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GEOLOGICAL AND GEOGRAPHICAL INVESTIGATIONS IN KONG FREDERIK IX's LAND,

MORPHOLOGY, SEDIMENTS, PERIGLACIAL PROCESSES AND SALT LAKES

BY

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WITH 37 FIGURES, AND 11 TABLES IN THE TEXT,
5 PLATES AND 2 MAPS

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Abstract

Søndre Strømfjord and its continuation, the valley of Sandflugtdalen, constitute a morphological border between two types of landscapes. Towards the north the main morphological direction of valleys and ridges runs ENE–WSW parallel with the folding axes and diaclases of the Precambrian, whereas ice erosion seems to have influenced the relief much more towards the south where the main lines run SE–NW.

The sediments found around Sandflugtdalen are surprisingly homogeneous silt deposits, regardless of their origin. The mean grain size is about 30 microns, the sorting is very good, and the content of both sand ($> 62\ \mu$) and clay ($< 4\ \mu$) very low.

There are several salt lakes in the area and a belt of water mosses (Drepanocladus aduncus) is often seen along their banks, at some places pressed together in ridges with a surface layer of 15–20 cm sphagnum peat with pure ice below Also hillocks, solifluction terraces and other periglacial forms are abundant in the area.

The salt lakes of this area are peculiar in that their ion content differs strongly from that of other salt lakes. The salinity is about 3 $^0/_{00}$, but sulphate ions are almost completely lacking. The reason is that in spite of the arid climate, evaporation is very low because of the low summer temperature (below 10°C) and in addition, the soil is kept moist by the slowly thawing permafrost. The area around the lakes is therefore covered with a rich and abundant vegetation. The 30–40 cm of the soil that will thaw during the summer months are consequently very rich in humus and have reducing conditions. Thus, sulphate ions contained in the water seeping through will be reduced to sulphide and precipitate in the soil together with the iron, whereas the chlorine ions, which do not produce insoluble compounds, will continue unchanged out into the lake.

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PREFACE

In 1962 I visited Greenland with the main task of making limnological and sedimentological investigations, however I took the opportunity also to study other geological and physiographic phenomena in the areas visited. Especially the region around the head of Søndre Strømfjord presented many interesting aspects. The scarse time at my disposal allowed only a preliminary reconnaissance, however, and a later working up of the collected material revealed that a second visit to these regions would be necessary.

By benevolence from professor, dr. AXEL SCHOU, head of the Geographical Institute of the University of Copenhagen, as well as from the foundation Carlsbergfondet, and the Ministry for Greenland the necessary means were granted for a new visit in the summer of 1965 with the necessary assistance for the field work.

I am greatly indebted to these institutions and hereby bring them my deepfelt thanks for the grants received. For all help and guidance I also wish to thank most cordially the scientific leader of Arctic Station at Godhavn, TORBEN ANDERSEN, M.Sc., as well as Mr. HARRY CHRISTENSEN and the Danish liaison officer, Major HERMANDSEN from the Danish Air Force, all of whom willingly yielded us the necessary assistance. Last, but not least, I am indebted to my two assistants, KIRSTEN and NIELS NIELSEN, both M.Sc., for excellent work in the field and for the very pleasant company they were to me.

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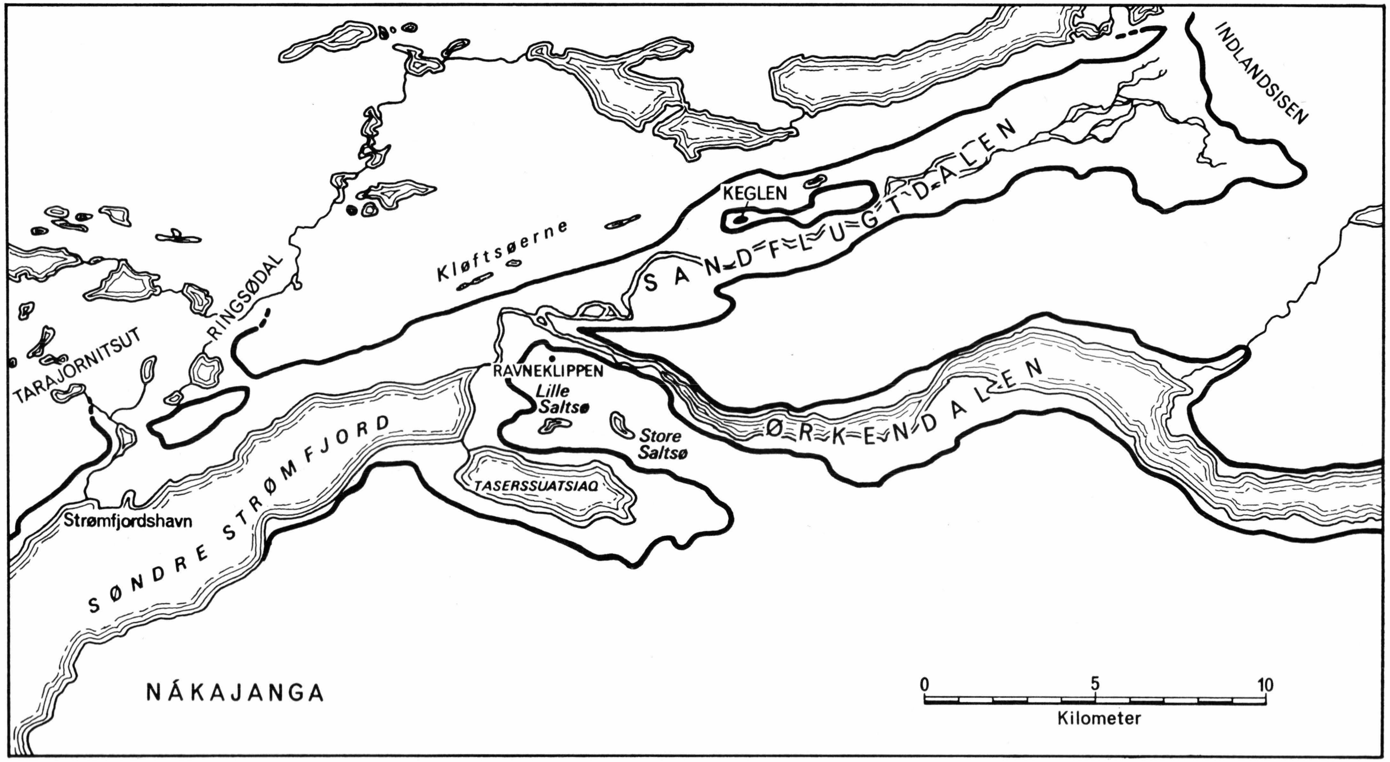


Map of the area round the head of Søndre Strømfjord.

INTRODUCTION

The area between Sukkertoppen Iskappe and Disko Bugt was long almost unexplored and only known to the Greenlanders who had their hunting grounds there for caribou; the primitive means of travel, common as late as in the 1930's by umiak (women's boat) as far upstream as possible and the rest of the way on foot, made life en route troublesome and gave only a superficial knowledge of the nearest surroundings.

With the building of the new airport at the head of Søndre Strømfjord it became possible to investigate the area in greater details, however, and on the basis of air photographs, excellent topographical maps have been drawn with a contour line interval of 50 m.

I. EARLIER INVESTIGATIONS

The first European visitor to these regions was the clerk O. V. Nielsen, at Holsteinsborg. In 1830, he went by dog sledge accompanied by three Greenlanders to the head of Amerdloq and farther on to Indlandsisen, which he climbed (Bobé, 1921). Presumably, he took the same route as Nordenskiöld and Hobbs did much later.

In 1879 J. A. D. Jensen and Kornerup travelled to the head of Nordre Strømfjord (Nagssugtôq) and farther upstream the river Kûk to Indlandsisen (Jensen, 1881). In 1884 Jensen revisited these regions and disembarked at the southern branch of Søndre Strømfjord at Umîvît south of Nákajanga, from where he continued through Aussivigssuit to Indlandsisen (Jensen, 1889). Pjétursson (1898) had visited the innermost part of Nordre Isortoq and left a few notes.

In 1909 Nordenskiöld was in these regions. He came through a valley, which from the northern branch of Ikertôq, at Maligiaq, leads to the big lake called Taserssuaq. From here, he continued to Indlandsisen, near the glacier Isúnguata sermia (Nordenskiöld, 1910, 1914). Although Nordenskiöld, contrary to J. A. D. Jensen, walked on the plateau itself and consequently had a better view, the whole region was still so unknown that the map of Holsteinsborg district (Meddelelser om

Grønland, vol. 61) presents it as a large, white spot with a few dotted lines to indicate the presumed course of the valleys up to Indlandsisen.

In 1926, the first expedition from Michigan University roughly followed NORDENSKIÖLD's route up to Isúnguata sermia, by HOBBS called "Nordenskiöld's Glacier" (HOBBS, 1927). This expedition lasted only a few days, whereas the second one from Michigan University, in 1932, (BELKNAP, 1941) stayed at the present Strømfjordshavn rather long and made observations along Sandflugtdalen up to Indlandsisen. Later, BÖCHER visited the area repeatedly (BÖCHER, 1949, 1959).

RØEN was here in 1959 together with BÖCHER and in 1962 together with the author, who also visited the district in 1965. Furthermore, RAMBERG, NOE-NYGAARD, and ASGER BERTELSEN have studied the area.

II. MORPHOLOGY

Studies of maps and air photos show very clearly that Søndre Strømfjord and its continuation, Sandflugtdalen, draw a line of demarcation between two areas whose main morphological direction lines in mountain ridges and drainage systems run nearly at right angles to each other, *viz.*: in the northern area ENE-WSW and in the southern part SE-NW.

The Northern Area

In a letter to J. A. D. JENSEN, SAMUEL KLEINSCHMIDT writes that as far as he knows the interior of the country is not high in altitude; it is said to consist of vast plains and low, hilly mountains (JENSEN, 1881). When travelling there in 1884 JENSEN and his companions climbed Pingo north of the lake Taserssuaq from where the view is described as follows: "While the wide valley east and west of the viewpoint presented itself as a long, straight street, allowing the eye to follow the numerous windings and ramifications of lakes and rivers, all the valleys towards the north and the south were hidden by parallel ENE-WSW going mountain ranges, which, especially towards the south, occurred with such a regularity that the landscape resembled huge ploughlands seen transverse to the furrows". (JENSEN, 1889).

In 1897, FRODA and PJÉTURSSON travelled via Nordre Strømfjord (Nagssugtôq) to Qardlínguit, and from here over the mountain to the valley occupied by the lake Ilivigdlup tasia (PETERSEN, 1898). FRODA describes the country as a highland at a level of abt. 300–450 m, from where undulating, small ridges and hills reach the height of 600–800 m and with small lakes everywhere. In the same report PJÉTURSSON wrote that from a mountain, about 400 m high, one saw towards the west fairly many grey, naked mountains of the same height as the observation mountain with numerous lakes in between. Both towards the south and the east the mountains had nicely rounded forms. Especially in the southern part of the area, visited on foot by FRODA and PJÉTURSSON, they noticed plenty of morainic material, and some of the rocks had faint, glacial striae running SE-NW. In the higher-lying places only erratic boulders were found, angular or more or less subangular, whereas the intermediary, lower stretches had enormous masses of gravel and sand mixed with boulders. So to say all projecting rock ridges had morainic gravel around them and from the rock core a ridge of gravel was often extending, mostly oriented towards the ice, whereas smaller heaps of gravel lay sheltered behind the rock.

NORDENSKIÖLD (1910) writes: "It is a queer landscape. The country is rather low-lying, intersected by wide valleys from which low, but steep, mountain chains rise. Countless numbers of lakes are seen in the valleys, some are large, but most of them are small: some of them, in any case, are distinct rock basins. Peculiar enough, no marked glacial topography is found.

Two factors have been of importance to the topography of the Greenland landscape: partly the strike and the gradient of the gneiss, partly the unusually high degree of weathering. It is evident that for long periods the ice has not covered more of the landscape than it does at present. It is obvious that the ice is in an alien area, where, perhaps as in earlier stages, it does not regenerate. Fluviatile gravel is seen, but no extended occurrences of moraine".

Later, NORDENSKIÖLD (1914) wrote: "Generally, the landscape does not have the character of plains. The valleys, as well as the low passes 300–400 m above sea level, are wide and flat and in between them broad, rounded ridges rise, here and there also isolated hills. The greater part of the area is covered with a loose layer consisting of angular stones, presumably a weathered and rebedded moraine, which is not of much thickness, however. Where the rocks lie in the open, they are frequently weathered and the ridge form is mostly determined by the strike and the gradient of the gneiss.

In summertime streaming water is scarce, and between the two large main valleys, Isortoq and Søndre Strømfjord with tributaries, the water has nowhere eroded valleys of some importance, whereas there are numerous lakes of various size, rock basins as well as lakes surrounded by moors and loose soil. Some are typical narrow valley lakes, others are irregular depressions bordered by rock ridges".

NORDENSKIÖLD presumed that he observed an old, during the Tertiary raised peneplain which had later cracked in the margin zones, whereas it did not break under the ice. He compares it with the transition zone between the central and the north-eastern part of Sweden. Both HOBBS (1927) and BELKNAP (1941) describe the landscape as roches moutonnées of moderate relief, predominantly carved by the ice.

The contour maps 66 V. 1, V. 2 and 67 V. 1, V. 2 from the Geodetic Institute (Enclosed 66 V. 2 and 67 V. 2) show that the northern area 1) falls into three sections. Southernmost towards Sandflugtdalen a rather low-lying region with hills between 200–500 m above sea level, which towards the north is bounded by the upper reaches of Isortoqelven to the point where this turns sharply NNW. From here, it continues with direction WSW towards Maligiaq and farther on along the north side of Amerdloq to Holsteinsborg. To the west, this zone becomes more and more narrow and finally, it is restricted to the valley with the lake Taserssuaq mentioned by NORDENSKIÖLD and HOBBS.

The surface of this section forms markedly flat valleys running WSW-ENE and with innumerable larger and smaller lakes, often in long chains (figs. 1 and 2). There are no tributaries and outflow from the lakes, but from the air one can observe them connected by fresh green vegetation bands, which hint at seepage of water through the dip. The landscape is so young that the streams have not yet eroded gullies between the lakes, and these have, as seen at many places in Greenland, no proper outlet, but only an overflow, *i.e.* a small ditch merely a few centimetres deep. Sometimes the small lakes are drained transverse to the longitudinal direction of the area into one of the deep valleys (Sandflugtdalen or Kûk).

During the period of snow melting these longitudinal valleys presumably make up one big lake with outlets at both ends into the deep valleys and through gaps in the mountain ridges. In summertime, however, water only seeps from the surface of the still thawing permafrost out into the lakes.

2) To the north we have the second, higher-lying section, bounded to the north by Nordre Isortoq and a valley which from its eastern part leads toward ENE to Kûk. The highest parts lie along the south bank of Nordre Isortoq and here reach heights of up to 1400 m. East of Kûk, the area is lower and reaches only 800 m at few places, but largely with a similar relief (fig. 3).

3) The third section, situated north of Nordre Isortoq, is again lower-lying and forms an archipelago area along Nordre Strømfjord; heights of 1000–1500 m are only found in a small area, at Akuliaruserssuaq, just north of Nordre Isortoq. To the east and northeast the heights are generally below 700 m and with decreasing altitudes towards the north and the east. Also here the landscape has changed. North of the inner

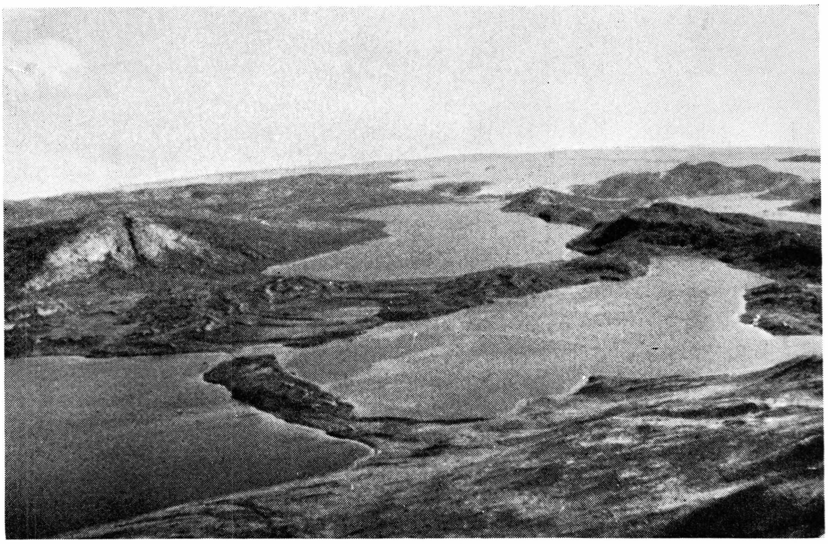


Fig. 1. Air photo of the plateau located just north of the innermost part of Sandflugtdalen, which can be discerned in the background to the right. In the foreground, the two long lakes Sáningassoq and Aujuitsup tasia.

Photo 2782.

Fig. 2. The plateau between Sandflugtdalen and the valley containing Isortoq-elven and with the glacier Isúnguata sermia in the background. The photo shows the many cirques and other evidence of glacial erosion and also that the steep valley sides turn towards the south.

Photo 2780.

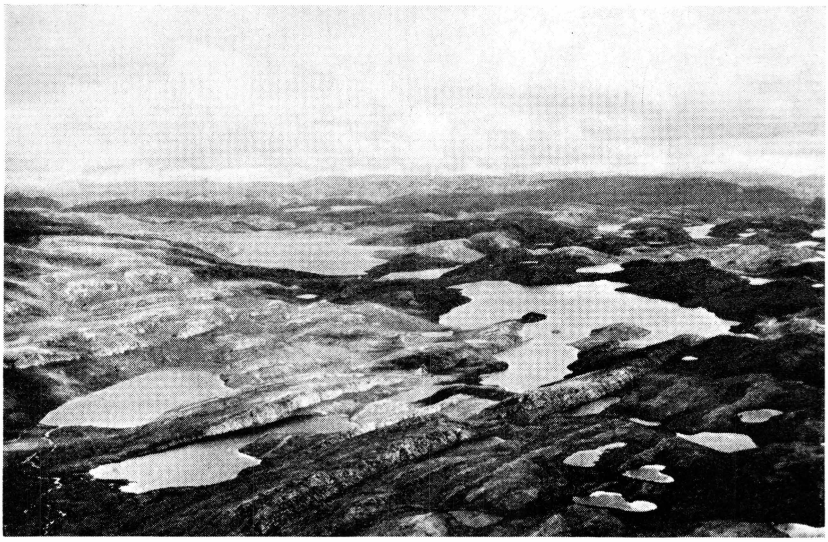


Fig. 3. The landscape north of upper Isortoqelven. It appears very clearly how the diaclases of the gneiss determine the relief with the steep southern walls and the more gently sloping northern valley sides. It is also seen that in some places the diaclases have caused formation of lakes, presumably shallow, beneath the steep southern walls, but also here are clear traces of cirques.

Photo 2781.

Fig. 4. Further to the north the valleys widen and loose sediments cover the floor in which the rivers meander. The valley sides are still parallel rock ridges with steep south sides and more gentle north sides.

Photo 2783.

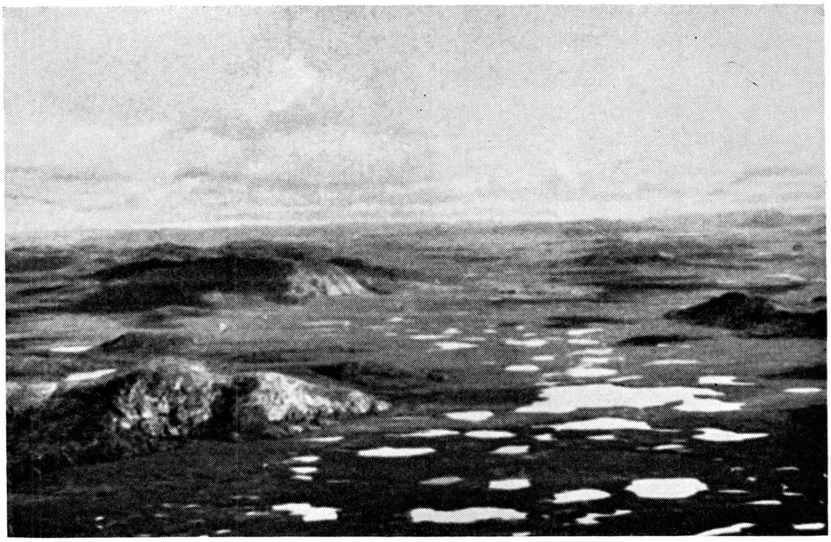


Fig. 5. Farther up towards Disko Bugt, whose icebergs are faintly seen behind the plain which is dotted with lakes in the loose sediments. The significant rows of rocks display the structure of the diaclases.
Photo 2784.

part of Nordre Strømfjord the valleys are wider and have small meandering streams (fig. 4) In the northernmost part, they have changed into green plains dotted with small lakes. Rising from the plains, parallel rows of mountain ridges still run in the direction WSW-ENE (fig. 5).

The Big and Deep Glacial Valleys

Belknap (1941) writes that these are of a special character. They are fed with glacial meltwater and do not have their maximum rate of flow in humid periods, but rather in summertime, and mostly their rivulets disappear in winter. They have an irregular gradient.

Two glacial valleys of this kind are found in the northern area: the valley of Kûk which opens on to the southern ramification of Nordre Strømfjord, Kûp akua, and the valley of Isortoqelven.

In its full extent, Kûk runs transverse to the catchment system of the plateau. The valley floor is even and near Indlandsisen it lies not more than 100 m above sea level. In 1879, J. A. D. Jensen and Kornerup travelled through the valley. Jensen (1881) gives the following description: "The river carries so much sand and clay which is deposited at the outlet into the fjord that the depth of it decreases so gradually that it is difficult to decide where the fiord ends and the river starts. At the mouth, the river divides into several branches between clay bars; onboard the umiak, however, we succeeded in rowing nearly up to Indlandsisen, where the river Kautoríssat discharges into the valley. At several places along the river the mountains give space to a broad foreland". At Kautoríssat water samples were taken; a later determination of the content of mud gives the following result:

158 g	water contained	0.0372 g	mud	=	0.235 g/l
157 g	– –	0.0312 g	–	=	0.198 g/l
150 g	– –	0.0325 g	–	=	0.215 g/l

The substantial quantities of mud cause a continuous growing of the mouth of the river farther out into the fjord; but already at that time the journey was so troublesome that it took four days because of strong current and the many clayey banks.

The innermost part of the valley of Isortoqelven is filled up by the glacier tongue Isúnguata sermia. The first 22.5 km of the valley run parallel to the general structural direction of the area, then it bends sharply towards NW until it meets the outlet from the lake Ilivigdlup tasia, where it turns WSW again and joins the Nordre Isortoq at Umîvik. The easternmost part of the valley forms the boundary between the southern area (Ikertoq Gnejsen) and the intermediate area (Isortoq Gnejsen). A more detailed description of the valley is not given. KORNERUP and JENSEN did not reach farther than to the mouth of the river. JENSEN (1881) writes that formerly the river is said to have been navigable for umiaks as far as up to its source at Indlandsisen, but in the course of time, much clay has accumulated, the course and the windings of the river have become so numerous and complicated, and the current flow so heavy that Umîvik can only be reached in July and August when the current is the weakest. At Umîvik samples were also taken of the river water for later determination of content of mud; the result was:

158 g	water contained	1.4424 g	mud	=	9.129 g/l
152 g	– –	1.4810 g	–	=	9.844 g/l

The Southern Area

The area bounded to the north by Søndre Strømfjord and Sandflugtdalen and to the south by Indlandsisen and Sukkertoppen Iskappe is even less known than the northern area.

In 1884, J. A. D. JENSEN visited the valley joining Søndre Strømfjord in Umîvît south of Nákajanga. He states (JENSEN, 1889) that the river flows into Søndre Strømfjord through a large horizontal terrace overgrown with willow scrub. Along the river banks and in the midstream islands several smaller sand dunes are seen, made by the fine sand and clay which the river carries along. The walk on the terrace is so even and comfortable that it would have been possible to use horse and carriage for transportation of luggage except for a few places where the river runs too close to the steep valley side. A well-worn path shows clearly that this easy access to the region to the east is used every year by many caribou hunters. After about 15 km the path leaves the river, takes more to the north and leads to a big lake, Angmalortoq, with a summer camp for caribou hunters at the southern bank. According to reliable Greenlanders, salmon is found there, which is peculiar since the lake has no outlet. The banks consist of white, laminated clay in thin, almost horizontal layers.

