Sophia Sound, the southern side of the inner Franz Joseph Fjord, Scott Keltie Island, Dusén Fjord, and the innermost part of Forsblad Fjord.

In one single place only did he succeed in making a more detailed investigation, viz. the locality in the outer part of Sophia Sound south of Robertson Island. Here *Mytilus edulis* L. was found up to a height of 25 metres above sea-level, fossil mussels were met with up to 51 metres, while a terrace at 71 metres proved to be unfossiliferous.

Mytilus was further found by the same expedition in the interior of Franz Joseph Fjord, at the mouth of a small valley north-east of Nordenskjöld Glacier. The height of this locality was supposed not to exceed 10 metres. To the record of this find NATHORST adds that a mussel as *Mytilus* cannot possibly live in a fjord in the immediate neighbourhood of a productive glacier.

In his paper: "Über die Lagerungsbedingungen eines Torffundes in N.O.-Grönland" (1931) BACKLUND gives some observations on raised beaches in the district just north of the area dealt with here, viz. the Gael Hamkes Fjord district. Most of his localities are situated in Loch Fyne and the Musk-ox Fjord; however, his observations do not deal with the contents of fossils to any great extent. In his paper: "Einige Untersuchungen zur Morphologie Ostgrönlands" (1932) POSER records some observations on raised beaches (pp. 7—17). He records fossils from a rather great number of localities, but as no further information as to the species is given, they must be assumed to belong to the same species as now live in the fjords of the district.

In Wollaston Foreland the maximum height of the fossiliferous strata was 23.5 metres, in Clavering Island 49 metres, and in three localities in the interior of Dusén Fjord, 57, 72, and 88 metres respectively.

A single observation made by the botanist of the expedition, TH. SØRENSEN, in Ymer Island deserves mention too. In an old raised

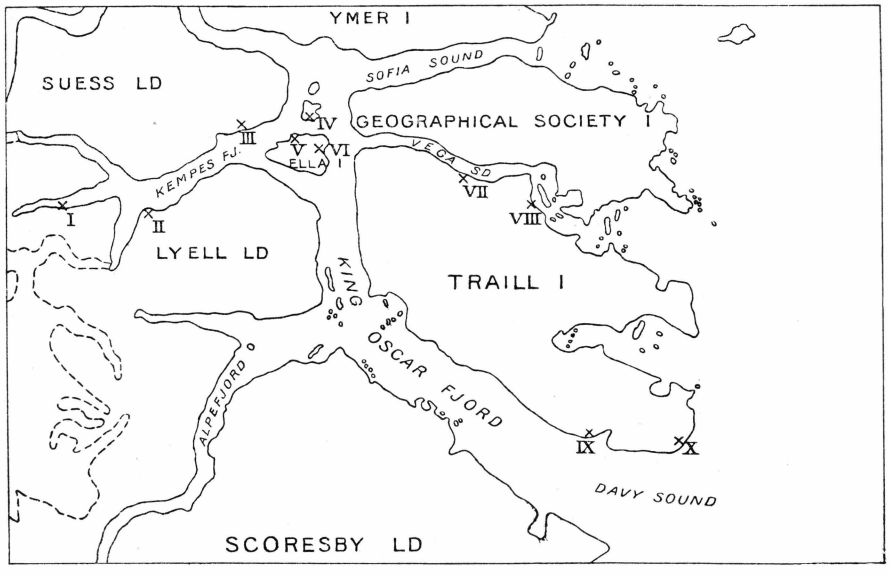


Fig. 1. Map of the central part of the King Oscar Fjord district, showing the position of the various localities.

beach, 50—60 metres above sea-level and now partially covered with vegetation, he found (summer of 1932) a whale-bone of a couple of metres' length.

The localities of the investigation recorded here lie on a line from the outer coast to the inner ramifications of the fjords (see map).

Before turning to the description of the localities, I shall give a list of the fossil molluscs. Two species, viz. *Axinopsis orbiculata* and *Modiolaria leavigata*, were not found during my investigation, but were taken in a fossil state in Hurry Inlet by the Danish East Greenland Expedition in the year 1900.

LIST OF FOSSILS FOUND IN POST-GLACIAL DEPOSITS IN EAST-GREENLAND

Scaphopoda:

Siphonodentalium vitreum SARS.

Gastropoda:

Lepeta coeca MØLLER.
Natica groenlandica BECH.
Margarita cinerea COUTHOUY.

Lamellibranchiata:

Nucula tenuis MONT.
Leda pernula MÜLL.
Portlandia arctica GRAY.
Portlandia lenticula MØLLER.
Mytilus edulis L.
(*Modiolaria laevigata* GRAY.)[1])
Modiolaria nigra GRAY.
Pecten islandicus MÜLL.
Astarte banksii LEACH.
Astarte borealis CHEMN.
Astarte elliptica BROWN.
Axinus flexuosus MONT.
(*Axinopsis orbiculata* G. O. SARS.)[1])
Tellina calcaria CHEMN.
Cardium ciliatum FABR.
Cardium groenlandicum CHEMN.
Mya truncata L.
Saxicava rugosa L.

