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ON THE TRACES OF THE ICE AGES IN NORDLAND, TROMS, AND THE SOUTH-WESTERN PART OF FINNMARK IN NORTHERN NORWAY

BY

OLE T. GRØNLIE

18 TEKSTFIG. AND 5 PL.

Introduction. In later years several authors have devoted a more or less close study to the quaternary geology of Northern Norway. In the first place are here to be mentioned TANNER 1930 (20) and NORDHAGEN 1933 and 1935 (14 and 15). The present author has also for many years been interested in quaternary geological problems and has in the course of time collected a varied material concerning these matters in that part of our country. On account of duties as a functionary I have had too little time for working out the material collected or the working has been so much retarded that something may have been forgotten and more or less lost when it was to be used. As it is the quaternary conditions of Northern Norway have at present got such an actuality that I find it appropriate to present a part of the material which I have been able to work out, and to take a preliminary view of the said problems.

CONTENTS

I. The Great Ice Age.

I have on former occasions maintained that in Northern Norway only two ice ages can be traced, a great glaciation which covered all or nearly all the land and the continental shelf and a last glaciation of less extent and thickness which filled all valleys and fjords and overflowed the lower mountain parties and a part of the continental shelf. With this I did not mean to say that Northern Norway only once has been totally glaciated. There may have been as many great glaciations as elsewhere known, but the last total glaciation seems to have been so great and has so deeply eroded that every trace of former glaciations have been blotted out and ancient interglacial deposits destroyed. Northern Norway is not, however, so minutely surveyed that it can be denied that traces of glacial erosion or interglacial deposits from a time previous to our great glaciation may be found, but to the present time no such finds have been done.

In the Alps four glaciations have been counted and in Germany three. The great glaciation in Northern Norway is most likely to be correlated with the next but one of these, the Riss glaciation in the Alps and the Saale glaciation in Germany. But apart from the correlation can it be said that the glacial erosion in the mountainous part of our country has, at all events, been so strong that the work must have been done by an ice sheet of great thickness and velocity. All loose material from preglacial times has been taken away and all weathered rock removed. Mountain wilds have been ground and levelled, tops and ridges were rounded, and deep troughs were formed on the bottom of the fjords etc. In short all the leading features of the landforms must be the work of the great total glaciation, either they are to be found in the inner land, on the outermost skerries or on the bottom of the sea.

In the inner land cirques and troughs are very seldom to be found and hardly ever on the eastern or south-eastern side of the mountains which everywhere is a stoss-side. If cirques are to be found they mostly appear within the loftiest mountain parties to which the inland ice did not reach during the last glaciation and therefore were only locally glaciated. All the islands off the coast have a stoss-side to the east or southeast where cirques and deeply eroded trough valleys very seldom are to be found. Hindøy, Andøy, Senja, Kvaløy, and

Fig. 1. Profile from east to west of Andøy, seen from Risøyhamn. Gr. phot.

Ringvassøy, and most of the other islands show this trait whether outlaying or near the coast of the mainland. On the west and northwest coast of the islands both cirques and trough valleys are common, but they are of a younger date, distinctly worked out in a land formerly eroded by an inland ice, for the fresh surface of their surrounding walls cuts an old one everywhere. Against the open sea projecting points are often cut by cliffs, the work of the sea in past and present time.

When trying to find out something about the extent and thickness of the ice sheet of the great glaciation the best facts to go upon are the ice worn landforms and the loose material, especially erratic blocks. Fig. 1 shows a cross section of Andøy from east to west along the southern flank of the mountain party north of Bjørnskin chapel. Such a profile cannot have been formed in any other way than by an ice sheet moving from east to west across the island. Other sections across this island prove the same fact. The loose material is a bottom moraine. At lower levels erratic blocks are common, but from about 300 m upwards blocks are not to be seen on the surface which often has been levelled to small flats or plateaus called »heier« by the population. The flowing ice sheet must have had great thickness and velocity, and at higher levels where the ice was relatively clean most of the loose material was successively taken away by the flowing ice. On the western side of the mountains younger local glaciers have cut cirques and troughs into the old ice scratched rocks. Farther to the north most of the islands tell the same story. In the high western part of Senja similar flats have been planed by the ice. The northern part of Kvaløy is a plateau land about 600 m above sea

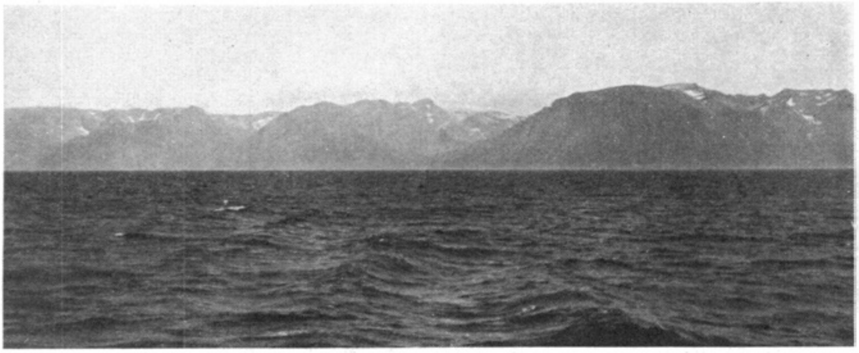

Fig. 2. Seiland in Finnmark, seen from the Sørøy-sound. Gr. phot.

level with a multitude of erratic blocks of foreign rocks. This plateau has once been overflowed by a great Balsfjord glacier. To the west it is cut by the steep walls of cirques and troughs (6) [1]. On Ringvassøy ice worn flats at higher levels are less conspicuous because the south-eastern part of this island consists of hard igneous rocks, but the northwestern part is cut by valleys and fjords for a greater part owing to erosion by local glaciers. The southern part of Vanøy is a plateau land, the lofty islands Arnøy and Kågøy have rounded forms and seem to have been overflowed by the ice, at all events Arnøy. Sørøy, Stjernøy, and Seiland are lofty islands with cirques and trough valleys due to a strong local glaciation, but taken as a whole the land-forms show that they once must have been overflowed by an inland ice (fig. 2).

The eastern part of Langøy in Vesterålen is strongly worked by the ice, and erratic blocks have been found to about 300 m a. s. l. In the western part of this island mountains rise to 1000 m or more, and some pointed tops are to be seen and may be primary nunataks, but a closer study is necessary to settle this question. Hadseløy is ice worn all over. The eastern side is a stoss-side, and at higher levels erratic blocks have been found to about 450 m, but after the time of the inland ice the north side has been strongly cut by local glaciers. The landforms in the western part of Lofoten islands have been treated by Th. Vogt (22). There are plenty of steep summits and a multitude of cirques cut by local glaciers, but he also found large flats — "heier" — at high levels. Such flats are easily found on

[1] The numbers in parentheses refer to the list of literature p. 69.

Fig. 3. A mountain formed by the inland ice in the eastern part of Vestvågøy, seen from SW. Riksheim phot.

topographic maps and by studying the outlines of the mountains. Fig. 3 is a mountain in the eastern part of Vestvågøy showing the work of the inland ice. Værøy must once have been overflowed by an inland ice. The eastern side is a stoss-side and the western side is for a greater part a vertical cliff. From a strandflat to the east the mountain side rises rather steeply, but in many places even, to the edge of the cliff. Fig. 4 shows an ice worn ridge with a direction about NE—SW. 450 m above sea level, and fig. 5 shows an erratic block lying close on the edge of the cliff to the west about 400 m a. s. l. This block has no doubt been transported and rounded by the ice, but now it has a thick weathered crust and must therefore have been in its present place for a rather long time. The island seen in the background is Mosken. To the left of the block is seen a square, the uppermost part of a landslip where stones of many foreign rocks have been found. Even Røst farther to the west seems to have been overflowed by an inland ice, for most islands there are flat on top like Vedøy, fig. 6.

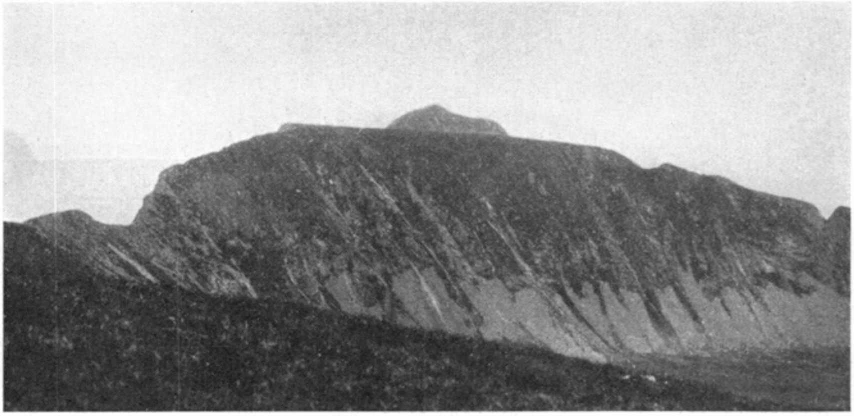

Fig. 4. A mountain ridge formed by the inland ice on Værøy.
Direction NE—SW. Gr. phot.

Vogt did not find erratic blocks on the flats in the western Lofoten, and therefore he could not decide on the time of their forming, if preglacial or glacial, but since erratic blocks have been found on Kvaløy to 600 m a. s. l., on Hadseløy to 450 m, and on Værøy to 400 m there can be no doubt as to the glacial origin of the said flats. Nor is it questionable that the Lofoten islands at a later date have been strongly locally glaciated. It is likely that some of the peaks there are primary nunataks, but no indubitable nunatak has yet been found, nor the uppermost level to which the surface of the inland ice did rise when it had its maximal thickness. 900 to 1000 m above the present sea level may not be too much if taken into consideration that flats to about 800 m a. s. l. have been planed by this ice sheet.

On the mainland the thickness of the ice sheet was much greater, and there is certainly no nunatak from that time to be found. The Tromsdalstind, above 1200 m high, has a rounded top and has no doubt been overflowed by the ice, and such must be the case with the Lyngen peninsula too. Stetind in the Tysfjord district is about 1400 m high (fig. 7), but there is a flat on top, and therefore this top must as well have been fully overflowed by the great ice sheet. Afterwards this summit must also have been nunatak for a long time because of its form. Fig. 8 shows the Børvasstinds to the south of the Skjerstad fjord. These mountain parties have nunatak form, but they have for all that been overflowed during the great ice age. The

Fig. 5. A weathered erratic block on the top of the western cliff on Værøy 400 m a. s. l. Mosken is seen in the background. Gr. phot.

nunatak form is of a later date. The large peninsula where the Svartis Glacier is situated rises to above 1600 m, but it has, however, been overrun by an ice flow from southeast, for scouring marks have been pointed out to above 1400 m a. s. l. with the direction SE—NW.

In Helgeland the Okstinds on the northern side of lake Røsvatn have the loftiest summits. This mountain party was explored by Hoel in 1908. Besides blocks from lower levels and scouring marks to great heights he also found a block of a red granite between the Oksskolt and Wilhelm II tind 1800 m a. s. l., a foreign rock in this locality. The Oksskolt is the highest summit there, 1912 m, and Hoel is of the opinion that this summit once has been overflowed by the ice.

According to what has been stated above, it must be supposed that the surface of the ice sheet of the great glaciation at the frontier rose to between 1900 and 2000 m above the present sea level in Helgeland, to between 1800 and 1900 m in the Salta district, to between 1700 and 1800 m in Troms fylke and to between 1500 and 1600 m in the southwestern part of Finnmark. If so all the mainland was covered by the ice sheet without a single nunatak rising above the ice, but as the thickness of the ice sheet was decreasing westwards it is likely that some nunataks did rise above the surface in the

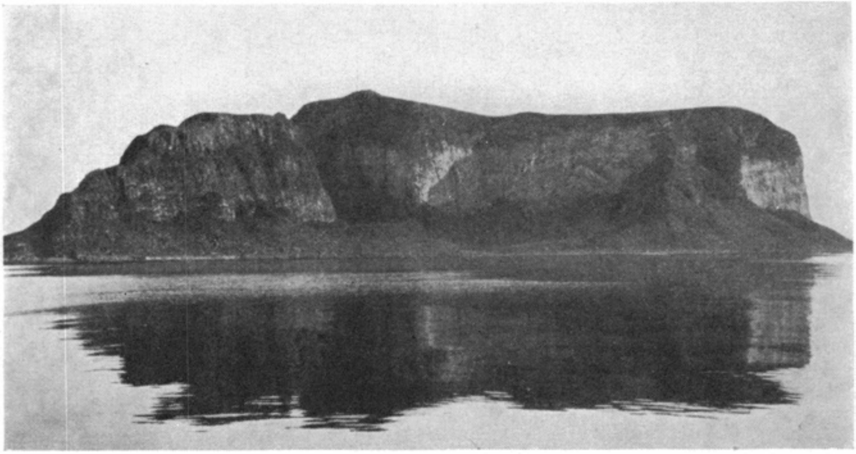

Fig. 6. Vedøy in the Røst group, seen from northeast. Supposed to have been formed by the ice. C. Dons phot.

western parts of the Lofoten islands. However, to locate such nunataks and fix the upper level of the surface of the ice during the maximal stand of the ice sheet may be a troublesome work, and only trained alpinists will be equal to this task.

