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THE GENERAL LIMNOLOGY OF ARCTIC LAKES AS ILLUSTRATED BY EXAMPLES FROM GREENLAND

BY

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WITH 29 FIGURES AND 13 TABLES IN THE TEXT
AND 1 PLATE

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Abstract

As the views of the limnology of arctic lakes up till now have almost exclusively been based on the observations of a few summer expeditions in Alaska and on the mountains in lower latitudes, the author has found it expedient in connexion with investigations into bottom samples from 16 lakes in North Greenland also to collect the great material of measurements distributed throughout the year which during the years 1954–57 were made by Dr. ULRIK RØEN. These observations of temperature, contents of oxygen, and electric conductivity, etc., together with investigations into the bottom samples show that the deep lakes in Northern Greenland are oligotrophic and very similar to the mountain lakes in Norway. The shallow lakes, on the other hand, show up to 65 per cent eutrophy. The surrounding rocks are also of importance for the biological type of the lakes, lakes in highly calcareous surroundings being just as eutrophic as normal Baltic lakes. The very short active biological period also exerts a strong influence on the chemical as well as the biological cycle of the lakes.

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PREFACE

During the years 1954–57 Dr. Ulrik Røen was scientific leader of the Arctic Station of the University of Copenhagen at Godhavn in North Greenland. Besides his chief task, that of studying freshwater Entomostraca, he also made a number of measurements of the physico-chemical conditions of the lakes and brought home a number of bottom samples from some of them. These bottom samples were handed to me for closer examination. After this had been finished I found it desirable to get an impression of these lakes myself and, as a checking of the indication of the bottom samples regarding the biological types of the lakes, to make measurements of their plankton production by the C^{14} method. In the summer of 1962 I therefore went to Greenland together with Dr. Røen and visited some of the lakes from which he had collected bottom samples. The expenses were covered by a grant from the Danish State Research Foundation and by the Ministry of Greenland granting us a free passage to Godhavn. I am highly indebted to the Research Foundation as well as the Ministry of Greenland for these grants, as, besides what was the main purpose of the passage, they also gave me an opportunity to study a number of other arctic conditions of a more geological and physico-geographical nature, of which an account will be given elsewhere.

I also owe a great debt of gratitude to the Board of Directors of the Arctic Station of the University for permission to use the Station as the basis of our investigations. I am also grateful to the scientific leader of the Station, Mr. Simon Lægaard, M. Sc., and Mr. Harry Christensen, the manager, for all the helpfulness and kindness shown to us during our stay at Godhavn and for kindly putting the ship of the Station at our disposal for our investigations.

First of all, however, I am indebted to Dr. Røen, as his rich experience and intimate knowledge of conditions in Greenland highly contributed to the success of the travels. As Dr. Røen's measurements from 1954–57 have been published in a purely zoological paper and thus will easily be overlooked by workers dealing with the general limnology of the lakes, I have found it necessary to shape this paper as a general limnological account of the arctic lakes. Therefore I am also much obliged to Dr. Røen for his kind permission to use unpublished material collected by him.

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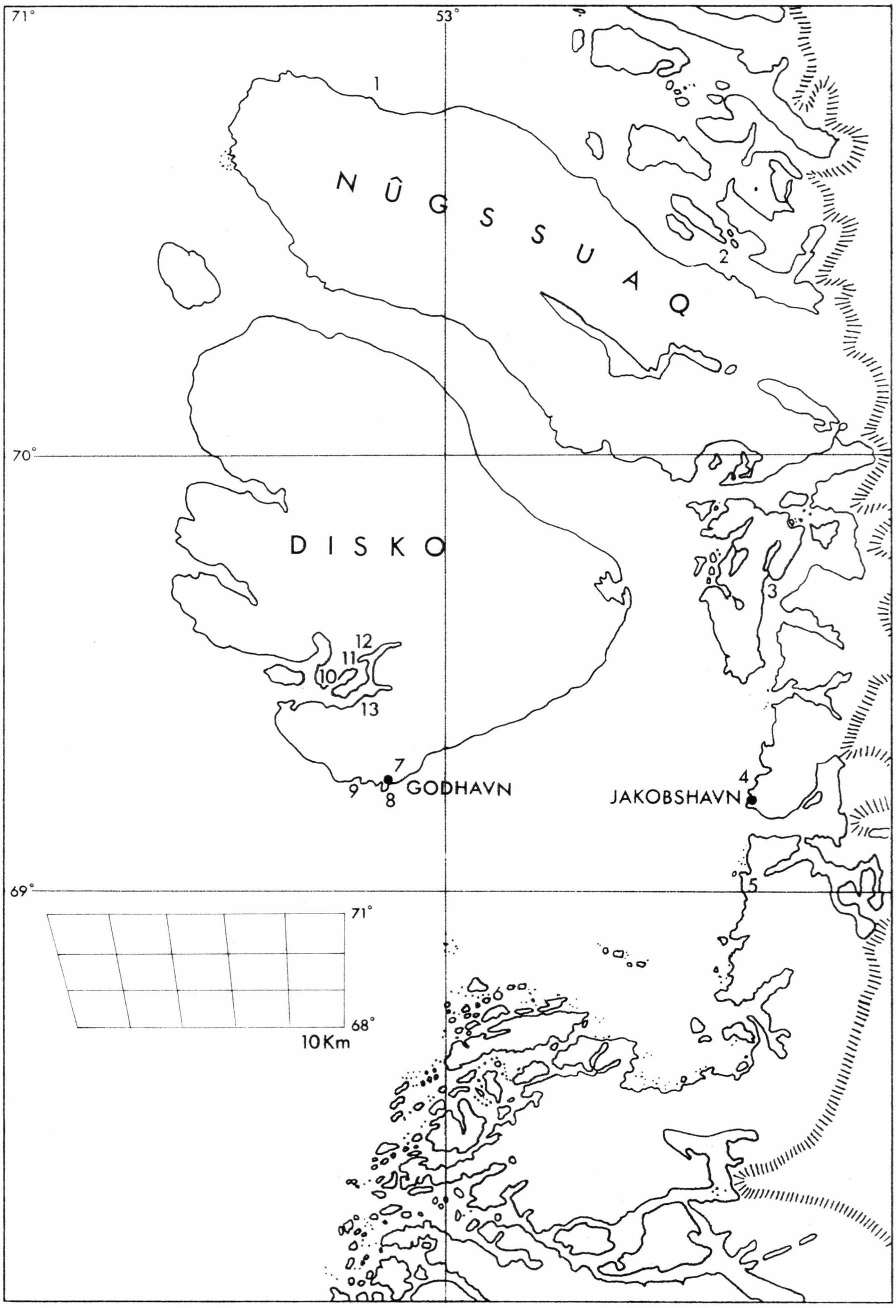

Fig. 1. Map of the Disko Bugt, West-Greenland, with the investigated lakes. 1. Niaqornat, 2. Ikerasak, 3. Taserssuaq, Atâ, 4. Pond at Rodebay, 5. Waterlake at Christianshåb, 6. Waterlake at Egedesminde, 7. The lake in Blæsedalen, 8. Lake "Thygesens Sø" at Godhavn. 9. Lake on Kangârssuk at Fortunebay. 10. Lake Evqitsoq, 11. Lake Lillesø, 12. Lake Mellemsø, 13. Lake at Qivítut.

INTRODUCTION

Limnological investigations in arctic areas mostly suffer under the fact that they have been made during summer expeditions and with only a few measurements in each place. The results appearing in that way therefore will often be more or less accidental, and the accounts in larger handbooks of the limnology of arctic lakes have to a great extent been based on investigations into mountain lakes in lower latitudes. Therefore it is of extremely great value that Dr. ULRIK RØEN during the three years when he stayed as chief of the Arctic Station of the University of Copenhagen at Godhavn made systematic measurements at all seasons, in fact during three years and a half. In this way we have for the first time obtained a real picture of the course of the year in arctic lakes, and the necessary material for a comparison with the lakes in lower latitudes.

It is only a certain number of the many lakes in which RØEN (1962) made measurements which are to be dealt with here, viz. the following:

West Greenland (fig. 1)

On the mainland.

1. The lake at Niaqornat (50)[1].
2. The lake at Ikerasak (55).
3. Taserssuaq, Atâ (58).
4. Pond in Rodebay (65).
5. The waterlake at Christianshåb (103)[2].
6. The waterlake at Egedesminde (107).

On Disko.

7. The lake in Blæsedalen (69).
8. Taserssuaq (Thygesens Sø) at Godhavn (85).
9. Lake on Kangârssuk at Fortunebay (67).
10. Lake Evqitsoq in Disko Fjord (62).
11. Lillesø in Disko Fjord (61).
12. Mellemsø in Disko Fjord (61).
13. The lake at Qivítut, Disko Fjord (64).

[1]) Figures in parenthesis refer to numbers of localities in RØEN (1962).

[2]) Many Greenland settlements have a »waterlake«, the water of which is used as drinking water.

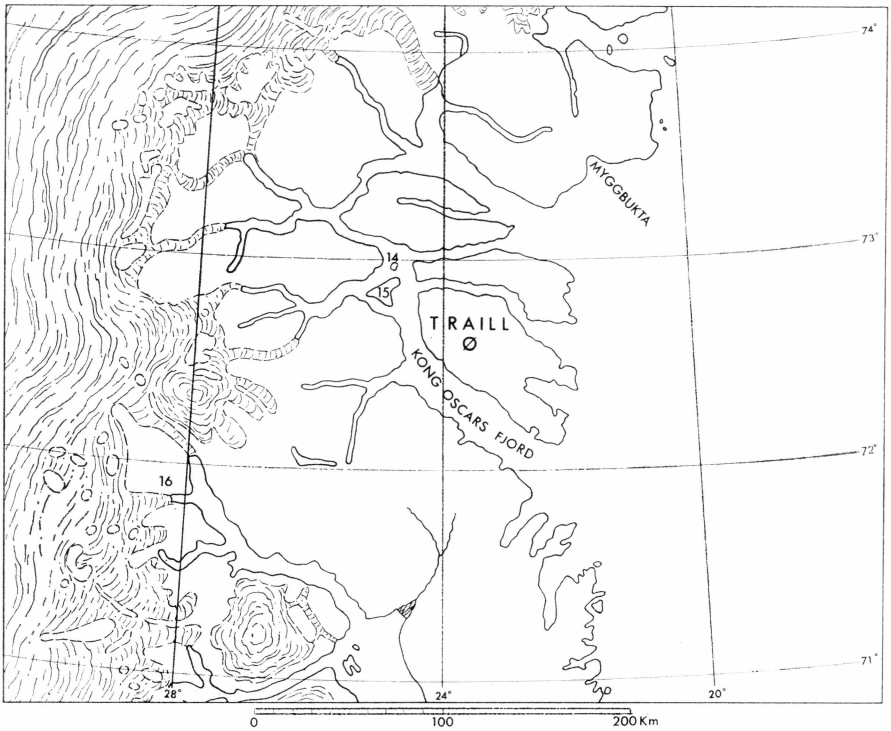

Fig. 2. The lakes investigated in East Greenland. 14. Maria Ø, 15. Ella Ø, 16. Ice-dammed lake in Charcot Land.

East Greenland (fig. 2)

14. Store Sø, Maria Ø (143).
15. Langsø on Ella Ø (148).
16. Ice-dammed lake, Charcot Land (170).

I. DESCRIPTION OF THE LAKES

1. **The lake at the trading station of Niaqornat** on the northwest side of Nûgssuaq.

Røen (1962) states that the lake is situated immediately east of the trading station. Towards the east and the west it is separated from the sea by a beach ridge about 25 m broad and 6 m high. Towards the north and south it is bounded by vertical basalt rocks. The lake is, if anything, triangular with sides 400 m in length. The bottom consists near the beach of black mud with a distinct smell of sulphuretted hydrogen. In the greater part of the lake the depth of the water is $2^1/_2$–3 m and fluctuations in the water level are very small. The influx of water into the lake is partly from melt water and direct precipitation, partly, but to a less extent, from spray from the sea across the beach ridge during gales. There is no outlet from the lake, and there is no vegetation of higher plants in it. It was not visited in 1962.

2. **The lake at Ikerasak** according to Røen (1962) is the same as that described by Vanhöffen (1897) under the name "Pflanzenreicher Teich von Ikerasak". Røen furthermore states that it is situated in the northern part of the trading station in a small valley the bottom of which consists of clay. The lake is circular with a diameter of about 100 m and is surrounded by a fringe of vegetation mainly consisting of *Myriophyllum* and *Batrachium*. Immediately outside the bottom falls steeply down to about 6 m. The whole bottom is covered by mosses, but there is also a little *Myriophyllum* and large amounts of filamentous algae, both sessile on other plants and free-floating in large lumps. The lake has an outlet, which, however, is rarely water-bearing. It was not visited in 1962.

3. **Taserssuaq, Atâ** (fig. 3). Atâ means 'lower part' (of the mountain) and refers to the situation of the trading station on a low isthmus, which cuts off the lake from the Atâ Sound with the high, steep mountains as a background. Although Steenstrup, Hammer, Engel, Laursen, and Porsild have all been there, none of them gives any detailed description of this isthmus. Engel (1910) is of opinion that

Fig. 3. The lake Taserssuaq, Atâ, as seen from the southern end. K. HANSEN phot.

the lake marks a fault running in a northeastern direction, but besides that he only mentions some soundings in the Sound and one in the lake which showed a depth of 100 m.

HOLMQUIST (1959) states that the lake is 8 km long and 1 km broad. RØEN (1962) states that its length is 9 km and the breadth 2.4 km in the broadest place. As measured on the map of the Geodetic Institute, Sheet 69 V. 2, Jakobshavn, 1:250,000, the lake is 8.5 km long and 1.9 km broad in the broadest place.

A rocky isthmus separates the lake from Atâ Sound at the south end of the lake. From this a beach ridge of sand stretches towards the east, through which the outlet of the lake in the course of time has been forced farther and farther east. On the north side of the rock there is a dome-shaped hill of grey clay, in which RØEN found shells of marine mussels. East of this the terrain is covered by vegetation and has many stones on the surface. The outlet from the lake is also full of large stones.

The lake is an old fiord. LAURSEN (1950) has measured a number of shore lines on the west side of the lake and on the rocks facing the Atâ Sound.

LAURSEN found two delta deposits with an outer edge of 60 m above sea level and the top 70 m above sea level. He found clay deposits up to 185 m above sea level and sand a little higher up. Therefore he

Shore lines, Atâ (Laursen, 1950)

At the boat harbour		*At Taserssuaq, Atâ*	
Outer edge m above sea level	Inner edge m above sea level	Outer edge m above sea level	Inner edge m above sea level
5.5	11.0	9.0	10.5
14.5	16.0	14.3	blurred
18.7	21.5	18.8	21.0
25.5	29.0	23.6	25.0
30.5	34.0	30.0	39.0
55.0	58.0	53.5	68.6
		76.0	81.5
105.0	120.0		
160.0	170.0		

places the highest marine beach line at 200 m above sea level, which is in good agreement with his measurements along the coasts of Vajgattet. The uppermost layers of clay are considered to be the earliest ones, corresponding to his Zone A with *Portlandia arctica*, which in his opinion is coeval with the early *Dryas*-clay in Denmark. The two delta cones at a height of 60–70 m in his opinion correspond to the terrace surface with the outer edge at a height of 55 m and to his Horizon D, the later high arctic zone corresponding to the later *Dryas*-clay in Denmark. The terrace with the outer edge at a height of 34 m is referred by him to his Zone F with *Mytilus edulis*, which he supposes to be coeval with the *Dosinia* layers and the *Tapes* deposits in Denmark (Atlantic time).

If Laursen's figures and connections are correct it means that the whole peninsula east of Taserssuaq, Atâ, in the early *Dryas* Period was submerged by the sea with the exception of the two heights, Marrait and Naujat.

Røen (1962) states that the greatest depth of the lake is 135 m and furthermore says that a large creek from the northern end turns towards the northeast. The depth in the creek is about 50 m. It is separated from the rest of the lake by a threshold of 20 m. The shore are here quite flat and pass evenly into large marshy areas.

Holmquist (1959) states that the southern end of the lake forms a basin with depths of 14 m, separated from the rest of the lake by a threshold of 9 m. The surface of the lake is by Røen stated to be 6 m above sea level.

In bottom samples taken at depths of 7–9 m at the south end of the lake Røen found shells of marine mussels, among them *Portlandia arctica*, *Mytilus edulis*, and *Balanus* sp.

The bottom of the lake consists of light grey, very soft ooze.

4. **Pond in Rodebay.** RØEN (1962) states that it is situated in the northwesternmost part of the trading station Rodebay, about 10 m above sea level, but towards the north only separated from it by a beach ridge about 25 m broad and covered with vegetation. The lake is somewhat irregularly oval, the longest axis being east–west and about 100 m long. The breadth is 70 m. The water level is variable so that large parts of the bottom occasionally may be dry. The bottom material is soft and black and smells strongly of sulphuretted hydrogen, but by being dried up changes into light yellow. The surroundings are marshy, with a rich vegetation characterized by a great supply of manure in the form of waste from the houses. HOLMQUIST (1959) is of opinion that sea water may sometimes at high water splash over the beach ridge adding salt water to the lake. On 19.7.1957 the salinity of the water was 7.0 per thousand and on the 20.7.1957 13.5 per thousand. The lake was not visited in 1962.

5. **The waterlake at Christianshåb.** RØEN (1962) states that the lake is situated 75 m above sea level, about 250 m north of the Radio Station. Its shape is very irregular. Its greatest extent is 200 × 100 m. The greatest depth measured was 4 m. The surroundings consist of low gneissic rocks with small vegetation-covered stretches between them. Along the shore of the lake the bottom consists of sand with some stones, and here there is a sparse vegetation of mosses. Farther out the bottom consists of dark mud. In the winter of 1956/57 a pumping station was built, and a boring was made through the bottom of the lake. This consisted of 1.5 m mud, the lower metre of which was mixed with sand. Below that there was 1.5 m pure quartz sand, and under that the firm rock. The lake has several small rather constant tributaries and an outlet to the sea. As water is being pumped up for drinking water for the town, the outlet is only functioning during the spring thaw. The lake was not visited in 1962.

6. **The waterlake at Egedesminde** is situated south of the town in a long valley which towards the east extends into a square basin. The lake is separated from the town by a ridge of gneiss, but the settlement is now also spreading over this. The total length of the lake is 2 km. At the east end the breadth is about 300 m, at the west end about 100 m. The surroundings are gneissic rocks, which slope steeply into the lake. Only at the west end of the basin there is on the south side so much littoral zone that a little vegetation can secure a foothold.

According to RØEN the greatest depth of the lake is 8 m. There are several tributaries from the south side. The outlet is at the west end towards Smallesund. The lake is used as water supply for the town.

For that reason a dam has been built across it a little west of the broad part. The pumping station is situated at the north side of the broad part. The lake was not investigated in 1962.

7. **The lake in Blæsedalen.** As a matter of fact, this term is not quite correct, as the lake is not situated in Blæsedalen, but in front of the mouth of the valley in a depression which towards the north is bounded by the morainic ridge that closes the valley and towards the south by the basalt-breccia plateau which rises as a dome with inclination towards the coast. Curiously enough this lake is hardly mentioned at all in the literature, although RINK, GIESECKE, STEENSTRUP, and PJETURS have passed it on their travels into the valley Blæsedalen. On RINK's map (RINK 1853), indeed, some lakes are marked, but they are situated in the valley of the river Rødeelv and with the direction north–south. PORSILD (1902) is the first to state that at the foot of the moraine, close to Skarvefjeld, there is a small lake surrounded by luxuriant marsh vegetation.

FRODA (1925) mentioned the lake and regretted that it had not been marked on his map of 1898 (FRODE PETERSEN 1898). He stated that, as far as he could see, it had had an outlet at some distance from the Rødeelv. On the map the lake is too small and has an outlet towards the south from the eastern end.

FOGED (1958) states that the lake is situated 80 m above sea level and that it is 300 m long. RØEN (1962) indicates that the length is 500 m and the breadth 150 m. The greatest depth measured is 5 m, and large parts of the bottom are only 3 m below the water level.

The lake now has an outlet towards the west to the Rødeelv, but previously it was considerably larger than it is today (fig. 4), a long inlet, now overgrown, running towards the south from the eastern end. The watershed, however, is situated at so high a level that the lake hardly ever had an outlet that way, as supposed by FRODA. The western end of the lake is being highly overgrown. In summer the inflow to the lake only comes from the mountain Skarvefjeld, on the slopes of which there are a multitude of springs. Towards the end of July 1962 some of these springs had begun to dry up, but the whole terrain and the overgrown part of the lake right up to the watershed was wet and marshy and still had frozen earth at the bottom. In the northeastern corner of the lake there are three rows of ramparts covered with a low willow-scrub (fig. 5). They have been formed by pressure of the ice from the ice-cover of the lake in winter in the same way as known from Danish lakes (K. HANSEN 1949), and they, too, show that the lake previously was larger and at any rate reached the hindmost of these ramparts.

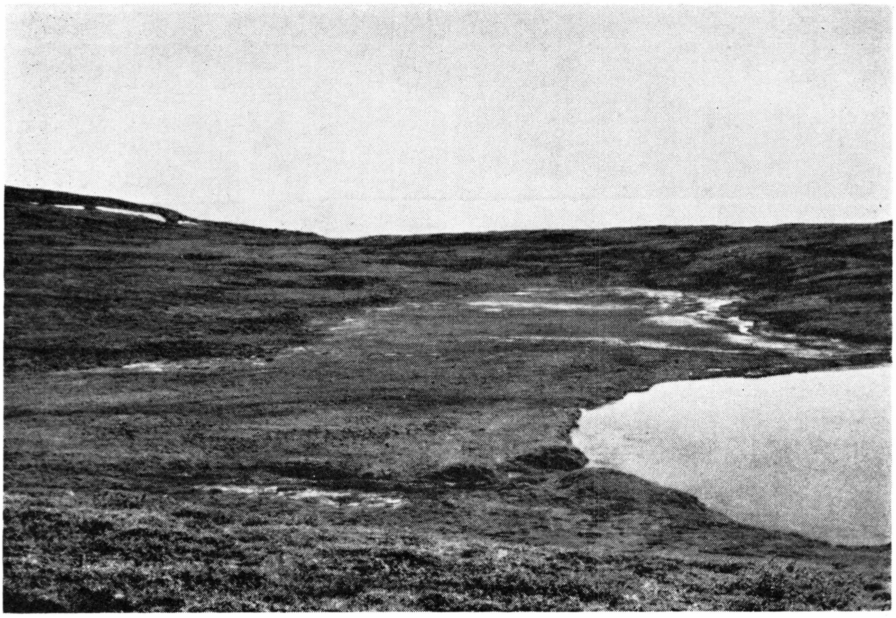

Fig. 4. The eastern end of the lake in Blæsedalen. The now overgrown branch reaches southwards between Skarvefjeld and the basalt-breccia plateau. However, the watershed is situated so high that the lake has no run-off to the south. K. HANSEN phot.