DESCRIPTION OF THE LOCALITIES

Loc. 1. Small promontory in the central part of Röhss Fjord.

The collections from this locality were made in a slope at the shore at 5 metres above sea-level; at greater altitudes the marine deposits were covered with vegetation. Just below the sod numerous *Mya truncata*, *Saxicava rugosa*, and *Mytilus edulis* were found. From 2—4 metres'

[1]) Has not been found in a fossil state within the area in question.

altitude argillaceous clay with scattered boulders was met with; at the 3-meter-level there was a rather cohesive bed consisting almost entirely of *Mytilus*-fragments (big specimens), in a good state of preservation. In this locality the following species were collected:

Mytilus edulis (large quantities).
Pecten islandicus (fragments).
Tellina calcaria.
Cardium ciliatum.
Mya truncata.
Saxicava rugosa.
— —
Lepeta coeca.

Loc. 2. Cape Hedlund, Kempe Fjord.

In the northernmost of the two small valleys that traverse the C. Hedlund peninsula the following observations and collections of molluscs were made.

The highest level where an unmistakable old shoreline from post-Glacial time was met with, is 51 metres above the sea. This altitude represents the highest point of the valley bottom, so possible higher marine limits will have to be sought for in the valley sides either along the mountains in the northern part of Lyell Land or at the back of the outermost small mountain which constitutes the cape itself and once rose above the sea as an island or a skerry.

In the middle of the valley the marine deposits are developed as distinct raised beaches, consisting chiefly of gravel and sand. The only lamellibranchs found here are species with thick valves, viz. *Mya* and *Saxicava.*

Along the northern side of the valley the fossiliferous strata consisted of a fine blue clay, in which the fossils were in a fairly good state of preservation.

The terraces in the middle of the valley were found at the following altitudes: 51 m[1]), 37 m, 21 m (*Mya* and *Sax.*), 19 m, and 7—8 m.

In the northern side of the valley the highest fossiliferous level was found to be at 32 metres. The collections are derived from 28—32 metres, and comprise the following species:

Mytilus edulis (numerous specimens).
Pecten islandicus.
Mya truncata.
Saxicava rugosa.

[1]) All the measurements of height were made by means of a small '*Paulin*' altimetre. Nos.: D 1664 and D 1701.

It must, of course, be borne in mind that marine clay-sediments deposited in somewhat deeper water may correspond to a raised beach found at present at a considerably greater altitude.

A general characteristic of the mussels seems to be a pronounced thin-valvedness compared with the same species from other localities, e. g. Ella Island or Vega Sound. This phenomenon, also observed by THORSON in the living molluscs within the same locality, is doubtless due to a smaller content of lime in the crystalline rocks constituting the mountains in the innermost parts of the fjords, as distinguished from the limy elements in the upper parts of the Eleonore Bay formation, in Ella Island, and the younger sediments which constitute the main part of the country to the east.

Loc. 3. Suess Land (the large valley south of Mt. Johnstrup).

The locality is situated just south-west of the large delta cone in the valley. The terraces can be traced for short distances only, the slope being interrupted by steep walls of solid rock. The following measurements were undertaken:

25 m Disturbed by solifluction (*Mya*, *Saxicava*).
30 m Terrace in a somewhat better state of preservation than that first mentioned (*Mya. Sax. Tellina calcaria*).
55 m Rather disturbed terrace with pebbles and gravel (*Mya* and *Sax.*).
95 m Terrace, forming a continuation of the front of the delta cone mentioned above.

The destruction caused by the solifluction is very conspicuous. The lack of smaller species is undoubtedly due to some extent to the coarseness of the material.

Loc. 4. Maria Island (southern side).

Continuous semicircular raised beaches can be traced from sea-level up to 25 metres' altitude. As to the lowermost beds the material consists mainly of pebbles, while the main constituents of the uppermost 5 metres are sand and gravel. In this upper part the following fossils were collected:

Mytilus edulis.
Astarte borealis.
Cardium ciliatum.
Mya truncata.
Saxicava rugosa.

Loc. 5. Cape Oswald, Ella Island.

The topographical conditions are in some measure reminiscent of those at Cape Hedlund. Along the inner side of the ice-polished mountain constituting the cape itself some rather well-preserved systems of old raised beaches were seen up to a height of 40—50 metres. The collecting of fossils took place all over the peninsula from sea-level to an altitude of 42 metres. The 20 metres level — the height of the valley bottom,

