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THE EAST GREENLAND ICE

BY

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WITH 140 FIGURES IN THE TEXT
AND 1 PLATE

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PREFACE

Fog and ice are invariably associated with each other. Looking back upon the twenty-five years (1913—38) in which I have been travelling in the Greenland waters, it seems to me that I have experienced a greater number of foggy than of clear days in and on the ice. During the sledge journeys in the autumn in Northwest Greenland the fog always lay over the open sea and often spread shoreward across the ice. During the sledge journeys in the spring we experienced long periods of foggy weather, and in the summer the fog always lay low over the wet ice tundra of the Polar Basin. And fog obstructed our view from the aircraft, whether we were looking from the shore across the Polar ice or we were approaching the ice from the east, when the belt of fog would be encountered where the warm water of the Atlantic met the cold stream of ice.

If one approaches the east coast of Greenland in a ship, the ice floes will be seen to pass by in the fog. It is impossible to decide their size or whether the ice is close-packed or open. Sometimes a ship may lay immovable in the ice belt for weeks. The phases of the moon and accordingly the amount of ebb and flood tide will change, and the wind will blow from different quarters. But conditions will remain unaltered, till suddenly one day the ice will scatter from no traceable cause, and the way to the shore will be free.

At the outset it seemed a hopeless task to subject the drift ice to a scientific investigation. The present paper was first planned to be a brief survey of the ice conditions along the east coast of Greenland during the years in which I visited this coast; but gradually the whole of the East Greenland Ice was included in the investigation, and thus it was possible to consider the quantities of ice found around Iceland and along the south coast of Greenland on a somewhat broader basis than done for the period covering the last 119 years by Th. Thoroddsen (1917) and C. I. H. Speerschneider (1930), and it became natural to go even farther back in time and to consider, also, the fluctuations in the climate in the past centuries.

My interest in this subject was first aroused on a fine summer day twenty years ago, which I spent in the company of FRIDTJOF NANSEN, who was then much occupied with a work he had just sent to press (NANSEN 1925). That day he ardently advocated the view that no fluctuations in the climate had taken place since the Middle Ages, but although the subject was new to me, there seemed to me to be some obscure points in his argumentation. Now, twenty years later, I have arrived at quite different views from those then advocated by NANSEN.

In 1911 FRIDTJOF NANSEN published his book on the earlier journeys to the Polar tracts, which he called "Nord i Tåkeheimen" ("In Northern Mist"). This title has reference both to the fog, which means an obstacle to all journeys in the Arctic, and to the obscurity of earlier historical sources; as is well known, our knowledge of the conditions prevailing in Iceland and southern Greenland in earlier times is derived from documents whose contents were transmitted verbally from generation to generation for centuries before they were written down.

To everyone who has occupied himself with the early history of Iceland and Greenland this is a well known fact, and during the preparation of the present work I have often felt the uncertainty of the material on which I based it. Just as, sailing in ice, one often strays into blind alleys, I have often had to cancel chapters already written because of the insufficiency of the material on which they were based. Nobody knows better than myself the uncertainty of much of the material utilised in the present paper; even information on the ice conditions within the present century should often be employed with great criticism.

However, in spite of this uncertainty, it grows constantly clearer the more one deals with the subject that the reports on the ice down through the ages contribute to our understanding of changes in the climate in the past centuries; these changes hardly amount to many degrees centigrade, but they have exerted a great influence on the life of man.

Every year the information supplied by a number of sciences, principally archaeology, zoology, glaciology and in most recent years meteorology, tells us that the conditions under which men and animals lived in Iceland and Greenland in former times differed from those known to prevail during the last few decades of the last century.

In the present work I have attempted to obtain contributions to our understanding of the earlier development in these regions from the drift ice. The available information on the drift ice is almost exclusively derived from the northern Atlantic; but the cause of the variations in the quantities of ice must be traced back to the Polar Basin, whence the information available is very scanty.

It was my hope that I should be able to compare the results arrived at as to the climatic fluctuations in Iceland and southern Greenland with the conditions in different European countries, but this has been impossible, a great part of the literature, including also the most recent literature, required for such a comparison being inaccessible at present owing to the war. For the same reason the investigation could only be carried up to 1939, and even the data from this year are incomplete.

Miles and kilometres are used somewhat indiscriminately, but in several instances I have given the distances in nautical miles, the only practical unit of measurement to ice navigators.

It is my pleasant duty to express my thanks to FRIDTJOF NANSEN, who first aroused my interest in the problems dealt with in the present paper, and to a great number of persons who have placed their experience from earlier times or from regions of which I have only a slight knowledge, at my disposal, persons who have given me information about subjects I had to touch upon and of which they had a much better knowledge than I, and persons with whom I have cooperated to a greater or smaller extent during my journeys in Greenland.

For information about the ice conditions along northwestern Greenland I thank Generals A. W. GREELY and A. BRAINARD (U. S. Lady Franklin Expedition 1881—84), PEARY's captain BOB BARTLETT, and PEARY's travelling companion on his trip to the North Pole, M. HENSON. I further thank Professor D. B. MACMILLAN and Professor E. EKBLAW (Crockerland Expedition 1913—17), and V. STEFANSSON for information about the ice conditions west of Greenland. I am likewise indebted to a number of Eskimos whom I met during my five years' stay in Northwest Greenland; mention should especially be made of the five Eskimos who accompanied PEARY to the North Pole, Dr. COOK's and MACMILLAN's travelling companions, ASTRUP's companion on his journey into Melville Bugt, and last but not least, the Eskimos who accompanied me on my numerous sledge journeys, and whose great experience contributed to their successful accomplishment.

My special thanks are due to Dr. KNUD RASMUSSEN, Mr. PETER FREUCHEN, and Captain P. PETERSEN for much valuable information about the ice conditions in Northwest Greenland.

For information about the ice conditions in other parts of the Polar Basin I also, in addition to FRIDTJOF NANSEN, thank OTTO SVERDRUP, N. A. TRANSEHE, Sir HUBERT WILKINS, Mr. C. B. EIELSON, and General U. NOBILE.

To ROALD AMUNDSEN I am especially indebted for some very interesting discussions on the ice conditions in the waters between Spitsbergen, Greenland, and the North Pole before and after his first flight over the Polar Basin in 1925.

As to the East Greenland Ice I have drawn support from my own experience as well as from the experience gained during the earlier exploration of the east coast of Greenland. I may here mention GUSTAV HOLM, C. RYDER, C. F. WANDEL, G. C. AMDRUP, N. HARTZ, H. DEICHMANN, J. P. KOCH, A. TROLLE, and the Greenlander TOBIAS GABRIELSEN, whose great experience of travelling in the Arctic and intimate knowledge of the ice conditions in Northeast Greenland were of great benefit to me when he accompanied me on my sledge journey from Scoresbysund to Danmarks Havn and back to Scoresbysund in 1927. I likewise thank EJNAR MIKKELSEN, KAJ R. DAHL, and the second mate on the Nathorst Expedition in 1899, I. MENANDER.

Not only before and after, but also during my voyages to East Greenland I was able to exchange knowledge with a number of persons who conducted expeditions to Greenland at the same time as myself. Thus I thank Dr. J. B. CHARCOT, Mr. J. M. WORDIE, Mr. BOB BARTLETT, Miss LOUISE A. BOYD, and Captain L. SCHELDERUP, because they always willingly informed me over the wireless of the ice conditions, which information was often very useful to me.

For information about the ice conditions near Angmagssalik I thank the earlier generation of ship's captains in the Royal Greenland Trade, viz. H. SCHOUBYE and JUL. HANSEN, whose great experience of these regions has been of great aid to me.

Special thanks are due to the captains serving on my own expeditions. The history of Arctic exploration affords several examples of strained relations between the leader of the expedition and the captain of the ship. If good cooperation is to be attained, the leader and the captain must have confidence in each other, for the leader will often try to induce the captain to perform manoevres which may mean a risk to the ship. However, I have only bright memories from my cooperation with the captains, whom I thank for the interest and understanding they have always shown me, viz. R. N. TVING (1920), H. G. NORDHOEK (1929 and 1931), H. ROSFELDT (1931, 1932, 1936, 1937, and 1938), J. C. WESTMAR (1932, 1933, and 1934), M. JØRGENSEN (1938), and the ice pilot L. M. COULETT SVENDSEN (1930).

What has been said about the captains applies in equal extent to the air pilots serving on the expeditions, who have with great interest and care supplied me with information about the ice. I here thank V. PETERSEN (1932 and 1933), E. OVERBYE (1932, 1933, 1934, and 1938), J. MÜNTER (1932), H. HARMS (1932), T. PETERSEN (1933), E. SUNDBYE (1938), R. MAYR (1938), and W. LONSDALE (1938).

Of the wintering members of my expeditions who have supplied me with observations on the ice I may especially mention Dr. P. GEL-

TING, Dr. E. NIELSEN, Dr. THORVALD SØRENSEN, the wireless operator A. DUEGAARD, and the author E. DRASTRUP.

The late author during many years of the year-books issued by the Meteorological Institute of Copenhagen, Mr. C. I. H. SPEERSCHNEIDER, has supplied me with valuable information, while the present author of the year-book, Mr. HELGE THOMSEN, has placed data from recent years as well as unpublished observations on the ice in 1939 at my disposal. I likewise thank Commander E. H. SMITH (Marion Expedition) and Dr. J. ZUKRIEGEL for numerous written data.

Of my collaborators in the preparation of the present work I am especially indebted to Messrs. A. KIILERICH and E. HOVMØLLER for much valuable information. At my request they have written a hydrographic and a meteorological report respectively on the conditions in East Greenland; both these papers are now in press. Furthermore I am indebted to Mr. GUDNI GUDJONSSON, who has translated several passages in the Icelandic literature to me and has called my attention to varions Icelandic papers, and with whose assistance I have prepared the diagrams showing the ice conditions around Iceland during the last 1100 years; to Dr. A. ROUSSELL, who has read the chapter on the Norsemen in South Greenland; and to Dr. ERIK HOLTVED and Mr. P. V. GLOB, who have read the chapters on the Eskimo migrations; in addition I thank Dr. HOLTVED for placing his manuscript on his investigations in Northwest Greenland at my disposal before publication.

Finally I thank my companion on numerous expeditions, Mr. G. SEIDENFADEN, who has taken the greater number of the photographs illustrating the present paper.

Copenhagen, *May 1944.*

I.
ICE TERMINOLOGY

INTRODUCTION

The subjoined account is chiefly based on personal experience and observations made on journeys along the coasts of Greenland during twenty-five years (1913—1938).

Since the climate of Greenland has changed during these twenty-five years, in unequal degree in the different parts of the country, I think it appropriate to give a brief summary of my journeys in the various districts in order to show in which years I visited the particular districts and from which periods within the twenty-five years my experience is derived.

In addition to my own observations I have received reports on the ice conditions from a great many members of my expeditions who have wintered in Greenland. The information gained in the summer is, of course, especially copious if the expeditions comprised more than one ship as well as airplanes. In 1935, Mr. E. OVERBYE, who had acted as pilot on several of my summer expeditions to East Greenland, with the permission of the Naval Ministry made ice observations and prepared ice charts at my request. As to the year 1939 Dr. A. MITTELHOLZER and my companion on several expeditions, Captain H. ROSFELDT, have supplied me with numerous observations. Finally, some of the Danish trappers wintering in East Greenland have given me important information about the ice, for instance a series of observations from the regions around Clavering Ø 1922—23, which is especially valuable since a member of my expedition, Dr. P. GELTING, supplied a corresponding series from 1931—32.

For the sake of clarity I have divided the coasts of Greenland into a number of districts; the journeys on which I visited the various districts are listed below.

1) Kap Farvel—Godthaab.

1913 August: Voyage from Godthaab to Copenhagen.
1916 April: Voyage from Copenhagen to Godthaab.
1918 Spring, voyage from Godthaab to Copenhagen.—South of Godthaab the ship sailed partly in the ice, partly along its edge.

1920 August: Voyage from Copenhagen to Julianehaab, passing the ice-belt, again passing the ice-belt south of Frederikshaab, and then proceeding northward along the coast.
1928 October, Voyage from Godthaab along the coast to Julianehaab, thence, passing close around Kap Farvel, to Copenhagen.

2) Godthaab—Disko Bugt.

1913 May: Voyage along the coast to Godhavn. In the summer a voyage in motorboat in Disko Bugt, around Disko, and several other trips in motorboat and an ascent of the inland ice.
1916 May: Journey in motorboat, by dog-sledge, and in umiak along the coast from Godthaab to the pass behind Nugsuak Halvø.
1918 March-April: Sledge-journey from the pass behind Nugssuak Halvø to Godhavn and thence to Holstensborg.
1920 August: Voyage along the coast, calling at Egedesminde and Godhavn.
1923 Summer: Various motorboat trips in Disko Bugt.
1928 Late summer: Sailings up and down the coast and various voyages in motorboat in Disko Bugt.

3) Disko Bugt—Upernivik.

1916 May: Trip by dog-sledge and umiak from the pass behind Nugsuak Halvø to Upernivik.
1918 January-March: Various sledge journeys in the Upernivik district and a sledge journey across the pass to Nugsuak Halvø.
1920 September: Motorboat trips in the Umanak district and by ship from Umanak to Upernivik.
1928 July-August: Motorboat trips in Umanak Fjord and its ramifications.

4) Upernivik—Thule.

1916 May-June: Journey by umiak and dog-sledge from Upernivik to Thule.
October-November: Sledge journey from Thule to Upernivik.
1917 February: Sledge journey Upernivik-Thule.
December-January: Sledge journey Thule-Upernivik.
1920 September: Voyage by ship from Upernivik to the Thule district.
November: Sledge journey from the Thule district to Upernivik.
1921 January-February: Sledge journey from Upernivik to the Thule district.
November: Sledge journey from the Thule district to Upernivik.
1922 February-March: Sledge journey from Upernivik to the Thule district.
November: Sledge journey from the Thule district to Upernivik.
1923 March: Sledge journey from Upernivik to the Thule district.
May: Sledge journey and boat trip from Thule to Upernivik.

5) Thule—Kap Brevoort.

1916 August: Motorboat trips in the Thule district.
1917 April: Sledge journey from Thule to Kap Brevoort.
1920 September: Voyages by ship in the Thule district.
October-November: Sledge journey in Kane Basin and the Thule district.
1921 March-April: Sledge journey from the Thule district via Fort Conger on Ellesmere Land to Kap Brevoort.
1922 April-July. Sledge journey from the Thule district to Kap Brevoort and back.

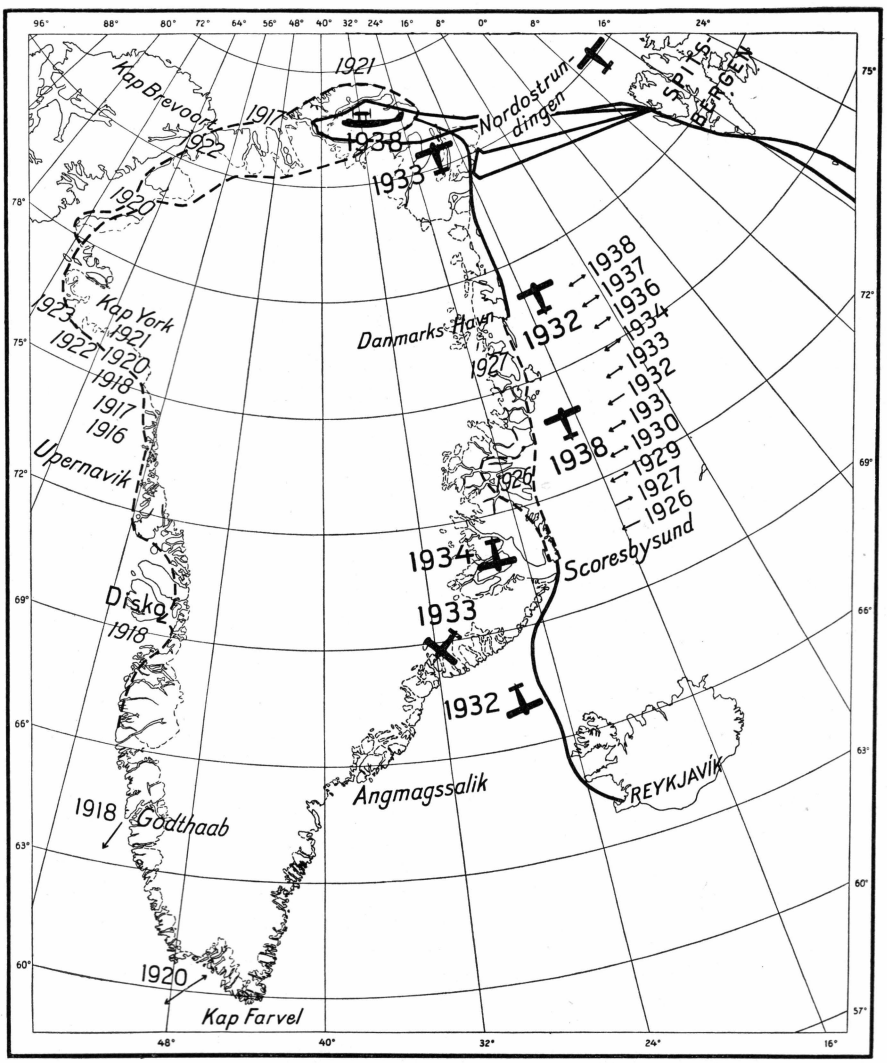


Fig. 1. Sketch map showing the years in which the author made ice observations in Greenland waters, from ships (arrows), from sledges (broken lines), and from the air (continuous lines).

6) Kap Brevoort—Nordostrundingen.

1917 May-July: Sledge journey from Kap Brevoort with excursions into the North Greenland fjords to and including De Long Fjord; return journey across the inland ice from the interior of St. George Fjord in August.

1921 April-July: Sledge journey from Kap Brevoort around the north of Peary Land and in August back across the inland ice from the head of Independence Fjord.

1933 August: Flights across the interior of Danmarks Fjord and the outer part of Independence Fjord.

1938 April-May: Expedition with one ship and two seaplanes to Spitsbergen. Flight from Copenhagen to Spitsbergen and thence two flights to Greenland and back. Return flight to Copenhagen.
1938 May: Flight from Spitsbergen across the interior of Peary Land and back to Spitsbergen.

7) Nordostrundingen—Danmarks Havn.

1933 August: Flight along the outer coast and across Skærfjord between Danmarks Havn and Franske Øer. By ship from Danmarks Havn to Norske Ø. Flights from Norske Ø to Nordostrundingen.
1938 May: Flight from Spitsbergen to Nordostrundingen, onwards to Mallemukfjæld and back to Spitsbergen.

8) Danmarks Havn—Scoresby Sund.

1926 August: By ship through the ice-belt to Scoresby Sund.
October-November: Sledge journey from Scoresby Sund to Myggbukta.
1927 March-June: Sledge journey from Scoresby Sund to Danmarks Havn and back. Voyage by ship from Scoresby Sund out through the ice belt.
1929 July-September: Ship's expedition in and out through the ice belt and in the summer from Sabine Ø to Davy Sund.
1930 July-August: Ship's expedition in and out through the ice belt and in the summer from Clavering Ø to Kong Oscars Fjord.
1931 July-September: Expedition with two ships in and out through the ice belt and in the summer between Hochstetter Forland and Liverpool Kyst. (Two stations with wintering members).
1932 June-September: Expedition in and out through the ice, two ships, two seaplanes. Voyages and flights from Danmarks Havn to Scoresby Sund. (Three stations with wintering members.)
1933 June-September: In and out through the ice with two ships and two seaplanes. Voyages and flights from Danmarks Havn to Scoresby Sund. (Wintering members at three stations.)
1934 July-September: Voyage in and out through the ice, one ship, one seaplane, between Clavering Ø and Scoresby Sund. (Two stations with wintering members.)
1936 July-September: Expedition between Hochstetter Forland and Scoresby Sund, one ship. (Two stations for wintering members).
1937 August-September: Expedition (one ship) to the interior of Scoresby Sund. (Four stations for wintering members).
1938 July-September: Expedition to East Greenland between Clavering Ø and Scoresby Sund, one ship, one seaplane. (One station with wintering members).

9) Scoresby Sund—Angmagssalik.

1932 June: Flight along the northern part of Blosseville Kyst.
August: Flight along the northern part of Blosseville Kyst from Scoresby Sund and onward to Reykjavik.
1933 August: Flight from the interior of Scoresby Sund to Kangerdlugssuak and back. Flight from the interior of Scoresby Sund towards Blosseville Kyst and back.
1937 September: Beset in the ice along the northern part of Blosseville Kyst.
1938 July: Beset in the ice along the northern part of Blosseville Kyst.

I have made no journeys south of Kangerdlugssuak, but I have had a view from the air (4000 m altitude) across the fjord and of the coast southward to a little north of Kap Dan.

10) Angmagssalik—Kap Farvel.

This coast is entirely unknown to me.

Besides on the sources mentioned above, the account is based on practically all the available literature on the ice in the Greenland waters.

As to North Greenland, comprehensive lists of literature are given in my glaciological and cartographical monographs (1928 and 1940 respectively).

As to West and East Greenland, Iceland, and Spitsbergen prior to SCORESBY (1820) detailed literature references are given in the present paper. Whenever possible, I have drawn support from the surveys of other investigators. As an example of an up-to-date synopsis I may mention Dr. L. BOBÉ's "Opdagelsesrejser til Grønland 1473—1806" (1936), but I wish to point out that I have read, also, the majority of the travelling reports summarised by Dr. BOBÉ.

As regards the literature on the East Greenland Ice after SCORESBY I think I have read practically all of it, but I have not considered it my object to enumerate in the present paper all the reports on expeditions that have passed the ice belt. In many cases such a report gives a very incomplete picture of the ice conditions. In this connection I may mention my own voyage in 1938, when the ship was beset in very heavy ice off Scoresby Sund. After the ship had got free of the ice, I observed from the air a perfectly compact ice belt along Liverpool Kyst, but a couple of days later the ship pushed through the ice off Clavering Ø in some few days, the ice being very open here. Thus a comparatively rapid voyage through the ice belt says nothing about the East Greenland Ice as a whole in the particular year.

A special position is occupied by the annual publications issued by the Meteorological Institute, Copenhagen, as well as the precursor of that periodical, viz. C. RYDER's paper of 1896. An immense material, notably from the period 1898—1939 is gathered in this publication, at times rather indiscriminately, as will appear from the present paper, but this is quite natural since the most recent compilers of the work have lacked practical experience in ice navigation.

It is to be hoped that this periodical will be continued in the future in a more up-to-date form containing information obtained from all the countries that are interested in the Polar ice. It seems reasonable to believe that by means of the intensified air traffic that is, no doubt, to come, our knowledge of the Polar ice will be very considerably increased.

ICE TYPES AND ICE TERMINOLOGY

An exhaustive description of the different types of ice would actually require extracts of the whole arctic literature, for in the course of time all travellers have described the ice phenomena encountered by them. However, a historical account of the treatment of the ice in the literature is beyond the scope of the present work; for such an account the reader is referred to ZUKRIEGEL's monograph of 1935 (cf. below), Here only some of the classicial descriptions will be briefly mentioned, and in addition the most recent attempts at an ice terminology will be considered.

As the present paper lays the main stress on the East Greenland Ice, it will be natural to begin with SCORESBY's paper of 1820, the first classical work on the sea ice, written on the basis of the great experience as ice navigators of the SCORESBYS, father and son. They do not attempt to give an ice terminology but their work contains definitions of the following terms in use among the whale fishers: 1) ice-berg, 2) field, 3) floe, 4) drift-ice, 5) brash-ice, 6) a. bay-ice, b. pancake-ice, 7) sludge, 8) hummock, 9) calf, 10) tongue, 11) pack, 12) patch, 13) stream, 14) open ice, or sailing ice, 15) heavy and light, 16) land-ice, 17) bight, 18) lane, or vein.

A good ice-terminology is likewise given by E. K. KANE (1856).

Mention may also be made of the paper by G. S. NARES (1878), who introduced the term *palæocrystic ice* for the ice found north of Robeson Channel, where he spent a winter and made numerous sledge journeys. And of K. WEYPRECHT's description (1879) of the ice around Franz Josef Land, based on a summer voyage in 1871 and a wintering in 1872—74.

On the basis of three winterings A. W. GREELY (1886) describes the ice conditions in Smith Sound and Robeson Channel and along the north coasts of Greenland and Grant Land, adding to the picture given by NARES a few years before.

A. KOLCHAK (1928) describes the East Siberian Ice on the basis of observations made on the Russian Polar Expedition 1900—1903.

L. Mecking (1906) describes the ice-drift in Baffin Bay, especially in relation to the weather conditions.

R. E. Peary (1907) adds further particulars to the picture given by Nares and Greely of the ice conditions in Robeson Channel and the regions north of Greenland, based on sledge journeys in 1900, 1903, and 1906.

In 1909 Fridtjof Nansen and Helland-Hansen published a great work on the ice north of Europe and Asia.

In 1910 R. E. Peary published a report on his journey from Grant Land to the North Pole; it gives, however, fewer observations on the ice than his work of 1907.

Fridtjof Nansen's report (1924) on his first journey to the Polar countries in 1882 gives a good idea of the seal hunting carried on at that time along the ice edge and in the ice between Jan Mayen and Spitsbergen; he likewise supplies interesting contributions to our knowledge of the movements of the ice between Iceland and Greenland.

Of the more recent literature on the ice, mention may be made of a brief description by the present author (1926) of the ice conditions in Robeson Channel and the waters north of Greenland, based on earlier observations as well as on my own observations in these regions in 1917, 1921, and 1922. This description was considerably enlarged in my paper of 1928.

Finn Malmgren (1927) has published an important paper on the melting of the ice north of Siberia.

In 1928 N. A. Transehe published a general survey of the ice in the Polar countries, advancing many new points of view. The paper is of importance since Transehe knew the ice conditions north of E. Siberia from personal inspection.

In 1931 Edw. H. Smith published a description, in my opinion the best so far, of the sea ice in the waters around the North Pole.

In 1935 A. Maurstad made an attempt to define the different types if ice, giving many precise definitions. However, the work is rather one-sided, because the author lays the main stress on the types of ice encountered by the Norwegian seal-hunters in the spring in the East Greenland Ice and north of Spitsbergen and Siberia, while the types occurring in the central part of the Polar Basin are but briefly dealt with.

In 1935 J. Zukriegel published a monograph with the pompous title "Cryologia maris". In places it is a mere bibliography of the literature dealing with ice, even from the earliest times. In 1933 he made a summer trip from Iceland to Spitsbergen and onwards to 82° N. lat., but as ice was scarce that summer, he did not see very much. Still his paper contains many new points of view; he seems to know the recent Russian literature on the ice conditions north of Siberia, and in con-

clusion makes a classification of the different types of ice, using the English, Russian, German, and French terms denoting these types. He likewise gives a code for ice reports, which was later modified by an international committee (cf. Met. Inst. publ. 1937).

Every attempt at an ice terminology will introduce new terms and definitions and correct mistakes in earlier works. In order that a uniform code for all the waters around the North Pole might be obtained, a modern monograph on the ice in the waters north of Siberia and another on the ice between the Canadian islands would be required. Both MAURSTAD and ZUKRIEGEL show a tendency to erect too many types of ice. The types of ice generally met with should, of course, be taken into consideration, but many of the types are of so little importance to navigation that a simplification is highly needed. Sailing in the East Greenland Ice south of 75° N. lat., a ship will meet with a mixture of a great many different types of ice, and it will be difficult to follow the aforementioned code. Moreover every season has its special types. Proposing, now, a new ice terminology with a view to navigation in the waters around Greenland, I wish to point out that only such types of ice as are met with in these waters are taken into account. As my terminology is based chiefly on my own experience in Greenland waters, it may have to be altered in the course of time.

The types of ice that may be met with in the waters around Greenland are as follows:

I. Glacier Ice.

Iceberg — floating ice detached from a glacier.
Calf ice — small pieces of glacier ice.

I. Fast Ice.

Ice foot — a belt of sea ice adhering to the coast, unaffected by the tide.

Fjord ice — ice formed in sheltered places and melting in the place where it is formed.
(Fjord ice + land ice is called *winter ice*).

Sikussak ice — fjord ice more than 10 years old, surface moutonnée.

III. Drift Ice.

Geographical types of drift ice:

Land ice — ice formed at the mouth of large fjords and bays, 1—3 years old, which drifts out to sea before melting.

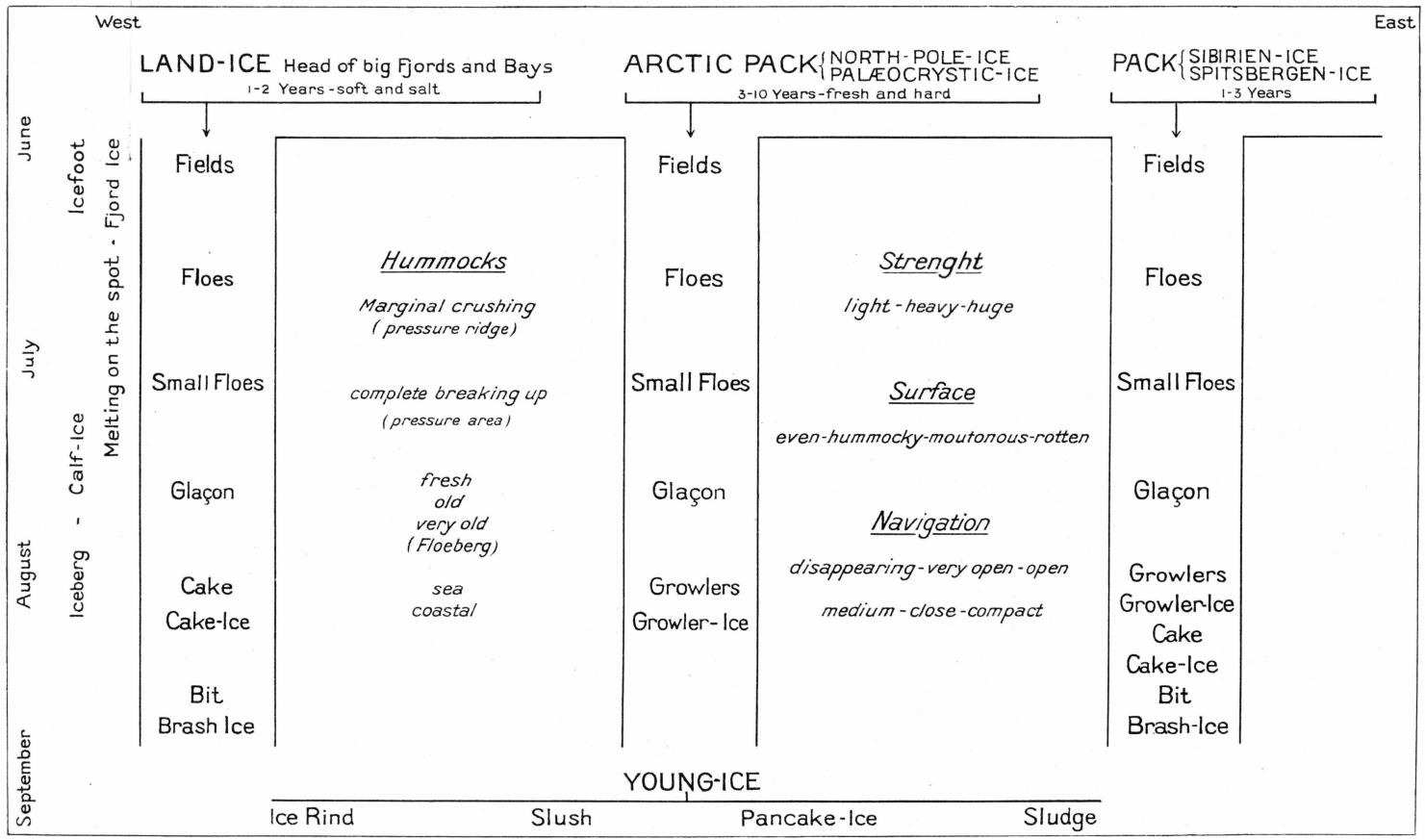


Fig. 2. Ice terminology commonly used in Greenland waters.

Pack — ice more or less hummocky, formed in the sea, 1—3 years old.

Subtypes: Siberian Ice (East Siberian Ice), formed in the waters north of E. Siberia.

Spitsbergen Ice (West Siberian Ice) — formed in the Kara Sea and the Barents Sea.

Baffin Bay Ice — ice formed in Baffin Bay and the waters around the Canadian islands.

Arctic pack — ice more than five years old; fresh and hard.

Subtypes: North Pole Ice — final stages developed north of 85° N. lat.

Palæocrystic Ice — formed in Lincoln Sea N. of Greenland and Grant Land, as a rule more than ten years old.

Forms of drift ice:

Field — an extensive area of floating ice, more than 5 km in diameter.

Floe — an area of floating ice, more than 1 km i diameter.

Small floe — an area of floating ice more than 200 m in diameter.

Glaçon — floe less than 200 m in diameter.

Growler — a piece of ice of hummocky origin, rising at least 1.5 m above the sea.

Growler-ice — accumulation of growlers.

Cake — a relatively flat piece of ice smaller than a small floe.

Cake-ice — accumulation of cakes.

Bit — a piece of ice less than 0.5 m in diameter.

Brash-ice — accumulation of bits.

Sea ice may be grouped according to

strength: huge, heavy, thick, light.

surface: with snow.

without snow: moutonnée, hummocky, level, honeycombed, rotten.

arrangement: compact, close, medium, open, disappearing.

Hummock — heaps of broken up sea ice resulting from pressure.

Hummocks may be grouped according to

age: recrystallised, more than 10 years old (floe-berg).

very old, more than 5 years old, hummocks entirely fused.

old, hummocks partially fused.

newly formed hummocks.

state: marginal crushing (pressure ridges).

complete breaking up (pressure area).

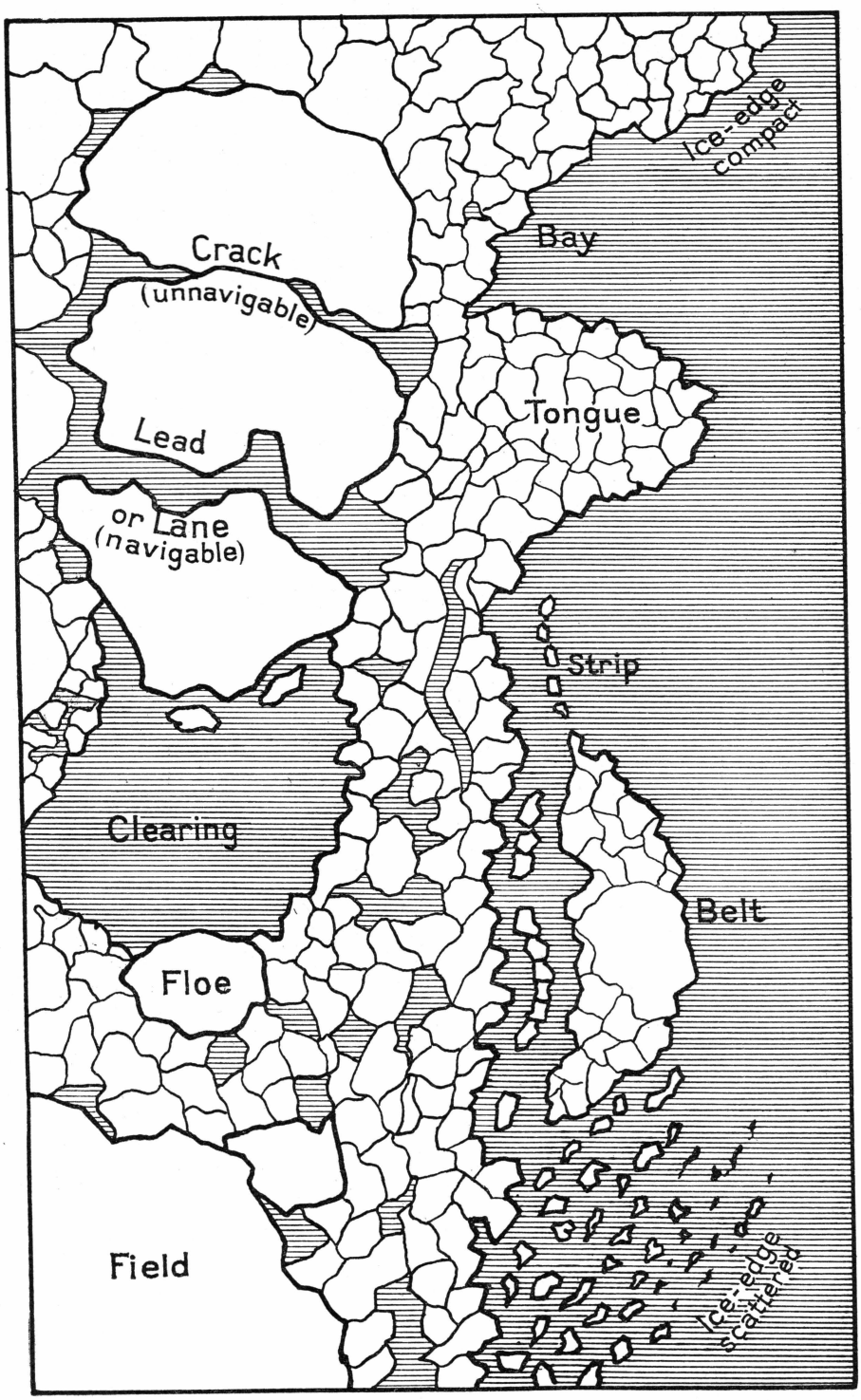


Fig. 3. Some ice terms commonly used.

Young ice.

Ice rind — hard ice formed of the surface layer of fresh-water overlying the salt sea water. Transparent, makes noise when passed by ships.

Slush or sludge — The initial stages in the freezing of sea water when it is of a gluey or soupy consistency and the surface of the water has taken on the appearance of cooling grease, with a peculiar steel-grey or lead tint. Makes no noise when passed by ships.

Pancake ice — Small circular cakes of new ice with raised rims.

Geographical Types of Ice and their Distribution in the Greenland Waters.

It will be natural to distinguish between two geographical types of ice, the *winter ice* and the *pack ice*. The pack ice is in constant drift and has not been formed along the east coast of Greenland. The winter ice is formed in the East Greenland waters and comprises two types, fjord ice and land ice.

Fjord Ice is formed in the inner ramifications of the fjords, generally in October. It melts in the place in which it has been formed in June and July. As a rule it is quite smooth.

Land Ice is formed in the outer part of the large fjords or in the lee of islands and in sheltered bays as well as in certain places in a more or less broad belt along the outer coast. It is formed during the period of calm weather that usually occurs in October and November, and reaches its first maximum about the middle or the end of October, only particularly unsheltered capes and coast stretches being free of ice in this period. From the end of November to the end of January the weather is, as a rule, unsettled with strong gales, during which large masses of the newly formed land ice will get detached in exposed places; this results in a minimum in the distribution of the land ice about the middle of February. In the succeeding calm period of March and April the land ice again spreads towards the east, reaching its second maximum at the end of April. This maximum may exceed the first maximum; it may, for instance, be mentioned that land ice is never formed along Liverpool Kyst during the first, but often during the second maximum.

In May the currents will in several places cause the outer part of the land ice to drift out of the bays, as in this month the drift ice often moves away from the shore, leaving open water, the so-called land-water, in many places off the shore.

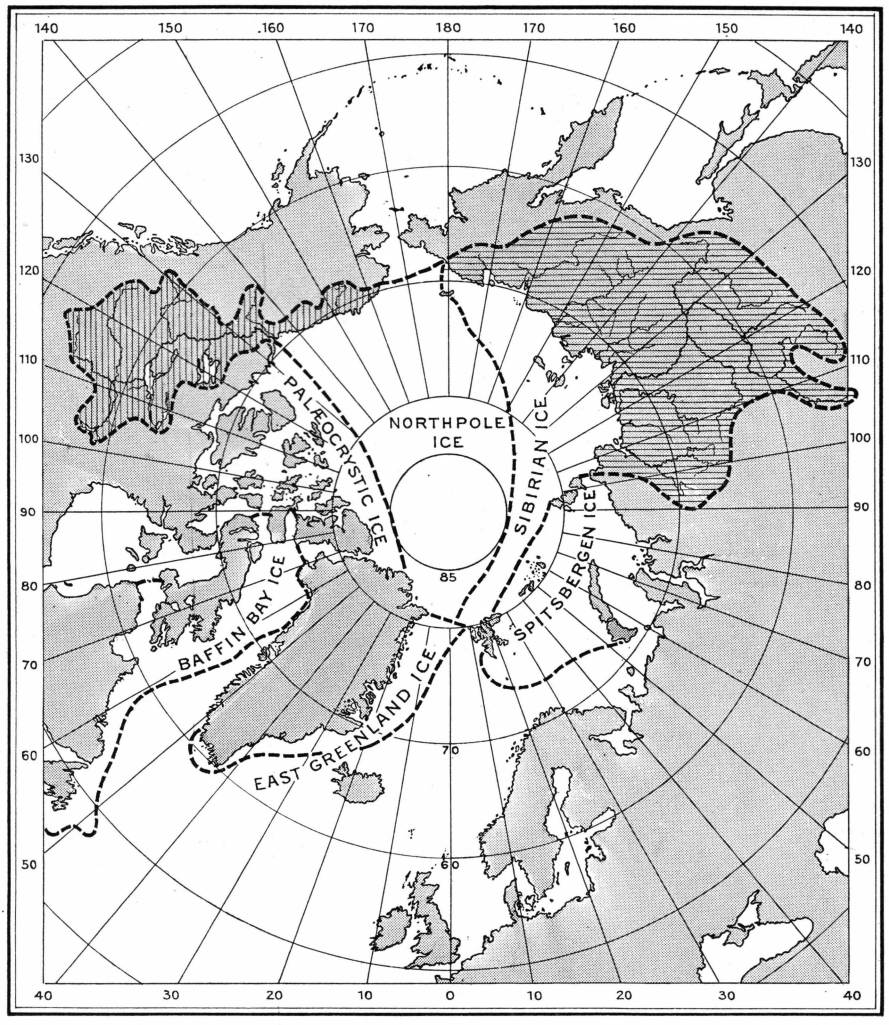


Fig. 4. The geographical extension of the different types of ice and the drainage areas of Siberia and North America, which supply fresh water to the Siberian Ice and the North Pole Ice respectively.

About June 1st the outer edge of the land ice reaches the stage in which it is encountered by ships that call at the coast at the height of the summer. The land ice then lies as a plug in the outer parts of the fjords; it depends on the climate in May, June, and the first weeks of July when it will melt, break, or drift away. In years with fine and calm weather and intensive illumination the land ice will break up into floes and drift away early; however, if easterly winds blow during this period, making the sky overcast, it will often remain for three or four weeks more, causing great difficulties for navigation along the coast.



Fig. 5. S. s. "Gustav Holm" in heavy North Pole Ice. Summer of 1932.

Observations have shown that the melting of the fjord ice is very constant, whereas the disappearance of the land ice varies considerably from one year to another.

The Pack Ice.

Palæocrystic Ice. In 1926 (Geogr. Review) and 1928 (pp. 382—392) I erected a number of ice types for North Greenland, and reintroduced, though with a somewhat altered definition, NARES's palæocrystic ice, found north of Grant Land and Greenland and bounded on the north by PEARY's Big Lane. Later on the existence of the Big Lane has been doubted, though observations by several expeditions would seem to show that it really exists.

The North Pole Ice is formed in the regions around the North Pole, that is to say, within the circle bounded by the 85 N. parallel[1]). It is many years old, as a rule several metres thick, and criss-crossed by old, more or less fused pressure ridges, which make the floes, sometimes of great extension, very stable. The surface of the floes are often

[1]) Large quantities of ice are carried here from the regions north of Alaska and will in the course of time be transformed into North Pole Ice.

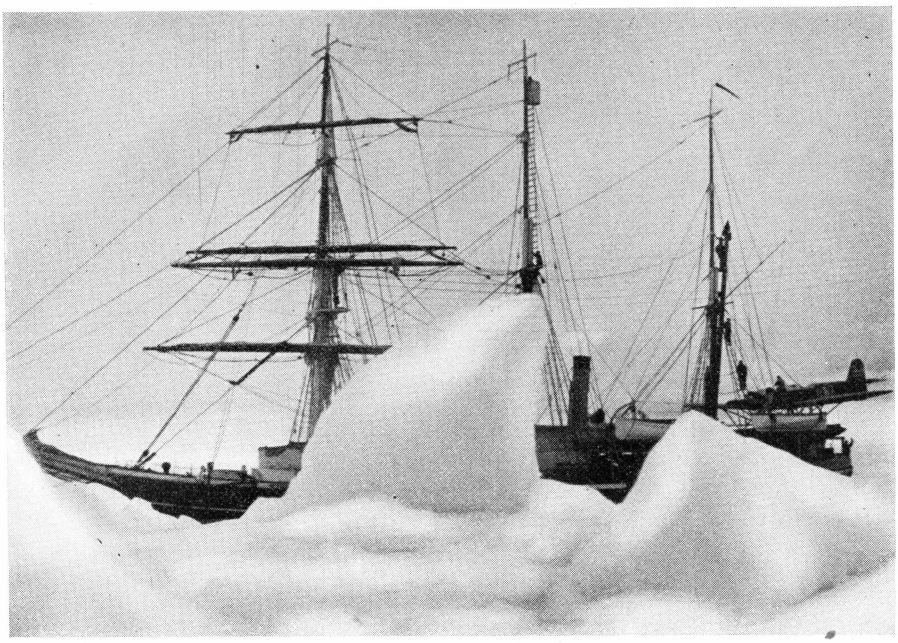


Fig. 6. Heavy North Pole Ice off the east coast of Greenland, 1932.

elevated two or three metres above the surface of the sea, and the ancient pressure ridges may be several metres higher. The edges of the floes are frequently girdled by younger, sometimes quite fresh, pressure ridges of considerable height. Stones or earth particles are not seen on these floes.

The North Pole Ice varies considerably in quantity from year to year. Thus in the summer it may be entirely absent off the central part of the east coast of Greenland; personally I experienced this in 1926 and 1930. On the other hand it may be present in large quantities throughout the summer, which was the case in 1929, 1937, and 1938. Large masses melt in the area between 70° and 75° N. lat. in the course of July and August, so very often there will be no North Pole Ice off the mouth of Scoresby Sund in late summer. In October or November, however, fresh masses of North Pole Ice will drift past Scoresby Sund. In the calm period February-May the North Pole Ice may in some years fuse somewhere off the northernmost part of East Greenland.

In 1905 members of the Belgica Expedition thought they observed a closely fused edge of North Pole Ice extending like a tongue from a point west of northern Spitsbergen southward to c. 76° N. lat. and onwards towards the coast, though leaving a belt of land water along the shore. South of this front of North Pole Ice the ice was very open.

Fig. 7. Floes of North Pole Ice at the height of summer, seen from the air. The arrows indicate old pressure ridges more or less fused.



Fig. 8. Surface of North Pole Ice at the height of the summer.

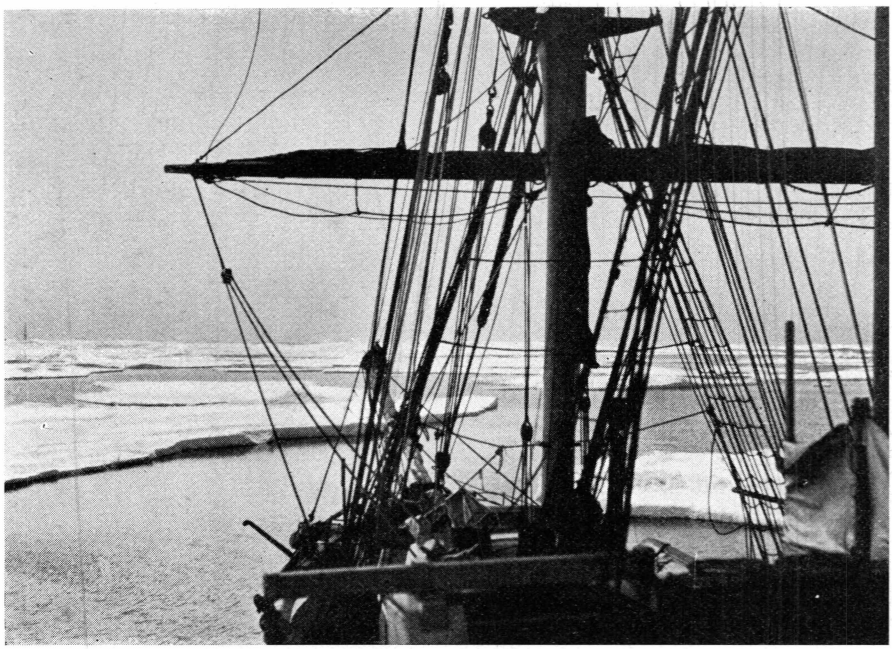


Fig. 9. Scattered floes of Siberian Ice.

On August 16th, 1933, I observed from the air a front of North Pole Ice extending northeastward from Nordostrundingen. No open water was seen north of this front, and no drift ice was visible south of it as far as Danmarks Havn. Accordingly the ice front must have been stationary at any rate for a couple of weeks.

In other years, notably in 1937 and 1938, there has been a constant drift of North Pole Ice southward along the east coast of Greenland; thus no ice front has formed in the spring or summer.

The Siberian Ice is formed in the waters north of Spitsbergen, Franz Josef Land, Novaya Zemlya, and the New Siberian Islands. It drifts past the north coast of Spitsbergen all the year round, and seems to be of a more continuous occurrence than the North Pole Ice, being very rarely entirely absent.

During the period 1929—1939 it was entirely absent between 70° and 75° N. lat. in July, August, and September 1936, but this is the only example known of the absence of Siberian Ice for three consecutive months. Large quantities of it melt between Spitsbergen and Iceland, the greater part between Iceland and Angmagssalik; no doubt only a small part of it reaches Kap Farvel. It is not as old and thick as the North Pole Ice, very little of it being apparently more than two or three years. This is in harmony with the fact that ships which have

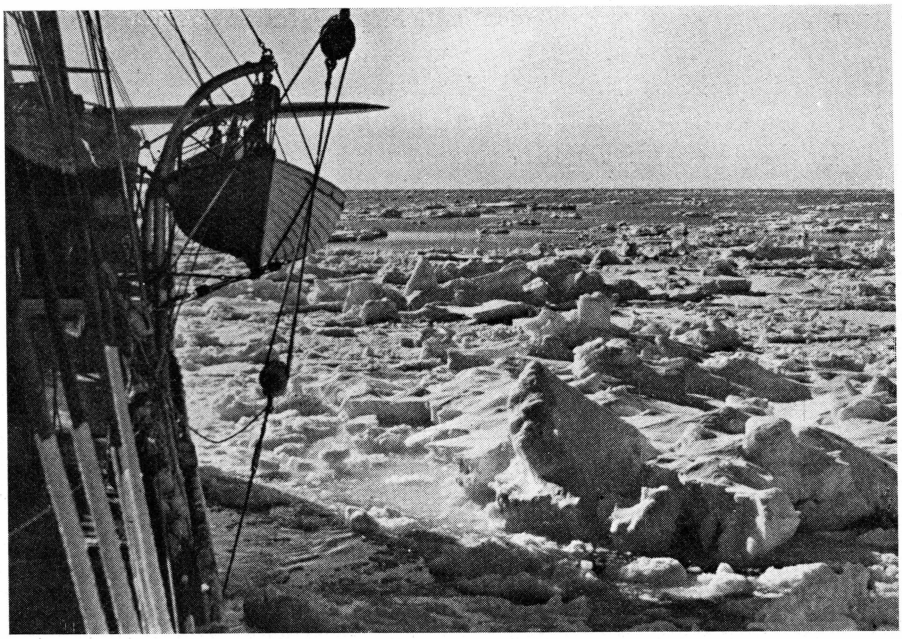


Fig. 10. Close-packed Siberian Ice.

drifted down from the New Siberian islands, viz. the "Fram" and the "Sedow", terminated their drift in a very few years.

The ice floes may be very large, but the ancient fused pressure ridges, so characteristic of the North Pole Ice, are absent or but slightly developed. The surfaces of the floes rarely rise one metre above sea-level, but heavy pressure ridges may occur along their margins.

Pebbles, gravel, and sand are often found on the surface of the floes, and drift-wood, especially of Siberian larch, is not rarely present.

Since the Siberian Ice will not probably fuse on its way past Spitsbergen, no ice front like that of the North Pole Ice is known. Even in the middle of August 1933, when open water was encountered as far as Nordostrundingen, where North Pole Ice is generally met with, Siberian Ice must have occurred far out at sea in 79° N. lat., there being no swell off Norske Ø during the days we stayed there. Although no ice was found south of Scoresby Sund in August and September that year, a belt of Siberian Ice, which prevented any swell north of 70° N. lat., occurred north of Scoresby Sund.

The Spitsbergen Ice. By Spitsbergen Ice I understand the ice that moves around South Cape on Spitsbergen and sometimes extends so far westward that it unites with the East Greenland Ice.

It may carry sand, stones, and plant remains from the eastern and southern parts of Spitsbergen to East Greenland and Iceland, and may

accordingly be of great geological and biological interest. The quantity of Spitsbergen Ice which in some years is added to the East Greenland Ice is probably inconsiderable; it would seem that in most years the ice does not drift so far westward, but melts south of Spitsbergen.

Of the 62 years from 1877 to 1939 whence regular observations on the ice are indicated on charts, observations from Spitsbergen are lacking from the years 1877, 1879, 1881, and 1886—1889. In the remainder of the years a triangle of open water, the so-called Whaler's Bight, generally extends north of 75° N. lat. The northern angle of this triangle lies near the northwesternmost point of Spitsbergen, the second angle in c. 75° N. lat., 0° W. long., and the third in 75° N. lat. in the immediate vicinity of Bear Island. From a very few years the ice is reported to have drifted westward between the southernmost point of Spitsbergen and Bear Island, either extending across the area in which the eatern limit of the East Greenland Ice generally occurs in April-July, or uniting with the East Greenland Ice. Some of these years will be dealt with below:

1884 In May the ice edge formed a bay the northernmost point of which was situated in c. 78°50′ N. lat., c. 7° W. long. The ice lay very near South Cape on Spitsbergen, so no very large ice masses can have passed this point.

1916 In May the Spitsbergen Ice extended into the area of the East Greenland ice stream, but it is probably doubtful whether Spitsbergen Ice drifted southward with the East Greenland Ice that year.

1917 In April the ice belt was very broad north of Iceland and extended northward to 76° N. lat., 0° W. long., whence the ice edge bent southward c. 100 km south of Bear Island. That is to say, there was a broad bay the head of which reached 76° N. lat. In May the ice extended farther southward, the head of the bay only reaching northward to c. 74°30′ N. lat. In June and July bays were formed northward the heads of which lay in c. 78° N. lat., but Spitsbergen was still entirely surrounded by ice. In August the whole west coast of Spitsbergen was free from ice, and very little ice was found along the east coast of Greenland. In April and May, in particular, large quantities of Spitsbergen Ice were no doubt carried southward by the East Greenland current.

1929 In April a well developed ice-free triangle extended northward to 80° N. lat. In May the Spitsbergen Ice joined the East Greenland Ice, the head of the bay lying in 78° N. lat. In June there was open water west of northern Spitsbergen, but between 79° and 78° N. lat. a belt of ice connected the Spitsbergen Ice and the East Greenland Ice. In June this connection was interrupted.

1935 In April the Spitsbergen Ice issued a tongue westward between 78° and 74° N. lat. into the area of the East Greenland Ice, but the edge of this ice stream lay far westward that year, so no connection was established. In May the tongue of Spitsbergen Ice shifted some distance northward, but still did not reach the East Greenland Ice.

It will be seen that in the period 1877—1939 the Spitsbergen Ice was very rarely connected with the East Greenland Ice. Only in 1917

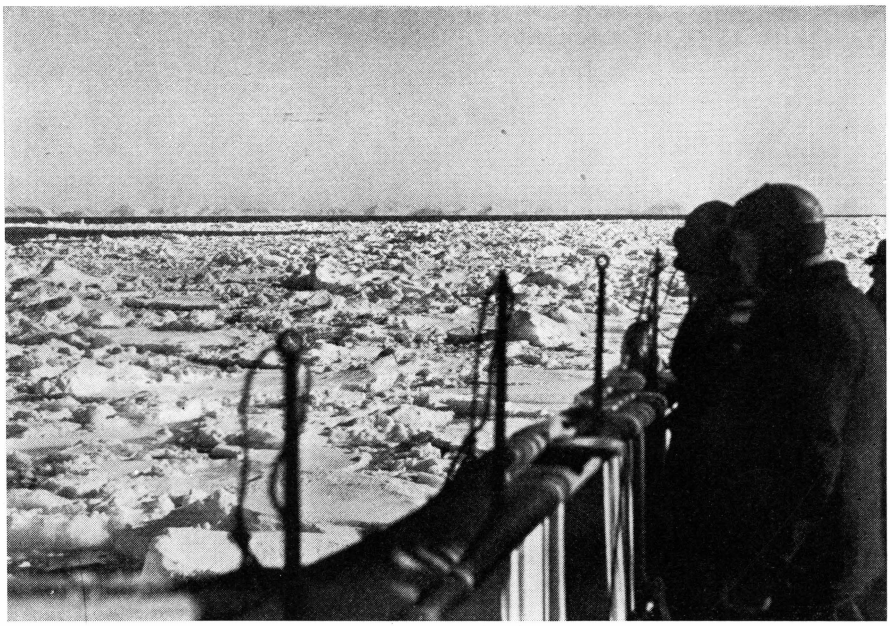


Fig. 11. Spitsbergen Ice west of Spitsbergen, April 1938.

was this connection established for some length of time, viz. for four months. In May the ice edge lay south of 75° N. lat. between the East Greenland Ice and Bear Island.

From the literature on the whaling period it appears, however, that in earlier times the "east ice" (Spitsbergen Ice) commonly joined the "west ice" (East Greenland Ice) almost on a level with Jan Mayen, i. e. in 75° N. lat. SCORESBY divides the ice years into what he terms "open seasons" and "close seasons".

By an "open season" he means a year in which open water extends northward to 80° N. lat. along the whole west coast of Spitsbergen. A "close season", or a "Südeisjahr" as it is called by the Germans, is a year in which the Spitsbergen Ice and the East Greenland Ice unite, forming a barrier towards the open water around the northeastern point of Spitsbergen. SCORESBY (1820, Vol. I, pp. 276—284) describes a number of years from 1803 to 1818 as follows:

1803 Medio April open water as far as 81° N. lat.
1804 Medio May a passage to the northern stations.
1805 End of April open water northward to 78° N. lat.
1806 A close season. A barrier of ice extended from 75°20′ to 79°30′ N. lat. Only three ships pushed through this barrier. North of the barrier there was a broad belt of open water, extending from at least 10° W. long. To at least 70° W. long. On May 24th SCORESBY reached the position 81°30′ N. lat., 19° E. long in the northeastern part of this open water.

1807 Likewise a close season. The best catch was secured between 75° and 76° N. lat.

1808 An open season, but on the return voyage the ships encountered a barrier of ice c. 10—20 miles broad in 74° N. lat., whence the "west ice" extended more than 100 miles eastward.

1809 A close season (no further data).

1810 As in 1804, i. e. a passage to the northern stations.

1811 A close season. Not till the end of May did the ships succeed in pushing northward through the ice barrier.

1812 A very close season. The ice formed a connection between the Siberian Ice and the East Greenland Ice between South Cape and Bear Island at the end of May. In June there was a passage northward to 79° N. lat. In July there was open water.

1813 Open water northward to 80° N. lat. from medio April.

1814 No data.

1815 An open season.

1816 No data.

1817 Much open water at the beginning of the season, but in June the Spitsbergen Ice joined the East Greenland Ice by a belt of ice 30—50 miles broad between 76° and 77° N. lat. The East Greenland Ice was much scattered. SCORESBY repeatedly pushed far into it and on July 29th, in latitude c. 74° N. longitude c. 11° W., he could distinctly distinguish the mountains around Kap Broer Ruys. There was open water westward, but fog prevented him from reaching the shore.

1818 This year, too, was exceedingly favourable. The edge of the East Greenland Ice lay much farther westward than the average limit indicated by SCORESBY on his map (Vol. II, Pl. 7). However, the ice belt seems to have been somewhat more close-packed than the previous year.

It will be seen that the years 1806 to and including 1812 included no less than five close seasons, while in 1817 and 1818 there was only a narrow belt of East Greenland Ice; in 1817 it was easy to push through the ice belt right in to the coast of Greenland.

It will be interesting to examine whether these ice conditions exerted any influence on the conditions around Iceland. SCORESBY records only small quantities of ice from the northern part of Iceland from May 1806.

1807 Ice along the northern part of Iceland from February to August. No open water visible.

1809 An open season; hardly any ice near Iceland.

1811 Next open season. Small quantities of ice near Iceland from January to March.

1812 A severe ice year. Ice along the northern part of the country from April to June.

It is interesting to note that in 1817, when the ice belt was extraordinarily narrow at any rate between 74° and 80° N. lat. and easily passable, large ice masses occurred along the north coast of Iceland from January to July, Isafjörður was blocked by ice, and in the spring the ice extended as far as Vestmannaeyjar.

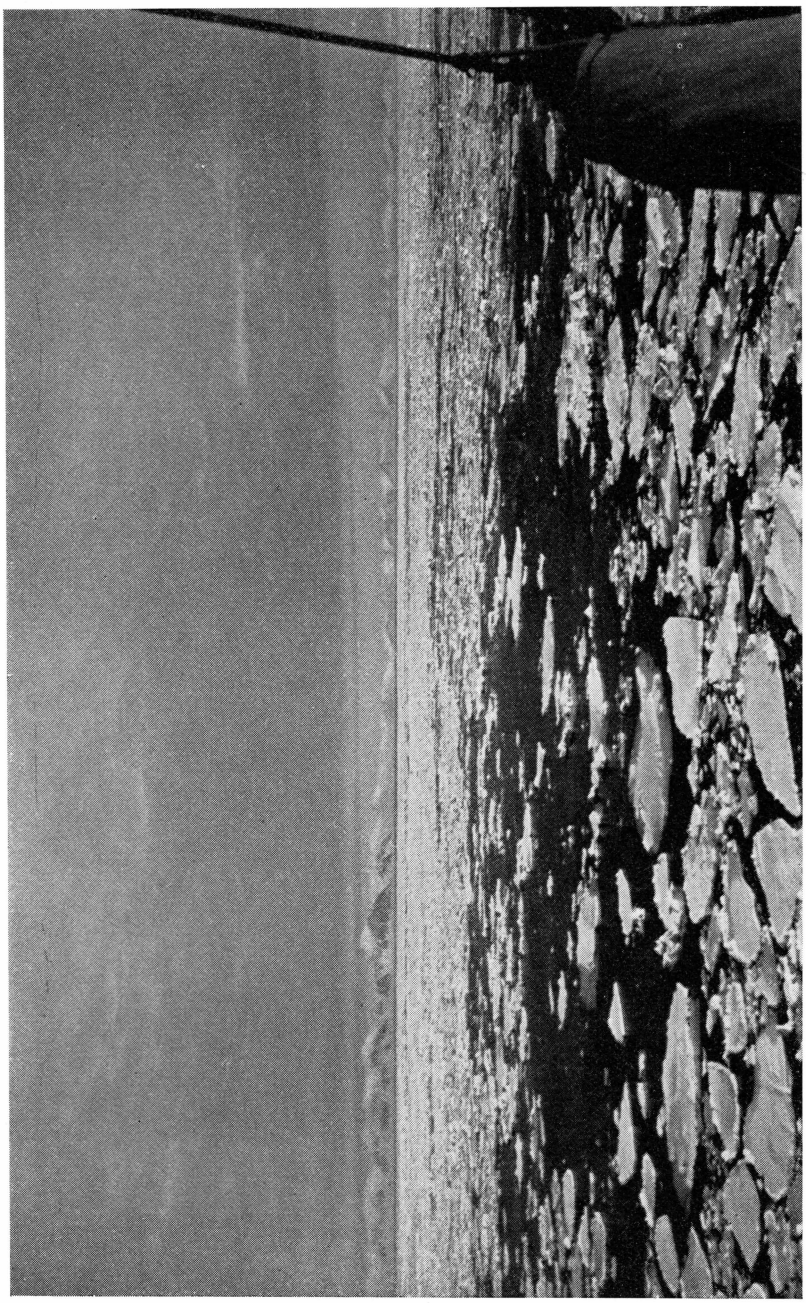


Fig. 12. Spitsbergen Ice west of Spitsbergen, April 1938.

From this we may conclude that a close season (a southern ice year) needs by no means be felt in Iceland. Conversely, there may be severe ice conditions around Iceland and at the same time very small quantities of ice between Spitsbergen and Northeast Greenland to some distance south of 74° N. lat. In this case it would seem that the ice drifted southward at the end of the winter and remained north of Iceland during the summer.

The Atlantic Ice. In periods of calm weather at the end of the winter and in the early spring rather considerable quantities of ice may form off the eastern limit of the Siberian Ice; this ice is especially known from the great seal hunts which culminated at the middle of the last century. Under favourable conditions the ice may cover extensive areas in the early spring, but if swell sets in, it will be broken into pieces and soon disappear. It is only of short duration, and very rarely extends as far south as Iceland. It would seem that it has been only slightly developed during the last decades, whereas it was at times widely distributed during the last century.

In erecting the six types of ice mentioned above, I am aware that as to the last three the question will naturally be asked whether a line of distinction can actually be drawn between them. I must admit at once that this may be difficult in many cases. In recent years, when seal hunting has decreased, and ships visiting East Greenland generally approach the ice edge somewhere between 70° and 75° N. lat. about July 1st, the Atlantic Ice has not, as a rule, been met with; if it has been present in the spring, it has long since melted.

The ice edge consists of small, thicker or thinner, washed floes, which during the last decade have, as a rule, been closely packed, while at the change of the century it seems to have been more scattered. Its more close-packed condition during recent years is no doubt due to a stronger circulation of the air, which causes more unsettled weather near the ice edge. It is noteworthy, also, that during the last decade the ice belt hardly ever exceeded the maximum width of former times, but has frequently been narrower.

A ship entering the ice edge at first sails among rather thin floes, whose surface is frequently covered with gravel and pebbles. In certain years these floes may be separated by floes so thin that they must be assumed to have been formed south of Spitsbergen in the early spring, and they rapidly melt. This was the case in 1931, when about one-third of the ice belt was made up of such floes, which melted rather suddenly about August 1st, making the ice belt easily passable.

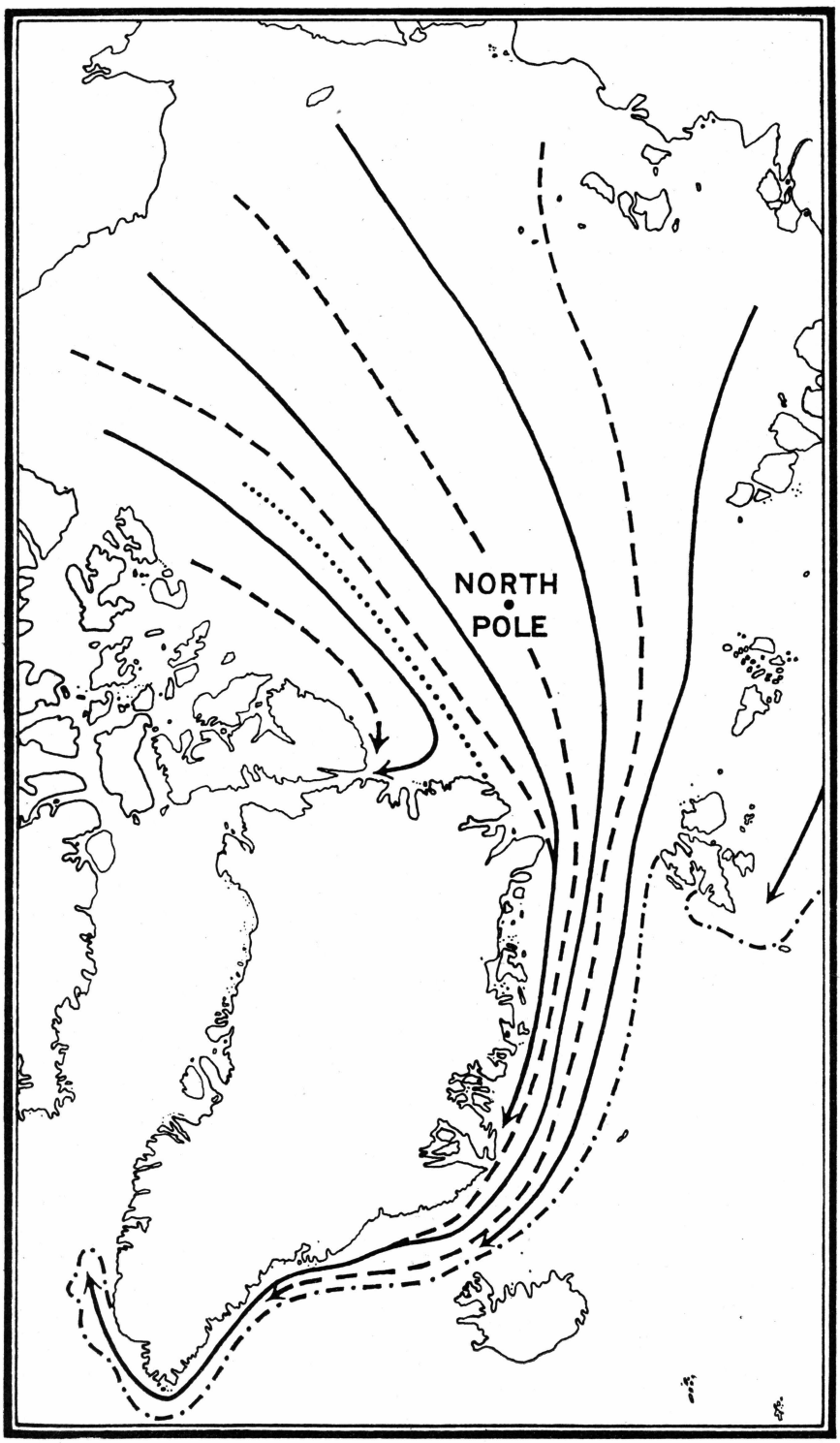


Fig. 13. Routes of ice drift in the Polar Basin and the Greenland waters. The dotted line indicates PEARY's Big Lane.

Near its middle, the ice belt often changes its character, the floes being higher, and gradually one passes into the belt of North Pole Ice. While a strong southward drift is often noticeable in the outer part of the ice belt in July, when North Pole Ice is abundantly present, the drift is frequently inconsiderable, or there may be no drift at all for long periods. Thus in July 1929 the "Godthaab" lay for about two weeks in practically the same place in the North Pole Ice belt.

In some years the North Pole Ice is entirely absent. During the period 1929—39 this was the case in 1930, when in about 75° N. lat. the ice belt, made up of Siberian Ice, was half as broad as in normal years, but the ice was very open and consisted of rather thin floes, and in 1936, when no North Pole Ice was found south of 76° N. lat. in July—September, and when, as stated above, Siberian Ice was entirely absent in August.

The actual difficulties in passing the ice belt are encountered in the North Pole Ice, where the ship may lie for weeks without moving, or moving inconsiderably at the change of the tide, until leads or clearings of open water may form rather suddenly from the west, enabling the ship to reach the land water. Of course one cannot tell exactly where the Siberian Ice ceases and the North Pole Ice, if present, begins; but that these two types of ice occur, will be seen from Fig. 13, which will be explained below.

Observations made by me along the north coast in 1917, 1921, and 1922 show that a surface current moves westward along the coast towards Robeson Channel; this observation was made repeatedly in holes and leads with open water and near pressure ridges along the most projecting capes of the coast. The ice masses of the whole area south of the Big Lane are pressed slowly towards Robeson Channel, through which the ice moves southward. The Big Lane proper should not be regarded as a zone of constant friction between largely stationary ice floes south of it and moving ice floes north of it. The Big Lane is a system of long narrow clearings of open water and of heavy pressure ridges, which arise when the floes south of it are arrested by the north coast of Greenland, while the floes north of it can move freely eastward into the Atlantic. The Big Lane is not encountered in the same place every year; its position may vary considerably according to the weather conditions.

Up to 1938 (cf. A Day in North Greenland (1935)) I still believed that a small group of islands was situated between Greenland and Spitsbergen, and that these islands formed the boundary between a current coming from the North Pole and another coming from Siberia. However, in 1938 (1940) it turned out that no such islands existed; but the drift of the Russian party from the North Pole in 1937—38 showed that the supposed

North Pole current actually exists, even though it must be admitted that the ice conditions in 1938 were exceptional. From Fig. 13 it will be seen that the East Greenland ice drift between Nordostrundingen and the north coast of Spitsbergen receives its supply of ice from a fan-shaped area extending from the Big Lane in the west to the north coast of Siberia in the east; the first ice masses encountered by ships

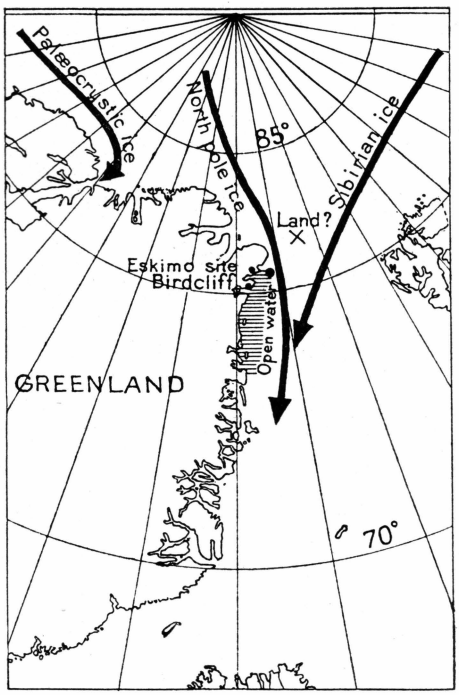


Fig. 14. Ice routes, reproduced from: LAUGE KOCH: A Day in North Greenland, 1935.

passing the East Greenland ice stream between 70° and 75° N. lat., originate from the north coast of Siberia, while the ice nearer the shore is derived from the regions around the North Pole, and that met with nearest the coast from the area between the North Pole and the Big Lane. It may therefore be claimed with a fair degree of certainty that the North Pole Ice is formed within the area bounded by the 85th northern parallel. The Siberian Ice is formed south of this area and accordingly far from attains the thickness and age which characterise the North Pole Ice.

If one visits East Greenland in several consecutive years, one learns to distinguish between the two types of ice, Siberian Ice and North

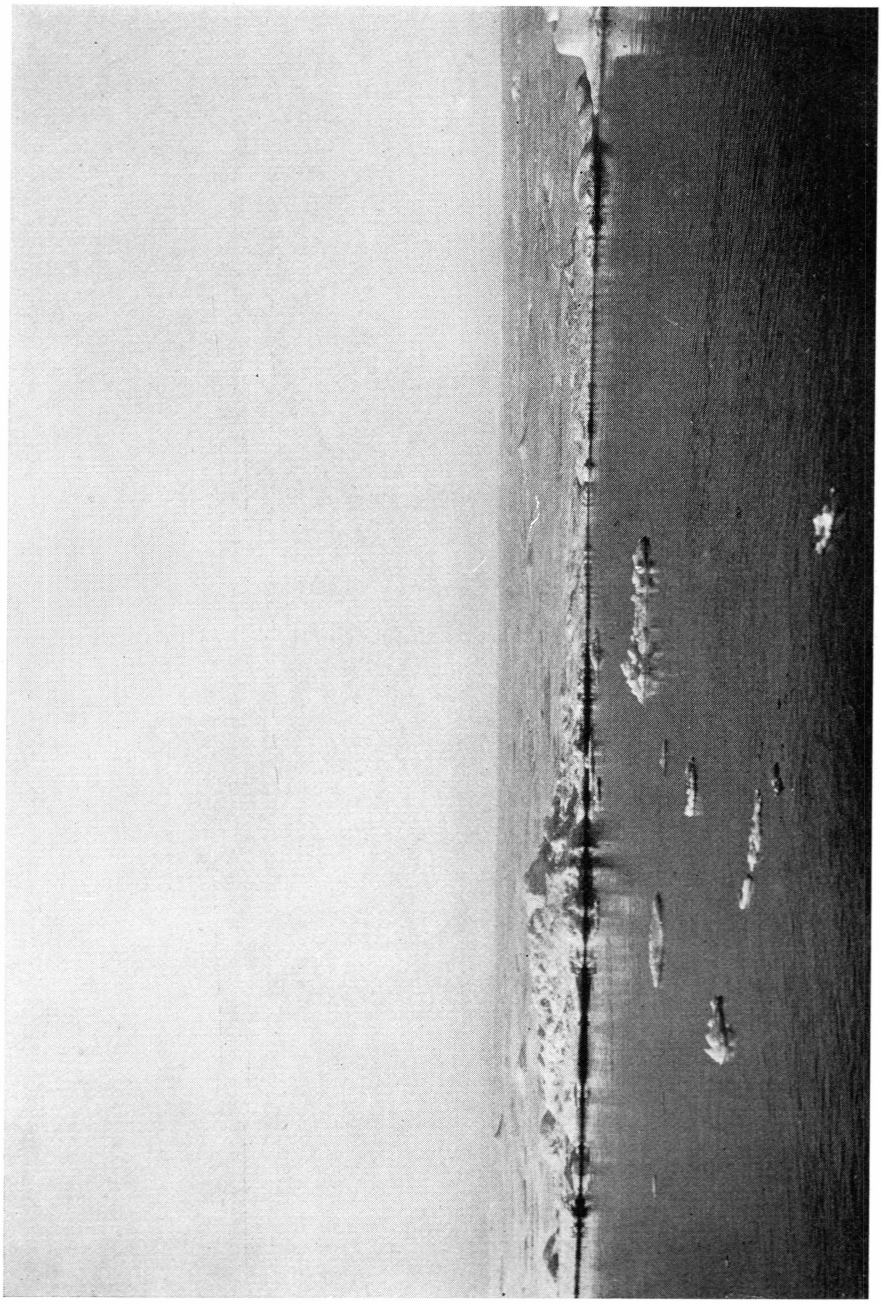


Fig. 15. Large field of North Pole Ice outside Northeast Greenland.

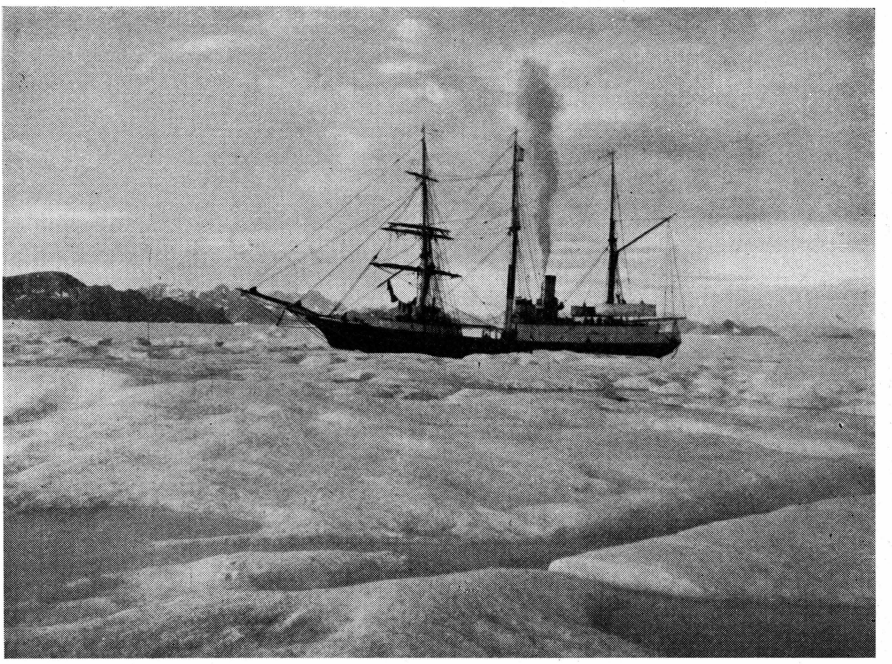


Fig. 16. Floe of North Pole Ice in open water outside Scoresby Sund.

Pole Ice, even though many transitions occur; of course shippers are glad if no North Pole Ice, or but small quantities, are met with. The heavy ice, whose hummocks and pressure ridges often rise above the ship's deck, is very difficult to pass, among other things because large parts of the ice occur below the water, which may be dangerous to the rudder and the propeller, and because large ice blocks may have been pressed in below the ice, which during the passage of the ship through the narrow leads between the floes, may break loose owing to the movements of the propeller and hit the ship from below with great force. Sailing in the East Greenland Ice, though proceeding only slowly, one may often say, "Yesterday we sailed in Siberian Ice, to-day we are in the North Pole Ice".

The different geographical types of ice are dealt with above according to their age. It goes without saying that the older the ice, the thicker it is and the larger are its pressure ridges. All these types have no doubt been influenced by the amelioration of the climate which has taken place during the last two decades; thus it is positively known that in the summer of 1936 the Baffin Bay Ice, which is usually several years old, had practically disappeared. The same was the case with part of the Siberian Ice and the Spitsbergen Ice in 1937—38. In recent years these

three types show a tendency to be only one year old. That the North Pole Ice also has grown younger during these years, is shown by the rapid drift of the PAPANIN group from the North Pole to near Scoresby Sund (May 1937—February 1938). Information about the palæocrystic ice is lacking from recent years, but if the amelioration of the climate continues, it may be taken for granted that all the different types of ice will be reduced in age, so that the palæocrystic ice will come to resemble the North Pole Ice as it was at the end of the last century, the North Pole Ice will come to resemble the Siberian Ice, and so on.

II.

RECENT ICE OBSERVATIONS IN EASTGREENLAND

FJORD ICE, LAND ICE, AND LAND WATER ALONG THE NORTHEAST COAST OF GREENLAND

The Winter Ice between Kap Brewster and Bass Rock.

Forming of the ice. The winter ice within this area is very uniform.

The fjords are nearly always free of winter ice in August. In periods of clear and calm weather about September 1st such thick new ice may form that it means a danger to motorboats without ice-sheathings, especially in the northern part of the area. In the latter half of September new ice will form in sheltered places in the interior of the fjords, but as a rule the fjords can be navigated by ships and large motorboats almost everywhere until the middle of October, when the fjords freeze up very rapidly.

During the last days of October and most of November the weather is, as a rule, clear and calm, and this period is absolutely the most suitable for sledge journeys on the fjords, the ice there being generally smooth; not till about Christmas will it be covered with snow. Sledge journeys along the outer coast are, of course, impossible during this period owing to open water.

If gales from the north set in shortly after the ice has definitely formed, trouble may arise in many places, for instance in the central part of Hall Bredning and in Young Sund. Strong foehn winds in the autumn may likewise give rise to the formation of open water, for instance in Føhn Fjord and Antarctic Sund.

It is characteristic of the fjords of East Greenland that practically no current holes occur. At the north side of Robertson Ø in Sofia Sund a current hole is sometimes found in October, which, however, apparently soon freezes up. An area of open water is further found in Loch Fyne; it is due to the tide, which here moves at a rate of up to 10 km at the turn of the tide. Open water is found here all the winter.

No very detailed information about Scoresby Sund is at hand. As to Danmarks Ø in the interior of the sound Ryder (1896) states

that the ice was safe about October 20th, 1891. He further reports a clear and cold period in November, succeeded by snowfall and bad weather.

In the fjords north of Liverpool Land (Davy Sund and the outer part of Kong Oscars Fjord) the conditions depend on the nature and extent of the pack ice; this will be dealt with below.

The conditions in the early autumn along the outer coast of Traill Ø and Geographical Society Ø are unknown. I suppose, however, that the ice forms late, for instance around Kap Parry. In 1926 I had excellent sledging on new ice without snow west of these islands at the end of October and the beginning of November; this would seem to be a common feature.

The ice forms early in the outer part of Kejser Franz Josephs Fjord, though with a few exceptions. In 1936, when there was no ice along the outer coast here and consequently a heavy swell made itself felt far towards the interior of the fjord, a member of the expedition, Dr. E. NIELSEN, left Eskimonæs on October 31st and met thin ice in Moskusokse Fjord. On his way to Waltershausen Gl. the open water extended right in to the glacier front. Not till November 6th was he able to pass on very thin ice just in front of the glacier.

On November 8th he left the Nordfjord station, crossing Franz Josephs Fjord on very thin ice from Kap Ovibos to Ymer Ø. On the same day he passed Dusén Fjord, likewise on thin ice, and along the south coast of Ymer Ø met open water. In the days November 9th—12th new ice formed, and he arrived at Ella Ø on November 12th. Not till the 16th could he start on thin new ice without drift ice floes towards Antarctic Havn.

On his continued journey he met heavy pressure areas and floes fused in the ice near Kap Biot and Kap Brown, and new ice in Fleming Fjord and Carlsberg Fjord. On November 27th there was still open water in Hurry Fjord 8 km from Kap Hope, whereas the interior of Rosenvinge Bugt was covered with ice.

Next autumn (1937) the same man made a sledge journey from Eskimonæs to Scoresbysund, but encountered quite different ice conditions. The ice began to form off Eskimonæs on September 27th. He started on October 21st, taking the route through Loch Fyne to Myggbukta. On the 24th he travelled past Kap Biot and Kap Franklin on new ice to Kap Humboldt, where he had to drive in a slight curve owing to open water in the mouth of the fjord. There was now no current hole off Robertson Ø.

The party arrived at Ella Ø over fine new ice on October 26th, and proceeded on fine ice to Antarctic Havn, which they reached on November 1st. Deep snow was met with from this point to Carlsberg

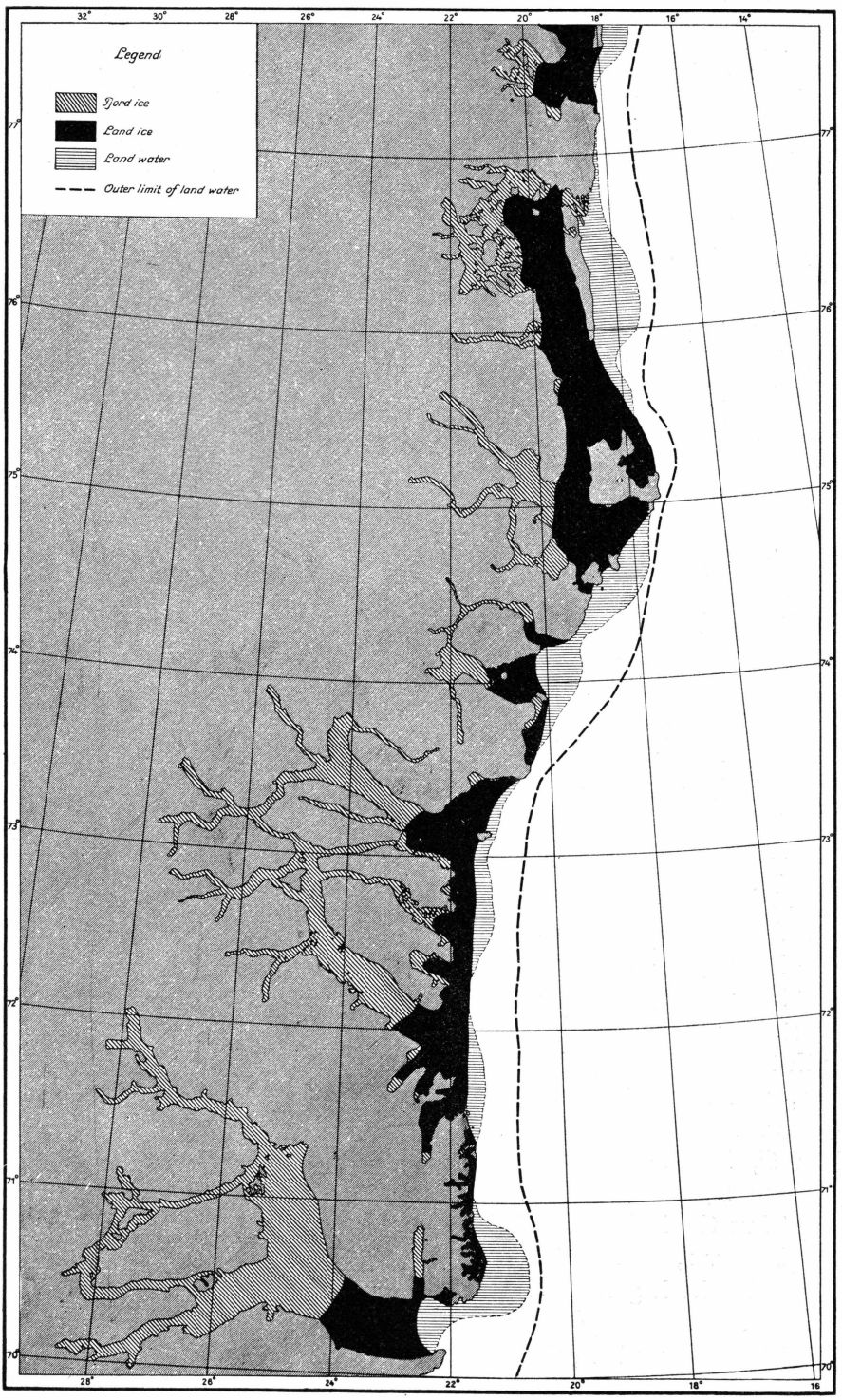


Fig. 17. General distribution of fjord ice, land ice, and land water along the central part of the east coast of Greenland.

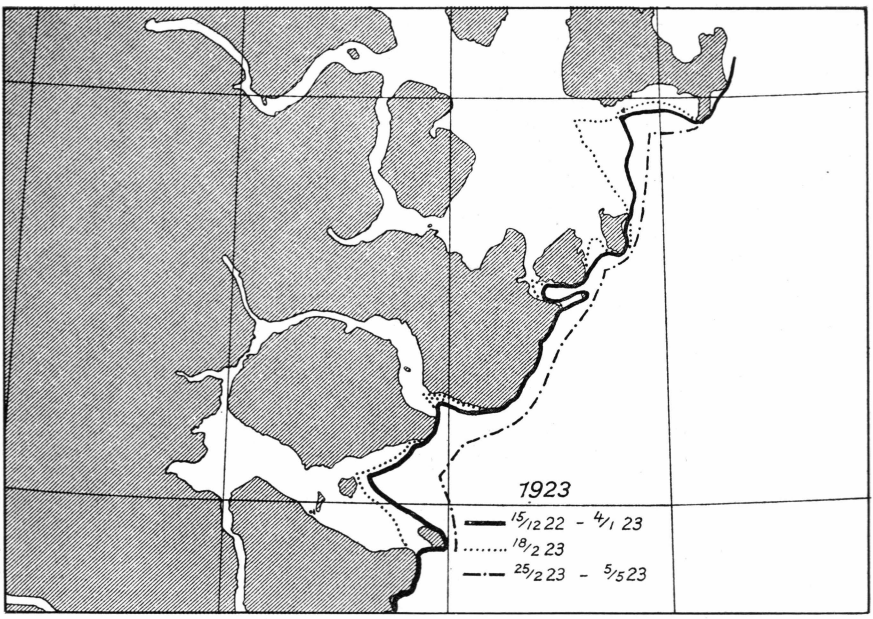


Fig. 18. Boundaries of fast ice during the winter 1922—23, according to Danish trappers.

Fjord, and as usual there were heavy pressure ridges near Kap Biot and Kap Brown. Many drift ice floes were enclosed in the ice of Fleming Fjord, and Nathorst Fjord was full of Polar floes. Carlsberg Fjord and Hurry Fjord were covered by smooth new ice. Travelling over the ice round Kap Hope, the party reached Scoresbysund on November 7th.

Two interesting series of observations (1922—23 and 1931—32) are at hand from the area between Kap Broer Ruys and Bass Rock. The first series was made by the trappers of Østgrønlandsk Kompagni (see Fig. 18) and the other by Dr. P. GELTING (Fig. 19).

Let us consider first the year 1931—32. By the middle of September practically no new ice had formed. In the normally calm period October 20th to the middle of November ice had formed between the Pendulum Øer, and from Bass Rock to Kap Broer Ruys only the outermost capes were free of ice, viz. the southernmost point of Bass Rock, Pendulum Ø, Kap Borlase Warren, Kap Mary, the easternmost point of Jackson Ø, and Kap Broer Ruys.

Thus the ice reached its extreme eastward limit on October 20th.

However, on November 16th a gale from the north broke up the ice, and a fresh gale on the 24th further broke up the ice and carried it away.

Then followed a calm period, and on February 12th the land ice reached its maximum distribution, which condition persisted without any very great alterations almost to the middle of May.

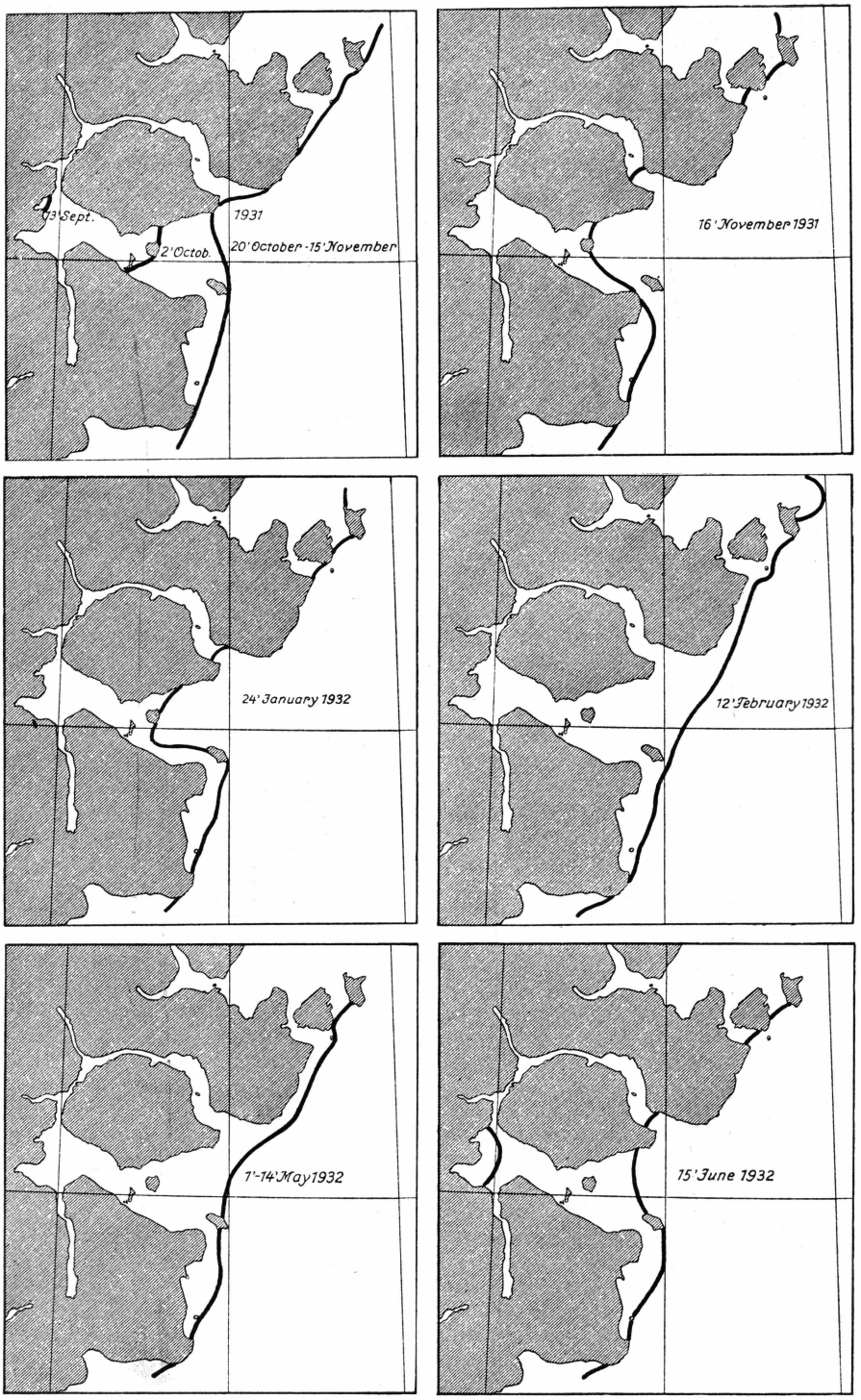


Fig. 19. Boundaries of fast ice 1931—32, according to Dr. P. GELTING.

By the middle of June the ice edge occurred some distance farther westward, though also farther east than on January 24th (cf. Figs. 19 and 20).

It will be seen from Fig. 20 that about the middle of June the melting of the ice around Jordanhill was in active progress. In the course of eight days it had advanced so much that only a narrow bridge of ice extended from Clavering Ø via Finsch Øer to the mainland.

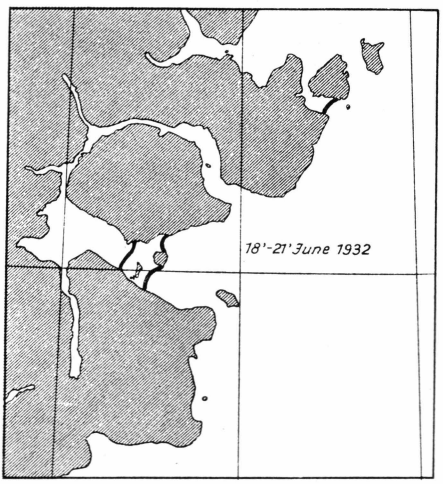


Fig. 20. Boundaries of fast ice in 1932, according to P. GELTING.

Turning now to 1922—23, it will be seen that as early as September 15th the ice extended farther eastward than during its maximum distribution in 1931—32. Furthermore, it was broken up by a number of northerly gales, namely, on November 6th, December 13th, and December 15th. The ice edge, which at that time lay near the coast, remained unaltered till January 4th, and reached its minimum distribution after a storm on February 18th, 1923. In the succeeding week of February new ice formed far eastward, which ice remained unaltered till May 5th.

Melting of the ice. These two series of observations show that the winter of 1922—23 was much colder than that of 1931—32, but both series show that a calm period occurs in the autumn, which is known from the literature also. In this period the ice as a rule forms round all, or nearly all, the capes from Bass Rock to Hold with Hope. Then follow several storms from the north, which break up the ice, making the capes and part of the coast free of ice until a calm period sets in at the end of the winter and the beginning of the spring, when the ice as a rule forms again around the capes. The melting of the ice begins about June 1st both out at sea and in the fjords,

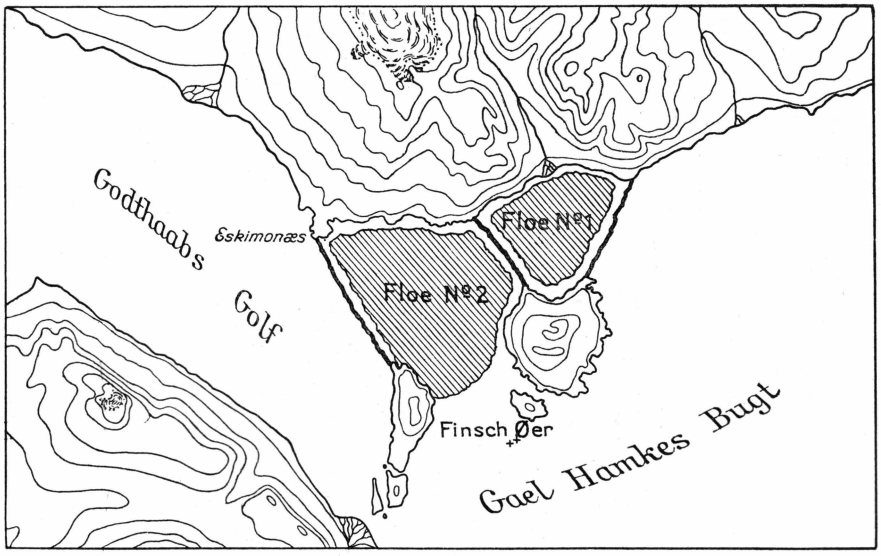


Fig. 21. The last two floes of land ice south of Clavering Ø (cf. the text).

the last to melt being the ice bridge from Clavering Ø over Finsch Øer to the mainland to the south.

The melting of the last part of the land ice between Finsch Ø and Clavering Ø is especially interesting. Unfortunately it was realised too late that here we have a measure for the melting of the ice in general, which may be used if we are to make an estimate of the formation and melting of the ice.

Fig. 19 shows that the north wind blowing out through Young Sund in the winter makes open water from Kap Mary to Elvsborg at the foot of Mt. Brinkley, the southernmost peak of the mountain range which extends across Clavering Ø, or, if the sound is frozen up, it will sweep the ice along the coast from Elvsborg to Jackson Ø free of snow, or make the snow hard-blown.

In the spring of 1927, on my way from Danmarks Havn, I tried to sledge along the south side of Clavering Ø to Kap Stosch, but had to give up travelling by this route owing to deep snow a little west of Elvsborg. However, I struck fine going down to Jackson Ø, whence I travelled through Tobias Dal and Loch Fyne to Kap Stosch.

Inside Elvsborg the ice remains till rather late in the summer. Thus on July 21st, 1929, the "Godthaab" was stopped by land ice near Elvsborg.

In the winter two, as a rule narrow, leads in the ice extend from the northeastern and the northwestern capes of St. Finsch Ø to the two outer points of Dødemandsbugten, respectively (cf. Fig. 21). In

the autumn of 1931 a Norwegian trapper was drowned in the outermost lead near the south coast of Clavering Ø, and in December 1931 a Danish trapper went through the ice in the same place and had his feet severely frost-bitten. Suggestions of a small lead are further noticeable from Eskimonæs to the northernmost point of Lille Finsch Ø.

When in June and July the melting of the ice advances from the interior of Godthaab Golf and from the sea, all the ice disappears except the two ice floes. The innermost one, between Eskimonæs, Lille Finsch Ø and Store Finsch Ø, cannot get out until fairly large parts of its margins have melted. The outermost ice floe remains in place for a long time, for it will have to melt rather considerably before it can slip out between the capes, drifting westward or eastward according to the direction of the wind. The date for its disappearance varies greatly but generally it disappears in the last week of July; in 1935, however, it did not disappear till the middle of August.

Between Kap Brewster and Bass Rock the melting of the ice is subject to great fluctuations. It will therefore be necessary to describe these phenomena in a normal year and then consider some abnormal years in which thaw set in either very early or very late. Generally the first thaw-water rivulets begin to flow about the middle of May. During the last half of May frost alternates with thaw, but the rivers increase in volume every day, while the snow on the winter ice is but slightly affected; the winter ice does not begin to melt until the beginning of June, when the snow grows soft, and it is impossible for dog-sledges to drive by day, sledging being only possible in the night in clear and frosty weather.

In May large holes with open water will form in several places along the edge of the winter ice. Where this takes place, notably south of Sabine Ø and in Gael Hamkes Bugt, part of the winter ice will drift out to sea, but otherwise the outer ice edge remains very constant during May-June. In the interior of the fjords the temperature rises considerably in the course of June, especially in the narrow fjords with high rocky walls, where the snow rapidly melts.

About midsummer the snow on the winter ice has melted and disappeared, but the smooth surface of the ice is almost unbroken, leads having only formed in a very few places.

About July 1st the fjord ice disappears in the course of a few days if the weather is calm and sunny (cf. Figs. 23–24). This disappearance has been preceded by a constant melting throughout the month of June, the ice-covering of the innermost fjord ramifications being accordingly very thin.

During the following two weeks the ice melts in Hall Bredning, the outer part of Kong Oscars Fjord, Franz Josephs Fjord, and Gael Hamkes



Fig. 22. Last-stage land ice in Young Fjord after heavy rain in July.

Bugt, while in case of cold weather during May-July a belt of land ice, which may persist till late in the summer, will still be left in many places about the middle of July.

On the whole the weather in June plays a great part for the navigation of the East Greenland fjords, which usually takes place about the middle of July. If easterly winds, which are generally accompanied by clouds, prevail in June and the beginning of July, the melting at the mouths of the fjords takes place very slowly, and remnants of this outer ice belt may then persist til far into August. This was the case in 1933, when a continuous belt of ice extended from Liverpool Kyst to Foster Bugt as late as August 7th. Davy Sund was not passable till August 21st, and off Traill Ø and Geographical Society Ø the winter ice persisted till the end of August.

In a normal year the eastern edge of the land ice extends, about July 1st, from the south coast of Scoresby Sund in an almost straight line to a short distance west of Kap Stewart, and there is still some ice in the outer part of Hurry Fjord. A narrow belt of land ice extends along Liverpool Kyst, only the eastern point of Rathbone Ø, Kap Greg, and possibly one or two more northerly points being ice-free. From Murray Ø the edge of the land ice runs as a nearly straight line to a point slightly west of the south coast of Broer Ruys Fjælde, and from Kap Broer Ruys some distance east of Holland Ø and Arundel Ø to the easternmost point of Jackson Ø, and onwards from the north side of this island to a little south of Kap Mary and thence towards Kap Herschel.

Thus about July 1st open water is found along the coast from a little west of Kap Stewart to Kap Swainson. A long stretch of open water occurs south of Kap Broer Ruys. Furthermore the north side of Jackson Ø, Kap Mary, and at any rate the coast from Kap Borlase Warren to Kap Wynn and the south coast of Pendulum Øer are free of ice.

About the middle of July the land ice disappears from the outer part of Scoresby Sund and the outer part of Franz Josephs Fjord. About one week later the last remnant of land ice off Godthaab Golf disappears, while the land ice between Kap Broer Ruys and Kap Krauss is the last to melt.

As stated repeatedly above, the weather is generally calm in May and June, and if wind is rare in July, water will flow out of the fjords owing to the rapid melting, and land water may form along the edge of the land ice; if not held back by the wind, the pack-ice is often removed some distance from the edge of the land ice.

It will be seen from Figs. 24 and 25 that at the beginning of July 1933 land water had formed from Scoresby Sund to Hold with Hope, while

16th. Subsequently the ship went to Gefions Havn in Dove Bugt without being troubled by ice. She left on the 19th, to start the return voyage around the north of Koldewey Ø.

A good deal of detailed information is further supplied by the yearly reports issued by the Danish Meteorological Institute; some of these observations will be dealt with here. Thus it is stated that in 1932 Mørkefjord froze up in October, and that in 1933 it became free of ice on July 26th, in 1938 about August 1st, and in 1939 at the end of July. Further, it is stated that in 1932 Bessels Fjord froze up on October 4th and became ice-free on July 21st, 1933.

The narrow western fjord ramifications within this area may in general be said to be free of ice from the end of July to about October 1st, or a little more than two months.

Hochstetter Bugt normally becomes free of land ice in the first half of August, Dove Bugt about the middle of the month.

While the ice of the western fjord ramifications melts at fairly constant dates every year the melting of the land ice may present great fluctuations, chiefly on account of the weather in June-August. Within the period 1929—1939 the land ice persisted all summer in the two years 1935 and 1937; in all the other summers the land ice seems to have drifted out in the course of August. According to earlier observations, the land ice seems to have persisted over the summer in Hochstetter Bugt in 1869 and 1870, in Dove Bugt in 1907 and 1937.

The Ice Conditions between Danmarks Havn and Kap Bridgman.

While in the area between Scoresby Sund and Bass Rock the fjord ice generally melts in July and land ice only exceptionally occurs in August, the land ice between Bass Rock and Danmarks Havn as a rule melts in August, but in some years it persists throughout the month, sometimes all summer.

In the area between Danmarks Havn and Kap Bridgman a very large part of the fjord ice as a rule persists during the whole summer, and quite exceptionally there is open water, at any rate in the outer parts of the fjords, in August; however, it should be added that very few observations on these regions are at hand.

In May 1900 R. E. PEARY passed Kap Bridgman on his way to Wyckoff Land. A map showing his travelling route was published in 1907, and on this map a fairly broad belt of land ice is indicated along the coast. In the days about August 1st, 1905, the Duke of Orleans visited Northeast Greenland by ship. He went ashore on the islands

On the 19th close-packed ice still occurred east and northeast of Shannon, whereas Hochstetter Bugt was free from ice.

On August 10th, 1934, I made an air reconnaissance from Eskimonæs to the middle of Hochstetter Bugt (cf. Fig. 33). The melting of the ice in the bay was in active progress, but owing to the ice pack the floes could not drift away. Ice floes occurred in Peters Bugt, while land ice was still found in Shannon Sund and northward. A large area of open water was observed east of Koldewey Ø.

Information about the ice conditions north of Bass Rock in 1935 is sparse. From Hochstetter Forland, however, Peters Bugt is reported to have been covered by winter ice as late as August 12th. Some days later a motorboat sailed in open water across Peters Bugt to Ardencaple Fjord, and west of Kuhn Ø to Albrechts Bugt, which was free of ice as far as a line from Kap Maurer to Kap Berlin; near the latter cape the motorboat was beset in the ice. As late as August 20th the ice in the central part of Hochstetter Bugt was unbroken; practically all the land ice between Bass Rock and Danmarks Havn persisted during the summer.