Two expeditions from Oxford University have visited the southernmost part of the area, namely in 1935 (Hayward, 1936) and 1936 (Mott, 1937). They started from Søndre Strømfjord along Safartôq and continued south to the northern marginal zone of Sukkertoppen Iskappe and the tongue which discharges into Evighedsfjord from Indlandsisen. These two firn areas are separated by a valley stretching towards SW to Evighedsfjord and with watershed southwest of the east-end of the big lake Tasersiaq along the northern margin of Indlandsisen, about 700 m above sea level. Already Bendixen (1921) mentions this valley, and it is clearly marked on the map of Sukkertoppen district in Meddelelser om Grønland, vol. 60 and 61 with accompanying atlas.

Further, Kaiser (1928) writes that the Sukkertoppen Iskappe is not an outlet from Indlandsisen, but "a number of coalescing ice caps which owe their existence to the considerable mountain heights of these localities". Thus, it is incorrect when Böcher (1956) states that "the glaciated firn around Evighedsfjorden is in direct connexion with the inland ice eastward".

The first of the expeditions from Oxford University was only made to get an idea of the area. From the second one, Sugden (Mott, 1937) describes the area northeast of Sukkertoppen Iskappe as a 4000 ft (1220 m) high plateau, deeply eroded by glacial valleys. Their direction and form and especially the fact that some of the valleys continue at the other side of Søndre Strømfjord, indicate a widespread influence of faulting. Thus, west of the fjord, the Sarfartôq valley continues in the Itivdleq fjord; but according to Sugden, the canyon of the upper part of Sarfartôq was cut into a structurally weak zone. The bottom of the lower Sarfartôq valley is covered with a thick layer of glacial silt that was apparently deposited at a time when the valley was a lake. On the whole the river leaves the impression that it has been eroded into the old lake floor which is now seen as a 24.38 m high terrace at the outlet into the fjord, whereas it only reaches 9.14 m at the mountain, "The Island", which rises from the valley floor and bars the view. These levels correspond fairly well to the shorelines at the mouth of Søndre Strømfjord.

SUGDEN is further of the opinion that the Tasersiaq valley is of typical glacial origin. Former, higher levels of the lake are indicated by raised beaches and promontories and it has presumably had an overflow into Evighedsfjord through the valley situated between Indlandsisen and Sukkertoppen Iskappe, which at that time is likely to have extended to the valley lying west of the lake, the outlet of which it has dammed towards NW.

The rocks found in the area visited by the Oxford Expeditions are a greyish-brown gneiss with numerous dolerite veins in it. The prevailing strike of the gneiss is ENE-WSW. In the neighbourhood of the fjord, the dolerite intrusions were found to be most frequent and to become more scarce at the western end of Tasersiaq. The gradient of the sheets towards NNW has contributed to the formation of escarpments with the steep slopes towards the NNE.

From maps and air photos made by Geodetic Institute in Copenhagen it appears that the topography of this southern area is quite different from the northern part. The main topographical direction of valleys and mountain ridges runs SE-NW, *i.e.* almost at right angles to the directions prevailing in the northern area.

The southern area can be divided again into a northern and a southern section. The boundary between them runs from Angujârtorfik at the south coast of Søndre Strømfjord, along the upper part of Angujârtorfiup kûa and Arnangarngup kûa, NE toward the upper reaches of Qangátap kûa, and then on to Indlandsisen.

The northern section (Pl. 1) is characterized by lengthy mountain ridges separated by wide and deep valleys alligned in a NW-SE direction. The rivers occupying the two easternmost valleys originate from Indlandsisen. The lake of Taserssuaq fills the central part of a valley terminating in the bay of Tatsip atâ, while the lake has its outlet toward SW to the next big valley, through which Angujârtorfiup kûa flows.

The mountains lying between these valleys are very different from the mountain ridges in the northern section. They are broader and have an uneven surface dotted with many lakes which do not lie in chains. These lakes, however, often traverse the longitudinal direction of the massif. Several of them have no outlet. The massifs are broken by wide, flat valleys with clear evidence of water erosion in the floor as well as erosion gullies in the end slopes. In general, the shape of the ridges is more rounded than in the northern section, and when steep, vertical walls occur they front on the SW.

On the whole, the southern section is higher-lying, 1000–1300 m, with the highest altitudes in the southwestern part, (Pls. I and II). However, it has more the appearance of a plateau bisected by fluvial erosion valleys running NW-SE. Southernmost, the whole zone is cut through by one erosion valley, Kangimut kûgtoq, which has its source in the west and falls toward the east in the direction of Indlandsisen. In the east-end it has outlet southward into the long valley with the lake of Tasersiaq; now, this drains toward the NW through the canyon of Sarfartôq, but as mentioned above, it may originally have had its outlet toward SW to Evighedsfjord through the valley between Indlandsisen and Sukkertoppen Iskappe.

Certainly, the appearance of these landscapes is mostly the result of an interaction between the structure of the gneiss and the erosion from ice and water.

The Folding Zones of the Gneiss

In the Greenland Precambrian, between Sukkertoppen Iskappe and Disko Bugt, two foldings are recognizable (Ramberg, 1948, Noe-Nygaard, 1952, Noe-Nygaard and Ramberg, 1961, Berthelsen and Noe-Nygaard, 1965, Noe-Nygaard and Berthelsen, 1952). The boundary between the foldings runs eastward from the Itivdleq fjord, across Søndre Strømfjord, and continues eastward to Indlandsisen.

The southern orogeny has been named the Kangâmiut complex by Ramberg (fig. 6). It is a hypersthene-bearing quartz-dioritic gneiss with the main strike in a SW-NE direction. The gradient is very steep. The complex is estimated to be of the same age as the Ketilides orogonies in South Greenland (Wegman, 1938). The Kangâmiut complex is fairly homogeneous and relics of obvious sedimentary origin are seldom. It has undergone a recrystallization and a metasomatic transformation under regional metamorphosis conditions corresponding to the granulite facies. The Kangâmuit complex is characteristic by the innumerable basic inclusions in the shape of thick swarms of vertical diabase dykes that interject the complex in south-westerly direction.

To the north and farther up to Jakobshavn, a younger orogenic complex is found, which Ramberg called the Nagssugtoqides. They are folded along NE-SW striking axes. Between Søndre Strømfjord and Nordre Isortoq the Nagssugtoqides dip toward the SW, in Nordre Isortoq toward the east, and farther northward they are horizontal. The Nagssugtoqides are divided into three zones according to degree of regional metamorphosis.

Southernmost lies the Ikertoq gneiss, stretching from the Kangâmiut complex toward the north to the line along the Amerdloq south of Holsteinsborg and farther eastward in the direction of the strike and up to Indlandsisen. The Ikertoq gneiss is strongly dominated by the fact that parts of the Kangâmiut complex were affected by this younger folding; thus, the diabases have been folded, distorted and recrystallized

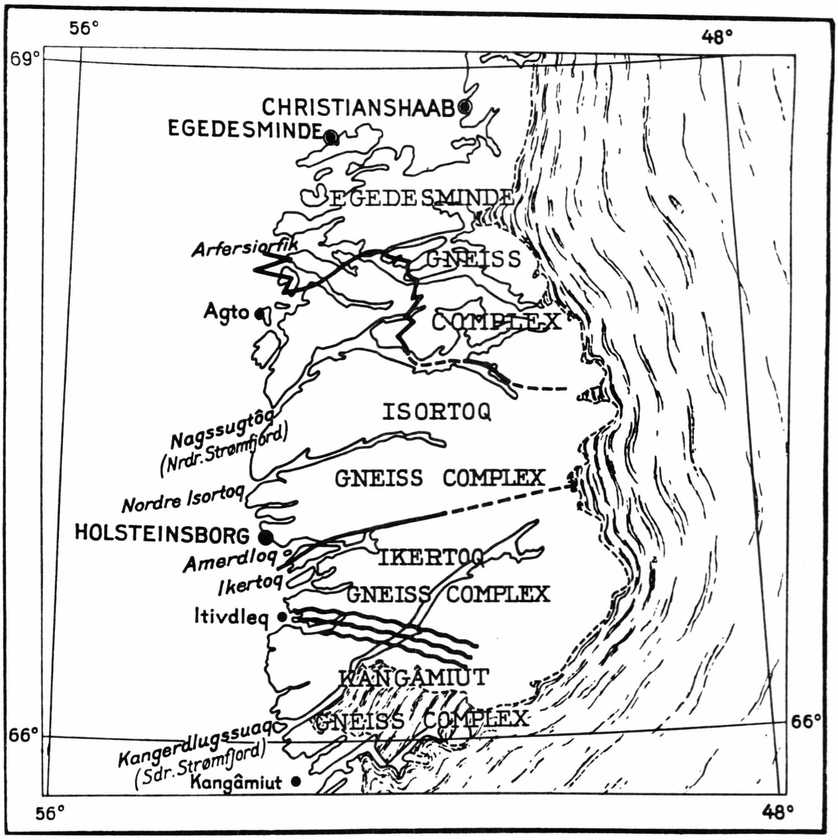


Fig. 6. Sketch map showing the different metamorphic facies of the Nagssugtoqides in West Greenland. The Egedesminde gneiss complex and the Ikertoq gneiss complex are formed in amphibolite and partly epidote amphibolite facies. The Isortoq gneiss complex is formed in granulite facies. The boundary zone between the old Kangâmiut complex and the younger Nagssugtoqides is also indicated. (RAMBERG, 1948)

into amphibolites affected by metasomalism and broken into large boudins.

North of the Ikertoq gneiss we find the Isortoq gneiss; this extends up to a boundary starting from the entrance of Arfersiorfik, takes a zigzag course southward to Ataneq, then curves first north-eastward to Arfersiorfik and along this towards the southwest to Kigssaviat at the south-western part of the island called Tunertoq. From here the boundary turns southward to Nagssugtôq and follows its southern branch, after which it is presumed to bend more toward the east and then up to Indlandsisen. The main rock of the Isortoq gneiss is a hypersthene-bearing quartz-dioritic gneiss (an enderbite similar to the main gneiss that is found in the older folding chain of the Kangâmiut complex). The enderbitic gneiss is homogeneous over large areas, but in general it is full of schlieren, inclusions and boudins of hypersthene-bearing amphibolites. The metamorphosis has occurred in granulite facies; it has a higher degree of metamorphism as compared with the north- and south-lying areas.

Northernmost lies the Egedesminde gneiss, which is a light rock of granodioritic composition, recrystallized in epidote-amphibolite and amphibolite facies.

The Ikertoq and the Egedesminde gneiss have many similar features. Both are granodioritic gneisses containing biotite and often also green hornblende and/or epidote; both of them have amphibolite bands and boudins, whereas ultrabasic rock is seldom observed. The difference between them is that rust-brown zones containing pyrites and graphite and a little marble are often encountered in the Ikertoq gneiss, which has a natural explanation as it is partly reactivated Kangâmiut gneiss with diabases. Marble is not found in the Egedesminde gneiss, whereas a large zone with albite porphyroblastic schists, unknown in the Ikertoq gneiss, is encountered here.

The Isortoq gneiss is more intensely metamorphosed than the other two gneisses, and a marked difference in composition can also be ascertained. The enderbite gneiss is poor in potassium and water, and the rate of Fe^{+++}/Fe^{++} is small compared to the main gneiss of the Ikertoq and Egedesminde complexes. The whole Nagssugtoqide complex has been formed by an orogenic deformation of an east-west geosyncline. The Ikertoq gneiss, however, is reactivated Kangâmiut gneiss.

Of still greater importance to the morphology of the area are the diaclases. Kornerup (1881) writes that everywhere between 60 and 70°N one has the impression that a certain relationship exists between the diaclases of the mountains and the relief of the landscape. The interfaces in every mountain ridge, every valley, sound, bay, small fjord and islet group are formed by the diaclases or the cleavage planes; but what especially leaps to the eye is the parallelism which is still distinguishable in the roof-shaped mountain ridges and consequently also the intervening groove-shaped depressions or valleys, in any case within the visual range, and it is surprising to notice the constant position in cleavage plane over long distances. The idea suggests itself that these diaclase systems have occasioned the occurrence and shape of all depressions and elevations in the original gneiss surface, and Kornerup expresses the hope that various problems concerning the fjords, especially their frequent parallelism and bifurcation, will find their solution here.

Finally, Kornerup suggests that it would be reasonable to presume that the fundamental elements of the present surface were already brought about before water and ice began their erosion work, but that the diaclases have been the indispensable contributing factor. For a satisfactory explanation of the evolution of fjords it should therefore neither be necessary to credit water and ice for supernatural forces, nor to postulate that the period of action has been tremendously long. The work of the ice has largely been to detach, disintergrate and remove the rock material that was already split by the diaclases, material which apparently long ago covered and partly constituted the surface of the ground prior to Indlandsisen. The later work of the ice was therefore mostly a rounding and smoothing of the angular forms, whereas a real cutting in solid rock presumably only took place under specific conditions.

Everywhere in this gneiss area the relief possesses a step-like appearance with steep, vertical walls towards south and west and more gentle slopes towards north and east; furthermore, the wide, flat east-west going valleys are characteristic with steep northern slopes and more gentle ones on the southern side, whereas valleys of this kind are more seldom in the direction N-S; when they do occur they are very deep.

Today, both contour maps and air photos from the area north of Søndre Strømfjord show clearly that the folding axes of the gneiss and the strike of the diaclases have been of great importance to the genesis of the landscape. Presumably, ice erosion has also contributed to the development of these long, wide valleys going WSW-ENE with their long chains of lakes.

The greater part of the Greenland lakes, which have been investigated more detailed so far, proved to be shallow (RØEN, 1962, K. HANSEN, 1967). Depths of 4–5 m are common for lakes located in the E-W going diaclase valleys, but few lakes are deeper than 10–12 m. This will presumably also be true for most of the lakes in the area discussed here; they are probably product of ice erosion, which has given the substratum an uneven, undulating form. From the air photo, fig. 1, however, clear cirques can be observed and some of the lakes look like cirque lakes presumed to be rather deep (STRØM, 1935).

Farther northward, at Naternoq in the Egedesminde gneiss, marine deposits have contributed to create the big clay plains (LAURSEN, 1950), but also here the emerging rocks lie in parallel rows and are marked by the strike of the diaclases (fig. 5).

Largely, the courses of Isortoqelven and Kûk coincide with the N-S striking diaclases, but what might have produced these deep valleys is difficult to say. Both rivers come from Indlandsisen, are extremely well watered with a very strong current, and both carry large loads of material, which may have caused a deeper erosion in the valleys; it seems, however, as if in any case the abrupt change of direction of Isortoqelven to a certain degree has been brought about by a weak zone in the gneiss along a N-S striking diaclase. Only further investigations in the valley can throw light on this problem.

Further, it is characteristic that the intermediate high-lying section coincides with the range of the intensely metamorphosed Isortoq gneiss. Both in the area discussed here and farther to the west the boundary to the Ikertoq gneiss stands morphologically very sharp, whereas the boundary between the Isortoq gneiss and the Egedesminde gneiss is by far less marked in the topography.

The conditions prevailing in the area south of Søndre Strømfjord and Sandflugtsdalen are quite different. Here, apparently no relationship exists between the morphological lines of direction and the structure of the gneiss. Mostly they seem to be transverse to each other, and this is true both within the ranges of the Ikertoq gneiss and the Kangâmiut complex (pls. I and II).

Air photos of this area show that the diaclases of the gneiss are striked in exactly the same direction as it is the case in the northern area, but they are less marked and sharp, and especially the E-W striking diaclases have not given rise to valleys. Here, as far as contour maps and air photos allow an interpretation, erosion forces from both ice and rivers have played a by far greater role than in the northern area, and additionally, some of the streams with source outside Indlandsisen are waterbearing the whole summer. In any case this is true for Arnangarngup kûa, the tributary to Sarfartôq, according to Hayward (1936) and Mott (1937).

On the map several of these streams show remarkable, winding courses, which might be an indication of a previous capture between some of them, or, that the valleys were dammed at the lower end and the rivers consequently forced to change direction. However, only more detailed field investigations can solve this problem. On the whole, this region between Søndre Strømfjord and Indlandsisen seems to present a rich working field for the study of the evolution of a landscape in a former glaciated gneiss area.

It appears from the foregoing that the two most intensively metamorphosed types of gneisses, the Kangâmiut complex and the Isortoq gneiss of the Nagssugtoqides, have been more resistant to the erosion than the less metamorphosed Ikertoq and Egedesminde gneiss. In the case of the Ikertoq gneiss its content of reactivated Kangâmiut complex is reflected also in the topography, the mountains here thus being significantly higher than the mountains within the Isortoq gneiss.

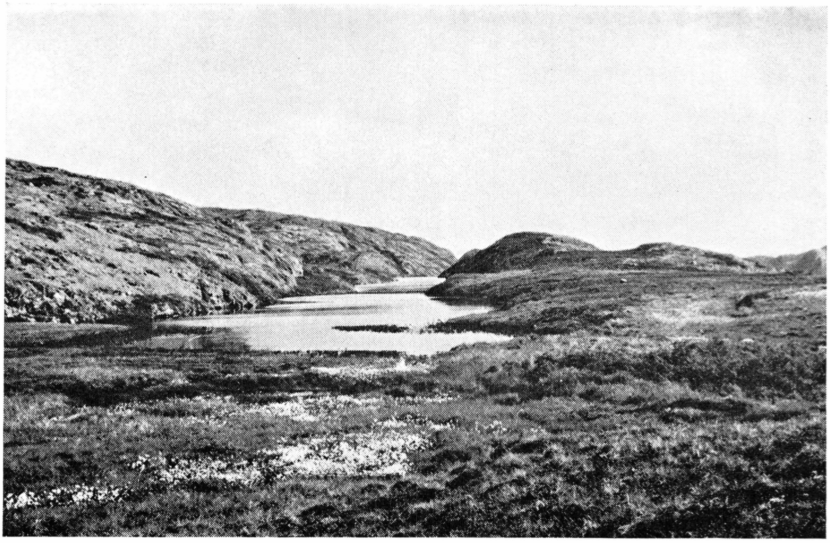


Fig. 7. Kløftsøerne 300 m a.s.l. on the northern slope of Sandflugtdalen. This cleft can be followed in a straight line all the way up to Indlandsisen.
Photo 2770.

III. SANDFLUGTDALEN

Map page 6

Morphology

Sandflugtdalen is the continuation of Søndre Strømfjord and extends 25 km farther up to Indlandsisen. The northern side is an unbroken, steep slope with the lower part covered with loose deposits, with an abundant vegetation and many willow scrubs, see pl. III. At some places big blocks are seen far up on the slope, which is so steep that one cannot imagine the blocks to have fallen down from above and then stopped at their present positions. They must simply have been deposited here formerly by an ice tongue, which has occupied the valley.

At a height of 350 m above sea level, a relatively narrow valley train has been formed, which is occupied by innumerable long and narrow lakes, called Kløftsøerne (fig. 7). The terrace can be followed all the way up to Indlandsisen. At some places, long, low rock ridges are seen outermost on the terrace. Behind it, the ground rises to heights of 550 m at the Søndre Strømfjord airport, whereas at Indlandsisen the height does not exceed 400 m above sea level.

The southern side of Sandflugtdalen has a more irregular form with traces of old cirques and glacial beds. Westernmost, Ravneklippen stands with vertical sides facing Søndre Strømfjord and Sandflugtdalen. To the east, is a large plain with the floor 140 m above sea level and

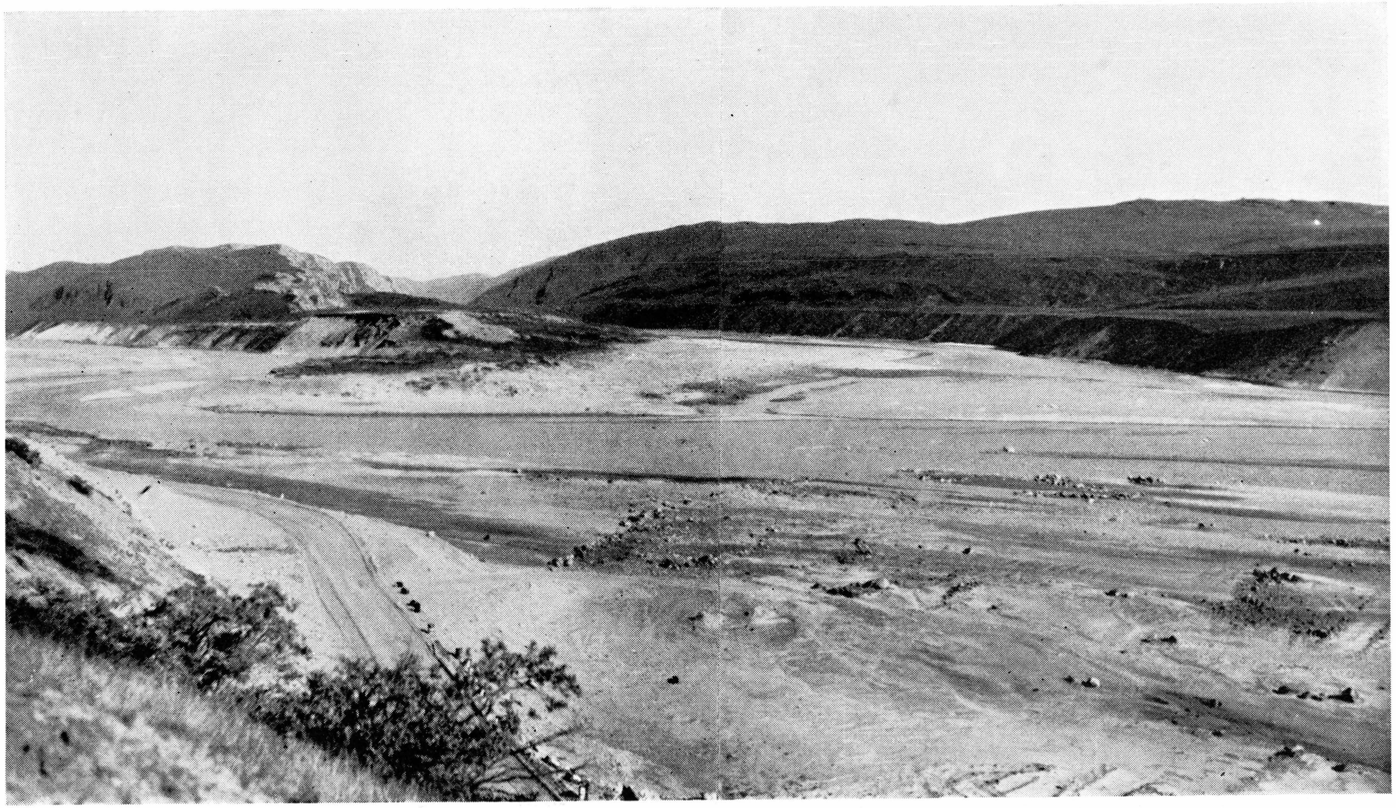


Fig. 8. Sandflugtdalen and its only terrace, here located 55 m a.s.l., at the entrance to Ørkendalen.

Photo 4186–87.

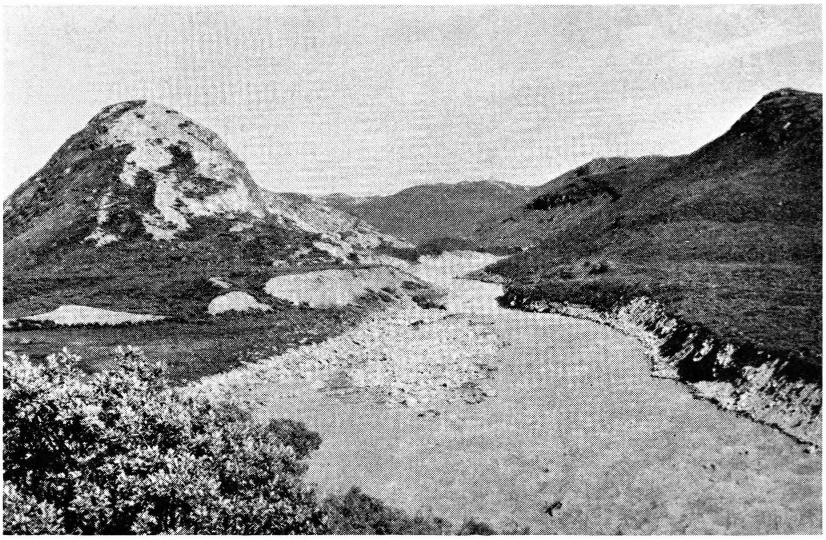


Fig. 9. South of Keglen, the narrow branch of Sandflugtdalen through which the river foams. Photo 2742.

above it a second flat area 186 m above sea level (barometer reading). A little farther to the east, Ørkendalen joins Sandflugtdalen, but east of Keglen the valley side is steeper and presents less marked traces of glacial erosion, and the sides are covered with a rich and dense vegetation (fig. 8). Keglen is the western part of a mountain ridge, which for 5 km splits Sandflugtdalen into two parallel valleys. The southern one is quite narrow and carries a meltwater stream from Indlandsisen; the gradient is rather steep (100 m in 5 km) and there are two cascades, one at the eastern end and another at the western end of the mountain ridge that divides the valley (fig. 9). North of this ridge, Sandflugtdalen is almost one kilometre wide; at Keglen the floor is 250 m above sea level and rises gently towards the east to 260 m. At the western end several moraine ridges are seen down the northern slope of the valley, which is probably also blocked towards the west by a moraine ridge. Also in the eastern end of the dividing mountain ridge, moraine mounds lie aslant down the mountain. The valley floor contains several larger and smaller lakes with swampy and peat-like banks and surrounded by a dense vegetation (fig. 10). In winter, when the ground is frozen, vehicles can go through this valley, but in summer, when the soil has thawed, it happens rather often that they get stuck in the soft ground.

