Glaciers in Upernivik Ø.

With special reference to the periglacial phenomena.

By J. Tyge Møller

In the summers 1956 and 1957 a glaciological expedition under the leadership of associate professor, *B. Fristrup,* M. Sc., was sent out to West Greenland and to North Greenland from the Geographical Institute at the University of Copenhagen. The expedition was part of the Danish contribution to the International Geophysical Year 1956—58. The investigations here mentioned have been carried out in Upernivik Ø (Ø = island) in West Greenland. In »Geografisk Tidsskrift« and »Meddelelser om Grønland« have been published some of the results obtained by the team working on the glacier Sermikavsak. The main purpose was glaciological investigations of Sermikavsak. This glacier was visited the first time in the summer 1956, when the work went on for one month. During this time the glacier was reconnoitred, and the surveying was prepaired; further, the meteorological station was established. The next summer the investigations proper were carried out. From the middle of June to the beginning of September the glaciological, meteorological and hydrographical observations were accomplished on Sermikavsak and in the area in front of the glacier, and the ice margin was surveyed. Unfortunately, the hydrographical investigations had to be reduced to some experimental work. In addition to the work mentioned above, Sermikavsak as well as other glaciers in Upernivik Ø were thoroughly photographed in order to make it possible to prove movements and modifications of the glaciers if any future investigation will be carried out in this region. During the work on the glaciers of Upernivik Ø the observations and small surveyings on which this paper has been based were carried out. The glacier Sermikavsak was picked out as an object of the research, because it was necessary to choose a glacier of a suitable

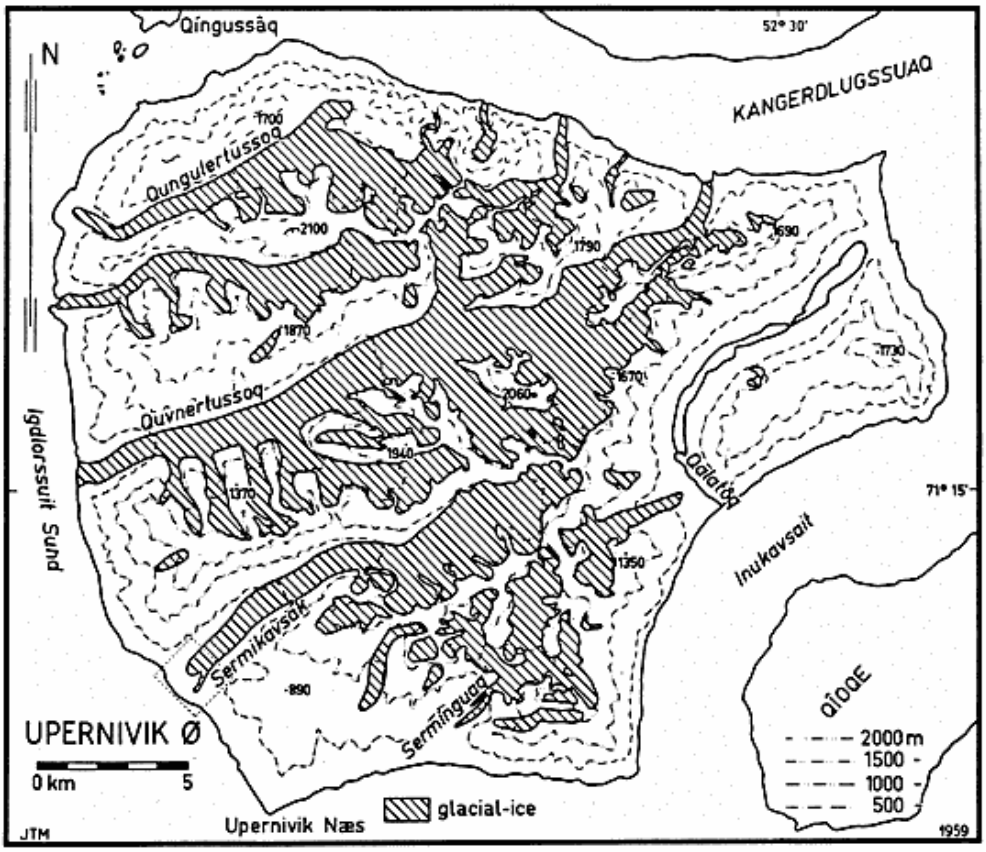

Fig. 1. Upernivik Ø (= island) in West Greenland. Partly based on a provisional map (about 1:50.000) made in 1956 by the Danish Geodetic Institute. The frame round the snout of Sermikavsak indicates the limits of fig. 2.

size and with an easy access and, at the same time, with the snout at some distance from the sea. Sermikavsak fulfils most of these conditions, though it is situated in a pronounced alpine area, in which the glacier is probably the only one that could be taken into consideration.

The *position of Upernivik Ø*, characterized by the snout of Sermikavsak (the poor glacier), is 71° 12' north, 53° 03' west of Greenwich in the Umanak district, West Greenland. To the north the island borders on the big ice-fjord, Kangerdlugsuaq. To the west Igdlorssuit Sund separates the island from Ubekendt Ejland (unknown island), which thus protects Upernivik Ø against the open sea, the Baffin Bay. As a consequence of this shelter the weather in Upernivik Ø may be very fine and sunny, simultaneously with the weather in Ubekendt Ejland being rainy and foggy. The greater part of Upernivik Ø is a very rugged, mountainous region, built up of gneiss and other transformed rocks. An exception is the most

southwestern corner of the island (fig. 1), which consists of a yellowish sandstone containing layers of coal. The last-mentioned area differs further from the rest of Upernivik Ø, being a very rounded, hilly region. The highest part of the sandstone area does not exceed an altitude of 900 m., whereas the alpine region reaches an altitude of more than 2.100 m., and but a small part of the island is below 1000 m. above sea level. Owing to the height conditions there are plenty of glaciers (of which the most southwestern is Sermikavsak) in Upernivik Ø. Nearly one third of the whole area is covered with constant ice and snow. The map in fig. 1. has been based on a provisional map (approximately 1 : 50.000), executed by the Danish Geodetic Institute by means of topographical maps and air photographs taken in 1953. Furthermore, the figure has been supplemented by the author. It shows the extension of the glaciers and the height conditions indicated by contour lines with an equidistance of 500 m. With regard to the distribution of ice-covered land and ice-free land the map in all probability gives a true picture of the conditions in Upernivik Ø; however, the use of air photographs implies the risk of overestimating the extent of the ice-covered areas, because it is very difficult to distinguish between constant snow and real glaciers. The precipitation and the melting-off in the period of photographing is of great importance. For instance, some of the air photographs were taken so early in the spring that the snow still covered the highest parts of the island. In 1957 it was the general impression that the extent of the glaciers had been reduced since 1953, when the photographs were taken. The great melting-off in the summer 1957, caused by the sunny weather, in connection with the very small precipitation the previous winter contributed to reducing the glaciers in the period mentioned above.