On August 19th, 1936, the "Gustav Holm" sailed from Sandodden towards Hochstetter Forland; a great many floes of fjord ice were encountered, but they drifted rapidly seawards, so Hochstetter Bugt can be said to have become free of ice that day. On the return voyage on the 23rd no ice was met with.

In August, 1937, the land ice extended from Sabine Ø to Kap David Gray and from Kap Børgen to some distance north of the southernmost point of Koldewey Ø, and calling at the different trapping stations was therefore impossible. Only the innermost fjord ramifications were free of ice, even Peters Bugt was almost constantly ice-covered.

On August 13th, 1938, the "Gustav Holm" tried to call at the trapping stration on Hochstetter Forland, but had to give up the attempt, unbroken winter ice extending between Sabine Ø and Shannon. Fairly ice-free water was found along the east side of Shannon. On the 15th an attempt was made to push into Dove Bugt, but without success, so the ship went around the north of Koldewey Ø, arriving at Hvalrosodden on the 16th. On the 19th the ship started southward to Gefions Havn, but next day was stopped by unbroken ice in the southern part of Dove Bugt. So she had to go north and east of Koldewey Ø, where she found fairly ice-free water. On the 23rd the ship tried to push into Hochstetter Bugt, but the waterway between Shannon and Pendulum Øer was filled with drift ice. An attempt to call at Germania Havn was unsuccesful.

In 1939 the "Gustav Holm" sailed northward past Shannon in fairly ice-free land water and reached the station Mørkefjord on August

month of 1931 and 1932, when, according to A. SCHWARCK, who stayed in this territory during these years, there was not very much fog.

In May a journey was made around Kuhn Ø and into Grandjean Fjord and Ardencaple Fjord. Near Kuhn Ø the snow was very deep and soft, especially along the south side of the island, and sledging was likewise difficult in Grandjean Fjord. In Ardencaple Fjord, however, the party encountered smooth ice in many places, whereas Smallefjord contained a belt, 6 km broad, of hummocked ice with many pools (end of May); probably a foehn storm in the autumn had broken up the ice and pressed the floes together some distance farther out.

June, which is normally very rainy and foggy within this area, in 1933 had many fine and clear days and only some few foggy days. The streams on land began to flow at the end of May, and from the middle of June there were many pools of thaw-water on the thin ice. July also generally had fine weather, with only eight foggy and rainy days.

From July 17th to 24th the ice grew more and more "rotten" and was dissolved into large floes, and large areas of open water occurred. On the 18th open water was observed in Peters Bugt and Ardencaple Fjord (from Muschelberg), whereas the greater part of the ice of Hochstetter Bugt remained unbroken; but on the 21st a lead formed, which extended across to Kuhn Ø. On the 25th the ice situation was as follows (seen from Muschelberg):

Ice in Hochstetter Bugt as far as a line from Muschelberg to Kuhn Ø; inside this line open water. Much open fjord ice in Ardencaple Fjord and in Grandjean Fjord.

On the 26th Peters Bugt was free of ice, and the ice of Hochstetter Bugt consisted of floes, which were carried by the wind towards the south coast of Hochstetter Forland.

On the 28th the north wind carried the ice southward, Peters Bugt was free of ice, but large continuous belts of fjord ice occurred near Grandjean Fjord and Kuhn Ø.

On August 1st Hochstetter Bugt was largely free of ice.

On August 3rd the Norwegian ship "Polarbjørn" was observed sailing in and out of Peters Bugt; even on the 2nd navigation was possible everywhere.

On the 4th a motorboat passed without difficulty through Shannon Sund and along the outer coast of Hochstetter Forland.

On August 7th the "Gustav Holm" arrived at the station. A reconnaissance from the air that day showed that Shannon Sund was blocked by close-packed ice resembling winter ice, and close-packed ice was likewise observed along the east and south coasts of Shannon. Large masses of drift ice were seen between Shannon and Koldewey Ø.

ice disappeared during the succeeding days, the middle part of Hochstetter Bugt, was free of ice on the 11th, but fresh ice masses arrived on the 13th. The temperature had now fallen to c. — 8° C. From the top of Muschelberg Shannon Sund was seen to be frozen up about the middle of September and large masses of polar floes were observed between Shannon and Kuhn Ø. During the following days the new ice spread rapidly, but on September 17th a northerly wind cleared the middle of the fjord of ice, whereas a belt of thick new ice 2—3 km broad was found along the coast. On the 24th all the new ice was broken up by a gale, but did not drift away except from Peters Bugt, which was thus free of ice. On the 26th fairly large masses of floes drifted into the middle of Hochstetter Bugt.

During the first half of October there came a good deal of snow and frequent fogs. The temperature was about — 10° C., the lowest temperature, — 14° C., was registered on the 14th. The middle part of Hochstetter Bugt was free of ice, but the new ice along the coast increased in thickness. During the latter half of October the climate was more stable, with temperatures about — 18° C. and often clear weather. On October 17th the bay was almost covered with ice, and on the 19th a sledge party travelled across Peters Bugt. On the 21st the ice in Shannon Sund was thick enough for sledging.

On November 2nd A. B. C. Madsen and A. Schwarck started from Kulhuse via Kap Maurer, Kap Berlin, and Clavering Stræde to Eskimonæs. The sea ice in Hochstetter Bugt seemed everywhere to be of the same age as near Kulhuse, whereas between Sabine Ø and Kap Mary it was apparently only a few days old, and many holes with open water occurred near Kap Mary. The trappers reported that not till then had the ice along the coast of Wollaston Forland been passable for sledges, new ice and open water having alternated all autumn.

The return journey took place at the beginning of February, and as the trappers stationed at Kap Hershel reported that only once during the winter had it been possible to sledge along the outer coast of Wollaston Forland, the party took the route through Kopasset to Albrechts Bugt. The party was storm-bound at Sandodden for some days, but during the rest of the journey travelled on sea ice covered with hard snow, thanks to the stormy period about the middle of February, and arrived at Kulhuse on February 26th. In the last week of February and the first week of March the weather was very unsettled, with heavy snowfalls and violent gales locally. In April the weather was generally fine, clear and calm. Owing to the heavy snowfalls at the end of March there was deep and soft snow around Kuhn Ø, whereas there was hard-blown snow everywhere around Shannon. May was extraordinarily foggy (altogether sixteen foggy days), unlike the same

in the fjords and from the American ship the "Morrissay", which made some voyages between the 25th and 30th July. It should be noted that observations are wanting from the central part of Dove Bugt.

In 1931 the Danish expedition ship "Godthaab" visited the south coast of Hochstetter Forland in the days August 14—17th. Very open ice and a fairly broad belt of land water were met with from Eskimonæs to Bass Rock. Hochstetter Bugt was entirely free of ice. On August 17th the ship went southward along the coast without being troubled by ice.

In 1932 the scientific station Kulhuse was erected on the south-western part of Hochstetter Forland, and from this station systematic observations were made, supplemented by observations made by the trappers at the Nanok stations near Kulhuse, at the mouth of Bessels Fjord, and on Hvalrosodden. It is therefore possible to give a fairly clear picture of the ice conditions in Hochstetter Bugt in 1932—33.

On July 28th, 1932, the present author flew from Eskimonæs across Wollaston Forland, along the east coast of Kuhn Ø and Hochstetter Forland to the southernmost point of Koldewey Ø, and along the east coast of this island to Danmarks Havn, which was free of ice so that it was possible to land. The flight was continued to Hvalrosodden and, after a short landing there, to Kap Daly, thence to the head of Tyroler Fjord and back to Eskimonæs (L. KOCH 1940, p. 282). A few remnants of much washed ice were observed east of Kuhn Ø, a solid sheet of winter ice extended from the southern part of Shannon Sund to the northern part of Dove Bugt, whereas the inner fjords were free of ice. The northern part of Shannon Sund and the sea between Shannon, St. Koldewey Ø, and the mainland were covered by winter ice, while the northern and western parts of Dove Bugt were free of ice (cf. Fig. 29).

On August 8th an air reconnaissance was made along the shore to Bass Rock. No ice was found along the coast, and not very much ice was observed in Hochstetter Bugt. Next day the "Gustav Holm" started from Eskimonæs, and arrived at Kulhuse on August 10th without meeting ice of any importance. On the 12th the ship worked her way through some polar floes in Shannon Sund to Bessels Fjord. On the 13th the ship went southward to Kulhuse, which she left on the 18th, passing Bass Rock about midnight of the same day.

Later on the Kulhuse station reported that large masses of ice had drifted into the fjord that day, the whole of Peters Bugt was filled, too, and sailing in motorboats was impossible. The last days of August the weather was rather unsettled, with fog and snow, and new ice was formed in several places.

On September 1st a gale from the north drove the ice out of the fjord. On the 6th and 7th fresh ice masses drifted in, but part of the

proached the land. On the 21st a broad belt of land water extented 30 miles out from the shore, enabling the Norwegian ship the "Sjöblomsten" to go up to fetch EJNAR MIKKELSEN.

It is interesting to note that in the years 1909—12 EJNAR MIKKELSEN observed the ice edge extending all winter from Kap David Gray to Bass Rock, but the deep western curve of the ice edge between Shannon and Bass Rock does not seem to be common. Nearly all other observations show that generally the ice extends in almost a straight line between Kap Philip Broke and Bass Rock till the late summer.

F. W. H. LAUB (1922, pp. 147—49) writes about a presumed current moving around Shannon and down through Shannon Sund. On p. 148 he gives a sketch of the ice conditions around and south of Shannon as observed by him on a journey on June 9—10th, 1910. Although primitive, and though no distinction is made between pack-ice and land-ice, the sketch gives a clear idea of the course of the ice edge at that time.

On July 20th, 1919, the Danish ship the "Dagny" passed Bass Rock on her northward route. The winter ice is reported to have extended from Bass Rock towards Shannon, probably to Kap Philip Broke. There seems to have been land water east of Shannon, for on the 21st, the ship reached the land water along Koldewey Ø without any difficulty and proceeded in this water almost to Danmarks Havn, which, however, was barred by drift ice. The ship cast anchor near Kap Bismarck, where the land water was a couple of miles broad. On August 6th the "Dagny" went southward again in land water, and reports that the winter ice in the fjords, that is to say the land ice, had now disappeared.

From 1922 the Danish ship "Teddy" reports that on July 15th the ice extended from the north side of Pendulum Ø to Kap Philip Broke, and thence about 15 miles eastward, when it turned northeastward. Probably there was land water along the southern part of Koldewey Ø.

In 1926 an English expedition under J. M. WORDIE visited Germania Havn. Hochstetter Bugt seems to have become free of ice as early as July 22nd.

In August, 1929, members of the hunting company "Nanok" entered Hochstetter Bugt onboard a Norwegian ship, which, however, was stopped by ice midway between Kap Rink and Muschelberg. It is not quite clear from the information given whether the ice was land ice or, which seems the more probable, a belt of drift ice. However, at the end of August the whole of Hochstetter Bugt was ice-free.

From 1930 an ice chart (cf. Fig. 28) drawn by A. SCHWARCK is at hand. It it based on information received from the trappers staying

pp. 402—04, where TROLLE mentions a number of details regarding the formation and melting of the ice about Danmarks Havn and gives interesting information of its thickness, chiefly around the ship (pp. 392—95)).

A number of interesting observations on the ice around Shannon in 1909—12 are given by EJNAR MIKKELSEN (1922, pp. 190—95), but unfortunately they are not accompanied by any chart. It appears from the description that in August 1909 there was open water off the southern part of Koldewey Ø until the 25th, when ice drifted into the waterway between Koldewey Ø and Shannon. In Shannon Sund and probably in Hochstetter Bugt there was open water. The ice in Frozen Bay persisted all summer, while along the east coast of Koldewey Ø there was a narrow belt of open water, which froze up by the middle of September. Open water was found all winter between Kap Philip Broke and Kap David Gray, continuing southward to Bass Rock and in a broad belt eastward from this point.

In 1910 the ice packed closely along the east coast of Shannon all summer; only on August 5th was a small space of open water found along the south coast of the island and some distance south of Kap Philip Broke. There was open water towards Bass Rock in the winter, but in no place did it reach the shore.

In the summer of 1911 there were frequent winds from the east and only little open water. A large area of open water was observed in the latter half of March between Kap Philip Broke and Kap David Gray, extending from this cape towards Bass Rock; however, this area decreased in size after a southeasterly gale on June 18th. The ice of Frozen Bay broke up into floes on August 9th, but owing to close-packed ice outside the bay it could not drift out and remained in the bay all the summer. Once or twice in July narrow leads of open water were observed along the east side of Koldewey Ø. Shannon Sund became free of ice on August 19th, while in Hochstetter Bugt the ice had broken up into floes as early as the middle of the month; it was free of ice on August 23rd after strong westerly winds, but the pack ice outside the bay prevented the winter ice from drifting southward.

At the beginning of April 1912 there was a large area of open water east of the southern part of Koldewey Ø, which extended almost as far as Haystack. A little south of Haystack a narrow lead with open water extended east of Shannon, connecting with the area of open water formed in March between Kap Philip Broke, Kap David Gray, and Bass Rock. In May much open water occurred south of Kap Philip Broke and southeast of Bass Rock. In July there was a heavy swell towards the shores of Shannon, so there was hardly very much ice outside the island at that time, but on July 14th the ice again ap-

Observations on the ice are indicated on the main chart of the expedition published on a scale of 1:400,000. The edge of the land ice between Bass Rock and Kap Philip Broke was the same in 1869 and 1870, showing a slight western indentation. Hochstetter Bugt does not seem to have been ice-free in any of these years, while open water occurred along the east coast of Shannon in July and August of both years. In 1869 the ship pushed northward to a little beyond 75°30′ N. lat., that is to say, a short distance north of Shannon, but there she met impenetrable ice masses. The same happened next summer, when on July 22nd the ship sailed in open water to some distance north of Shannon.

About the middle of September 1869 an excursion was made to Fligely Fjord, where new ice, formed at the beginning of the month, was met with; this means that the fjord has been free of ice in the summer. About November 1st a sledge journey was made to Tyroler Fjord and Clavering Ø. Smooth ice is recorded from the water north of Clavering Ø, which should probably be taken to mean that the ice was young and that the inner part of Tyroler Fjord was free of ice in the summer of 1869.

From March 8th to April 27th, 1870, the expedition made its large sledge journey northward to Kap Bismarck. Nothing is reported about the ice except that north of Haystack it was several years old.

On July 14th, 1870, a boat trip was made to Clavering Ø. Land ice was encountered along the coast some distance west of Kap Mary, and the party then proceeded on foot.

On July 29th, after being stopped by land ice a little north of Koldewey Ø, the Captain from an altitude of c. 200 m observed open water at the southernmost point of Koldewey Ø.

The next to visit these regions was the Norwegian Captain Knudsen, who in August 1889 met open water in Hochstetter Bugt and pushed with his ship far into Ardencaple Fjord.

The Danmark Expedition, which wintered in Danmarks Havn in 1906—08, made numerous sledge journeys between this place and Bass Rock, thus in November 1906 around Koldewey Ø, in November and December to Pendulum Øer, in November-January 1907—08 to Shannon and Bass Rock, in April-May to Ardencaple Fjord and Shannon, and in April 1908 to Dove Bugt and Bessels Fjord.

It will be seen that all these sledge journeys were made either in the late autumn, the winter, or the early spring. However, the reports on the journeys give no clear information about the ice conditions between Bass Rock and Danmarks Havn. We must therefore be content to say that Dove Bugt and probably Hochstetter Bugt, also, have in the main been free of ice in August 1906 and 1908, whereas in 1907 the ice of Dove Bugt persisted during the summer (cf. M. o. G. Bd. 41,

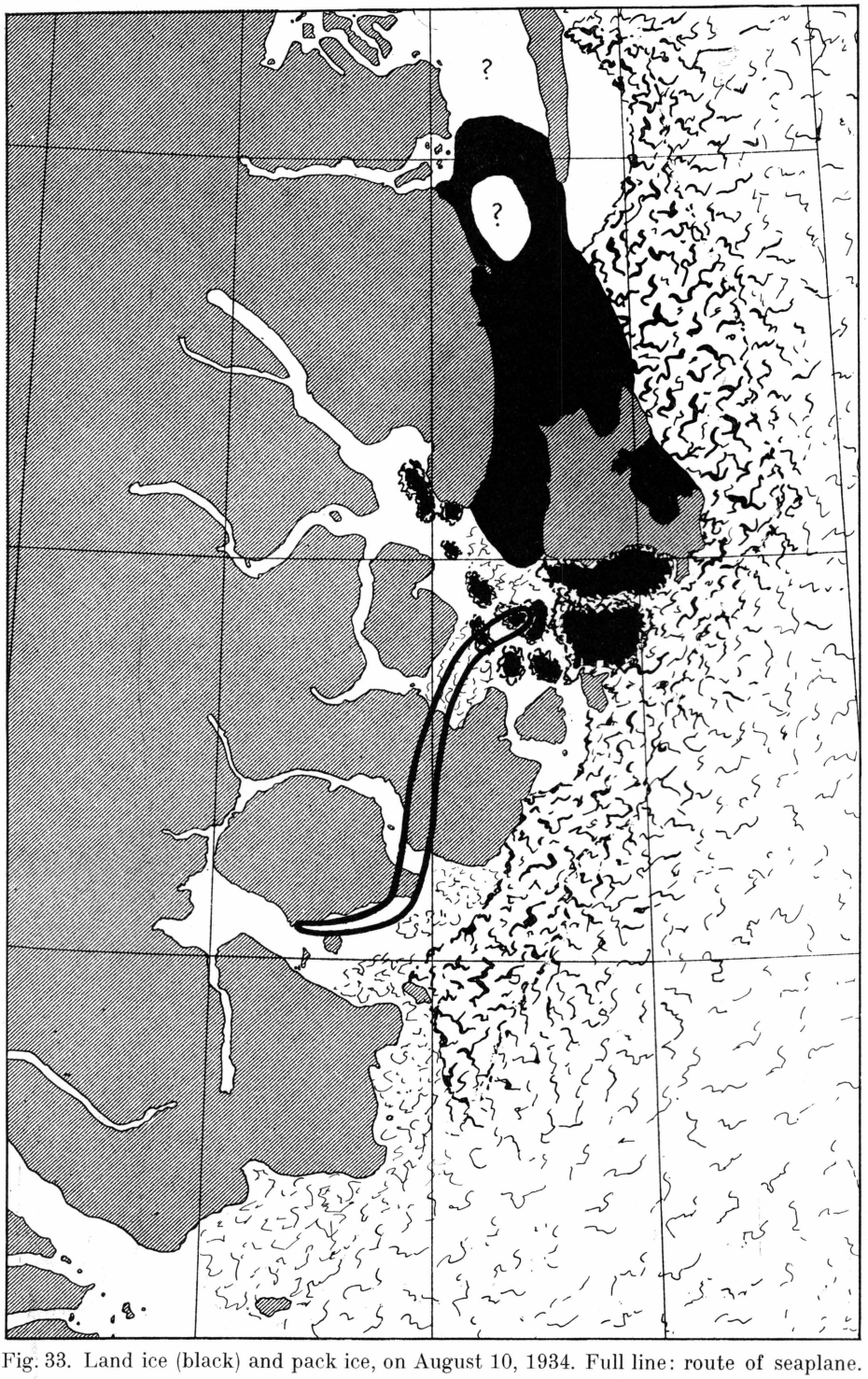


Fig. 33. Land ice (black) and pack ice, on August 10, 1934. Full line: route of seaplane.

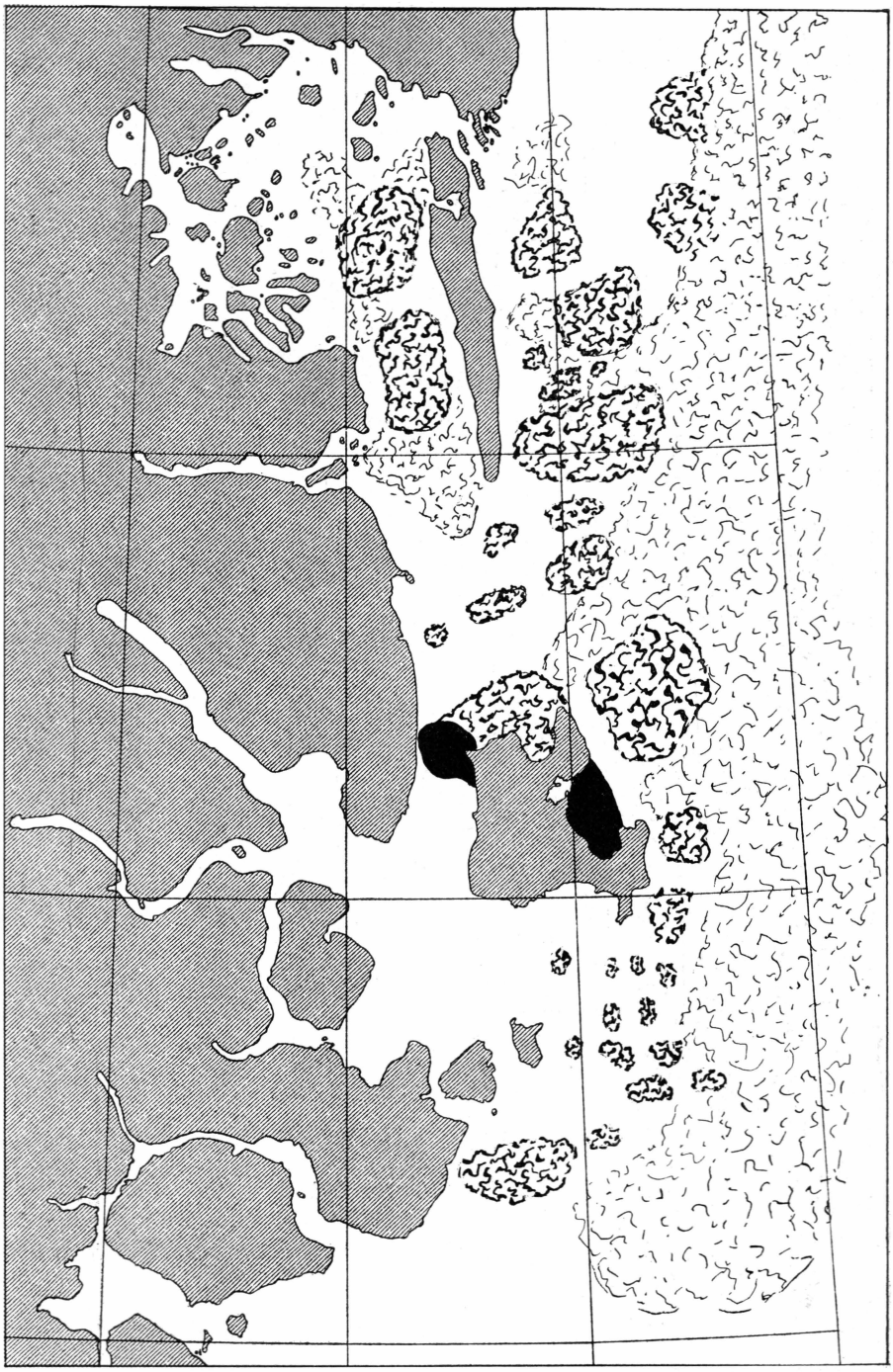


Fig. 32. Land ice (black), drift ice, and pack ice, August 19, 1933, according to various observations from the air.



Fig. 31. Land ice (black), drift ice (lightly shaded), and pack ice (heavily shaded), August 7, 1933, according to various observations from the air.

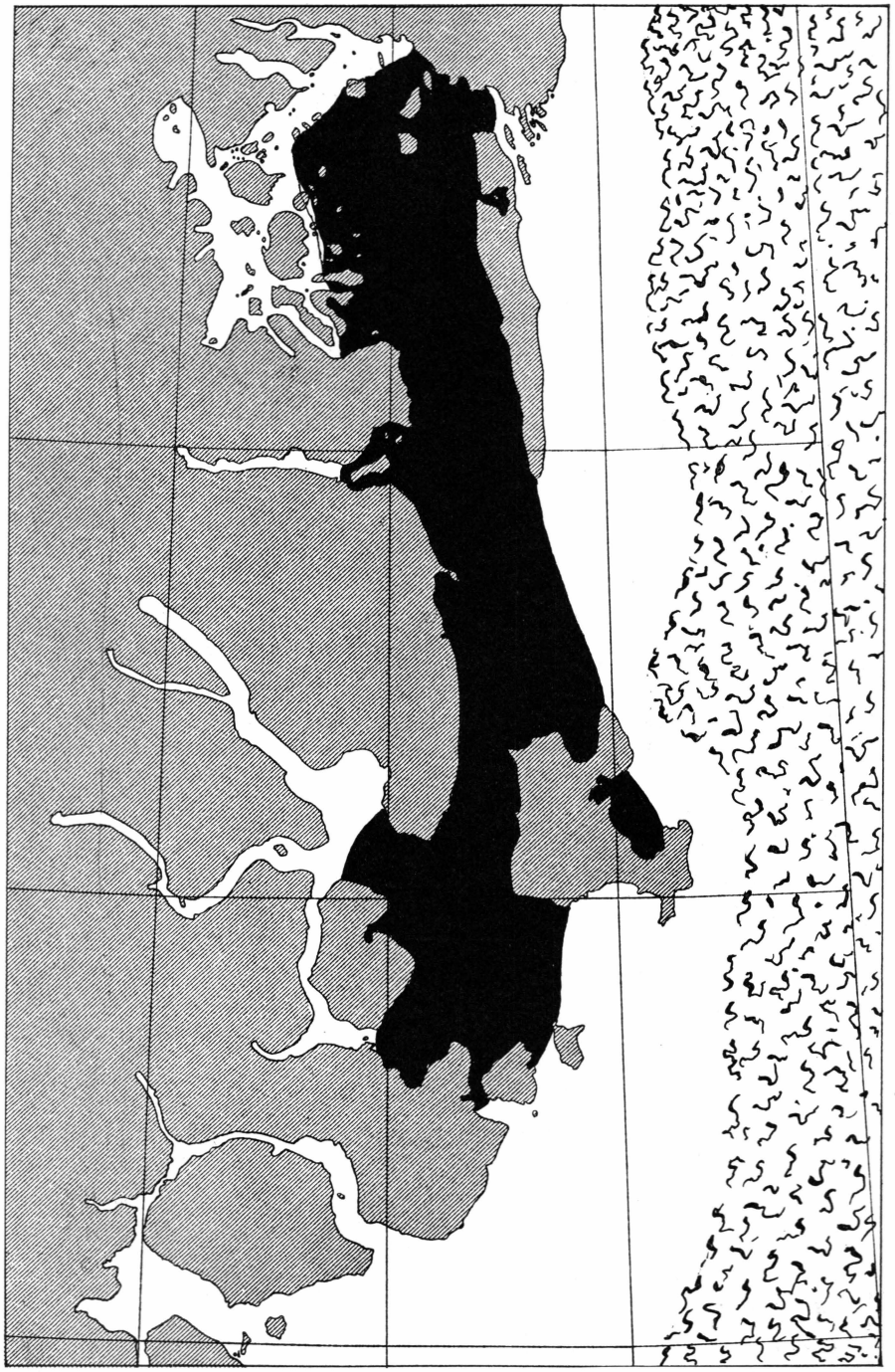


Fig. 30. Land ice (black) and pack ice (shaded) on July 24, 1933, according to various observations from the air.

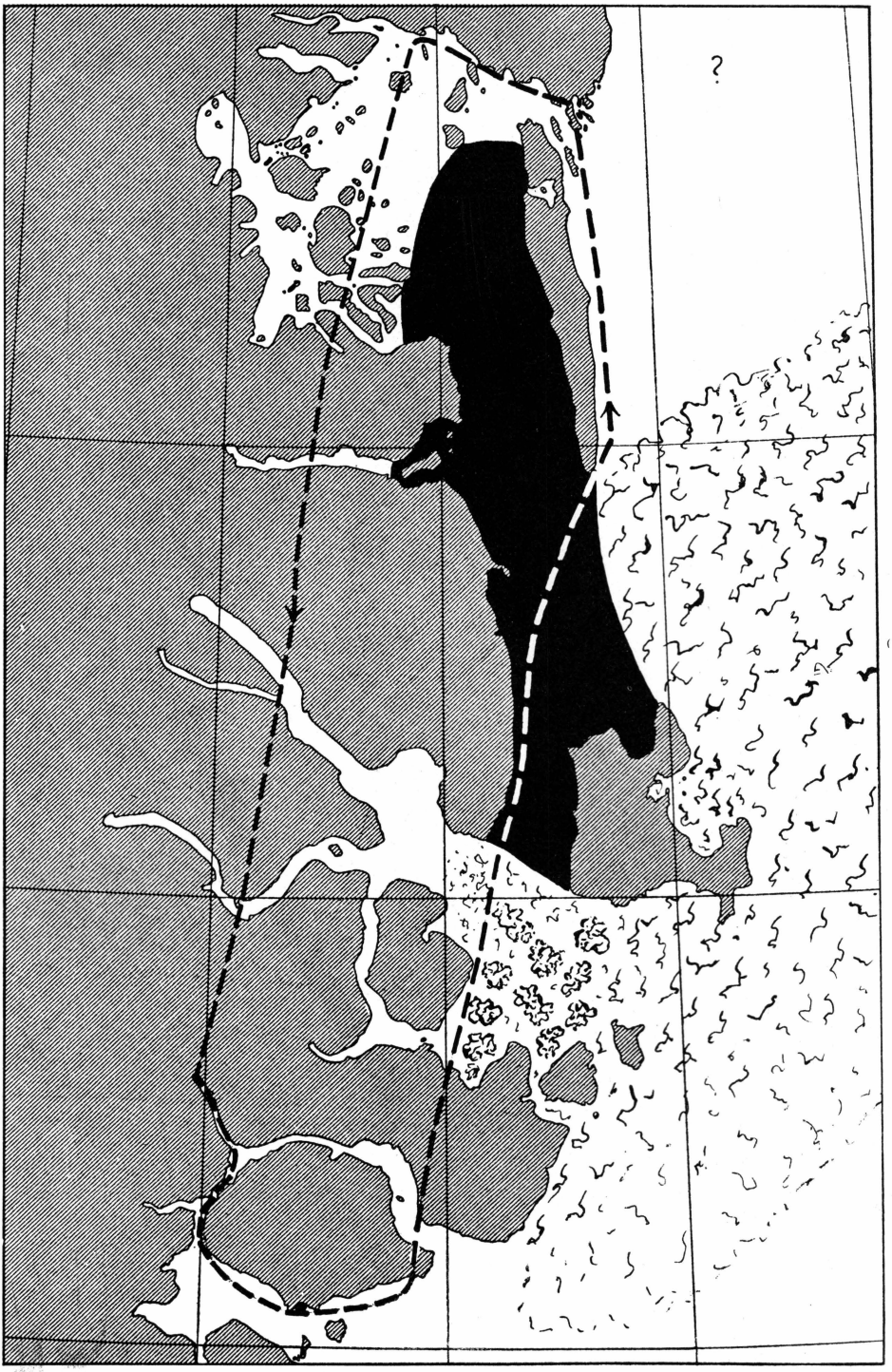


Fig. 29. Land ice (black) and pack ice (shaded) on July 28, 1932. Broken line: route of seaplane.

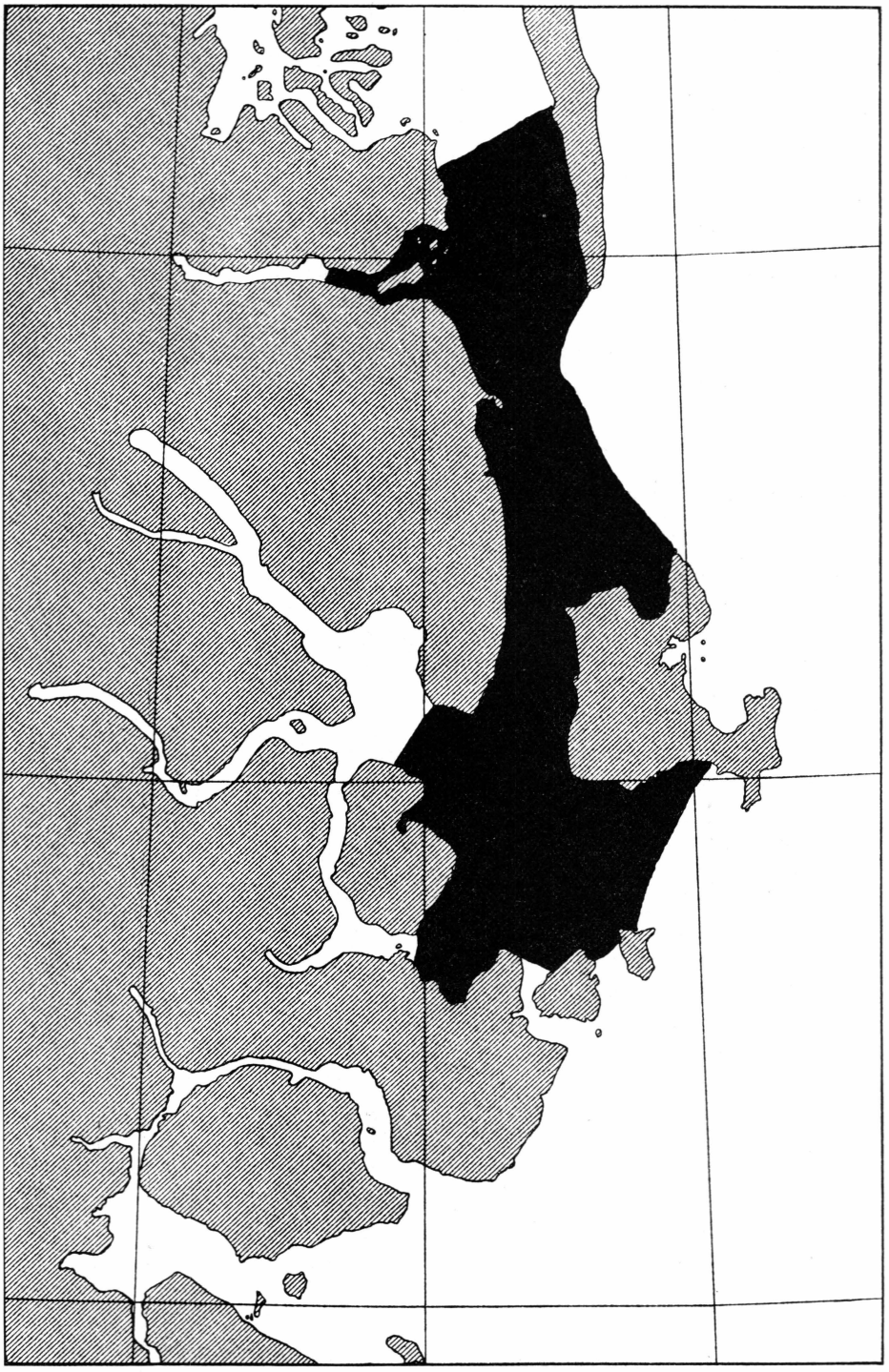


Fig. 28. Land ice (black) on July 25—30, 1930, according to A. Schwarck. Pack ice not indicated.

The melting of the land ice depends on the climate in the early summer and generally it is of some consequence whether it is a light or a heavy ice year.

In the heavy ice years 1929, 1934, 1935, and 1937 the land ice disappeared rather early, navigation being only impeded by pack ice, which the easterly winds had carried into the fjords.

If the ice belt is narrow, clouds will occur over the land ice in the spring and delay the melting. Conversely, a broad ice belt will often be accompanied by clear weather in the spring and excessive melting of the ice in the mouths of the fjords.

The Ice Conditions between Bass Rock and Danmarks Havn.

Geographically this area differs in many respects from the regions situated south of it. In the west we find a number of narrow fjords surrounded by high mountains; as far as is known to me, these fjords become free of ice every summer.

Long and broad fjords do not occur. Towards the sea the coast is sheltered by a series of islands: Pendulum Øer, Shannon, and Store Koldewey Ø, owing to which the land ice persists till late in the summer, forming a continuous ice sheet in the outer part of Hochstetter Bugt, Shannon Sund, and the greater part of Dove Bugt. Generally the ice melts in the course of August, but not rarely it persists all summer and, if so, during the succeeding winter, also.

Northeasterly currents moving into the fjords are of little importance here; drift ice often occurs in the open water between Koldewey Ø and Shannon as also between Shannon and Pendulum Øer.

Locally the ice conditions are much marked by the foehn winds. Such winds are of common occurrence in the interior of Grandjean Fjord. Ardencaple Fjord is perhaps the Northeast Greenland fjord which is most frequently swept by foehn winds and this sets its mark not only on the ice-cover of the fjord itself, but the effects are traceable far out in the waterway between Shannon and Kuhn Ø. Foehn winds are likewise common in Bessels Fjord and Mørkefjord.

As is well known, the area was discovered and mapped by the Koldewey Expedition 1869—70 (1873), the first expedition which spent a winter in Northeast Greenland and the report on the expedition still remains an important source of our knowledge of the country.

On August 5th, 1869, the expedition ship cast anchor at Germania Havn, and from August 7th and during the rest of the month the ship made numerous trips in the land water between Shannon and Pendulum Øer. Furthermore an excursion by boat was made to Kap Borlase Warren, where icebergs and floes were met with.

the outer part of Kong Oscars Fjord, whence it disappeared at the end of July.

In 1937 the land ice had disappeared from the whole area at the end of July.

In 1938 (cf. Fig. 36) about 30 km of ice occupied the outer part of Scoresby Sund on July 25th, while open water was observed in Davy Sund on July 19th. Only about Mästers Vik was there an ice plug c. 20 km broad, which disappeared at the end of July.

In 1939 only small masses of drift ice occurred along the east coast of Greenland, but the land ice persisted exceptionally long. On July 26th the "Gustav Holm" tried to enter Young Sund, but was stopped by the land ice, which lay across the mouth; however, on August 4th it had disappeared. On July 27th there was no ice in Gael Hamkes Bugt between Clavering Ø and Store Finsch Ø. On the 31st the ship passed Kap Broer Ruys, but a little west of Broer Ruys Fjælde met the edge of the land ice, which extended southward even past Bontekoe Ø. On August 1st the ship sailed southward along the ice edge to Traill Ø. On August 8—10th the ship again attempted to go into Foster Bugt, but did not succeed. On August 27th the ice in Foster Bugt had broken up, and the ship went through it past Kap Wijkander and onwards through Sofia Sund to Ella Ø. On August 30th the ship sailed out of Sofia Sund again and met open ice in Foster Bugt.

Altogether it may be said that the first minor areas with open water appear in the interior of the fjords in the last days of June. In the first week of July all the narrow fjord ramifications become free of ice. In the second and third weeks Scoresby Sund, Kong Oscars Fjord, Franz Josephs Fjord, and Godthaab Golf become ice-free. As a rule the outermost areas of land ice likewise disappear during this period. In especially favourable years, however, all the land ice may disappear about the middle of July, while in unfavourable years large areas of land ice may persist till the middle of August or even longer. But after September 1st no examples of summering winter ice within this area are on record except from Carlsberg Fjord and Nathorst Fjord, though in the ten-year period dealt with here the two fjords have probably been cleared of winter ice every year. Theoretically Davy Sund may be occupied by land ice all summer, which will persist during the succeeding winter, but this does not seem to have taken place in the ten years dealt with here.

As soon as the land ice has disappeared from the mouth of a fjord, drift ice may enter it. In several fjords an inward current moves along the north coast and an outward current along the south coast.

about August 1st land water extended from Bass Rock to some distance north of Danmarks Havn. The land water did not last very long, but if we had not been delayed by Colonel LINDBERGH's visit, the ship might have gone north of Danmarks Havn.

It would seem that in the period after the end of the war (1918) till the more intensive navigation set in about 1930 some few Norwegian sealers sometimes sailed up in such land water. When the seal hunting along Blosseville Kyst had ceased in July and the ice conditions were favourable, the ships might approach the coast south or north of Scoresby Sund and go north in the land water. Unfortunately very little is known about these voyages; most Norwegian trips to Northeast Greenland were "hunting trips", and for competitive reasons it was desirable that no information should be given about them.

The m. s. "Dagny" reports, however, that in August 1919 she met a Norwegian vessel in Germania Havn. The vessel had gone up in land water along the coast from some distance south of Scoresby Sund, but Franz Josephs Fjord had been barred by ice. On July 27th, 1926, WORDIE met a sealer near Clavering Ø which had sailed northward in land water along the coast from c. 69° N. lat. Personally I met two Norwegian sealers in Young Sund at the end of July 1929; they had approached the coast a little south of Scoresby Sund and had sailed northward in open water along the edge of the land ice. The first fjord with open water encountered by them was Young Sund.

Normally the outermost belt of winter ice melts everywhere within this area at the beginning of August, perhaps with the exception of Carlsberg Fjord.

In 1929 the land ice extended from Mt. Brinkley to Jackson Ø on July 21—25th.

In 1930 land ice still lay off Traill Ø about August 20th.

In 1931 all the land ice disappeared at the end of July.

In 1932 all the land ice disappeared about July 20th.

In 1933 the land ice, as stated above, persisted exceptionally long (especially in the southern area between Liverpool Kyst and Franz Josephs Fjord) even after the land ice had disappeared northward as far as Danmarks Havn.

In 1934 the land ice melted very early. At the end of July Carlsberg Fjord was entirely free of ice; no doubt the land ice had definitely disappeared about the middle of July.

In 1935, also, the land ice melted rather early, probably in the latter half of July except in Carlsberg Fjord, Nathorst Fjord, and Fleming Fjord.

In 1936 the land ice had disappeared about July 20th except in

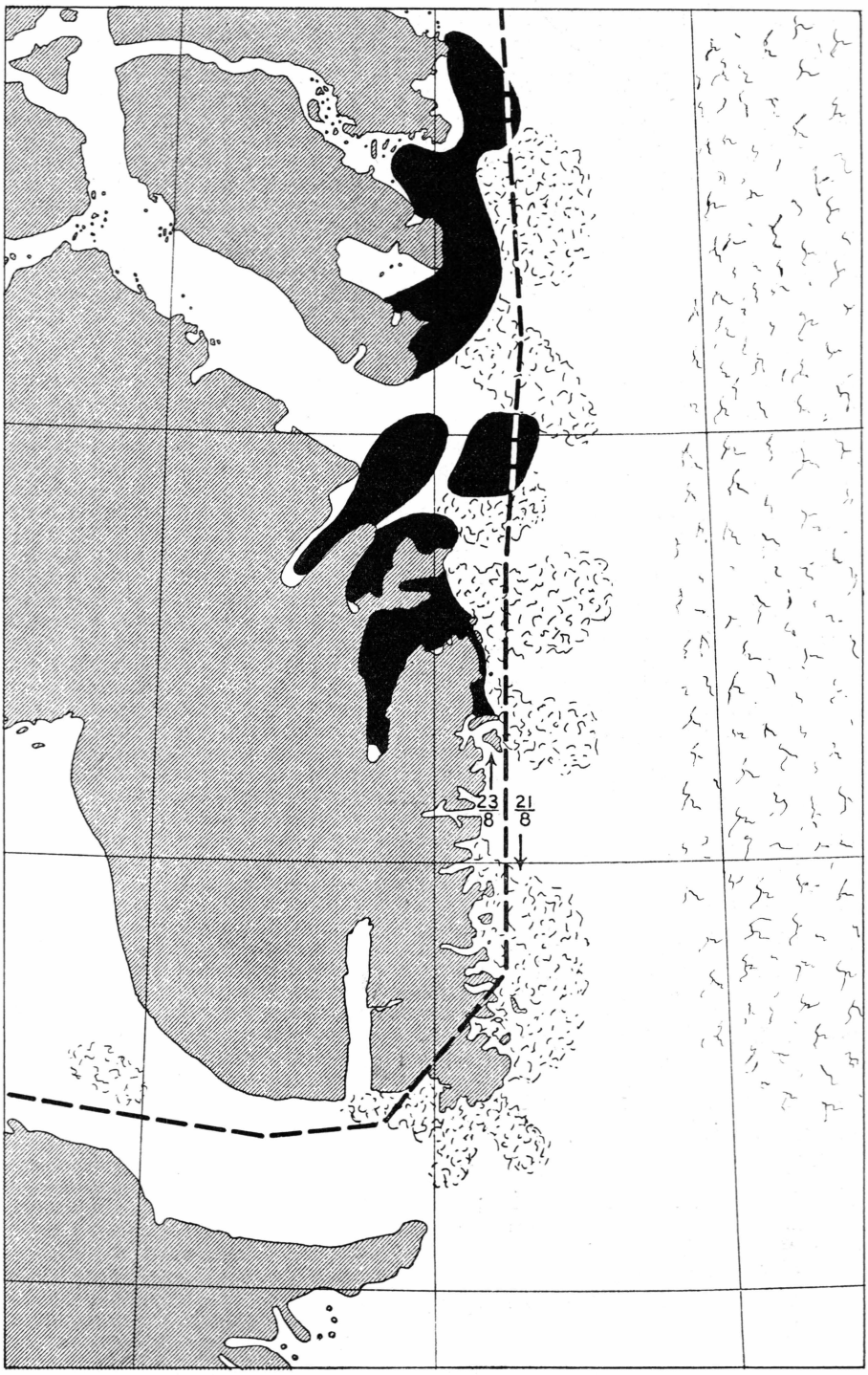


Fig. 27. Land ice (black), and pack ice (shaded), August 21, 1933. Broken line: route of seaplane.

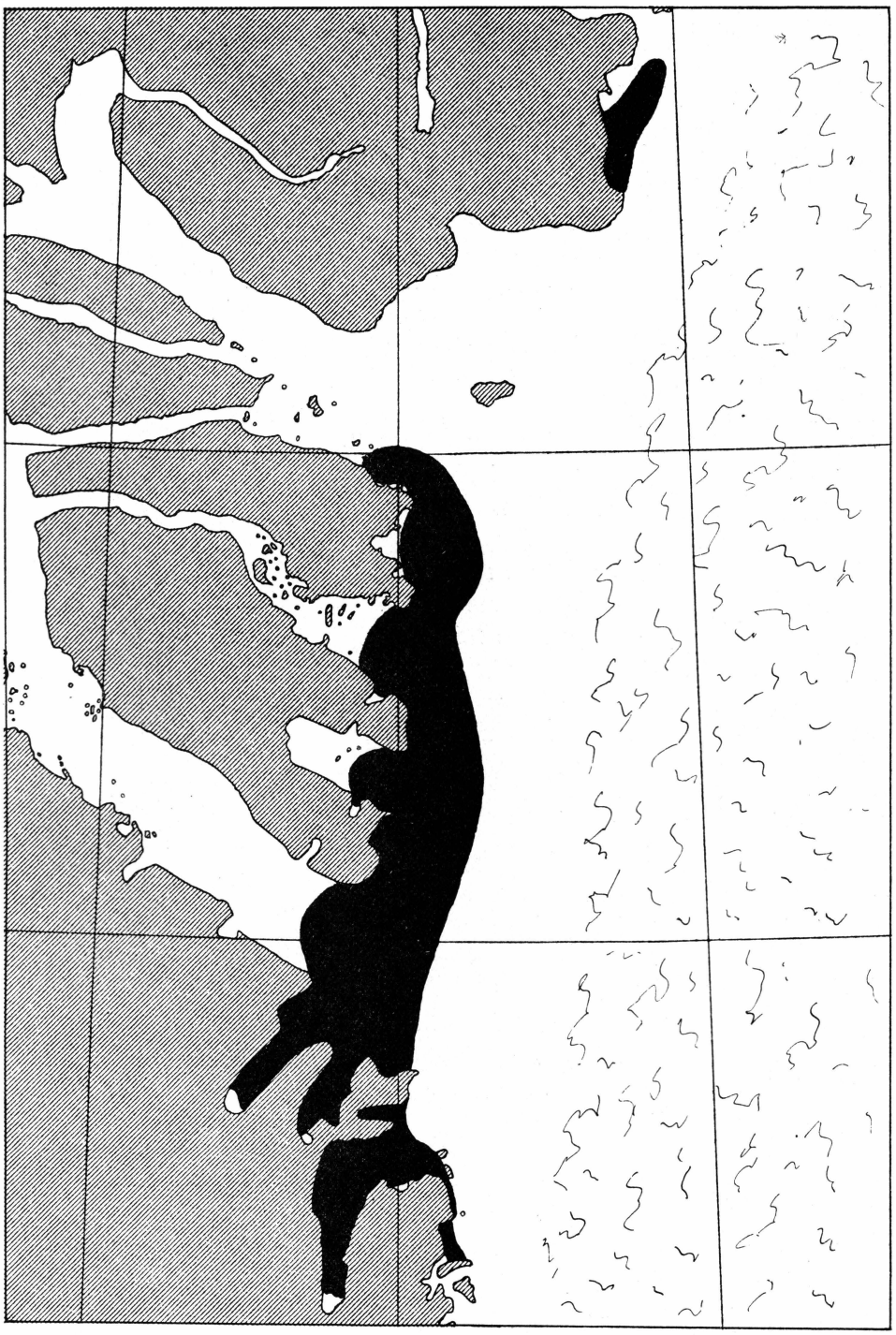


Fig. 26. Land ice (black) and pack ice, August 7, 1933, observed from the air.

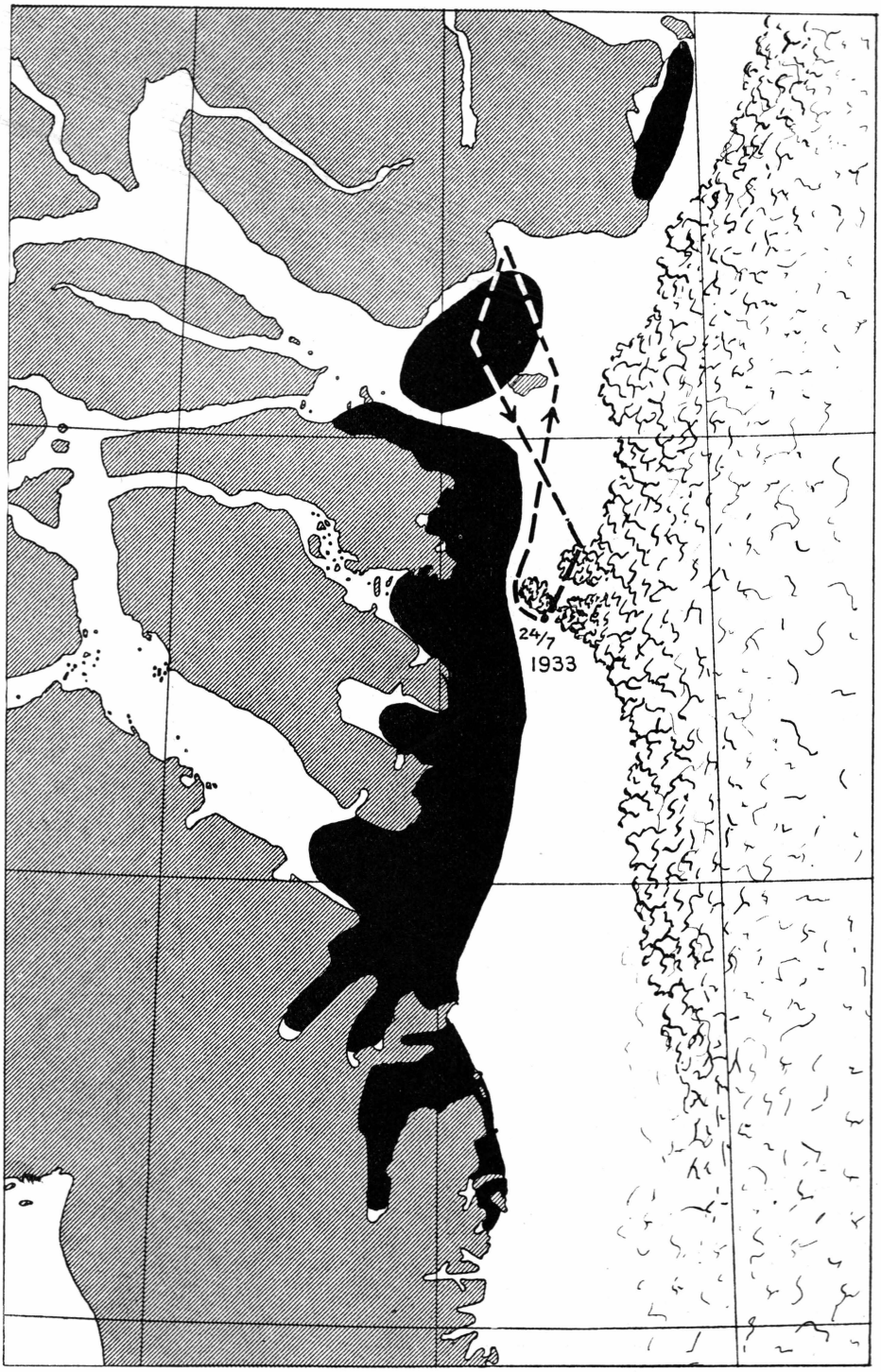


Fig. 25. Land ice (black) and pack ice, July 24, 1933. Broken line: route of seaplane.

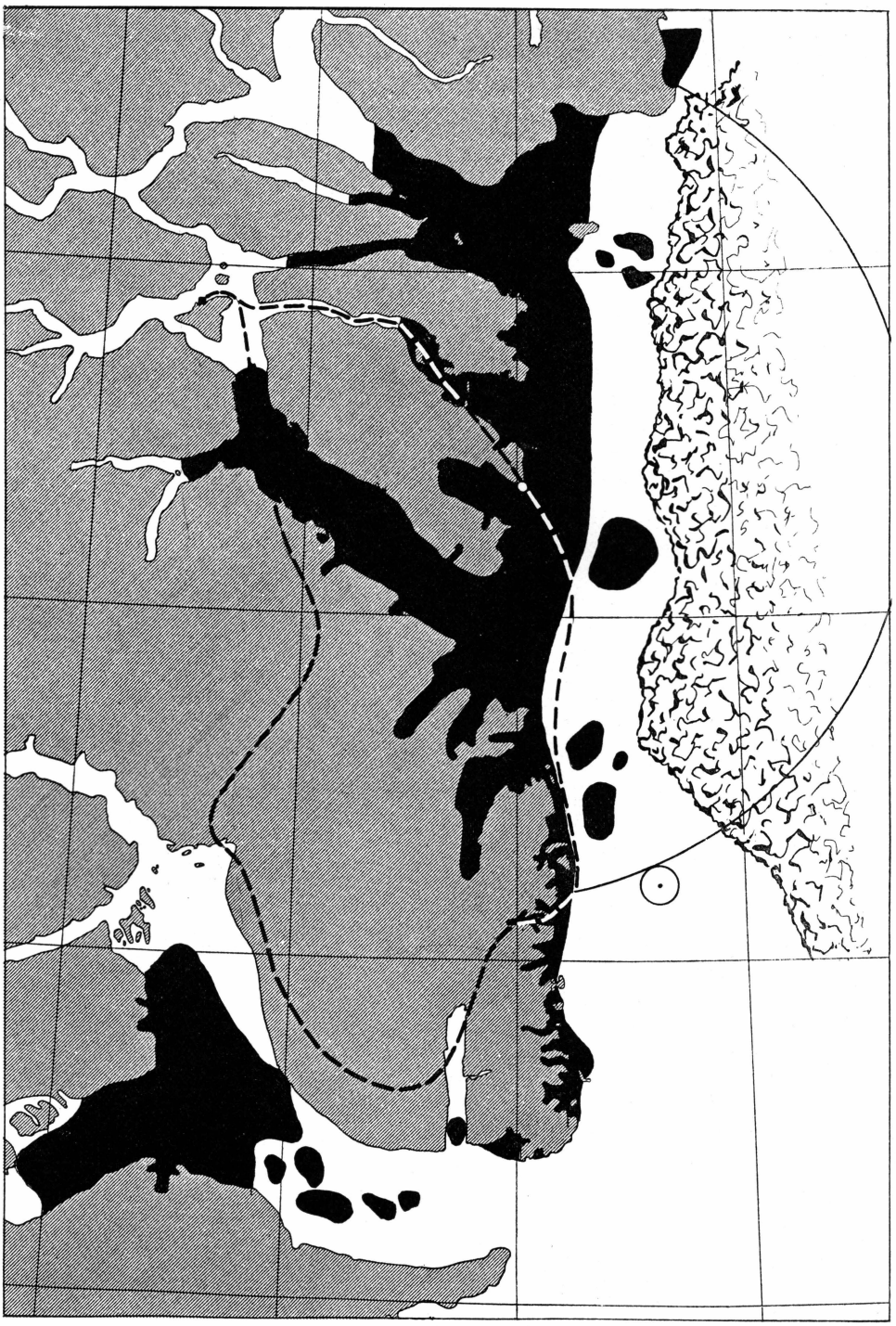


Fig. 24. Winter ice (black) and pack ice (shaded), July 8, 1933. Broken line: route of sea-plane. The big circle shows the area observable from a height of 1000 m above Kap Parry, the small circle the area observable from the masthead of the "Gustav Holm".

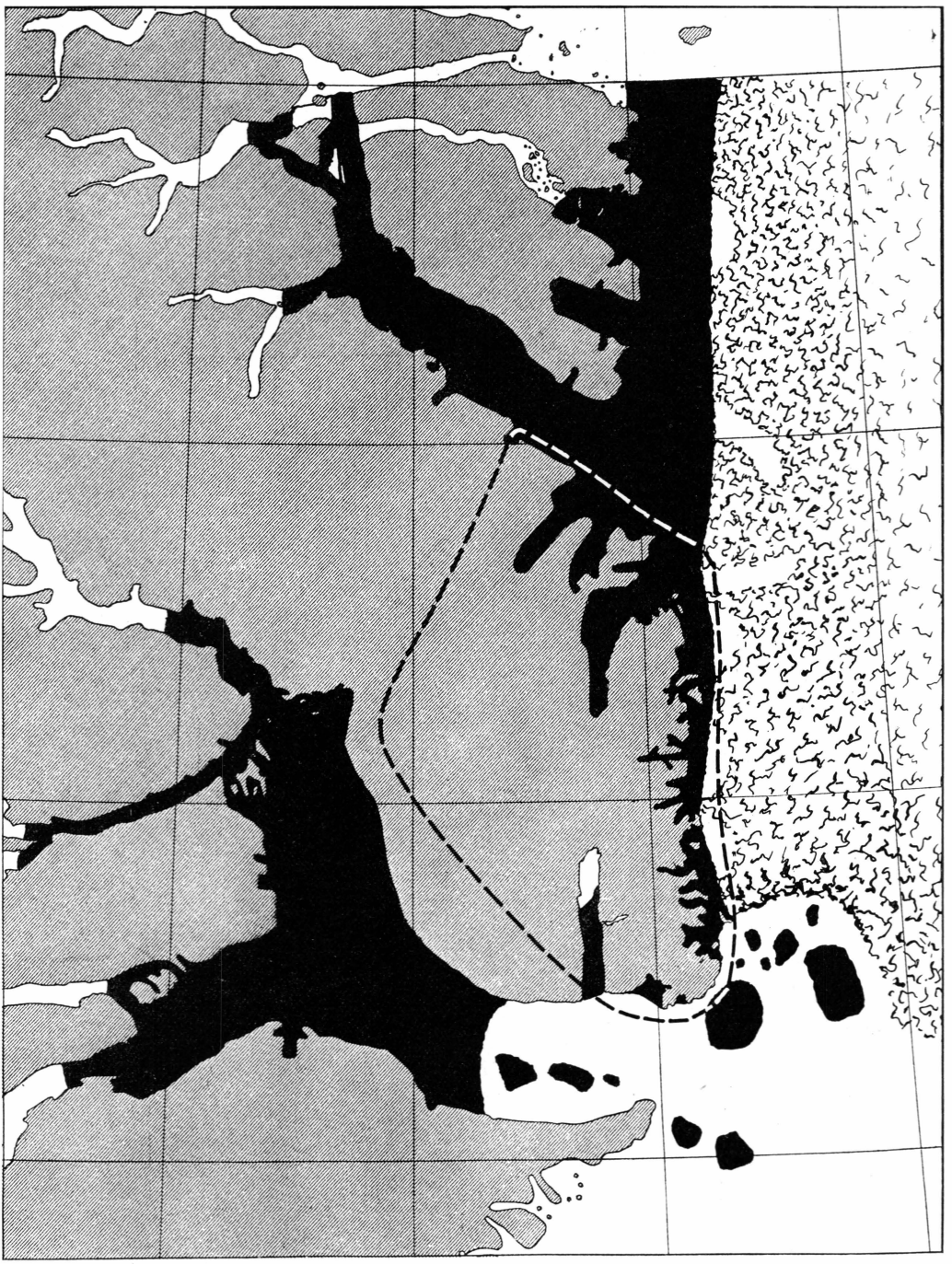


Fig. 23. Winter ice (fjord ice + land ice) (black) and the pack ice (shaded) outside it, on June 26, 1933. Broken line: route of seaplane.

Rosio and Île de France and then proceeded north-northeastward along the edge of the land ice.

In 1906—08 the stretch of the coast treated here was visited and mapped by some members of the Danmark Expedition, and copious information about the ice conditions is found in the papers published by this expedition. Thus J. P. Koch (1917, pp. 409—411) describes the ice conditions. The maps (M. o. G. Bd. 41, Pls. 4—5) are of special value, because 1) inland ice, 2) fjord ice and land ice and 3) the pack-ice outside are indicated. J. P. Koch writes:

"The border line between the drift ice and the solid ice is sharply defined, and even though it may vary a good deal, not only according to the seasons, but also from one year to another, it is, however, in the main so stable that I have considered it right to indicate it in the maps (Pl. IV and V)."

The observations made on the numerous sledge journeys carried out by the Danmark Expedition are incorporated in these two maps. However, the publications of the expedition contain very sparse information on the melting of the fjord ice. We know that at the end of the summer of 1907 Mylius-Erichsen met open water in Danmarks Fjord, but it is not stated how far out the open water extended; one receives the impression that at the time the sledge journey took place (July-September, and November), the whole area indicated on the map as fjord ice was in all essentials covered with ice, the greater part of which had persisted during the summer. The expedition had no opportunities of making observations on the melting of the ice north of Danmarks Havn during the summer months. Only pack-ice is indicated on the map, but it is known that the pack-ice was frequently very open and that open water occurred in several places along the edge of the land ice. Thus the report (M. o. G. Bd. 41, p. 137) runs as follows: "June 10th. From Nordost Runding to Mallemukfjæld the 2nd party had proceeded along open water of indeterminable extent, which now reached close to the land. The passage round Mallemukfjæld was difficult and scarcely free of danger."

It is very natural that the reports of the Danmark Expedition say comparatively little about the ice conditions, for during sledge journeys it is rather difficult to make reliable observations of the ice on which one travels; this is only possible in the early autumn before the snowfalls begin. When the ice is covered with snow and the darkness of the autumn begins to set in, it requires great experience to determine the age of the ice. In the spring, also, it is extremely difficult to determine the age of the ice if this is not very old (sikussak). However, such ice is not found in East Greenland south of Nordostrundingen. The greater number of the observations recorded from the sledge jour-

neys of the Danmark Expedition are therefore given as follows: struck thin ice, or: reached open water, etc. The report (M. o. G. Bd. 41, p. 111 etq.) on the large sledge journey says that open water was met with south of Mallemukfjældet, which was passed with difficulty on April 22nd. Furthermore it is mentioned (Op. cit. p. 137) that on its return journey at the beginning of June J. P. KOCH's party met open water from Nordostrundingen to Mallemukfjældet, but it was impossible to decide how broad this belt of open water was. In April and May (Op. cit. pp. 142—150) the party met new ice and open water east and south of Île de France, and as late as October 13th another sledge party met new ice and open water near Mallemukfjældet (Op. cit. p. 168).

On his journey at the end of September and in the first half of October 1909 from Shannon to Brønlund's grave EJNAR MIKKELSEN met much open water as far as Danmarks Havn. North of this point a good deal of drift ice had evidently approached the shore, so he could proceed to Brønlund's grave without difficulty.

On his long sledge journey in 1910 EJNAR MIKKELSEN met open water some distance off Nakkehoved and from Nordostrundingen to Bagatellerne, but apparently it was not very broad. No open water was observed from Bagatellerne to Hagens Ø, but south of this island new ice and open water occurred at any rate as far as Île de France. New ice likewise occurred halfway up Skærfjord, while there was open water along Germania Land to and including Danmarks Havn (September-October), where the open water attained a considerable breadth.

In May-June 1912 KNUD RASMUSSEN and PETER FREUCHEN travelled across the inland ice from Thule to Danmarks Fjord and onwards to the head of Independence Fjord. They report that the fjord ice was several years old.

In 1921 the present author travelled around the north of Greenland, spending the last half of May on the east coast of Peary Land and June in Independence Fjord, and everywhere met ice several years old. It is, of course, very difficult to determine the boundary between the land ice and the pack ice if viewed from the sea ice or a low shore; however, the present author received the impression that from Kap Bridgman to Herlufsholms Strand the edge of the land ice occurred some distance farther seawards than in 1907 as indicated by J. P. KOCH. On the other hand, the edge of the land ice off Herlufsholms Strand was found nearer the shore than indicated by J. P. KOCH. Ice several years old was found at the mouth of Fr. Hyde Fjord and in Independence Fjord.

In 1933 the present author flew from Danmarks Havn to a little south of Norske Ø and subsequently (August 16th) from this island to the interior of Danmarks Fjord, and in the afternoon of the same

day along the coast to Amdrups Land, across Nordostrundingen to Kap København on Peary Land and back to Norske Ø. On these flights as well as on the voyage to Norske Ø open water was observed along Germania Land north of Danmarks Havn and in Skærfjord. The edge of the land ice was encountered at Kap Louise, whence it extended to Kap Jaque. The south coast of Île de France was free of ice, whereas there was land ice along the east coast except its northernmost point, but thence the ice extended in a curved line outside the outermost islands to the southernmost point of Norske Ø. Here the ice formed a peninsula (cf. L. Koch 1940, Pl. 16) leaving only the northernmost point of Hovgaards Ø free of ice, but a broad lead extended northwestward from Norske Ø to Hovgaards Ø (cf. Fig. 138).

It should be emphasised that the observations recorded above are the first ones made from the air in these regions in the late summer. I have pointed out elsewhere that during the flight from some distance west of Danmarks Fjord to the outer coast and back to Norske Ø we were troubled by clouds, which rendered observations very difficult.

Dansk Nordøstgrønlands Ekspedition 1938—39 altered the position of the head of Ingolfs Fjord, which I observed through a hole in the clouds but was unable to draw accurately. E. Knuth, Eigil Nielsen, and E. Drastrup covered larger or smaller parts of this coast on sledge journeys, all of which, like those of the Danmark Expedition, were made in the spring. In a couple of places Knuth (1942, p. 115) criticises my corrections of the map of the Danmark Expedition, especially along the east coast of Hovgaards Ø. I passed this stretch twice at a height of c. 200 m and had a good view of the coast and the glacier front, the snow having melted away. I therefore maintain my map of this coast as published in M. o. G. Bd. 130, Pl. 16.

Knuth likewise altered the position of the glacier front from Bagatellerne to Schnauders Ø, indicating the whole east coast of Lamberts Land as free of floating inland ice. I admit that it is extremely difficult to distinguish the boundary between the inland ice and the sea ice from the air, but on a sledge journey it is still more difficult to determine the accurate position of this boundary. Moreover the front may no doubt vary here. It is even probable that the front will recede after a number of light ice years, so Knuth's ice edge seems in no way improbable; in 1909 Mikkelsen found similar conditions; however, owing to the uncertainty of the question I maintain for the time being the glacier front as it was observed by me during the flight in August 1933.

In May 1938 the present author flew from Kings Bay, Spitsbergen, to a point a little south of Nordostrundingen and onwards along the coast to Mallemukfjældet. Some days afterwards a second flight was made to some distance north of Nordostrundingen and onwards to

Fr. Hyde Fjord, the interior of J. P. Kochs Fjord, across Independence Fjord and the mouth of Danmarks Fjord and back to Spitsbergen. Observations on the ice conditions are given in M. o. G. Bd. 130, Pl. 21.

Large areas of open water were observed along the coast from some distance south of Mallemukfjældet to north of Nordostrundingen. Wandels Hav and all the fjords in Peary Land were covered with fjord ice, but the inner half of Fr. Hyde Fjord, the inner half of J. P. Kochs Fjord, the whole of Independence Fjord, Hagens Fjord, and the whole of Danmarks Fjord as far as a line from Kap Eiler Rasmussen to Nakkehoved must be assumed to have become free of ice a short time before, fresh icebergs with sharp edges, which had been exposed to thaw to a slight extent only, occurring everywhere in these fjords. They were hardly free of ice in 1937, the summer of that year being very cold in East Greenland, and the ice conditions very bad. More probably the fjords were free of ice in 1936, when no ice was observed along the coast from Scoresby Sund to Bass Rock from July to the end of October. In that year open water probably extended as far as Nordostrundingen, but unfortunately the expedition ship was unable to push farther northward owing to lack of time.

It was likewise observed during the flight that Academy Gl., Marie Sophie Gl., and the glacier front at the head of Hagens Fjord were situated far more to the westward than observed in 1921 and 1933 and than indicated on HØEG-HAGEN's map drawn in 1907. While in 1921 large numbers of close-packed icebergs had accumulated in front of Vildt Land, in 1938 the inner part of Independence Fjord was free of bergs.

To sum up: Open water was observed along the coast from Nakkehoved to some distance south of Mallemukfjældet in the spring of 1907, 1910, 1938, and 1939. It may vary in breadth and position, but it seems to be a constant phenomenon along this coast from May-June to some time in October. There would likewise seem to be open water, sometimes throughout the summer, around Île de France and south of this island, which in some years (in May-June and in September-October) communicates with the open water east of Koldewey Ø. From Orleans Sund to and including Norske Ø the winter ice seems as a rule to persist during the summer, being held back by the skerries in front of the glacier ice of Jøkelbugt.

Not very many observations on the small and narrow fjords along this coast are at hand. In 1906 and 1907 Skærfjord seems to have been covered with ice, while in 1910 and in 1933 it was free of ice, but not in 1939. It appears from the map (L. KOCH 1940, Pl. 16) and Fig. 138 that in 1933 the ice did not disappear except from a small area inside Lynn Ø in Dijmphna Sund. In the same year only the innermost part of Ingolfs Fjord was free of ice; the land ice extended only to Henrik Krøyers

Holme. The ice had disappeared from Antarctics Bugt. It would seem that under the favourable ice conditions of the last twenty years it might often have been possible for a ship to push northward in land water as far as Nordostrundingen; it is deplorable that no attempts were made in 1925, 1926, 1930, 1932, and especially in 1936.

As regards the ice conditions north of Danmarks Havn in 1938—39 Dr. EIGIL NIELSEN states as follows:

A reconnaissance from the air shortly after the middle of August 1938 showed that the ice in Skærfjord was still unbroken, whereas there was open water in Fladebugt and the inner fjord ramifications. In the autumn a sledge journey was made to Kap Mérite on summering ice. In October-November a belt of land ice about 4 km broad occurred off Germania Land.

Rather late in the spring of 1938 a storm broke up this belt of ice, which before the actual melting took place was only 2—0 km wide. In June land ice several kilometres broad was met with off Norske Ø. About the middle of April open water was found 2 km from Mallemukfjældet and near Eskimonæs on Holms Land it nearly reached the coast. The winter storms had broken up the ice and carried it out of the outer parts of Dijmphna Sund and Ingolfs Fjord, and thin ice had formed in April. Thin ice was likewise found off Kap Jungersen, Amdrups Land. Farther northward the open water reached the shore in April, there being no land ice around Henrik Krøyers Holme. Land ice occurred in the interior of Antarctics Bugt, extending as far as Nordostrundingen in a belt about 1 kilometre broad[1]). From Nordostrundingen to Nakkehoved the land ice was 3 km broad, but from the middle of April to June 1st there was open water as far as the eye could reach from Nakkehoved to Mallemukfjældet, apart from narrow rims of land ice and occasional scattered ice floes.

[1]) It is a question whether this land ice should not be regarded as ice frozen to the ground, that is to say, a kind of ice-foot.

DRIFT ICE IN THE FJORDS DURING THE SUMMER

The Ice Conditions in Scoresby Sund in the Summer.

Observations **1926—27.** — During my wintering at Scoresbysund I had the opportunity to make a number of observations on the ice conditions in the vicinity of the colony. Some of these are mentioned in Medd. om Grønl. Bd. 76 (cf. i. a. Fig. 9).

Prior to my arrival at Scoresbysund at the beginning of August, 1926, various facts were known concerning the ice conditions of the surrounding regions. Thus it had turned out that the so-called Hartz Havn provided no suitable anchorage for ships, being too exposed to drift ice. To begin with Dr. CHARCOT and his expedition ship the "Pourquoi-Pas?" used the so-called Amdrups Havn; however, this harbour provided no shelter for ships that anchored in it, for in the summer a fairly strong current runs along the coast from the southern part of Liverpool Kyst, constantly carrying ice floes into Amdrups Havn and onwards out of the harbour, past the colony of Scoresbysund to Ferslews Pynt, and thence to Rosenvinge Bugt and towards Kap Hope. Moreover the bottom of Amdrups Havn presents no good anchorage, and the north wind blows with the force of a hurricane down the mountains. At present it is no longer used as a harbour.

In the autumn of 1926 my house was built on Ferslews Pynt, as I expected that owing to the strong current which runs past this cape there would be open water off the cape. Great was my astonishment, however, when this current, which in August and September had carried ice floes past the cape at a rapid speed, suddenly ceased about October 1st, so when the ice formed in the course of October, there was no current at all off the cape.

In June, 1927, the ice broke around Ferslews Pynt, but no current was noticed till the beginning of August, when it increased in intensity until it culminated in the first half of September.

In the mouth of Scoresby Sund there was open water throughout the winter of 1926—27; it extended westward in the middle of the fjord almost to a point just south of Kap Hope.

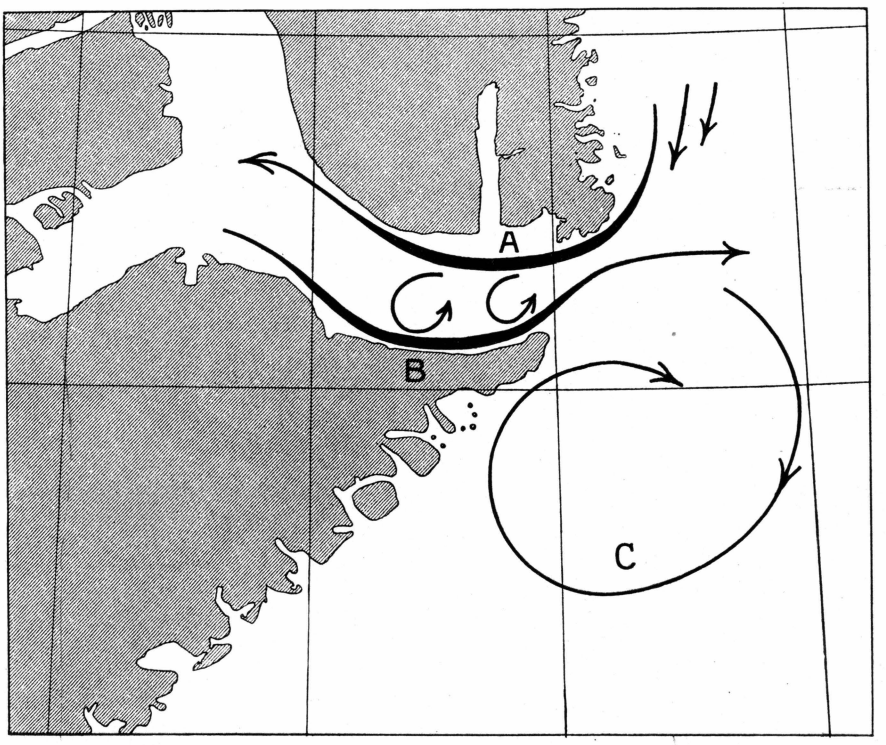


Fig. 34. Direction of currents at the mouth of Scoresby Sund.

In October, 1926, the ice formed along the coast from Kap Tobin to a few kilometres south of Kap Hope and thence, curving slightly, to some distance west of Kap Brewster.

During a gale by the middle of November the ice broke around Kap Hope and as far as Kap Stewart, but soon after the ice formed again off both capes. An Eskimo settlement erected at Kap Stewart in 1925 was abandoned some years later because the distance from the settlement to the ice edge was too great in the winter.

Observations in **1932.** — Scoresbysund was visited several times by seaplane, and I was able to observe the fairly strong current which carried the ice floes near to the coast between Kap Tobin and Kap Hope.

Observations in **1933.** — When the two expedition ships arrived at Scoresby Sund shortly after midsummer, the ice in Rosenvinge Bugt had not yet broken, and about July 1st land ice was still found near Kap Tobin and Kap Hope. A thick sheet of ice still lay in Hurry Fjord near its mouth, but about July 1st it had melted so much that it began to move, causing great difficulties for the navigation by motor-boats. About midsummer that year the edge of the land ice in Scoresby Sund occurred exceptionally far westward (cf. Fig. 23).

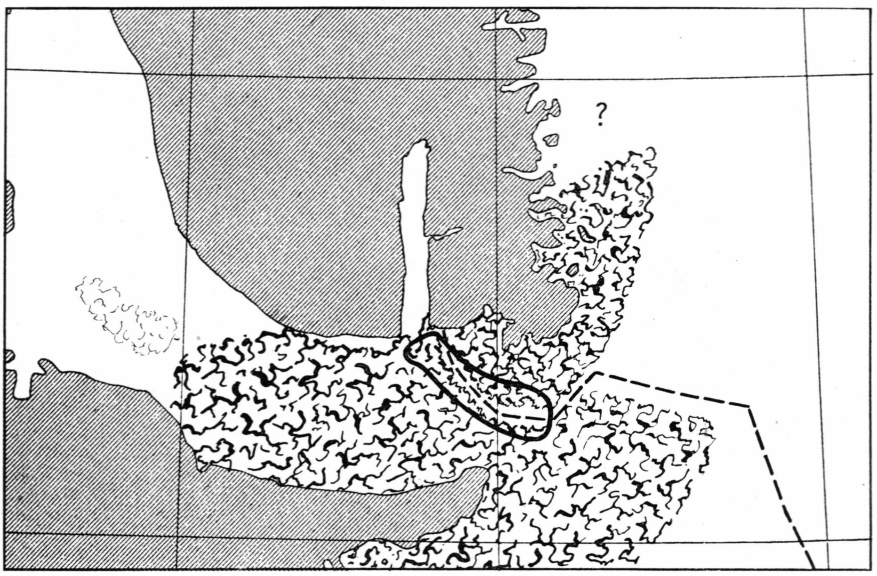


Fig. 35. Pack ice in the mouth of Scoresby Sund, Sept. 10, 1934. Full line: air route, broken line: ship's route.

Observations in **1934.** — This year the expedition became closely acqainted with the currents in the outer part of Scoresby Sund. Throughout the summer, drifts of ice arrived, the late summer being characterised by several gales from the east.

After the ship had got out of the ice almost off Kap Simpson, she encountered a narrow belt of ice, about one kilometre broad, near Kap Tobin (cf. Fig. 38); but it was so closely packed that the ship could not push through it, i. a. because of the heavy swell. The ice belt was somewhat broader southward (c. 3—4 km), and extended as far as Kap Brewster.

In the morning the wind blew from the northeast at a force of 6—8, and in the evening it was freshening again. In the course of the night of September 3rd the ship became ice-bound and began to drift into the fjord, almost reaching Kap Hope in the morning of September 4th. A strong northerly wind blew out of Hurry Fjord, which was entirely free of ice, and when the storm ceased about noon of September 5th, she had drifted to some distance southwest of Kap Stewart. That day the Scoresbysund radio reported open water and swell off the colony. On September 6th the ice carried the ship some distance nearer the shore. On September 7th Scoresbysund radio reported scattered ice, but no swell. The current now began to move out of the fjord, but the ice around the ship did not change.

On September 8th the ice was more open, and the ship made her way to Kap Stewart, where the ice lay close to the shore, and it was

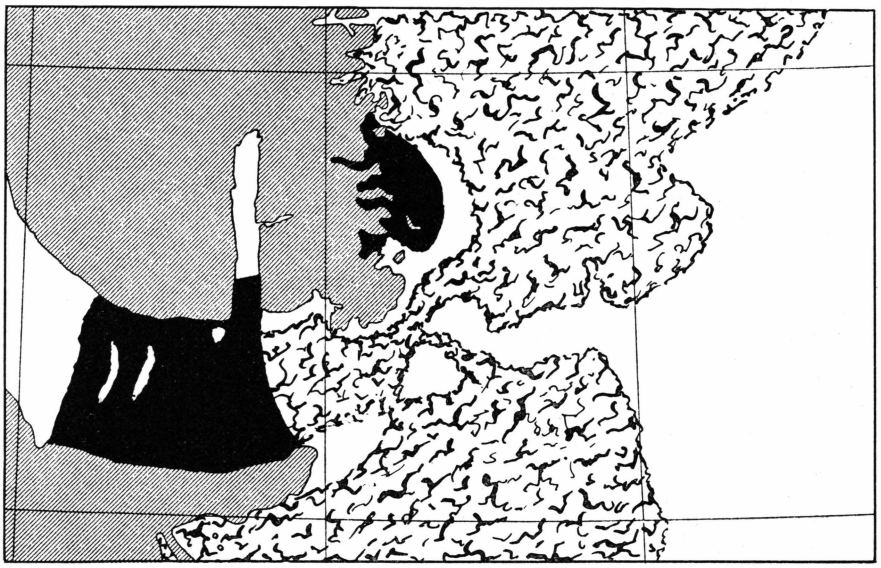


Fig. 36. Winter ice (black) and pack ice at the mouth of Scoresby Sund, on July 25, 1938, observed from the air.

impossible to go into Hurry Fjord. The ship therefore proceeded southward, but was soon beset in the ice. On September 9th it blew up from the north, but the ship reached Kap Hope, where the ice was very scattered, though the drift was severe.

On September 10th a lead of open water formed from a point c. 4 km south of Kap Hope to about the middle of the fjord; from Kap Brewster a fairly unbroken drift ice edge extended in a tongue east-northeastward (cf. Fig. 35). The ship sailed through this lead, passing the outer point of the ice edge at 1.30 a. m. of September 11th.

Thus, in the course of ten days, we had experienced a northerly gale which carried the ship with close-packed floes along the north coast of Scoresby Sund to some distance west of Kap Stewart, had observed open water in the middle of the fjord between Kap Tobin and Kap Brewster, and a tongue of closely packed ice which extended northeastward from Kap Brewster.

During the succeeding two years, **1935** and **1936**, I had hardly any opportunity of observing the ice in Scoresby Sund. In 1937, however, the expedition was to gain much experience as regards the ice conditions in the outer part of Scoresby Sund.

On August 7th, **1937**, the ship approached Kap Greg on Liverpool Kyst without having encountered any serious obstacles from the ice, but was here headed by a northeasterly wind, which forced large ice masses southward and towards the coast. It was impossible for

the ship to push farther northward, so she turned and went into Scoresby Sund.

On leaving Nordostbugten on August 17th, the ship was in a difficult position. According to his instructions, the captain of the ship had to try to go to the northern stations, even though such an attempt seemed hopeless; for we knew by wireless from Scoresbysund that the ice conditions in the mouth of the fjord were very bad. In the afternoon we found the whole mouth of the fjord to be closely packed with ice from a little west of Kap Stewart, and a rather strong wind blew from the north. There was, however, a narrow passage along the south coast of Jameson Land, the ship passed Kap Stewart in very shallow water and turned into the ice-free Hurry Fjord.

Near Kap Hope a kayak-man informed us that the whole of Rosenvinge Bugt was filled with close-packed ice, so in the evening of August 18th we went to Fame Øer, where we stayed next day also. But as the weather improved on August 20th, the ship started southward again. Heavy pack-ice was encountered in the outer part of Hurry Fjord, and the ship was labouring hard. On August 23rd she reached almost the middle of Rosenvinge Bugt, where she was much impeded by the ice and suffered a good deal of damage owing to the heavy pressure.

On August 24th a gale suddenly came up, which scattered the ice, enabling the ship to reach Scoresbysund.

Unsuccessful attempts to leave the fjord were made both on August 25th and 27th, heavy ice being met with off Kap Tobin.

On August 28th the ship went into the fjord again to go to Gurreholm. Following the coast, the ship reached Hall Bredning off Kap Leslie in the morning of August 29th; however, when it cleared, the whole of Hall Bredning towards Bjørne Øer and Kap Leslie as well as some distance towards Danmarks Ø and Kap Stevenson was filled with close-packed ice. In order not to be enclosed in the ice, the ship had to turn back immediately and in the afternoon reached Scoresbysund, where the unloading of the goods of the expedition took place.

On September 1st the "Gertrud Rask" arrived in the harbour, and on September 2nd there was a heavy swell. On September 5th the ice packed in the harbour, and both ships were enclosed by the ice till the evening of September 6th, when the ice was less packed, and the "Gertrud Rask" left the colony.

The "Gustav Holm" was not ready to leave till next day, and in calm weather and open water reached Kap Tobin. Here it came on to blow from the north and there was a heavy snowfall, and in the early afternoon the ship was beset in the ice a little east of Kap Hodgson. It was thick weather, and the wind blew at a force of 7. In the night the ship drifted with the ice into the fjord at a rapid rate and in the morning

of September 7th was near Kap Hope. On September 9th the ship still drifted with the ice along the coast of Jameson Land.

On September 10th the drift almost ceased. The position of the ship was then 70°33′ N. lat., 23°53′ W. long.

On September 11th the ship lay immovable in the ice. On the 12th the ice began to drift eastward, and in the afternoon the ship, using her engines, approached Kap Stewart.

On the 13th the ship made little progress, but still made her way some distance from the shore. In the night of the 14th she drifted some distance into the fjord, but in the day worked her way slightly eastward, being now in the southern part of the fjord.

In the morning of September 15th a strong west-northwesterly gale with driving snow set in, lasting for eighteen hours and preventing all observation, but it set the whole ice mass in the southern part of Scoresby Sund in a rapid eastward motion.

When the gale ceased, the ship had passed Kap Brewster, and on the 16th to 18th she drifted in a large circular curve south of Kap Brewster. On the 19th she was to start a second circular drift, when the ice scattered somewhat. Shortly after midnight of September 21st the ship got free of the ice.

Observations in **1938.** — This year, also, interesting observations were made of the conditions in the outer part of Scoresby Sund. On July 16th the ship entered the pack-ice a little south of Kap Brewster and at first made good progress. But northeasterly winds set in, which packed the ice around the ship, and for the following days she drifted southward, not getting free of the ice till July 24th.

On July 25th a request was received from the "Gertrud Rask", which lay outside Scoresby Sund on her way to the colony, that a reconnaissance of the ice should be made from the air. The reconnaissance was made the same evening (cf. Fig. 36), and for the second time a marked ice tongue was observed to extend in a northeastward direction from Kap Brewster.

On August 30th the seaplane flew from Kong Oscars Fjord to Scoresbysund and back; that day, also, a well developed ice tongue was observed (cf. Fig. 40).

The experience gained in the above-mentioned years, may be summed up as follows:

In the latter half of June a surface current began to make itself felt from Rathbone Ø southward along the coast to Kap Tobin and onwards into the fjord past Kap Hope and Kap Stewart along the south coast of Jameson Land towards Bjørne Øer in Hall Bredning. This current (marked A in Fig. 34), at first very slight, increased in force and seemed to culminate in the first half of September.

About the middle of October the current seemed to disappear. It depends, of course, to a great extent on the wind, being naturally very strong during protracted northeasterly winds, which force the ice, and accordingly the upper water layers, onwards.

A corresponding outgoing current (marked B in Fig. 34) occurred along the south coast of Scoresby Sund from Kap Stevenson to Kap Brewster and some distance onwards. As the peninsula on which Kap Brewster is situated extends in a northeasterly direction, the ice is pressed northward, that is to say, against the current moving southward along Liverpool Kyst. This causes a standstill of the current coming from the north some distance off Liverpool Kyst, which, again, gives rise to the peculiar phenomenon that a bay of open water occurs in the fairly broad belt of ice off Kap Tobin (cf. Figs. 35. 36, 40).

Circular eddies form between the inward-moving northern current and the outward-moving southern current. On September 14th, 1937, the ship was caught in such an eddy in the middle of the fjord; such circular eddies were repeatedly observed in the middle of the fjord when bearings were taken to icebergs and pressure ridges. Strong northeasterly gales will naturally increase the force of the inward-moving current, and if such gales are succeeded by westerly winds, the current moving outward from Kap Brewster (C in Fig. 34) may in certain cases be so strong that "back water" is formed southeast of Kap Brewster, as was the case in 1937.

Generally ships calling at Scoresbysund should not shape a direct course from Iceland to the colony, but should follow the ice edge to the latitude of Kap Tobin and approach the coast in the bay of open water that is sometimes formed in the pack-ice here. In case of heavy ice and strong currents, ships should take care not to go so near the shore that they run the risk of suffering damage, as happened to EINAR MIKKELSEN in 1923. If the southern part of Scoresby Sund is heavily filled with ice, a ship staying in the interior of the fjord should try to sail out or drift with the ice parallel to and fairly near the south coast. There seems to be no danger of heavy pressure ridges till near Kap Brewster, where a number of icebergs will always run aground.

It is to be deplored that no safe harbour is found in the outer part of Scoresby Sund. In some years it will be possible for a ship to spend the winter immediately south of the colony, but she will always run the risk of being forced on to the shore by the drift ice before the land ice has grown strong enough to prevent it. There is no possibility of wintering at Kap Hope. Favourable wintering conditions may be found near Fame Øer, but in the late summer of 1926 I observed that drift ice, drifting into the fjord after a gale, filled Hurry Fjord as far

northward as the delta of Ryders Elv. Here, too, the ship may be run ashore by the ice.

In Nordostbugten, at the mouth of Schuchert Elv off Gurreholm, there may be possibilities of wintering, and the harbour at Danmarks Ø (cf. RYDER's description) presents good possibilities for a wintering; however, both these harbours are situated at such a great distance from the colony of Scoresbysund that they are of little practical value.

In the bay near Kap Stevenson on the south coast wintering may be possible, also, if no calving glaciers are found there.

Finally, calm wintering harbours may no doubt be found in the interior of Scoresby Sund, thus near Røde Ø, possibly in Flyverfjord, and in Rype Fjord.

The Drift Ice in the Fjords in the Northeastern Part of Jameson Land, Davy Sund, and Kong Oscars Fjord.

The three fjords, Carlsberg Fjord, Nathorst Fjord, and Fleming Fjord, open towards the northeast and will naturally be filled with ice when the wind is blowing from that quarter. The ice will also make its way into Davy Sund, the current being especially strong near Kap Simpson, and sometimes onwards up Kong Oscars Fjord, where it may form a compact mass from the southern part of Kongeborgen to the mouth of Segelsällskapets Fjord; but the ice is stopped by the numerous islands situated at the mouth of this fjord, so only minor drift ice floes have ever been observed inside the islands; occasionally they are carried by the current past Kongeborgen to the south coast of Ymer Ø, where they melt.

It has become mythical that Carlsberg Fjord is hardly ever free of ice; it will be seen from the notes below, however, that during the decade 1929—39 it has been free of ice almost every year, but the land ice remains exceptionally long in the fjord owing to its very narrow mouth. The ice breaks much earlier in Nathorst Fjord, and even earlier in Fleming Fjord, owing to a warm local wind blowing out of Ørsteddalen.

Our knowledge of the drift ice in the different years may be summed up as follows:

As is well known, in **1899** NATHORST, sailing southward through Kong Oscars Fjord, was stopped on August 20th by land ice, which extended from a little east of Antarctic Havn to a little east of Drømbugten. It is not known whether this ice later drifted out of Davy Sund.

In **1900** the AMDRUP-HARTZ Expedition found Nathorst Fjord, Fleming Fjord, Davy Sund, and Kong Oscars Fjord to be free of ice on August 24th, whereas the land ice was still unbroken in Carlsberg Fjord on September 1st.

In **1926** the Cambridge Expedition led by WORDIE sailed in open water down through Kong Oscars Fjord, Davy Sund, and along Liverpool Kyst on August 23rd. No observations regarding Carlsberg Fjord are on record, but probably the fjord was free of ice on September 1st, for in October of the same year I found the fjord to be filled with drift ice floes (as to my observations in the autumn of 1926, cf. L. KOCH 1929, pp. 240—243). I further found Nathorst Fjord and Fleming Fjord to be largely covered by new ice, in which several ice-floes were enclosed, and numerous floes were likewise observed in the ice of Davy Sund. Kong Oscars Fjord was covered by thin smooth ice without any floes.

In **1929** the ice of Davy Sund must have disappeared at any rate at the beginning of August, for about the middle of August a Norwegian vessel sailed without difficulty to Antarctic Havn, but at the end of August the "Godthaab" encountered rather close-packed floes near Haslum Øer, and some distance south of the islands the ice packed so closely that our plan of passing out through Davy Sund had to be given up. As will be seen from the report on the expedition (L. KOCH 1930 pp. 200—203), the ship was ice-bound on September 9th in c. 73° N. lat., 19° W. long. and was beset in the ice till the 19th. On September 16th the ship was off the mouth of Davy Sund and had drifted to 21°30′ W. long. It is beyond any doubt that the September gales had pressed the ice not only into Davy Sund, but also some distance up Kong Oscars Fjord (cf. L. KOCH 1930, Fig. 4).

In **1930** the expedition ship was stopped by the land ice edge on August 17th; the ice edge extended from the southernmost point of Kongeborgen to the islands in the mouth of Segelsällskapets Fjord. On August 20th we sailed along the edge of the land ice, which extended from Kap Parry towards Murray Ø. It is not known whether this large mass of land ice drifted out in the late summer.

On August 23rd, **1931**, the "Gustav Holm" cast anchor in Fleming Fjord near Kap Brown after sailing in clear water down through Kong Oscars Fjord. On August 25th the ship left the place homeward bound, and did not encounter the ice till some distance outside Kap Wardlaw.

From the succeeding period various information about the ice conditions around the Kap Brown station is at hand. Thus it is reported that on September 1st Nathorst Fjord was almost covered by new ice, and much new ice had formed in Fleming Fjord. On September 6th there came wind from the north, and Nathorst Fjord was almost filled with drift ice. On September 9th Carlsberg Fjord was observed from a mountain peak to be free of ice except for a narrow rim of summering land ice, whereas both Nathorst Fjord and Fleming Fjord were free of ice. During the following days, however, fairly thick new ice formed

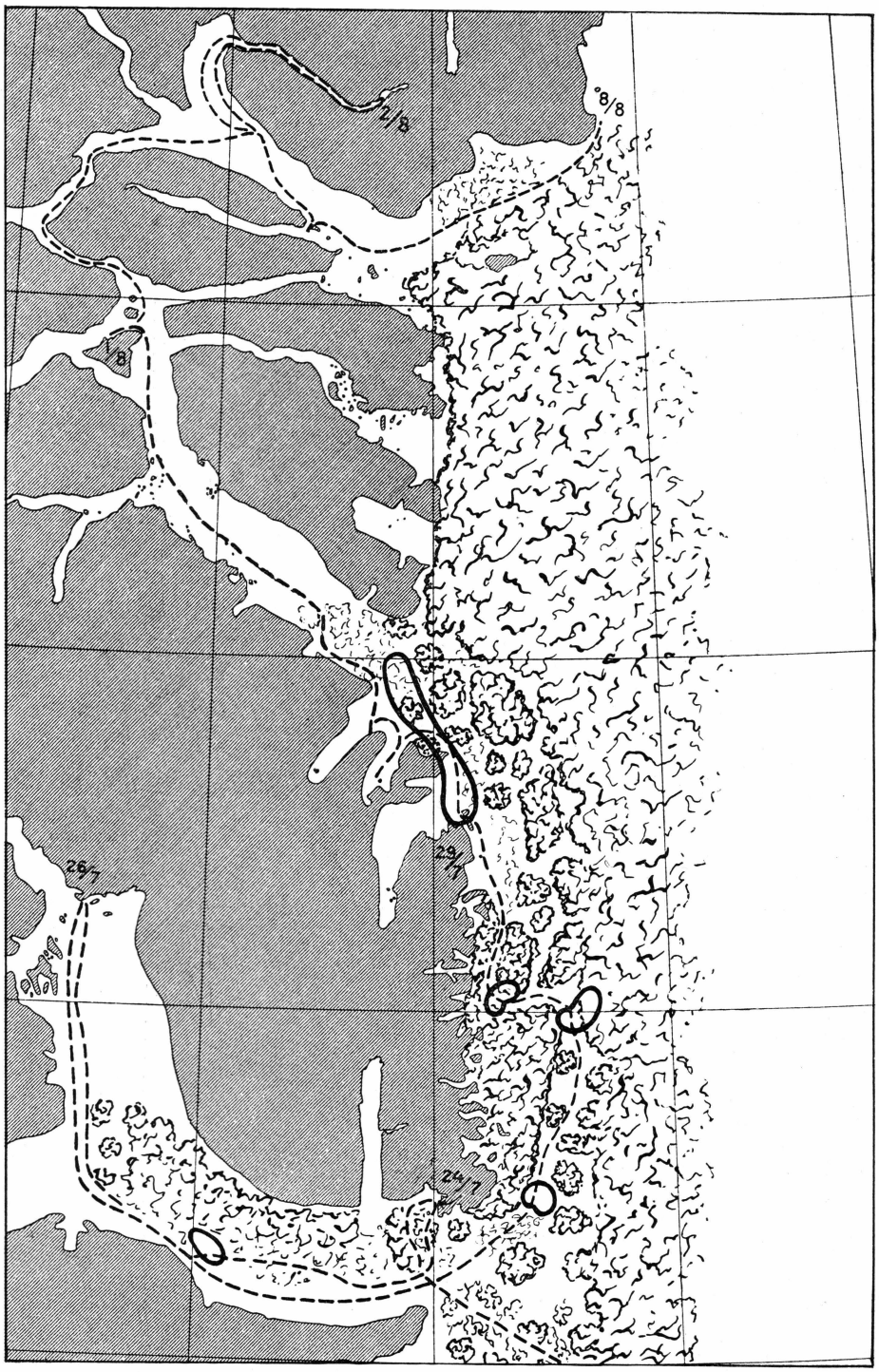


Fig. 37. Drift ice along the east coast of Greenland, July 23—Aug. 8, 1934. Full line: air routes, broke n line: ship's routes.

in Nathorst Fjord and Fleming Inlet. On September 17th, 18th, and 24th Fleming Fjord was filled with drift ice, whereas it was free of ice on the 21st and 26th.

On October 5th the innermost five kilometres of Fleming Fjord were covered with new ice, whereas the remainder of the fjord was closely packed with fjord ice, while around Kap Biot there was open water. On October 20th an attempt was made to start with dog-sledge from the Kap Brown station towards Ella Ø, but about ten kilometres north of Kap Biot the party was stopped by open water, which reached Traill Ø some distance south of Haslum Øer. In the period October 20th to 29th the ice still lay in Fleming Inlet, and the edge of the land ice extended from some distance west of Kap Simpson to Kap Brown. On October 29th the sledge party rounded Kap Biot and reached Antarctic Havn. As late as October 25th there was open water at Kap Syenit.

It will be seen from the above that Fleming Fjord, the outer two-thirds of which were filled with drift ice, froze up about October 10th, whereas up to the end of October there was open water around Kap Biot and Kap Syenit. At the end of October the drift ice extended almost to the line Antarctic Havn-Drømbugten; some few large ice floes were enclosed in the ice farther northward; the innermost of these floes lay south of Haslum Øer, but otherwise Kong Oscars Fjord was covered by new ice.

1932. — According to reports from Norwegian trappers, open water occurred around Kap Biot about the New Year, and sledging from the north to Fleming Fjord was not possible till February 1st. As early as the latter part of May there was open water in Davy Sund as far as a line Antarctic Havn-Drømbugten.

On August 1st the s. s. "Godthaab" visited the house at Kap Brown, and hydrographical investigations were made in Davy Sund, where Professor R. SPÄRCK registered exceptionally high water temperatures, but no ice was met with. On August 28th the "Gustav Holm" and the "Godthaab" sailed from Ella Ø without encountering any ice.

1933. — Figs. 23 and 24 show the ice conditions in 1933. On June 26th open water extended in almost a straight line from Kap Greg to Bontekoe Ø, whereas Kong Oscars Fjord was frozen up till July 8th, when Murray Ø and the eastern cape of Bontekoe Ø were free of ice, and Kong Oscars Fjord was free of ice as far as the middle of Kongeborgen.

On July 24th (se Fig. 25) the land ice still lay in Carlsberg Fjord and some distance down Liverpool Kyst, while Kap Wardlaw was free of ice.

As late as August 7th (se Fig. 26) the ice conditions had not changed essentially. Not till August 21st did the ice begin to drift out of Davy Sund, leaving an open passage along the south side of Traill Ø, while not only the three fjords in Jameson Land (Carlsberg Fjord, Nathorst Fjord, and Fleming Fjord), but also the east coasts of Traill Ø and Geographical Society Ø were blocked by land ice (cf. Fig. 27).

1934. — On July 26th the three fjords in Jameson Land were free of ice. On July 29th, when the ship lay near Murray Ø, a reconnaissance was made from the air, which showed that there was open water off Kap Wardlaw and along the north side of Canning Land, while large masses of drift ice occurred farther north (cf. Fig. 37).

Before the ship reached Kap Wardlaw, a strong northerly current had packed the ice along the coast, so the ship had some difficulty in making her way into Nathorst Fjord. It would seem that near Kap Wardlaw the outward-moving current was much stronger than the inward current.

In the course of the summer ice continued to drift round Kap Simpson into Davy Sund and onwards along the south coast of Traill Ø. Large ice masses likewise drifted up past Kongeborgen all summer, and at times part of the south coast of Ymer Ø was blocked by drift ice that came from the south, a phenomenon unknown in previous summers.

On August 28—29th a northeasterly wind drove the ice at a rapid speed into Davy Sund. The ship, which had gone into Mästers Vik, had difficulty in getting out and in, taking aboard two camps near Kap Syenit. The ship had then to go north at a rapid speed, for the ice still advanced, filling the outer part of Kong Oscars Fjord as far as Kongeborgen. This was distinctly observed from the air on September 1st (cf. Fig. 38).

1935. — Observations from the air are at hand, showing that on August 28th the land ice remained unbroken in the three northern fjords of Jameson Land, and drift ice filled Davy Sund and Kong Oscars Fjord to north of Mästers Vik. Scattered ice was found south of Ymer Ø as far as the mouth of Antarctic Sund and the whole of Sofia Sund. It is unknown whether part of this ice had drifted up through Kong Oscars Fjord from the south or it had been pressed in past Robertson Ø (cf. Fig. 39).

1936. — No land ice was observed along the outer part of Liverpool Kyst on July 24th, and Nathorst Fjord, Fleming Fjord, and probably Carlsberg Fjord were free of ice. West of a line Kap Biot-Drømbugten as far as Haslum Øer the ship encountered fjord ice, but it had thawed so much that the advance of the ship was not impeded very much.

Throughout August and at the beginning of September there was no drift ice along the coast or in the fjords, and at the beginning of September Carlsberg Fjord was free of ice.

1937. — On August 7th Captain SCHELDERUP reported that the three northern fjords of Jameson Land, as well as Davy Sund and Kong Oscars Fjord were free of ice. However, a few days afterwards drift ice entered Davy Sund, but for the most part remained outside a line Antarctic Havn-Drømbugten till the end of August, when it reached Haslum Øer.

1938. — On August 10th the "Godthaab" reached Mästers Vik from the north, where she met the first drift ice of any importance. Large masses of drift ice occurred in Davy Sund and along the northern part of Liverpool Kyst, but the ice was scattered owing to the calm weather.

On August 17th the ship reached Fleming Fjord, where the drift ice packed so much, that it was impossible to fetch a depot on the shore. The drift ice extended to some distance north of Antarctic Havn. Occasional floes occurred near Haslum Øer on August 18th.

On August 26th a reconnaissance from the air showed that scattered ice floes occurred even north of Mästers Vik. Drift ice was observed farther eastward, but owing to the calm weather it was fairly open, and navigation was easy. The ice extended over two-thirds of Fleming Fjord, but now it was so scattered that it was possible to fetch the depot. Nathorst Fjord was almost filled with ice, whereas the inner half of Carlsberg Fjord was ice-free (cf. Fig. 40).

1939. — On July 30th the edge of the land ice extended from Kap Wardlaw northward to Bontekoe Ø. At the beginning of August land ice occurred at the mouth of Davy Sund, but it was broken up by a heavy swell on August 14th.

If we look at the thirteen years from which observations on the ice conditions are available, we shall see that in 1899 and 1930 Davy Sund was barred by land ice. In 1932, 1934, and 1936 the land ice had disappeared before August 1st. In the remaining years the ice must be assumed to have melted about the middle of August.

As regards Carlsberg Fjord we must assume that the land ice which was observed on September 1st, 1900, remained till next year. In the period 1929—1939 the land ice in the fjord melted or drifted out every year. In some years, thus in 1934 and 1936, the fjord was free of ice before August 1st.

Navigators frequenting East Greenland have put forward the theory that if strong gales force the pack ice into the fjords and through Davy Sund up into Kong Oscars Fjord about September 1st, these

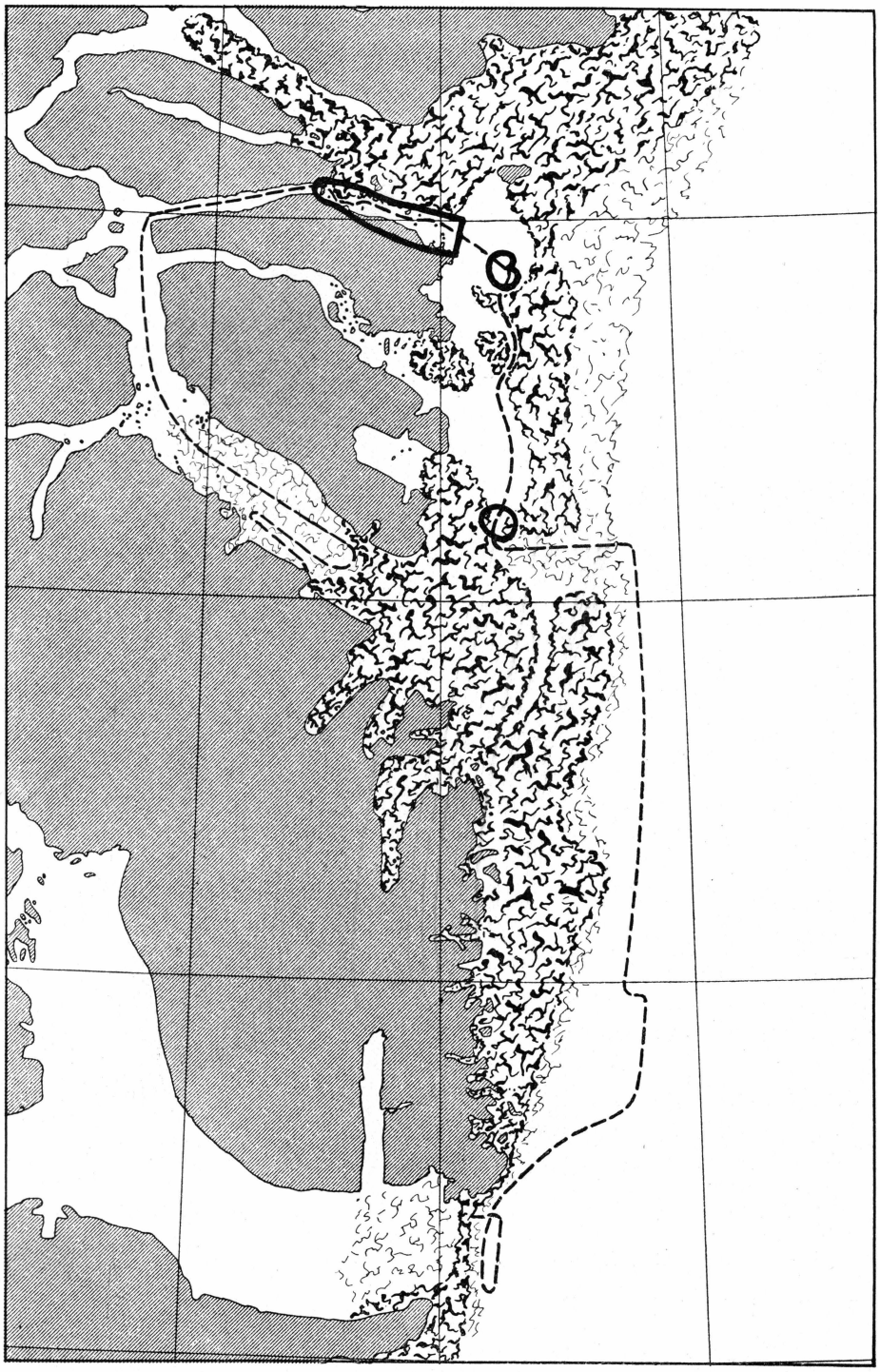


Fig. 38. Drift ice along the east coast of Greenland, Aug. 29—Sept. 2, 1934. Full line: air routes, broken line: ship's routes.

ice masses will fuse and remain stationary; in the course of the winter this layer of fused drift ice floes grows so thick that it remains there, forming a barrier in Davy Sund next summer at any rate till about September 1st.