An ice flow of such dimensions as here supposed would obviously move on across the continental shelf till the ice no longer was in contact with the bottom. Then advanced lobes would be broken off and float away as ice bergs. If at the same time an eustatic sinking of the sea level was greater than the isostatic sinking of the land in the peripheric part of the glaciated area, the depth of the sea would be relatively less than now, and therefore it is likely that calfing did not take place till at the outer border, the edge, of the shelf. It is also likely that the ice had played a part in the forming of the continental shelf. Ice masses pressed out through valleys and fjords no doubt eroded at and off the mouths of the fjords, but farther on the ice streams would unite to a continuous sheet all over the shelf, depositing loose material and levelling the bottom. In 1933 I accompanied C. Dons in the motor cutter "Gunnerus" of Trondheim on a cruise to the west coast of Senja for soundings and dredgings. As the ship was fitted out with a powerful dredging apparatus, rather coarse material could be dredged from the bottom in a series of stations on the Svendsgrunn stretching from Senja westwards to the edge of the

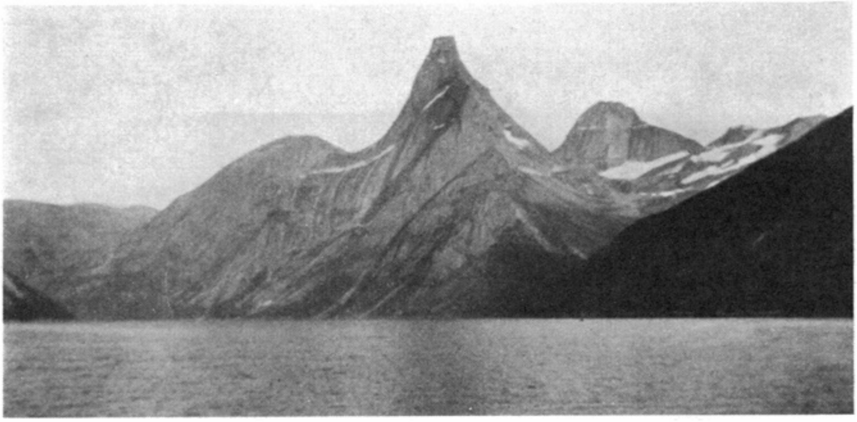

Fig. 7. The Stetind in the Tys-fjord district, about 1400 m high, flat on top and supposed to have been overfloved by the great ice sheet. Gr. phot.

continental shelf. Besides gravel and pebbles boulders to about 30 cubic dm were common everywhere, mostly of igneous rocks. Mica schist and limestone were not to be seen, and of sedimentary rocks only a block of a sandstone has been noted. Dredgings in other places have given similar results. It seems to be a fact that such material is to be found especially on the bottom to leeward of islands high enough to check the lower layers of a moving ice sheet.

Observations of scratchings, stoss-sides, and other forms of ice erosion tend to show that the ice sheet must have moved rather independently of the land surface below if sufficiently thick. If the ice stream crossed the boundary land with a thickness of 1000 m or more valleys and fjords could not settle the drainage. They would soon be filled with ice and moraine material till the whole land was levelled to a plateau slightly dipping to the west and northwest, and over this plateau the ice took a short cut across our country. The eroding work has for the most part been done at high levels, and only where the direction of a valley or a fjord was the same as the direction of the moving ice has the erosion come lower down and in some places reached the bottom and eroded there. Finds of erratic blocks at high levels at a distance of 100 km and more from their homestead show a transport for a long way at high levels. Such a block of swedish granite has been found on the eastern side of the Tromsøysund near Tromsø at about 200 m a. s. l., on Kvaløy at 370 m, and a multi-

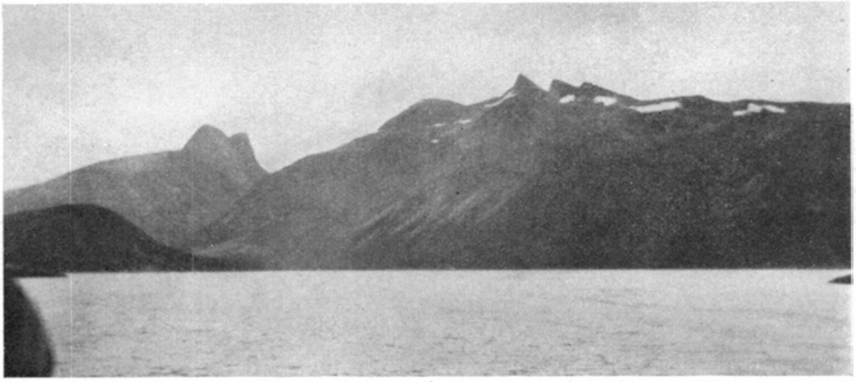

Fig. 8. The Børvasstinds, overflowed by the great ice sheet, but nunataks during the last glaciation. Gr. phot.

tude of the same rock has been found on the west slope of the Kirkesdal at about 450 m, and in the Målselvdal 6—7 km farther to the east at 575 m. Besides blocks of the swedish granite many other rocks have been found as erratics to high levels, on the plateau to the north of the Tromsdalstind to 650 m, on Kvaløy to 600 m, but as their homestead cannot be pointed out, they are of less interest. Of this kind are some huge blocks of a grey granite found on the west coast of Andøy 15—20 m above sea level, but at so low a level also blocks of swedish granite and blocks of gabbro are common.

I have on former occasions treated the eroding work of the great ice cheet, the levellings of plateaus, the roundings of tops and ridges, and the excavations of rock basins in the fjords more detailed (6 and 7) and shall not repeat it here, but generally speaking it can be said that the ice sheet of the great glaciation so thorougly has made its work that all loose material and weathered rock from former days had been taken away. The ice sheet and glaciers of the last ice age, therefore, only found bare, smooth, and fresh rock surface where little was to be done and little has been done. The remaining work would only be to form bottoms and side slopes in the valleys and other details at lower levels.

II. The Last Ice Age.

1. STAGES OF THE ICE BORDER FROM THE MELTING PERIOD

I have formerly called attention to the fact that there along sounds, fjords, and valleys in Northern Norway is a more or less distinct line of partition between a lower concave and an upper convex part of the side slopes (6). At this line between different curving parts moraine terraces and dry river beds either in loose material or in solid rock are often to be found. Erratic blocks and polished rock surface are also common in that level. Such marks show that the edge of a glacier must have been stationary there for some time, and that some melting of the ice on the surface has taken place before recession of the ice from this line.

Such terraces and river beds are often to be found at more levels in the same locality, but the uppermost and oldest ones rise commonly from the coast eastwards in such a way that it must be supposed that they have been formed at the same time, and mark a distinct stage of an inland ice during its melting period. Marks of that kind do not give any information of the maximal stand of the ice sheet, but they can give a hint of the dimensions to be taken into consideration. On the following pages I will give an account of some observations along such border lines.

On Sørøy in southwestern Finnmark about 1 km east of Sørvær is a defile stretching north-south at about 190 m a. s. l. Ice that once must have filled the defile to above 210 m has retired southwards and downwards and during its recession three moraine ridges have been deposited, quite small, but easily pointed out. Between the uppermost ridge and the mountain side is a lakelet. It is likely that the moraines there have been deposited at the border of an ice sheet in melting and not by a local glacier. On the mountain slope east of Hasvåg on the same island is an ice border line 240 m a. s. l. At the mouth of a little valley there must have been an ice dammed lakelet, now a bog. About 300 m to the south of this valley is a lake between the mountain side and a moraine ridge. No local glacier has, however, deposited this moraine, but an ice mass retiring from the land slope. Farther south from Hasvik westwards is a lowland, a former sound, across the island. The mountain party south of this lowland, the southernmost part of Sørøy, rising to 172 m, has been overflowed by an inland ice

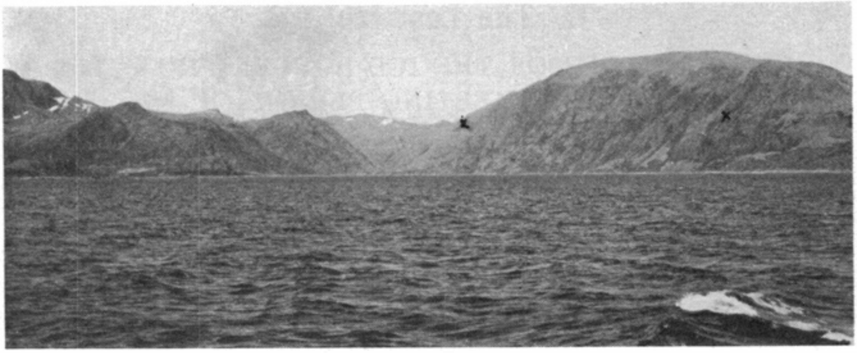

Fig. 9. Sørøy in Finnmark with the Øy-fjord, seen from the Sørøy-sund, rounded by the great ice sheet, but below a cliff a younger ice border line can be seen. Gr. phot.

of little thickness and velocity, for on this part of the island there is a multitude of blocks and boulders of foreign rocks.

On the eastern side of Sørøy the Øyfjord stretches westwards from the Sørøysund. On the northern side of this fjord a horisontal line is seen on the mountain wall about 250 m a. s. l. Above this line is a cliff supposed to have been undermined by an ice sheet with its surface at the 250 m line (fig. 9). On the southern side of the Stjern-sund about 5 km east of Øksfjord is a moraine terrace about 320 m a. s. l. and on the opposite side of this sound the steep mountain walls may have been undermined by an ice stream in the sound with its surface at the said level. Along the Kvænangenfjord marks of a similar stage of an ice sheet are to be seen in many places. From Badderen at the head of the fjord leads a road to some copper mines, now abolished. At about 110 m is a terrace of sand and gravel which likely has been deposited between the mountain side and an ice tongue retiring out the fjord. At 260 m a. s. l. is a wide moraine terrace on the eastern side of a valley, and on the opposite side of this valley is a moraine ridge between the river bed and the western mountain slope, and beyond this ridge a lake has washed out shore lines at more levels. The river bed is a canyon, for a part cut in hard packed moraine.

At about 300 m a. s. l. there seemed to have been an ice dammed lake stretching northwards in the valley which at that level is relatively flat. The lake stage was naturally an advanced melting stage. Along

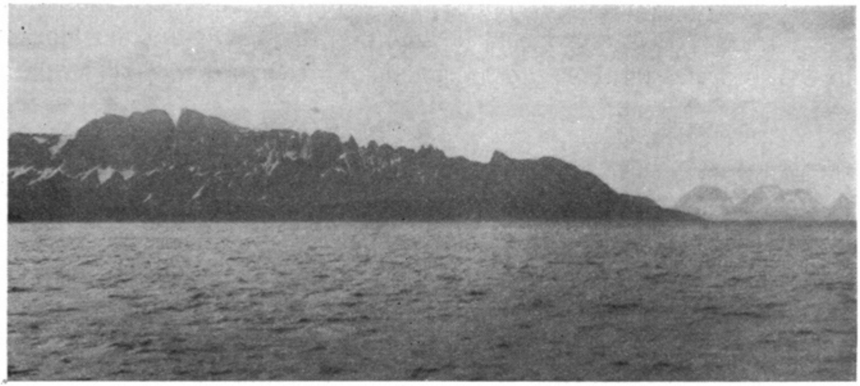

Fig. 10. Ice border line on the north flank of the Kvænangstinds, marked by snow patches in the middle of the mountain wall. Seen from the north. Gr. phot.

the north side of the fjord between Alteid and the Jøkelfjord there are some rock pillars at about the same level, they must have been formed by river action at the border of a glacier. A line is seen at about the middle height of the north flank of the Kvænangtinds, but not measured (fig. 10). Similar lines have been seen along the Nord-Reisa fjord seemingly at a corresponding level.