Four glaciers valleys, of which Sermikavsak is the most southwestern, debouch on the west coast of Upernivik Ø. The direction of the valleys is about north east—south west. From the Igdlorssuit Sund west of Upernivik Ø it is possible to get a view to the interior of the island, and the approach to this is only possible through glacier valleys and melt-water gullies. Between these the slopes are so steep that only in few places it is possible to walk along the shore. The glaciers debouching into the Kangerdlugsuaq descend steeply to the sea. In fact, there is only an easy access to the valleys of Sermikavsak, Serminguaq (the small glacier) and Qalatog. The last-mentioned valley is a river-valley, which drains off two small

glaciers and the oblong lakes which at a height of 250 m. separate the rest of the island. It is a conspicious feature of most of the glaciers in Upernivik Ø that especially the western parts solely receive affluxes of ice from the southern sides of the valleys. Furthermore the south eastern ice lobes are covered with gravel and rocks and are stretching more towards west than the rest of the glacier. These distinctive features are caused by the height conditions of the island and also by the fact that the glacier valleys are situated in a northeastern—southwestern direction. Even if the midnight sun is shining for several months in this part of Greenland the southern sides of the glacier valleys have a very small chance of being reached by the sunbeams because the sun only rises very little above the horizon. The glacier valleys are cut so deep in their south western parts the the the southern sides of the valleys are permanently in shade. (The drawing-back of the contour lines from the coastline has to be noticed). Owing to this only the icestreams from the southern slopes can exist under the present climatic circumstances. In any other place the snow will melt away before a glacier can be formed. The lateral glaciers from the northern sides of the valleys have only been slightly developed. In the central parts of Upernivik Ø the shade conditions are of smaller importance, because the entire area, owing to the height, is exposed to the sun. The central parts of the island are covered by an ice-cap with some nunataks, which have probably never been eroded by glacial ice.

The ice-cover of Upernivik Ø can be divided into three glacial areas. The two northern glaciers seem to originate from the same small ice-cap. Only the northernmost branch has a name in the maps, Qungulertussoq. According to the inhabitants in Igdlorssuit, the only village in Ubekendt Ejland, the name is standing for »the glacier with the sour plants« (*Cochlearia officinalis*?). The glacier immediately south of Qungulertussoq wast just called »the central glacier«. South of this the greatest glacier in Upernivik Ø is situated. It is named Quvnertussoq (the heavily crevassed glacier). This is a suitable name, because the surface all the way to the snout is cut up into small pieces by several systems of crevasses. Quvnertussoq is the only glacier which has more than one outlet of some importance and, furthermore, the only one which stretches out to the coast; however, the production of this glacier is very small; for instance, in the summer 1957 it calved only once. Sermikavsak is the most sharply delimited glacier in Upernivik Ø, having only a

slight connection with the glacier system from which Serminguaq originates. The last-mentioned glacier has, as mentioned above, been reduced since 1953. Thus, the very narrow glacier stretching out between Sermikavsak and Serminguaq in 1957 had disappeared or was at least completely covered with gravel and rocks.

As far as the *climatic conditions* in Upernivik Ø are concerned it just has to be mentioned that the dry and sunny weather characterizing the Umanak Bay is predominant here too. High temperatures occur frequently in connection with foehns (in Greenland called »Southeast«), which in summer are able to raise the temperature to a little below 20° centigrade (as an average of a period of 24 hours), while the normal maximum temperature is 10—12° centigrade. The high temperatures in connection with the extremely low humidity manifests itself in a increasing of the melting-off, which is normally determined by the great incoming radiation. The precipitation seems to be very vayring too; thus, it should be mentioned that in 1956 the snow in the middle of June melted off to a line about 400 m. above sea-level, while this limit in 1957 moved to 1000 m. in the shaded side of the valley and 1200 m. in the sunny side. Of course, these limits have to be regarded as the result of all the weather conditions in the year in question and not as the result of an exceptional great melting-off or small precipitation. As far as the latter is concerned, it is obvious that only a small part of the precipitation is falling on the very surface of the ice. A great part of the supply of snow to the glaciers is coming from the steep sides of the valleys in the shape of avalanches.

In the summer 1957 it was tried to estimate the size of the running-off by placing a small dam across a little melt-water river coming from the most south-western part of the glacier. Just behind the dam, with a known profile of the flow through, a self-recording river-gauge was placed. The discharge which was recorded close to the shoreline was very delayed (2—4 hours) in spite of the short distance from the glacier. The discharge was at its minimum about 2 o'clock p. m. (G.M.T.). After this point it rose steeply to the maximum at about 11 o'clock p. m. (G.M.T.) and the next day steadily decreased to the minimum. With regard to the time, all the melt-water rivers followed the same scheme. The effects of the foehn on the run-off appeared through the recordings of the water-level, the maximum of which, reached in the evening, remained almost constant through the whole night. The next morning the increase started from this level, the maximum of the