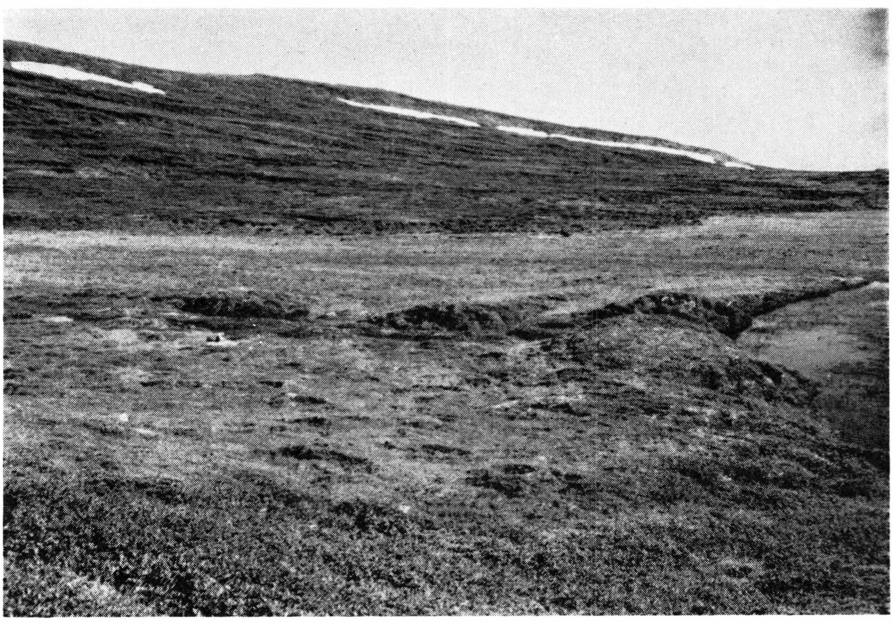

Fig. 5. The three series of ramparts in the northeastern corner of the lake in Blæsedalen which are folded up by the ice cover of the lake. K. HANSEN phot.

Fig. 6. "Thygesens Sø" at Godhavn is now sourrounded by the town. In the background Skarvefjeld and the valley Blæsedalen. K. Hansen phot.

8. **Taserssuaq, "Thygesens Sø" in Godhavn** is situated on a gneissic island which has gradually been connected with Disko by a system of beach ridges, which from the mouth of the river Rødeelv have spread towards the west and now completely closed the east end of the former sound. The gneissic area is intersected by broad low flat valleys running north–south, with a marshy bottom, some of them containing shallow lakes. "Thygesens Sø" is the northernmost and deepest of these lakes. It is situated at 9 m above sea level, is 300 m in length and about 100 m broad, and has a northward outlet. Rink (1853) mentions it and says that drinking water for the town is fetched there except in winter, when it freezes solid so that water must be fetched from the spring Lyngmarkkilden. Bachmann (1921) states that it is 1000 m long, obviously including the whole of the marshy bottom of the valley south of the lake. The maximum depth is stated to be one metre. Furthermore, he remarks that near it there is an Eskimo hut, by which the lake is polluted somewhat. At that time the use of the lake for supplying drinking-water had already been abandoned, for Porsild (1921) states that Godhavn has always had the best drinking-water, which is taken from the large springs, which run summer and winter. In summer the water is taken from the springs in Lyngmarksbugten, in winter the drinking-water is fetched from a spring near the Arctic Station.

Now both sides of the lake are built up, and as there is no sewage, all refuse is thrown on dung-heaps oustide the houses. Indeed, all that can be eaten at all is consumed immediately by the numerous dogs, which in North Greenland function as a kind of scavengers and are seen to come galloping from all quarters of the town whenever they scent that a refuse bin has been emptied, but still numerous tins and other inedible refuse are left.

The lake is 3 m deep (fig. 6). The shores are flat and marshy, with a rich vegetation of *Hippuris* and *Potamogeton.* The water is distinctly yellowish brown, but rather clear. The white disk can be seen right down to the bottom.

9. **The lake on Kangârssuk, Fortunebay.** From Godhavn a narrow fringe of gneissic rocks stretches in front of the basalt mountains along the south of Disko. The westernmost point is the promontory Kangârssuk on the east side of Laksebugt. GIESECKE (1910) in his diary of 1807 wrote that the promontory mainly consists of syenite and hornblende schist. Towards west there is a small lake which contains salmon. In 1812 he wrote that the islands near Kangârssuk consist of fine-flaked hornblende schist overlying fine-grained granite. The headland itself consists of greenstone-like basalt. The whole promontory was sea bottom in the past and is covered with all kinds of blocks from the Archean era. In the middle of it there is a small lake in which there are salmon in summer.

The promontory is about 1300 m in the direction east–west and about 650 m north–south. Across the promontory there is a long, broad depression with two lakes. Between these there is a flat marshy area with peat, and here a pals about 1 m high was observed in 1962. The western lake has an outlet towards the south through a narrow valley. The eastern lake, which was the object of the limnological investigations, has no real outlet, but like so many of the lakes in Greenland only an overflow, i.e. a drain a few decimetres deep and of the same breadth in the southeastern corner.

The south coast of the lake is formed by vertical gneissic rocks, but along the north side there is a slightly sloping, rather narrow plain between the lake and the vertical gneissic rocks. Behind these the high basalt mountains make their appearance. This plain is in some places evenly sloping and covered with vegetation, but in several places there is here a multitude of rolled gneissic blocks. Through crevices in the gneiss numerous small rivulets are seeping into the lake. In several places the vegetation forms tussocks and strange crests (fig. 7), but these crests do not seem to have the double-sided structure characteristic of ice ramparts.

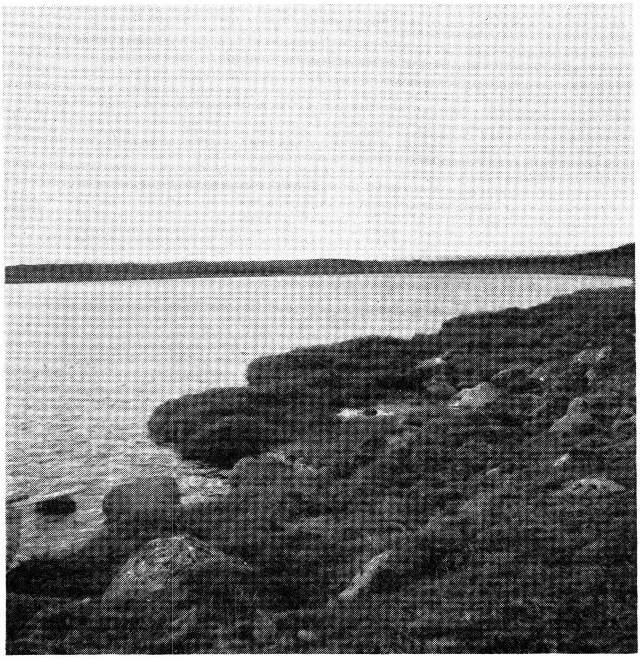

Fig. 7. The northern shore of the lake on Kangârssuk at Fortunebay with tussocks and crests of vegetation. K. Hansen phot.

The lake is just situated completely in the gneissic area and not, as stated by Røen (1962), in basalt. Røen furthermore states that the lake is situated 10 m above sea level, that its length is 800 m and its breadth about 300 m. The greatest depth is indicated to be 7 m, but the greater part of the lake is only 4–4.5 m deep. There is no vegetation in the lake. Near the shore the bottom is stony, but farther out it consists of light mud.

10. **Lake Evqitsoq in Disko Fjord** (fig. 8) is situated on the north side of the middle branch of Disko Fjord, Kangerdluarssuk, running north, about 4 km northeast of the trading station Disko Fjord, on a low promontory consisting of Archean rock. Formerly the trading station Evqitsoq was situated there. The name means 'the one washed clean' because the gneiss there is particularly white and without any vegetation of algae. Towards the basalt mountains the soil is dry and heather-covered, but towards the sea it is more marshy (Porsild 1902).

Porsild furthermore states that at the trading station the soil is so moist that it is only necessary to dig some spits of the mossy vegetation to obtain a hole which, amongst other things, may be used for fetching water. Such water may be quite clear, but its taste is not good.

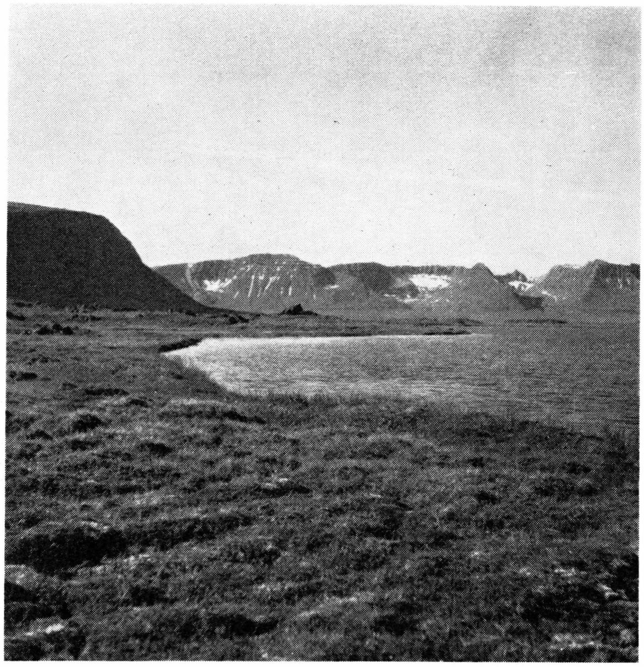

Fig. 8. Evqitsoq. In the background the basalt mountains in Disko Fjord with the many deep glacial cirques and the glaciers on the top.

It is evident that there are dissolved humus substances in it. The trading station still existed in 1921, but later it has been closed down and the buildings moved farther out towards the mouth of the branch of the fjord to the present trading station Disko Fjord. The lake is situated in the middle of the promontory. PORSILD (1902) states the greatest depth to be 7 m. HOLMQUIST (1959) and RØEN (1962), however, maintain that they have been unable to find depths greater than 5.5 m. RØEN indicates the length of the lake to be 400 m and its breadth to be 300 m. Aerial photographs, however, show that the lake is pear-shaped, and that the ratio between the length and the breadth must be a little higher than RØEN's statements. PORSILD (1902) stated that by the shore facing the basalt mountains there is a luxuriant heather vegetation, by the other a bog, which by the side facing the coast passes into a willow scrub 1–$1^1/_2$ m high, which receives the whole outlet from the lake. This is only functioning during the spring thaw and does not form any actual river.

In aerial photographs it is clearly seen that the lake is not completely surrounded by gneissic rocks, but its inmost shore is bounded by talus at the foot of the basalt mountains. In this talus there is a furrow through which melt water from the glaciers on the mountain tops runs into the lake. The bottom of the lake slopes down steeply. RøEN states that the bottom consists of dark mud with numerous chironomid larvae.

From the innermost part of the Kangerdluarssuk a gneissic area stretches to the innermost part of the easternmost branch of Disko Fjord, Kuánerssuit. This gneissic area, which in relation to the surrounding basalt mountains is rather low, is called Eqalúnguit itivnerat, which means 'the crossing to Eqalúnguit, the great place for catching salmon'. PORSILD is the only one who previously has described this area in detail. He writes (PORSILD 1902) that at the end of the fiord in the corner of the root of the Kasorssuak peninsula the boundary between Archean rock and basalt is very sharply defined, as there is here a considerable fault line, which can be followed a good distance inwards. The layers of gneiss are horizontal and form beautifully terraced slabs. The apparently highest top of gneiss is situated at 220 m above sea level. On Eqalúnguit itivnerat there are three lakes, which PORSILD called Lillesø, Mellemsø, and Langesø. Of these only Lillesø and Mellemsø will be discussed here. PORSILD tried to map them, but he states himself that as he had no measuring instrument with him these sketches cannot lay claim to any appreciable accuracy.

11. **Lillesø.** Fig. 9 shows PORSILD's survey. The lake is almost circular, with a diameter of about 300 m. Fig. 10 shows that the shores of the lake almost the whole way round consist of vertical rocks. Only towards the southwest the shore is flat and marshy, and here is

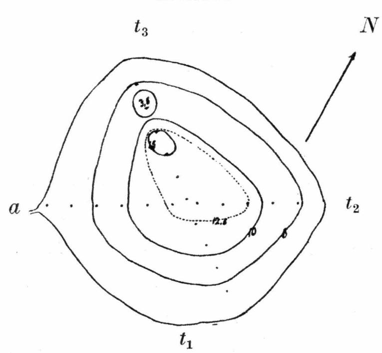

Fig. 9. The map of Lillesø with PORSILD's soundings.

the outlet through a broad, flat valley, which in the last part towards the fiord has a steep fall. During the spring thaw the whole of this valley is undoubtedly a violent stream, but already in the month of July the outlet consists of a narrow ditch, through which the water from

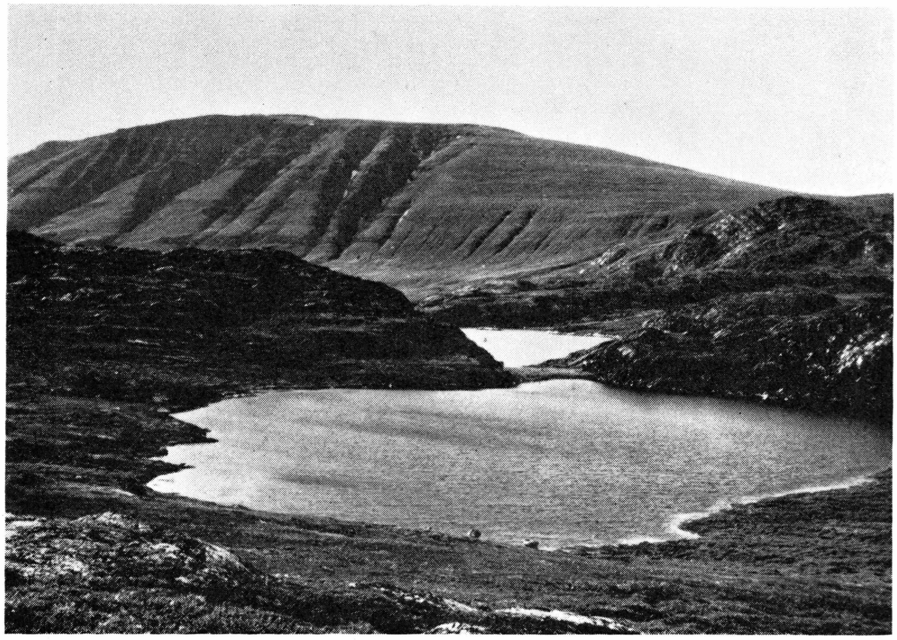

Fig. 10. Lillesø with its outlet to Disko Fjord 24 m below the lake surface. Only in springtime is the outlet filled with water. K. HANSEN phot.

the lake oozes out. PORSILD states that the greatest depth is 15 m, but HOLMQUIST (1959) and RØEN (1962) cannot find any depths greater than 12.5 m. HOLMQUIST states that the bottom seems rather dead with slightly crumbled plant residues, but without a smell of sulphuretted hydrogen. On the other hand there are numerous fish in it (*Gasterosteus*) BACHMANN (1921) and RØEN (1962) state that the lake is situated 24 m above sea level.

12. **Mellemsø.** Fig. 11 shows PORSILD's survey of Mellemsø. This lake is considerably larger than Lillesø. PORSILD (1902) gives the length as 1 km and the breadth as 300 m. In the aerial photographs, however, it can be seen that if the breadth is 300 m the length must approach 1500 m. PORSILD also states that the lake crosses the gneissic area from trap wall to trap wall. This is not correct, for only on the east side does it reach the basalt mountains, the other sides are bounded by gneissic rocks. BACHMANN (1921) states that the lake is situated 35 m above sea level. PORSILD gives its maximum depth as 36 m, RØEN found no depths greater than 26 m and is of opinion that the difference between PORSILD's and his own measurements of depths in Evqitsoq, Lillesø, and Mellemsø is due to the fact that PORSILD took soundings with a

harpoon-line of hide of the bearded seal, which stretches so much that all depth-recordings should be reduced by 26 per cent.

Mellemsø

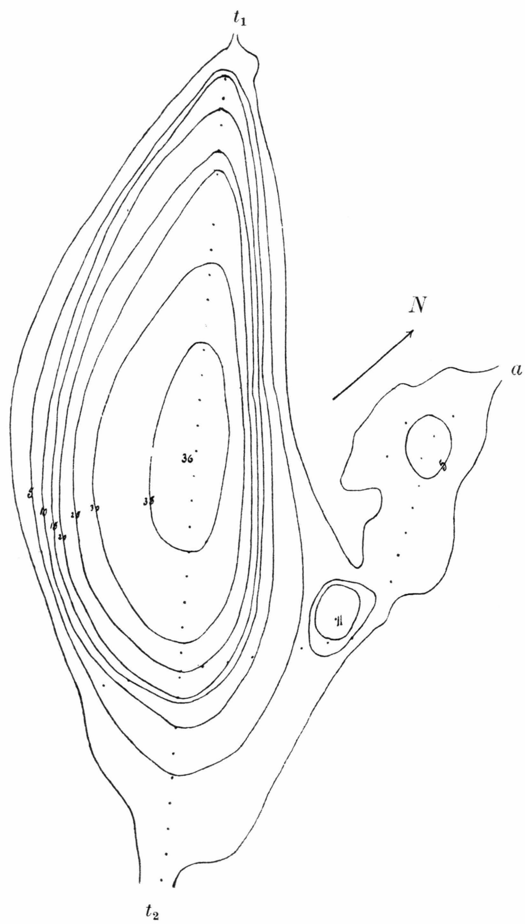

Fig. 11. The map of Mellemsø with Porsild's soundings.

The shore of the lake is everywhere surrounded by rocks except at the eastern end. In several places, however, there is a stony zone before the bottom of the lake falls in terraces to a greater depth (fig. 12).

Porsild (1902) writes that on the rocks, which go steeply into the water, there is no vegetation of higher plants, not even *Fontinalis* or *Limnobium* species, whereas the surface of the rocks is covered by a low but dense coating of stalky colonies of diatoms.

Holmquist (1959) states that the bottom of Mellemsø does not seem to be quite so dead as that of Lillesø. In Mellemsø, too, there are many

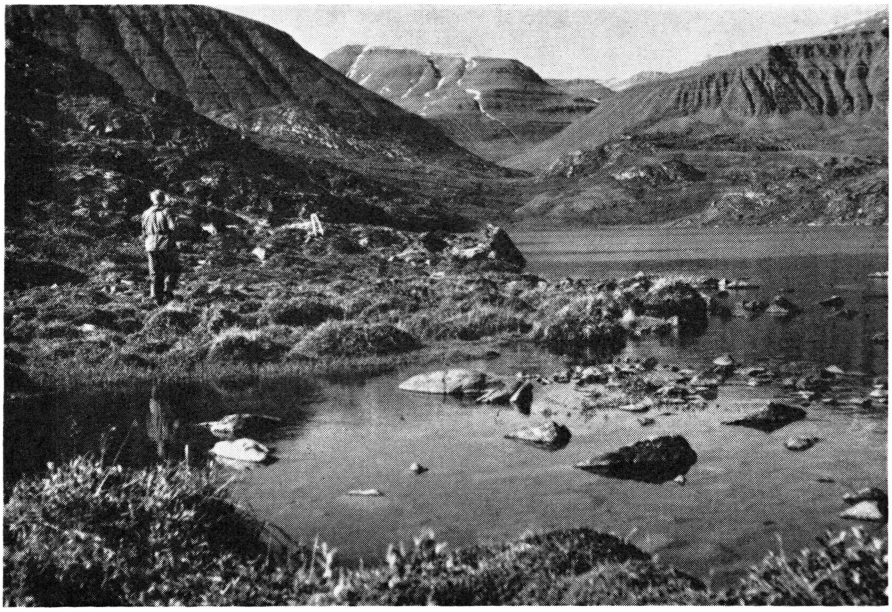

Fig. 12. Mellemsø. K. HANSEN phot.

fish (*Gasterosteus*). No bottom samples were taken in 1962, but the material brought home by RØEN in 1957 was a soft brownish mass.

13. **Qivítut** is situated on a small promontory on the south side of Disko Fjord, a little west of the northern mouth of the valley Blæsedalen. GIESECKE (1910) states that the promontory consists of granite, which south of the promontory is overlaid by basalt, which, again, is overlaid by reddish brown amygdaloid with layers of ferruginous clay. At the top there is columnar basalt.

STEENSTRUP (1901) stated that the gneiss on the small promontories stands out at the foot of the basalt mountains. The peak on these promontories at Qivítut is 83 m. RØEN (1962) gives the length of the lake as 400 m in the direction NW–SE. He gives the breadth as 200 m. The lake is surrounded by marshy terrain with a rich vegetation. The shores are sharply cut off. In shallow water the bottom is clayey or stony and overgrown with mosses. In deeper water there is greyish brown ooze with some chironomid larvae. The greatest depth is stated by RØEN to be 4.5 m. There is no inflow, but a small outlet towards the northwest. The lake was not visited in 1962.