At Olderelv farm on the eastern side of the Lyngenfjord two lateral moraine levels have been measured 300 and 400 m a. s. l. From the head of this fjord the Signaldal stretches in southeasterly direction to the frontier where a cairn marks the point of contact between Norway, Sweden and Finnland. In this valley about 25 km from the sea a melt water river has once cut a canyon in the eastern mountain slope in the solid rock. The bottom of the canyon is situated about 550 m above sea level. The upper wall of the cut is about 50 m high, the opposite wall about 15—20 m, and the canyon is about 30 m wide and 1 to 2 km long. The river once cutting there must have started its work above 600 m above the present sea level, and the great mass of rock taken away is for a part to be found at the northern end of the canyon where the river had found a passage down to the bottom of the valley. Fig. 11 shows the southern part of the canyon seen from northwest. The mountain seen in the background is Paras. About 100 m below in the same mountain side is another cut, marking a younger stationary stage of the ice border, but this cut is neither long nor deep.

At Breivik farm at the northern end of Breivikeid is a moraine terrace about 280 m a. s. l., but beyond that the mountain sides along the Ulsfjord and the Sørfjord are so steep and naked that no border lines are to be seen.

Near the northern point of Renøy is a moraine terrace 175 m a. s. l., and at Rottenby farm near the south end of the same island is a similar terrace 192 m a. s. l. At Kraknes farm on Kvaløy near the southern mouth of the Kvalsund is a moraine terrace 198 m a. s. l. This border line is rising southwards on the same island to 220 m. On the east side of the Tromsøysund is a nearly continuous lateral moraine level, about 210 m a. s. l. at Movik farm 10 km north of Tromsøy and about 250 m a. s. l. near the mouth of the Ramfjord. Along the Balsfjord this level is not easily pointed out, but in the valley between the heads of the Balsfjord and the Lyngenfjord it is found 430 m a. s. l., at lake Sagelvvatn at 400 m, in the Målselvdal near the Øvrebygd at 575 m, at the mouth of the Sanddal, a side valley to the Dividal, at 680 m, and at the mouth of the Annavassdal at 700 m a. s. l.

At Ganslåt near the mouth of the Malangenfjord a lateral moraine has been measured 193 m a. s. l., but all other lateral moraines along this fjord are to be found at lower levels, thus at Andsnes at 145 and 150 m a. s. l.

At Vikstrand on the southeastern side of Senja is a moraine terrace 260 m a. s. l., at the head of the Sørreisa fjord a similar terrace 300 m a. s. l., and at Løvdal farm east of the sound between Andørja and the mainland a terrace 260 m a. s. l. On the plateau between the Gratangenfjord and the Herjangenfjord are terraces between 190 m and 270 m which must have been deposited in an ice dammed lake between glaciers in the said fjords.

Between Harstad town and the Kvæfjord goes a direct road to Borkenes along a wide valley. The bottom of this valley is covered by a thick ground moraine to above 200 m a. s. l. Lateral moraines are to be found on either side to above 240 m. There are similar moraines on the west coast of the Gullesfjord at Flesnes at about 210 m, at Gunnesdal to about 230 m, on either side of the Sortlandsund at about 220 m, on the Hadseløy to above 160 m. These lateral moraines show that there once has been a large glacier in the Vågsfjord and the Andsfjord sending strong offshoots through more defiles westwards from the Gullesfjord to the Sortlandsund where

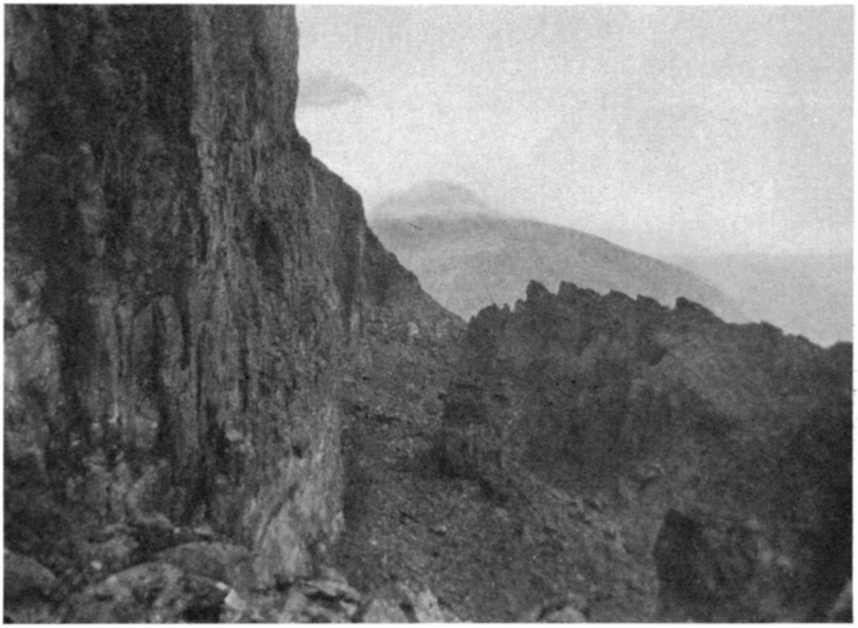

Fig. 11. Canyon cut by a melt water river in the east slope of the Signaldal 25 km from the head of the Lyngen fjord 550 m a. s. l. Gr. phot.

they merged into an ice stream that moved on through the Hadselfjord to the open sea off the western coast of Langøy and Vestvågøy.

The Andsfjord glacier sent two broad ice tongues across Andøy, a southern tongue over the marshy lowland at Bjørnskin, and a northern wider tongue westwards over the Dverberg lowland. This northern tongue has marked its way by lateral moraines and terraces on its southern flank at 240 m a. s. l., and on its northern flank it has undermined outstanding points to perpendicular cliffs that now cut a formerly ice worn surface. The face of Arnipen is such a cliff.

The western part of Vestvågøy is a large glacier trough where ice both from the north and the south has merged together. A thick ground moraine covers the bottom of the trough and rises finely both to the west and to the east. About 10 km to the east of Eggum is a lateral terrace 125 m a. s. l. To the east of this trough blocks and boulders have been found to about 300 m between Valberg and Borge and to the east of Valberg to 340 m. These finds show that the ice sheet must have been quite thin and the movement inconsiderable.

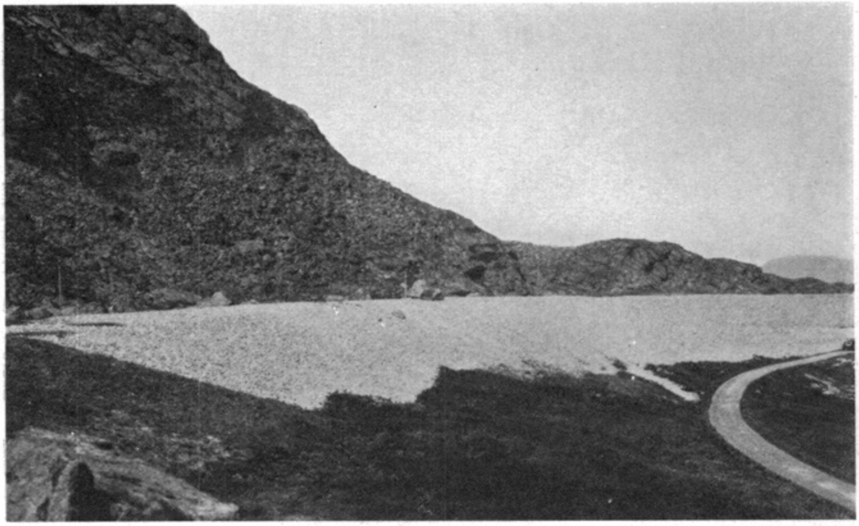

Fig. 12. A strand wall of cobbles on the north-eastern side of Værøy near the north point. Gr. phot.

The outer border of this ice sheet seems to have stopped against the eastern side of Flakstadøy so that this island was scarcely surrounded by the ice during this stage.

It must be supposed that this last inland ice rose to above 100 m on the east side of Værøy. If so this island must have been surrounded by the ice perhaps with the exception of the middle part of its west coast. On the east coast near the north point of the island is a terrace of cobbles of foreign rocks. The foreign material no doubt has been carried by the ice, but at a later date the terrace has been formed by the sea (fig. 12).

The last ice sheet cannot have reached so far out as Røst. I have surveyed the Røstland rather closely but could not find foreign rocks or other marks of a late glaciation.

Between the Ofotenfjord and the Salta—Skjerstadfjord lateral terraces are rare. In the Håkvikdal south of the Beisfjord near Narvik are, however, some terraces between 200 and 270 m no doubt deposited in an ice dammed lake, but this lake must have existed at a relatively late date. Farther south not a few peaky mountain tops are to be found within that district which must have been nunataks for a long time, most likely during a greater part of the last ice age. They

Fig. 13. A dry river bed in level with a defile between Saltdal and Bjellådal about 844 m a. s. l. Gr. phot.

are often like a hat with a lower party, a rim which must have been covered by the last ice sheet, and a crown more or less as nunatak, rising above the ice.

From the Saltdal at Bergulnes farm runs a line of telegraph through the Bjellådal southwards to the Rana district. It passes the watershed between the Saltdal and the Bjellådal at a level of above 800 m. The topographic map has 844 m and by two aneroid measurements 820 m have been found. Just at the level of the divide is a river bed showing that a river must have passed from Saltdal to Bjellådal at that point (fig. 13). In the northern part of the Bjellådal was at that time an ice dammed lake. This lake was dammed by an ice tongue from the south, an offshoot from a large glacier in the Dunderlandsdal as pointed out by Rekstad (18). At the northeastern end of the present lake great terraces of sand and gravel are to be found which must have been deposited by the said river, for at the present time only small brooks are to be found there, running on hard ground and surrounded by bare rocks so it would not be easily understood whence they should have taken such masses of loose material as there deposited if it be deposited by them.

The ice dammed lake had during its highest stand an outlet through a defile northwards to a valley called the Harrodal. Fig. 14 shows a shore line from that time 765 m a. s. l. The bottom of the dry river bed at 764 m is flat and its width is 100—150 m. The river

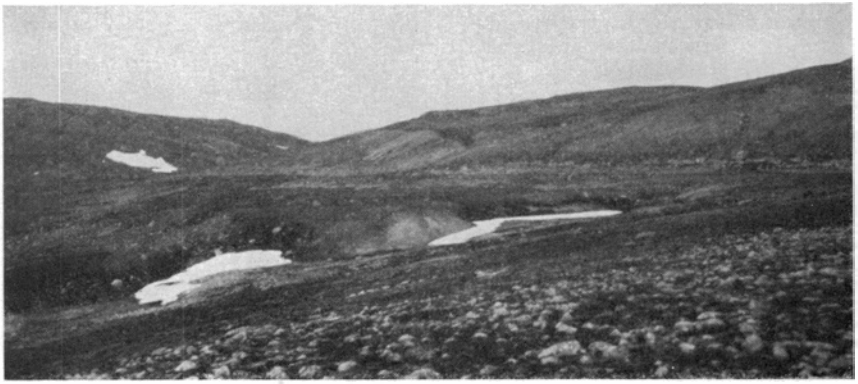

Fig. 14. A shore line showing the level of the older ice dammed lake in the Bjellådal 765 m a. s. l. The outlet of the lake went northwards from the patch of snow seen to the left on the photo. Gr. phot.

started at the point where a patch of snow is seen to the left on the photo.

The bottom of the Harrodal lies about 600 m above sea level, and in the valley was a lake dammed by the glacier in the Saltdal. In this lake the loose material carried by the said river from the Bjellådal and other glacial rivers was deposited. Fig. 15 shows 5 terrace steps washed out in these deposits. While the lake existed the level of the ice surface in the Saltdal must have been situated at about 650 m. Such a level of the ice border has farther south been marked by a shore line of a border lake not far below the Hesjehomp telegraph hut.