At the reunion of the two branches of Sandflugtdalen the valley floor makes up a wide alluvial plain with a braided river system. This alluvial plain lies 11.4 m lower than the valley floor with the lakes. The border between them is covered with a large sand drift sheet, however

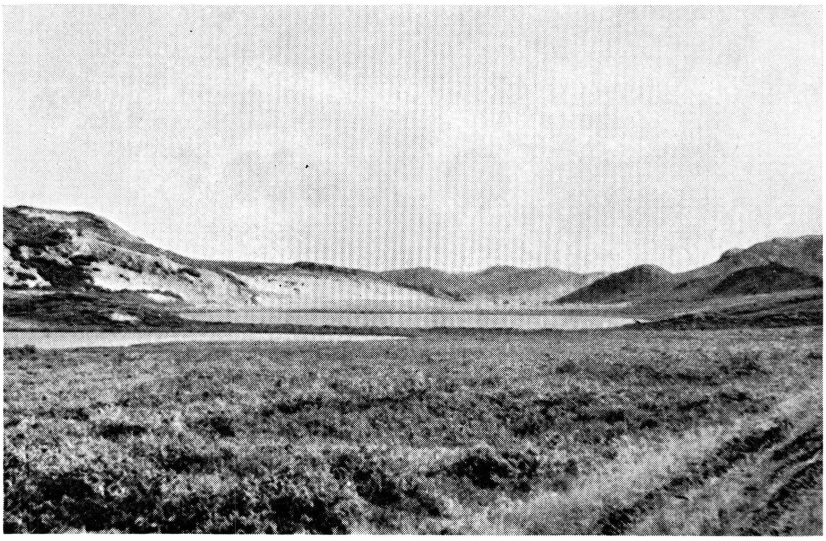


Fig. 10. The wide branch of Sandflugtdalen north of Keglen. In the background drift sand high up on the slopes. Photo 2730

Fig. 11. The area with drift sand at the eastern part of the wide branch of Sandflugtdalen. Photo 2733.

(fig. 11), which does not only spread over the valley floor, but at some places also extends far up the northern valley side (fig. 12). Thus, the border between the alluvial plain and the more elevated valley floor cannot be directly observed, but in a few places along the northern side the river has cut out a vertical cliff into the drift sand under which some-

Fig. 12. The innermost part of Sandflugtdalen is a braided river plain. Sand drift extends far up the northern valley side. Photo 2734.

thing looking like stratified, grey clay of a thickness of some metres can be observed (fig. 13). It differs from common clay by lacking cohesivity. Probably, it was deposited in a dammed lake. How long this extended into Sandflugtdalen, however, cannot be decided presently.

On the innermost plain large herds of caribou can be seen. To the east, Sandflugtdalen is barred by a 150 m high rock wall, above which one can see Indlandsisen and in front of it a dark, stony moraine bank (Pl. III). At both ends of this wall Indlandsisen discharges two glacier tongues with streaming melt water into the valley; the river in Sandflugtdalen seems mostly to be fed by the southern tongue. BELKNAP (1949) states that just below this glacier tongue the river has a cascade with a fall of 64 m in 90 m, of which the 12 m is direct fall.

BÖCHER (1949, 1956, 1959) writes that in Sandflugtdalen, west of Keglen, there are four river terraces, but none east of Keglen. He does not explain in detail, where the three upper terraces may be found, but in the text accompanying some of the photos the cirques and the glacial beds are described as river terraces; as for instance the two situated at the southern side of the valley, 140 and 186 m above sea level. In many places in Greenland one can observe glacier tongues descending from the heights and forming large steps on their way. It is steps of this kind and other results of erosion by local glaciers that BÖCHER mistakes for river terraces. Other terrace-like plains in Sandflugtdalen apparently owe their existence to sand drift or landslide.

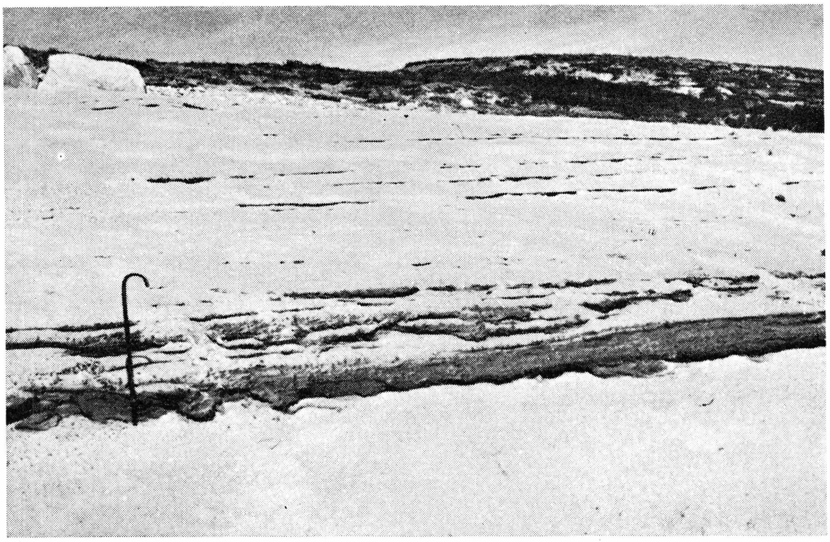


Fig. 13. The river has cut its way into the northern side of the valley and uncovered a profile of grey, stratified, but very loose silt which has been deposited under very quiet conditions. Photo 2741.

Sandflugtdalen has only one genuine river terrace. It lies at Ravneklippen at a level of 55 m above sea level (fig. 8), and can be followed inland as far as to the innermost alluvial plain of the valley.

This is also in good accordance with what is known from other large river valleys. J. A. D. Jensen (1889) writes that in most of the big valleys there is a horizontal terrace. He is walking on one through the valley which terminates in Umîvît, south of Nákajanga; it continues farther on to a lake with banks of white, flaky clay. Kornerup and Jensen (1881) write that the river discharging into Nagssugtôq occupies the whole width of the valley up to the margin of Indlandsisen and along its banks one sees a terrace about 10 m above sea level nearly the whole way. At the mouth of Isortoqelven everything tends to indicate, however, that this river has washed away most of the low terrace and has cut its way into it with numerous branches that often have a strong current. Also Hayward (1936) describes similar terraces in the valley of Sarfartôq, north of Sukkertoppen Iskappe.

Climate

All previous visitors to these regions have emphasized the remarkably dry climate prevailing here which accounts for the fact that the lakes are without drainage in summer and that several of them are salt lakes. Admittedly, in summertime reduced drainage from lakes is common also in other regions of Greenland, *e.g.* around Disko Bugt.

On his excursion to Indlandsisen, Nordenskiöld measured height of barometer and wind force in the days June 28–July 3, 1909. He was surprised that the temperature was as high as 15–16°C, which he found unique for arctic regions. He believed it must be due to the high coastal mountains which do not allow passage of the cold air from the sea, and further due to the winds blowing from Indlandsisen, mostly warm Foehn winds.

During the second expedition from Michigan University, meteorological stations were established 366 m above sea level on a mountain which was called "Mount Evans". Apparently, it is the mountain WNW of the present Strømfjordshavn. Another meteorological station was established on Indlandsisen, but it only functioned in August 1927 and in February and March 1928 (Church, 1941). From these stations temperature were measured, and the records were compared with those taken at Holsteinsborg.

Table I. *Monthly mean values for Holsteinsborg (H), "Mount Evans" (E), Inner coastal regions (G) and Indlandsisen (I) for august 1927 and for January–March 1928*

	Mean temp. °C				Daily mean range °C			
	H	*E*	*G*	*I*	*H*	*E*	*G*	*I*
Aug. 1927	7.7	7.0	7.9	2.9	4.65	9.15	10.6	3.28
Jan. 1928	−8.3	−15.5			0.55	4.3		
Febr. 1928	−9.4	−18.8		−18.8	3.7	4.4		7.1
March 1928	−6.7	−7.5		−10.2	4.4	6.5		6.0
Average Jan.–March	−8	−14.1		−12	2.21	5.2		6.56
	Mean wind speed m/sec.				**Relative humidity °/₀**			
	H	*E*	*G*	*I*	*H*	*E*	*G*	*I*
Aug. 1927	2.32	3.66	1.65	1.05	45.8	45.8	63.9	81.2
Jan. 1928	5.4	4.24			54.9	81.75		
Febr. 1928	4.47	3.04		4.1	52.5	82.10		90
March 1928	5.1	4.4		6.8	56.4	68.35		74.5
Average Jan.-March......	5.1	3.9		5.5	54.6	77.4		83.2
	Precipitation in mm							
	H	*E*	*G*	*I*				
Aug. 1927	3	29.8	1.8	9.15				
Jan. 1928	3.08	6.37						
Febr. 1928		5.6		11.7				
March 1928	1.8	6.86		2.9				
Average Jan.-March......	4.9	18.8		14.6				

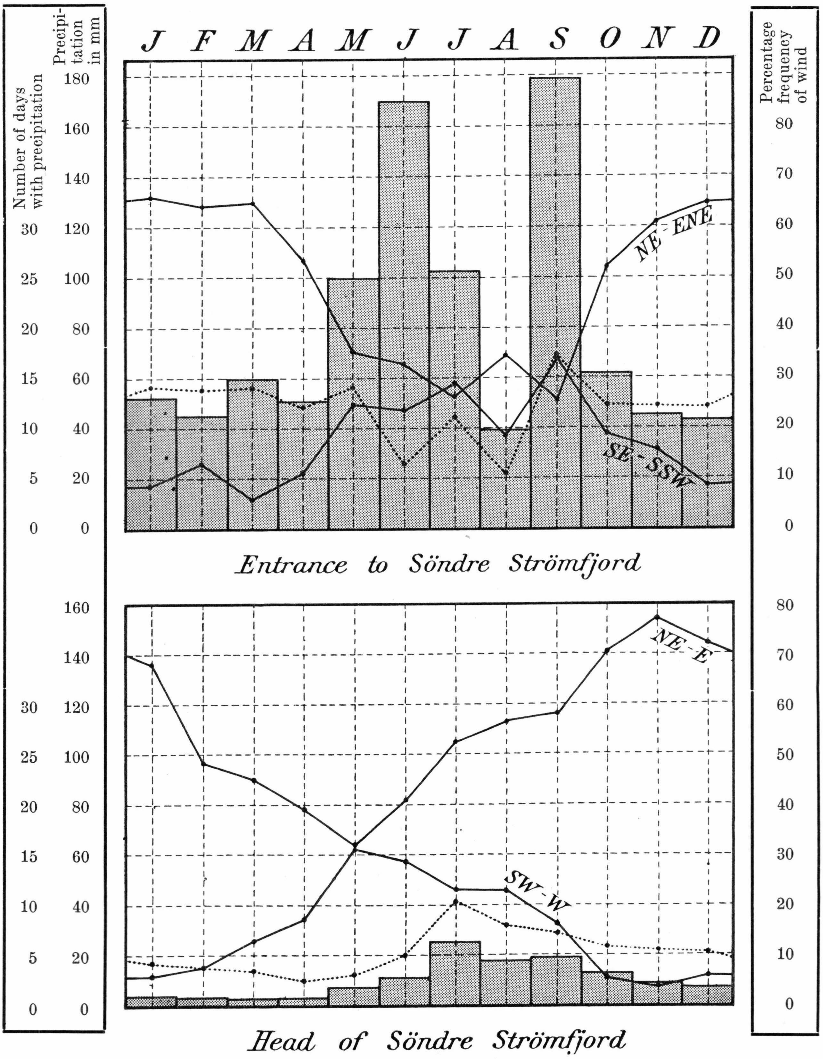


Fig. 14. Conditions of wind, amount of precipitation, and number of days with precipitation at Søndre Strømfjord. Mean precipitation in mm rendered by histograms. Dotted curves: number of days with precipitation. Full-drawn curve: percentage frequency of winds decisive of precipitation. The material refers to measurements within the period 1941–48 (head of the fjord) and 1943–45, 1946–48 (entrance of the fjord). (Böcher, 1954).

Table I shows some of these measurements. It should be taken into account, however, that they only show climatic data from one single year, which may differ essentially from normal conditions. For this reason the material, procured by Böcher (1949, 1954) from U.S. Weather Bureau, which at least covers a couple of years, is more useful. These diagrams (figs. 14 and 15) show the difference between the climate pre-

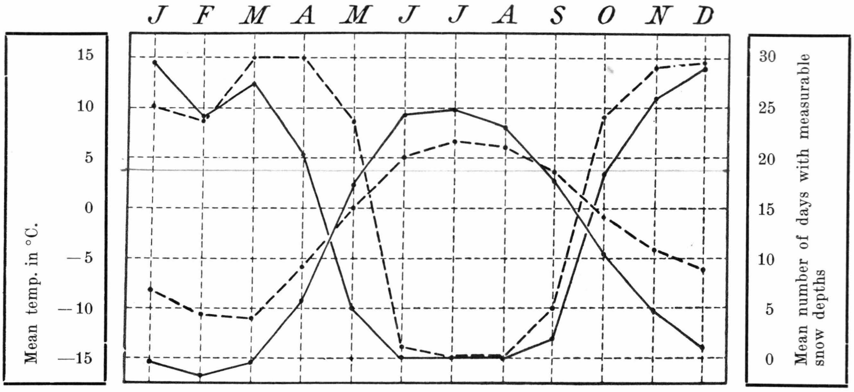


Fig. 15. Curves showing annual range of mean temperature and mean number of days with measurable snow depths at stations 2 (full-drawn curves) and 3 (stippled curves). The two stations give the difference between the entrance to Søndre Strømfjord (3) and the head of the fjord (2). (BÖCHER, 1954).

vailing at the mouth and at the head of Søndre Strømfjord. It appears that in summer, the highest monthly mean temperatures are measured inland, where in winter the values are considerably lower than at the coast, but at both stations the mean temperature for the warmest month does not exceed 10°C. The most pronounced climatic difference between coast and inland is reflected in the precipitation values, which inland do not exceed 13 mm, whereas the values are as high as 170 mm for June and 180 mm for September at the coast. The number of rainy days is also considerably higher at the coast than inland, something not unknown to many Greenland travellers, since the air traffic between Søndre Strømfjord and the towns along the coast is impeded over and over again due to fog and rain along the coast, while Søndre Strømfjord has bright sunshine.

When, in spite of the low precipitation, the country does not seem dry and desert-like at all— but, on the contrary, displays a dense and abundant vegetation, the explanation is that the low average temperature also gives a rather low evaporation. Further, the dense vegetation delays the thawing of permafrost with the consequence that some decimetres below the surface the ground is always moist, also in summer.

BÖCHER is of the opinion, and no doubt correctly, that the dry climate is due to the sheltered position of the region behind the coastal ranges. On the other hand he is wrong when he characterizes the climate as a steppe climate and refers to KÖPPEN (1931) stating that the boundary between forest and steppe climate lies where the annual mean precipitation in cm is double the mean temperature plus 14 at the place, in areas with summer rain, and plus 7 in areas with rain all the year round. A close study of Köppen reveals that the boundary discussed is valid for his climate types B (desert and steppe climate) on the one side and his types A (tropical rain climate), C (warm, temperate rain climate), and D (boreal or snow-forest climate) on the other.

All these types have the common feature, however, that mean temperature for warmest month is higher than 10°C, which distinguishes them from climate type E, the tundra climate. This temperature boundary is the first, essential criterion to distinguish the different types of climate classified by Köppen, and similarly for other climate systems. Since Böcher's own diagrams clearly show that in the areas treated here, the warmest month has a mean temperature not exceeding 10°C, this classifies it as a tundra climate, a term which is used everywhere in the circumpolar area north of the timber line, both in North America and Siberia. Additionally, the steppe landscape includes vast plains, whereas Böcher's steppe areas in Greenland are only small, isolated plots surrounded by arctic tundra. It should be obvious that the climate in these plots cannot be a steppe climate simultaneously with arctic climate everywhere in the surroundings.

Tedrow and Harris (1960) divide the tundra region into two climatic types of vegetation:

1. The typical arctic tundra in regions with a very low rate of precipitation, cold and short summers and a long and extremely cold winter; hereto belongs the north coast of Alaska, arctic Canada, and the Canadian archipelago, Greenland, Spitzbergen, and the north coast of Siberia.

2. The maritime tundra with a somewhat warmer maritime climate with a high rate of precipitation evenly distributed over the year, and a chilly, comparatively long summer and a rather mild winter with much snow. Iceland, Scandinavia, and the north coast of Russia belong to this type.

Weathering and Sediments

Nordenskiöld (1914) states that the rocks in the interior of Holsteinborg district have been weathered at least to the same degree as along the coast and considerably more than in Sweden. Close to the ice margin strongly crumbling gneiss can be observed, sometimes with resistant inclusions standing out against the surroundings. Typical frost weathering with a disintegration of the rock into angular pieces is only seen in steep walls; in general, the weathering is partly of a chemical nature and proceeds in such a way that the gneiss crumbles into a coarse-grained sand, which thereafter becomes more and more yellowish-brown by oxidation. The scree was not investigated in detail, but Nordenskiöld finds that the felspar has not undergone marked changes. The weathering attacks the rock in many ways and penetrates rather deeply, 0,5–1 m, in some places. Apparently, different types of rock have also a different degree of resistance.

NORDENSKIÖLD states that the weathering, where it is most effective, seems to be related to an oxidation of scattered grains of pyrite. A quite diverging chemical process was found in another place, where the soil, with an apparently earlier pyrite-bearing inclusion in the gneiss, was covered with a centimetre-thick crust of pure sulphure. Exactly the same form of weathering was found by KELLEY and ZUMBERGER (1961) in the Antarctic.

Furthermore, NORDENSKIÖLD mentions different examples of weathering, which have resulted in rock shapes quite similar to the canopy rocks in the Egyptian desert, which are described by JOHANNES WALTHER (1924). In other cases, the weathering results in hemispherical depressions, which in NORDENSKIÖLD's opinion can only partly be due to wind erosion, but to a greater degree to the influence of deliberated salt, the presence of which has actually been demonstrated in this area, and which greatly facilitates disintegration.

BELKNAP (1941) distinguishes between disintegration and decomposition and writes that in the semi-arid climates disintegration will be the dominating shattering process. BELKNAP mentions a few examples of exfoliation, but maintains that it is less frequent than was to be expected and by far less frequent than in the desert regions in the southern hemisphere, presumably because the daily temperature fluctuations are much weaker in North Greenland and because unusually high temperatures do not occur here.

BELKNAP claims that frost shattering is rather seldom in these areas, because the daily temperature fluctuations keep within a rather limited range, and that there are two short periods of the year, where the temperature fluctuates above and below zero. The first one occurs towards the end of the summer, where BELKNAP believes that there cannot be much water in the soil, and it will therefore not be affected by the continuous alternation between frost and thaw. In his opinion all frost erosion takes place in springtime after the snow melting. He forgets, however, that throughout the summer season the permafrost is only slowly thawing and consequently, the ground under the vegetation is always moist. When the frost sets in in autumn, the water contained in the ground will freeze from above and downwards, but sinec the permafrost lies only a few decimetres below the surface, specific conditions may result in such a great hydrostatic pressure that it will be able to enlarge already existing fissures. Based on laboratory investigations and studies in Alaksa, TABER (1943) believes that the growth of ice crystals has a more destructing effect than the mere expansion of volume during the freezing itself. The slower the frost penetrates,

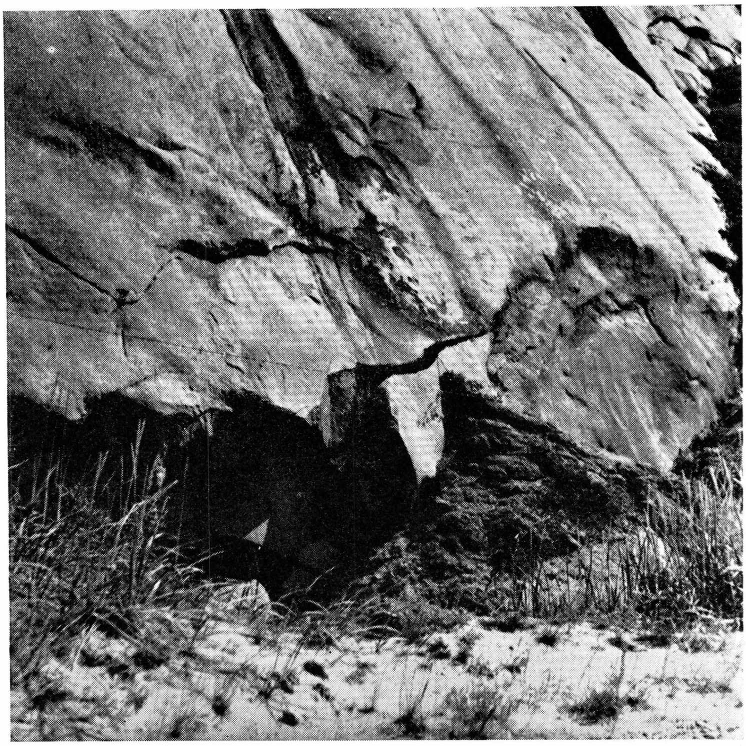


Fig. 16. Frost shattering at Ravneklippen, partly by way of exfoliation.
Photo 4201.

the easier it is for the ice crystals to grow under pressure and shatter the rock.

Much evidence is pointing toward frost as an important factor in the weathering process in Sandflugtdalen. All over, one finds naked rocks intensely frost-weathered, and both exfoliations (fig. 16) and block disintegration (fig. 17) are seen. It is evident that the shattered blocks will again be attacked by the frost, and it is a noteworthy fact that while the valley sides in the Scandinavian high mountains in Lapland are covered with a thick layer of coarse gravel and stones right up to the very top of Kebnekaise, something similar is not found in these regions of Greenland. The mountain sides are either naked or they have a surface layer of very fine-grained material with only a few big blocks, as seen on the northern slope of Sandflugtdalen. Only seldom one finds accumulations of large blocks beneath the slopes.

Beforehand, it might be expected that the chemical weathering was weak or in any case slow in rate because of the low temperature all the year round. As mentioned above, NORDENSKIÖLD presumed that chemical weathering is mainly due to an oxidation of the ferruginous

Fig. 17. Shattered rocks with block disintegration at Taserssuatsiaq. Photo 4194.

minerals. BELKNAP, on the contrary, writes that since the summer temperature can be as much as 24°C (75°F), rock exposed to the sun must be heated to still higher temperatures, and in the wide, flat valleys and on their slopes, a carpet of vegetation protects the underlying material against air and sun. 15–50 cm below the surface the frozen subsoil thaws and by capillary action this humidity is soaked to the surface in sufficient quantities for the weathering process.

Furthermore, BELKNAP gives examples of chemical weathering products observed, as epidote, kaolin, and chlorite were often found by the microscopical investigation of thin slices from rock samples taken in the region around the head of Søndre Strømfjord. He further states that secondary minerals of this kind are not found in the coastal rocks at Holsteinsborg. This is not quite correct; in any case epidote and chlorite can be observed as components in the unweathered gneiss (NOE-NYGAARD, 1952, NOE-NYGAARD and RAMBERG, 1961). Both in 1962 and in 1965 samples of the loose top soil in Sandflugtdalen were taken for detailed analysis by EJNAR JENSEN in the chemical laboratory of the Royal Veterinary and Agricultural College at Copenhagen.

This analysis has not been accomplished so far, but a soil sample from Godthåb (JENSEN, 1965) gave the result that two thirds of the sample consisted of quartz, oligoclase and hornblende. The amount of quartz diminishes with decreasing grain size, and the same is the case, though in a smaller scale, with the amount of oligoclase. The clay fraction is still rich in oligoclase. Diopside, garnet, epidote, and magnetite occur in small quantities.

The last third of the sample consists of clay minerals, almost exclusively of biotite and trioktaedric vermiculite. The amount of these minerals increases with decreasing grain size. A third clay mineral, presumably either kaolinite or a chlorite rich in iron, is found in very small quantities. It deserves notice, however, that the gneiss proper in the Godthåb area is rich in plagioclase, hornblende, and biotite and it also contains vermiculite. Finally, JENSEN writes that the sediment from Godthåb looks more like a powder produced by stone grinding.

All this points to a very weak chemical weathering in these regions and is further quite in accordance with weathering processes in the Antarctic (BLAKEMORE and SWINDALE, 1958, KELLEY and ZUMBERGER, 1961).