14. **Store Sø, Maria Ø** (fig. 15). The island Maria Ø consists of the Pre-Cambrian Eleonore Bay formation. The lake Store Sø is situated

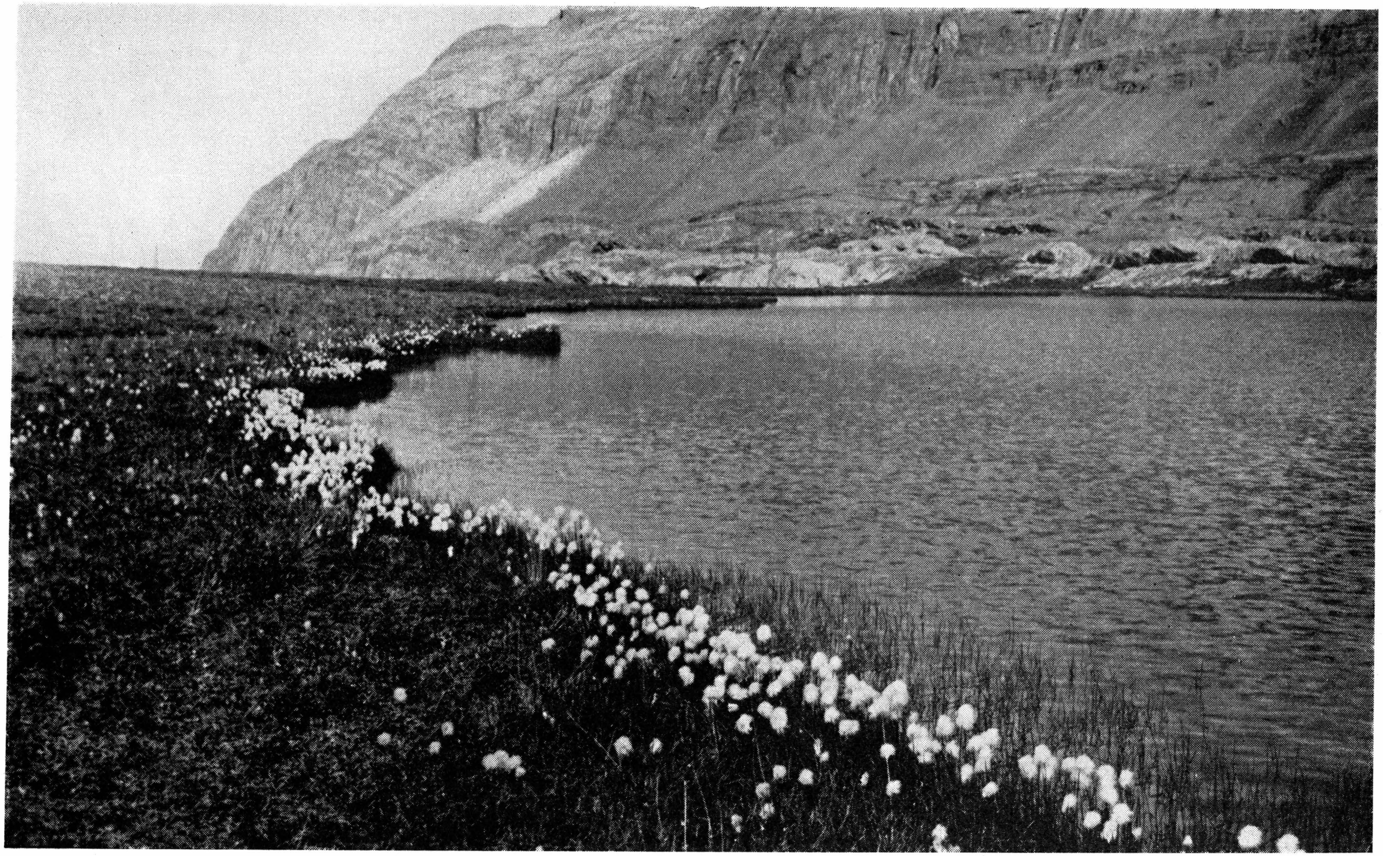

Fig. 13. Langsø on Ella Ø. Eastern end seen from the west. G. Seidenfaden phot. (Søgaard Andersen 1946).

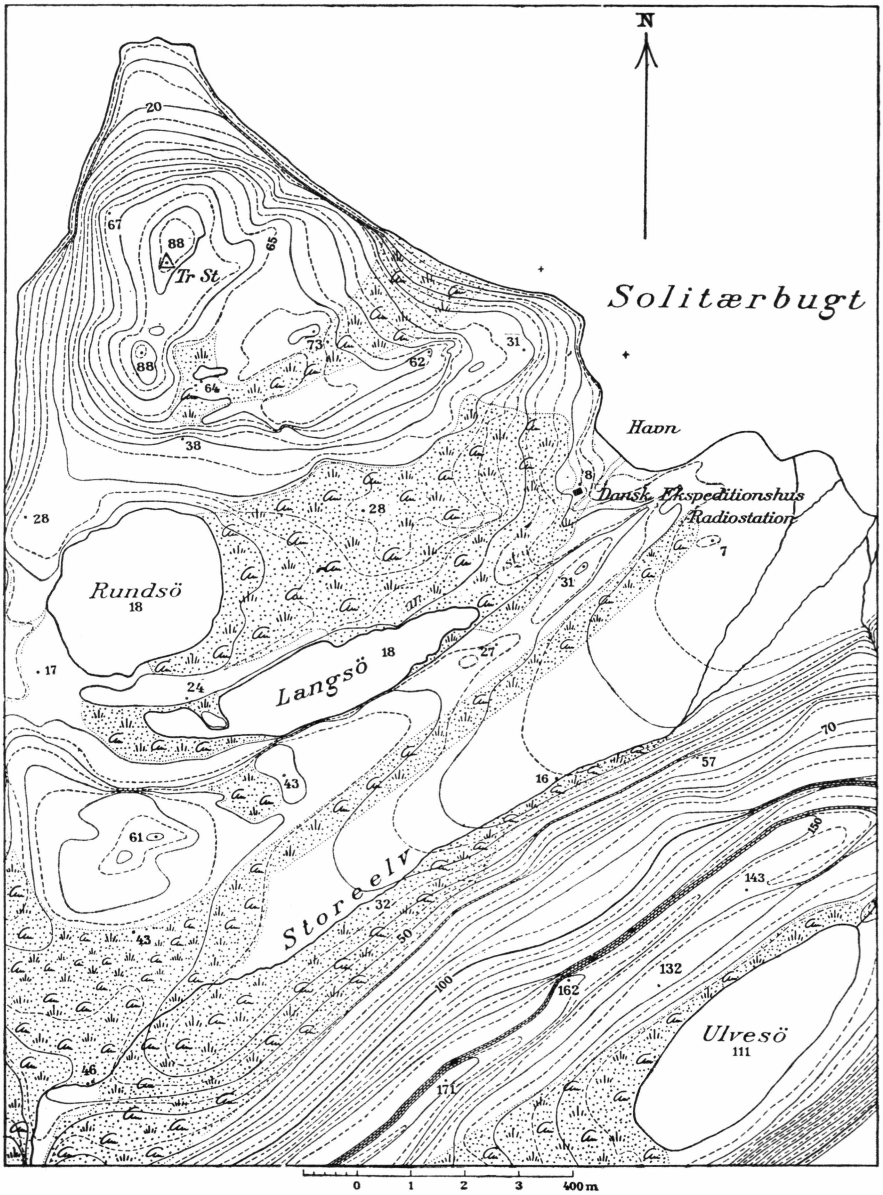

Fig. 14. Kap Oswald on Ella Ø. The figures give the height in metres. The dotted areas are covered with a dense or an almost dense vegetation. After SØGAARD ANDERSEN 1946.

in a broad depression which towards the south is bounded by a steep rock wall with the dolomitic limestone series of the formation, which forms the southern part of the island. The bottom of the depression consists of a quartzite belonging to the variegated series of sandstones

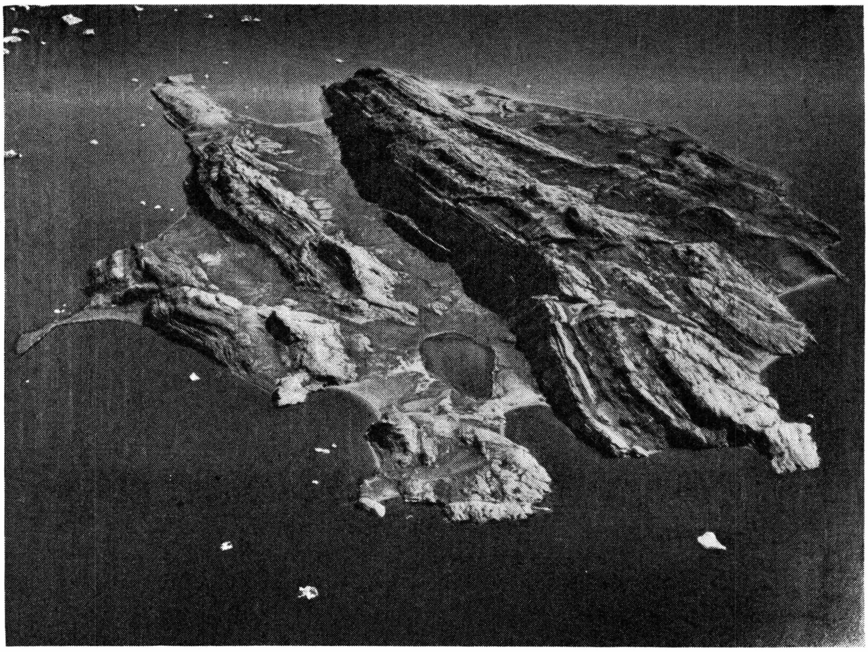

Fig. 15. Maria Ø with Store Sø. Brenneisen phot. (Eha 1953).

and schists of the Eleonore Bay formation. The high wall forming the boundary between the two sections of the formation is due to a fault (Teichert 1933, Eha 1953). Røen visited the lake in 1958 and states (Røen 1962) that it is separated from the sea by a beach ridge of coarse gravel. The lake is 1 km long and 500 m broad. In shallow water the bottom is somewhat stony, farther out there is light grey mud. The water is very clear and the bottom can be seen everywhere in the lake. At the northern end there is a luxuriant vegetation of *Potamogeton filiformis* and *Scorpidium*. There is a growth of *Drepanocladus*. The lake has no outlet proper but an overflow, which functions only during the spring thaw.

15. **Langsø on Ella Ø** (figs. 13 and 14). Langsø has been described by Søgaard Andersen (1946). It is situated on the Kap Oswald peninsula on the northern tip of the island Ella Ø and serves as a reservoir of drinking water for the Danish expedition house there. The surroundings consist of the dolomitic limestone series of the Pre-Cambrian Eleonore Bay formation (Poulsen and Wienberg Rasmussen 1951). The lake is 650 m long and 140 m broad. The area is 5 ha. The greatest depth is 2 m, but more than half of the bottom of the lake is only 1 m below the surface of the water. Røen (1962) remarks that Søgaard

ANDERSEN's measurements must have been made at a particularly low water level in the lake. SØGAARD ANDERSEN furthermore states that both long sides of the lake are formed by naked rocks, but at both ends the shore consists of solifluctional soil with a chamaephyte vegetation here mixed with *Carex* and Gramineae. The lake has no outlet, but an overflow during the spring thaw at the northeastern end. The bottom material varies highly with the depth. SØGAARD ANDERSEN states the following composition of his samples:

Table 1.

Depth in metres	0.1–0.9	1–1.25	1.3–2	Total
Number of samples	22	7	11	40
Limestone concretions	19	3		22
Black and grey gyttja	2	5	10	17
Stones or sand and stones	4	1	..	5
Black gyttja mixed with sand	..	2	1	3
Sand and detritus	2	..	..	2
Peat	1	..	..	1
Potamogeton and *Batrachium*	3	..	..	3
Moss	1	..	..	1

In SØGAARD ANDERSEN's opinion the cause of the absence of the limestone concretions at greater depths than 1 m is that in winter under the ice there are so great quantities of CO_2 in the water that this should dissolve the limestone while the upper part of the bottom of the lake should be protected against this by being frozen up in the ice. As, however, the black gyttja contains 37 per cent of calcium carbonate, this cannot be correct. The cause of the fact that the limestone concretions in Langsø on Ella Ø are found in shallow water only, as in the Danish lakes (Tystrup Sø), is that the algae which form the limestone crusts are not found at greater depths, but sit on stones or the hard bottom near the shore. The ice-cover of the winter will also squeeze limestone concretions and stones against the shore and form more or less pronounced ramparts.

RØEN (1962) states that the bottom consists of light grey mud covered by a layer of algal filaments. The only vegetation is some *Potamogeton filiformis* along the shore.

16. **Ice-dammed lake in Charcot Land.** RØEN (1962) states that this lake is situated in a valley in the southern part of Charcot Land. A small lateral glacier issuing from Daugaard-Jensens Gletscher forms the south side of the lake. The lake is 3 km long and 1.5 km broad.

The water level is not constant. During the nine days from the 1st to the 10th of August 1958 the water level rose by some 1.5 m. The nearest surroundings of the lake are completely without vegetation, with steep gravelly and clayey slopes. The greatest depth of the lake could not be measured, but about 100 m from the edge of the lake a depth of 18 m was measured. The bottom consists of fine sand, clay, and mud, and the water is milky with suspended clay. The transparency was only 25 cm. There was no vegetation in the lake, which has three inlets. There is an outlet under the glacier.

II. HYDROGRAPHY

The climate around Disko Bugt is arctic. Fig. 16 shows the monthly mean temperatures for Jakobshavn for more than 75 years, the highest and lowest values for the mean temperatures of the months and the highest and lowest temperatures measured which have been found during the period. From these figures it appears that the summer on the whole is cold, but that there are very great variations from year to year. In the months of June to August the temperatures may vary from $-5°$ to $+21°$C. No part of the year is quite frostless. June has on an average six frosty days, but the maximum is 20 frostless days. July is practically completely frostless. August has on an average two frosty days, but the maximum is 11 days, and in September the average is 18 days. On the whole the precipitation is scarce, 215 mm for the whole year. July and August are the most rainy months (HELGE PETERSEN 1928).

From Godhavn meteorological observations are available only for a shorter period. Fig. 17 shows the mean temperature, the average monthly maximum and minimum temperatures and the highest and lowest values for these during the period 1925–1935. Furthermore the precipitation during the same period according to HELGE PETERSEN (1951). The mean temperature in summer is not widely different from that of Jakobshavn, but the extremes are considerably smaller. The precipitation is appreciably greater than in Jakobshavn. HELGE PETERSEN does not think that the observation period is sufficiently long for a closer working up of the figures. PORSILD (1921) states that the summer on Disko is a little less warm, the precipitation a little greater and the weather rougher than at Jakobshavn in the inmost part of the bay. Only from the middle of July can real summery weather be taken for granted, during which roughness is an exception of short duration.

In summer a cold north wind is blowing in Baffins Bugt, and then a dense white wall of fog is seen out there, but ashore there is sunshine and calm weather. Sometimes the fog drifts into Disko Bugt, but as a rule no farther than Fortunebay, more rarely it drifts right to Godhavn.

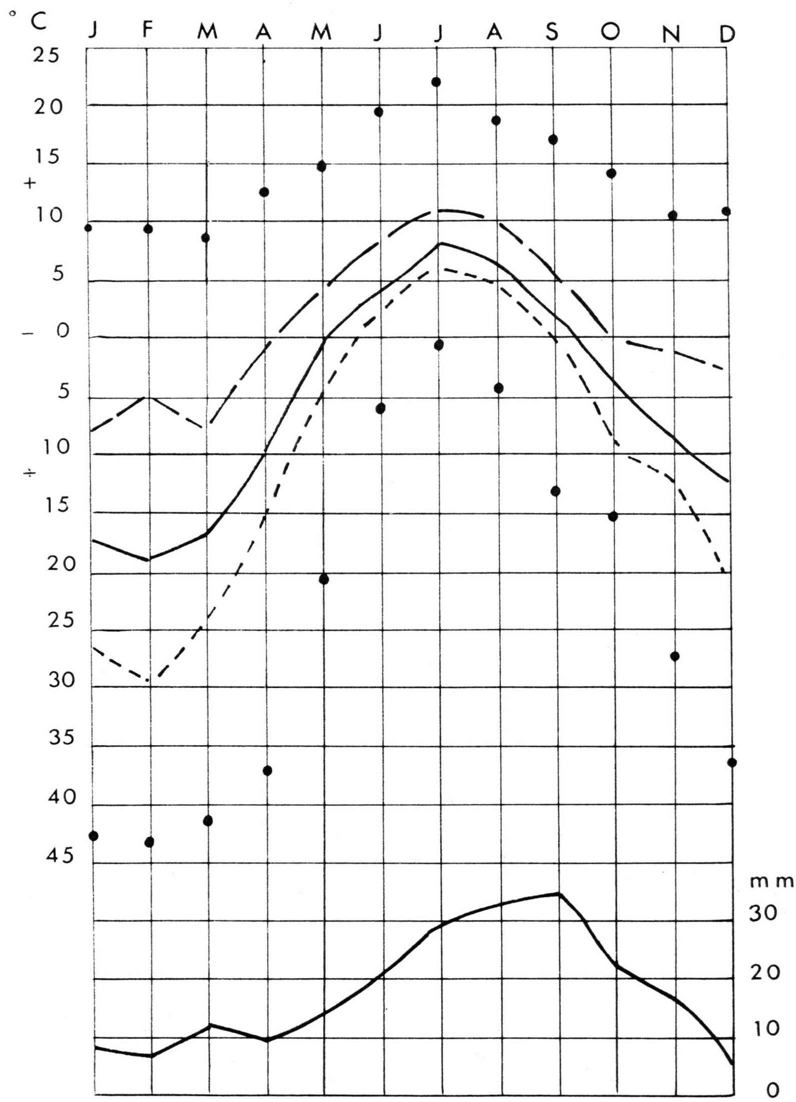

Fig. 16. Above, monthly mean temperatures, highest and lowest monthly mean temperatures and absolute maximum and minimum temperatures. Below, monthly mean precipitation at Jakobshavn (after PETERSEN 1928).

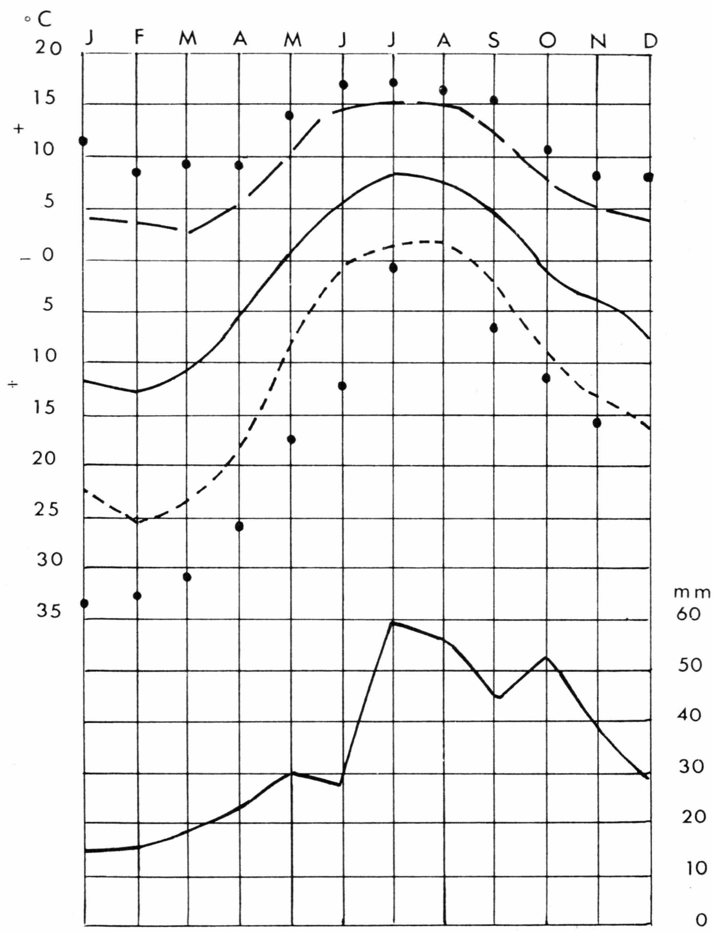

Fig. 17. Above, monthly mean temperatures, highest and lowest monthly mean temperatures and absolute maximum and minimum temperatures at Godhavn in the period 1925–1935. Below, monthly mean precipitation (HELGE PETERSEN 1951).

From East Greenland there are regular observations only from Scoresbysund and from the previous Norwegian weather station in Myggbukta. Figs. 18 and 19 show the monthly mean values of temperature and precipitation for these two stations according to HELGE PETERSEN (1951) and HOVMØLLER (1947). They show that the summers are somewhat colder than at Disko Bugt and that the precipitation is scarce, viz. 317 mm in Scoresbysund and only 78 mm in Myggbukta. At the last station, however, this is due to special local conditions.

On Ella Ø SØRENSEN (1941) measured the following mean values of temperature during the period September 1931 to June 1934 (see Table II).