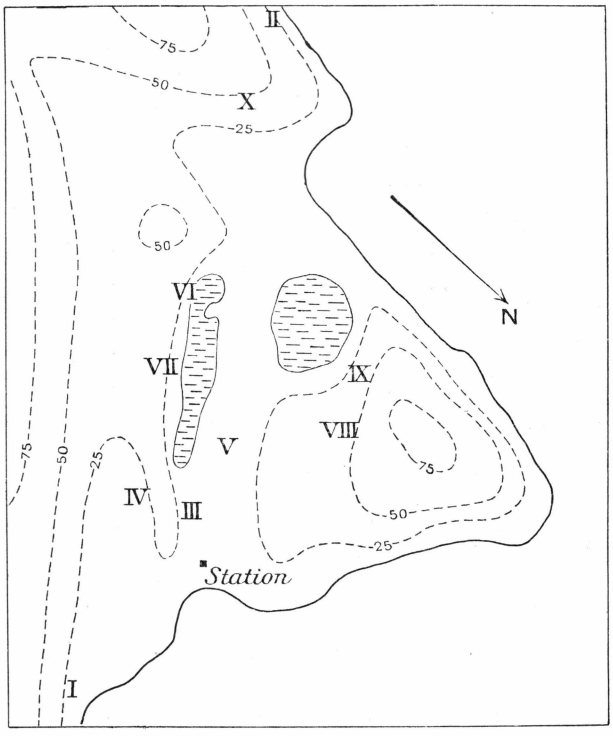


Fig. 2. Map of the Cape Oswald peninsula, showing the localities I to X. Based on a map constructed by SIMONSEN and STENØR during the winter of 1931—32.

where two small lakes are now found, — seems to be the most fossiliferous bed of the peninsula, the material consisting of clay, which in many places is destitute of vegetation.

The collections are derived from ten different localities at varying heights.

I) 0—2 m (Perhaps partially washed down from higher levels).
II) 2—5 m Slope with plastic bluish-grey clay.
III) 9—10 m Pebbles and gravel.
IV) 15 m Plateau with clay and scattered stones.

V) 20 m Large plain (the whole valley-bottom).
VI) 20 m Plateau, clay with scattered stones.
VII) 22 m, 23 m, 25 m } Well-developed old beaches, gravel.
VIIa) 28—30 m Raised beaches, gravel and pebbles.
VIII) 30 m Raised beaches, gravel.
IX) 35 m Raised beaches, gravel.
X) 42 m Not very conspicuous terrace, consisting of gravel and pebbles, somewhat disturbed by solifluction.

The fossils collected in the various localities:

Mytilus edulis	(from 3 to 28 metres above sea-level)					
Pecten islandicus	(from sea-level to 9 m above)					
Astarte banksii	—	—	20	-	—	
Astarte borealis	—	—	5	-	—	
Astarte elliptica	—	—	20	-	—	
Cardium ciliatum	—	—	20	-	—	
Tellina calcaria	—	—	35	-	—	
Mya truncata	—	—	42	-	—	
Saxicava rugosa	—	—	42	-	—	

Loc. 6. Bay south of Cape Elisabeth, Ella Island.

The marine deposits in this locality represent two different forms of evolution, occurring partly as regular raised beaches, which consist chiefly of gravel, partly as marine clay deposited in rather deep water (according to kind information given me by THORSON, the depth of the water has been about 20—25 metres, judging from the fauna). These clayey deposits, which have, in some way or other, escaped erosion, have a rather wide horizontal extent. They contain a well-preserved fauna rich in species.

Clay deposits are also found at greater altitudes, lying in cup-shaped depressions protected against solifluction by a threshold of the solid rock. The collections of fossils were made in two places, viz. in a northern one at rather great altitudes, and in a southern one at somewhat lower levels.

Northern locality:

12—17 m Well-preserved semicircular beaches, gravel.
(23 m) Clay, scattered stones. (*Mytilus*, *Mya*, *Saxicava*).
(33 m) Plateau (rather large area) with clay and scattered stones. (*Mytilus*, *Pecten isl.*, *Mya*, *Saxicava*).

