

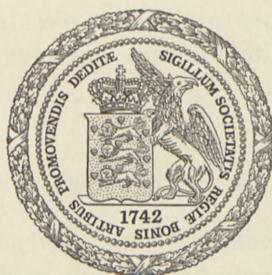
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TWO NEW WEST GREENLAND LOCALITIES  
FOR DEPOSITS FROM THE ICE AGE AND  
THE POST-GLACIAL WARM PERIOD

BY

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KØBENHAVN

I KOMMISSION HOS EJNAR MUNKSGAARD

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## CONTENTS

	Page
Introduction .....	3
The clay plain at North Strømfjord.....	3
On the distribution of <i>Portlandia (Yoldia) arctica</i> and its ecology .....	6
Canada .....	6
Alaska .....	7
The north coast of Asia .....	7
European Russia .....	7
Spitzbergen .....	9
East Greenland .....	10
West Greenland .....	14
Conclusion .....	16
On the distribution of <i>Pecten groenlandicus</i> .....	17
Why is <i>Portlandia (Yoldia) arctica</i> extinct along the greater part of West Greenland? And why has it not immigrated again?.....	18
On remains previously found of an arctic fauna in raised deposits far within North Strømfjord.....	22
The locality at South Strømfjord.....	24
<i>Cyprina islandica</i> .....	25
<i>Panopaea norvegica</i> .....	27
The other molluscs.....	29
<i>Balanus Hammeri</i> .....	29
Conclusion.....	31
Summary .....	31

### Introduction.

On a journey which the then Royal Inspector of South Greenland, O. BENDIXEN, made some years ago with the purpose of preparing a topographic-statistical description of the Holsteinsborg District in West Greenland, he collected a number of shells of marine animals from raised deposits. Mr. BENDIXEN himself realized that they were remains of marine animals from the Quaternary period thus testifying that formerly this district was considerably below the present level of the sea.

These shells Mr. BENDIXEN has been kind enough to hand over to me for identification, and I now give an account of this collection which is of no small quaternary-geological interest.

The shells derive from two localities, one situated at North Strømfjord (Nagssugtôk of the Greenlanders), the other at South Strømfjord (Kangerdlugssuak of the Greenlanders). These fjords cut deep into the country, and form administratively the northern and southern limits of the Holsteinsborg district.

The collection contains parts of three faunas: a high-arctic, an arctic, and a boreal. We shall begin with the locality at North Strømfjord, whence there are representatives only of the high-arctic element.

### The clay plain at North Strømfjord.

Mr. BENDIXEN has given me the following information concerning this locality which gives a good idea of the local conditions and will make it easy to find the place again in a later investigation.

On the northern side of North Strømfjord 18 miles inside the entrance of the fjord there is a bay by BENDIXEN called Depot

Bay, and on the western side of this there is a point with a deposit of fine clay; this point is bounded by low mountain ridges towards the fjord which have prevented its being washed away by the fjord water; on the southern side alone the clay plain is connected with the fjord by two creeks, one on either side of a low ridge which cuts through the plain dividing it for a stretch into two parts. A river has forced its way through the clay plain to the eastern creek, and on the slopes of this river-course the fossil

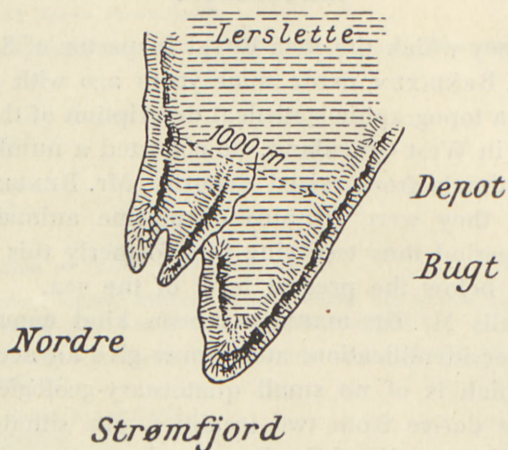


Chart 1. The clay plain (Lersletten) in North Strømfjord and surroundings.

shells were found in the uppermost part of the layer to a height of about 70 m above the sea. Reference is made to the attached sketch (chart 1) of the clay plain with its surroundings prepared after Mr. BENDIXEN's draft in his diary.

The fossils collected in this place (fig. 1) belong to two species of bivalves, viz.

*Portlandia (Yoldia) arctica* (Gray), 6 specimens, length up to 20 mm.

*Pecten groenlandicus* Sow., 4 specimens, length up to about 20 mm.

Both these bivalves have the shells connected and the cavity between them filled with a stony nucleus of clay. That they have been deposited in fine clayey mud in calm water can be concluded from the fact that *Pecten groenlandicus*, the shells of which are very fragile, have been preserved, and that the pe-

riostracum has been partly preserved in *Portlandia* (*Yoldia*) *arctica*.

The predominant representative of the high-arctic element is *Portlandia* (*Yoldia*) *arctica*. In order to make this clear we shall thoroughly discuss below the distribution at the present time of this bivalve which is of the greatest importance as a

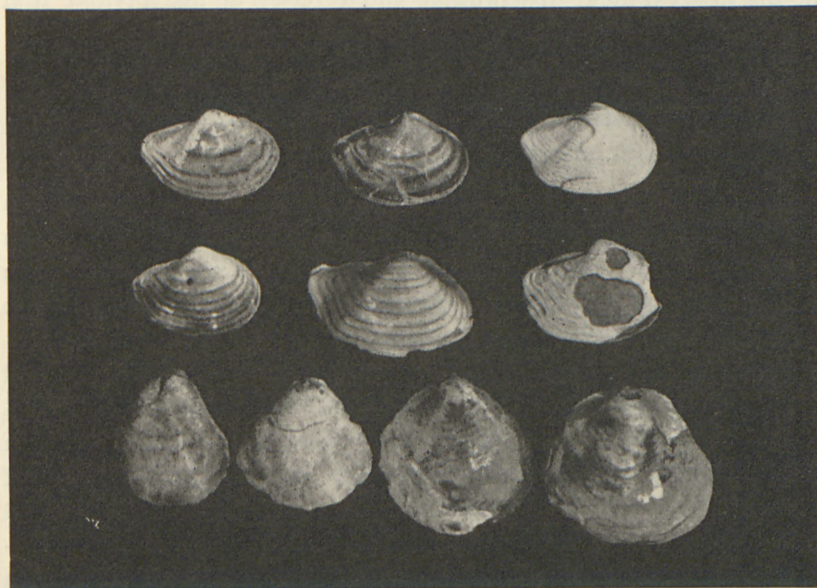


Fig. 1. *Portlandia* (*Yoldia*) *arctica* and *Pecten groenlandicus*. ( $\times 1\frac{1}{8}$ ). The clay plain in North Strømfjord, from the uppermost part of the deposit, about 70 m above the level of the sea.

leading fossil, going like a red thread through the history of the investigation of the Ice Age<sup>1</sup>. In elucidation hereof the present author has already given in Danish a contribution, but

<sup>1</sup> In the literature on the Ice Age the designations "Yoldia-sea", "Yoldia-clay" and "Yoldia-time" have been adopted long ago. This is in so far unfortunate as the mollusc after which they were named is not a *Yoldia*. The genus *Yoldia* was established by H. P. C. MØLLER (Index Molluscorum Groenlandiæ p. 91. Naturhist. Tidsskrift, vol. 4, 1842—43), for a bivalve which he erroneously believed to be identical with the Polar Sea bivalve *Nucula arctica* Gray; it appears from MØLLER's detailed description that his *Yoldia arctica* is an entirely different mollusc, *Yoldia hyperborea* (Lovén) Torell. *Nucula arctica* Gray was later referred to HANCOCK's genus *Portlandia* and in the zoological literature it is generally called *Portlandia arctica* (Gray) (cf. G. O. SARS: Mollusca Regionis Arcticæ Norvegiæ, 1878, p. 37), while geologists often retain the designation *Yoldia arctica*. For the guidance of the reader it is called *Portlandia* (*Yoldia*) *arctica* in this paper.

this account came in an appendix to the paper by another author<sup>1</sup>. Besides, in the 38 years which have passed since then so many new contributions have appeared, especially from Russian, Swedish, Danish, Norwegian, and Canadian sources (Siberian Ice Sea, Barents Sea, Spitzbergen, Greenland, the Archipelago north of Canada, and Arctic Alaska) in elucidation of the geographical distribution and ecology of this bivalve that an up-to-date account is desirable.

**On the distribution of *Portlandia (Yoldia) arctica*  
(cf. chart 2, p. 11) and its ecology.**

We shall begin with Canada. *Portlandia (Yoldia) arctica* is known from the western side of the narrow channel which separates Northwest Greenland from Arctic America, viz. from Discovery Bay on Grinnell Land (81°41' N), 5 fms.<sup>2</sup> In the Stockholm Riks-Museum I have seen numerous specimens dredged by the Swede E. NILSON (1894) near Baffin Land (72°38' N 77°10' W and 72°27' N 74°52' W) at depths of 10½ and 13—19 fms. The southernmost place near eastern Canada in which the species was found alive lies on the east side of Hudson Bay, where it was dredged in Richmond Gulf (about 56° N), on a muddy bottom, in 15—25 fms.<sup>3</sup> From the high-arctic archipelago north of America it is mentioned also from the following localities: Assistance Bay (74°40' N 94°16' W) and the coast of Barrow Strait, 7—20 fms.<sup>4</sup>; Port Kennedy (72° N 94° W), 15 fms.<sup>5</sup>; north of Beechey Island, 74 fms.<sup>6</sup> The SVERDRUP expedition found it to be common in Gaasefjord on the southern side of King Oscar's Land (about 76½° N 89° W); at

<sup>1</sup> HELGI PJETURSSON: Om Forekomsten af skalførende Skurstensler i Búlands-hófdi, Snæfellsnes, Island. Med Bemærkninger om Molluskfaunaen af Ad. S. JENSEN. D. Kgl. Danske Vidensk. Selskab, Overs. 1904, No. 6, pp. 386—392.

<sup>2</sup> E. A. SMITH: On the Mollusca collected during the Arctic Expedition of 1875—76. ("Alert" & "Discovery"). Ann. Mag. Nat. Hist., Ser. 4, vol. XX, p. 142. 1877. ("*Leda glacialis* Leach").