The loose surface layers in Sandflugtdalen and surroundings are of three kinds: partly river terrace, partly more intensely disintegrated rock and morainic deposits, and finally wind-transported sediments to some degree mixed with the two first-mentioned types.

PJÉTURSSON (1898), who travelled on the south side of the inner part of Nordre Isortoq, writes that huge quantities of morainic deposits are found here as boulders, gravel and sand, whereas enormous quantities of a very fine-grained sediment seem to be deposited in the valleys.

KORNERUP (1881) and JENSEN (1889) term it a fine clay, which, when moist, becomes slimy and slippery, but upon drying it prossesses a crust of a light-grey, powdery material, which fills the air with white clouds of dust at the faintest gust of wind. Also PJÉTURSSON mentions that large clouds of dust float over the valley of Isortoqelven.

NORDENSKIÖLD states that a little north of Sandflugtdalen the hills and plateaus near Indlandsisen are often to a great extent covered with a dust-like fine soil, now overgrown by vegetation. He supposes that this fine soil originates from dried-up glacial mud from the floor of the river valley, carried up to the plateau by the wind and deposited here. During this author's visit to Søndre Strømfjord various samples were taken for later granulometric analysis.

Fig. 18 shows the river terrace at the quarry situated at the north side of Sandflugtdalen. It is built up of sand, gravel, and numerous stones, but now rather disturbed by road construction. From the lower-lying road one could see that it rested on two arched rocks which ex-

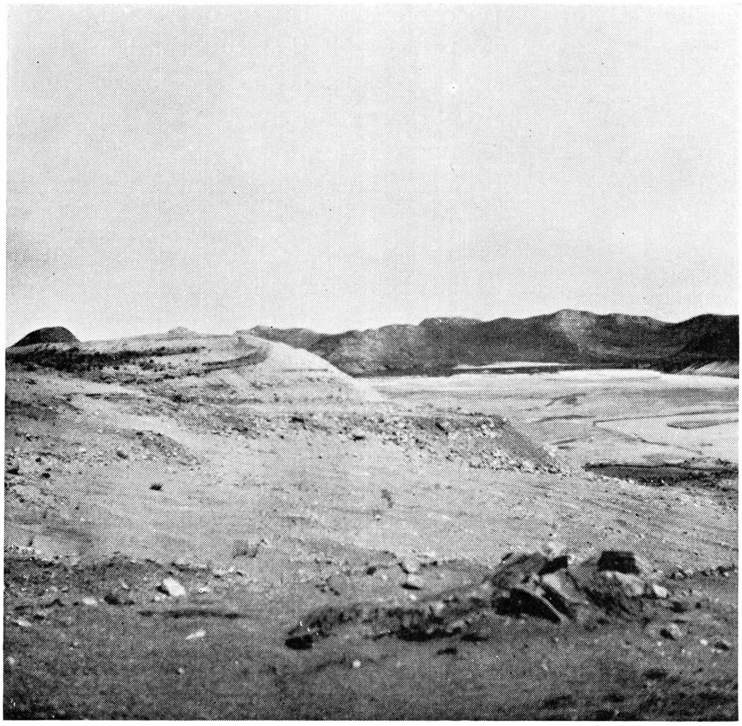


Fig. 18. The river terrace, built up of sand and gravel, off the quarry at the north side of Sandflugtdalen.

tended down to the river. On the surface some flat sand ridges were observed.

Table II

Analysis No.	Md μ	Q_3 μ	Q_1 μ	So	$> 62\ \mu$ %	< 4 %
440	67	100	46	1.48	56.6	0.5
441	44	65	30	1.48	26.6	0.7
442	53	140	31	2.12	44.1	0.5
524	26	36	18	1.41	4.1	0.6

Table II and fig. 19 show the mechanical composition of sediments deposited in water. The analyses 440 and 441 were taken from the surface of the river terrace, 441 from one of the small, flat ridges. 442 was taken a bit down on the side, where sliding had revealed a small vertical section with moist sand. In fig. 18 it can be seen as a dark band. Finally, 524 was taken innermost in Sandflugtdalen, where horizontal layers of fine-grained clay were found under the drift sand.

A comparison between values and course of curves of the samples from the terrace at the quarry reveals that all three samples are well-sorted So < 2.5, though the two samples from the surface of the terrace, which is presumably to some degree rebedded by the wind, are somewhat better sorted than the deeper-lying layers, and the sand from the small ridge is a little more fine-grained than the sand from the surface. The samples 440 and 442 must be classified as coarse silt and very fine sand,

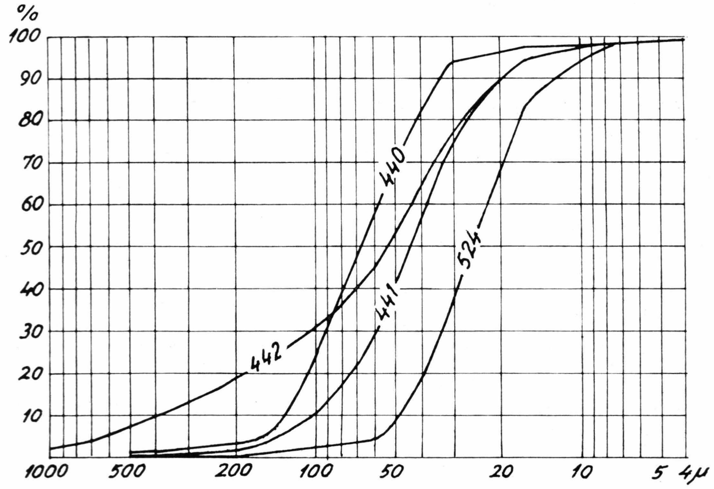


Fig. 19. Granulometric analysis of sand from the terrace in Sandflugtdalen. Sample 440 was taken from the surface, 441 from a flat sand ridge on the surface, 442 somewhat below the surface of the small vertical cliff seen in fig. 18. 524 is the fine stone powder under the drift sand innermost in Sandflugtdalen shown in fig. 13.

441 as coarse silt, but besides 13 % fine sand 442 has also 6 % medium sand and 8 % coarse sand. The samples 440 and 441 consist so to say exclusively of angular quartz grains and smaller quantities of mica and dark minerals, but in 442 grains larger than 0.3 mm are rounded, smaller grains are angular.

Sample No. 524 must also have been deposited in water, in a lake dammed by the moraine bends that closed, towards the west, the valley north of Keglen. Also in the eastern part of the valley, moraine ridges are seen down the southern slope. In this lake the fine sediment has been deposited as a pure silt sediment, whose sedimentary nature corresponds to our late-glacial clay, from which it differs, however, by its total lack of cohesivity. It is a grey, loose, fine stone powder, an outwash of the most fine-grained material, ground by Indlandsisen and it has not been chemically weathered.

Table III and fig. 20 show the granulometric composition of samples of soil and sediments of different origin. The two analyses, 478 and 525,

Table III

Analysis No.	Md μ	Q_3 μ	Q_1 μ	So	> 62 μ %	< 4 μ %
475	36	54	24	1.50	15.5	1.5
476	32	51	19	1.84	14.8	2.2
477	39	57	25	1.52	20.9	4.3
500	32	50	19	1.64	14.7	7.1
478	320	410	250	1.28	99.4	0.6
525	212	300	140	1.46	92.0	

are of drift sand. 478 was taken from the dune beneath Ravneklippen, where the sand has been blown up from the river plain in the valley floor 50 m below. 525 was taken in the drift sand section innermost in Sandflugtdalen (fig. 11); also here the sand has been blown high up on the slope. Both samples are well-sorted and range from medium to very fine sand.

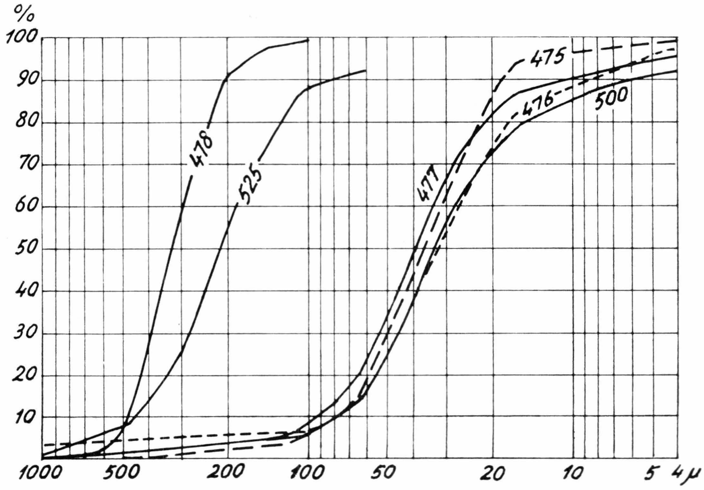


Fig. 20. Granulometric analysis of different soil samples. 475 and 477 were taken about 150 m up on the valley slope behind the hotel at the airport. 476 is weathered soil from Kløftsøerne, and 500 a soil sample taken in an excavation at the western end of the lake Taserssuatsiaq. 478 is drift sand from the dune beneath Ravneklippen and 525 is drift sand from the innermost part of Sandflugtdalen.

Of the remaining analyses, 475 and 477 were taken on the northern slope of Sandflugtdalen, just behind the airport and in altitudes between 150 and 200 m. No doubt, it is moraine material which has, in the course of time, been further shattered by frost, but it is also mixed with considerable quantities of wind-swept silt or dust. 476 is weathered soil taken near the lakes, Kløftsøerne, at a height of 300 m above sea level, and finally analysis No. 500 is a soil sample taken at the western end of Taserssuatsiaq south of Ravnefjeldet. In the summer of 1962, the American archaeologist, professor JOHN M. CAMBELL, excavated some Eskimo ruins here, and the soil sample was taken at the bottom of this excavation, just above the frozen soil at a depth of 75 cm below the surface. Presumable, this material is original moraine.

From both table and figure it appears that these four samples, of the most different origin, have nearly the same granulometric composition. The mean grain size lies about 34 μ and the content of sand is low, between 14 and 20 %. They must be described as mainly silt sediments; they are considerably more fine-grained than the sand from the river terrace, but coarser than the lake sediment taken from the innermost part of Sandflugtdalen (analysis No. 524). The sorting is almost identical in all four samples.

The four samples 475, 476, 477 and 500 contain in all fractions grains of quartz, mica and dark minerals. The quartz grains are angular in all fractions, whereas the dark minerals are somewhat rounded in the fractions bigger than 0.25 mm. In the two samples of drift sand (478 and 525) the grains bigger than 0.5 mm have been rolled, and in the finer fractions, besides the angular grains of quartz, mica and dark minerals, many grains are also seen with more or less rounded angles and edges.

NORDENSKIÖLD describes the fine, wind-swept dust as a yellowish, unstratified, slightly disintergrating and extremely fine sand looking like the Swedish Mo (0.2–0.02 mm); it has a strong resemblance with loess, but NORDENSKIÖLD is well aware that in essential respects it differs from the genuine loess.

HOBBS (1931) and BÖCHER (1949) are both terming these silt deposits loess and think that the most important difference from genuine loess is lack of lime and lack of cohesivity. BÖCHER also maintains that the Greenland silt deposits are not so lime-free as stated by NORDENSKIÖLD and points out that he has samples containing 10.5 milliequivalents Ca per 100 gr. sample. Converted, however, this is not more than 0.5 % $CaCO_3$, and though one of the samples contains 26.6 milliequivalents Ca per 100 gr. this only gives 2.2 % $CaCO_3$, a percentage generally agreed upon as being lime-free.

For comparison, the following values from loess samples collected by the author are given below:

	% $CaCO_3$
Loess Rocourt, Belgium, old partly decalcified loess...	7
Kesserler Bergen Belgium Wurm loess	14

MALYCHEF states the following values for the clacification of loess:

Bassin du Rhône, environ de Lyon	15–25
Bassin du Po, Piemont	7–12
Bassin du Dniepr	11.5–51.5

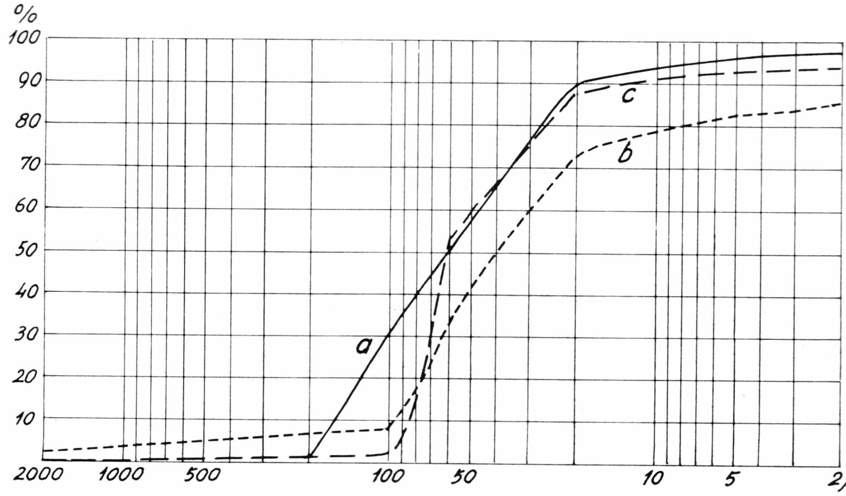


Fig. 21. Granulometric composition of the a) by NORDENSKIÖLD (1914) and b) and c) by BÖCHER (1959) published analyses of so-called loess. b) from Nákajanga, c) from the northern slope of Sandflugtdalen near the airport.

BÖCHER (1949) also gives granulometric analyses of his loess samples. However, one can find many types of marine sand with the same high content of grains below 100 μ. In 1959, BÖCHER published two analyses of so-called samples of loess. Fig. 21 and table IV show the granulometric composition of these samples.

Table IV

Sample	Md μ	Q_3 μ	Q_1 μ	So	$> 62\ \mu$ %	$< 4\ \mu$ %
a.................	60	115	31	1.93	50	2.5
b	40	67	18	1.93	34.9	7
c	62	72	31	1.57	53.3	17

Sample *a* was taken by NORDENSKIÖLD near Indlandsisen, *b* is BÖCHER's location 16 (Nákajanga), and *c* location 19 (Sandflugtdalen at the airport). A comparison between tables IV and V, reveals the great difference between what NORDENSKIÖLD and BÖCHER call loess and the genuine loess. The mean grain size in table IV is much larger, the sorting not so good, and in the two samples the content of sand and silt is nearly the same. These samples, in any case, cannot be termed loess.

The name loess is a term adopted in the scientific nomenclature from the Rhinelanders, who use it for a soil type common there. But it has a quite wide distribution in the temperate climate zone (v. RICHT-

HOFEN, 1877). The classic description of loess should be the one given by v. RICHTHOFEN of Chinese loess (v. RICHTHOFEN, 1877, 1901). In translation, it runs as follows:

"Loess is brown-yellowish and so crispy that it is easy to tear apart with the fingers, though solid enough—even where it has been attacked by destroying forces as for example running water—to stand with steep walls, several hundred feet high. It is so fine-grained that it can be rubbed into the pores of the skin, whereafter only a few sand grains are left, and these are angular and without traces of rounding. By repeated washing out this sand can be separated from the chiefly clayey mass. Furthermore, loess contains considerable amounts of calcium carbonate.

Even on the tiniest piece of loess a certain texture can be observed; the loess is traversed partly by extremely fine, partly by coarser tubes, branching out like reeds and frequently covered with white rims of calcium carbonate, but apart from this the loess is very porous and without the compact structure of clay. Loess is completely lacking stratification and is inclined to cleave off vertically".

Later, the sense of the term loess has been extended quite a lot and given rise to a good deal of confusion and discussion.

SCHIEFERDECKER (1959) confines himself to define loess as an unstratified eolian sediment of a light yellow colour with particle size 60–85 $^0/_0$ smaller than 50 μ or as an eolian deposit of same origin as the covering sand, but more fine-grained, at least 60 $^0/_0$ of the grains lie between 10 and 50 μ.

PLAISANCE and CAILLEUX (1958) define the term in greater detail. Loess is: "Terre limoneuse, facile à désagréger et à labourer, pas trop argileuse ni sableuse. Le minérale le plus fréquent est le quartz, puis la calcite, les feldspaths, les minéraux argileux. La fraction dominante est celle des limons. Grain médian 0,025 mm. La teneur en calcaire va de 0 à 33 $^0/_0$. Le loess s'est formé sous climat froid, périglaciaire par dépôt de poussières apportées par le vent en pays steppique, parfois conjointement avec de la neige. Après son dépôt il à pu être repris par solifluction ou en traîné par ruisellement vers les fonds".

MALYCHEF (1929–33) describes a number of loess types in Europe, Asia, and North America and makes the conclusive definition: Loess comprises a group of rocks, yellow of colour in different shades from a greyish pale yellow over a strong yellow to red or brown. These rocks are loose, though coherent enough to form vertical walls. They are seldom stratified. They have a common, solid texture and an earthy fracture. They are porous and thus permeable.

The main part of loess is fine quartz grains, it has often a considerable content of $CaCO_3$, sometimes more than 20 $^0/_0$, and a trifle clay. The latter is always accompanied by ferrihydrate, which adds the yellow shade to the loess, the grain size varies between 0.01 and 0.05 mm.

Butzer (1965) and Flint (1957) maintain the existence of two kinds of loess. Periglacial loess originating from outwash deposits from easily accessible moraine clay and from rock surfaces in tundra and arctic barrens. The other type is desert loess, found in desert regions and distinguishable from the first type by its wider range of grain sizes. Both Butzer and Flint stress the content of $CaCO_3$, which Butzer states as from 10 to 50 % and Flint as up to 40 %, and both of them indicate that loess is generally believed to be a wind-transported sediment.

Table V

No.	Md μ	Q_3 μ	Q_1 μ	So	$> 62\ \mu$ %	$< 4\ \mu$ %
334	26	38	16	1.54	11.5	5.5
551	22	34	17	1.41	2.6	17.1
552	26	39	19	1.44	4.2	6.8
554	22	30	18	1.57	0.9	6.6

Table V and fig. 22 show the granulometric composition of four samples of European loess. No. 334 is taken at Gross Denckel near Braunschweig in Germany. 551 is Wurm loess from Kesselt in Belgium. 552 is decalcified Riss loess from Rocourt in Belgium, and finally 554 originates from Bergisch Gladback in the Rhineland, northeast of Cologne. Prior to the analysis all samples were treated with normal hydrochloric acid to remove the $CaCO_3$.

A comparison between these figures and the figures in tables III and IV shows very clearly that the Greenland silt deposits are somewhat coarser than the European loess and more poorly sorted. They also contain considerably more sand (the fraction larger than 62 μ). As, additionally, the Greenland silt deposits differ from genuine loess by being non-calcareous and appear as a loose, incoherent, fine powder, and as they are mostly an admixture of wind-transported dust and fine material of other origin, it must be considered misleading to term them loess.

Similar silt deposits are found everywhere in the arctic regions, for example in Alaska, both in the plains at Point Barrow and in the river valleys in Central Alaska (Black, 1951, Taber, 1943, Tuck, 1940). As in Greenland, they can be of very different and complex origin. They contain material brought about by vulcanic activity, glaciation, organic processes and weathering and can be classified as residual, eolian or fluviatile deposits (Taber, 1943). The purely wind-swept deposits are called loess, but it is extremely difficult to decide whether they actually

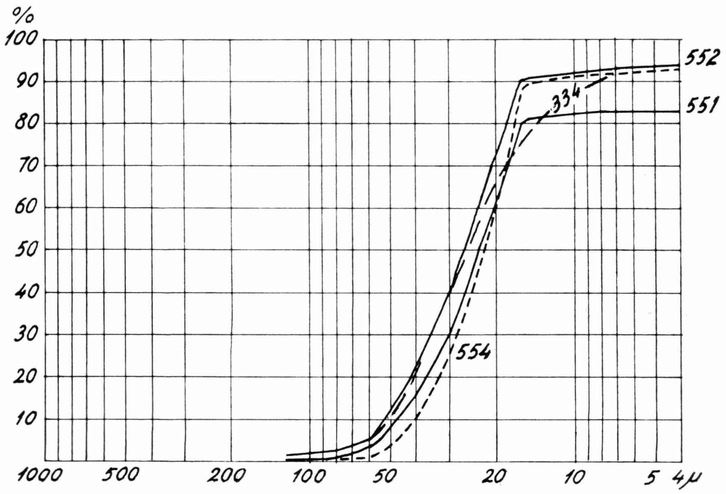


Fig. 22. Granulometric composition of samples of European loess.
334: Loess from Gross Denckel at Braunschweig, Germany.
551: Loess from Kesselt, Belgium
552: Loess from Rocourt, Belgium
554: Loess from Bergisch Gladbach, the Rhineland.

are pure wind sediments. TABER's granulometric analyses of silt deposits from the river valleys of Central Alaska show a mean grain size between 40 and 50 μ and a content of sand of 30–40 $^0/_0$, i.e. almost of the same composition as the analyses in table IV, but distinctly coarser than the European loess samples in table V. The content of $CaCO_3$ is also very low. None of the samples shown in TABER's tables are termed loess, but silt.

Even though similar dust deposits in Alaska are by some authors termed loess and sediment and soil samples from Sandflugtdalen undeniably comprise wind-swept dust deposits, the granulometric and chemical analyses show so high a degree of homogeneity with sediment samples of very different origin that it is impossible to extract the wind-swept deposits from those of other origin. Additionally, the Greenland deposits differ in so many respects from the European loess that it will be more correct to use the neutral term silt deposits.

As early as in the middle of the last century, Russian soil scientists have distinguished between high tundra with a comparatively dry mineral soil and low tundra of peat soil with bog or marsh-type vegetation. As previously mentioned the chemical weathering will proceed very slowly in regions of that kind. Of the three most important agents for the formation of soil, the content of carbon dioxide in the soil, the humus, and the hydrolysis of the soil water, the latter can here be left out of account because of the low temperature.

The process of podsolization will therefore be the basis of the soil development. It proceeds so slowly, however, that fully developed podsol profiles seldom occur, and then only locally. The result will therefore be that on well-drained slopes an arctic, brown earth (dry tundra) develops, whereas in the depressions peat and glei (wet tundra) will develop.

No methodically pedological investigation was made neither during the author's visit in 1962 nor in 1965, but when digging in the vegetation-covered slopes it was found that even down to the permafrost there was a homogeneous, brown, fine-grained mineral soil with a high content of organic substance quite corresponding to descriptions of arctic brown earth from Alaska. (DREW and TEDROW, 1957, DOUGLAS and TEDROW, 1960, KELLY and NYGÅRD, 1951, TEDROW and HILL, 1955, TEDROW and CANTLON, 1958, TEDROW, DREW, HILL and DOUGLAS, 1958).

If instead of loess and steppe, the terms dry and wet tundra are used, a better accordance will be achieved between the type of soil and BÖCHER's determinations of pH and electric conductivity, and also full accordance is achieved between climate, soil, and vegetation as compared with other polar regions.

Of special interest is the fine dust or stone flour under the drift sand innermost in Sandflugtdalen (Analysis 524). It must have been deposited in a lake or in any case under very quiet conditions and should thus correspond to late-glacial stone-free clay, from which it differs, however, by being quite loose. This and the almost total lack of clay minerals in the Greenland, fine-grained and well-sorted sediments give rise to the question: From where does the Danish late-glacial clay get its solidity and its content of clay minerals?

The only reasonable answer seems to be that the Danish late-glacial clay contains finely ground, older pre-quarternary sediments which the Scandinavian ice sheet has passed over and incorporated in its moraine.

A similar conception concerning the origin of the Swedish glacial clay types has earlier been advanced by COLLINI (1950), 1956), HÖRNER (1946, 1947, 1951) and WIKLANDER (1950).

Another striking feature of the soil in the region around the head of Søndre Strømfjord is that all soil samples (*cf.* tables VI and VII p. 57 and 59), whether they consist of talus, weathered soil from Kløftsøerne, original moraine or wind-swept dust, have a mean grain size of 20–35 μ and are well-sorted. Moraine clay as we know it from Scandinavia apparently does not exist.

On the whole the assumption should be justified that in the region between Sandflugtdalen and Disko Bugt the ice movement has been parallel with the structural elements of the gneiss, and these have been the dominating factor in the evolution of the landscape.

During the melting period until the present position of Indlandsisen, a local glacier tongue has probably occupied the valley north of Keglen. In the southern area the ice movement has been SE-NW up to Sandflugtsdalen. The many cirques and stepped traces of glaciers on the southern side of the valley suggest that the ice reached down into Sandflugtdalen and partly blocked it; the sand deposits along the northern side of Sandflugtdalen were made of the moraine belonging to this SE ice. Gradually, as the glacial tongue in the valley beneath Keglen melted away, a lake was formed here in which the fine stone flour under the drift sand was deposited up to a level corresponding to the then existing valley floor, *i.e.* the present river terrace of Sandflugtdalen.