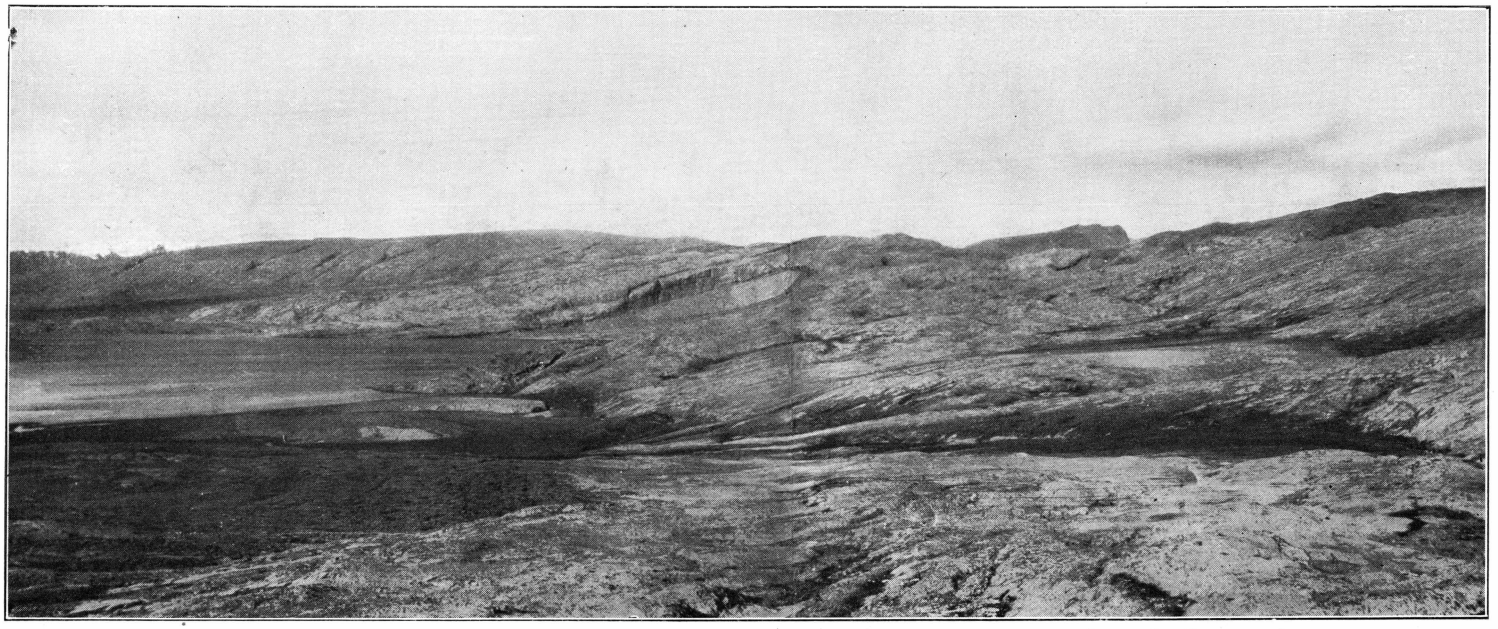


Fig. 3. The two plateau-shaped hills at the southern locality of Cape Elisabeth (Loc. 6) where rather great collections were made (to the left). To the right, higher-lying fossiliferous clay deposits.

(36 m) Clay (fragments of *Mya* and *Sax.*).
37 m Marked terrace.
(42 m) Clay-plateau. (*Mytilus*, *Pecten*, *Tellina*, *Mya*, *Saxicava*).
(45 m) Clay-plateau. (Same fossils).
(47—48 m) Clay-plateau, partially covered with vegetation (moor), (*Mytilus*, *Tellina*, *Mya*, *Saxicava*).
(49 m) Clay-plateau with occasional boulders. (*Nucula?*, *Mytilus*, *Mya*, *Saxicava*).
50 m Marked terrace, traceable for a long distance.
(52 m) Plateau. (Same fossils as at the 49 m level).
(57 m) Plateau with clay, gravel, and scattered stones. (*Mytilus* (highest level!), *Mya*, *Saxicava*).
(67 m) Plateau, gravel (somewhat clayey). (*Mya* and *Saxicava*).
79 m Very marked abrasion-terrace in the solid rock.
99 m Highest, somewhat doubtful, marine limit.
(The steepness of the rock wall behind has not allowed possible marine deposits at greater heights to be preserved.)

Southern locality:

Homogeneous bluish-grey marine clay forming two flat plateau-shaped hills rising above the surrounding river-deposits. Maximum height above sea-level 13 metres. (See fig. 3).

In order to make out possible differences in the composition of the faunas at different levels, the collections of fossils were made at the top of the hills (13 m) as well as at the base (6 m). The content of fossils proved to be the same at the two levels, the only difference being, that the state of preservation was rather bad at the top. The following fossils were collected here:

Nucula tenuis.
Portlandia arctica.
Portlandia lenticula.
Leda pernula.
Mytilus edulis.
Astarte borealis.
Axinus flexuosus.
Tellina calcaria.
Cardium ciliatum.
Mya truncata.
Saxicava rugosa.
— —
Siphonodentalium vitreum.

These clay deposits may possibly correspond to the terrace at 50 metres' altitude (see page 10).

Loc. 7. Midway between King Oscar Fjord and the bend of Vega Sound.

Clay slope, 11 metres above sea-level. (Owing to the shortness of the visit no further investigations in a vertical direction could be made). The following — well-preserved — species were collected:

Mytilus edulis.
Astarte borealis.
Tellina calcaria. (A couple of these had been excavated by *Natica* sp.)
Cardium ciliatum.
Mya truncata.
Saxicava rugosa.
— —
Lepeta coeca.

Loc. 8. Central part of Vega Sound (at the bend of the fjord).

Here the mountains, which according to KOCH (9) consist of red and grey members of the Devonian strata, occur some distance inland. Consequently there is a rather broad foreland, which in some places is covered with moraine deposits[1]) — this may be observed in the large ravines and river beds — in other places by talus and vegetation. The former marine limits are, on the whole, seen to be well-preserved in the moraine areas, where the solifluction has not, apparently, been very active. At the highest levels abrasion terraces occur in the basalt.

Along the entire stretch from the point where the great plains in the interior of Traill Island descend to the coast of Vega Sound, to the point where the fjord from a north-southerly direction again takes an east-westerly trend, marine deposits are found in the foreland. Still some distance to the west, viz. in the large delta marked on the map in L. KOCH: Geology of East Greenland (op. cit.), very marked terraces are to be seen at varying levels. (See the plate.)