<sup>3</sup> WHITEAVES: Catalogue of the Marine Invertebrata of Eastern Canada, p. 127. Geol. Survey of Canada. 1901.

<sup>4</sup> SUTHERLAND, Journal of a voyage in Baffin's Bay and Barrow Straits, vol. II, App. p. 202. 1852. ("*Nucula (Yoldia) arctica*").

<sup>5</sup> WALKER: Notes on the Zoology of the last Arctic Expedition etc. Journ. Roy. Dublin Society, vol. III, p. 72). 1860. ("*Nucula truncata* Brown").

<sup>6</sup> REEVE in BELCHER, The last of the Arctic Voyages, vol. II, p. 396. 1855. ("*Nucula portlandica* Hitsch." & "*Nucula siliqua* Reeve").

a depth of about 14 m nearly 600 specimens were taken in one haul<sup>1</sup>. Farther west near arctic Canada it was taken by the Canadian arctic expedition in Dolphin and Union Strait (about 70° N 115° W), off Stapylton Bay, in about 30 fms., mud<sup>2</sup>.

On the arctic coast of Alaska it was taken off Collinson Point, 3 fms., mud and gravel, and off Sea Horse Islands (70°24' N 161°25' W), 9—10 fms., mud<sup>2</sup>. DALL records *Portlandia* (*Yoldia*) *arctica* from the eastern side of Bering Strait, in Norton Sound on Alaska<sup>3</sup>. But he does not mention it in his (later) lists of the molluscs of the Bering Sea, and it has not been collected in this sea either by the Vega expedition or by ARTH. KRAUSE, so it goes hardly south of the entrance proper to the sea between America and Asia.

*Portlandia* (*Yoldia*) *arctica* is extremely common along the north coast of Asia, as it has been taken in many places from Cape Wankarema (176°6' E) to the western side of the Kara sea, according to LECHE<sup>4</sup>; it occurs in large numbers at depths of 5—15 fms., but has also been met with so deep as 85 fms. Of special localities MOSSEVITCH further mentions the western side of the northern Novaya Zemlya island, the mouths of the rivers Ob, Jenissei, and Lena, and the Lapteff sea and the area at the island of Kotelnyi and the New Siberian islands<sup>5</sup>.

Off European Russia *Portlandia* (*Yoldia*) *arctica* was unknown until the end of the last century, when Prof. KNIPOWITSCH, to whom we are indebted for important hydrological and biological

<sup>1</sup> J. A. GRIEG: Brachiopods and Molluscs, p. 6. Rep. of the Second Norwegian Arctic Exped. in the "Fram" 1898—1902, No. 20. 1909.

<sup>2</sup> W. H. DALL: The Mollusca of the Arctic Coast of America collected by the Canadian Arctic Expedition. Rep. of the Canadian Arctic Expedition 1913—18, Vol. III, Part A, pp. 8, 10 and 16. Ottawa 1919. — DALL entered the species partly under the name of *Leda* (*Portlandia*) *arctica* Gray, partly as *Leda* (*Portlandia*) *collinsoni* n. sp. It appears both from the description (p. 19) and the figures (pl. II, figs. 3, 4) of the latter that it is only one of the numerous varieties of *Yoldia arctica*; among other things it is said about it: "The curious vermiculation of the surface is probably in great part if not entirely a function of the periostracum"; it is just one of the characteristics of *Yoldia arctica* that fine and dense, undulating concentric stripes can be seen under a lens.

<sup>3</sup> W. H. DALL: Catalogue of Shells from Bering Strait; Proc. California Acad. of Sciences, Vol. V, p. 250. 1873—74.

<sup>4</sup> Kgl. Sv. Vetensk.-Akad. Handl. Bd. 16, Nr. 2, 1878, p. 23 & Vega-Expéditionens Vetensk. Iakttag., Bd. III, p. 444, 1883.

<sup>5</sup> N. MOSSEVITCH: Contributions à la Systématique, l'Écologie et la Distribution de *Yoldia arctica* Gray récente et fossile. Matériaux de la Commission pour l'Étude de la République Autonome Soviétique Socialiste Iakoute, Livr. 19. Leningrad, 1928.

investigations in the waters north of Russia, in a series of papers has given us the following information:

On the south coast of Novaya Zemlya, i. e. in the eastern part of the Barents Sea *Portlandia* (*Yoldia*) *arctica* is abundant, attaining a very considerable size; but here it lives, it is true, at the great depth of 93 fms. and in a cold current, the deeper layers of which in summer show so low temperatures as  $-1.6^{\circ}$  and  $-1.8^{\circ}$  C.<sup>1</sup>

Along the west coast of Novaya Zemlya (the northern island) the Norwegian zoologist ØKLAND took it in the following places: Mashigin fjord, 7—8 m, clay from the glaciers, rather common; Litchutin Island, 5 m, clay, common<sup>2</sup>. It has also been taken at the mouth of the Petschora river<sup>3</sup>.

Finally, it lives in the White Sea in which very peculiar hydrographical conditions prevail. The deeper water layers (below about 15 fms.) of this cauldron-shaped basin are secluded from free interchange with the water masses of the ocean by a narrow and rather shallow inlet, retaining, therefore, constantly a very low temperature which is nearly the same as the absolute minimum of the surface water ( $-1.4^{\circ}$  to  $-1.6^{\circ}$  C.). The conditions in the shallower parts of the White Sea are entirely different (especially in Onega Bay), since a strong heating of the water takes place here in summer. It now appears that *Yoldia arctica* generally occurs only in the deeper parts of the White Sea (below about 20 fms.), where the yearly amplitude is small (at a depth of 40—50 fms. it is not greater than about  $2^{\circ}$  C., as the temperature fluctuates between  $+0.5^{\circ}$  and  $-1.4^{\circ}$  C.), and which Prof. KNIPOWITSCH, therefore, called the "cold area"<sup>4</sup>. There is an exception, however, as KNIPOWITSCH also found large numbers of living *Yoldia arctica* in the bay near Kandalakscha (in the northwestern corner of the White Sea) at small depths

<sup>1</sup> N. KNIPOWITSCH: Zur Kenntniss der geologischen Klimate, p. 284. Verhandl. d. Kais. Russ. Mineralog. Gesellsch., Bd. XL, 2. 1903.

<sup>2</sup> JAMES A. GRIEG: Molluscs, Brachiopods and Echinoderms from Novaya Zemlya. Rep. of the scient. results of the Norwegian Expedition to Novaya Zemlya 1921, No. 26, p. 7, 1924.

<sup>3</sup> N. KNIPOWITSCH, *ibid.*

<sup>4</sup> N. KNIPOWITSCH: Eine zoologische Excursion im nordwestlichen Theile des Weissen Meeres im Sommer 1895. (Ann. du Musée zool. de l'Acad. Imp. des sci. St.-Pétersbourg. 1896, p. 304). Idem: Zur Kenntniss der geologischen Geschichte der Fauna des Weissen und des Murman-Meeres (Verhandl. Kais. Russ. Mineralog. Gesellsch. St. Petersburg. Bd. XXXVIII, Nr. 1, 1900).



(up to a depth of 14 fms.) and at a temperature which in the first half of July rises to  $3.6^{\circ}\text{C}$ .—"eine sehr merkwürdige Tatsache, die für mich jetzt vollständig unbegreiflich ist", writes KNIPOWITSCH (l. c. 1896, p. 307 and 1900, p. 20)—cf. with this p. 10 and pp. 13—14.

According to O. TORELL's classical investigations<sup>1</sup> *Portlandia* (*Yoldia*) *arctica* lives at Spitzbergen on clay bottoms from 5 to 30 feet; he found it especially in the clay carried down from the glaciers at 8 to 15 feet depth. According to the same author it is very rare on the west coast of Spitzbergen, where the bottom temperature is  $+1^{\circ}\text{C}$ ., whereas it is abundant in the ice-filled Hinlopen Strait on the east coast<sup>2</sup>.

In the Stockholm Riks-Museum I have seen *Portlandia* (*Yoldia*) *arctica* from the following Spitzbergen localities: Storfjord, 4—7 and 5—10 fms.; Bellsund 15 fms.; Isfjord, 10—20 and 20—40 fms.; Hinlopen Strait, 55 fms. Russian expeditions also have taken it in large numbers near Spitzbergen, at only small depths, mainly  $3\frac{1}{2}$ —10 fms. The majority of the stations at which living specimens were secured were lying near glaciers; the bottom temperatures in summer ruled between  $-1.2^{\circ}$  and  $+2.5^{\circ}\text{C}$ .<sup>3</sup>

Finally, ODHNER, who has worked up the collection of molluscs from the Swedish expedition to Spitzbergen in 1908 under the leadership of Prof. G. DE GEER, records *Portlandia* (*Yoldia*) *arctica* from 20 stations in Isfjord<sup>4</sup>. Its vertical distribution lies between 6—8 and 100 m. It is most abundant in the inner parts of the fjord and in shallow water; at depths of 6—8 and 19—27 m, 161 and 111 living individuals respectively were taken in a single haul, and it was so dominant here that the number of individuals represented 53.2 and 67 per cent. of the total number of molluscs. The places of capture are situated most densely in the immediate vicinity of the glaciers, and it occurs close to the edge of the glaciers; but it was also found in places where no glacier debouches, i. e. although it often occurs in the out-

<sup>1</sup> O. TORELL: Bidrag till Spitsbergens Molluskfauna, p. 148. 1859.

<sup>2</sup> O. TORELL: Undersökningar öfver istiden. III. Öfvers. K. Sv. Vetensk.-Akad. Handl. 1887, Nr. 6, p. 434.

<sup>3</sup> N. KNIPOWITSCH: Zool. Ergebn. d. Russ. Exped. nach Spitzbergen. Mollusca und Brachiopoda. I, II und III. Ann. du Musée Zool. de l'Acad. Imp. des sci. St.-Pétersbourg, T. VI, 1901 (p. 502) & T. VII, 1902 (p. 395).

<sup>4</sup> NILS H.J. ODHNER: Die Molluskenfauna des Eisfjordes, p. 58—60. Kungl. Svenska Vetenskapsakad. Handl., Bd. 54, No. 1. 1915.

flowing glacier water it is not strictly bound up with such localities. The temperature limits lie between  $-0.59^{\circ}$  and  $+3.7^{\circ}$  or  $+4^{\circ}$ , which is a little more than hitherto indicated. The highest temperatures apply to the localities where the water is most shallow, i. e. where the insolation has a direct heating influence, but—ODHNER adds—as the bottom in all the localities consists of more or less soft mud, it is probable that the temperature of the bottom is somewhat lower than that of the water. The salinity of the water lies between 33.40 and 34.18 ‰. The species attains its maximal size in the outer and deeper parts of the fjord<sup>1</sup>. ODHNER was the first—and presumably hitherto the only one—to examine the diet of this mollusc; its food consists of different microorganisms of plankton and benthos which are devoured together with the mud.