IV. STORE SALTSØ AND SURROUNDINGS

The air photo plate IV shows an L-shaped lake on the plateau between the valley Ørkendalen and the large lake Taserssuatsiaq. This is by Böcher named Store Saltsø. It lies in a valley, the floor of which is shown in the profile fig. 23. The valley, which can also be seen in plate I, starts at the fjord south of Ravneklippen. The profile is drawn on the basis of the 50 m contour interval of the map and a barometric determination of the pass point 267 m and the level of the lake 205 m above sea level, but it gives a somewhat too even gradient of the western part of the valley floor; in reality this rises by two steep steps with intervening, more level parts. From the pass point the valley floor falls first as a short, rather steep wall and then it slopes gently towards Store Saltsø. In both steps the rocks protrude into the valley.

Fig. 24 shows a pass leading from the northern part of the lake to Ørkendalen. This pass is also formed like two steps which contain a shallow, overgrowing lake. By levellings made by Kirsten and Niels Nielsen, then geography students from the University of Copenhagen, the pass height was determined to lie 426 m from the lake and at a height of 21.5 m above the lake surface, which gives a contour line of 226.5 m above sea level.

The lake has no outlet and no proper inflow either, but from the surrounding hills water will seep from the slowly thawing permafrost throughout the whole summer, and in the central part of the valley the water gathers to an ever running brooklet.

Böcher (1949) states that around the lake are four terraces, and that the erosion slope of the lowermost one is under development. Further,

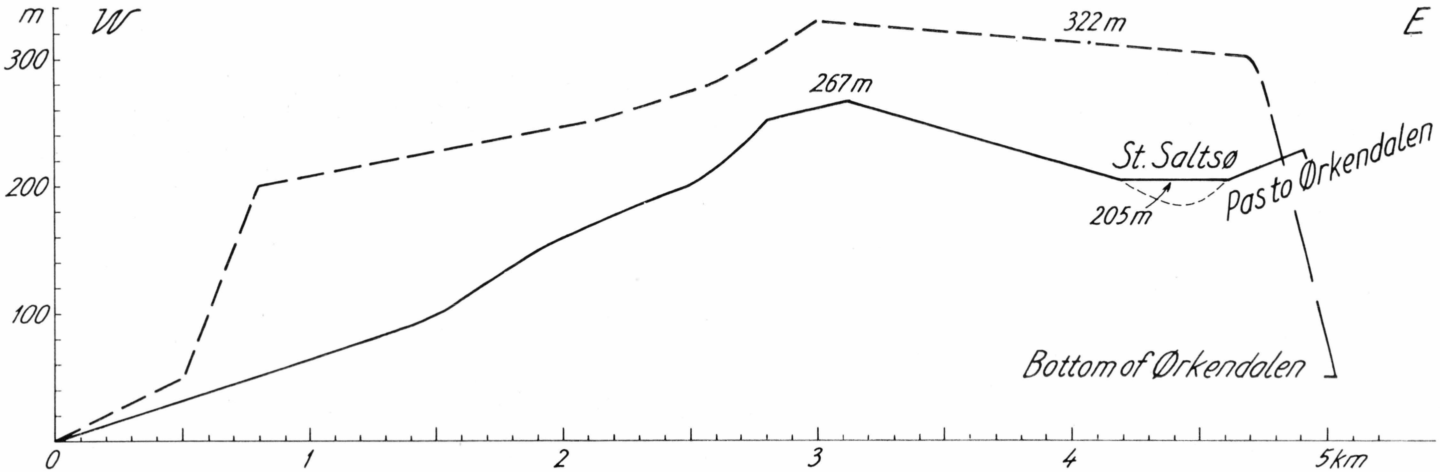


Fig. 23. Profile through the valley of Store Saltsø (full-drawn line) and through the mountain ridge between this and Sandflugtdalen and Ørkendalen (dashed line). The pass point 267 m, level of lake 205 m, and the point at the mountain ridge 332 m a.s.l. have been measured barometrically by a Paulin instrument. The pass height 226 m between the lake and Ørkendalen determined by levelling made by Kirsten and Niels Nielsen.

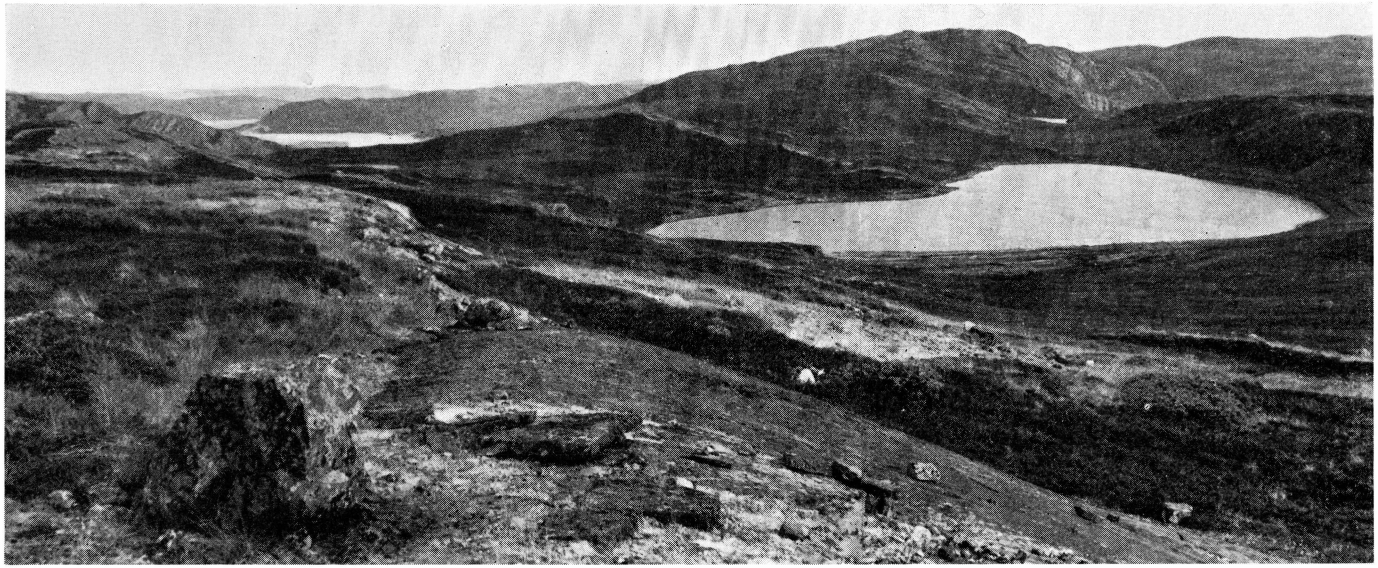


Fig. 24. View of Store Saltsø from the NW. In the background to the left Ørkendalen and the pass between this and Store Saltsø with the lowermost of the two shallow lakes. At the nearest shore of Store Saltsø the peat ridges are seen as a light, striped section.
Photo 4282–83.

it is described that along the western bank of the lake these terraces are particularly broad and peculiar by their composition of alternate layers of mainly loess and mainly dead mosses (*Drepanocladus aduncus*); the thickness of the layers ranges from 0.5 to 2 cm and in some places they contain remains of daphniae. In front of each erosion slope of the terraces there is a more or less narrow depression, which BÖCHER assumes is a result of erosion, as the impact of wave power should have washed away the loess; thereby a deposit should develop, mainly composed of mosses which in the course of time will subside and form a depression.

On the basis of these so-called erosion terraces BÖCHER formulates extensive conclusions as to the advance and the retreat of the ice margin as well as to changes in the climate, and he associates these terraces with similar ones along the banks of some lakes at the present Strømfjordshavn, by J. A. D. JENSEN (1889) called Tarajornitsoq. Here, RAMBERG should have found four terraces, of which the uppermost one lies so high that when it was formed the lake must have been ice-dammed.

BÖCHER now advocates that the lowermost of the so-called terraces at Store Saltsø should be the oldest one, and that the water level of the lake after the melting of the ice should have been lowered to below present level, and that the water already at that time should have received its saline character. During this lowering the lake had a rich vegetation of *Drepanocladus aduncus*, which was exposed to a rain of loess particles. In certain periods, BÖCHER believes, the supply of loess was greater than in others. After a drying-up period, another should have followed during which the water level rose again to a level above the uppermost terrace at Store Saltsø and to the second from the top at Tarajornitsut. BÖCHER is further of the opinion that the reason for these oscillations of water level is that the climate during the lowering of the water level became more continental and during the rises again more oceanic, which should have brought about an advance of the ice margin to Keglen; furthermore, that the heavily loaded glacial rivers in Sandflugtdalen then deposited the uppermost terrace of the valley. After this, a more continental period should have followed during which the uppermost terrace at Store Saltsø and the second from the top at Tarajornitsut, were formed. Later, there has been another change of climate to the more continental and a lowering of the water level in Store Saltsø and at Tarajornitsut, and BÖCHER now suggests that these three lower terraces were formed at the same time as the three terraces in Sandflugtdalen, which should mean that there have been three stagnation periods during the retreat of the ice margin; each time a terrace slope was formed, climatic stability and stagnation of the ice margin should have prevailed.

Straight away, several objections can be raised against this description of the development. As mentioned earlier, there are not four river terraces in Sandflugtdalen, but only one, and it can be followed as far back as east of Keglen. Furthermore, as the present-day comparatively dry and continental climate is due to the fact that the region is located in the rain shadow of the coastal ranges, it is not clear, and it is not explained by Böcher either, what should have brought about this continuous alternation between oceanic and continental climate. Store Saltsø lies in a valley floor, the lowest pass point of which is 21.5 m above the present water level of the lake. When the ice sheet, which is supposed to have covered the whole area, melted away, its melting water found an outlet through Ørkendalen, until it dropped to a level corresponding to this pass point. Since then, further drops in water level have only been possible by evaporation and perhaps seepage through fissures in the rock. It is not unreasonable to assume that a similar development has taken place at Tarajornitsut, but here the lowest pass point us unknown, and as long as the topographical details in this region remain uninvestigated, the theory is far beyond reason that any synchronization should exist between the lowering of water level here and at Store Saltsø. From the carbon-14 datings published later by Böcher (1959) it also appears very clearly that the water level of Store Saltsø has dropped gradually. According to the datings, the moss sample from the uppermost of these so-called terraces should originate from 380 B.C. ± 120, and from the lowermost one from 870 A.D. ± 120. These figures should then mean that at the time referred to, the mosses died at these two levels, presumably because the water level sank to below the moss vegetation and left it dry.

Böcher therefore changes his explanations of how the terraces were formed and says that the deposits were made under successive lowering of the water level of the lake; but that it is not certain whether depositing took place at the bank or close to it. In autumn, the mosses growing near the bank died and in the course of the winter they were torn off and sank to the bottom of the lake. In summer, they have been exposed to dust fall, which in certain summers has been so great that layers of pure loess deposited upon the mosses. In this way the deposits came to consist of alternate layers of moss and loess. Böcher maintains his assumption, however, that periodical alternations in water level and salinity occurred, and that the latter has been so strong at times that the mosses died out and only loess was deposited; now Böcher speaks about six instead of four terraces.

At the visit of this author to Store Saltsø in 1962 it became soon evident that it was not an example of erosion terraces but of folding; neither solifluction nor ice pressure from the winter ice cover of the lake

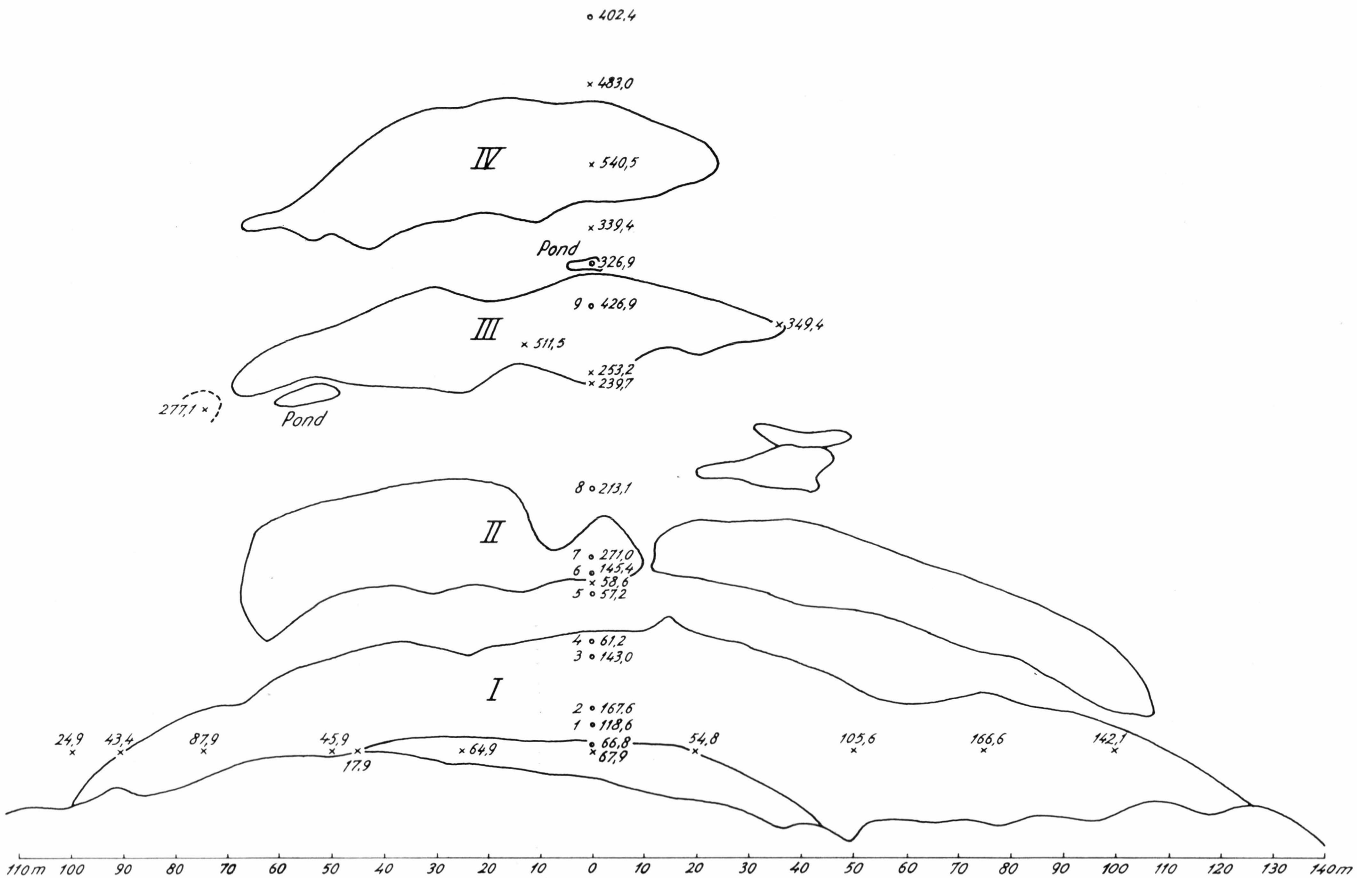


Fig. 25. Area survey of the peat ridges at Store Saltsø. The numbers indicate the height in cm above water level of Store Saltsø, x is the bench mark, o the drilling point. Measured and drawn 1:500 by Kirsten and Niels Nielsen.

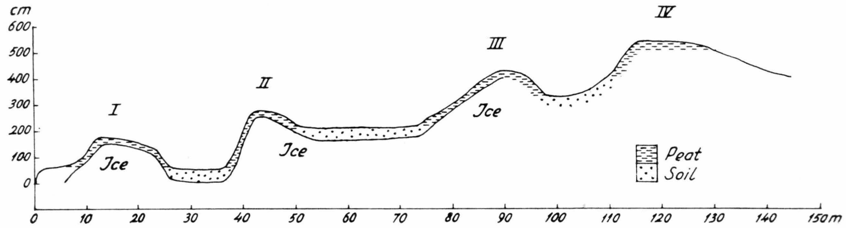


Fig. 26. Profile through the peat ridges at Store Saltsø. The values indicate height above water level of the lake in cm. Measured and drawn by KIRSTEN and NIELS NIELSEN.

seemed to offer a reasonable explanation of their form, however. Unfortunately, no time was left for a more detailed investigation, and it became therefore one of the main tasks for the research team to West Greenland in 1965 from the Geographical Institute at the University of Copenhagen to study these occurrences of peat. For this purpose KIRSTEN and NIELS NIELSEN made an area survey and a mapping of the four lowermost of the peat ridges (fig. 25). Simultaneously, a profile was levelled through their centre line (fig. 26). The map shows the contour lines and the heights of the surface in centimetres above the water surface of Store Saltsø.

In fig. 24 this ridge system is seen as a light, striated section along the front edge of the lake, and it appears how small an area the ridges occupy. The map fig. 25 shows that only the two lowermost ridges form weakly curved bends along the bank of the lake; the others are shorter and more irregular in their curving.

Peat ridge I lies right at the lake. It is 225 m long and 30–36 m at the broadest place, but narrows at both ends. The highest point of the profile is 167 cm above the water surface of the lake. The map also shows that the ridge surface is weakly curved longitudinally. Towards the lake the moss peats bend downwards (fig. 27) and form a steep slope. The surface is level and intersected by a wide-meshed network of frost cracks, which right at the lake are so deep that blocks of peat are just on the point of falling down into the lake (fig. 28). The same is distinctly seen on BÖCHER's pictures. (BÖCHER, 1949, plate 2).

The peat is redbrown and consists of paper-thin layers of water mosses (*Drepanocladus aduncus*). It is more or less dust-containing, but there is no alternation between layers of moss and dust as indicated by BÖCHER. The upper parts contain so much dust that the colour of the surface is dirty yellow, and when one walks upon these soft moss mats the dust rises; the deeper-lying layers are dustfree and moist. In the dust-filled frost cracks, the vegetation has gradually gained a foothold.

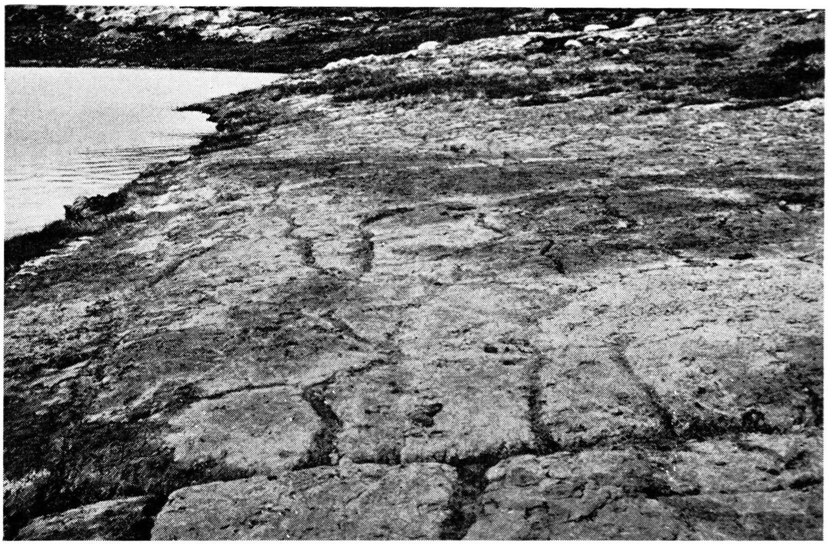


Fig. 27. The lowermost peat ridge at Store Saltsø, bisected by frost cracks.
Photo 2728.

Fig. 28. Right out at the lake the frost cracks are so deep that the outermost flake is at the point of falling down.
Photo 2726.

The measured profile includes a place where the outermost part of the peat has fallen down, so that the edge of peat ridge I lies 7 m from the water edge. Simultaneously with the measuring, some diggings were made with the following result:

Hole 1
15 cm almost pure dust with thin layers of moss
15 cm almost dustfree moss peat
pure, clear ice

Hole 2
15 cm almost pure dust
20 cm moss in thin layers
pure, clear ice

Hole 3
16 cm pure dust
34 cm pure peat
pure, clear ice

In the depression between ridge I and II the digging was made in earthy clay until the ice was met with at a depth of 50 cm. The soil is moist, and in the depression willow and other plants are growing.

Peat ridge II is somewhat shorter than ridge I, and a transverse depression divides it into two parts, of which the southernmost is 77.5 m long and 22 m broad and the northernmost 95 m long and 12.5 m broad (fig. 29). Diggings gave the following result:

Hole 6
42 cm peat
pure ice

Hole 7
20 cm peat
pure ice

The depression between ridge II and ridge III is somewhat more moist and overgrown with low willow scrub, in the southern part there is even a small pond. In the depression the ice lies 54 cm below the surface.

Peat ridge III is considerably shorter than the two foregoing, and while these are curving weakly parallel with the shore, then ridge III and the following ones are more straight-lined. Ridge III is 105 m long and has at both ends the same shape as I and II, but midway it has an especially high hump and on the front side the peat layers are heavily disturbed (Pl. V), folded and contorted. In hole 9, at the top of the ridge, there is pure ice 20 cm below the surface, and as in the other ridges the peat layers bend slightly backwards, in this case towards the depression between III and IV. At the highest point of the dome, a bit south of the profile line, pure ice is also met with at a depth of 20 cm. In two places

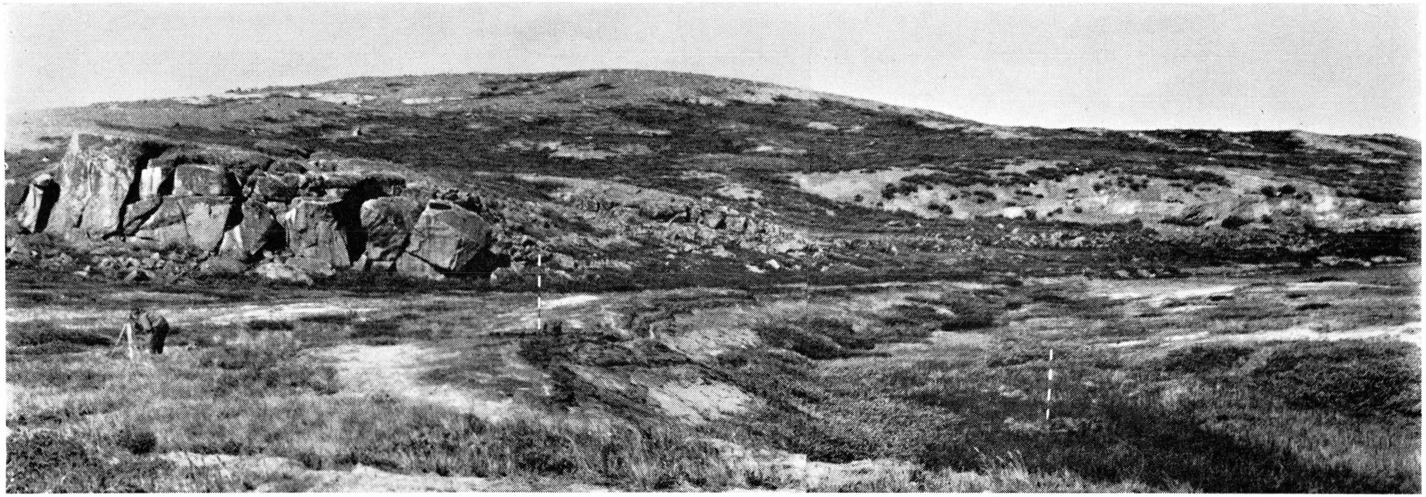


Fig. 29. Peat ridge II and the depression between I and II. The front side is steep, but the ridge is bending slightly backwards. Photo 4273–75.