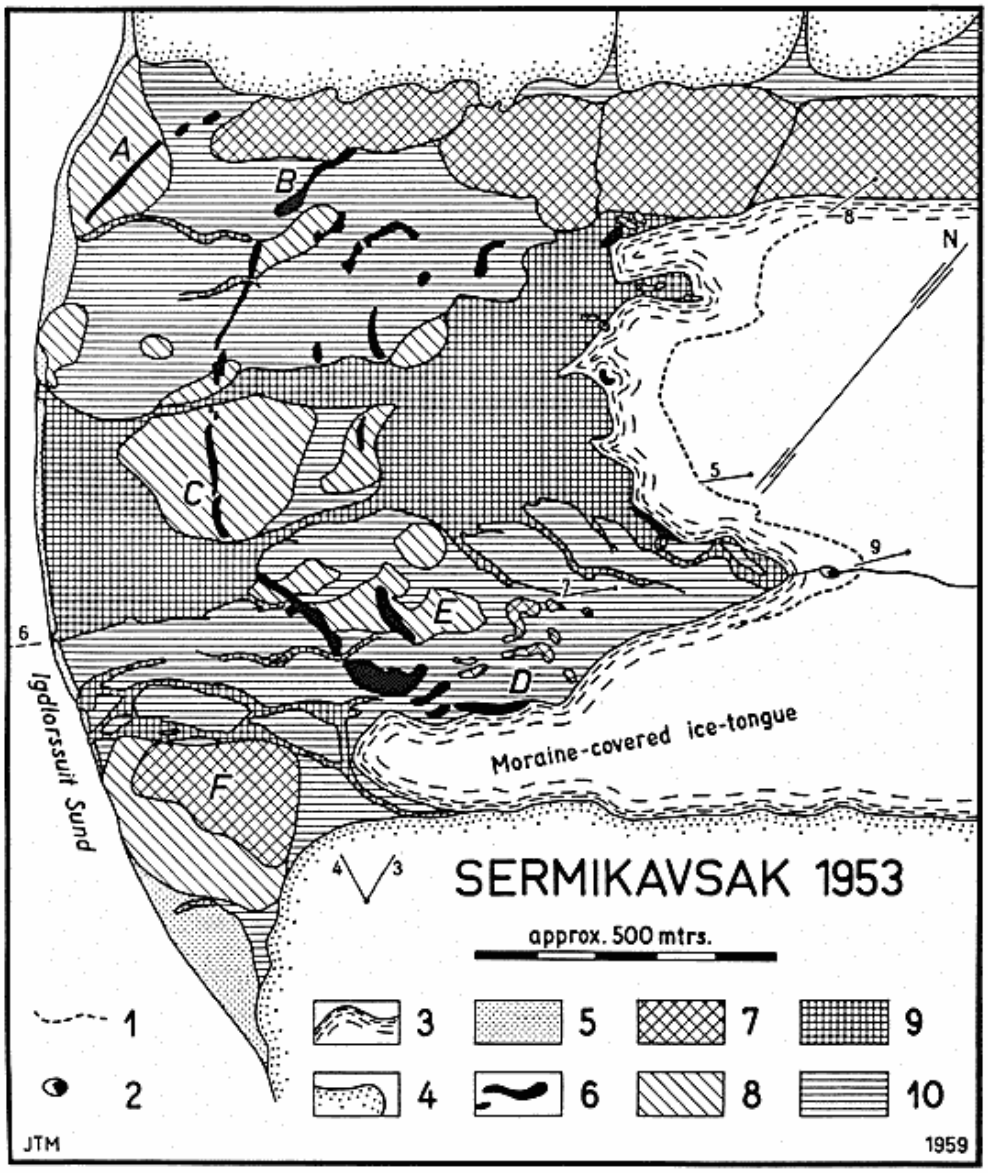

Fig. 2. Sketch-map of the landscape in front of Sermikavsak (the poor glacier) 1953; partly based on air photographs. The place and the direction in which the figures 3-9 have been taken are indicated by a dot, a line and the number of the figure. Signs: 1, the ice margin 1957; 2, debris cone; 3, the ice margin 1953; 4, solid rock; 5, beach ridge; 6, terminal moraines; 7, moraines containing glacial ice; 8, moraines not containing glacial ice and not eroded by melt-water rivers; 9, outwash plains 1953; 10, outwash plains formed by melt-water rivers before 1953.

day before. This process was repeated through the entire foehn-situation and, finally, the small dam usually was washed away by the continuously increasing stream. These observations can only be used as a hint of the progress of the run-off. When the weather was clouded the water-level curve was nearly straight for a whole

period of 24 hours. It was impossible to place instruments in the two water-courses through the terminal moraine BCD (fig. 2), as the stream was violent enough to transport rocks of a weight of 25 kg or more. Almost the entire run-off from Sermikavsak is streaming through these openings in the terminal moraine; however, the discharge is constantly varying, because the situation of the melt-water rivers to the east of the moraine BCD is steadily changing. Thus, the importance of one of the openings in the terminal moraine is increasing at the expense of the other. — Behind the beach ridge at the coast of Igdlorssuit Sund some ice and snow was left in the summer 1957. Here the upper layers of the snow had been transformed into needle in vertical position, a not unusual phenomenon of rime; however, in this case the length of the needles was up to one meter.

The *glaciological investigations proper* solely included the lower parts of Sermikavsak and the area between the snout and the shoreline at Igdlorssuit Sund. The glacial ice-cover named Sermikavsak stretches over an area of 22 sq.km. The north-eastern part of the glacier consists of an almost rectangular basin about 7 km. long and 2 km. wide. In its south-western part the basin has an outlet (fig. 1) 1 km. wide and terminating in the snout 500—1000 m. from the shoreline. The glacier is on all sides surrounded by high mountain ranges which rise to about 500—1000 m. above the surface of the glacier. As already mentioned, Sermikavsak only receives glacial affluxes from the southern side of the valley, where several cirques are situated. Some nunataks in the shape of high, narrow mountain ranges are found in the inner part of the glacier basin. From the western part of the basin and through the outlet the glacier is descending past a number of ice-falls, each of a height of 200—300 m. The ice-falls, in connection with the narrowings in the upper end of the outlet and the glacial affluxes from the branch valleys, have caused the division of the glacier into several systems of crevasses. Opposite the cirque, at a distance of 6 km. to the northeast of the snout, no less than three systems of crevasses were found, because in this place the glacier turns aside, sliding down over an ice-fall. Owing to the crevasses, Sermikavsak is only accessible in the lower parts. At the glaciers north of Sermikavsak the climbing conditions were much worse. Near the snouts, or at least just east of these, great systems of crevasses and ice falls make the glaciers almost unapproachable. The crevasses on Quvnertussoq reach the snout that is rising vertically from the sea.

Fig. 3. The snout of Sermikavsak 1957. In the background the big northern lateral moraine. In front of the snout the northeastern outwash plain. Between this and the southern slope of the valley are seen som ice-filled mounds, partly formed by melt-water erosion. To the right the big debris cone and below that a small part of the moraine-covered ice lobe. In front of the central part of the snout an area furrowed parallel to the direction of the valley.

In the lower parts of Sermikavsak the surface is rather plain. Only at the sides of the valley some deep, though short, lateral crevasses existed. In the direction of the movement of the glacier lie some parallel melt-water gullies, which in several cases disappear through glacier mills and continue their course under the ice. Remainders of collapsed meltwater-gullies were found on the surface at a few places, as for instance in the northern part of the glacier where the deep cut in the snout (fig. 2) is probably a collapsed melt-water tunnel. A part from this place in the northern, most recessed part of the snout, the ice margin consists of very even slopes. Most of the glacier is almost white, having but small amounts of gravel scattered on the surface. Still, near the bed the glacier is black with mud (fig. 3). This comparatively clean part of Sermikavsak consists of a broad lobe in the middle with narrower lobes on each side. The lobes are separated by melt-water gullies, which at several places have eroded gorges to a depth more than 25 m. below the surface. In the summer 1957 no traces of any big melt-water streams under the ice could be found. The only

real glacier outlet was found in 1953 as well as in 1957 in the snout near the most south-western part of the arrow pointing towards the north. This ice cave was in 1957 about 1½ m. high and 1½ m. wide, whereas a glacier outlet in the snout of Quvnertussoq was 10 m. high and 20 m. wide. Contrary to the northern two thirds, the third of Sermikavsak nearest to the southern side of the valley is characterized partly by being covered with moraine materials, partly by stretching out to a line much nearer to the shoreline than the rest of the glacier. As a consequence of the dark colours of the moraine materials on the ice surface, this ice lobe looks very much like a lateral moraine. However, in several steep slipping surfaces on the northern side of the dark ice lobe the ice can be seen very clearly.