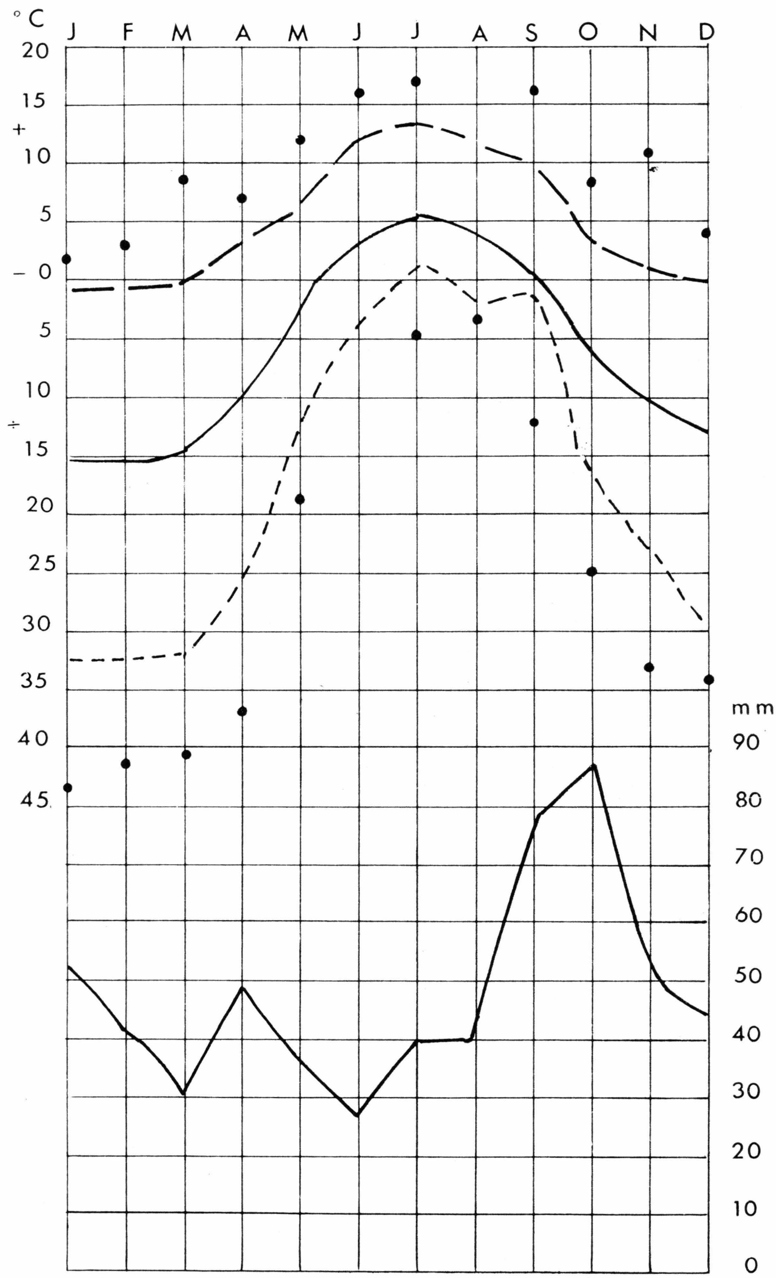

Fig. 18. Above, monthly mean temperatures, highest and lowest monthly mean temperatures and absolute maximum and minimum temperatures at Scoresbysund in the period 1925–1941. Below, monthly mean precipitation (Helge Petersen 1951).

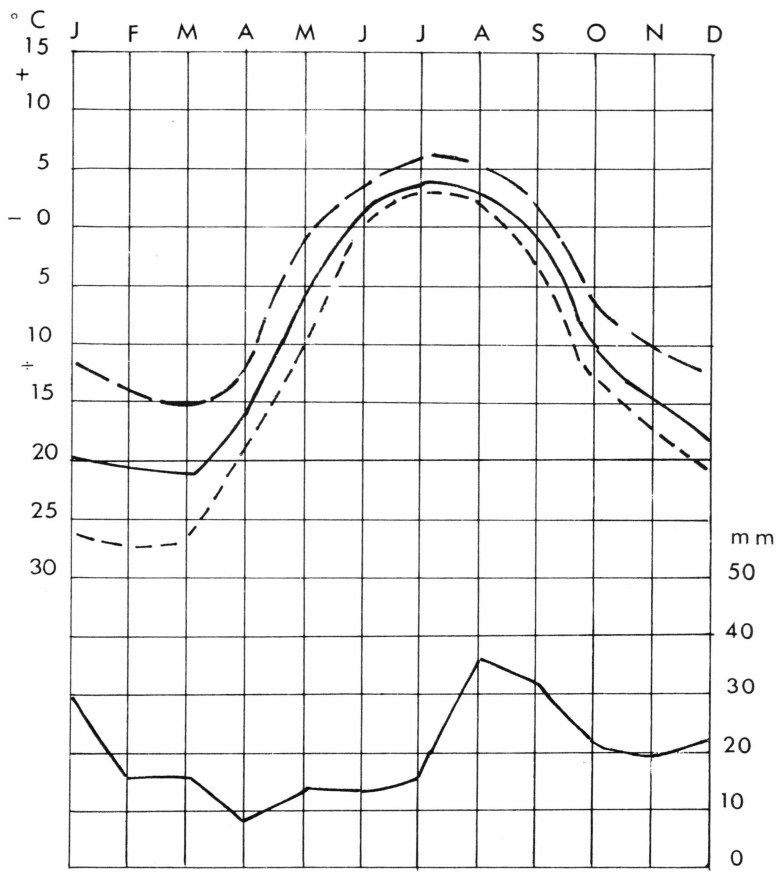

Fig. 19. Above, monthly mean temperatures, mean maximum and minimum temperatures at Myggbukta in the period 1922–1937. Below, monthly mean precipitation (HOVMØLLER 1947).

Table II.

Mean temperatures, Ella Ø (SØRENSEN 1941.)

	1931	1932	1933	1934
January	..	−19.2	−15.9	−23.7
February	..	−12.6	−18.6	−25.0
March	..	−14.2	−17.5	−17.2
April	..	−17.9	−19.2	−11.4
May	..	− 0.8	−10.5	− 4.2
June	..	6.2	3.9	3.0
July	..	9.6	10.2	..
August	..	8.4	9.0	..
September	0.6	(4.0)	3.5	..
October	− 9.8	− 7.9	− 7.0	..
November	−11.1	−18.3	−11.1	..
December	−22.4	−17.2	−12.9	..

A characteristic feature of these northern regions is the scant humidity of the air and hence its great clearness and transparency. Thus, from Godhavn it is possible to see distinctly the country north of Jakobshavn, which is situated at a distance of 108 km and the highest altitude of which is 665 m. SØRENSEN (1941) also emphasizes this as characteristic of the region around Ella Ø in East Greenland and states that this causes that the direct insolation from the sun is greater there than in Denmark in spite of the fact that the sun is considerably lower and its beams fall more obliquely.

The Ice-Cover

It is obvious that the arctic climate must influence the physico-chemical as well as the biological annual cycle of the lakes. One of the most characteristic features of these lakes is that they are frozen up for a great part of the year. Previously there was only sporadic information about that. RØEN's systematic observations through three years therefore are a very valuable supplement to our knowledge of it. RØEN (1962) states that on an average the lakes around Disko Bugt are ice-free for only two and a half months a year. From his rich material we can here as examples adduce his observations from the lakes in Disko Fjord.

The lakes begin to freeze up already in September and the ice then grows in thickness until April or May and they are not ice-free until the end of June. In Ikerasak, which indeed is situated somewhat farther north, there was on 11/5 1957 2.1 m ice and on 9/6 the same year there were large floes in the middle of the lake, and about "Thygesens Sø" in Godhavn RØEN states that on 31/5 1957 more than $^1/_3$ of the lake was ice-covered. On 13/6 1955 and 1957 there were still large floes in the lake in Blæsedalen, and 17/5 1957 there was 1.2 m ice in the water lake of Christianshåb. This means that the active biological period is considerably shorter than the period in Denmark. Investigations through five years made by the Freshwater Biological Laboratory of the University of Copenhagen (K. HANSEN 1965) show that the lakes in Denmark do not freeze up until about late in December, and are again ice-free about the 1st of April. If it is considered that the active biological period in the lakes in Denmark is over towards the end of September, it will in Disko Bugt be only half as long as that in Denmark.

From East Greenland SØGAARD ANDERSEN (1946) states that the ice-cover on Langsø on Ella Ø in 1933 started on the 19th of September and that the lake was completely covered with ice on 25/9. In October the ice was so thick that it would bear. On 1/2 1934 the ice was 1 m thick. Then the thickness grew more slowly until April when the maximum thickness 1.25 m was reached. From then on it became

Table III.

	Evqitsoq m ice	Lillesø m ice	Mellemsø m ice	Qivítut m ice
1955				
21/1	0.8	0.7	0.8	0.8
9/7	Ice-free	Ice-free	Ice-free	Ice-free
22/9	Thin new ice in southern half	Thin new ice in southern part	A little ice between stones close to the shore	New ice in southern part
16/11	0.4	0.4	0.3	0.45
1956				
4/2	1.5	1.6	1.5	1.6
18/4	1.8	1.7	1.8	1.9
6/7	Ice-free	A few quite small floes	Floe in the middle of the lake	Ice-free
19/10	0.2	0.2	0.1	0.25
1957				
4/1	1.05	0.65	0.75	1.1
12/2	1.2	..	..	1.3
2/3	1.5	1.1	1.2	1.6
9/4	1.6	1.3	1.3	1.7
9/6	Thick ice in large parts of the lake, open water only in NW part	Shore thawed, ice pressed against north shore	Ice melted along shores of the lake, otherwise very brittle	Thick ice in large parts of the lake, open water only in NW
20/7	Ice-free	Ice-free	Ice-free	Ice-free

thinner. On the 1st of June it was 1 m thick, on the 10th 0.85 m, and not until the 20th of June 1934 was the lake again ice-free.

It appears from the table that the thickness of the ice increases and decreases fairly uniformly in all the lakes in Disko Fjord, also in the lake at Qivítut, which in contrast to the others is situated at the foot of a north-facing slope of the high basalt mountains, where the sun both in the spring and the autumn is behind these mountains most of the day.

From Alaska HOBBIE (1961) states that the lakes there may be covered with ice as late as the 26th of July.

Optical Conditions

The only determinations of optical conditions in the Greenland lakes are the measurements shown in Table IV, which were made by CHARLOTTE HOLMQUIST in Taserssuaq, Atâ.

Table IV.

Depth m	Light lux 25/7 1956	Light lux 18/7 1957
0	>5000	5000
5	>5000	5000
10	4700	..
15	1500	2300
20	675	1100
25	200	525
30	75	225
35	41	104
40	..	42.5
45	10.3	21
48	6.8	..
50	..	11.7

Both days the sun was shining at the place, but the measurements in 1956 were made before 4 o'clock p.m., while in 1957 they were made at 11 o'clock a.m., when there were a few bright clouds in the sky.

Temperature

From RØEN's many measurements of temperature the annual changes in temperature in the lakes Evqitsoq, Lillesø, Mellemsø, and Taserssuaq, Atâ, are shown as examples in figs. 20, 21, 22, 23, and 24.

In the shallow lakes, which are here represented by lake Evqitsoq there are two full periods of circulation, in which the temperature is 4° C. in the whole water mass. One is in June, immediately after the ice has gone, or perhaps even before it has completely disappeared, the other in September a short time before the lakes freeze over.

Under the ice the temperature on the surface soon falls to 0° C., while the temperature at the bottom keeps at 4° C. as late as the beginning of February, after which that also decreases slowly.

In the summer months something completely corresponding takes place. The surface temperature in the course of July increases quickly.

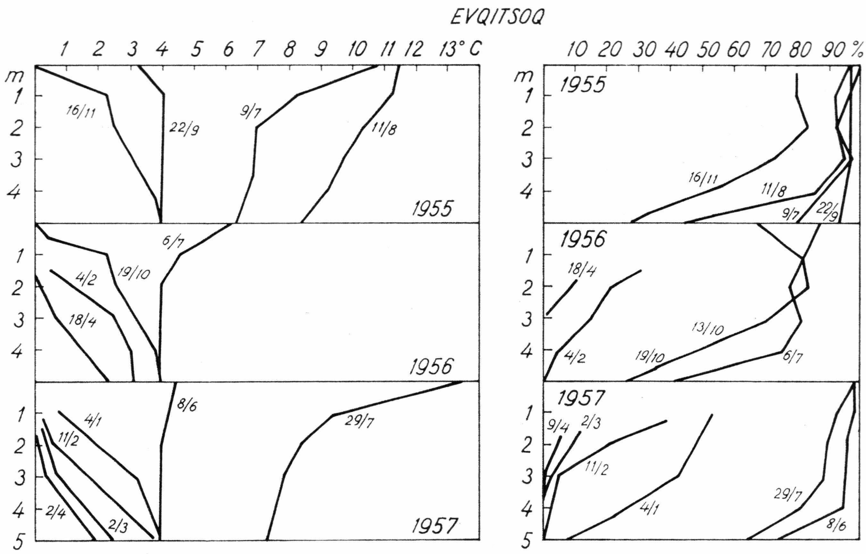

Fig. 20. Temperature and oxygen in Lake Evqitsoq (RØEN 1962).

The maximum value and the time of its appearance may vary from year to year. In Evqitsoq the highest surface temperature measured in 1955 was 11.5°C. on 11/8, but in 1957 13.8°C. was measured on 29/8. In "Thygesens Sø" RØEN measured the highest surface temperature in 1954 12.8°C. on 10/7, in 1955 12°C. on 4/7, in 1956 15.4°C. on 18/7, and in 1957 15.4°C. on 3/8. This is in perfect agreement with what might be expected under the prevailing climatic conditions there, with the above-mentioned great variations of the extremes.

The bottom temperatures, on the other hand, vary much less in the lakes only 3–5 m deep. In Evqitsoq the highest bottom temperature measured was 8.3°C. on 11/8 1955. This is still more evident in "Thygesens Sø" in Godhavn (fig. 24). In this lake, which is only 3 m deep, the difference between the temperatures on the surface and at the bottom in summer is still greater. In 1954 the difference on 27/6 was 7.5°C., and in 1957 7.2°C. on 3/8. In Evqitsoq as well as in "Thygesens Sø" a thermocline is developed in the upper metre of the water mass. In the two deeper lakes, Lillesø and Mellemsø, there are, indeed, two full periods of circulation at the same times as in the shallow lakes. The course of the temperature in winter is much the same as that in the shallow lakes, still, the bottom temperature during the winter only falls to 3°C. In Lillesø in summer a slightly developed thermocline is formed at a depth of 5–8 m and in the still deeper Mellemsø this is still more slightly developed. The surface temperature in these lakes in summer is also somewhat lower than that in the shallow lakes.

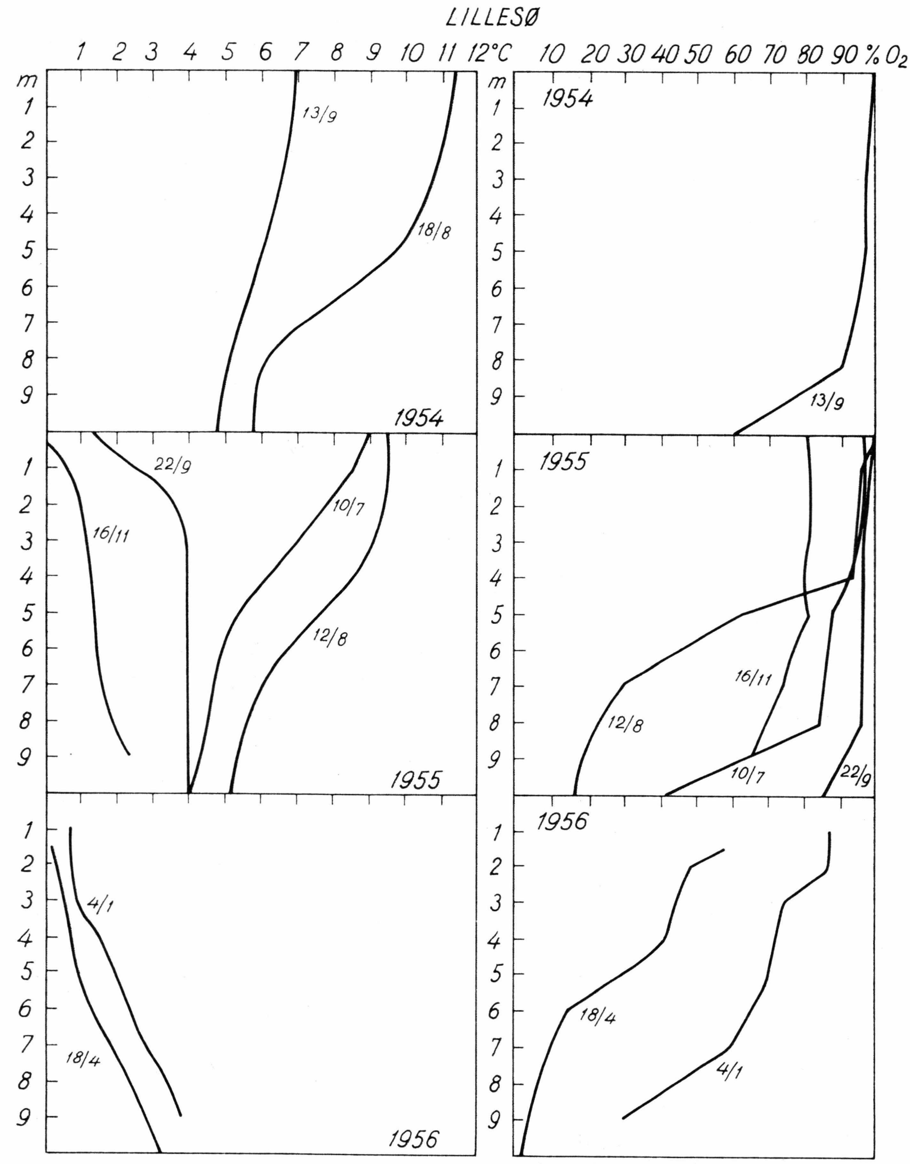

Fig. 21. Temperature and oxygen in Lillesø (Røen 1962).

Turning to the very deep Taserssuaq, Atâ, we see that from a depth of about 20 m the temperature is almost all the year round 4° C., and the surface temperature fluctuates within still narrower boundaries. The highest surface temperature measured by Røen in this lake is 7.5° C. on 18/7 1957.

The Greenland lakes thus are dimictic and should, if anything, be grouped under Yoshimura's term of Subpolar Lakes, but still differ

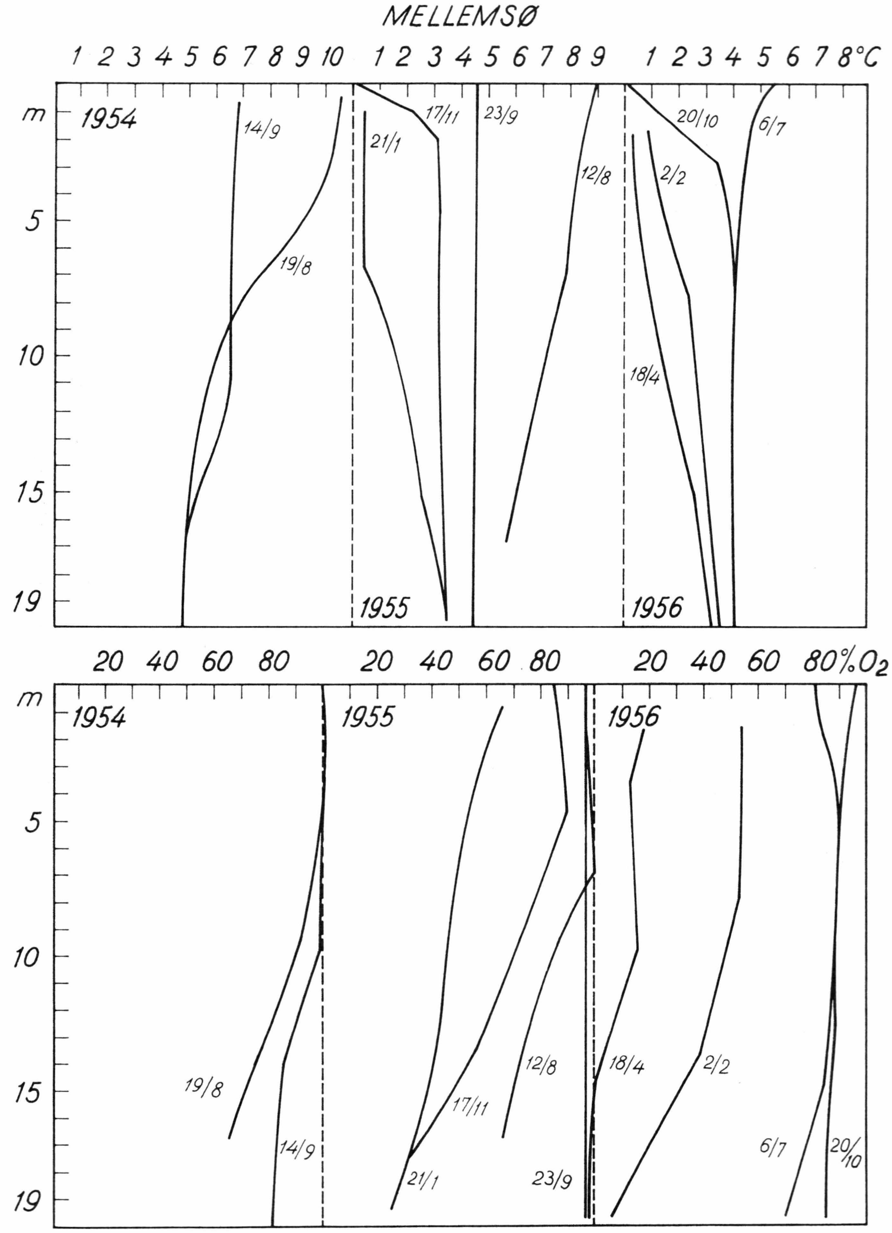

Fig. 22. Temperature and oxygen in Mellemsø (RØEN 1962).

from these by having a considerably greater temperature gradient in summer. Flakevatn in Central Norway (STRØM 1934), which by HUTCHINSON (1957) is adduced as an instance of a subpolar lake has much steeper temperature curves in summer. This may, however, be due to the fact that the temperature was measured as late as the 28th of August and that the surface temperature somewhat earlier in summer was higher.

Røen's measurements through three years were made at considerably shorter intervals than those of Strøm, and in Taserssuaq, Atâ, which, as regards conditions of depth, if anything, must be compared with Flakevatn, the highest summer temperature was measured as early as 18/7. The shallower lakes, on the other hand, have their maximum summer temperature about the middle of August. A much closer thermic agreement is observed between the Greenland lakes and Bessvatn and other lakes in Jotunheim (Strøm 1935) as well as the lakes on Moskenesøy in Lofoten (Strøm 1938), even though these Norwegian lakes are situated at a somewhat more southerly latitude and in a pronouncedly oceanic climate. Hutchinson (1957) states that in many lakes a heating of the water takes place under the ice in winter. Something like that has not been ascertained in the lakes discussed here. Livingstone (1958) maintains that no arctic lakes in Alaska have a summer stratification, but he has made too few measurements for so categoric a statement, and Hobbie (1961) has shown that it is not of general validity.