While the melt water river was running across the watershed to the Bjellådal, the surface of the glacier in the Saltdal must have been much higher, at least 900 m above the present sea level. The Dunderlandsdal glacier which dammed the lake in the Bjellådal must have been of similar dimensions and no doubt was connected with the Saltdal glacier through a glacier in the Lønsdal at about 1000 m above the present sea level and parallel to the frontier. Despite the great elevation of the surface of the ice at that time the supply of ice from Sweden across the frontier must for all that have ceased or was about to be so, and the time of the ice dammed lakes must therefore represent a rather advanced stage of the melting of the last inland ice. After that time the glaciers in our valleys may have been dependent only of local supply of ice, and it is likely that they soon were reduced to dead ice masses as the local supply scarcely was great enough to

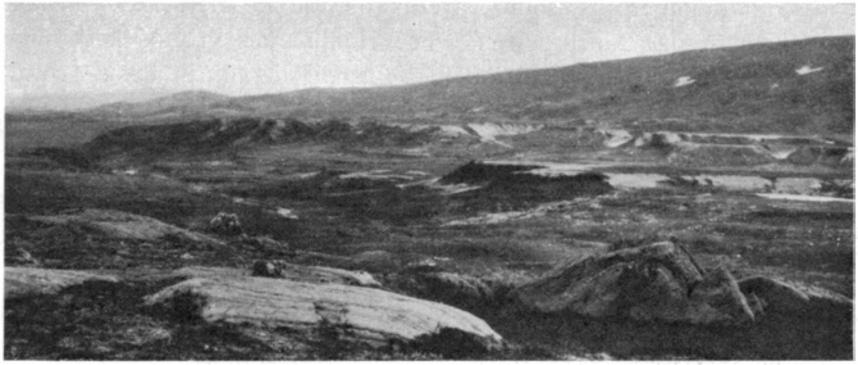

Fig. 15. Terraces deposited in an ice dammed lake in the Harrodal about 600 m a. s. l. Gr. phot.

keep them moving. This, however, only holds good in Nordland. In Troms, on the contrary, the valley glaciers still were fed from the east, and perhaps in the Tysfjord district as well.

The Røvassdal is a side valley to the Dunderlandsdal, stretching northwards into the Svartis area. On the western side of this valley is a lake, Rengårdsvatn, 364 m above sea level, and to the south of this lake the entrances of three grottos lie on a line near 400 m a. s. l. The lake must once have been dammed by the ice to above 400 m, and during this time water must have forced its way down along crevices in the rock, a limestone, and there formed the grottos now found there. To one of the grottos, the Larshol, the entrance is narrow and difficult to pass, but once through, the passage opens into a veritable valley, falling with the dip of the mountain side. There is a roof of mica schist and on the bottom is running a brooklet which disappears in some narrow crevices about 70 m a. s. l. In the narrow passages near the entrance no running water is now to be seen. Of the same age or perhaps somewhat younger is a cavern in the opposite side of the Røvassdal, the Grønli grotto. This grotto has three entrances, the uppermost one at 236 m a. s. l.. The outer part of some of the passages leading inwards to the subterranean galleries has been filled up with ground moraine pressed in by the ice. In this material blocks and boulders of granite have been found. These blocks must have been carried at least 10 km from their homestead. The brook running through this grotto has a subterranean course for several km and falls from a level of about 260 m to 50 m a. s. l.

Still younger are some caverns on the northern side of lake Langvatn in the Rana district. The Hammernes grottos have their entrances at a level about 200 m. Further details of these grottos are to be found in a paper by Dr. Gunnar Horn: Über einige Karsthöhlen in Norwegen. — Mitteilungen über Höhlen- und Karstforschung. Jahrgang 1937.

On the preceding pages some scattered observations have passed in review, moraine terraces, dry river beds cut by melt water rivers along the edge of valley glaciers, shore lines washed out in ice dammed lakes etc. Such marks have been found at several levels and must therefore be of different age. Those which have been found on outlying islands must be the oldest and are supposed to date from an early part of the melting period, but not even those are likely to mark the maximal stage of the surface of the last inland ice. With ice surface is here meant the surface of the ice flow from the east, not the surface of glaciers in locally glaciated areas above the level of the inland ice. Such locally glaciated areas were the Svartis peninsula and a greater part of the Lofoten and Vesterålen islands which no doubt did rise above the level of the last inland ice.

2. THE MAXIMAL THICKNESS OF THE LAST INLAND ICE

To fix the thickness of the last inland ice at its maximal stage will be, after all, no easy task as it would call for detailed investigations within the loftiest mountain parties. The present writer has had neither time nor strength to take on such investigations, but in travelling inland I have always tried to collect material concerning this question, and if I was not able to form an opinion based on direct observations in the field I have been going over the topographic maps in order to find a hold. Rolling mountain plateaus with ground moraine cover in depressions and naked knolls scantily weathered may have been overflowed by the last inland ice as well as ridges with ice-worn forms, especially if they have been flattened on top and are stretching southwest—northeast. Summits rising steeply from a flatter base must be supposed to have been nunataks, at any rate for a long time, during this glaciation. Cirques are to be found on outlying islands at or near the present level of the sea, but on the mainland they rise to higher levels, increasing with the distance from the coast. It is true that some cirques are of a younger date, engraved after the recession of the inland ice from the outer coast line, and some cirque glaciers are yet working, but it can, however, scarcely be doubted that also at the maximal stage of the ice sheet local glaciers eroded in cirques and trough valleys on the lee shore of land parties too high to be overrun by the inland ice or situated above the level of the flowing ice sheet.

By comparing scattered observations and statements derived from the maps I have come to results seemingly fair. Between Børgefjell and Sulitjelma the last ice flow seems to have passed the frontier with its surface about 1500 m above the present sea level. Between Sulitjelma and Ofoten the elevation was 1300—1400 m, and in Troms fylke 1200—1300 m. The surface of the ice sheet had a faint westerly or northwesterly dip. West of lake Røsvatn the land surface seems to be ice worn to about 1300 m, and the Reinfjell ridge running south—north and rising to 800—900 m has been flattened on top by an ice flow from the east. Cirques are not to be found in this district except between the Lukttinds and the Dårtinds. The highest summit of the Lukttind group is 1344 m high and is supposed to be a nunatak from about 1200 m upwards. The land west of the inner part of the Vefsenfjord with summits above 800 m was completely covered by the ice, and on the Alsta island the ice surface must have been situated between 800 and 900 m. The well known summits "the Sju Søstre" were then nunataks. Dønmannen near the southern end of Dønna island may have been nunatak from about 500 m. At similar levels lay the surface of the ice west of the Svartis area. Lovunden island is supposed to have been nunatak above 400 m, the steep uppermost part of Hestmona island nunatak from 450 m. On the coast of the mainland this level rises to about 800 m. This is in quite good accordance with statements by Granlund from 1935: On Dønna and Tomma islands weathered rock down to 500 m, in Sjona glacial sculpture to about 700 m, nunataks above 800 m (2).

In the Beiarn district all the rock ground seems to have been overflowed by the last inland ice. Two summits, Tellingen 1248 m and Ramgjeiltind 1237 m, must on account of their peaky form have been nunataks from 1100—1150 m upwards. The ice flow was not thick enough to cross the mountain party west of the Beiardal, and it therefore parted in two different ice streams, the one going northwards to the Saltafjord and the other making its way through the Dunderlandsdal and the Ranafjord to the outer coast.

On the southern side of the Salta-Skjerstadfjord the highest summits of the Børvasstinds and the Beiartinds must have been nunataks above 1000 m. North of this fjord the Steigtind has likely been nunatak from about 650 m, some peaky summits near the mouth of the Follafjord from 700 m, Landego island from 500 m upwards.

On the map of Narvik mountain parties with cirques and nunataks are to be found above 1000 m, on the map Ofoten to above 900 m and on Tjelløy between the Tjellsound and the Ramsound to 850 m.

Along the southeastern coasts of Lofoten islands the surface of the ice flow seems to have sunk to 450 m at Svolvær and to between 400 and 300 m on Vestvågøy. On Værøy it is supposed to have been situated between 100 and 150 m above the present sea level.

As for Troms fylke only maps of the south and southeastern part are fit for the said use, and therefore not much can be made out of them. The level of the ice surface must have sunk there as farther south to the west and northwest. On Rolla and Andørja the surface must have been situated between 700 and 600 m, on Hindøy between 600 and 500 m, on Grøtøy at about 500 m, on the southern part of Senja at about 400 m above the present sea level. Farther north the surface lay still lower, between the islands in the northern part of Troms fylke at about 300 m, around the southern part of Sørøy about 300 m. It is known that in the eastern part of Troms fylke between the heads of the Lyngenfjord and the Balsfjord and the great lake Altevatn, is a series of lofty summits between 1200 and 1500 m above sea level. The botanist Reidar Jørgensen, who has ascended most of these summits, has embodied his impressions of these mountains in a skeleton form, a "Normalgipfel". From the bottom of a valley about 200 m above sea level the mountain side rises to about 1100 m where it passes into a "Blockmeer" less steep and covered with a multitude of blocks (13). I think it likely that the surface of the inland ice at its maximal stage is to be found in the Blockmeer 1150—1250 above the present level of the sea.

In conformity with what has been stated above the last inland ice must have had its greatest thickness in Helgeland, and there it must have advanced far out on the continental shelf. North of the Svartis area the ice flow also passed the present coast line with a considerable thickness and no doubt covered a large part of the bottom of the shallow sea off shore. Between the Ranafjord and the Saltafjord there is so long a distance that scarcely the said ice streams did merge

Fig. 16. A moraine deposited by a local glacier at Bleik on Andøy. North of the moraine shore lines are to be found to 26 (48?) m a. s. l. Gr. phot.

into one, at all events near the coast of the mainland, but there local glaciers from the Svartis area were great enough to fill the interspace between them, and therefore it must be supposed that there still was a continuous ice front facing the sea from the southern Helgeland to the Lofoten islands. At the same time a strong local glaciation of these islands must have contributed to increase the ice streams on both sides of these islands.

North of Hindøy a large Vågsfjord glacier was flowing westwards. Farthest to the south great ice masses were pressed through pass valleys westwards to the Sortlandsund. A part of the front was running up against the southern mountain party of Andøy and was turned off to the south. Farther north two wide ice tongues crossed the lowlands of Andøy without overflowing the middle and northern mountain party. On the western side of these mountains local glaciers worked at the same time more or less in contact with the inland ice. On the eastern side of the mountains the inland ice did not everywhere get contact with the mountain side because local glaciers had come into being there before the arrival of the front of the inland ice. Along the east side of the northern mountain party is a moraine ridge at some distance from the mountain side and this ridge seems to have been built by the inland ice and local glaciers in common. This ridge tells so much in the field that it is seen on the topographic map. Fig. 16 shows a moraine deposited by a local glacier at Bleik west of the northern mountain party. This moraine cannot, however, have been built while the inland ice had its maximal stage, for then the coast off Bleik must have been blocked up by the inland ice, and the local glacier may have been greater and advancing into the sea merging together with the inland ice.

The high western part of Senja was not overflowed by the inland ice during the stage here dealt with, but a narrow glacier tongue, however, crossed the island through a valley from the Gisund at about the middle of the island. Both north and south of this passage the west coast lay on the lee side of high mountain parties, and all the fjords there were filled with mighty glaciers fed locally. To what extent these glaciers were in contact with the inland ice before the melting period set in is not easily conjectured, but like the glaciers on the west coast of the Svartis area they may have filled up a space between the northern flank of the Andsfjord glacier to the south and of a great Malangenglacier to the north. After the melting of the ice barrier west of Senja these fjord glaciers have been true local glaciers for a long time.

On the west coast of Kvaløy north of the Malangen glacier similar fjord glaciers have existed and have forced their way far into the island, but only one has cut across to the east coast. This cut is the Kalfjord. Through this passage the last Balsfjord glacier sent a branch westwards to the sea, but else only local glaciers have been at work cutting deeply into an old plateau land formerly levelled by the great ice sheet, and there is, therefore, a distinct difference between the old plateau to the east with its erratic blocks of foreign rocks and the fresh surface of the steep walls surrounding the cirques and trough valleys in the western part.