In 1930 the first drift ice masses possibly fused so as to form land ice far up Kong Oscars Fjord, but as a rule, I think, we may take it for granted that gales will clear the fjords of drift ice at the end of September and the beginning of October. At any rate the theory about drift ice masses fusing about September 1st and remaining in the fjords during the winter seems to hold good only quite exceptionally, and probably it is likewise an exception that Davy Sund, as in 1931—32, is more or less ice-free in January and that there is open water in the middle of the sound at the end of May.

The Drift Ice at the Mouth of Franz Josephs Fjord.

Normally there is a rather strong current off Kap Broer Ruys and easterly winds increase its force considerably. At times a belt of close-packed ice extends from Hold with Hope down towards Bontekoe Ø a short time after a gale, but the ice will rather soon spread into Foster Bugt. Easterly winds, however, will often press the ice close towards Kap Franklin and the islands outside Kap Humboldt, but generally the ice drifts from Kap Broer Ruys towards Bontekoe Ø, and more open ice is found in Foster Bugt.

At times the drift ice packs closely around Kap Franklin as far as Margrethedal and across to Kap Graah. On rare occasions the drift ice is pressed into Franz Josephs Fjord as far as Kap Weber, but these drift ice masses do not seem to remain very long in the fjord. On the whole, rather few observations on the ice conditions of Franz Josephs Fjord are at hand.

As a rule a plug of land ice is found in the mouth of the fjord until the middle of July, but generally it melts about July 20th, leaving free access to the fjord. No examples are on record that the ice has persisted during the summer; even in the unfavourable ice year 1923 the "Annie" seems to have been troubled by drift ice, but not by winter ice.

Around Kap Franklin the inward current is the strongest, though it is rarely strong enough to carry ice masses of any importance westward past Margrethedalen; the southeastward current moving past Kap Graah to Brochs Øer, where a number of icebergs are always stranded, seems to be much stronger.

Navigators have advanced the theory that the current moves through Davy Sund into Kong Oscars Fjord and onwards through Sofia Sund to Franz Josephs Fjord. This popular theory, however,

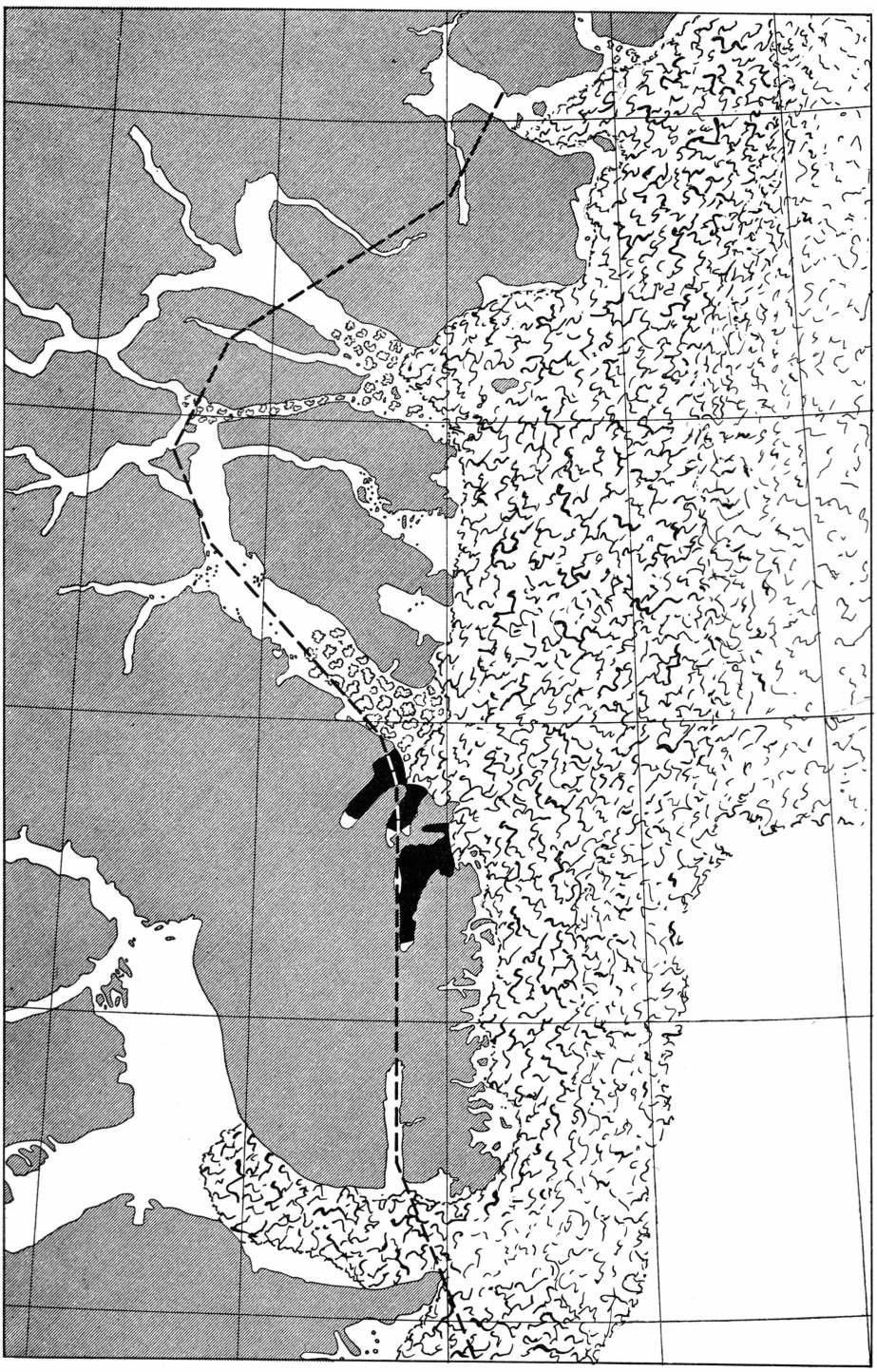


Fig. 39. Land ice (black) and pack ice, Aug. 28, 1935. Broken line: air route. Observed by E. Overbye.

does not probably hold good, but must be viewed in connection with the fact that the northeast wind presses the ice into Davy Sund, while the mouth of Franz Josephs Fjord is situated in the lee of Hold with Hope. Most ships do not enter Franz Josephs Fjord till August, and with a single exception (in 1939) the fjord has then been free of land ice.

In **1926** I passed the mouth of Franz Josephs Fjord between Kap Humboldt and Kap Franklin on thin new ice which had repeatedly been broken by the wind, as evidenced by pressure ridges. During the continued journey in Franz Josephs Fjord it proved that no drift ice had become fused into the thin ice.

On July 24th, **1929**, the edge of the land ice, according to the Norwegian trappers, extended from Murray Ø to Bontekoe Ø and onwards to Kap Broer Ruys and Jackson Ø.

On August 4th the "Godthaab" entered Franz Josephs Fjord without meeting any ice.

On September 7—8th the drift ice occurred far seawards, the wind blew from the north, and the whole of Foster Bugt was free of ice. It seems that north winds clear the waterway between Kap Broer Ruys, Bontekoe Ø, and Kap Franklin of ice, but belts of close-packed ice with intervening ice-free zones will then occur south of Bontekoe Ø towards Liverpool Land. When the wind changes, blowing from the east, the ice is pressed towards the coast. Such belts of ice separated by open water occurred off Geographical Society Ø and Traill Ø.

In the last half of July **1930** the "Godthaab" passed Kap Franklin without being troubled by ice.

In **1931** Miss BOYD's expedition in the "Quest" entered Franz Josephs Fjord on July 17th.

1932. — As far as I could make out from the air, remnants of ice still remained in Franz Josephs Fjord on July 15th, but it might have been possible to pass the ice near Kap Franklin.

On July 8th, **1933**, (cf. Fig. 24) the ice extended from Murray Ø to Bontekoe Ø, the easternmost point of which was free of ice, and onwards to some distance east of Myggbukta. The land ice still lay in nearly the whole of Sofia Sund, the outer part of Dusén Fjord, and the outer part of Franz Josephs Fjord from a distance west of Kap Graah to the middle of the south coast of Gauss Halvø (Fig. 25). On July 24th the melting of the ice was so far advanced that the land ice only remained around Brochs Øer, and a large loose floe of winter ice occurred between Kap Bennet and Kap Franklin. A few days later the mouth of the fjord was free of ice.

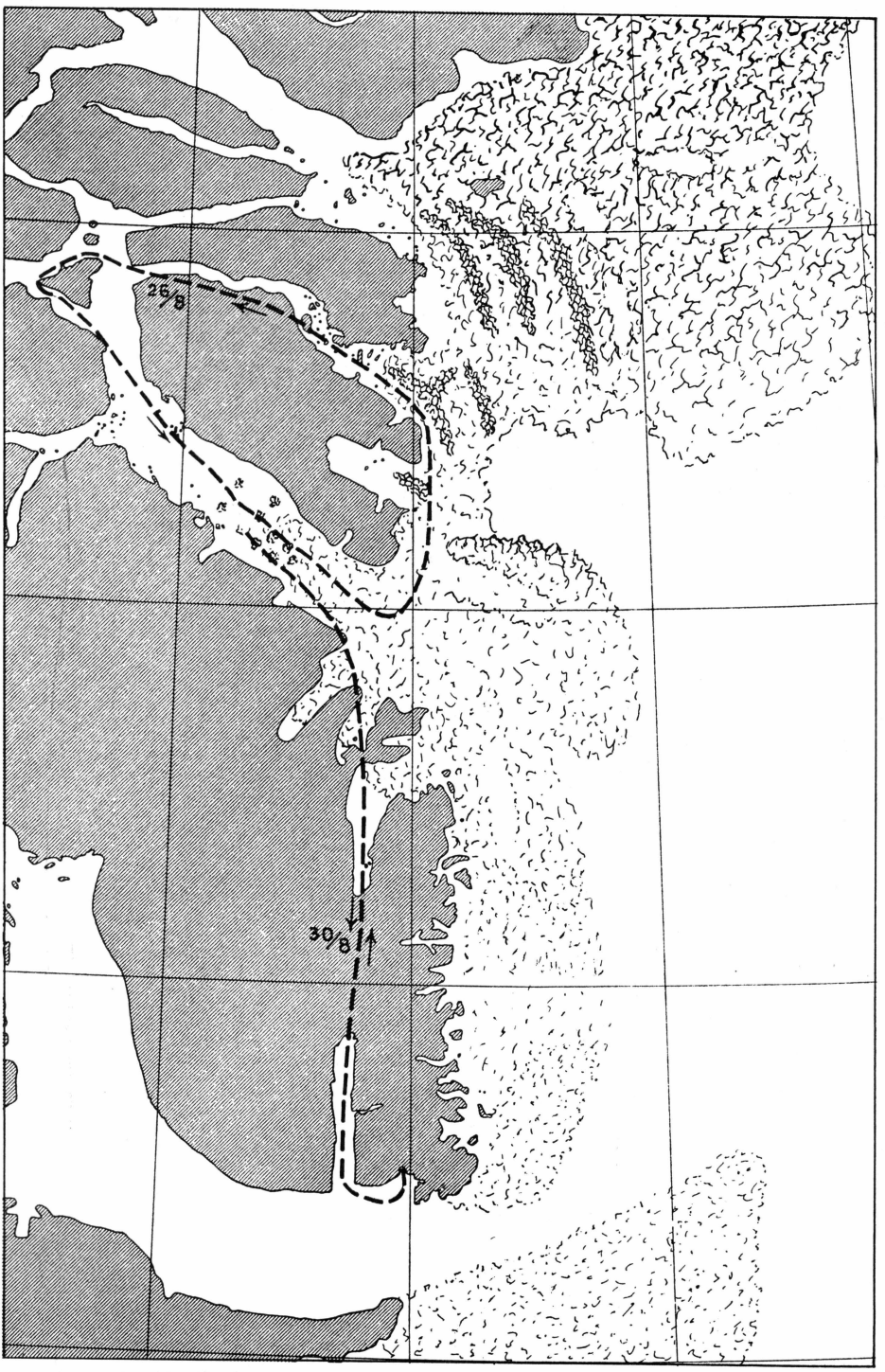


Fig. 40. Pack ice, August 26—30, 1938. Broken lines: air routes.

1934. — On August 5th there was apparently no land ice in the mouth of the fjord. On the 8th the mouth was free of ice, but rather large masses of drift ice occurred in Foster Bugt.

A reconnaissance from the air on August 31st showed that the ice packed against the coast from Kap Broer Ruys to west of Kap Franklin. The south coast of Gauss Halvø was free of ice, but a belt of close-packed drift ice almost reached Kap Weber and was pressed towards the north coast of Ymer Ø. The Vinter Øer were surrounded by ice, and the ice likewise packed around Brochs Øer. From Bontekoe Ø to Kap Simpson leads of open water were observed inside a belt of much packed ice (cf. Fig. 38). Later in September the pack ice drifted out of Franz Josephs Fjord, which was thus free of ice before the winter ice formed.

1935. — On August 28th there was no winter ice in Franz Josephs Fjord, whereas drift ice extended to a point west of Kap Graah, and Foster Bugt was filled with ice (Fig. 39).

1936. — No ice at the mouth of Franz Josephs Fjord at the end of July.

1937. — The fjord seems to have been free of ice at the end of July, but at the beginning of August large ice masses drifted into the fjord and once or twice seems to have reached to halfway between Kap Franklin and Kap Weber.

1938. — Scattered ice in Foster Bugt as far as Kap Franklin on July 29th, but no ice west of the cape. On August 22nd and 23rd much ice in Foster Bugt, which was especially close-packed round Kap Franklin and as far as Margrethedalen, whence it extended towards Kap Wijkander.

1939. — On August 1st the "Gustav Holm" observed land ice which extended from Kap Broer Ruys to Bontekoe Ø and farther southward. As there was nothing to indicate that the ice was going to break up, the ship went northward, returning to Foster Bugt on August 27th, where she met close-packed ice around Kap Franklin, but made her way through and proceeded through Sofia Sund to Ella Ø. On the 30th the ship sailed out of Sofia Sund and met scattered floes near Bontekoe Ø.

It will be evident from the above that the mouth of the fjord is as a rule cleared of winter ice in the latter half of July. An exception is formed by the year 1939, when the ice did not disappear till the beginning of August.

In August and the beginning of September strong easterly winds may drive the pack ice into the fjord as far as Kap Weber, but it would seem that these ice masses soon drift out again, often on account of the strong winds from the northwest (foehn winds) in the autumn.

The Drift Ice in Godthaab Golf and Young Sund.

From the two series of observations on the ice conditions between Kap Broer Ruys and Bass Rock for 1922—23 and 1931—32 respectively (see Figs. 18—20) it will be seen that the greater part of Gael Hamkes Bugt is not covered by winter ice in the middle of the winter, and the ice formed during calm periods in the spring is consequently not particularly thick. In the early summer open water will therefore as a rule be found from Kap Borlase Warren to a little east of Sandø at the mouth of Young Sund, though ice extends across this sound to a little west of Kap Breusing. The area around Kap Mary is free of ice as far as Fossil Elv, whence the ice edge extends to the northernmost point of Jackson Ø.

In the first half of July large ice masses drift out of Gael Hamkes Bugt, and about the middle of the month the ice forms a rather narrow belt, enclosing Finsch Øer, across the fjord. The disappearance of the last ice has been treated above.

In August, when the land ice has disappeared from Gael Hamkes Bugt, fairly large masses of drift ice are found along the north coast of Hold with Hope between Jackson Ø and Finsch Øer. When the wind blows from the northeast, the whole southern part of the bay may be filled with pack ice; the current, which, of course, is stronger when the wind blows from the east, seems to move from Kap Borlase Warren past Kap Mary, along the south coast of Clavering Ø to Eskimonæs, and onwards to Kap Stosch. In summers with drift ice this current carries ice masses in between Clavering Ø and Finsch Øer and into Godthaab Golf. After passing Kap Stosch, the ice melts in the water around Jordanhill, rarely reaching the mouth of Copeland Fjord.

In fine weather at the end of July and during the greater part of August local fjord winds favour the drift of the ice floes into Godthaab Golf. Thus in the early morning it is generally calm. About 10 a. m. a fjord wind will begin to blow into the Golf, increasing gradually in force, to culminate at c. 3—4 p. m. It dies down in the evening, and at 9—10 p. m. it will be quite calm again. This fjord wind is light east of St. Finsch Ø, attaining its greatest strength between Kap Stosch and Jordanhill. The calm is often broken about midnight by a fjord wind which blows out of the Golf, but it is rarely as strong as the day wind. It culminates at 2—3 a. m., and dies down in the early morning.

When there is much drift ice in the outer part of Gael Hamkes Bugt, the afternoon wind in the fjord is often accompanied by fog, which frequently does not spread beyond Finsch Øer and Eskimonæs for several hours, but sometimes the whole of Godthaab Golf is filled with fog in the evening.

Climbing the mountains around Kap Stosch, one may make the observation that the afternoon fjord wind blows only to a height of 200 m, above which height it is calm. The fog in the Golf likewise does not generally rise above c. 200 m.

The conditions described here are known from a series of summers with periods of fine, clear weather, but, of course, meteorological disturbances may interfere. Thus light easterly winds coming from the drift ice and not locally marked will fill Godthaab Golf with fog, which may set in at all hours of the day and night and occur far above a height of 200 m.

The explanation of the regular winds from the east in the afternoon, and at the height of the summer, also, from the west in the morning, is no doubt that gradually as the influence of the sun increases in the day, the large ice-free areas south and west of Wordie Gl. are heated, the air will ascend, and be replaced by cold air from Gael Hamkes Bugt accompanied by fog. In the evening, when the sun is lower in the sky, the heat surplus over the land has been eliminated, and in the morning the fog lifts. If there is only little drift ice in Gael Hamkes Bugt, no fog will appear in Godthaab Golf. This area and the ice-free land areas westward are in the shade, while the midnight sun still illuminates the ice-free sea of Gael Hamkes Bugt. This gives rise to a suction from the sea in the early morning, which creates a fjord wind in Godthaab Golf of short duration but extremely constant. Whether afternoon fjord winds or easterly winds drive the ice floes into Godthaab Golf, a constant drift of ice will generally take place towards the interior of the fjord past Eskimonæs and Kap Stosch. The great majority of these floes melt between Kap Stosch and Jordanhill, numerous fresh water rivers with warm water emptying along that stretch, partly by way of Loch Fyne, partly from the coasts south and north of Jordanhill.

None of the ice floes passing St. Finsch Ø on their westward drift will pass the island again. Some floes are carried by west winds or by the current, which evidently moves along the coast of Kap Stosch, to Stille Ø and Finsch Øer, among which they strand and melt.

According to several years' observations Young Sund freezes up about October 1st. The gales which blow eastward from Zackenberg with great force, as a rule keep the north-south-trending part of Young Sund free of snow, but at the same time carries large masses of gravel and sand from Wollaston Forland out on to the ice. In spring, when the sun begins to warm, the sand particles will accelerate the melting, Young Sund north of Basaltø becoming ice-free very early, sometimes at the end of June, while land ice, which normally melts or drifts out about the middle of July, lies from Basaltø to some distance

east of Sandø. A few examples show that the land ice may remain till the end of July; this was the case for instance in 1924.

When Young Sund has become free of winter ice, drift ice may enter its mouth, but it rarely passes beyond the hunting post Sandodden, so a good anchorage sheltered from the ice may be found off the river in Lille Sødal.

Of all the fjords of Northeast Greenland Young Sund is often the first to become free of ice. It has therefore frequently been visited by Norwegian hunting vessels, which went up in the land water, while the land ice barred their way to the other fjords.

The Drift Ice North of Danmarks Havn.

As is well known, the members of the Danmark Expedition on their sledge journeys in the early autumn struck large stretches of open water along the coast between Danmarks Havn and Nordostrundingen. Generally these belts of open water were quite narrow, but off Mallemukfjældet the open water attained a considerable width.

Open water was further found south of Île de France and east of the southern part of Koldewey Ø, an observation previously made. Large spaces of open water were encountered southeast of Shannon and especially southeast of Pendulum Øer both in spring and autumn, which is in fairly good agreement with the observations made during the wintering of the German expedition in Germania Havn in 1869—70.

The hydrographer of the Danmark Expedition, Alf Trolle, gathering the available information on open water, resumes his view as follows (1913, pp. 402—407):

"South of N. E. Runding the main current takes the direction towards Shannon Isl., that is, out from the land and the main portion of the pack-ice follows with it. Then, eddies and whirlpools are probably formed in under the land, and the part of the drift-ice which comes in here is probably set in irregular movement, therefore, and becomes greatly compressed and screwed. As it is a comparatively small part of the drift-ice, however, which comes in here, there is a tendency to the formation of openings."

Trolle likewise deals with the observations made on open water southeast of Shannon and east of Bass Rock. He summarises his view as follows (Op. cit. pp. 406—407):

"The difference between the conditions S. E. of Shannon Isl. and the conditions N. of this island along the coast as far as Mallemukfjæld (80°13′ N. L.) is, therefore, that on the latter stretch there is a part of the Polar Current, where the current conditions are comparatively

calmer (region of the coastal water) and where the drift-ice, therefore, can freeze, whilst S. E. of Shannon Isl. even the main current reaches in to the land with a relatively sudden increase in the rate of flow, so that there is more movement in the ice here and a tendency to the formation of openings."

EJNAR MIKKELSEN, who had the data supplied by the Danmark Expedition to draw upon, devotes a special chapter, in which he gathers all his observations on the ice in the years 1909—1912, to the ice conditions especially around Shannon and Bass Rock (1922, pp. 190—213).

Furthermore, he disproves TROLLE's view, propounding an entirely new theory about the ice conditions between Nordostrundingen and Danmarks Havn, a theory which is especially expressed on his Pl. 5.

All later expeditions can confirm that practically every year spaces of open water are found in certain places along the coast between Shannon and Nordostrundingen from the early spring till late in the autumn. Attention should especially be called to the area of open water along the southern part of Koldewey Ø. EJNAR MIKKELSEN states that open water was encountered here in 1905, 1906, 1908, 1911, and 1912, but not in 1907. Later open water has been met with here in 1919, 1920, 1932, 1933, 1938, and 1939.

Moreover there is evidently often open water south of Île de France, which is sometimes connected with the open water east of Koldewey Ø. A broad belt of open water has been found by all observers off Mallemukfjæld; it narrows towards the north, but as a rule extends almost as far as Nordostrundingen. In May and June, in which months the weather is normally calm, and sometimes in April, also, there will probably always be open water in these two places. The ice conditions met with in the spring suggest that new ice or open water is found throughout the winter along the stretch from Mallemukfjæld to Nordostrundingen. The area of open water near Koldewey Ø, which sometimes extends northward to Île de France, does not seem to be constant during the winter.

TROLLE's cautious remarks from 1913 quoted above evidently give a fairly correct picture of the actual conditions. The ice that comes from the north is highly packed when it reaches Nordostrundingen. After passing this point the ice continues southward forming a slightly eastward curve, but gradually it bends towards the east coast of Greenland, which it approaches off Shannon. This is immediately evident if we consider the drift of the Russians from the North Pole in 1938. From Nordostrundingen to Shannon the coast forms a curve towards the west, while the Russians drifted in a curve towards the east. Thus the distance of the Russians from Nordostrundingen and from Shannon was c. 65 km, while their distance from Norske Ø was c. 250 km.

TROLLE is of opinion that circular currents are formed on the inner side of the current passing Nordostrundingen, and where these circular currents touch the coast, flowing towards the north, open water will form in calm weather all the year round.

Unfortunately we lack almost all knowledge of the configuration of the sea-bottom in these regions. We know, however, that a submarine shelf extends from a point slightly south of Nordostrundingen along the east side of Shannon, the 1000 m contour lying probably at a distance from the coast of 150 km from Nordostrundingen to Shannon, but then bends eastward, its distance from the coast between Norske Ø and Danmarks Havn being almost 300 km. We also know that submarine shoals occur off Shannon, Koldewey Ø, Germania Land, and Franske Ø, but their extent and depth are not precisely known.

The drift of the Russians in 1938 did not take place along the edge of the 1000 m deep but nearer the shore. They passed across the shoal off Shannon, but it is not evident from their route whether the current carried them towards the edge of the shoal.

It is a general rule, however, that when the current meets such a shoal, part of it passes across it, though at a reduced velocity, while another part of it passes across the outer edge of the shoal at a great velocity.

As long as we do not know very much about the configuration of the sea-bottom, it is, of course impossible to decide whether the shoals may force some of the warm water towards the surface, but it seems little probable. It seems more probable that the configuration of the sea bottom may increase the eddies which naturally occur off the coast west of the actual Polar Current. And these eddies might quite probably create open water along the coast between Shannon and Nordostrundingen.

EJNAR MIKKELSEN raises objections against TROLLE's conception that an eddy occurs west of the main current, saying as follows (l. c. p. 199):

"The coastwater, which forms the boundary between the solid land-ice and the drifting pack-ice will probably mark the inner termination of the polar current, as all ice outside the coastwater drifts to the south, whatever the direction of the wind, and the theory put forth by TROLLE to the effect that the main current follows an imaginary line rather far out to sea from Nordost-Rundingen to Shannon Island, does not seem quite correct, as nothing but a continuous drift to the south could form a coastwater free of ice and extending along the coast during the greater part of the year."

On Pl. 5 MIKKELSEN marks off an area almost in the place where the Belgica Expedition in 1905 encountered firmly fused ice. He calls

this an "Area, usually covered with unbroken ice adhering to Icebergs etc. grounded on Belgica-shoal".

The drift of the Russians showed that no such area is found. As early as 1933, when the "Gustav Holm" reached Norske Ø, there was entirely open water here, and the temperature of the water was very high. Unfortunately we were unable to measure the depth of the sea and cannot, therefore, contribute to the elucidation of the question as to the depth of the water near the Belgica shoal; however, no stranded icebergs were found on the shoal. (It should be added that the only bergs that may strand here are those formed in the bay north of Amdrups Land, and they are not very high.)

On the flight in May 1938 I observed that north of the latitude of Mallemukfjæld no islands or shoals prevent the passage of the ice along the northeast coast of Greenland. EJNAR MIKKELSEN's assumption as to a division of the ice stream, a western branch of which is supposed by him to follow the coast and give rise to open water there, must therefore be rejected for the benefit of TROLLE's theory of eddies.

As to the occurrence of open water south of Shannon and Pendulum Øer the case is somewhat different, TROLLE's explanation being unsatisfactory. Both EJNAR MIKKELSEN and LAUB think they observed a current passing southward through the sound between Shannon and Koldewey Ø and then eastward along the south coast of Shannon. In ice-free summers a large number of the icebergs from the interior of Dove Bugt will drift southward along Hochstetter Forland to strand in Shannon Sund, which is on the whole very shallow. This might suggest that a current moves west of Shannon. Hochstetter Bugt can therefore be compared to a fjord out of which water is constantly flowing, giving rise to open water at its mouth.

EJNAR MIKKELSEN gives a number of examples showing that there is open water south of Shannon throughout the winter. Evidently, however, precise observations of the extent of this area of open water are not available. From recent years a number of observations are at hand showing that the edge of the fast ice extends from Bass Rock to Kap Philip Broke; this is in contrast to EJNAR MIKKELSEN's observations, according to which the ice edge should extend from Sabine Ø to Kap David Gray. Here, too, we lack knowledge of the configuration of the sea bottom and of exact measurements of the current that possibly flows west of Shannon and its velocity, and as to whether it flows during all or only part of the year. We also lack information about the number of winters in which the open water reaches Kap David Gray or whether the ice edge normally lies between Bass Rock and Kap Philip Broke, which seems to be commonly the case.

As to the open water recorded to extend from Bass Rock southward to Jackson Ø, it will be seen from the two observation series from 1922—23 and 1931—32 that almost every year a fairly firm ice belt will form between Bass Rock and Jackson Ø in the calm period in the autumn and the calm period in the spring, but every winter this ice is broken up by northerly gales. Here another factor, viz. the north wind, must be taken into consideration if open water forms in places where the coast extends in an east-west direction; this is the case south of Shannon between Kap Philip Broke and Kap David Gray, and along the coast from Bass Rock to Mt. Brinkley on the south coast of Clavering Ø.

Not till we know the configuration of the sea bottom, will it be possible to decide whether eddies afford conditions for the formation of open water between Jackson Ø and Bass Rock and south of Shannon, but there is hardly any doubt that another factor within these areas, namely the strong northerly gales, will be of importance for the formation of open water along these shores, which are sheltered from the ice stream, and the same is no doubt the case south of Nordostrundingen.

As regards the broad belt of open water off Mallemukfjæld and Koldewey Ø, however, the wind seems to be of no importance. That eddies providing conditions for the formation of open water may occur as far south as Gael Hamkes Bugt, seems to appear from the fact that along the sheltered coast of Foster Bugt from Kap Broer Ruys to Kap Franklin the north wind, which blows at great force down through Loch Fyne and the lowland near Myggbukta, is unable to prevent the formation of a solid ice-covering.

A strong current moves around Kap Broer Ruys, and consequently there is sometimes open water here in the winter; however, the current does not move into the bay, but continues southward towards Bontekoe Ø, at times with a narrow belt of open water extending towards this island along the outer side of the edge of the land ice.

There are, of course, years in which the North Pole ice stream will carry large ice masses southward, or years in which largely easterly winds prevail. In such years open water will, of course, not form in the aforementioned places, but since the spring, notably April, May, and sometimes June, is calm, large areas with open water will occur nearly every year in the early summer between Jackson Ø and Nordostrundingen. And if no too heavy ice masses are carried southward and no very severe easterly winds blow in the month of July, a broad belt of open water may be met with from Jackson Ø to Shannon and from Mallemukfjæld to a little south of Nordostrundingen.

The ice conditions between the northern part of Shannon and the southernmost point of Koldewey Ø seem always to be severe. However,

if a ship reaches the land water off Koldewey Ø, she may no doubt in several years push far northward in the month of July.

The finding of drift-wood in the interior of Danmarks Fjord and along the outer coast is regarded by EJNAR MIKKELSEN as evidence of the presence of a branch of the Polar Current close to the shore. To this it should be urged that drift-wood has also been found along the shores of Robeson Channel and in the interior of Independence Fjord; in both places, however, the drift-wood is generally very old. And since large whale bones have been found in Independence Fjord in company with drift-wood, it would seem to be derived from a period in which the ice conditions differed from those of the present day. In summers when the North Pole Ice is entirely absent the drift-wood found south of Nordostrundingen may quite well have drifted down from the Siberian Ice, carried either by the wind, which would have been possible in 1933, or by the eddies, which seem to move towards and northward along the shore in several places.

THE GLACIERS OF EAST GREENLAND FROM THE NORTHERNMOST POINT OF GREENLAND TO ANGMAGSSALIK AND THEIR PRODUCTION OF ICEBERGS

1) The stretch from Kap Morris Jesup to Nordostrundingen.

In eastern Peary Land only Ymer Gl., Balders Gl. and a small glacier in Fr. Hyde Fjord north of Tordenskjolds Fjæld reach the sea; none of these glaciers are productive. At the head of Independence Fjord, Marie Sophie Gl., Academy Gl., and Hugh Lee Gl. descend into the water; the last-mentioned glacier is unproductive, Marie Sophie Gl. is not particularly productive (cf. L. Koch 1928, pp. 320—322), while Academy Gl. is very productive, normally filling the interior of Independence Fjord as far as Lyngholmene with close-packed bergs.

A large and broad glacier descends into Hagens Fjord. It produces some icebergs, at any rate I observed numerous icebergs in front of it in 1933. In 1938 I observed many icebergs, whose edges were not yet rounded by melting, to be enclosed in the ice throughout Independence Fjord, so both this fjord and Hagens Fjord must have been free from ice in one of the intermediate years. The nunatak in front of Hagens Fjord and part of the east coast of Vildt Land were entirely free from icebergs.

Comparing the observations from 1892 (Peary), 1895 (Peary), 1907 (Mylius-Erichsen), 1910 (Einar Mikkelsen), 1911 (Knud Rasmussen and P. Freuchen), 1921 (present author), 1933 (present author), and 1938 (present author), one gains the impression that from 1892 to one of the years between 1933—1938 Independence Fjord, and no doubt also Hagens Fjord, have not been free from ice. The great accumulation of icebergs off Academy Gl. and the glacier at the head of Hagens Fjord would accordingly be the result of half a century's production of bergs, which became detached shortly before 1938 and spread into the two fjords and towards Wandels Hav.

No glacier reaches the water in Danmarks Fjord. In 1938 occasional bergs were seen in the northern part of the fjord. Theoretically there

is a possibility that bergs 20—30 m high may on rare occasions drift from Navy Cliff into Wandels Hav and be carried southward with the East Greenland ice stream; in such cases they might run aground on the Belgica Bank. However, as far as is known, bergs of that height have never been observed between Nordostrundingen and Danmarks Havn, but if the present amelioration of the climate continues, icebergs from Academy Gl. may be met with along the east coast of Greenland in the future.

2) Glaciers between Nordostrundingen and Danmarks Havn.

Active glacier fronts are found slightly south of Nordostrundingen and especially north of Antarctics Bugt. Rather small numbers of icebergs not particularly high are produced.

In Ingolfs Fjord two local glaciers are found on the north coast and two on the south coast. As the fjord is nearly always frozen up, ice fragments from these glaciers no doubt very rarely reach the East Greenland ice stream. The bergs produced by the glaciers are extremely small.

In Dijmphna Sund a few local glaciers reach the shore, probably without producing any bergs. A few bergs are, however, produced by the glacier which issues northward from Nioghalvfjerds Gl. and descends into Dijmphna Sund, but they hardly drift out of the fjord, a submarine ridge, probably a moraine, extending from Hovgaards Ø towards Mallemukfjældet.

Nioghalvfjerds Gl. and Zachariaes Gl. are unproductive, the glacier ice passing evenly into sea ice many-years old, so in the spring, at any rate, it is practically impossible to see where the glacier ice ceases and the old sea ice begins.

No bergs are produced in Jökelbugt. Here the glacier ice floats on the water and is bounded on the east by skerries. The floating glacier is very low.

Kofoed-Hansens Gl. produces numerous bergs, which fill the waterway north of the northern part of Germania Land and Orleans Sund. Skerries east of this sound no doubt prevent the bergs from drifting eastward into the sea.

3) The iceberg production between Danmarks Havn and Sabine Ø.

A system of highly productive glaciers occurs within this area, namely Storstrømmen Gl., L. Bistrups Gl., and Soraner Gl. The first two, in particular, produce so many bergs that a veritable iceberg

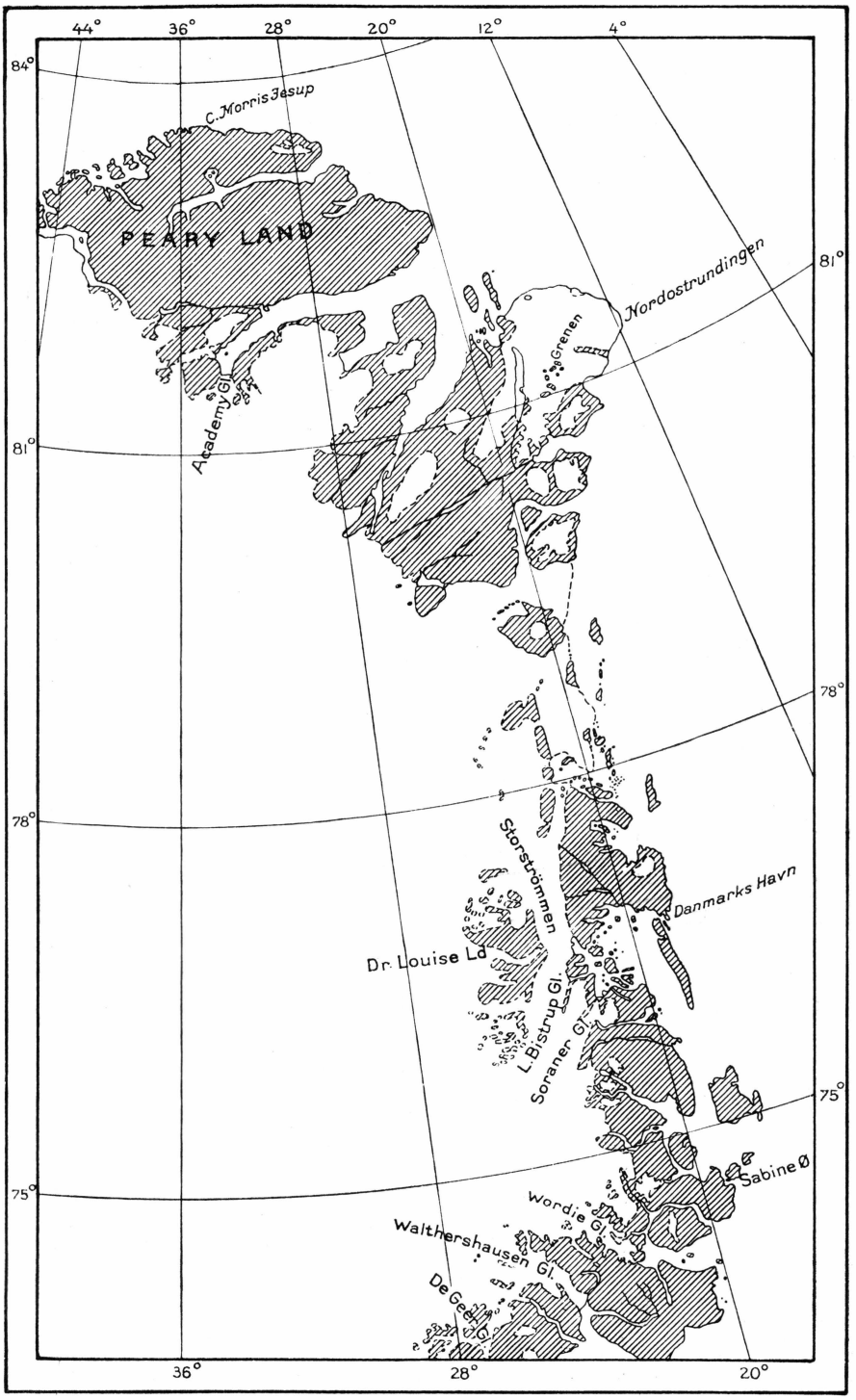


Fig. 41. Map showing the most important glaciers in Northeast Greenland.

bank is formed in front of them, which is kept in place by the many islands situated in the interior of Dove Bugt. In years in which the sea ice in Dove Bugt does not melt, no bergs will, of course, drift past the iceberg bank, but in years when the ice in Dove Bugt breaks up for instance about the middle of August, the bergs will drift out of the bay. Many of them will strand on the numerous islets, but a large number will drift southward, most of them into Shannon Sund owing to the eastward-moving current between Koldewey Ø and Shannon. Here, too, many bergs will run aground along the flat shores of the sound, but a number of them will pass around the south of, and several also north of, Shannon in spite of the westward moving current. A great many of these bergs will strand on the bank east of Shannon, while some of them will drift southward along the coast with the East Greenland ice stream.

Apart from the icebergs derived from the interior of Dove Bugt practically no bergs are produced along this stretch of coast. Glaciers descend into the sea in Bredefjord and Smallefjord, but their production of icebergs is of no importance. Each of these fjords has, in addition, a local glacier, which descends into the sea but is unproductive. Heinkel Gl. descends into the water at the head of Grandjean Fjord, but produces practically no bergs.

4) The iceberg production between Sabine Ø and Scoresby Sund.

Within the large fjord complex in this area surprisingly few glaciers descend into the sea. The broadest is Waltershausen Gl., which produces some few small bergs.

Little productive glaciers within this area are: Nunatak Gl. at the head of Geologfjord, Nordenskiölds Gl. at the head of Kejser Franz Josephs Fjord, Hisinger Gl. at the head of Dickson Fjord, and Gully Gl. at the head of Alp Fjord. Nordenskiölds Gl. is not quite unproductive, and a number of the many bergs which form an iceberg bank in Kjerulffs Fjord, probably originate from this glacier. The other glaciers are practically unproductive. Very small local glaciers, which descend into the sea but are unproductive, are found in Geologfjord (one), Hisinger Fjord (two), Franz Josephs Fjord (two), and Dickson Fjord (two).

Two highly productive glaciers are found within the area, viz. 1) De Geers Gl., which receives a supply of ice from Evers Gl., Hambergs Gl., and especially the deep-lying large Victor Madsens Gl., and 2) Jætte Gl. De Geers Gl. is particularly productive. Every summer, from the beginning of July to the end of September, large numbers

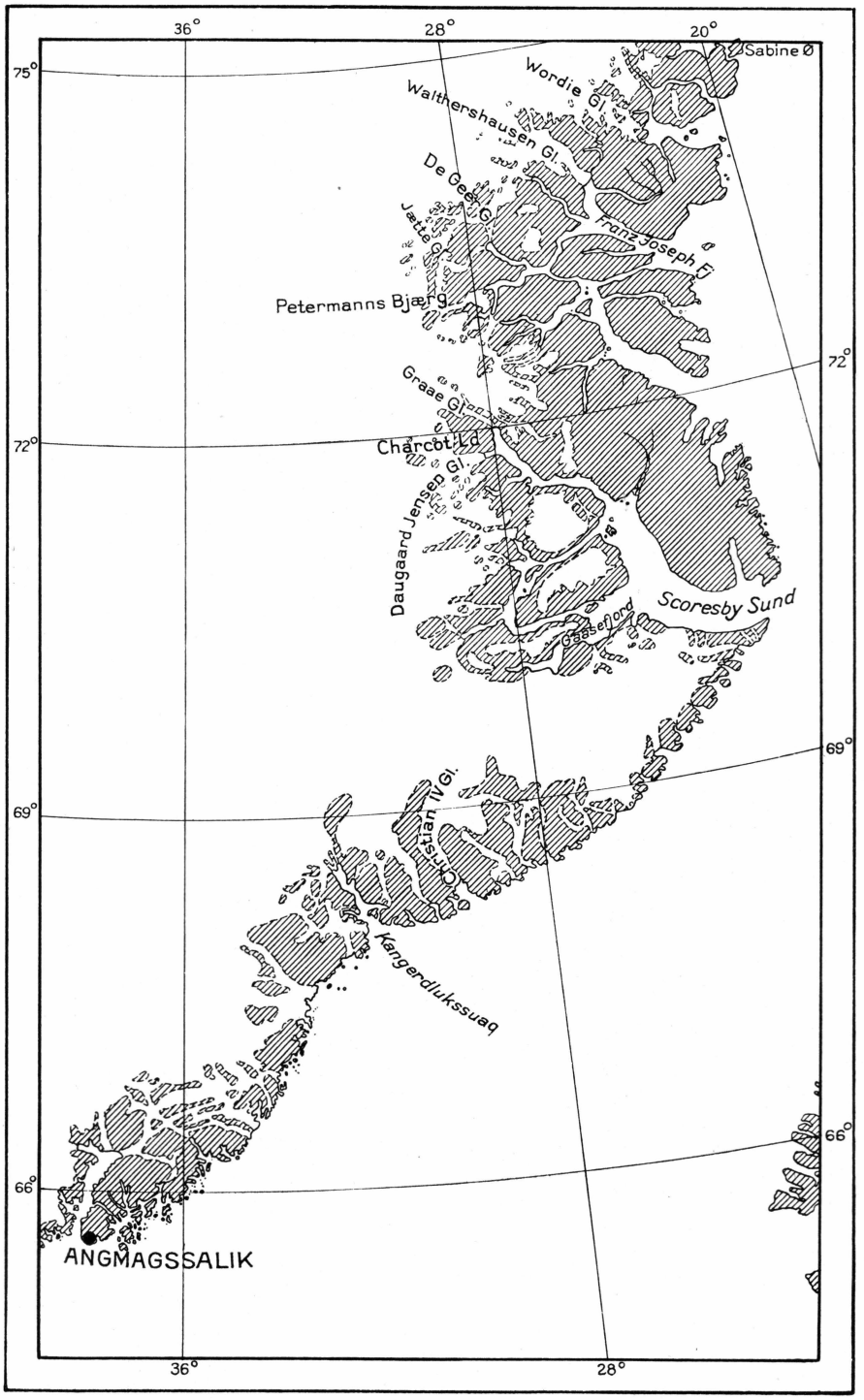


Fig. 42. Map showing the most important glaciers in East Greenland.

of huge icebergs are detached from these two glaciers and drift out through Franz Josephs Fjord. Some of them pass through Antarctic Sund and many of the latter strand north of Ruths Ø, while others run aground in the waters around Ella Ø, where they melt; at any rate none of them seem to pass south of Haslum Øer and thus do not reach the sea. The number of bergs drifting through Antarctic Sund seems to vary considerably from year to year; in 1929 and 1930 not very many bergs occurred here.

The remainder of the bergs pass along the north of Ymer Ø. Some drift towards Waltershausen Gl. and into Moskusokse Fjord, where they run aground and melt, but the larger ones drift out through Franz Josephs Fjord, forming a row of stranded bergs from Vinter Øer past Brochs Øer and Kap Mackenzie to Franklin Ø. A few reach the sea and drift southward with the East Greenland ice stream.

Glaciers descending into the sea are found both along the northwest and east coasts of Liverpool Land, but they are practically unproductive.

5) The iceberg production in the interior of Scoresby Sund.

Two local glaciers, whose iceberg production is of no importance, are found in the outer part of Nordvestfjord. A local glacier with a very small production is found northwest of Bjørne Øer. Six glaciers descend into the sea between Rype Fjord and Røde Ø; some of them produce a number of small bergs, but very few of them reach the outer part of the sound. Two very productive local glaciers, which occupy almost the whole outer part of Gaasefjord, are found on the south side of this fjord; some of the bergs produced here drift into the outer part of Scoresby Sund. About twelve glaciers descend into the sea along the south coast of Scoresby Sund from the mouth of Gaasefjord to Kap Brewster; some of them produce bergs, but they are of no importance for the total production. Finally, two large glaciers, Graaes Gl. and Daugaard-Jensens Gl., are found at the head of Nordvestfjord. Graaes Gl. is short and steep and not particularly productive, while Daugaard-Jensens Gl. is by far the most productive of all the glaciers in East Greenland. At the beginning of July a procession of very high and large bergs begins to drift out of the fjord. They are so numerous that navigation in Hall Bredning is often difficult, and throughout the summer a constant drift of large bergs is taking place along the south coast of Scoresby Sund and out into the sea.

6) The iceberg production between Kap Brewster and Angmagssalik.

Many glaciers descend into the sea along this stretch of the coast, but between Kap Brewster and Kangerdlugssuak the iceberg production is inconsiderable, not even the large Christian IV Gl. is particularly productive.

The glaciers at the head of Kangerdlugssuak produce many, but not very large, bergs, a great many of which melt in the fjord itself.

Between Kangerdlugssuak and Angmagssalik, also, a great many glaciers descend into the sea. Some of them produce bergs of medium size, but really large bergs are not produced here.

I have no personal knowledge of the iceberg production south of Angmagssalik. Many and large glaciers are found along this coast, but no great production seems to take place.

Summary.

In regard to its iceberg production the east coast of Greenland cannot compare with the west coast with its few but extremely productive glaciers, or the north coast with its characteristic long but unproductive glaciers, which extend as depressions far into the inland ice. Such glaciers are entirely absent from the east coast, because the water-shed of the coastland from a short distance south of Nordostrundingen to Angmagssalik lies a little higher than the inland ice. From the mountain Grenen south of Nordostrundingen a topographical mountain chain extends across the western part of Lamberts Land, Alabama Nunatakker, Dronning Louises Land, the regions north of Petermanns Bjærg, Sorte Hest, Charcot Land to the innermost nunataks west of Gaasefjord, and south of this fjord the northern half of Christian IX's Land forms an oblong elevation with an east-west axis north of Kangerdlugssuak, while the southern part of this land forms an elevation with an axis striking north 20° west.

Since, thus, the whole stretch from Nordostrundingen to Angmagssalik lies on a higher level than the inland ice, this is only drained towards the east through occasional high-lying passes, and it is characteristic that the most productive glaciers reaching the sea move either in a northward or a southward direction, that is to say, in parallel valleys in the mountain range, or at any rate have their catch basins within the mountain range. This is the case with the following highly productive glaciers: 1) Storstrømmen Gl., L. Bistrups Gl. Soraner Gl., 2) De Geers Gl. with its different tributary glaciers and Jætte Gl., and 3) Daugaard-Jensens Gl., which issues from a catch basin situated in the mountain chain proper, with highly crevassed tributary glaciers

mostly coming from the south. I should think, though with every reservation, that these three glacier systems supply more rather than less than 80 per cent of all the icebergs of East Greenland north of Angmagssalik. Thus none of them are actual inland ice bergs, for only the uppermost layers of the inland ice may pass across the mountain range and contribute to the ice quantities of these glaciers.

If these 80 per cent were to be distributed over the three glacier systems, it might be supposed that Daugaard-Jensens Gl. produced 40 per cent, Storstrømmen Gl., Bistrups Gl. and Soraner Gl. 25 per cent, and De Geers Gl. and Jætte Gl. 15 per cent. About half of the iceberg production of Daugaard-Jensens Gl. may be assumed to reach the open sea. Probably De Geers Gl. and Jætte Gl. contribute with only about one-third of their production to the icebergs in the East Greenland Ice, while the remainder melt in the fjords. It is difficult to calculate the quantity of ice that reaches the East Greenland ice stream from the Storstrømmen, Bistrups, and Soraner Gls., for this supply does not go on regularly every year, but in pulsations, the bergs accumulating in the fjords to pass in abundance out into the sea in favourable years.

Glaciers of secondary importance are Nordenskiölds Gl. and Graaes Gl., both of which are short and steep and descend from high-lying passes in the mountain chain. Similarly, the glacier at the head of Kangerdlugssuak is short and steep.

Productive glaciers of secondary importance are Kofoed Hansens Gl., whose bergs do not reach the open sea, and two local glaciers in Gaasefjord. Large but slightly productive glaciers are Waltershausen Gl. and Christian IV's Gl. The huge Wordie Gl. is separated from the sea along its whole front by a low moraine and accordingly produces no bergs.

In the literature dealing with the East Greenland Ice great numbers of bergs are often mentioned in connection with the occurrence of large quantities of ice. This is due to a mistake. On the contrary, the occurrence of numerous bergs in the waters off the east coast of Greenland is evidence of small quantities of ice, the bergs having thus had a free passage into the sea.

III.

THE EAST GREENLAND ICE IN THE PRECENT CENTURY

QUANTITY OF ICE IN THE ATLANTIC IN THE PERIOD 1898–1938

Introduction.

In this chapter a survey is taken of the quantities of ice present along the coasts of Spitsbergen and the east and southwest coasts of Greenland on the basis of the ice charts issued every year by the Danish Meteorological Institute.

The period treated goes from 1898 to 1938. It is true that ice charts were published even prior to 1898, but they are too unreliable, I think, to be included in the present investigation; the same applies to the year 1939, as the data at present available from that year are rather incomplete.

It must be borne in mind that the period comprised by the investigation is characterised by more favourable ice conditions than those prevailing during the preceding forty years; notably the last half of the period investigated is characterised by many exceptionally favourable ice years. Thus it may be mentioned that the period includes only one heavy ice year in which the ice edge persisted for a fairly long time even south of Bear Island (1917); and in another year (1902) ice occurred as far south as Vestmannaeyjar near the south coast of Iceland; but it had no connection with the ice masses north of Iceland, so in the period in question Iceland actually had no heavy ice year.

In the present survey the average ice limit indicated in recent years by the Meteorological Institute, will be disregarded. The five ice charts published every year will be treated apart. The individual areas bounded by the parallels 85, 80, 75, etc., and the meridians 0, 10, 20, etc., will be indicated by letters (cf. Fig. 43). Thus those of the North Atlantic will be designated A, B, C, etc., those around Spitsbergen a, b, c, etc., and those around Southwest Greenland α, β, etc.

In order to obtain as objective a material as possible Mr. E. Hovmøller made an estimate of the quantity of ice found within each tenth of these areas on the basis of the quantity of ice, observed or conjectured, indicated on the ice charts of the Meteorological Institute.

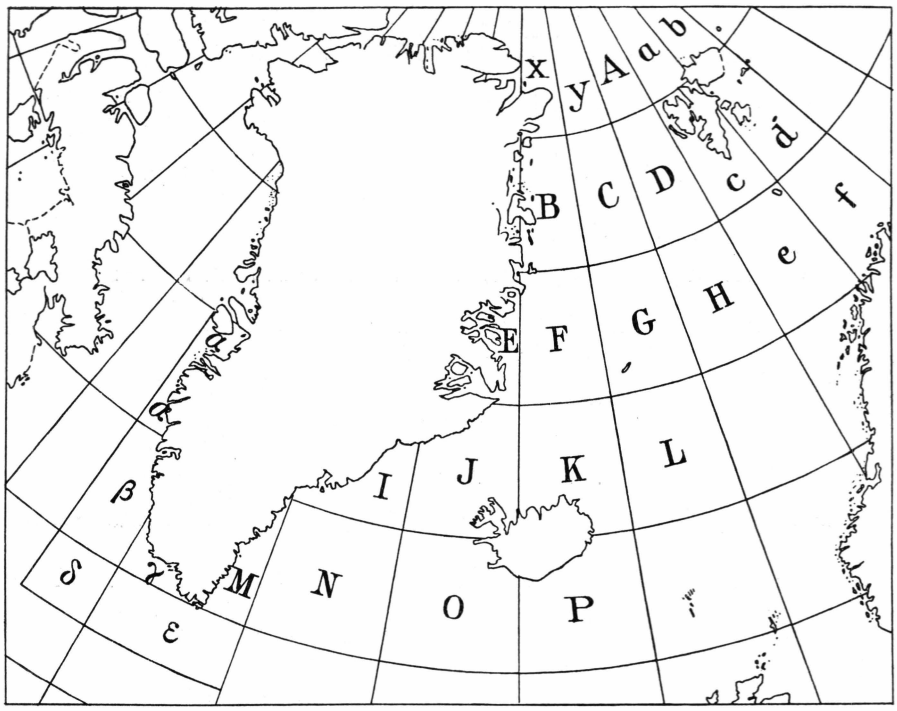


Fig. 43. Areas of drift ice (cf. the text).

The size in km² of each area has been computed by Mr. I. M. DANBO. The areas marked A, C, D, H, L, N, and D were calculated mathematically, as they contain no land areas. From the water area computed for F a small land area of East Greenland has been deducted, while the areas of Jan Mayen and Bear Island have been deducted from G and e respectively. The land areas were measured by means of a Conradi roll planometer. The constant of the apparatus (value of one vernier unit) was determined for each map separately with a view to the shrinking of the maps.

The land areas of B, E, I, J, K, M, α, β, δ, γ, ε, and a, b, c, d, e, and f were measured on the following maps: for Greenland: the most recent maps on a scale of 1:250,000 and 1:5,000,000, and for Iceland: map on a scale of 1:1,000,000, all issued by the Geodetic Institute of Copenhagen; for Spitsbergen: map on a scale of 1:2,000,000 issued by Norges Svalbard- og Ishavs-Undersøkelser; and for Norway: map on a scale of 1:2,500,000 published in Stieler's Atlas. The probable average error varies according to the scale of the maps from — 0.5 $^0/_{00}$ to 3.5 $^0/_{00}$, so the areal values calculated must be regarded as practically accurate.

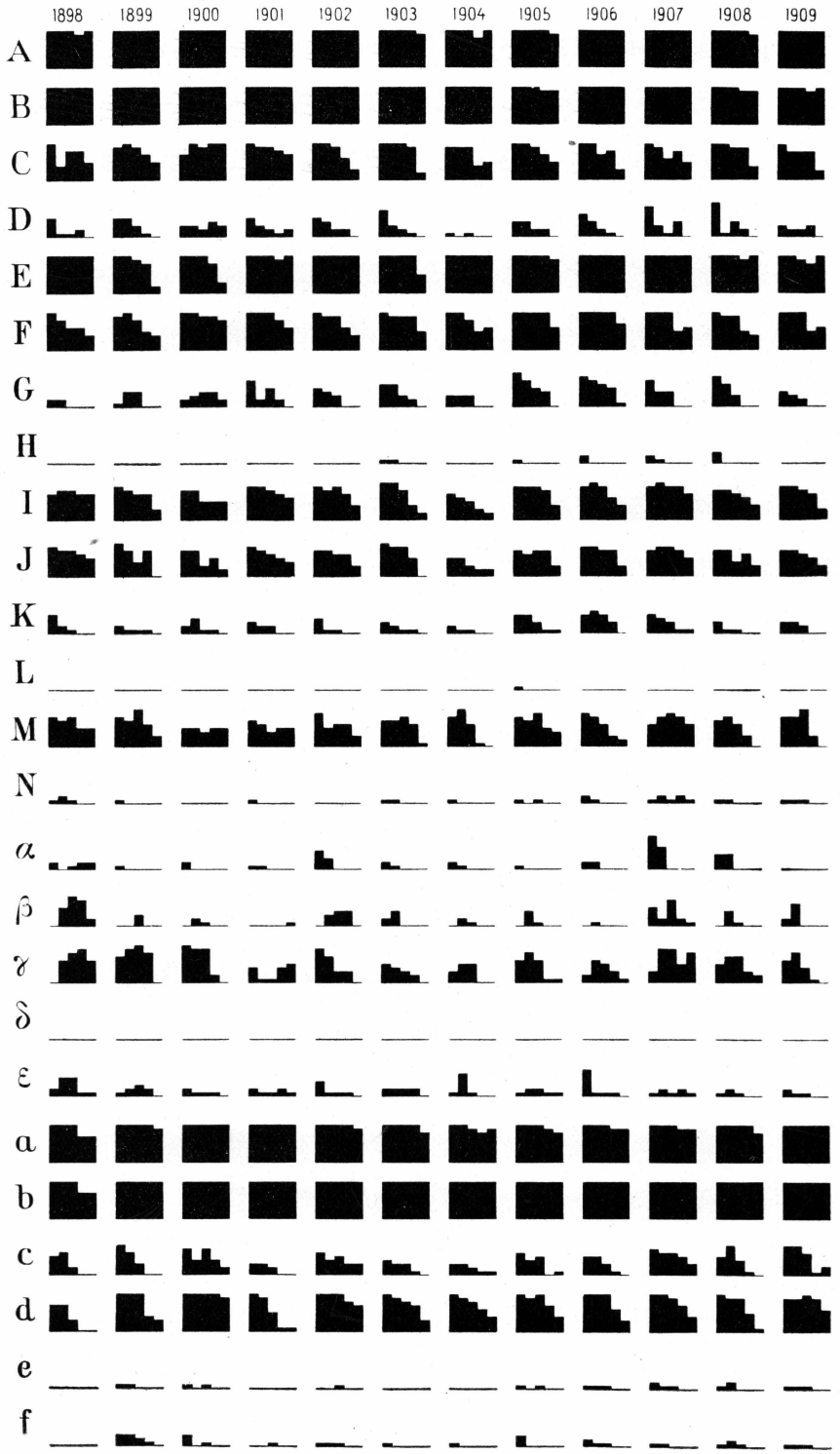


Fig. 44. Ice quantities April-August 1898—1909 in East Greenland waters (A—N) West Greenland waters (α—ε), and Spitsbergen waters (a—f). Cf. Fig. 43.

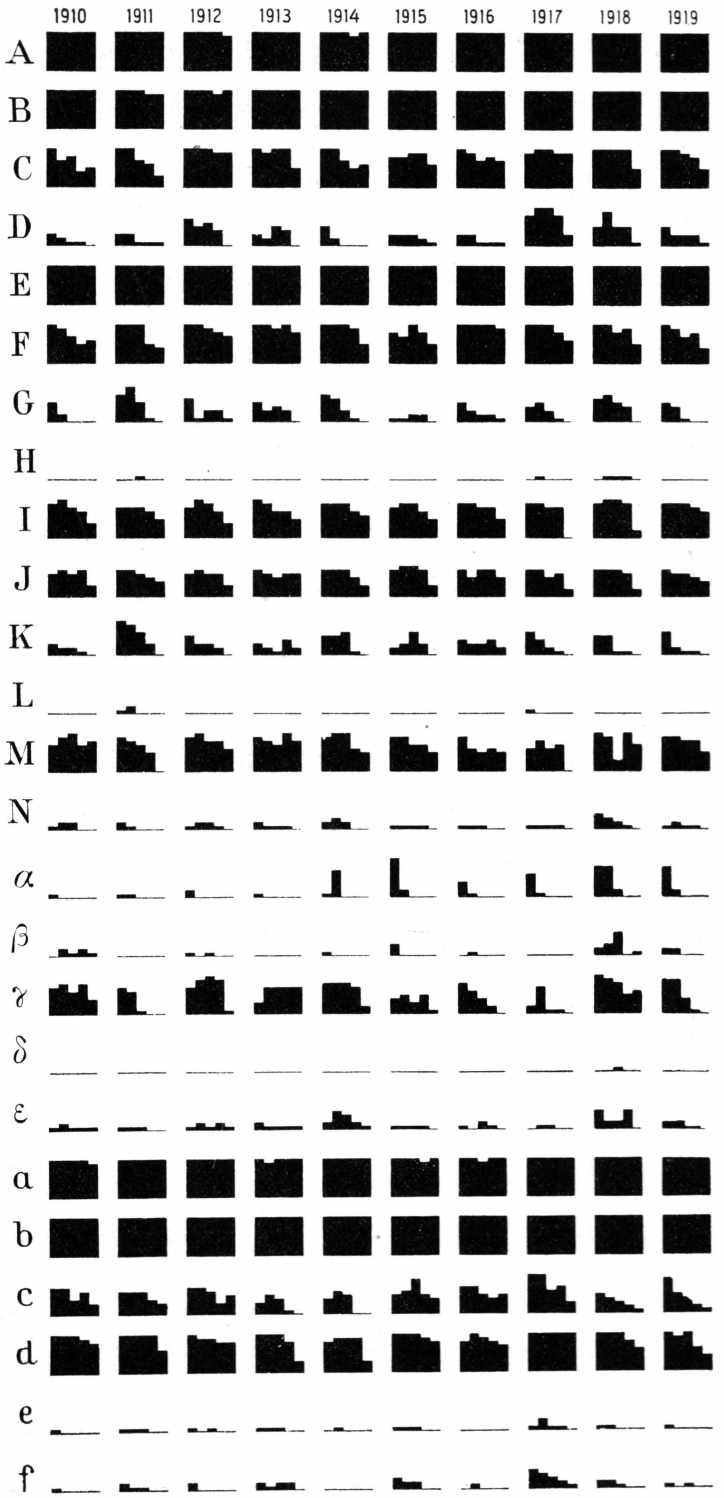


Fig. 45. Ice quantities April-August 1910—19. Cf. Fig. 44.

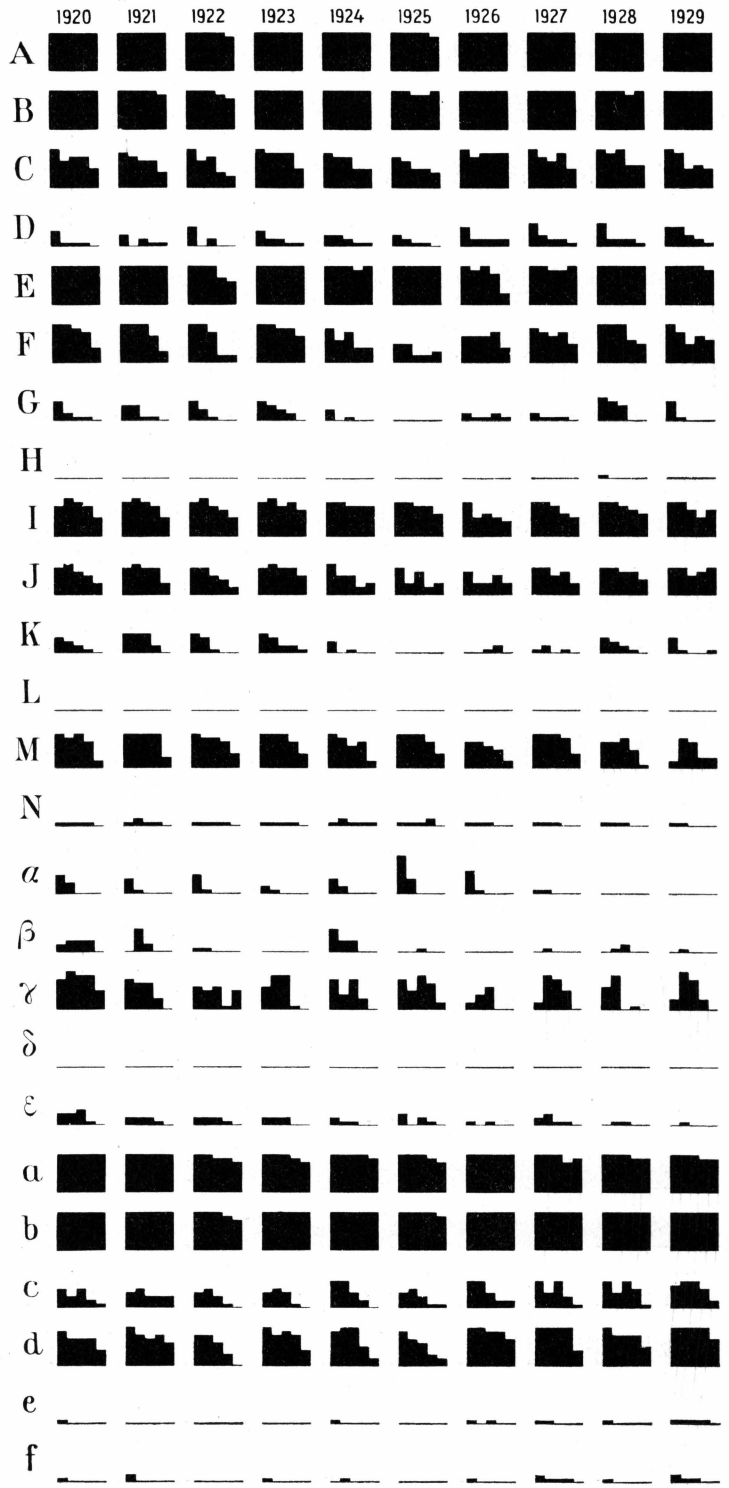


Fig. 46. Ice quantities April-August 1920—29. Cf. Fig. 44.

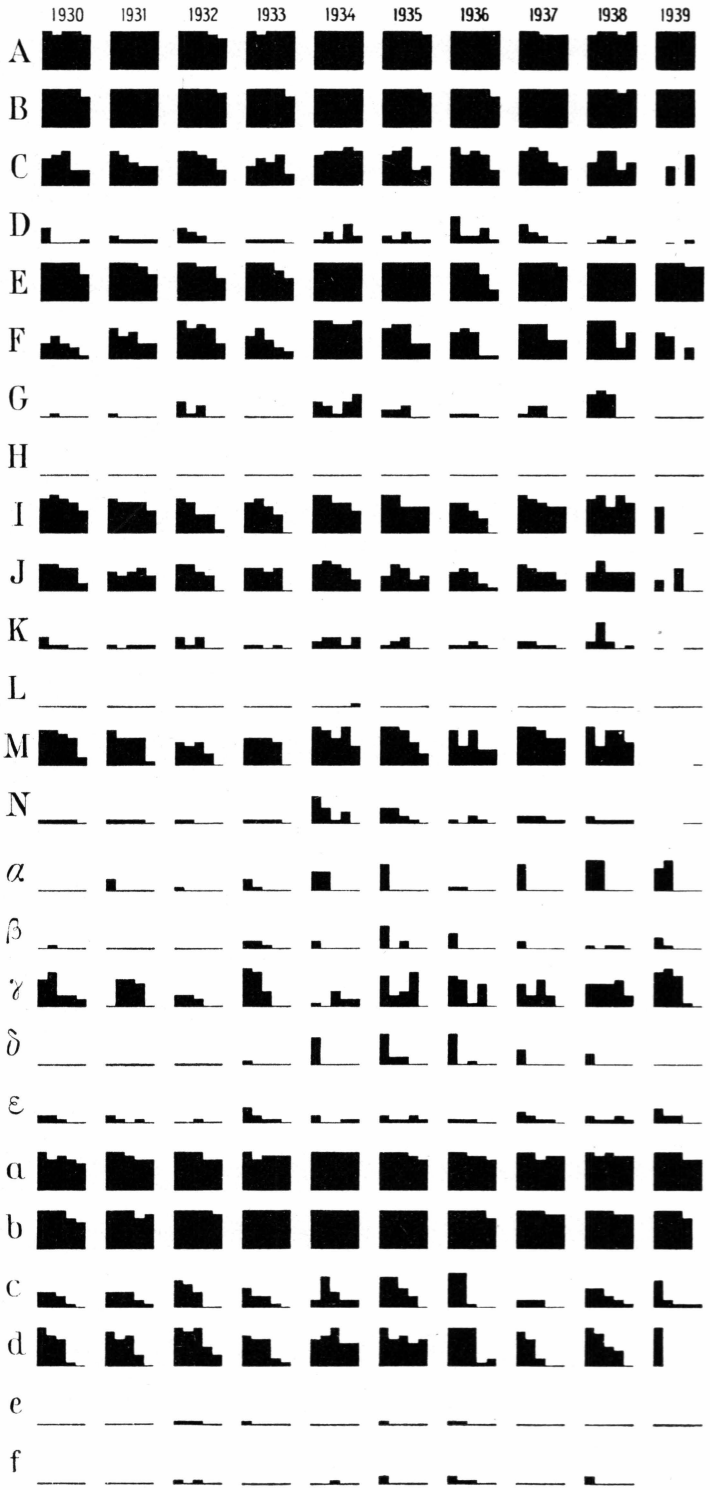


Fig. 47. Ice quantities April-August 1930—39. Cf. Fig. 44.

On the basis of this material the quantity of ice in km² for each area was calculated by Mr. I. M. DANBO for each of the five summer months of the years 1898—1938, and the values thus arrived at are represented in Figs. 48—49.

Before considering the individual curves in the graphs drawn on the basis of the calculated numerical values it will be necessary to make various reservations regarding the material of observations on which the graphic representation is based. In the first place it should be pointed out that the ice charts only show the ice conditions during the five summer months April-August since navigation in these waters can only take place in the summer; as a matter of course no material is at hand from the remaining seven months of the year.

Thus it is only quite exceptionally that large ice masses drifting down from the north have been ascertained, for this mostly takes place in the seven winter months. It is deplorable, also, that no observations are available for September, for observations reported from Angmagssalik and Scoresbysund show that in September there is normally less ice than in August. Thus the available material does not even comprise the whole melting period.

There is good reason, also, to point out various possible sources of error in connection with the ice charts, for instance:

1) The observations have been made by a large number of observers, whose estimates of the ice encountered near the ice edge or farther into the ice belt have no doubt often been highly individual. Thus the terms "heavy unbroken ice fields", "heavy packice", "thin ice floes", "scattered ice", etc. are applied differently according as the observer is an experienced ice navigator or for instance a man who is passing the ice belt for the first time.

2) The impressions of the ice gained from a small vessel and from a large ship differ greatly, since from the crow's nest of a large vessel one has a good view of a much larger area of the ice than from the small ship. And an even more different impression is received from an airplane at a height of some 1000—3000 m. At first one will generally take a fairly optimistic view in estimating the ice conditions from an airplane, but it will soon be realised that if a ship is to push through the ice, about 50 per cent of the area must be open water.

3) Sometimes the observer will indicate the ice edge where the ship meets the first ice; however, the first ice encountered may be a narrow belt of ice which has perhaps been removed a great distance from the actual ice edge.

4) It is nearly always difficult to determine the position of the ice edge, since fog, as a rule, occurs at the transition from the warm

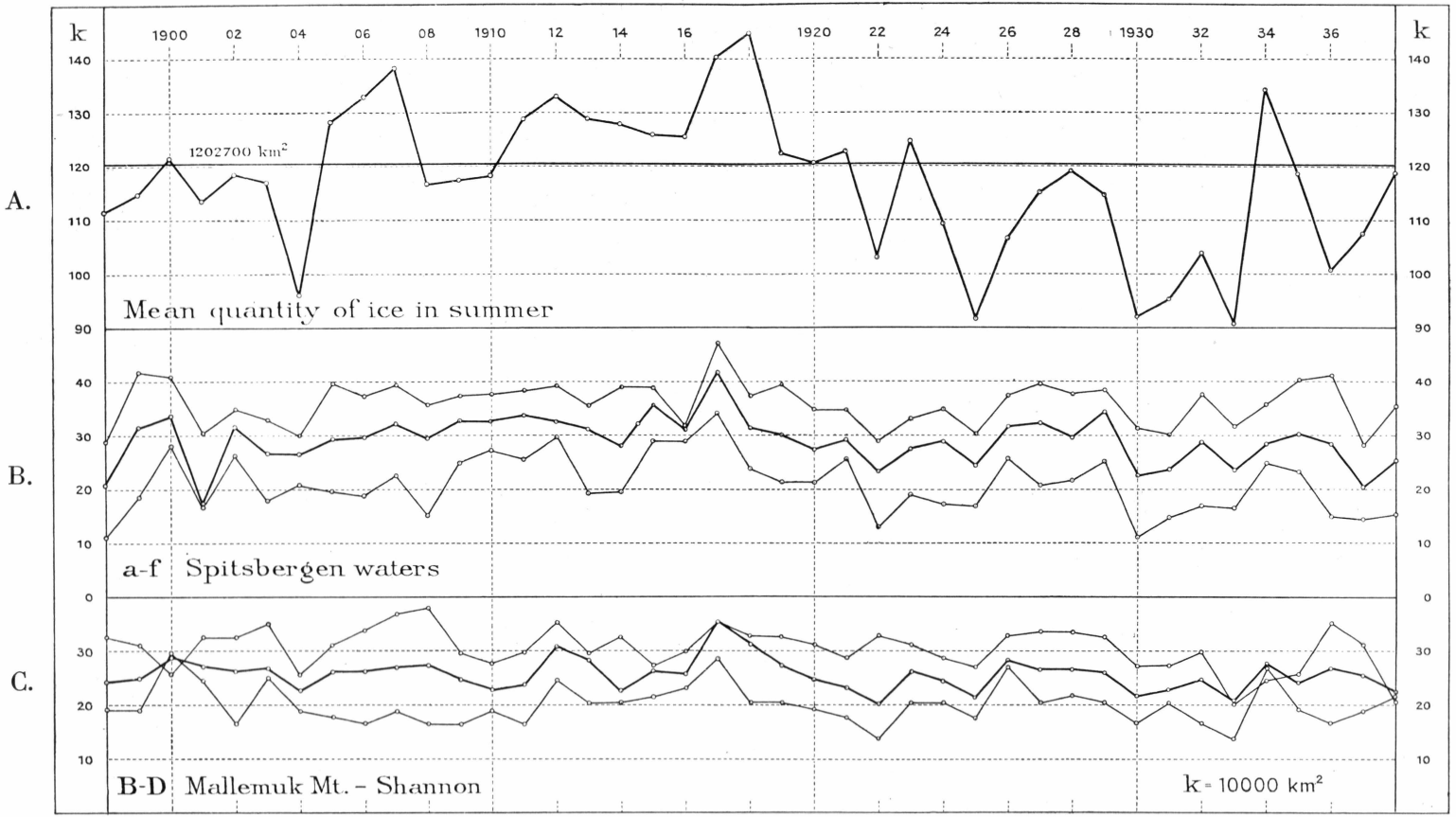


Fig. 48. Curve A shows the mean quantity of ice in summer in km² for each year in the E. Greenland, S. Greenland, and Spitsbergen waters. As to curves B and C, see Fig. 49.

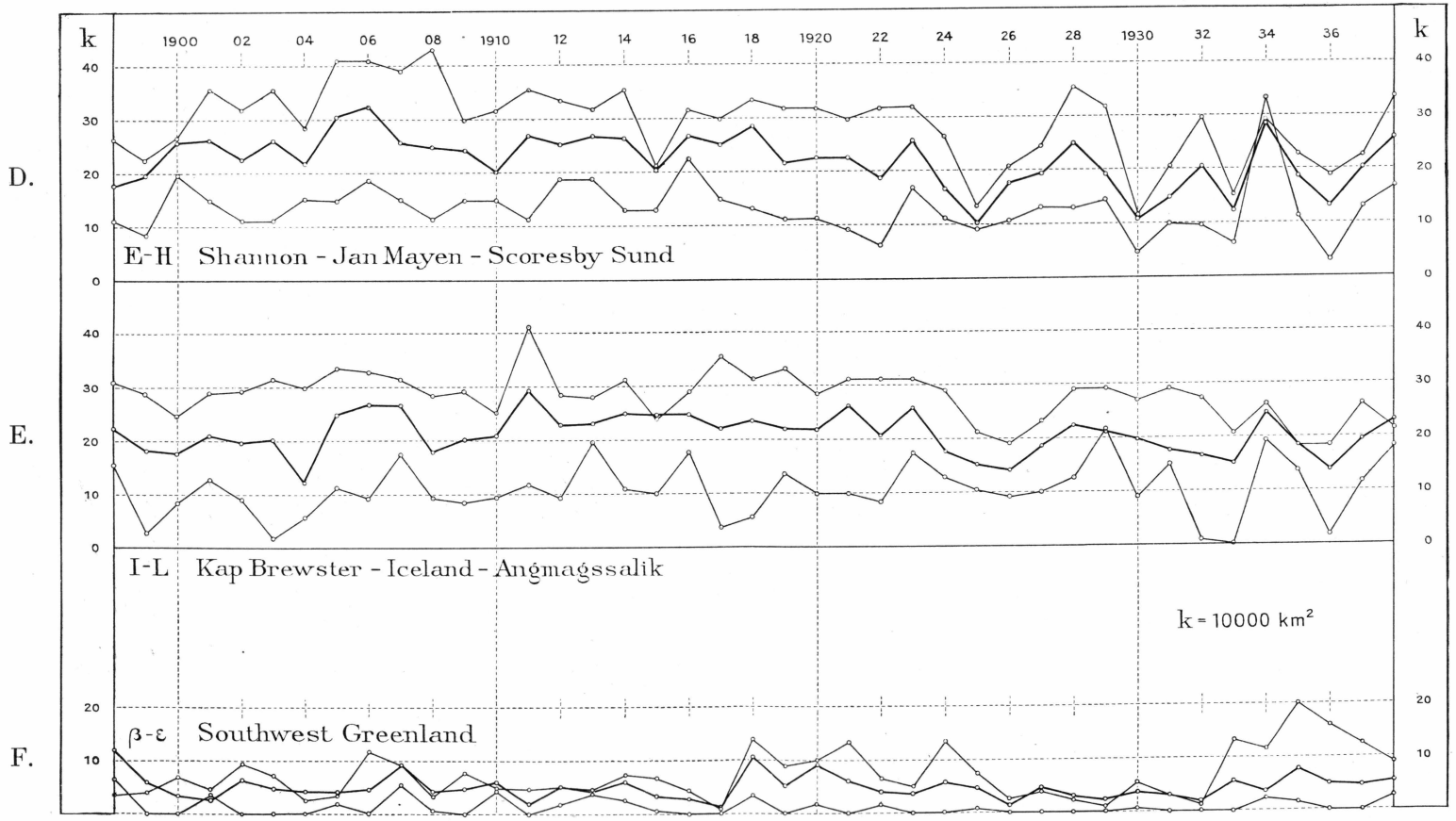


Fig. 49. Curves B—F show the quantities of ice (in km²) for each year in the individual areas. The upper curve indicates the ice quantity in April, the lower curve the ice quantity in August, and the middle curve the mean ice quantity of the period April—August.

waters of the Atlantic to the cold water along the ice, so it is very rarely possible to make astronomical place determinations near the ice edge.

5) Before the ships were provided with wireless not many years ago, the determinations of longitude were often very unreliable; the ships had frequently been at sea for a long time before reaching the ice edge, and the ships' clocks, especially in small vessels, were often very primitive. Thus the early whalers as a rule gave only the latitudes, not the longitudes.

6) Until quite recently navigation along East Greenland took place on the basis of an English Admiralty map on which the coast was indicated in the main from ancient expedition maps, which were not accurate. Moreover the map was on such a small scale that for this reason alone the bearings were very unreliable.

7) Errors may likewise arise if the Meteorological Institute has conjectured the position of the ice edge over long distances because no observations are available.

8) The Meteorological Institute has published an ice chart for each month. However, great alterations in the position of the ice edge may take place in the course of one month and owing to the scarcity of the observation material only the position of the ice edge either at the beginning or the end of the particular month may be known.

9) The available information about the land water along the east coast of Greenland is very insufficient.

10) There are no doubt often large stretches of open water both north and west of Spitsbergen (cf. SCORESBY 1820 and GRAY 1875), but after the cessation of the whaling industry in these tracts, observations have not generally been made here.

The areas x and y are not considered here, since no observations are available from these tracts. I wish to point out, however, that medio August 1933 the whole area of x, which is situated immediately south of Nordostrundingen, and large parts of the area of y were free of ice.

The areas O and P are not dealt with, because the ice masses that have occurred here in the present century are so inconsiderable that they have never represented one-tenth of the area. In earlier times, however, fairly considerable ice masses occurred in P and sometimes also in O. Ice was observed in great quantity in P for the last time in 1888.

The curves in Figs. 48—49 show the average quantity of ice in km^2 for the five summer months of every year within the five areas operated with, and the average ice quantity

of the whole area during the summer. Thus the last-mentioned curve gives the character of the individual years as ice years.

It appears from the curves that from 1898 an increase of the quantity of ice has taken place, culminating in 1917 and 1918, after which it decreased considerably till 1933, to increase suddenly in 1934, but subsequently it seems to have decreased again.

The average quantity of ice for all the years dealt with here within all the areas for the months April-August amounts to 1,202,700 km², whereas the average quantity of ice within the individual decades varies greatly. Actually it is impossible to give a normal ice edge.

To avoid operating with too high figures the term k = 10,000 km² is introduced in Fig. 48 and the following figures.

The Melting of the Ice South of Nordostrundingen—Amsterdam Island.

I will here describe the melting of the ice as I know it from sailings during a number of years in the waters along the east coast of Greenland between 70° and 75° N. lat. South of Angmagssalik (65° 36′ N. lat.) the melting of the ice no doubt begins at least one month earlier, and north of Danmarks Havn (76° 46′ N. lat.) about one month later. The melting may also differ greatly in the different years, as can be seen from the distribution of the land ice from year to year, the land ice being subject to the same conditions of melting as the innermost part of the ice stream.

Extraordinary conditions may exceptionally occur, thus in the autumn of 1936, when no drift ice was found south of Shannon as late as November 1st—the first ice that drifted down in November was no doubt subject to melting even at this late date—and the winter of 1938—39, when a rainfall occurred at Danmarks Havn at about the New Year.

1) Melting near the shore. As early as April the temperature of the air above the land may be heated to 0°, and this warm air is carried out across the ice by westerly winds, which, if not causing an actual melting, will give rise to an increased sublimation of the snow on the ice-floes.

Strong foehn winds may likewise give rise to positive temperatures, which are traceable some distance into the ice belt. In April, at any rate, the temperature is so high that even rather small spaces of open water among the floes will not freeze up. In May an increased heating of the land takes place, and this heat naturally has a greater effect on the ice than that of April.

In June the heating of the land continues, the thaw is in active progress in the interior of the fjords, which in connection with the heat from the surface of the land may provide conditions for the formation of water in favourable places. In July this development is further increased, and at the same time the surface of the ice is exposed to melting, the temperature above the drift ice being almost constantly positive during this month. About August 1st all the snow on the ice floes will have melted, and all the thin floes formed at the end of the winter or in early spring have disappeared.

During the month of August an intense surface melting is taking place both day and night and both in sunny and overcast weather, more especially in rainy weather. In the first days of September night frosts are of common occurrence, the surface melting ceases, and from the middle of the month the small floes between the larger ones begin to fuse. At the end of September the temperature will be negative in the day also, and the melting process that has been going on during the summer will accordingly cease.

The Norwegian ships which visited the central parts of East Greenland from 1926 and onwards as a rule fixed the date of August 25th for their departure from the coast, in order to be sure that they might escape through the ice belt before the minor floes began to fuse; for once they have become fused, they cannot be removed even by a ship with a fairly strong engine. The Danish ships generally fixed the date for their departure at September 1st, after which date the voyage out through the ice belt may cause great difficulties, especially if large quantities of ice are present.

2) Melting near the Gulf Stream. Along the stretch from Amsterdam Island (79° 45′ N. lat.) to some distance west of Kap Farvel the ice belt is, as a rule, subject to constant melting throughout the year by the action of the Gulf Stream. The Whaler's Bight west of Spitsbergen is nearly always free of ice. If large ice masses are present, the so-called North Bay will form in June between Spitsbergen and Jan Mayen, no doubt principally on account of melting.

In calm periods at the end of the winter and in the spring it may be so cold that ice (Atlantic Ice) may form outside the actual ice edge. This ice may cover vast areas; thus in May, 1917, it issued a large tongue north of Jan Mayen, and it may exceptionally be so thick that it may drift as far south as Iceland, as was the case in 1821 and 1824. However, generally it is so thin that it soon disappears. As a rule the ice stream between Spitsbergen and Iceland will be subject to melting in the winter, also, owing to the warm water of the Gulf Stream.

If the ice drifts as far as Iceland, all the ice that reaches the east and south coasts will melt near the shore. Along the north coast, also,

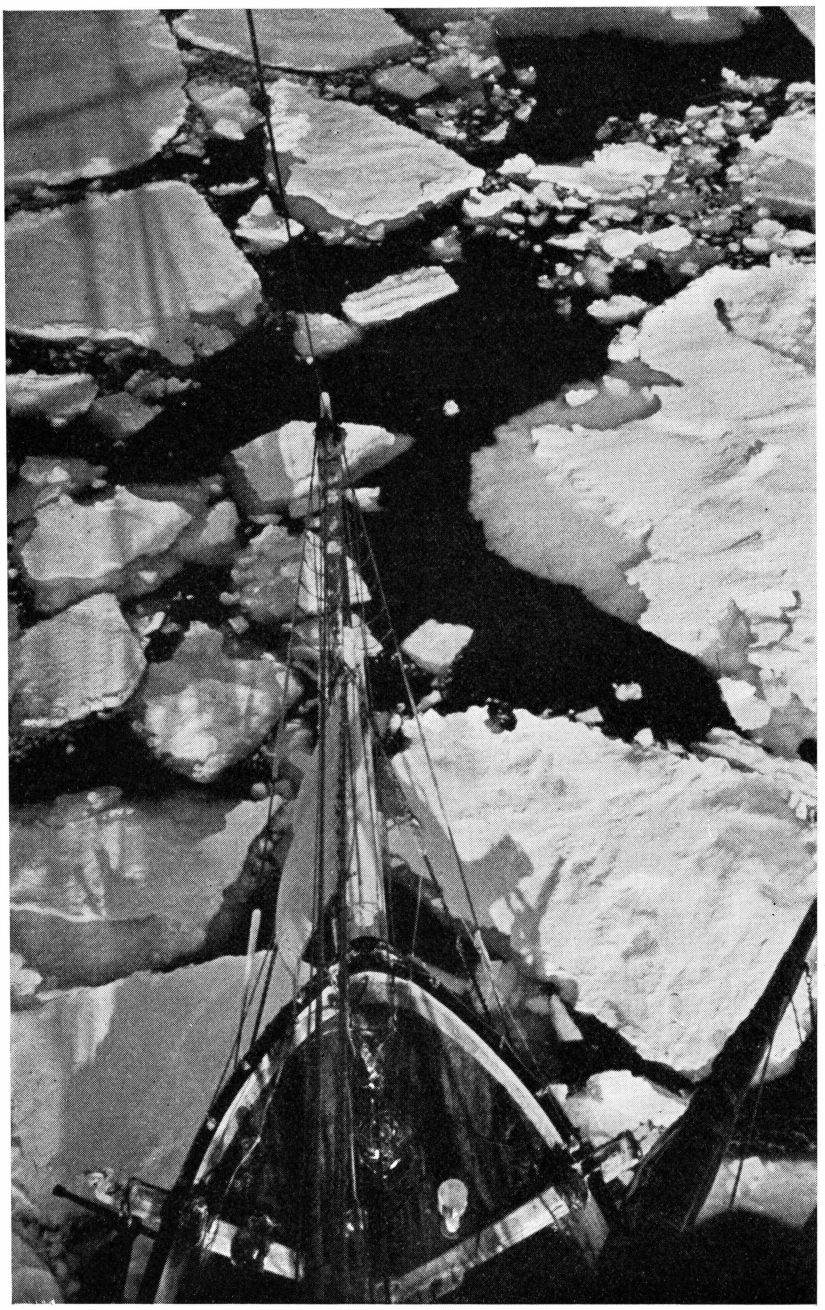


Fig. 50. Pack ice in summer. Open water between the floes.

extensive melting is going on, at any rate during the summer, on account of the heat from the land. If there is a strong north-flowing branch of the Irminger Current, it sometimes carries large ice masses to the east and south coasts, where they melt. The melting along the west-flowing warm Irminger Current always means a catastrophe to the ice stream. This melting takes place along a line from Cape North on Iceland across the sea to Angmagssalik, reducing the width of the ice stream south of this line. It has been mentioned above that the Atlantic Ice only very rarely reaches Iceland. Nor does the Spitsbergen Ice probably pass the line just mentioned, and it is a question whether the greater part of the Siberian Ice does not disappear here.

On reaching this line, the large ice fields occurring north of it will be broken to pieces by the waves, and only the small and thick floes will drift southward; the ice stream that passes Kap Farvel is not only narrow, but the pieces of ice, here called the "Storis" (not to be translated into "great ice" but rather into "thick ice"), are as a rule small but very thick. Actually it is the thickest fused pressure ridges representing the last remnants of the originally large floes of North Pole Ice which, in a somewhat melted and rounded state, may be met with in an almost intact condition as far south as c. 65° N. lat.

Thus the ice belt has entirely changed its character before reaching Kap Farvel. In the spring the "Storis" may be carried by wind and currents up the west coast of Greenland as far as Egedesminde, melting along the route owing to the heat from the shore, or it may be carried by the wind into Davis Strait, where the warm current will cause it to melt.

The Character of the Ice Belt.

Anybody who has sailed in the East Greenland Ice knows that it is never homogeneous over very wide stretches; it is no regularly flowing stream of uniform floes. One sometimes gets this impression on sailing in the Spitsbergen Ice. The North Pole Ice consists, as a rule, of very heavy floes, among which there occur thin, quite young floes, and during the voyage large spaces of open water may suddenly arise, apparently without any cause. This is the reason why some ships may succeed in passing the ice belt in a short time, while others are bound up among the ice floes for a long time, unable to move.

The heterogeneity of the ice belt is due to several causes. I shall mention some of them.

1) The currents are nearly always strongest in the outer part of the ice belt, decreasing towards the shore.

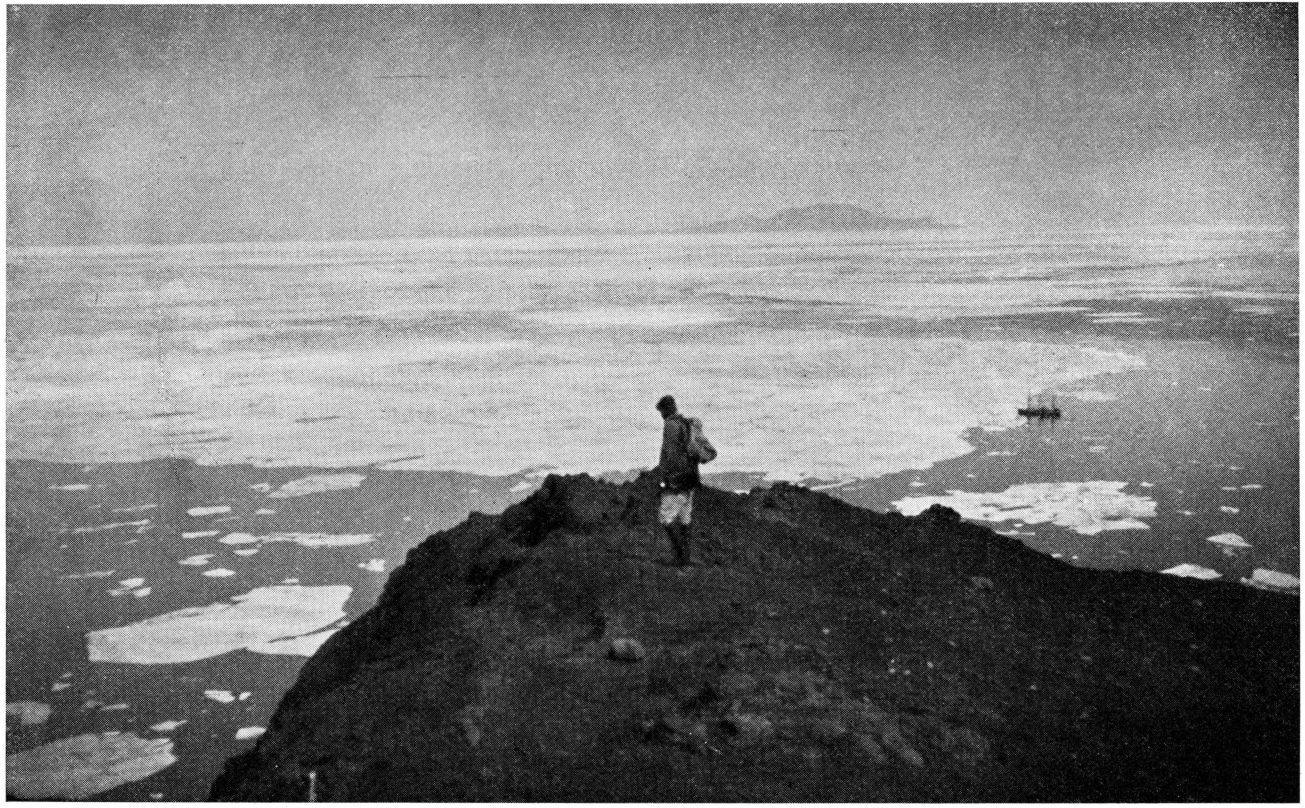


Fig. 51. Pack ice and land ice (in the background) seen from the top of Bontekoe Ø, looking westward, July 15, 1932.

2) The velocity of the currents is not the same everywhere. This appears distinctly from KIILERICH's map (1945). Thus it will be seen that the currents are particularly strong along the shoals in front of the shore, whereas they move much more slowly across the shoals. Accordingly the configuration of the sea bottom may be reflected in the velocity of the current, especially when the ice belt is not too close-packed.

3) The velocity of the current seems to be seasonally conditioned. Thus the currents seem to be weak in spring and autumn, culminating in August and September, at any rate near the shore. Very little is known about the force of the currents in winter in the ice belt, but it would seem that periods with stronger or weaker currents alternate.

4) The currents may vary from year to year and within longer or shorter periods of time, but very little is known about this point.

5) On various charts branches of the Polar Current flowing in an easterly direction are indicated in different latitudes; thus i. a. two branches of the Polar Current flow eastward, one north of and one south of Jan Mayen; according to log-books and other data it would seem that now one now the other branch is the strongest.

In 1826, when the coasts of Iceland were otherwise free of ice, a large drift of ice-floes including some icebergs suddenly appeared, moving from the east in between Vestmannaeyjar and the south coast of Iceland. This phenomenon, never observed either before or after, is no doubt due to the currents having carried large quantities of ice eastward into the Atlantic a fairly great distance north of Iceland.

Examples are likewise at hand showing that ships drifting with the ice have been carried in a southeasterly direction by the currents south of Jan Mayen (cf. E. MIKKELSEN, 1922, p. 210).

6) Local currents which bend in a northerly direction occur near the shore north of Hold with Hope. A number of such currents are known from the area north of Sabine Ø. They often give rise to the formation of open water at different points along the shore, even early in the year. A local current moving out of the mouth of Scoresby Sund in a north-easterly direction from Kap Brewster not rarely causes the drift of ice to stop off Liverpool Land, an ice-free bay forming in the ice belt almost off Kap Tobin.

7) The wind contributes perhaps to an even greater extent than the sea currents to make the ice belt heterogeneous. A number of computations of the average velocity of the Polar Current are available in the literature, and these computations are probably fairly correct; however, if one has experienced a gale in the ice belt, especially when there is much open water among the floes, and the floes and the ship

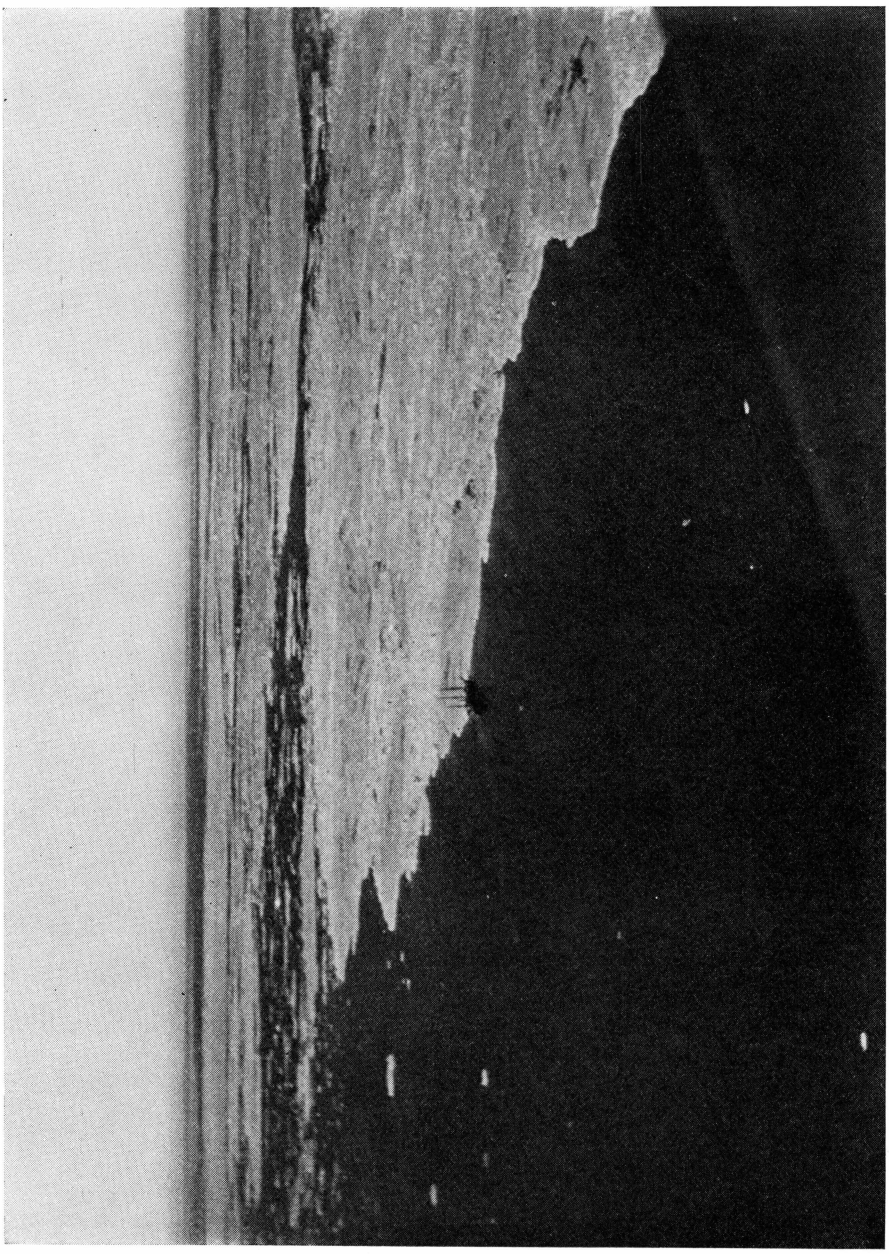


Fig. 52. Navigable pack ice seen from the air. The ice consists mostly of large floes separated by clearings and lanes.

are carried on by the wind at a rapid rate, one will be aware that the wind plays an important part in regard to the ice-drift. Near Nordostrundingen northwesterly winds, in particular, are of importance for the ice; here the wind may give rise to open water along the coast even in winter. Farther southward northerly winds dominate, and between Sabine Ø and Scoresby Sund easterly winds in addition to northerly ones play a considerable role, especially in the late summer. Between Iceland and Angmagssalik as also south of this area southerly winds are frequent.

It will be seen that the different directions of the wind within the different zones contribute greatly to pack the ice in different directions.

In the ice belt proper along the coast westerly winds rarely occur, though in the interior of the fjords they may blow locally with great force, especially in the form of foehn winds. I do not remember having experienced westerly or southerly winds of greater force than 3 in the ice belt north of 70° N. lat.

8) Calm weather will normally cause the ice to scatter, especially if intensive melting is going on.

9) It often happens that gales in the winter and spring form clearings with open water in the ice belt. These clearings freeze up, forming thin floes among the heavy ice floes. In 1931 about one-third of the ice belt off Hold with Hope consisted of such thin floes. They disappeared rather suddenly about August 1st, when the ice belt changed its character. If easterly winds set in at such a time, the ice belt may, of course, become much narrower. Thus it appears from the ice charts for 1921 that high easterly winds in the course of about one week in July reduced the ice belt to half its former width.

10) Fusion of the ice floes may likewise make the ice belt heterogeneous. This was especially pointed out by the Belgica Expedition in 1905; a compact ice edge was encountered not very far from Spitsbergen, along which the expedition ship sailed right on to the regions around Danmarks Havn, the ice being very scattered south of the ice edge. As mentioned above, EJNAR MIKKELSEN attaches great importance to this phenomenon, assuming that the ice near the Belgica Bank and north of it is nearly permanently fused, an assumption, however, which according to later investigations does not hold good.

In these northern regions there may, of course, occur such large and highly fused fields in the spring that they form an ice front for a short time, south of which the ice drifts southward at a greater rate than the large floes. This is actually the same phenomenon that may be observed when a gale is coming on in the ice: the small floes will drift along at a rapid rate, if there is any room for them to move in, whereas the large

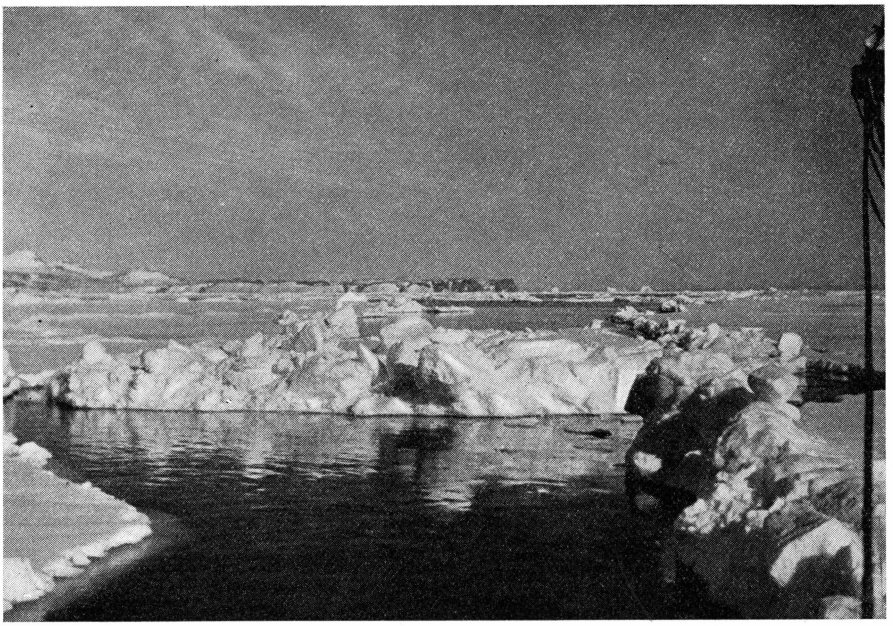


Fig. 53. Ice plug between two large floes.

floes will drift more slowly. Open water will therefore always form in the lee of the large floes.

The so-called ice front observed by the Belgica Expedition and assumed by EJNAR MIKKELSEN to be permanent north of Danmarks Havn, no doubt persists for a very short time only. A more permanent ice front, observed by me about the middle of August, 1933, extending in a northeasterly direction from Nordostrundingen, occurs so far northward that there are better conditions for its persistence in the late summer. I do not think, therefore, that the Meteorological Institute is right in assuming that in the late summer of 1936, similarly as in 1905, large ice masses occurred north of Shannon throughout the summer. Had they been there, larger or smaller pieces would have broken off and drifted southward along the coast, and this was not the case; no ice drifted down along the coast from the end of July to the beginning of November. Probably, therefore, the solid ice front occurred much farther northward in the summer of 1936 than assumed by the Meteorological Institute. Fusion of ice floes persisting during the summer is no doubt a phenomenon which is only found at about and north of 80° N. lat.

As explained above, there are many causes of the heterogeneity of the ice belt. It has been mentioned elsewhere in the present paper that in some years practically no North Pole Ice is found along the east

coast of Greenland in the month of July. In such years the Siberian Ice, if present in large quantities, may reach the shore almost off Shannon. Drift-wood may be carried some distance north of Danmarks Havn by north-flowing currents, but drift-wood rarely occurs there. Easterly winds may possibly also carry Siberian Ice towards the shore north of Danmarks Havn, but this probably takes place quite exceptionally.

As far as I have observed, the drift-wood found in Danmarks Fjord and in Independence Fjord is very old, and has probably arrived there at a time when the climate was different from the present climate.

However, the main cause of the heterogeneity of the ice belt is that the afflux of ice from the Polar Basin is not continuous, but takes place in the form of pulsations (cf. below).

Pulsations in the Polar Basin.

The material from which we may find out when the ice drifts from the Polar Basin into the East Greenland Sea is very sparse. The observations recorded from Scoresbysund and Angmagssalik seem to show that an ice-free period may occur here at the end of the summer. A large drift of ice entering one of the zones marked B—D, E—H, etc. on the map (Fig. 43) will be termed here a pulsation.

The winter observations from Scoresbysund and Angmagssalik show that this pulsation, assumed to begin in the north about September 1st, as a rule reaches Scoresby Sund in October and Angmagssalik at the end of November; the arrival of the ice may, however, vary within several months from year to year. Furthermore, the observations show that it is no continuous pulsation, for both in December (1926) and January (1927 and 1928) the water off Scoresby Sund may in periods be entirely free of ice. Sometimes only very small ice masses are present off Angmagssalik in December, and in January, 1930, there was no ice at all. The quantity of ice may vary considerably in the other winter months also.

It must be admitted that these two observation stations are situated so far south that the above-mentioned factors causing the heterogeneity of the ice belt have had ample opportunity of exerting their influence on the ice belt along the way from Nordostrundingen to Scoresby Sund and Angmagssalik respectively; however, it may probably be taken for granted that on passing Nordostrundingen in the winter the ice belt is heterogeneous, since gales in the Polar Basin will render the ice more or less close-packed.

It is impossible from the available data to form an idea of the effects of the winter pulsations when the ice leaves the Polar Basin.

For practical reasons the various pulsations of the winter months will be treated as one, the winter pulsation, and the result of this winter pulsation is the quantity of ice present in each of the aforementioned zones in April, and indicated on the ice chart of the Meteorological Institute for April.

In this month the melting of the ice begins, and in especially favourable ice years, thus in 1933 and 1936, practically all ice south of Nordostrundingen will melt during the summer. A regular melting without any pulsations during the five summer months was only ascertained in two years within the period treated here, viz. in 1902 and 1903. The melting curves show that in all the other years pulsations occurred at any rate in one of the zones, thus in anyone of the five summer months there will accordingly be more ice than in the previous month.

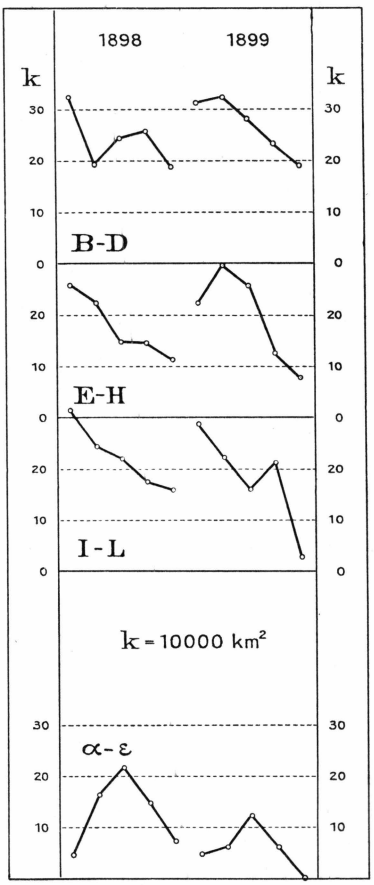


Fig. 54. Curves showing the variation in the quantity of ice in the individual areas in the five summer months (cf. Fig. 55). Cf. also the text.

The curves for the melting and for the quantities of ice present in April and August show clearly that the ice quantities found near Julianehaab and those present in the more northerly zones are not directly comparable. At the beginning of April large ice masses may accumulate in the zone I—L, and these ice masses will reach Julianehaab in the course of the summer.