As mentioned above, the glaciers in the valleys of east-western direction in Upernivik Ø are characterized by their southernmost moraine covered ice lobe, which is stretching much more towards west than the rest of the glacier. The length of the ice lobe and the cover of moraine material on the surface of this lobe is due to the fact that the lobe is situated in the shades of the northern side of the valleys, the melting-off thereby being considerably reduced. Further, the greater part of the supply to the glaciers is coming from the southern slopes of the valleys; this causes a greater transport of ice and, consequently, of moraine material to the southern ice lobes. The increased amount of moraine material is more insulating, resulting in a further reduction of the melting-off (Kuhlman 1959). A consequence of this is that the snout of the moraine-covered ice lobe of Sermikavsak is situated about 400 m. nearer to the shoreline than the rest of the glacier. This ice lobe is still moving, a fact which became evident when, in 1956, a surveying point was placed on this part of the glacier, then considered as a tolerably stable lateral moraine. During the summer 1957 the point had moved, whereas the cairn built over the point was intact. Probably the ice in this lobe is moving very slowly, even compared with the rest of the glacier. The southern ice lobe of Sermikavsak seems to behave as a medium between the central parts of the glacier and the northern lateral moraine, which is described later on.

The moraine systems of Sermikavsak have but a small extent. Although the glacier has several glacial affluxes no medium moraines are visible. Lateral moraines, or at least the results of a glacial erosion in the sides of the valley can be seen on the slopes

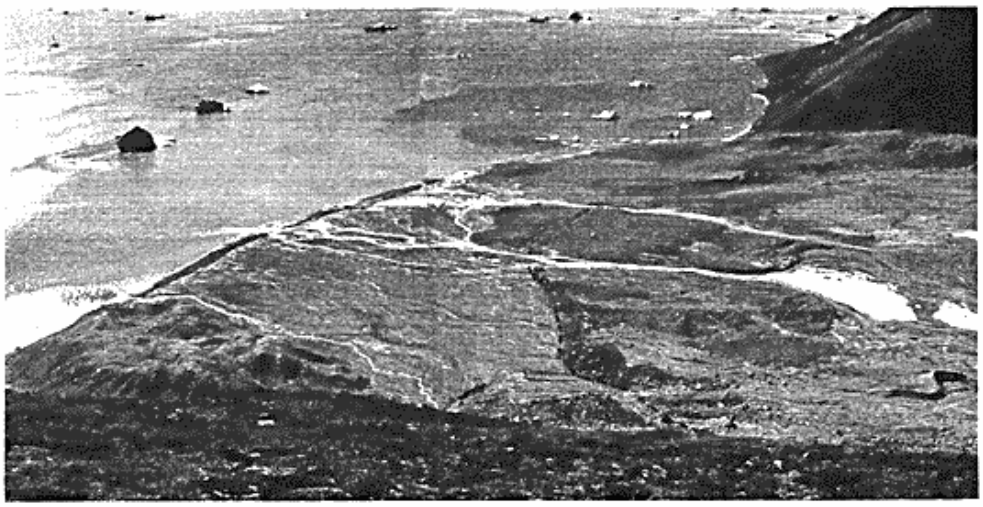

Fig. 4. The coast at Sermikavsak 1957. In the front the southern side of the valley. To the left the moraine area southwest of the moraine-covered ice lobe, which lies hidden under the valley-side. To the right the moraine-system BCD emphasized by a dotted line. In the upper part of the picture the outmost part og the northern lateral moraine (A) and the isolated moraine islands near the shoreline. Further, the beach ridge in front of the western outwash plain.

near the shoreline (fig. 2 and fig. 3). The northern lateral moraine can be followed to the westernmost ice-fall at a distance from the shoreline of about 5 km. towards north east. It appears clearly that the sides of the valley have been greatly eroded. At several places thin layers of gravel and rocks, in the course of time deposited on less steep parts of the southern slope, have been covered with vegetation. To a height of about 50 m. above the ice surface big scars of recent date have been cut in the vegetation and the debris by the glacier. The most powerful erosion takes place in the outmost parts of the turns in the outlet from the inner glacier basin, for instance near the ice-fall situated at the westernmost cirque valley. Quvnertussoq has several medium moraines, which all come from the smaller branch glaciers in the southern side of the valley. The moraine deposits on the glacier surface are joining as the ice is approaching the shoreline and, in this case too, they are the cause of the dense cover of moraine material on the southern parts of the glacier. Lateral moraines along this glacier are only found at the northern side of the valley. According to the air photographs the glacier north of Quvnertussoq reached in 1953 as far as to the shoreline, while in 1957 the snout had retired about 200 m. This was partly du to an actual withdrawal of the glacier, partly due to the fact that the small, shallow creek in front of the snout was going to be closed by a beach ridge in which the material, origin-

ating from the glacial erosion, was transported to the sea by the melt-water rivers. In front of the glacier valleys on the west coast of Upernivik Ø fans of deposits are stretching out in Igdlorssuit Sund. The deposit fans in front of Sermikavsak and the two northern glacier valleys rise a little above sea-level. The southern part of the glacier (the central glacier) north of Quvnertussoq is completely covered with rocks and gravel. The shoreline to the north and to the south of the creek just mentioned has been formed by moraine material (partly originating from the moraine cover of the glacier and partly from the lateral moraine), which has been pushed out into Igdlorssuuit Sund in continuation of the sides of the valley. The southern slopes of the deposit fans in the sea in front of Qungulertussoq are thus protected by the southern moraine-covered ice lobe of this glacier, while the snout otherwise is situated at a distance of about 500 m. from the shoreline. In profile the deposit fans and lateral moraines stretching out into the sea from the shoreline look like beaks.

In 1957 the glacier Serminguaq had retired so much that almost no clean ice surface could be seen below the level of 500 m. Apparently, this glacier has never reached any considerable size, and the northwestern lateral moraine has developed but little. In the lower part of the southwestern slope the bed-rock is greatly scarred by glacial erosion. The last glacier visited in the summer 1957 stretches to the river Qalatoq. This glacier has lateral moraines on both sides. The snout has retired from the position which appears from fig. 1. The two lakes above Qalatoq receive the greater part of their water supply from the glacier which looks like a hand with a pointing finger. Judging from the vegetation in the valley, the water-level in the lakes may oscillate about 1 m. In some years it looks as if the ice does not melt away (1953?). However, in the summer 1957 the ice had melted away, and the water had the colour of light emerald green cause by the great quantity of materials washed out by the melt-water rivers.