The southeastern part of Ringvassøy along the Grøtsund is a highland with rounded summits, and plateaus of a noteworthy extent are not to be found, but on the lee side of these mountains large local glaciers have been at work, the largest being the Skogsfjordvatn glacier. These glaciers cannot have been in any intimate contact with the inland ice flow in Kvalsund and Langsund. Along the border of the said local glaciers great melt water rivers must have been in action, for on the east side of the Skogsfjordvatn glacier there are two dry river beds, the one a 5 m deep canyon starting at 170 m and ending at 130 m, the other nearly parallel to the former starting at 153 m and ending at 120 m above the present sea level. At lower levels similar beds are also to be found, but they are neither so deep nor so continuous.

The surface of the last glacier in the Tromsøysund must have been situated between 350 and 400 m above the present sea level at its maximal stage, for some horisontal lines in ground moraine are to be seen at that level on the east side of the sound about 10 km north of Tromsøy. Offshoots from this glacier were the glaciers which made their way through Kvalsund and Langsund and merged together between the islands north of Ringvassøy, forming an ice plateau about 300 m a. s. l.

Glaciers of similar dimensions as the Malangen and Balsfjord glaciers also filled Ulsfjord, Lyngenfjord, Nordreisafjord and Kvænangenfjord and all sounds between the islands in the western part of Finnmark, and off the mouths of the fjords and sounds these glaciers merged into one, forming an ice barrier with a continuous front against the sea between Vannøy in Troms and the southern part of Sørøy in Finnmark. A part of the west coast of the last named island must have been blocked up by the ice to some extent, but possibly not the northern part of its west coast.

3. EVIDENCES OF FOSSILS AND LIVING PLANTS OF A LAST ICE AGE

On the previous pages I have tried to give an account of the probable dimensions of an ice sheet presumed to be the maximal stage of a last ice age. It may then be a question whether the said stage be only a melting stage of the great ice age or actually an independent ice age separated from the former by an interglacial period. The ice sheet of the great ice age was no doubt so thick and moved so quickly that scarcely no space was left for local glaciers even if some nunataks may have risen above the surface of the ice. During the melting of this great ice sheet some remnants of ice may have been left on the west side of islands, but if so they were for a greater part "dead" glaciers with slight eroding power and cannot, therefore, have done the eroding work the traces of which are so conspicuous there. It is therefore more likely that these glaciers were of local origin starting their work at the beginning of the last glaciation, going on during the advance and maximal stage of the last inland ice and the following melting period if the climatic conditions were favourable for their existence and supply.

Of interest in this connection is further an occurrence of loose material with fossils found in the town of Tromsø, in a quarry on the St. Hans Haug. In the lower part of the quarry 42 m a. s. l. was a slate rock of relatively thick foliation and there sand and gravel had been pressed into the rock between the plates to a thickness of about 6 cm, and in this material were shell fragments of which the two mollusk species *Mya truncata,* Lin. and *Littorina rudis,* Maton could be determined. Besides the shells there was found a stone with an impression of a leaf of*Alnus incana* of the same type as now is living on the Tromsøy. *Alnus* could not have lived on Tromsøy while a glacier filled the Balsfjord or was near there, and *Littorina rudis* is a boreal gastropod. The occurrence must therefore be interglacial. About 150 m north of the quarry and 10 m higher shells have been found pressed into moraine material 6 m below the surface. A similar occurrence was found by Kiær near the top of the island 3 m below the surface. Among the species found was also *Cyprina islandica,* Lin., a typically boreal species (7).

It may be objected that this fossiliferous material is not strong and the reasoning less convincing but then the botanists step in helpfully. Nordhagen mentions a good many plants which he calls interglacial hibernates. These plants are only to be found either within a limited area in Northern Norway or in the loftiest mountain parties in Southern Norway or within both these areas but not elsewhere in Scandinavia or adjoining parts of Europe. Nordhagen is of opinion that these plants have immigrated to our country during an interglacial period and here survived later ice ages in ice free and protected places (14 and 15). As during our great ice age, the last total ice sheet, in my judgement, was so thick that practically the whole land was overflowed by the ice, it is not thinkable that vegetable life could survive in Northern Norway and find resorts which were not eroded by the ice. The occurrence of these plants, therefore, appears to me to be an important and strong proof of an interglacial period between our great glaciation and a last glaciation, the last ice age. The last interglacial period was long enough for the immigration of a new flora, and during the last ice age there were plenty of resorts for a hardy mountain flora to be found.

III. The Late Glacial Shore Lines.

1. SOME GENERAL REMARKS

The shore lines in Northern Norway have for a long time been known and supposed to be marks of past sea levels, and after the time of Bravais about 100 years ago many interested men have measured them and dealt with them. Among others must chiefly be named Karl Pettersen, Andreas Hansen, Helland, and Tanner. After getting an appointment in Northern Norway also the present author began to take an interest in the shore lines and in the course of time I have collected a material of levellings within an area stretching from Bindalsfjord in the southern Helgeland to Hammerfest in Finnmark.

I have never had much time left for working out this material, and therefore I have not been able to give a summary of it till now. Nor was the former way of working by drawing of isobases much practical in use when the material increased as more levels were pointed out. When Helland measured shore lines in Troms fylke only two levels were taken into consideration, broadly speaking the lines b and f by Tanner, but by including fainter lines it soon appeared that in the northern part of Troms fylke were at least 5 lines and in the southern part 6 lines, and still more complicated was the situation in Nordland where only a few measurements left no doubt that above 12 different levels were there to be found. To follow all these levels in the field so closely that each single line could be known apart was practically impossible. Drawing of isobases must very commenly be postponed in anticipation of new and better material, and in that way the working could be retarded for years.

Tanner, in his book from 1930 where he deals with the quaternary geology of the northernmost part of Finnland, rejects in many points the old views, and his line of arguments comes so often across habitual theories and conceptions that one must go in for reconsideration and test, and so far has his criticism been useful, but more important than the criticism were his positive contributions in pointing out a new way of graphic figuration of the shore lines, the epeirogenetic spectrum. It is clear that if this method can keep what it promises it would be a find and an excellently valuable means in the study of the shore lines. I have tested the method on my material and have come to the result that it is indispensable. If the levels cannot be identified by the aid of the spectrum they can even less be identified by the field work, for the shore lines lie often so close to each other or they are so faint that they cannot be followed continuously for a longer distance.

I have up to now only dealt with material collected by myself for it was always at hand, and the localities were known from the field work so their relative value could be compared.

Tanner has used in constructing his epeirogenetic spectra the Tapes line — or more definitely the b-line — as the leading line when inserting the localities in a spectrum. This implies, however, that the b-line has been safely fixed during the field work. It may have been done with sufficient exactitude on the coast of Finnmark and Northern Finnland, but even in the southern part of Troms fylke some insecurity is met with, and more difficult it is in Nordland fylke where the b-line is not in general better developed than any other line. In order to get a more safe notion than scattered and casual values could give, I have, therefore, in applying all the levellings at hand made out the line from place to place southwards, and the result of this work are the isobases of the b-line, pl. 1. As will be seen the isobases run, broadly spoken, parallel and equidistant. Only in the northern part of Troms fylke and the adjoining part of Finnmark a diverging course is initiating, and the distance between the 5 m isobase and the 10 m isobase is greater than the mutual distance between the other isobases. Whether this is correct or not cannot be safely said, for in the peripheric part of the once glaciated area the shore lines lie so near together that a younger line may have been mistaken for the b-line during the measurements.

2. THE SHORE LINE DIAGRAM

Plate II is a diagram drawn after the method of Tanner to a scale about that of his from 1930 both vertically and horizontally, vertically 1 m to 1 mm, horizontally 200 m to 1 mm. For the diagram only 312 measurements have been chosen out of the material from Northern Norway, in the first instance because the whole material is not yet worked out with suffient accuracy, and also because a diagram in the said scale would be inconveniently crowded if too much material was inserted. Besides the levellings from Northern Norway, however, 8 levellings from Novaya Zemlya have been included because they were easily fayed in though they belong to another area of depression. This adaptation must depend on a law-directed parallelism between

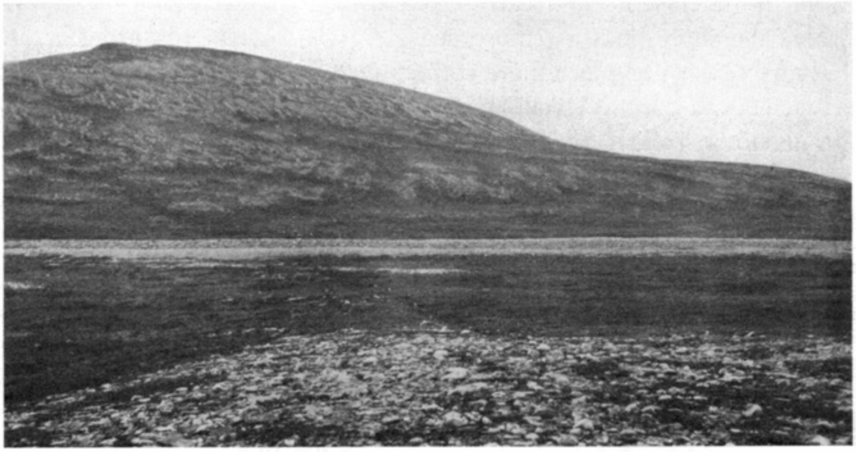

Fig. 17. A strand wall of cobbles with a shore line washed out on the distal side of the wall at Hasvåg on Sørøy 51,8 m a. s. l. Gr. phot.

the movements in different depressions at the same time which would have been difficult to make out without the aid of the diagram, and it is a proof of the usefulness of the method. It is not easily done to insert the levellings in their proper place in such a diagram, and I do not dare to believe that this end always has been attained, but the departure cannot be great.

The uppermost lines p to n′ whether found in Northern Norway or in Novaya Zemlya are very doubtful marine shore lines. The measurements concerning them have mostly been carried out in places on the open coast where the rock surface was intensely weathered or have been taken on sounds and fjords where lines may have been washed out by running water at the ice border. All the figures from Novaya Zemlya above 272 m have besides only been found by aneroid.

The uppermost shore line which certainly is marine is n, pointed out in not a few localities. At Hasvåg on the west coast of Sørøy in Finnmark this line is very sharply engraved in an open situation to the sea 51,8 m above sea level, and on Trenyken, one of the islands of the Røst group, it is found at the entrance to a cave 39,9 m a. s. l. As this line is marking the upper marine boundary in such outlying places, it is supposed to be the oldest marine shore line after the maximal stage of the last glaciation (fig. 17).

The lines from m to d_4 are rather accurately fixed in number and position in the diagram, for a greater part of the levellings are from the later years and carried out with great care. Farther down where the shore lines are more densely crowded the measuring errors have a greater play, and there corrections of some importance must be expected when more levellings are taken into consideration and diagrams to a greater scale are used. This applies especially to the c-lines and the a-lines.

For evading new difficulties regarding the designation I have always used the same letters as Tanner on lines identical with his. If in my diagram lines were found which were not to be identified with any lines in Tanner's diagrams, or if some lines were doubtful, I have only noted such lines with a point.

The levellings used for the drawing of pl. II are to be found on the following pages. The figures have been taken directly out of the journals written during the field work. In these journals remarks have generally been passed on every single locality and each shore line which was pointed out. These remarks have been left out in the list of the localities in order to save place. But as the relatively best localities have been chosen for the diagram, only the remarks on each individual shore line are really missing in the list.