Various sections and collections of fossils were made in six localities along this stretch of the coast (A—F). The most easterly of these (A)

[1]) The morainic material is undoubtedly derived from the west, e. g. it may have been carried here by a glacier descending through Vega Sound. Farther east, however, this is not the case. On the surface of the basalt sills, which, owing to later erosion, appear at present as 'covers' along this part of the northern shore of Traill Island, ice striation in a S.W.—N.E. direction is met with everywhere. This means that during the Ice Age glaciers from the interior of Forsblad and Alp Fjord extended through Segelsällskapet Fjord and Holms Vik and covered the large plains in the central part of Traill Island (here crystalline boulders are found everywhere). Undoubtedly the ice reached the sea through Mountnorris Inlet and the funnel-shaped mouth of Vega Sound. The block of Cape Parry was then a 'nunatak', probably with its own ice-cap.

is situated at the mountain at the base of which NATHORST has marked an Eskimo-winterhouse on his map (11), just south of the largest island of the Scott Keltie group. The remaining five localities are distributed along a stretch of 5—6 km in a northwesterly direction.

A: Steep slope in the eastern side of a small delta, 16 metres above sea level, consisting mainly of gravel and pebbles. The following species were found:

Mytilus edulis (fragm.).
Astarte borealis.
Tellina calcaria. (A single specimen excavated by *Natica* sp.).
Mya truncata.
Saxicava rugosa.

41 m Marked terrace (with numerous fragments of *Mya* and *Saxicava*). Slope with solifluction.
80 m Rather disturbed terrace. (No fossils met with).
95 m Abrasion-terrace in the basalt with pebbles and rather big boulders of foreign origin, (viz.: boulders derived from he 'limestone-dolomite-member' and the two tillite series of the Eleonore Bay formation, Devonian conglomerates, and several crystalline blocks).

B: 1 km west of loc. A.

Collection of shells derived from a coastal slope, 9—10 metres above sea-level:

Astarte banksii.
Astarte borealis.
Tellina calcaria.
Mya truncata (remarkably big specimens).
Saxicava rugosa.

30 m Terrace traceable for a long stretch, in places still preserved as semicircular beaches, everywhere with shell fragments (*Mya* and *Sax.*).
80 m Marked terrace.
The slope above this level is perfectly covered with vegetation and talus.

C: A few hundred metres west of loc. B — lower part perfectly covered with vegetation.

64 m Gravel and pebbles (*Mya*-fragments).
84 m Gravel and pebbles.

(93)
(104) } Slope along a ravine (doubtful *Mya*-fragments).
(108)

130 m Terrace with clay and scattered boulders (several shell fragments, cfr. *Mya truncata*).

138 m Terrace, pebbles and argillaceous clay. (Numerous indeterminable shell fragments; highest fossiliferous strata.)

216 m The highest unmistakable marine limit within the district. Fine systems of raised beaches in an abrasion-terrace in the basalt; (allochtone boulders) can be traced in a northwesterly direction between the rivers.

D: 1 km west of loc. C.

The collections are derived from a slope in a small ravine.

(2—3 m) *Astarte borealis.*
Tellina calcaria.
Mya truncata.
Saxicava rugosa.
(9 m) *Cardium ciliatum.*
Mya truncata.
Saxicava rugosa.
— —
Margarita cinerea.

E: 3 km west of loc. D.

5 metres above sea-level. Plastic bluish-grey clay (overflown old moraine). Owing to the insignificant height above the sea (short duration of the erosion) the shells are here very well-preserved, and a great number of small species with thin valves are still present. The following species were met with:—

Nucula cfr. *tenuis* (fragm.).
Mytilus edulis.
Modiolaria nigra.
Astarte banksii.
Astarte borealis.
Axinus flexuosus.
Cardium ciliatum.
Cardium groenlandicum.
Mya truncata.
Saxicava rugosa.
— —
Natica groenlandica.

F: A little north of the last-mentioned locality (D).