During the research-work in the summer 1957 the snout at that time was surveyed (Møller 1959). However, owing to lack of time the surveying could not be continued beyond this. The map figure 2 has been worked out on the base of air photographs 1953 (about 1 : 40.000) which have been enlarged to about 1 : 6.000. Of course, the map must only be regarded as a sketch, because it has not been possible to adjust the air photographs with regard to horizontal level. In the scale here available (about 1 : 18.000) the errors are

after all insignificant. Moreover, a certain weight has been attached to representing the morphological elements instead of producing an exact topographical map. — It has to be mentioned that no error of any importance has been found when it was possible to compare the map with later measurements. It was rather difficult to choose signs for the map. First it was tried to apply the signs used in the Danish morphological maps; however, the moraine landscape mentioned here and those in Denmark cannot be immediately compared. Therefore, in this map only few and simplified signs have been used and, as far as possible, the importance has been attached to grouping the morphological elements as in the Danish literature on morphology (Rosenkrantz 1939 and Schou 1949).

The bed-rock north of Sermikavsak consists of gneiss. The wall of rock is rising very steeply to a height of more than 1200 meter above sea-level with a very rough and inaccessible surface, which in the upper parts has probably never been eroded by glacial ice. The sides of the valley are cut up by numerous melt-water rivers supplied from snow drifts on the top of the mountains (only the two greatest of the melt-water rivers have been marked in fig. 2). The southern slope of the valley in fig. 2 consists of sandstone containing coal. The rather soft sandstone rises in rounded hills to about 900 m. above sea-level. Apart from some deep canyons, especially on the south coast, the sandstone area is covered with vegetation. The southern part of the valley in front of Sermikavsak is characterized by the yellow gravel and rocks from the sandstone area.

The lateral moraine along the northern side of the valley of Sermikavsak is clearly seen in fig. 3. — The direction in which the picture has been taken appears from fig. 2 (small arrows marked by the number of the picture). The distance between the place where the picture has been taken and the northern lateral moraine is about 1500 m. The highest part of the lateral moraine (just northeast of the snout) rises about 200 m. above sea-level. It appears from the figure that the slope of the moraine facing the glacier is very steep, too steep to consist of gravel and rocks only. The lateral moraine follows the northern side of the valley at a distance of 6 km. from the shoreline towards north east, steadily decreasing in height. In the eastern part the lateral moraine consists of two mounds parallel to each other. Nearest to the glacier stands the high, steep mound mentioned above. Between

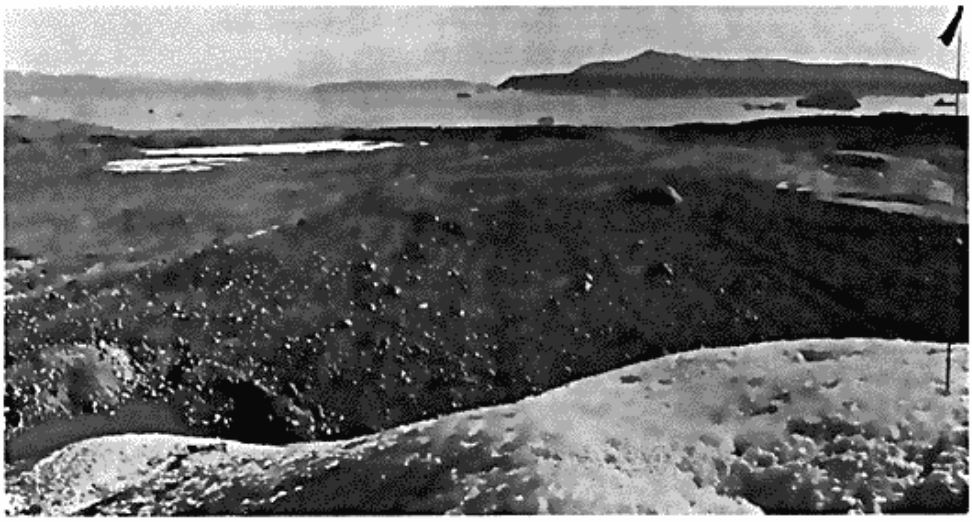

Fig. 5. A view from the central part of Sermikavsak towards southwest 1957. In the foreground a small terminal moraine. In front of the snout and furrowed parallel to the valley an area corresponding to the withdrawal of Sermikavsak since the air photographs were taken in 1953. In the background and to the right outwash plains behind which the terminal moraine BCD can be seen; further, Igdlorssuit Sund (= sound), Ubekendt Ejland (unknown island) and to the left Nugssuaq (the great peninsula). The bamboo pole is 2 m. long and placed 45 m. above sea-level.

this and the valley slope lies a low, rounded mound completely covered with vegetation. The hollow between the mounds is at several places partly filled up with water. The mounds are probably lateral moraines originating from different periods of the life of the glacier. The content of moraine material in the mounds is probably almost equal; however, the mound nearest to the glacier contains no doubt great quantities of glacial ice, which acts as a cement in the northern moraine and favours the steepness of the slope, facing the glacier. This lateral moraine filled up with ice looks just like the southern moraine-covered ice lobe; however, contrary to this, the northern lateral moraine is a completely isolated mound which does not take part in the movements of the glacier. The moraine material in the lateral moraine is probably more equally dispersed in the ice than that of the southern ice lobe, which is covered with a relatively thin layer of moraine material. Probably, the high northern lateral moraine is a remainder from a period when the glacier had much larger dimensions. At this place the great content of gravel and rocks has had steadily increasing insulating effect, resulting in a very slow melting-off. Owing to its age, the low mound mentioned above does not contain glacial ice; therefore, it has shrunk to become insigni-

Fig. 6. Sermikavsak August 1934 (Reginald Orcutt phot.). It is possible to catch a glimpse of the terminal moraine BCD (fig. 2 and 4) in the right part of the figure.

ficant. It was obvious that the younger moraines contain large quantities of glacial ice; consequently, the surface was cut up by numerous fissures produced by the melting-off, whereas the older moraines without glacial ice have an undisturbed surface and are of very small dimensions. — It has to be emphasized that the ice mentioned here is glacial ice, and not the phenomenon permafrost, which was not examined at this occasion —. Though the northern lateral moraine has probably formed a part of Sermikavsak and participated in the life and movements of the latter, the moraine is now quite different from the rest of the glacier. It looks so much like a lateral moraine that it seems justifiable to name it thus. This is supported by the fact that, southwest of the snout, the cover of vegetation is increasing and the height of the mound falling with a decreasing distance to the shoreline. Near this the lateral moraine is a low mound covered with vegetation and with the same aspect as the mound between the high moraine and the slope as mentioned above. In fig. 2 the westernmost part of the lateral moraine has been marked with an A; it can further be seen in fig. 5 outmost to the right. In this part the surface of the moraine has not been cut up by fissures and shrinkings, which normally disclose an underground melting-off. Behind the northern

lateral moraine melt-water rivers are running which receive their water supply from snow drifts on the mountains north of Sermikavsak through the melt-water gullies in the steep slope. The melt-water rivers carry large amounts of gravel which is deposited between the slope and the moraine, at a few places eroded by the rivers, (fig. 2 and 3), whereupon the streams carry the gravel out to the plains in front of Sermikavsak.