Turning to East Greenland we find that *Portlandia (Yoldia) arctica* is absent in the southern part. Thus, it has not been found alive in the Angmagssalik District; it is true that a specimen has been taken in Sermilikfjord in the Angmagssalik District, but its shells were empty<sup>2</sup>. The southernmost place on the east coast at which it has been taken alive, is in a river mouth in Mikis fjord in Kangerdlugssuak ( $68^{\circ}10' N$ ); here the 7th Thule Expedition 1933 took 3 specimens in two dredge hauls at a depth of 3.5—4 m, sandy clay, and 18 specimens at 7—8 m on clay bottom<sup>3</sup>. A little farther north 15 living specimens were taken in Turner Sound ( $69^{\circ}44' N$ ) at about 6 m<sup>4</sup>.

Farther to the north, from about  $70^{\circ}$  up to about  $73\frac{1}{2}^{\circ} N$  *Portlandia (Yoldia) arctica* is among the most common of the molluscs; this was shown first by investigations made by Swedish expeditions (NATHORST 1899, KOLTHOFF 1900<sup>5</sup>) and Danish

<sup>1</sup> In NATHORST'S book: *Två Somrar i Norra Ishavet*, 1. D., 1900 it is recorded (p. 297) that the expedition in 1898 took *P. arctica* alive at the limit of the pack-ice north of Spitzbergen ( $81^{\circ}14' N$   $22^{\circ}50' E$ ), where the depth was 80 fms. and the bottom temperature  $2^{\circ} C.$ ; but NILS ODHNER records that this mollusc is *Portlandia intermedia*.

<sup>2</sup> E. BERTELSEN: Contributions to the animal ecology of the Fjords of Angmagssalik and Kangerdlugssuak in East Greenland. *Medd. om Grønland*, Bd. 108, No. 3, 1937, p. 25.

<sup>3</sup> E. BERTELSEN, l. c. p. 25.

<sup>4</sup> AD. S. JENSEN: On the Mollusca of East Greenland, I, Lamellibranchiata. *Medd. om Grønland*, Vol. XXIX, 1905, p. 317.

<sup>5</sup> R. HÄGG: Mollusca und Brachiopoda gesammelt von der Schwedischen zoologischen Expedition im J. 1900. *Arkiv för Zoologi*, Bd. 2, No. 2, 1904, p. 14. — AD. S. JENSEN, l. c., p. 318.

(RYDER 1891—92, AMDRUP 1900<sup>1</sup>). Later numerous bottom samples were taken with the PETERSEN grab during the three years expedition to Christian X's Land in 1931—1933 under the leadership of LAUGE KOCH, and numerous dredge hauls were also made

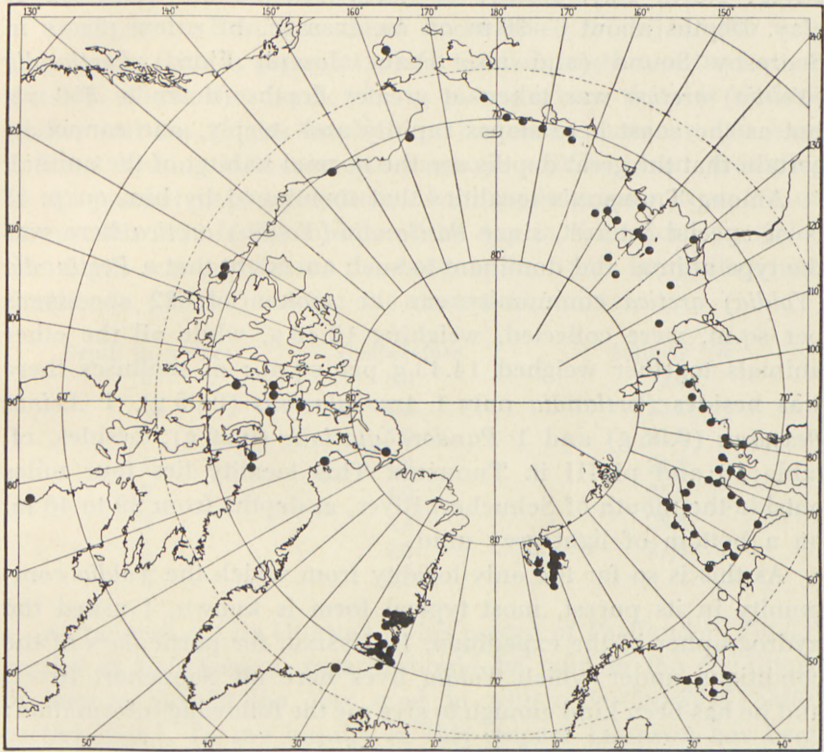


Chart 2. The present distribution of *Portlandia (Yoldia) arctica* worked out on the basis of the treatises quoted on pp. 6—14, with additions after EKMAN<sup>2</sup>.

in Scoresby Sound and the Franz Joseph Fjord complex; these investigations also showed that *Portlandia (Yoldia) arctica* is extremely common in these areas.

In the Scoresby Sound area *Portlandia (Yoldia) arctica* was taken in the following places<sup>3</sup>: Off Cape Tobin; off the mouth

<sup>1</sup> AD. S. JENSEN, l. c., p. 317.

<sup>2</sup> SVEN EKMAN: Tiergeographie des Meeres, 1925, p. 250, Abb. 140.

<sup>3</sup> G. THORSON: Contributions to the animal ecology of the Scoresby Sound fjord complex. Medd. om Grønland, Bd. 100, No. 3, 1934. This paper also contains an excellent map showing the situation of the localities.

of Hurry Inlet; Hurry Inlet, off Konstabel Point; east side of Hurry Inlet; Hurry Inlet by the Fame Islands; west coast of Jameson Land off the Bjørn Islands; off Cape Hooker; Hekla harbour; off Cape Leslie; Northeast fjord off the delta of Schuchert River; North Bay, Northwest fjord. The bottom consisted of clay. Depths about 6—90 m on an average. In a few places in Scoresby Sound (and also Franz Joseph Fjord) *Portlandia (Yoldia) arctica* was taken at greater depths (down to 350 m), but as the coast here slopes rapidly and steeply, one cannot be certain that the great depths are the normal habitat of the animal.

Among THORSON'S localities that mentioned by him on p. 43 is of special interest, since *Portlandia (Yoldia) arctica* here was the type animal and dominant to such an extent that a *Portlandia (Yoldia) arctica* community can be spoken of; 82 specimens per sq.m. were collected, weighing 19.40 g, while all the other animals together weighed 14.43 g per sq.m.; of molluscs there was besides *Portlandia* only 1 *Arca glacialis* (0.05 g), 1 *Axinus flexuosus* (0.05 g) and 1 *Pandora glacialis* (0.20 g); besides, cf. table 13 and pl. III in THORSON. This locality lies four miles outside the mouth of Schuchert River, at depths from 29 to 46 m, on a bottom of light grey mud.

As this is so far the only locality from which the *Yoldia* community in its purest, most typical form is known, I asked the hydrographer of the expedition, H. USSING, for particulars of the conditions under which *Yoldia* lives here off Schuchert River, and he has been kind enough to give me the following information:

St. VII. Depth: 25 m. <sup>23</sup>/<sub>7</sub> 1933<sup>1</sup>.

Depth in metres	Temperature	Salinity ‰
2	+ 7.97	17.94
10	— 0.95	28.64
20	— 1.12	32.21

Also other localities in Scoresby Sound, and by the way in Franz Joseph Fjord too, showed a distinct *Yoldia* community, with a great dominance of *Portlandia (Yoldia) arctica*. THORSON writes that this community was especially associated with the brackish water off river mouths, where large glaciers near the

<sup>1</sup> July is the warmest month in the water.

heads of the fjords descended, carrying a material which gives to the water a milky appearance and covers the bottom with a layer of loose, light-grey clay or mud. In deeper water, or at greater distances from the river mouths, the *Yoldia* community passes evenly into the surrounding communities.

In northern East Greenland *Portlandia* (*Yoldia*) *arctica* may also be met with in places at which the temperature of the bottom water is above the usual, viz. in places where there is shallow water, and the bright sunshine of the arctic summer can have a direct heating influence. An example will be given according to the journal kept by SPÄRCK of the hydrography at st. 28, on August 4th 1932 in the middle of the day in Northfjord, in which the depth was only 8 m, the bottom fine, soft, grey clay, and *Portlandia* (*Yoldia*) *arctica* the dominant animal:

Depth in metres	Temperature	Salinity ‰
0	6.6	13.5
1/2	5.3	23.1
1	5.0	24.5
1 1/2	4.9	24.8
2	4.9	25.0
3	4.4	26.6
5	4.3	27.6
8	4.1	

As pointed out by ODHNER in his record of *Portlandia* (*Yoldia*) *arctica* at Spitzbergen, regard should be paid to the conditions of temperature in the clay mud in which *Portlandia* (*Yoldia*) *arctica* lives<sup>1</sup>. To my inquiry in this respect THORSON has been

<sup>1</sup> The foot in *Portlandia* (*Yoldia*) *arctica* is a very large muscular organ having, as in other nuculids, a deep furrow along the middle which indicates that the lateral parts can be spread out, so that the foot becomes disc-shaped, and the mollusc can, as some authors believe, hereby creep like a gasteropod. But according to DREW the foot is wedge-shaped in closed condition in the nuculids and can be pushed far down into the bottom, whereupon the lateral parts are spread out to the sides and their borders are bent backwards; the foot buried in the bottom thus acts as an anchor by means of which the mollusc can sink into the mud, when the retractor muscles of the foot contract. DREW has watched living nuculids (*Yoldia limatula*, *Nucula delphinodonta* and *N. proxima*) for hours "in dishes containing the soft mud in which the animals normally live; they all burrow with rapidity and in the same manner, but in no case was a specimen observed to creep, even for the shortest distance". GILMAN A. DREW: Some Observations on the Habits, Anatomy and Embryology of the Protobranchia. Anat. Anz., 15. Bd., 1899, p. 496. — Idem: *Yoldia limatula*, p. 9, Note\*. Memoirs from the Biological Laboratory of the Johns Hopkins University, IV, 3, 1899. — Idem: Locomotion in *Solenomya* and its Relatives. Anat. Anz., 17. Bd., 1900, p. 258.

kind enough to give me the following information: "Through many examples from the east Greenland fiords I can confirm that the mud layer on the bottom where the depth is 5 to 15 m has a considerably lower temperature in summer than the bottom water just over the mud. While the bottom water at these depths may even reach a temperature of about 4° C., mud samples from the same depths were much colder; they were icy to the touch and their temperature was hardly more than 1/2° C."