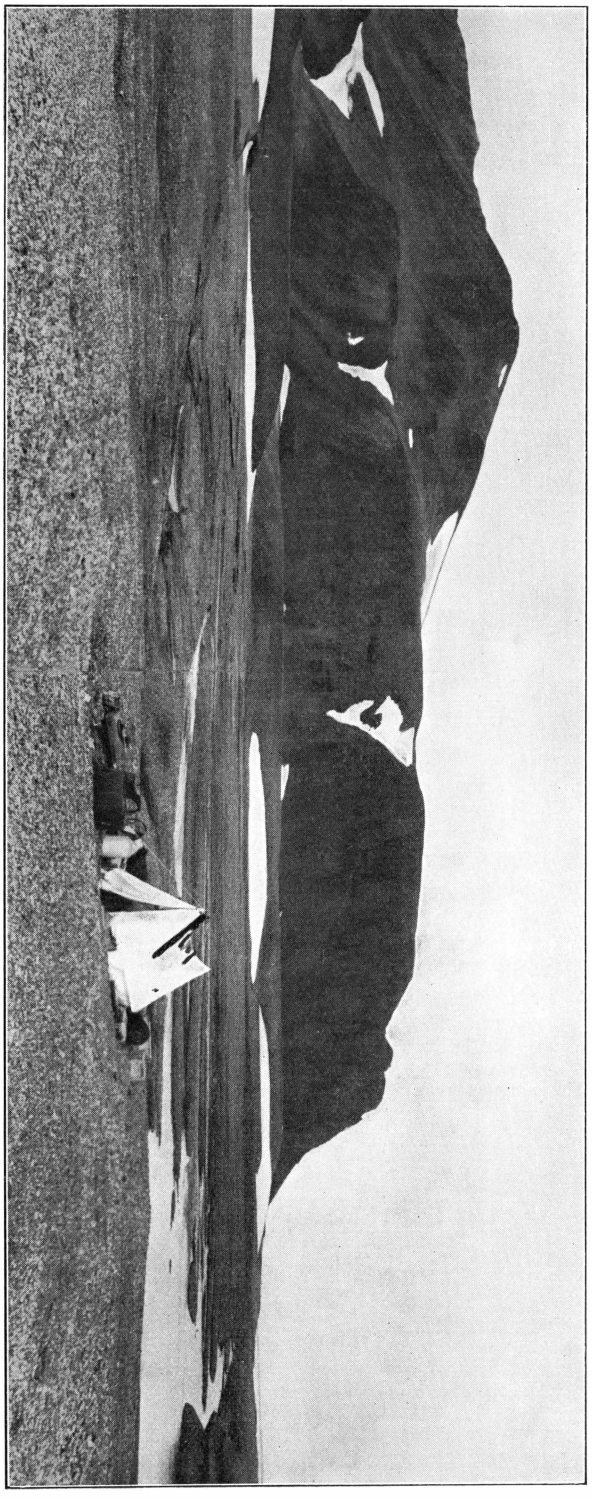


Fig. 4. Cape Simpson, south-eastern corner of Traill Island. Front of the old delta cone, 20 m. In the foreground the recently formed delta.

The collection is only derived from material washed out from a large river and now deposited in the delta. (*Astarte bor.*, *Card. cil.*, *Card. groenl.*, *Mya tr.*, *Saxic. rug.*).

Loc. 9. Drømbugten, South-eastern shore of Traill Island.

At the western side of the bay (in reality the term 'bay' is rather misleading, since Drømbugten should rather be termed a short fjord), a few raised beaches can be seen at the mouth of a valley running in a west—northwesterly direction behind Mt. Forchhammer.

15—20 m Rather disturbed terraces (with *Mya* and *Saxicava*).
56 m Marked terrace (no fossils found).

On the eastern side of Drømbugten at a height of a few metres some valves of the same two species were found.

Loc. 10. Delta south of Cape Simpson.

20 m Front edge of the old delta cone in the middle of the valley (see below).
27—53 m Nearly continous system of semicircular raised beaches along the southern side of the valley. (Fragmentary shells of *Mya* and *Saxicava*).
55 m Marked terrace in the valley side.

(A small collection derived from a river slope, the fossils embedded in sand, proved to include the following species:

Astarte borealis.
Cardium ciliatum.
Mya truncata.
Saxicava rugosa.)

DISCUSSION OF THE VERTICAL DISTRIBUTION OF *MYTILUS EDULIS* L.

As regards the heights given here for the occurrence of *Mytilus edulis*, it will be evident that the variation in these is due to the insufficiency of observations and the too small number of localities, which in reality excludes the possibility of comparing supposed synchronous levels. So we are unable to give 'a general *Mytilus* level' at a certain height.

As may be seen from the preceding chapter, fossil valves have been met with up to a height of 138 metres above sea-level — in that locality the highest marine limit is 216 metres. In the northerly district, viz. the Gael Hamkes Fjord district, the highest fossiliferous level was at about 50 metres, and in Dusén Fjord at 88 metres, according to POSER (13).

The fact that in many localities fossils have not been found at greater altitudes is evidently due to two factors, viz. the coarseness of the material in which they are embedded, and the distance from the outer coast, where the precipitation is much more considerable. In both cases the result will be the same: in the spring the quantity of the percolating water will be greater and so cause a more profound disintegration of the valves. Another factor, which tends to obscure the conditions and which is especially met with in the innermost parts of the fjord system, is the cover of vegetation. Concerning the state of preservation of the terraces in the rocks of different petrographical type and age see BACKLUND (2), pp. 11—12.

As mentioned above, *Mytilus* was found by NATHORST at an altitude of 25 metres in the outer parts of Vega Sound and by DUSÉN (on the same expedition) at 10 metres in Franz Joseph Fjord.

During the investigation last winter *Mytilus edulis* was met with in the following localities, mentioned from west to east (maximum-altitudes in each locality):

Röhss Fjord (loc. 1) — 5 metres, Cape Hedlund (loc. 2) — 32 metres. Maria Island (loc. 4) — 20—25 metres, Cape Oswald (loc. 5) — 28 metres. Cape Elisabeth (loc. 6) — 57 metres, Vega Sound (loc. 7) — 11 metres. Vega Sound (loc. 8) — 16 metres.