Altogether it is very difficult to trace the movements of the ice from zone to zone, since local factors may cause it to drift in many different directions at highly different velocities. If, however, we are to examine whether pulsations issue from the Polar Basin during the five summer months also, we must choose the area B—D, which lies nearest the Polar Basin and which has, no doubt, the calmest weather during the summer.

During the whaling period this area was particularly well known, while the observations made here in recent years are rather sparse. However, an investigation may give an idea of the pulsations during the summer months.

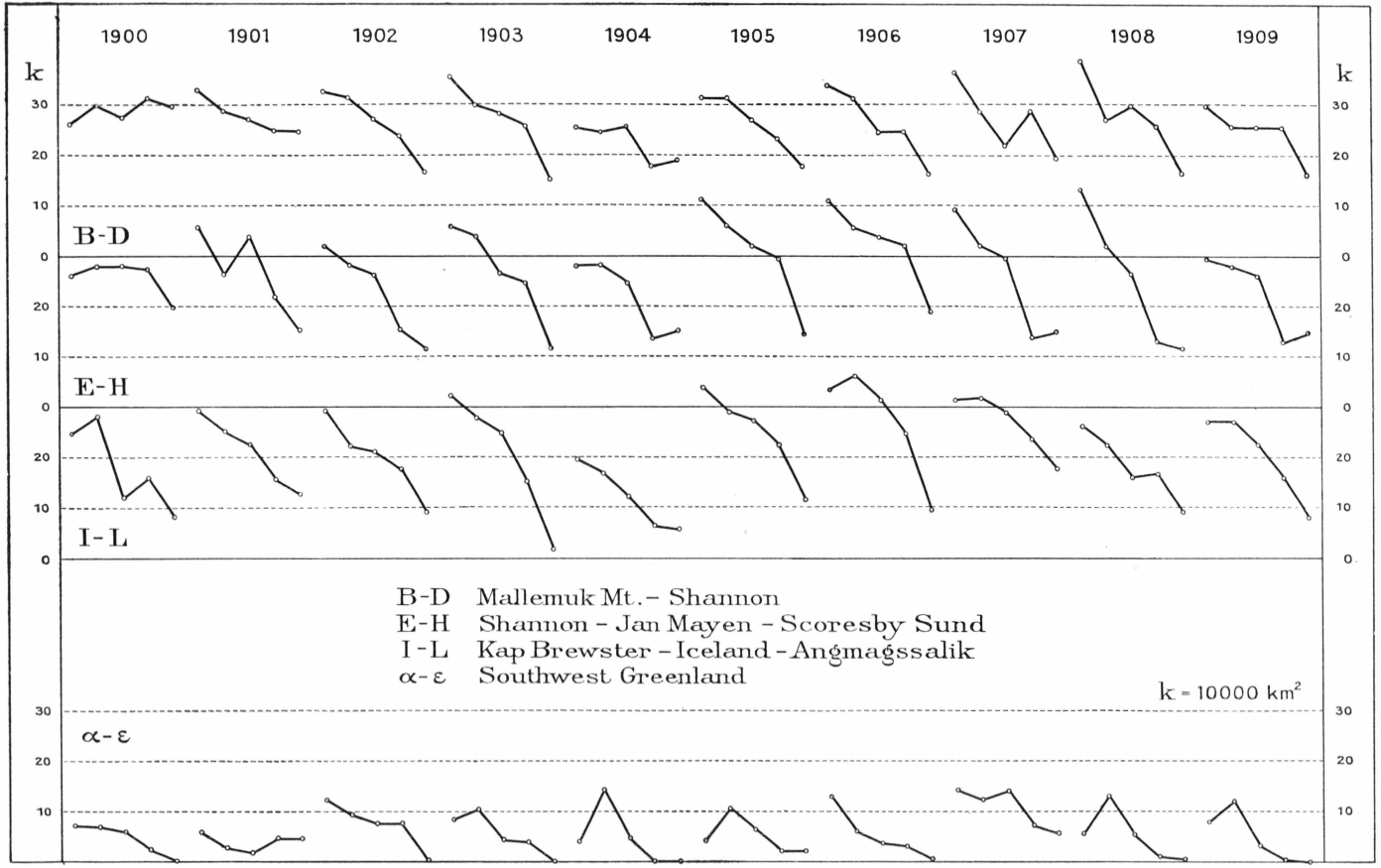


Fig. 55. For explanation, cf. Fig. 54 and the text.

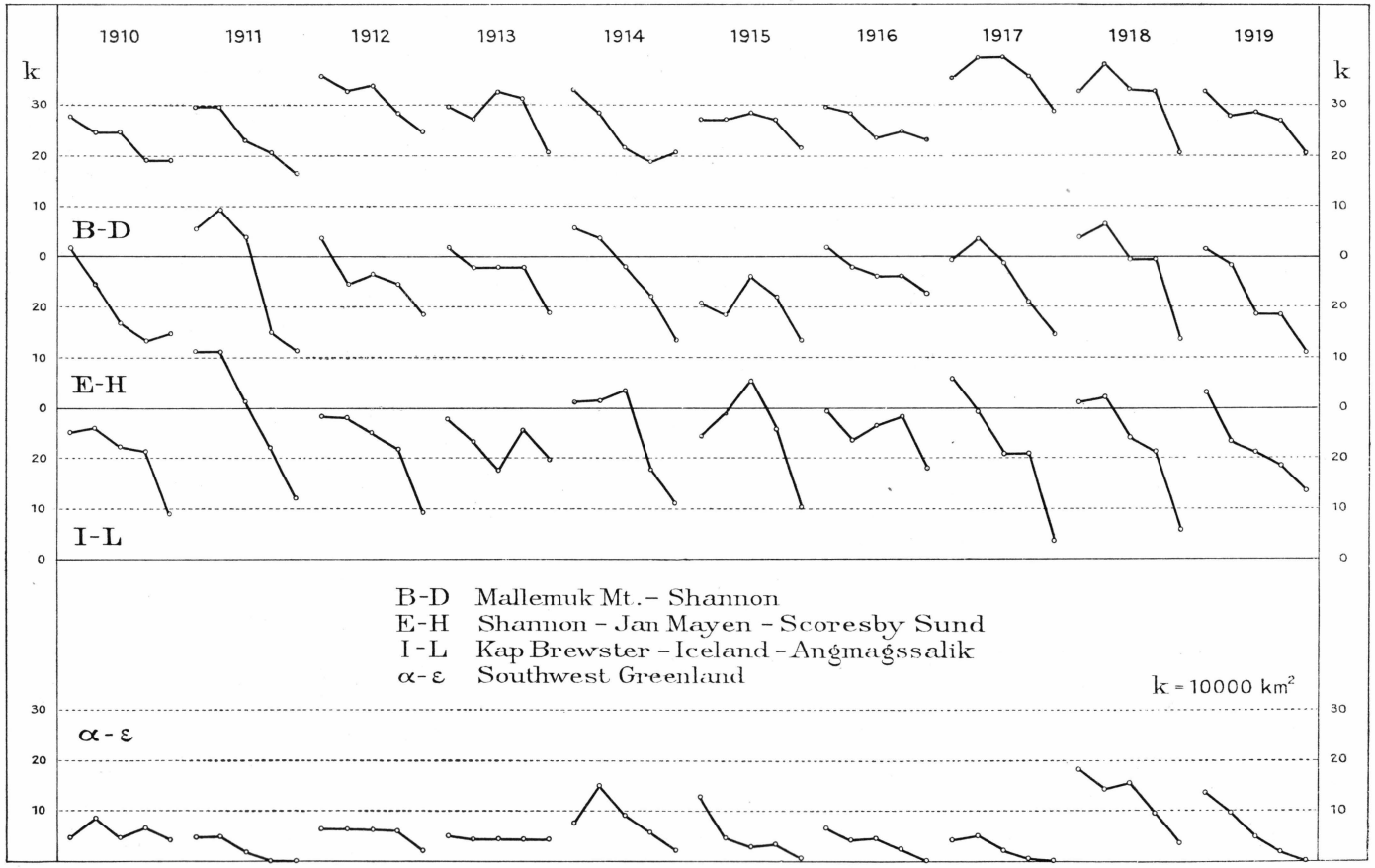


Fig. 56. For explanation cf. Fig. 54 and the text.

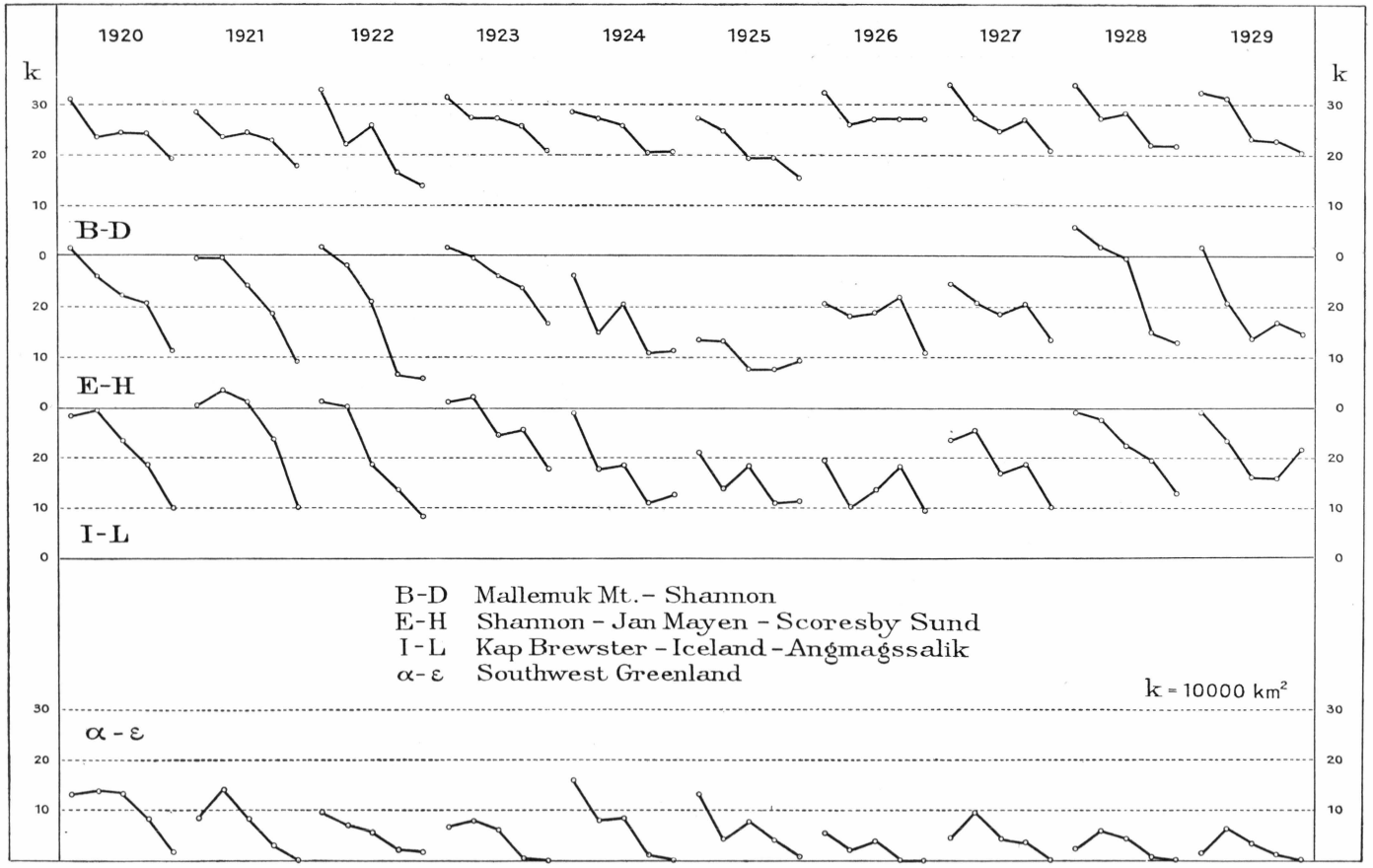


Fig. 57. For explanation cf. Fig. 54 and the text.

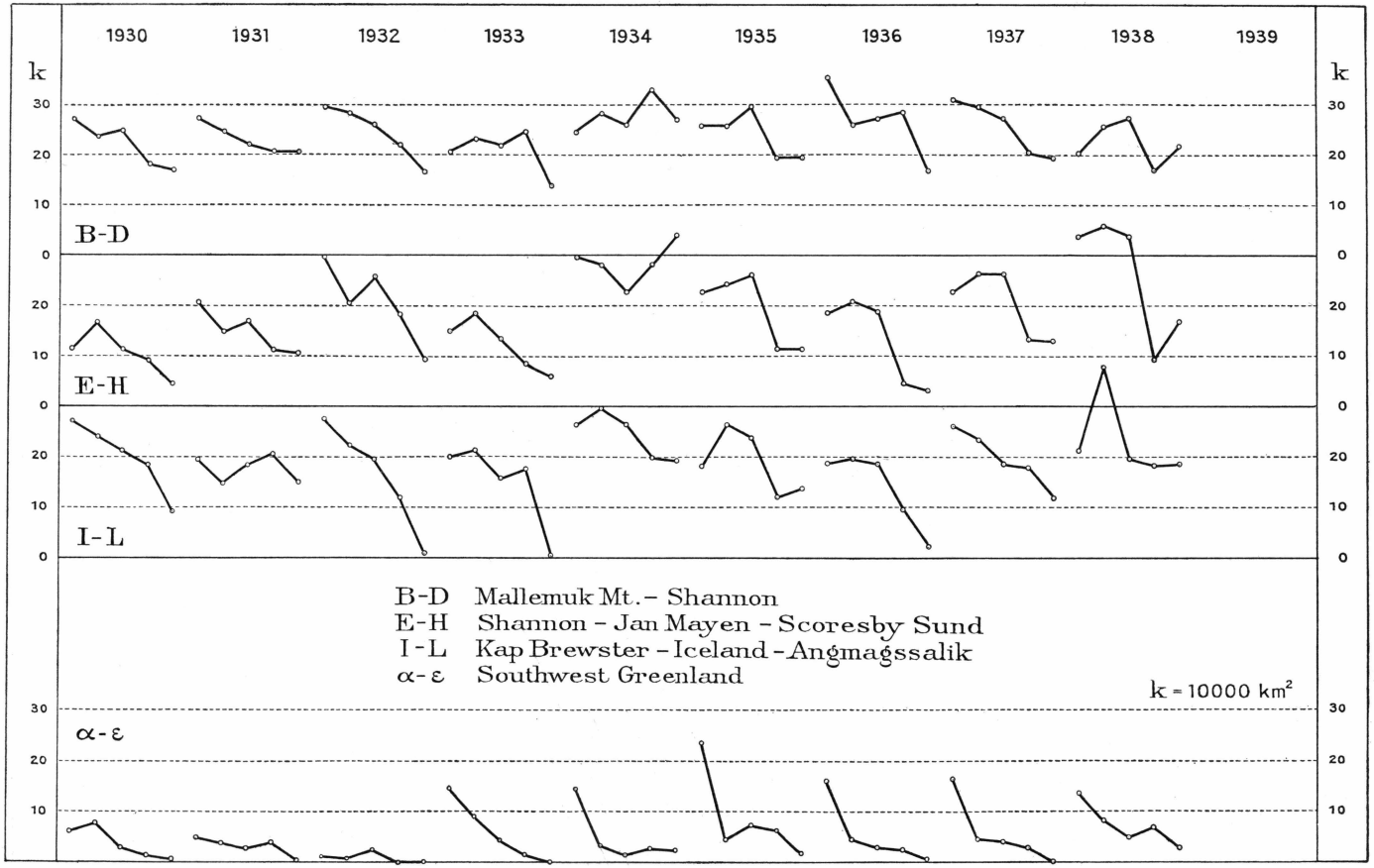


Fig. 58. For explanation cf. Fig. 54 and the text.

The investigation is made in the following way: the figure for the ice quantity of each month is deducted from the ice quantity of the preceding month, thus that for May is deducted from that of April, that of June from that of May, etc. If negative values are arrived at by this subtraction, it means that a greater quantity of ice has drifted down in the month dealt with. The figures are given in Figs. 54—61, from which it appears that in sixteen of the 41 years treated no pulsations took place in the areas B—D in the summer.

If the figure arrived at is 0, a minor pulsation has, of course, taken place, for melting is going on in this area also, but in view of the small number of data available, these small pulsations are not taken into account.

It will be seen that in April-May there have been seven pulsations in the areas B—D; in May-June thirteen, most of them, however, small; in June-July eight, possibly nine, but I am in great doubt as to the pulsation recorded from June-July, 1936; and in July-August four, all of them small except one (1938) (cf. Fig. 59).

The table shows that in the first years occasional great pulsations occurred at intervals of several years, but none of them exceeded 8.0 k. In 1934, however, there were two pulsations, one in April-May amounting to 4.3 k, the other in July-August of 6.8 k, totalling 11.1 k. In 1938 there were three pulsations, one in April-May of 5.3 k, one in May-June of 1.3 k, and one in July-August of 5.7 k, altogether 12.3 k, which is quite extraordinary and shows that the exceptionally strong outpour of ice from the Polar Basin known from the drift of the PAPANIN-group from the North Pole to near Scoresby Sund, from May 1937 to February 1938, was continued during practically the whole summer of 1938. Hence it is not to be wondered at that precisely that summer Angmagssalik exhibits the heaviest ice year within the period dealt with here; the ice belt off Angmagssalik can be said to have been in the winter stage during the whole summer and autumn of that year.

It will be seen from the table that the summer pulsations may be of great importance for the quantities of ice found along the east coast of Greenland during the summer, especially in extreme cases, as for instance in 1934 and 1938, both of which years exhibit exceptionally large ice masses in the summer. However, the winter pulsation plays a greater role. Thus it will be seen that in 1918, the year exhibiting the largest quantities of ice within the period in question, there was a great pulsation in April-May, but none after that time, the outpour of ice from the Polar Basin after this pulsation having evidently ceased in the main, and during the rest of the summer a considerable reduction of the ice quantities took place owing to intensive melting. Conversely, the lightest ice summer, 1933, shows a

pulsation of 3.0 k in April-May and one of 2.7 k in June-July (evidently it was this pulsation my expedition encountered between Bass Rock and Koldewey Ø in the first half of August). I am inclined to reduce the figure 2.7 somewhat; the pulsation was probably much smaller.

Altogether these figures, if not from extreme years, should be treated with some caution, as observations are sparse from these latitudes, and the ice may be retained or scattered by wind and currents.

It would be tempting to call attention to the two not quite inconsiderable pulsations in 1900, in April-May and June-July respectively, amounting to 8.0 k, the highest figure but three within the period, and to infer from this that the ice with which the AMDRUP Expedition drifted from Scoresby Sund to Angmagssalik might be due to the former of these pulsations. However, as stated above, great caution should be used in dealing with these questions. Actually the ice character of each summer should be estimated on the basis of 1) the quantity of ice found in each zone at the beginning of April (the result of the winter pulsation), 2) summer pulsations, if any, in the zone B—D, and 3) the quantity of ice found in the different zones on September 1st (for many years the result of the winter pulsation + the summer pulsations), and, of course, 4) the melting of the ice.

It is immediately obvious that for instance the quantity of ice found near Julianehaab in the summer is principally due to the ice quantity of the winter pulsation, whereas the ice quantity on September 1st in the zone B—D is chiefly due to the summer pulsations.

The number and intensity of the summer pulsations are possibly suggestive of a more or less intense cyclonic activity over the Polar Basin in the summer. It is remarkable, at any rate, that the two highest values for pulsations occur in the most recent years, when the cyclonic activity was strongest, and when the melting of the ice north of Siberia was exceptionally high.

The Velocity of the Ice Drift.

The velocity of the ice drift was treated by MEINARDUS in 1906 (pp. 234—239). He points out that it depends on the velocity of the Polar Current and on the temperature. However, we know very little of these two factors. MEINARDUS calls attention to a third factor, the gradient of the atmospheric pressure over the Polar Current at the different latitudes. On p. 236 he gives a table of this gradient, and points out that between Spitsbergen and Greenland, i. e. between 80° and 75° N. lat., it attains a maximum between February and March, while between 75° and 70° N. lat. the maximum occurs between March and April, and along the coasts of Iceland in April and May.

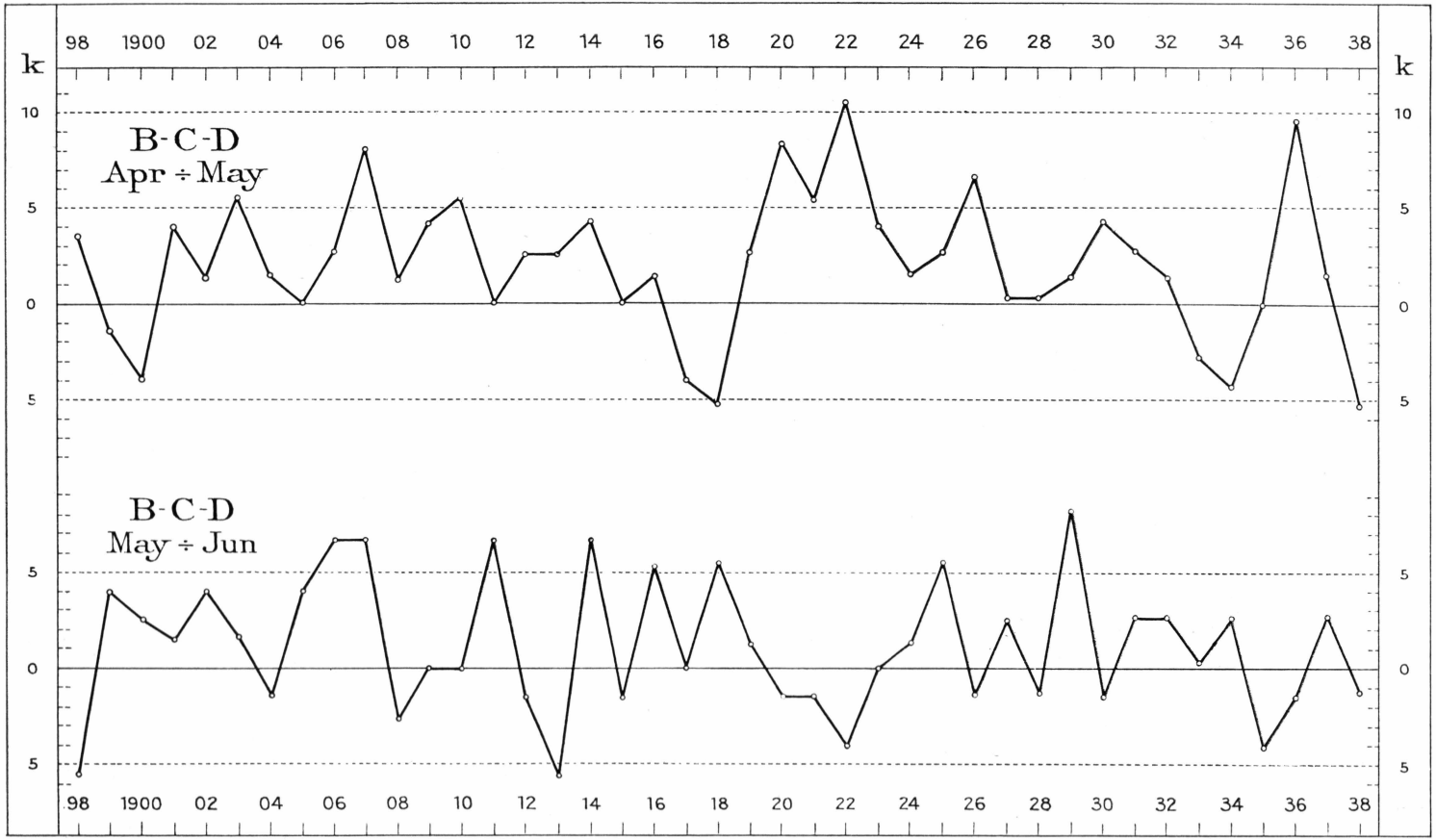


Fig. 59. Pulsations in the areas B—C—D in the various summer months (cf. the text). If the curve is above the 0-line, it indicates the amount of melting, if below, the pulsation.

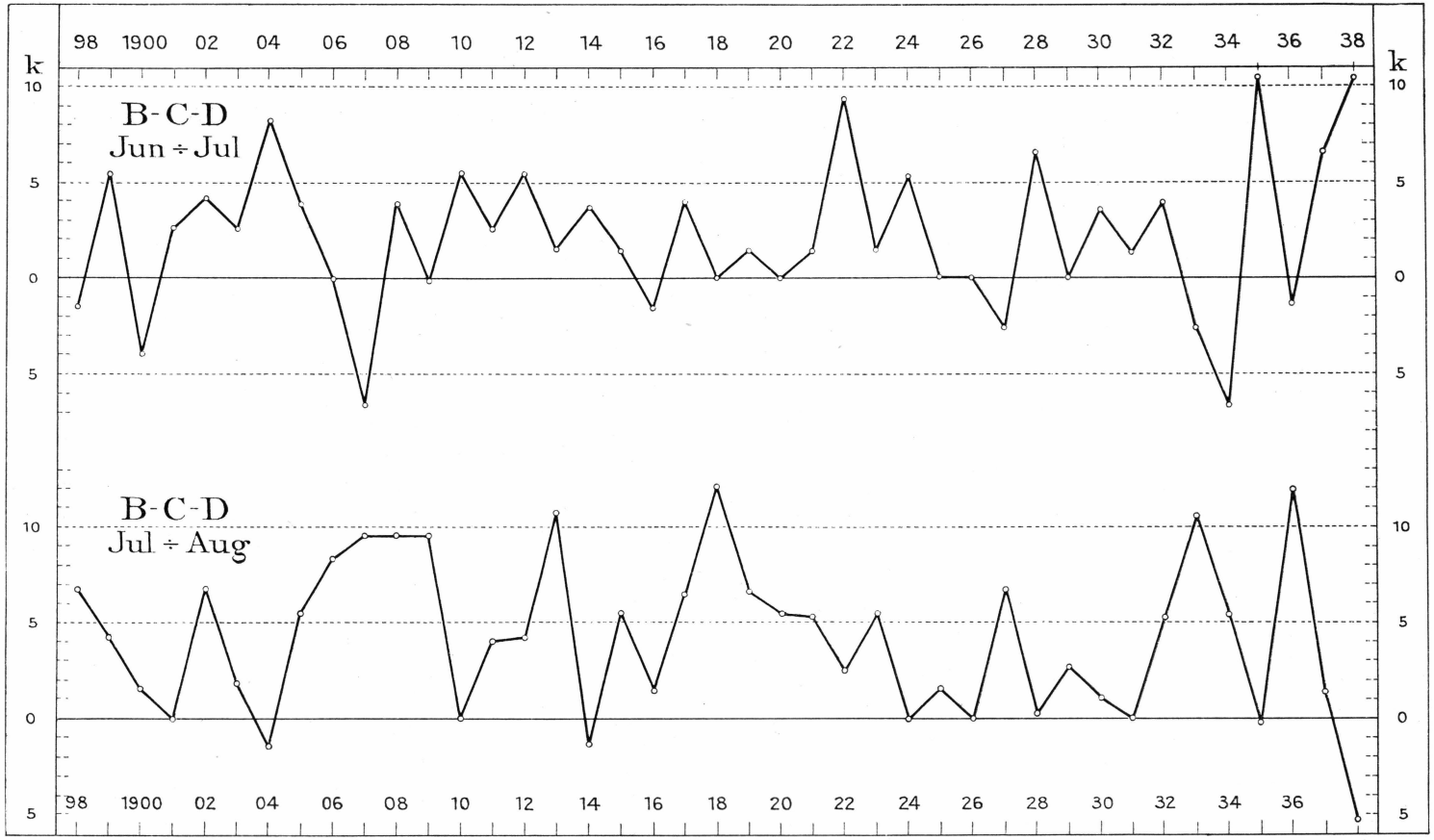


Fig. 60. Cf. the text to Fig. 59.

From this he computes a velocity of 5 miles in twenty-four hours between 80° and 75° N. lat., about 10 miles between 75° and 70°, and 6—7 miles near Iceland, and a mean velocity of 6—7 miles for the whole stretch from 80° N. lat. to Iceland.

He points out, however, that a number of authors record highly different velocities for the drift of the ice. Thus SCORESBY recorded velocities of 8.5, 12—13, 14, and even 20 miles in twenty-four hours between 80° and 73½° N. lat. In 1777 whaling ships drifted from 79° N. lat., 5° W. long. to 62° N. lat., 40° W. long. at an average rate of 12 miles. From October 1869 to May 1870 the "Hansa" drifted from 74° to 61° N. lat. at an average rate of 4.6 miles. The lower velocity is due to the "Hansa" being nearer the shore than the whaling ships

Other authors, for instance KOLDEWEY, MOHN, and ÅKERBLOM, record very different velocities (cf. MEINARDUS 1906).

In 1922 (pp. 203—211) EJNAR MIKKELSEN treated the velocity of the ice-drift. On p. 206 he gives a statistic survey of the dates on which the pack-ice front passes between Angmagssalik and Kap Farvel based on observations made during fifteen years, between 1884 and 1913, and arrives at an average velocity between these two points of 6.5 miles in twenty-four hours.

In addition he mentions ten ships which drifted down along the east coast of Greenland in the period 1769—1911. He divides these ten "drifts" into two categories, those in one category having taken place near the shore, the others in the ice belt or near its edge. For ships which have been beset in the ice near the shore the figures vary from 4.6 to 15 miles in twenty-four hours. Farther out to sea the drift is more rapid. He arrives at the conclusion that in the inner part of the ice belt near the shore the ice seems to move at a rate of c. 5 miles in twenty-four hours, in the outer part of the ice belt at c. 14 miles.

In 1931 SPEERSCHNEIDER dealt with the velocity of the ice drift, stating (p. 47) that in the period 1899—1929 the ice front in the autumn was on an average c. 2 months in passing from Angmagssalik to Kap Farvel, which means a velocity of 9 miles in twenty-four hours.

According to these figures there seems to be some disagreement as to the rate at which the ice belt moves. EJNAR MIKKELSEN, indeed, points out (l. c. p. 207) that the velocities are different in the northern and the southern part of the ice belt and in its outer and its inner part. Moreover—as appears from KIILERICH's map (1945) mentioned above—highly different currents are met with in the ice belt. Thus some currents move northward along the northeast coast of Greenland, which will cause the ice to stop on its way southward, at any rate for a short period. In the summer the wind may carry the inner part of the ice belt into the fjords and sounds, which may delay the ice drift for several

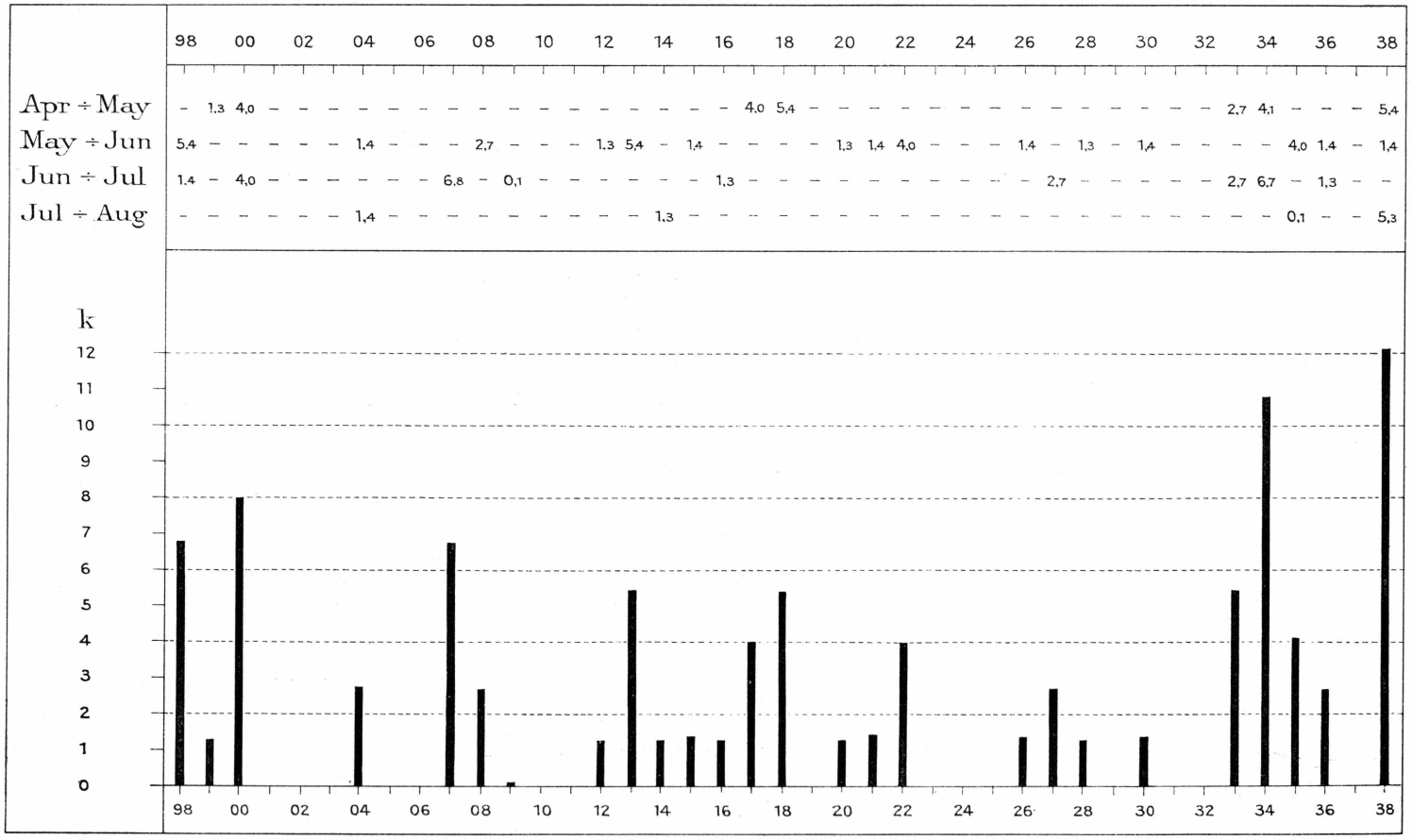


Fig. 61. Pulsations in the areas B—C—D, their distribution over the individual months and their extent in km² (k = 10,000 km²).

weeks. And finally MEINARDUS (1906), though he does not deal very much with it, points out the temperature as a factor of importance for the velocity.

Even in the far north strong winter gales may break up the ice, forming leads and clearings between the floes which freeze up again as soon as the gale ceases. This ice will naturally be the first to melt, and it disappears at the end of July, when a compact ice belt may suddenly be dissolved in the course of a few days into scattered old ice floes with much open water between. If at this time a gale sets in, for instance from the northeast, which happens fairly commonly off the central part of the east coast of Greenland, the wind will pack these floes together, and the ice belt thus formed will drift southward or westward at a rapid rate, making room for a more rapid drift of the compact ice masses north of it.

On the other hand, if the ice is very open, for instance off Nordostrundingen at the end of August and the beginning of September, ice may form between the floes during a calm period, and even if a gale breaks up this new-formed ice, the negative temperature of the air will prevent it from disappearing; it will be packed by the wind between the older floes, and as soon as the gale ceases, the open water will freeze up again.

The winter pulsations differ from the summer pulsations in that each time the ice is broken up by wind and currents in the winter, more ice will be formed, while in the summer the quantities of ice will be diminished owing to the action of wind and currents.

The observations available from Scoresbysund, made during a short number of years only, indicate that the ice takes one or one and a half months to pass from Scoresby Sund to Angmagssalik. Information about the drift of the ice is lacking from the coasts north of Scoresby Sund, but if we assume that the ice covers the distance from Nordostrundingen to Scoresby Sund in about two months, this agrees fairly well with the drift of the Russians from the North Pole to Scoresby Sund. Disregarding all the local factors, we arrive at the result that in general the ice takes between five and six months to drift the 3000 km from the line Nordostrundingen—Amsterdam Island to Kap Farvel.

From this it will be evident that the ice found west of Kap Farvel at the beginning of April, or the ice which passes this place in the course of the summer, is derived entirely from the winter pulsations; no example is recorded of ice originating from the summer pulsations in the area B—D reaching Kap Farvel till September 1st. Accordingly the curves for April—August for the area α—ε on the one hand and the areas B—D, E—H, I—L, or the Spitsbergen ice on the other hand

are not directly comparable. In other words: the ice found in the bay off Julianehaab in the summer results entirely from the pulsations of the previous winter.

Extreme Ice Years.

In the accompanying table the six lightest and the six heaviest ice years within the period 1898—1938 are indicated by figures. They were chosen from the annual curve on p. 126 (Fig. 48a).

The figures for the six lightest ice years will be seen to range between 90 and 100 k (the year 1936 is dealt with below).

It is a characteristic of these years that April does not exceed 125 k, and that August for three years shows 40—50 k. In 1925 and 1930, the years with the highest April-values, there was a small quantity of ice off Julianehaab in August, while in other years the water here may be free of ice. In other words, in the six lightest ice years the winter pulsation was inconsiderable. On April 1st only small ice masses occur south of Nordostrundingen, the ice belt being especially narrow between 70° and 80° N. lat. It will be seen from Fig. 61 that summer pulsations occurred in several of these six years; this seems to show that when small, these pulsations have only a slight effect on the quantity of ice during the summer.

Two of the severest ice years show more than 140 k, the other four more than 130 k. In all six years April has more than 150 k and August more than 70 k while all the favourable ice years had April-values below 125 k. August 1934 was entirely abnormal.

High April and May values are fairly common. However, while a particularly low April value as a rule indicates a favourable ice year, especially high April and May values need not indicate severe ice years.

The following years had more than 160 k in April: 1905, 1906, 1907, 1908, 1911, 1917, 1918, 1919, while the years 1906, 1907, 1908, 1911, 1914, 1917, 1918, and 1938 had more than 150 k in May. The record figures for the period are given in heavy type in the table. It will be seen that all the record figures of the period fall within the six most favourable years, while not all the record figures of severe ice years fall within the six heaviest ice years; if they fail to do so, this is especially indicated.

The six most favourable ice years.

1933. — It will be seen from the table that this year shows record figures for no less than six of the eleven columns. Not very many data are at hand as to the winter of 1932—33 in Greenland. The ice reached

	Aar	Apr.	Aug.	B—C—D		E—H		I—L		Julianehaab	
				Apr.	Aug.	Apr.	Aug.	Apr.	Aug.	Apr.	Aug.
1933.....	**90.6**	**117.1**	**44.1**	**20.4**	**13.8**	14.9	6.0	20.3	**0.0**	5.5	0
1925.....	91.6	120.5	64.9	27.1	17.7	13.0	9.4	21.0	10.8	4.3	0.6
1930.....	91.9	118.5	50.2	27.1	16.6	**11.2**	4.5	27.1	8.9	3.5	0.6
1931.....	95.5	118.0	68.3	27.1	20.4	20.5	10.0	19.3	14.8	2.6	0
1904.....	96.0	124.6	68.2	25.8	19.0	27.9	14.9	19.6	5.5	4.2	0
1936.....	100.7	145.9	46.8	35.2	16.6	18.6	**3.0**	**18.4**	1.9	4.9	0
1918.....	**144.6**	**178.3**	78.1	32.5	20.4	33.6	13.0	31.2	5.5	10.3	3.3
1917.....	140.2	166.0	89.3	35.2	**28.5**	29.8	14.9	35.6	3.8	1.4	0
1907.....	138.1	174.8	94.0	**35.6**	19.0	39.2	14.9	31.2	17.5	8.9	5.5
1934.....	134.6	154.5	**118.0**	24.4	27.1	29.8	**33.6**	25.9	19.4	3.5	2.3
1912.....	133.0	158.9	94.8	35.2	24.4	33.6	18.6	28.4	9.1	5.2	1.9
1906.....	132.7	177.4	72.2	33.9	16.3	41.1	18.6	33.0	9.1	4.6	0.3
						42.9	(1908)	**40.8** (1911)	**21.3**	(1929)	

Scoresby Sund from the north on October 5th, 1932, and passed Angmagssalik on November 21st and Kap Farvel on January 10th, that is to say, on fairly normal dates.

That fairly large quantities of ice drifted down in the course of the winter, is evident from the fact that more ice than is normal was found west of Kap Farvel in April, while in May-June the quantity of ice was almost normal. Near Spitsbergen there was less ice than normally, though it extended southward to Bear Island in April.

What specially characterises the ice chart for April is the very narrow belt of ice between Iceland and Spitsbergen. In April there was a small quantity of ice near Cape North on Iceland, but otherwise Iceland was entirely free from ice that year.

In May-June the temperature was low along the central part of the east coast of Greenland, for the land ice persisted extraordinarily long; thus, for instance, there was not open water in Davy Sund till the end of August. Only in 1939 within the period 1929—39 was there more ice than in 1933. On midsummer night my two expedition ships passed a scattered belt of heavy ice floes off Scoresby Sund. Observations from the air about July 1st showed that very little ice occurred south of Scoresby Sund; at this time a ship might reach the northern part of Blosseville Kyst without being hindered by ice. About the middle of July a broad belt of land water formed along the coast, which about the middle of August extended as far as Danmarks Havn. This belt of land water persisted throughout the summer, since practically no easterly winds occurred.

In the first half of August large masses of pack-ice were encountered between Sabine Ø and the south point of Koldewey Ø; it was pressed against Shannon, where it was difficult to penetrate. The graph on p. 149 shows that within the area B—D there was a summer pulsation in April-May and another in June-July; the latter is probably represented by the pack-ice occurring between Sabine Ø and Koldewey Ø at the beginning of August.

During that month there was no pack-ice along the coast between the southernmost point of Koldewey Ø and Nordostrundingen except a few large floes which had been fused with the front of the Nioghalvfjerds Gletscher. From the aircraft no ice was visible eastward even from great altitudes, but the circumstance that there was no swell around Norske Ø during the stay of the "Gustav Holm" there about the middle of August might suggest that a belt of Siberian Ice occurred far out to sea. The ship stopped at Norske Ø, but it might have sailed in open water along the coast to some distance north of Nordostrundingen, whence a solid edge of unbroken ice without clearings extended northeastward (according to an air observation near Nordostrundingen from an altitude of c. 1,000 m).

At the end of August the ice which lay between Shannon and Koldewey Ø at the beginning of the month had drifted as far as and south of Sabine Ø and seems to have been rapidly melting. At the end of August, as stated above, large masses of land ice drifted out of Davy Sund and no pack ice occurred south of Scoresby Sund.

Apart from inconsiderable quantities of very open ice south of Sabine Ø and possibly a small quantity of Siberian Ice west of Spitsbergen, no ice was found in the North Atlantic about September 1st as far as a line extending from a little north of Nordostrundingen to 82° N. lat., 0° W. long. and probably onwards to East Spitsbergen (cf. Fig. 138).

To sum up, the year 1933 was characterised by small quantities of ice about April 1st, two minor pulsations in the zone B—D in April-May and June-July respectively, which were of little importance, and extremely small quantities of ice in August; thus not only α—ε and I—L show nil for August, but E—H and especially B—D show almost nil.

1925. — This year resembles 1933 in many respects, but fewer data are at hand. On April 1st the quantity of ice occurring west of Kap Farvel was fairly normal, in May there was a little ice here, in June somewhat more, in July the quantity of ice was normal, and some ice was present as late as August.

Comparatively small quantities of ice were found near Spitsbergen, in August there was open water around almost the whole of Spitsbergen.



Fig. 62. Ice charts for the six most favourable ice years since 1898 copied from the year-books of the Danish Meteorological Institute.

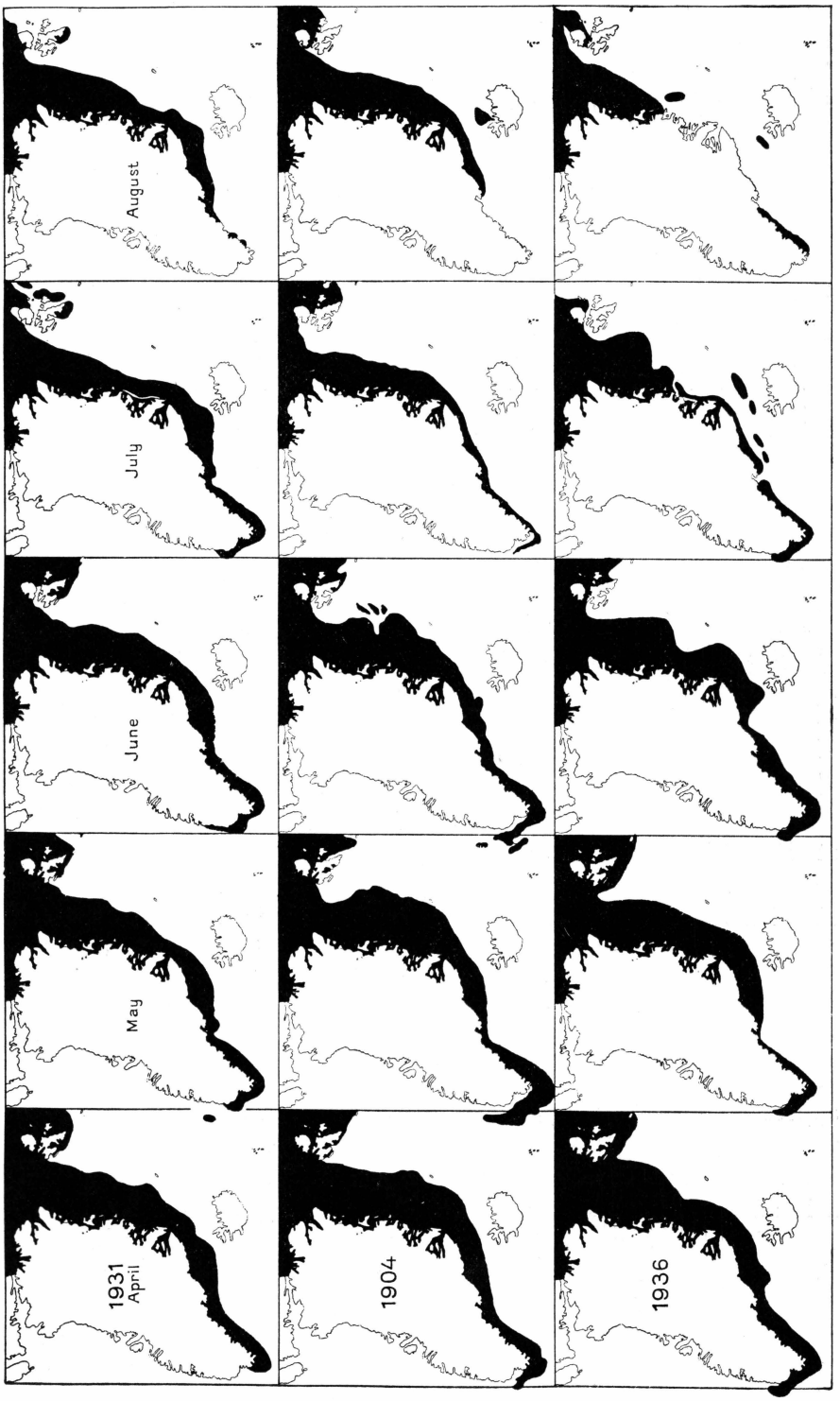


Fig. 63. Cf. the text to Fig. 62.

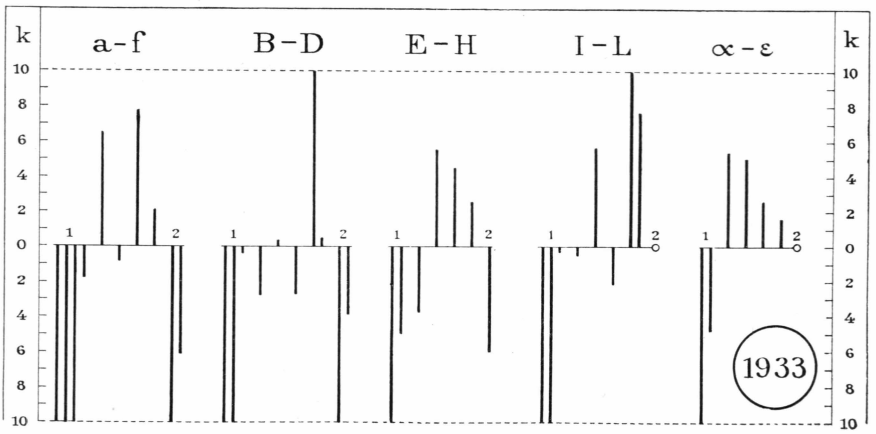


Fig. 64. Diagram showing the quantities of ice (in km²) (k = 10,000 km²) in the Spitsbergen waters (a—f), the E. Greenland waters (B—D, E—H, I—L, cf. Fig. 43), and the W. Greenland waters (α—ε). 1 indicates the ice quantity in April, 2 in August, the four intermediate lines, if above the transverse line, show the amount of melting (May less April, June less May, etc.), if below the transverse line, they show the amount of the pulsations. Cf. the text.

No information is at hand about the land ice. From the beginning of April the ice belt between Iceland and Spitsbergen was very narrow. No pulsations can be demonstrated. Unfortunately no data are at hand for the area north of Scoresby Sund for August.

It would have been interesting to know the conditions near Nordostrundingen this year. We may assume that very little ice occurred in the Atlantic south of a line Nordostrundingen-Amsterdam Island at the beginning of September.

1930. — In April and May a good deal of ice occurred west of Kap Farvel, but only small quantities were found there in June-July-August. Along the northern part of Spitsbergen there was very little ice in May, in July it was possible for a ship to pass round this group of islands, and in August the islands were entirely free from ice, a phenomenon not observed since 1899. Curiously enough a good deal of ice occurred between Spitsbergen and Iceland in March, but it disappeared completely, especially north of 70° N. lat., where the ice belt was very narrow.

In the first days of July the "Godthaab" sailed through the ice belt off Sabine Ø; if hydrographic observations had not to be made from the ship, it would no doubt have been possible to push through the ice belt in twenty-four hours, for it consisted of rather small scattered floes, all of Siberian Ice.

Along the east coast of Greenland fairly large quantities of land ice occurred, which persisted till late in the summer. Thus the ice was

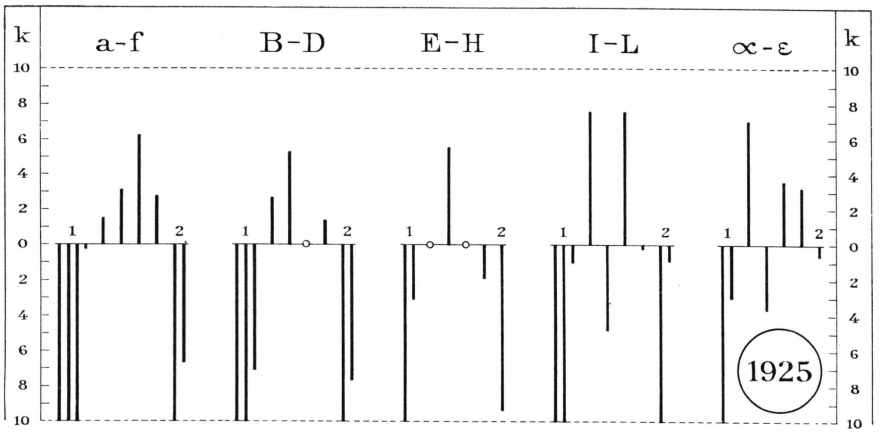


Fig. 65. Cf. the text to Fig. 64.

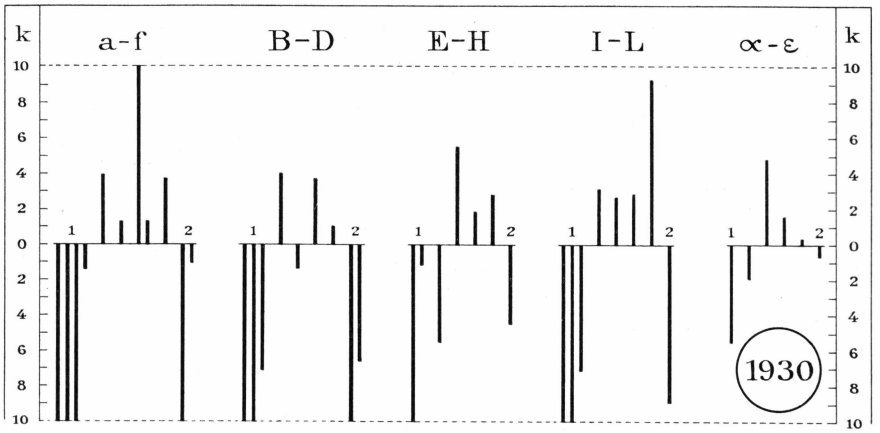


Fig. 66. Cf. the text to Fig. 64.

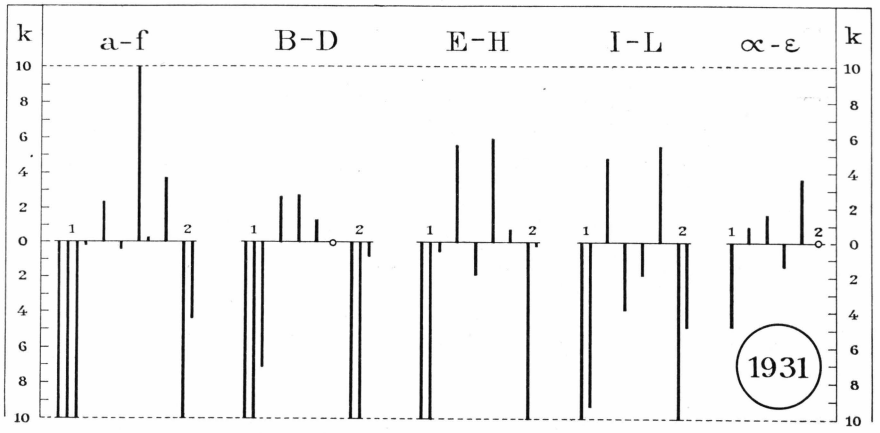


Fig. 67. Cf. the text to Fig. 64.

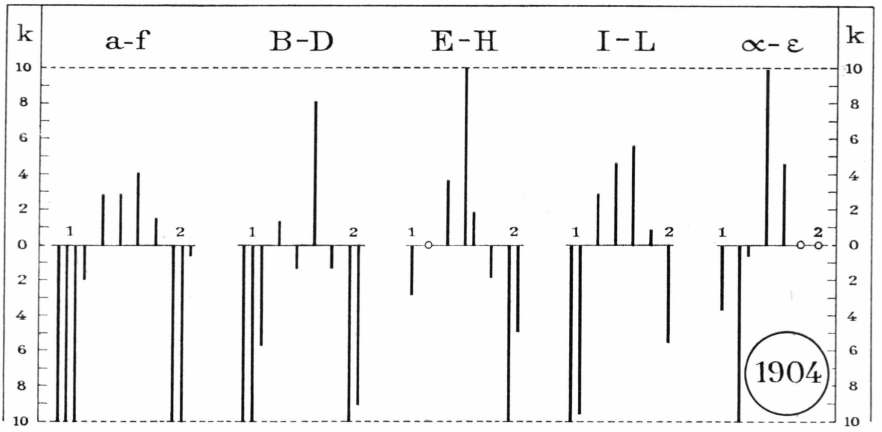


Fig. 68. Cf. the text to Fig. 64.

unbroken in Davy Sund about the middle of August, its edge extending from Murray Ø, some distance outside Kap Parry northward to Brochs Øer. In August practically no ice occurred south of Shannon. The ice chart issued by the Meteorological Institute shows some ice between Shannon and Scoresby Sund as well as south of this fjord; actually the ice was disappearing (cf. p. 22); it was so scattered that is was possible to sail in it for hours in all directions without being troubled by the ice.

In the latter half of August a northerly gale lasting for several days set in. This gale apparently carried some ice (probably land ice) southward to near Scoresby Sund, but as a whole hardly any ice occurred south of Shannon about September 1st.

1931. — Comparatively few data are at hand from the winter of 1930—31. The first ice passed Scoresby Sund on October 12th, it reached Angmagssalik on December 15th, and passed Kap Farvel on January 22nd.

There was not very much ice west of Kap Farvel in April, but in July the ice had about its normal extent.

The winter was mild around Spitsbergen. In June there was much open water along the north coast of these islands, in July they were almost free of ice, in August some ice occurred along the north coast of the northeastern part of the group, but as in July all the straits were free from ice.

Land ice is not recorded from this year. Conditions would seem to have been normal. A belt of land-water formed in July, it increased gradually and in August attained a considerable breadth; at the same time the ice outside it between Clavering Ø and Scoresby Sund was very scattered. Very little ice occurred outside Davy Sund on September 1st.

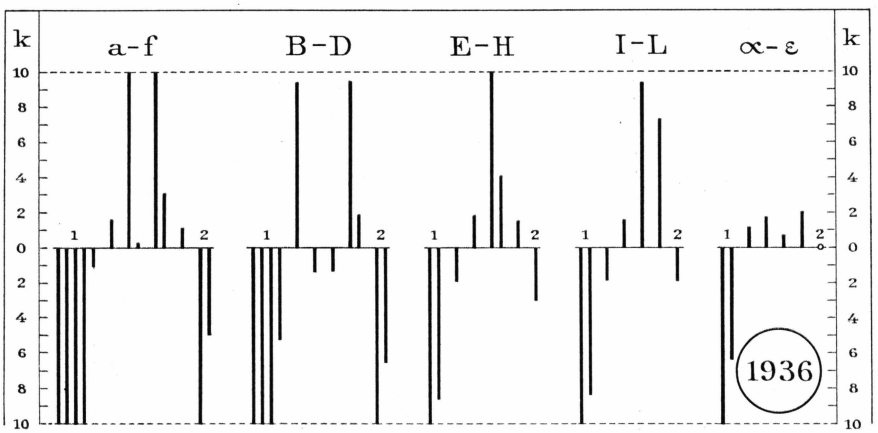


Fig. 69. Cf. the text to Fig. 64.

1904. — Not very much ice occurred west of Kap Farvel in April, but in May large quantities of much scattered ice drifted westward. The ice decreased considerably in quantity in the course of June, disappearing entirely in July.

The north coast of Spitsbergen began to be free of ice in June, and much open water occurred north of Spitsbergen in July. In April and May the ice belt between Spitsbergen and Iceland was not particularly narrow, but in June and July large quantities of ice disappeared owing to the action of the wind or to melting. Only scanty information is at hand from August; it may, however, be taken for granted that no ice occurred south of Angmagssalik, and probably not south of Scoresby Sund either. In August, curiously enough, a drift of scattered ice was found from Cape North towards Skagafjörður in Iceland, which was otherwise free from ice all the year round.

According to the records of the Meteorological Institute the ice conditions off the northern part of the east coast of Greenland were rather unfavourable during the summer. The ice belt was close-packed, and as late as the first half of August the land ice was unbroken along the coast between 73° and 75° N. lat. This is another example showing that the land ice often lingers long in the so-called "light ice years".

1936. — In April-May-June only small quantities of ice were found west of Kap Farvel, and hardly any ice seems to have occurred there in June. West Spitsbergen and all its straits were entirely free from ice in July, and in August the whole group of islands was almost free from ice. Not very much land ice was found in East Greenland. The ice belt between Spitsbergen and Iceland was narrow in April and May, in June the ice edge had an irregular course, and in July prac-

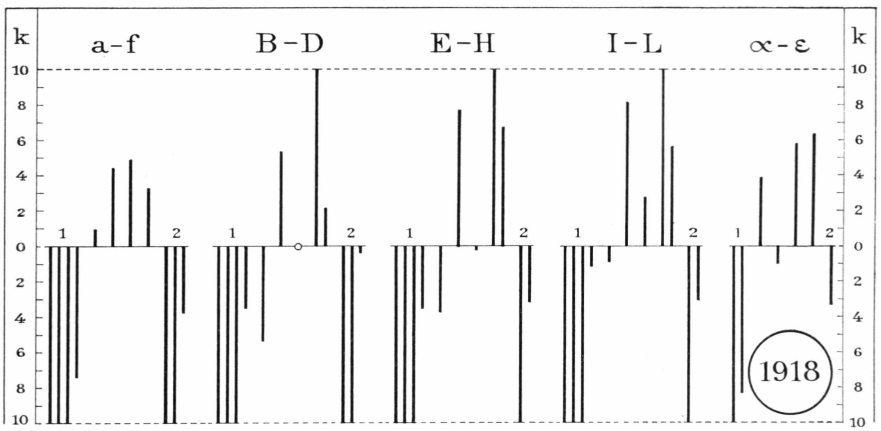


Fig. 70. Cf. the text to Fig. 64.

tically no ice occurred south of Shannon. The greater part of the areas with scattered ice indicated on the charts of the Meteorological Institute should therefore be accepted with reservation.

The "ice belt" along the east coast of Greenland consisted of few and scattered floes; from the crow's nest only three or four small floes were visible at a time, so they could hardly be termed an ice belt. My expedition ship, which left Akureyri in Iceland one of the last days of July, did not encounter any ice till she cast anchor off Scoresbysund, but some very small floes were sighted along Liverpool Kyst.

During August-September and practically the whole of October there was no ice along the east coast of Greenland south of Shannon; even in November only small quantities of ice passed Scoresby Sund. The Meteorological Institute assumes that fairly large ice masses occurred north of Shannon in July and August, and indicates an unbroken ice edge in July; this must, accordingly, be based on observations made from a ship. I do not think, however, that the assumptions of the Meteorological Institute will hold good; I should think that the unbroken ice edge indicated for July is the edge of a narrow belt of Siberian Ice that probably occurred here, as in 1933.

The summer of 1936 was by no means characterised by calm weather, and I can hardly imagine that the ice edge extended far seawards from Shannon without pieces of it having been broken off and drifted southwards in the months June-November.

Although the statistics for the whole year show a quantity of ice a little over 100 k, I include 1936 among the lightest ice years because in my opinion we must assume that an unbroken edge of Polar ice, whence no ice drifted southward along the east coast of Greenland, occurred near Nordostrundingen or even farther northward. The sum-

mer was extraordinarily warm in the central part of East Greenland, the ice disappeared very suddenly between June and July, and no new ice appeared till some time in October. During a great part of July, the whole of August-September and the greater part of October a heavy swell was running towards the shore from Scoresby Sund to some distance north of Eskimonæs.

It is deplorable that no data are at hand from the regions around Nordostrundingen from the late summer; various signs suggest that this summer was the most favourable ice summer known altogether, and I should think that no ice at all occurred south of the line Nordostrundingen-Amsterdam Island after September 1st.

Severe Ice Years.

1918. — The harbingers of this, the severest ice year of the period, were traceable rather early in the autumn of 1917. After an ice-free period of about two months the ice arrived at Angmagssalik on October 19th and as early as November it passed Kap Farvel on its way westward.

In April 1918 an ice belt nearly 200 km broad occurred west of Kap Farvel, extending as far as Frederikshaab. In May the ice belt grew somewhat narrower but spread to the latitude of Godthaab. In June the ice belt widened to c. 200 km and extended as far as the mouth of Godthaabs Fjord. In July it only reached Frederikshaab and at the same time decreased somewhat in width, but as late as August no inconsiderable ice masses were found along the coast as far as Frederikshaab as well as off Fiskernæsset.

Curiously enough not very much ice occurred near Spitsbergen this summer, the west coast, in particular, was free from ice during the five months of observation, and even though ice occurred as far south as Bear Island till the first days of May, it was no doubt possible to sail around Spitsbergen in July and August. The temperature of the water in the fjords of the west coast was exceptionally high that year, so we can hardly imagine that the great winter pulsation that affected the waterway along the east coast of Greenland was of any importance near Spitsbergen.

Ice appeared near Iceland as early as December 1917, both at Cape North and at Grimsey, and in January and February ice occurred along the whole north and northeast coasts from Cape North to Seydisfjörður. During the following two months the ice lay very near Cape North, but the coasts were free from ice. The same was the case in May; some distance from the north coast, however, the ice belt was very broad.

Land ice is not reported from Northeast Greenland from this year. Nor is any reliable information available about the waterways between

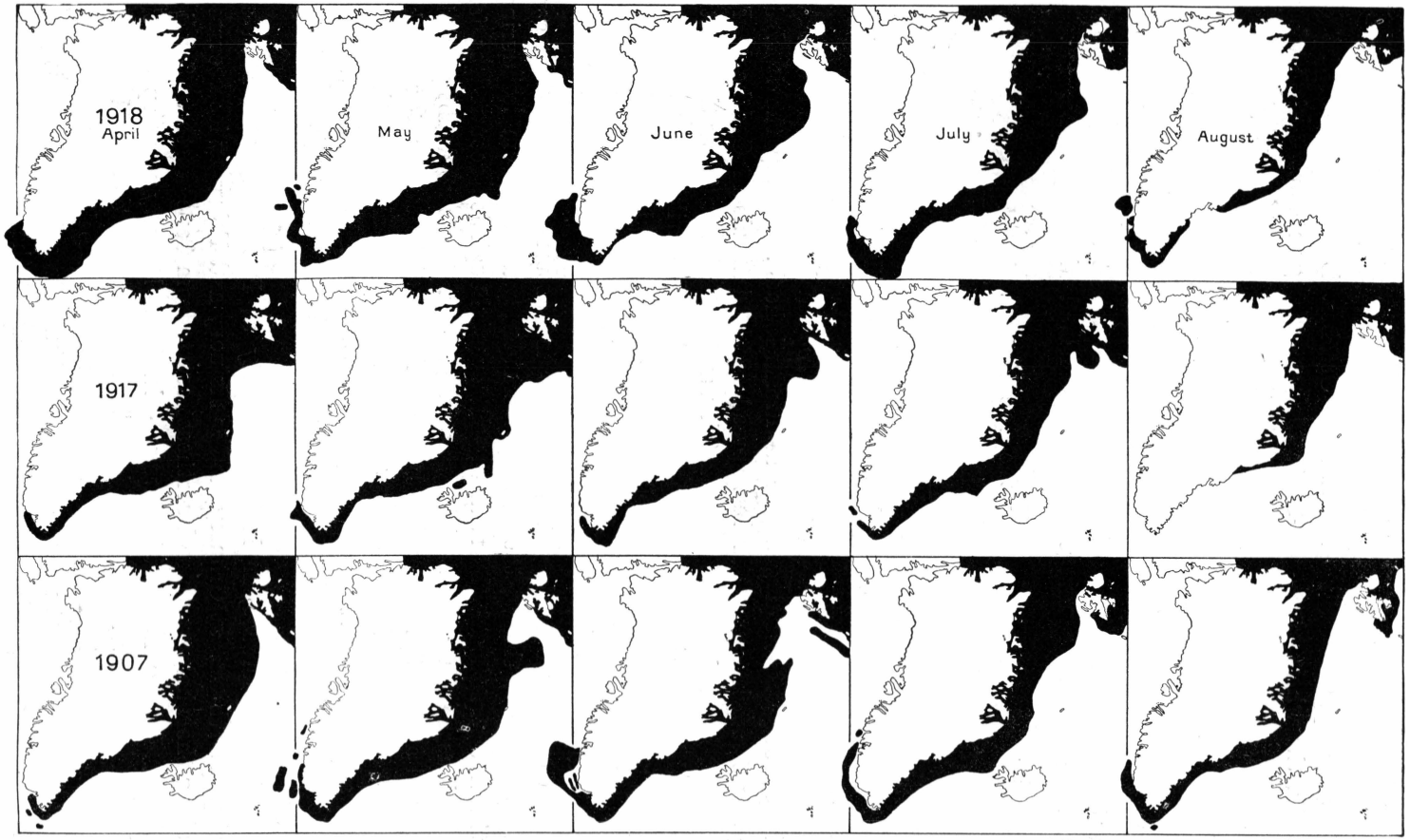


Fig. 71. Ice charts for the six heaviest ice years since 1898, copied from the yearbooks of the Danish Meteorological Institute.

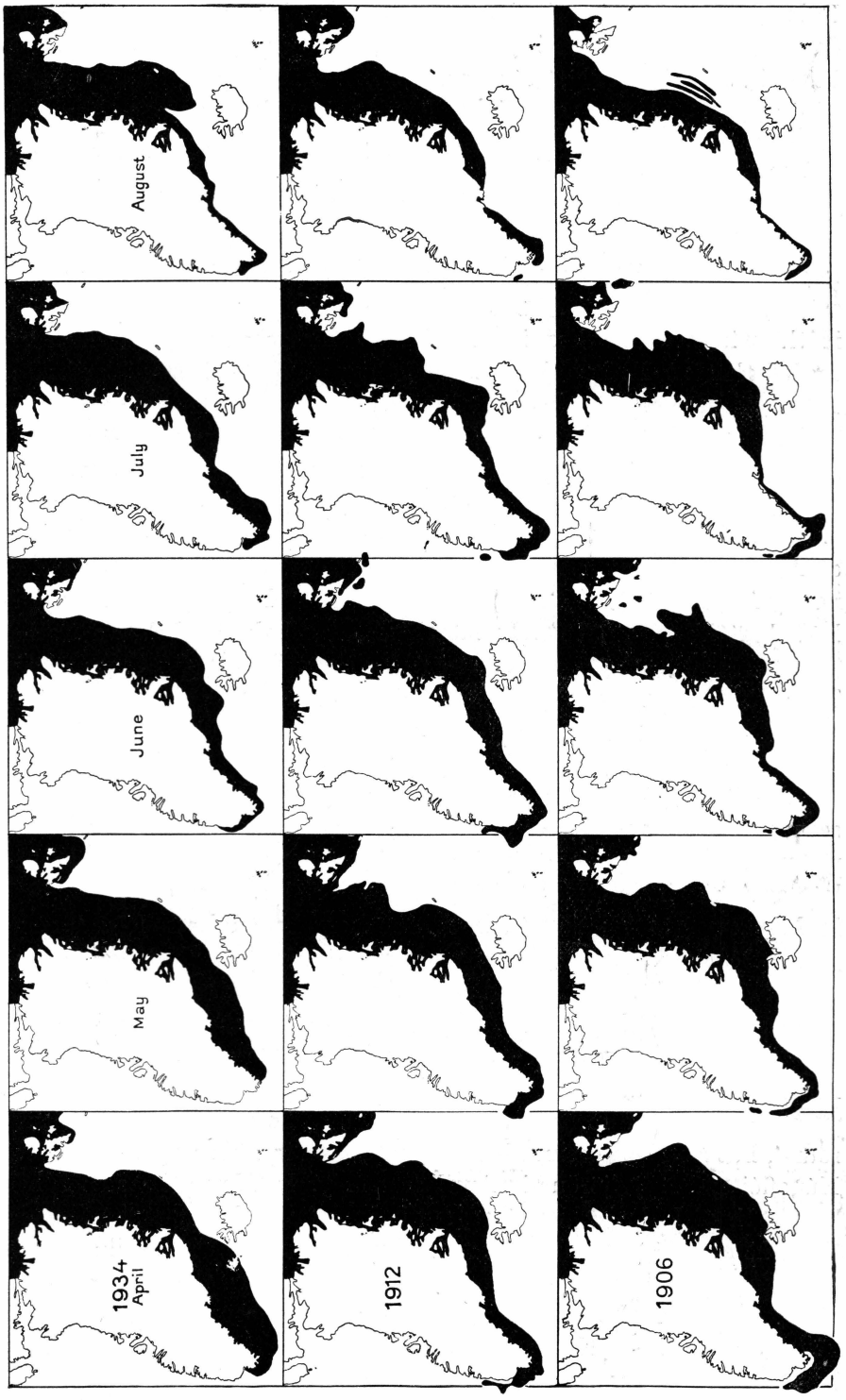


Fig. 72. Cf. the text to Fig. 71.

Iceland and Spitsbergen in April, but the ice belt seems to have enclosed Jan Mayen and to have increased in width in May. It remained fairly broad in June and July, but was very narrow in August; thus there was open water off Angmagssalik, and probably only a very narrow belt of ice farther northward.

Taking the assumptions of the Meteorological Institute as to the position of the ice edge in the different summer months as a basis, we shall see that this year was characterised by the occurrence of very large ice masses in April and May. In the zone B—D there was a pulsation, possibly a continuation of the early and very large pulsation in the winter, but otherwise a melting commenced in May which exceeded that of all the other years of the period, so that on September 1st only a narrow belt of ice was found along the east coast of Greenland.

The ice conditions around Spitsbergen this year differ distinctly from those of East Greenland, being favourable throughout the summer.

1917. — This year differs greatly from 1918 though the quantities of ice were about the same. A small quantity of ice arrived at Angmagssalik on November 29th, 1916, after an ice-free period of nearly four months. In December, January, and February Angmagssalik had short ice-free periods. In March and April the ice belt was rather narrow, not till May did ice quantities of any importance appear here. There was not very much ice west of Kap Farvel in April, but the quantity increased in May, to decrease in June and July, and in August the water was entirely free from ice.

Near Spitsbergen strong northerly winds at the end of the winter seem to have given rise to a considerable pulsation, and thus in these waters we have the most typical southern ice year of the period. As late as April the ice extended to about 76° N. lat. near 0° W. long. and in May even to 74° N. lat., both Spitsbergen and Bear Island being entirely enclosed by the ice and situated far from the ice edge during these two months. In June and July a bay of open water formed towards Spitsbergen, but the coast was not free from ice, and Bear Island was quite surrounded by ice. Not till August was the west coast of Spitsbergen in the main free of ice, but the ice edge still reached Bear Island.

The coasts of Iceland were practically free from ice all the year round, but some ice occurred near Cape North in February and between Húnaflói and Eyjafjörður in April and May. In May a broad ice belt lay north of Iceland, but at some distance from the coast.

The ice belt along East Greenland was very broad in April and May between 75° N. lat. and Iceland, and Jan Mayen was entirely enclosed by it. In June and July large quantities of ice occurred between Angmagssalik and Cape North as well as farther northward. In August the ice belt was very narrow, notably south of 70° N. lat., and extended

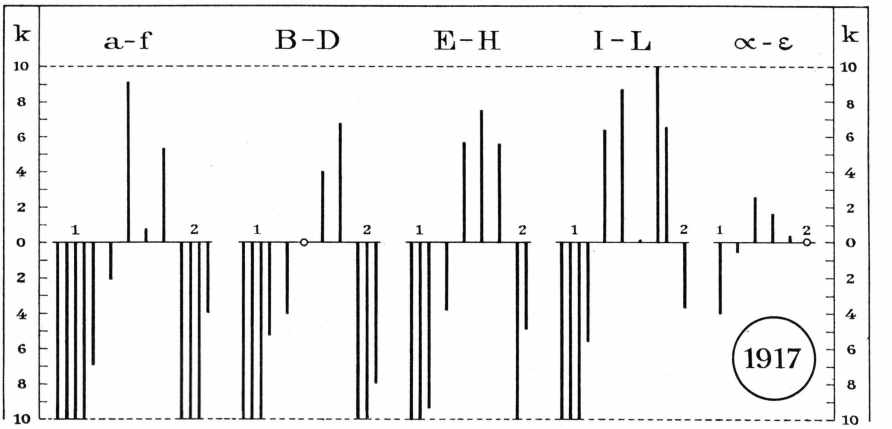


Fig. 73. Cf. the text to Fig. 64.

only a short distance south of Kangerdlugssuak. Accordingly the year was characterised by the presence of very large ice masses between Spitsbergen and Bear Island on the one hand and Northeast Greenland on the other, and by a very broad ice belt extending southward to a line Angmagssalik-Cape North and farther eastward in April-May-June, while in the winter as well as during the whole period April-July not very much ice occurred south of the line Angmagssalik-Cape North, and in August this waterway was entirely free from ice.

The winter pulsation this year must have been widely different from that of 1918. It commenced at the end of the winter and was especially violent near Spitsbergen, and since the greater part of the ice masses were Siberian Ice and Spitsbergen Ice, they melted in the course of the summer before reaching south of the line Angmagssalik-Cape North. The summer of 1917 was, indeed, wery cold around Spitsbergen, but in September 1917 very little ice occurred south of the line Nordostrundingen-Amsterdam Island, and the great winter pulsation in 1918 did not, unlike the pulsation in 1917, consist of Siberian Ice and Spitsbergen Ice, but of North Pole Ice, and thus had no connection with the 1917 pulsation.

The centre of the short winter pulsation in 1917 was found near Spitsbergen, that of the prolonged winter pulsation in 1918 near Northeast Greenland.

1907. — On November 3rd, 1906, a broad ice belt appeared off Angmagssalik. It persisted there, retaining its great width, till September 1907 and with decreasing width during the rest of the year. Accordingly Angmagssalik could not be visited by ship that summer.

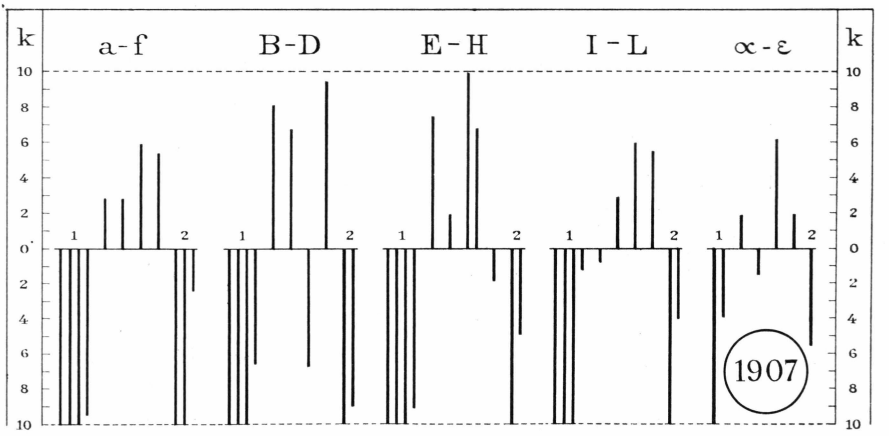


Fig. 74. Cf. the text to Fig. 64.

The winter pulsation must have been very strong, at any rate at the end of the winter. Easterly winds in the spring are recorded from both Kap Farvel and Spitsbergen. In April the ice conditions were difficult west of Kap Farvel; there was, indeed, open water from Julianehaab northward to Sukkertoppen, but considerable ice masses lay not far from the coast. In May the ice belt west of Kap Farvel grew broader, the coast was blocked by ice almost as far as Fiskernæsset, and ice occurred not far from the shore off both Godthaab and Sukkertoppen. In June exceptionally large quantities of ice rounded Kap Farvel, forming a broad belt as far as Godthaab. In July the ice belt was narrower, but extended farther northward. In August the ice reached Fiskernæsset, and even in September a narrow belt of ice extended as far as Frederikshaab.

Near Spitsbergen there were particularly large ice masses south and east of the islands, and Bear Island was entirely surrounded by ice in April, May, and June. The ice remained along the southern part of Spitsbergen in the month of July, while large spaces of open water seem to have occurred north of Spitsbergen, so the north coast could be visited by ships in August and September.

Near Iceland the ice belt was broad during the first months of the year; in January and May the ice reached the western fjords and Cape North, in February the north coast was free from ice, but the ice was not very far off and reached Grimsey, and in March the ice occurred not far from the north coast and lay close up to the northwest coast.

This year, also, a very broad belt of ice was found off Northeast Greenland; in April and May it reached Jan Mayen, and even in June

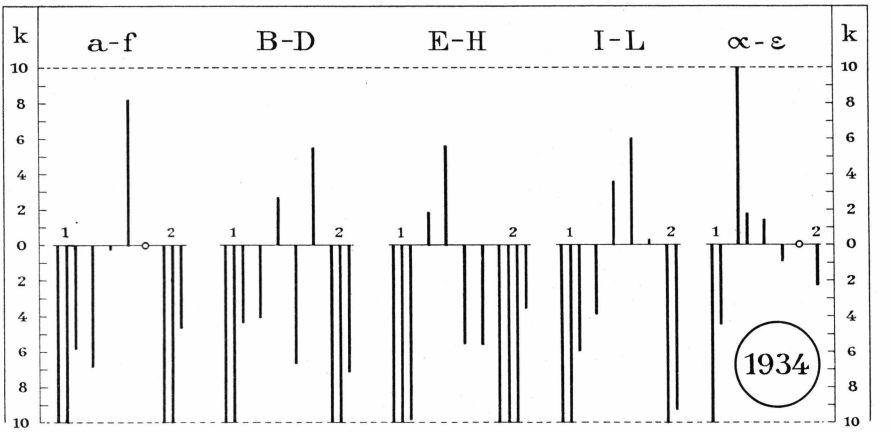


Fig. 75. Cf. the text to Fig. 64.

the ice edge occurred near Jan Mayen. In July and August the ice belt grew much narrower, in September it seems to have been broader, but no evidence of this is at hand.

This year is regarded as a severe ice year principally on account of the occurrence of large quantities of ice west of Kap Farvel, much ice south of Spitsbergen, and a broad ice belt between Iceland and Spitsbergen in April-June.

1934. — Not very many data are at hand from this year, and they are in some degree conflicting. The ice charts are to a great extent based on conjectures.

Ice is assumed to have occurred west of Kap Farvel in April, but not in May-June. Small quantities of ice seem to have been present in July and possibly in August also.

Peculiar conditions seem to have prevailed near Spitsbergen. In April the ice conditions were fairly good, but in May large ice masses drifted up along the west coast from the south; in June-July the conditions improved somewhat, but in August large ice masses seem to have appeared again, coming from the north.

No ice occurred near Iceland during the year. The Meteorological Institute assumes that large quantities of ice were present between Kap Farvel, Angmagssalik, and Cap North in April, and a good deal of ice still occurred here in June and July, but in August the ice seems to have almost disappeared within this area.

The ice between Iceland and Spitsbergen reached Jan Mayen in April and May, it receded somewhat from this island in June and July, while in August it seems to have enclosed the island again. It does not appear from the chart whether the indication of ice masses round Jan

Mayen in August is based on observations; probably, however, it is correct, for during these years a permanent wireless station was found on Jan Mayen.

In the report of the Meteorological Institute for this year Mr. JENNOW of the "Østgrønlandsk Fangstkompagni "Nanok"" makes the following statement (p. 1):

"This year there has not been more ice than is usually the case, rather less. Occasional difficulties have been caused by the easterly and north-easterly winds which forced the ice into all the crevices of the coast."

In support of this peculiar contention Mr. JENNOW mentions a number of examples of land ice having broken up comparatively early along the coast from Carlsberg Fjord to and including Dove Bugt. It has been pointed out repeatedly in the above that in severe ice years the land ice often breaks up rather early, there seems even to be a tendency to a certain connection between the breaking up of the land ice and the presence of large ice masses off the coast in the early summer, which is quite natural in so far as a broad ice belt in May-June affords good conditions for calm and clear weather along the coast; as stated above, the breaking up of the land ice depends on the weather in these months. Conversely, a narrow ice belt affords a possibility that the cloudy weather of the Atlantic may spread across the ice belt with easterly winds in the early summer, which means a protection of the land ice against the sun's rays.

Mr. JENNOW's contention, that 1934 was a favourable ice summer, because the land ice broke up early, may therefore rather be regarded as supporting the contrary conclusion of that drawn by Mr. JENNOW. Thanks to an intensive reconnaissance from the air, in which Mr. JENNOW did not take part, it was possible for the ship to visit the interior of Scoresby Sund and to sail along the coast northward to Sandodden, but not north of this point, even though the navigation that summer was encumbered with many and great difficulties. In July the whole ice belt off the mouth of Scoresby Sund consisted of very heavy ice, no doubt North Pole Ice, and from the air the ice belt from Scoresby Sund to some distance north of Shannon was observed to consist of very close-packed heavy floes throughout the summer.

According to the chart of the Meteorological Institute, two pulsations occurred in the course of the summer, one in April-May, another in June-July, and more ice was present in the zones B—D and E—H on September 1st than on April 1st. The observations made during the sailings of the "Gustav Holm" in the East Greenland waters and on the numerous air reconnaissances along the central part of East Greenland showed that it was a severe ice year with a constant drift

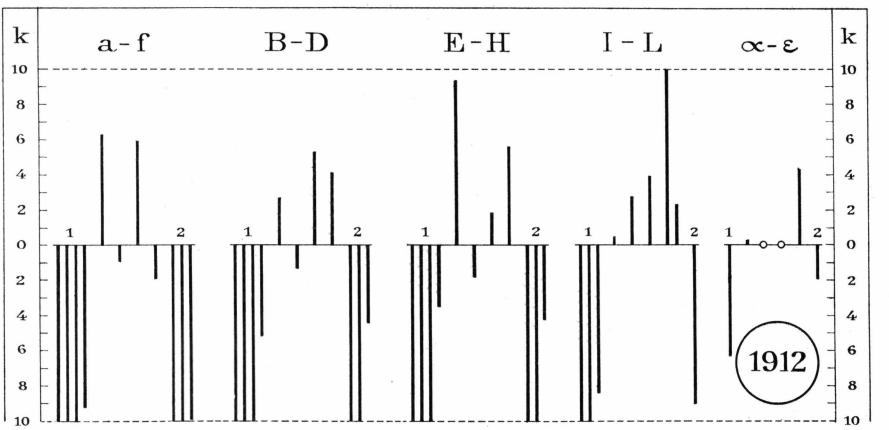


Fig. 76. Cf. the text to Fig. 64.

of very large floes southward along the coast. And the statistic material shows, in fact, a great increase of the ice within the zone E—H both in June-July and in July-August.

1912. — On November 14th, 1911, the ice reached Angmagssalik from the north and in February 1912 large ice masses passed Kap Farvel. In April a rather narrow ice belt appeared off Frederikshaab, increasing somewhat in width in May, when it only reached as far as Ivigtut. In June the ice belt grew still broader and now extended as far as Fiskernæsset, blocking up the coast over a considerable width as far as Frederikshaab. In July fairly large ice masses were still present west of Kap Farvel, but in August only small quantities of ice were found here.

Large ice masses occurred south of Spitsbergen, thus Bear Island was enclosed in ice in April, May, and June, and both in July and August a good deal of ice occurred south of Spitsbergen. In April, May, and June the ice between Spitsbergen and Iceland extended almost as far as Jan Mayen.

In July considerable ice masses occurred near East Greenland, especially along its northern part. In August the ice belt was narrow, no ice was found outside Angmagssalik, and the "Whaler's Bight" was relatively broad.

The coasts of Iceland were hardly touched by the ice, but a broad ice belt lay off Iceland, especially in April and June.

This year is especially characterised by the ice south of Spitsbergen and the broad ice belt along the northern part of the east coast of Greenland.

1906. — Judging from the available data from Angmagssalik, considerable quantities of ice must have drifted down as early as the

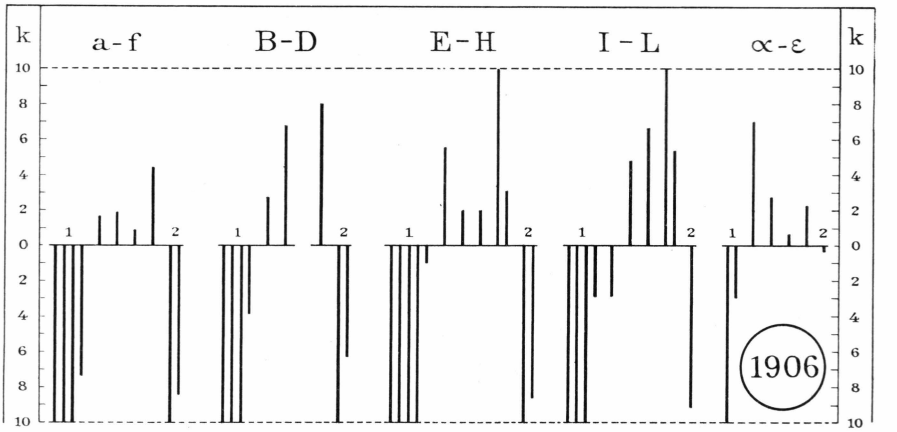


Fig. 77. Cf. the text to Fig. 64.

middle of October 1905. In April 1906 a very broad ice belt was found west of Kap Farvel, which issued a tongue towards Ivigtut. In May the ice belt was much narrower, but extended as far as Frederikshaab, and ice occurred between Fiskernæsset and Godthaab. In June the ice belt extended to some distance south of Fiskernæsset, in July it increased in width, but in August it was narrow and only extended as far as Ivigtut. The "Whaler's Bight" near Spitsbergen was well developed from April, in May it was very broad, and in July and particularly in August it was possible for a ship to visit the north coast of Spitsbergen.

A broad ice belt occurred near Iceland from April to and including July, and in May the greater part of the north coast was blocked by ice.

Between Iceland and Spitsbergen the ice belt was very broad off Northeast Greenland, but its edge had an irregular course. Jan Mayen was partly surrounded by the ice or lay at the edge of the ice belt from April to and including July. Not till August did the ice belt grow narrow and extended only as far as Angmagssalik. No ice apparently occurred off the southwest coast of Greenland in August.

Summary. — A common feature of these six ice years is a strong winter pulsation resulting in the presence of large ice masses north of at any rate 65° N. lat. on April 1st.

In 1918 the winter pulsation, which commenced in the previous autumn, lasted till May and consisted of North Pole Ice. In 1917 the pulsation caused the waters around Spitsbergen and south of it to be filled with Siberian Ice, which melted before it reached the waters west of Kap Farvel.

In several of these severe ice years the winter pulsation would seem to have been very strong and was not succeeded by any summer

pulsation. In some of the years comparatively small quantities of ice occurred south of the line Nordostrundingen-Amsterdam Island about September 1st, owing to the small number, or entire absence, of summer pulsations.

An exception, however, is formed by the year 1934, which exhibits fairly abnormal conditions. As we have a better knowledge of a similar year, viz. 1938, this will be dealt with in more detail below, for comparison.

Especially ill-famed Ice Years.

It will no doubt surprise many that the two years which have for the last few decades been regarded as especially difficult for ice navigation along the east coast of Greenland, viz. 1923 and 1935, in the curve showing the mean quantity of ice exhibit about the normal ice quantity of the period, 1923 lying slightly above, 1935 slightly below.

That navigation along East Greenland was exceptionally difficult in these two years is due to special causes.

Unfortunately no continuous information is available from Scoresbysund for the year 1923, it is only known with certainty that a close-packed ice belt occurred outside the fjord in September. The data available from Angmagssalik, are, however, very interesting. It will be seen that not very much ice was found here in the summer months (June and onwards), but large quantities of ice drifted down during the last half of September and especially in October. From this we may infer that tolerably good ice conditions prevailed along the central part of East Greenland till the middle of the summer, as is known from observations made by the men of the "Teddy".

As is well known, the "Teddy" reached East Greenland after a fairly successful voyage by the middle of July. Rather large stretches of land water were found until the end of July, when strong easterly gales began to make themselves felt, continuing at short intervals till some time in October.

The ice belt was not particularly broad in the early summer, so evidently there must have been much land ice, which did not drift out till late in the summer. The Norwegian vessel "Annie" had difficulties in leaving Myggbukta, and when at last it reached the drift ice, it was almost immediately beset in the ice and was lost with all hands. The "Teddy", too, was beset in the ice near the place where the "Hansa" was beset in the ice in 1869, and as the "Teddy"s engine, which was almost constantly in disorder, was of little use, the drift of the "Teddy" was surprisingly like that of the "Hansa".

However, the "Hansa" was a sailing vessel. If the engine of the "Teddy" had worked better, the ship might have got out of the ice

off Scoresby Sund owing to the currents moving out of the fjord. But the "Teddy" did not get free of the ice and therefore, like the "Hansa", drifted southward into the waterway between Iceland and Greenland, no doubt not very far from the ice edge. Like the "Hansa", the "Teddy" drifted towards the shore near Angmagssalik, and all the members of the expedition succeeded in reaching the shore and getting into communication with the Eskimos at Angmagssalik. Thus the members of the expedition were saved, but the ship was lost.

The curve in Fig. 48 shows that in 1923 the quantities of ice found along the east coast of Greenland were fairly normal, and the "Teddy" had no great trouble in reaching the shore. But towards August 1st, when the "Teddy" and the "Annie" were to utilise the land water that normally forms at this season, strong easterly winds set in, packing the ice towards the shore and into the fjords, and this is the actual cause of the ill repute of this ice year. Furthermore, it is no doubt due to the strong easterly winds that ice did not appear in appreciable quantities outside Angmagssalik till the end of September; in October large quantities of ice occurred here.

Similar conditions undoubtedly prevailed in 1935. While rather small quantities of ice were present off the mouth of Scoresby Sund from the middle of April to the beginning of July, very heavy ice masses appeared here in July, August, September, and the first days of October, which caused great difficulties for navigation.

North of Myggbukta a Norwegian ship was subjected to such a great pressure in the drift ice that it was left for a short time by the crew. It was, however, saved later on.

The Danish ship "Godthaab" was unable to make its way to the shore, and observations from the air showed that at the height of the summer constant easterly winds pressed the ice into all the fjords (cf. Fig. 39).

The ship that was to visit Scoresbysund succeeded in pushing through the ice, though with difficulty. Later on, during the greater part of October and November, hardly any ice occurred off the mouth of Scoresby Sund.

Off Angmagssalik the ice belt was very open in February, but during the remainder of the year there were comparatively large quantities of ice even at the height of the summer. This year, also, land ice occurred north of Scoresby Sund, which persisted fairly long, at the same time as the ice belt in the early summer was relatively narrow.

These two ice years are examples of summers in which navigation was very difficult. The ice belt was narrow in the early summer, and hence the land ice persisted long. Strong easterly winds prevailed

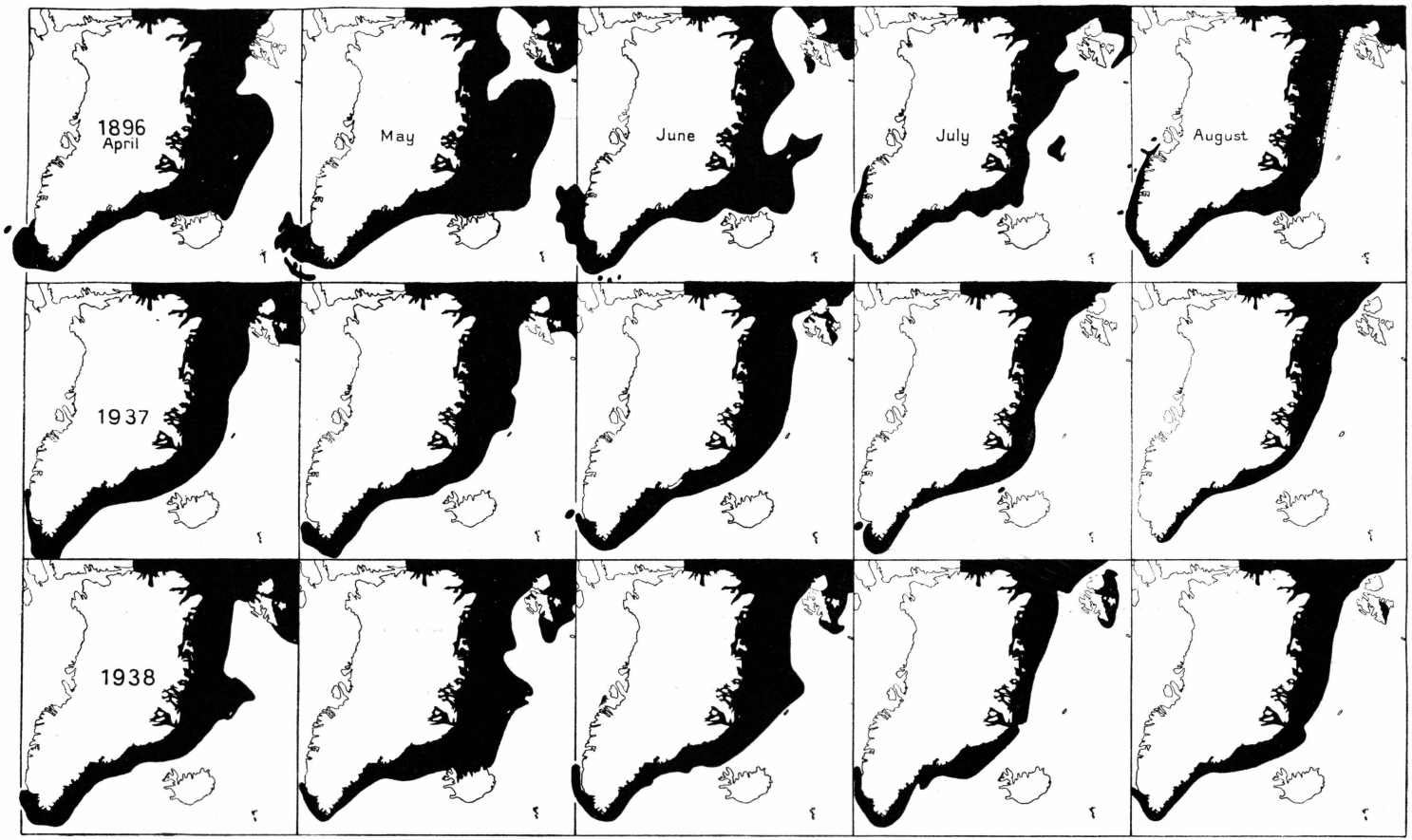


Fig. 78. Heavy ice years specially mentioned in the text, copied from the year-books of the Danish Meteorological Institute.

during the period of navigation, packing the ice towards the shore and making navigation exceedingly difficult; in 1923, in particular, the easterly winds kept the ice belt quite close to the shore and in the fjords during the whole height of the summer, and not till the autumn did these ice masses reach Angmagssalik. 1923 is the only year within the period dealt with here in which large ice masses occurred off Angmagssalik in October.

In the years 1935, 1922, 1921, and 1907, also, large ice masses drifted past Angmagssalik in the summer months. The heaviest ice year near Angmagssalik was 1938, when so much ice drifted down every month as otherwise normally occurred in the winter months only. The causes of this will be dealt with below.

Fig. 78 shows the ice situation in the five summer months of 1896 according to the ice charts published by the Meteorological Institute. The year is distinguished by particularly large quantities of ice, especially in the early summer, and is repeatedly referred to in the literature (cf. OTTO PETTERSSON, 1900) as a year with exceptionally large quantities of ice. However, the available data from this year are so sparse that the ice charts, notably for July and August, cannot be regarded as fully reliable. Still I considered it most correct to copy them here.

The Four-Year Period 1936—39.

It will be seen from Figs. 81 and 83 that both near Scoresby Sund and Angmagssalik the two years 1936 and 1939 were record years as regards small quantities of ice in the summer. Thus in three months of each of these two years there was no ice at all off the mouth of Scoresby Sund, which is not known to have happened in any other year during the period in which ice observations have been made there; off Angmagssalik the water was ice-free for four months, which has not been reported previously in the present century from this place.

In the two intermediate years, 1937 and 1938, there was an almost continuous ice-drift off Scoresby Sund all summer, and, as stated above, 1938 was the severest of all the ice years known from Angmagssalik. Below I shall try to explain these phenomena.

It has been pointed out above that 1936 was probably the most favourable ice year in the North Atlantic within the present century, as it would seem that as early as July hardly any ice occurred south of the line Nordostrundingen-Amsterdam Island, and this condition remained unaltered during the months of August, September, and October. After this exceptional summer a little ice appeared off Scoresby Sund in November, but not till December did the actual drift of ice past the mouth of the fjord begin.

Hardly any ice was found near Angmagssalik in June and July, and in August, September, October, November, and the first half of



Fig. 79. Ice conditions in the Polar Basin in August 1937, copied from the yearbooks of the Danish Meteorological Institute, showing extremely favourable ice conditions north of E. Siberia and in the Barents Sea.

December there was no ice at all. Occasional floes appeared at the end of December, but not till about February 1st did a broad belt of ice reach this place.

In the first four months of 1937 large ice masses were found off the mouth of Scoresby Sund. In May and June the ice drift came to

a standstill, but at the beginning of July heavy ice masses again drifted southward, and this drift continued during the remainder of the year. Especially in September the ice packed closely outside the fjord. Large quantities of ice were present off Angmagssalik from February to and including August. During September, October, and the first two-thirds of November there was relatively little ice, but from November 21st and onwards there again was much ice.

In 1938 large quantities of ice occurred outside Scoresby Sund from the beginning of the year to August, rather small quantities occurred in August, September, and part of October, but from November and throughout the winter to June 1939 heavy ice masses were found here. During nearly all the months of the year a thick ice belt lay off Angmagssalik; there was no improvement in the ice conditions in the late summer and the large quantities of ice persisted throughout the winter till the beginning of July, 1939, when they suddenly disappeared.

Altogether it may be said that after the record-like scarceness of ice in the summer and autumn of 1936, there was during thirty months, from January 1937 to July 1939, with occasional short intervals due either to pulsations from the Polar Basin or to local conditions (wind, currents, melting, etc.) in the North Atlantic, a record-like drift of ice past Scoresby Sund and Angmagssalik, and this drift was succeeded by another record summer in 1939 with practically no drift of ice past Scoresby Sund for more than four months and past Angmagssalik for almost five months.

These observations are interesting because the drift of the PAPANIN group from the North Pole to Scoresby Sund from May 1937 to February 1938 falls within these thirty months with a continuous drift of ice.

As is well known, the PAPANIN group was landed by aircraft at the North Pole on May 21st, 1937. It was expected that the camp would not be removed very far from the Pole during the year, so that it might be fetched by aircraft next spring. However, things developed quite differently. In the course of June and July the ice-floe with the PAPANIN group drifted some distance southward towards the Atlantic, and during the remainder of the year the camp drifted southward at a rapid rate, about 200 km a month; when the floe passed Nordostrundingen about December 1st, the rate increased to 300 km, and in January to about 650 km.

On February 19th, 1938, the members of the group were taken onboard an ice-breaker near Liverpool Kyst. The ice belt must have been very compact, for the drift was unaffected by the local east-west moving currents and moved across the East Greenland shoals without being affected by the configuration of the sea-bottom. This would seem to show that the local currents which may affect the ice drift in an east-westerly direction across or near the edge of the shoals (cf.



Fig. 80. Ice conditions in the Polar Basin in August 1938, copied from the yearbooks of the Danish Meteorological Institute, showing the most favourable ice conditions along the north coast of Asia ever known.

KIILERICH's map 1945) can only exert their influence if the ice belt is scattered.

In the summer of 1937 navigation was very difficult along the central part of the east coast of Greenland. As stated above, a Norwegian ship was left by the crew for a short time north of Myggbukta.

An American expedition under the leadership of Miss LOUISE A. BOYD was able to push into the Kong Oscars Fjord complex, but was troubled by the ice both during the inward and the outward voyage. In July Captain SCHELDERUP onboard the well-known Norwegian vessel the "Quest", which had passed the winter near the coast, went southward along the coast in a narrow belt of land water from Clavering Ø to Liverpool Kyst; near Scoresby Sund the ship struck open water, but the captain reported over the wireless that exceptionally heavy ice masses had constantly been visible to the eastward. The Danish expedition ship the "Gustav Holm", which for various reasons did not reach the mouth of Scoresby Sund till August 7th, had to go into this fjord; in spite of repeated attempts it was impossible to visit the stations north of Scoresby Sund, and during August and September the expedition was greatly troubled by the ice in the mouth of and outside Scoresby Sund. All the ships that visited East Greenland this summer reported heavy and close-packed ice; even near the ice edge the ice was North Pole Ice.

In 1938 navigation was somewhat easier, though various troubles were met with. In July the expedition ship "Godthaab" sailed from Iceland towards Scoresby Sund. Just south of the mouth of this sound the ship was beset in heavy ice, and drifted some distance southward before getting free of the ice. Later in the summer I observed both from the ship and from an aircraft that the ice belt was very close-packed and consisted of heavy floes of North Pole Ice. Similar conditions were met with by the "Gustav Holm" north of Clavering Ø, and the "Gertrud Rask" likewise encountered very heavy ice near Scoresby Sund.

That it was possible to carry out the navigation in the East Greenland waters according to plan this summer, was no doubt due to the calm weather that prevailed during the whole summer and prevented the heavy ice floes from packing so that in spite of the large ice masses present along the central part of the coast it was possible to push through the ice belt in several places. However, if a gale had blown up from the east, the picture might have changed entirely in the course of a few hours, rendering navigation difficult, notably since the ice extended far into the mouth of the fjords during a great part of the summer.

In May 1938 I had the opportunity to observe the ice belt between Spitsbergen and Northeast Greenland in its whole breadth in four different places, as I crossed this area in airplane twice from Kings Bay, Spitsbergen, to Northeast Greenland.

On May 1st nearly the whole north coast of Spitsbergen was free from ice, there was open water north of Amsterdam Island as far as 81° N. lat., and the distance from this island to the ice edge in a westerly direction was more than 100 km. West of Spitsbergen the

ice edge consisted of small, but thick floes crushed by the swell, and beyond this zone and right across to Greenland lay large unbroken ice fields criss-crossed by heavy pressure ridges, in other words, the ice belt consisted throughout its width of North Pole Ice. No Siberian Ice occurred north and west of Spitsbergen in May 1938.

It is characteristic of the summers of 1937 and 1938 that the ships visiting East Greenland did not encounter Siberian Ice, but found heavy floes of North Pole Ice right out to the ice edge.

While, as stated above, severe ice conditions prevailed along the east coast of Greenland between the two record years 1936 and 1939, an almost continuous drift of heavy North Pole Ice taking place during 30 months from the New Year 1937 to July 1939, the ice conditions north of Siberia exhibit records of quite a different kind.

The ice charts for 1936 show good ice conditions from Spitsbergen eastward, which is quite natural, since, as shown by SCHERHAG (1936), they have constantly improved during recent years. Thus in August Spitsbergen was almost free from ice, scattered ice was found south of Franz Josef Land, Novaya Zemlya was entirely free from ice, but the ice lay from a little north of its northernmost point across to the mouth of the Yenisei. A rather narrow belt of land water extended some distance east of Kap Tscheljuskin to some distance east of the mouth of Kolyma River, touching only the southernmost point of the New Siberian Islands.

In the summer of 1937 the ice conditions along the coast of Siberia were even better. In August Spitsbergen was entirely free from ice. Scattered ice occurred south of Franz Josef Land, whence the ice edge extended to the island Ensomhed, around which the water was free of ice. The New Siberian Islands were free from ice, the ice edge lying a great distance north of them, and the coast along the Bering Strait was likewise free from ice.

In August 1938 the ice conditions were still better, the ice situation north of Siberia this year being the best hitherto known within the present century. Spitsbergen was entirely free from ice, there was open water as far as Franz Josef Land, and the ice edge extended a great distance north of 80° N. lat. to the northernmost point of Severnaja Zemlya. There was open water off the New Siberian Islands from Kap Tscheljuskin to the mouth of Kolyma River, east of which scattered ice occurred along the coast towards the Bering Strait.

Unfortunately no information is available about the ice conditions north of Siberia in 1939 and subsequent years, but it can be established that up to this year 1938 was the year poorest in ice recorded from the north coast of Siberia, and 1937 follows closely upon it. This means that there can have been no particular drift of Siberian

Ice into the Atlantic in these years, since it must in the main have melted in or near the spot in which it was formed. And this means, again, that with such vast ice-free areas along the whole north coast of Siberia as occurred in these two summers, the ice in the Polar Basin cannot have been very much packed. This must have afforded a possibility for an exceptionally strong ice drift from the North Pole towards the Atlantic in the years 1937 and 1938, no matter whether this ice drift, which, as shown by the observations from East Greenland, actually took place, is due to an increase in the velocity of the Polar Current or to special wind conditions or to both these factors.

The curves for these two remarkable years, 1937 and 1938, show that the quantity of ice in the summer of 1937 was below the normal, and in 1938 it was likewise below, but very near, the normal.

This may be due to several causes, i. a. Siberian Ice was completely lacking in these two years, as stated above. However, an increased cyclonic activity may have rendered the ice belt narrower, but more packed; the drift of the Russian camp from the North Pole must be regarded as a proof that the velocity within the ice belt was exceptionally great. It is characteristic that the coast of Iceland was not practically influenced by the ice during these two years; only in June and July 1937 did occasional floes appear off Cape North, and during a short period in May 1938 scattered ice was found along the whole north coast of Iceland.

From the observations made from the shore, from ships, and from the air during these two years it would seem that the drift of ice, which commenced off Scoresby Sund about the New Year of 1937 and from May 1937 to February 1938 carried the PAPANIN group with increasing velocity from the North Pole to near Scoresby Sund, continued throughout the summer of 1938 and the following winter past Scoresby Sund and Angmagssalik, where the ice drift suddenly stopped at the beginning of July 1939 to be succeeded by a summer in which these places were entirely without ice for several months.

If the ice conditions around Spitsbergen and along the north coast of Siberia constantly improve in the future, a cold and relatively calm winter in the Polar countries may retain the ice masses, no longer closely packed, in the Polar Basin. Such a cold winter may then, possibly, be succeeded by a summer in which practically no ice will occur south of the line Nordostrundingen-Amsterdam Island in August; but it is likewise possible that such summers will alternate with periods with a narrow, but rapidly drifting, continuous ice belt for several years.