In the fjord area north of Scoresby Sound *Portlandia (Yoldia) arctica* has been taken in several localities, distributed as follows:

Fleming Inlet; Forsblad Fjord; Solitar Bay, Ella Island; Dusén Fjord; Isfjord, Franz Joseph Fjord; Eleonore Bay, Franz Joseph Fjord; North Fjord, Franz Joseph Fjord; Moskusoksefjord; Cape Bennet; Mackenzie Bay. The bottom consisted of clay, the depths were generally from about 8 to 90 m<sup>1</sup>.

As far as I know there is no record to the effect that *Portlandia (Yoldia) arctica* has been taken in the sea farther north in East Greenland, but there can be no doubt that it occurs there. It is true that the Danmark Expedition 1906—1908, which explored this area, did not bring home a single specimen, but this negative result should not be misinterpreted. THORSON who did me the favour to go through the molluscs collected by this expedition informed me that the whole collection bears the aspect of having been collected in quite shallow water on the vegetation, and here *Yoldia arctica* never lives.

As fossil in raised strata, in heights of about 5—120 m above sea level, *Portlandia (Yoldia) arctica* was, on the other hand, taken in the following localities in northeastern Greenland from 76°10'—82°46' N by the geologists of the Danmark Expedition: Great Koldewey Island; an island due north of Edwards Island in Dove Bay; north of Sne Ness; Hval Plain; Île de France; east coast of Peary Land<sup>2</sup>; (cf. chart 3, p. 19).

In older records of the molluscs of West Greenland *Portlandia (Yoldia) arctica* is stated to occur in different places,

<sup>1</sup> R. SPÄRCK: Contributions to the animal ecology of the Franz Joseph Fjord and adjacent East Greenland waters. Medd. om Grøn., Bd. 100, Nr. 1, 1933, p. 28 and table 3. — G. THORSON: Investigations on shallow water animal communities in the Franz Joseph Fjord and adjacent waters. Medd. om Grøn., Bd. 100, Nr. 2, 1932.

<sup>2</sup> AD. S. JENSEN: Quaternary Fossils collected by the Danmark Expedition. Medd. om Grøn., XLIII, 1917, pp. 621—632.

especially in the area round Disko Bay. In a previous paper the present author, however, showed that these records in all cases referred to "dead" shells, which had either been taken up from the sea bottom or belonged to specimens of a very old, fossil appearance and consequently could not be taken as a proof of the present occurrence of the species there<sup>1</sup>.

Although energetic collecting has been done off West Greenland both in the last and present centuries by Swedish and especially by numerous Danish expeditions and private persons, no living specimen of *Portlandia (Yoldia) arctica* has hitherto been found from the southernmost parts up to Upernavik district. So late as the summer of 1936 23 samples were taken with the grab and 3 with the dredge near Upernavik, where the depths varied from 8 to 64 m, and the bottom consisted of clay and sandy clay, but *Portlandia (Yoldia) arctica* was not to be found. In the same district 6 samples were taken at Prøven with the grab and one with the dredge, depths 8—19 m, the bottom consisting of sand and sandy clay, but no *Yoldia* was to be found<sup>2</sup>.

From northern West Greenland WALKER mentions it from Melville Bay, 80 fms., but without stating whether they were living specimens or "dead" shells<sup>3</sup>. On August 17th 1936 VIBE took 6 samples with the grab and one with the dredge in Melville Bay (Savigsivik), where the depth was 23 m and the bottom consisted of sandy clay, but he did not get any specimen of *Portlandia (Yoldia) arctica*<sup>4</sup>. This negative result indicates that *Yoldia* does not live in Melville Bay, and the dubious record in WALKER has therefore been omitted on chart 2 and chart 3.

Still farther north, in North-Star Bay, VIBE took 10 samples with the grab and one with the dredge; the bottom consisted of clay, the depth was 14 m, but he got no *Portlandia (Yoldia) arctica*<sup>5</sup>.

We thus come to the surprising result that not a single living

<sup>1</sup> AD. S. JENSEN: On the fossil quaternary Mollusc-Fauna of Greenland. Medd. om Grønl., XXIX, 1905 (1909), pp. 289—290.

<sup>2</sup> CHR. VIBE: Preliminary investigations on shallow water animal communities in the Upernavik- and Thule districts. Medd. om Grønl., Bd. 124, Nr. 2, 1939, tables 1, 2, and 3.

<sup>3</sup> D. WALKER: Notes on the Zoology of the last Arctic Expedition under Captain Sir F. L. M'Clintock, R. N. The Journ. Roy. Dublin Society, Vol. III, 1860, p. 72 ("*Nucula Portlandica*").

<sup>4</sup> CHR. VIBE l. c. table 5.

<sup>5</sup> CHR. VIBE l. c. table 4.

*Portlandia (Yoldia) arctica* has been found on the west coast of Greenland, from the southernmost parts right up to Thule ( $76\frac{1}{2}^{\circ}$  N). Not until Murchison Sound, in about  $77\frac{1}{2}^{\circ}$  N does it occur; I have myself seen recent specimens from this place, collected by the Swedish zoologist A. OHLIN at a depth of 40 m; the specimens are kept in the zoological museum in Lund.

### Conclusion.

On the basis of the examination of the localities at which *Portlandia (Yoldia) arctica* lives, and on the information available of the conditions prevailing there, we can form an idea of the life habits of this mollusc:

*Portlandia (Yoldia) arctica* is very sensitive to changes of temperature, being a "stenotherm" animal form, since it can bear only a slight variation in the temperature of the sea water, viz. from its absolute minimum (i. e. freezing point, which varies somewhat according to the salinity, and which may sink to about  $-2^{\circ}$  C.) to about  $+2.5^{\circ}$ . In shallow water, which is strongly heated in summer, it has apparently accustomed itself to bear higher temperatures, as the temperature of the bottom water may rise as high as  $4^{\circ}$  C.; but the clay mud in which the mollusc lives (i. e. its "bio-climate") is considerably colder than the bottom water and is hardly much over  $0^{\circ}$  C. Therefore *Portlandia (Yoldia) arctica* is a circumpolar animal form widely distributed in high-arctic seas; outside this area it is met with only in places where an icy current flows in (the south side of Novaya Zemlya), or where a cauldron-shaped deep is secluded from interchange with the ocean and so has icy water at the bottom (the White Sea), in other words under conditions as in high-arctic seas<sup>1</sup>.

*Portlandia (Yoldia) arctica* is not very sensitive to changes in the salinity, being an "euryhaline" animal form. The salinity in the places where it lives, near glaciers or at the mouths of large rivers, is often low, in east Greenland it has been found to be so low as  $27.6\text{ ‰}$ ; but it can also thrive in very salt water, e. g. over  $35\text{ ‰}$  on the south side of Novaya Zemlya.

<sup>1</sup> In the White Sea *Portlandia (Yoldia) arctica* should, according to KNIPOWITSCH, be regarded as a survivor from the glacial period.



In high-arctic areas it occurs often in very large numbers.

The bathymetric distribution of *Portlandia (Yoldia) arctica* generally falls between about 6 and 100 m.

Its food consists of different micro-organisms from plankton and benthos, which it devours together with the mud in which it lives.

The ability of *Portlandia (Yoldia) arctica* to subsist in such places as where glacier rivers discharge their masses of clay which colour the outflowing water milky white, covering the bottom with a layer of light grey mud, is remarkable.

Owing to the adaptability mentioned here *Portlandia (Yoldia) arctica* is presumably the most typical high arctic of all the shell-bearing animal forms; it thrives well in the icy mud discharged by the glacier rivers on the bottom of the icy seas, and can only subsist under the very hard conditions which the Polar Sea offers living organisms.

### On the distribution of *Pecten groenlandicus*.

Together with *Portlandia (Yoldia) arctica* another mollusc, *Pecten groenlandicus*, was taken on the clay plain at North Strømfjord.

The four specimens present should — on account of their considerable size, length up to 20 mm—be referred to the arctic form, since the Atlantic form, var. *minor* Locard, is a dwarf form which only attains a length of up to about 11 mm, while the species in arctic seas may attain a size of 32 mm and by COLLIN was called var. *major*<sup>1</sup>.

From West Greenland it is not known farther south than Umanak Fjord; still farther north it is known from Baffin Bay, Melville Bay, and Cape York, as also from Sherard Osborn Fjord on the north coast of Greenland (THORILD WULFF coll.). In high-northern seas it is one of the most common molluscs, and it is frequently taken together with *Portlandia (Yoldia) arctica*, e. g. in Scoresby Sound; by way of an example it can be mentioned that a dredge-haul from the North Bay taken at

<sup>1</sup> AD. S. JENSEN: The Danish Ingolf Expedition, Vol. II, 5, Lamellibranchiata, p. 32.

a depth of 10 to 18 m, on light grey clay contained 22 *Pecten groenlandicus* together with 108 *Portlandia (Yoldia) arctica*; another dredge-haul from the same locality, from the same kind of bottom, and made on the same day, yielded 69 *Pecten groenlandicus* besides 280 *Portlandia (Yoldia) arctica*<sup>1</sup>.

*Pecten groenlandicus* may thus live under the same conditions as *Portlandia (Yoldia) arctica*. It may be added, that *Pecten groenlandicus* probably is the only lamellibranch which, in Northeast Greenland fjords, constantly occurs at temperatures below 0° C.<sup>2</sup>.

### **Why is *Portlandia (Yoldia) arctica* extinct along the greater part of West Greenland? And why has it not immigrated again?**

While *Portlandia (Yoldia) arctica*, according to the above, goes down to 68°10' N on the east coast of Greenland, it stops on the west coast as far north as about 77<sup>1</sup>/<sub>2</sub>° N.