Another observation, of a somewhat older date, may be mentioned here: At the first bend of Musk-ox Fjord at a height of 12 metres above sea-level the author found in 1929 some fragments of *Mytilus* together with a fragment of a *Buccinum*-like gastropod embedded in a fine blue clay.

The supposition of the existence of a westerly gradient in the fossiliferous terraces, as suggested — with an interrogation mark — by BACKLUND was neither confirmed nor the contrary during my investigation. The circumstance that *Mytilus*, for instance in the central part of Vega Sound (loc. 8), was not met with at higher levels than 16 metres does not, of course, exclude that it has not formerly occurred here at greater altitudes. The valves of *Mytilus* being rather thin and easily crushed and disintegrated, I should think that the nearness of the outer shore has been of importance (see above).

In the locality at Cape Elisabeth, *Mytilus* was traced from 2 to

57 metres, so it seems rather impossible that deposits of inter-Glacial age, or deposits with fossils on a secondary place in a supposed ice-dammed lake should be present here.

Considering the fossils on the whole, it will be evident, that the species decrease in number in a vertical direction, even at small altitudes. That this is a primary feature, at any rate to a certain degree, I consider possible. If we leave the highest fossiliferous horizons out of consideration, where only the strong valves of *Mya* and *Saxicava* are preserved, a poorer fauna will be found in the upper series, evidently with a more 'cold' character. Below these upper horizons there is a zone with *Mytilus*, *Pecten isl.*[1]), and the whole assemblage of other species, which zone can be traced downwards to a few metres above sea-level. At the most recent beach we have a picture of the present conditions, the main difference between this and the older beaches being the absence of *Mytilus*.

As *Mytilus* is the only boreal mussel indicating a milder period in this region in post-Glacial time, the following observation may possibly be of interest in this connection. Some of the shells, especially of *Mya truncata*, collected at inconsiderable altitudes in company with *Mytilus*, attain a very considerable size compared with the species now living in the same fjords. According to kind information given me by Dr. SPÄRCK and Mr. THORSON, this phenomenon should rather be connected with salinity than with changes in temperature. If there was a longer summer at that time, the period of growth must have been longer, too; further, a better mixing of the fresh water constituting the surface water — a result of the melting of the fjord-ice and the glaciers — with the more saline elements at the greater depths might be supposed. No observations supporting this last supposition were, however, made during the zoologic-hydrographical investigation carried out by SPÄRCK and THORSON in the summer of 1932. As late as in August there was everywhere a marked difference between the uppermost fresh water layer and the lower saline one. If, therefore, we are to regard the big size of the shells as dependent on salinity, we must take into consideration possible changes in the sea itself, as for instance variations in the breadth of the East Greenland ice-current. This may cause variations in the salinity, at any rate in the areas near the coast. Possibly, however, two or more of these factors have acted together, and the whole matter may prove to be of a more complex character than assumed.

Considering the results arrived at by AD. S. JENSEN and POUL HARDER (9) during their investigations of the distribution of *Zirphæa*

[1]) *Pecten islandicus* MÜLL. Formerly regarded, by HARTZ and AD. S. JENSEN, as an indicator of a warmer period too; during the investigations made by THORSON found to be living in several localities in the fjords.

crispata and *Anomia ephippium* in the post-Glacial deposits of Disco Bay in West Greenland, we find that towards the end of the post-Glacial period the climatic conditions in West-Greenland have been very similar to those of East-Greenland. At present we are only able to form an opinion as to the last half (with regard to time) of the curve. (Cf. Op. cit. pag. 406).

As to the finds of fossil molluscs indicating a mild climate in Arctic regions in post-Glacial time, a general view has been given by JENSEN and HARDER (Op. cit.). A brief summary shall be given here: Iceland: The indicator of a warmer period is here the small gastropod *Purpura lapillus* L., now living along the southern and southwestern shore of Iceland. It has been found in a fossil state by BARÐARSON (3) along the northern shore of Iceland 17 metres above the present sea-level. The highest marine terrace in these regions is estimated at 70—80 metres by THORODDSEN.

Spitzbergen, Franz Joseph Land, and the coast of Siberia bordering the Arctic Sea: In all these tracts the indicator of a warmer climate is *Mytilus edulis* L., in some localities (Spitzbergen) associated with other boreal species. As a general feature may be mentioned that the finds of boreal mussels are confined to rather low altitudes above sea-level, which may indicate that the warm period has been comparatively recent, only little antedating the present.

West-Greenland: The investigations by JENSEN and HARDER have revealed the same features in the vertical distribution of the fossil boreal mussels in Disco Bay; here the highest level at which they have been met with is about 30 metres, while the highest marine limit is a little more than 100 metres.

If we compare these results with the observations from East-Greenland, we shall find that within the region in question marine limits occur at altitudes of more than 200 metres, so the highest altitude at which *Mytilus edulis* was observed, viz. at about 60 m (57 m), is very likely the maximum altitude of the boreal molluscs within this part of East Greenland.