3. LEVELLINGS USED IN THE DIAGRAM

1. Sørvær on Sørøy	3,8 6,5 11,1 12,6 18,3 28,8 43,2.
2. Bleik on Andøy	4,4 5,5 13,2 15,4 17,5 20,7 23,4 24,5 26,6 40,4 48,1.
3. Eggum on Vestvågøy ...	4 5,9 7,8 9,9 11 13,8 16,5 18,6 24,2 26 42.
4. Høines on Vestvågøy ...	4 8 10,9 18,1 20,1.
5. Kvalnes on Vestvågøy ...	4 8,3 10,3 17,8 18,5.
6. Skagen in Bø, Langøy ...	5 6,1 11,3 15,3 22,2 26,2 35,8.
7. Knutstad on Vestvågøy...	4,4 8,3 20,4.
8. Bø on Andøy	3,3 6,7 13,7 16 18,3 24,4 28,6.
9. Vik on Vestvågøy	2 3 4 4,6 5,9 7,9 10,3 14,1 19 24,1 55 68.
10. Toften on Langøy.........	6,1 11,9 15 19,7 29,6 38,1 62?
11. Trenyken on Røst	4,6 7,9 9,6 16,5 39,9.
12. Bergvik on Hadseløy ...	7,6 17,7 18,7 28,9 31,7.
13. Risøyhamn on Andøy ...	7 15,7 16,2 18,9 28,1 30,1 32,1.
14. Langnes on Hadseløy ...	6,9 17 20,9 30,2.

15. Valberg on Vestvågøy ...	5,5 12? 17 23.
16. Hadseløy, east	8,4 17,3 33,3.
17. Vedøy on Røst	5,2 8,2 8,7 9,6 11,4 17,1 33,5 36,3 37,6 48,7.
18. Værøy, north	2 4,6 5,6 6,2 7,9 9,6 11,4 15 17,6 31.
19. Hasvåg on Sørøy	3,4 4,8 5 7 7,5 7,8 9,3 11,8 13,8? 14,3 15 16,7 18,5 20,5 21,5 22,5 24,4 26,9 28 29,3 32,1 34 35,6 37,7 39 40,5 41,6 51,8.
20. Helgøy	9,6 15,8 29.
21. Holand on Langøy	5,6 9,4 19,3 40.
22. Skogsfjord on Ringvassøy	3 4 9,7 16,8.
23. Vengsøy west of Kvaløy	9,9 12,1 18? 21,2 23 24,9 39,9.
24. a. Hasvik on Sørøy, west	7 16,2 31,2 33,2 56,9 60,3?.
b. Værøy, south	2,8 6 10,4 14,4 17,7 32 34,3 41,9 61,8 80,5.
25. Hasvik on Sørøy, east ...	4,1 6,3 9,2 13,3 20,2 22 24,6 30.
26. Breivik on Senja	10,2 17,5 20,4?
27. Sandvik on Senja	10,3 19.
28. Mefjordvær on Senja ...	10,4 18,1? 19,1 44,4?.
29. Strand opposite Sortland	6,2 9,1 21,8 35,1? 41,3.
30. Kjerringvik on Senja, west	10,8 21,2.
31. Finnsæter on Senja, west	11-22.
32. Mellemjord on Vannøy...	11 12 23 27,4 34,3.
33. Rekvik on Kvaløy	4 13,6 23,3 26,2 43,4.
34. Tronjord on Kvaløy	5,9 11,5 26,3.
35. Bukkemyr on Senja	11,4 22.
36. Finnvik on Ringvassøy...	5,4 12,3 25.
37. Gryllefjord on Senja ...	11,2? 12,2 23,7.
38. Tromvik on Kvaløy	12,4 19,6 23,6 36,9.
39. Meltefjordnes on Sørøy...	3,6 9 12 31,2 41,2 58 64,3.
40. Finnsæter, Kvæfjord ...	6 12,4 25,7 47,3.
41. Vasstrand on Kvaløy ...	5,5 15,4 27 29,8 51,8.
42. Kårvik on Ringvassøy ...	2,4 3,9 12,4 24,1 25,1.
43. Andersvik on Karlsøy ...	7,3 13,3 28,1 30,1 32,1.
44. Fuglnes at Hammerfest...	3 4 6,5 10 13,7 19,2 26 30 34,6 41 51,4.

45. Gresnes, Kvæfjorden ... 3,3 9,5 15 28,5 48.
46. Simavik on Ringvassøy .. 6,9 14,2 32,5 42.
47. Hersfjord on Langsund... 5 13,5 30 32,5 50,6.
48. Sigerfjord, Sortland ...... 8,5 14,3 22,8 30,2 36,7 38,7.
49. Løkvik on Senja .... 14,2 29,5.
50. Karlsøy near the church 7,3 14,5? 14,9 32,7.
51. Skatøren on Langsund... 3,5 6,5 14,3 25 29,5 33,6 53,2.
52. Bjarkøy .... 14,3 32,1 33,1? 39,9 42,1.
53. Futrikelv on Kvaløy ...... 7,8 14,9 34,1.
54. Gamnes on Ringvassøy .. 6,6 14,8 23,5 36,3.
55. Buvik on Kvaløy .... 14,7 32.
56. Gunnesdal, Kvæfjord ... 5,7 8,6 15 32,5 42,5 55,4 73,7?
57. Kalfjord .... 6 14 36,3.
58. Elvevoll on Reinøy ...... 3,1 6,8 7,8? 15,8 34.
59. Lanes on Senja .... 6,4 15,4 33.
60. Ganslåt on Senja .... 6,6 15,4 34,5 67,9.
61. Kattfjord .... 1,3 5,9 15,5 32,4.
62. Flesnes, Gullesfjord ...... 3,5 15,8 32,4 35 40,4.
63. Ersfjordbotn on Kvaløy 5,3 17,2 34 52,9.
64. Greipstad on Kvaløy ... 3,3 3,8 5,8 16,3 28,8 35,7 39,3 42.
65. Krabbenes on Kvaløy ... 6,7 15,8 38.
66. Kraknes on Kvaløy ...... 6,1 15,9 38,4.
67. Glimma on Ringvassøy .. 6 15,5 35,4 38,9 48,1.
68. Røsnes on Ringvassøy ... 3,6 6,3 14,6 16,3 23,8 38,9 39,7.
69. Fursæter, Gullesfjord ... 3,5 16,4 33,2 39.
70. Finnkrokan on Reinøy ... 6 15,8 24,8 32,6 39,3.
71. Vang on Senja .... 8 16,4 37,7.
72. Finnland on Kvaløy ...... 6,9 16, 7 17,8? 40,3.
73. Storelv on Kvaløy .... 6,5 16,7 17? 23,2? 41,1.
74. Bakkejord on Kvaløy ... 7,1 15,8 19,8 38,3 53,6.
75. Håkøybotn on Kvaløy ... 7 18 43,4.
76. Strømsnes on Senja ...... 7,8 17 40,4.
77. Skittenelvhaug, Grøtsund 7 17,2 39,7? 40,6.
78. Håkøy .... 17,3 25,2 26,5 42.
79. Mjelde on Kvaløy .... 6,2 16,7 38,4.
80. Skjervøy .... 9,3 19,1 31,5 48,2 50,9 55,4.
81. Bay east of Øksfjord ... 4 7,5 17,7 28,7 39,2 63,1 86,7 94,3?.

82. Movik, Tromsøysund ... 6,2 7,7 17,4 38 41,7.
83. Vågnes, Grøtsund .... 5 7,5 17,6 38,6 41,5.
84. Rottenby on Reinøy ...... 6,6 15,9 25,6 27 34,1 40,2 70,6 93,4?.
85. Borkenes, Kvæfjord ...... 2 3,3 17,7 42 53,4 90,5?.
86. Snarby, Grøtsund ...... 8,6 17,9 29,1 38 44,3? 45,2.
87. Rødberghamn, Malangen 2,1 3,1 5,2 8,6 16,9 26,3 39,9 48,4 51,8.
88. Sandnes on Tromsøy ... 4,6 7 17,7 40,1.
89. Innpollen in Rognsund... 3 8 18 22 41 45 61 (aneroid).
90. Jøkelfjord .... 11 22,3 25,3 32 35,2 49,1 55,9 66,3 76,4.
91. Strømsbukt on Kvaløy ... 7,1 18,1 30 41,7 50,6 68,6.
92. Tenskjær, Malangen ...... 8,2 19,7 33,9 50,9.
93. Eidstrand, Ulsfjord ...... 10,5 18,7 28,7 36,8 50,8 78 99,4 118,4 136.
94. Våg west of Harstad ... 11,4 18,5 26,2 40,4 45,2 56,5 83,9 86,5?
95. A Bay north of Sandnes on Tromsøy .... 7,6 18,4 27 36,6 42,5.
96. Nord-Lenangen, Ulsfjord 7,8 18,6 28 32,7 37,8 46,9 67,8 75,4.
97. Stakkevollene on Tromsøy .... 7,9 17,8 18,5 27,5 37,9 38,5 42,4 44?
98. Workin on Tromsøy ...... 6,9 7,8 18,4 44.
99. Myrlund on Senja .... 9,6 18,7 35,2 48,6.
100. Tomasjord, Tromsøysund 3 6,6 7,1, 19,4 26,8 29,4 30 39,8 41,2 65,9 72,5 92,9?.
101. Skognes on Senja .... 10,7 18,5 33,3 42 48,3.
102. Slåtnes on Kvaløy .... 7,4 19,5 37,3 44.
103. Fritsvoll, Malangen 8 10 19,5 31,3 38,7 44,9 50,1 62,1 71 77,3
104. Sand on Sandøy .... 7,5 13,9 18,9 35,1 36,3 41 49.
105. Gjøvik, Malangen .... 3,9 10 19,1 26,6 30,6 37 44 49 51,4.
106. Sverresborg, Hungeren... 7,5 19,3 30 41,4 46,2 57,4 68 71,5?.
107. Mølnevik, Vågsfjord ...... 19,5 51,5 54,5 60.
108. Steinbakken on Kågøy... 6,5 9,7 12,9 19,6 46,6.
109. Andsnes, Malangen ...... 3,4 19,8 43,5 50,1.
110. Sollien, Tromsøysund ... 7,5 19,3 29,3 37,5 45 70,3?.
111. Bentsjord, Tromsøysund 3,6 10,9 20 38,8 47,5.
112. Valanhamn, Kvenangen 2,4 12,4 20 31 41,6 48,9 56 58,1.

113. Harstad	8 12 20 35 47 57 (aneroid).
114. Oldervik, Ulsfjord	7,3 11 20,5 34,5 37,5 44,5 46,8 52,8.
115. Alteidet, Kvænangen ...	2,5 11 13,3 20 24 34,9 45,7 52,9 57,9 77,6?.
116. Kanebogen, Trondenes...	8,1 12,7 20,8 37,3 48 58,5.
117. Klauvnes on Uløy	7,8 20,4 31,4 48,3 55,2.
118. Stonglandseidet	20,7 49.
119. Sør-Lenangen	10,2 21 37,7 45,7 53,8.
120. Vassvik	11,4 20,9 51,2.
121. Kraknes, Rossfjord	10,8 21 34,6 46,5 57,9.
122. Selnes, Ulsfjord	10,5 20,8 21,3 30,1 43,6 51,9 100?.
123. Bukskin, Gisund	7,4 12 21,4 50,6.
124. Bakkeby, Malangen	11,1 21,5 40,3 50,2 58,5.
125. Bjorelvnes, Gisund	10,6 21,2 52, 3 56,1.
126. Bundjord, Gisund	11,5 21,5 36,5 47,2 55.
127. Holmeslet, Tromsøysund	7,7 21,5 31,6 41,2 49,5.
128. Laukslet, Ramfjord	8 22,2 53,2.
129. Bakkelund, Oksfjord	2,1 7,1 12,9 21,9 34,9 60.
130. Bakkeby, Nord-Reisa ...	4,9 20,3 21,9 31,4 39,9 53 55 61,4? 64,9.
131. Storvik, Malangen	6,3 12 13,9 22,5 37,8 48,7 50,4 60,3.
132. Nålelv, Burfjord	6 15,1 22,7 33,6 61,9 65,8 79,1.
133. Vikstrand, Senja	12,5 23 58,3.
134. Mortenhals, Malangen ...	6,5 11 12,4 23,2 52,1 66 69,2 71,2.
135. Sætra on Uløy	9,3 23,1 41,4 39,4 51 62,8?.
136. Kilbotn on Hindøy	7,7 8,7 12,7 22,8 35,9 37,8 45,5 47,5 59,1 61,5.
137. Vinje on Dyrøy	8,5 26,5 46,3 61,5.
138. Breivik, Ulsfjord	10,6 21,6 40,3 51,3 62,9 77,7.
139. Kongsvik, Tjellsund	7,5 12,5 24 38 52 58 (aneroid).
140. Haugrud, Malangen	11,4 12,8 23,4 27,1 37,9 39,1 52 58,2 62,1 75,9.
141. Storslet on Uløy	9,5 21,8 40,1 51,3 62,5.
142. Langhamn on Dyrøy	9,5 23,6 60,6.
143. Storvik, Nord-Reisa	3,6 9,5 22,4 34,7 38,6 57 62,3 73,9 79,9 91,5?
144. Skogen east of Finsnes...	9,6 18,7 35,2 48,7 51,6?.
145. Sandnes, Kvænangen ...	2 3,4 6,1 13,1 20,2 23,4 38,7 57,6 66,6 69,9 84,1?.