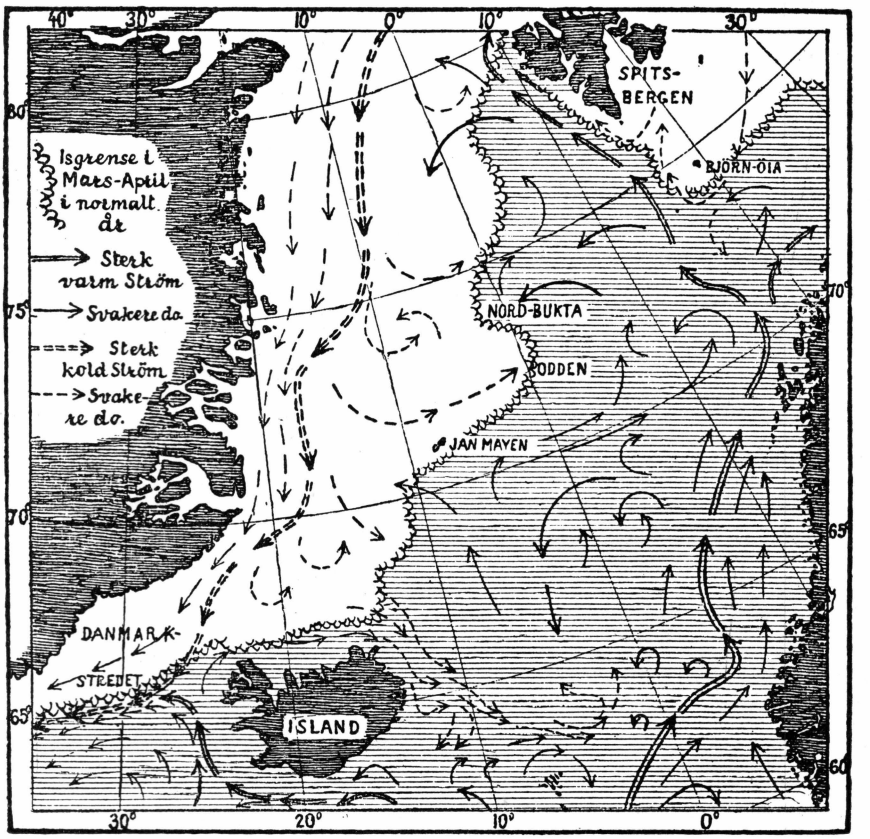


Fig. 81. Map showing currents and ice conditions in the North Atlantic. After Fridtjof Nansen 1924.

Fridtjof Nansen on his famous drift in the "Fram" across the Polar Basin (1894—96) noted a layer of cold water about 200 m thick which covered the surface of the basin. Later expeditions have found that this layer of cold water is at present only about 100 m thick, which means that especially heavy pressures ridges may extend through the cold layer to the subjacent warmer layers so that a melting of the ice from below would seem possible. If the cold layer constantly decreases in thickness, an increasing quantity of ice in the Polar Basin will begin to melt from below. The North Pole Ice will then more and more assume the character of Siberian Ice and be subject to melting to a much greater extent than previousby before reaching southerly regions.

Some Remarks on the Nord-Bukta.

In 1922, mentioning the East Greenland Ice, Einar Mikkelsen states that conditions were favourable for entering the ice belt off the

east coast of Greenland between 74° and 75° N. lat. On pp. 212—213 he gives a list of 32 ships which have pushed through the ice in the period 1822—1912, and 40 per cent. of these ships entered the ice belt between 74° and 75° N. lat. MIKKELSEN explains this by assuming that some distance from the coast off Danmarks Havn an area of permanent land ice extends northward, while south of this area the ice is supposed to be very open, especially after a cold and calm winter.

FRIDTJOF NANSEN (1924) describes his first voyage to the Arctic in the sealing vessel the "Viking" in the summer of 1882, giving an excellent account of the Norwegian sealing industry in the North Atlantic in the years of its culmination. On p. 23 he publishes a chart of the ice and currents in these waters, which shows (see Fig. 81) that there is a bay in the ice south of 75° N. lat., while south of the bay there is a tongue of ice termed by the Norwegians "Odden". It appears from the text, notably pp. 26—30, that the bay and the tongue are phenomena which the sealers expect to encounter almost every year.

Thus on p. 29 NANSEN says (translated from the Norwegian): "Northeast of Jan Mayen the drift-ice in the spring often forms a large headland towards the east, which consists largely of young ice from the winter or the same spring, and which the sealers generally simply call "Odden" (the headland). It evidently owes its existence to a branch of the Polar Current, which here moves in an eastward direction."

NANSEN goes on to say that a large eddy, or perhaps two, occurs in the sea between Jan Mayen and Spitsbergen. The warm Atlantic water flowing northward in these eddies, bends westward between the 74th and 75th and between the 77th and 78th parallels. According to NANSEN, a branch of the Polar Current flows eastward, participating in the great cyclonic circulation.

In NANSEN's opinion the bay in the ice is formed by the warm Atlantic water flowing westward, while "Odden" is formed when the Polar water flows eastward. He says (l. c. p. 30) (translated from the Norwegian): "This bay is called by the sealers the "Nord-bukta" or the "Bayis-bukta", because the ice found there is mostly new ice, bay ice, and not old ice."

Since EINAR MIKKELSEN's theory of a permanent area of ice north of Danmarks Havn must be abandoned, there is reason to direct our attention to NANSEN's explanation of the Nord-bukta as resulting from circular currents. We are greatly in need of a modern investigation of these eddies, which probably include vertical movements, in the sea north of Jan Mayen. The reader is referred to KIILERICH's chart (1945) which shows westward-moving currents in this place.

An examination of the ice charts published by the Meteorological Institute from 1898 to 1939 shows that in some cases the ice edge forms

a bay about the 75th parallel and south of this a tongue; however, these phenomena are not by far so common within this period (1898—1939) as in the eighties according to NANSEN's description of the seal fishery. The ice charts show the occurrence of the bay and the ice tongue in the following years:

1899 A bay between the 75th and 76th parallels in June.
1901 A bay between the 74th and 75th parallels in August and a marked ice tongue.
1903 A bay between the 75th and 76th parallels in July, probably in August also, and an ice tongue.
1904 A bay between the 75th and 76th parallels in May and June, an ice tongue in July.
1905 A bay between the 74th and 76th parallels in June and between the 73th and 76th parallels with an ice tongue in July.
1906 A bay between the 74th and 75th parallels in June with an ice tongue and a smaller bay in July about the 76th parallel.
1907 A bay between the 75th and 76th parallels in June with a well defined ice tongue.[1]
1908 A bay between the 75th and 76th parallels in June with a well defined ice tongue.
1911 A bay between the 73th and 76th parallels in April with a well defined ice tongue.
1915 A flat bay between the 73th and 76th parallels in April, the ice tongue of small extent.
1927 A bay between the 74th and 75th parallels with a small ice tongue in June.
1932 A bay between the 73th and 77th parallels with a marked ice tongue in June.
1934 A flat bay between the 75th and 77th parallels (with a slightly developed ice tongue).
1938 A bay between the 74th and 76th parallels with an extensive ice tongue in April, May, and, less well defined, in June.

It should be pointed out that in these years the seal fishery was less intensive than in the eighties, so the material at hand is mostly rather incomplete, which is also evident from the ice charts.

It appears, however, from the material at hand that in two years, (1934 and 1938) there was a bay in the ice edge in April, in two years, (1904 and 1938) in May, in ten years, (1899, 1904—08, 1911, 1927, 1932, and 1938) in June, in three years (1903, 1905, 1906) in July, and in two years (1901, 1903) in August. In the period 1898—1918 the bay was developed in 12 years, in the period 1918—1938 in four years, probably because the ice belt was exceptionally narrow in this period, the ice hardly reaching the area of the eddies.

The Nord-bukta, which most frequently occurs in June, is not limited to years with particularly broad ice belts; thus it was present in 1904 and 1932, in which years there were only small quantities of

[1] From May a large tongue of very thin ice far to the eastward between the 74th and 76th parallels is reported.

ice. On the other hand the bay is not reported from several years with fairly large quantities of ice, of which 1918 should especially be mentioned. Altogether it may probably be said that in order that the bay may form, the ice must extend so far seawards as to reach the slightly known eddy in the sea between Jan Mayen and Spitsbergen. NANSEN's contention that the ice of the tongue is nearly always thin (Atlantic Ice) is not altogether supported by the ice charts, which rather convey the impression that the ice of the tongue consists of fairly thick but scattered floes. Probably Atlantic Ice is formed between the heavy floes. The seals especially give birth to their young on the thin floes, and the sealers generally hunt them there.

For the last twenty years ships have only exceptionally entered the ice belt by way of the Nord-bukta, probably because in recent years the ice belt has been narrower and often more compact, so it is of small consequence where it is entered. Thus in the thirties it would seem that most ships entered the ice in c. 74° N. lat. in July; it appears, however, from the charts of the Meteorological Institute that the Nord-bukta, if present, as a rule occurs between the 75th and 76th parallels in June.

Thus it would seem that for the last twenty years the Nord-bukta has been of less importance for navigation than assumed by EINAR MIKKELSEN. Information about it will probably be scarcer in the future owing to the decrease of the seal fishery in these waters in recent years.

Ice Observations from Scoresbysund.

Detailed information about the ice conditions at the mouth of Scoresby Sund is available from July 1924 to and including 1939.

By far the greater number of these data have been supplied by Mr. H. HØEGH, the manager of the colony of Scoresbysund, and are accordingly very uniform. They are supplemented by the observations of the Eskimos living at the colony and the outposts Unartoq near Kap Tobin, Ikterajevit near Kap Hope, and, as to 1925—28, Ivssorigseq near Kap Stewart; in recent years Eskimos have likewise lived for shorter or longer periods near Kap Greg on Liverpool Kyst.

In the immediate vicinity of the colony it is possible to make observations from an altitude of c. 200 m, near Kap Tobin from c. 100 m. In addition valuable data are supplied by the Eskimos after sledge journeys and the climbing of mountains.

A comprehensive observation material is at hand from the last fourteen years, but it would have been desirable that the observers should have had a number of concrete questions to answer each month.

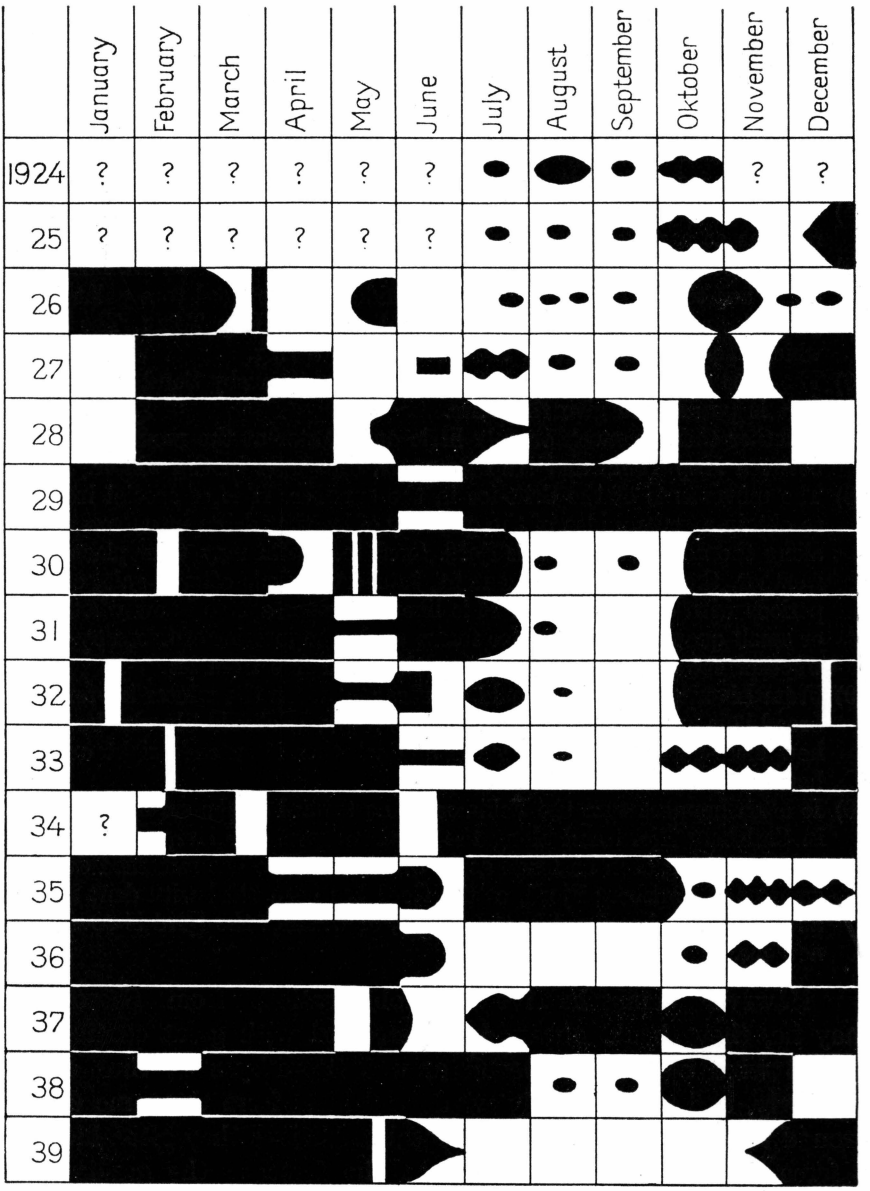


Fig. 81. Graphic representation of the ice observed from Scoresbysund in the period 1924—39. The width of the black belts indicates the quantities of ice observed.

Below I shall attempt to outline a number of such questions for future observation. Thus the following features should be observed:

1) The character of the ice outside the fjord, i. e. the position of the ice edge, whether the ice is scattered or close-packed, whether large spaces of open water occur or the open sea is visible beyond the ice, or whether no ice is

at all found outside the fjord. Whether the swell spreads to the colony even though some ice is found outside the fjord, and whether large quantities of ice occur south of the fjord and only small quantities north of it.

2) When Hvalrosbugt between Ferslews Pynt and Kovait freezes up, when it finally freezes up, and when the ice drifts out in the summer.
3) When Rosenvinge Bugt between Kap Tobin and Kap Hope freezes up and when the ice drifts out.
4) When Hurry Fjord freezes up definitely and when the last ice, which often remains as a plug at the mouth of the fjord, drifts out.
5) When Scoresby Sund between Jameson Land and Christian IX Land freezes up. When there is open water in the middle of the fjord to a point south of Kap Stewart, south of Ikterajevit, and south of Kap Tobin. The dates on which the ice drifts out of the fjord in the spring.
6) The date when the ice plug at the mouth of Scoresby Sund gets detached, if it is possible to give this date.
7) Whether there is much or only little open water at the mouth of the fjord between Kap Tobin and Kap Brewster, especially in the winter.
8) The movements of the drift-ice in the summer. It is of special importance to obtain a general idea of the quantity of ice that drifts into Scoresby Sund along the north side of this fjord. Such ice drifts may take place in calm weather, though to a small extent, in short periods after a gale, or in long periods with easterly winds. It is likewise important to know whether large or small quantities of drift ice freeze up in the interior of Scoresby Sund, or whether the autumnal gales sweep the fjord free from ice.
9) From Liverpool Kyst it should be observed when the winter ice forms, how broad it is, and when it melts or drifts away. It should likewise be observed how close-packed the drift ice is and whether it extends right out to the horizon.
10) It often happens that the Eskimos go northward in the spring to hunt bear in Carlsberg Fjord and along the northern part of Liverpool Kyst. Observations should then be made as to whether the ice has remained during the summer in Carlsberg Fjord, or the fjord has been filled with drift ice in the autumn which has fused in the winter, or whether the fjord is covered with new ice.

However comprehensive the observations from Scoresbysund may be, they should always be interpreted with great caution, since special wind conditions prevail around Scoresbysund; thus easterly, northerly, and northwesterly winds will blow from the same direction around the colony, and owing to local conditions they often blow with a force that is out of proportion to the force of the gradient wind blowing for instance along Liverpool Kyst. Northerly and easterly winds which carry large masses of drift ice into Scoresby Sund and onwards along its north coast often blow with such violence that the whole of Rosenvinge Bugt and of Hurry Fjord as well as the area some distance outside the latter fjord are free from ice during the gale. But as soon as the gale ceases, the close-packed ice masses will spread into Rosenvinge Bugt, filling it completely, and it may likewise enter Hurry Fjord, spreading even beyond Fame Øer.

Westerly winds, and doubtless also foehn winds, may blow with great force in the southern part of Scoresby Sund and across Knud Rasmussens Land; during such periods there is often calm weather at Scoresbysund. This wind is of special importance for the ice drift, as it presses the ice northward, and the water flowing out of Scoresby Sund will then cause the ice to remain off Liverpool Kyst.

Southerly winds, unlike the northerly winds, seem to blow with less force around Scoresbysund than the gradient wind. Finally we must assume that there will always be some currents in the mouth of Scoresby Sund, since water will flow out below the large glaciers in the interior of the fjord even in the winter. As soon as the thaw sets in, huge water masses will, of course, flow out of this, the largest fjord complex of the world. In calm weather there will therefore always be open water at the mouth of the fjord and strong currents may carry the ice far outside the fjord, especially in the spring, if the ice belt is scattered.

Survey of the Observations on the Ice Conditions outside Scoresby Sund in the Years 1924—1939.

January. Observations from 13 years (1924, 1925, 1934 lacking). Close-packed drift-ice outside the fjord in ten years, viz. 1926, 1929, 1930, 1931, 1933, 1935, 1936, 1937, 1938, and 1939. Exceptions are:

1927 The first drift-ice from the north appeared on January 29th, there being hardly any ice in the autumn of 1926.

1928 In the middle of January there was a heavy swell in the fjord, and on the 22nd the ice arrived. There had been much ice in October and December 1927, but not till the end of January was there a continuous drift of ice outside Scoresby Sund.

1932 At the end of the month the ice lay far from the shore.

February. Observations from 14 years (1924 and 1925 lacking). In the following ten years there was close-packed ice outside the fjord: 1926, 1927, 1928, 1929, 1931, 1932, 1935, 1936, 1937, and 1939. Exceptions are:

1930 No "Storis" visible from February 9th—20th.

1933 No ice during short periods about the middle of the month.

1934 Only small quantities of ice at the beginning of the month.

1938 Varying ice conditions with much open water during short periods.

March. Observations from 14 years (1924 and 1925 lacking). Close-packed ice occurred in the following twelve years: 1927, 1928, 1929, 1930, 1931, 1932, 1933, 1935, 1936, 1937, 1938, and 1939. Exceptions are:

1926 No ice visible out to sea till March 28th.

1934 The ice lay almost on the horizon from March 16th.

April. Observations from 14 years (1924 and 1925 lacking). In ten years there was close-packed ice outside the fjord, viz. in 1928, 1929, 1931, 1932, 1933, 1934, 1936, 1937, 1938, and 1939. Exceptions are:

1926 Open water far seawards.
1927 Large quantities of ice, but it lay at a great distance from the shore.
1930 No drift ice visible after April 18th.
1935 The ice outside the fjord was very scattered.

May. Observations from 14 years (1924 and 1925 lacking).
Close-packed ice outside the fjord in five years, viz. 1929, 1933, 1934, 1936, and 1938. Exceptions are:

1926 Open water as far as the horizon during the first week of May. Later the ice again approached the shore.
1927 Large spaces of open water were seen in the ice far outside the fjord.
1928 A belt of open water (20 miles) outside the fjord during the first three weeks of May.
1930 Open water outside the fjord for a couple of days.
1931 Much open water outside the fjord.
1932 Much open water outside the fjord.
1935 The ice was very open.
1937 No large floes visible between May 1st and 17th.
1939 No ice during a few days at the end of the month.

June. Observations available from 13 years (1924, 1925, and 1926 lacking).
Close-packed ice outside the fjord in four years, viz. 1928, 1930, 1931, and 1938. Exceptions are:

1927 Much open water outside the fjord.
1929 Much, but very scattered ice.
1932 Hardly any large floes from the middle of June.
1933 Hardly any ice outside the fjord.
1934 No large floes visible during the first half of the month; later on the ice was very close-packed.
1935 The ice hardly visible after June 20th.
1936 As in 1935.
1937 No ice from June 6th to the end of the month.
1939 A narrow belt of ice at the end of the month.

July. Observations available from 16 years.
Close-packed ice outside the fjord in four years, viz. 1929, 1934, 1935, and 1938. Exceptions are:

1924 Only a very narrow belt of ice outside the fjord.
1925 Only winter ice at the end of the month. Swell in the fjord.
1926 During the first half of the month swell, later some ice drifted into the fjord, but the ice belt was narrow.
1927 A very narrow belt of ice during the last half of the month.
1928 Variable ice conditions, but mostly close-packed ice.
1930 Much ice at the beginning of the month, later on the ice was scattered.
1931 Scattered ice from July 8th.
1932 Varying ice conditions, though mostly scattered ice.
1933 Hardly any ice.
1936 No ice.
1937 Varying ice conditions, a few times open water with large drifts of ice outside the fjord.
1939 No ice.

August. Observations available from 16 years.
Close-packed ice in five years, viz. 1928, 1929, 1934, 1935, and 1937. Exceptions are:

1924 The ice was very open.
1925 Swell at the end of the month.
1926 Scattered ice north of the fjord, close-packed ice south of it.
1927 Scattered ice.
1930, 1931 Very little ice.
1932, 1933 Hardly any ice.
1936 Ice-free water.
1938 Only little ice.
1939 Very little ice.

September. Observations available from 16 years.
Close-packed ice outside the fjord in four years, viz. 1929, 1934, 1935, and 1937. Exceptions are:

1924 The ice belt was very open.
1925 Ice-free water, but drifts of ice passed the mouth of the fjord on September 12th and 17th.
1926 Mostly open water.
1927 A drift of ice at the beginning of the month, otherwise ice-free water.
1928, 1930 Very little ice.
1931 Nearly ice-free water.
1932, 1933, 1936 Ice-free water.
1938 Only little ice.
1939 Ice-free water.

October. Observations available from 15 years (1924 lacking).
Close-packed ice outside the fjord in two years, viz. 1929 and 1934. Exceptions are:

1925 Drifts of ice on the 11th and the 31st, otherwise open water.
1926 The ice arrived from the north about October 15th.
1927 Scattered ice until the 24th, when a large drift of ice arrived.
1928 The ice arrived from the north on October 6th.
1930 Ice-free water until October 12th, when the ice arrived from the north.
1931 Ice-free water till the ice arrived on October 5th.
1932 As in 1931.
1933 A drift of ice arrived on October 8th.
1935 Close-packed ice during the last half of the month.
1936 The first drift of ice arrived about the middle of the month.
1937, 1938 The ice-belt was mostly close-packed, but in both years there were drifts of ice with open water between.
1939 Ice-free water.

November. Observations available from 15 years (1924 lacking).
Close-packed ice outside the fjord in eight years, viz: 1928, 1929, 1930, 1931, 1932, 1934, 1937, and 1938. Exceptions are:

1925 A large drift of ice arrived on November 5th.
1926 No ice after November 22nd.
1927 Scattered ice until November 24th.
1933 Ice appeared now and then.
1935, 1936 Varying ice conditions with drifts of ice interspersed with open water.
1939 The ice arrived about November 10th and soon became close-packed.

December. Observations available from 13 years (1924, 1933, and 1936 lacking). Close-packed ice outside the fjord in six years, viz. 1927, 1929, 1931, 1934, 1937, and 1939. Exceptions are:

1925 The large floes arrived from the north on December 11th.
1926 Very little ice outside the fjord.
1928 The large floes lay at a great distance from the shore.
1930 No ice at the end of the month.
1932 Open water off the fjord about the middle of the month.
1935 Occasional drifts of ice interrupted by open water.
1938 Varying ice conditions with ice drifts but not very much open water.

Ice Observations from Angmagssalik.

Continual observations of the ice are available from Angmagssalik since the year 1899. The situation of Angmagssalik is unfavourable for ice observations since it lies at the mouth of a large north-south directed fjord, and the frequent gales that blow out of this fjord may give rise to the formation of land water in all the months of the year; this belt of land water is often so broad that the ice almost disappears on the horizon.

The situation of Angmagssalik is unfavourable in another respect also. As far as a point slightly north of Angmagssalik the ice stream is generally very broad, especially in the spring, but precisely north and east of the colony the ice stream meets the warm Irminger Current from the south, which causes considerable melting of the ice belt. A glance on the ice charts of the Meteorological Institute shows that the ice belt is much reduced in width near Angmagssalik; from Cape North on Iceland to a little south of Angmagssalik the ice edge has almost a westerly direction.

Of the series of observations available from the east coast of Greenland, that from Angmagssalik covers the longest period of years. The place has the advantage that from the mountains nearby one has a view of about 40 miles seawards and may thus follow the width of the ice belt, so the Eskimos hunting in the mountains may supply valuable information. Observations are lacking for only 14 months of the 39 years during which observations have been made.

I have made an attempt to represent graphically the ice conditions for one year, though I am aware that this is a very difficult experiment,

since here, as from Scoresbysund, precise data are sometimes lacking. Often ice is reported as far as the horizon observed from considerable altitudes. Furthermore it is repeatedly mentioned that the ice belt is so and so many miles broad, and that open water was visible beyond it. Of more local importance is information about the width of the land water between the shore and the ice belt. Much valuable information is likewise given about close-packed or open ice; it is, however, desirable that certain terms should be defined with a view to future observations, so that the different observers may use the same terms to denote the same phenomena.

On the basis of the available series of observations I shall, with great reservation, illustrate the ice conditions (cf. Figs. 82 and 83).

The following facts will appear from these figures:

January	Observations	at	hand	from	37 years.	In 1930 no ice at all.
February	—	—	—	37	—	No year entirely without ice.
March	—	—	—	37	—	
April	—	—	—	38	—	
May	—	—	—	38	—	
June	—	—	—	39	—	
July	—	—	—	38	—	1911 and 1912 entirely without ice.
August	—	—	—	39	—	Seven years, viz. 1903, 1908, 1909, 1912, 1929, 1936, and 1939 ice-free.
September	—	—	—	38	—	Nineteen years, viz. 1899, 1900, 1902, 1903, 1906, 1908, 1909, 1912, 1916, 1917, 1926, 1927, 1929, 1930, 1932, 1933, 1936, 1937, and 1939 ice-free.
October	—	—	—	38	—	Twenty-one years free of ice, viz. 1899, 1900, 1901, 1903, 1906, 1908, 1909, 1911, 1912, 1916, 1918, 1919, 1925, 1926, 1927, 1930, 1931, 1932, 1933, 1936, and 1939.
November	—	—	—	36	—	Seven years ice-free, viz. 1910, 1915, 1925, 1928, 1930, 1936, and 1939.
December	—	—	—	37	—	No year ice-free.

Three years, viz. 1912, 1936, and 1939 were free from ice during four months consecutively. 1936 had the longest ice-free period, lasting more than five months, viz. the last half of June, and from the middle of July to December 19th. In five years, viz. 1903, 1908, 1909, 1927, and 1930, three consecutive months were ice-free. In ten years, viz.

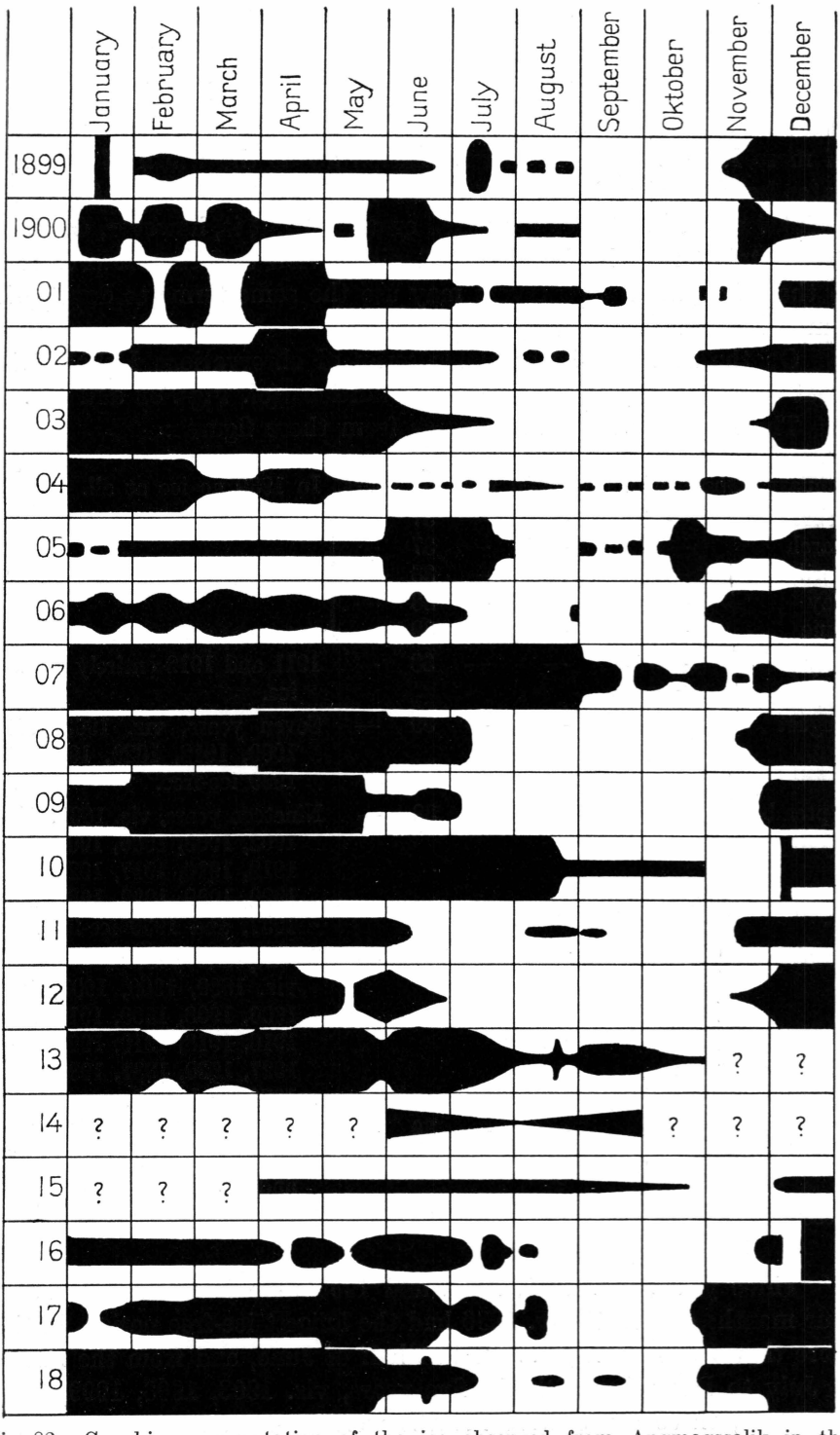


Fig. 82. Graphic representation of the ice observed from Angmagssalik in the period 1899—1939. The width of the black belts indicates the quantities of the ice observed. August 1905 is erroneously indicated as free from ice.

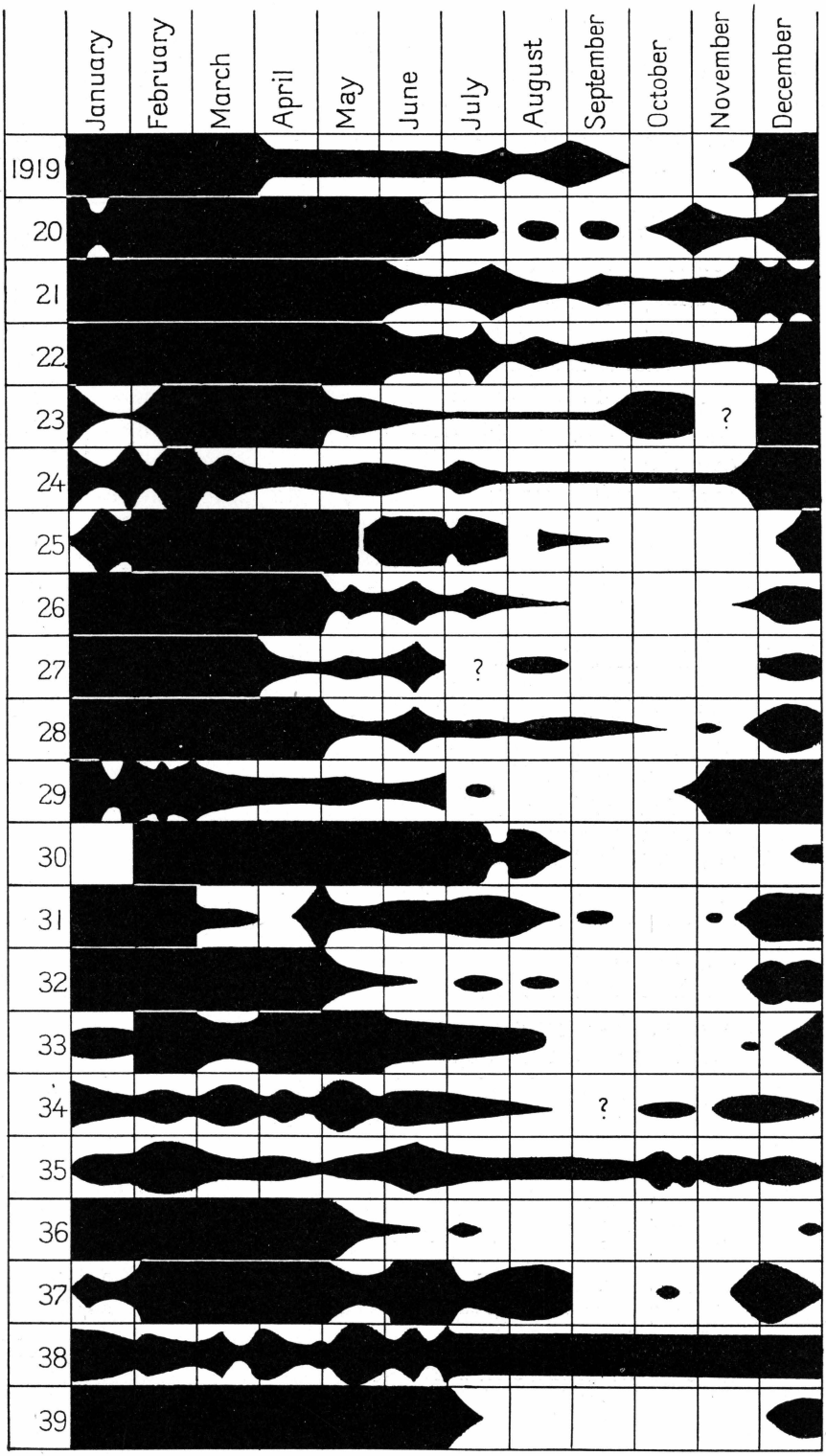


Fig. 83. Cf. the text to Fig. 82.

1899, 1900, 1906, 1911, 1916, 1925, 1926, 1929, 1932, and 1933, two months were ice-free. In eight years, viz. 1901, 1902, 1910, 1915, 1917, 1918, 1919, and 1937, one month was ice-free. For three years, viz. 1905, 1913, and 1934, the summer observations are so deficient that no statistics can be based on them. Finally, in ten years, viz. 1904, 1907, 1914, 1920, 1921, 1922, 1923, 1924, 1935, and 1938, no month was entirely free of ice.

In 1923 there was little ice at the height of summer, but at the end of September heavy ice-masses drifted down, and October quite exceptionally exhibits very heavy ice masses.

The years 1907, 1921, 1922, 1935, and 1938 must be characterised as heavy ice years. It would seem that in 1938 large ice masses passed Angmagssalik not only during the winter, but also during the whole summer and autumn.

The analysis exhibits no actual periods with uniform ice conditions.

The two years 1899 and 1900 were light ice years. The severe ice year of 1907 was followed by two years, 1908 and 1909, with only small quantities of ice, and the relatively severe ice year 1910 was succeeded by the light ice years 1911 and 1912.

In 1914 and 1915 the summers seem to have been especially favourable. As early as the end of March, 1915, and during the rest of the year there was very little ice. Unfortunately observations are lacking for the winters of these two years.

Favourable ice conditions were likewise met with in 1926 and 1932 and, as stated above, 1936, which must be characterised as the most favourable of all the years.

Nothing can be inferred from the observations as to an improvement of the ice conditions in recent times. With some reservation we may perhaps say that the conditions have become more extreme in recent years, since the two severe ice years, 1935 and 1938, occur before and after the very light ice year 1936. But the severest ice year next to 1938 is 1907, and the most favourable next to 1936 is 1912.

It is a general rule that heavy ice masses occur from January to June, when a marked reduction of the ice masses takes place. From the statistics for the ice-free months it appears that September is ice-free in nearly half the number of years, while October is ice-free in well over half of the years.

The dates for the arrival of the ice from the north in the autumn are very interesting. In the three years 1902, 1917, and 1929 the ice arrived in October, in twenty of the 41 years whence observations are at hand the ice arrived in November, and in five years, viz. 1915, 1925, 1930, 1933, and 1936, it arrived in December.

Favourable ice conditions north of Scoresby Sund will, of course, also make themselves felt near Angmagssalik. Thus the favourable ice period near Scoresby Sund 1924—1927 is reflected in the graph (Fig. 83), and the same applies to the years 1930, 1932, 1933, and, of course, 1936.

It is interesting to note, however, that in the ill-famed year 1923 there were only small quantities of ice off Angmagssalik in June, July, August, and the first half of September; not till after the middle of this month did exceptionally large ice masses drift down from the north.

Accordingly, from unfavourable ice conditions in the late summer off Myggbukta and Scoresby Sund we can conclude nothing as to the ice conditions in the early summer, for instance off Angmagssalik. In 1923 rather large ice masses were no doubt present off the central part of the coast, but quite possibly strong easterly winds have forced this ice towards the coast, so that it did not reach Angmagssalik till the end of September and in October.

Similar conditions probably prevailed in 1937, when very small quantities of ice occurred off Angmagssalik in September, October, and the first three weeks of November, while farther northward constant easterly winds kept the ice close to the shore. It is interesting that in 1938 large ice masses passed Angmagssalik in all the months of the year. It is true, that considerable quantities of ice occurred along the coast farther northward also, but owing to the calm weather the ice was scattered, so from the point of view of navigation the conditions along the central part of the coast this year are not of the most unfavourable.

IV.

STATISTICAL TREATMENT OF THE ICE AROUND ICELAND AND SOUTHERN GREENLAND

ICE OBSERVATIONS FROM ICELAND AND SOUTH GREENLAND

Early Literature on the Ice Conditions.

The first data on the conditions in Iceland are due to the Irish monk DIKUIL (825), who wrote them down as they were reported to him by other Irish monks living in Iceland prior to the year 800. He says that no ice was found along the south coast, but ice was encountered north of Iceland after a day's voyage from the north coast.

The Irish monks withdrew or were expelled by the Scandinavian vikings, who settled down on the island in great numbers at the end of the 9th century; the Landnám time (migration period) proper lasted from 870 to 930, during which period Iceland became almost as densely populated as Norway at that time.

The Saga time lasted from 930 to c. 1030. The sagas, however, were not written down till two or three hundred years later, and many of them must be characterised as historic novels, at times probably only little reliable historically. This is possibly the reason why the information about the climate found in the sagas is rather sparse. Two vikings, however, are mentioned directly in this connection. One is the Swede GARDA SVAVASSON, who is reported to have sailed around the whole of Iceland in 864 and to have stayed near Húsavík on the north coast all the winter without observing any ice. The other is the Norwegian FLAKI VILGERDARSSON, who is reported to have stayed for some time about 865 in the northern part of Breiðifjörður on the west coast. In the spring he climbed a mountain, whence he saw a fjord filled with ice (cf. below p. 204). Polar bears are mentioned in some of the sagas (cf. p. 207).

Unlike the sagas, the annals, of which a large number are available, supply various information about the natural conditions.

The earliest annals up to about 1100 are very brief and say nothing about the weather. The annals from the 12th and 13th centuries are more comprehensive, culminating in the 14th and 15th centuries until the year 1430. The information about the ice is, however, sparse, probably

due, to some extent, to the limited communication between the different parts of the country. The annals mostly deal with the so-called bad years (catastrophic years) and the disasters due to the different catastrophes (ice, volcanic eruptions, earthquakes, epidemics, etc.). References to the climate are often found, but it is not always clear whether ice occurred or not.

No annals are at hand from the period 1430 to 1578, and only one annal is preserved from the period 1578 to c. 1640, when annals were common again up to the year 1800.

The sagas give an optimistic picture of life in Iceland, while the annals give a locally marked pessimistic impression. It is no wonder, therefore, that over and over again one is confronted with the view that the Landnám time and the Saga time were happy periods (with a mild climate) in contrast to the succeeding times described in the annals, which appear to be times of depression with many and extensive natural catastrophes.

The bad years described in the annals are dealt with at greater length in a paper from the end of the 18th century by HANS FINSEN (translated and published in Danish 1831). These bad years set in during the latter half of the 13th century, beginning in 1275, when the country was surrounded by drift ice.

Recent Literature on the Ice around Iceland.

Professor TH. THORODDSEN (1884) was the first to give a oomplete account of the occurrence of the drift ice along the coasts of Iceland on the basis of the local literature, which he knew better than most others.

THORODDSEN describes how a year with much drift ice sets its mark on the life in Iceland: fishing is impossible, merchant vessels cannot reach their ports of destination, the constant cold, accompanied by fog and snow, prevents the vegetation from developing, and as a consequence the cattle will die from starvation. The drift ice is characterised as one of the worst evils of the country.

After mentioning the well known sea currents near Iceland, THORODDSEN enumerates a number of years in which the west coast between Reykjanes and Látrabjarg—that is to say, Faxaflói and Breiðifjörður—which is otherwise free of ice, was affected by the ice. Thus he states that in the winter of 1347—48 the inner ramifications of Faxaflói froze up. In 1692, 1699, 1742, and 1880—81 both Faxaflói and Breiðifjörður were frozen up, a circumstance reported in the earlier Icelandic literature to be a great misfortune for the country.

According to THORODDSEN, the 13th century included two very heavy ice years, viz. 1260 and 1275. From the 14th century six years

are mentioned; ice is reported near the east coast in 1320, and in 1348 the whole of Iceland was surrounded by ice. Only one ice year is recorded from the 15th century, viz. 1470, when the drift ice lay around the greater part of the island. Six ice years are mentioned from the 16th century, but none of them would seem to have been very heavy.

As regards the 17th century, information is at hand about twenty-five years, six of which must be regarded as heavy, viz.: 1605, when the ice reached Grindavík, 1609, when the ice reached Krísuvík, 1615, when the ice extended beyond Reykjanes to Vogur, 1639, when the ice reached the outer cape of Reykjanes, 1694, when the ice reached Vestmannaeyjar, and 1695, when the ice surrounded the whole island except Snæfellsnes. Finally, the ice in 1685 is reported to have persisted along the north and east coasts till August 29th.

As to the 18th century, data are available about forty-one years. About 1797 it is mentioned that, for the first time, no ice was observed around Iceland whereas ice occurred along the east coast in 1782, 1792, and 1796. Five heavy ice years are mentioned: in 1745 the ice surrounded almost the whole island, in 1759 the ice extended to the south coast, in 1766 the ice extended from Látrabjarg around the country to Reykjanes, and the same was the case in 1790 and 1791.

A paper by C. Ryder (1896) gathers all the available information on the ice conditions of the North Atlantic, especially around Iceland, in the years 1877—1892; it includes sixteen charts illustrating the ice conditions in these years. Later on Ryder, as chief of the Danish Meteorological Institute, had the opportunity to organise the yearly publications of that office on the ice conditions, including ice charts, at first of the North Atlantic, but from 1901 of all the arctic seas.

In three articles Meinardus (1906) discusses the ice conditions around Iceland in the period 1801—1900 on the basis of Thoroddsen's and Ryder's papers, and the yearly periodicals issued by the Danish Meteorological Institute, pointing out a number of facts.

Of these facts it may be mentioned that April and May represent the culmination of the Icelandic ice season, which lasts from January to July. The months of September, November, and December are characterised as poor in ice, while in October ice has only been observed once in the course of these hundred years, namely in 1894. (It has been impossible to ascertain whence this statement on the ice in October 1894 is derived, but it is not correct).

Meinardus calls attention to the remarkable absence of ice in the years from about 1840 to the middle of the fifties, and on his application to Thoroddsen the latter confirms this in a letter.

MEINARDUS further tries to demonstrate the existence of a 4-5-year period in the ice drift near Iceland; he likewise tries to associate the quantity of ice with the variations of the solar spots, and compares the variations of the climate postulated by BRÜCKNER in 1890 with the ice periods near Iceland.

However, this is now only of historical interest. The same applies to his speculations on the causes and consequences of the ice drift, the variations in the ice near Iceland, and its influence on the temperature of the water and the air of the surrounding regions. Perhaps he treated the information recorded from the 19th century too schematically; thus he did not pay due regard to the period with but little ice in the forties; not least the ice conditions of the present century have shown that those of the 19th century cannot be used as a basis for prognostic considerations as to the ice conditions in the future. Consequently, on studying the ice conditions of the present century one arrives at results quite different from those arrived at by MEINARDUS.

In 1913 OTTO PETTERSSON advanced his sensational theory on variations in the climate in historic and prehistoric times, which gave rise to a discussion on the medieval fluctuations of the climate. The geophysical aspect of his theory will not be considered here.

On pp. 25—28 PETTERSSON discusses the climate in Iceland during the Middle Ages, and after quoting the available information on the climate during the Saga time and the Landnám time, and polemising against FRIDTJOF NANSEN, who in his great work "Nord i Taakeheimen" (1911) mentions that the climate of Iceland has not changed in historic times, he quotes ARNGRIM JONSEN (1593), who held a different view from that of NANSEN; thus he states that the first inhabitants of Iceland were able to cultivate corn.

After quoting THORODDSEN (1884), who states that as far as he has been able to make out, the yearly ice drift near Iceland has not been mentioned until the 13th century, PETTERSSON (p. 27) draws the conclusion that from the 13th century Iceland began to be blocked by the Greenland drift ice to a far greater extent than at the present time.

PETTERSSON's works received a sharp reply from THORODDSEN (1914), who points out that the sagas as a whole show no interest in the climate, and that the drift ice has always been such a common phenomenon near Iceland that there was no reason to record the ice years in the sagas. He mentions several examples of the presence of polar bears in the Landnám time. He likewise states that extremely bad years are mentioned in several of the sagas, notably from 976, and the time before and after seems to have included a number of severe winters.

The same is reported to have been the case in the last ten years of the 10th century and the beginning of the 11th century.

THORODDSEN is of opinion that the catastrophes experienced by the Icelandic population during the 13th and 14th centuries were not due to a deterioration of the climate, but to four other causes, viz.:

1) The violent fights and struggles during the Free State time, when the best men of the country were killed and some of the most able families were extirpated. 2) The transition from the "Herremoral" of the viking period to the introduction of Christianity, which must have relaxed the energy of the inhabitants. 3) The fact that Iceland was associated with Norway, which was then rapidly declining. 4) The trade monopoly, which meant an unfortunate interference with business life.

THORODDSEN points out that, as demonstrated by him, the written sources of information afford grounds for assuming that during the so-called golden era of the Saga time the Icelanders lived under less severe climatic conditions.

He then goes on to mention the Icelandic forests, the number of cattle, the making of bridle-paths, which he views in relation to the present distribution of the glaciers, etc., and he concludes by establishing that no great alterations of the Icelandic climate have taken place in historic times, and that during the whole Free State time the climate was not very much milder than in the succeeding centuries. Periods with bad climate were replaced by periods of mild climate, but in historic times Iceland has never experienced climatic troughs or mountains lasting for long periods, to say nothing of centuries (p. 216).

In spite of THORODDSEN's great authority on all Icelandic questions, the matter was not settled. Already next year EDV. BULL (1915) polemised against the view maintained by THORODDSEN, viz. that the Icelandic climate has not changed in historic times. BULL enumerates a number of bad years within the period 1291—1392, claiming that this period is clearly worse than the times before and after. He concludes by saying that the main point is not whether the climate of Iceland during the Saga time was essentially better than at present, but whether a decided deterioration of the climate may be ascertained to have taken place at a certain time.

THORODDSEN (1915) immediately published a reply to BULL's article, in which he also discussed grain production and horse and cattle breeding, but concludes by quoting a paper by Dr. BULL from 1913 (p. 9) which says that "Problemet om Forholdet mellem Klima og Historie endnu ikke er modnet til Løsning" (the problem of the relation between climate and history is not yet ripe for solution).

A number of other scientists criticised PETTERSON's theory on different grounds, and others, too, besides those mentioned here have treated the supposed deterioration of the Icelandic climate in the 13th and 14th centuries.

By far the most important information on the drift ice around Iceland is supplied by THORODDSEN (1916—17). It is deplorable that this significant paper has only been published in Icelandic.

One chapter (pp. 355—432) deals with the sea ice along the shores of Iceland. It is an extension of his paper in the Ymer of 1884, but while the latter contains a graph showing the distribution of the ice around Iceland in the period 1800 to 1883, his paper of 1916—17 contains a graph (pp. 357—58) representing the ice conditions in the period 1781—1915 (redrawn in Pl. 1).

On pp. 358—59 THORODDSEN mentions the settler Hrafna Flóki [FLAKI VILGERDARSSON], who spent the winter of 865 at Vatnsfjörður near Barðaströnd (cf. p. 199). In the spring he climbed a high mountain, whence he looked down into a fjord filled with drift ice and therefore called the country Iceland. According to THORODDSEN, FLÓKI probably climbed Hornatær, the highest mountain (c. 700 m) in the neighbourhood of his residence. From this mountain he looked across Arnarfjörður and several of the western fjords, possibly Strandir and Húnaflói too. THORODDSEN adds that if Arnarfjörður was full of drift ice, it must have been a severe ice year. However, since FLÓKI possibly had a view of Húnaflói also, which is often filled with ice even in years when there is only little ice, this report cannot be taken to show that there was much ice near Iceland in 865.

THORODDSEN discusses in more detail why drift ice is not reported more frequently from the Landnám time and the Saga time. Thus, he says, the sagas were not written down till a couple of centuries after they took form; they were family histories, which in those times were protected like sacred treasuries and gave special consideration to genealogical tables, feuds, and struggles, whereas nature phenomena are rarely mentioned. He maintains, however, that bad weather and ice must have occurred in the Landnám and Saga times also, and adds that protracted periods of severe weather have rarely occurred in the history of Iceland except caused by or in connection with drift ice.

It would seem that THORODDSEN, sometimes on a very vague basis, has assumed the presence of ice even when bad weather and catastrophes may have been experienced without being due to the ice. Thus he states (pp. 360—61), though pointing out that the reports are not very clear, that 35 vessels were lost in the year 1118, and he goes on to

say (translated from the Icelandic): "It is improbable that the ships were lost in the open sea if they were not crushed by the ice." This does not seem very convincing.

He further mentions a number of disasters that took place in various years prior to 1200, and assumes that they were due to the ice. Thus ice is assumed to have been present, though this is not on record, in the severe winters of 976 and 1056. Large ice masses are reported from the year 1145, but it is not stated where they occurred. In 1181 the growth of grass was poor, and in 1187 a great number of cattle died all over the country. But to conclude that all these disasters were due to the presence of ice, is perhaps to go a little too far.

Looking through his papers from 1884 and 1917, it is interesting to compare the number of heavy ice years found by THORODDSEN. These may be tabulated as follows:

	Ice conditions mentioned		Heavy ice years mentioned		Number of years in which the weather is mentioned
in the papers of.....	1884	1917	1884	1917	1916—17
13th century	5	6	2	3 + 1	40
14th —	6	8	1	2	61
15th —	1	2	1	1	24
16th —	6	10	0	1	48
17th —	25	43	6	8	98
18th —	41	50	5	6	100
19th —	83	99	6	6	100

On reading through THORODDSEN's description of the ice conditions of the past centuries, one receives a somewhat different picture of the occurrence of the ice from that given for instance by MEINARDUS (1906) and partly by SPEERSCHNEIDER (1917), (see below). It is, at any rate, remarkable that during a number of years heavy ice occurred near the northwest fjords as far as Látrabjarg, while ice was sparse around the remaining part of Iceland. It is quite correct that this has rather rarely happened in recent years, but in previous centuries it seems to have been a fairly common phenomenon.

In 1680 the ice entered Breiðifjörður in February. It is added that old people did not remember this having ever taken place, and the young people who had grown up at Breiðifjörður had never seen ice before. In several years it was so cold that the interior of Breiðifjörður and Hvammsfjörður froze up; this took place in 1203, when thirty men are reported to have walked across the ice from the island Flatey to the mainland in the month of July.

In April 1669 Hvammsfjörður was covered with fjord ice.

In 1672 the whole of Ísafjörður and all its ramifications were filled with drift ice, and ice (probably fjord ice) occurred in Hvammsfjörður also.

In 1699, he says, even Hvalfjörður north of Reykjavík froze up.

In 1742 the interior of Breiðifjörður froze up.

In 1767 Patreksfjörður was covered with fjord ice about the middle of May, and drift ice was found in the fjord at the end of the month.

From a number of years ice is reported to have occurred as far south as Látrabjarg. As pointed out by SPEERSCHNEIDER, this may be due to an exceptional width of the ice belt or to westerly winds, which carry the ice towards this part of the coast.

In some years the ice passes westward even beyond Vestmannaeyjar to Grindavík, Reykjanes, and occasionally into the southern part of Faxaflói almost as far as Reykjavík. Thus in April 1695 the ice extended past Reykjanes as far as Hítarós; ice had not then been observed near Suðurnes for eighty years. Of course the fjords in the interior of Faxaflói froze up, making it possible to walk from Akranes to Reykjavík. The ice persisted till the latter half of May. From the north coast no open water could be discerned beyond the ice, even from the highest mountains; from the south coast, however, the open sea was visible beyond the ice, but it was impossible for ships to make their way to the shore.

In 1766 and 1791 the ice likewise reached as far as Reykjanes.

1826 was a peculiar year. No ice is reported from the north coast, but on May 26th, in clear weather, boundless ice masses were observed from Vestmannaeyjar drifting towards these islands. Large icebergs were fused in the ice, which entirely covered the strait between Iceland and the islands, and no open water was visible south of them. It took only four or five hours for the ice drift to pass.

It deserves mention that in some years, for instance in 1824 and 1827, smooth ice, in contradistinction to berg ice, is reported from the east coast. Berg ice should no doubt be taken to mean ice floes with pressure ridges, while the smooth ice is probably Atlantic Ice formed in the months of spring between Iceland and Spitsbergen.

As stated by THORODDSEN, the ice generally approaches Iceland near Horn (Cape North), reaching the shore farther eastward. It may then be carried by the current down along the east and south coasts as a narrow or broad belt.

In several years the Icelandic coasts have been blocked by ice for longer or shorter periods from Látrabjarg in the northwest around the whole country to Reykjanes, while in other years the ice chiefly occurred in the northwestern fjords, and in some years, finally, the ice may

appear first along the east coast, but generally it lies along the north coast.

Protracted periods with ice, lasting for instance from December to the end of the summer, even during the first part of September, are particularly troublesome to the Icelandic population. But the ice may also bring something good, especially in earlier times. Thus bears will often arrive with the ice; bears have been caught along the whole coast of Iceland except along the west coast between Látrabjarg and Reykjanes. It seems, however, that bears have sometimes gone ashore in years when there was not very much ice[1]). Normally the bears remain in the drift ice, and there is nothing to indicate that they have gone ashore in Iceland to breed. In East Greenland I have experienced that when a fairly broad belt of ice suddenly melts, as happened for instance in 1936 between Scoresby Sund and Sabine Ø, the bears will walk or swim ashore; suggestions in the Icelandic literature would seem to show that when drift ice, even small quantities, approached the north coast of Iceland, the bears that happened to be near the shore and thus had got into the warm current where the ice melts, would go ashore. Accordingly the presence of bears need not mean that there has been abundant ice, but merely that the ice has suddenly melted when the bears were near the shore.

Prior to the time of the whalers, from about the year 1600, a greater number of bears no doubt lived near the ice edge, and thus there were greater possibilities for them to go ashore in Iceland. In the Middle Ages bear skins were used in the Icelandic churches before the altar, in order that the clergymen should not get cold. In dry churches such a bear skin might last for about a hundred years.

But other animals, also, live in the drift ice. Thus when the ice approaches the north coast there will often be ample opportunity of hunting seal. Generally only small seals occur, but in 1718, it is reported, large numbers of Greenland seals (*Phoca grönlandica*) were found near Melrakkaslétta.

Walruses rarely appear near Iceland. In 1672, however, a walrus was observed in Dýrafjörður in the west country. In 1708 ice occurred along the north coast once or twice, and when it disappeared on June 10th, many walruses approached the shore.

In earlier times large whales arrived with the ice. Small whales, narwhals and dolphins (a term including different small species of whale) likewise occurred along the coasts of Iceland.

Large masses of drift-wood are recorded from several years, thus from 1749 and 1750.

[1]) In October 1773 a bear with two cubs arrived at Dýrafjörður (the only example showing that ice has occurred near Iceland in October).

The presence of icebergs is often reported; they may be carried by the current even to some distance south of Reykjanes, though they rarely reach thus far. Their occurrence is independent of the greater or smaller quantities of drift ice; it may perhaps be claimed that in years with no drift ice the occurrence of icebergs is the more probable.

In 1932, during my flight from Scoresbysund to Reykjavík at the end of August, not a single ice floe was observed south of Scoresby Sund, whereas a large number of icebergs occurred in the sea between Greenland and Iceland very near the northwest coast of Iceland.

The information on the ice conditions within the individual centuries given by THORODDSEN may be summarised as follows:

1201—1300	The	whole	country	was	surrounded	by	ice[1]) in	4 years.
1301—1400	—	—	—	—	—	—	2	—
1401—1500	—	—	—	—	—	—	1	—
1501—1600	—	—	—	—	—	—	1	—
1601—1700	—	—	—	—	—	—	8	—
1701—1800	—	—	—	—	—	—	6	—
1801—1900	—	—	—	—	—	—	6	—
1901—1939	—	—	—	—	—	—	1	—

The year within historic times in which ice was most abundant around Iceland was absolutely 1695.

In his paper of 1916 THORODDSEN gives more detailed information about the ice than in 1884, but in the latter paper he gives a brief, but very instructive, description, which will be quoted in extenso here. It runs as follows (translated from the Swedish):

"1695. — The drift ice surrounded the whole country with the exception of Snæfellsnes, which is unexampled in history. In most places it was present in such large quantities that open water could not be seen from the highest mountains, and the merchant vessels could not make their way to the shore.

The ice drifted from the north country to the east country, then southward, and as early as April it reached Þorlákshöfn, whence it continued all the way to Mýrar (to Hítarós). From the northwest the ice drifted past Látrabjarg into Breiðifjörður. At the beginning of May it was possible to walk or ride outside all the fjords of the north country."

In 1917 C. I. H. SPEERSCHNEIDER published a comprehensive survey of the ice conditions of the Arctic seas. On pp. 9—12 he treats the ice conditions around Iceland on the basis of THORODDSEN's paper of 1884, RYDER's article of 1896, and the yearly publications of the Danish Meteorological Institute. On p. 10 the paper contains the table reproduced below:

[1]) "Surrounded by ice" generally means that ice occurred from Látrabjarg eastward to Vestmannaeyjar or Reykjanes.

The appearance of ice at Iceland during 109 years (1800—1892 and 1895—1910).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Number of years with ice in the various months	26	34	45	58	61	44	22	15	4	0	3	4
Number of years in which the first ice has appeared in the various months.....	24	14	17	18	6	5	1	2	0	0	0	3
When ice has been observed for more than 3 months, it first appeared	14	5	8	3	0	0	0	0	0	0	0	2
When ice first appeared in January it was last observed	3	1	4	1	4	1	5	5	0	0	0	0

SPEERSCHNEIDER does not deal very much with ice-free periods and periods rich in ice. He writes on p. 11:

"Any decided period for the appearance of ice can not be found. At times years with no ice interchange with years rich in ice, at other times plenty of ice or no ice for a succession of years. Thus from 1827 to 1840 ice was observed in about 30 different months all told, while from 1840 to 1854 only in 4 months. Of the 16 years from 1895 to 1910 only two (1896 and 1902) had ice for more than 3 months, the other years had only very little ice."

Furthermore, SPEERSCHNEIDER takes a survey of the ways in which the ice reaches Iceland, a somewhat one-sided survey, however, as he did not know THORODDSEN's work of 1916—17 and therefore only takes the brief information on the ice in the 19th and 20th centuries into consideration. The same paper contains five ice charts for the months April-August, which show the average limit of the ice in 1898—1913.

The most important source of information about the ice conditions around Iceland at the present day is the yearly periodical issued by the Danish Meteorological Institute, entitled "The Ice Conditions of the Arctic Seas", which first appeared in 1893, and which contains all the available information on the ice conditions, those around Iceland of course included, accompanied by ice charts for the months April—August. During the first years this periodical was published in Danish and French, then, up to 1926, in Danish and English, and since 1927 in English only.

Once again, in 1925, the dispute flared up as to whether the climate of Iceland was ameliorated during the Saga time or it had remained unaltered during historic times. The occasion was POUL NØRLUND's

(1924) paper on the excavations at Herjolfsnes in southern Greenland (see below).

It was FRIDTJOF NANSEN who in 1925 started the polemics against POUL NØRLUND's assumption of a milder climate in southern Greenland during the first time of the Norse settlers there. In a chapter entitled "Isforholdene og Klimaet paa Island" (pp. 24—34) NANSEN recapitulates the different views as to the Icelandic climate during the Middle Ages, and concludes by saying that judging from all the available sources of information the climate of Iceland and the ice conditions along its shores have in all essentials remained unaltered since the time of the first settlers, even though there, as everywhere, periods of cold years have alternated with periods with a milder climate.

Fluctuations of the Climate in Iceland.

It will be evident from the above that the Icelandic sources of information as far back as the 9th century contribute more than those of any other country to our knowledge of the distribution of the East Greenland Ice. Professor THORODDSEN, Iceland's greatest authority so far in the field of natural science, during his whole life advocated the view that the climate of Iceland had not changed for centuries, as far back as it was possible to trace it.

It is a fact, however, that in the Landnám time from 870 to 930 an extensive migration took place from Europe to the north coast of Iceland. In the Saga time from 930 to 1030 there was a lively communication by sea with foreign countries as well as an extensive traffic between the various parts of the country. One can hardly imagine that many and heavy ice years occurred within this period, it is especially difficult to believe that there were many ice summers, that is to say, summers in which the drift ice blocked up to three-fourths of the coasts of Iceland, making all navigation impossible most of the summer. Hence theories as to less ice around Iceland during the first part of historic times constantly come up. Possibly, however, careful pollen investigations of the Icelandic bogs around the earliest house ruins may lead to a solution of the problem.

What especially makes the early discussion on fluctuations of the Icelandic climate less topical, is the fact that it has not been sufficiently defined to what extent the climate must have differed from the climate of to-day in order to render the medieval migration and the first flowering of culture in Iceland possible.

THORODDSEN wrote his first survey of the ice conditions in Iceland immediately after the two heavy ice years 1881 and 1882. The only

period with a mild elimate to which he gave attention was the fourteen-year period 1840—1854. In 1916—17 he treated the Icelandic ice conditions for the last time. In the intermediate years an amelioration of the climate had indeed taken place, but the culmination of this amelioration did not occur till after THORODDSEN's death and consequently he never himself experienced a real and protracted amelioration of the climate like that known from the last two decades.

Speaking about an amelioration of the climate, one must realise that it need not be very marked to create favourable conditions for navigation around and immigration into Iceland. It may even be maintained that during the last half century, from 1894 to the present time, ice conditions have on the whole been so good that not even one year can be characterised as a heavy ice year.

If, therefore, the climate during the Landnám time was like the Icelandic climate of the forties of the last century and the thirties of the present century, and the climate during the Saga time was like that of the first forty years of the present century, this would suffice to afford conditions for intensive navigation and colonisation in Iceland, and for a flowering of culture in the Saga time.

It must be borne in mind that the so-called bad years were due to many other causes (volcanic eruptions, epidemics among animals and men, depression of the social conditions in Norway, with which Iceland was associated commercially), but until now these catastrophes have not been considered in statistic treatments of the ice.

Remarks on the Ice-maps.

Below a new method of division will be attempted, based on the width of the ice belt north of Iceland, which will be characterised as narrow (A-year), broad (B-year), or very broad (C-year). Consideration is only given to the ice belt during the month in which it reaches its maximum width, irrespectively of the month in which it happens. The length of the period in which the ice remains near Iceland is not taken into consideration, since this is due to currents and the wind. However, by this method we gain an impression of the quantity of ice which passes southward between Greenland and Iceland every year, especially in years rich in ice.

A-years. — The ice belt is narrow all the year round. This means that the outer limit of the ice belt during its maximum width is not very distant from 67° N. lat., 20° W. long. When the ice belt is narrow, the occurrence of the ice along the shores of Iceland will always be of short duration.

A. 1. — The ice belt does not fill the waterway between Iceland and Greenland. Iceland is free of ice throughout the year.

A. 2. — The ice belt touches the north or the west coast. Iceland is almost free of ice.

A. 3. — The ice enters Húnaflói and shows a tendency to persist there for some time.

A. 4. — The ice is carried by the northern branch of the Irminger Current along the shore to the east coast, in rarer cases to the south coast, and sometimes as far as Vestmannaeyjar.

B-years. — A broad ice belt north of Iceland. In about 67° N. lat. the ice edge occurs near 15° W. long.

B. 1. — The ice belt does not reach the coast. Iceland is free of ice.

B. 2. — The ice belt reaches the north or east coast along a short stretch.

B. 3. — The ice belt lies along the whole north coast, and part of the ice may be carried by the current down the east coast.

C-years. — A very broad belt of ice north of Iceland. In c. 65° N. lat. the ice edge occurs near 12° W. long.

C. 1. — The whole east coast is skirted by a broad belt of ice.

C. 2. — The northwest, north, east, and south coasts of Iceland are surrounded by large ice masses.

C. 3. — The west coast, also, comes into touch with the ice masses, ice drifting into Breiðifjörður or Faxaflói, and the inner ramifications of these two bays are frozen up.

Turning now to the influence of the ice on the climate and the navigation, we shall find that in years of types A. 1 and A. 2 hardly any influence is traceable. Type A. 3 may affect the climate of the north country for a short period, while type A. 4 affects the climate of the south country, too, for short periods; both the latter types may cause great trouble to navigation for short periods.

All the B-types give rise to a more or less cold climate in the north country, but often clear weather in the south country. Locally they may greatly hamper the navigation.

The C-types affect the climate and navigation of the whole of Iceland, as a rule at the end of the winter, during the whole of the spring, and sometimes throughout the summer also.

However obvious is the influence of the ice on the weather, at any rate in heavy ice years, such weather situations may, of course, arise in which other factors are predominant.

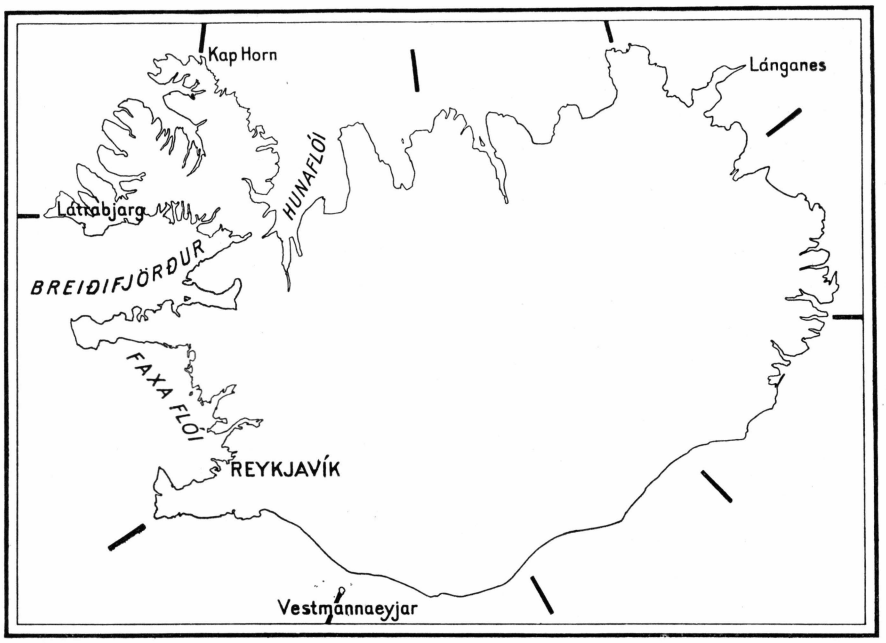


Fig. 84. The districts (each c. 140 km long) into which the coast of Iceland has been divided for the purpose of indicating the occurrence of the ice.

Figs. 85—98 show these types worked out on the basis of the good ice charts available for the last sixty-two years. This period may conveniently be divided into three periods of twenty years each.

All the ice years within the period 1920—39 will be seen to have A-values, even low A-values, with the exception of the years 1938, 1932, and 1921, which have B-values, the ice belt being narrow throughout this period with the exception of these three years.

In eight of the years the drift ice did not fill the waterway between Greenland and Iceland, and Iceland was thus free of ice all the year round.

Six years were of the A. 2 type, that is to say, the ice touched the coasts of Iceland.

Three years were of type A. 3. Of these mention should especially be made of the year 1929, when the ice occurred rather far from the coasts of Iceland to and including the month of June. In June the ice belt between the Denmark Strait and Spitsbergen attained only half its normal breadth. In July, however, very abnormal ice conditions prevailed within the triangle Angmagssalik-Cape North, and Scoresby Sund, and in July and August the ice reached the shore between Cape North and Skagatá. The "Meteorologisk Instituts Aarbog" 1929 (pp. 11—12),

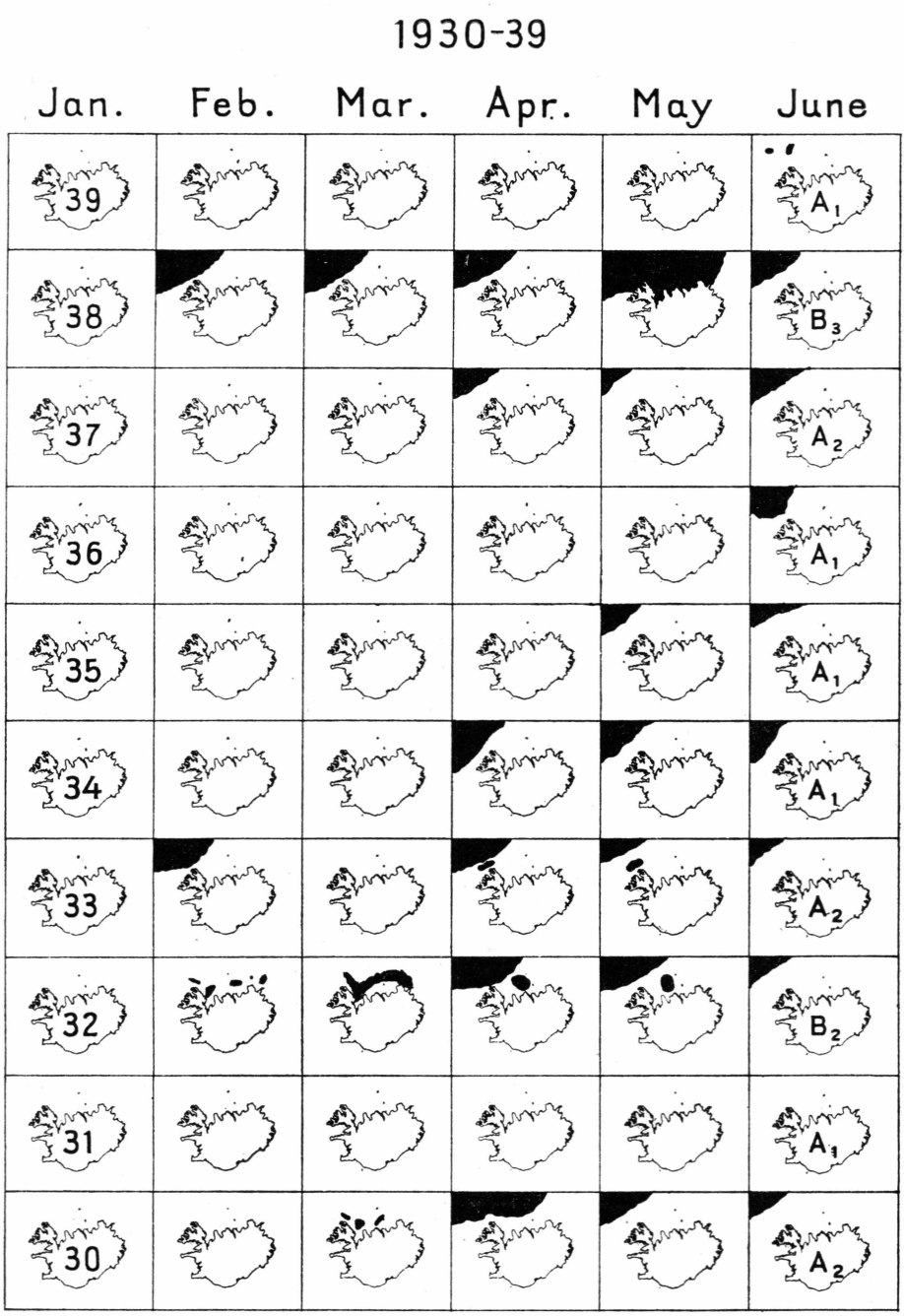


Fig. 85. Monthly ice charts of the Icelandic waters from 1877—1939, according to the year-books issued by the Danish Meteorological Institute and the papers by RYDER and other authors.

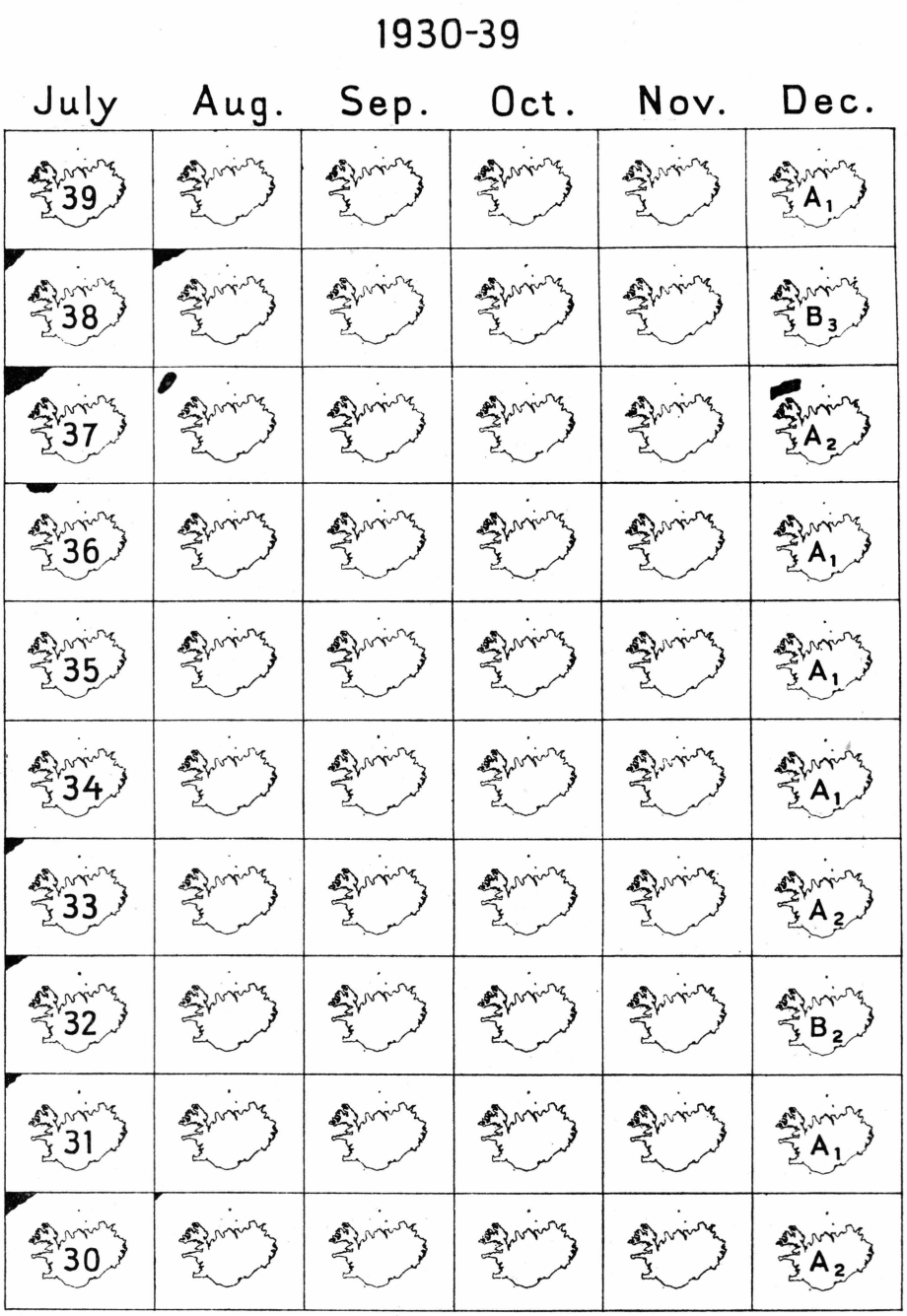


Fig. 86. Cf. the text to Fig. 85.

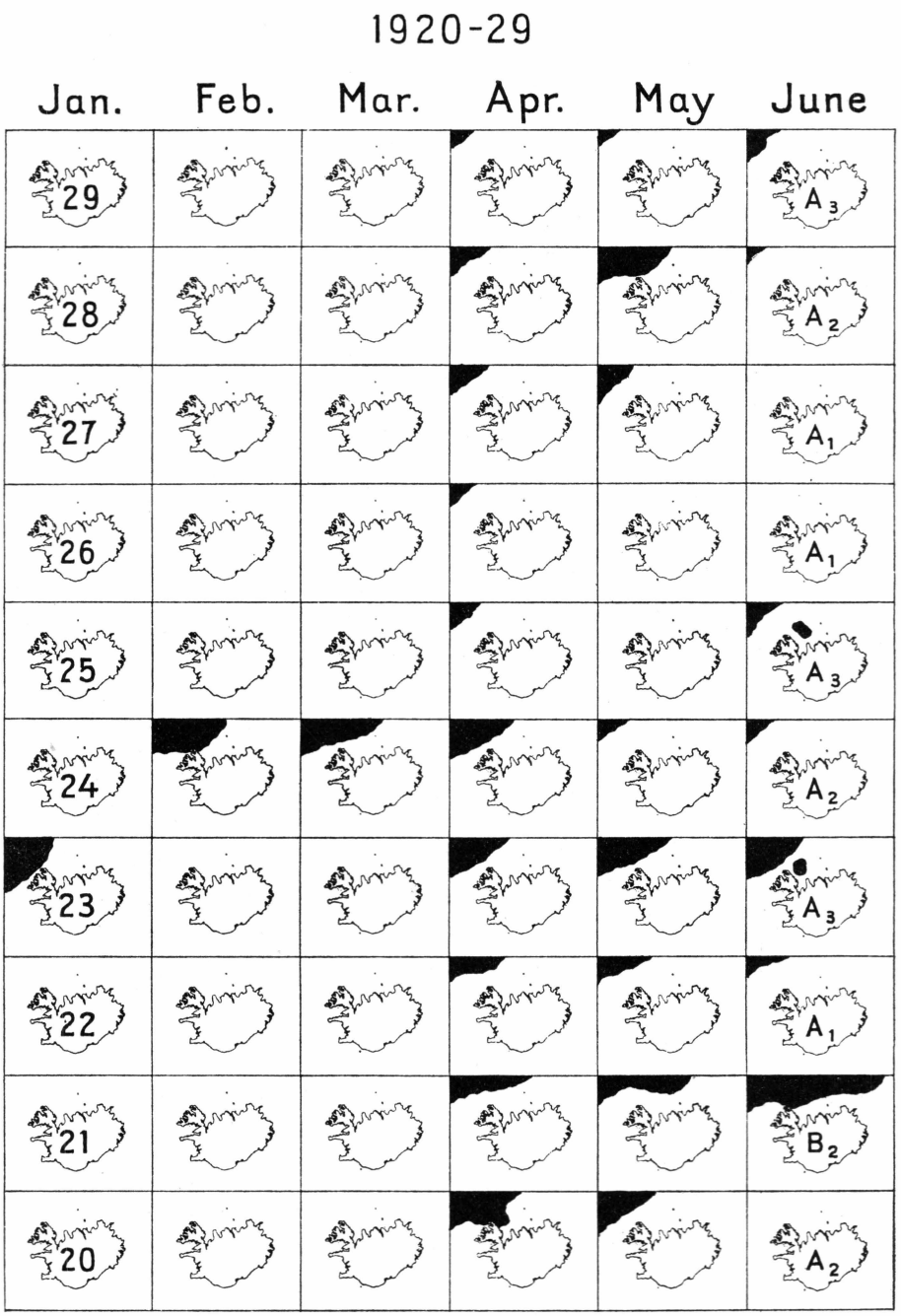
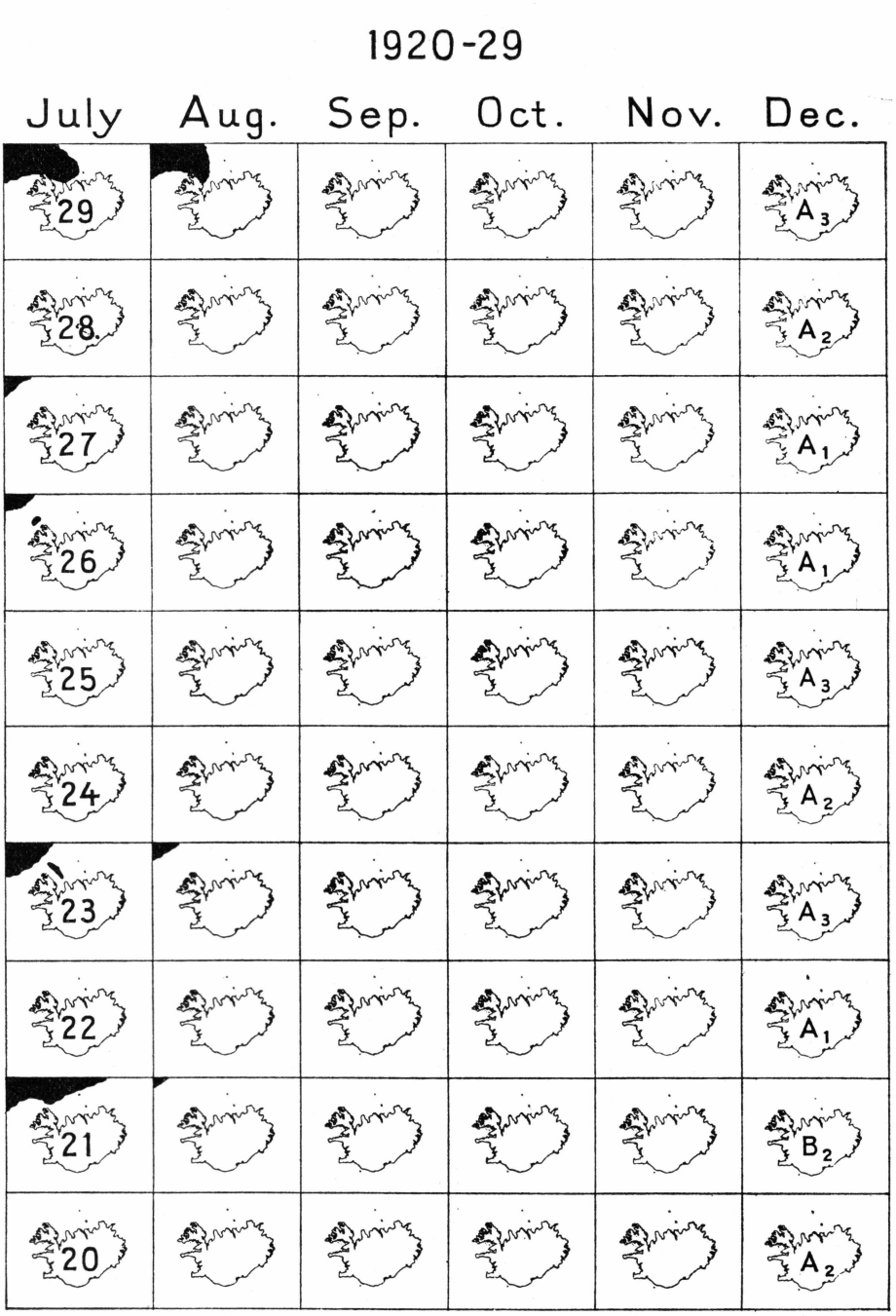


Fig. 87. Cf. the text to Fig. 85.



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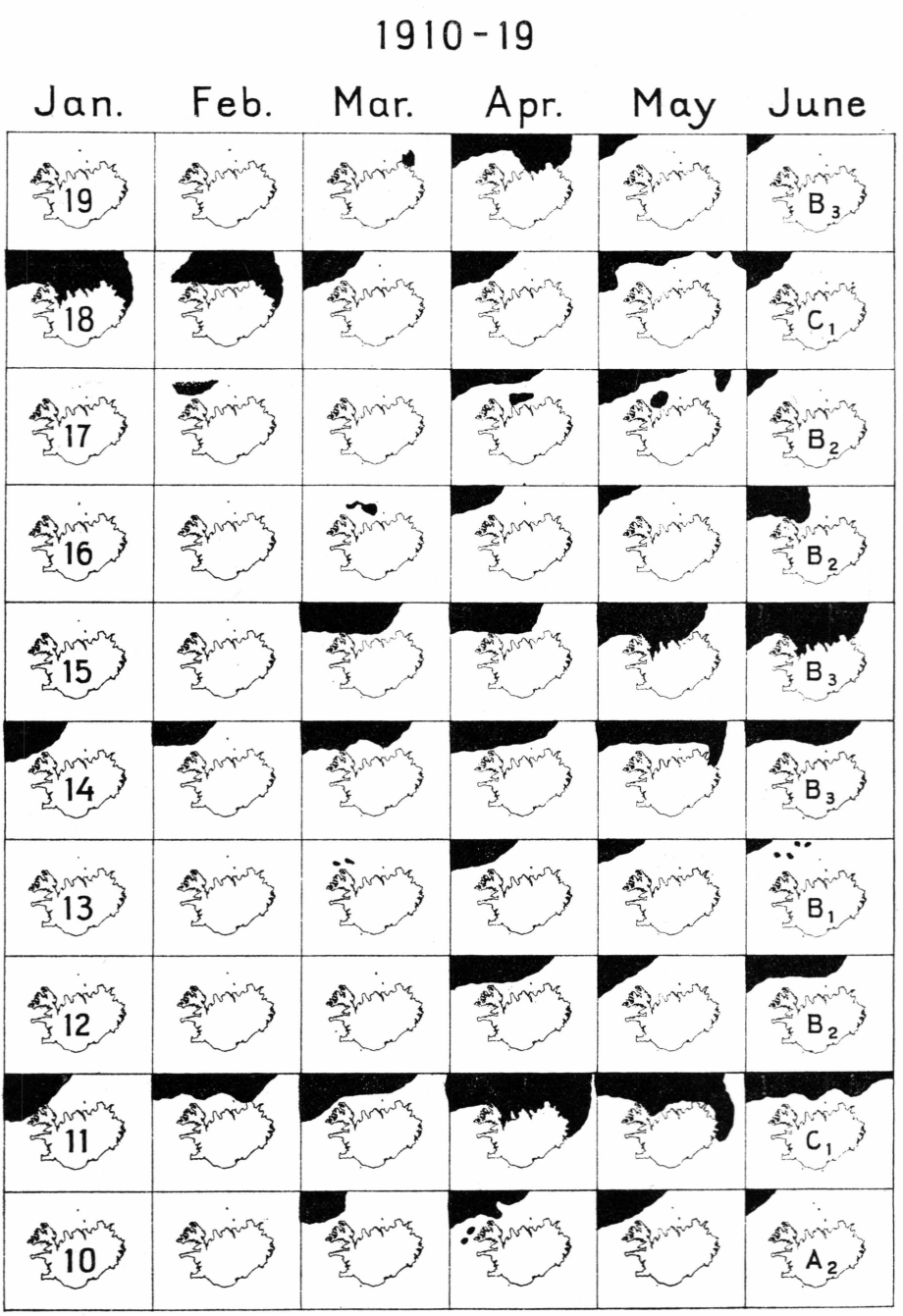
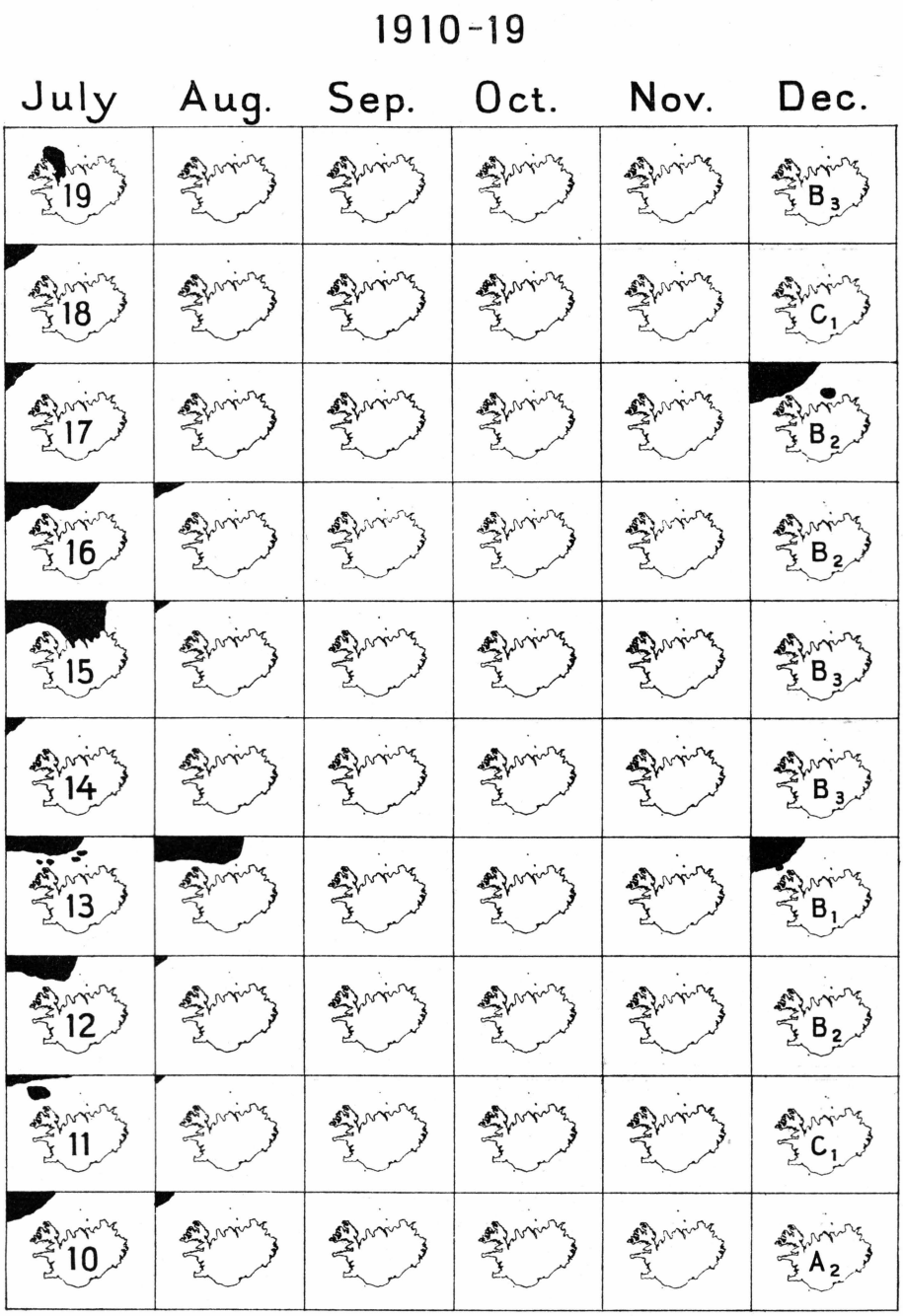


Fig. 89. Cf. the text to Fig. 85.



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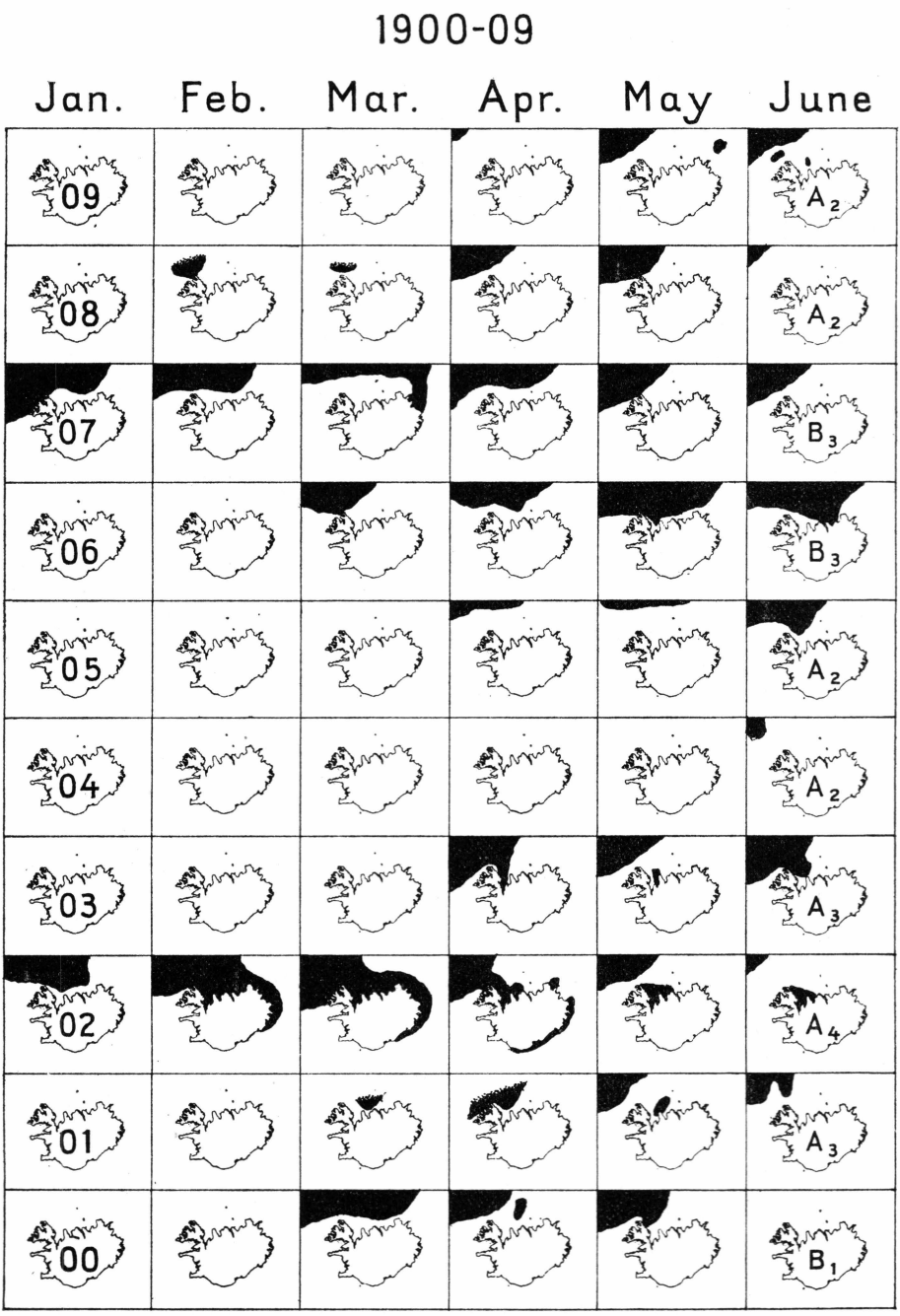
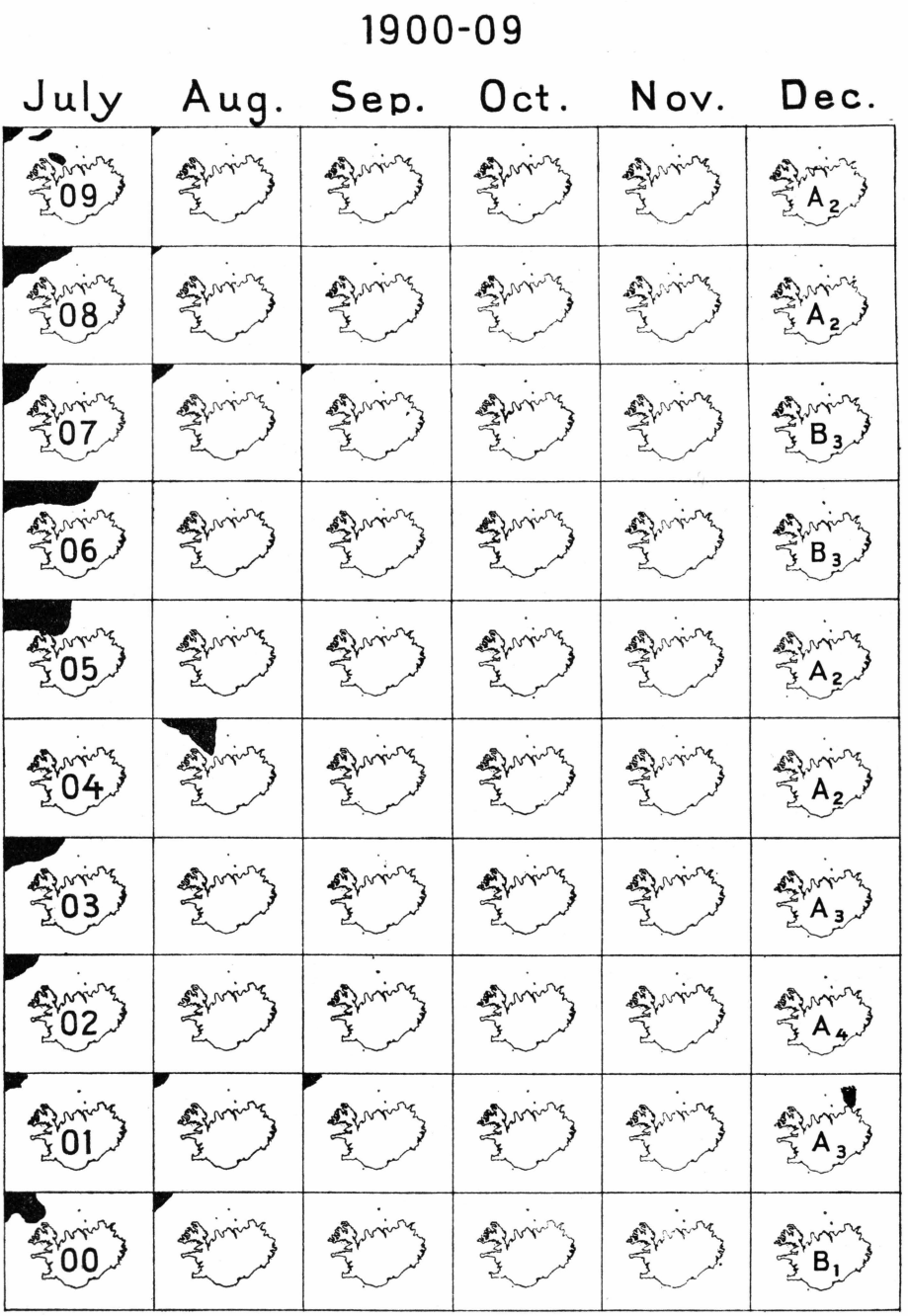


Fig. 91. Cf. the text to Fig. 85.



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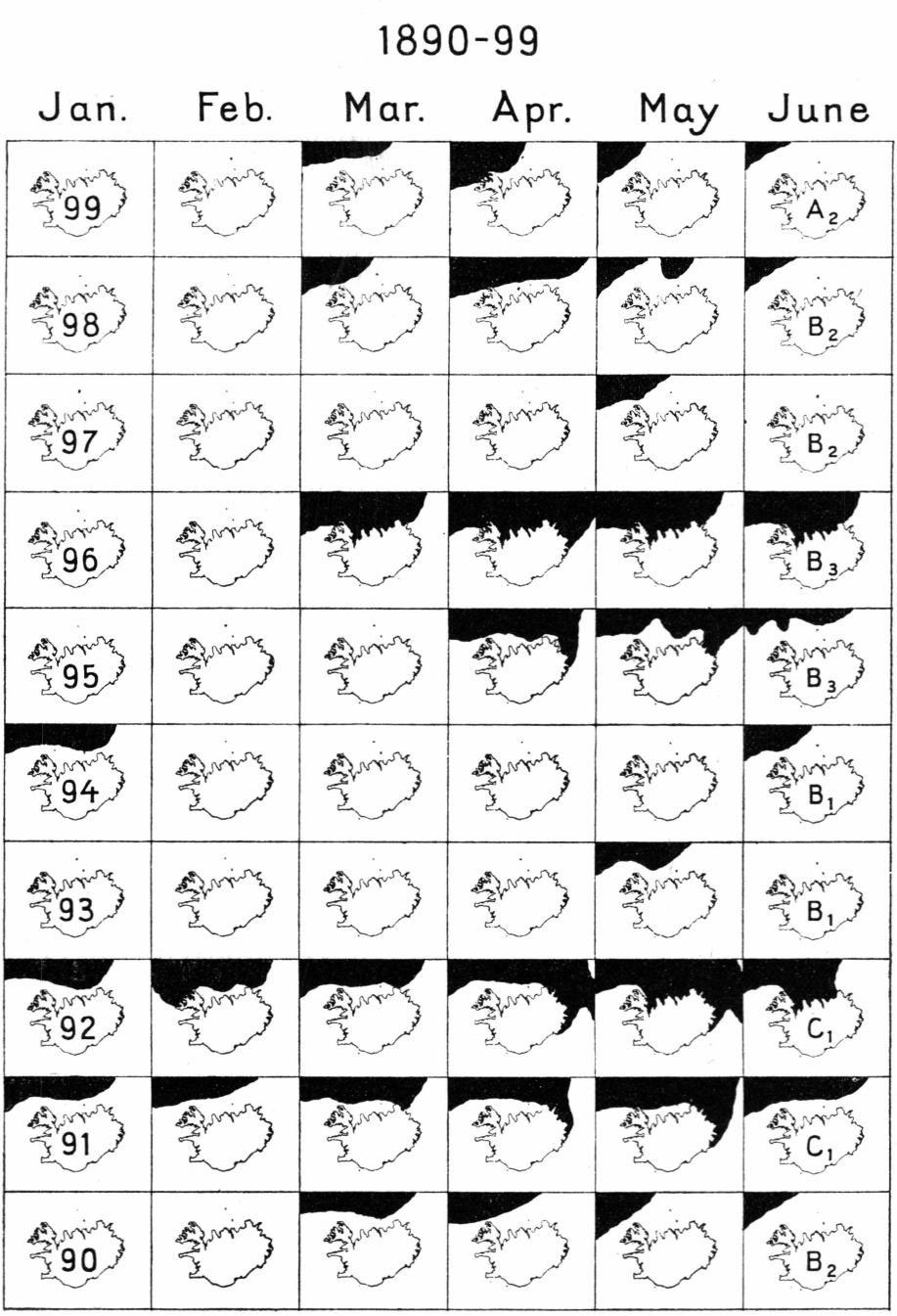
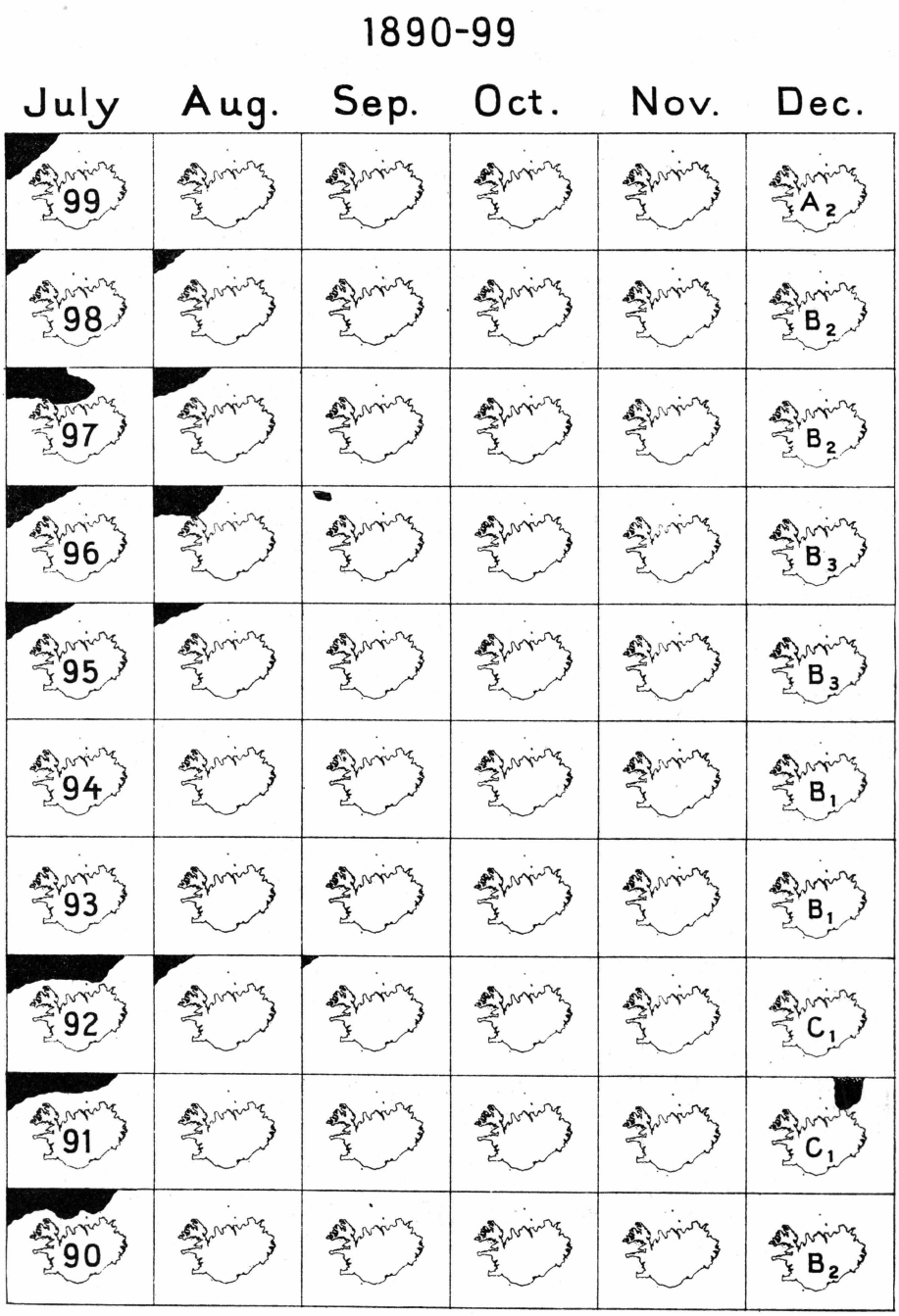


Fig. 93. Cf. the text to Fig. 85.