In the very shallow lakes cold water from the permafrost is seeping into the lakes during the whole summer time, which is probably the reason for the low bottom temperatures in these lakes.

Conditions of Oxygen

Whereas there is a certain agreement between conditions of temperature in all the lakes, the shallow lakes being comparable with the upper 20 m of the deeper lakes, the oxygen curves show distinct differences between the shallow and the deep lakes. Figs. 20–23 show the curves of saturation with oxygen for the same four lakes converted from Røen's statements in ml/l. In Taserssuaq, Atâ, there is during the whole summer a saturation with oxygen of more than 90 per cent in the whole water mass. This is in full agreement with what was previously found in North Norwegian lakes and mountain lakes (Strøm 1933, 1934, 1938). As the lake is covered with ice for about 8 months a year and as the period of circulation in spring is quite short and only goes down to about 20 m, the great content of oxygen in the deeper part of the lake must be due to the sterility of the lake, for as the temperature there all year round is 4° C., no circulation can take place. The greatest extent of the lake is north–south, and the maximum forces of the wind from these points of the compass rarely exceed 5–6 Beaufort in June, July, and August. With winds from other points of the compass the lake is protected by the high mountain crests, and it is too narrow in the direction east–west for any great waves to develop. There

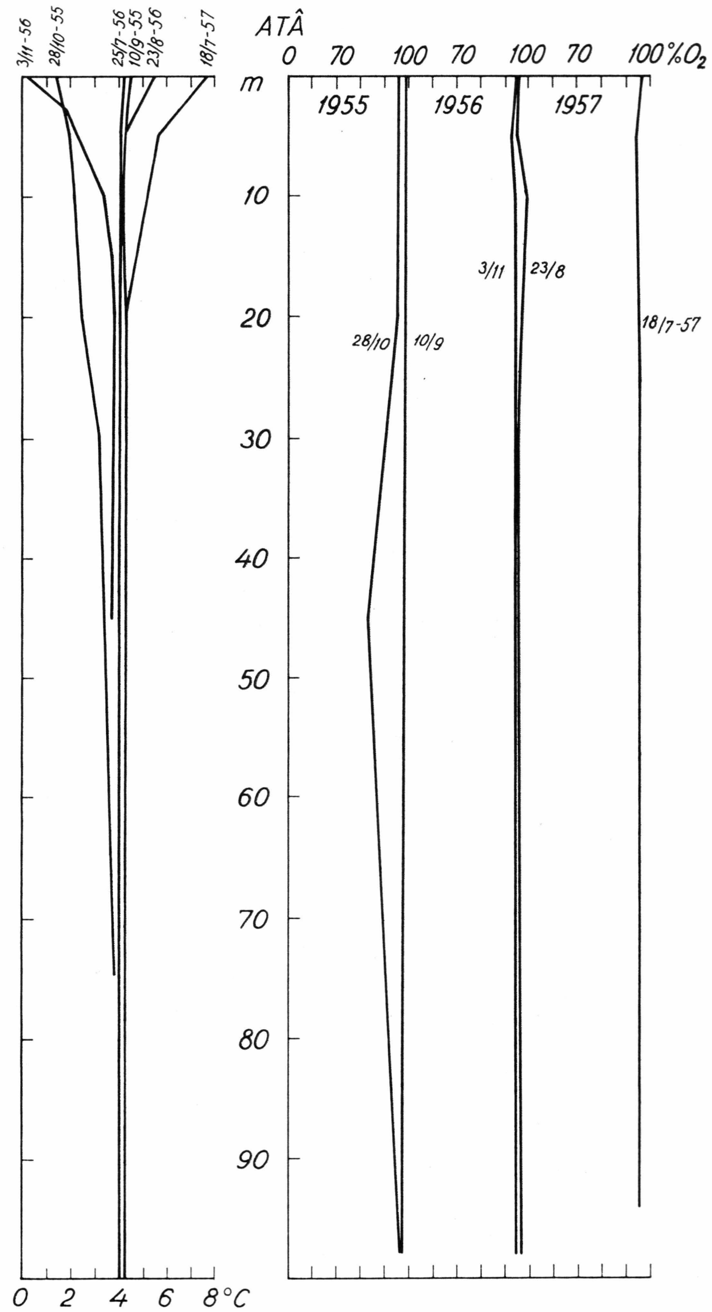

Fig. 23. Temperature and oxygen in Taserssuaq, Atâ (RØEN 1962).

are only two observations from the winter term, both of which were made early in winter. Towards the end of October 1955 there was a small oxygen deficiency at a depth of 50 m. The greater part of the lake was still ice-free at the time, only the southern part was covered with 15 cm ice. In November, on the other hand, the saturation with oxygen was 95 per cent throughout the water layer and the lake at that time was covered with a layer of ice of 40 cm (Røen 1962).

Still, there is something strange about the great content of oxygen even in the deepest layers of water, as the lake is an old fiord, and

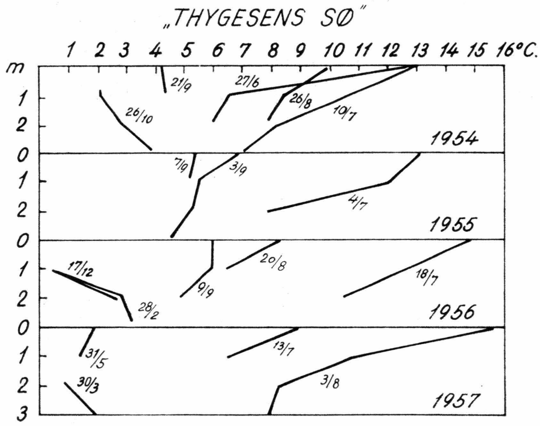

Fig. 24. Temperatures in "Thygesens Sø" (Røen 1962).

Holmquist (1959) found *Mysis litoralis* in it. This is a brackish water form, and only a few specimens were found, but the water was quite fresh at a depth of 70 m.

In Mellemsø, which is 20 m deep, the oxygen curve in summer takes approximately the same course as that of Taserssuaq, Atâ. In winter, as might be expected, there is under the ice a considerable loss of oxygen, which in April ends in total oxygen deficiency at the bottom.

In Lillesø, which is 10 m deep, there is apparently a deficiency in oxygen at the bottom during the whole of the summer. Only in September 1955 was there a saturation with oxygen of more than 80 per cent, and in August there was in the oxygen curve a distinct fall while indeed there is a thermocline in the temperature curve, but much less pronounced.

In the shallow Lake Evqitsoq there is also a high deficiency in oxygen at the bottom except during the two circulation periods in June and September, but conditions may vary highly from year to year.

On the whole it may perhaps be said that in the deep lakes in Greenland the oxygen curve takes the same course as that of oligotrophic lakes in lower latitudes, and the shallower the lakes in Greenland, the more do their oxygen curves approach a form like those of eutrophic lakes in Europe and North America.

Chemical Composition of the Water

In 1962 water samples were taken from the surface of all the lakes visited. These samples were analyzed at Danmarks Geologiske Undersøgelse.

Table V and fig. 25 show the results of the analyses. Table VI and fig. 26 show similar analyses of water samples from some of the same lakes published by Foged (1958). It appears from this material that the Greenland lakes have very soft water, as might only be expected.

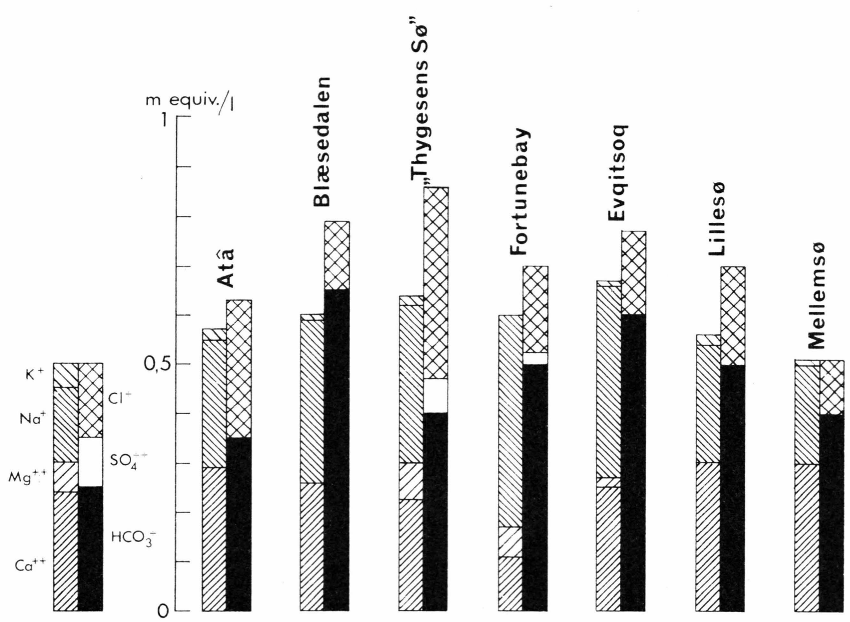

Fig. 25. Chemical composition of lake water samples taken 1962. In milliequivalents per litre.

In none of them is the sum of respectively anions and cations larger than 1 milliequivalent. From Danish lakes only a few similar analyses are available, and of these only Madum Sø and Store Øksesø in Himmerland and Løvenholm Langsø in Djursland have equally soft water. As regards analyses of ground water, water of the same type has been found only in the sandy areas of West Jutland (Ødum and Christensen 1936). The difference in the analyses to be ascertained between the various lakes and between the analyses of 1958 and 1962 according to

Table V.

	Taserssuaq, Atâ		Blæse-dalen		"Thyge sens Sø"		Fortune-bay		Evqitsoq		Lillesø		Mellemsø	
	mg/l	m eqv/l	mg/l	m eqv/l	mg/l	m eqv/l	mg/l	m eqv/l	mg/l	m eqv/l	mg/l	m eqv/l	mg/l	m eqv/l
$HCO_3^{\div}$	21	0.35	40	0.65	24	0.40	31	0.50	37	0.60	31	0.5	24	0.40
$SO_4^{\div\div}$	Tr	..	Tr	..	3.2	0.07	1.4	0.03	Tr	..	Tr	..	Tr	..
$Cl^{\div}$.........	10	0.28	5	0.14	14	0.39	6	0.17	6	0.17	7	0.20	4	0.11
$NO_3^{\div}$.......	<1	..	<1	..	c.1	..	0	..	0	..	<1	..	<1	..
Ca^{++}.......	5.9	0.29	5.3	0.26	4.7	0.23	2.3	0.11	5.1	0.25	6.3	0.31	6.0	0.30
Mg^{++}......	Tr	..	0.1	..	0.8	0.07	0.7	0.06	0.2	0.02	Tr	..	Tr	..
Fe^{++}.......	<1	..	<0.1	..	0.10	..	<0.1	..	0.05	..	<0.1	..	<0.1	..
Mn^{++}......	0	..	0	..	0	..	0	..	0	..	0	..	0	..
Na^{+}........	5.9	0.26	7.6	0.33	7.4	0.32	10	0.43	9.0	0.39	5.2	0.23	4.5	0.20
K^{+}.........	0.7	0.02	0.3	0.01	0.8	0.02	0.2	..	0.4	0.01	0.6	0.02	0.3	0.01
SiO_2........	4.0	..	9.0	..	1.6	..	3.6	..	7.8	..	5.8	..	5.8	..
$PO_4^{\div\div\div}$....	0.1	..	0.2	..	0.1	..	0.2	..	..	..	0.1	..	0.3	..
CO_2 free.....	2.2	..	4.4	..	18	..	8.8	..	6.6	..	4.4	..	6.6	..
pH.........	7.1	..	7.22	..	6.65	..	6.80	..	7.15	..	6.94	..	6.85	..

Table VI.

	Waterlake Egedesminde		Blæsedalen		Tributary to Blæsedalen		"Thygesens Sø"		Qivítut	
	mg/l	m eqv/l	mg/l	m eqv/l	mg/l	m eqv/l	mg/l	m eqv/l	mg/l	m eqv/l
$HCO_3^{\div}$	55	0.9	49	0.8	61	1.06	31	0.50	31	0.50
$SO_4^{\div\div}$......	0.8	0.02	0.7	0.015	0.8	0.017	0.5	0.01	1.5	0.031
$Cl^{\div}$.........	9.0	0.25	4.0	0.11	5.6	0.14	18	0.51	22	0.62
$NO_3^{\div}$.......	c. 0.5	..	0	..	c. 0.5	..	0	..	c. 0.5	..
Ca^{++}.......	17	0.85	5.7	0.28	9.7	0.48	5.7	0.28	5.7	0.28
Mg^{++}	2,0	0.16	1.5	0.12	3.3	0.27	1.7	0.14	1.6	0.13
Fe^{++}.......	< 0.1	..	0.26	..	0.26	..	0.2	..	< 0.1	..
Mn^{++}	..	..	..	..	..	..	..	..	..	..
$Na^{+} + K^{+}$ ...	3.7	0.16	12	0.53	9.4	0.41	14	0.60	17	0.74
SiO_2........	2.0	..	1.0	..	6.0	..	0.6	..	1.6	..
$PO_4^{\div\div\div}$....	0	..	0.1	..	0.2	..	0.1	..	0	..
CO_2 free.....	4.4	..	4.4	..	8.8	..	6.6	..	4.4	..
pH.........	..	..	7.0	..	6.4	..	7.5	..	7.4	..

information given by WERNER CHRISTENSEN, State Geologist, may be due to the fact that in the case of so small quantities of dissolved substances as those considered here, the methods of analysis are not so accurate that such differences cannot arise. In all analyses the bicarbo-

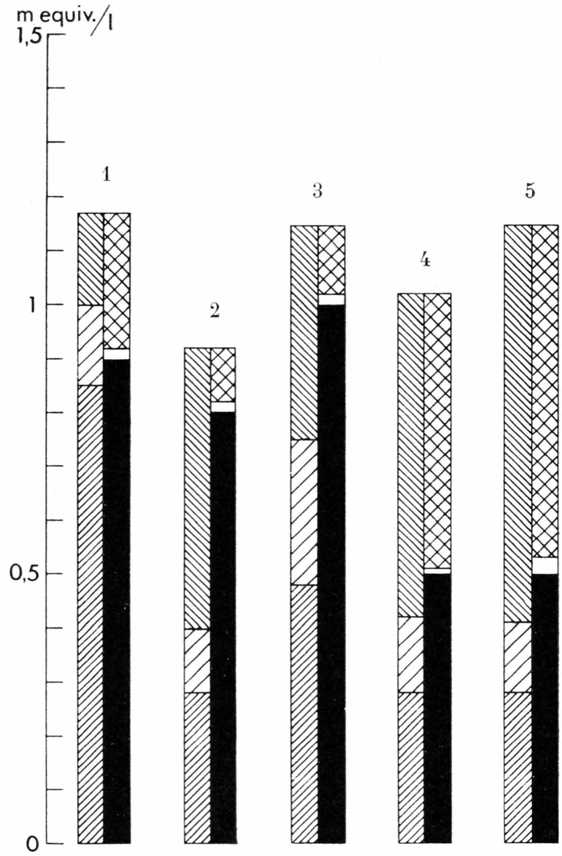

Fig. 26. Chemical composition of some lake water samples from the water lake at 1) Egedesminde, 2) the lake in Blæsedalen, 3) a tributary to the lake in Blæsedalen, 4) "Thygesens Sø" and 5) the lake at Qivítut. (FOGED 1958).

nate ion is the dominant ion and the content of Ca^{++} and Mg^{++} is so small that the water must be assumed to contain $NaHCO_3$.

Apparently there is no difference between the content of ions in the lakes from gneissic areas and that from basalt areas. This also holds good at a comparison with the much larger number of water analyses published by FOGED (1958).

On the whole the content of SiO_2 is low. In the samples from 1962 it is greatest in the lake in Blæsedalen and in Lake Evqitsoq, which can both be assumed to obtain water from basalt areas. In FOGED's analyses

Table VII.

Lake	Date	Conductivity	pH Actual	pH Highest	pH Lowest	Alkalinity meq/l	Ca	Mg	Cl	Fe++	Total Fe
		μmho					mg/l	mg/l	mg/l	mg/l	mg/l
Niaqornat...........	5–8 1956	710	9.4	9.5	6.6	1.97	21.1	7.5	..	0.04	0.25
	7–7 1957	580	7.9	8.0	6.8	1.62	16.4	7.0	136.8	..	..
Ikerasak............	7–8 1956	650	..	..	..	..	..	..	..	..	..
	10–3 1957	910	7.5	7.6	6.2	3.11	60.2	31.4	..	0.02	0.21
	4–7 1957	710	7.2	7.3	6.1	1.58	32.9	16.2	170.0	..	..
Taserssuaq, Atâ	18–10 1954	52	..	..	..	0.17	4.2	0.5	..	0.06	0.06
0 m	20–7 1955	50	6.9	7.6	5.8	0.17	4.3	0.3	..	..	..
90 –	– –	50	7.2	7.6	5.8	0.20	4.1	0.7	..	..	..
	10–9 –	48	6.9	7.2	5.8	0.11	3.4	0.3	..	0.06	0.06
	28–10 –	26	6.7	6.9	5.7	0.19	5.3	1.5	..	..	..
0 m	26–7 1956	50	6.8	7.9	5.8	0.17	4.7	1.6	..	..	..
55 –	– –	62	6.8	7.8	5.8	0.20	4.0	0.7	..	..	..
	23–8 –	68	7.3	7.3	5.8	0.25	2.6	0.6	..	..	..
	3–11 –	26	6.3	7.3	5.4	0.33	4.4	0.7	12.0	..	..
	11–6 1957	53	7.1	7.4	5.8	..	..	..	..	..	..
Rodebay............	17–6 1957	4100	8.3	8.3	6.6	1.20	56.3	92.0	..	..	..
	19–7 –	>5000	..	..	..	1.71	298.8	139.6	3856.4	..	..
	20–8 –	..	..	..	..	..	..	..	7455.0	..	..
Christianshåb	25–8 1956	59	6.2	7.1	5.8	0.25	3.1	1.5	..	..	..
	30–10 –	47	6.7	7.0	5.4	0.27	4.0	0.8	..	..	..
	17–5 1957	54	7.2	7.3	6.3	0.32	2.2	1.1	..	..	..
Egedesminde........	15–5 –	80	6.3	7.1	5.3	0.40	2.8	2.6	..	..	..
Blæsedalen..........	20–2 1956	180	6.6	7.4	6.4	1.56	21.2	4.8	..	0.22	0.94
	4–5 –	240	6.6	7.8	6.5	2.52	27.0	6.7	..	0.04	4.76
	1–2 1957	130	7.1	7.3	6.5	1.38	10.5	3.1	..	..	..
	23–2 –	162	6.7	7.1	6.2	1.81	16.7	19.8	..	..	..
	1–4 –	196	7.1	7.3	6.4	2.08	20.2	3.4	..	..	..
	2–5 –	240	6.6	7.3	6.5	2.61	21.6	6.4	..	..	..
	13–6 –	58	7.1	7.1	5.7	0.46	3.9	2.4	..	..	..
"Thygesens Sø"	4–7 1955	50	6.8	7.1	5.5	0.29	4.5	0.4	..	0.05	0.16
	3–9 –	62	7.8	8.5	6.3	0.31	0.3	2.1	..	..	..
	28–2 1956	141	6.7	7.1	5.9	0.46	9.6	4.5	..	..	..
	17–12 –	170	6.7	7.7	6.4	0.86	11.8	5.0	..	..	..
	20–3 1957	475	7.3	7.5	6.8	3.17	42.2	34.3	..	0.13	2.10
	30–3 –	520	7.3	7.6	6.8	5.11	44.4	35.9	..	0.51	4.62
	31–5 –	77	7.1	7.3	5.0	0.44	4.5	1.6	..	..	..
Fortunebay	6–9 1956	62	6.8	7.2	5.8	0.48	3.3	0.4	..	..	..
	21–2 1957	115	7.0	7.2	5.8	0.99	2.9	4.9	..	..	..

(to be continued)

Table VII (cont.)