On the surface of the glacier several small moraines, medium moraines are found which at a close examination appear as ice mounds with a thin cover of moraine materials. In the right part of fig. 6 it is possible to catch a glimpse of several great, dark moraines, most likely the recent terminal moraines (near D, fig. 2). Some moraine formations (5—10 m. high), which partly are remainders of melt-water erosion, are seen in the figures 2, 3 and 7. All of them appear to contain glacial ice. In several moraines the ice has melted away. Like the lateral moraines without glacial ice these formations are very small (less than 1 m.) and are difficult to see in the field. In continuation of the moraine-covered southern ice lobe an isolated, hilly area is situated (fig. 2 and 4 entirely to the left). The eastern part of this area is obviously containing glacial ice and rises to a height of about 50 m. in contrast to the western, ice-free parts of the hills, which only rise to about 10 m. above sea-level. Across the valley in front of Sermikavsak several systems of mounds — probably terminal moraines — are situated. The mounds can be seen very clearly when the landscape is regarded from above, as in fig. 4 (taken from a point about 200 m. above sea-level on the southern slope of the valley). Apart from the terminal moraines from C to D, all the mounds are very small, only rising 2—5 m. above the surface. As mentioned above, considerably greater quanities of moraine material must have been available in the southern parts of the valley. The terminal moraine is here of compartively great extension, and the moraine material is rather coarse. This distinction between the different parts of the terminal moraines is clearly seen in fig. 4. It is possible to find two systems of terminal moraines from different periods (A and BCD, fig. 2). East of the system BCD there is no possibility of recognizing terminal moraines, because the surface has been disturbed too much by the melt-water rivers. The terminal moraine BCD is very well preserved, partly as a consequence of the large-grained material, partly because it has been protected by remainders of moraine areas situated to the east. The terminal moraine A

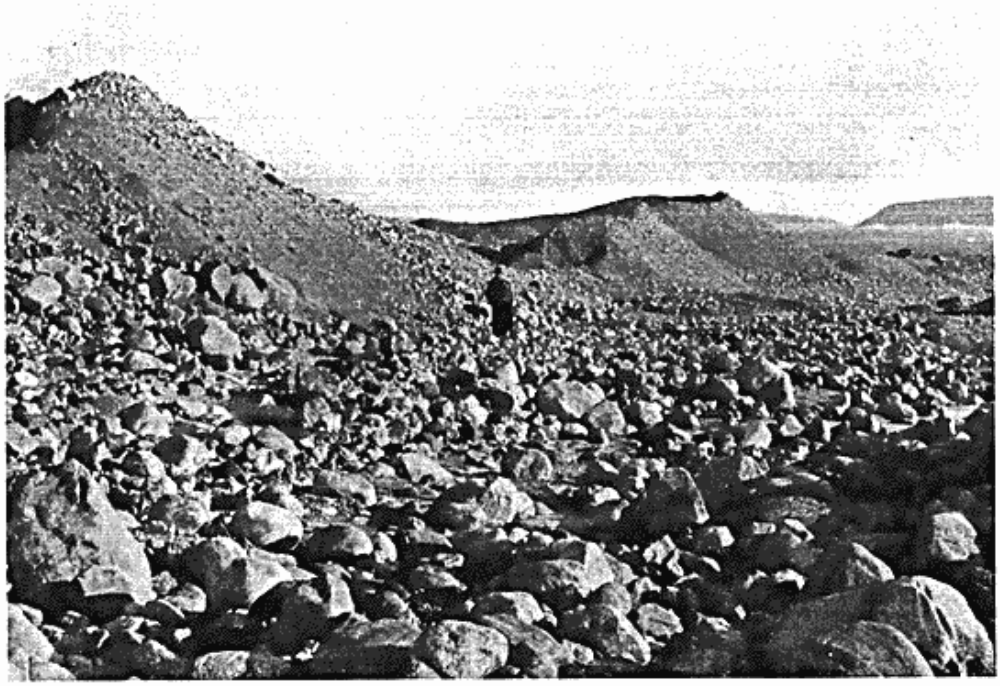

Fig. 7. Moraine mounds in the southern part of the valley 1957. Contain glacial ice and are partly formed by meltwater-erosion. The person is a little below medium height.

must originate from a period when the snout of the glacier partly has been situated at some distance to the west of the shoreline.

The dating of the terminal moraine is difficult without special investigations. It is possible to make an estimate of the age through an examination of the extent and the age of the vegetation in front of and behind the terminal moraines. However, this method is questionable, because the surface has been eroded so much by the melt-water rivers. The best judgment of the state of the front can be obtained on the basis of air photographs from different periods of the life of the glacier. In august 1934 the American explorer Reginald Orcutt from New York passed by the west coast of Upernivik Ø. He photographed Sermikavsak just when the boat was outside the southern part of the valley. The original negative has been lost during the Second World War, and only a small, rather poor copy has been available. From this copy (fig. 6) it clearly appears that at that time the front of Sermikavsak was situated at the place of the terminal BCD, perhaps a little behind the recent moraine. Especially the southern parts of the terminal moraine (fig. 2, D) are very easy to recognize because of the large, marked rocks. Some dark, high moraines, obviously containing large

amounts of glacial ice, are seen near the snout (fig. 6). The greater part of the remainders of these moraines are now rather small, as it appears from fig. 4, and at short distances they are difficult to see among the rocks and the melt-water gullies. The terminal moraines formed in the summer 1957 are all very small too in spite of their content of glacial ice. A small crescent-shaped mound, behind which some melt-water has been dammed up, is seen to the left in fig. 5. The size of the mound appears from the bamboo pole (2 m. high) placed to the right. In several cases stratified clay has been deposited in the water behind the mound and later become visible when the glacial ice in the moraine has melted away, allowing the water to run off. Small terminal moraines are very frequent in front of Sermikavsak — as it appears from fig. 2 — near the northern part of the snout. On the other hand, none of the moraines formed in 1957 reach the size of the terminal moraines from the 1930ies mentioned above.