If we compare the observations of this kind from the various Arctic regions as made by the authors just mentioned (Op. cit.), it seems most natural to draw a parallel between the *Tapes*-period, so well-known in Scandinavia, and such a warm period in the Arctic as indicated by the said factors.

If this be the case, we shall have a relatively good measure for the rate of land-rise since then within the areas in question.

REMARKS ON THE LAND-RISE IN EAST GREENLAND IN LATE POST-GLACIAL TIME

Considering the repeated tectonical movements in the East Greenland marginal zone, which as late as in Tertiary time was subjected to crustal dislocations and eruptions, to which the main features of the present topography in certain areas are due, one cannot help being struck by the thought, that, owing to different degrees of compensation, slight after-effects of these tectonical disturbances might be traceable within the various areas, e.g. slight block movements may have effected ununiform elevation of the individual tectonical units.

This factor together with the old tendency to an epeirogenic rise of the central gneiss block make the conditions which one must take into consideration when discussing the question of raised beaches, more complicate.

Another point, too, set forth by BACKLUND, may possibly be of

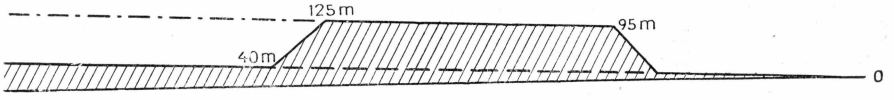


Fig. 5. Sketch showing the course of the river-bed when the old delta cone was deposited, and the present course of the stream.

importance, viz. the great difference in the precipitation in West and East Greenland — the present climate in East Greenland being very dry — may possibly have given rise to an ununiform covering of snow and a different amount of melting and evaporation in the marginal zone of the inland-ice within the said period, which may again have brought about differences in the subsequent isostatic release movements.

On the whole it may easily be seen that until a systematical levelling has been undertaken, no conclusions of lasting significance can be drawn.

In connection with the supposition that a land-rise of about 60 metres should have taken place in these parts of East Greenland since the *Tapes*-period, may be mentioned a phenomenon which may be observed in several of the large valleys where an old delta cone furnishes evidence of another height of the sea in rather recent time, thus for instance the delta already mentioned on the southern side of Suess Land (loc. 3, Fig. 5).

As may be seen, the land-rise in this locality has taken place so rapidly during the latest periods, that the river has been unable to carry away the material accumulated along its lower course in earlier times.

A narrow canyon marks the present river-bed; in this way an inland delta behind the old delta cone has come into existence, while in front thereof we have a recent delta of inconsiderable height.

At Cape Simpson exactly the same conditions, but on a smaller scale, may be observed (see fig. 4).

These observations in connection with the finding of *Mytilus edulis* at 57 metres would seem to indicate a relatively rapid rise of land in East Greenland in the latest post-Glacial periods.

As regards the suppositions of a recent subsidence of certain parts of Greenland, only one or two observations, which seem to indicate a stagnation in the land-rise up to the present time, shall be mentioned here.

In many places outwashed caverns and holes and rather marked abrasion terraces may be seen along the present highwater level, for instance, along the northwestern coast of Ella Island, where the rocks consist of hard limestones and dolomites belonging to the Cambrian-Ordivician series. On examining the rock wall at greater altitudes where former marine limits might be supposed to have set their marks, nothing similar can be seen. In other words: the present height of the water seems to have prevailed for a rather long time.

Another point to be mentioned here: In places where nearly continuous raised beaches occur from sea level up to about 10 metres there is an obvious difference between the lowermost beach and the next one as compared with two successive beaches at a height of, for instance, 5—6 metres. The lowermost beach will prove to be much higher and to contain much more accumulated material, and behind this beach there will often be a small lagoon, which will be filled with water at high tide. This example, too, seems to indicate a stagnation in the land-rise.

From these examples a marked decrease in the rate of land-rise, or even an interruption, would seem probable.

Even if a recent subsidence of the land has not been ascertained with certainty, it seems very probable, from observations on the old Eskimo house ruins on Clavering Insel made by the archæologist H. LARSEN of the Danish three year expedition to East Greenland, that such a subsidence has taken place. In this connection may be mentioned a series of observations in more southerly parts of the east coast made in the summer of 1931 by TH. VOGT (16). In the said paper the author further records a number of observations from Spitzbergen on the position in relation to the high water mark of a number of old Dutch

oil refineries (about 300 years old). His observations both on the south-east coast of Greenland and on Spitzbergen point towards a recent subsidence.

As subsidence is a well known phenomenon on the west coast of Greenland (see i.a. FRODA (5)), and must now be considered very probable on the east coast and on Spitzbergen, there is hardly any doubt that this shifting of the shore line within the various areas is due to the same causes. In other words, the view held by previous authors (VOGT) that the subsidence of the areas in question is a direct consequence of an increased glaciation in contrast to the preceding post-Glacial warm period, affords the most natural and at the same time the most satisfactory explanation.

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Photograph showing the large delta to the west of the bend of Vega Sound, with terraces at varying altitudes.