Lake	Date	Conductivity	pH Actual	pH Highest	pH Lowest	Alkalinity meq/l	Ca	Mg	Cl	Fe++	Total Fe
		µmho					mg/l	mg/l	mg/l	mg/l	mg/l
Evqitsoq............	15–9 1954	65	..	..	..	..	..	..	..	..	..
	9–7 1955	66	7.0	7.8	6.9	0.54	5.2	1.0	..	0.06	0.14
	11–8 –	62	..	..	..	..	..	..	..	..	..
	22–9 –	65	7.3	7.5	6.3	0.51	4.6	1.1	..	..	..
	16–11 –	84	7.0	7.4	6.3	0.60	6.2	2.1	..	0.04	0.11
	4–2 1956	144	6.6	7.2	6.3	0.74	7.2	1.8	..	0.02	0.02
	18–4 –	155	7.1	8.3	6.9	1.04	8.5	4.1	..	0.06	0.15
	6–7 –	56	6.8	7.6	5.9	0.51	3.8	2.6	..	..	0.30
	19–10 –	109	7.0	7.3	5.8	0.77	4.0	2.8	..	..	..
	4–1 1957	115	7.4	7.5	6.5	0.82	5.6	2.2	..	..	..
	11–2 –	135	7.3	7.4	6.5	0.97	7.5	2.2	..	..	..
	2–3 –	158	7.0	7.2	6.2	1.28	5.2	3.6	..	0.03	0.07
	9–4 –	164	6.3	7.2	5.8	5.06	5.9	3.8	..	..	..
	8–6 –	55	6.2	7.3	5.2	0.43	3.3	1.5	..	..	..
Lillesø..............	13–9 1954	49	..	..	..	..	..	..	..	..	..
	10–7 1955	38	7.5	7.8	5.9	0.31	4.5	0.5	..	0.04	0.06
	12–8 –	41	7.4	8.0	5.6	0.25	3.4	1.3	..	..	..
	22–9 –	44	7.2	7.4	5.8	0.29	3.4	1.8	..	..	..
	16–11 –	58	6.9	7.3	5.9	0.30	4.9	2.0	..	..	..
	18–4 1956	285	8.6	9.0	7.4	7.40	16.9	7.0	..	..	..
	6–7 –	38	7.2	8.0	5.9	0.31	3.6	1.8	..	0.04	0.12
	20–10 –	54	6.9	7.2	5.9	0.51	3.5	2.3	..	..	..
	4–1 1957	120	7.6	7.6	6.9	0.58	4.2	1.2	..	..	..
	9–4 –	230	7.5	7.8	6.3	0.89	3.5	2.6	..	..	..
Mellemsø ...... 0 m	14–9 1954	39	..	..	..	..	..	..	..	..	..
17 –	– –	41	..	..	..	..	..	..	..	..	..
10 –	10–7 1955	42	7.2	8.0	6.0	0.28	3.1	0.8	..	0.06	0.10
0 –	12–8 –	37	7.4	7.5	5.9	0.20	3.3	0.2	..	..	..
10 –	– –	36	6.9	7.5	5.9	0.20	3.5	0.3	..	..	..
17 –	– –	36	6.8	7.5	5.9	0.22	3.7	0.5	..	..	..
1 –	23–9 –	35	7.3	7.6	5.7	0.30	2.6	0.8	..	..	..
14 –	– –	34	7.3	7.6	5.7	0.27	2.2	1.0	..	..	..
	17–11 –	34	7.2	7.5	5.7	0.27	4.0	0.2	..	..	..
	2–2 1956	102	7.1	7.2	5.8	0.28	3.8	1.4	..	0.02	0.03
20 m	– –	56	6.1	6.8	5.6	0.23	3.6	0.1	..	..	0.06
	6–7 –	27	6.7	7.9	5.6	0.22	2.7	1.2	..	..	0.06
	20–10 –	62	7.5	7.6	5.4	0.45	2.7	1.9	..	..	..
	4–1 1957	86	7.5	7.6	6.6	0.49	2.1	4.5	..	..	..
	9–4 –	148	..	..	..	0.50	3.2	1.3	..	..	..
Qivítut.............	8–6 1957	74	7.3	7.4	6.1	0.38	3.5	1.8	..	..	..
Store Sø, Maria Ø ...	20–7 1958	225	7.5	8.2	6.3	1.81	24.6	8.6	19.2	..	..
Langsø, Ella Ø......	15–7 –	200	7.5	8.3	6.6	2.62	24.1	8.0	6.4	..	..
Ice-dammed lake, Charcot Land.....	1–8 1958	34	6.6	7.6	5.5	0.33	4.2	1.6	0.4	..	..

the figures for SiO_2 are considerably smaller, and in this case the analyses from the inlet to the lake in Blæsedalen clearly differ from the other analyses by their greater contents of SiO_2. This inlet comes from the basalt breccia at the foot of Skarvefjeld, whereas the content of SiO_2 is quite small in the lake itself. This is presumably due to the fact that FOGED took his samples of water at another time than that at which the samples from 1962 were taken, as the content of SiO_2, indeed, varies highly concurrent with fluctuations in the population of diatoms (JØRGENSEN 1957).

The contents of Fe^{++} and PO_4^{---} as ordinarily in the lakes are quite low and there is no difference to be seen between lakes in gneiss and lakes in basalt areas. In FOGED's analyses, on the other hand, the lake in Blæsedalen with its inflow clearly differs from the others, being a lake which obtains its water from the basalt breccia, but if we examine FOGED's other analyses, we find that the lakes in the gneissic area in the Kangeq region north of the Svartenhuk peninsula have a still greater content of iron, from 0.19 to 0.43 mg/l.

RØEN (1962) determined conductivity, pH, alkalinity, and contents of Ca^{++} and Mg^{++} in a great many lakes in Greenland. Table VII shows those of his determinations which originate from the lakes discussed here.

Of these the lakes at Niaqornat, Ikerasak, and Rodebay immediately prove to differ from the others by their very great electric conductivity, alkalinity, and content of chloride ion, whereas the contents of Ca^{++} and Mg^{++} are not very much greater than those in the other lakes. The lake at Niaqornat according to RØEN is separated from the sea only by a beach ridge. The lake at Rodebay is stated by RØEN to be situated 10 m above sea level, but HOLMQUIST states that it, too, is only separated from the sea by a beach ridge over which the sea presumably splashes at high water. All the three lakes are situated in immediate proximity to settlements and presumably are also highly polluted.

In all the lakes there is a pronounced annual variation in the electric conductivity and a parallel variation in alkalinity and contents of Ca and Mg.

As an example of this annual cycle fig. 27 shows the electric conductivity in Lake Evqitsoq. The reason why this has been chosen is that RØEN from there has the amplest observation material, but the other lakes can without difficulty be adapted to this diagram.

It is seen that the electric conductivity and hence the content of dissolved ions in the water of the lake are quite small in June, July, and August, viz. 55–65 μmho. In the course of the winter the conductivity increases gradually, reaching its maximum in April, and then

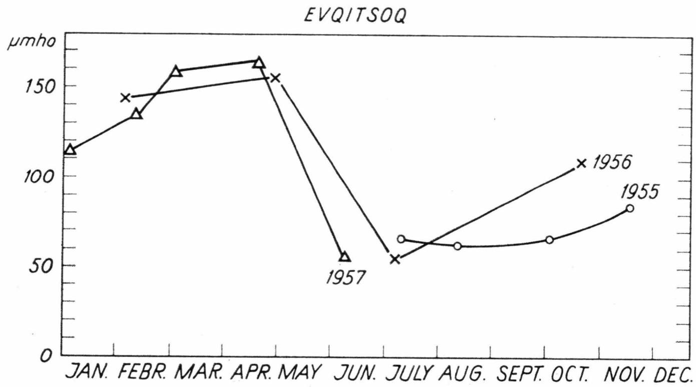

Fig. 27. Yearly variations in the electric conductivity in Lake Evqitsoq. (RØEN 1962).

falls abruptly. RØEN's determinations include the years 1955–57 and it is evident that the course is the same and the values almost the same during all the three years.

Such variations in the conductivity of the lakes also occur in European lakes. Fig. 28 shows some instances of this from the very eutrophic Sorø Sø in Denmark (JOHNSEN *et al.* 1962), the two Lunzer lakes in Austria (MÜLLER 1938), and the oligotrophic lake Øvre Vangsvatn in Norway (HAUGE 1957). These variations, however, are of much smaller size than those of the Greenland lakes. STRØM (1948) and MÜLLER (1938) explain them as due to dilution of the water of the lakes with melt water during the spring thaw. This may, of course, play some part, but as "Thygesens Sø", Lillesø, and the lake at Fortunebay are surrounded by low rocks, which in part are drained off away from the lakes, it must be supposed that the water formed by the melting of snow has disappeared before the ice on the lake has broken up. Conditions are somewhat different in the case of the lakes Evqitsoq, Mellemsø, and the lake in Blæsedalen, as these also receive some melt water from the glaciers on the tops of the surrounding basalt mountains, but this supply, too, soon ceases.

RØEN (1962) explains these variations by stating that in winter so thick a cover of ice is formed on the lakes that the ion concentration in the remaining volume of water must necessarily increase very highly. This explanation can at any rate be used with reference to the very shallow lakes, such as "Thygesens Sø", the lake in Blæsedalen, the lake at Fortunebay, and Lake Evqitsoq, which only have depths of 3–5 m and an ice-cover in winter which in April has a thickness of 1.5–2 m. In the case of the deeper lakes (Lillesø and Mellemsø) RØEN's interpretation would in advance seem to be insufficient. The chemist at the Freshwater Biological Laboratory of the University of Copenhagen,

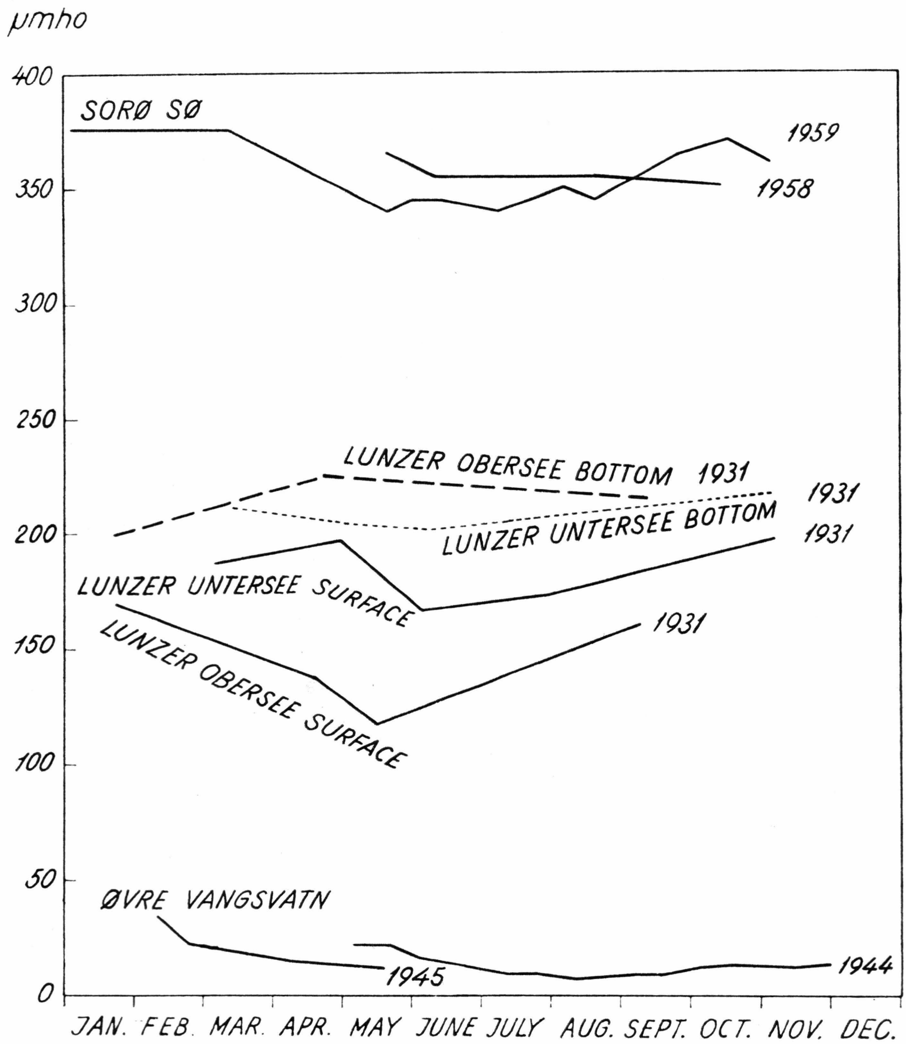

Fig. 28. Yearly variation in the electric conductivity in Sorø Sø, Denmark, Lunzer Ober- und Untersee, Austria, and Øvre Vangsvatn, Norway.

Mr. Aage Rebsdorf, however, has made the following calculations. The temperature curves suggest that also in winter there is a slight stratification in these two lakes. This makes it probable that the high values of electric conductivity immediately below the ice may very well be due to a decreased volume of water between the ice cover and the thermocline. An increase in the conductivity of about 100 μmho corresponds to an increase of about 1 meq/l ions. As calculated for NaCl such an increase in concentration gives rise to an increase in the specific gravity of 0.000031. The difference in specific gravity of pure water between 0°C. and 1°C. is 0.000059, i.e. nearly 2 meq/l NaCl can be tolerated in a layer of water with the temperature of 0° above a lower layer of water with the temperature of 1° C. to start a circulation. The conductivity figures from about 2 m and 20 m in Mellemsø on 2/2 1956 show that $\varkappa_{2\text{ m}} = 102\ \mu$mho, whereas $\varkappa_{20\text{ m}} = 56\ \mu$mho.

The difference in conductivity thus corresponds to about 0.5 meq/l ions, and as the difference in temperature is 2.8° C. the equilibrium is stable, and no exchange takes place between the water immediately below the ice and the deeper layers of water.

In the case of the lakes in Disko Fjord the supply of dissolved salts from outside must be very slight. In winter the lake is covered by a thick ice-cover and the soil round it is frozen. In summer the lakes only receive water from the surface of the slowly thawing permafrost in the ground. Therefore it must be the quantities of organic substance produced during the summer which at the decay again supply the necessary nutrient salts to the water of the lake, and the extremely slight run-off in summer through a very small overflow which presumably has stopped completely already towards the end of August, contributes to the increase of the content of ions in the water of the lake. In the case of "Thygesens Sø" it should be added that this is exposed to some pollution, and the lake in Blæsedalen presumably has water supplied from the surrounding basalt breccia the whole year. The springs at the Arctic Station, which also come from the basalt breccia, at any rate are water-bearing all the year round. The water in these springs has an electric conductivity of 60–70 μmho (LETTEVALL 1962). Two of the East Greenland lakes also in summer have a very great electric conductivity. Of these Langsø on Ella Ø is a very eutrophic lake, whereas Store Sø on Maria Ø is oligotrophic, but presumably can obtain some admixing of sea water.

III. THE FLORA AND FAUNA OF THE LAKES

It is not possible to give an exhaustive description of the flora and fauna of the lakes discussed here, for although numerous botanical and zoological expeditions have made collections in Greenland, it is mainly the flora and fauna of the land and the sea that have been objects of these. Furthermore, the material collected has been handed over to the respective museums in Copenhagen and worked up systematically by specialists on the various groups of plants and animals. An examination of these papers will be unprofitable, as the statements of locality in many cases are so inaccurate that they cannot be identified. Therefore it will be necessary to restrict the references to flora and fauna to the very few papers in which it is expressly stated that the references are to some of the lakes dealt with here.

Porsild (1902) gives the following description of the vegetation of higher plants in the lakes on Eqalúnguit itivnerat (Lillesø and Mellemsø). He found it remarkable that the boundary between the lakes and the contiguous mossy bogs is so sharply defined. Even though the species of mosses on the outermost edge of the bog and on the shore of the lake are the same, there is always a sharply cut-off cliff facing the lake. A very conspicuous feature is, furthermore, the absence of floating mosses or of phanerogams with floating leaves.

Nearest to the shore there are representatives of hygrophilous plants of the mossy bog, viz. *Harpidium uncinatum*, *H. exannulatum*, and *H. revolvens* besides *Calliergon sarmentosum.* The most impressive plant on the shore is *Hippuris vulgaris* var. *maritima*, which may form populations of a considerable size. Among them there are thin forms of *Equisetum arvense* and *E. variegatum.* At nearly the same depths of water as the mosses there are *Callitriche autumnalis* and *Batrachium paucistamineum* var. *eradicatum*, which, however, do not appear in lower water than 30 cm. Next, there is a zone with *Potamogeton mucronatus* and submerged forms of *Harpidium fluitans.* This zone starts at a depth of 80 cm.

About the lake in Blæsedalen Porsild stated that it seemed to be practically devoid of plants. Close to the shore there was a little *Calli-*

Table VIII.

	Christianshåb	Egedesminde	Blæsedalen	"Thygesens Sø"	Lillesø	Mellemsø	Qivítut
Melosira ambigua	..	..	+	..	..	..	..
– *granulata*	..	..	+	..	..	..	..
– *distans* v. *lirata*	..	+	..	..	..	..	..
Cyclotella comta	..	..	+	..	..	..	..
– *stelligera*	+	+	..	..	..	..	..
– *kützingiana*	+	+	..	..	..	..	..
– – var. *planetophora*	..	+	..	..	..	..	..
– – – *radiosa*	+	+	..	..	..	..	..
Tabellaria fenestrata	..	..	+	+	+	+	..
– – var. *intermedia*	..	..	..	..	..	..	+
– *flocculosa*	+	+	..	+	+	+	+
Meridion circulare	..	..	..	..	..	+	..
Diatoma elongatum var. *tenuis*	..	..	..	..	..	..	+
Opephora martyri	..	..	+	..	..	..	..
Ceratoneis arcus var. *amphioxys*	..	..	..	..	..	+	..
– – – *genuina*	..	..	..	..	..	+	..
Fragilaria brevistriata	..	..	+	..	..	..	..
– *capucina*	..	..	..	+	..	..	+
– *construens*	..	..	+	..	..	..	..
– *crotonensis*	..	..	..	+	..	..	+
– *lapponica*	..	..	+	+	..	..	..
– *pinnata*	..	..	+	+	..	..	+
– *virescens*	+	..	..	..	+	..	..
– – var. *subsalina*	..	+	..	+	..	..	..
– *parasitica*	..	..	..	..	+	..	..
– *elliptica*	..	..	..	..	+	..	..
Synedra ulna	..	..	+	..	..	..	..
– *paludosa*	..	..	..	+	..	..	..
– *nana*	..	..	..	+	..	..	..
Peronia heribaudi	+	..	..	..	..	..	..
Eunotia pseudopectinalis	..	+	..	..	..	..	..
– *quinquenodis*	..	..	..	..	+	..	..
– *lunaria* var. *genuina*	..	..	..	+	+	..	..
– *senaria* – *quinaria*	..	..	..	..	+	..	..
– *impressa*	..	..	..	..	..	+	..
– *faba*	..	..	..	+	..	..	..
– *leptoceros*	..	..	..	+	..	..	..
– *arcus* var. *genuina*	..	..	..	+	..	..	..
– *major*	..	..	..	+	..	..	..
– *robusta* var. *diadema*	..	..	..	+	..	..	..
– *diodon*	..	..	..	+	..	..	..
Achnanthes linearis	+	+	+	+	..	..	+

(to be continued)

Table VIII (cont.)

	Christianshåb	Egedesminde	Blæsedalen	"Thygesens Sø"	Lillesø	Mellemsø	Qivítut
Achnanthes linearis var. *pusilla*	..	+	..	..	..	..	..
– *peragalli*	..	..	+	..	..	..	..
– *østrupi*	..	..	+	..	..	..	..
– *microcephala*	..	+	..	..	..	..	..
– *holsti*	..	+	..	..	..	..	..
– *minutissima*	+	..	..	..	..	..	..
– *cryptocephala*	..	..	..	..	..	..	+
Diploneis elliptica var. *genuina*	..	..	..	..	+	..	..
Neidium iridis var. *ampliatum*	..	..	..	+	..	..	..
Stauroneis javanica	..	+	..	..	..	..	+
– *anceps* var. *elongata*	..	..	+	+	+	..	..
– – – *amphicephala*	..	..	..	+	+	..	..
– *phoenicenteron*	..	..	..	+	+	..	..
Anomoeneis exilis var. *lanceolata*	+	..	..	..	..	..	..
– *serians* var. *brachysira*	+	..	..	..	..	..	..
Caloneis silicula var. *genuina*	..	..	..	+	..	..	..
Navicula järnefelti	..	+	+	..	..	..	..
– *pellicosa*	..	..	+	..	..	..	..
– *clementis*	..	..	+	..	..	..	+
– *explanata*	..	..	+	..	..	..	..
– *lagerstedti* var. *palustris*	..	..	+	..	..	..	..
– *opportuna*	..	..	+	..	..	..	..
– *certa*		+	..	..	..	..	+
– *subatomoides*	..	+	..	+	..	..	+
– *ventralis*	+	+	..	+	..	..	+
– *clementoides*	..	..	..	..	..	..	+
– *viridula* var. *slevicensis*	..	..	..	+	..	..	..
– – – *rostellata*	..	..	..	..	+	..	..
– *rhyncocephala*	..	..	..	+	+	+	..
– *radiosa* var. *genuina*	..	..	..	..	+	+	..
– *lanceolata* var. *cymbula*	..	..	..	..	+	+	..
Pinnularia hustedti	+	..	..	..	..	..	..
– *balfouriana*	..	..	..	+	..	..	..
– *borealis*	..	..	..	..	..	+	..
– *subcapitata* var. *stauroneiformis*	..	..	..	..	..	+	..
– *viridis*	+	..	..	..	..	..	..
– – var. *elliptica*	..	..	..	..	+	..	..
– – – *clevi*	..	..	..	+	..	..	..
– *tabellaria* var. *wolfenbergeri*	..	..	..	+	..	..	..
– *microstauron*	..	..	..	+	..	..	..
– *stauroptera* var. *clevi*	..	..	..	+	..	..	..
– *sublinearis*	..	..	..	+	..	..	..
– *mesolepta* var. *stauroneiformis*	..	..	..	+	+	..	..

(to be continued)

Table VIII (cont.)

	Christianshåb	Egedesminde	Blæsedalen	"Thygesens Sø"	Lillesø	Mellemsø	Qivîtut
Amphora ovalis	..	..	..	+	..	..	..
– – var. *pediculus*	..	..	..	..	+	..	..
Cymbella incrasata	+	..	..	..	..	..	..
– *microcephala*	..	..	+	..	..	..	..
– *ventricosa*	..	..	+	+	..	..	+
– – var. *lunula*	..	..	..	+	+	+	..
– *gauemanni*	+	..	..	..	..	..	..
– *affinis*	..	..	..	+	..	..	..
– *maculata*	..	..	..	+	+	..	..
– *cuspidata*	..	..	..	+	..	..	..
– *naviculaeformis*	..	..	..	+	..	..	..
– *cymbiformis*	..	..	..	..	+	..	..
Gomphonema angustatum	..	..	+	..	..	..	..
– *rosenkrantzi*	..	..	+	..	..	..	..
– *subtile*	..	..	..	..	..	..	+
– *parvulum*	..	..	..	+	..	..	..
– *acuminatum* var. *coronatum*	..	..	..	+	+	..	..
– – – *elongatum*	..	..	..	+	..	+	..
– *gracile*	..	..	..	..	+	..	..
– *constrictum*	..	..	..	..	+	..	..
– *capitatum*	..	..	..	..	..	+	..
Denticula tenuis	..	..	+	..	+	..	..
Epithemia sorex	..	..	+	..	..	..	+
– *zebra* var. *percellus*	..	..	..	..	+	..	..
– *argus* var. *alpestris*	..	..	..	..	+	..	..
Nitzschia frustulum	+	+	+	+	..	..	+
– – var. *perminuta*	..	..	+	+	..	..	..
– – – *perpusilla*	..	..	..	..	..	..	+
– *palea*	+	..	..	..	..	..	..
– – var. *fontienda*	..	..	..	..	..	+	..
– *communis*	..	..	..	+	+	..	..
– *subtilis* var. *palaea*	..	..	..	..	+	..	..
– *inconspicua*	..	..	..	..	+	..	..
Surirella delicatissima	+	..	..	..	..	..	..
– *linearis*	..	..	..	+	..	..	..
Microneis microcephala	..	..	..	+	+	..	..

ergon richardsoni and *C. stramineum* as well as *Limnobium alpestre*. The plankton contained multitudes of Entomostraca and mosquito larvae.