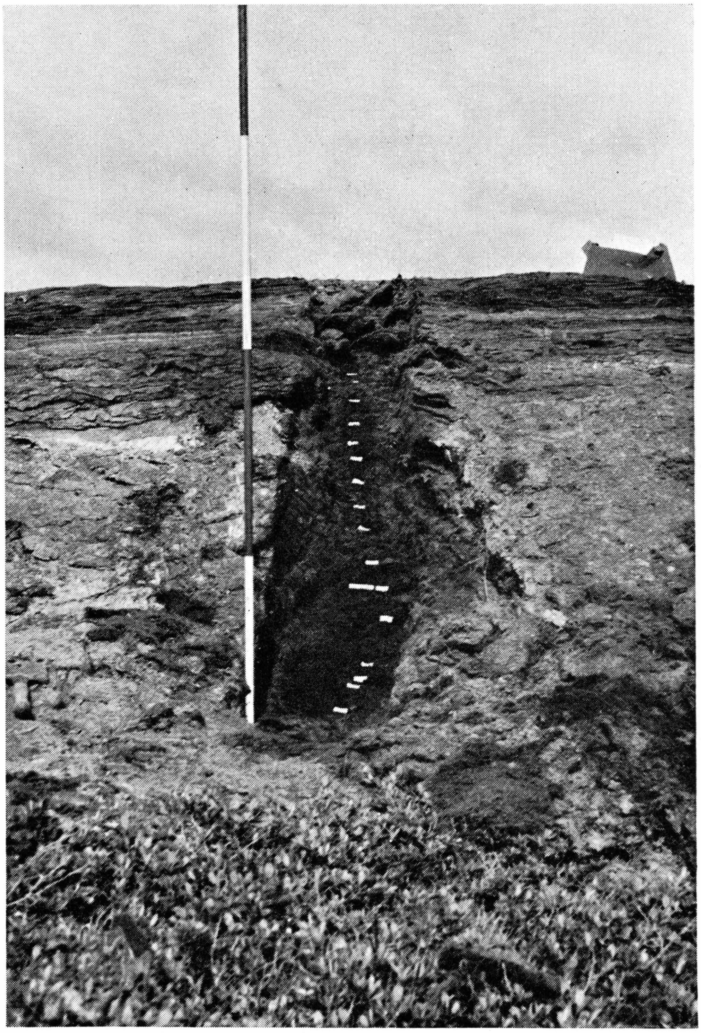


Fig. 30. Along the front of ridge III a trench was dug right on to the ice core, the surface of which was marked with white labels. Three labels next to each other mark the border between peat and mineral soil.

trenches were dug in this peat ridge from the top down the front side. Along the whole trench ice was found under the peat. Fig. 30 shows one of these trenches where the surface of the ice is marked by small white labels; three labels next to each other mark the lower edge of the peat. The depression between ridge III and IV is covered with vegetation and is waterlogged at a few places.

Peat ridge IV has still less the character of a terrace, but is a broad, domed belt of moss peats with an undulating surface with big depressions and water holes. It is shorter and wider than the other ridges, with a length of 92 m and a width of 23 m. South and east of it, there is a tangle of domes or big hillocks overgrown with Salix and Betula. Some of these domes contain red water moss peat, others are earth hummocks, but they are not arranged in ridges or any other regular system.

On the basis hereof, it can be concluded that these peat ridges are not erosion terraces, but that they are produced by frost pressure and consequently must be palsar. The name is Finnish, and palsar are found everywhere in the arctic and sub-arctic regions. In Russia they are termed Bugry, and the Samoyeds in Siberia call them Moga or Ladj (HÖGBOM, 1914).

Already REUSS (1891) mentions them from Finmarken, and they have also been described by FRIES and BERGSTRØM (1910), G. LUNDQUIST (1944, 1951, 1953), J. LUNDQUIST (1962), HOPPE and BLAKE (1963), WRAMMER (1965), SVENSON (1962), from northern Scandinavia.

In Iceland they are called Rústir or Rusti and are mentioned by for example THORODDSEN (1913), HANNESSON (1927), STEINDÓRSSON (1945) and THORARINSSON (1951). Also from Alaska and Labrador such palsar are known (SHARP, 1942, WENNER, 1947).

The genuine palsar consist of peat and rest on peat, but examples of palsar with a core of mineral soil or with sand lenses are also known of, and to the latter type the palsar at Store Saltsø must be referred. Palsar have not been mentioned previously from Greenland, but in 1962 RØEN and the present writer found a small pals in the swampy area on the watershed between the two lakes on the promontory called Kangârssuk at Fortunebay on the south coast of Disko. It was about 1 m high and has contained an ice core, which had melted away and left an air space, ca. 0.5 m high. The ceiling of the pals still contained a little ice, and remains of fallen, partly thawed peat moss lay on the floor. BACHMANN (1921) published a photo from a lake in the stage of being overgrown, situated at Nordfjord, Disko; here, some remarkably large hummocks are seen, some of which might very well be palsar.

In the profile fig. 26 the ice layers are connected as if they constituted the upper edge of the permafrost, because when digging one could follow the ice surface unbroken from one depression to the next one.

It is possible, however, that the palsar contain more and thinner ice layers or ice lenses.

As it is the case with most periglacial processes, it is difficult to give a quite safe explanation of the origin of these palsar; they might have arisen by pressure from the underlying ice, presumable on the border between the peat and the lower-lying mineral soil. A determination of the age is not possible. BÖCHER's carbon-14 datings only tell us that the lowermost of them in any case is younger than 900 A.D., but the question whether the other ones had already been pressed up at that time, or whether the whole complex is quite recent, cannot be decided.

What the carbon-14 datings show is, however, that the water surface of the lake has been gradually lowered since 380 B.C.; but since the carbon-14 dated peat sample has now been pressed higher up by the ice than its actual level when the water fell so much that the mosses died, a calculation today of the annual lowering of the water surface can only be approximate. If it is presumed that the sample lay at a level vertical under the present one on a line from the shore to the bottom of the depression above ridge IV, the position of the peat sample at the time in question should have been 300 cm above the water surface today. For a period of ca. 1400 years the mean annual lowering of the water level will then be 1.25 mm, which should have been brought about by evaporation and possibly seepage through fissures in the rock.

What RAMBERG has seen of terraces at Tarajornitsut must be left open; but BÖCHER's description of the terraces and his photos of some of them (BÖCHER, 1959, fig. 11) show that they are also palsar and formed in the same way as the palsar at Store Saltsø, but it is not at all certain that they were formed at the same time. Thus, there is no basis for using these palsar as indicators of changes in climate and movements of Indlandsisen.

BÖCHER's explanation that the depressions between the pals ridges should originate from an outwash of the loess, followed by a subsidence of the peat, cannot be true either, since, in that case, peat should be found at the bottom of these depressions, but they contain mineral soil.

BÖCHER's statement of the findings of dead daphnia in the dried up parts of the depressions can be supplemented by the fact that both in 1962 and 1965 numerous small snail shells and salt crusts were found on the lower part of the sloping back sides of the ridges. The interpretation should be justified that the water, which gathers in these depressions during spring thaw, cannot percolate into the ground because of the permafrost, but becomes stagnating and evaporates. If this is repeated year by year the concentration of the salts dissolved in the water will gradually become so high that they will liberate as salt crusts.

Table VI

No.	Md μ	Q_3 μ	Q_1 μ	So	$>62\ \mu$ %	$<4\ \mu$ %	$CaCO_3$ %
479........	29	48	18	1.63	14.5	3.5	1.5
480........	28	46	17	1.64	13.4	4.5	2.0
481........	28	46	15	1.75	14.7	5.4	2.0
519........	36	50	24	1.44	12.9	3.4	
520........	36	50	23	1.48	14.0	6.1	

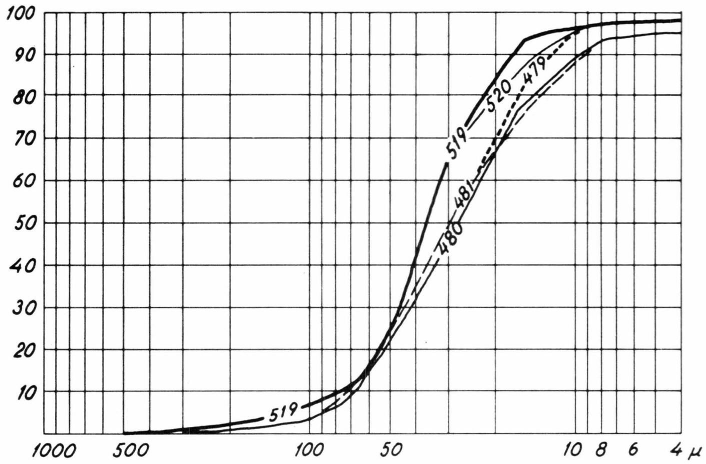


Fig. 31. Granulometric analysis of dust from the pals ridges. 479, 480, and 489 were taken in 1962, 519 and 520 in 1965.

Table VI and fig. 31 show the granulometric composition and the lime content of samples of dust deposits on the palsar. The samples 479–481 were taken in 1962, and the samples 519 and 520 in 1965. A comparison between these and the analyses of the European loess in table V p. 42 reveals that the dust from the palsar differs essentially from the loess. Both Md and the quartiles are larger than in loess, and the content of sand (grains above 62 μ) is also higher. Broadly speaking, one can characterize the difference so that in loess the fraction 16–31 μ dominates, whereas in silt from the palsar the fraction 31–62 μ is the dominating one. The relation becomes still more evident when using a triangle diagram (fig. 32). It shows very clearly that the loess samples lie quite separated from the Greenland dust samples, and that the samples from 1965 are somewhat coarser than those from 1962. This opens the discussion whether loess is a wind-transported sediment or can be classified as soil, *i.e.* whether the sediment has been subject to chemical weathering after being deposited. (EMILSSON, 1931, GRAHMANN, 1932, HOLZER, 1952, MÜNIETSDORFER, 1926, SYMPOSIUM ON LOESS, 1945). The Greenland dust deposits differ from the European loess by their somewhat coarser grains, by a lower content of $CaCO_3$ and by total lack of cohesivity. This points towards the answer that loess is a soil, made by weathering of finely grained dust deposits under semi-arid conditions and a thin, sparse cover of vegetation.

Above the pals ridges there are also pressed up ridges of mineral soil and a large terrace of creeping soil. It continues along the southern bank of the lake, a bit up the slope, in the system of creeping soil terraces, which remind us of the Danish sheep tracks, though on a larger scale. These have also been brought about by frost action (ØDUM, 1924).

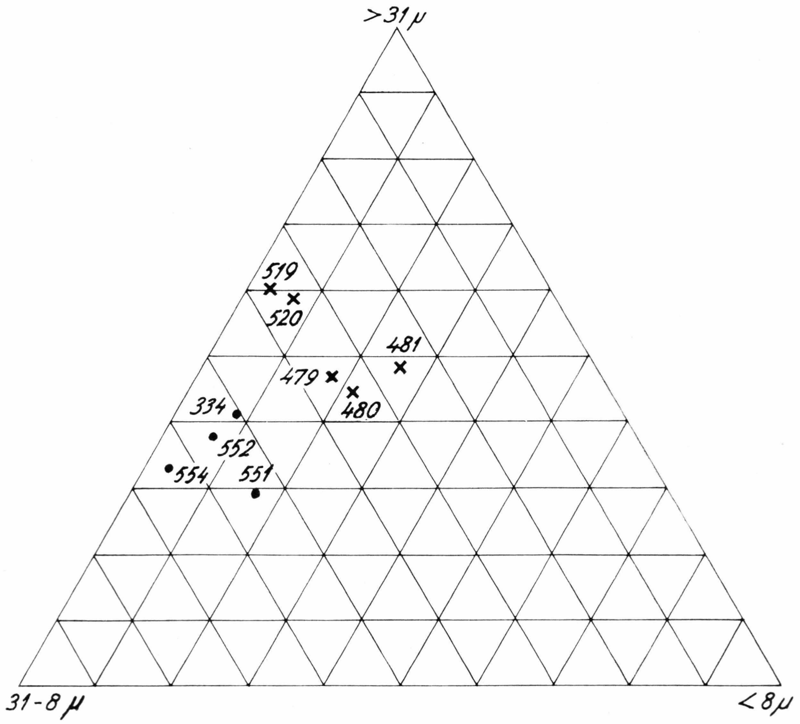


Fig. 32. Triangle diagram showing the difference between the granulometric composition of European loess samples (o) and dust from the pals ridges (x).

In the south-eastern part of the lake a wide valley with gently sloping floor terminates; also here the utmost part towards the lake consists of Drepanocladus peat.

Creeping soil terraces with big stones are found along the eastern side of the lake, and along the bank one sees vertical flakes of Drepanocladus mosses pressed up along the bank by the winter ice cover of the lake in the same way as previously described from Denmark (HANSEN, 1949).

Table VII

No.	Md μ	Q_3 μ	Q_1 μ	So	$> 62\ \mu$ %	$< 4\ \mu$ %
482	31	48	21	1.52	15.2	3.1
488	26	36	15	1.55	9.3	4.8
491	27	44	20	1.48	17.2	4.9
494	20	37	11	1.82	16.5	4.9
518	20	28	14	1.42	9.4	6.4
521	36	55	22	1.58	18.8	4.4
522	26	38	11	1.85	6.8	7.7

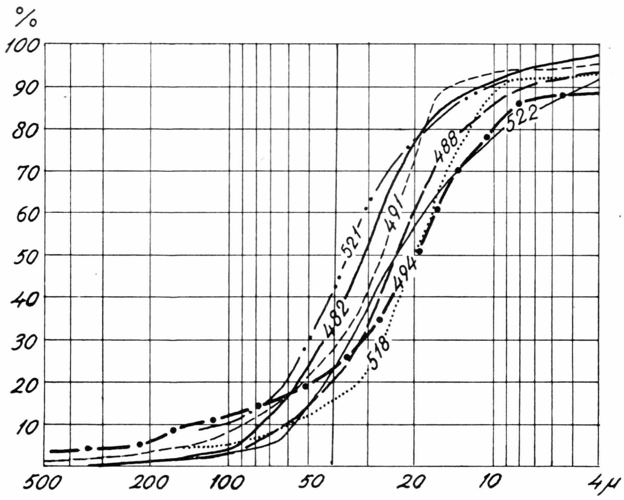


Fig. 33. Granulometric analyses of samples of soil and creeping soil around Store Saltsø. 482, 488, 518, and 521 are creeping soil, 491 is soil from the lake shore south of the palsar. 494 originates from flakes of foliated soil and moss peat from the eastern lake shore. 522 is mineral soil from the depressions between the palsar.

In the north-eastern corner of the lake another wide valley terminates and here, facing the lake, an even slope is found covered with Drepanocladus mats, intersected by a wide-meshed net of frost cracks with a few embryonal formations of palsar.

Table VII and fig. 33 show the granulometric composition of the soil around Store Saltsø. The variations are rather great, but the sorting surprisingly good. The soil outside the creeping soil areas (491 at the bank south of the palsar and between the pals ridges 522) does not differ essentially from the creeping soil and differs from the dust in the pals ridges mostly by its content of sand and clay.

V. THE SALT LAKES

Far back in time it has been known that round the head of Søndre Strømfjord there were lakes with saline or alkaline water (J. A. D. Jensen, 1881, 1889). In the missionaire Hans Christoffer Glahn's diary from the 4th of February 1768 such salt lakes and salt liberations are mentioned, and Samuel Kleinschmidt wrote in 1879 to J. A. D. Jensen that on the north side of the innermost part of Søndre Strømfjord there should be a rather large area with almost no water, and the little water actually found had a saline or alkaline taste.

As mentioned previously, it is not true that no water is found here, on the contrary, the area is abundant in lakes, but the water of more of them is actually saline or alkaline.

During his travel in 1884, J. A. D. JENSEN found such a lake, which he called Tarajornitsoq. He states its position to 66°56′ N, 50°53′ W, abt. 600 feet above sea level and a few hours' walk from the fjord.

A water sample was analysed by K. RØRDAM, and the proportions were the following, calculated on 10.000 units of water:

Cl	9.03	MgO	5.10
SO_3	0.76	CaO	–
CO_2	7.21	Na_2O	11.11
		K_2O	0.79

Total salt content: 34.00

This gives a salinity of 3.4 ‰. Later on, BÖCHER (1949 and 1959) brought new knowledge of these salt lakes and he also tried to find JENSEN's Tarajornitsoq. BÖCHER (1949) divides the lakes of the area into 4 groups:

A. poor in salt, acid lakes
B. poor in salt, neutral lakes
C. lakes with rather saline, alkaline water
D. lakes with saline, highly alkaline water

Table VIII and fig. 34 show the chemical composition of these water samples according to BÖCHER and supplemented by two analyses of water samples from Store Saltsø, taken in July 1962 and July 1965 respectively. All analyses were made by Danmarks Geologiske Undersøgelse (The Geological Survey of Denmark) and for BÖCHER the chief chemist VERNER CHRISTENSEN, has further converted RÖRDAM's analysis from Tarajornitsoq so that it appears in the same form as the other ones.

BÖCHER has been of the opinion that J. A. D. JENSEN's Tarajornitsoq must be one of the lakes he calls Brayasø, Limnæasø, or Hundesø, which are situated in a valley NW of Strømfjordshavn.

By salinity is understood the concentration of the ions present. CLARKE (1924) also includes SiO_2, Al_2O_3 and Fe_2O_3, but as most of SiO_2 occurs as undissociated silicic acid, and since Fe_2O_3 and Al_2O_3 only occur in very small quantities, it is more satisfactory to define the salinity as the concentration of Na, K, Ca, Mg, CO_3, SO_4, and Cl, after bicarbonate has been converted into carbonate (HUTCHINSON, 1957).

Calculated on this basis it will be seen that the salinity of the Greenland salt lakes is very low. The highest degree of salinity is found in

TAble VIII

	Lake near Strømfjords-havn 3/8–1946		Lille Saltsø 26/8–1946		Brayasø 21/9–1956		Tarajornitsoq 1884	
	mg/l	mval/l	mgl/	mval/l	mg/l	mval/l	mg/l	mval/l
CO_3^{--}					174	5.80	983	32,77
HCO_3^{-}	317	5,20	397	6,50	767	12,60		
SO_4^{--}	2	0,04	2	0,04	123	2.56	91	1.90
Cl^{-}	154	4,34	169	4,77	1246	34,97	903	25,47
Ca^{++}	25	1,25	30	1,50	15	0,75	0	0,00
Mg^{++}	41	3,37	62	5,10	180	14,80	308	25,30
Na^{+}	114	4,96	65	2,83	929	40,48	824	35,84
K^{+}			44	1,13			66	1,68
Fe^{++}					< 0,1			
Mn^{++}								
SiO_2	15		13		1,2			
pH	8		8–9		8,95			
Sp Conductivity µmho					3100			
Salinity ‰	0,6		0,8		3,4		3,2	

	Store Saltsø 20/9–1946		20/9–1956		4/7–1962		3/8–1965	
	mg/l	mval/l	mg/l	mval/l	mg/l	mval/l	mg/l	mval/l
CO_3^{--}	408	13,60	234	7,80	168	5,60	231	7,70
HCO_3^{-}	878	14,40	964	15,80	939	15,40	979	16,05
SO_4^{--}	48	0,94	40	0,83	35	0,73	37	0,77
Cl^{-}	708	19,97	570	16,07	520	14,66	570	16,07
Ca^{++}	32	1,60	30	1,50	38	1,90	20	1,00
Mg^{++}	236	19,41	182	14,97	150	12,33	195	16,05
Na^{+}	514	22,35	553	24,03	400	17,39	446	19,39
K^{+}	206	5,27			170	4,35	185	4,37
Fe^{++}			< 0,1		0,1		0,08	
Mn^{++}			0					
SiO_2	10		4,4		0,6		8,95	
pH	ab 9,5		ab 9,5		8,9			
Sp Conductivity µmho			3300				3100	
Salinity ‰	3		2,6		2,4		2,7	

Brayasø and Tarajornitsoq with 3.4 and 3.2 ‰, the lowest degree of salinity in the lake at Strømfjordshavn with 0.6 ‰. If one agrees with RAWSON and MOORE (1944) that the border between fresh water and salt water lies at a salt content of 200–300 mg/l (0.2–0.3 ‰) these Greenland lakes fall under the term salt lakes.

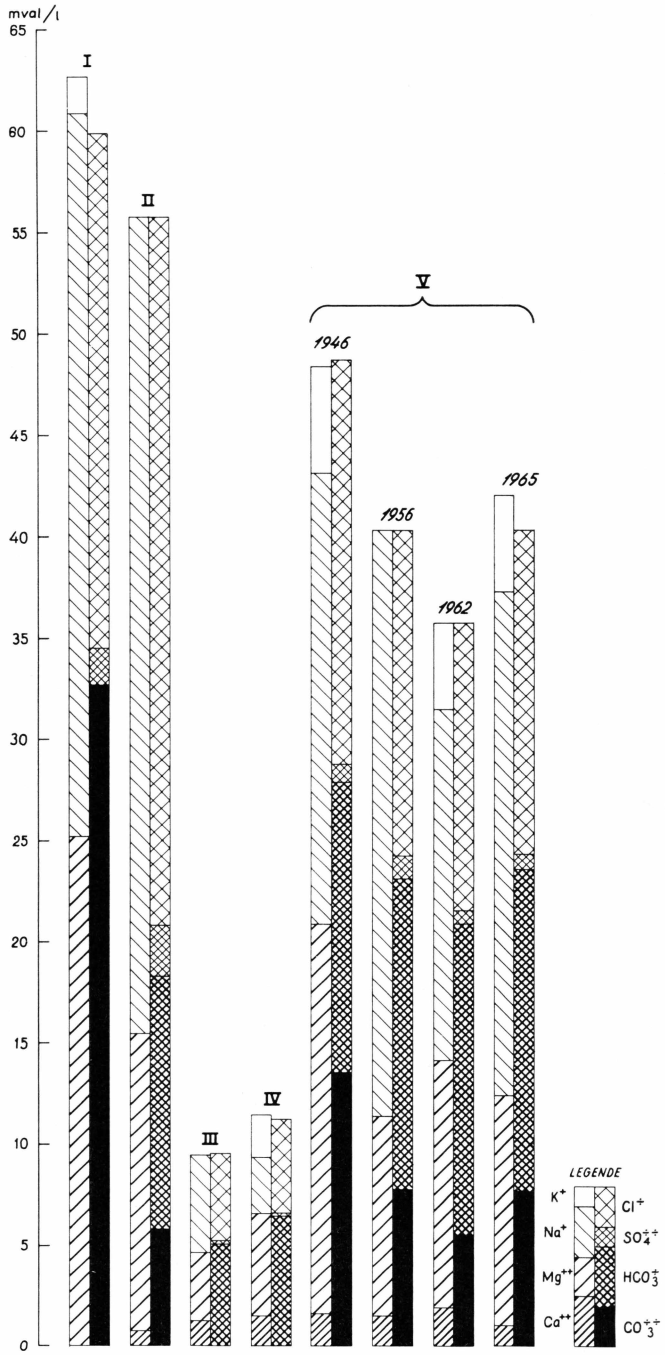


Fig. 34. The ion content in water samples from saline lakes at the head of Søndre Strømfjord.

I. Tarajornitsoq
II. Brayasø
III. Lake near Strømfjordshavn
IV. Lille Saltsø
V. Store Saltsø

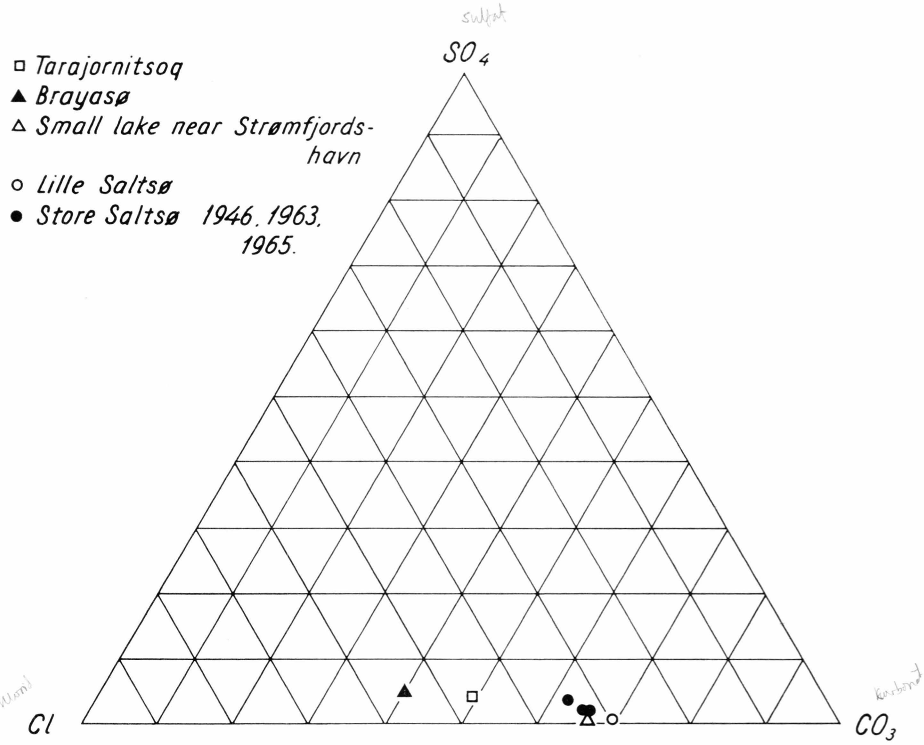


Fig. 35. Triangle diagram showing the interrelation between the anions in the Greenland salt lakes after convertion into milliequivalents/litre.

The diagram also shows that the salinity of Store Saltsø fluctuates somewhat. In the period 1946–62, the salinity decreased from 3–2.4 ‰, but in 1965 it increased again to 2.7 ‰.

Both the table and fig. 34 show that for all these lakes it can be said that the content of Ca^{++} is very low or is lacking, but all the lakes, with exception of the two least saline, contain both carbonate ions and bicarbonate ions.

Among the cations the alkalis are the most dominating, but there is also a rather considerable content of magnesium.

Hutchinson (1957) divides the saline waters into three types on the basis of the dominating anions and he distinguishes between carbonate lakes, sulphate lakes and chloride lakes, with all possible intermediate stages in between, as a matter of course.