146. Nyheimen, Malangen ... 12,9 23,8 38,4 53,4 64,4.
147. Rotsundelv, Rotsund .... 3,8 6,4 10 24,4 41,2 51,9 60 62,3.
148. Hamnes on Uløy .... 10,3 23,9 42,3 53,1 60,1 63,3.
149. Ulvik, Tjellsund .... 7,4 12,1 24,3 41,2 59.
150. Andersdal, Balsfjord .... 12,8 24,4 51,6 58,9.
151. Sakrijord, Ramfjord ...... 8,3 23,2 33,9 45,8 59.
152. Målsnes, Malangen ...... 13,5 14,7 24,5 33 49 55 64 80,6.
153. Sørvik on Hindøy .... 9,2 13,5 24,9 39,5 45,4 51,8 60,1 62.
154. Lunneberg, Sør-Reisa ... 14,2 25,3 48,8 60,9 76,5.
155. Gausvik on Hindøy ...... 8,5 11,6 13,6 18,2 25,2 40,3 41,3 55,3 59,6 66,7 69,9?.
156. Stensland, Tjellsund ...... 8,3 13,9 24,8 38,8 43,2 56,8 68,5 71,3.
157. Skogan, Tjellsund .... 7,7 13,6 25,4 41,5 44,1 57,5 72.
158. Skarmok, Ulsfjord .... 7 13,5 22,4 28,3 35 43,8 58,2 69,1.
159. Strømsnes, Sørfjord ...... 6,3 9,8 11,9 16 25 36,2 44,5 58,8 65,2 72.
160. Skogli, Balsfjord .... 14,2 25,3 41,2 50,4 61,3 63,3.
161. Horvik, Tjellsund .... 8,4 12,4 25 38,6 58 80,5?.
162. Furstrand, Vågsfjord ... 14,2 25,1 64,1.
163. Hammervik, Lyngen ...... 10,4 16,7 25,1 38,6 41,2 43,5 53,7 62,8 64,4.
164. Tømmerbukt, Kvænangen 2,8 5,2 7,5 10,1 11,9 14,8 18,1 24,9 26,2 36,7 43,5 47,5 50,4 53,8 56 59,6 62,5 64,6.
165. Sandtorg, Tjellsund ...... 8,7 13,8 25,4 39,6 42,4 56,9 66,7.
166. Malangseidet, Balsfjord... 7,6 14,7 26,2 40,8 56,4 61,8.
167. Sandstrand, Vågsfjord ... 8,4 14,5 26 27 45,3 47,4 59,2 65,4 67,9 73,7.
168. Bakland, Tjellsund, east 8 14,6 26,2 45,7 59 75,7.
169. Engenes, Lyngen .... 10,7 25,9 33,7 45,1 55,8 66.
170. Kastneshamn .... 10,5 26,4 63 68,4.
171. Badderen, Kvænangen ... 4,2 7,9 13,8 19,8 26,3 32 36,3 44,7 50,1 60,9 68,8 75 88?.
172. Sommerbukt, Sørfjord ... 12,6 15,5 26,4 48,2 59,8 74,1 75,8.
173. Smørskar, Sør-Reisa ...... 7,8 14,4 15,1 26,8 51,8 65 67,4 81,9.
174. Naustvik, Sør-Reisa ...... 14,6 15,6 26,5 53,6 67,5 87,7 114,7?.
175. Elvebakken, Astafjord ... 14,5 27,6 44,8 56,8 72,5 74.
176. Renså, Astafjord .... 15,7 26,2 27,9 42,3 43,6 56,6 72,3.

177. Gottesjord, Sør-Reisa ... 15,1 19,2 25,8 26,9 53,2 68 83.
178. Sørfjorden, Malangen ... 4,2 6,2 9,3 14,4 28 61,9 64,6 75,9 87,2.
179. Tytebærvik, Kjosen ...... 7,1 13,7 27,5 45,3 48,1 60 61,8 75,5.
180. Rødberg, Tjellsund ...... 8 10 14,4 27 45,7 59,7 74,7 76.
181. Svartnes, Balsfjord ...... 14,9 27,6 42 53 66,5 67,5?.
182. Skagstad on Engeløy ... 3,1 5,6 11,3 17,3 20,1 23 25,1 28 35,3 37,4 41,3 47,2 50,4 52,1 58,5 61,6 68,4 92.
183. Nygård, Astafjord .... 15,1 28,5 38 44,9 58,4 74,7 .
184. Stornesbukt, Sørfjord ... 6,9 15,4 25,5 27,3 29,3 50,4 62 64,7 75,5 79,5.
185. Myklebostad on Engeløy 3 7,2 17,8 29,6 30,6 39,4 46,3 63,7 68.
186. Lyngseidet, Lyngen ...... 13,6 28,8 47,8 49,3 63,2 73,6 76,2.
187. Olderelv, Lyngen .... 3,9 10,5 13,6 29 48 62,1 75,7.
188. Skognes, Sørfjord .... 8 15,6 17,6 27,8 42,7 51,4 63,4 65,8 80,1.
189. Storelv, Sørfjord .... 7,9 15,2 17,8 24,8 27,2 42,2 53,4 59,8 74,8 83,4.
190. Ørnes, Lyngen .... 13,8 29,2 49,8 65,9 78,1.
191. Lakseidet, Malangen .... 12,8 26,2 72,8 89,4.
192. Laksvassbukt, Balsfjord . 15,3 28,4 67,6.
193. Balteskar, Grovfjord .... 16,6 30,9 46,8 60 77,6.
194. Middagsbukt, Balsfjord . 3,5 9,5 15,7 30 48,4, 66,9 78.
195. Bogneset, Tysfjord ...... 3 13,2 19,7 31,9 43,5 48,8.
196. Porsøya, Ofoten .... 13,3 30,1 48,2 64,1 67,4 74,9 79,2 84,3.
197. Leirvik, Sagfjord .... 3 14 21,6 30 31,5 40 55 71,8.
198. Repvik, Efjord .... 3,4 6,2 14 17 24,6 25,6 28 33,8 39,3 53,7 63,4 67,3 78.
199. Vika on Vega .... 2,5 6,8 18 27,1 37,8 41,4 63,2 65,9 81,4 98,5.
200. Kroken, Lyngen .... 14 16,3 31,2 50,7 64,3 81,7.
201. Djupvikpollen, Sagfjord . 3,3 6,6 17,3 24 31,2 47,7 55,8 82,4.
202. Elvebakken, Balsfjord ... 4 8,6 12,3 15,1 18 30,9 37,6 45,8 50 62,4 73,1 80,5.
203. Brennsundvik .... 2,8 6,9 13,5 14,6 19,2 21,2 37,9 49,8 60,7 63,7 68,9 70,9 78,9 92,7.

204. Grov, Grovfjord .... 6,3 9,6 12,8 19,7 26,4 31,6 46,4 63,1 64,7 80,7.
205. Årsandvik, Grovfjord .... 9,8 16,2 32 47,7 68,5 81,2.
206. Mælen, Balsfjord .... 3,6 7,6 11,6 15,2 18 25,2 32,8 52,4 72,2 79,4 81,3.
207. Lien, Ofoten .... 10,4 14,7 31,9 51,7 54,2 66 81,8.
208. Tennes, Balsfjord .... 13,4 17,6 31,7 78.
209. Lilandskaret, Ofoten ...... 8,6 14,6 22 32,5 51,9 68 71 82,7.
210. Gullvik, Sagfjord .... 3,1 12,8 23,4 32,4 39,4 47,4 65,7 79,9 83.
211. Kjær, Tysfjord .... 3,4 6,5 18 21,6 29,4 37,1 40,9 53,6 64,8 83,9.
212. Skrovkjosen, Tysfjord ... 3,2 6,8 12,7 19,4 27 32 43,4 46,5 66 69,7 73,5 83,8 100.
213. Dalen, Lyngen .... 14,8 29,8 32,6 43,5 53,8 69,2 71 82,6.
214. Djupvik, Ofoten .... 9,3 10,3 15 33 52,3 61,7 68,2 85,3 87,3.
215. Leinesleira, Leikanger ... 2,9 5,8 13,9 22,4 28,3 35,4 37,6 49,3 58,8 68,9 76,7 82 94.
216. Soløy, Lavangen .... 8,9 17,3 30,7 34,6 48,3 52,6 70 83,6.
217. Balkjosen, Folla .... 2,5 5,2 10,3 16,5 22 34,6 48,8 66,3 70,9 83,5 99,6.
218. Storsteinnes, Balsfjord ... 6,8 12,9 16,3 23,6 33,6 36,2 49 72,2 80,2 83,6.
219. Årstein, Gratangen ...... 4 10,7 18,7 23,7 27,4 34,4 37,9 49,3 58,3 61,3 82,2 85,5 93,7.
220. Skjenken, Folla .... 6,1 19,5 21,7 35,3 38 48,9 59,9 94,2.
221. Bakken, Ofoten .... 8,5 14,2 31,6 33,8 53,1 55,3 70,5 78,5 86,3.
222. Nordfold, Folla .... 3 6,7 15,7 21,7 27,5 38,6 54 60,1 69,3 84 95.
223. Bjørn on Dønna .... 6,7 10,7 17 23,5 29,2 37,6 51,8 60 73 75,9 79,4 92,3.
224. Marknes, Balsfjord ...... 16,9 32 34,8 76,1 83,6.
225. Kobbenes, Efjord .... 3,8 7,4 12,7 18,6 23,5 25,2 28,9 38 40,1 43,4 57,3 68,2 70,2 75,1 82,5.

226. Elvesletta, Ofoten .... 7,6 14,5 30 31,5 37 51,1 71 82,4 90.
227. Kjerringøy .... 3,1 6 13,5 21,2 39,6 51,9 60,7 80 96,2.
228. Gratangsbotn .... 6,7 8,3 14,9 18,7 26,4 46,8 49,6 63,2 71,6 74,9 79,6 93,3.
229. Brattfjord, Folla .... 2,1 4,9 11,7 19,9 27,2 39,2 53,8 71,3 83,2 96,7 106,3?.
230. Eidet, Folla .... 5 6,9 15,7 22,4 31,2 44,8 50,8 75,3 82,6 96,7.
231. Heldal, Folla .... 3,5 9 12,6 17 22,5 26,5 28,5 38,6 42,1 45,3 52,6 62,8 75 85,9 100.
232. Lien, Sagfjord .... 3,4 11 15,4 18,1 22 24 32,5 49,2 62,8 70 76 87,7.
233. Mjelde .... 5,9 14,2 21,2 39,9 51,8 59,5 68,2 80,7 95,3.
234. Hopen, Folla .... 3,3 6,2 8,3 16,2 23,7 35,3 37,5 52,2 63,5 72,1 83,7 99,9 102,2.
235. Nord Fugløy .... 3,1 6,3 9,2 12,1 16 23,8 27,6 35,4 39,4 57 69,2 81,7 88,7.
236. Kirknes, Lyngen .... 7,4 10,7 22,4 28,7 33,9 52,4 56,3 70,2 78,4 85,5.
237. Movik, Folla .... 3 7,7 15 21 24,4 34,4 48,5 50,2 59,3 67,6 79,3 82,7 97,2.
238. Stefjord, Tysfjord .... 3 5,1 7,5 12,6 15,8 25,4 33,7 46,7 54,7 65 66,7 79,2 89,7 100,2.
239. Stavnes on Åmøy .... 2,7 9,8 18,2 29 38,1 48,1 56,8 60 70,3 85,3.
240. Øyjord, Folla .... 7 10,2 13,2 16,8 20,1 26,6 39,2 47 53,2 58,4 68,5 82,7 85,1 99,1.
241. Fossland on Tomma ...... 3 10,6 15,1 20 26,8 31,1 38,9 40,7 47,1 51,6 60,8 62,8 69,8 79,3 84,8 91,9.
242. Reinvik, Folla .... 2,8 4,8 9,5 17 24,6 33,5 36,5 43,5 49,8 52,6 62,4 85 91,3.
243. Fagervik .... 7,5 14,3 21 27,7 42,5 50,7 71,2, 89,5 95,5.
244. Stavfjord, Folla .... 4 10 15,7 20,1 27,5 39,2 45,2 53,5 69,1 71,9 84 87,2 104,4.