Investigations of *the movements of Sermikavsak* were one of the main objects of the expedition. Originally it was intended to survey a row of bambo poles drilled into the ice surface in the lower parts of the glacier. However, the poles were only surveyed once, partly caused by the lack of time, and partly because the northern lateral moraine was very difficult to climb, and it was very hard to get a view of the glacier from anywhere else. On a rough estimate, the speed of the southern moraine-covered ice lobe on a part with the rest of the front is about 2—5 m. in one year. In the middle of the white ice lobe the speed must be about 15—25 m. in one year at some distance from the front. Unlike these poor estimates it has been possible to make a judgment of the withdrawal of the snout during the last years, based upon Reginal Orcutt's photograph, air photographs and the map of the snout 1957 (Møller 1959). In 1953 the distance between the terminal moraine BCD and the snout was 600—700 m., while during the years 1953—57 the snout has withdrawn about 150 m. further towards north east. — These figures do not apply to the southern, moraine-covered ice lobe —. As will be seen, the average withdrawal is about 30—40 m. in one year (the exact figures are 34 and 38 m. respectively) for both periods in question. While some importance can be attributed to the absolute size of the withdrawal, the withdrawal in the individual year and in the different parts of the snout is probably very varying. Thus, the southern moraine-covered ice lobe seems to have been stationary in the

Fig. 8. The front of Sermikavsak near the northern lateral moraine 1957. In June the ice stretched out to the right in the picture. In the background the moraine area (F) southwest of the moraine-covered ice lobe. Notice the rucksack and the rounded rocks.

period 1934—57. The very procedure of the melting-off implies the possibility of rather great variations. As mentioned above, several places in the lower parts of the snout are covered with mud and sand, while the rest of the snout is rather clean and white. A certain content of moraine material in the ice will accelerate the melting-off, owing to the dark colours of the surface, especially in this area with the great incoming radiation. If, on the other hand, the content of moraine material rises above a certain limit the material will gradually act as an insulating cover, and the melting-off will decrease again (Kuhlman 1959). By a certain, constant content of moraine material in a certain part of the glacial ice the melting-off will increase in the start and then decrease steadily, because the concentration of moraine material in the ice is gradually rising. This is revealed at several places on the snout of Sermikavsak by the flat shape of the lowest parts of the ice. In a longitudinal section the glacier has the shape of a duck's head with a beak. This low, flat part of the snout is then exposed to erosion from the numerous, steadily alternating melt-water streams. As soon as the moraine materiale has been washed away the erosion and the increased melting-off (caused by the removal

of the material) may make the withdrawal go on in jerks in the course of a few days, even a few hours. Thus, the snout of the glacier retired 5 m. in three days from the small mound (fig. 5), which was a terminal moraine in the beginning of the summer 1957. The northern part of the snout in fig. 2 was entirely flat. The narrowing in the northern part of the snout has been caused by the collapse of a melt-water tunnel in which the outermost parts have melted away. In the summer 1957 the narrowing had disappeared; however, the contour lines in the former tunnel allow to follow it as a valley towards north east. At some distance to north east of the snout the tunnel passes into a melt-water gully, which separates the northernmost ice lobe from the rest of the glacier.

Just in front of the glacier is an area which is furrowed parallel to the direction of the glacier (fig. 5). These furrows are not a result of the melt-water erosion, because the moraine material here is coarse and the area is protected against the melt-water rivers which, coming from the gullies on both sides of Sermikavsak, unite in an acute angle in front of the snout. Therefore, there is an almost undisturbed area between the rivers and the snout. It is difficult to explain how the furrows have been formed; however, the complete lack of melt-water erosion can be interpreted to the effect that the area still remains as when the ice left it. The distance from northeast to southwest in the area corresponds to the withdrawal of the glacier in the period 1953—57. If so, the furrows are probably remainders from the time when the snout reached so much further to south west that the ice was still moving across the area. As the ground is quite filled up with water it is very difficult to move here. Probably some glacial ice is still left in the area. Corresponding furrows are seen in the moraine area C (fig. 2 and 4). Judging from the lastmentioned picture, the furrows are situated on both sides of the terminal moraine from 1934. It is likely that the glacier had stopped for some time at the now visible terminal moraine after a brief advance a little further towards south west. The furrows do not seem to be the result of solifluction, because the gradient of the terrains in question is very small, and no signs of a separation of the moraine materials are seen.

Being dispersed irregularly in the glacier, the moraine material has probable been carried to the snout in jerks. This explains the big concentration of moraine material seen in fig. 6. Great disturbances in the surface in front of Sermikavsak have only been

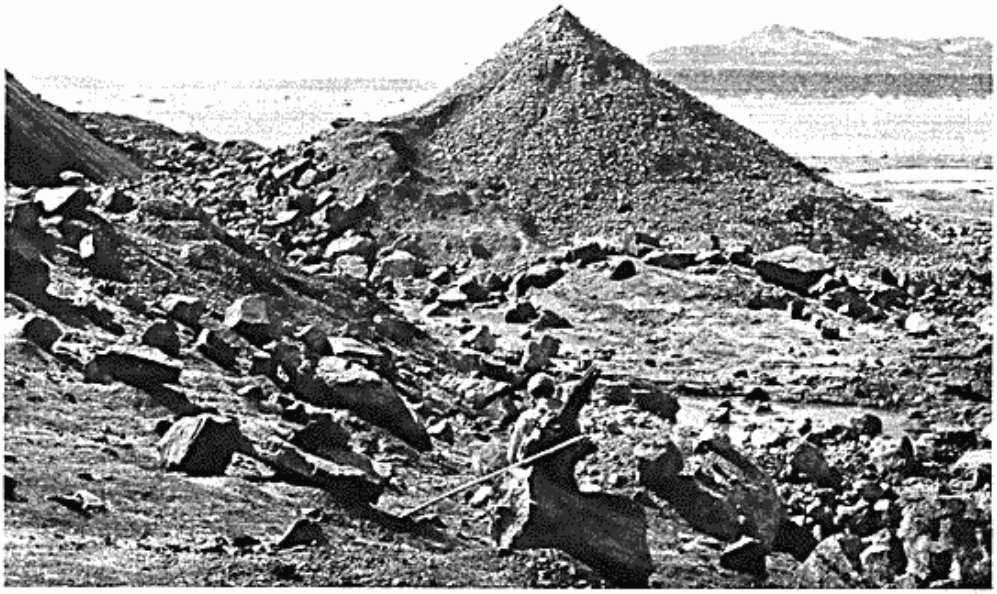

Fig. 9. Debris cone (9 m. heigh) between the white and the moraine-covered ice lobe 1957. To the left it is possible to catch a glimpse of the steep northern side of the southern ice lobe. Notice the sharp-edged rocks.

found near the northernmost, narrow ice lobe (fig. 7). The rocks which are of considerable size must, judging from their rounded shape, have been transported in the bottom of the glacier. They came to the surface of the snout along shear planes a few metres above the bottom of the valley. Very small mounds, which have to be considered as shear moraines, are seen just in this part of the snout (fig. 2). The snout of Sermikavsak stood in the summer 1957 entirely to the right of the picture, which was taken in August. The withdrawal is partly attributable to the melting-off, partly to the melt-water erosion caused by the river running between the glacier and the northern lateral moraine. The moraine below the big rock above to the right is filled up with glacial ice and is an offshoot of the northern lateral moraine. — On the other hand, a very great part of the moraine material is transported on the surface of the glacier, down to which the rocks probably fall from the high, steep slopes of the valley. All the time the transportation takes place on the surface, and at last the moraine material has simply been left back on the bottom of the valley as the glacier draws back. Therefore, a very big part of the erratics are sharp-edged (fig. 9); this is for instance the case in the southern part

of the moraine BCD, where it is possible to catch a glimpse of the big rocks in fig. 4. The presence of the large quantity of edged rocks on the surface of the southern ice lobe and, moreover, the distribution of the erratics in the valley seem to indicate that the cover of moraine material on the southern parts of the glaciers facing Igdlorssuit Sund has been caused by rocks fallen down to the ice surface from the southern slopes and especially from the steep slopes along the southern glacial affluxes.