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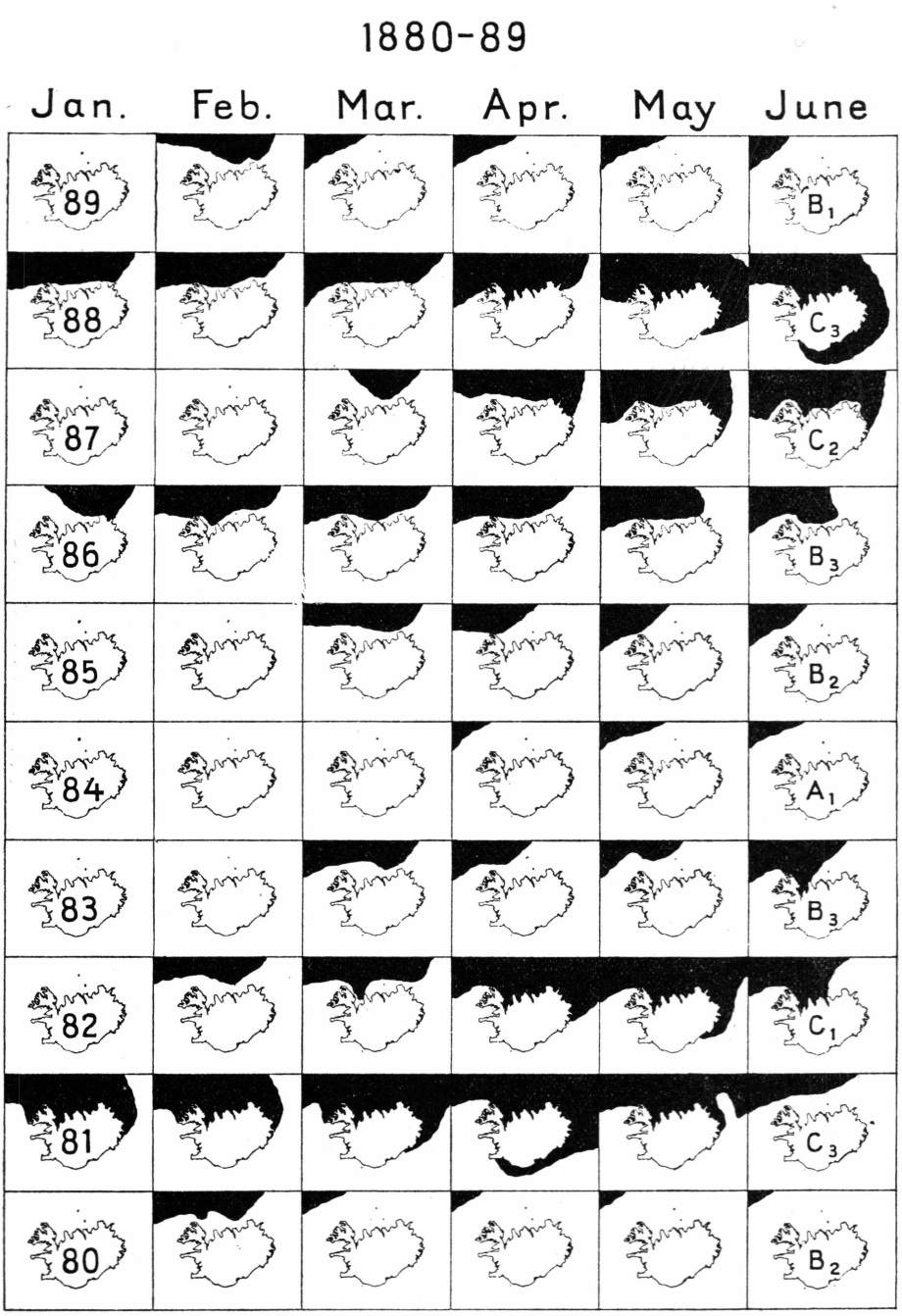

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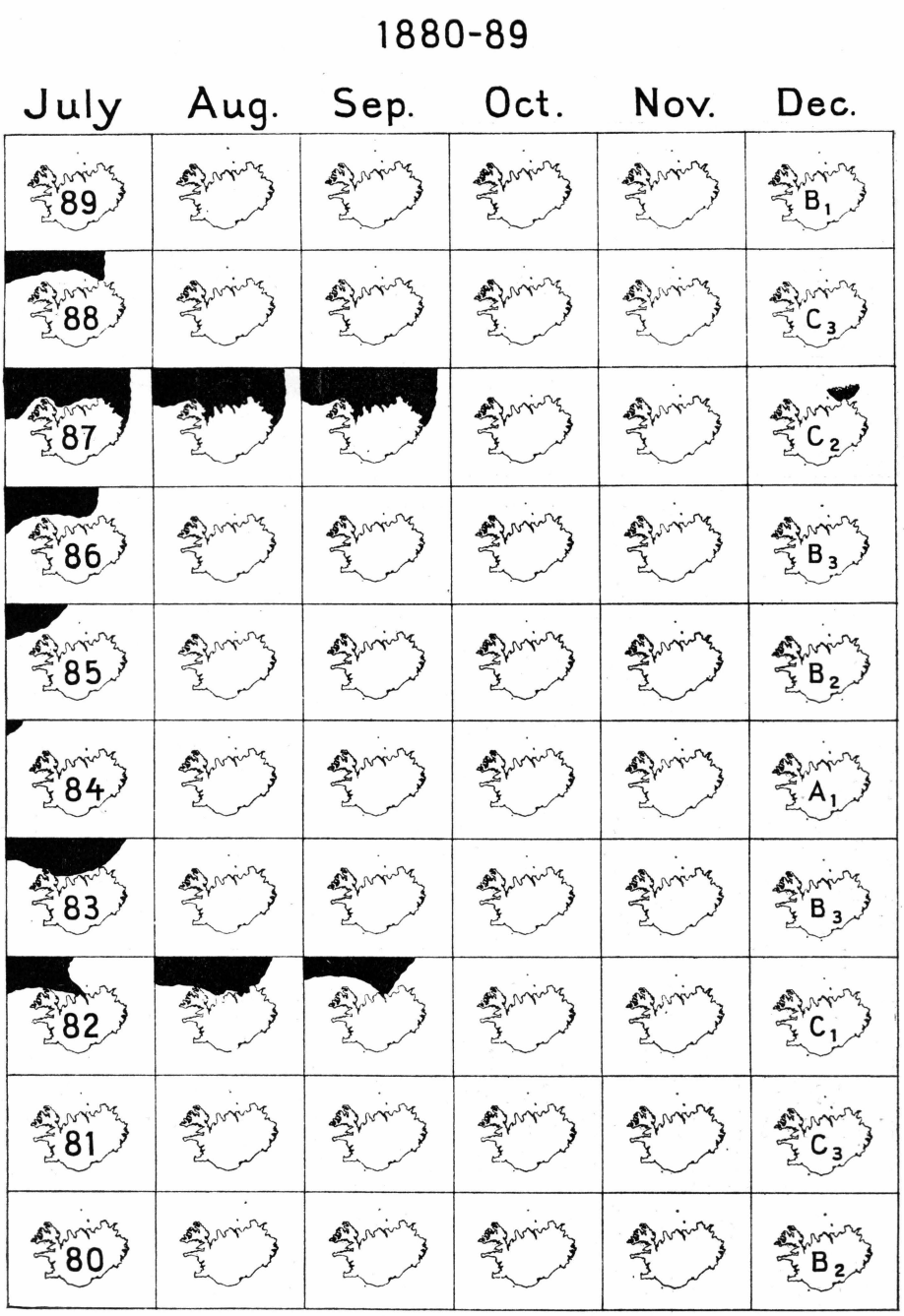


Fig. 96. Cf. the text to Fig. 85.

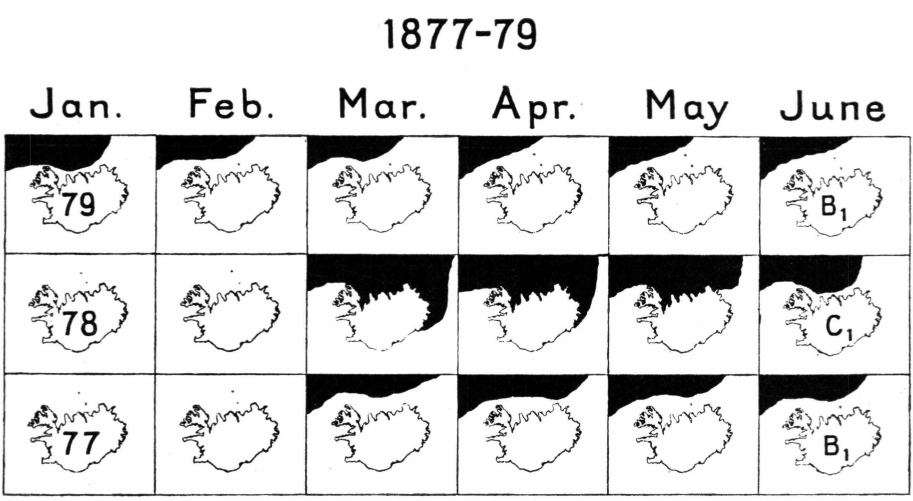


Fig. 97. Cf. the text to Fig. 85.

contains the following passage, which probably explains the peculiar ice conditions in July and August of that year: "A little before the middle of July strong northerly winds were blowing between Jan Mayen and Greenland and also north of Iceland, while southerly winds were predominant south of Angmagssalik. These conditions have probably been the cause of the great accumulation of ice on the northwest coast of Iceland."

These years represent the period of the most favourable ice conditions known from Iceland: in eight years the ice lay at a great distance from Iceland all the year round, in one year (1938) ice occurred along the whole north coast during a short period, otherwise only small areas of the north coast were in touch with the ice for short periods. The ice was entirely absent from the east and south coasts.

In no year within the period 1900—1919 did the ice remain at a distance from Iceland all the year round.

The period includes eight A-years, but one of them, 1902, shows the highest possible A value, a narrow belt of ice reaching Vestmannaeyjar for a short period. Furthermore ten B-years and two C-years.

In the third period 1880—99 the conditions in Iceland were more severe than during the two periods of the present century just described.

The year 1881 may probably be characterised as the severest ice year in Iceland after 1800. As early as January the whole northwest, north, and east coasts were blocked by ice, which condition lasted till the beginning of May. In April the ice began to spread to the south coast, and in May a very broad belt of ice extended along the east

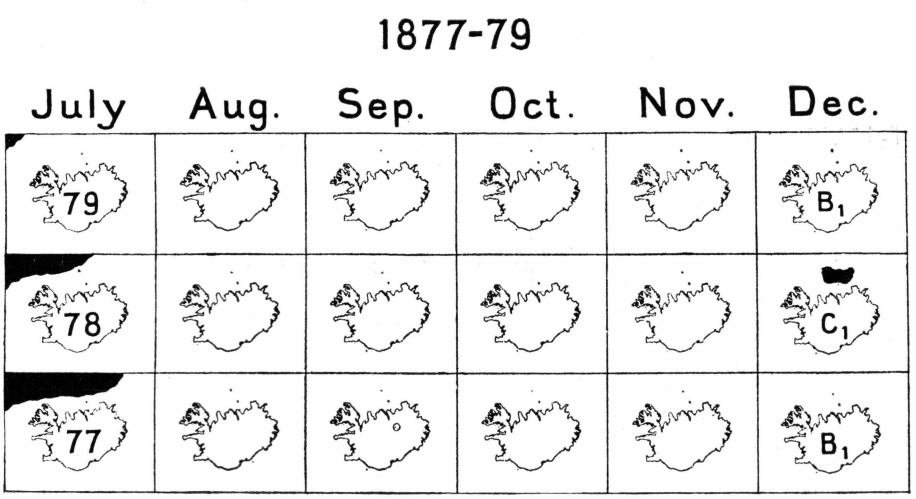


Fig. 98. Cf. the text to Fig. 85.

coast and a fairly broad ice belt along the south coast as far as Reykjanes.

On considering the last sixty years, it will be seen that the period

1920—39	includes	17	A-years,	3	B-years,	0	C-years,	altogether	17	months	with	ice
1900—19	—	8	—	10	—	2	—	—	48	—	—	-
1880—99	—	2	—	12	—	6	—	—	67	—	—	-

This shows that despite all the variations in the individual years, a constant improvement of the ice conditions around Iceland has taken place since the culmination of the heavy ice years at the beginning of the eighties of the last century, the breadth of the ice belt having constantly decreased from this time to the present.

The Iee between 65° N. lat. and Kap Farvel.

As stated above, the ice changes its character in the area between Iceland and the Angmagssalik district. The chief cause of this is that slightly north of 65° N. lat. the drift ice meets the westward-moving Irminger Current, which forces the north-south-moving Polar Current westward, and large ice masses melt where the two currents meet.

The Gulf Stream issues some few warm branches towards the Polar Current, and easterly winds occur especially in front of the margin of depressions moving north- or northeastwards, but north of Iceland the swell is hardly traceable very far into the ice belt.

South of 65° N. lat. conditions are quite different. Heavy gales, often blowing from the south, may even in the winter give rise to a

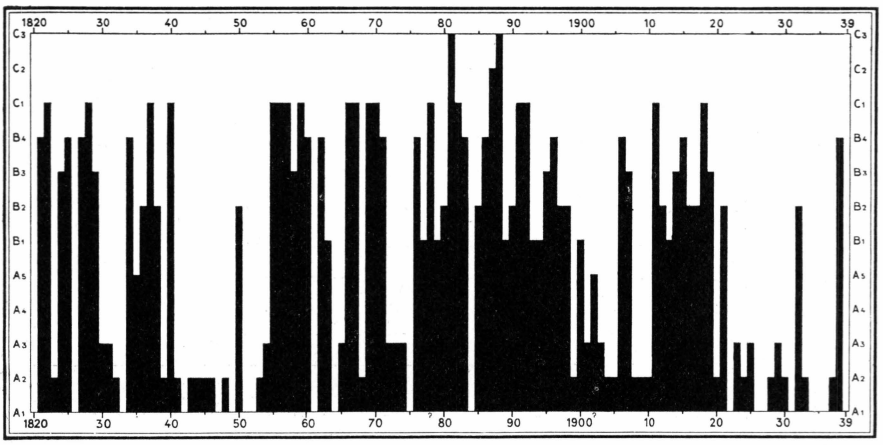


Fig. 99. Diagram showing the quantities of ice according to the A-B-C-method.

heavy swell, which is traceable through the whole width of the ice belt right in to the shore. The ice belt is therefore often exposed to considerable melting even in the winter, and the floes exhibit a highly washed character.

The result is that south of 65° N. lat. 1) the ice belt is only half as broad as north of this parallel, 2) most of the thin ice (Siberian Ice) disappears, and 3) the large ice fields are crushed to pieces, so the ice now consists mostly of relatively small, but thick, floes of the fused hummocks of the North Pole Ice.

Unfortunately very few observations are at hand from these regions as far south as Kap Farvel; thus the available material does not suffice for a graphic representation of the occurrence of the ice in the areas M and N (cf. Fig. 43).

The Ice West of Kap Farvel.

The drift ice in Julianehaab Bugt in the period 1820—1930 has been treated statistically by C. I. H. SPEERSCHNEIDER (1931), who for a number of years prepared the ice reports issued by the Danish Meteorological Institute, and in the period 1901—1938 by G. J. A. HANSEN and P. P. SVEISTRUP (1943). Mr. SVEISTRUP has informed me that the reports sent home by the Danish governors at Julianehaab and other places, kept in the Danish State Archives, contain a number of observations on the ice conditions in these regions. This material is difficult of access and has not been utilised so far; however, the information given in the reports about the period after 1820 will hardly cause any great alterations in the results arrived at by SPEERSCHNEIDER mostly on the basis of ships' log-books.

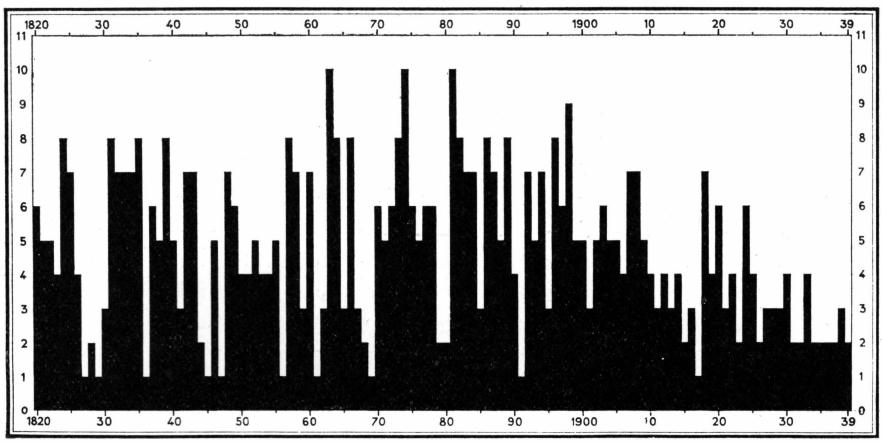


Fig. 100. Quantity of ice west of Kap Farvel 1820—39, according to SPEERSCHNEIDER and the recent information supplied by the Danish Meteorological Institute.

SPEERSCHNEIDER's above-mentioned paper on the ice conditions in Davis Strait 1820—1930 contains a number of observations, some also from the period prior to 1820, and a curve (Pl. 1), which shows the state of the ice in Davis Strait in the period dealt with, prepared according to a system by which each year is classified in a scale with marks from 0 to 10 according to the westward or northward drift of the ice every month, the number of months in which ice has occurred, the number of months with a great extension of the ice, "the monthly means of the limits of the ice (respectively the westward and northward) during the years 1898—1922", and "a mark based only on estimation" (p. 50).

He regards the wind as the main factor of influence on the occurrence of the ice west of Kap Farvel. Thus he says (p. 46):

"The point of time when the ice drifts past Cape Farewell only depends upon the wind."

On p. 47 he says:

"When the extension of the ice in some odd years has been uncommonly great it is not necessarily a proof of extraordinary great masses of ice but first of all a proof of special wind conditions. "A severe ice year" therefore ought to be called "A year with pronounced or abnormal wind conditions", as the wind is the source while the condition of the ice is the visible effect."

He is aware, however, that the occurrence of larger or smaller quantities of ice along the east coast of Greenland is of importance in this connection. Thus he says (p. 47):

"With much ice along the east coast of Greenland the ice drift begins earlier at Cape-Farewell and gives frequently more ice than normally in Davis-Strait the following summer."

On the basis of information received from the Meteorological Institute SPEERSCHNEIDER's observations are carried up to 1938 (Stat. Opl. om Grønl. Nr. 1, 1942); they are represented in Fig. V and in a curve (Fig. IV) showing the quantity of ice present every decade. It is said about the curve (p. 400) (translated from the Danish):

"From this it appears that comparatively small quantities of "Storis" were present from 1840 to 1870 and from 1900 to 1938, while the quantity of "Storis", in so far as the observations may be assumed to be characteristic, was much larger prior to 1840 and in the period 1870—1900."

In the aforementioned paper of G. J. A. HANSEN and P. P. SVEISTRUP (1943) an attempt is made to find out the causes of the fluctuations in the quantities of ice present west of Kap Farvel, since these fluctuations are of importance for the migration of seals, the navigation, and the economic development of the district as a whole. However, the paper does not claim to have solved the problems dealt with, but merely provides a basis for discussion.

The authors are not aware that an investigation of the ice quantities in the Julianehaab district only will not suffice to explain the fluctuations. Moreover, only the quantities of ice present in the five summer months are taken into consideration, though precisely from this place several data on the occurrence of the ice in the remaining seven months are available.

The analysis is based on the ice charts issued by the Meteorological Institute in the period 1901—1938; the authors explain their method as follows (l. c. p. 6): "From these maps we have copied the outline of the ice on transparent paper (typewriting-paper), allowing the easterly limit to follow the meredian through Cape Farvel; the areas thus drawn were cut out, and all areas from the same year were weighed to an accuracy of $^1/_{10}$th milligram."

The values thus found are given in a table (l. c. p. 7) and a curve (l. c. p. 10), which largely agrees with the curve (cf. Fig. 49 F) resulting from our investigations by a somewhat different method; but the ice values arrived at by us for 1918 and 1920 are smaller, those for 1935 greater than those arrived at by the aforementioned authors. On pp. 30—31 these authors sum up their results, pointing out "that there is no single cause, but that the fluctuations are due to the interaction of a number of factors", of which they mention

"... the temperature of the Gulf Stream (measured between the

Hebrides and the Faroes) in the previous year. It seems possible to demonstrate a statistical connection between the decreasing quantity of arctic ice and the rising temperature in the Gulf Stream, and this connection stands out most clearly when we consider the quinquennial sliding averages."

The supposed connection is expressed partly by a correlation coefficient partly by a regression equation. The correlation coefficient is of such a size that we may be fairly justified in assuming that the connection is a reality and is not due to mere chance owing to the material used; the regression equation found would seem to show that the connection is so intimate that it may be used for prognostication; however, the result is due to a miscalculation. The actual regression equation shows that the assumed connection between the temperature of the Gulf Stream and the quantities of ice present near Julianehaab is of no value in a prognostic respect.

The authors go on to say (p. 30):

"On observing the annual variations we find very considerable differences between the Gulf Stream temperature and the quantity of arctic ice. Most of these differences can be explained by information as to air temperatures in the Arctic Ocean. When it has been a particularly cold year in the Arctic, it would seem that the ice freezes together, with the result that in the first year relatively small quantities of ice come into Julianehaab Bay, but much larger quantities the following year."

The two authors attach special importance to two years, viz. 1917, when there was only a small quantity of ice west of Kap Farvel in the summer, and 1918, when the quantity of ice attained its absolute maximum. They say (p. 6):

"It may also be imagined that as the year 1917 was a disproportionately small ice year, most of the ice which should have gone adrift in 1917 was frozen up and did not break away till the following year; in that way 1918 received a correspondingly disproportionate quantity."

The authors are not right in their assumption that the ice which reached Julianehaab in 1918 had been "frozen up" around Spitsbergen in 1917; the ice found near Julianehaab in 1918 had no connection with the ice masses around Spitsbergen in 1917, but represented a fresh pulsation of heavy North Pole Ice, which drifted down along the east coast of Greenland in the winter of 1917—18, whereas the large ice masses occurring around Spitsbergen in the early summer of 1917 consisted of comparatively thin Siberian Ice and melted in the course of the summer before reaching the Denmark Strait.

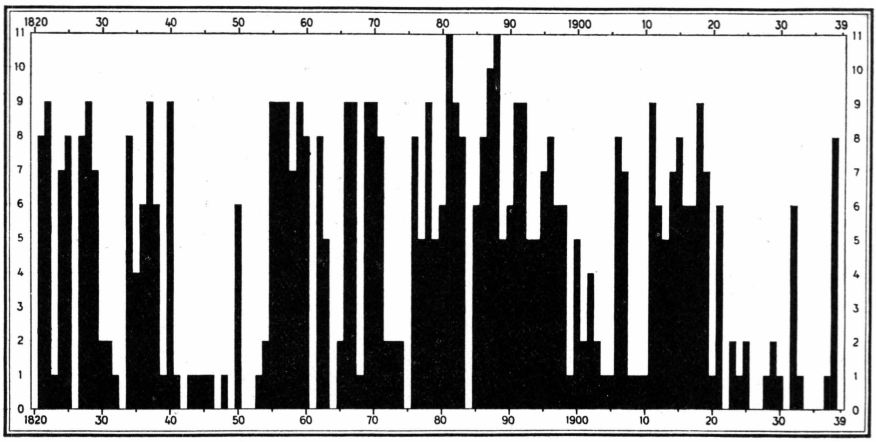


Fig. 101. Quantities of ice (Storis) along the west coast of Greenland in August in the period 1820—1939. The figures indicate: 0) Kap Walløe, 1) Kap Farvel, 2) Nanortalik, 3) Julianehaab, 4) Ivigtut, 5) Frederikshaab, 6) Fiskernæsset, 7) Godthaab, 8) Sukkertoppen, 9) Holstensborg, 10) Egedesminde.

From the quantity of ice present in the Julianehaab district we can only conclude how much North Pole Ice has drifted down along the east coast of Greenland the previous winter.

The Occurrence of the Ice West of Kap Farvel in August.

As it would seem (cf. below) that in the first centuries after the year 1000 the Norsemen were able to sail west of Kap Farvel without meeting ice in the month of August. I think it will be interesting to investigate how often navigation has been possible in this month during the last 119 years.

On the basis of SPEERSCHNEIDER's paper of 1931 and the data supplied by the Meteorological Institute after this year I have drawn a diagram (Fig. 101) showing the quantity of ice present west of Kap Farvel in August in the period 1820—1939. No reliable information is available from 1822, and some uncertainty prevails as to a few years, especially if ships have left Disko Bugt north of Godthaab without calling at the more southerly colonies, but altogether the data are so comprehensive that they give a good idea of the ice conditions in this month.

It is shown (Fig. 101) in how many years Julianehaab Bugt was free from ice in August, (49 of the 119 years 1820—1939 were free of ice) and how far up the west coast the ice extended every year. A comparison of this curve and SPEERSCHNEIDER's curve shows that they differ at some points, though the main result is largely the same, viz. that there

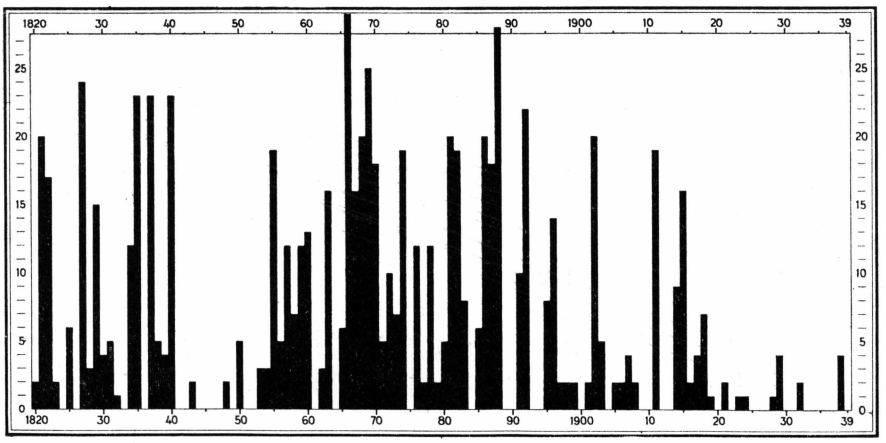


Fig. 102. Diagram showing the number of weeks with ice around Iceland. The ordinate indicates the number of weeks. Based on THORODDSEN's paper of 1916—17 and the ice charts of the Danish Meteorological Institute. For further details, cf. below pp. 246—47.

was a decrease of the ice quantity towards the middle of the last century and, after a culmination around 1880, another strong decrease up to the present day.

It will be interesting, now, to compare these two diagrams with the available diagrams on the occurrence of ice near Iceland.

A Comparison between the Greenlandic and the Icelandic Curves for the last 119 Years.

The curves showing the ice quantities in decades, represented in Fig. 104 have been prepared on the basis of the following two Greenlandic and three Icelandic diagrams:

I) SPEERSCHNEIDER's diagram showing the ice west of Kap Farvel for the whole year (cf. Fig. 100),

II) My diagram showing the occurrence of the ice west of Kap Farvel in August (cf. Fig. 101),

III) The diagram showing the number of weeks with ice near Iceland (cf. Fig. 102),

IV) The diagram showing the number of weeks with ice multiplied by the number of areas of the coasts of Iceland along which ice occurs (cf. Fig. 103), and

V) A diagram showing the width of the ice belt between Iceland and Greenland according to the A-B-C-method (cf. Fig. 99).

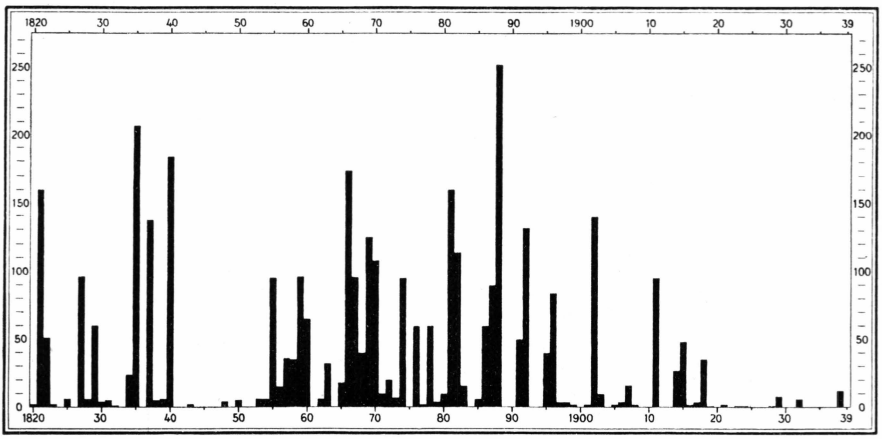


Fig. 103. Diagram showing the number of weeks with ice around Iceland multiplied by the number of areas with ice (cf. Fig. 84). Based on THORODDSEN's paper (1916—17) and the ice charts of the Danish Meteorological Institute. For further details cf. below pp. 246—47.

It will be seen that on the whole the five curves agree fairly well, but the Greenlandic curves show a more even course than the Icelandic ones; the slight disagreements found are no doubt due to some extent to deficiencies of the material.

The curves show three maxima, a, b, and c, and three minima, x, y, and z. The maximum a is very marked in the curves II, III, and V, only curve I shows a minimum here. Maximum b is marked in all the curves, and maximum c in all the curves except curve I. Maxima x and z are marked in all five curves, y in all curves except curve I, which exhibits a small maximum. The slight rise of z in curves IV and V is due to the fairly large quantities of ice that drifted towards Iceland in 1938.

The Icelandic curves show greater agreement with the Greenlandic curve II than with curve I. The minimum found in the Icelandic curves within the decade 1870—79 does not seem to have made itself felt in the Greenland waters. Of the Icelandic curves, curve IV is no doubt that which most accurately reflects the actual conditions.

Thus the curves show clearly that in the decade 1840—49 the ice quantities near both Iceland and Greenland were inconsiderable. Subsequently the ice quantity near Iceland shows an increase (apart from a decrease in the period 1870—79, which was not traceable near Greenland) up to the period 1880—89, after which it decreases gradually, though with a small minimum in the period 1900—1909 and a small maximum in 1910—19.

To sum up: The five curves show good agreement as regards the fluctuations in the quantity of ice found near

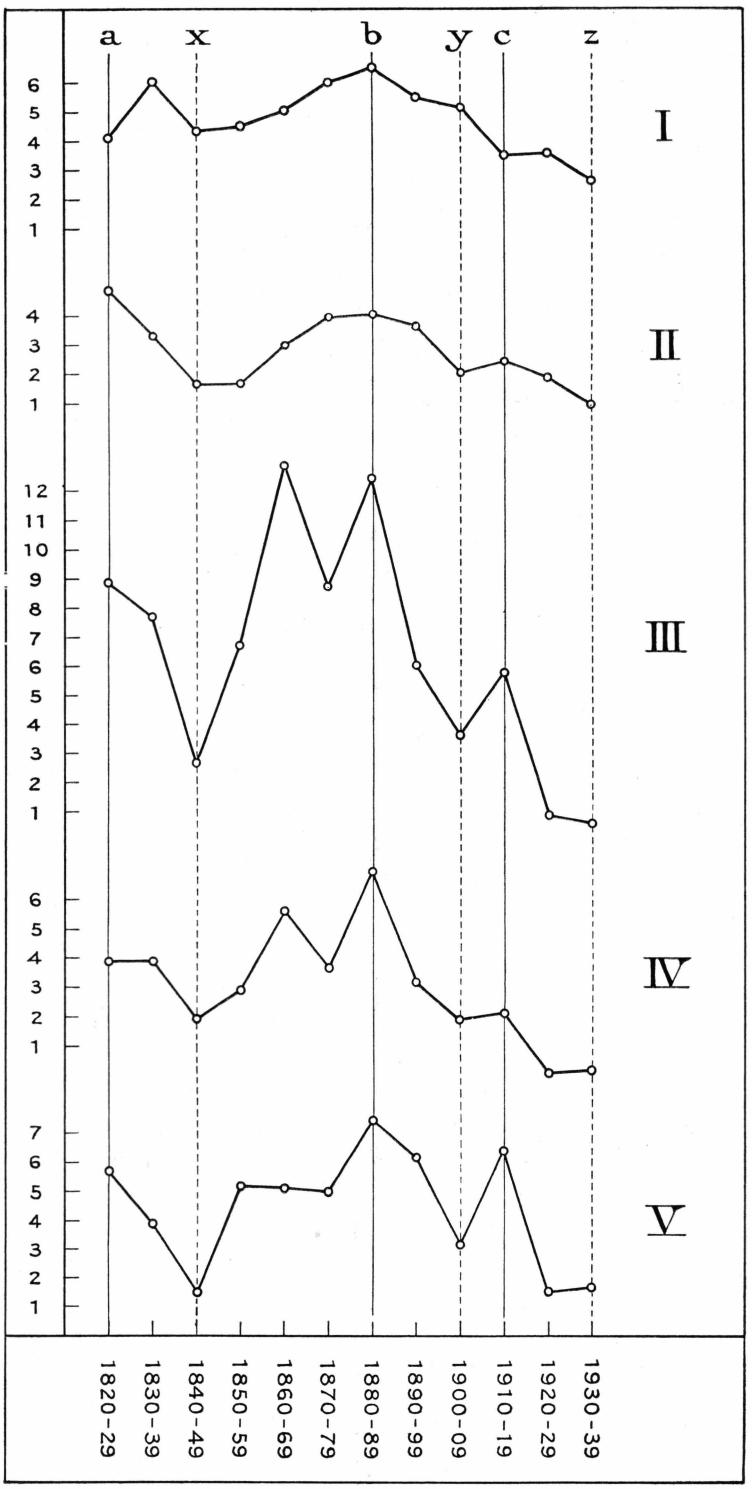


Fig. 104. Curves showing the ice quantities in decades 1820—1939, around Greenland (I—II) and Iceland (III—V), cf. the text.

Iceland and southwestern Greenland during the last 119 years. Since in both places the ice quantity is an important climatological factor, it is natural to assume that there is a definite association between the climates of these two regions.

Statistical remarks by Mr. E. HOVMØLLER.

I have asked Mr. E. HOVMØLLER to make some remarks on the numerical treatment of the information about the ice found near Iceland after the year 1780 (see Pl. 1). Mr. HOVMØLLER's remarks run as follows:

"On the basis of the available material the following figures have been computed for each year (reckoned from October to September):

1) the number of weeks in which ice occurred (p),

2) a figure indicating (according to a scale 0—10) how many tenths of the shore were in contact with the ice for a shorter or longer period (q). It is assumed in the sequel that the material permits a determination of p and q with a reasonable accuracy, i. e. an uncertainty of 1—2 weeks at most as to p, and as to q an uncertainty of one unit at most.

It is most convenient to use one, and only one, figure in the characterisation of each ice year. It would be most satisfactory to use a figure which is proportional to the mean extension of the ice during the year. However, this method is only applicable for the period 1877—1939, that is to say, the years for which it is possible to prepare fairly reliable charts of the distribution of the ice along the shore in each month. If the extension of the ice is indicated according to the aforementioned scale 0—10, we shall find by addition of the twelve monthly means—provided the charts are correct—a figure which is very nearly proportional to the mean extension of the ice in the course of the year.

For the years up to 1877 it is generally impossible to draw sufficiently accurate ice charts. We shall then have to consider the following possibilities 1) to be content with the number of weeks (p), 2) to be content with the figure for the extension of the ice (q), or 3) to use a combination of these two numerical values.

If we confine ourselves to employing the number of weeks, the figures for the very heavy ice years will, it is true, be highest, but still too small as compared with the other figures, since in these years the ice will not only persist longer than in other years, but in the period in which it occurs it will generally have a more extensive distribution than in less heavy ice years.

If only the figure for the extension of the ice is employed, a similar error will be introduced, for in the years in which the extension of the ice is greatest (i. e. in which the largest number of areas are in touch with the ice for shorter or longer periods), the ice will usually persist for a particularly long period.

Accordingly it will be reasonable to combine the two numerical values p and q in such a way that we arrive at a figure which takes

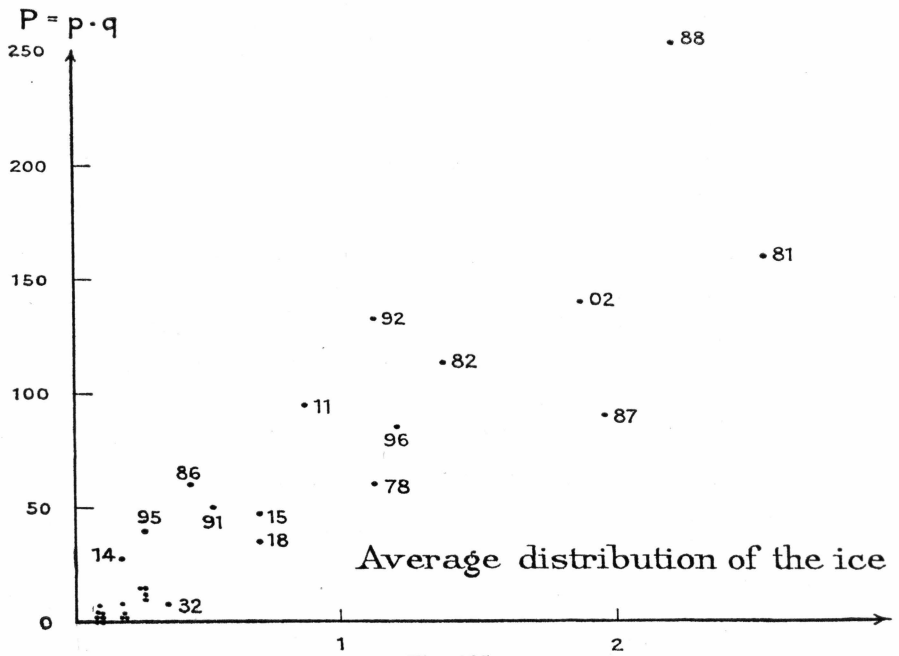


Fig. 105.

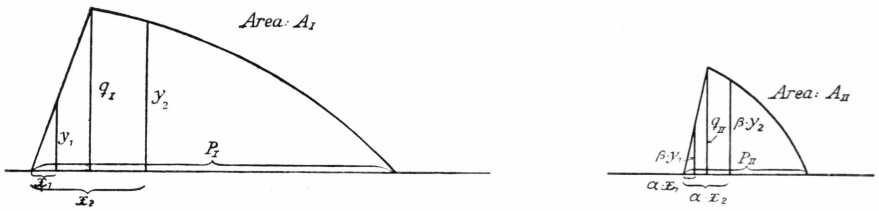
equal account of the duration and the distribution. The simplest possibility arithmetically—an addition of the figures—will not come into consideration, p and q not being of the same denomination; an alteration of the time unit employed or of the scale of distribution would change the interrelations of the different sums. The simplest possibility after this, viz. a multiplication of the figure, is much better (the "product method").

The product of p, which indicates the number of weeks with ice, and q, which indicates the length of the stretch of coast touched by the ice, is exactly proportional to the average distribution of the ice along the coast, if all the curves which indicate the extension of the ice in each individual year as a function of time can be assumed to have resulted from a multiplication of one and the same standard curve (the abscissa values being multiplied by one figure and the ordinate values by

another which, however, may be equal to the first-mentioned one)—cf. below.

Strictly, however, it is further required that none of the stretches of coast which are in contact with the ice in the course of the year should be free of ice at the time of the maximum distribution of the ice.

The last-mentioned condition will, as a rule, be approximately fulfilled. But the extension of the ice in the different years is, of course, less uniform than necessary if proportionality between the product p. q and the mean distribution of the ice should be obtained; in some



$$A_I = \int y\,dx \qquad A_{II} = \int (\beta y)\,d(\alpha x) = \alpha\beta \int y\,dx,$$

$$\text{thus:} \quad \frac{A_{II}}{A_I} = \alpha\beta,$$

$$\text{and since moreover} \quad p_{II} = \alpha \cdot p_I, \quad q_{II} = \beta \cdot q_I,$$

$$\frac{p_{II}\,q_{II}}{p_I\,q_I} = \alpha\beta = \frac{A_{II}}{A_I}.$$

few years rather considerable deviations from the normal form of the "distribution curve" may occur.

An idea of the applicability of the product method may be obtained by employing it on the years (1877—1939) for which the average distribution of the ice can be seen directly from the ice charts. The result will appear from Fig. 105. As will be seen, the scattering is not inconsiderable, but still there is a fairly marked tendency to proportionality, and it seems justifiable to use the product method for the whole material from 1780—1939.

When, thus, a certain figure P = p·q has been computed for each year, the question arises whether a secular variation can be demonstrated within the period considered. A final proof of the existence of a secular variation must, of course, require more in this case where the figures in themselves are rather uncertain as measures of the element investigated than when we are concerned with ordinary meteorological observations. It can hardly be disputed, however, that the alterations in the average distribution and frequency of the ice which have taken

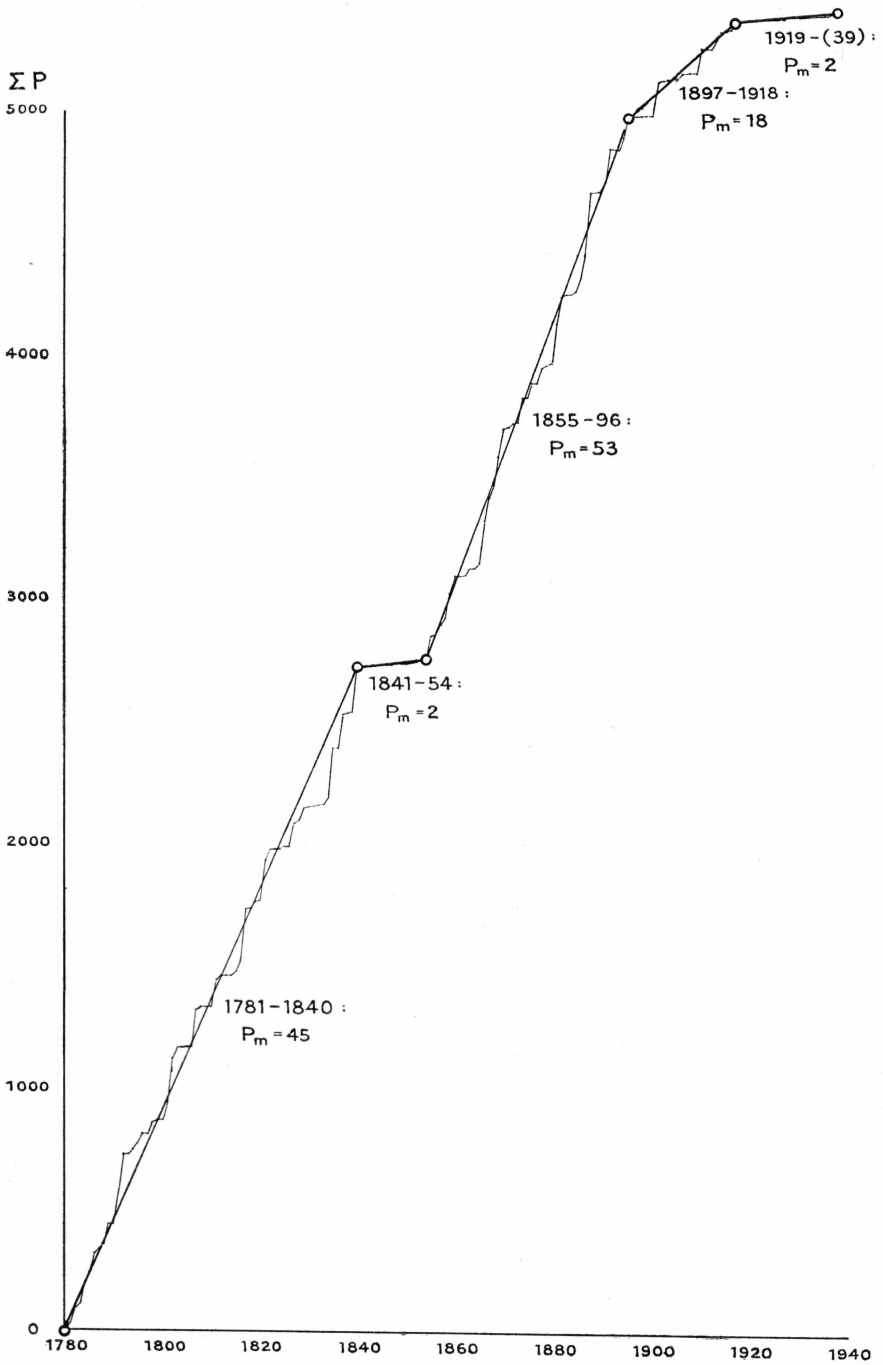


Fig. 106. Cf. the text.

place in the course of the period considered here, are remarkably great. As shown by the summation curve (Fig. 106), the period 1781—1939 may be naturally divided into five sections of unequal duration and very different mean values of the product P, viz.

1781—1840: $P_m = 45$
1841—1854: $P_m = 2$
1855—1896: $P_m = 53$
1897—1918: $P_m = 18$
1919—1939: $P_m = 2$

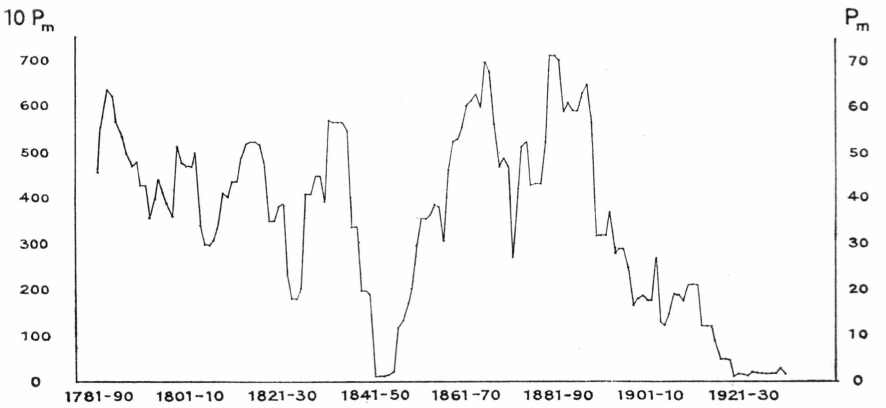


Fig. 107. The ice around Iceland represented on the basis of moving-averages for ten-year periods.

Such a great variation will, of course, be manifested, more or less distinctly, if the material is divided in the usual way into equally long periods, or if moving-average tabulation is used. If the comparatively short, nearly ice-free period 1841—54 is to "tell to full advantage", care must be taken that one of the sections comes wholly within this period, or, respectively, if we use moving-average tabulation, each of the table values must comprise fourteen years at the most. Fig. 107 shows the curve that will arise if moving-averages for ten-year periods are used.

As a kind of explanation of the variations illustrated by the figure a certain tendency of persistence as regards the ice quantities near Iceland might be imagined. However, this tendency—if it does exist—must be of a rather complicated nature; even in the periods with the greatest quantities of ice within the series of years treated, an icefree period of a duration of at least one month has occurred every autumn, and similarly, one or some few years with no or hardly any ice have often occurred between two heavy ice years. This must be viewed in relation to the fact that the ice is not (or only to a very limited extent)

formed on the spot, but drifts with the sea currents. It is a natural and very reasonable assumption that the secular variations in the quantity of ice near Iceland are in the main a consequence of corresponding variations in for instance the temperature and wind conditions of the Polar Basin. If a decisive proof of this correlation should once be obtained—either statistically or by means of physical considerations—the material which supplies information about the distribution of the ice around Iceland through the centuries will be of interest i. a. as evidence of the considerable and far-reaching consequences to which changes in the climate of the Polar Basin may give rise even outside the strictly Arctic regions.

V.

ICE CONDITIONS IN THE PAST CENTURIES

THE ICE AROUND ICELAND DURING THE LAST 1100 YEARS

The Ice Conditions according to the Literature.

As mentioned above, THORODDSEN made two attempts to represent graphically the quantity of ice occurring around Iceland.

The first graph was published in 1883, and shows the advance of the ice every month from 1800 to 1882; the quantity and occurrence of the ice are indicated by lines of different thickness.

The other graph, dealing with the period from 1781 to and including 1915, was published in 1917 (pp. 357—358). In this graph, also, he distinguishes between the different quantities of ice, indicating them by lines of seven different thicknesses. The graph is reproduced, re-drawn, in Pl. 1 of the present paper. The plate shows (above) in which weeks ice was present (according to THORODDSEN), then (in the middle) the number of weeks each year in which ice was present, and (below) the quantity of ice found by multiplying the number of weeks with the quantity of ice (expressed by lines of different thickness, viz. 1—7) given by THORODDSEN. The first two diagrams have been carried up to date, but this was impossible for the third one, since we did not know the basis for THORODDSEN's estimate of the ice quantities.

A third attempt at a graphical representation of the occurrence of the ice is recorded in a paper by THORARINSSON (1941, Fig. 2). He also gives four graphs (winter, spring, summer, and the whole year) for the occurrence of ice along the coasts of Iceland from 1688 to 1938. The quantities of ice are indicated on a sketch-map by means of thin, heavy, or dotted lines, but the map is published on such a small scale that it cannot be reproduced here. It should be added, however, that his sketch shows good agreement with the more recent attempts at graphic representations of the occurrence and quantity of the ice, which will be dealt with below.

In 1943 THORARINSSON published an important paper on the oscillations of the Icelandic glaciers during the last 250 years. He gives two curves (p. 50)showing the oscillations of the outlet glaciers of Dranga-

jökull and Vatnajökull respectively, from which it appears that the outlet glaciers of Vatnajökull had the same extent in 1700 as in 1900, while those of Drangajökull had a somewhat greater extent in 1700 than in 1900; he found two "Hochstands" (maxima), one in 1750—60, the other in 1840—50. On p. 47, mentioning a great advance in 1830-40—1840-50, he says: "Some of the Vatnajökull outlet-glaciers at their maximum in historical times." And (p. 50) he concludes by saying: "On the whole, the glaciers have been receding since the middle of the 19th century, and they are at present smaller than at any time since the 1680-ies." If this is correct, it would seem that the culmination of the Icelandic glaciers in historical times occurred between c. 1700 and 1900.

This result is surprising to me in so far as there is a connection between the occurrence of drift ice along the coasts of Iceland and the distribution of the glaciers, for on reading THORODDSEN's paper (1884) on the drift ice and his later paper (1916—17) I received the impression that the severe ice years commenced about the year 1600 and lasted for three centuries. If so, we must go back a hundred years more than done by THORARINSSON. I therefore made up my mind to investigate whether the change in the climate actually took place about the year 1600, and this induced me to make an attempt to represent graphically the variations in the quantities of ice during all the eleven centuries whence information is at hand. It was a difficult task, and the result must, of course, be accepted with some reservation. In order that it should not be too subjective, I worked out the diagram in collaboration with Mr. GUDNI GUDJONSSON, drawing support from THORODDSEN's paper (1916—17).

The area between Látrabjarg in the northwest and Reykjanes in the southwest was divided into nine parts (cf. Fig. 84), each corresponding to a stretch of coast of c. 130 km (in heavy ice years, when the ice extended southward into Breiðifjörður or northward into Faxaflói, we operated with ten areas), and calculated how many of these units were filled with ice in the individual years.

Thus we got an idea of the quantities of ice found around Iceland in the years mentioned in the literature. As the time for the presence of ice is frequently recorded in the literature, we were, as a rule, able to give the periods with ice fairly accurately. In some cases, however, it is only stated in the literature that the ice remained till "late in the summer" or that ice occurred, but not when; in such cases we have indicated ice in April and May. From one year it is only reported that twenty-two polar bears were killed (cf. the graph Fig. 108); if it is only reported that icebergs (which need not have any connection with drift ice) have stranded near Iceland, this is, of course, not indicated in the graph.

In several cases severe winters are recorded in the literature, sometimes even cold summers, and fairly often widely distributed fjord ice or prolonged freezing of lakes and rivers. THORODDSEN assumes that these cold periods are due to the presence of large quantities of drift ice in the immediate neighbourhood of Iceland. We have not followed THORODDSEN as to these years, but have indicated fjord ice and periods of cold by one symbol, while drift ice is not indicated unless expressly mentioned in the literature, since in our opinion cold periods need not necessarily be due to the presence of drift ice; thus about 1350 no less than five consecutive years with a cold climate are mentioned in the literature, but drift ice is not recorded from any of these years.

Our results naturally depend largely on personal judgment. The farther back we go, the greater is the factor of uncertainty. For each year we have calculated the number of weeks with ice, and by multiplying this number with the number of units with ice, we arrived at a figure representing the occurrence of the ice for each year. However, on comparing our graph with THORARINSSON's graph for the period 1688—1800 and THORODDSEN's graph for the period 1781—1800, we noted with satisfaction a great agreement between these graphs and ours, though they have been prepared on different bases.[1])

As stated above, THORODDSEN's graph (1917) goes back to 1780. However, he was hardly aware of the range and effect of the fluctuations in the quantities of ice which appear directly from his graph (1917). In 1914 (p. 216) he says as follows (translated from the Danish):

"Conditions have varied during all the centuries. Periods of bad and good years have replaced each other in irregular oscillations on either side of the normal. But in historical times there have been neither climatic troughs nor peaks extending over very long intervals, to say nothing of several centuries at a time."

In 1917 (p. 4) he makes a similar statement (translated from the Icelandic):

"However, the climatic conditions and the climate in the different years are mentioned in so many places in the sagas that they suffice to show that the climate during the Landnám time and the Saga time did not differ from that of the most recent centuries, and there is no reason to believe that it was either more favourable or more unfavourable than during the last centuries, whence abundant data are available."

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[1]) Since Figs. 85—97 are chiefly based on the information supplied by the year-books of the Meteorological Institute and the papers by RYDER and other authors, in which small quantities of ice approaching the coast for some few days are sometimes disregarded, while Figs. 115—116 are based exclusively on the data given by THORODDSEN (1917), who records even such small quantities of ice, they show minor discrepancies as regards some few months.

It will be seen that as to the occurrence of the ice and the climatic fluctuations during the whole period we arrive at a result which differs essentially from that arrived at by THORODDSEN, though our view is based chiefly on his extracts from the literature.

THORODDSEN's view was supported i. a. by FRIDTJOF NANSEN and several philologists, who will probably claim that our curves (cf. Figs. 117—118) do not represent the quantities of ice, but only the number of ice records in the literature and that accordingly they give a false picture of the ice conditions around Iceland. The sagas, it will be maintained, laid the main stress on family history, not on the climate, and this might be the cause of the low figures for ice for the first centuries up to c. 1200. The increase in the number of ice years on record from the 13th century might then be due to the detailed information supplied by the first annals, while the lack of ice reports between the 14th and 17th centuries might be due to the partial cessation of the writing of annals.

Similarly, the great increase in the number of ice years reported from the 17th century may be due to the renewed flowering of the annal writing, and the almost regular rise of the curve from the end of the 16th to the end of the 19th century might then be due to the increasing information about the ice, not to a rise in the number of ice years.

To this it may be objected that the material available from 1780—1915 not only shows a culmination of the number of weeks with ice between 1780 and 1800, but also an amelioration of the climate between 1840 and 1853 (mentioned by THORODDSEN in his letter to MEINARDUS 1906) and a deterioration of the climate between 1860 and 1880, succeeded by an amelioration, the full effects of which we have experienced during the last two decades, that is to say, after THORODDSEN's death. It would seem that neither THORODDSEN nor NANSEN was aware of the climatic fluctuations required to provide sufficiently favourable conditions for a population living on the north coast of Iceland. The last two decades, besides revising our knowledge of climatic fluctuations, have supplied such a wealth of information, chiefly archaeological and zoological, that an increasing number of scientists adhere to the assumption that changes of the climate have actually taken place in historic times.

Below I shall mention some of the facts which suggest such great changes of the climate in Iceland and Greenland in historic times. The small quantities of ice present in the Landnám and the Saga time agree well with the conditions under which Iceland was discovered and populated and had its first great period of culture, as described in the literature. The first deterioration of the ice conditions in the 13th centruy pointed out by THORODDSEN (especially in 1884) almost coincides with the period of unfavourable climate postulated by EDVARD BULL, which

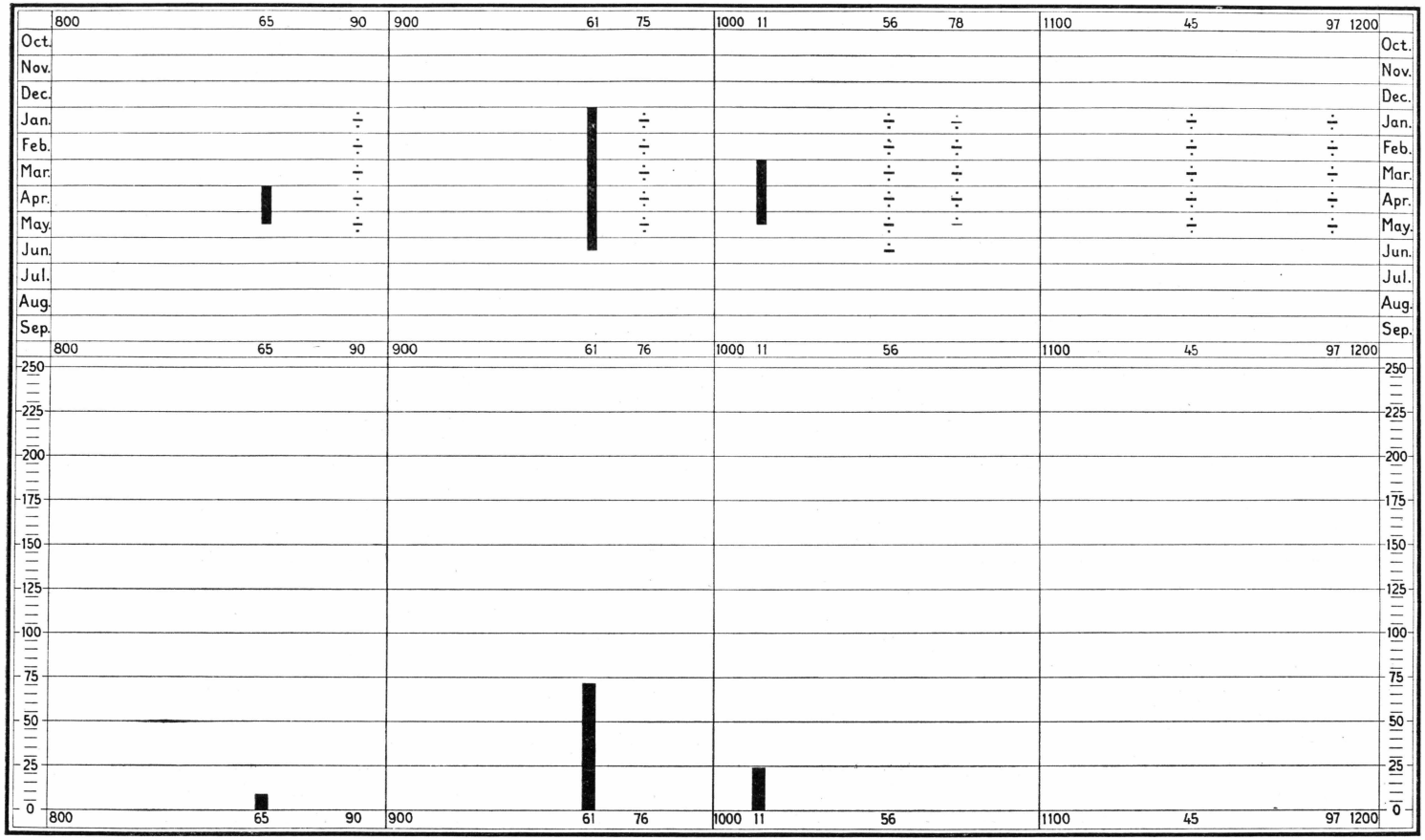

Fig. 108. Graph showing the occurrence of the ice around Iceland in the period 800—1200 according to the literature. Above: black belts indicate the number of weeks from which ice is reported, ÷ indicates severe winters with no observations of the ice. Below: Number of weeks multiplied by number of areas with ice.

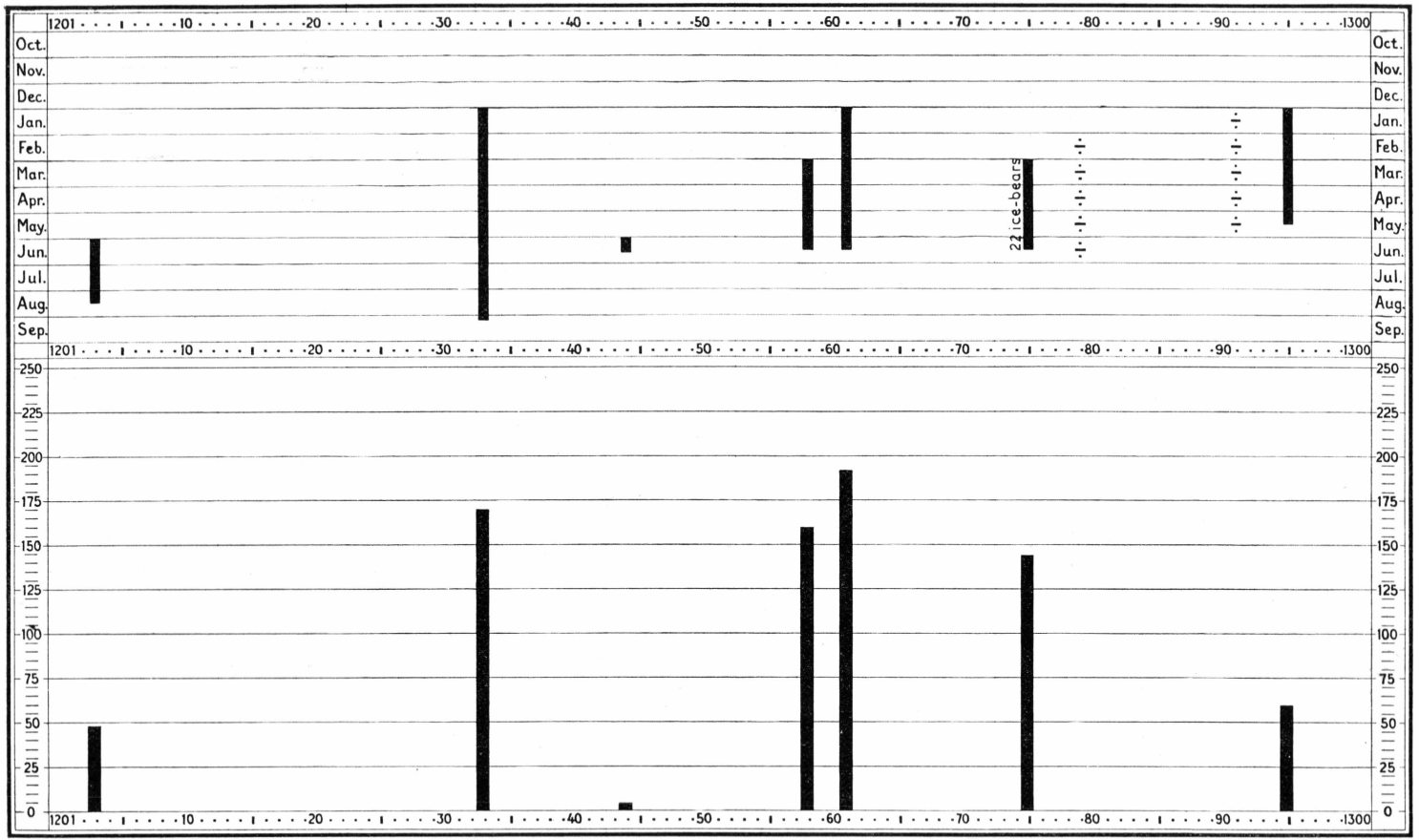

Fig. 109. Graph showing the occurrence of the ice around Iceland 1201—1300, according to the literature. Cf. the text to Fig. 108.

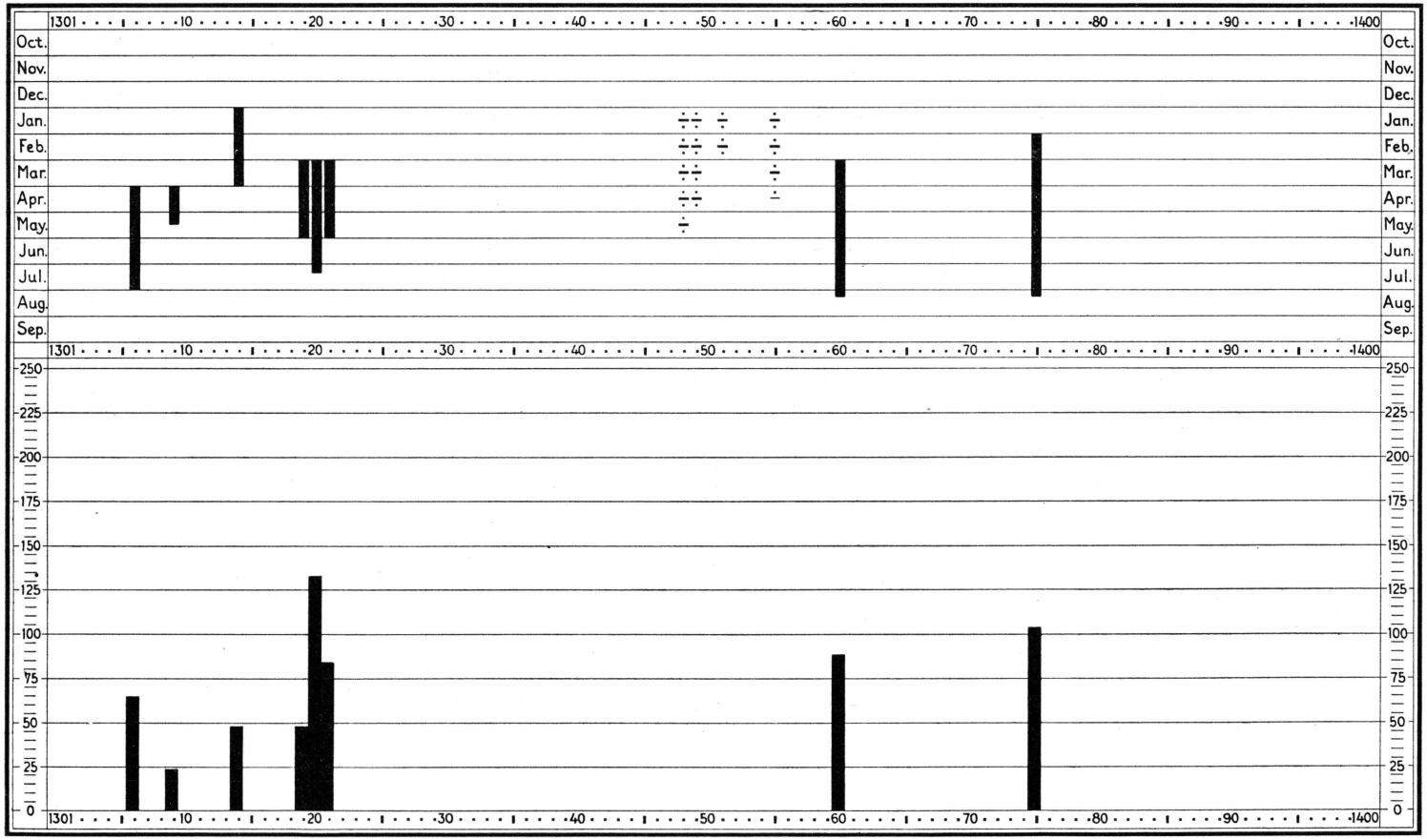

Fig. 110. The occurrence of the ice around Iceland 1301—1400, according to the literature. Cf. the text to Fig. 108.

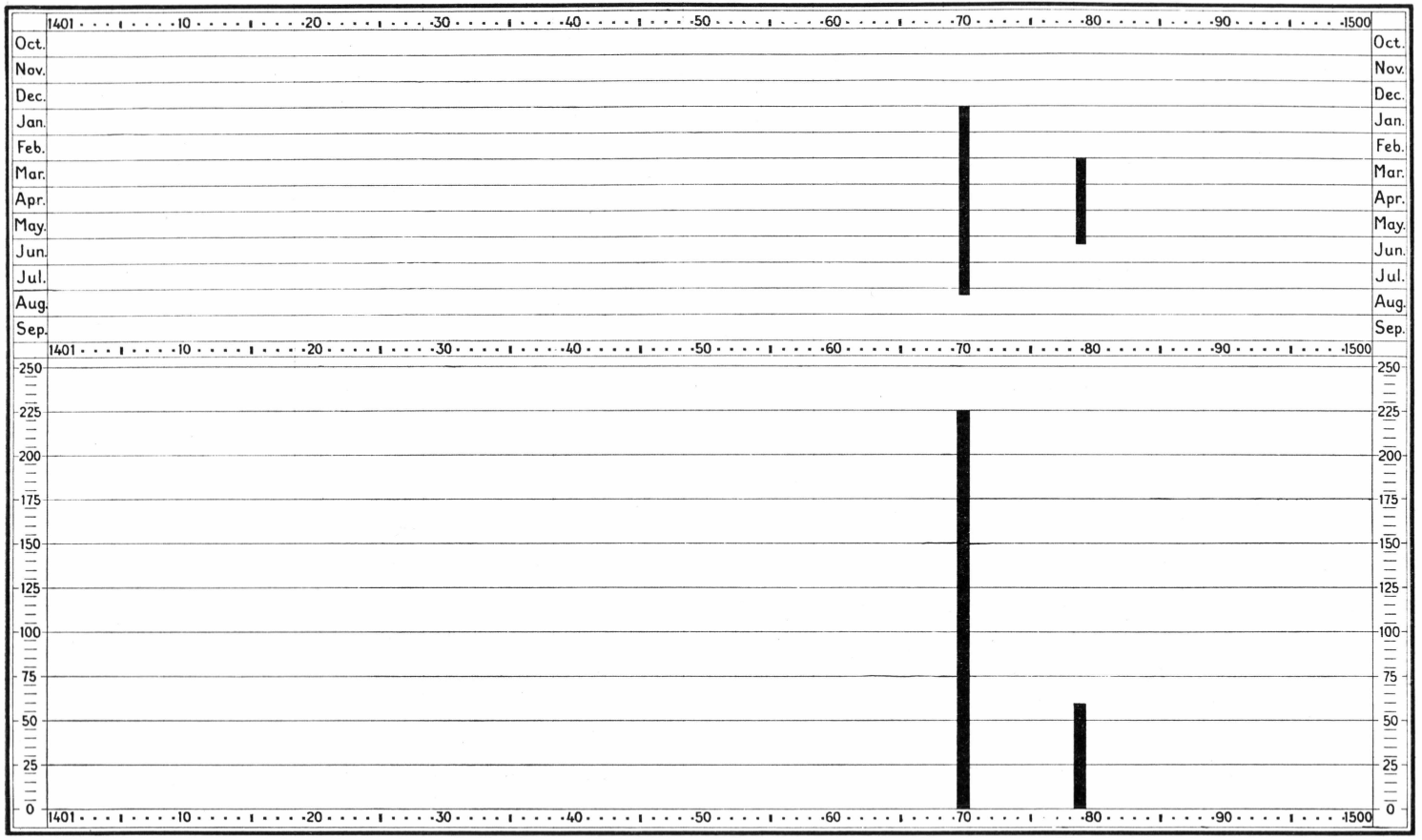

Fig. 111. The occurrence of the ice around Iceland 1401—1500, according to the literature. Cf. the text to Fig. 108.

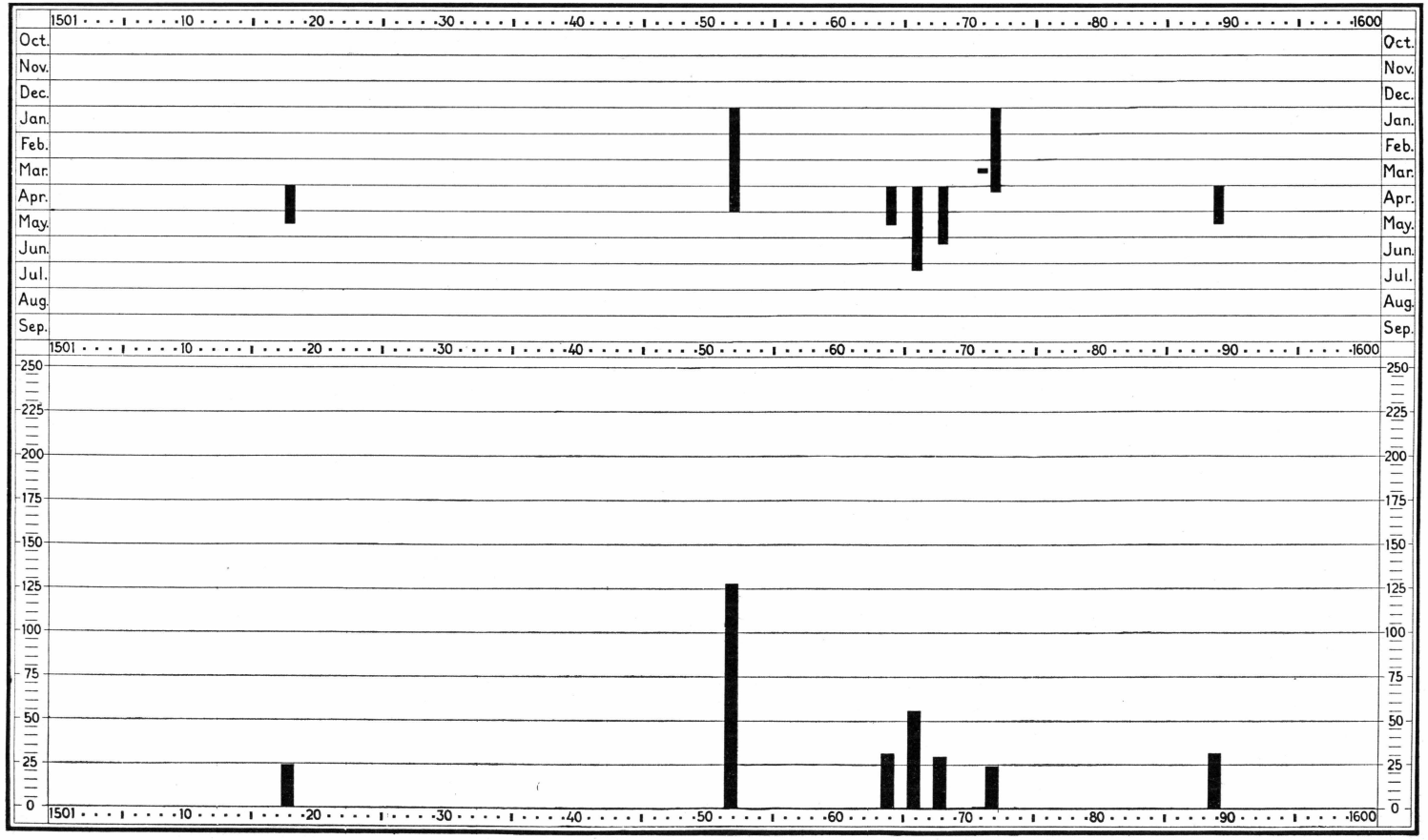

Fig. 112. The occurrence of the ice around Iceland 1501—1600, according to the literature. Cf. the text to Fig. 108.

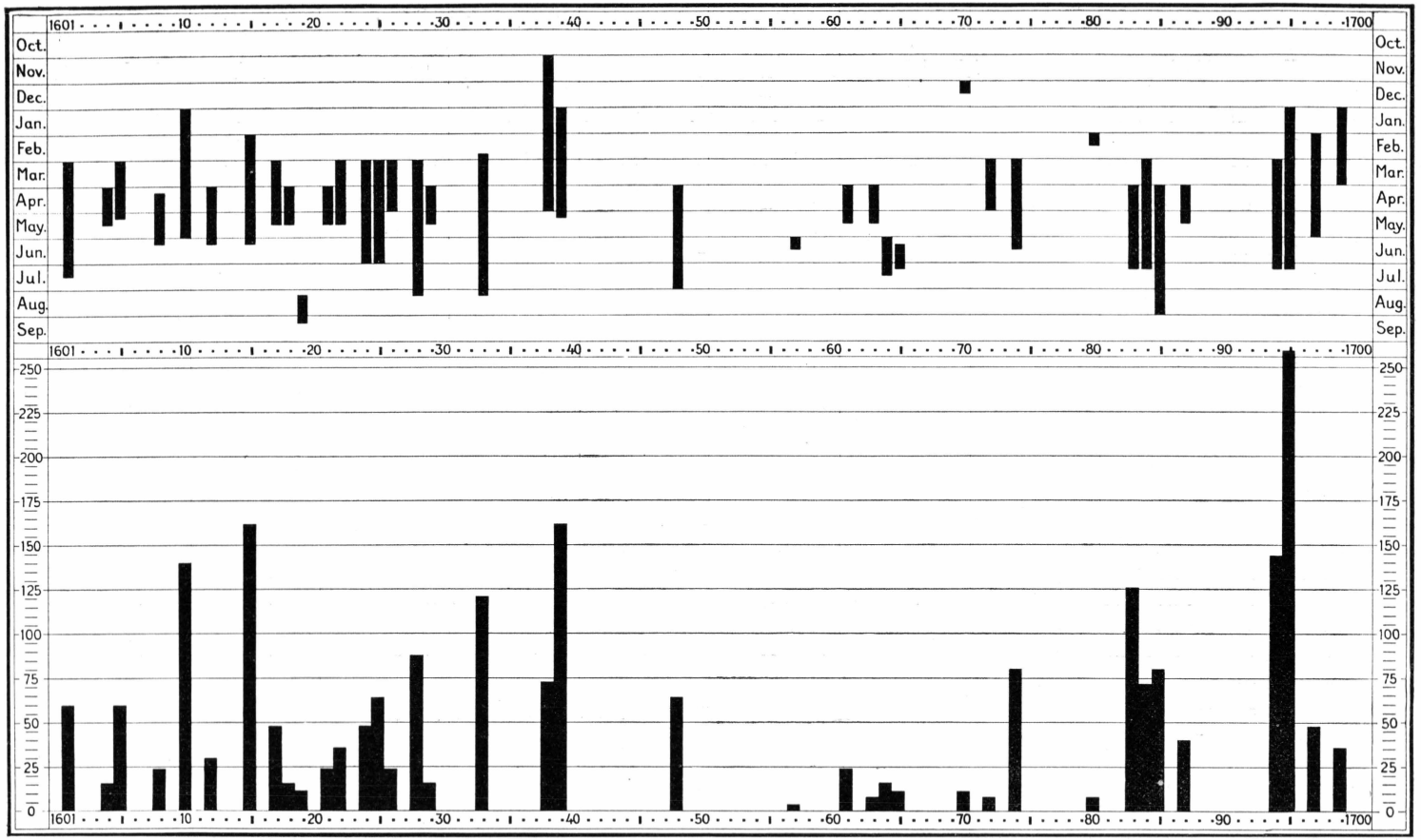

Fig. 113. The occurrence of the ice around Iceland 1601—1700, according to the literature. Cf. the text to Fig. 108.

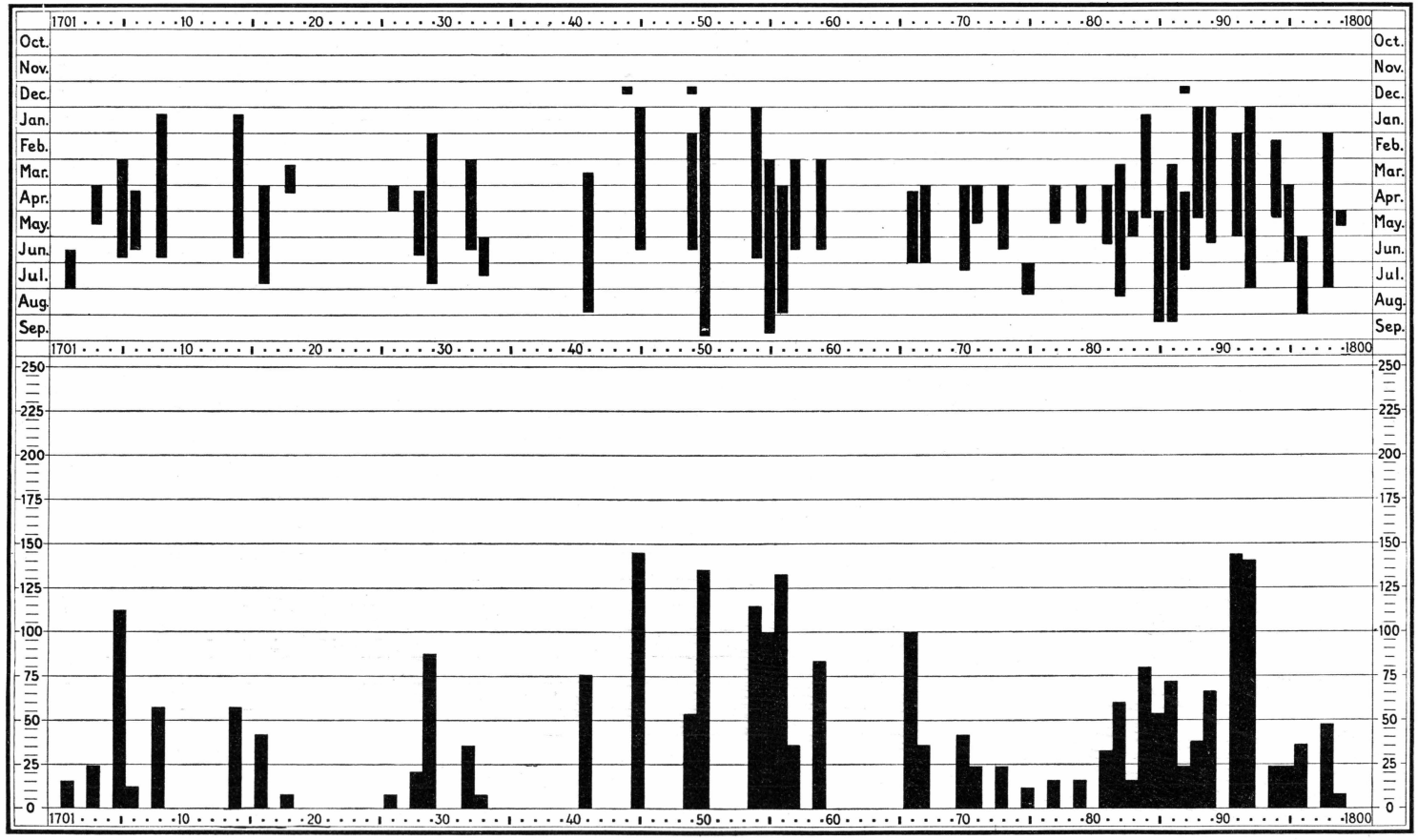

Fig. 114. The occurrence of the ice around Iceland 1701—1800, according to the literature. Cf. the text to Fig. 108.

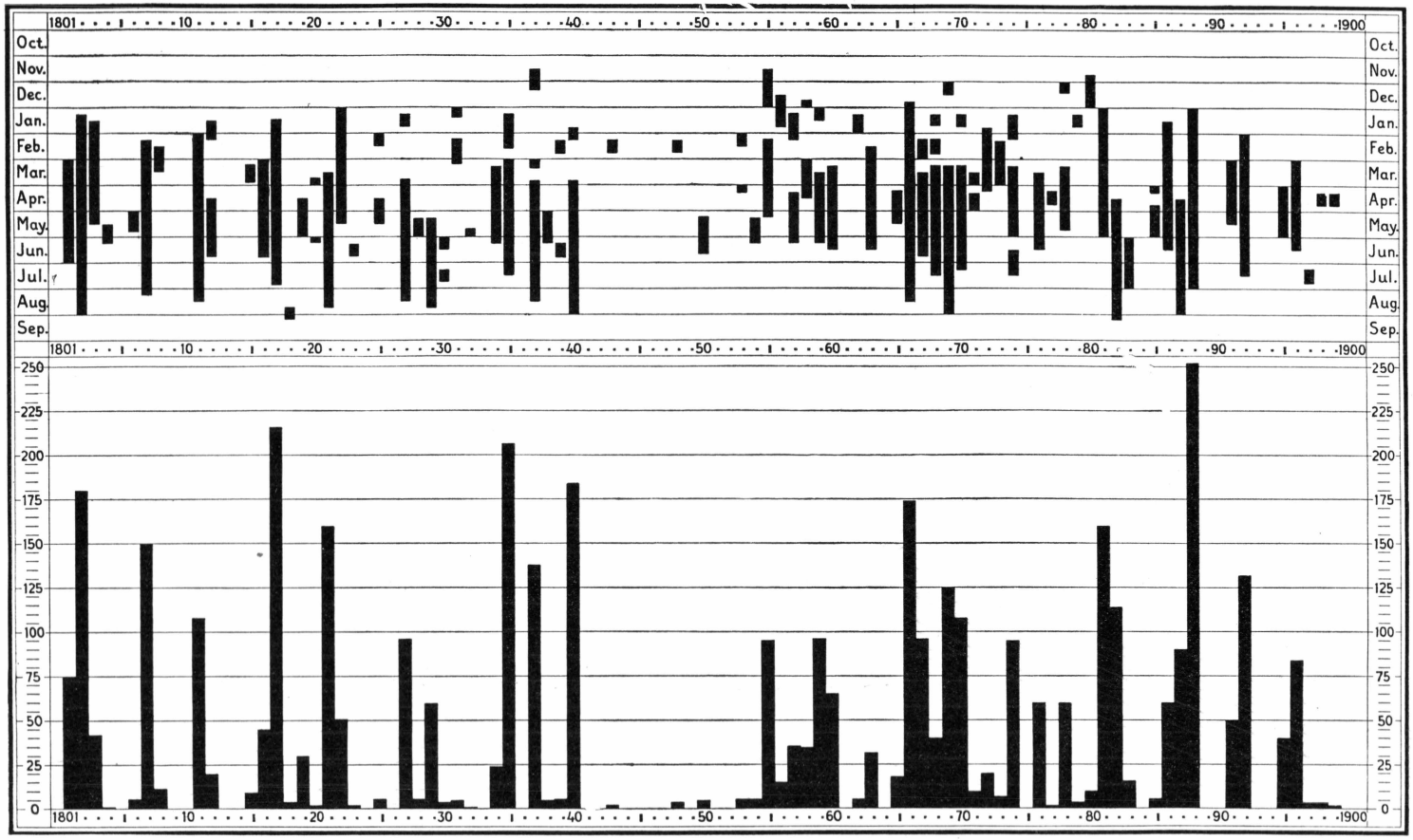

Fig. 115. The occurrence of the ice around Iceland 1801—1900, according to the literature. Cf. the text to Fig. 108.

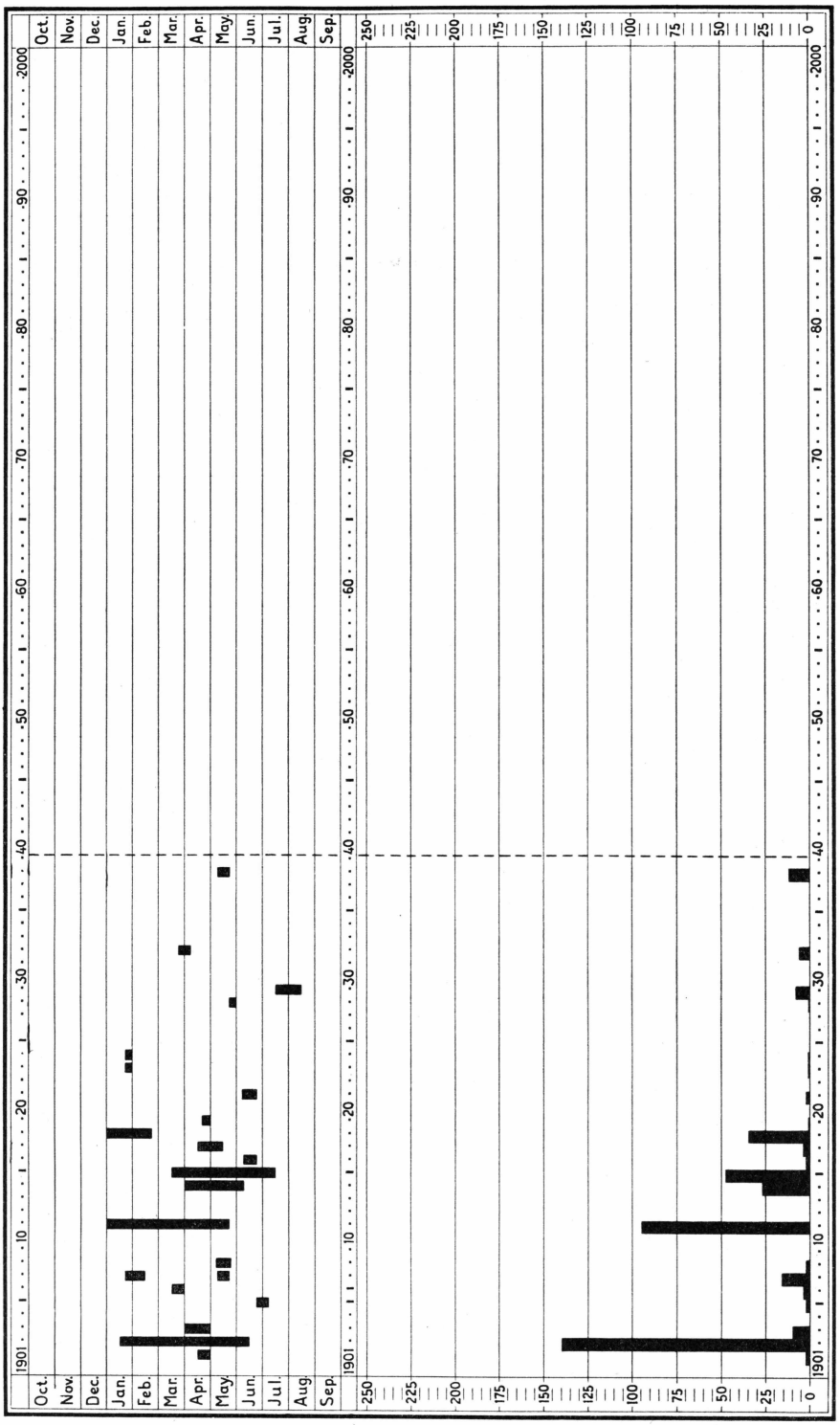

Fig. 116. The occurrence of the ice around Iceland 1901—1939, according to the literature. Cf. the text to Fig. 108.

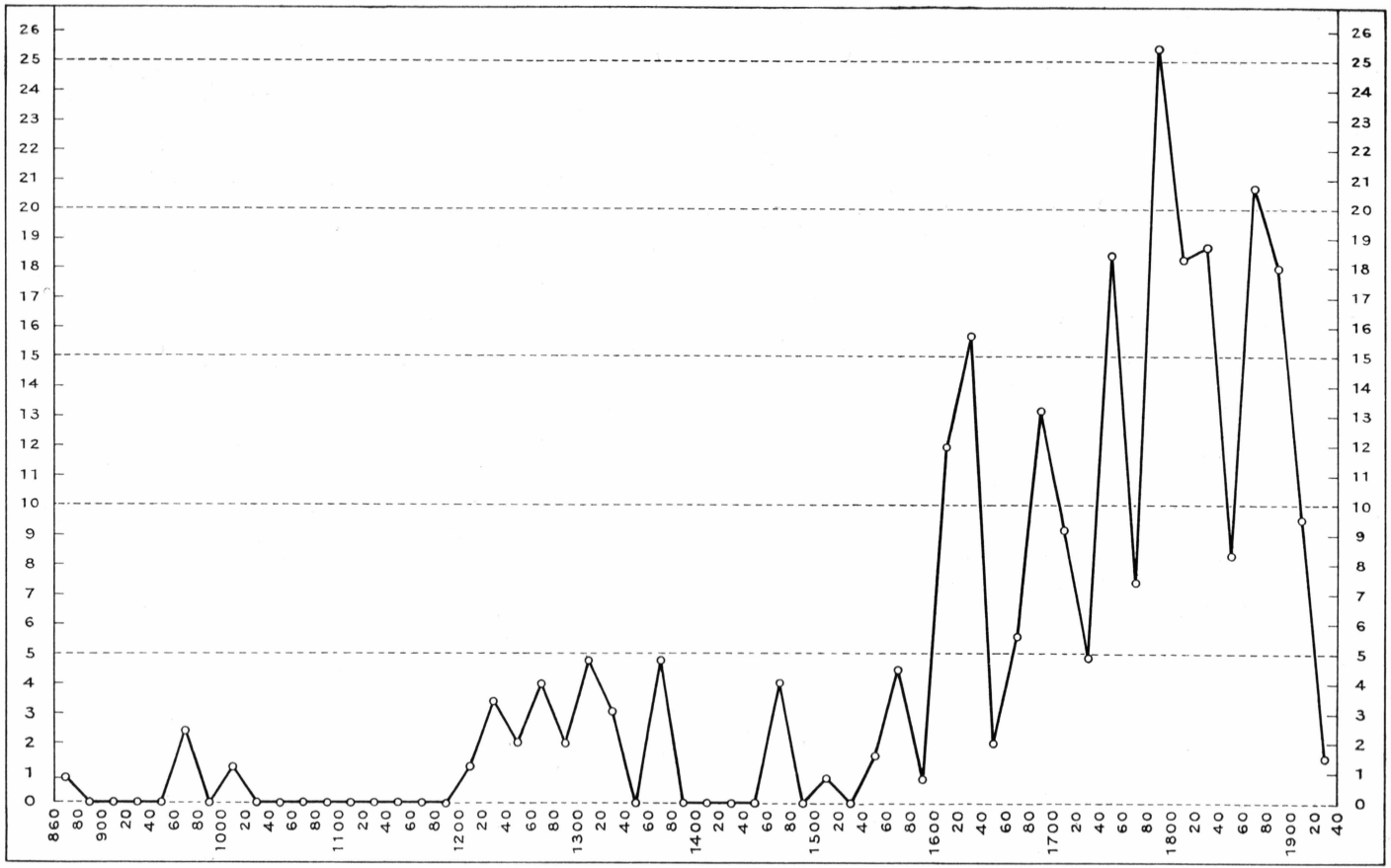

Fig. 117. Curve showing the number of weeks with ice around Iceland for twenty-year periods from 860 to 1939.

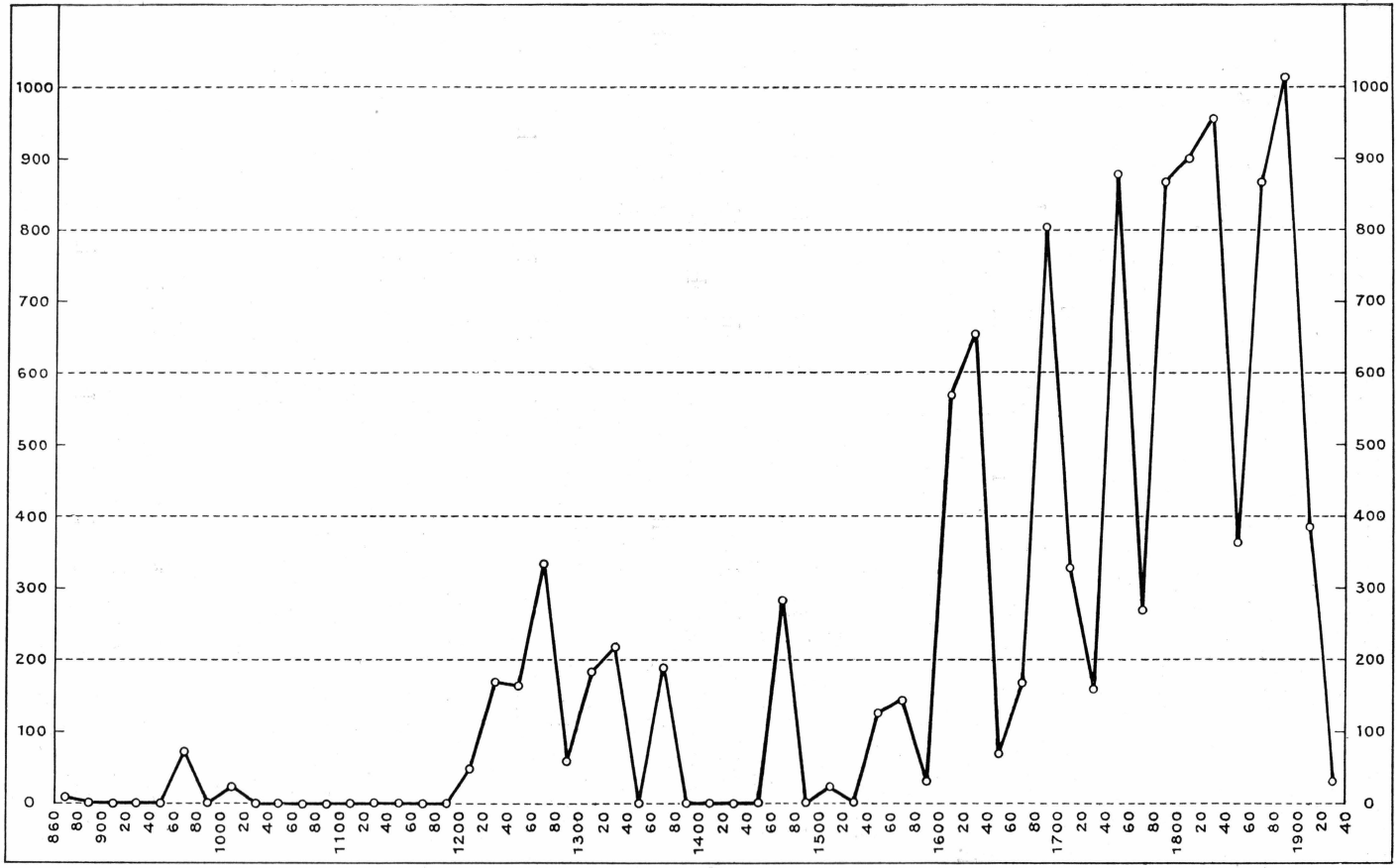

Fig. 118. Curve showing the number of weeks with ice multiplied by the number of areas with ice around Iceland, for twenty-year periods from 860 to 1939.

in his opinion broke the power of the Icelandic people for a long period. The curve shows, however, that as regards the quantity of ice the 13th and 14th centuries cannot by far compare with the period 1600—1900. Whether the curve for the 15th century, whence very few data are at hand, should actually be so low as shown in our graph, may be disputed, but the records from the 16th century are so abundant that the curve for that century must be regarded as fairly reliable.

THORODDSEN uses the picture "troughs and ridges". On considering the curves (see Fig. 117 and Fig. 118) one is tempted to use the expressions "lowlands and mountain chains". If so, a lowland occurred in the Saga time, a low mountain chain from 1200—1400, and from 1600—1900 actual alps. The curve shows distinctly that not till the last two decades has this mountain range been passed and the level of the Saga time reached again.

If we consider the two curves (Figs. 117 and 118) as true expressions of the quantity of ice and accordingly of the fluctuations of the climate in Iceland, it would be tempting to draw conclusions from them as to the history of the Icelandic people, but this is beyond the scope of the present work. It should merely be mentioned that the year 1784, when the Danish Government seriously contemplated the removal of all the Icelanders from the island to place them on the heaths of Jutland, falls within the twenty-year period which exhibits the greatest number of weeks with ice. The quantities of ice around Iceland at that time were so immense as never before or later in the history of the country.

The archaeological and zoological investigations in recent years support the assumption of a mild climate in the 14th and 15th centuries, as shown in our curve.

After of the greater part of this chapter had been prepared Mr. GUDJONSSON called my attention to an article in Icelandic in the Icelandic periodical "Skírnir" (Reykjavik 1926), in which JON EYTHORSSON (pp. 113—33) deals with changes of climate in Iceland and Greenland since the Landnám time. This article draws greatly on THORODDSEN's paper of 1916—17 but is not very clear. It is interesting to note, however, that EYTHORSSON arrives at entirely the same result as I arrived at on reading THORODDSEN's brief paper of 1884. Thus EYTHORSSON writes (p. 128) after giving a table of light ice years, moderately good years, severe years, and the number of people who died from starvation every century (translated from the Icelandic):

"It will be seen from the table that the 17th century shows the greatest number of severe years, next comes the 18th century."

After mentioning the power of resistance of the nation against influences from abroad during the ages and pointing out that cattle

plague, volcanic eruptions, etc., likewise play a part, EYTHORSSON writes (p. 129):

"But altogether there would seem to be more reason to assume that a period with severer weather prevailed in the country in the 17th than in the 14th century."

Thus EYTHORSSON was aware of the influence of the severe climate of the 17th century on the history of Iceland. Curiously enough, this paper is not quoted by THORARINSSON in 1943.

To sum up: The diagrams and the two curves Figs. 117 and 118 constitute a first attempt to represent graphically what is reported in the Icelandic literature about the occurrence of ice along the shores of Iceland during the last eleven hundred years. How much importance should be attached to these curves, is a matter of judgment; in our opinion, however, the Icelandic literature is so rich that practically all heavy ice years must be assumed to be mentioned in it in some way or other. At any rate it is so well known that no essential information can be expected to be derived from it in the future. Possible alterations of the curves must be based on other material, for instance on pollen analyses; however, as to Iceland such an investigation is still in its initial stages.

At present no further information about the fluctuations of the climate of Iceland can be derived from the available material. It will be interesting, therefore, to make a comparison with the available data from southern Greenland during the Norse times and from the whole of Greenland as to the migrations of the Eskimos in order to find out whether the curves are liable to reflect fluctuations in the climate in the waters surrounding Iceland and Greenland (see below).

The Climate of Iceland and the Growing of Cereals according to Thorarinsson.

After the present paper had been sent to the printers, I received from Stockholm an important new paper by SIGURDUR THORARINSSON (1944). In this paper the growing of cereals in Iceland is discussed at length (pp. 131—172), and in the English summary THORARINSSON says as follows (pp. 211—212):

"From North and East Iceland there is no contemporary evidence of the cultivation of cereals, probably because all such cultivation had ceased there before the end of the 12th century. In the 13th and 14th centuries grain growing diminished in the other districts. A description of Iceland dated c. 1350 states that: "grain, but only barley, is grown in a few places in the South country". Contrary to the current opinion that grain growing had ceased completely in the 15th century, the

author thinks he can prove that it continued in the district round the S part of Faxaflói until towards the end of the 16th century (cf. Fig. 63 and Table VII).

The evidence points to *barley* being the main cereal crop in ancient times, but is not absolutely conclusive as to whether any other cereals were also grown.

In the 17th, 18th, and 19th centuries occasional cereal growing experiments were made in various parts of the country. These were sometimes successful, more especially in the S and SW districts, but were never persisted in. Not until the 1920:ies were any continuous cultivation trials begun, and since 1928 barley and oats have been continuously cultivated on a large scale with excellent harvest results at the Sámsstaðir Experimental Station in Fljótshlíð (Fig. 64). In the 1930:ies successful grain growing trials have been undertaken in all parts of the country.

. . . . . .

Opinions have been, and still are, divided as to the cause of the retrogression and final cessation of the old-time cereal growing in Iceland. In the last decades that discussion has included the question whether the climate in the countries round the North Atlantic deteriorated in the late Mediaeval times (c. 1300). Such a change is, *inter alia*, supposed to have contributed to the disappearance of the norsemen from Greenland and to an economic depression in Norway. Some students regard the fact that cereals used to be grown in ancient Iceland as one of the most decisive proofs that the climate was more favourable in the days of the vikings and for a few centuries after them than it has been after A. D. 1300; while others definitely maintain that the climate did not deteriorate in late mediaeval times and that the retrogression and cessation of cereal growing in Iceland must be wholly ascribed to economic and social causes. The author takes up an intermediate position, and holds that even if social and economic causes, and particularly changing conditions of trade, may well have contributed to the retrogression and cessation of cereal growing, there are nevertheless strong reasons to think that fluctuations of climate in historical times are reflected in the history of cereal growing in Iceland. Originally, cereal cultivation was obviously conditioned by the climate. The successful recent experiments are, in the author's opinion, one result of the exceptionally favourable conditions obtaining all round the North Atlantic during the last few decades. As yet we know too little of the history of grain growing in Iceland, however, to determine the exact time when—if at all—a deterioration of the climate did occur in the late Middle ages, but in the *pollen analysis* we have a means of supplementing our knowledge."

It will be seen that the results arrived at by THORARINSSON as to the grain-growing in Iceland are in good agreement with the results arrived at by us and expressed in the curve Fig. 118. On p. 142 THORARINSSON says as follows (translated from the Swedish):

"It may therefore be regarded as beyond doubt that the grain-growing which took place in Iceland fairly continually after the beginning of the Landnám time about 870, ceased towards the end the 16th century, that is to say, after it had been going on for about seven hundred years. The next attempt at growing grain, and the only attempt in the 17th century, took place around 1650 and then on only one farm, Hlíðarendi in Fljótshlíð."

It appears from an Icelandic description of 1666 that the attempt to grow grain in the 17th century was carried out by an Icelander, who about 1640 during a stay in Holland had taken an interest in grain-growing. It would seem that the grain ripened in most years. The experiments were made in one of the most favourable places in southern Iceland, and looking at the curve in Fig. 118, we shall find that it took place during a period in which the quantities of ice present around Iceland were very sparse.

Thus THORARINSSON's investigations of the grain-growing in Iceland seem to lend great support to the fluctuations of the climate assumed by us, since grain was grown from the first colonisation to about 1600, and apart from a single attempt in the 17th century (cf. above) was not resumed til about 1920 *after the three cold centuries.*

Causes of Fluctuations in the Quantities of Ice.

OTTO PETTERSSON (1915) explains the scarceness of ice in South Greenland during the Norse period by assuming that the warm Irminger Current was very strong; however, very little is known about fluctuations in the strength or possibly in the temperature of the Irminger Current.

OTTO PETTERSSON's explanation seems one-sided and little probable; the small quantity of ice that occurred during the Norse time is no doubt due to the different conditions prevailing in the Polar Basin at that time.

Some authors have explained the favourable conditions for navigation along the southeast coast of Greenland at the end of the Middle Ages on the basis of vague statements to the effect that the ice chiefly remained northward; in the late summer, in particular, the ice did not extend very far down the east coast. This view is on the whole unfamiliar to earlier navigators, who knew that the ice which resists melting along the stretch, 3000 km long, from Nordostrundingen to Kap Farvel is chiefly the heavy pressure ridges many years old and gradually fused

which were formed in the Polar Basin and constitute the ridges in the old floes around the North Pole. The last remnants of these ridges come to southwestern Greenland in the form of growlers.

Only the recent summers, for instance 1925, 1930, 1933, 1936, and 1939, when but small quantities of ice were found south of the line Nordostrundingen-Amsterdam Island, give us an idea of the ice conditions in the North Atlantic in the Viking time, especially in the late summer.

In the eighties FRIDTJOF NANSEN, as is well known, found a cold surface layer of sea water c. 200 m thick in the Polar Basin. The most recent investigations have shown that from that time up to the present this cold layer has been reduced to about half its thickness, being now hardly 100 m thick.

In NANSEN's time the pressure ridges in the Polar Basin might theoretically attain heights of 20—24 m before their lower parts reached down into the warm layer of water. At the present day, when the cold water layer is hardly 100 m thick, the summits of the ridges may rise to a height of 10—12 m at most before the melting from below begins. Such heights were found by NANSEN, but it must be borne in mind that his observations were mostly made on the Siberian Ice, not in the central and western parts of the Polar Basin; moreover it must be assumed that by movements in the water below heavy pressure ridges the warm water from below may reach the lower part of these ridges, even though they do not reach a depth of 200 m. If we suppose that the cold water layer will continue to decrease, e. g. to 50 m, the ridges will only be 5—6 m high. In other words, the thinner the cold water layer, the more will the appearance of the North Pole Ice resemble that of the Siberian Ice and the old worn ridges in the floes will gradually disappear. As a whole the ice will be subject to such considerable melting on its way southward that the greater part of it will disappear north of Iceland in the late summer. If we imagine that the cold surface water in the Polar Basin in the Norse time was only c. 50 m thick, this explains why there was hardly ever ice off southern Greenland during the greater part of the summer.

ICE CONDITIONS IN SOUTH GREENLAND IN THE MIDDLE AGES

Introduction.

Various information about the ice conditions in Southwest Greenland in former times is supplied by the literature, it may even be said that this information, which covers the period from the end of the 10th century up to c. 1500, at several points is much more reliable than the data available from the corresponding period in Iceland.

Already during the Landnám time the Norsemen in Iceland were aware that west of the land in which they had settled lay a large country; it was occasionally sighted and possibly visited some few times during the Icelandic Landnám time.

The actual emigration from Iceland to Greenland, which was merely a continuation of the emigration from Norway to Iceland, commenced after a three-year exploration voyage to Southwest Greenland half a century after the cessation of the Landnám time in Iceland. The Greenland Landnám time seems to have been of shorter duration than the Icelandic.

About the year 1000 the two Norse settlements erected in Greenland, the East Settlement, comprising the Julianehaab district, and the West Settlement, comprising the Godthaab district, had a total population of more than 3000.

The immigrators were in all essentials Norse farmers, who lived like the farmers in Iceland, though with the difference that hunting in Greenland was more plentiful and played a much greater role than in Iceland.

The Greenland community of Norsemen produced a surplus of improved agricultural products, as for instance butter and cloth, and hunting yielded ivory, especially in the form of walrus teeth, more rarely narwhal teeth, cordage of walrus skin, and in rare cases living bears or bear skins. These products formed the basis of the trade with Europe.

Below I shall briefly summarise certain facts concerning the colonies of Southwest Greenland.

982[1]. — Erik the Red, born in Norway, was proclaimed an outlaw in Iceland, and therefore set out for the country west of Iceland. He passed the winter on an island near Julianehaab, and in the early summer of 983 discovered Eriksfjord (Tudnuliarfik Fjord), which later became the centre of the colonisation. In the same summer he sailed northward along the coast as far as Godthaab Fjord, where the West Settlement was later established.

After passing the winter on another island near his wintering site of the year before, he made (in 984) a voyage to explore the east coast of Greenland[2]).

After this voyage he spent the winter in his first wintering place and returned to Iceland in 985.

986. — In 986 when Erik the Red set out with 25 ships to colonise Greenland, the actual Landnám time in Greenland began. About 500—700 men and women must have been on board the ships, and they brought with them both cattle and horses. However, only fourteen ships reached the shores of Greenland, but during the succeeding years people were constantly arriving from Iceland, and it was not long before the colonisation comprised 280 farms, about two-thirds of which were found in the East Settlement and one-third in the West Settlement.

Archaeologists distinguish between two divisions of the East Settlement, viz. the East Settlement (the fjords around Julianehaab) and the Middle Settlement (the fjords around Ivigtut), where no excavations have hitherto been made.