Fig. 35 is a triangle diagram which should show the relationship between the anions CO_3, SO_4, and Cl. It reveals that with increasing salinity in these Greenland lakes, the type will change direct from carbonate lakes to chloride lakes, whereas the content of sulphate is surprisingly low in all cases.

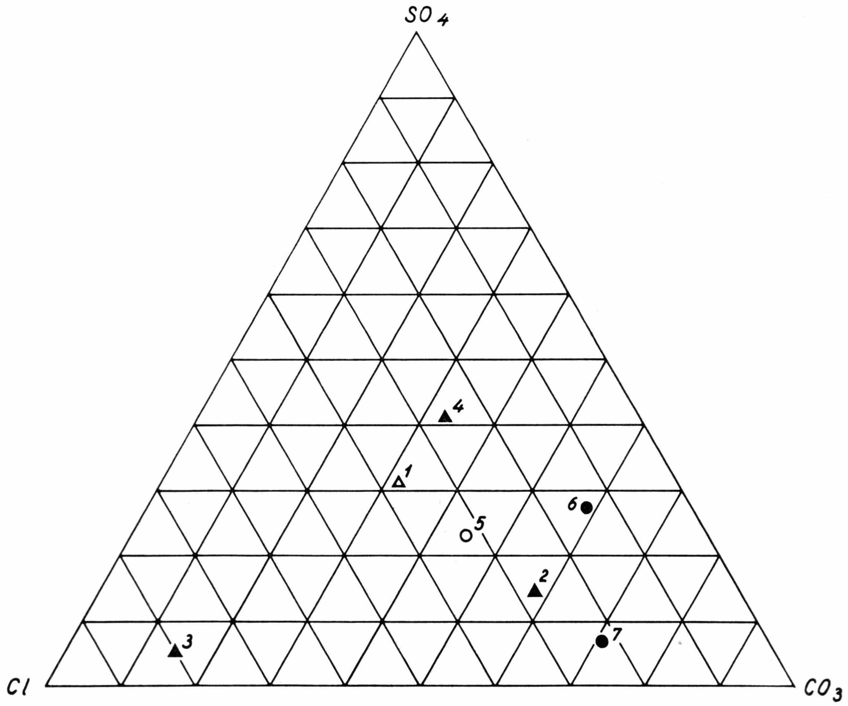


Fig. 36. Triangle diagram, showing the interrelation between the anions in the different North American salt lakes. 1. Utah Lake. 2. Pyramide Lake. 3. Winnemuca Lake. 4. Walker Lake. All in the Lahontan Basin, Nevada. 5. Tular Lake, California. 6. Pelican Lake, Oregon. 7. Bluepoint Lake, Oregon. The salinity of these lakes ranges from 1.3 ‰ in Utah Lake to 4.9 ‰ for Tulare Lake. Clarke (1924) converted into m.equiv./l.

This is something quite unique. Fig. 36 shows triangle diagrams from salt lakes in North America with a similar salt content as the Greenland lakes. The figures have been converted from Clarke (1924).

The diagram shows clearly that in all these lakes the sulphate ion makes up a considerably higher percentage of the total content of anions than in the Greenland lakes. The same is true of the lakes in western Tibet investigated by Hutchinson (1937, 1957) and shown in fig. 37.

This is due to the fact that in a lake with increasing salinity the calcium carbonate will udfælde precipitate as the first one, which results in a relative increase of sulphate and chloride in the remaining brine. With a continued increase of the salinity the solution product of calcium sulphate will be passed and the latter precipitates as gypsum ($CaSO_4$ $2H_2O$). Not until this stage, will the chloride ions become the dominating ones. The normal development is therefore from carbonate lakes

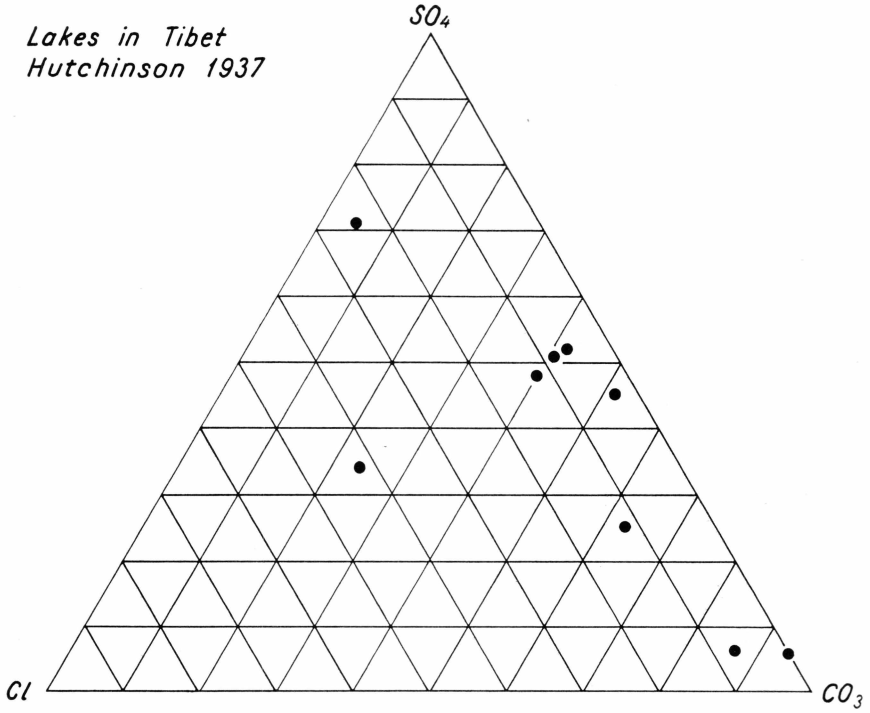


Fig. 37. Triangle diagram showing the interrelation between anions for some salt lakes in western Tibet. (After HUTCHINSON).

over sulphate-chloride lakes and into chloride lakes (HUTCHINSON, 1957).

As in Greenland, the Antarctic also has lakes which do not follow this rule, but apparently go from the carbonate stage directly into the chloride stage. The lakes in the Antarctic are more complex, however. Some of them are frozen all the year round and possibly get supplies of mineral components from sources at the bottom (ANGINO and ARMITAGE, 1963, ANGINO, ARMITAGE, and TASH, 1962, 1964, 1965 a.b., ARMITAGE and HOUSE, 1962, CLARK, 1965, HAMILTON, FROST and HAYES, 1962).

In order to explain the diverging behaviour of the Greenland salt lakes it is necessary to study the sources of their ion content. The content of dissolved salts in lakes and rivers originate from two sources. One is the chemical effect of percolating water in the soil layers, especially in the source areas of the river systems. This chemical weathering is dependant partly upon the climatic conditions and partly upon the kind of rocks through which the water is percolating and during which the water absorbs CO_2 and humus, which together with the hydrolysis of the water have a dissolving and decomposing effect on the mineral particles of the soil.

Table IX

	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Salt Lake City, Utah												
Temperature °C	−1.2	1.9	4.9	9.6	15.6	21.1	25.6	23.7	18.0	12.2	6.0	−0.7
Precipitation mm	30	40	45	53	55	19	19	33	22	30	48	49
Winnemucca, Nevada												
Temperature °C	−2.1	0.7	4.2	8.1	12.2	17.1	21.4	20.7	14.9	8.8	3.3	−1.3
Precipitation mm	26	25	24	21	22	18	5	5	10	16	17	27
Fresno, California												
Temperature °C	7.7	10.3	12.5	15.4	19.2	24.0	27.4	26.7	22.6	17.2	11.9	7.7
Precipitation mm	43	39	39	24	11	2	0.2	0.2	5	14	24	36
Boise, Idaho												
Temperature °C	−1.3	1.4	5.7	10.2	13.9	18.4	22.9	22.2	16.5	10.3	4.7	−0.1
Precipitation mm	43	40ö	33	30	35	75	6	5	13	31	32	39

Fig. 15 (page 30) shows temperature and precipitation at Søndre Strømfjord in Greenland (Böcher, 1949). It appears that the mean temperature for the warmest month is 10°C and further, that the mean temperature lies above zero only from the middle of April till mid September. The whole year round the precipitation is very low and does not exceed 25 mm for the most rainy month.

Table IX shows temperature and precipitation for a number of stations in the neighbourhood of the lakes in North America, reproduced in fig. 36. It will be seen that in these regions the temperature goes above 20°C for July and August, and from April until October the mean temperature is above 10°C. Only for December and January does it go a little below zero.

Although these regions are arid, apart from the Lahontan Basin in Nevada, the amount of precipitation is considerably greater than at Søndre Strømfjord in Greenland. Only as far as Central California and Oregon are concerned, the two warmest months are practically rainless.

In Tibet the precipitation is admittedly not much higher than at Søndre Strømfjord, but for July the mean temperature goes as high as to 17.6°C. This means that in these regions the seeping water is hydrolysed to a much higher degree than in Greenland, which intensifies the influence of water considerably on the minerals of the soil.

In Greenland, not only is the air temperature lower than it is in the mentioned parts of North America, but the soil is also frozen and only the uppermost 20–30 cm will thaw during the summertime. This means that it is only the content of CO_2 and humus acids in the soil water that are effective chemical agents, and furthermore, as the temperature under the dense vegetation cover is low, the weathering processes will proceed very slowly.

In 1962, different soil samples were taken in order to examine the mineral content of the soil, especially in the clay fraction, but the results are not available yet. The fact that the chemical weathering in Greenland is very weak and proceeds slowly appeared from an analysis of a soil sample from Godthåb (JENSEN, 1965). This showed that, in spite of the high content of fine-grained material, the sample has more the character of a powder, made chiefly by mechanical transformation of rocks rather than chemical decomposition. The same lack of chemical weathering is also known from the Antarctic (KELLY and ZUMBERGER, 1961, BLAKEMORE and SWINDALE, 1958).

The second supplier of ions to fresh waters is the atmosphere. This supplier has previously been somewhat neglected, but during the last decades it has become more and more evident that this source plays a very important role in many cases, especially in lakes with a very low content of ions, but also in salt lakes. Thus, GORHAM (1961) states that in "The English Lake District" many of the small lakes surrounded by volcanic rocks contain water with less than 0.2 millieqv. per litre of the total amount of salts. Hereof precipitation presumably contributes with almost the total content of chloride, sulphate, sodium, and potassium, more than 80 °/₀ of the magnesium content, and more than half of the calcium. The remaining calcium, supplemented by bicarbonate ions, originates from the weathering of the soil. ERIKSSON (1955) states that as far as southern Sweden is concerned the chloride content of the rivers comes mainly from the atmosphere. From Finland GORHAM (1961) states the following figures:

	kg/ha/year					
	Ca.	Mg	Na	K	SO_4	Cl
Precipitation Kuopio	2.7	0.4	1.0	0.6	9.3	1.5
River discharge Vuoksi	12.2	3.9	6.0	5.4	17.7	4.9
Precipitation Jyväskylä	4.2	0.4	1.4	0.9	11.6	3.2
River discharge Kymijoki	10.6	3.6	5.6	4.1	15.5	6.4
Precipitation in per cent of river discharge:						
Kuopio/Vuoksi	22	10	17	11	53	31
Jyväskylä/Kymijoki	40	11	25	22	71	50

Thus about 20 °/₀ of the content of natrium, 10–20 °/₀ of the amount of potassium, 10 °/₀ of the magnesium, 20–40 °/₀ of the calcium, 30–50 °/₀ of the chloride and 50–70 °/₀ of the sulphate are added to these rivers from the atmosphere.

The atmosphere gets the majority of these chemicals from sea spray when large waves break during gales and produce foam patches with a lot of bubbles in. When bursting, the bubbles make millions of drops which will be thrown high up into the air, where they evaporate and form salt particles which can act as condensation cores for clouds and raindrops, or, they may be captured by raindrops.

About 99 % of the amount of natural sea spray is found in the so-called giant particles with a radius larger than 0.8 μ. The speed of fall is extremely low for these particles, but they can be sifted from the air even by such small obstacles as grass, spruce and pine needles etc. Being hygroscopic and therefore generally wet, these particles will rarely be whirled up into the air again when they have first been caught by vegetation, from where they can be washed down into the soil by rain (Gorham, 1961, Eriksson, 1955).

Swedish investigations have shown that in rainwater collected at the beginning of rainy periods, under the outer part of pine crowns, the Na-content was five times higher than in rainwater collected at unsheltered places. Junge and Gustafson (1957) found near Boston, Massachusetts, that in two containers standing next to each other, one of which was open all the time, the other one only during rain, the first one contained in average 25 % more chloride and this because of dry fallout. Eriksson (1955) has calculated that in Sweden the supply of chloride to the vegetation from the condensation cores is sufficient to balance the amount of chloride measured in the run-off. In Japan, Hanya (1951) found that 14 % of the chloride content in the rivers originate from the rain and 41 % from dry fallout.

Clarke (1924) has made three analyses of sea water: from the North Atlantic between Norway, the Faroes and Iceland, from the White sea, and from the Arctic Ocean between the White Sea and Novaja Semlia. Converted into equivalents per 100 g salt, the result will be $Cl/SO_4 = 9.87$. This is quite in accordance with Gorham (1961) when his figures are converted into equivalents. The figure for Cl/SO_4 is here 9.83.

Table X shows the mean content of sulphate and chloride in the precipitation for 1955 at a number of European stations. The figures were taken from Egnér and Eriksson's tables (1955 and 1956) and have been converted into milliequivalents per m^3 per year. It appears from the table that even for coastal stations as Lista and Vinga, which are located in the uttermost islands in the archipelago, the quotient Cl/SO_4 is only $^2/_3$ of that of sea water. The reason is, of course, that in the winds blowing from the interior and seaward, the fallout from the atmosphere contains many kinds of pollution such as dust particles, pollen and not to forget chimney smoke of different kind.

In the Baltic, even the coastal stations Sylfasta in Gotland and Tvärminne in Finland show a still lower Cl/SO_4 quotient than the Danish stations though these are situated considerably inland.

Table X

	precipitation mm	SO_4 mval/m³	Cl mval/m³	Cl/SO_4
Sweden:				
1. Riksgränsen, Lapland	483	1.25	1.51	1.21
2. Erken, Uppland	411	2.23	0.62	0.28
3. Vinga, Bohuslän	395	4.79	30.40	6.40
4. Sylfasta, Gotland	397	2.07	1.26	0.61
5. Alnarp, Skåne	581	4.70	4.80	0.80
Norway:				
6. Ås, Oslofjorden	509	2.61	1.53	0.59
7. Vågåmo, Ottadalen	666	0.31	0.42	1.35
8. Lista	748	8.11	51.9	6.40
Finland:				
9. Kuopio	338	1.43	0.33	0.23
10. Tværminne	387	1.87	3.17	1.69
Denmark:				
11. Ødum, Jylland	457	3.87	4.22	1.09
12. Askov, Jylland	596	5.44	12.09	2.22
13. Tystofte, Sjælland	476	4.45	4.66	1.05

The fact that particles originating from sea spray can be thrown very high up into the air is demonstrated in KÖHLER's determinations from the mountain station Halde in the northernmost Norway (KÖHLER, 1923, 1937). On the basis of KÖHLER's measurements, GORHAM (1961) has calculated the interrelation between the ions of the white frost on the Halde peak, the content of chloride being fixed at 100, and the following values were found:

Ca	Mg	Na	SO_4	Cl
2.4	7.6	56	16	100

Converted into equivalents, the quotient of Cl/SO_4 will be 8.6, which lies very close to that of sea water.

From Greenland, no measurements of the precipitation are available, but we have analyses of the ion content of Indlandsisen. (JUNGE, 1958, MELLOR, 1964, LANGWAY, 1962). Additionally, more analyses have been made of the salt crusts found at several places in the innermost part of the Søndre Strømfjord region. These salt crust must have been brought about by evaporated precipitation which has not been able to seep into the ground because the permafrost lies too close to the surface. At Store Saltsø for example, the salt crusts are found at the lowermost and the rear parts of the peat ridges, because the water in the depressions between the ridges has found no outlet. In the course of time an increasingly strong solution of salt has therefore gathered in such depressions, and finally the salts have precipitated in such quantities that it can be scraped loose with caution.

Analyses from Site 2 on Indlandsisen in North Greenland gave the following figures in mg/l:

	Na	Ca	K	Cl	SO_4
Average of the uppermost 100 m....	0.029	0.035	0.011	0.037	0.25
Sample taken 300 feet below the surface	0.097		0.077	0.156	0.315

Converted into milliequiv./l. this gives a Cl/SO_4 quotient of 0.21 for both samples.

Table XI

	1 %	2 %	3 %		4 %	5 %	6 mvl/g
Cl	8.02	2.60	9.07	Cl	10.2	3.0	1.9
SO_3	46.07	22.06	44.31	SO_4 ...	55.2	64.6	6.0
CO_2	0.78	2.16					
MgO	2.72	13.88	3.48				
CaO			3.21	Ca	0.49	2.9	0.25
Na_2O	30.09	9.59	28.19	Mg	5.00	0.45	2.1
H_2O	0.91	8.29	4.99	Na	22.2	25.6	6.9
$Fe_2O_3 + Al_2O_3$	2.55	4.00		K	3.8	1.7	1.5
H_2O	8.76	37.05					

Table XI shows analyses of salt crusts:

1 and 2 Salt crusts from the plain at Itivnik within Ikertôq (JENSEN, 1889)

3 Salt crusts from talus slope in the valley Ilivilik, PJÉTURSSON, 1898

4 Salt crusts from Store Saltsø
5 Salt crusts from salt lake at Strømfjordshavn } (BÖCHER, 1949)

6 Salt crusts from Store Saltsø 1965

Converted into equivalents per 100 g the analyses have the following values for Cl/SO_4:

Analysis	1	0.23
–	2	0.158
–	3	0.22
–	4	0.25
–	5	0.062
–	6	0.25

There is a good interrelation between these figures, with the exception of two samples with a markedly high content of sulphate. However, there is also a good accordance with the analyses from Indlandsisen, and it is evident that considerably more sulphate than chloride has been conveyed to the soil surface by fallout from the atmosphere. When in spite of this, the salt lakes prove to be very poor in sulphate ions the reason must be that since the permafrost only lies 20–40 cm below the surface the whole soil profile that thaws in summer is only developed as the humus horizon A of the podsol profile. Here, the sulphate ions are reduced to sulphide and will precipitate together with the iron, whereas the chloride ions, which cannot form insoluble compounds, join the soil water into the lake, which will thus be almost sulphateless.

Even though the Søndre Strømfjord region has a very low rate of precipitation, sufficient water will be conveyed to the ground in summer, especially in valleys like the one containing Store Saltsø, to allow an extremely dense and abundant vegetation; consequently the soil is very rich in humus and reducing conditions prevail.

Contrary to this, the temperate and sub-tropic arid regions that have salt lakes show a very sparse or no vegetation. This is also true for the regions in Tibet with salt lakes. Here, therefore, the content of humus in the soil becomes very low and reducing conditions will consequently only be made on a very low scale, and these salt lakes will get a significantly higher amount of sulphate than is the case in the Greenland salt lakes.

The rather low salinity of the lakes allows both vegetation and fauna. BÖCHER (1949) states that in Lille Saltsø there are scattered specimen of *Potamogeton filiformis*, whereas no macroscopic vegetation was found in Store Saltsø, only plankton and very few microscopic sedentary algae, for example *Oedogonium sp.* Also the lake Limnæasø is without vegetation apart from possible phytoplankton (BÖCHER, 1959).

From the lake Brayasø, however, BÖCHER (1959) mentions *Potamogeton filiformis*, *Rhizoclonium riparium*, some *Spirogyra*, *Zygnema*, *Mougeotia* and *Oedogonium* and representatives for the genera *Synedra*, *Closterium*, *Cosmarium* and *Nostoc*.

RØEN (1962) states the following entomostratic fauna from these lakes:

	1	2	3	4	5
Daphnia pulex		+	+	+	+
Macrothrix hirsuticornis	+				
Eurycercus glacialis		+	+	+	+
Acroperus harpae	+				
Alona affinis	+				
Alonella nana	+				
Chydorus sphæricus		+		+	
Limnocythere sanctipatrici...	+	+			
Diaptomus minutus		+	+		+
Clyclops scutifer	+	+	+	+	+

1. Lake of Limnæasø. 2. Lake of Baryasø. 3. Salt lake near Strømfjordshavn. 4. Lake of Lille Saltsø. 5. Lake of Store Saltsø.

BIBLIOGRAPHY

Angino, E. E. and Armitage, K. B., 1963: A geochemical study of Lake Bonney and Lake Vanda, Victoria Land. Antarctica.—Journ. Geol. Vol. 71. Chicago.

— Armitage. K. B. and Tash, J. C., 1962: Chemical stratification in Lake Fryxell, Victoria Land, Antarctica.—Science. Vol. 138.

— Armitage, K. B. and Tash, J. C., 1964: Physiochemical Limnology of Lake Bonney, Antarctica.—Limnology and Oceanography. Vol. 9. Seattle.

— Armitage, K. B. and Tash, J. C., 1965 a: A chemical and limnological study of Lake Vanda, Victoria Land, Antarctica.—Univ. of Kansas, Science Bull. Vol. XLV.

— Armitage, K. B. and Tash, J. C., 1965 b: Ionic content of Antartic ice samples. —The Polar Record. Vol. 12. Cambridge.

Armitage, K. B. and House, H. B., 1962: A limnological reconnaissance in the area of McMurdo Sound, Antarctica.—Limnology and Oceanography. Vol. 7. Seattle.

Bachman, H., 1921: Beiträge zur Algenflora des Süsswassers von Westgrönland.—Mitt. Naturf. Ges. Luzern. Heft VIII.

Belknap, R. L., 1941: Physiographic studies in the Holsteinborg District, Greenland.—Rep. Greenland Exp. Univ. of Michigan II, nr. IV. Ann Arbor.

Bendixen, O., 1921: Sukkertoppen Distrikt.—Meddr Grønland. Bd. 61, p. 95.

Berthelsen, A. and Noe-Nygaard, A., 1965: The Precambrian of Greenland.—In: Rankama, K., ed.—The Precambrian. Vol. 2. New York, London.

Black, R. F., 1951: Eolian deposits of Alaska.—Arctic. Vol. 4. Quebec.

Blakemore, L. C. and Swindale, L. D., 1958: Chemistry and clay mineralogy of a soil sample from Antarctica.—Nature. No. 4627.

Bobé, L., 1921: Holsteinborg distriktets historie.—Meddr Grønland. Bd. 61, p. 87.

Butzer, K. W., 1965: Environment and Archeology. An introduction to Pleistocene Geography. London.

Böcher, T., 1949 a: The botanical expedition to West Greenland 1946.—Meddr Grønland. Bd. 147, nr. 1.

— 1949 b: Climate, soil and lakes in continental West Greenland in Relation to Plant Life.—Meddr Grønland. Bd. 147, nr. 2.

— 1954: Oceanic and continental vegetational complexes in Southwest Greenland. —Meddr Grønland. Bd. 148, nr. 1.

— 1956: Area-limits and isolation of plants in relation to the physiography of the southern parts of Greenland.—Meddr Grønland. Bd. 124, nr. 8.

— 1959: Floristic and ecological studies in Middle West Greenland.—Meddr Grønland. Bd. 156, nr. 5.

Church, J. E., 1941: Climate and evaporation in alpine and arctic zones.—Rep. Greenland Exp. Univ. of Michigan, part II. Ann Arbor.

Clark, R. H., 1965: The oasis in the ice. In: Hatherton, T.: Antarctica. London.

Clarke, F. W., 1924: The data of geochemistry.—U.S. Geol. Surv. Bull. 770.

Collini, B., 1950: Om våra kvartära lerors mineralogiska sammensätning.—Geol. Fören. Stockholm. Förh., bd. 72.

— 1956: On the origin and formation of the Fennoscandian quarternary clays.—Geol. Fören. Stockholm. Förh., bd. 78.

Douglas, L. A. and Tedrow, J. C. F., 1960: Tundra soils of arctic Alaska.—Transact. 7 Intern. Congr. of Soil Science 4.

Drew, J. V. and Tedrow, J. C. F., 1957: Pedology of an arctic brown soil profile near Point Barrow.—Proc. Amer. Soc. of Soil Science 21.

Egnér, H. and Eriksson, E., 1955 and 1956: Current data on the chemical composition of air and precipitation.—Tellus 7 and 8. Stockholm.

Emilsson, S., 1931: Lössbildung auf Island. Soc. Sci. Islandica II. Reykjavik.

Eriksson, E., 1955: Air borne salts and the chemical composition of river waters. —Tellus 7. Stockholm.

Flint, R. F., 1957: Glacial and Pleistocene Geology. New York.

Fries, Th. och Bergström, E., 1910: Några iagttagelser öfver Palsar og deras förekomst i nordligsta Sverige.—Geol. Fören. i Stockholms Förh. 32.