The latter is the more strange as formerly it extended much farther to the south on the West Greenland coast, as is shown by its occurrence in the raised strata. The last locality recorded from North Strømfjord lies in about 67<sup>3</sup>/<sub>4</sub>° N. That it was formerly common appears from the fact that it has often been found in raised strata on that part of the west coast of Greenland which has been specially explored, viz. the Disko Bay area (about 68<sup>1</sup>/<sub>2</sub>°—69<sup>1</sup>/<sub>2</sub>° N). Thus I have been able to examine *Portlandia (Yoldia) arctica* collected in the past from the following localities: clay-terraces at the inner end of Southeast Bay; Orpigsôk south of Christianshaab; Kiakusuk north of Christianshaab; the Clay Bay at Claushavn; Niakornak at Jakobshavn. It appeared from a special investigation made in the summer of 1906 by JENSEN and HARDER that *Portlandia (Yoldia) arctica* is very common in the raised strata on the south and southeast coasts of Disko Bay: On the north side of the large clay-plains between Tasiursarssuak and Southeast Bay (e. g. Padusarniarfik and Sarpiussak), at

<sup>1</sup> G. THORSON l. c. 1934, pp. 43—44.

<sup>2</sup> Cf. G. THORSON, Medd. om Grønland, Bd. 100, Nr. 6, p. 112. 1936.

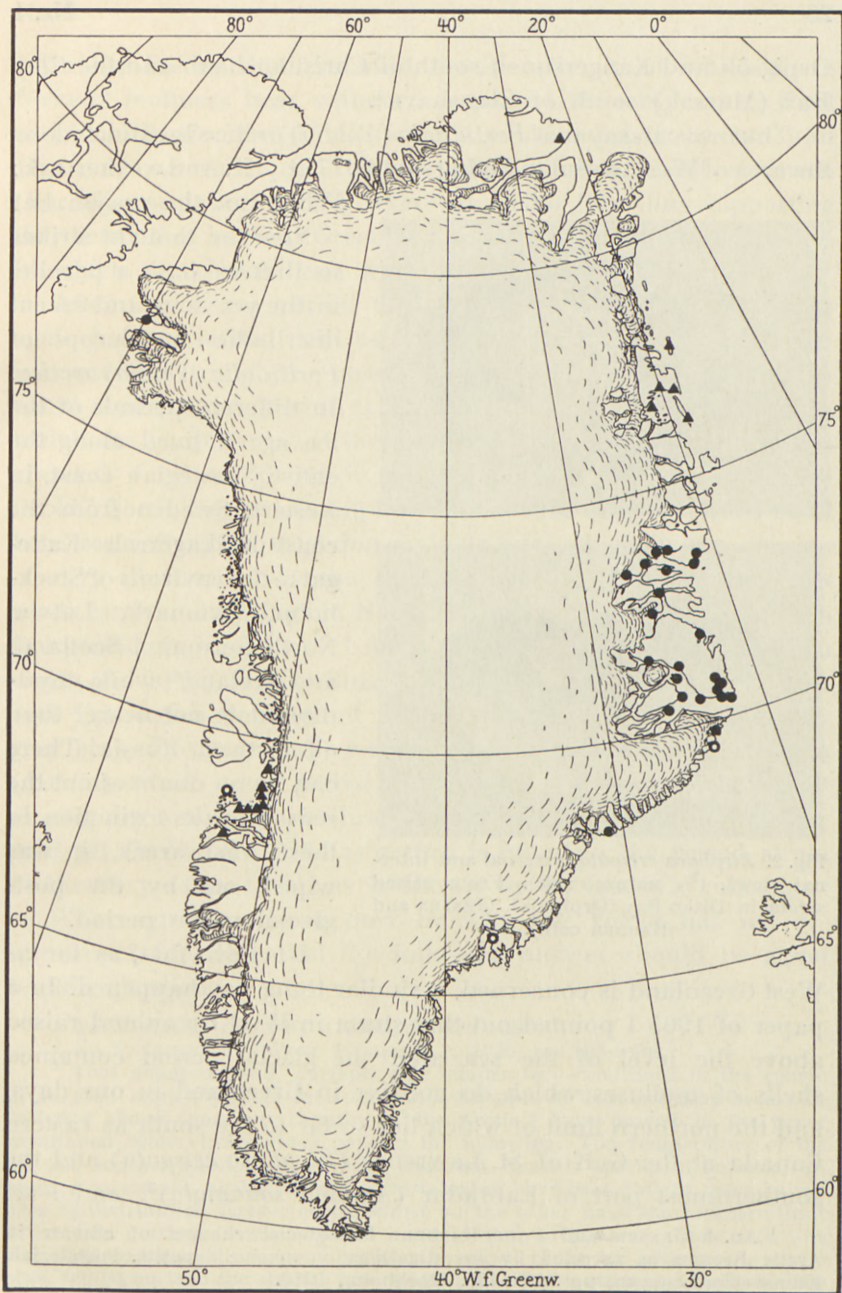


Chart 3. Sketch map of Greenland showing distribution of *Portlandia (Yoldia) arctica*.

- Occurrence of Recent specimens.
- Occurrence of dead shells on the bottom of the sea.
- ▲ Occurrence of fossil shells in raised inland strata.

Orpigsôk and Kangersunek south of Christianshaab and the Clay Bay (Marrak) south of Claushavn<sup>1</sup>.

Thus we can say that *Portlandia (Yoldia) arctica* is extinct along the area of West Greenland lying south of  $77\frac{1}{2}^{\circ}$  N. And we then ask: What can the reason be?

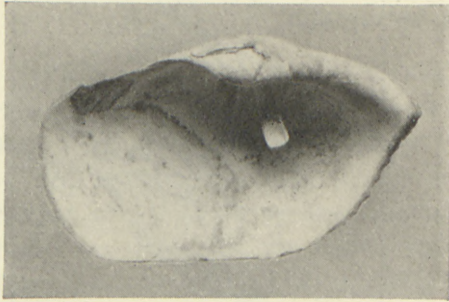


Fig. 2. *Zirphaea crispata*, external and internal views. ( $\frac{3}{4}$  natural size). From raised strata in Disko Bay (Orpigsôk). (JENSEN and HARDER coll.).

Now the thought strikes us that we have a parallel in the previous and recent distribution in Europe of *Portlandia (Yoldia) arctica*. In different periods of the ice age it lived along the entire Norwegian coast, in western Sweden from the coast of Skagerrak—Kattegat to the environs of Stockholm, Denmark, Latvia, North Germany, Scotland, and Iceland<sup>2</sup>, while nowadays it is not nearer than off northern Russia. There can be no doubt about the reason for its extinction in these vast areas, it was wiped out by the post-glacial warm period.

I believe that, as far as West Greenland is concerned, a similar thing has happened. In a paper of 1905 I pointed out that strata in West Greenland raised above the level of the sea after the glacial period contained shells of molluscs which do not live in Greenland in our days, and the northern limit of which lies so far to the south as eastern Canada at the Gulf of St. Lawrence (*Zirphaea crispata*) and the southernmost part of Labrador (*Anomia squamula*)<sup>3</sup>, and I set

<sup>1</sup> AD. S. JENSEN and POUL HARDER: Post-glacial changes of climate in Arctic Regions as revealed by investigations on marine deposits. Postglaziale Klimaveränderungen, pp. 402—406. Stockholm, 1910.

<sup>2</sup> On the American side it was once distributed right down to New England, while its southern limit is now in Richmond Gulf on the eastern side of Hudson Bay.

<sup>3</sup> On the European side of the Atlantic they have their northern boundary in West Finmark, and in the "warm area" of the White Sea and Murman coast respectively; westward they reach Iceland.

forth the theory that the mild marine climate of which these boreal molluscs bear witness has passed the temperature limit at which *Portlandia (Yoldia) arctica* could subsist<sup>1</sup>. JENSEN and HARDER<sup>2</sup> succeeded in 1906 in again finding these southern (boreal) species in raised layers at Disko Bay thus supporting the theory that in West Greenland there was a post-glacial period in which the climate was warmer than it is now<sup>3</sup>.

After this warm period the climate of West Greenland has again become colder; and as far as the temperature in its fjords is concerned it might be possible that *Portlandia (Yoldia) arctica* could again thrive there, at any rate in some of the fjords in which the temperature at the depth suitable for this mollusc lies about 0° C. But hitherto it has not been found in any of the "cold" fjords. Several examples of this could be given, but I shall here restrict myself to giving a single one, which in my opinion is very illustrative. In the summer of 1911 Dr. V. NORDMANN made several dredgings in North Strømfjord from near its mouth to its head. In his journal I find no less than 14 stations at which depth (6—60 m), temperature (−1.2°—+1.5° C.), salinity (3.09—3.45 ‰) and bottom (sand mixed with clay, grey clay, greasy grey clay, fine grey clay) were of such a nature that *Portlandia (Yoldia) arctica* could thrive there; but it was completely absent among the numerous molluscs which came up with the dredge. And yet *Portlandia (Yoldia) arctica* is found in the raised strata at the very same fjord, as is shown by BENDIXEN's collection!

What can the reason then be why the *Yoldia* has not reappeared? I believe that the following answer should be given to this question:

<sup>1</sup> AD. S. JENSEN l. c. 1905 (1909), pp. 292—297.

<sup>2</sup> AD. S. JENSEN and POUL HARDER l. c. 1910, pp. 403—404.

<sup>3</sup> That changed wind, current, and temperature conditions in the course of an even relatively short interval (the last couple of decades) have been able to bring about enormous changes in the Arctic I have proved in the paper mentioned below, from which appears the following: The temperature of the air and sea has risen, so that many southern (boreal) species of animals, including mammals, birds, fish and invertebrates, have been able to extend their area of distribution farther north, whilst on the other hand the southern limit for certain northern (arctic) species has retreated northwards. Along with this rise of temperature there has also been a retreat of the ice boundary in arctic seas, whilst on land the glaciers have been in a recessive stage and the boundary of the ground-ice is moving northwards. (AD. S. JENSEN: Concerning a change of climate during recent decades in the arctic and subarctic regions, from Greenland in the west to Eurasia in the east, and contemporary biological and geophysical changes. D. Kgl. Danske Vidensk. Selskab, Biol. Medd. XIV, 8, 1939).

After the *Yoldia* had been pushed back far northwards during the post-glacial warm period its larvae would have to go south if the species was to regain its old places of occurrence. But as is well known the currents of the sea along the west coast of Greenland go northwards, thus preventing the spreading of the larvae in a southerly direction<sup>1</sup>.