AAGE ROUSSELL (1941, p. 11) publishes the subjoined list of the farms dealt with in the medieval literature, enumerating what has hitherto been found of them. ROUSSELL points out that some of the farms must, of course, have been destroyed in the course of time, so the list will never be quite complete.

	West Settlement		Mid. Settlement		East Settlement	
	document	ruins	document	ruins	document	ruins
Churches	4	3	..	..	12	9
Monasteries	..	..	..	..	2	2
Farms	90	74	..	24	190	176

This list shows that both as regards history and archaeology the available material on the life and activities of the Norsemen in Southwest Greenland in the Middle Ages is very copious.

[1]) The first years given are hardly precise; they may vary from one to some few years.

[2]) Cf. POUL NØRLUND 1942.

1126. — In 1126 Greenland had its first bishop; Christianity had been introduced into Greenland almost simultaneously with the Landnám time, or about the year 1000.

During the following years the Roman Church contributed greatly to maintain the connection between Greenland on the one hand and Iceland/Norway on the other.

In **1261** Greenland was subjected to the Norwegian crown, probably chiefly because the Norwegian king declared himself willing to undertake a more regular communication by sea with the settlements. However, at that time the power of Norway was already declining, and this decline was soon traceable in Greenland also, especially from the end of the 13th century.

In the years **1350—1360** the West Settlement was completely destroyed by Eskimos migrating from the north.

In **1367** one of the king's ships, the "Knarren", was wrecked near the Norwegian coast, and after that time every form of regular communication seems to have stopped.

In **1377** or **1378** the last bishop living in Greenland died. Bishops to serve in Greenland were indeed appointed for some time onwards, but they never reached the country.

In **1379** the Eskimos seem to have made a serious attack on the East Settlement.

In **1380—1385** several ships which had been beaten off their course reached Greenland, but the crew was not allowed to exchange goods with the Norsemen on account of the trade monopoly of the Norwegian king.

In **1406** a ship manned with Icelanders on a voyage from Norway to Iceland was beaten off her course and drifted towards Greenland, where the ship and her crew remained for the next four years.

Detailed information about a wedding in Hvalsø Church is at hand from **1408.**

In **1410** the ship left Greenland and returned to Norway. This is the last reliable record of a ship calling at Greenland.

In the period **1411—1500**, however, communication must not rarely have been established between Europe and Greenland outside the trade monopoly. This is evident from the fact that both in 1413 and 1431 the Danish king complained in England that trade and fishery with the tributary countries were carried on, though such trading with the tributary countries had been prohibited. In 1432 and 1449 treaties were concluded between the Danish and English kings, according to which trading and communication by ship with the tributary countries of the Danish king were to be closed to the English, and in 1444 this prohibition was enforced by the English king.

In the years 1482—83 and 1491 pirates and privateers seem to have carried on freebooting along the coasts of Greenland.

From c. 1540 ships from Hamburg are reported to have been beaten off their course and drifted towards Greenland. Thus a report, to which POUL NØRLUND gives credence, tells about a man called JON GRØNLÆNDER, who went ashore about this time and found a man (a Norseman) lying dead on the shore. JON GRØNLÆNDER is reported to have brought home a worn iron knife which lay near the dead body.

Previously it was assumed that the Norsemen in Greenland had succumbed at the beginning of the 15th century; however, POUL NØRLUND's excavations in the churchyard at Herjolfsnes in 1921 brought to light dresses made on European models which must date back to about the year 1500. It must therefore be regarded as probable that the last Norsemen were alive up to about 1540.

As stated above it is a fact that the Norsemen lived in Southwestern Greenland for more than five hundred years, viz. from shortly before the year 1000 to some time after 1500.

Unfortunately it is impossible to give a more precise chronology for these five hundred years. That changes of the climate have taken place, is evidenced by the various sailing directions and recent palæobotanical investigations. That a cultural development has likewise taken place during these five hundred years must be taken for granted, but so far our conjecture as to such a development is based on very few reliable data.

It is to be hoped that it will be possible in the future to establish a reliable chronology for the Norse culture, as such a chronology will be of the greatest importance i. a. in dating the Eskimo cultures.

All the information about the life and doings of the Norsemen in Greenland recorded in the medieval literature has been collected in the monumental work "Grønlands historiske Mindesmærker", Vols. I—III, 1838—45, which will for ever maintain its position as one of the most important works dealing with the life of the Norsemen in Greenland.

In the course of the hundred years this work has existed it has, of course, become obsolete on many points. Thus the researches of philologists have resulted in a distinction between reliable and less reliable saga reports, so a revised edition of the work is highly desirable. The investigations of recent years within archaeology, zoology, and palæobotany have secured much fresh information. A revised edition must, like the old one, take a survey of our knowledge of the medieval topography and habitations of Greenland. This might perhaps supply a basis for a revision of the philological appreciation of the reliability of the written sources.

Above mention has been made of the report by JON GRØNLÆNDER from c. 1540, which till quite recently was regarded as purely fictitious, but which must now be regarded as probable.

In one respect the "Grønlands historiske Mindesmærker" deserves great credit, namely because it reproduces the sagas in their original shape, and makes no attempt to compare the reports of the sagas with the natural conditions which were later known to exist in Greenland.

However, there are a few exceptions. Dealing with the localities within the so-called Nordsetor[1]), the work mentions for instance Eysunes, which means the place where coal-bearing beds are found. Since a hundred years ago coal was only known from the so-called Upernivik snæs in Umanak Fjord, it was taken for granted that Eysunes was situated there. Later investigations have shown that large quantities of coal are found in many places southward along the coasts right down to a little north of Godhavn. It is likewise interesting that the work does not deal with the ice conditions of later times, but simply takes it for granted that the Norsemen on their voyages to Greenland and the countries west of Greenland were not troubled by ice of any importance.

Recent Literature on the Climate.

Of the investigations around the change of the century there is reason to mention those of GUSTAV HOLM (1883) and DANIEL BRUUN (1915), both of whom made a careful survey of the Norse settlements, and that by FINNUR JÓNSSON (1898), who on the basis of the present topography could locate the most important place names mentioned in the medieval documents.

In the second decade of the present century a controversy arose as to whether the climate of Southwest Greenland during the time of the Norse settlement was the same as now or whether it was milder than at present. The background of this controversy was the ice conditions known to prevail at the end of the last century.

It was FRIDTJOF NANSEN, who in his great work "Nord i Tåkeheimen" (1911) started this controversy, which became particularly heated because NANSEN held the view that the voyages from southern Greenland to Wineland had never taken place.

NANSEN furthermore treated the life and doings of the Norsemen on the assumption that the ice conditions at that time were like the conditions prevalent at the end of the last century, and thus arrived at several very peculiar conclusions directly at variance with our present knowledge.

[1]) Nordsetor = The hunting districts north of the two settlements.

Many of NANSEN's opinions were criticised—or purely rejected—by philologists, but DANIEL BRUUN (1915) as well as HOUGAARD (1915) and STEENSBY (1917) assume that the ice conditions during the Wineland voyages were similar to those prevalent about the year 1900.

In 1913, however, a paper by OTTO PETTERSSON was published in which the question as to a change of the climate in Greenland was considered from quite new points of view (pp. 29—52). This chapter is of special value because FINNUR JÓNSSON had read through OTTO PETTERSSON's manuscript (cf. l. c. p. 37), and on a direct question asked by PETTERSSON as to whether the sagas supplied information about the ice conditions around Greenland, FINNUR JÓNSSON replied as follows (translated from the Danish):

"They (the Norsemen) went to Wineland from Greenland as if there had never been any ice obstructions, on the whole there is never any suggestion of such obstructions along the coast of the ancient East Settlement."

To explain this OTTO PETTERSSON assumes that the Irminger Current south of Iceland was stronger a thousand years ago than at present, and that consequently

1) the climate of the East Settlement was milder than at present, the sea outside the settlement being free of ice, and
2) that Baffin Bay and the Labrador Current issuing from this bay were icefree, too, which affected the climate of New Foundland and northern Europe, in other words, the Polar ice melted in higher latitudes than at present (p. 30).

OTTO PETTERSSON deals also with the ancient sailing directions for navigation around Greenland, and reproduces (Figs. 16—17, p. 50, cf. Fig. 119) the so-called "Eriksstefna", Erik the Red's sailing route, which seems to have been used in the period 1000—1200. It runs from Snæfellsnes on Iceland across to Gunnbjørns Skær (Angmagssalik), thence southward along the east coast of Greenland to Prins Christians Sund and onward to Herjolfsnes. Routes II and III indicate IVAR BAARDSON's routes used about 1350. One of these (II) runs from Reykjanes on Iceland in a slightly southwesterly direction towards the east coast of Greenland about midway between Angmagssalik and Kap Farvel; at a fairly great distance from the coast the route bends southward around Kap Farvel and thence northwestward to the Julianehaab Bugt. Route III extends from Bergen in Norway to a point south of Kap Farvel, whence it bends northward towards Herjolfsnes.

His Fig. 17 shows the present route to Greenland from Bergen. The ice belt is indicated according to our knowledge in 1903. The route runs at a great distance south of Kap Farvel, along the ice edge, which

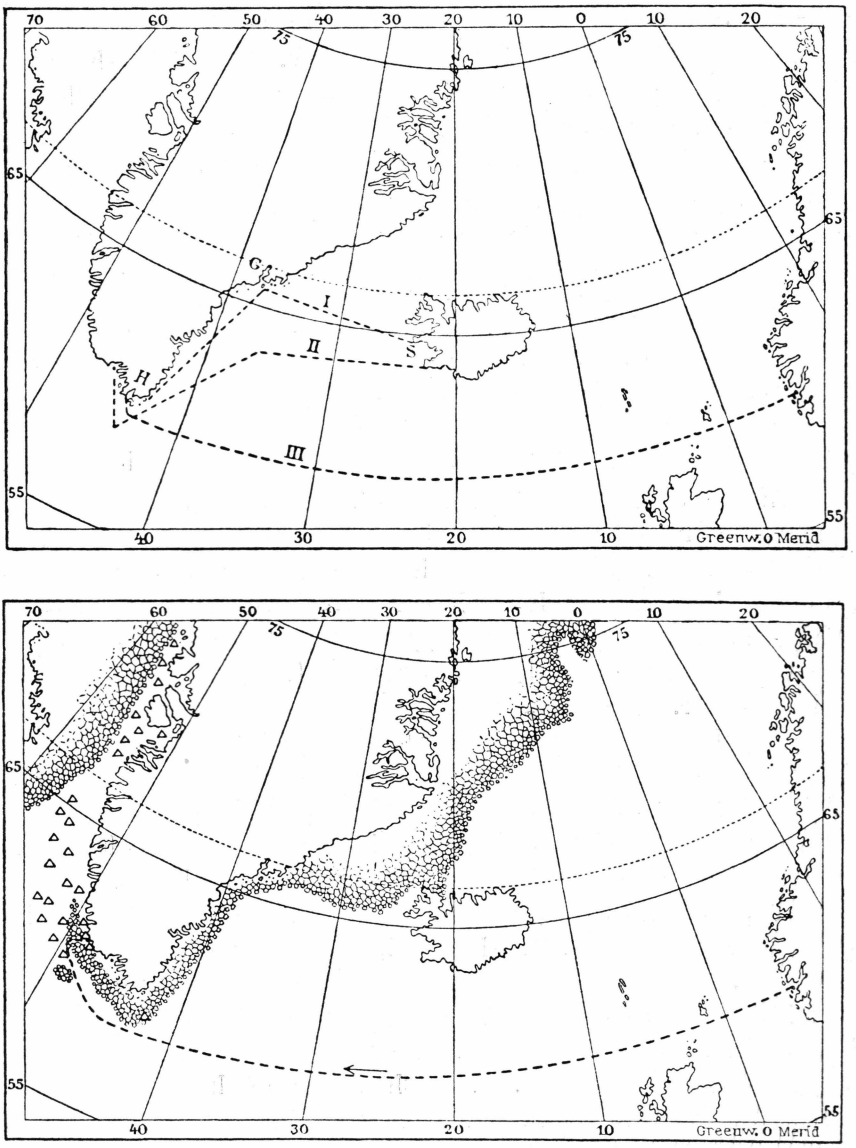

Fig. 119. Otto Petterson's Figs. 16 and 17 showing the three ancient routes and a more recent route (summer of 1893).

extends northward to near Frederikshaab, where the route bends towards the shore.

Otto Pettersson further mentions the "King's Mirror" from about 1250, that is to say, from about a hundred and fifty years before the time of Ivar Baardson. On reading this document (cf. below), one gains the impression that ice conditions similar to those about the year 1900 prevailed at that time.

On pp. 33—34 PETTERSSON sums up the sailing directions as follows:

1) The ancient sagas, from the period 900 to c. 1200, say nothing about ice troubles experienced by the Norsemen; at that time they still followed the routes given in the "Eriksstefna".

2) In the "King's Mirrer" (c. 1250) it is said that he who sails towards Greenland will meet much ice in the sea, so the seafarers are warned against approaching the east coast of Greenland too soon. However, no new route is recommended.

3) About one hundred and fifty years later, at the time of IVAR BAARDSON, the old route had been abandoned, the course being now laid farther southward to avoid the ice.

OTTO PETTERSSON goes on to say (translated from the Swedish):

"These statements by reliable authors from different times give a picture of the deterioration of the ice conditions around Greenland, which, of course, took place in the course of some centuries, until, finally, in the course of the 13th and 14th centuries the Polar current with its ice masses sometimes entirely surrounded both Iceland and Greenland, blocking also the west coast of the last-mentioned country in the summer.

In all the succeeding centuries the east coast has remained inaccessible and all expeditions sent out to rediscover the East Settlement had bad luck."

PETTERSSON held the view that the first Norsemen who went to Greenland did not go south around Kap Farvel, but through the archipelago north of this cape, especially through Prins Christians Sund, which, of course, is only possible if the southern part of the coast is entirely free of ice.

Changes of the climate in Greenland were not discussed till after the publication in 1924 of POUL NØRLUND's important excavations at Herjolfsnes carried out in 1921. In Chapter 10 of that paper NØRLUND discusses the possibility of a change in the climate of Greenland in the late Middle Ages. On p. 228 he quotes GUSTAV HOLM's report on his investigations in 1880 as follows:

"It seems difficult to understand how sufficient winter fodder for the cattle could be collected in those days if we are not to assume that the climate was milder, so that the cattle could be kept out a longer time of the year than is now the case. That the ice drifting along the coast has increased in historical times is mentioned in old records, and seems to be a necessary assumption if we want to understand how the early Norse settlers were able to sail to and from the district of the present Julianehaab; and further, no one will be able to deny that this ice, now

lying everywhere outside this part of the country, considerably increases the severity of the climate."

NØRLUND writes that it appears clearly from the literature that in the Middle Ages it was necessary to alter the ancient sailing routes on account of the drift ice. He also points out that ice is not mentioned in the earliest sagas; but he calls attention to EINAR SOKKESON's saga of 1130, in which it is reported that drift ice arrived but soon drifted away again (POUL NØRLUND, 1924, p. 232).

As to IVAR BAARDSON's sailing route NØRLUND says that BAARDSON must have known the ice and its dangers, though apparently he did not know of any ice obstacle near the East Settlement. The ice to be avoided occurs off Gunnbjørns Skær (Angmagssalik), whereas no dangerous ice is reported to occur around Kap Farvel.

On p. 235 NØRLUND mentions the description in the "King's Mirror" from c. 1250, which runs as follows:

"As soon as most of the great ocean has been traversed, there is such a great superfluity of ice on the sea that nothing equal is known in any other place in the whole world, and it lies so far from land that there is no less than four or more days' journey thereunto if one travels on the ice, but this ice lies more to the north-east or the north outside the land than to the south and south-west or to the west, and therefore any one who wants to make land should round it, heading south-west and west until he had passed all the places where ice is to be expected, and then make straight for land. But it has continually happened to people that they have sought land too soon and have therefore got into this ice."

NØRLUND discusses this paragraph and points out that the ice is reported to lie more to the northeast or north than to the south and southwest, or to the west. The ice especially occurs rather far up the east coast, and for this reason the course should be laid towards the southwest and west "past the ice before land is sought" (NØRLUND, 1924, p. 236).

After this attempt to invalidate the mention of the ice in the "King's Mirror" and IVAR BAARDSON's record, NØRLUND says (1924, p. 236):

"That Herjolfsnes was really, until the beginning of the 15th century at least, "the common port for Norsemen and traders", is most vigorously confirmed by the excavations in 1921."

After mentioning a cap found in one of the graves at Herjolfsnes, he writes (1942, p. 118) (translated from the Danish):

"This cap thus becomes a very important document for the medieval history of Greenland, evidence that as late as towards 1500 there must have been communication by ship between Greenland and Europe."

An even stronger proof of the existence of a favourable climate up to the end of the Norse colonisation in Greenland is in NØRLUND's opinion supplied by the state of the graves investigated by him (many of them dated back to the latter half of the 15th century); they were found in frozen soil, but were interwoven with plant roots. NØRLUND gives the following explanation (1924, p. 241):

"We must suppose, then, that the coffins, crosses, or dresses that are best preserved originate from burials that took place at midsummer time when the thaw had reached its deepest level. They lay from the beginning immediately on the frozen bottom and only thawed during the warmest season every year. In this way the putrefaction of the body took place slowly and at long intervals without damaging the surrounding shroud. Later on the summer-temperature fell, and what was still left of these interments became encased in the frozen earth which also preserved those plantroots that had had time to penetrate into these deeper layers during the summer."

The chapter ends by the following statement (pp. 242—43):

"I do not consider the question here discussed definitely settled by our investigations. But it is not saying too much, I think, if we hold that weighty evidence has been brought forward to show that a deterioration of the climate and ice conditions has taken place in Greenland since the Middle Ages, and with a climate of the nature here in question even a very slight change in temperature might have the most far-reaching effects."

A popular up-to-date description, including, also, the latest results of excavation, was published by NØRLUND in 1942.

A last attempt to maintain the view that the climate of Southwest Greenland has not changed since the time of the Norse settlers is found in FRIDTJOF NANSEN's paper of 1925, in which he polemises against NØRLUND, but no essential new views are put forward. Since then it seems to have been the general opinion of archaeologists, zoologists, and palæobotanists that the climate *has* changed since the time of the Norse settlers, and the evidence of this seems to become more and more comprehensive, especially after the modern investigations following upon NØRLUND's excavations at Herjolfsnes and continued with increasing vigour till shortly before the beginning of the war (1939).

Before ending the treatment of the literature on the climatic changes, I shall briefly mention the sailing routes frequently commented upon in the literature.

The first mention of such a route is made in the "Eriksstefna" from c. 983—c. 1200, but no ice is reported.

The "King's Mirror", from c. 1250, gives a very gloomy picture of the ice conditions.

Ivar Baardson, c. 1350—1400, says expressly that the old route cannot be followed any more because more ice has arrived; this statement supplies positive information, but it would seem that the ice is especially found along the east coast, near Gunnbjørns Skær.

In this connection it is interesting to note what Thoroddsen writes in Árferði (1917, p. 364) on the ice conditions in Iceland (translated from the Icelandic):

"Ice years are rarely recorded from the first four centuries, and if so, with doubt; ice is recorded from the years 865, 1010—12, 1015?, 1106, 1118?, and 1145."

It seems to me, however, that for several of these years the records of ice are so doubtful that nothing can be founded on them. As to the 13th century (the century dealt with in the "King's Mirror") Thoroddsen (1917, pp. 364—65) writes as follows:

1203, an exceptional summer. Drift ice near the shore about the middle of August. At the beginning of July thirty men went from Flatey across the ice to the mainland.

1233, a severe ice winter, drift ice all summer.

1244. Minor ice floes drifting in the outer part of Húnaflói (it is interesting that this year is mentioned though there was not very much ice near Iceland).

1258. Drift ice around the country, which filled all the fjords.

1261. Drift ice around Iceland.

1274. Twenty-two Polar bears killed in Iceland.

1275. Twenty-seven Polar bears caught in Iceland. Drift ice surrounding almost the whole country.

1279. The sea was frozen up, so it was possible to travel with horses on the ice many miles from the shore. The ice remained till the late summer, a phenomenon which had never been experienced before. Only from a few places was it possible to go out fishing.

1295. Many whales in the winter, which were washed ashore.

Ivar Baardson's century is described as follows:

1306. Drift ice along the north coast.

1309. Many whales drifted right in to the shore.

1314. Famine in the north country. The drift ice disappeared after Easter.

1319. Drift-ice outside the eastern fjords and Síða, persisting till about midsummer. Ships wrecked off the eastern fjords and near Vestmannaeyjar.

1321. Drift ice in the sea around Iceland.

1348. The frost was so severe that the sea froze up to such an extent that it was possible to ride on horses from all the outermost capes and on all the fjords and bays. (No drift ice is mentioned).

1360. (1917, pp. 365—66). Drift ice present near the shore till after the middle of August.

1375. Drift ice present near the country till the last half of August.

The records about the occurrence of ice near Iceland are in good agreement with the sailing directions and seem to show that during the first centuries (1000—1200) navigation near Greenland was not, or only exceptionally, impeded by the ice. In the century dealt with in the "King's Mirror" (1200—1300) relatively large ice masses occurred, but it did not cause so much trouble that Herjolfsnes was abandoned as a port. From IVAR BAARDSON's century (1300—1400) fewer ice-years than from the preceding century are recorded from Iceland.

The Coasts along which the Norsemen Lived and Travelled.

The picture we have gained of the Norse time in Greenland is founded to a great extent on the medieval documents.

The most important result of the recent excavations is the discovery that the Norsemen have lived in Greenland for at least one hundred years longer than previously assumed (viz. up to c. 1500).

All the zoological material brought home by the archaeologists in recent years has been worked up by Dr. M. DEGERBØL. The modern paleobotanical methods of pollen investigations have been commenced, also, and may no doubt yield important results in the future (IVERSEN 1934).

Below I shall mention the coasts which were visited by the Norsemen.

1) The East Settlement (the Julianehaab district) (986—1500; 1540?). Five modern excavations have been made within this district, viz. the excavations of Herjolfsnes (1921), the most important port, Garðar (1926), the bishop's residence from 1126, Brattahlið (1932), the oldest and for long periods the most important farm of the East Settlement, and Hvalsø (1941), a large farm with the famous church which has given its name to the fjord behind the present Julianehaab, and a number of farms inland (1943).

Nearly all the farms (c. 190), churches (c. 12), and monasteries (2) mentioned in the documents have been rediscovered. The names of nearly all the fjords and of many farms as well as the names of several of the men that lived on the most important farms are known.

Horse and cattle breeding was the chief way of gaining one's livelihood. The domestic animals were as follows: cow, sheep, goat, horse, pig, and dog. Hunting played a fairly important role, the seal most frequently hunted was *Cystophora cristata*, but other seals and whales were hunted also. Reindeer were occasionally hunted. The same applies

to the bear, but its bones rarely occur, possibly owing to the favourable climate, owing to which only small quantities of ice occurred off the East Settlement.

The East Settlement was naturally the cultural centre of Greenland.

2) The West Settlement (c. 1000—1350). Modern excavations were made in this district in the years 1930, 1932, 1934, and 1937. So far 74 farms and three churches have been found. As in the East Settlement, horse and cattle breeding was the most important trade, and the domestic animals were the same as in the East Settlement.

Hunting played a more dominant role than in the East Settlement and was of a somewhat different character. Of the land animals the reindeer was especially hunted. Hunting of fox and hare, which in the East Settlement played an inconsiderable role, was commoner in the West Settlement.

Only some few bear skeletons have been found, whereas many bones of walrus, which was rather rare in the East Settlement, have been excavated. No remains of *Cystophora cristata* have been met with, whereas *Phoca groenlandica* and *P. vitulina* were extensively hunted.

Of special interest is the finding of identifiable whale bones. DEGERBØL (1936, pp. 51—52) says as follows about this find:

"For the first time we have whale bones, dating from Norse times, capable of being classified (see the foregoing list). It is worth noting that species which have been extremely rare guests in Greenland waters like *Balæna australis* and *Lagenorhynchus albirostris* are represented; to some extent this also applies to *Globicephalus melas*, which, however, in recent times with the altered natural conditions has proved to be a more frequent visitor to Greenland than formerly. It is obvious that the finding of a few bones of these otherwise more southerly whales does not permit of far-reaching conclusions as to natural and climatic conditions in Norse times, but possibly the explanation is that at that time too West Greenland had a milder climate or merely warmer summers."

3) Wineland. — The considerable migration from Scandinavia during the Middle Ages culminated during the Wineland voyages about the year 1000. However, they comprise only some few voyages and winterings.

In 1917 STEENSBY treated the documents about Wineland, so I may refer the reader to his paper; on p. 200 it contains a map which shows the sailing route from Greenland to Wineland. This route runs from the West Settlement in a slightly northerly curve towards the southern part of Baffin Land and onwards along the coast of Labrador.

In my opinion the information about KARLSEFNI's voyage is very clear, especially the first part of it. The expedition started from the East Settlement, sailing to the West Settlement, and thence to the Bjørneøen (probably Disko). As the distance between Greenland and Baffin Land is only about 300 km, it must be taken for granted, notably in view of the favourable ice conditions assumed to prevail at that time that the Norsemen very soon discovered Baffin Land. If KARLSEFNI knew that this land existed, it is natural that his large and well equipped expedition would run no risk at the start, but sailed along the coast from the East Settlement to Disko in order to utilise the northerly winds frequently blowing here to cross the strait to Baffin Land, when he could sail along the coast to Wineland.

In future Wineland investigations attention must be directed towards another point, namely the question as to the northern limit of the distribution of the wine during the Norse times; if the climate was milder at that time than about the year 1900, the limit must have occurred farther northward than at present. This question can, no doubt, be elucidated by means of pollen-analytical investigations.

4) Nordsetor. — According to FINNUR JÓNSSON Icelandic names are found as far as Nordre Strømfjord and the fjord north of it, that is to say, northward to 63°30′ N. lat. Farther northward there were extensive hunting fields, called Nordsetor, which the Norsemen evidently soon began to utilise.

It might now be asked: What were the Norsemen seeking in these hunting fields? And the reply will be: Principally walrusses.

There is no reason to believe that a change of the climate causes any essential alterations in the migrations of the walrusses. We must assume that at that time as at present walrusses were of rare occurrence near the East Settlement, whereas they were common and went ashore along the outer coast both north and south of the West Settlement. Farther northward the migratory walrusses approach the shore between Holstensborg and Egedesminde, especially near the present outpost Agto. The coast north of this stretch is sparsely visited by walrusses, they are only found in a few places, for instance Nugsuak, Kap Cranstown and the cape north of the outpost Kraulshavn. Only as far north as Kap York is the walrus common again, having its breeding places at the mouth of Wolstenholme Fjord and between Northumberland Ø and Etah, where large numbers of walrusses are present all the year round.

As the walrus is very shy, it possibly left the outer coast around the West Settlement after it had been hunted for some time, or became rare, whereas it might no doubt for a long time be hunted between Holstensborg and Egedesminde, especially in the autumn.

Seals were hunted on excursions northward, where they were very abundant.

Evidently Polar bears were hunted on Bjørneøen (Disko), the bears probably drifting across the ice from the west in the winter.

The narwhal is especially met with far northward. Its teeth are of greater value than walrus ivory.

It must be taken for granted that the coast as far as Egedesminde and the whole of Disko Bugt was not inhabited by Eskimos at any rate during the first 250 years of the Norse times; the Norsemen had all the hunting to themselves.

Unfortunately the sagas do not state precisely when Eskimos were first met with by the Norsemen. Possibly the Wineland Eskimos or Indians were the first natives encountered. Possibly, also, the Eskimos, whose house ruins and implements were found on the Norsemen's arrival in the country, were met with on the east coast about the year 1000, but the Eskimos, if any, seem to have disappeared soon.

The Nordsetor no doubt has its history which may perhaps once form the basis of a chronology, but unfortunately practically nothing is known about it.

Walrusses and seals were no doubt present all the time in such abundance that the Norsemen noted no great variation in the stock of these animals. If there was a deterioration of the climate in the 13th century, the number of bears and narwhals possibly increased. The forests of Markland (situated north of Wineland, supposed to be Labrador) therefore possibly again became of importance (cf. reports on a voyage from Markland in 1347 in Grønl. histor. Mindesm. 1838—45).

Unfortunately the position of Krogsfjordshede at the time when the Norsemen first came into touch with the Eskimos has not yet been established. Possibly this area was not occupied by the Norsemen till about 1250; precisely in this century rich in ice (13th century) they may have moved farther northward owing to altered hunting conditions. While during the first 250 years of the stay of the Norse settlers in Greenland the Nordsetor seems to have been limited to Davis Strait as far as 70° N. lat., in 1267 this hunting area was extended so as to include Baffin Bay. In this year some clergymen sent a vessel on a voyage northward from Krogsfjordshede which, judging from the description, must have gone to Melville Bugt and probably as far as Inglefield Gulf; some Norse remains found by Therkel Mathiassen and E. Holtved at Inugsug and on Inglefield Land, respectively, would seem to show that the voyage in 1266 opened up new hunting fields which were utilised during the subsequent years. A runic stone found north of Upernivik dating from 1333(?) may be taken as evidence of the wintering of Norsemen there.

The character of the intercourse between Norsemen and Eskimos is unknown. Possibly some trading has been carried on, but possibly, also, their relations were of a hostile nature. But the Norsemen at any rate secured bear skins, narwhal teeth, walrus teeth, and walrus skins from the new hunting fields.

We know positively that the Eskimos who lived near Krogsfjordshede about 1250, about a hundred years later spread southward and destroyed the West Settlement. In the course of these hundred years the Nordsetor changed from a peaceful Norse hunting field to a battle field, where the Eskimos were victorious. After the destruction of the West Settlement the Norsemen lost their hunting fields for bear, narwhal, and drift-wood, and walrus-hunting became doubtful.

In the work "Grønlands historiske Mindesmærker" (1838—45) the following place-names from "Nordsetor" are mentioned: Greipar, Karlsboder, Bjørneøen, Eysunes, Æðanes, Nordskagi or Landsend, and Krogsfjordshede.

According to the same work Greipar was situated immediately north of 67° N. lat., Karlsboder north of Gl. Egedesminde(?), Bjørneøen is the present Disko, Eysunes (Eyso = coal) the Upperniviksnæs in Umanak Fjord. Æðanes is the later Kap Cranstown, while nothing is stated about Nordskagi.

As to Krogsfjordshede, which together with Greipar is assumed to be the second main station of the Norsemen in Nordsetor, various information is supplied by the sagas, thus for instance they mention the height of the sun on a certain day, the presence of the midnight sun on July 25th, and night frost. On the basis of a number of very doubtful calculations the place is assumed to lie in 75° N. lat., and since no great fjord is found on the west coast of Greenland in this latitude, Krogsfjordshede is assumed to have been situated near Lancaster Sound (cf. Grønl. historiske Mindesmærker Vol. II, p. 885).

The sagas give some distances in days' voyages; thus the distance from Lysufjord (63° N. lat.) to Karlsboder is stated to be a six days' voyage, from Karlsboder to Bjørneøen three, or a total of nine days' rows; the distance is 700 km, so it seems rather improbable. According to "Grønlands historiske Mindesmærker" a voyage from Godhavn along the outer coast to Kap Cranstown, thence to Upperniviksnæsset in Umanak Fjord and back to Godhavn east of Disko is equal to twelve days' rows, but this distance is likewise c. 700 km. If the days' rows covered the same distances as those farther south, the Norsemen would have reached as far as Upernivik in twelve days' rows.

In 1911 FRIDTJOF NANSEN discussed the question and came to the result that Krogsfjordshede was situated not far from Disko, at any rate south of the Nugsuak Halvø in 70° N. lat. This theory was ac-

cepted in all essentials by DANIEL BRUUN (1915) and POUL NØRLUND (1942).

The only one of these old place names which it is possible to locate is apparently Bjørneøen (Disko). Probably THORFIN KARLSEFNI reached this island with his large ships on his way to Wineland (cf. above). As Disko Bugt from the point of view of navigation is to be regarded as a land-locked sea, it is natural to assume that the Norsemen felt at home here during the first centuries of their stay in Greenland.

It is impossible to locate Eysunes. As is well known, coal-bearing beds occur from a little east of Godhavn northward along the coast to near the northernmost point of Disko, on the south and north coasts of Nugsuak Halvø, on Upernivikснæsset, and, though to a less extent, northward almost as far as Prøven.

During the time of the Norse settlers in Greenland eiderducks no doubt bred in large numbers on the islands around the present Egedesminde, and large flocks of eiderducks probably occurred around Mudderbugten. If we accept NANSEN's considerations and disregard the distances (days' rows) stated, Æðanes might be the region around Mudderbugten, in which case Krogsfjordshede must have been situated somewhere near the northern part of Vaigat (NANSEN, NØRLUND), and Eysunes near the present outpost Aumarutigset on the south coast of Disko (the word is the Eskimo word for coal, and it is the southernmost place in West Greenland in which coal occur in quantities).

If this theory is correct, Nordskagi cannot be located. The word means a projecting cape or the end of the country, and thus geographically it means a boundary, in this case a northern boundary of an area well known as a hunting field. Two capes present themselves in this connection. One is the Umanak Halvø north of Disko, which forms the boundary of the land-locked sea Disko Bugt, a cape which it is in no way easy to pass in small boats. The other is the westernmost point of Holms Ø, north of which the coastal landscape changes its character completely; south of this point the inland ice is only exceptionally visible, while north of it one has a full view of the inland ice, lands and islands forming merely the foreground of it.

Nordskagi is stated to be situated south of Krogsfjordshede, so it seems most probable that Nordskagi was the westernmost point of Umanak Halvø; if so, Krogsfjordshede must have been situated somewhere in Umanak Fjord.

It does not seem reasonable to assume that Krogsfjordshede was situated near Lancaster Sund or in the Thule district, especially because it must be taken for granted that these regions were densely populated by Eskimos about the year 1200; more probably it was found in the outer or northern part of Umanak Fjord. This would be in accord with

the fact that Eskimos were living near Krogsfjordshede in 1266, and it would also be in accordance with the voyage of the clergymen in 1267, for they started from a large fjord. They crossed Melville Bugt in bad weather and probably reached a point near Northumberland Ø, where, as stated in the sagas, they sighted a mainland with glaciers to the south. Evidently they went ashore here and found Eskimo remains. Then they returned in three days without encountering any traces of Eskimos on the islands south of Snefjell, a mountain familiar to them. Snefjell may be Mt. Haffner, one of the most prominent mountains of Greenland, situated in the northern part of Melville Bugt, or a mountain near Upernivik, Eskimo remains having been found near both places.

It is of importance to know the precise position of Krogsfjordshede, for if this place can be located, we should have good evidence of how far southward the Eskimos had spread in 1266.

It is probably doubtful whether remnants of the houses at Greipar or Krogsfjordshede will ever be met with, but there is a hope that fresh excavations at the Eskimo sites may throw new light on the importance of the Nordsetor to the Norsemen.

5) The coast from some distance south of Angmagssalik to Kap Farvel. During the period from c. 1000 to c. 1200 the ships visiting the settlements in Greenland evidently started from Iceland and sailed westward till land was sighted, and then, from a little south of Angmagssalik, went southward along the coast to Kap Farvel.

This stretch of the coast is about 700 km long. Apart from GRAAH's and GUSTAV HOLM's voyages in umyaks, both of which were made under difficult ice conditions, this coast has not been investigated till quite recently, and only if Angmagssalik Eskimos should settle there again and they are informed of the value of finds from the Norse time, may further evidence of the life of the Norsemen in these regions be secured.

Various events mentioned in the sagas must doubtless have taken place here. Thus the historically rather unreliable Flóamanna Saga mentions THORGILL ORRABEINSFOSTRE's voyage and shipwreck on the east coast of Greenland. Though many fictitious additions have been made, the description contains so many details that the voyage must be assumed to have actually taken place.

This voyage is treated at length by DANIEL BRUUN (1915, pp. 73—80). In the "Grønlands historiske Mindesmærker" the voyage is stated to have taken place in the years 998—1002, while DANIEL BRUUN thinks that it took place in the years 1001—1004.

In the years c. 1050—60 a man by name LODIN often sailed along the east coast to secure the dead bodies of wrecked seamen, in order

that their bones might be buried in consecrated soil. He was called "Lig-Lodin" (dead-body LODIN).

In 1125 a merchant by name ARNBJØRN set out with two ships from Norway towards Greenland. The ships were wrecked off the east coast of Greenland. Four years later a Norseman named SIGURD NJALSSØN, who often made hunting voyages to East Greenland, especially in the summer, found the dead bodies of ARNBJØRN and his men as well as the wrecks of the ships near the mountain Hvitserk; the largest ship was in such a good state that it could be saved and carried to the west coast.

In 1188 or 1189 the ship "Stangfolden" on her way from Norway to Iceland was wrecked off the east coast of Greenland. Eleven or twelve years later the wreck and the dead bodies of seven men were found in a rocky cave; among them was the clergyman INGEMOND, and a report on their death written by him in runic letters was found near him. INGEMOND's brother, EINAR THORGEIRSSØN, must have been wrecked at about the same time. It is reported that he crossed the inland ice in company with two other men, but they succumbed near the East Settlement, where their dead bodies were found and later buried at Herjolfsnes.

In 1189, or almost simultaneously with the wreckage of the "Stangfolden", the Greenlander ASMUND KASTANRASTE arrived in Iceland. He had followed the east coast of Greenland, having visited Finsboder, which is described as a hunting place of the Norsemen in East Greenland, and Kors Øer (near Angmagssalik). The ship must have been built in Greenland, for wooden nails were used instead of iron nails.

No reports of shipwrecks near the east coast are available from the 13th century, when the ice conditions were severe. The "Thorlakssudden", which was wrecked in 1382, probably approached the coast rather far southward, for some men of the crew seem to have reached the East Settlement in the same year.

These sparse and doubtful data tell us that prior to the year 1200 some ships were wrecked along the east coast of Greenland, evidently near the coast, not in the ice outside. Furthermore it would seem that in the period 1000—1200 Norsemen from the west coast have made hunting trips up along the east coast in the late summer and autumn, as the wrecks and sometimes the dead bodies of the crews have been found and identified.

A report on an actual coastal voyage from the East Settlement to Angmagssalik and thence to Iceland is at hand from 1189.

6) The Angmagssalik district. — That part of Greenland which was first discovered by the Norsemen and where, possibly, their first

wintering in Greenland took place (c. 970) is described in detail by GUSTAV HOLM (1918) and will not, therefore, be dealt with here.

7) Svalbarde or the coast north of Angmagssalik. — This area is mentioned in several places in the "Grønlands historiske Mindesmærker", thus in Vol. II, pp. 203—07 and 208, Vol. III, pp. 8, 13, 46, 50, 51, 211—13, 460, 492, 503, 517, 770, and 846. Many of the statements are probably doubtful; thus the statements about the Eskimos living along this stretch of the coast are very obscure, and it is doubtful whether they refer to this coast at all.

In the saga "Hauksbog" it is stated that it is a four days' voyage from Langenes to Svalbarde northward in the sea bay. If Svalbarde means Scoresby Sund, this statement is quite probable, the distance from Langenes to Kap Brewster being 530 km.

Furthermore it is stated that there is one day's voyage from Kolbeinsey in the north to the desolate coasts of Greenland, but this statement is regarded as exaggerated.

The distance from Kolbeinsey to the nearest point of East Greenland, namely Kap Dalton, is 350 km or c. 190 nautical miles. If this distance was to be covered by a ship in twenty-four hours, it would mean a speed of c. 8 miles, which would not be impossible for a viking ship under sail if the sea was calm and the wind favourable. Thus it is not beyond the limit of possibility that this remark *may* have reference to an actual event.

Svalbarde (Scoresby Sund or the surrounding regions) is stated to have been discovered or rediscovered in 1194 (Grønlands historiske Mindesmærker, III, pp. 8, 46, and 905). In 1285, it is stated, ADELBRAND and THORVALD, HELGES Sønner, discovered the so-called "new Land" west of Iceland. In the same year the Dunøer were discovered[1]). The discovery must have caused some sensation, for King ERIK of Norway sent one of his men by name ROLF to Iceland, whence he was to start on a voyage of discovery to the new land and Dunøer. However, the voyage came to nothing.

About the year 1516, when WALKENDORFF gathered information about Greenland, it is mentioned that the greater part of the ice came from Troldebugten (Op. cit. Vol. III, p. 492). It is not clear what Troldebugten shall be taken to mean; possibly it is the bay in the North Atlantic bounded by the ice edge extending along East Greenland and Spitsbergen southward to Bear Island, but it *may* just as well be the mouth of Scoresby Sund. In years with only little ice (cf. the remarks

[1]) "Grønlands historiske Mindesmærker" supposes that the new land is New Foundland, but GUSTAV STORM (1888, pp. 263—64) shows that the new land is East Greenland.

on the ice conditions in Scoresby Sund, pp. 87—88) ice is constantly carried southward along Liverpool Land and into Scoresby Sund by the current found there in the summer. This ice often accumulates some distance inside the mouth of the sound, and if the wind blows from the west, it may suddenly drift out; thus there may often be rather considerable ice-masses immediately south of the mouth of Scoresby Sund, while hardly any ice occurs north of it.

According to L. Bobé (1936), Jacob Ziegler seems to have communicated with Walkendorff when he wrote his work "Scondia" (1536). Ziegler gives several latitudes (Grønlands historiske Mindesmærker, Vol. III, p. 503), which are compared with Scoresby's map, and a closer accordance is pointed out between this map and Ziegler's description; thus Kap Gladstone, the northernmost point of Murray Ø, and Davy Sund between Kap Simpson and Kap Moorsom are stated to be in good accordance with Ziegler's latitudes.

In conclusion the authors of "Grønlands historiske Mindesmærker" sum up the scattered reports on the geography of Greenland, saying i. a. (p. 846) (translated from the Danish):

""Svalbardi i Hafsbotn", the cold shore in the bay of the sea, which according to the annals was discovered in 1194, is no doubt the stretch of coast visited in 1761 by Folkert Bohn[1]) from "Østerland Föhr" and later rediscovered by Scoresby and named by the latter Liverpool Coast, within which a large bay seems to occur, to which Scoresby's sound leads. The distance, four days' voyage from Langenes on the northeastern coast of Iceland, seems to be fairly correct. At a shorter, though probably wrong, distance from Kolbeinsey stated to be one day's voyage, that is to say, south of Svalbarde, uninhabited land occurred (III, 8, 212)."

From this it would appear that the Icelanders sometimes, at any rate, visited these coasts, even though it was no doubt very sporadically.

Reference may likewise be made to the paper by Gustav Holm (1925).

That I have dealt with the shores visited by the Norsemen at some length is due to the fact that the periphery of a cultural area may often give surprising cultural particulars about this region.

Not the slightest trace of the Norsemen has been found outside the East Settlement and the West Settlement, neither in Wineland nor Markland, Nordsetor (with the exception of the runic stone north of Upernivik, some very doubtful stone piles in Jones Sound, and Norse remains found in the Eskimo houses at Inugsuk, Thule, and on Inglefield Land), the coast south of Angmagssalik as far as Kap Farvel, the Angmagssalik district, and the coast from Scoresby Sund to Angmagssa-

[1]) Considered in more detail on p. 770.

lik. On finding Norse remains in Eskimo houses or middens, it should of course be noted whether they are derived from encounters with living Norsemen or from robberies of the settlements after the Norsemen had died. As examples of Norse remains which are of no value to chronology, mention may be made of some pieces of bell metal which are found in several places from Scoresby Sund in the northeast to Inugsuk in the northwest.

It will be evident from the above that around the year 1000 the Norsemen knew the coasts of Greenland from the Angmagssalik district southward past Kap Farvel and up the west coast to and including Disko Bugt, and in addition the coasts of southern Baffin Land as far as the mouth of St. Lawrence River. During the succeeding two centuries this area was not extended by new discoveries, and the voyages to the lands west of Greenland seem to have ceased rather soon.

Judging from the available data on the ice conditions in Iceland, these two centuries seem to have been favourable, navigation not being hindered by ice.

In the 13th century, when the ice conditions were no doubt more unfavourable, the sphere of interest of the Norsemen was extended; thus in 1266 they reached the Thule district and no doubt continued navigation on these districts.

In 1194 the regions round Scoresby Sund were discovered; they were rediscovered in 1285. Attempts were made to start a new expedition to these tracts, but they were unsuccessful, probably because the ice conditions were extremely unfavourable at that time.

From the 14th century reports are at hand on the peculiar voyage from Markland in 1347. In the same century Nordsetor lost its importance as a hunting field, and was entirely lost after the destruction of the West Settlement about the year 1350.

About the year 1400 only the East Settlement remained as the Norse sphere of interest and for the next hundred years it was secretly visited, chiefly by English vessels, which were not very much troubled by ice. The Norsemen died out at the beginning of the 16th century before the severe deterioration of the climate set in around 1600.

THE PERIOD BETWEEN THE EXTINCTION OF THE NORSEMEN AND THE WHALING TIME

It has been stated above that the Norse culture area during its culmination in Greenland extended from Scoresby Sund in the northeast around the south of Greenland to Smith Sound in the northwest.

From the period 983 to 1410 numerous records are at hand about ships that have visited Greenland, and even though the picture given of the possibilities of navigation are brighter for the first half than for the latter half of the Norse period, the ice conditions during these four centuries cannot have presented serious obstacles to the navigation of Julianehaab Bugt, where the Norse power reached its culmination and persisted for the longest space of time.

The available information about the navigation of Greenland during the next two centuries, from 1410 to 1612, is very sparse. Thus from the 15th century we only know that in 1472 or 1473 King CHRISTIAN I of Denmark on the initiative of King ALFONSO of Portugal equipped an expedition commanded by DIDRIK PINING and POTTHORST.

On this cruise PINING is reported to have been ashore near the mountain Hvitserk somewhere between Angmagssalik and Scoresby Sund and to have cut a compass in the cliff. It is definitely known that some fighting was going on with the Eskimos, who possessed kayaks. Hence we may conclude that there was hardly any ice along that part of the coast in the late summer of that year.

POUL NØRLUND's excavations at Herjolfsnes in 1921 showed that commercial intercourse took place in secret between the Norsemen throughout the 15th century.

From the 16th century a number of scattered reports about ships that have visited Greenland are at hand.

In 1537 and 1539 some Hamburg vessels, which were to call at Iceland, were beaten off their course and drifted towards Greenland. They came quite near to the shore, probably near the southernmost cape.

In 1542 a caravel was sent out to Greenland. It reached the country, but met no living inhabitants. It is natural to assume that the reports about the so-called JON GRØNLÆNDER from c. 1540, who is reported to have visited Greenland three times and there to have come across a dead man (the last Norseman), have some connection with these voyages.

In 1576 the English explorer FROBISHER sighted the east coast of Greenland in c. 61° N. lat. and sailed around its southernmost point.

In 1578 FROBISHER went ashore on the southern part of the west coast; he was not aware, however, that it was Greenland.

In 1579 the Danish king sent out JAMES ALDAY to rediscover Greenland. ALDAY sailed around the north of Iceland, but near Angmagssalik encountered a narrow belt of ice, which prevented him from reaching the shore.

In 1582 the Danish King sent out a new expedition under the leadership of MOGENS HEINESEN. He, too, approached the east coast of Greenland, having sailed around the north of Iceland, but could not go ashore owing to ice.

In 1585 JOHN DAVIS set out on his first voyage to Greenland. He sighted its southernmost cape, which he called Kap Farvel, because off the cape there was a narrow belt of ice which prevented him from going ashore. However, some distance up the west coast he reached the shore.

In 1586 DAVIS made his second voyage to Greenland. This time the ice belt around Kap Farvel was much broader. Like the previous year he sailed into Godthaab Fjord to trade with the natives.

In 1587 DAVIS made his third and last voyage to Greenland, which proceeded almost like the two previous ones.

In 1605 the Danish King CHRISTIAN IV, who took perhaps an even greater interest in the re-discovery of Greenland than his father, equipped an expedition consisting of three ships. The expedition was joined by three English seafarers, of whom JAMES HALL should especially be mentioned; he had previously sailed in the waterways between Greenland and America, possibly in company with DAVIS. After a gale experienced near Kap Farvel the vessels tried to approach Kap Desolation on the west coast, but for eleven days had to struggle with the ice.

After a quarrel between the English seafarers and the Danish nobleman LINDENOW, the latter parted from the other two ships and went to the coast, where some trading was carried on with the natives, after which he returned home with his ship.

The other two ships proceeded northward, and HALL pushed as far as 68°35′ N. lat. The expedition returned safely to Denmark.

In 1606 King CHRISTIAN IV equipped a second expedition consisting of five ships. JAMES HALL acted as pilot. The ships made a wide circuit around the ice near Kap Farvel and reached the west coast. The expedition was instructed to visit the east coast also, which was assumed to be still inhabited by Norsemen. However, the expedition failed to reach this goal.

In 1612 some British merchants sent out an expedition under the leadership of JAMES HALL. On this expedition HALL was killed by an Eskimo. During his voyages HALL explored and provisionally mapped the west coast of Greenland from the region around Godthaab northward to Egedesminde.

In 1652, 1653, and 1654 Captain DAVID DANNEL set out from Denmark to Greenland. In all three years he attempted to go ashore near Angmagsalik, but did not succeed owing to the ice. He then sailed along the ice-edge to some distance south of Kap Farvel and subsequently went into Godthaab Fjord to trade with the Eskimos.

Considering now the available information about these centuries, we find that during the first two centuries (983 to c. 1200) it was evidently possible for ships to go from Iceland or Norway to both the east and west coasts of Greenland south of 70° N. lat. without being impeded by ice.

The picture of the centuries 1200—1500 is more obscure. It would seem that ice often occurred along the east coast, but in these three centuries it was easy to call at the Herjolfsnes harbour.

The circumstance that Herjolfsnes maintained its leading position as a port of trade right up to the end of the Middle Ages shows that the deterioration of the climate, which for other reasons must be assumed to have taken place (cf below), set in after 1550.

From the period 1500—1600 information is very sparse. There does not seem to have been very much ice around Kap Farvel during the first three quarters of the century, but at the end of the century and at the beginning of the 17th century the picture changed completely; large masses of ice were now constantly met with around Kap Farvel, and it was difficult or impossible to go by ship into Julianehaab Bugt.

THE WHALING PERIOD

In 1614 a concession was granted to the Dutch company "Noordsche Compagnie" for fishery and trading on or to the coasts between "Nowazembla" and "Straat Davies" including Spitsbergen and Bear Island.

The word "coasts" here does not refer to the coasts of the country, but actually denotes the ice edge, along which a flourishing whale fishery now developed.

It is true that at the beginning of the 17th century the whale fishery was chiefly concentrated along the west coast of Spitsbergen and Jan Mayen with bases on the shore, and at the beginning of the 18th century along "Straat Davies" or the west coast of Greenland northward to 70° N. lat.; but it was not long before whale fishery took place in the ice or along its edge. From the beginning of the 17th century the ice edge every year extended from Novaya Zemlya, via Spitsbergen, the west coast of which was, as a rule, free of ice, onwards past Jan Mayen, as a rule likewise free of ice in the summer, and southward to the northeastern point of Iceland, the north coast of Iceland being often blocked by ice as far as Látrabjarg on the west coast. From this place the ice continued in a broad belt to a great distance south of Kap Farvel and then bent northward up along the west coast of Greenland, which was generally free of ice in the summer from c. 62° to 73° N. lat. This picture persisted till the beginning of the present century, a change of the conditions not having set in till the last twenty years.

No navigation took place inside the ice edge, so the east coast of Greenland was not visited during the whole 17th and 18th centuries. Sometimes, however, there was a possibility for the whalers to approach the shore, but no records are at hand about ships having visited Northeast Greenland during the whaling period until Scoresby went ashore in Scoresby Sund in 1822.

The east coast south of Scoresby Sund was not visited by ships until 1883 by A. E. Nordenskjold, and even till the beginning of the

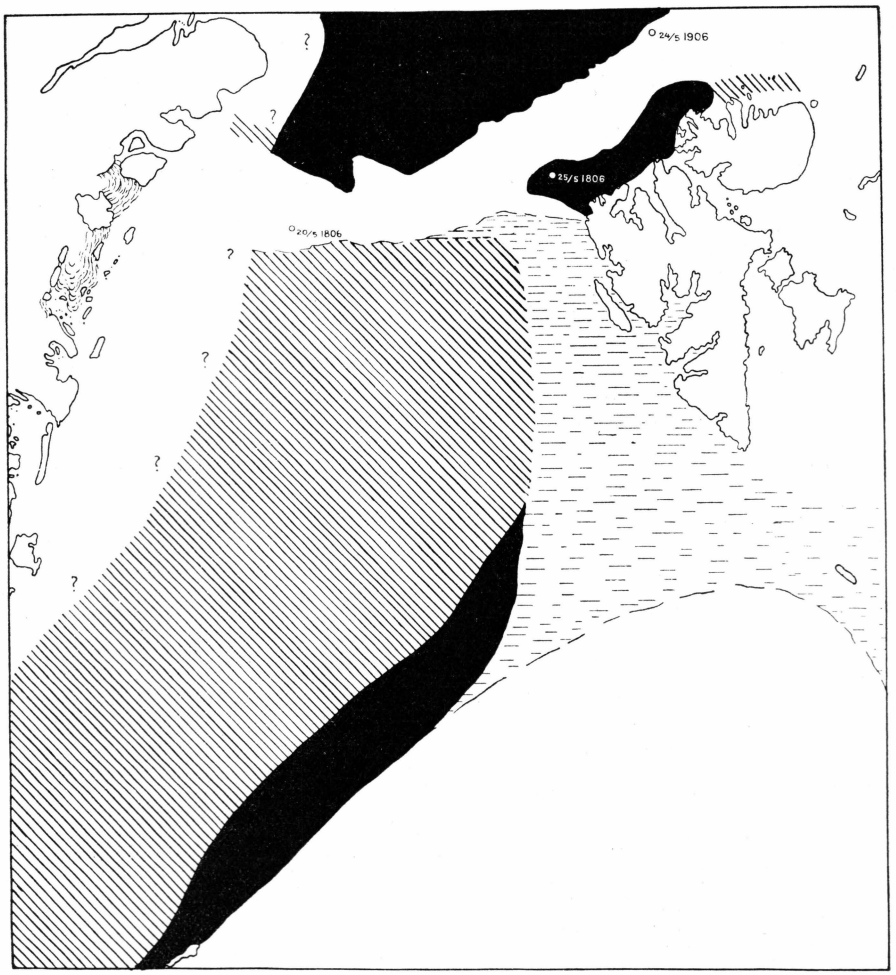

Fig. 120. Ice conditions in 1806. Prepared on the basis of Scoresby's Pl. VII (1820, Vol. II) and his text. Black areas: ice observed; shaded area: supposed extension of ice; lightly shaded area: navigable ice. It was a close season. Noteworthy is the broad belt of open water north and west of Spitsbergen.

present century the southern part of the east coast with the exception of Angmagssalik was regarded as practically inaccessible. This view was altered by the British and Danish expeditions in the third decade of the present century.

Brief Survey of the Whaling Period.

In 1596 Dutch seafarers discovered Bear Island and Spitsbergen.
In 1608 British whalers started whale fishery near Spitsbergen.
In 1611 Jan Mayen was discovered by Dutch whalers.

In 1612—1618 disputes arose between the different nations about the right to utilise the whaling grounds near Spitsbergen.

In 1615 a Danish naval fleet, numbering six vessels, visited Spitsbergen in order to maintain Denmark's rights.

In 1618 British, Dutch, and Danish whalers divided the harbours of Spitsbergen between them. Later the Germans and the Basques (Spaniards and Frenchmen) likewise took possession of harbours there.

In 1623 regular fishery by British whalers stopped.

In 1635—1640 the German free cities of Hamburg and Bremen commenced whale fishery near Spitsbergen.

C. 1640 the whale fishery along the west coast of Spitsbergen ceased.

The first period. In the first part of the whaling period whales were caught along "Old Greenland" (denoting both Spitsbergen and the east coast of Greenland at that time):

The first ships that reached Spitsbergen found the west coast to be free of ice, and immense numbers of whales were met with everywhere along the coast and in bays and fjords.

From 1618 large fleets, by far the greatest percentage of which consisted of Dutch ships, arrived at the west coast of Spitsbergen. The ships took shelter in the bays, and the crew carried on whaling from boats. The blubber was extracted in large oil refineries, which were built on the shore, even on Jan Mayen. The largest oil refinery was found at Smeerenberg on Amsterdam Island; it comprised many large buildings, and up to 12,000—14,000 men might be gathered here in the summer.

Shipwrecks rarely took place. Merchant ships also arrived to carry home the blubber, but no precise figure for the ships visiting Spitsbergen during this period is known.

After about thirty years (c. 1640) the whaling fishery along the coasts ceased, the huge number of whales having simply been caught, and whales now had to be hunted in the open sea, along the ice edge and among the ice floes.

During the second period the whales were hunted in the open water of the so-called Whaler's Bight, bounded on the east by the west coast of Spitsbergen northward to $79^1/_2°$ N. lat., on the west by the ice edge extending in a southwesterly direction from this point.

From about 1650 the ships entered the ice in c. 79°—80° N. lat., where they moored at a large floe and drifted southward with the ice to c. 73° N. lat., when they sailed out of the ice again. Whales were hunted during the drift. If the catch was insufficient, the ships sometimes went northward again to make a second drift.

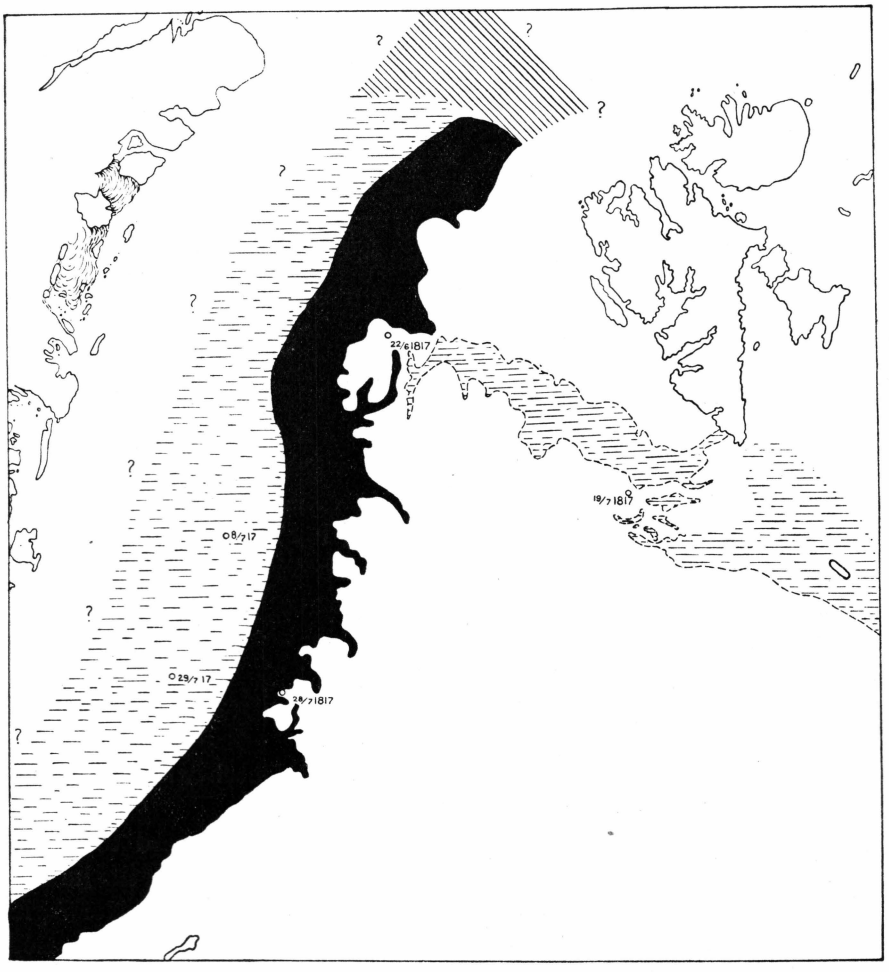

Fig. 121. Ice conditions in 1817. Prepared on the basis of SCORESBY's Pl. VII (1820, Vol. II) and his text. For explanation of the symbols cf. Fig. 120. Noteworthy is the close season and the open ice along the east coast of Greenland. Note the positions of the ships in the open ice inside the black belt.

Thus the whaling industry had completely changed and in the first place required particularly strong and well equipped ships, and secondly great personal skill from the ships' officers and crew. During the first period, in particular, many ships were wrecked in the ice. As late as 1685 more than 10 per cent of the Dutch ships were wrecked, and the German losses were even greater. The third period, viz. the culmination of the whaling industry, covers the years 1669—1778, that is to say, a period of a little over one hundred years. During these years 14,167 Dutch ships went to Spitsbergen, 561 of which were lost. This means that c. 140 Dutch ships visited Spitsbergen every year.

In the period 1670—1720 an average of 46 ships started from Hamburg every year, which means a total of 2,289 ships during these fifty years. From Bremen 15—20 ships set out every year, and from Emden some few ships, but this ceased in 1757. Finally, some few Danish, Norwegian, and Spanish vessels started out.

In 1732 the English government granted a state subsidy to the whaling industry, and in the period 1750—1779 about half a hundred ships annually, or one-third the number of Dutch ships and about twice the number of German ships, took part in the whaling fisheries.

In the period 1670—1720 no doubt c. 250 whaling vessels and from 1720 to c. 1780 c. 200 ships visited Spitsbergen every year.

The fourth period, the decline. Towards the time of the French revolution the Dutch participation in the whaling industry was much reduced, and during the blockading of the continent during the Napoleonic Wars it was, of course, only the British whalers who could carry on their trade. As late as 1814 the British whalers carried on successful hunting near Spitsbergen, but after that time the hunting grounds seem to have been almost empty, the large baleen whales had become almost extinct in these waters, and from now on towards the middle of the century the number of whaling ships visiting Spitsbergen was constantly decreasing.

After the end of the Napoleonic Wars the Dutch whalers tried to resume the whale fisheries, but without success.

About 1840 the number of ships that went northward to the ice edge between Jan Mayen and Spitsbergen increased again, as the hunting of seals had now begun, especially from 1846, when the Norwegian SVEN FOYN started regular hunting. Seal-hunting had been little noticed when the whaling industry was at its height.

[Curiously enough intensive seal hunting had been carried on near Jan Mayen about 1760—70. Small sealing vessels in a number of many hundreds from different countries met here in the spring to hunt seal].

This hunting was carried on during the latter half of the 19th century from a varying number of ships, as a rule less than fifty, from England, Denmark, Hamburg, Bremen, and Norway, and during this half century nearly 200,000 seals were caught every year without causing any perceptible decrease in the stock of seals.

About the year 1900 the hunting yielded no profit, and was therefore given up by the Danes and the Germans, while the English and Norwegian hunters built new and larger ships with steam-power and continued their hunting. From the beginning of the present century the hunting has considerably decreased, probably in the first instance be-

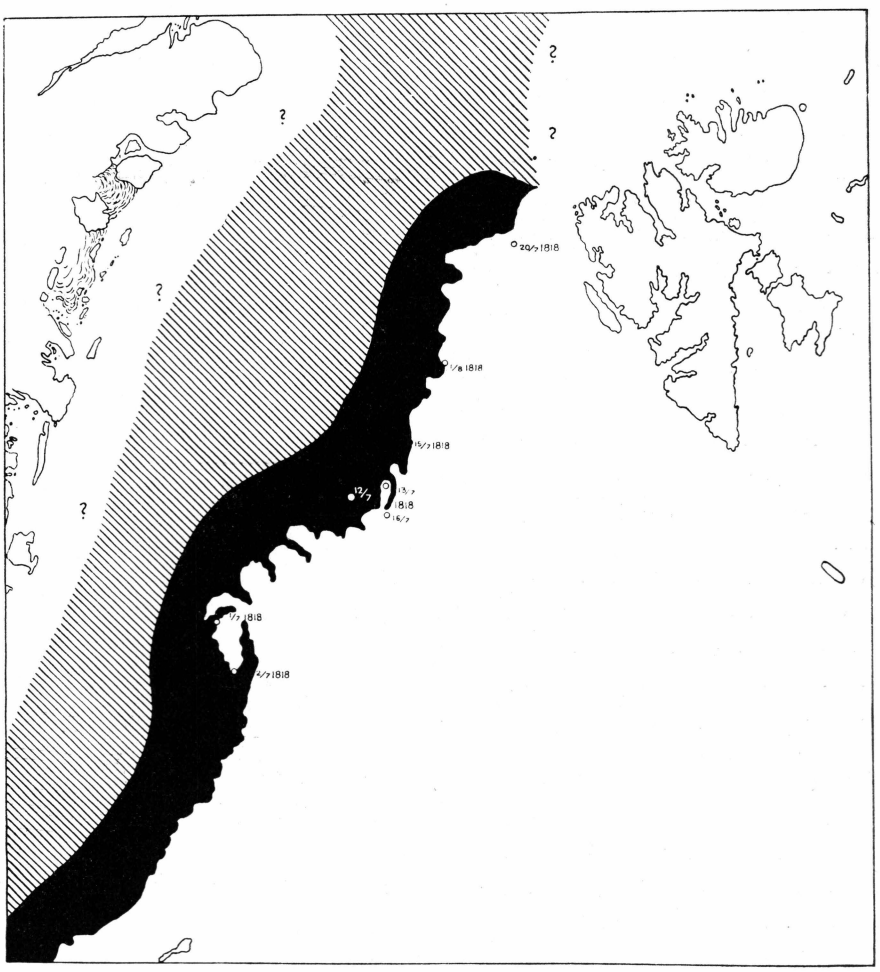

Fig. 122. Ice conditions in 1818. Prepared on the basis of SCORESBY's Pl. VII (1820, Vol. II) and his text. For explanation of the symbols, cf. Fig. 120. It was an open season.

cause the seals have been killed off by reckless hunting; however, that it has almost ceased now, is no doubt also due to the change of the climate in the present century.

Prior to 1750 the smaller and more dangerous finbacks were hunted from the west coast of Iceland. In the period 1750—1780 this hunting passed into English and American hands, but it never came to play any great role.

Whaling in Davis Strait. From c. 1715 Davis Strait was a much utilised fishing ground. In 1717, about a hundred years after the whaling along Spitsbergen was started, the Dutch seafarer FEIKES HAAN published his famous description of the harbours along the west

coast of Greenland between Holstensborg and Upernivik, and Dutch whalers now started an intensive whaling in these tracts; thus a total of 3161 ships, of which 62 were lost, carried on whale fishery in Davis Strait in the period 1719—1778. However, the hunting grounds in Davis Strait never became of the same importance as the hunting grounds along Spitsbergen. Thus about 1770 only one-fourth of the Dutch ships went to Davis Strait, while three-fourths went to Spitsbergen, but in 1829, 88 English ships went to Davis Strait and only one to Spitsbergen, while in 1834 the numbers were 69 and 7 respectively. The Dutch ships predominated over the English, German, and Danish ones in Davis Strait as near Spitsbergen up to 1780.

The losses of ships were comparatively small, since good harbours were found, especially on the south coast of Disko, whence whaling was carried on both northward and southward.

During the Napoleonic Wars the British whalers continued their hunting activity in the Davis Strait area, and in 1818, when whales were becoming scarce around Disko, they discovered a new large hunting ground in the northern part of Baffin Bay. The presence of whales here was ascertained by BAFFIN as early as 1616, but not till 1817 did a whaling ship, whose voyage is described by O'REILLY, reach Melville Bugt, and in the summer of 1818 a great many whalers went northward past Kap York in the wake of Ross and PARRY's expedition ships the "Alexander" and the "Isabella", when they discovered these regions.

It was British whalers who predominated in this northern fishing ground, but gradually American whalers arrived also, and after Ross & PARRY's expedition about 60—100 ships annually took part in the fisheries.

The ice in Melville Bugt caused great trouble and many shipwrecks. Thus in 1830 the British whaling fleet, that year numbering 97 ships, was overtaken by a catastrophe, nineteen ships being lost. Strangely enough, however, all the officers and crews, numbering more than one thousand men, were saved. In the same year twenty-four ships returned home without having secured any catch and the remainder had secured only a poor catch.

As late as 1834, 69 British ships pushed north of Melville Bugt, but subsequently the number constantly decreased, and about the year 1900 the whaling in this territory had almost ceased. During the first decade of the present century whalers only occasionally pushed north of Melville Bugt; from this bay, also, the whales had disappeared.

A very copious literature is available concerning this, the greatest activity of the white race in the Arctic, which, if it is taken to include



Fig. 123. Ice chart showing the conditions in August 1874, after Capt. David Gray (Peterm. Mitt. 1875, Tafel 6). Note the open water north and west of Spitsbergen almost in the places where Scoresby found open water in 1806.

both the whaling and the seal-hunting, may be said to have lasted for about three hundred years, viz. from c. 1600 to c. 1900.

The most important works dealing with this activity are those written by Martens 1855, Zorgdrager 1750, Scoresby 1820, Lindeman 1869—71, and Nansen 1924.

This literature supplies good information about the size and equipment of the ships, the earnings of the whalers, the life onboard the vessels, the number of seamen, the different species of whales, their size and number, and about other arctic animals encountered on the voyages. But if you study the literature to gain information about the ice, you will be disappointed, for in general the ice conditions are only described

in broad features. Only SCORESBY gives more detailed information about the position of the ice edge in the various years and about the character of the ice.

The almost complete lack of information about the position of the ice edge is naturally due to several causes. In the first place the whalers were rarely, or never, interested in taking longitudes, probably only the latitudes being determined in those days. SCORESBY, however, forms an exception. From about 1650 the whalers kept their experience as to the best hunting-grounds secret from their competitors. And finally, it should be remembered that the hunting near the ice edge was as a rule carried on in very foggy weather.

Thus only a very rough picture of the ice conditions during the whaling period is available, although more than two hundred ships, on an average, gathered along the ice edge every year, at any rate during the first two centuries, and from c. 1600 to c. 1900 we have practically no information about variations in the position of the ice edge. This is all the more deplorable, since the ships, staying just outside or a short distance inside the ice edge, had ample opportunity to make observations on the ice during these three centuries.

ESKIMO ARCHAEOLOGY AND CLIMATE

The Archaeological Excavations.

Below an attempt will be made to take a survey of the Eskimo archaeology and subsequently to examine whether it supplies any information about the climate of Greenland.

A country so well investigated archaeologically as Greenland has of course yielded a wealth of archaeological finds. Thus much collecting work has been done in West Greenland during the 19th century, but as a rule not systematically.

Of the more recent expeditions which have done archaeological work in other parts of Greenland I may mention, from the east coast, the expeditions led by GUSTAV HOLM, C. RYDER, and G. C. AMDRUP, and the Danmark Expedition, and from the north coast PEARY's expeditions, which, however, were mostly interested in Eskimo implements still in use, the Second Thule Expedition, and the Bicentenary Jubilee Expedition. The work was generally limited to the finding of graves and minor excavations of house ruins, but rarely according to any plan.

As far as is known to me, the first systematic excavation of a midden in Greenland was carried out by P. FREUCHEN and the present author on the Second Thule Expedition in the summer of 1916. In the early summer the well-known American whaler Captain COMER, who on his many voyages to the fishing grounds around Southampton Island, had got accustomed to associate with the Eskimos and had bought ancient remains as well as modern hunting gear from them, which he sold to American museums, had begun excavations in a large midden near Thule. His aim was to secure as many implements, chiefly of bone and stone, as possible in the shortest possible time. His collections have been described by WISSLER (1918).

However, COMER kindly agreed to P. FREUCHEN and the present author commencing a systematic excavation of the midden, and in the course of the summer a profile parallel with the coast and extending through all the layers of the midden was exposed. Gradually as the frozen soil thawed, we collected all the objects that appeared, keeping the material from the individual layers separate. One layer was entirely

interwoven with baleen, of course mostly waste, but also numerous objects made of baleen especially attracted our attention. The excavation was continued all summer, and the outermost third of the midden was dug out.

The collections, which are now found at the National Museum of Copenhagen, were worked up by THERKEL MATHIASSEN (1927) and became of importance for his systematical excavations in Arctic Canada on the Fifth Thule Expedition 1921—24; he found there a culture highly reminiscent of that represented in COMER's midden near Thule, and he therefore called this culture the Thule Culture.

After the comprehensive Danish excavations in Arctic Canada it was natural to commence a systematical archaeological investigation of Greenland. This was done by THERKEL MATHIASSEN, who in 1929 began digging near Inugsuk, in 1930 at Kangamiut, in 1931—32 at Angmagssalik, in 1933 in Disko Bugt, and in 1934 at Julianehaab. At the same time excavations were made in Northeast Greenland, viz. by HELGE LARSEN 1931—32 at Dødemandsbugt, Clavering Ø, by P. V. GLOB 1932—33 in Franz Josephs Fjord and Kong Oscars Fjord, by M. DEGERBØL 1932 and HELGE LARSEN 1935 at Kangerdlugssuak, by E. HOLTVED 1935—37 around Thule and on Inglefield Land, and finally by E. KNUTH 1939 on Amdrups Land.

The map in Fig. 124 shows the distribution of these excavations. It will be seen that they cover the shores of Greenland fairly well. While prior to the excavations the migrations of the Eskimos along the coasts of Greenland were rather obscure, we now have a fairly clear picture of them, though, of course, many questions still await their solution.

Greenland presents many good conditions for dating the life and doings of the Eskimos. In the first place the Norse colonisation at the end of the Middle Ages is of importance if we are to date the early finds. The first few centuries of this period, from 985 to c. 1200, tell nothing about the Eskimos except that Eskimos lived in Southwestern Greenland prior to that period.

The Norse settlers appear to have got into communication with the Eskimos northward about 1250, when the Eskimos apparently lived as far south as Umanak Fjord. In 1266 the first ship visited the Thule district, but no contact with the Eskimos was established. In the period 1250—1350 the contact became gradually more frequent, but subsequently it changed its character, the Eskimos destroying the West Settlement in the years after 1350. In the following fifty years the East Settlement, also, suffered great damage from the constantly increasing numbers of Eskimos.

Along the whole west coast of Greenland from Inglefield Land to Kap Farvel and up the east coast to Danmarks Havn traces of the

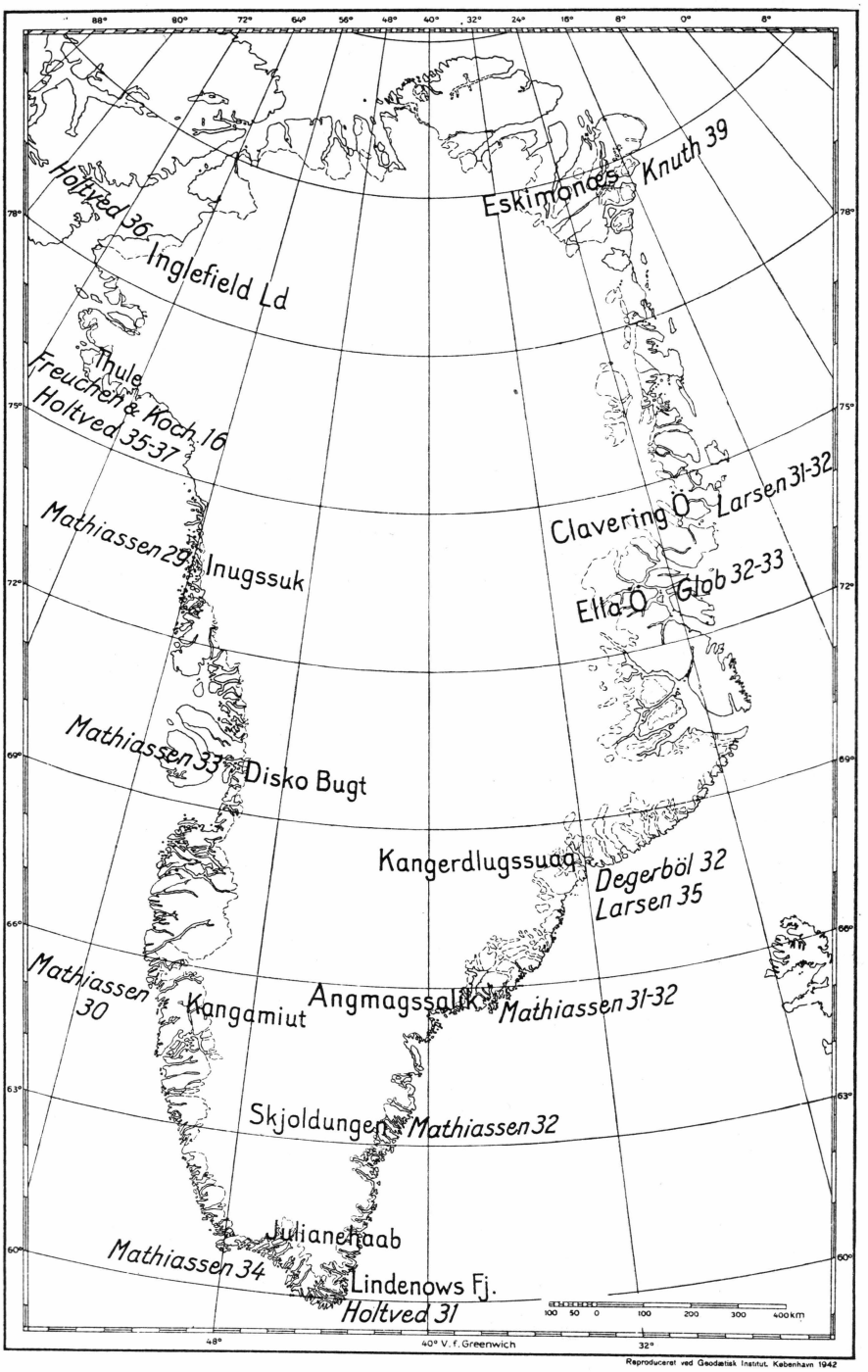

Fig. 124. Recent archaeological excavations of Eskimo remains in Greenland. The localities as well as the names of the investigators are indicated.

influence of the Norse settlers during the period from about 1250 to about 1400 have been found, and thus the Eskimo remains found can be fairly accurately dated. The time of the whalers, which mainly comprises the west coast and lasted from c. 1650 to c. 1850, likewise supplies fairly exact dates.

In 1721 the Danish colonisation in Greenland began, and during the succeeding half century the colonies still existing in West Greenland were established.

In the 19th century the European culture came into contact with isolated tribes, thus in 1818 with the Eskimos living at Kap York, in 1822 with the Eskimos on Clavering Ø, and in 1884 with the Eskimos at Angmagssalik.

Modern archaeology chiefly works with statistics of the types of tools. However, hitherto these statistics have given no definite solution of the development of the culture. Not least HOLTVED's excavations in the Thule district and on Inglefield Land show how cautious we should be in drawing conclusions on the basis of some few finds comprising a small number of tools. Thus it has turned out that COMER's midden, which came to give its name to the Thule Culture distributed over the whole of Arctic Canada, actually belongs to a somewhat later culture, viz. a transitional form to the Inugsuk Culture.

As to the development of the culture in East Greenland after the year 1600 there are still many obscure points; we are greatly in need of excavations in the interior of Scoresby Sund, thus of the large settlement near Røde Ø, possibly the largest settlement in Northeast Greenland, and the large settlement on Murray Ø north of Liverpool Kyst. As regards the supposition of one or several migrations around the north of Greenland we know less at present than we thought we knew a few years ago.

The Different Cultures.

HALL's expedition 1871—73 found numerous remains of an earlier Eskimo habitation on the flat shores south of Hall's Grave. Many implements were collected by the Eskimos JOE and HANNAH, but these collections were lost when the "Polaris" was wrecked by the ice.

At present only some small tent-rings occurring in scattered groups of two or three are to be found on this coast. They seem to be very old, as the stones are fairly deeply buried in the gravel.

In 1922 the present author discovered a house ruin on Hall Land (c. 81°20′ N. lat.). My attention was attracted by this ruin because it differed from the tent-rings in that the front side was made up of very large stones, and there was no earthen mound and no vegetation around it. The Eskimos, who accompanied me, had no doubt that we were

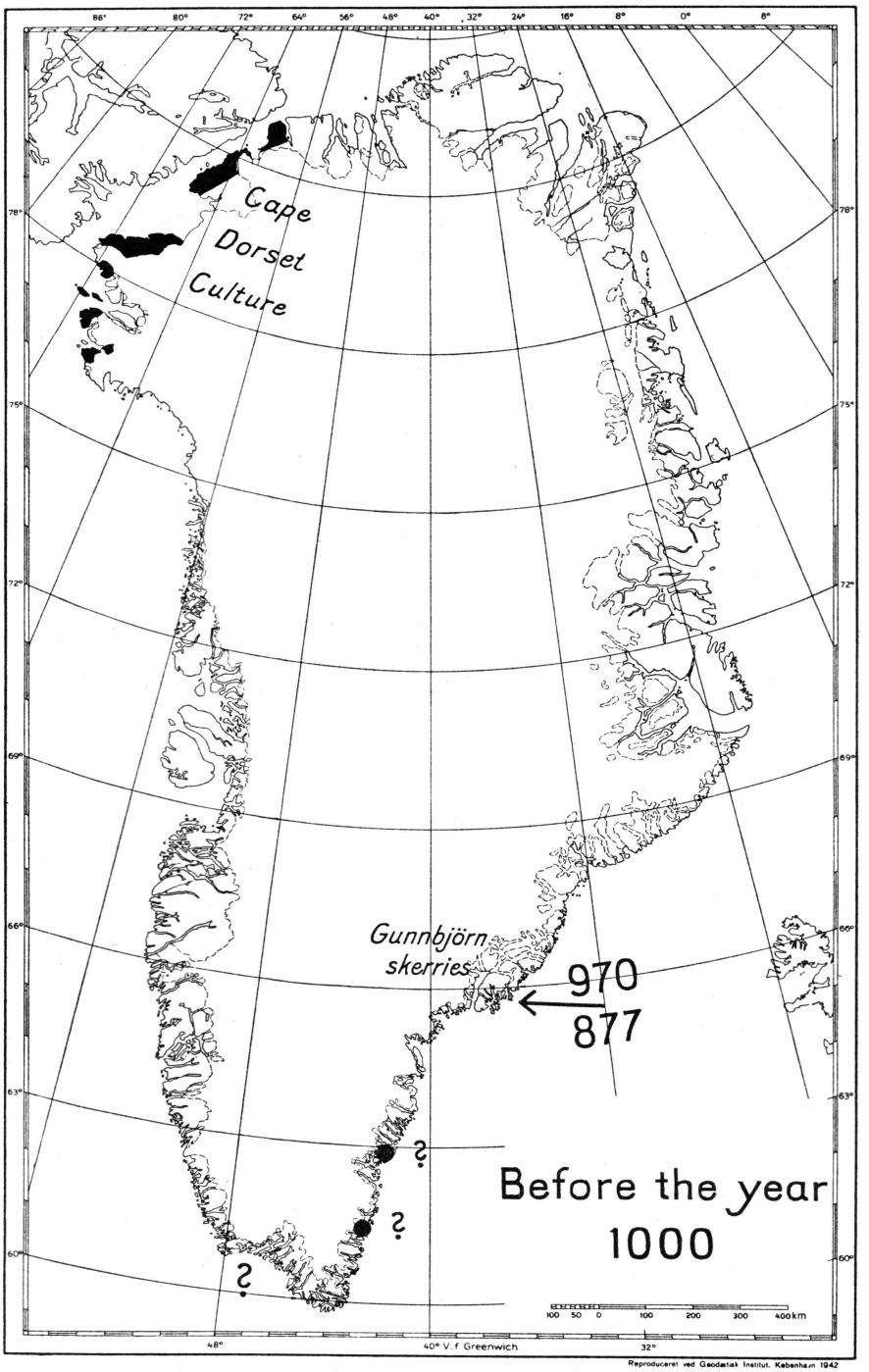

Fig. 125. Supposed distribution of the Eskimos in Greenland prior to the year 1000.

confronted by the remains of a house the front side of which was fairly well preserved (THERKEL MATHIASSEN 1928).

A cursory investigation yielded some few and small implements and a small flat lump of meteoric iron. I did not anticipate that these very modest finds of implements were of particular importance; however, they were so characteristic that THERKEL MATHIASSEN (1928) determined them as belonging to the Cape Dorset Culture known from the eastern part of Arctic Canada.

Later on E. HOLTVED's investigations on Inglefield Land have yielded fairly large collections of remains of the Cape Dorset Culture. HOLTVED (1944) maintains that the Dorset people are the first Eskimos who immigrated into Inglefield Land and probably into Greenland as a whole.

A number of the harpoon forms have been used for hunting on the ice, others for salmon fishery. Bows and arrows were used in hunting both reindeer and birds, while whaling hardly took place, no implements of baleen having been found. It is not known with certainty whether kayaks were known at that time. Walrusses were caught, but this may possibly have been done from the ice. The dog-sledge was perhaps the chief means of communication. The people probably lived in winter houses built of stone, though snow-huts were probably also used.

This does not say much about the climate that prevailed in Inglefield Land at the time the Dorset people lived there. It is important, however, that hunting from the ice played a great role. This might suggest that the Dorset people were able to sustain life under conditions similar to those which have prevailed during the last three centuries around Kane Basin, hardly without access to the open sea, and mostly hunting the animals from the sea ice.

The people may have lived in Inglefield Land even if the climate was colder than at present. A few finds in West Greenland suggest that they may have reached Disko Bugt. It is not impossible, either, that they may have spread to Northeast Greenland, but sufficient evidence of this is not yet available. For the time being we are only certain that they have lived on Inglefield Land and Hall Land.

The Thule Culture, as defined by THERKEL MATHIASSEN (1930), is abundantly represented on Inglefield Land. HOLTVED (1944) is of opinion that it has come to Greenland as an independent immigration without any connection with the Cape Dorset Culture. Thus it would be the second immigration into Greenland from the west. It is not noticeably influenced by the Cape Dorset Culture and shows no association with the Norse Culture. Since, however, it shows a close association with the later Inugsuk Culture, HOLTVED assumes that it has been prevalent on Inglefield Land during the 11th and 12th centuries.

During this period the kayak was known, and the kayak implements were in rapid development. Some whaling was carried on. Very little can be said about the climate, but it would seem to have been somewhat better than at the beginning of the present century.

The Eskimo remains found by the first Norsemen on their arrival at southwestern Greenland at the end of the 10th century, must have been derived from either Dorset people or Thule people. If they were derived from Thule people, the Cape Dorset Culture must date very far back, no doubt several centuries prior to the 10th century. If they were derived from Dorset people, the culmination of the Dorset Culture in Greenland must have occurred about the year 1000; their arrival to Greenland must have taken place one or two centuries earlier, if they migrated around the south of Greenland, or at any rate as far as Kap Farvel, prior to the year 985.

While, thus, the appearance of the Cape Dorset Culture outside the area Smith Sound-Robeson Channel is lost in obscurity, we know a little more about the Thule Culture. It has probably spread southward to the Thule District, and possibly also around the north of Greenland.

About the year 1200 the Thule Culture developed into a new culture. About 1250 the development was so far advanced and such new types had appeared that we may begin to speak of a new culture phase, viz. the Inugsuk Culture.

Holtved has demonstrated a third immigration into Greenland from the west at the transition from the Thule Culture to the Inugsuk Culture, namely the immigration of the so-called Ruinø people, who were bearers of a culture which was strongly influenced by the Punuk Culture located around the Bering Sea. This immigration set its mark on the Inugsuk Culture in several respects, but the peculiar character of the immigrated people was absorbed by the Inugsuk Culture, which was now in rapid development. However, the Inugsuk Culture never gained any firm foothold on Inglefield Land; Inugsuk-remains are found there, but the main part of the finds belong to the Thule Culture.

Holtved's excavations on Inglefield Land have likewise thrown light on another archaeological find made by me in North Greenland in 1921, namely the kayak found in Morris Bay. It was described by Therkel Mathiassen (1928) and in his opinion does not date farther back than the 17th century.

Since, however, the contact between the Eskimos living at Thule and the more southerly districts ceased completely about the year 1600, and the only expedition to the Kap York district which was joined by a Greenlander with a kayak (Kane's expedition 1853—56) must be left out of consideration, because, according to Markham (1875), this kayak was devoured during a period of starvation in the winter of 1857—58,

the kayak found at Morris Bugt must belong to the Thule or the Inugsuk Culture and is evidence of different and better climatic conditions than those prevailing in Kennedy Channel about 1900. I have never had any doubt that the kayak was old, for the wood was of precisely the same consistency as the remnants of another kayak I found in 1921 near the ancient house ruins in Cash Fjord. These ruins no doubt date back to the Thule Culture or the earliest Inugsuk Culture, that is to say, to the 13th century. The archaeological history of northern Inglefield Land ends at the transition from the Thule Culture to the early Inugsuk Culture.

Turning now to Thule itself, we find only vague traces of the Thule Culture. But there are many traces of the period called the "older transitional period" by HOLTVED and fixed by him at c. 1200—1300. The name implies that many implements of the Thule Culture have been replaced by new ones. A Norse influence is traceable, but the Inugsuk Culture has not yet taken form.

According to HOLTVED (1944), a migration took place across Melville Bugt to the Inugsuk settlement in the Upernivik district early in the transitional period, i. e. probably during the first half of the 13th century; the settlement after which the culture has been named dates from c. 1250—1300. The Inugsuk Culture has developed somewhat differently at Inugsuk and at Thule, which suggests that the communication across Melville Bugt was rare during the last half of the 13th century. After the year 1300 it increased again, which according to HOLTVED is due to the Ruinø people. In the 14th century there was a lively communication across Melville Bugt, it was fairly constant in the 15th century, while it decreased in the 16th century to cease entirely about the year 1600.

After being influenced from the south (the Norsemen) and the west (the Ruinø people), this cultural stage appears as a highly developed kayak culture (Inugsuk Culture) about the year 1300. It culminates in the Thule district about 1400—1450 and ceases about 1550. During its culmination (c. 1400) the Inugsuk Culture, which in North Greenland attained a flowering comparable only to the Eskimo cultures along the Bering Sea, seems to have been represented not only within the Thule district, but also in Ellesmere Land and to have spread southward to Ponds Bay and far down the southwest coast of Greenland, a lively communication having taken place across Smith Sound and from Disko Bugt to Thule, probably especially with import of timber.

Considering now the Inugsuk Culture in Disko Bugt (THERKEL MATHIASSEN 1934), we shall find that the migration reached this bay shortly after 1300. The Inugsuk Culture in Disko Bugt comprises the period 1300—1500, though with some alteration from 1450 to c. 1500, and here reaches a culmination. Disko Bugt will always easily become

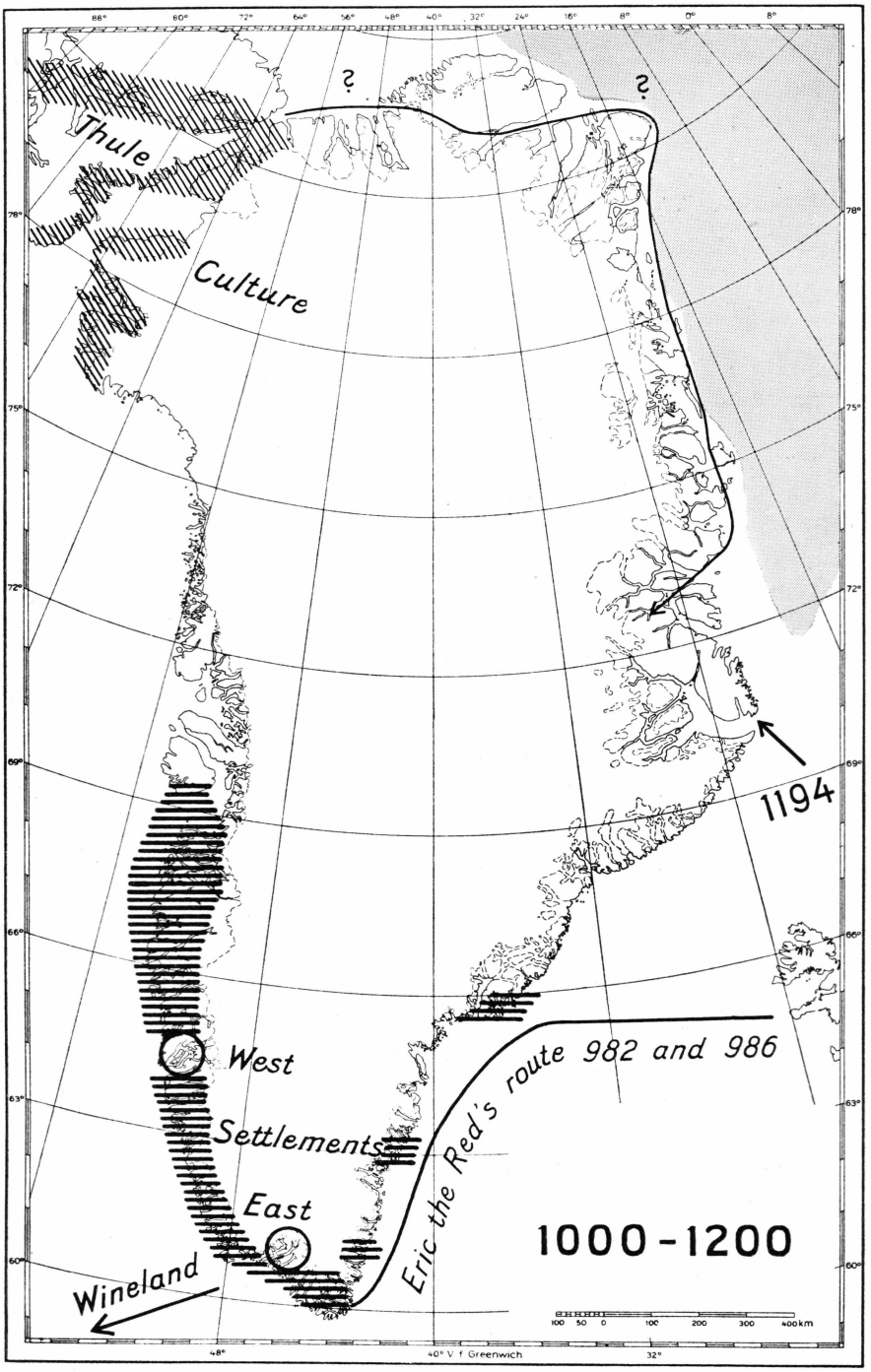

Fig. 126. Distribution of the Eskimos (light shading and light line) and the Norsemen (heavy shading and heavy lines) in Greenland in the period 1000—1200. The supposed extension of the ice is indicated (above, right).

a centre, it being easy to circulate among the different regions; from a cultural point of view the bay becomes a land-locked sea with good connection between the settlements.

In the period 1500—1600 the Inugsuk Culture changed its character; thus the people now lived in small square houses. Shortly after this period a new flowering of the Eskimo culture set in around Disko Bugt, when c. 1650 an increasing number of whalers arrived at the bay, established a centre for the whale fishery there, and commenced trading with the Eskimos. About this time the large common houses were introduced with room for many Eskimo families, a house type which later spread to the southeast coast of Greenland.

Some of the largest and oldest middens are located near the large glaciers in the interior of Disko Bugt; especially renowned is the not yet systematically excavated settlement Sermermiut outside Torsokataq Gletscher. At the beginning of the present century it might be difficult to make one's way to this ancient site on account of the large numbers of icebergs, which may still cause great trouble. In 1913 Mr. M. P. PORSILD and the present author attempted to reach Sermermiut in a motorboat, but we had to give up the attempt, the fjord being entirely filled with close-packed bergs. It is a question whether this ancient settlement in front of the large glaciers was not erected under different climatic conditions from the present.

The trade between the whalers and the Eskimos declined c. 1734, when the first Danish colony in Disko Bugt, Christianshaab, was established.

The next locality in which modern excavations have been made is Kangamiut (TH. MATHIASSEN 1931), a little north of Sukkertoppen. This area is situated a short distance north of the West Settlement, which, as is well known, was destroyed c. 1350—60, when the migration of Inugsuk people began. The migratory wave continued onwards, but some of the Inugsuk people stayed at Kangamiut, where a marked Inugsuk Culture persisted from c. 1350 to c. 1500.

In the period 1500—1600 new types of implements arose, while the old ones disappeared. During this period a special Southwest Greenland development is noticeable, which may be traced northward to Disko and southward to Julianehaab.

The next area in which excavations have been carried out is the southern part of the Julianehaab district south of the East Settlement (THERKEL MATHIASSEN 1936).

According to THERKEL MATHIASSEN, the Inugsuk Culture originated at Kangamiut, in the Julianehaab district, and at Angmagssalik c. 1350; however, in a popular book (1935) he corrects this to c. 1400 as regards Angmagssalik, but he holds the view that after destroying the West Settle-

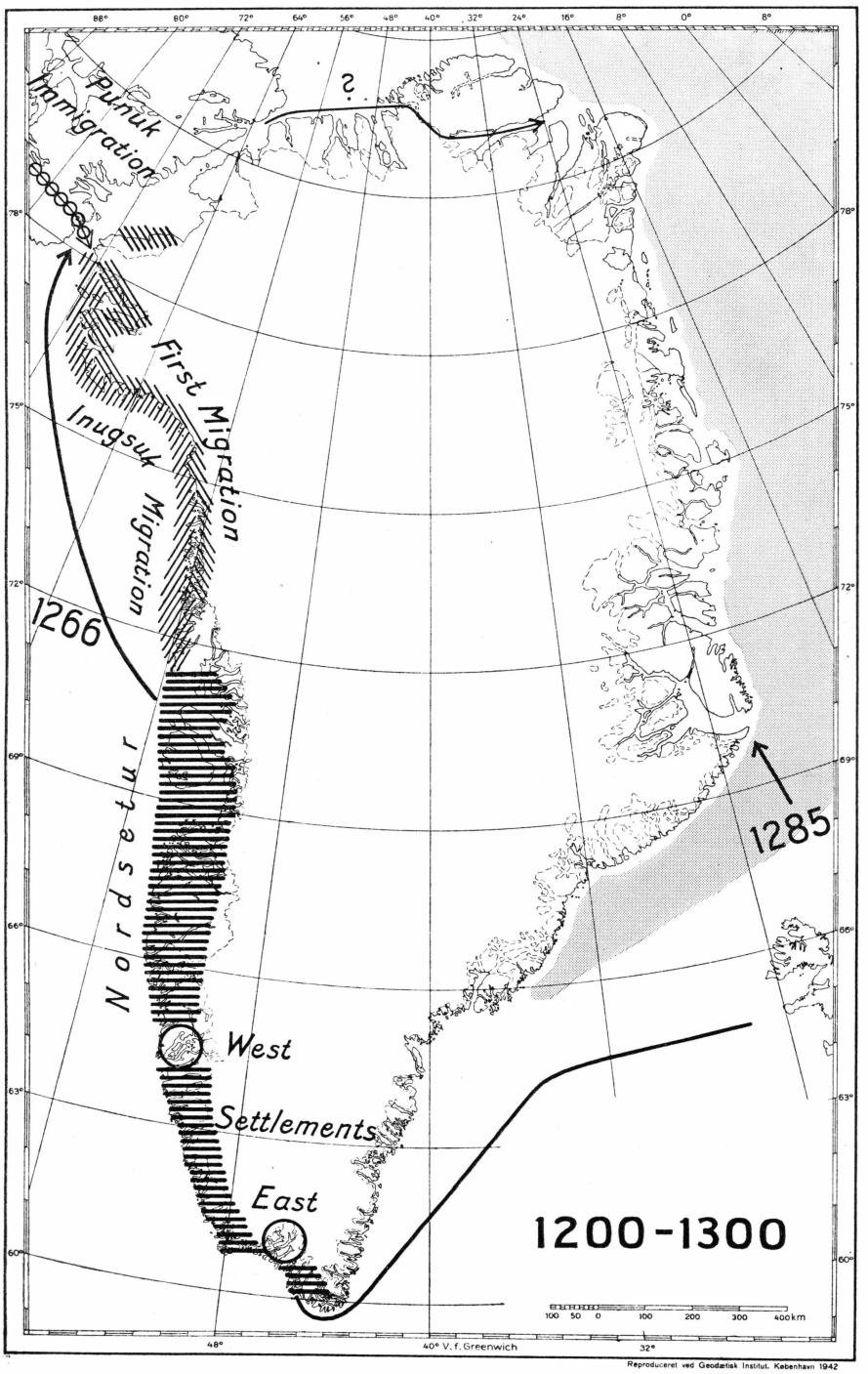

Fig. 127. Distribution of the Eskimos and the Norsemen in Greenland in the period 1200—1300 (cf. Fig. 126). Supposed extension of the ice indicated.

ment, the Inugsuk people spread rapidly along the coast past the East Settlement to Angmagssalik.

There are various obscure points about this very rapid migration. As is well known, the first serious attack on the East settlement took place in 1379, but Herjolfsnes, the southernmost harbour of the East Settlement, maintained its dominant position as a trading station towards the year 1500 (according to P. NØRLUND's excavations). T. MATHIASSEN mentions that the earliest settlement in the Julianehaab district lies halfway into the fjords, probably it was erected there with a view to hunting from the ice.

IVAR BAARDSON's description of the East Settlement (cf. FINNUR JONSSON, 1930) was written shortly after the destruction of the West Settlement, but it does not give the impression that any particular feeling of danger prevailed in the East Settlement. The greater number of the Norsemen lived far up the fjords, but Herjolfsnes was located at the outer coast, so it is hard to imagine, as assumed by MATHIASSEN, that a migration of Eskimos took place along the outer coast past the East Settlement as early as c. 1350. It is even more difficult to imagine an Eskimo habitation at so early a date halfway towards the interior of the fjords.

MATHIASSEN's assumption as to a migration past the East Settlement about 1350 is not in harmony with P. NØRLUND's aforementioned excavations at Herjolfsnes, which showed that the Norsemen lived in the Julianehaab district about 100 years longer than previously assumed. It is a question whether this migration did not take place c. 100 years later than assumed by MATHIASSEN.

The earliest stages of the Inugsuk Culture persisted long among the Eskimos living in the Julianehaab district after the disappearance of the Norsemen; there was no influence from other quarters, and apparently no cultural development was going on here. The Danish colonisation meant a fresh impetus to the development, when the people by their voyages to the east coast came to form the connecting link between the Angmagssalik Eskimos and the Eskimos living on the southwest coast at any rate up to the beginning of the 18th century.

Angmagssalik. As stated above THERKEL MATHIASSEN (1933) writes that the result arrived at by modern archaeology is that the Angmagssalik district received its first inhabitants within the period 1350—1500, but that a more precise date cannot be given. MATHIASSEN tries to date this period more precisely by means of reports in GUSTAV HOLM's work dealing with Gunnbjørns Skær (1918) in the Angmagssalik district. These skerries, as is well known, were discovered in 877.

In c. 1385 the Viking BJØRN JORSALFAR was beaten off his course and called at Gunnbjørns Skær (which had once been in-

habited). His men observed eight "farms" on the shore, but did not investigate them.

From reports on PINING and POTTHORST's voyage in 1476 we know positively that Eskimos were living at Angmagssalik at that time.

THERKEL MATHIASSEN regards BJØRN JORSALFAR's statement that Angmagssalik had previously been inhabited and that eight "farms" were seen, as a proof that the Angmagssalik district was inhabited by Inugsuk people about twenty years after the destruction of the West Settlement.

However, there may be several possibilities. In the first place we know that some Icelanders wintered in the district c. 970, and secondly, that possibly a ship-wrecked crew wintered there c. 1028. Thirdly, other Icelanders or Norsemen, whom gales may have forced on to the shore, have spent a winter there. Moreover the Icelandic sagas contain several reports on Eskimos (trolls) living on the east coast of Greenland. Finally, we do not know whether descendants of the Eskimos who migrated around the south of Greenland after the time of the Norse settlers (Dorset Culture people?), or of Eskimos who shortly after the year 1200 possibly migrated around the north of Greenland (Thule Culture Eskimos?), lived there.

Gradually the originally pure Inugsuk Culture near Angmagssalik was changed. About 1700 a fresh migration came from the south, and the number of inhabitants was greatly increased.

Shortly after this migration, that is to say, at the beginning of the 18th century, communication with the west coast was rare.

At the beginning of the 19th century the communication with the west coast practically ceased. The tribe living at Angmagssalik was discovered by GUSTAV HOLM in 1884.

Kangerdlugssuak (THERKEL MATHIASSEN 1934, M. DEGERBØL 1936, HELGE LARSEN 1938). — As stated above, the Inugsuk Culture spread northward beyond Angmagssalik. Thus collections are at hand from Kangerdlugssuak which according to MATHIASSEN show that a migration has taken place in the latter part of the 15th or the early part of the 16th century. Some Eskimos settled in this place, while the rest proceeded northward. It is interesting, as established by MATHIASSEN, that only one migration, namely that of the early Inugsuk Culture from the west coast, has passed this stretch of the coast; the later migration about the year 1700 did not reach so far, but stopped immediately south of this place.

MATHIASSEN quotes an ancient myth noted down by GUSTAV HOLM in 1884. According to this myth the place was inhabited about the year 1800. MATHIASSEN is of opinion that Eskimos lived here for

about two hundred years. He assumes that they suffered the same fate as so many other small isolated groups of people, viz. degeneration owing to isolation, constant intermarriages, etc. The communication with Angmagssalik probably persisted almost up to 1600.

As regards the remaining part of the east coast of Greenland from Scoresby Sund to Nordostrundingen, notably two recent excavations deserve mention, namely that made by HELGE LARSEN at Dødemandsbugt, Clavering Ø, and the excavations of scattered remains in the Franz Josephs Fjord—Kong-Oscars Fjord area made by P. V. GLOB. A number of excavations carried out north of Clavering Ø in recent years show no typical features, and, as stated above, modern excavations are lacking from the interior of Scoresby Sund. The picture of the archaeology of Northeast Greenland is accordingly somewhat obscure.

Dødemandsbugt. According to HELGE LARSEN (1934) the first migration to the Angmagssalik district and northward along the coast took place in the 15th century and part of the 16th century.

The earliest migration passing Scoresby Sund from the south is assumed to have taken place some time in the 16th century and spread to some distance north of Clavering Ø. Some of these migrators, which represented the Inugsuk Culture, settled near Dødemandsbugt, others possibly pushed as far as Danmarks Havn or even farther northward.

About the year 1500 this migration, according to HELGE LARSEN, met Eskimos coming from the north, and at the end of the 16th and during the 17th century a mixed culture of a special Northeast Greenland character developed on Clavering Ø. The people representing the first stage of this mixed culture apparently lived in settlements with many houses; they carried on whale fishery, and the boring technique was highly developed.

At the beginning of the 18th century the culture changed its character, entering its second stage. It would seem that there was a migration of people from the south, who possibly had lived in the interior of Scoresby Sund and now replaced the Eskimos representing the first stage; at any rate the whaling stopped, and narwhals came to play a greater role. This was only natural if the migrators came from the interior of Scoresby Sund, to which the big whales do not make their way, but where narwhals are plentiful.

The people representing this second stage seem to have lived in smaller and more scattered settlements. Neither the changes in regard to whaling nor the altered method of hunting land animals can be due to changes of the climate.

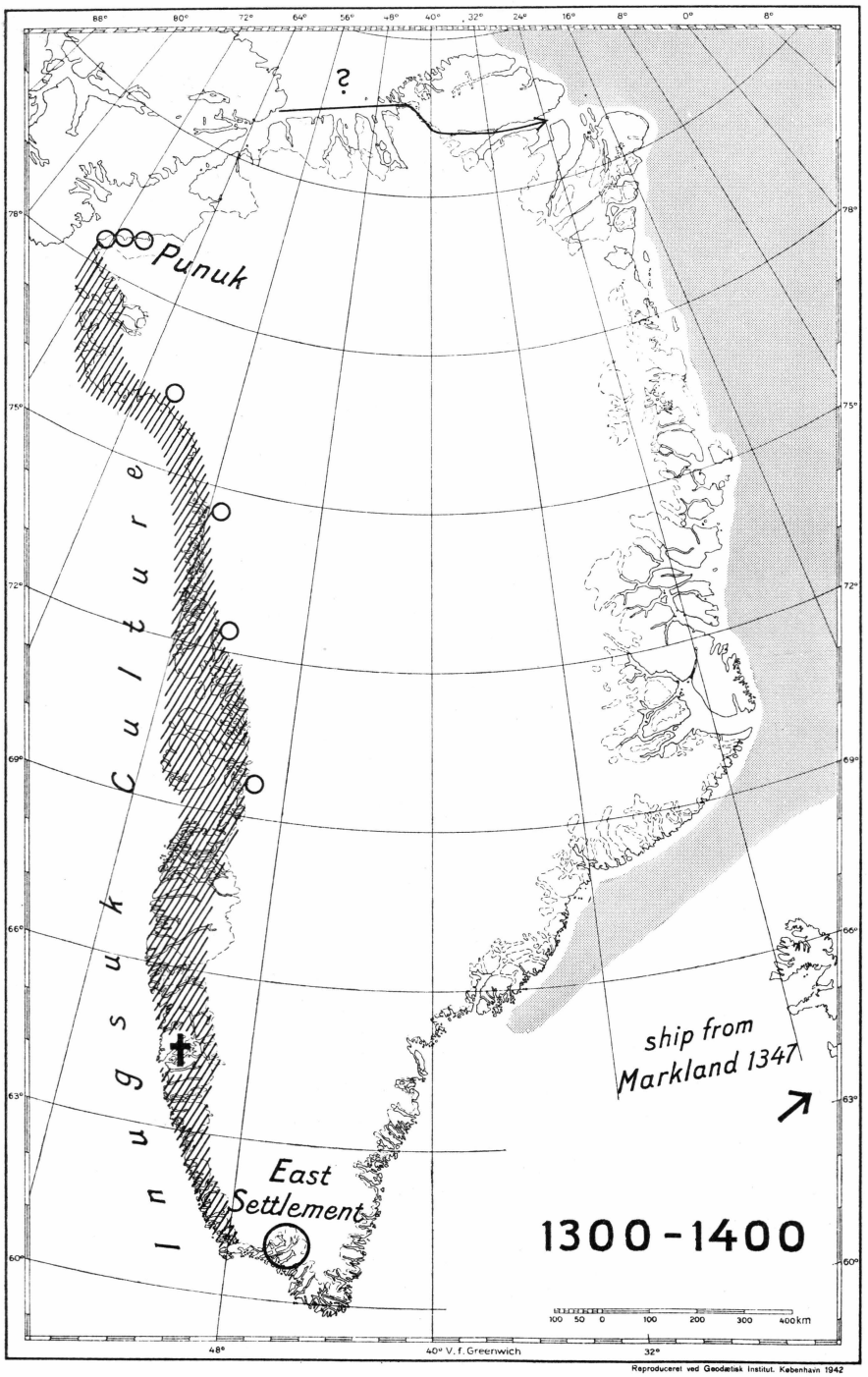

Fig. 128. Distribution of the Eskimos in Greenland in the period 1300—1400. At the end of the century the Norsemen were restricted to the East Settlement. Supposed extension of the ice indicated.