A debris cone (fig. 9) is situated in the melt-water gully between the southern moraine-covered ice lobe and the rest of the glacier. Small debris cones have been noticed at several place in Upernivik Ø. About 10 m. above the bottom of the valley on the steep snout of Qungulertussoq stood a row of small cones at the same level and all about half a metre high. These cones, which were not subjected to any close examination, were covered with gravel. In reality, they correspond to the moraines on the surface of a glacier and are an insulation-phenomenon. This is no do doubt the case of the debris cone at Sermikavsak too. Here is only one large cone, 9 m. high and containing a great lump of glacial ice, covered with gravel. The cone can be seen in the air photograph of 1953, in which the shape of the lump appears to be an isolated, but very irregular formation. In the summer 1956 the lump looked like a cone when regarded from certain angles, and in 1957 a very regular cone had been developed. While, in 1953, the cone was situated to the north east of the snout, this had in 1957 retired so much that the cone then stood just west of the snout very close to the moraine-covered ice lobe (seen to the left in fig. 9 as a steep, dark wall). Probably the debris cone has been formed by a big lump of glacial ice, isolated either by a fall or by melt-water erosion. As the ice has melted away the content of gravel has slipped down to the surface around the lump and in this way formed the recent cone as the only possible result, provided the base of the lump, if only approximately, had the shape of a circle. The characteristic result has at any rate been caused by the original shape of the ice lump. The debris cone contained still in 1957 some glacial ice.

The greater part of *the valley in front of Sermikavsak* is characterized by the melt-water rivers. Fig. 2 shows areas in which the melt-water rivers ran in 1953, as well as areas formed by rivers before 1953. The rivers are detained by the terminal moraine BCD, which has caused the formation of the outwash-plain in which the rivers are constantly changing beds (fig. 3 and 5). The breaking-

through of the north-western melt-water river is seen to the left in fig. 5. Just after the rivers have broken through the terminal moraine the water is spreading and covers a great area, shaping another outwash-plain to the south west of the terminal moraine. This outwash-plain has been formed because the melt-water rivers are restrained in their outlets into Igdlorssuit Sund. The tidal difference at the west coast of Upernivik Ø is about 2 m. When the sea-level is rising the wave action takes place at increasing levels; in this way a beach ridge can be formed in a very short time (Møller 1958). The top of the beach ridge is about half a metre above the surface of the western outwash-plain. The melt-water rivers are only able to keep very few outlets in the beach ridge. Fig. 4 was taken at high tide. The water from Igdlorssuit Sund has flown through the outlets and is covering small areas behind the beach ridge, where melt-water deposits have been shaped by numerous melt-water rivers. The surface of Igdlorssuit Sund is covered with a thin layer of melt-water containing outwashed clay. The limpid salt water is stirring up at the lee side of the icebergs. The limpid water flowing out from the melt-water river in the lowest part of the picture originates from glaciers and snowdrifts several kilometres from the shoreline in the sandstone area. This river, following the southern side of the valley, changes bed from time to time and is sometimes situated south of the moraine hill F (fig. 2). But few moraine areas have not been eroded by the melt-water rivers. The undisturbed moraine areas are scattered in the landscape as islands, especially in the shelter of terminal moraines containing heavy materials. Especially the areas in the northern side of the valley very near to the shoreline look like moraine islands (old moraine landscapes, »hill islands«). The moraine island A is covered with vegetation, and a tomb has been found in the southern part.

The above comments on the investigations in question should only be regarded as a description of some observations in an interesting, but small-sized marginal landscape. Even if it is tempting to compare the marginal landscape in Denmark with that in Greenland this is obviously impossible, because the glacial formations in front of Sermikavsak compared with the corresponding formations in Denmark (terminal moraine, outwash plains, old moraine landscapes and marginal moraines) have entirely different dimensions in proportion to each other and to the glaciers which have created the formations. Still, perhaps, the attention has to be

drawn to the moraines in which the content of glacial ice is of very great importance as compared with the content of real moraine material.

SUMMARY

Owing to the shade conditions the alpine valley glaciers in Upernivik Ø receive their supply from branch glaciers on the southern sides of the valleys. For the same reason the lower parts of the glaciers consist of a broad, almost white ice lobe to the north of a narrower lobe covered with moraine material. The last-mentioned lobe has not retired as much as the rest of the snout because of the insulating moraine cover and the shade conditions. Along the northern side of Sermikavsak a high, lateral moraine is stretching, probably a rest of the glacier, now entirely isolated and motionless. The size of the moraines depends on their content of glacial ice. Thus, the northern lateral moraine at several places rises to 200 m. above the bottom of the valley, while the moraines without glacial ice are very small. A debris cone in front of the southern part of the snout consists of a big lump of glacial ice containing moraine material. The moraines in front of Sermikavsak cannot be compared with moraines in Denmark before their content of glacial ice has melted away whereupon they are very small (less than $^1/_{10}$ of their former height). The ice mentioned in this paper is glacial ice, not permafrost.

Several systems of small terminal moraines are situated in front of Sermikavsak. Based on photographs from different periods of the life of the glaciers the withdrawal can probably be estimated at about 30–40 m. on an average in one year. The area in front of Sermikavsak is characterized by melt-water rivers; even some undisturbed moraine areas are still left as islands in the outwash plains. Some of the moraine islands are furrowed parallel to the direction of the valley. The furrows are still existing, probably because the withdrawal has gone on for only a short time. The furrows do not seem to be the result of solifluction. Owing to the content of dark moraine material in the glacial ice, the melting-off is increasing until the relative content of moraine material attains a certain limit, whereupon it acts as insulation, and part of the ice will remain for some time as a motionless rest covered with moraine materials. As a consequence of the uneven distribution of these materials in the glacier the moraines are scattered as heaps of unequal size in front of Sermikavsak. Rounded rocks and gravel have been transported to the surface along shear planes in the entire extent of the snout; especially in front of the southern parts of the glacier large quantities of edged rocks have been left back, originally fallen down to the ice surface from the steep slopes of the valley and then transported on the surface of the glacier.

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