The only possibility of finding *Yoldia* in the southern part of West Greenland would be if it had subsisted as a survivor (relict) from the glacial period in some "cold" fjord; I dare not deny the possibility of its surviving as such, but hitherto it has not been found.

### On remains previously found of an arctic fauna in raised deposits far within North Strømfjord.

In the year 1879 the geologist KORNERUP travelled by woman's boat (Umiak) in North Strømfjord and its southern principal branch and a river debouching there (Nagssugtôk river) which springs from the inland ice<sup>2</sup>. More than 150 km from the mouth of the fjord KORNERUP found the following bivalves, determined by TRAUSTEDT, in a low clay terrace along the sides of the river: *Mya arenaria* L., *Mya truncata* L., *Saxicava rugosa* L., (= *S. arctica* L.), *Astarte striata* Leach (= *A. Montagu* Dillw. var. *striata* Leach), *Cardium ciliatum* Fabr., *Pecten islandicus* Ch. and *Telina calcarea* Ch.<sup>3</sup>.

This fauna resembles that which now lives in West Green-

<sup>1</sup> There can be no doubt that *Portlandia (Yoldia) arctica* has pelagic larvae. THORSON kindly informed me that in August 1932 he watched larvae taken by plankton hauls in Northfjord, in the Franz Joseph Fjord area, of a very characteristic, barrel-shaped appearance which he had no doubt were the larvae of a taxodont mollusc. In Northfjord *Portlandia (Yoldia) arctica* was the dominant species, and as other taxodont molluscs can be left out of consideration, THORSON considers it very likely that the pelagic larvae observed were *Portlandia (Yoldia) arctica*. The peculiar thing in this type of larva—in contrast to other molluscan larvae—is, according to THORSON, that in its free-swimming stage it develops exclusively on its own yolk mass, and does not absorb nourishment from the outside which is made impossible because its shells are completely surrounded by surface cells (test cells). It is thus possible for it to spread through the sea without running the usual risk of pelagic larvae of perishing through the absence of nourishment.

<sup>2</sup> Reference is made to an excellent chart by the leader of the expedition I. A. D. JENSEN in Medd. om Grønland, 2. Hefte, 1881, plate V.

<sup>3</sup> A. KORNERUP: Geologiske lagtagelser fra Vestkysten af Grønland, p. 187; Medd. om Grønland, 2. Hefte, 1881.

land. Thus we find remains both of a high-arctic and of an arctic fauna in the raised strata in North Strømfjord; this

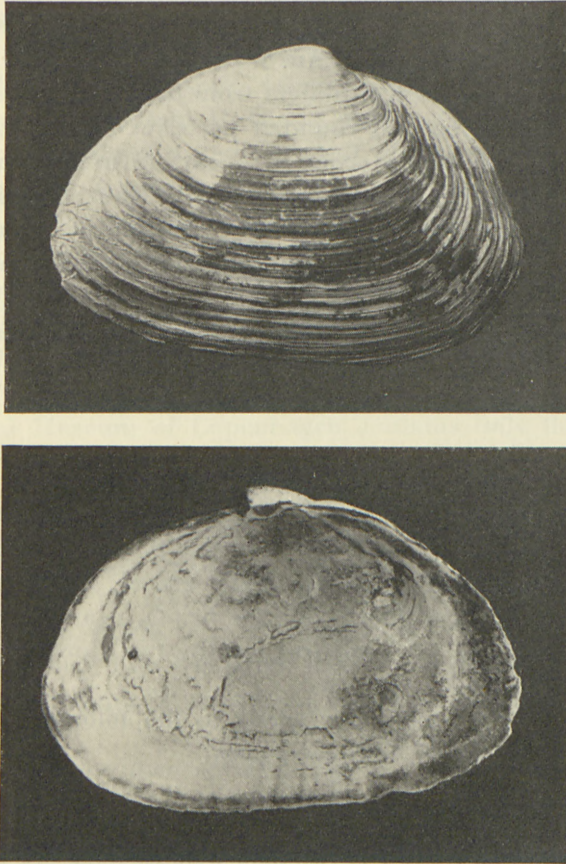


Fig. 3. *Mya truncata f. ovata*, external and internal views. ( $\frac{0}{11}$  natural size).  
From raised deposits far within North Strømfjord (collected by KORNERUP).

arctic fauna probably corresponds to that found in South Strømfjord and discussed in the next chapter.

The recorded occurrence of *Mya arenaria* which—as I showed on a previous occasion<sup>1</sup>—is not an arctic species, seems to be against this supposition. An examination of the shells kept in the Zoological Museum of Copenhagen, six in all, shows, however,

<sup>1</sup> AD. S. JENSEN: Studier over nordiske Mollusker, I, *Mya*. Vidensk. Medd. Naturhist. Foren. 1900, p. 133.

that they resemble, truly enough, *Mya arenaria* in their contours, but that they agree with *Mya truncata* in the decisive characters: the safest distinguishing marks are found in the ligament plate in the left valve and the ligament pit in the right valve and in the beak of the left valve (cf. AD. S. JENSEN l. c. fig. 1 a, b and fig. 2 a, b). This variety, which differs from the typical *Mya truncata* by the oblong shape and rounded posterior end of the shell, I called *A. truncata* forma *ovata*. It occurs in arctic seas, also in West Greenland. Thus, it was taken by V. NORDMANN in 1911 in North Strømfjord, at depths from 6 to 18 and 80 metres, where the bottom consisted of clay, the temperature being by the end of July about 0° C.

The fauna found by KORNERUP in the raised strata at the Nagsugtök river is thus as a whole arctic.

### The locality at South Strømfjord.

According to Mr. BENDIXEN there are, inside the head of the Itivdlek-Fjord, in the region between this fjord and South Strømfjord, deposits of clay, and especially gravel, with huge masses of shells, especially a little inside the beach, near the lake which fills up part of the interval between the two fjords<sup>1</sup>; the height is about 35 m above the sea.

The shells collected here belong to the following species of molluscs, gasteropods, and barnacles:

*Pecten islandicus* Müll. 1 shell of an adult specimen (alt. 104 mm, lat. 97 mm). A fragment, also of an adult specimen, with holes bored by the polychaete *Polydora* on the inner side.

*Cardium ciliatum* Fabr. Fragments of 6 shells of large and medium-sized specimens.

*Astarte borealis* Ch. 1 shell of an adult specimen.

*Cyprina islandica* L. 1 left valve of an adult specimen (alt. 77 mm, lat. 81 mm). A fragment of a shell, also of an adult specimen, with holes bored by *Polydora* both on the outer and inner sides.

*Panopaea norvegica* Spengl. One right valve, rather thick, of

<sup>1</sup> This plain is known under the name Itivnek and formerly was the place where the Greenlanders carried their woman's boats from one fjord to the other.



an adult specimen (alt. 49 mm, lat. 82 mm). 1 left valve of a somewhat smaller specimen (alt. 45 mm, lat. 68 mm).

*Saxicava arctica* L. 2 right valves, rather thick, 30 and 31 mm long; one with two holes bored by *Natica*, of which, however, only one penetrated the valve.

*Mya truncata* L. 1 shell, 50 mm long.

*Buccinum undulatum* Møller. 2 specimens.

*Balanus Hammeri* Ascan<sup>1</sup>. 8 shell plates, alt. max. 75 mm.

Among the fossils from this locality one notices *Cyprina islandica* in the first place, as it can be taken for granted that it no longer lives in Greenland.

*Cyprina islandica*, has, it is true, previously been included in the lists of the molluscan fauna of Greenland by MØRCH (1857 and 1877), and POSSELT (1898), but in my opinion on doubtful grounds. The Greenland collection of molluscs kept in the Zoological Museum of Copenhagen contains only the following (dating from the first half of the last century):

a. A right valve, according to the label taken in Davis Strait. It is of a very old appearance, and may derive from a submarine layer or may have been carried passively out into the strait from a deposit on land.

b. The two valves of a shell, 43 mm long, according to the label originating from RUDOLPH, who was a physician in Jakobshavn. Periostracum is preserved, but there are no traces of the soft parts.

The latter specimen seems to me to be dubious; it may also be that a change of labels has taken place in the course of time, since it is unthinkable to me that such a mollusc as *Cyprina islandica* should have escaped attention if it did live at Greenland nowadays. Its size is in itself remarkable, so it cannot have been overlooked, as the west coast of Greenland is well explored as far as the coastal belt is concerned. It should also be borne in mind that *Cyprina islandica* is often washed ashore on the beach off which it lives; but it is not found among the large

<sup>1</sup> Everywhere in the literature the name is written erroneously *Hameri*, because ASCANIUS used this spelling by a mistake; he says himself that he named the species after the county sheriff in Finmarken G. HAMMER who was the first to find and give him this barnacle. The specific name should, therefore, be written *Hammeri*, according to HJ. BROCH: *Cirripedia Thoracica* von Norwegen und dem Norwegischen Nordmeere, p. 90. Vidensk. Selsk. Skrifter, I, Mat.-Naturv. Klasse, 1924, No. 17. Kristiania 1924.

number of shells washed ashore and brought home from Greenland. I have myself looked for it during my Greenland expeditions

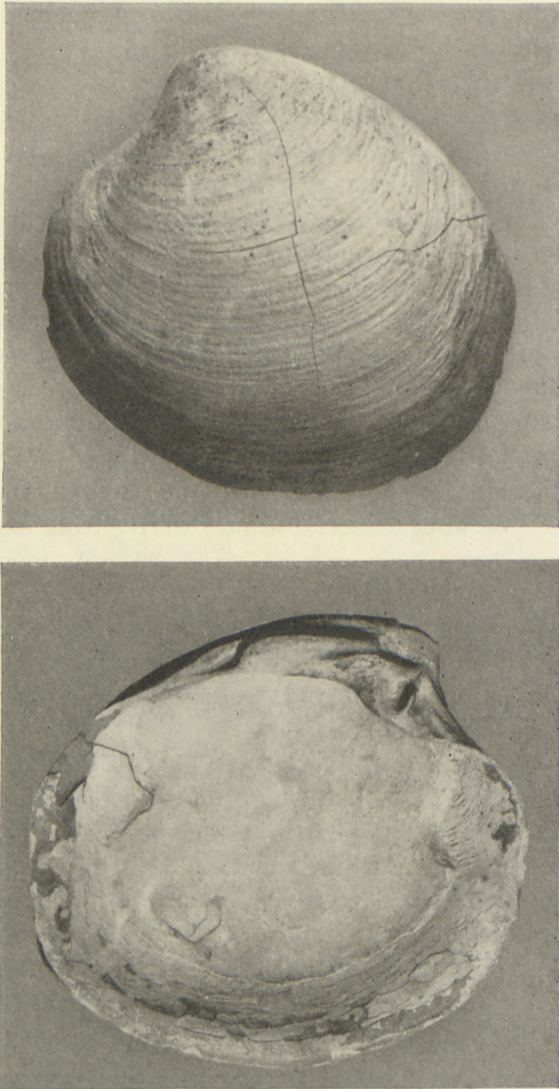


Fig. 4. *Cyprina islandica*, external and internal views. ( $\frac{3}{4}$  natural size). From raised deposits in South Strømfjord.

by dredging or among the shells washed ashore, e. g. in Disko Bay, where Jakobshavn is situated, but in vain.