PORSILD's description of the vegetation of higher plants in the lakes on Eqalúnguit itivnerat can also be applied to "Thygesens Sø" and the lake at Fortunebay and Lake Evqitsoq. The shores of all the lakes consist of rock descending stepwise to the bottom, and the actual littoral zone is therefore in most places quite narrow. The vegetation of higher plants thus is restricted to a fairly narrow fringe even in places where the rocks form flat and broad steps.

On the cryptogamous flora there are statements in BACHMANN, FOGED, and VANHÖFFEN. Diatoms are those most thoroughly investigated. Table VIII shows the distribution of diatoms according to BACHMANN (1921), FOGED (1958).

FOGED (1958) set up the following spectra for these lakes:

	C %	E %	B %	T %	Q %
Acidophilous	39.2	15.6	0.8	0.6	13.2
Indifferent	51.0	61.6	22.0	85.4	40.0
Alkaliphilous	7.2	12.0	76.2	11.0	45.2
? ? ?	2.6	10.8	1.0	3.0	1.6

It is evident that the indifferent and acidophilous species are dominant in the gneissic region (Christianshåb, Egedesminde, "Thygesens Sø", and Qivítut), whereas the alkaliphilous species are dominant in the lake in Blæsedalen, which is situated in basalt breccia. FOGED states that this difference between lakes in gneissic regions and lakes in basalt regions is general in Greenland.

The diatomaceous flora of Lillesø and Mellemsø recorded by BACHMANN (1921) cannot be directly compared with that of the other lakes, as the majority of the species occurring there are not identical with those in the lakes investigated by FOGED. However, it is evident that these two lakes, which are also situated in gneissic terrain, have no species in common with those in the lake in Blæsedalen.

Table IX shows the rest of the algal flora as recorded by VANHÖFFEN (1897) from the lake at Ikerasak and by BACHMANN (1921) from the waterlake at Egedesminde, the lake in Blæsedalen, "Thygesens Sø", Lillesø, and Mellemsø.

The crosses in parentheses indicate that this is a question of scraped-off material, while the rest is true plankton. VANHÖFFEN, however, does not state whether his lists from Ikerasak refer to plankton samples, only, or whether they also include scraped-off material.

It is evident that in all the lakes with the exception of the waterlake at Egedesminde and the lake in Blæsedalen the desmids are the dominant group of algae together with the diatoms. At Egedesminde the flagellates are the group richest in species, whereas they are almost completely missing from the other lakes. The lakes cannot, however, be

Table IX.

	Ikerasak	Egedesminde	Blæsedalen	"Thygesens Sø"	Lillesø	Mellemsø
Cyanophyceae						
1. Chroococcaceae						
Aphanothece sp.	..	..	..	+	..	..
– *microscopica*	..	..	..	..	+	..
Microcystis sp.	..	..	..	+	(+)	..
Chroococcus sp.	..	..	..	(+)	+	..
2. Oscillatoriaceae						
Oscillatoria sp.	..	..	..	+	..	..
– *tenuis*	..	..	..	..	(+)	(+)
– *sancta*	..	..	..	..	..	(+)
– *curvipes*	..	..	..	(+)	..	..
3. Nostocaceae						
Nostoc sp.	..	..	..	..	+	..
– *kihlmani*	..	..	..	+	(+)	..
– *spongiaforme*	+	..	..	..	..	..
Anabaena affinis	..	..	..	..	..	(+)
– *augstumali*	..	..	..	..	..	(+)
– *contorta*	..	..	..	..	..	(+)
4. Scytonemaceae						
Scytonema sp.	..	..	..	(+)	..	..
Tolypotrix sp.	..	..	..	(+)	+	..
5. Rivulariaceae						
Rivularia borealis	+	..	..	..	..	..
– *bialosettiana*	..	..	..	+	..	..
Flagellata						
Cryptomonas sp.	..	+	..	..	..	..
Dinobryon sertularia	..	+	..	..	..	..
– *sociale*	..	..	..	..	..	(+)
– – var. *stipitatum*	..	+	..	..	..	..
– – – *bavaricum*	..	+	..	..	..	..
– *divergens*	..	+	..	..	..	..
Hyalobryon ramosum	..	..	..	+	..	..
Peridineae						
Peridinium willei	..	+	..	..	+	..
– *elpatiewskyi*	..	..	..	..	+	..
– *cinctum*	..	..	..	..	+	..
– *inconspicuum*	..	..	..	..	..	(+)

(to be continued)

Table IX (cont.)

	Ikerasak	Egedesminde	Blæsedalen	"Thygesens Sø"	Lillesø	Mellemsø
Desmidiacea						
Arthrodesmus triangularis	..	..	..	..	+	..
– *incus*	..	..	..	..	(+)	(+)
Closterium sp.	+	..	..	..	..	..
– *striolatum*	..	..	..	+	+	..
Cosmarium dentiferum	..	..	..	+	+	..
– *botrytis*	+	..	+	+	+	(+)
– *turpini*	..	..	..	+	+	(+)
– *crenatum*	..	..	..	+	..	..
– *protractum*	..	..	..	+	+	..
– *Margaritiferum*	..	..	..	+	+	(+)
– *depressum*	..	..	..	+	+	..
– *granatum*	..	..	..	..	+	..
– *punctulatum*	+	..	..	..	..	..
– *subtumidum*	+	..	..	..	..	..
– *platydesmium*	+	..	..	..	..	..
– *hexagonum*	+	..	..	..	..	..
– *undulatum*	+	..	..	..	..	..
– *meneghinii*	+	..	..	..	..	..
Desmidium swartzii	..	..	..	+	..	..
Euastrum bidentatum	..	..	..	+	..	..
– *verrucosum*	..	..	..	+	(+)	..
– – var. *alatum*	..	..	..	+	..	..
– – – *rhomboideum* forma *groenlandica*	..	..	..	+	..	
– *elegans*	..	..	..	+	+	..
– *dubium*	..	..	..	..	(+)	..
– *denticulatum*	..	..	..	..	(+)	..
– *oblongum*	..	..	..	..	..	(+)
Gonatozygon monotaenium	..	..	..	+	..	..
Genicularia elegans	..	..	..	+	..	..
Hyalotheca sissilens	..	..	..	+	+	..
Pleurotaenium trabecula	..	..	..	+	..	..
– *coronatum*	..	..	..	+	..	..
Staurastrum polymorphum	..	..	..	+	+	(+)
– *sebaldi* var. *productus*	..	..	..	+	..	..
– *dejectum*	..	..	..	+	..	..
– *pachyrhynchum*	..	..	..	..	+	..
– *aristiferum*	..	..	..	..	+	..
– *telipherum*	..	..	..	..	+	..
– *saxonicum*	..	..	..	..	+	(+)
– *vestitum*	..	..	..	..	(+)	(+)
Xanthidium antilopaeum var. *hebridarum*	..	..	..	..	+	..
– *groenlandica*	..	..	..	..	+	..

(to be continued)

Table IX (cont.)

	Ikerasak	Egedesminde	Blæsedalen	"Thygesens Sø"	Lillesø	Mellemsø
Zygnemaceae						
Spirogyra groenlandica	+	..	..	..	..	..
– *weberi* forma *intermedia*	+	..	..	..	..	..
Chlorophyceae						
1. Volvocaceae						
Eudorina elegans	..	..	..	+	+	..
Gonium sp.	..	..	..	..	..	(+)
2. Palmellaceae						
Cloeococcus schroeteri	..	..	..	+	..	..
3. Heterocontae						
Botryococcus brauni	..	..	..	+	..	..
4. Tetrasporaceae						
Tetraspora natans	+	..	..	..	..	..
– *lacustris*	..	..	..	+	..	..
– sp.	..	..	..	+	..	..
Schizochlamys gealtinosa	+	..	..	..	..	..
Apioxystis sp.	..	..	..	+	..	..
– *brauniana*	+	..	..	..	..	..
5. Characiaceae						
Characium groenlandicum	+	..	..	..	..	..
6. Hydrodictyaceae						
Pediastrum boryanum	+	..	..	..	..	..
– – var. *longicorne*	..	..	+	+	..	..
– *granulatum*	+	..	..	..	..	..
– *longicorne*	+	..	..	..	..	..
7. Oocystaceae						
Oocystis naegelli	..	..	..	+	..	..
8. Scenedesmaceae						
Scenedesmus sp.	+	..	..	..	..	..
Crucigenia rectangularis	..	..	..	+	..	..
Dictyosphaerium ehrenbergianum	+	..	..	..	..	..
– *pulchellum*	+	..	..	..	..	..
Ankistrodesmus pyrenogerum	..	..	..	+	..	..
Coelastrum proboscideum	..	..	..	..	+	..
9. Oedogoniaceae						
Oedogonium sp.	+	..	+	(+)	..	..
Bulbochaete sp.	+	..	+	(+)	..	..
10. Colechaeaceae						
Coleochaete ikerasakensis	+	..	..	..	..	..
– *scutata*	+	..	..	..	..	..
11. Ulotricaceae						
Microspora sp.	..	..	..	+	..	..

Table X.

	Niaqornat	Ikerasak	Atâ	Rodebay	Christianshåb	Egedesminde	Blæsedalen	"Thygesens Sø"	Fortunebay	Evqitsoq	Lillesø	Mellemsø	Qivítut	Maria Ø	Ella Ø
Branchinecta paludosa		+		+	+			+							
Lepidurus arcticus							+		+					+	+
Holopedium gibberum						+		+		+					
Daphnia pulex	+	+		+	+		+	+					+	+	+
– *longispina*										+					
Scapholeberis mucronata					+			+							
Simocephalus vetulus		+			+	+	+	+		+		+	+		
Ceriodaphnia quadrangula					+			+				+			
Bosmina longirostris											+			+	
– *coregoni obtusirostris*					+	+		+							
Macrothrix hirsuticornis			+	+								+			
Eurycerus glacialis					+		+	+	+	+			+		
– *lamellatus*		+													
Acroperus harpae			+		+	+	+	+		+		+	+		
Alona guttata		+													
– *intermedia*										+					
– *rectangula*			+			+		+			+	+			
– *quadrangularis*			+			+	+	+			+	+			
– *affinis*					+	+					+				
Graptoleberis testudinaria						+				+					
Alonella nana		+	+			+				+	+	+			
– *excisa*		+						+		+					
Chydorus sphaericus			+	+				+						+	+
Polyphemus pediculus					+	+	+	+		+			+		
Eucypris affinis hirsuta										+			+		
– *virens*		+													
Prionocypris glacialis	+														
Cyprinotus incongruens				+											
Candona candida		+				+		+		+	+	+			
– *rectangula*			+												
– *falcata*			+							+		+			
– *lapponica*				+											
Diaptomus minutus			+		+	+		+			+	+	+		
Eucyclops serrulatus		+													
Cyclops scutifer			+		+	+	+	+	+	+	+	+	+	+	+
– *vernalis*					+	+	+	+				+			
– *strenuus*							+								
– sp.											+				
Bryocamptus tikchikensis			+			+									
Canthocampus sp.		+													
Moraria mrazeki			+												
Maraenobiotus insignipes			+												
Heterolaophonte strömi										+					
– sp.										+					
Anuraea aculeata var. *brevispina*							+								
Pleurixus exiguus		+													

compared completely, as the samples have been taken at different times. At Egedesminde on 24/6, when a great part of the lake was still frozen over and the temperature of the water 5.6° C. In "Thygesens Sø" BACHMANN took his samples on the 6th and the 20th of July and on the 12th and the 20th of August. So it is no wonder that the floral list is the richest here, with a total of 45 species. The temperature of the water was 15.6° C., and BACHMANN adds that zooplankton is dominant in the sample from the 20th of August. In Lillesø and Mellemsø the plankton samples were taken on the 13th of July, the temperature of the water being 10.6° C. In Mellemsø the whole sample was scraped-off material. The sample from the lake in Blæsedalen was taken on the 15th of August. The temperature of the water was 8.7° C.

On the zooplankton there are records in VANHÖFFEN (1897), BACHMANN (1921), and RØEN (1962). Table X shows a grouping of these records as regards the crustaceans.

VANHÖFFEN furthermore records the following species from the lake at Ikerasak:

Table XI.

Rotatoriae.	Protozoa.	Vermes.
Asplanchna priodonta	*Vorticella campanula*	*Nematodeae*
Polyarthra platyptera	*Podopkrya fixa*	
Philodina roseola	*Clathrulina elegans*	
Eosphaera najas	*Arcella vulgaris*	
Catypna sp.	*Cothurnia crystallina*	
Monostylis lunaris		
Salpina redunca		
Euchlanis dilatata		
Dinocharis sp.		

He also states that the zooplankton appears in so great amounts that the free-floating or torn-off drifting plants evidently are far from being able to nourish the rich fauna. To maintain so many animals in these small lakes the higher plants must contribute materially, either directly by giving a substratum of nutrient or indirectly by giving nourishment to diatoms or other lower plants and offering them an opportunity to settle. The other lakes, which are without higher plants, therefore are more poorly populated.

A close examination of BACHMANN's and VANHÖFFEN's floral lists shows that the lakes clearly are different, the waterlake at Egedesminde containing an almost pure *Dinobryum* material, the lake in Blæsedalen containing almost only diatoms, and the lake at Ikerasak almost exclusively Chlorophyceae. Lillesø and Mellemsø are poor in phytoplankton, but the poor population includes Cyanophyceae, Chlorophyceae, and a few flagellates and Peridineae.

The zooplankton does not enable us to determine the trophic state of the various lakes. A remarkable feature is the crustacean fauna poor in species in Langsø on Ella Ø in East Greenland. This at the same time contains a rich fauna of chironomids, which has been treated in detail by Søgaard Andersen (1946).

IV. BOTTOM SEDIMENTS OF THE LAKES

In a fresh condition all the samples consist of soft, highly aqueous, olive green mud. By being dried up the samples become rather different in appearance.

1. **The lake at Niaqornat.**

The dried sample is loose and sandy, of a dark brown colour and contains small concretions of clayey ironstone. Under the microscope it appears to be dominated by organic detritus with a distinct tissue structure and by small sharp-edged mineral grains. There are also numerous chitinous remains of crustaceans, whereas few diatoms were observed.

2. **The lake at Ikerasak.**

In a dried condition the bottom sample forms very light olive greyish green lumps, which under the microscope prove to contain structureless, fine, organic detritus, a few tissue fragments, and some diatoms and mineral grains.

3. **Taserssuaq, Atâ.**

In a dried condition the bottom sample is a light grey, very fine-grained powder, which forms loosely connected lumps and if anything, looks like a loess deposit. Under the microscope small sharp- edged mineral grains and a little structureless, fine, organic detritus are practically all that can be seen. Diatoms are very scarce.

4. **The lake at Rodebay.** Plate I, fig. 1.

When dried up the sample is dark brown, if anything peat-like, and clearly sandy. Under the microscope bits of tissue are almost all that can be seen, only with crossed nicols can a few scattered mineral grains be seen. Diatoms occur, but are scarce. The sample must be characterized as a tyrfopel.

5. **Vandsøen (the waterlake) at Christianshåb.**

In a dried state the sample is a greyish yellow powder. The greater part is a structureless, organic, fine detritus and some diatoms. Plant residues with a distinct tissue structure also occur, but the destruction of these is far more advanced than in those of Rodebay.

6. **Vandsøen (the waterlake) at Egedesminde.** Plate 1, fig. 2.

In a dried state the sample looks like the samples from Christianshåb and Atâ, a fine, pale grey powder. Under the microscope sharp-edged small mineral grains and structureless, organic, fine detritus are seen, but there are also many diatoms, far more than in the sample from Christianshåb.

7. **The lake in Blæsedalen.**

In a dried state the sample consists of pale grey, very light, hard, fine-grained lumps. Under the microscope it is seen that diatoms and structureless, fine organic, detritus are dominant, whereas mineral grains play a more subordinate part. The sample must be characterized as a diatomaceous gyttja.

8. **"Thygesens Sø" in Godhavn.** Plate I, fig. 3.

In a dried state the sample forms a pale grey, gritty mass. Under the microscope it is seen that diatoms and structureless, fine organic, detritus are dominant, still there are few fragments of tissue and mineral grains. The preparation looks very much like the bottom samples from the lake Borresø in Denmark.

9. **The lake on Kangârssuk, Fortunebay.** Plate I, fig. 4.

In a dried state the sample is of the same kind as those from Blæsedalen and "Thygesens Sø". Under the microscope it is seen that diatoms are dominant together with structureless detritus. Mineral grains seem to play a more subordinate part. Plant residues with tissue structure occur, but very sparsely. The sample must be characterized as a diatomaceous gyttja.

10. **Lake Evqitsoq.**

In a fresh state this bottom sample deviates by being pale yellowish brown, but otherwise soft and aqueous like the other samples. When dried it is pale grey and forms very light lumps. Under the microscope numerous diatoms and much structureless, organic detritus are seen. There are also a few plant residues with tissue structure. The sample must be characterized as a slightly ochreous diatomaceous gyttja.

11. **Lillesø.** Plate I, fig. 5.

In a dried state the sample consists of light yellowish brown lumps. Under the microscope the picture is completely dominated by the mineral grains, even though there are also some diatoms. Organic detritus seems to be very sparse.

12. **Mellemsø.**

The sediment looks completely like that of Lillesø, forming light, yellowish brown lumps. Under the microscope it is seen that mineral grains are dominant here, too, but there seems to be a somewhat greater content of diatoms. The organic substance consists of structureless, fine detritus.

13. **The lake at Qivítut.**

In a dried state the sample forms a loose, yellowish brown, fine-grained powder. Under the microscope almost only mineral grains and considerable quantities of brown structureless detritus are seen.

14. **Store Sø, Maria Ø.** Plate I, fig. 6.

In a dried state the sample forms pale, greyish green, fine-grained lumps. Under the microscope only mineral grains and a little structureless, organic, fine detritus are seen.

15. **Langsø, Ella Ø.**

The sediment is a calcareous gyttja. The microscope shows a basic mass of fine crystals of calcite and some diatoms.

16. **Ice-dammed Lake, Charcot Land.**

The sample is clayey, fine-grained sand.

As in the case of the investigations of the bottom samples from Danish and Swedish lakes, the bottom samples from the Greenland lakes have been analyzed for their three main constituents: organic substance, mineral substance, and diatom silicic acid. The last constituent has been determined as alkali-soluble SiO_2, and the mineral substance has been determined as the difference between total SiO_2 and alkali-soluble SiO_2 (K. HANSEN 1959, 1961, 1962). The organic substance is represented by the loss on ignition (I in the table). Furthermore the contents of $CaCO_3$, $MgCO_3$, organic carbon and nitrogen, and in some of the bottom samples also the content of iron have been determined.

As appears from Table XII, the contents of organic substance vary very much from lake to lake. The highest values, higher than 40 per cent., are found in the lakes at Ikerasak, Rodebay, Fortunebay, and Langsø on Ella Ø. Less than 10 per cent. is found in Lillesø, Mellemsø, Atâ, and the lakes on Maria Ø and in Charcot Land in East Greenland.

Table XII.

	I	C	C % of I	N	C/N	D	M	$CaCO_3$	$MgCO_3$	Fe_2O_3
	%	%		%		%	%	%	%	%
1. Niaqornat	31.4	13.8	44	1.12	12.3	3.2	31.3	3.25	1.2	..
2. Ikerasak	47.0	18.6	39,8	1.82	9.7	10.0	23.8	2.25	1.72	..
3. Atâ	4.7	2.4	50.5	0.56	4.2	10.8	41.2	0.68	2.18	..
4. Rodebay	48.6	26.0	53.5	2.10	12.4	7.8	19.3	1.21	1.1	..
5. Christianshåb	35.8	18.2	51.9	1.70	10.7	10.1	34.6	0.76	0.85	..
6. Egedesminde	21.2	10.0	47.0	1.30	7.9	14.3	33.1	0.40	0.67	..
7. Blæsedalen	15.3	7.3	47.7	0.98	7.4	22.4	29.6	2.38	2.02	3.3
8. "Thygesens Sø"	31.7	15.9	51.5	0.98	16.3	17.3	28.2	1.09	1.2	..
9. Fortunebay	40.0	16.7	41.0	1.26	13.2	19.7	19.4	1.49	0.96	1.7
10. Evqitsoq	13.9	9.1	65.5	1.26	7.2	35.6	20.4	1.78	1.05	1.3
11. Lillesø	7.2	1.9	26.2	0.40	4.7	3.2	41.7	3.22	3.14	5.4
12. Mellemsø	6.7	3.3	48.5	0.56	5.8	4.2	39.2	4.07	4.84	..
13. Qivítut	5.6	4.0	71.5	0.28	14.0	2.5	43.4	0.15	1.46	..
14. Maria Ø	4.3	2.5	60.0	0.28	9.5	2.1	40.2	0.80	1.53	..
15. Ella Ø	43.3	18.4	42.3	1.68	10.9	3.7	11.5	3.74	2.1	..
16. Charcot Land	5.1	2.4	47.0	0.70	3.4	2.4	36.9	1.25	2.3	..

I = Loss on ignition, C = org. carbon, N = org. nitrogen, D = diatoms, M = mineral matter.

The contents of $CaCO_3$ and $MgCO_3$ on the whole are low, only Langsø on Ella Ø being highly calcareous, which is due to the fact that it is situated in a calcium dolomite area. The contents of $MgCO_3$ are remarkable high as compared with the contents of $CaCO_3$, in some of the lakes even higher than the contents of calcium carbonate, but it is not possible to trace any connexion between this and the rocks in the mountains surrounding the lakes.