Gorham, E., 1961: Factors influencing supply of major ions to inland waters, with special reference to the atmosphere.—Bull. Geol. Soc. of America. Vol. 72.

Grahmann, R., 1932: Der Löss in Europa.—Mitt. Gesell f. Erdkunde zu Leipzig.

Hamilton, W., Frost, J. C. and Hayes, P. T., 1962: Saline features of a small ice platform in Taylor Valley, Antarctica.—U.S. Geol. Surv. Prof. Paper, 450 B.

Hannesson, P., 1927: Frà Öbydum I.—Rjettur XII. Akureyri.

Hansen, K., 1949: Ispresning i Tystrup Sø og Esrum Sø 1946–47.—Geografisk Tidsskrift. Bd. 49.

— 1967: The general limnology of arctic lakes as illustrated by examples from Greenland.—Meddr Grønland. Bd. 178, nr. 3.

Hanya, T., 1951: Average composition of Japanese freshwaters and some considerations on it.—Intern. Assoc. of Hydrology. Bruxelles Assemblé.

Hayward, H. O. B., 1936: The Oxford University Greenland Expedition 1935.—Geogr. Journ., Vol. 88. London.

Hobbs, W., 1927: The first Greenland Expedition of the University of Michigan.—The Geogr. Rev. Vol. XVII. New York.

— 1931: The origin of the loess associated with glaciation, based upon studies in Greenland. C. R. Congr. Intern. Geogr., Paris.

Holzer, H., 1952: Ein Beitrag zur Frage der Herkunft des Lösses auf Sedimentpetrographischer Grundlage.—Zeitschr. f. Gletscherkunde, nr. 2. Innsbruck.

Hoppe, G. och Olson Blake, I., 1963: Palsmyrar och flybilder.—Ymer.

Hutchinson, G. E., 1937: Limnological studies in Indian Tibet.—Intern. Rev. für Hydrobiologie.

— 1957: A treatise on limnology. London, New York.

Högbom, B., 1914: Über die geologische Bedeutung des Frostes.—Bull. Geol. Institut, Uppsala. XII.

Hörner, N. G., 1946: Uppsala-moränens finfraktion.—Geol. För. i Stockholm. Förh. 68.

— 1947: Granulometric aspect of some late glacial deposits of central Sweden.—La Geologie des Terrains dans l'Ouest de l'Europe.—Sess. Extraord. d. Soc. Geol. de Belge, 19. Bruxelles.

— 1951: Suspended matter in some present-day glacial waters as compared to late glacial varved clay.—Sedimentation et Quaternaire.—Compt. Rendu du Congres en France 1949. Bordeaux.

Hållan, K., 1913: Undersökning av en frostknöl (Pals) å Kåitajänkimyr i Karesuanda Sockn.—Geol. För. i Stockholm. Förh. 35.

JENSEN, E., 1965: The low-plastic clay from Godthåb, Greenland.—Meddr Grønland. Bd. 165, nr. 4.
JENSEN, J. A. D., 1881: Beretning om en undersøgelse af Grønlands Vestkyst fra 66°55′–68°30′ n.b. i 1879.—Meddr Grønland. Bd. 2, Nr. 5.
— 1889: Undersøgelse af Grønlands vestkyst fra 64–67° n.b.—Meddr Grønland. Bd. 8, Nr. 2.
JUNGE, C. E. and GUSTAFSON, P. E., 1957: On the distribution of sea salt over The United States and its removal by precipitation.—Tellus, vol. 9. Stockholm.
— 1958: Snow analyses supplied to SIPRE by Air Force Cambridge Research Center.
KAISER, O., 1928: The Inland Ice.—In VAHL, AMDRUP, BOBÉ and AD. S. JENSEN "Greenland I". København.
KELLY, C. E. and NYGÅRD, J., 1951: Exploratory study of the principal soil groups of Alaska.—U.S. Dep. Agr. Monograph 7.
KELLY, W. C. and ZUMBERGER, J. H., 1961: Weathering of a quartz diorite at Marble Point, McMurdo Sound, Antarctica.—Journ. Geol. vol. 69, Chicago.
KORNERUP, A., 1881: Geologiske iagttagelser fra vestkysten af Grønland i 1879.—Meddr Grønland. Bd. 2. Nr. 6.
KÖHLER, H., 1923: Zur Kondensation des Wasserdampfes in der Atmosphaere.—Geogr. Publ. Oslo. Vol. 2.
— 1937: Studien über Nebelfrost und Schneebildung und über Chlorgehalt des Nebelfrostes, des Schnees und des Seewassers im Halldegebiet.—Bull. Geol. Inst. Uppsala 26.
KÖPPEN, W., 1931: Grundriss der Klimakunde.—Berlin.
— 1936: Das geographische System der Klimate.—In: W. KÖPPEN und R. GEIGER: Handb. d. Klimatologie. Abt. B.
LANGWAY, C., 1962: Some physical and chemical investigations of a 411 m deep Greenland ice core for climate change.—Symposium of Obergurgl. Intern. Union of Geodesy and Geophysics. Assoc. Scientific Hydrology.
LAURSEN, D., 1950: The stratigraphy of the marine quarternary deposits in West Greenland.—Meddr Grønland. Bd. 151, nr. 1.
LUNDQUIST, G., 1944: De svenska fjällens natur.—Stockholm.
— 1951: En palsmyr sydost om Kebnekaise.—Geol. För. i Stockholm. Förh. 73.
— 1953: Tilläg til Palsfrågan. Geol. För. i Stockholm. Förh. 75.
LUNDQUIST, J., 1962: Patterned ground and related frost phenomena in Sweden.—Sveriges Geol. Unders. Ser. C., nr. 583.
MALYCHEFF, V., 1929–33: Le loess. I–V.—Rev. Geogr. Physique et Géol. Dynamique. Vol. II–VI. Paris.
MELLOR, M., 1964: Properties of Snow.—CRREL Rep.
MOTT, P. G., 1937: The Oxford Univ. Greenland Exp., West Greenland, 1936.—Geogr. Journ. Vol. 90. No. 4. London.
MÜNIETSDORFER, F., 1926: Der Löss als Bodenbildung.—Geol. Rundschau, 17.
NOE-NYGAARD, A., 1952: A new orogenic epoch in the Precambrian of Greenland.—Proc. Intern. Geol. Congress 18th Session Great Britain, part XIII. 1948.
— and RAMBERG, H., 1961: Geological reconnaissance map of the country between lat. 69°N. and 63°45′N., West Greenland.—Mecdr Grønland. Bd. 123, nr. 5.
— and BERTHELSEN, A., 1952: On the structure of a high metamorphic gneiss complex in West Greenland.—Meddr Dansk Geol. Foren. Bd. 12, nr. 2.
NORDENSKIÖLD, O., 1910: Från Dansk Sydvästgrönland.—Ymer. Bd. 13. Stockholm.
— 1914: Einige Züge der physischen Geographie und der Entwicklungsgeschichtes Süd Grönland.—Geogr. Zeitschr. 20. Jhg. Leipzig.
PETERSEN, F., 1898: Opmålingsekspeditionen til Egedesminde Distrikt, 1897. Beretning om rejsen.—Meddr Grønland. Bd. 14, nr. 3.I.

PJÉTURSSON, H., 1898: Geologiske Optegnelser på Opmålingsekspeditionen til Egedesminde Distrikt 1897.—Meddr Grønland. Bd. 14, nr. 3.II.
PLAISANCE, G. et CAILLEUX, A., 1958: Dictionnaire des sols. Paris.
RAMBERG, H., 1948: On the petrogenesis of the gneiss complexes between Sukkertoppen and Christianshåb.—Meddr Dansk Geol. Foren. Bd. 11, nr. 3.
RAWSON, D. S. and MOORE, J. C., 1944: The saline lakes of Saskatchewan.—Canada Journ. Research. Vol. 22 Section D.
REUSCH, H., 1891: Fra en rejse i Finmarken. Det nordlige Norges geologi.—Norges Geol. Undersøgelser.
RICHTHOFEN, F., 1877: China I. Berlin.
— 1901: Führer f. Forschungsreisende. Leipzig.
RØEN, U. I., 1962: Studies on freshwater Entomostrata in Greenland II.—Meddr Grønland. Bd. 170, nr. 2.
SCHIEFERDECKER, A. A. G., 1959: Geological Nomenclature. Gorinchem.
SHARP, R. P., 1942: Ground ice mounds in Tundra.—Geogr. Rev. 32.
STEINDÓRSSON, S., 1945: Studies on the vegetation of the central highland of Iceland.—The Botany of Iceland. Vol. III, nr. 4. København.
STRØM, K., 1935: Sammensatte botnsjøer og litt om geomorfologiske sjøtyper i Norge.—Norsk Geogr. Tidsskrift. 5.
SVENSON, H., 1962: Några iagttagelser från Palsområden.—Norsk Geogr. Tidsskr. XVIII.
— 1964: Structural observations in the minerogenic core of a Pals.—Svensk Geogr. Årsbok, 40. Lund.
SYMPOSIUM ON LOESS, 1945.—Amer. Journ. of Science, 243. New Haven.
TABER, S., 1943: Perrenially frozen ground in Alaska, its origin and history.—Bull. Geol. Soc. of America. 54.
TEDROW, J. C. F. and HILL, D. C., 1955: Arctic Brown Soil.—Soil Science. Nr. 80, pp. 265–275.
— and CANTLON, J., 1958: Concepts of soil formation and classification in arctic regions.—Arctic. Nr. 11. Quebec.
— and DREW, I. V., HILL, D. E. and DOUGLAS, L. A., 1958: Major genetic soils of the arctic slope of Alaska.—Journ. of Soil Science. Nr. 9.
— and HARRIS, H., 1960: Tundra soil in relations to vegetation, permafrost and glaciation. Oikos. Vol. 11, pp. 239–249. København.
THORARINSSON, S., 1951: Notes on pattern ground in iceland with particular reference to the Icelandic flás.—Geogr. Annal. Vol. 33. Stockholm.
THORODDSEN, T., 1913: Polygonboden und Tufur auf Island.—Petermann Mitt. Vol. 59.
TUCK, R., 1940: Origin of the muck-silt deposits at Fairbanks, Alaska.—Bull. Geol. Soc. of America. Vol. 51.
WALTER, J., 1924: Das Gesetz der Wüstenbildung in Gegenwart und Vorzeit. Leipzig.
WEGMANN, C. E., 1938: Geological investigations in southern Greenland.—Part I. Meddr Grønland. Bd. 113, nr. 2.
WENNER, C. G., 1947: Pollen diagrams from Labrador.—Geogr. Annal. Vol. 29. Stockholm.
WIKLANDER, L., 1950: Differentialtermisk analys av några kvartära svenska lera.—Geol. För. i Stockholm. Förh. 72.
WRAMMER, P., 1964: Fynd av Palsar med mineraljordkärna i Sverige.—Geol. För. i Stockholm. Förh. 86.
ØDUM, H., 1924: Om de såkaldte fårestiers natur.—Naturens Verden. København.
ÅMAND, R., 1967: Palsstudier i Nordnorge.—Svensk Geogr. Årsbok. Vol. 43. Lund.

Færdig fra trykkeriet den 9. september 1970.

PLATES

Plate I

Air photo showing the area Iperâríssap nunâ SE of the upper Søndre Strømfjord. One notices the wide, flat ridges and three of the deep valleys. In the background to the left Umîvît, from where the wide valley Aussivigssuit extends towards the east and splits up into two valleys that entwine the rock ridge Pinguarssuk.

In the centre, the rock ridge Manîtsut kitdlît, the central part of which contains a wide, flat valley; the northern part has outflow to Umîvît and the southern part to the lakes in Qangátap kûa *i.e.* to the lake Taserssuaq.

Copyright: The Geodetic Institute, 17.7.1948. Route 507 Gl-N 4848.

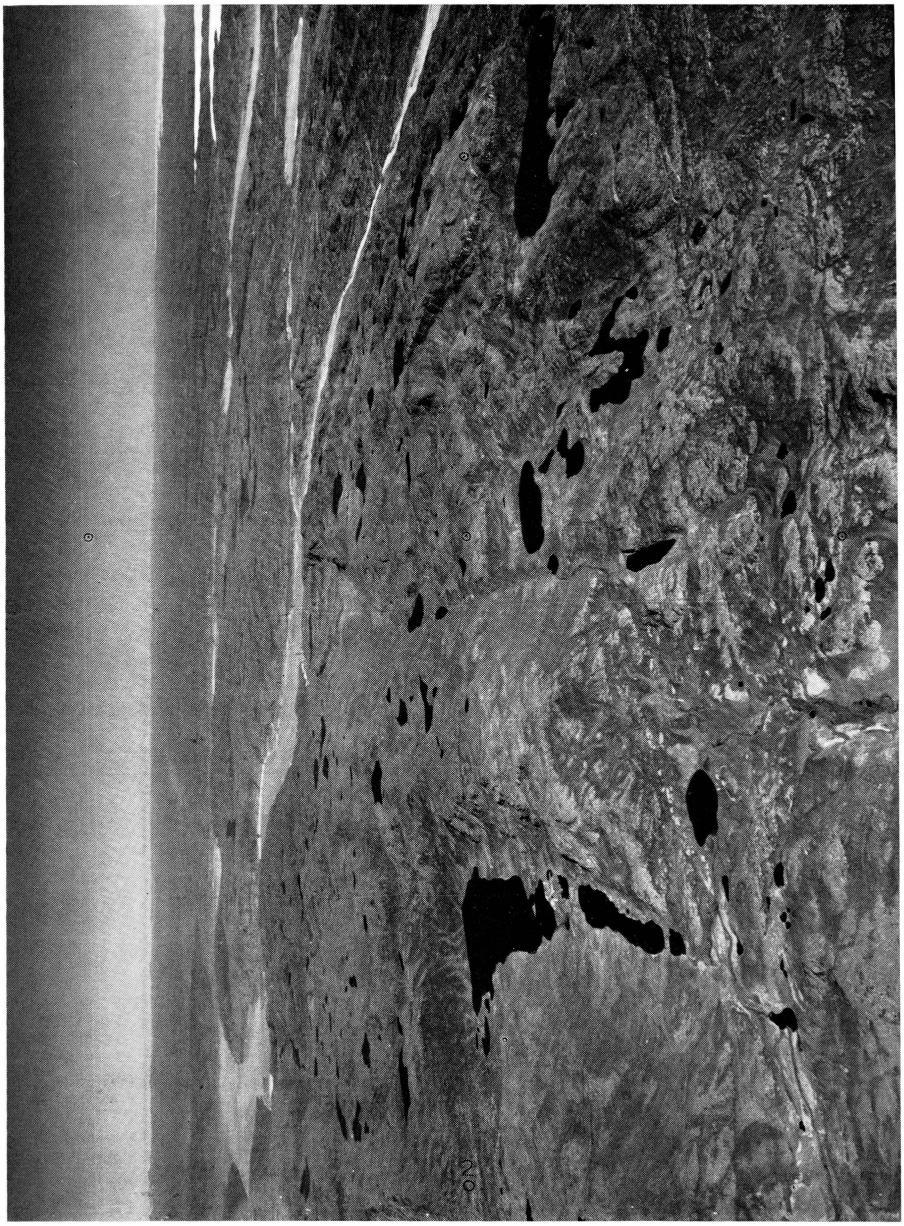

2

Plate II

The region just north of Sukkertoppen Iskappe. The valley in the foreground running left-right is the erosion valley Kangimut kûgtoq that inclines to the east toward Indlandsisen. North of it the plateau with the flat erosion valley Qôrulûp kûa. In the background the deep valley of Sarfartôq.

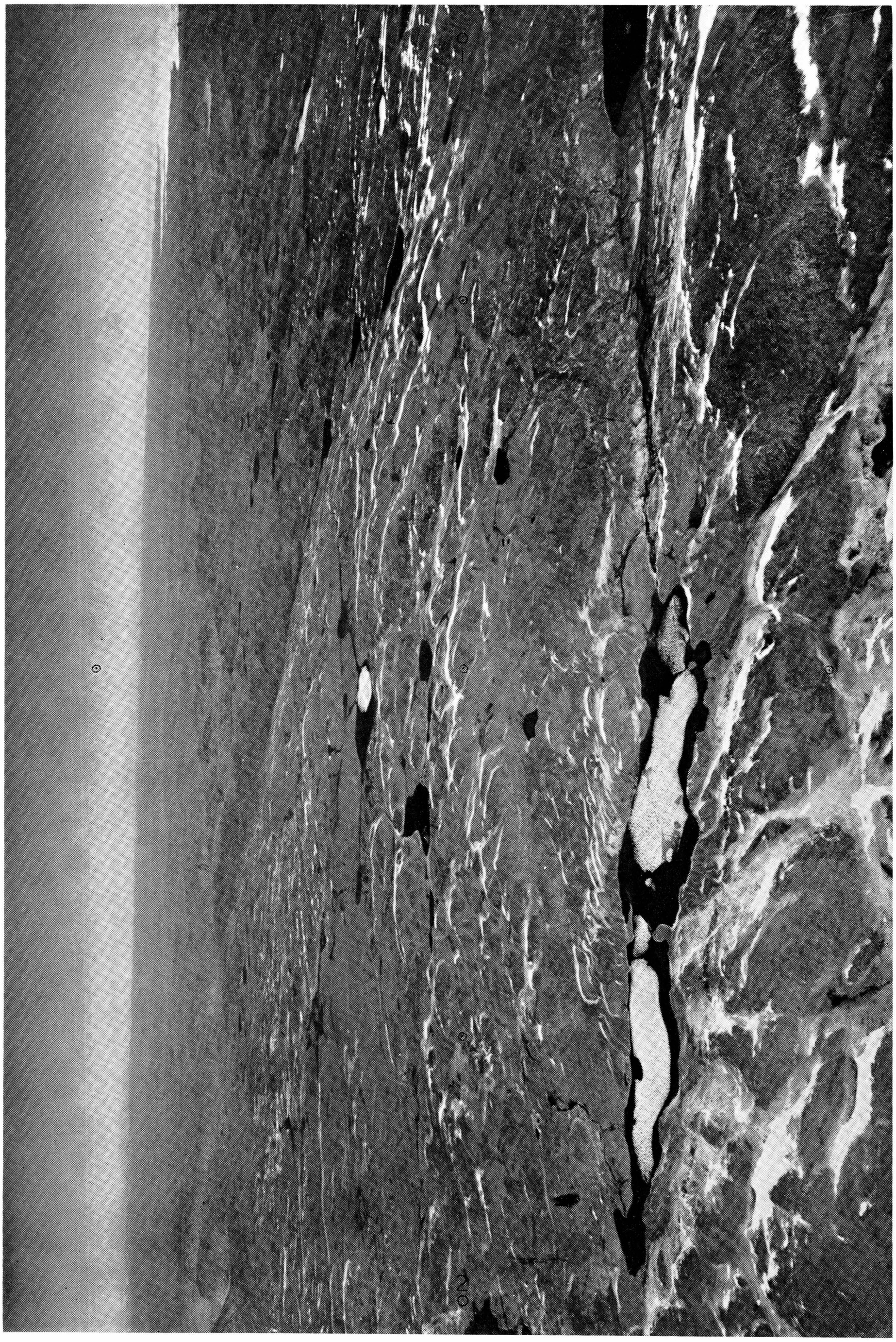


Plate III

Air photo of the innermost part of Sandflugtdalen. Behind it, Indlandsisen with the two glacier tongues feeding the melt-water river. To the right, Ørkendalen and to the left the glacier Isúnguata sermia, whose melt-water flows out through the Isortoq valley. On the plateau between this and Sandflugtdalen one can see Langsøerne and the straight-lined cleft with Kløftsøerne. In the middle of the picture Keglen and behind this, at the rejunction of the two valleys, the large plain and also the sheet of drift sand can be observed. While the north side of Sandflugtdalen is quite straight-lined with a smaller or broader talus, the south side is heavily eroded by glaciers and with inumerable cirques.

Plate IV

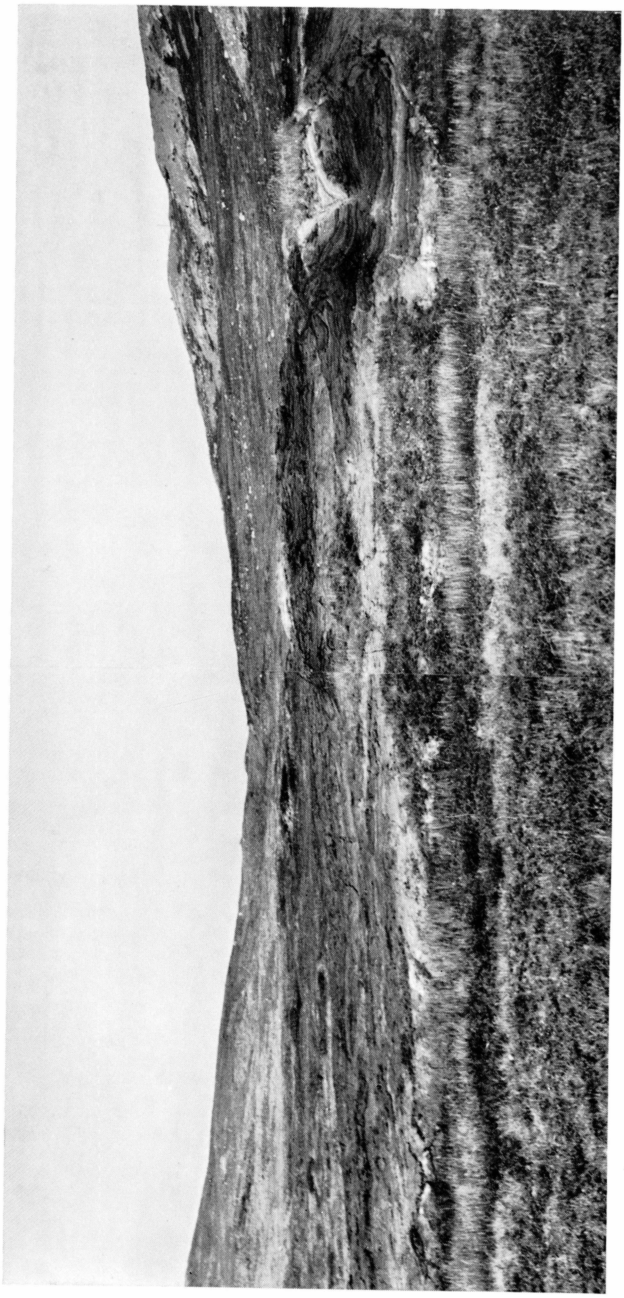
In the foreground, Kløftsøerne and behind them Sandflugtdalen, Ørkendalen and the innermost part of Søndre Strømfjord. Behind Ørkendalen the plateau with the L-shaped Store Saltsø and the big lake Taserssuatsiak. Behind it, the large melt-water valley terminating in Umîvît. Right in the background Indlandsisen and Sukkertoppen Iskappe are faintly seen.

Plate V

In front, peat ridge III with the heavily disturbed peat layers and behind it ridge IV with a steep front side. In the background ridge V overgrown with willow and birch; to the left a large terrace of creeping soil.

Photo 4268-69-70.

PLATE V.



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SÆRTRYK: MEDDELELSER OM GRØNLAND. BD. 188, NR. 4. [KAJ HANSEN].

66 V.2 SØNDRE STRØMFJORD ØST

MAP I

Compilation scale 1:200 000 on oblique photography 1948.
Names, populated places and other details 1950.
A few essential corrections 1965.

Udtegnet i 1:200 000 på grundlag af skråfotografering 1948.
Navne, bebyggelse og andre topografiske enkeltheder 1950.
Enkelte rettelser 1965.

Trykt ved Geodætisk Institut (A. 77/70) 1970
Copyright

1:250 000

kilometer 1 0 2 4 6 8 10 12 14 16 18 20 22 24 25 kilometer
1 millimeter = 250 meter

statute miles 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 statute miles
1 inch = 3,946 statute miles

GEODÆTISK INSTITUT

SÆRTRYK: MEDDELELSER OM GRØNLAND. BD. 188, NR. 4. [KAJ HANSEN].

67 V. 2 NORDRE STRØMFJORD ØST

MAP II

Compilation, confer diagram:
a) Plane table work 1:250 000, 1934.
b) Plotting 1:200 000 on oblique photography 1936.
Planimetric detail revision on vertical photography.
Names, populated places and other details 1950.
A few corrections 1968.

1:250 000

kilometer 1 0 2 4 6 8 10 12 14 16 18 20 22 24 25 kilometer
1 millimeter = 250 meter

statute miles 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 statute miles
1 inch = 3,946 statute miles

Topografisk grundlag, jævnfør diagram:
a) Bordmåling i 1:250 000, 1934.
b) Udtegning i 1:200 000 på grundlag af skråfotografering 1936.
Lineær revision på grundlag af lodret fotografering.
Navne, bebyggelse og andre enkeltheder 1950.
Enkelte rettelser 1968.

Trykt ved Geodætisk Institut (A. 77/70) 1970