The literature also contains records to the effect that *Cyprina islandica* occurs in other arctic seas. On a previous occasion I have gone critically through these records also, and I succeeded in showing that they are erroneous<sup>1</sup>.

After deleting the arctic localities for *Cyprina islandica* its present range of distribution should be limited as follows:

In North America *C. islandica* occurs from Cape Hatteras to New Foundland Bank and the southern part of the Gulf of St. Lawrence. In Europe it is distributed from southwestern France to the Murman coast and the "warm area" of the White Sea, and westwards it extends over the Faroes to Iceland; from the Kattegat it enters the Sound and through the Belts it penetrates into the southwestern Baltic.

*Cyprina islandica* has not, as previously presumed, a boreal and arctic distribution, but is a distinctly boreal form.

On account of this knowledge of the present distribution of *Cyprina islandica* this mollusc can be reckoned to be a leading fossil *par excellence*: Its presence in deposits on land gives evidence that they were formed under boreal climatic conditions.

Among the rest of the shells two belong to a mollusc which possibly lives no longer in Greenland, viz. *Panopaea norvegica*. The literature contains numerous records of this mollusc in different sea areas, and it is described as having a circumpolar distribution. But if the original records be examined it is found that they nearly always refer to "dead" shells. As regards Greenland, we have from here only empty shells<sup>2</sup> dredged in the following place:

North Strømfjord, 375—380 m, bottom temperature 0.2 C. V. NORDMANN legit 1911. Two valves with periostracum partly intact and connected by the ligament, but empty; length 66.5 mm, altitude 45 mm. Also a right valve, length 61.5 mm, altitude 39 mm; a left valve, length 61 mm, altitude 38 mm.

In addition some ten fossil specimens have been collected in the raised strata at Pagtorfik in Umanak district, up to 110 mm long, with shells connected.

<sup>1</sup> AD. S. JENSEN: Studier over nordiske Mollusker. II. *Cyprina islandica*. Vidensk. Medd. naturhist. Foren., 1902, pp. 33—42.

<sup>2</sup> POSSELT writes (Grønlands Brachiopoder og Bløddyr, 1898, p. 94), that *P. norvegica*, according to WOODWARD'S Manual, was taken alive in Baffin Bay. I have not been able to find anything to this effect in WOODWARD.

In European waters *Panopaea norvegica* occurs alive, at any rate in the North Sea, especially on the Dogger Bank, according to JEFFREYS. G. O. SARS has taken a young specimen near Lofoten, and AURIVILLIUS two specimens (long. max. 65 mm) in Kvæningen Fjord, in the northernmost part of Tromsø county,

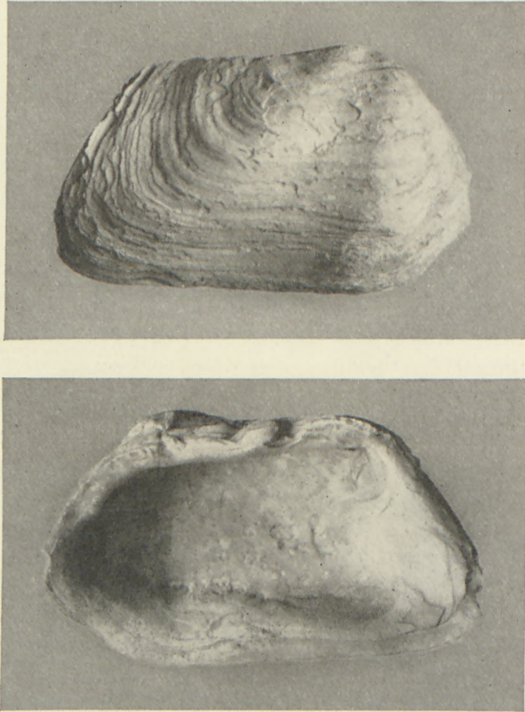


Fig. 5. *Panopaea norvegica*, external and internal views. ( $\frac{7}{10}$  natural size).  
From raised deposits in South Strømfjord.

on the boundary towards West-Finmarken. Further, the Icelandic zoologist, BJARNI SÆMUNDSSON long ago sent me a specimen taken on line near South Iceland (Vestmannø) in 65 fms.; it was 100 mm long, 58 mm high and contained the soft parts; finally, SÆMUNDSSON informed me that he had still another specimen from the same place, also alive, about 70 mm long. It has also been taken alive near the Skaw, in a few places in the eastern Kattegat, and off Landskrona.

If conclusions should be drawn only from the places in which *P. norvegica* has been found to occur alive—from northern

Norway and southern Iceland to the North Sea and the Sound—it should be regarded as a boreal form, and its occurrence in Greenland then derives from a warmer period than the present. But as *P. norvegica* lives buried in the bottom and therefore is difficult to take with the dredge the possibility exists that it may be found alive in arctic seas, from which only its empty shells are now known.

A different form of *P. norvegica* was described by DONS as var. *triangula*: shell thick, shape triangular, length: altitude = about 4:3; greatest length 70 mm. In *P. norvegica f. typica* the shells are of medium thickness or thin, trapeziform, length: altitude = 5:3; greatest length 102 mm. DONS regards the variety *triangula* as a high-arctic form like the variety *uddevalensis* of *Mya truncata*, and the typical form as boreal<sup>1</sup>. All the shells found in Greenland belong to *f. typica* and should thus be referred to the boreal climatic period.

It can be said about the remaining molluscs from this locality, viz. *Pecten islandicus*, *Cardium ciliatum*, *Astarte borealis*, *Saxicava arctica*, *Mya truncata* and *Buccinum undulatum*, that they live in West Greenland waters and are common there nowadays and thus belong to an arctic fauna. On the other hand, it is probable that some of the species recorded have lived together with *Cyprina islandica*, since they have a wide distribution and occur both in boreal and arctic seas. This is the case of *Mya truncata*; the only valve available is rather elongate and may occur both in arctic and boreal seas<sup>2</sup>. On the other hand, *Pecten islandicus*, *Cardium ciliatum*, the thick-shelled *Saxicava arctica* and *Buccinum undulatum* may be regarded as belonging to the arctic faunistic element.

As regards the distribution of *Balanus Hammeri* the following can be said: This barnacle, remarkable from its size, which, as a fossil, was first known from Scandinavia under the name *Balanus Uddevallensis*, is given the following distribution by CHARLES DARWIN in his famous work on the *Cirripedia*: The British islands, Finmarken, the Faroes, Iceland and Mas-

<sup>1</sup> CARL DONS: Zoologiske Notiser X. *Panopæa norvegica* var. *triangula* nov. var. Det Kgl. Norske Vidensk. Selskabs Forhandl. Bd. IV, Nr. 2, 1931, p. 5, Fig. 1—4.

<sup>2</sup> AD. S. JENSEN: Studier over nordiske Mollusker, I, *Mya*, pp. 153—156, Fig. 8 a, b and c. Vidensk. Medd. Naturhist. Foren., 62. Aarg., 1900 (1901).

sachusetts<sup>1</sup>. Since then its northern limit has been extended to the White Sea<sup>2</sup> and Nova Scotia<sup>3</sup>. BROCH also records *B. Hammeri* from a series of localities along the Norwegian coast at depths from about 40 to 120 metres<sup>4</sup>. In the Zoological Museum of Copenhagen are specimens from the North Sea and the Skagerrak (NE of the Skaw, 70 fms. and 33 miles SE of Okso,

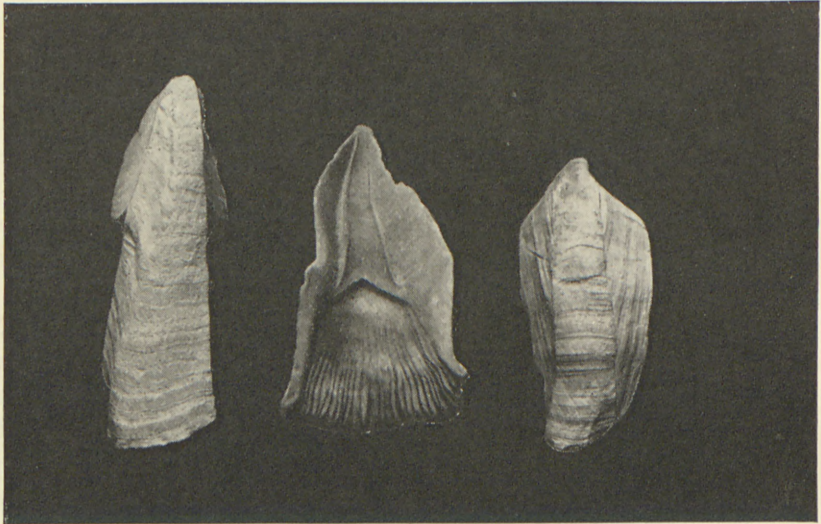


Fig. 6. *Balanus Hammeri*, 3 shell plates, that in the middle seen from the inside, the two others from the outside. ( $\frac{2}{3}$  natural size). From raised deposits in South Strømfjord.

259 metres). From Greenland it was known only as a fossil, but in 1911 V. NORDMANN got a living specimen up with the dredge in North Strømfjord from a depth of 14—38 m and at a bottom temperature (end of June) of  $0.3^{\circ}$ — $0.2^{\circ}$  C. According to the distribution hitherto known *B. Hammeri* would be characterized as a purely boreal species<sup>5</sup>; but it actually appears that it can also live under arctic conditions at a temperature which, in the middle of the summer, is very near  $0^{\circ}$  C. *Balanus Hammeri* should consequently be designated both as a boreal and arctic

<sup>1</sup> DARWIN: A monograph on the sub-class *Cirripedia*, vol. II, p. 277. The Ray Society, 1854.