No remains of musk-oxen have been found from the earliest stages of the Inugsuk Culture, whereas such are at hand from the earliest stages of the mixed culture. It would seem that musk-ox hunting was carried on up to the extinction of the mixed culture in the first half of the 19th century, but neither SCORESBY nor CLAVERING and SABINE, who visited the country about 1820, observed the slightest trace of musk-oxen. Musk-oxen were, however, found by the German expedition 1869. Thus it would seem that musk-oxen, though possibly in small numbers, occurred from 1600 to c. 1800, when they may have disappeared, to immigrate again about the middle of the 19th century. No traces of musk-oxen have been found in the ruins in Franz Josephs and Kong Oscars Fjords.

Thus the first migration of musk-oxen from c. 1600 to 1800 does not seem to have extended farther south than to Clavering Ø. The later migration from c. 1850 to the present time had not yet ceased ten years ago; in 1932—34 the musk-oxen in the interior of Scoresby Sund had reached Nordvest Fjord, but not Milne Land and Gaase Land.

From 1600 to 1800 reindeer were commonly hunted by the Eskimos, but SCORESBY, CLAVERING, and SABINE saw no traces of reindeer. From 1869 to the change of the century reindeer were of common occurrence, but then seem to have disappeared rather suddenly, and they have not reappeared in Northeast Greenland in the present century. The periodical occurrence of these two animals (musk-ox and reindeer) says nothing about changes of the climate.

In 1823 CLAVERING met twelve Eskimos at Dødemandsbugt, but subsequently they disappeared from this place. Archaeology tells us that animal bones abound even in the youngest houses. The Eskimos have not died from starvation, but have wandered away, probably northward.

P. V. GLOB's (1935) excavations in the large fjord complex comprising Franz Josephs and Kong Oscars Fjords show that the earliest culture on Clavering Ø, the Inugsuk Culture, which came there from the south, is not represented at all within this area. The migration must accordingly have taken place along the outer coast.

GLOB maintains that he found pure Thule Culture in a single grave within the area investigated by him. Unfortunately, however, these finds are too uncertain and insufficient to be taken as evidence of a pure Thule Culture. But they may be taken as an indication of an immigration from the north extending right down to the interior of Scoresby Sund prior to the Inugsuk migration from the south.

All the houses within the area investigated by GLOB are of a typical mixed East Greenland culture. Some houses show that this culture

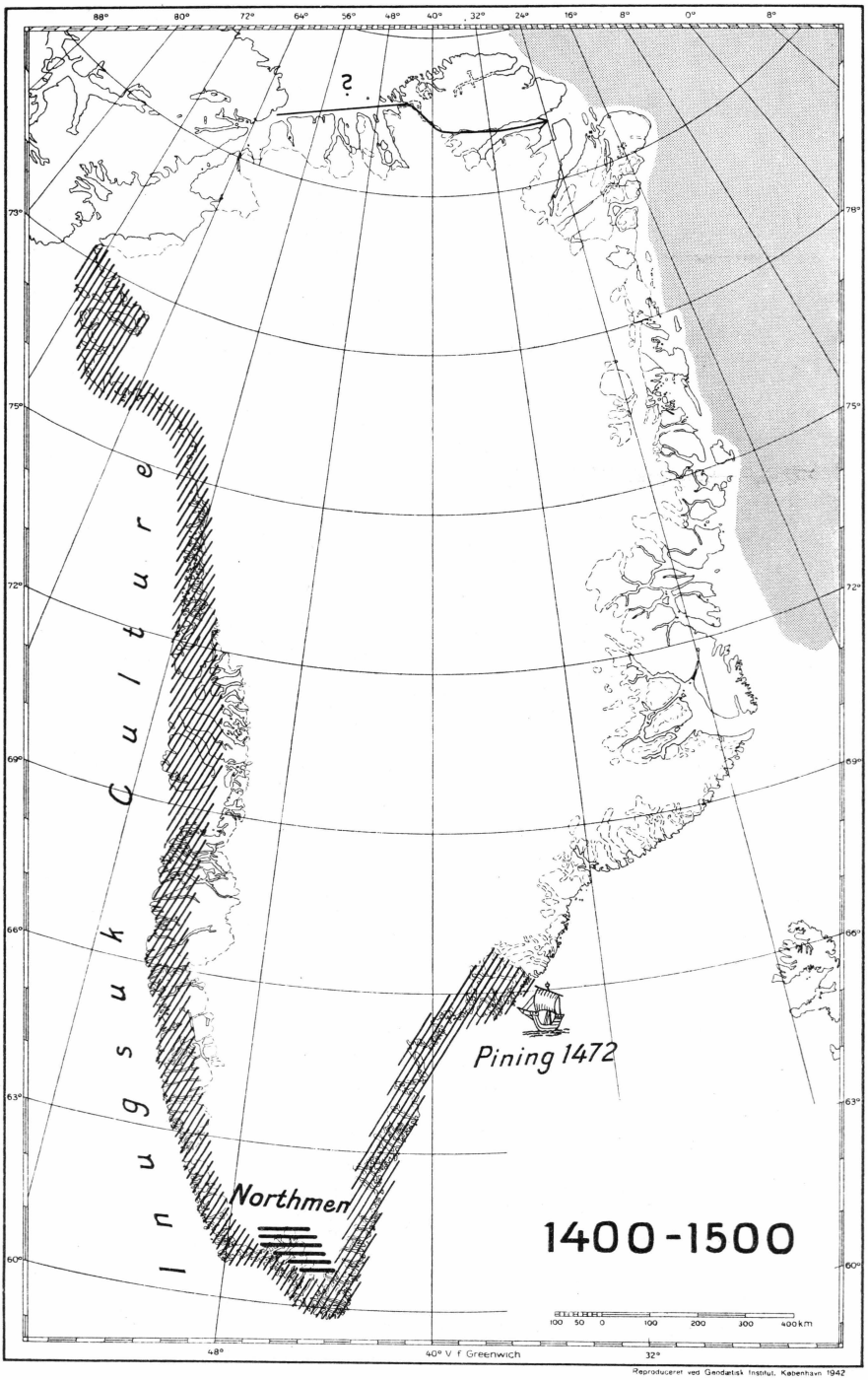

Fig. 129. Distribution of the Eskimos in Greenland in the period 1400—1500. Norsemen still present in this century. An expedition visited East Greenland in 1472.

was degenerating, the settlements are in many cases small and very scattered; GLOB states, however, that the population did not die out in these regions.

The finds made by the Danmark Expedition in more northerly regions as well as the finds made by E. KNUTH[1]) in the spring of 1939 south of Nordostrundingen give no clear picture, both the Inugsuk Culture and particularly the early East Greenland mixed culture being represented, whereas no traces of pure earlier cultures have been found.

Survey of the Eskimo Migrations in Greenland.

What does the above tell us about possible fluctuations in the climate?

It is peculiar that during the centuries with a mild climate about the middle of the Middle Ages human beings for the first time migrated around the whole globe, the Eskimos reaching the outermost coasts of the Atlantic, and the Scandinavians crossing the Atlantic. It is hardly quite by accident that this circulation was completed during a period in the history of mankind with a relatively fine climate.

Considering now the migrations of the Eskimos and the historic conditions in West Greenland on the whole, we shall see that towards the end of the period with a fine climate and during part of the period with a postulated deterioration of the climate various things happened which do not suggest that the postulated deterioration of the climate made itself specially felt in West Greenland. Thus it turns out that

1) the immigration of the Thule Culture into Northwest Greenland,
2) the development from the Thule Culture into the Inugsuk Culture,
3) the immigration of the Ruinø people (Punuk Culture) into Greenland,
4) the journeys of the Norsemen to the Thule district for about a hundred years beginning in 1266 (the wintering of the Norsemen in the Upernivik district in 1333), and
5) the supposed migration around the north of Greenland within the period 1200—1400

occurred partly at the end of the postulated "fine period" prior to 1200 and partly in the postulated "bad period" 1200—1400.

During the late Middle Ages two communities or cultural centres, which at first had no intercourse with each other, were found in Greenland: to the south the Norse community, which had been established after the first years of migration about the year 1000 with an extensive

[1]) So far only very little has been published from this expedition.

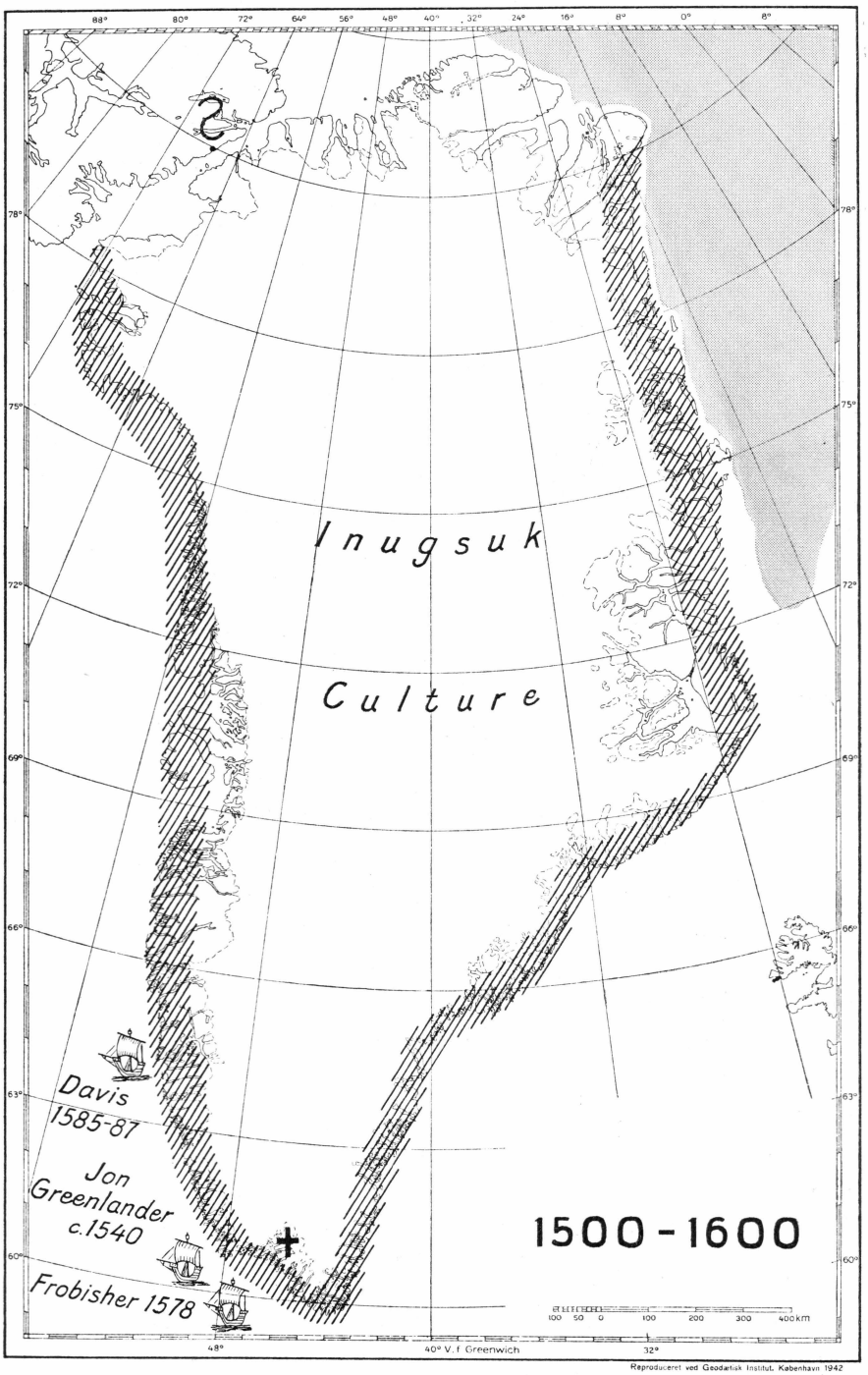

Fig. 130. Culmination of Eskimo distribution in Greenland, 1500—1600. The last Norsemen were killed at the beginning of the century. English expeditions at the end of the century.

habitation both in the East Settlement and in the West Settlement; and to the north the sphere of the Eskimo culture, spreading from Baffin Land along the coasts of Smith Sound to the Thule district.

The cultural area of the Norsemen experienced a rapid flowering from the year 1000 to c. 1250. When the economic decline set in, the inhabitants made exploration journeys northward and thus came into contact with the Eskimos. This contact, which, no doubt, was not always peaceful, was maintained for about a hundred years, but the initiative gradually passed over to the Eskimos, who about 1350 destroyed the West Settlement; but as late as 1410 the East settlement was not in danger, and up to about 1500 there was a brisk trading communication between Europe and Herjolfsnes, an additional fact showing that the climate had not changed essentially. The decline of the Norse culture, therefore, was in no particular degree due to a change of climate, but to the circumstance that the communication with Norway was now rather uncertain because this country, which during the time of the Vikings had been a leading sea-power, had now entered a period of decline.

About 1250 the Eskimo cultural circle was in a rapid development, and though there was some influence from the west, it was essentially self-contained. About 1300 this culture with its highly developed kayak began an immense expansion towards the south. Before that time minor migrations had taken place across Melville Bugt, but now a regular migration commenced along the west coast of Greenland, the Eskimos settling down on all islands and peninsulas in Melville Bugt. The Inugsuk Culture had become independent of hunting from the ice. Constantly larger numbers of Eskimos migrated southward to new hunting grounds, no doubt lured on, also, by the Norse ships, which from time to time made the Eskimos understand that a foreign culture different from their own was found in the south.

After the extinction of the West Settlement (c. 1350) the East Settlement persisted for nearly a hundred and fifty years, until its power was definitely broken about 1500; the Inugsuk migration had then already passed Southwest Greenland and had pushed far up the east coast. There is no basis for believing in a deterioration of the climate which forced the Eskimos to migrate from the north to the south; shoals of big whales and seals were found everywhere, reindeer were plentiful in southern Greenland, and when the migrating people reached East Greenland, they met large seals migrating along the east coast, which lured the Eskimos northward at any rate to some distance south of Scoresby Sund. Whales occurred farther northward, too, and there were good conditions for hunting reindeer and musk-oxen; it was not till they reached the regions round Danmarks Havn that the kayaks

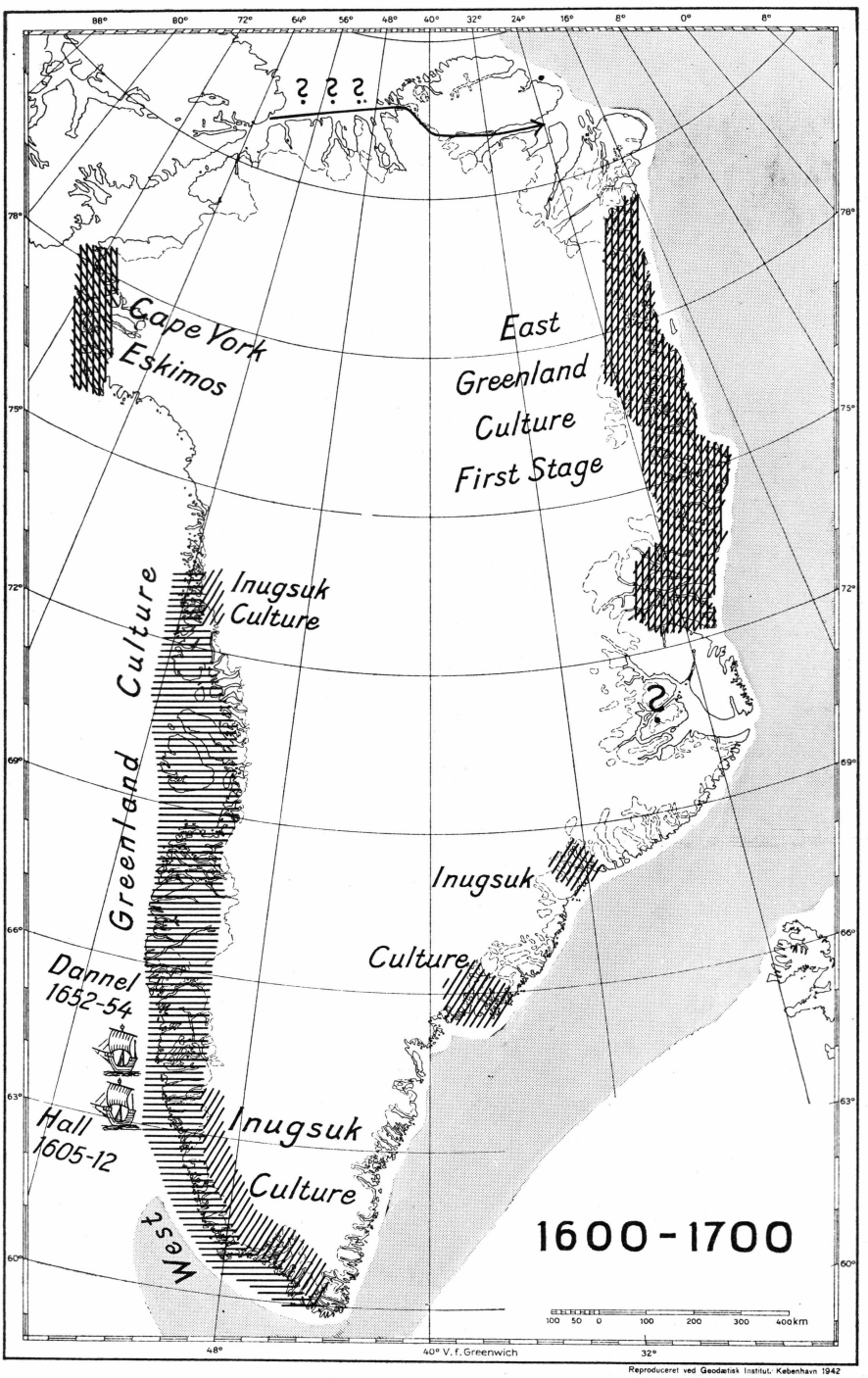

Fig. 131. The Eskimo population has been separated into several tribes. Note the great extension of the ice. Danish expeditions to the west coast.

were less useful owing to the short season with open water, and drift-wood was rare.

During the period c. 1250 to c. 1550 the Eskimo (Inugsuk) Culture conquered that of the Norsemen and reached its greatest flowering in Greenland thus far. At the end of this period probably all the coasts and fjords from Baffin Land across North Devon to Ellesmere Land as also Greenland from Etah to Kap Farvel and the east coast at any rate as far north as Danmarks Havn were inhabited by Eskimos.

The history of Iceland tells us that a severe deterioration of the climate took place in Iceland in the 17th century. Simultaneously with this deterioration of the climate the Eskimo realm of the 16th century in Greenland was divided into isolated tribes. Thus around 1600 communication ceases between nearly all the Eskimo settlements where the natural conditions were difficult, for instance between the inhabitants of the Thule district and the Eskimos living at Upernivik. The intercourse between the Julianehaab district and the Angmagssalik district did not cease entirely, but decreased considerably. Communication between Angmagssalik and Kangerdlugssuak was totally stopped. The same was the case with the communication between Kangerdlugssuak and Kong Oscars Fjord and Scoresby Sund as well as with Dødemandsbugt.

In the 17th century the following tribes were left of the large Eskimo population inhabiting Greenland in the 16th century: 1) the Thule Eskimos, 2) the West Greenlanders, 3) the Angmagssalik Eskimos, 4) the Kangerdlugssuak Eskimos, and 5) the Dødemandsbugt Eskimos.

Most recent development of the Eskimo cultures.

The further development of the Thule Eskimos. — The intercourse between the Thule Eskimos and the inhabitants of Baffin Land was likewise interrupted, perhaps even at this time, but up to about 1850 these Eskimos still lived on either side of Smith Sound. About 1850 the tribe had been reduced to about one hundred and fifty members. Kayaks were used no more, the people gained their livelihood by means of hunting from the ice, having the large bird cliffs of the Kap York district to fall back upon.

The first new development came in 1864 with a fresh migration from Baffin Land, when the Eskimos again learned to use kayaks and to hunt reindeer with bows and arrows; the salmon spear was likewise re-introduced.

The whaling period, which commenced in 1818 in these regions and ended about 1890, was of only slight material importance to the tribe; however, the tribe was supplied with timber, which was highly needed.

For the next thirty years the small tribe of Polar Eskimos, numbering 200—300 individuals, came to play a greater part in the history of Polar exploration than any other Eskimo tribe.

A number of Polar expeditions which in the period 1891—1923 had their headquarters in the Thule district or in its vicinity, engaged a large number of Eskimos, not only men, but whole families. On long sledge journeys the small group of Eskimos, who up to 1891 had lived quite isolated and in a perfect Stone Age stage, now became acquainted with the inland ice of Greenland, the whole north coast as far as Danmarks Fjord in the east, the Polar Basin within the triangle Peary Land, the North Pole, and the northernmost point of Axel Heiberg Land, all the coasts of Grant Land, Grinnell Land, Ellesmere Land as far as Jones Sound and the regions northwest of it, and finally Melville Bugt and the coast farther southward as far as Disko Bugt.

The man who has exerted the greatest influence on the tribe was no doubt Rob. E. Peary, who led the following expeditions to the above-mentioned regions:

1) 1891—92. Headquarters in Mac Cormick Bay. Astrup accompanied by an Eskimo made a trip to the northern part of Melville Bugt.

2) 1893—95. Headquarters in Bowdoin Bay. On these first two expeditions Peary employed the Eskimos on short journeys within the district familiar to them.

3) 1896 and 1897. Summer expeditions in a ship to the northern part of Melville Bugt to fetch the large meteoric stones. Peary took the Eskimo families by ship to the place where he wanted their assistance.

4) 1898—1902. Four-year expedition with a wintering ship to either side of Smith Sound. It was Peary's plan to take a number of Eskimos by ship to the north coast of Greenland to utilise them on long sledge journeys. However, these plans were not carried into effect, but Peary travelled, accompanied by Eskimos, along the north coast of Greenland as far as Kap Clarence Wyckoff in the east and along the north coast of Grant Land as far as Cape Thomas Hubbard on Axel Heiberg Land in the west; in addition he made a dash towards the North Pole, travelling as far as 84°17′ N. lat., and spent the winter with Eskimos as his sole companions near Ft. Conger.

5) 1905—06. Many Eskimo families were taken by ship to Cape Sheridan on the north coast of Grant Land; in 1906 some of them travelled back alone to the Thule district. Many sledge journeys were made to Lake Hazen and the interior of Grant Land as well as one longer trip towards the North Pole (as far as 87°06′ N. lat.).

6) 1908—09. PEARY again took a great part of the tribe by ship to Cape Sheridan, whence he started on a journey towards the North Pole, which he reached, accompanied by the negro HENSON and five Eskimos, in April 1909. Many Eskimos accompanied him with auxiliary sledges part of the way. Two of PEARY's companions made a journey, accompanied by Eskimos, to the northernmost point of Greenland.

7) 1908—09. Dr. FR. A. COOK, accompanied by two Eskimos, made a sledge journey from Etah to the northernmost point of Axel Heiberg Land and thence along the west coast of the land to Jones Sound, where the party spent the winter. Next spring the party reached Etah, whence they proceeded across Melville Bugt to the Danish colonies in West Greenland. After this journey Dr. COOK proclaimed that he had been at the North Pole, though he had only been so far north that Axel Heiberg Land had constantly been kept in view.

PEARY's journeys during nearly twenty years were of enormous importance to the Eskimos. Their bows and arrows were replaced by rifles, they were well equipped for the journeys, and many Eskimos got accustomed to travelling under the command of white men. Generally, however, the sledge journeys were so long that the Eskimos were unable to utilise the hunting fields; only after Dr. COOK's journey did the Eskimos sometimes hunt bears along the east coast of Ellesmere Land in the spring.

Even before PEARY's journey to the North Pole Danish influence began to make itself felt among the Polar Eskimos, at first to a very small extent, and the Eskimos sometimes travelled from the southern part of the district to the Danish colonies.

8) 1903—04. MYLIUS-ERICHSEN, HARALD MOLTKE, and KNUD RASMUSSEN spent the winter at Thule. Their journey to Thule and back took place by sledge across Melville Bugt, which was thus opened up as a sledge route.

9) 1907—08. This year KNUD RASMUSSEN again used Melville Bugt as a route between Danish West Greenland and Thule, and in 1910, in company with PETER FREUCHEN, he established the colony of Thule, going there by ship. They stayed there for three years, during which a lively traffic by dog sledges was commenced across Melville Bugt; this traffic was particularly intensive during the World War 1914—18 and was not reduced till the middle of the twenties.

In 1912 KNUD RASMUSSEN and PETER FREUCHEN, accompanied by two Polar Eskimos, travelled across the inland ice to Northeast Greenland and back.

In 1916—18 KNUD RASMUSSEN led a sledge journey along the north coast of Greenland, returning to Thule across the inland ice in 1917.

KNUD RASMUSSEN's activities among the Polar Eskimos in the period 1903—18 became of the greatest importance to the tribe. The communication between Thule and the Greenlanders in the Upernivik district was almost permanent, a number of sledge journeys taking place across Melville Bugt every year. In 1910 a missionary station was erected among the Polar Eskimos.

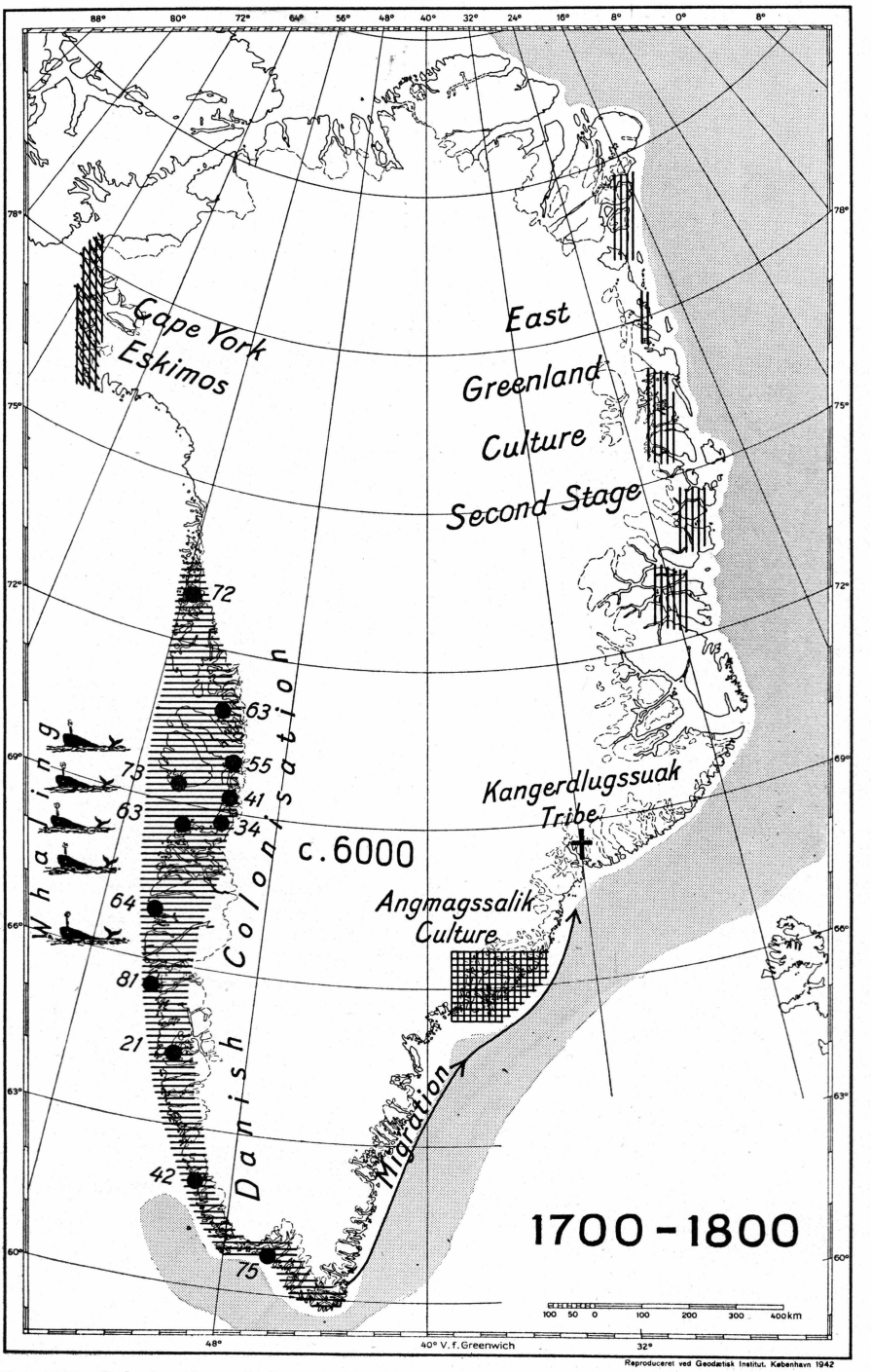

Fig. 132. Culmination of the whaling industry. During this century all the Danish colonies (comprising c. 6000 Eskimos) on the west coast were established (the figures indicate the year (17..) in which the individual colonies were established). Eskimos still fairly widely distributed in Northeast Greenland. Great extension of the sea ice.

10) In 1919 GODFRED HANSEN accompanied by several Eskimos made a sledge journey to the northernmost point of Grant Land, Cape Columbia, to establish a depot there for ROALD AMUNDSEN.

11) As an offshoot of PEARY's expeditions a luxuriously equipped American expedition under the leadership of DONALD B. MACMILLAN stayed at Etah in the years 1913—17. Various sledge journeys (e. g. in 1914) were made to "Crocker Land" assumed to be situated northwest of Axel Heiberg Land. In 1915 MACMILLAN made a sledge journey to Kong Christian IX's Land northwest of Jones Sound, while E. EKBLAW travelled around Grinnell Land. Eskimos participated in all these journeys.

In 1916—17 several members of the expedition were transported southward to the Danish colonies by sledge. In the subsequent years it was a general rule that a number of Eskimos went by sledge to Grinnell Land in the spring to hunt musk-oxen.

12) In 1920—23 the present author led an expedition, with Igdluluorssuit as a base, which comprised sledge journeys northward with Eskimos (in 1920 to Washington Land, in 1921 around the north of Greenland and back across the inland ice, and in 1922 to Kap Brevoort on the north coast of Greenland) and in the autumn and winter across Melville Bugt to Danish West Greenland.

In 1922 the Canadian Government prohibited musk-ox hunting west of the line Smith Sound-Robeson Channel; this meant that all hunting trips to Ellesmere Land ceased.

The period of the great journeys of discovery had thus come to an end. The few smaller expeditions which have since then taken place to these regions have utilised the working power of the Eskimos, their equipment and dogs, to a small extent only. After 1923 a part of the tribe has moved somewhat farther southward and now depends more and more on fox-hunting, which was formerly chiefly carried on by women and children. Even up to 1920 not very many goods were to be had at Thule, and the life of the Eskimos, especially in lonely settlements, was still very primitive. In the winter of 1921—22 the Spanish flu caused the death of a large number of Eskimos. It was evident this winter that after twelve years' influence Christianity had only gained little ground among the population, and several shamans had still great influence among the Eskimos.

It will be appropriate to mention here some small birds which have been, and still are, of immense importance to the life and culture of the Polar Eskimos, viz., the little auks. They are restricted to two areas in the Thule district, we may almost speak about two large bird cliffs, one extending from Etah in the north along the shore to Igdluluorssuit, comprising also the south coast of Hakluyt Ø and Northumberland Ø. The other, southern, area extends from a little north of Pitugfik Gl. to a little east of Kap Melville in the northern part of Melville Bugt. The little auks breed in millions in holes in the evenly

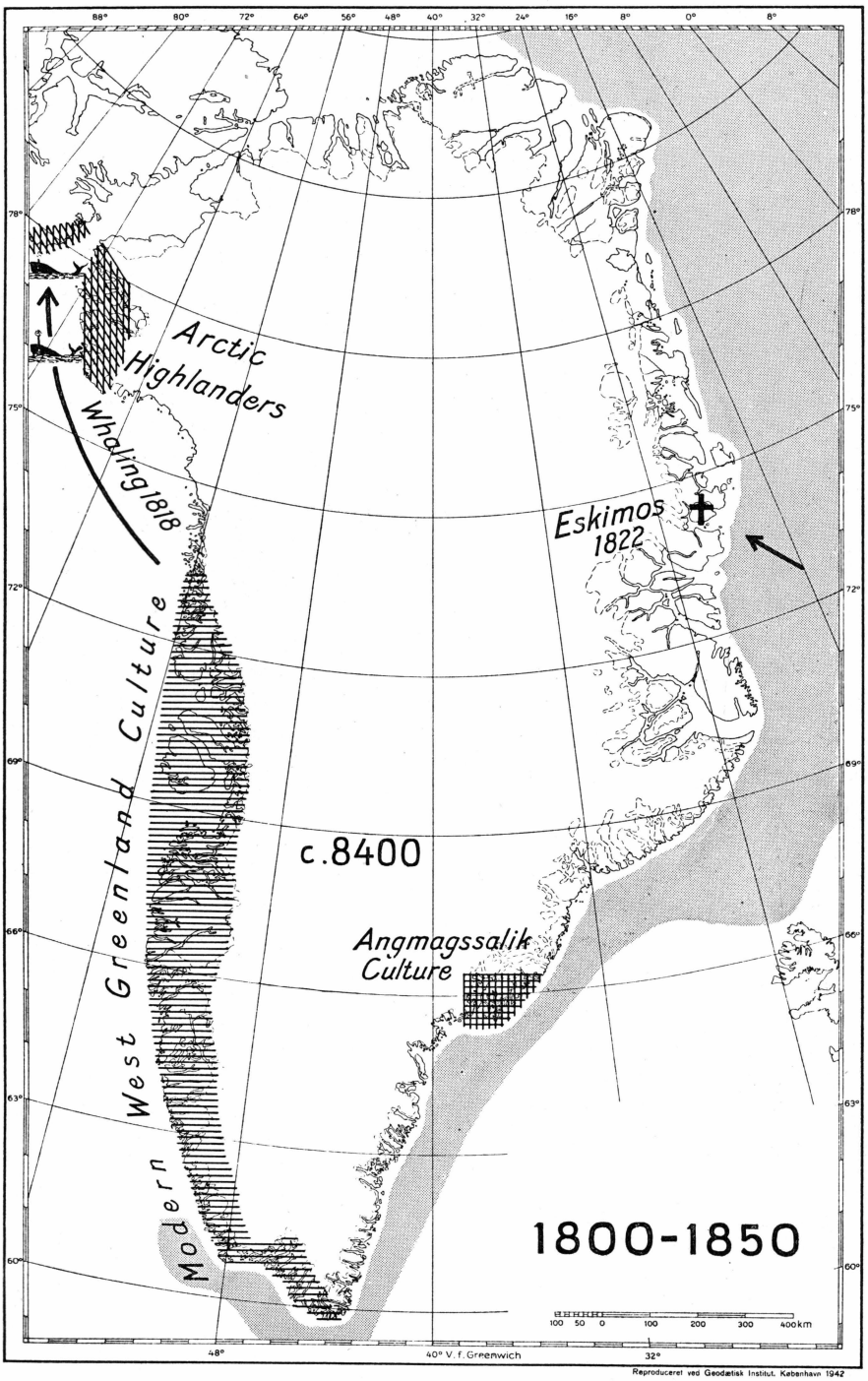

Fig. 133. Only three Eskimo tribes left. The Eskimos in Northeast Greenland die out. Whaling industry removed to Smith Sound. Great extension of the sea ice.

sloping cliffs. It is possible to walk on the cliffs, and it is no doubt due to these bird cliffs, which meant a kind of providence to the Eskimos, that the Polar Eskimos did not die out in the three cold centuries 1600—1900. Right up to the present day it has been customary for old people to live near the bird cliffs; besides shifting for themselves, they might then cache depots of eggs and birds in the summer and might prepare under-garments of the birds' skins. In the last few years the importance of the bird cliffs has, of course, decreased somewhat.

While up to c. 1920 the Polar Eskimo women always wore fox-skin trousers and the men bear-skin trousers and fox-skin coats, the women and especially the men now to an increasing extent wear reindeer coats, because the trade with the Polar Eskimos is based on fox-skins. A considerable export of reindeer skin is now taking place from Lappland to Thule, especially after the prohibition of musk-ox hunting.

Although the copious expedition literature tells much about the Polar Eskimos, it is peculiar that the only monograph on the Polar Eskimos published in the "Meddelelser om Grønland" was written by Professor H. P. STEENSBY, who stayed among them for a couple of weeks in the summer of 1909; consequently his monograph (149 pages, 2 pls.) is chiefly based on the literature available at that time. For comparison it may be mentioned that up to May 1944 the papers in the "Meddelelser om Grønland" dealing with the Angmagssalik tribe amounted to about 4000 pages and c. 80 plates. A great part of the literature on the Polar Eskimos (expedition reports and more or less popular books) must be regarded with criticism.

As late as 1920 the tribe was so primitive (it still comprised many heathens) that it might have been possible to write a detailed monograph on this peculiar small isolated tribe. Now it will be more difficult, but it is to be hoped that a scientific monograph on the tribe will be worked out before it is too late.

The development of the West Greenland tribe which began about the year 1600, showed a flowering about 1650 when the whaling period set in, as the whalers carried on a lively trade with the Eskimos.

The whaling industry had not yet ceased when HANS EGEDE arrived at Godthaab in 1721, and the Danish colonisation commenced. The present Danish colonies in West Greenland were founded in the course of the 18th century, though in the Upernivik district it took some time before the colonisation was started. A description of the development of the individual colonies is beyond the scope of the present paper.

One after the other of the Greenland products was demanded and improved, often with the result that the production ceased. This was

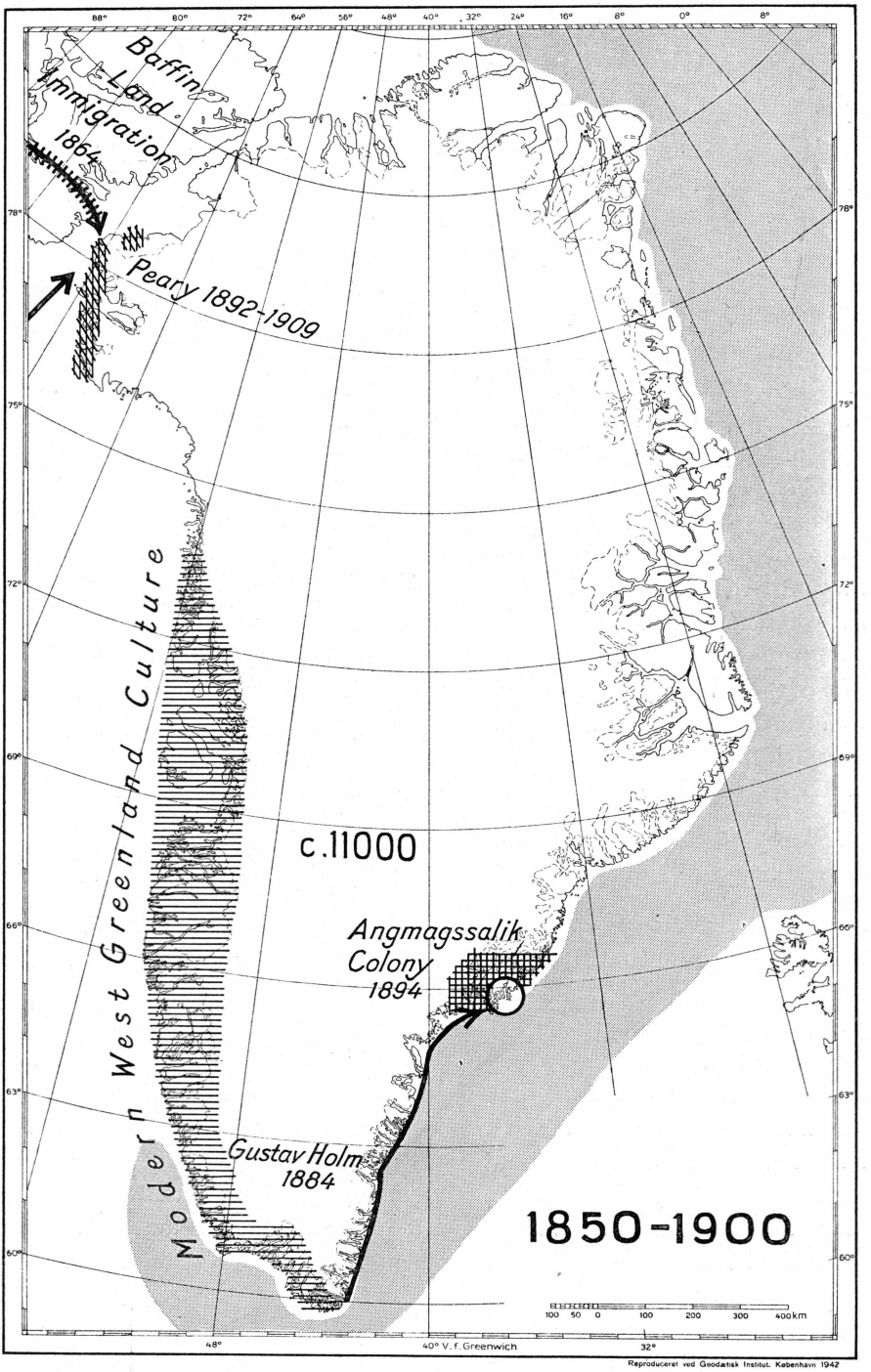

Fig. 134. New immigration of Eskimos into Greenland. The Angmagssalik tribe is discovered and a colony established. Very great extension of the ice.

the case with the whales in Disko Bugt around 1800 and with the whaling industry on the whole in the 19th century. The same applies to the catching of eiderducks in the Egedesminde district about 1820 the reindeer hunting in the large ice-free areas of the west coast between Egedesminde and Godthaab about 1850, and the sealing industry throughout the whole of West Greenland at the beginning of the present century.

The Eskimo population has constantly increased in number, thus it has been more than doubled during the last hundred years. This increase continued unaffected when the climate grew milder about 1880. The introduction of fire arms had played great havoc with the seals. When the old hunting methods were used, nearly all the wounded seals were caught; when the hunting was carried on by means of guns, large numbers of seals were lost. It is natural therefore that a smaller and smaller number of seals were caught at the colonies and subsequently near the outposts and minor settlements.

About 1920, when the number of seals had been considerably reduced, the whole mode of life of the population had to be changed, so that they utilised the increasing number of fish in the warmer and warmer water off the west coast of Greenland. As a consequence the umiak, which enabled the Eskimos to travel along the coast, has practically disappeared. The kayak and the hunting associated with it has likewise been much reduced, notably of course, along the central part of the west coast.

Although during the last ten years there have been excellent conditions for a migration northward along the east coast, and along the west coast into Melville Bugt and to the Thule district and the regions around Kane Basin, where space could be provided for a large migration, the authorities have taken no steps to bring about such a migration.

A modern migration northward from the Upernivik district. — From the end of the nineties to about 1922 an interesting migration took place from the Upernivik district without any initiative on the part of the authorities, since the population, who for the last half of the 19th century had not migrated north of the outpost Tasiusak, began to settle farther northward. This was no doubt due to two circumstances; the milder winters with the consequent bad ice and unpleasant humid climate around Upernivik, and the general reduction in the number of seals there.

This migration was further extended after the Literary Expedition 1903—04 had established connection with the Kap York Eskimos and made the Eskimos acquainted with the abundant bear hunting in the southern part of Melville Bugt.

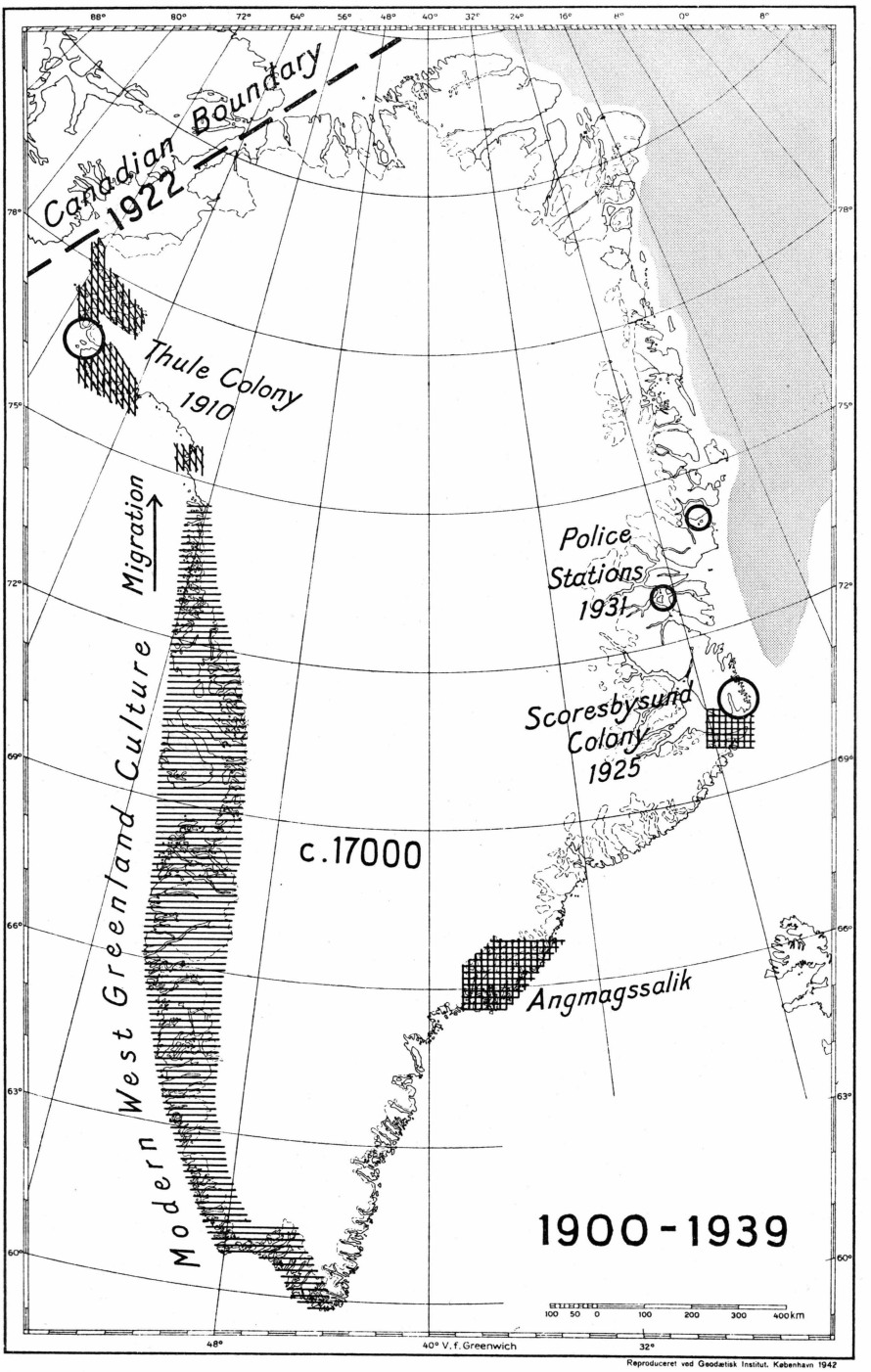

Fig. 135. Colonies established at Thule and Scoresbysund. Canada prohibits hunting trips west of Smith Sound. Initial Eskimo migrations. Recession of the sea ice.

During KNUD RASMUSSEN's many journeys to Thule in the interval between this expedition and 1918 the population spread to the regions around Djævelens Tommelfinger, and in 1922 an outpost was erected on the peninsula of the Nugsuak Halvø; at the same time the migration stopped, not pushing northward beyond Holms Ø. The population which had immigrated, had good seal hunting, especially in the spring when they hunted from the ice, and in the autumn and part of the winter, when they hunted by means of nets.

Without the authorities noticing it, this population exterminated numerous eiderduck colonies on the outer islands between Tasiusak and Holms Ø. In the period 1916—23 the present author had the opportunity to observe this migration. Quite commonly a family chose an island with eiderduck colonies for its summer camp site. This was of course very destructive to the eiderduck colonies of the islands. I have often visited Eskimo families in the winter who had cached several thousand eiderduck eggs, which were used as food for the dogs[1]).

In the winter the Eskimos travel up into Melville Bugt to hunt bears. Intensive bear hunting has likewise been carried on near the settlements of Kap York and Kap Seddon. In 1923, when the author last visited these regions, the bears in Melville Bugt were in rapid decline.

As regards the east coast of Greenland, conditions are far from clear. During the 17th century with its unfavourable climate the uniform settlements of the Inugsuk Culture divided into a number of tribes each with its history. The southern tribe at Angmagssalik was cut off from West Greenland, but about 1700 a fresh migration reached this region. Angmagssalik and Iceland are situated so near each other that their climates are directly comparable. The curves (pp. 258—59) show an amelioration of the climate in Iceland in 1720—40. It is natural to assume that the migration up the coast to Angmagssalik took place during this period.

During the succeeding deterioration of the climate about 1800 the migration from the south stopped and was not resumed during the short period of a milder climate 1840—53. It was not till the end of the next deterioration of the climate in 1853—94 that GUSTAV HOLM, going in umiak up along the southern part of the east coast, reestablished the connection with Angmagssalik, but from that time up to the present

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[1]) In the early summer of 1923 I went in a motorboat to one of the outermost groups of islands within the district to examine whether eiderducks were breeding there. On my arrival I met an Eskimo family who had settled there, so even this remote eiderduck colony was going to be totally destroyed.

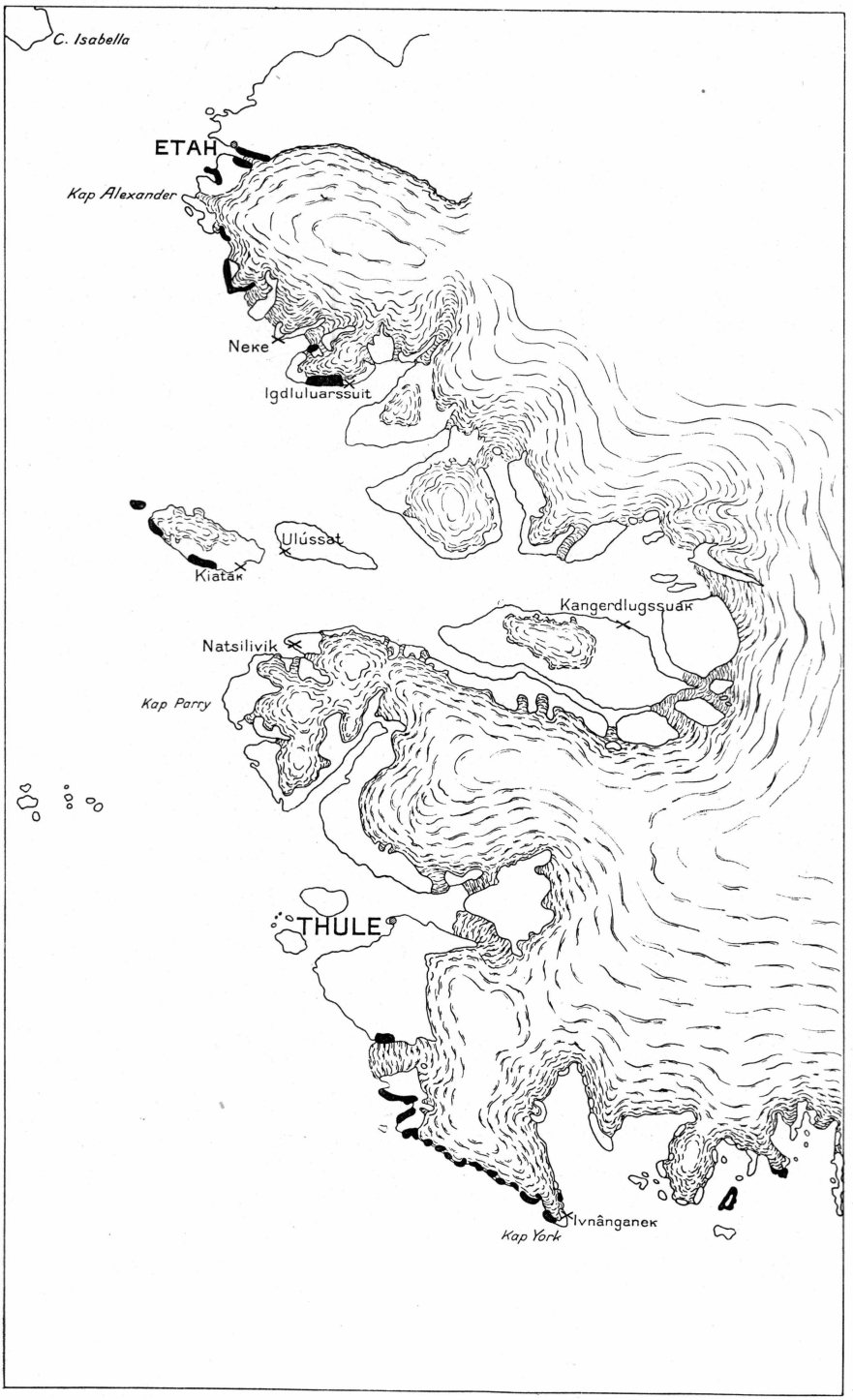

Fig. 136. The settlements in the Thule district most commonly inhabited by Eskimos during the last fifty years. Black areas indicate bird-cliffs with little auks.

the communication with Angmagssalik has taken place directly from Europe to Angmagssalik.

The communication with West Greenland along the coast was re-established in 1931 by H. G. WATKINS, who sailed from Angmagssalik to Julianehaab in a small boat with an outboard motor, and during the following years, when the Sixth and Seventh Thule Expeditions in large motorboats sailed along the coast to Angmagssalik and one right up to Scoresby Sund. These voyages in connection with the highly improved ice conditions in recent years have induced the Eskimos living at Angmagssalik to return to the ancient settlements south of the colony.

The Kangerdlugssuak tribe, which, as stated above, was isolated from the Angmagssalik district about the year 1600, seems to have survived the bad climate of the 17th century, but to have succumbed during the severe climate in the period 1780 to 1840.

Turning now to the Eskimos who lived in the area of Franz Josephs Fjord and Kong Oscars Fjord, we are confronted with the problems that are still unsolved within the archaeology of the East Greenland Eskimos.

A single find from Scoresby Sund and another from Kap Harry (GLOB 1935) are suggestive of a pure Thule Culture, but these finds are too insignificant to be taken as proofs of an early immigration of Thule Culture Eskimos around the north of Greenland in the period 1200—1400. Some few very doubtful records from the Saga time might suggest that Eskimos lived in the area already at that time; in that case, they must have come either from the south prior to the year 985 or perhaps more probably from the north in the period 1000—1200.

At Dødemandsbugt the ancient mixed culture seems to have become extinct about 1700, that is to say, at the transition to the improved climate during the 18th century. In the large fjord complex and at Dødemandsbugt as well as at Kangerdlugssuak the Eskimos seem to have been extinguished during the severe climate in 1780—1840.

Problems Concerning the Eskimo Migrations.

The investigations during recent years in Greenland have shown that within the period in which it has been inhabited its climate has been subject to very great fluctuations, which have exerted a considerable influence on the life conditions of man. In discussing the life conditions in Greenland we cannot, therefore, take it for granted, as done by FRIDTJOF NANSEN (1911 and 1925) regarding the life con-

ditions of the Norsemen and by KNUD RASMUSSEN (1918) as regards a migration of Eskimos around the north of Greenland, that the conditions in earlier times were the same as at present.

However, in spite of the intensive investigations carried out during the last twenty-five years, the picture we have gained of the life and activities of man in Greenland is very obscure. Evidence of prehistoric culture is at hand, but we have no knowledge of the time and extent of the development of these cultures in Greenland. First of all we know very little about their routes of immigration into Greenland, and the main interest within Eskimo archaeology will therefore now be focussed on Ellesmere Land. Here a number of migratory routes may come into consideration, viz.

1) the route from Jones Sound along the east coast of Ellesmere Land,
2) the route over land from Heureka Sound between Ellesmere Land and Grinnell Land (PETER FREUCHEN has informed me that according to his Eskimo father-in-law the latest immigration of Eskimos into Greenland in 1864 took place by this route),
3) the route by way of Greely Fjord-Lake Hazen to Hall Basin, and
4) the route up or down through Kennedy Channel.

The two last-mentioned routes were possibly used by the people of the Cape Dorset Culture. GREELY's findings near Fort Conger likewise seem to show that at any rate one of these routes was taken by the people of the Thule Culture, and the well preserved sledge found by GREELY's expedition on the east coast of Grant Land where Robeson Channel is narrowest suggests that Eskimos lived here some time in the 19th century; otherwise the sledge would have fallen to pieces, since sledge lashings can hardly be assumed to have persisted through several centuries.

Considering now the north coast of Greenland, it may be established at once that we have no decisive archaeological proof that a migration has taken place around the north of Greenland. The traces of ancient culture found in Northeast Greenland may be supposed to be due to the Eskimos who reached Kap Farvel prior to the year 1000 and who possibly lived an isolated life in the interior of Scoresby Sund during long periods. However, such an explanation is not very probable. The distance between the Eskimo remains found in Northwest Greenland (a meat-cache near Hand Bay) and in Northeast Greenland (remnants of a bow at the head of Brønlunds Fjord) is only 370 km, and

taking the route through J. P. Kochs Fjord and Wandels Dal (the former Peary Channel) it is easily covered by sledge.

It will be natural to assume that an Eskimo migration along the north coast of Greenland, if any, must have taken place in periods with a mild climate, when the East Greenland fjords were free of ice in the summer. It is well known that within the period (1876—1921) in which the north coast of Greenland was discovered and mapped on sledge journeys the fjords of northern Greenland were covered by ice even in the summer. In 1938 I saw from the air that there had been open water in the fjords south of Peary Land at any rate during one summer in the period 1933—38. It must be taken for granted that for different periods within the last 1000 years the North Greenland fjords have been free of ice in the summer and have thus afforded conditions for a much better hunting of marine animals than that known for the period 1876—1921. The periods from c. 1000 to 1200 and from 1400 to some time in the 16th century may be assumed to have been favourable for a migration around the north of Greenland.

Our knowledge of the life and doings of man in East Greenland is likewise very scanty. As stated above, we do not know positively whether an immigration has taken place from the north, and if so, at what time. An earlier immigration from the south is also very doubtful, though it must be regarded as probable that some few Eskimos lived in Southeast Greenland as late as 1000. Whether Eskimos lived in the interior of Scoresby Sund during the great Inugsuk migration northward along the coast is still a matter of doubt.

In Figs. 130—133 I have suggested the distribution of the different cultures in Northeast Greenland. It is probably beyond doubt that the younger mixed culture has been represented throughout the interior of Scoresby Sund. This is not indicated on the map in Fig. 132 because in my opinion we must await fresh excavations in this region, before we can decide which cultures have been represented there. I have likewise been very cautious in indicating Eskimo habitations between Angmagssalik and Kap Farvel, especially as regards the most recent centuries. Evidently this coast was more extensively inhabited than appears from Figs. 131—133, and within the present century the Eskimos have temporarily lived both north and south of Angmagssalik, but owing to our scanty knowledge of these conditions I have preferred not to give too much on the maps. It might be possible to connect the various migrations along this coast with the occurrence of the ice near Iceland. Thus it is quite probable that the immigration assumed by THERKEL MATHIASSEN to have taken place about the year 1700, took place during the period comparatively poor in ice about the year 1730.

The west coast of Greenland still presents many unsolved archaeological riddles. Thus we do not know positively which Eskimo culture prevailed in southern Greenland before the arrival there of the Norsemen, nor do we know when and where the Norsemen met living Eskimos for the first time.

Our present knowledge of the earlier Eskimo cultures in Greenland may, with reservation, be summarised as follows:

The earliest culture, the Cape Dorset Culture, has been traced with certainty in Northwest Greenland from Thule to and including Hall Land. Indications of it have further been found in Northeast Greenland and along Disko Bugt, and very possibly the Eskimo habitations in the Julianehaab district prior to the year 1000 should be referred to this culture. The Cape Dorset Culture, according to our present knowledge of it, tells nothing about the climate in Greenland.

The next culture, the Thule Culture, prevailed in the Thule district for a couple of centuries until c. 1200, when it attained such a great development that is passed into a higher culture, the Inugsuk Culture. This cultural development was further accentuated by the immigration from the west of the Punuk Culture, which, however, was soon absorbed by the Inugsuk Culture.

About the year 1200 an immigration took place across Melville Bugt, but subsequently the Eskimo migrations across this bay stopped for some time, possibly owing to a deterioration of the climate in the latter half of the 13th century. After that time the great migration of the Inugsuk Culture set in, spreading from the Thule district southward along the west coast and up along the east coast almost as far as Nordostrundingen and lasting from c. 1250 to c. 1600.

Direct proofs of a difference in the climate at that time and about the year 1900 in the Thule district are 1) that kayaks were found in Kane Basin during the Thule Culture, 2) that the kayak was highly developed in the Thule district prior to 1200, and 3) that immigrations took place across Melville Bugt before the 13th century and the subsequent period, and that Eskimo house ruins from this period are found practically throughout Melville Bugt wherever conditions are suitable for a settlement.

Archaeology tells us that about 1600 the flowering and wide distribution of the Inugsuk Culture along the whole west and east coasts of Greenland were suddenly replaced by degeneration and isolation. The Inugsuk people living along nearly all the coasts of Greenland was split up into isolated tribes, and wherever the coast was difficult to pass during bad climate all habitation ceased and even

travelling stopped. This isolation lasted from 1600 to 1900, the area inhabited by the Eskimos decreasing constantly. Not till the present century have Eskimo tribes again commenced to spread along the coasts, which had been uninhabited for three centuries.

Although many problems within Eskimo archaeology still remain unsolved, 1) the rich flowering of the Eskimo culture in the Thule district from c. 1000 to 1200, 2) the great migration of Inugsuk people c. 1250—c. 1550 nearly all over the coasts of Greenland, and 3) the sudden splitting into isolated tribes after c. 1600, several of which became extinct in the period 1600—1900, suggest a surprising agreement between the development of the climates in Greenland and Iceland.

CONCLUDING REMARKS

The information on the drift ice in the Greenland waters gathered in the present work is based on my own observations during twenty-five years as well as on the available literature on the subject, and on the archaeological literature in so far as it throws some light on the ice conditions that prevailed in former times. It should be pointed out that two papers now in press, written by my two collaborators, Messrs. E. HOVMØLLER and A. KIILERICH, and dealing with the meteorology and the hydrography, respectively, of these regions, supplement the present paper at various points.

The geographical types of the ice occurring around the North Pole which have been erected in the present paper show some points of resemblance to glaciers, for in both cases we are concerned with a transport of ice from an area of alimentation with a surplus of ice to an area of ablation. However, the resemblance is only partial. In the case of glaciers the most important factors are temperature, precipitation, and gravitation, while in the case of the drift ice the most important factors are temperature, wind, and current.

Let us consider more closely the conditions relating to the drift ice.

1) In the Polar Basin the temperature is negative all the year round except in July and August. The period of melting at the surface of the ice around the North Pole hardly exceeds fifty days, and it is often interrupted in the night by temperatures at or below zero. During this period the Polar Basin resembles a wet tundra. No glacier ice is formed on the sea as in Antarctica (cf. L. KOCH 1928).

In the winter the cold penetrates through the ice, which will freeze on the under side. If the temperature rises, the water supplied to the Polar Basin by the warm currents will have a higher temperature, so the cold water layer beneath the ice will be thinner, too. (From the end of the last century till the present time the thickness of the cold water layer below the ice, as is well known, has decreased from c. 200 to c. 100 m). When this water layer grows sufficiently thin, the lowermost

part of the largest pressure ridges will begin to melt, and the ice will not drift very far southward before melting.

2) Precipitation.—The precipitation in the Polar Basin is inconsiderable and plays a quite subordinate part in the formation of ice.

Of greater importance is the large supply of fresh water to the Polar Basin carried by the large rivers; thus the North Pole Ice receives the surplus of the precipitation from Mackenzie River, which has a drainage area of c. 2,025,000 km², while the Siberian Ice receives fresh water from an area comprising the East Siberian rivers, which drain an area of c. 5,100,000 km², and the Spitsbergen Ice receives large quantities of fresh water from the West Siberian rivers. This fresh water, which remains at the surface, freezes readily and contributes to some extent to the increase of the ice. (See Fig. 4).

3) Wind.—What the precipitation is to the glaciers, the wind is to the pack-ice. If it were quite calm over the Polar Basin, the ice would be of uniform thickness, and the currents would, no doubt, be unable to transport this ice away. However, every gale will give rise to pressures and tensions in the drift ice, which will result in the formation of pressure ridges and clearings; during the greater part of the year, however, the clearings will freeze again immediately after the gale has ceased. Thus more ice will form after every gale, and if it blows in the direction of the current, the velocity of transport will be considerably increased.

Fig. 137 shows the extension of the different types of drift ice around the North Pole at the end of the winter; for the East Greenland Ice and the Spitsbergen Ice the area of extension which has generally been met with in the present century is shown, while for the other types of ice the maximum extension is given. The following figures indicate the areas covered by the different types of ice (million sq. km) shown on the map (Fig. 137):

The Palæocrystic Ice: c. 0.77 (Sweden and Norway: 0.77).
The North Pole Ice: c. 4.04 (British India: 4.68).
The Siberian Ice: c. 2.17 (Greenland: 2.18).
The Spitsbergen Ice: c. 1.85 or, like
the Baffin Bay Ice: c. 1.90, somewhat less than Greenland.

The East Greenland Ice: c. 0.87 (Sweden, Norway, and Denmark: 0.89).

A piece of ice formed near the north coast of Alaska and transported across the North Pole southward along the east coast of Greenland and up the southern part of the west coast as far as Godthaab will travel a distance of nearly 7,000 km.

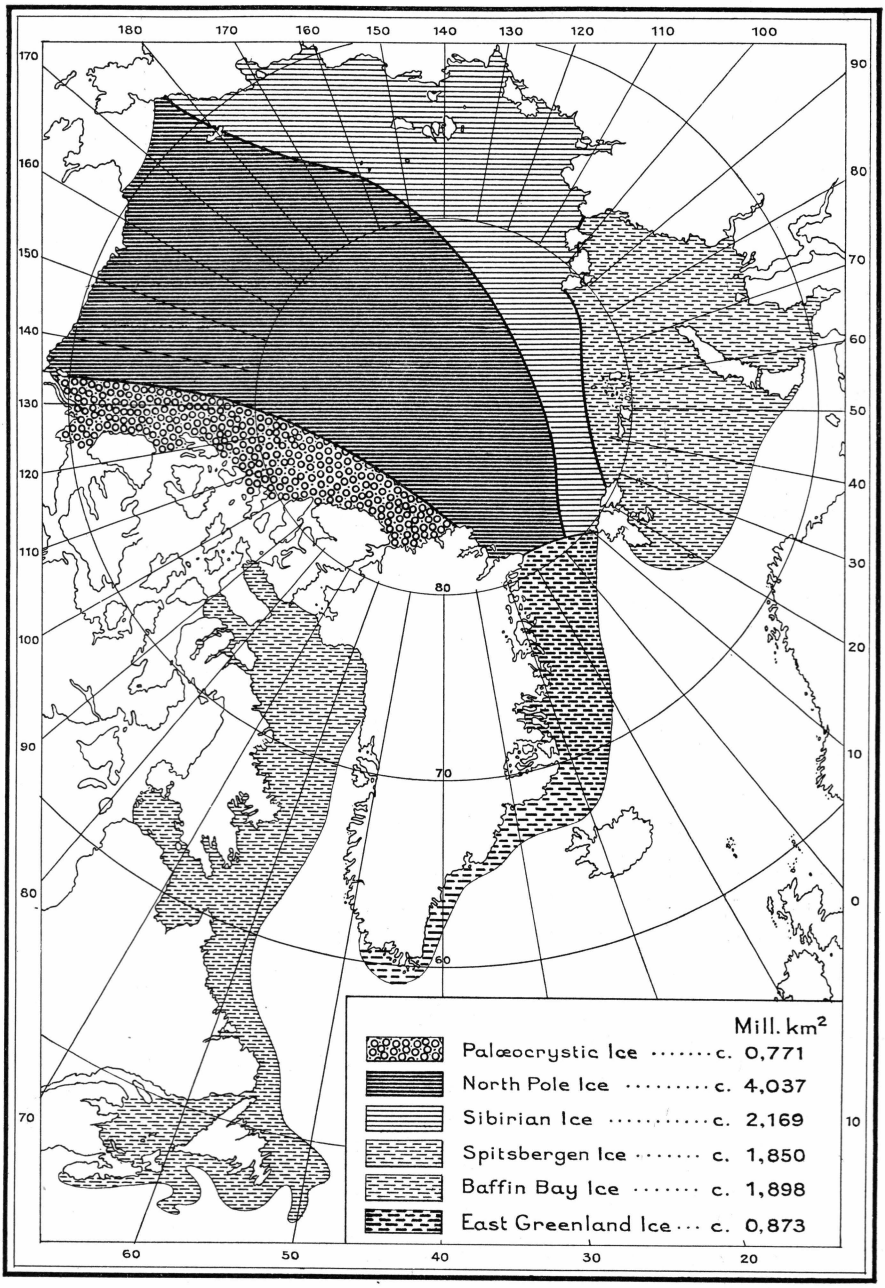

Fig. 137. The various types of ice and their geographical distribution around the North Pole.

It is a well-known fact that in the present century the climate has changed considerably in the regions around the North Pole. This phenomenon has been the subject of numerous investigations, notably in recent

years, and a very copious literature, comprising meteorological, glaciological, hydrographic, archaeological, zoological, and botanical observations, is available.

The whole problem is rather complicated. There are several dissimilarities between the different places, both as to the temperature conditions in the various years and as to the time when the great climatic change of this century appeared. Taking this into consideration, there is nothing surprising in the fact that certain years (1881, 1938) have had relatively much ice in part of the Arctic Sea and but little ice in other districts.

In some of the last twenty years (1925, 1930, 1932, 1936, and 1939(?)) nearly 5 million sq. km of ice, or, in other words, nearly half the ice masses around the North Pole, have melted during the summer owing to the aforementioned change of the climate. Thus, at the end of August 1936 all the Spitsbergen Ice, the East Greenland Ice, and large portions of the Siberian Ice had disappeared.

Fig. 138 shows the ice conditions along the northeast coast of Greenland about the middle of August 1933. It will be seen that the sea from Danmarks Havn to Nordostrundingen was free of ice; even from a height of several hundred metres no drift ice was observed along this stretch; however, small quantities of (Siberian) ice seem to have been present far seawards, as there was no swell.

Similar ice conditions have probably prevailed here in August of most of the favourable summers of the last two decades; before this time, however, the Atlantic has, according to the literature, never been observed to be practically free of ice as far as a line Nordostrundingen—North Spitsbergen.

In fig. 139 I have indicated the ice not very old in the Northeast Greenland fjords. In this ice numerous icebergs with fresh fracture surfaces and disengaged from the glaciers shortly before were observed in the North Greenland fjords in May 1938. During a flight in August 1933 I observed old sikussak ice, which held the icebergs in position along the edges of the glaciers. The observations show that in one of the years 1934—37 practically all the sikussak ice melted away.

The scientific material hitherto published from the Polar Basin is rather scanty; even the bathymetrical conditions within this vast area are almost unknown. A considerable increase may be expected when the material from the "Sedow" Expedition and the drift of the PAPANIN group southward from the North Pole has been worked up. If such favourable ice conditions as those mentioned above are experienced in future times, a well-equipped meteorological and hydrographical expedition, using a ship built for ice navigation and carrying a seaplane, will, no doubt, be able to secure important results from the regions around Nordostrundingen.

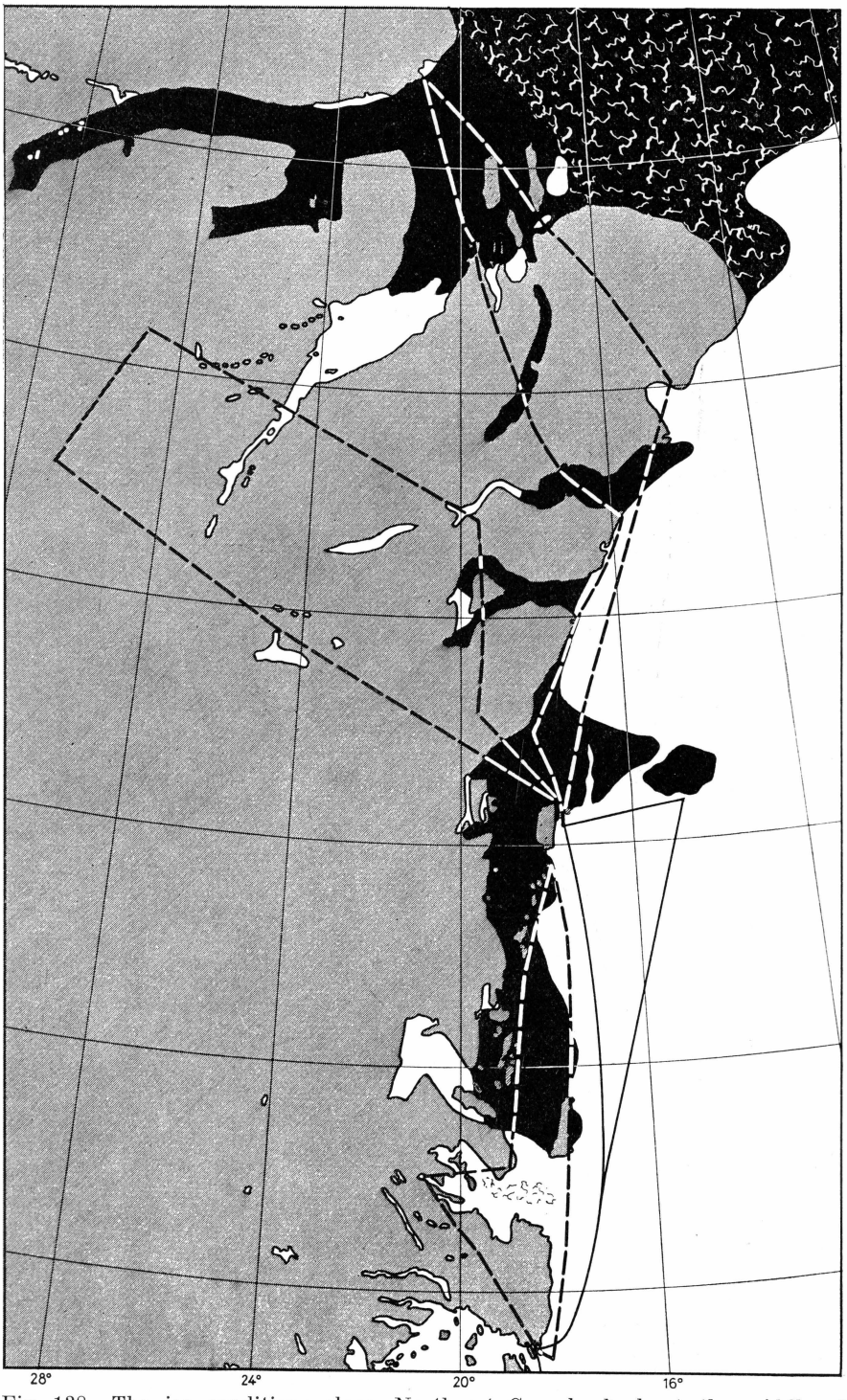

Fig. 138. The ice conditions along Northeast Greenland about the middle of August 1933. Full line = ship's routes, broken lines = air routes. Black areas = fjord ice (in the N.E. pack ice), white areas = open water.

Chapter II gives a description of the ice conditions near the coast of East Greenland. A brief summary of the contents of this chapter will be given below.

Open water is found in the interior of the East Greenland fjords from about July 1st to about October 1st. Since the climate is very stable here in the summer, seaplanes may navigate the inner ramifications of the fjords during this period, especially the waters around Ella Ø. In the southern fjords there may be calf ice and icebergs, while in the northern fjords strong foehn winds may give some trouble.

Up to about July 1st the land ice found in the mouths of the fjords may mean a serious obstacle to the entrance of ships into the fjords. This ice does not melt in the place in which it is formed, but will drift out at some time between July 1st and September 1st. The time for this drift depends, no doubt, on many factors, e. g. the temperature during the autumn and winter, the amount of precipitation, and the strength of the gales blowing in the winter; however, without generalising too much we may say that the land ice shows a tendency to disappear early if the ice belt off East Greenland in the spring is broad, while it will persist long if the ice belt is narrow in the early summer, when in May—June the clouds of the Atlantic may spread over the coasts and prevent radiation from the sun.

A very interesting phenomenon is the occurrence of areas of open water along the east coast of Greenland; such areas are sometimes found even in the winter in the following places:

1) From a little south of Nordostrundingen, where a narrow belt of land water extends, culminating in width off Mallemukfjældet, and disappearing a short distance south of this mountain. The causes giving rise to this land water are, no doubt, as follows: strong northwesterly winds, the fact that the ice stream south of Nordostrundingen bends eastward away from the shore, and the presence of eddies, the ice stream issuing a branch towards the shore and another northward past Mallemukfjældet.

The presence of bird cliffs—the northernmost bird cliffs in Greenland—near Mallemukfjældet and of the former fairly considerable Eskimo habitations north of this place seems to be associated with this area of almost permanently open water.

2) Off the southern part of Koldewey Ø. Sometimes the open water extends almost as far as Île de France. It has not been observed in the winter, but will often form in the early spring and persist till late in the autumn. It is, no doubt, solely due to the presence of eddies, the Polar Current issuing a branch towards the waterway between Shannon and Koldewey Ø, which bends northward along the west side of Koldewey Ø.

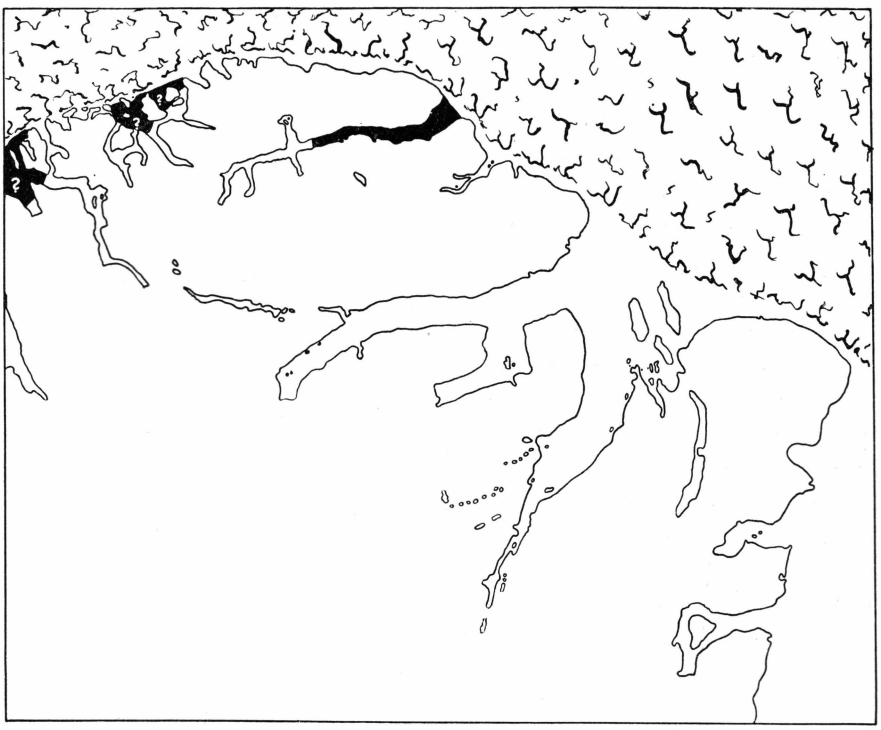

Fig. 139. Northeast Greenland. Black areas indicate the distribution of the sikussak ice in May 1938.

3) Along the stretch from Bass Rock to Jackson Ø (sometimes also off Shannon), where the coast-line runs in a southwesterly direction. Eddies are not reported from this place, but the strong northerly gales in winter blow away from the shore, in the lee of which a broad belt of open water is found throughout the winter and spring.

A number of former Eskimo settlements between Shannon and the southern part of Clavering Ø are situated along or near this area of open water.

4) In the mouth of Scoresby Sund, where open water of varying extension occurs throughout the year, no doubt owing to tide water currents which move into and out of this large fjord complex, and to a considerable flow of fresh water out of the fjord.

The present and a fairly large former Eskimo settlement as well as the large bird cliffs situated on either side of the area are no doubt associated with the open water.

As will be seen, these areas of open water, which, of course, are covered by drift ice for shorter or longer periods, are due to various causes. Not rarely, especially in calm weather in the month of July, a more or less broad belt of open water will form along the coast north-

ward from Scoresby Sund. The formation of this land water, of such great importance to navigation, is principally due to the strong heating of the air over the ice-free coast-land and a considerable flow of thaw-water out of the fjords.

As soon as the land ice has disappeared, the drift ice will often be carried by the wind and currents into the East Greenland fjords; it seems to be a common phenomenon that a current moves inward along the north coast, while another current moves out of the fjord along the south coast. These local currents seem to increase in velocity in the course of the summer, culminating at the beginning of September, to decrease again when the winter sets in. They are, of course, increased by easterly winds, and in years in which such winds are especially prevalent, large ice masses will drift far up the fjords at the height of the summer, causing great trouble to navigation. In Scoresby Sund these in- and outward-moving currents are especially strong, and since, owing to the configuration of the coast near Kap Brewster, the outward-moving current will be forced northeastward towards the main current along Liverpool Land, a peninsula of drift ice, which extends far seawards, will not rarely form off Kap Brewster; north of this ice tongue a deep bay in the ice edge will extend towards the mouth of the fjord. In extreme cases large eddies will form south of Scoresby Sund.

As along the west side of the East Greenland Ice, alternating currents and eddies occur along its east side, also.

A rather permanent vortex, probably with vertical movements of the water, occurs near 75° N. lat., where the so-called Nord-bukta, previously of such great importance for the seal hunting, is sometimes formed, most frequently in June.

The Irminger Current flows as a permanent warm current west of Iceland, reducing the East Greenland Ice to about half its width between Northwest Iceland and Angmagssalik, where the thin floes will melt and the large thick floes of North Pole Ice will be crushed to pieces.

The average quantity of ice found in April—August between Spitsbergen and southern Greenland in the period 1898—1938 was 1,202,700 sq. km. The largest quantity was found in 1918 (1,445,600 sq. km), the smallest in 1933 (906,800 sq. km). The ice does not drift regularly from the Polar Basin into the Atlantic, but arrives in the form of pulsations. As a rule the ice masses passing between Northeast Greenland and Spitsbergen in September will appear off Scoresby Sund in October and off Angmagssalik, where about half of the period September—October is free of ice, in November.

Observations from these two places show, however, that the time for the arrival of the ice varies somewhat, and that the ice drift is often

irregular till late in January, large areas of open water forming between the individual pulsations even in this month. During the winter the ice drift will gradually become more regular, but pulsations may occur at any time of the year. As a rule the largest quantity of ice passes between Iceland and Greenland in April—May.

An attempt has been made to compute, though on a very scanty material derived from the sea between Northeast Greenland and Spitsbergen, the time and amount of the summer pulsations. These pulsations are most frequent in May—June, but may sometimes take place later in the summer also. As a rule they are rather small; fairly considerable summer pulsations are only recorded from the end of the period (1934 and 1938).

Some caution is required if we are to distinguish between North Pole Ice and Siberian Ice in the ice belt between 70° and 75° N. lat. in the summer, except under extreme conditions. As a rule both types of ice are present, at times the boundary between them is sharp (e. g. in 1931), at other times it is more indistinct. In some years the North Pole Ice is dominant (1934, 1937, 1938), in other years the Siberian Ice will predominate (1930).

One of the two types of ice may dominate in the winter also. The heaviest ice year in the present century, 1918, provides a fine example of a winter pulsation lasting from November 1917 till the beginning of May 1918, when the pack ice consisted almost exclusively of North Pole Ice. In the previous year (1917), the next-heaviest ice year in this century, the ice consisted almost exclusively of Siberian Ice, which enclosed Spitsbergen and Bear Island till late in the summer, but it was thin and melted north of Iceland.

A far more complicated and no doubt very rare development took place after the summer of 1936, which was exceptionally poor in ice. Large ice masses consisting exclusively of North Pole Ice drifted southward almost without interruption from December 1936 to July 1939 (i. e. for 32 months), and this period was succeeded by a summer with very small quantities of ice. At the same time eastern Siberia experienced the two summers poorest in ice known so far. It was during this outflow from the Polar Basin that the four Russians under PAPANIN drifted from the North Pole to near Scoresby Sund, viz. from May 1937 to February 1938. We can safely say that in no other period within the present century could this drift have taken place so rapidly.

No corrections have been made in the ice charts copied from the year books of the Danish Meteorological Institute. In some years, notably the most recent years, the ice belt is shown too broad, and in many cases ice is indicated from the shore out to a thin narrow belt of ice, inside

which there was practically open water. In the present work I have therefore introduced the term "disappearing" for an ice belt which has practically melted and will disappear entirely if a light easterly wind sets in; it would have been practical if this term had been employed in the recent summers, which have mostly been very poor in ice.

Observations made during a voyage through the ice belt off the east coast of Greenland will give no general impression of the character of the ice belt; for the ship may enter the ice masses of a pulsation, or it may perhaps enter the ice belt in the interval between two pulsations. Observations from the air give more reliable information about the ice belt.

Of special importance are observations made from permanent stations on land all the year round. The most important information about the ice quantity has been supplied from Iceland, Angmagssalik, and Scoresbysund. It goes without saying that the information supplied by the Icelandic stations is especially important when the ice belt is broad, but if the ice belt is narrow, the observations made from Angmagssalik and Scoresbysund will be of greater interest. However, one should be cautious in drawing conclusions as to the causes of abnormal ice conditions on the basis of these observations, for the causes are to be found in the practically unknown Polar Basin.

It is desirable that in the future ice charts based on the observations made at the Icelandic stations should be worked up for every month. The observations from Angmagssalik and Scoresbysund would be more valuable if the observer would draw a sketch of the ice conditions as seen from each locality once a month. The establishment of observation stations along the coast north of Scoresby Sund would likewise be of value, though it would be difficult to find suitable places for observations of the ice in winter. Thus the conditions around Sabine Ø are too locally marked, while Bass Rock, Shannon, Danmarks Havn, and the regions south of Nordostrundingen are so low that it is impossible to gain a sufficiently wide view of the ice; but it might, at any rate, be observed when the first ice arrives in the autumn. (In heavy ice years the ice drift off these places will probably be nearly permanent).

Chapters III—V deal with the variations in the occurrence of the ice in historic times. Such copious information on the ice conditions in earlier times is available, especially from Iceland and Southwest Greenland, that it is possible to trace the fluctuations in the quantities of ice from year to year for more than a hundred years. For the years 1877—1939 it was even possible to prepare ice charts for every single month.

In two papers (1884 and 1916—17) THORODDSEN has represented graphically the number of weeks with ice near the Icelandic coasts and has given estimated values for the quantity of ice. The last-mentioned paper contains a graph showing the occurrence of the ice as far back as 1780 (re-drawn in Pl. 1 of the present paper).

On the basis of ice observations made since 1899 is it possible to give a graphic representation of the occurrence of the ice off Angmagssalik, and the same can be done for Scoresbysund on the basis of ice observations made since 1924. SPEERSCHNEIDER (1931) has gathered the available information about the occurrence of the ice in West Greenland as far back as 1820. By means of rather intricate methods he draws a curve which shows the quantities of drift ice present in Southwest Greenland from and including that year.

In order to obtain a basis for comparing the ice observations made from Iceland with those from Southwest Greenland I had to treat the observation material according to partially new methods. THORODDSEN's diagram was extended so as to cover the whole period 1820—1939. To gain an idea of the ice quantities it was investigated how large parts (more accurately, how many tenths) of the coast of Iceland were in contact with the ice at the time of its maximum extension. The figure arrived at was multiplied by the number of weeks with ice (the product method). In addition a diagram was prepared on the basis of the width of the ice belt near Iceland (the A-B-C method), which yielded similar results to that of the product method. From each of these two series of numbers, average values were calculated for each decade, which were plotted against time in a diagram. SPEERSCHNEIDER's figures (1931) from Southwest Greenland were likewise represented in a curve with a point for each decade, for comparison. An investigation of the ice conditions in Julianehaab Bugt in August showed similar figures to those arrived at by SPEERSCHNEIDER's intricate method.

The three Icelandic and the two Greenlandic curves (cf. Fig. 104) present great similarities, though the Greenlandic curves are smoother than the Icelandic. The curves indicate considerable fluctuations in the quantities of ice near Iceland and Southwest Greenland in the last 119 years, which are, no doubt, principally due to fluctuations in the climate of the Polar Basin. The fluctuations in the ice quantities have, of course, set their mark on the climate in both places. Particularly remarkable is a short period (1840—54) during which the quantities of ice were small. After a culmination about the year 1880 the quantity of ice gradually decreased, being remarkably small in the period 1920—39.

It appears distinctly from THORODDSEN's description of the occurrence of the drift ice near Iceland during the past centuries that the ice

increased considerably in quantity about the year 1600; it was alreday pointed out by EYTHORSSON (1926) that the data gathered by THORODDSEN were to be interpreted in this way. To ascertain whether this view, held by EYTHORSSON and myself, was correct, I decided to attempt to give a graphic representation of the quantities of drift ice on the basis of THORODDSEN's description. This work was carried out in co-operation with Mr. G. GUDJONSSON, and the result is shown in Fig. 118.

A careful examination showed that the Icelandic literature did not contain a single unmistakable proof that heavy ice masses occurred near Iceland prior to the year 1200, while many reports on heavy ice years are available from the 13th and, to a less extent, from the 14th century. The quantity of ice seems to have decreased somewhat in the 15th and 16th centuries, but no unmistakable evidence is supplied by the Icelandic literature as regards the time before 1550. The available information about the latter half of the 16th century and the following three centuries is so copious that we can say that about the year 1600 a period poor in ice was succeeded by a period with large quantities of ice near Iceland. Accordingly we may speak of three cold centuries (1600—1900).

Just as this paper was to be sent to the press, a new paper by S. THORARINSSON appeared, in which, among other subjects, he treats the growing of cereals in Iceland in historic times. He thinks there is sufficient evidence for assuming that in ancient times, prior to the year 1200, cereals were grown all over the country. From about 1200 to about 1600 the growing of cereals was limited to the southwestern part of the country and after 1600 it ceased altogether, and was not resumed till about 1920, with great success, at any rate in southwestern Iceland. The history of cereal-growing strikingly confirms the fluctuations in the climate which GUDJONSSON and the present author think it possible to deduce from the ice reports in the Icelandic literature.

It has been claimed (EDV. BULL) that a deterioration of the climate about the year 1300 was a concurrent cause of the breaking of the power of the Icelandic people after the Viking time. However, according to the most recent investigations this change of the climate was in no way so far-reaching as that of the three cold centuries (1600—1900).

As the fluctuations in the quantities of ice which have been determined on the basis of the Icelandic literature must be regarded with reservation, it is natural to ask whether the available information about the activities of the Norsemen in Southwest Greenland, comprising the Viking time and the 15th century, might not invalidate or confirm the picture outlined above.

About the voyages of the Norsemen before the year 1200 FINNUR JÓNSSON, the eminent authority on this subject, said in 1913 (translated

from the Danish: ". . . they travelled about as though there were no ice at all". On the basis of the excavations at Herjolfsnes POUL NØRLUND demonstrated that this place was the principal Norse harbour during the nearly 500 years in which Norsemen lived in Greenland. It is true that the "King's Mirror", written about the middle of the 13th century, says that ships should not approach Southeast Greenland too early. This has been considered, notably by FRIDTJOF NANSEN, as a decisive proof of the prevalence of just as heavy ice conditions during the whole Norse time as at the end of the 19th century. An investigation of the ice conditions around Iceland at the time the "King's Mirror" was written shows that a deterioration of the ice conditions had taken place shortly before. Thus the description in the "King's Mirror" is marked by the contemporary conditions; in the next century whence IVAR BAARDSON's description is at hand, the ice conditions were somewhat better, which seems to appear from his description.

To sum up: Exceptionally small ice quantities probably occurred in Southwest Greenland prior to the year 1200. In the 12th and 14th centuries a deterioration of the ice conditions took place, just as in Iceland, but Herjolfsnes could still be used as a harbour.

About the 15th and 16th centuries we know that

1) right up to the extinction of the Norsemen in Greenland (at the beginning of the 16th century) European ships called at Herjolfsnes, and
2) at the time of, or immediately after, the burials which took place in the church-yard at Herjolfsnes shortly before 1500, the climate must have been fairly mild, the coffins being interwoven with plant roots.

Scattered reports on European ships which have called at Southwest Greenland about the middle of the 16th century can hardly be taken as evidence against the occurrence of large ice masses near Southwest Greenland, but they are in good accord with the general picture of a warm climate prevailing in the 15th and 16th centuries.

Thus it seems that the Norsemen were troubled by the deterioration of the climate in the 13th century (cf. the "King's Mirror"); however, before the extermination of the Norsemen an amelioration of the climate set in, so the Norsemen did not die out owing to a fall in the temperature, but more probably on account of a failing communication with Europe and the advance of the Eskimos from the north.

Turning now to the Eskimos, we shall see that archaeological excavations of Eskimo house ruins, too, have something to tell us about this question.

Prior to the year 1200 we find, in addition to the two culture centres Iceland and Southwest Greenland, a third culture, the Thule Culture, along Smith Sound, which was a kayak culture in rapid development. As is well known, the Eskimo culture in these regions has during the last few centuries been based on hunting from the ice; to develop here, the ancient kayak culture required a climate different from that which prevailed near Smith Sound during the last century.

Gradually this culture passed into the so-called Inugsuk Culture, partly owing to an immigration from the west. After a short standstill in the 13th century, during which Melville Bugt was probably difficult to pass, the culture spread southward by a migration which became fatal to the Norsemen. The migrating tribes proceeded past Kap Farvel and up the east coast, and in the course of a very short time spread practically to the whole of the east coast of Greenland; at its culmination about the year 1500, this culture dominated the whole coast of Greenland from Kap Alexander in the west almost as far as Nordostrundingen in the east.

Archaeology tells us that about the year 1600, or simultaneously with the greatest deterioration of the climate in historic times, the whole of this uniform Eskimo culture was divided into a number of tribes owing to an interruption in the communication between the Eskimos, especially in those places along the coast in which bad ice conditions made travelling troublesome. However, as late as the beginning of the 17th century there were still five, possibly six, Eskimo tribes in Greenland, but after the three cold centuries they had been reduced to three, viz. the Kap York Eskimos, the West Greenlanders, and the Angmagssalik Eskimos.

While, thus, the first cold period (c. 1200—1400) presented no serious obstacles either to the Norsemen or to the Eskimos, the second cold period (c. 1600—1900) was a catastrophe to the Eskimos; the present population must be regarded as relicts of the representatives of a large uniform Eskimo culture which was distributed all over West and East Greenland about the year 1500.

The curves in Figs. 117 and 118 show that the quantity of ice near Iceland in the three cold centuries (1600—1900) varied considerably, periods with much ice having alternated with periods with little ice. If the quantity of ice is taken as evidence of the mean temperature, it would seem (cf. Fig. 118) that the cold as well as the mild periods have grown constantly colder during this time until the beginning of the present century, when an exceptionally mild period set in.

The curves representing 20-year-means show that four mild intervals occurred from 1600 to 1900, viz.

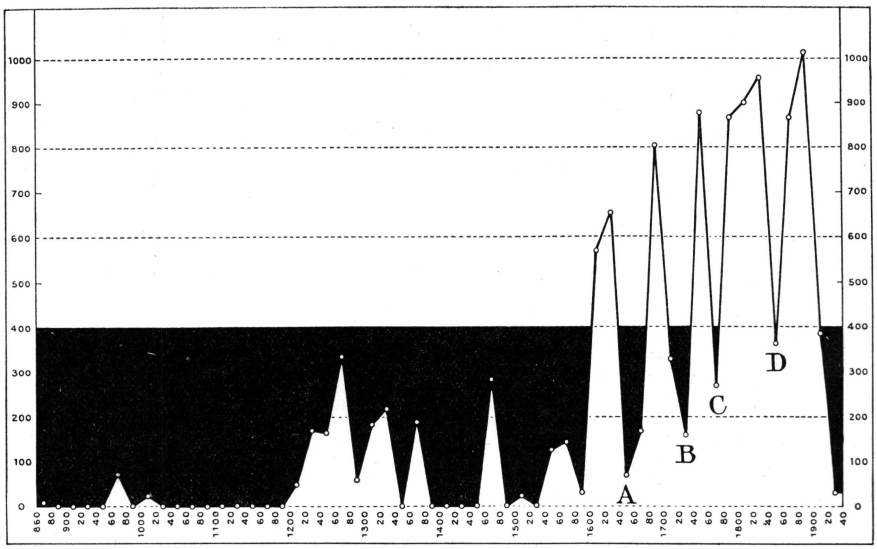

Fig. 140. Copy of the curve in Fig. 118 (p. 259). Black areas indicate the periods in which codfish have been able to multiply along the southwest coast of Greenland (cf. pp, 350—353).

A) 1640—1680, culminating 1640—60,
B) 1700—1740, culminating 1700—20,
C) 1760—1780, and
D) 1840—1860.

It will be interesting to see whether indications of these fluctuations are recorded from Southwest Greenland (see Fig. 118 and Fig. 140).

As to A).—In Eskimo middens near Sukkertoppen bones of large specimens of codfish have been found (*Gadus callarias* L.) in house ruins, which can be stated to date back to the latter half of the 17th century (the settlement Utorqait, cf. DEGERBØL 1936, p. 133).

As to B).—Various information is at hand, of which the following should be mentioned (SPEERSCHNEIDER 1931, p. 48):

"1747. The notes of Jens Olsen Walløe say that an old Greenlandwoman remembers that Jacobshavn-Icefiord has been navigable a good bit in.

1751. It is told that the ice leaves Julianehaab-Bay about the end of July or in the beginning of August and usually reappears about the end of November.

Note: This seems earlier than nowadays."

Furthermose H. RINK (1857, II, p. 221) states that in the days of EGEDE American ships are reported to have carried on cod-fishery on the banks near Davis Strait. Finally DEGERBØL (1936, p. 133) states that large bones of codfish (*Gadus callarias* L.) have been found in Eskimo middens in the Sukkertoppen district, which settlement dates back to the first half of the 18th century, and that codfish bones have been found in Eskimo settlements in the Julianehaab district which date back to the 18th century (Op. cit. p. 132).

As to C).—No information is available from Southwest Greenland.

As to D).—RINK (1857, I, pp. 140—142 and II, pp. 221—226) as well as AD. S. JENSEN and PAUL HANSEN (1930, pp. 7—8) supply detailed information about large cod-fisheries in Southwest Greenland in the period 1845—51, carried on near the coast, by Greenlanders and Danes, as well as on the banks, chiefly by British ships.

The two last-mentioned authors say (Op. cit. p. 7) that two periods with an abundance of codfish near Greenland are reported from the last century; as to the first period their statement is based on data supplied by Dr. H. RINK (1852, pp. 23—43, 1857, II, pp. 223—226). However, this statement is rather vague; it runs as follows: "According to the reports of old people to RINK, codfish has been present in immense numbers in the Julianehaab district and has spread as far northward as Disko Bugt; but later codfish did not appear for a great number of years." (Translated from the Danish). According to RINK (1852, p. 29) the codfish appeared in the years 1819—21; however, the reports on the ice conditions available from these years do not indicate a favourable ice period. RINK says (1857, II, p. 123) that the year of 1817 was the heaviest ice year in the Davis Strait about which information is at hand. SPEERSCHNEIDER (1931, pp. 10—11) supplies various information about the ice conditions in the period 1817—1822. Thus he says that in 1817 Godthaab Fjord was partly filled with "Storis" from August 16th to September 7th. In 1818 Disko Bugt was filled with ice in June. The information about 1819 is not very clear, but the quantities of ice seem by no means to have been small. In 1820, he says, the ice extended as far as Frederikshaab, while in 1821 the ice reached Godthaab in July, the quantities of ice being larger "than what now is considered the normal, at least its extension was far more northerly".

As shown by the curves, large ice masses occurred near Iceland in this period. It would seem that codfish appeared along the coasts of Greenland in one or two years—it is impossible to say which—and since the codfish is always present not very far from Southwest Greenland, it would seem that it may appear there for a short period even if there is much ice. Probably, however, the codfish will require a mild,

not too short period with little ice if it is to breed near Southwest Greenland.

If we assume that the codfish is only present in large numbers near Southwest Greenland if ice is found near Iceland during less than ten weeks in the course of twenty years, Fig. 140 will give an idea of the periods in historic times in which codfish have been plentiful in Southwest Greenland (cf. also Fig. 118). The codfish has only been absent from Southwest Greenland during shorter or longer periods within the three cold centuries 1600—1900.

It is deplorable that hardly any post-glacial investigations, such as are so familiar to Scandinavian geologists, have been made in Greenland. In 1906 P. Harder and Ad. S. Jensen (1910) observed glacial beds overlain by marine beds containing a fauna corresponding to that which lived in the place about the year 1900. These beds were overlain by beds containing a high-arctic fauna. The overlying beds bore evidence of a constantly warmer climate, and about 10 metres above sea-level the beds contained a fauna which must have lived in a much milder climate than that which then prevailed in the place. Unfortunately these investigations have not been continued.

The circumstance that the present amelioration of the climate is of an entirely different order of magnitude on Spitsbergen and for instance in southern Scandinavia, and that some glaciers near Vatnajökull, in contrast to the Scandinavian glaciers, have had their greatest extension since the Ice Age within the last 250 years, warns us to be very cautious about a synchronisation of Arctic and Scandinavian conditions. It is obvious that there is no parallelism between the temperature variations from year to year in Scandinavia and Greenland; and it is an open question whether such parallelism exists between fluctuations of a somewhat longer duration, say between 10 and 100 years. The conclusions arrived at by means of geological investigations, i. a. concerning the question whether the climate of the Viking time was better than the present climate, are not definite enough to yield a solid basis for comparisons either vertically (concerning climatic changes in a certain place) or horizontally (concerning synchronic features observed in different places).

The temperature fluctuations ascertained in historic times do not amount to very many degrees, but in regions in which the possibilities for existence approach the limit, small changes in the climate are so significant that they have been, and still are, of the greatest importance to plants, animals, and human beings.

The result of this investigation may be summarised in the following facts:

In the period 800—1200 there was hardly any ice in the summer near Iceland and the southern half of Greenland.

In the period 1200—1400 there was somewhat more ice in the summer near Iceland and the southern half of Greenland.

In the period 1400—1600 the ice decreased in quantity in the summer near Iceland and the southern half of Greenland.

In the period 1600—1900 there were exceptionally large quantities of ice in the summer near Iceland and the southern half of Greenland.

In the period 1920—1939 there was hardly any ice.

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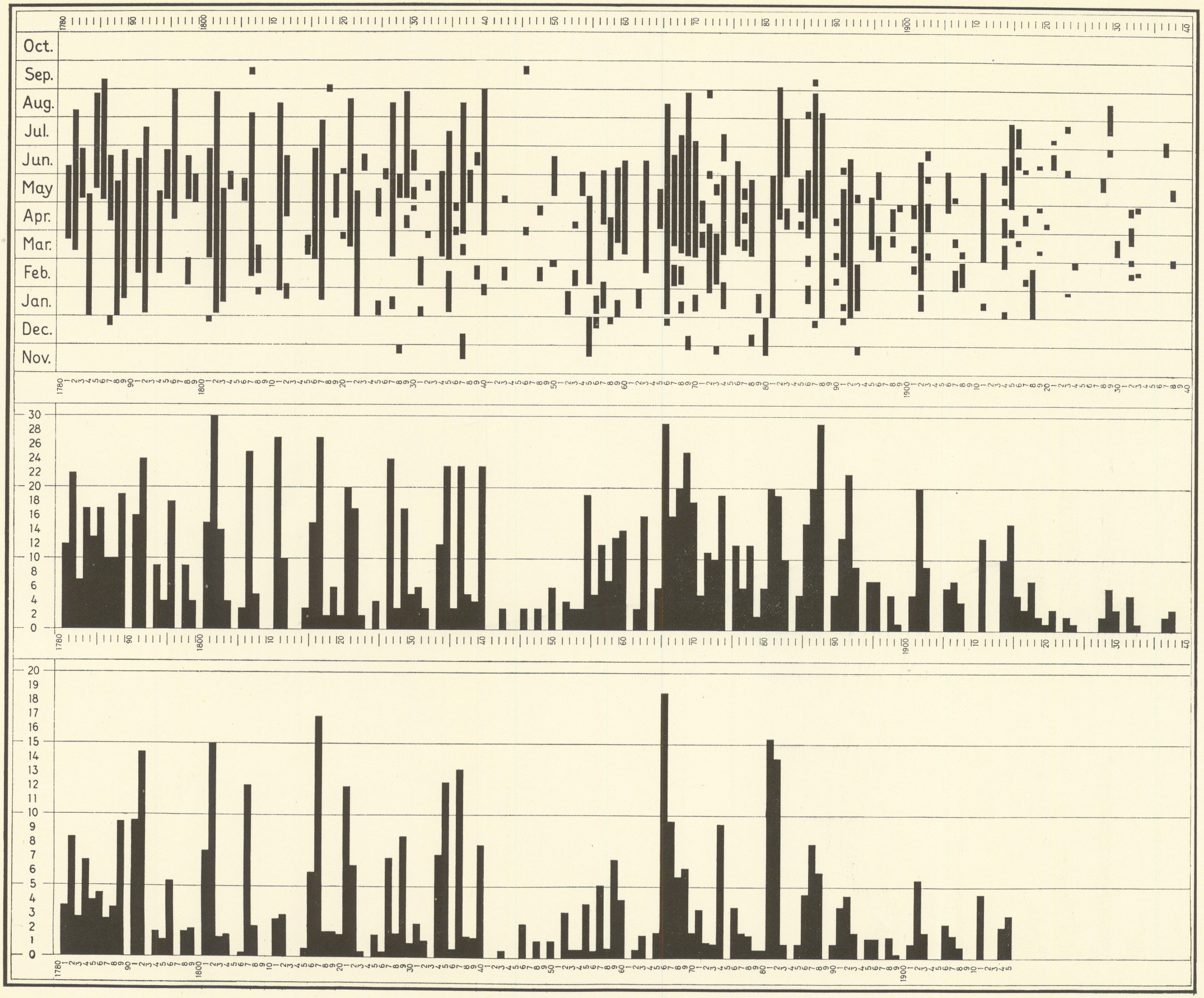
ERRATA

P. 138, lines 8—9 from above: "in Danmarks Fjord and" to be deleted.
- 152, line 1 from above (table): for "Aar" read "year".
- 245, - 9 - below: for "on a sketch-map" read "in a graph".
- - - 8 - - : - "map" read "graph".
- 271, text to Fig. 119: for "1893" read "1903".
- 279, line 10 from below: } for "1267" read "1266".
- 282, - 3 - above: }

Færdig fra Trykkeriet den 23. April 1945.



For explanation of the plate, see the text on p. 245.