V. THE PLACE OF THE LAKES IN THIENEMANN'S SYSTEM OF LAKE TYPES

The system of lake types set up by THIENEMANN and highly misunderstood by NAUMAN and BERG, is, as well-known, intended to characterize lakes partly by their state of trophism, partly by their humus state. This basis is solid enough, as both problems are of fundamental importance for the biological state of the lakes (K. HANSEN 1962). On the other hand, it has proved difficult to find a way of making clear the state of trophism as well as the humus state.

As characteristic of the state of trophism, THIENEMANN first tried to use the course of the oxygen curve during the summer period (THIENEMANN 1915). However, this proved not to be an applicable method. Attempts at using the electrical conductivity (as a measure of the content of ions in the water), or the contents of certain substances such as phosphorus and nitrogen have not been successful, either, simply because the quantitative conditions of these substances vary during the year and from year to year.

Later THIENEMANN (1922) and LUNDBECK (1926) tried to use the composition of the chironomid fauna as an indicator of the biological type of the lakes. This, indeed, was better, but in the table in question, there were a number of spaces which were blank or were characterized as still unknown chironomid fauna.

One of the reasons why so many attempts were unsuccessfull evidently was that many of the limnologists viewed the terms of oligotrophy and eutrophy as absolute contrasts without considering the fact that actually there are a number of stages from total oligotrophy to total eutrophy. The two extremes probably cannot be found at all in nature. It seems highly possible that if the chironomid faunas of the lakes were dealt with statistically and the number of oligotrophic forms were compared with the number of eutrophic forms, we might get quite a number of intermediate stages in the same way as has been done here in the case of the contents of diatoms in the bottom samples. THUNMARK (1945) and JÄRNEFELT (1952) have tried to use the algal flora for such a determination of types.

But here, too, there are difficulties as the quantity as well as the composition of the population of phytoplankton may vary from year to year. Furthermore, if the method is to be used over a large area the geographical distribution of the various species will be involved, too, so that the presence or absence of individual species may be due to the fact that the limit of their area of distribution has been passed and therefore has nothing to do with the state of trophism of the lake.

Søgaard Andersen's investigations into the chironomids of the East Greenland lakes (Søgaard Andersen 1946) is an excellent example of this, as he states that most of the species found in the lakes in East Greenland examined by him are different from those in the North and Central European lakes, but by another method he arrives at the result that the lakes have some features in common with eutrophic lakes and others with oligotrophic lakes, and finally that there are some lakes which are halfway between eutrophy and oligotrophy.

In spite of the fact that Søgaard Andersen in the whole of his argumentation entertains the correct view that the lakes in East Greenland represent various stages between oligotrophy and eutrophy, and that the shallow lakes are closer to the eutrophic stage and the deeper lakes are closer to the oligotrophic ones, he concludes with the erroneous view that it is the long duration of ice cover and the consequent short period of vegetation which reduces the productivity of the lakes, and that all lakes would have been eutrophic if the period of vegetation had been longer, whereas now all of them are oligotrophic.

In previous works (K. Hansen 1959, 1962) it has been shown that the inorganic constituents of the bottom samples are suitable for characterizing the biological types of the lakes. The inorganic constituents of the bottom sediments are partly biogenetic, partly abiogenetic. The biogenetic constituents consist of the valves of diatoms, which can be represented by alkali-soluble SiO_2, and calcium carbonate; the main reason for this is that the plants through the photosynthesis remove so much CO_2 from the water that the content of $Ca(HCO_3)_2$ is changed into $CaCO_3$, which is precipitated and gradually deposited on the bottom of the lake (Wesenberg-Lund 1901). The abiogenetic constituents consist of mineral substance, which is represented by the difference between total SiO_2 and the alkali-soluble SiO_2. If, then, the biogenetic components are traced in percentages of the sum of biogenetic + abiogenetic components, the eutrophy may be expressed in percentages.

The humus state of the lakes was originally characterized by the colour of the water measured in Ohle or Hazen units as well as by the power of the water to reduce $KMnO_4$. However, no reliable numerical value can be obtained in this way, as the colour may be due not only to the content of the acid humus, but may also be due to other substances, e.g. iron and H_2S. Thus SØGAARD ANDERSEN's statement (1946) that the yellowish brown colour of the water under the ice in winter in Langsø is a sign of the presence of acid humus is undoubtedly wrong, as the colour according to his own statement disappears when the ice melts and the water gets rid of the sulphuretted hydrogen. It is no doubt this gas which under the ice gives a yellow colour to the water, for water containing humus does not lose its colour in summer.

The water's ability to reduce $KMnO_4$ cannot be used as a measure for the content of humus, as the water partly can contain substances which are not humus substances, but still reduce $KMnO_4$ (THUNMARK 1945), partly there are certain humus substances, especially in the peat substance, which are not oxidized by $KMnO_4$.

A much better criterion of the content of acid humus in the sediments of the lakes is the rate C/N (carbon: nitrogen). BOYSEN-JENSEN (1914) and WACHSMAN (1933) showed that in the mud deposits in the Limfjord and the Gulf of Maine, respectively, the rate of C/N was rather constantly fluctuating around 10. The investigations into the bottom sediments in Danish lakes showed that this also held true of lakes with gyttja, but in lakes in which the bottom sediments were dy or contained peat substance (tyrfopel), the rate rose to much more than 10. In various kinds of peat and in the mineral dopplerite, too, the rate C/N was much higher than 10 (K. HANSEN 1959), and from a comparison with bottom sediments from Swedish lakes (K. HANSEN 1961, 1962) it appeared that it was the peat substance in the bottom sediments rather than the contents of acid humus colloids that gave rise to the high C/N rate. In the marine humus this rate can also rise considerably above 10, especially off the mouths of large rivers carrying large quantities of vegetable matter or detached masses of peat into the sea, where they are deposited. In other places the rate might fall considerably below 10 (VAN ANDEL and POSTMA 1954.)

The diagram fig. 29 shows the distribution within THIENEMANN's system of lake types of the Greenland lakes dealt with here, with trophism as abscissa and humus state as ordinate.

The diagram shows that among the lakes in Greenland there is the same distribution as that found in the case of the lakes in Denmark and in Sweden. The lakes at Christianshåb, Egedesminde, Lillesø and Mellemsø and Qivítut in Disko Fjord as well as Taserssuaq, Atâ, and the lakes on Maria Ø and in Charcot Land in East Greenland, which have less than 35 per cent eutrophy, must be characterized as oligotrophic. The two most eutrophic lakes are Langsø on Ella Ø with 79 per cent eutrophy and Evqitsoq in Disko Fjord with 65 per cent eutrophy. Intermediate stages are represented by "Thygesens Sø" in Godhavn, the lake in Blæsedalen, and the lake at Fortunebay.

In the case of the East Greenland lakes the diagram shows complete agreement with SØGAARD ANDERSEN's statements. Langsø on Ella Ø in calcareous terrain is eutrophic. The two others in terrain with sandstone and shale or gneiss are oligotrophic. Among the four lakes,

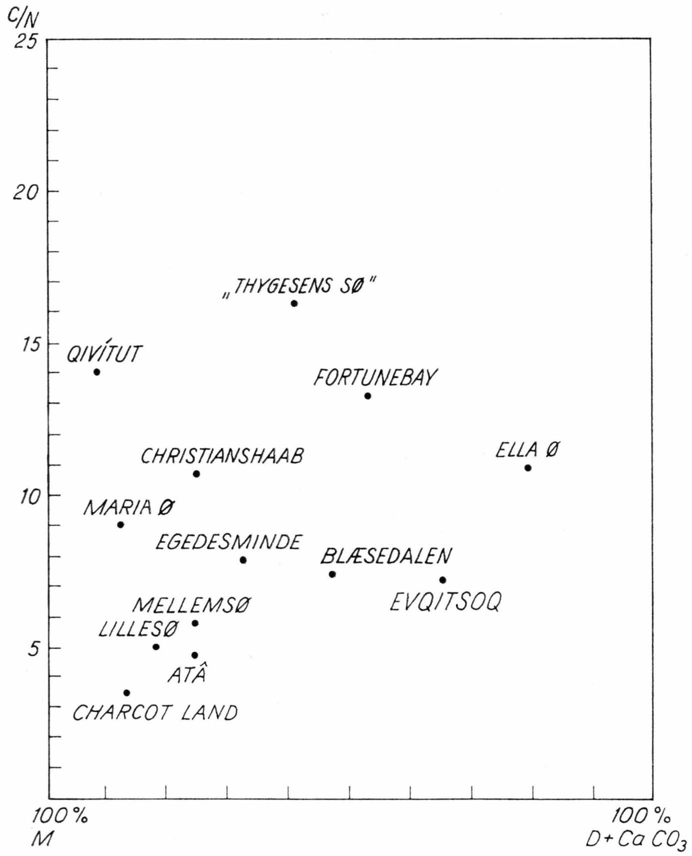

Fig. 29. Trophism and humus state of the lakes in Greenland. Abscissa. To the left 100 % oligotrophy, to the right 100 % eutrophy. M = mineral matter, D = diatoms. Ordinate the humus state. C/N = organic carbon: organic nitrogen.

"Thygesens Sø" and the lakes in Blæsedalen, at Fortunebay and Evqitsoq, the first-mentioned is undoubtedly somewhat polluted by the surrounding settlement, and in the diagram it is therefore shown to be somewhat more eutrophic than it would be in the pure natural state.

The lake in Blæsedalen obtains its water from the basalt area, and water analyses show that this lake has the highest content of SiO_2, viz. 9 mg/l. This will probably have a stimulating effect on the development of the diatom flora.

The lakes at Fortunebay and Evqitsoq (L) (probably both of them), obtain some of their water from the basalt mountains, but so does Mellemsø, which is much more oligotrophic.

These four lakes have a state of eutrophy which is of the same magnitude as that of Borresø and Almind Sø in Denmark as well as Örsjön and Frejen in Central Sweden. They are a little more eutrophic than Stråken near Anaboda in South Sweden.

The oligotrophic group of lakes with less than 30 per cent eutrophy are on the whole less oligotrophic than such lakes as Grane Langsø in Denmark, which has 4.8 per cent eutrophy, but are more oligotrophic than Fiolen in South Sweden, which has 27.6 per cent eutrophy (K. HANSEN 1961). For comparison with Erken in Central Sweden the following figures can be adduced:

	I	C	N	D	M	$CaCO_3$	C/N
St. 1	9.4	5.26	0.84	4.8	41.4	1.1	6.3
St. 2	14.0	6.90	1.12	8.3	38.4	1.0	6.3

This gives a eutrophy of 12.4 and 19.7 per cent, respectively.

The hydrographic determinations do not give any assistance to the determination of the trophism of the lakes. In summer they have all a fairly high percentage of oxidation at the bottom, except Lillesø. RØEN's measurements of electric conductivity and alkalinity offer nothing regarding appreciable differences between the lakes.

Nor does the phytoplankton give any help towards a determination of the trophism of the lakes. BACHMANN (1921) himself remarks that the lakes are rich in species, but on the whole poor in plankton. Table XIII shows the distribution of the number of species in the various lakes.

Table XIII.

	Ikerasak	Egedesminde	Blæsedalen	"Thygesens Sø"	Lillesø	Mellemsø
Diatomeae...........	..	17	22	31	21	17
Cyanophyceae	2	0	0	9	6	5
Flagellatae	0	5	0	1	0	1
Peridineae...........	0	1	0	0	3	1
Desmidiaceae........	10	0	1	22	23	8
Chlorophyceae.......	14	0	3	13	2	1
Total..............	26	23	26	76	55	33

These figures not only include samples of true plankton, but also scraped off material, however even if, on the basis of BACHMANN's statements, it is possible to separate the true plankton, all lakes are still rich in species. These figures are not, however, comparable, as BACHMANN in "Thygesens Sø" took samples on the 6th and the 12th of July and on the 12th and the 20th of August 1908. Here all species were recorded as they developed through the summer.

The waterlake at Egedesminde was visited by him on the 24th of June when a large part of the lake was still frozen over and the temperature of the water was only 5.6° C. Lillesø and Mellemsø were visited on the 13th of July, and RØEN's measurements of the conductivity just show that this is the time when the algal flora has reached its highest development and used most of the nutritive salts accumulated in the water during the winter, and finally the lake in Blæsedalen was visited on the 15th of August, thus at a time when the vital processes in the lake were dying out.

The only fact is that BACHMANN by all his samplings shows that the desmids are the dominant group of algae, and that the other forms occur more sparsely.

The result of these investigations therefore must be that all the deeper lakes are oligotrophic and that only the very shallow lakes, less than 5 m deep, have so great a percentage of eutrophy that they may be termed mesotrophic-eutrophic.

As regards the humus status of the lakes, "Thygesens Sø", the lake at Qivítut, and in part the lake at Fortunebay have such a high rate of C/N that they may be characterized as dystrophic, which is in good agreement with the fact that these lakes are in part surrounded by marshy stretches with peat and acid humus. Other lakes such as Lillesø and Mellemsø, Taserssuaq, Atâ, Lake Evqitsoq, and the waterlake at Egedesminde have a very low C/N rate, which must mean that the organic substance in the gyttja largely originates from proteins, and this, again, means that the total production of plant material is in equilibrium with what the fauna can consume. This, too, is in full agreement with the statements of the biologists, as appears most distinctly from VANHÖFFEN's remark that in the lake at Ikerasak the zooplankton occurs in such great quantities that the free-swimming or floating plants are far from able to nourish the rich fauna. In order to maintain so many animals in this lake the higher plants must contribute considerably, either directly by providing a nutrient substance or indirectly by giving nourishment and the opportunity of adhering to the diatoms and other lower plants which he could not obtain.

One might wonder that the lake in Blæsedalen only has a C/N rate a little below 10, since it has a large, old, now overgrown area at one end. The explanation is presumably that this lake has a very great circulation of water, as throughout the summer large quantities of water are supplied from numerous springs on the slope of Skarvefjeld.

The lakes at Niaqornat, at Rodebay, and at Ikerasak cannot be fitted into this system of types. They have a state of trophism of 19.5, 37.2, and 24.8 per cent eutrophy, respectively, which characterizes them as oligotrophic; but RØEN's measurements of the conductivity show a much higher content of ions than those made in the other lakes. This is connected with the fact that the two first are lagoons which are only separated from the sea by a beach ridge and the water of which is brackish, as shown by RØEN's determination of the contents of chloride ions in the water. This also influences the C/N rate, the bottom sample from the pond at Rodebay being so completely dominated by vegetable fragments that it might be characterized as a tyrfopel. Still its C/N rate is only 12.4, i.e. smaller than that of "Thygesens Sø". Thus here the lake is so polluted that the bottom samples have supplied an extra content of nitrogen. The lake, indeed, has a pH of 8.3.

If one wants to use these investigations as a basis for comparing the limnology of the North Greenland lakes with that of other lakes in arctic and sub-arctic regions, difficulties will arise because the number of measurements is limited and all were taken in the summer. Such a sparse material has been collected from northern Scandinavia, arctic Canada, and Alaska.

The greatest similarity with the deeper Greenland lakes (Lillesø, Mellemsø, and Taserssuaq, Atâ) is shown by the lakes on Moskenesøy in the Lofoten group in Northern Norway (STRØM 1938). Several investigations from Alaska have been recorded. Of these JUDAY's and his collaborators' investigations of the gyttja of Karluk Lake are of some interest (JUDAY *et al.* 1932). This lake has an extraordinarily high content of SiO_2 (60–73 per cent) and it is supposed that this is exclusively due to the contents of diatoms in the gyttja, which would constitute 80–90 per cent of the mass. As far as can be seen, these figures are based on what can be seen in an ordinary light microscope, but it is forgotten that it is not possible at all to see the content of clay in the sample or altogether the mineral substance with grains smaller than 16 μ. Even in a polarizing microscope this only appears as a foggy, greyish mass. A way of determining the contents of diatoms in the gyttjas which is only fairly accurate, is to determine them as alkali-soluble silicic acid, for their valves consist of opal. Instead, like Mrs. TUTIN (1955), one might count them and then determine the weight on the basis of a standard value for the contents of SiO_2 in the diatoms.

In the gyttjas from Danish, Swedish, and Greenland lakes, the silicic acid of diatoms, even from the gyttjas richest in diatoms, does not exceed 71 per cent of the total silicic acid; in the cases mentioned above some of the diatoms have got into Julsø by way of the Gudenå river (HANSEN 1961), and the total content of SiO_2 at most constitutes 52–56 per cent of the dried sample. The high content of SiO_2 in Karluk Lake is also remarkable, as, indeed, it is stated to be a eutrophic lake, and experiences from Danish and Swedish lakes show that the highest contents of SiO_2 occurs in oligotrophic lakes (Grane Langsø and Erken), and that in these lakes it is the mineral substance which is completely dominant as compared with the diatoms. There is hardly any other explanation of the high content of SiO_2 in the gyttja from Karluk Lake than assuming that in this lake, too, there is great supply of mineral matter. Besides, the lake is situated at much lower latitudes than the North Greenland lakes and under completely different climatic conditions.

VI. SUMMARY

When summarizing the various investigations discussed above we arrive at the result that the arctic lakes are characterized by their very short period of biological activity, which in most places ranges from the middle of June to a week or so into September. During the whole winter the lakes are inactive because of the thick ice-cover and because of the winter dark. (At Disko Bugt the sun does not appear above the horizon during the period from 21 November to 22 January.)

Because of this short active period the production of phytoplankton immediately after the melting of the ice shows a violent development, which later in summer is greatly checked by the zooplankton, which is quite dominant. This development is seen most clearly in the annual variations in the conductivity, alkalinity, and contents of Ca and Mg in the water.

All the fairly deep arctic lakes are pronouncedly oligotrophic, whereas the shallow lakes show a eutrophy of up to 65 per cent. Shallow lakes in limestone areas are pronouncedly eutrophic.

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Plate I.

Fig. 1. Sediment in the lake at Rodebay with numerous plant fragments. Prep. 1546. 300 ×.

— 2. Sediment from the waterlake at Egedesminde. Small mineral grains and structureless organic detritus and some diatoms. Prep. 1556. 300 ×.

— 3. Sediment from lake "Thygesens Sø" in Godhavn. Diatoms and structureless detritus, but also some plant residues. Prep. 1547. 300 ×.

— 4. Sediment from the lake on Kangârssuk, Fortunebay. Diatoms and structureless detritus. Prep. 1543. 300 ×.

— 5. Sediment from lake Lillesø in Disko Fjord. Mineral grains and diatoms. Prep. 1540. 300 ×.

— 6. Sediment from lake Store Sø on Maria Ø in East Greenland. Exclusively mineral grains. Prep. 1560. 300 ×.

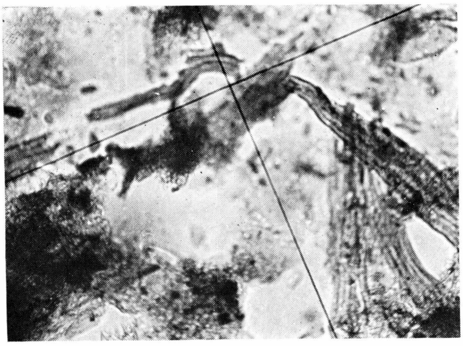

Fig. 1.

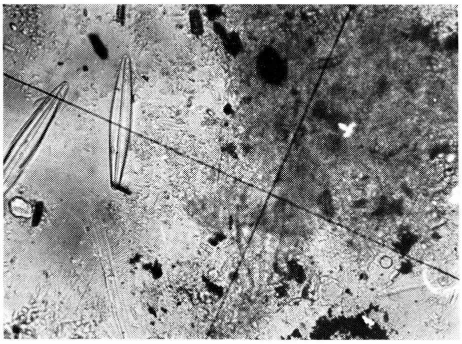

Fig. 2.

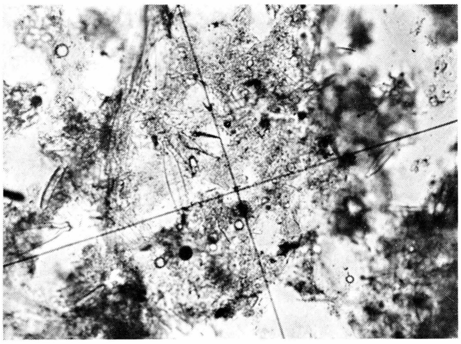

Fig. 3.

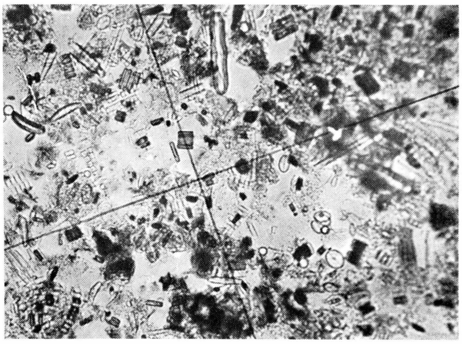

Fig. 4.

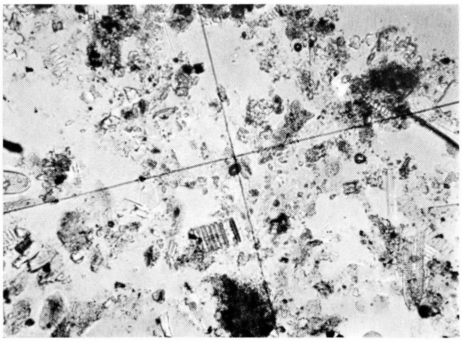

Fig. 5.

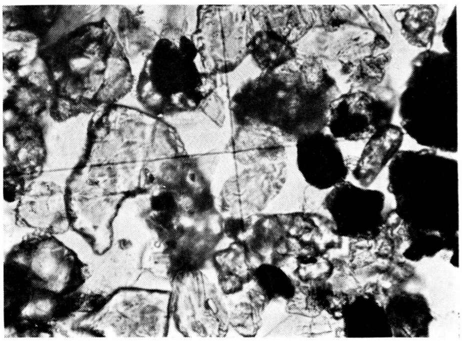

Fig. 6.