<sup>2</sup> WELTNER: Die Cirripeden der Arktis. Fauna Arctica, I, p. 298. 1900.

<sup>3</sup> DAWSON: The Canadian Ice Age, 1894, p. 262.

<sup>4</sup> HJ. BROCH l. c. 1924, pp. 89—90.

<sup>5</sup> Cf. HJ. BROCH l. c. 1924, pp. 114—115.

species. It is also in good agreement with this that in the series of strata in Disko Bay (Orpigsôk and South East Bay) *B. Hammeri* is frequently met with in the layers the fauna of which resembles that living at present in West Greenland<sup>1</sup>.

### Conclusion.

From the locality at South Strømfjord we have, according to the above, two fauna-elements represented, viz. a boreal and an arctic. The certain representative of the boreal element is *Cyprina islandica*, which no longer lives in Greenland, but belongs to warmer seas. The other species are good arctic species, at present occurring in Greenland. Most likely *Pecten islandicus* and *Cardium ciliatum* together with *Buccinum undulatum* and the thick-valved *Saxicava arctica* represent an arctic level; the two last mentioned forms are found exclusively in arctic waters, and *Pecten islandicus* and *Cardium ciliatum* have such narrow distributions that they occur only now and then together with *Cyprina islandica*, whereas the latter, in many places, lives together with *Astarte borealis*, *Mya truncata*, and *Balanus Hammeri*. To which group *Panopaea norvegica* should be reckoned is doubtful; in Greenland it has hitherto been taken only as a fossil, living specimens are only known from more southern seas; but, being a species which lives buried in the sea bottom, it may have escaped capture in Greenland.

### Summary.

We see thus that remains of animal species of high-arctic origin have been found in the raised shell deposits at North

<sup>1</sup> For completeness' sake it should be mentioned that Inspector BENDIXEN found still another deposit from the Quaternary period in Holsteinsborg District with remains of marine animals. The fjord Ikertôk is situated south of the Holsteinsborg settlement and has three branches, of which Avatdlek runs to the southeast. At the head of Avatdlek fjord Mr. BENDIXEN found marine shells in a deposit 70—80 metres above the present level of the sea, i. e. on the same level as in Depot Bay. Three shells were brought home of *Mya truncata*, very thick ones, the posterior end short, obliquely cut off and sloping forwards to the ventral side, and thus having a high-northern appearance. There is also a valve of *Tellina calcaria* Chemn. (with a hole bored by *Natica*).

Strømfjord; at South Strømfjord they are of an arctic and boreal character. The question then arises in what sequence these faunas have followed each other.

The detailed stratigraphy of these deposits being unknown, reference must be made to a paper by the geologist POUL HARDER, whose early death we regret, and the present author, in which, on the basis of investigations which we made in 1906 into the raised marine deposits in the southeastern part of Disko Bay, we have been able to form the following review of the quaternary-geological history of this region<sup>1</sup>.

The oldest layers (horizon A) were deposited in a sea on the bottom of which lived high-arctic forms such as *Portlandia (Yoldia) arctica*.

Then follow layers (horizon B) with a fauna indicating a climate which was not high-arctic but rather like that of the present time, i. e. arctic.

In the next layers (horizons C and D) the gradual change of the fauna indicates that the climate has gradually become colder until it became high-arctic characterized by *Portlandia (Yoldia) arctica*; at the same time a considerable sinking occurred, so that the sea-level stood about 100 m higher than at present.

The fauna in the following layers (horizon E) shows that these were deposited under conditions similar to those which now prevail in the sublittoral region; these layers have been formed at a time when the land had again been raised to a height of about 50 m below the present level and the climate had become almost as at present.

In the most recent link in the series (horizon F) the southern (boreal) forms *Anomia squamula* and *Zirphaea crispata* are found which were hitherto unknown in Greenland, the latter in such large numbers that it was found to be common throughout the whole deposit of strand gravel up to 7 m in thickness. The occurrence of these boreal forms shows that the temperature rose during the further raising of the land, so that there has been a temperature maximum at a time when the sea stood only about 10 m higher than at present, but single specimens of them were also taken up to a height of about 30 m.

<sup>1</sup> AD. S. JENSEN and POUL HARDER, l. c. 1910, pp. 402—406 and the scheme with the horizons (p. 405).



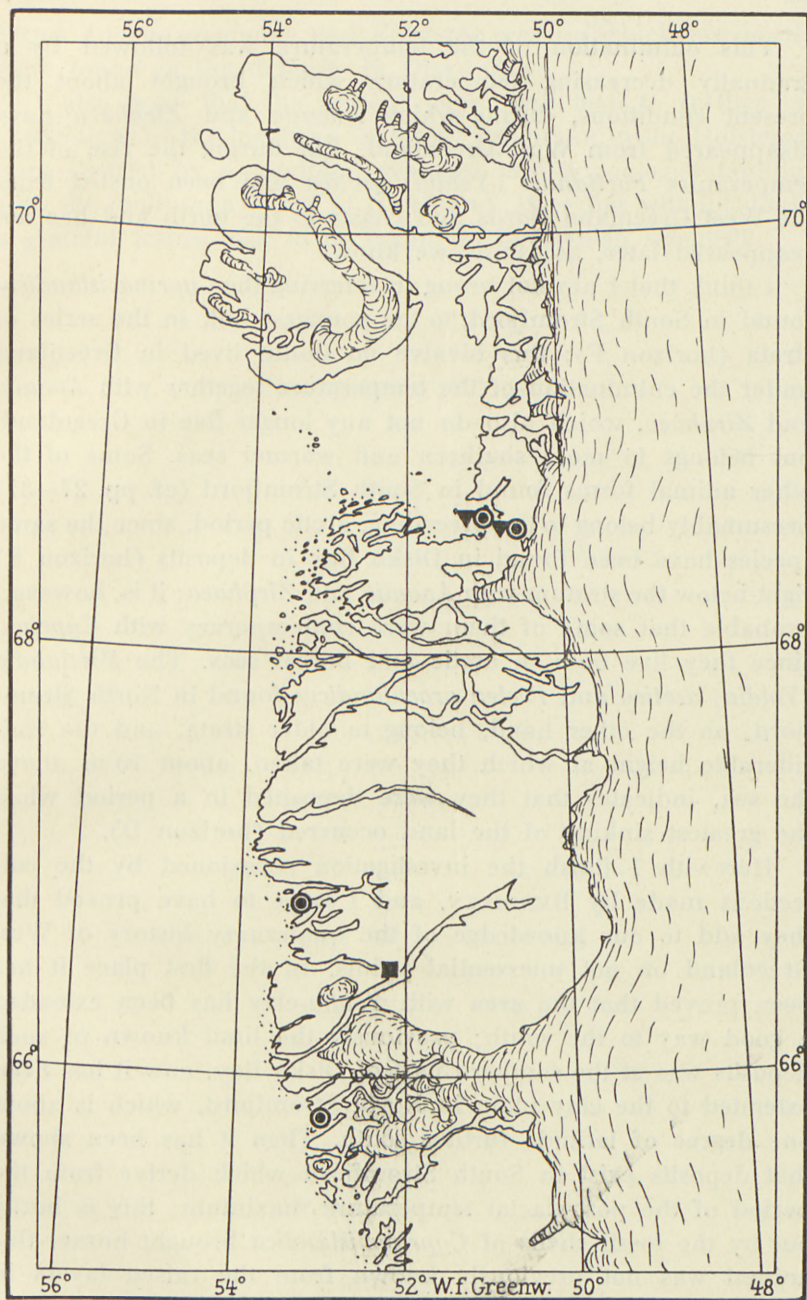


Chart 4. Localities for fossil shells of thermophile molluscs in raised strata on the west coast of Greenland from the post-glacial warm period.

- *Anomia squamula*.
- ▼ *Zirphaea crispata*.
- *Cyprina islandica*.

This culmination of the temperature was followed by a gradually decreasing temperature which brought about the present conditions, during which *Anomia* and *Zirphaea* have disappeared from West Greenland. But during the rise of the temperature *Portlandia* (*Yoldia*) *arctica* had been ousted from the West Greenland fjords and coasts to the north and has not reappeared later, as far as we know.

I think that I am not wrong in referring the *Cyprina islandica*, found in South Strømfjord, to the youngest link in the series of strata (horizon F); this bivalve no doubt lived in Greenland under the culmination of the temperature together with *Anomia* and *Zirphaea*, which also do not any longer live in Greenland, but belongs to more southern and warmer seas. Some of the other animal forms found in South Strømfjord (cf. pp. 27—31) presumably belong to the preceding, arctic period, since the same species have been found in Disko Bay in deposits (horizon E) right below the stratum with *Anomia* and *Zirphaea*; it is, however, probable that some of them were contemporary with *Cyprina*, since they live both in arctic and boreal seas. The *Portlandia* (*Yoldia*) *arctica* and *Pecten groenlandicus* found in North Strømfjord, on the other hand, belong to older strata, and the considerable height at which they were taken, about 70 m above the sea, indicates that they were deposited in a period when the greatest sinking of the land occurred (horizon D).

Herewith I finish the investigation occasioned by the collections made by BENDIXEN, and I hope to have proved that they add to our knowledge of the quaternary history of West Greenland on not unessential points. In the first place it has been proved that the area with *Yoldia*-clay has been extended a good way to the south; previously the limit known of such deposits was at the southern part of Disko Bay, now it has been extended to the clay plain in North Strømfjord, which is about one degree of latitude further south. Then it has been shown that deposits exist in South Strømfjord which derive from the period of the post-glacial temperature maximum; this is borne out by the fossil shells of *Cyprina islandica* brought home; this animal was not previously known from the raised layers in West Greenland, and as a leading fossil it equals the boreal

forms *Anomia squamula* and *Zirphaea crispata* which previously were found in the deposits in Disko Bay.

I also hope that the present paper will lead to further investigations of the localities found by BENDIXEN in the Holsteinsborg District by a qualified geologist and a zoologist familiar with the molluscan fauna of Greenland. Here lies without doubt a grateful future task to be taken up by Danish scientists.