245. Hestun on Hamnøy	2,8 7 9,5 15 18,6 38,3 56,4 62,1 64,7 86 108.
246. Straumen, ytre, Tysfjord	3,3 7,6 12,7 14,7 21,6 25,3 31,2 37,1 40,1 45,3 54,3 56,8 75,1 105,1.
247. Vevelstad	3 10 14 19,4 25,3 30,4 40,8 70 89,1 109.
248. Brattland, Lurøy	3,4 10,9 16,5 19,6 33,9 39,7 45,6 56,2 62,5 69,5 87,5 90,4.
249. Mosvoll, Meløy	3,6 5,9 8,9 16,9 27 34,1 37,9 41,7 47,7 49 51,1 54,2 62,3 69,4 89,6.
250. Bjørnsvik, Folla	3 7,9 13,8 15,4 21,5 28,3 40,5 54,5 72,8 84,1 103.
251. Kvarsvik, Gildeskål	3 12,7 23,1 37,8 40 47,5 68,3 76,8 86,1 93,7 (-1?) 96,7?
252. Riksen on Hannesøy	2,5 11,3 21,3 28 37,8 49,1 61,2 76,6 81,8 83,8 97,9.
253. Botnfjord, Folla	7,7 12,9 15,4 (-0,8?) 22 42,5 55,8 69,9 87,5.
254. Lysfjord	5,7 14,6 17,4 24 31,7 45,3 50 53 56,7 62,7 84,9 92,5 98,4 103,9.
255. Eide, Velfjord	6,7 14,5 18 19,6 40 57,5 61,2 72,2 87,9 101,2 107,7 121,6.
256. Kjeldal, Bjerangsfjord ...	6,4 15,4 19,9 21,9 30,7 40,5 69,3 80,5 90,7 99 108,6 118?.
257. Visthus, Visten	6 11,8 22 35,4 38,5 42,5 53,2 64,5 77,5 88,5 105,9 122,9.
258. Sørfjord, Rødøy	3,1 7,1 10 22,1 24,2 28,4 37,7 60,7 68,9 87,1 100.
259. Sandåg, Glomfjord	3 8,8 14,8 30 47,7 66,6 73,5 82,7 92,6.
260. Breivik, Tjongsfjord	3,3 8 10,4 20 29 32,6 41,6 49,2 58 72,8 92,6 100,4.
261. Storvik, Gildeskål	3,1 11,5 22,1 26,9 41,4 64,1 75,6 94,5.
262. Våtvik, Melfjord	4 10,1 17,6 21,6 (+ 1 ?) 32,9 43 49,7 55,9 70 84,2 (0,5?).
263. Laingen, Vefsen	3,5 7 13,6 21,6 22,6 32,2 40,7 53,3 60,1 68 75,6.

264. Musken, Tysfjord .... 3,3 8,1 14,8 28,6 36,2 41,9 49,2 57,2 66 78,7 102,3.
265. Sjunkfjordbotn, Folla ... 8,4 10,2 15,5 21,6 30 40,6 55 70,2 78,2 108.
266. Malm in Vik .... 3,5 6,8 20,1 22,1 28,4 41,3 65,5 114,6 131,5.
267. Botnet, Bindal .... 5,9 18,1 35,2 41,9 46 62,4 73,5 85,9 101,5 103.
268. Sandnes, Nesna .... 3,4 6,9 15,3 33,6 36,7 40,4 77 84,7 88 98,5 109,1.
269. Gjervikvalen, Rødøy ...... 3,1 6,2 8,2 12,6 21 25,3 42,9 49,5 56,6 60,2 75,8 81,8 99,4.
270. Moen, Gildeskål .... 3,7 7 9,2 12,7 19,7 21,5 37,4 41,4 52,8 56,7 63,5 83 86,9.
271. Holand, Holandsfjord ... 3 3,7? 10,2 20,3 31,5 43,2 54,7 60 78,4 80,4 92,3 101,4 104,4.
272. Bjørnå, Visten .... 9,4 22,4 38,1 44,4 47 49,9 67,6 84 95,1.
273. Leiren, Leirfjord .... 4,4 7,7 9 13,2 17 20,9 31,6 39,1 49,4 54,3 60,3 70 73,3 80,6 88,5.
274. Sørnes, Vefsen .... 3,9 14,4 21,8 28,1 34,3 37,9 43,7 54,1 64,8 75 92,8 96,4 103,6.
275. Tuv, Bodin .... 3,6 8,6 14,9 22,4 36 42,2 49,8 61,7 82,5 84?
276. Kalvik, Folla .... 8,4 15,4 25,9 40,3 43,4 51,8 61,5 82,4 100,3 118,4? 126?
277. Hestvik, Folla .... 8,9 14,4 25,7 40,2 43,2 55,4 85,4 99,3.
278. Mørsvikbotn, Folla .... 2,6 5,2 7,3 10,3 17,7 26 44,8 53,4 62,2 74 87,6 100,1 106,3.
279. Engan, Folla .... 8,9 16,8 27 42,4 53,9 59,7 62,8 77,5 86,2 104,6 106,2.
280. Glomfjord .... 11,8? 13,8 17,3 27,3 42,6 68,6 101,5 146,3?.
281. Røsvik, Folla .... 7,8 8,8 14,6 23,1 42,5 54,6 71 98,6.
282. Botteløra, Holandsfjord 3,5 8,8 15,8 22,1 43,7 64,5 104,9 108,7?.
283. Hommelstø, Velfjord ... 6,6 16,8 31,4 45,4 57,4 63,2? 64,6 70,6 90,5 108,5 121,9.

284. Kvarv, Folla	3,3 8 13,4 25,6 31,7 41,5 44,5 57,3 72 86,4 87,4 104,3.
285. Sørfjordmoen, Folla	5,5 16,4 25,3 41 61,9 85,5 109,6.
286. Vasås, Bindal	5,9 12,6 18,4 38,4 42 45 55,3 57,3? 68.
287. Hellemobotn, Tysfjord ...	3,9 8,7 14,5 23,6 29,4 40,9 45 63.
288. Stiauren, Sjona	3,2 5,8 12,8 16,7 25,9 38,3 39,3 78,9 89,4 96,7 104,6.
289. Melfjordbotn	2,9 6,2 11,7 15,8 22,6 33,9 35,4 42,7 45,7 52,1 62,5 72,7 79,1 83,6 100,4.
290. Torkelseng, Folla	9,4 29 45,9 54,2 57,1 69 74,1 97,5.
291. Søfting, Vefsen	2,3 6,8 8 17,5 22,6 29,1 45,6 52,8 67,8 81,2 92,4 103,8 114,2.
292. Dokmo, Beiarn	5,5 16 21,4 26,9 32,3 35,2.
293. Sjonbotnet, Sjona	3,6 8 13,7 17,9 24 31,6 34,5 45 59,2 68,5 108,6.
294. Børjeør, Velfjord	9,6 15,5 22,3 32,6 39,9 47,8 57,4 64,8 75 76,6 85 95,4 114,1 125,3.
295. Breivik, Salten	4 9,5 23,6 26,6 33,4 38,9 46,7 52,2 56,1 64 68,3 76,2 86,8 105,4 112,5 120,6.
296. Halsøy, Vefsen	9,6 20,5 47,3 56,7 68,9 70,4 80,8 94,3 102,8 117,7.
297. Lillegården, Folla	2,4 10 15,3 26,6 44,7 59 74,8 105,7.
298. Sukhoi Noss, Novaya Zemlya	2,6 19,5 64,6 75,7 82,4 84,5 87,9 107,9 115,7 141,1 156,1 175,6 179 203.
299. Utnes, Utskarpa	11,6 27,4 38,4 43,4 47,9 68 75,4 94 107,2? 117,7.
300. Elsfjordstrand, Rana ...	7,5 17,5 25,6 29,4 42 44 55,4 64,6 80 87,6 101,4 121,7 131,1?.
301. Misvær, Salta	4 9,7 16,5 25,4 44 62,3 95,3 104,4 108,3 115,7 117?.
302. Storjord, Beiarn	16 29,1 35,9 44,8 59,7 66,1 71,5 78,5 98,5 102,3.
303. Lande, Tosen-Bindal ...	6,5 20,9 34,3 45,5 56,1 63,2 95,4 104.
304. Ravnå, Nord-Rana	59,4 70 74,4 79,7 88,6 98,4 104,6.

305. Osbak, Beiarn	22 31,9 36,6 39,3 49,3 54,8 104,7 110,7.
306. Tolå, Beiarn	43,4 50,8 69,3 94 109,6 116,7 121,6.
307. Setså, Salta	1,5 2,9 4,4 9,5 17 26,4 34,5 46,2 59 91,1 105,5 126,1.
308. Weber Ridge, N. Z.	2,9 13 31 42,2 52,3 61,3 68,8 76,5 81,5 99,5 111,9 117,9 132,3 150,6 156,2 171,3 215,3 218.
309. Serebryanka, N. Z.	3,9 10,5 18,2 30,9 42,2 52,2 68,5 79 102,5 118,2 137,6 152,7 156,3 175,5 198,7 270?.
310. Ytteren, Nord-Rana	7 16,8 24,5 34,5 39,9 43,3 64,5 82 113.
311. Bjørnå, Nord-Rana	54,1 54,7 67,6 72,4 79,8 81,2 83,9 93,2 100,4 105,1 116,1 119,6.
312. Blåfjell Basin N. Z.	2,8 14,8 21 32 34 37,6 54,2 72 83,2 95 101,7 116,5 121,4 133 165 201 220.
313. Svartishei, Nord-Rana ...	53,9 63 76 85,1 95 98,5 106,1 116,9 131,4.
314. Nordenskiölds Plateau, N. Z.	1,9 19,1 31,3 53,8 70,8 111,5 117,5 141,9 204,8.
315. Øivindgård, Saltdalen ...	34,6 47,6 55,6 71,6 94,4 113,6.
316. Rusånes, Saltdalen	49,3 55,9 66 70,2 72 76,1 87,9 95 111 130,8.
317. Pomorskaya, N. Z.	3 14 25,4 32,3 40 42 56,5 72 82,9 98 107 115 121,9 135 138 156 159,6 197 215.
318. Bergulnes, Saltdalen	82,6 84,9 88,7 92 94,1 99,8 105 115 125,5.
319. Gribovii, N. Z.	2,5 14,5 20,9 31,1 32,4 42,8 43,8 57,8 72,3 81,7 88,2 99,4 110 119 121,9 144,7 153,6 158,5 184,4 212,9 240 270 310 325 350 370.
320. Archangel Bay, N. Z. ...	3,2 11,7 23,3 36 48,9 58,8 66,4 73,1 78,5 90 103,4 106,9 127,2 145,3 164,3 169,5 186,9 203,2 218,9 238,9 271,8 295 305 315 322.

4. THE UPPER MARINE BOUNDARY

If following the shore lines from outlying islands eastwards along sounds, fjords, and valleys it appears that gradually lower and younger lines represent the upper marine boundary. In that way the shore lines give information of the recession of the ice front, and were only the material of measurements sufficiently good and detailed it should have been possible to reconstruct the stand of the ice border during the engraving of every single shore line. So complete a material is not yet at hand, but as it is, the ice front can be reconstructed for some of the best fixed shore lines or bundles of lines. The n-line marking the upper marine boundary at Hasvåg is sharply engraved on the outside of a large strand wall of cobbles and boulders of medium size. The locality lies open to the sea, and the breakers have once had a free play there. The shore line is situated 51,8 m above the present sea level, and the top of the wall rises to 52,5 m. Farther to the south on the same island the surf may have reached to about 60 m, but no shore line proper is there to be found. In Nordland this line has been pointed out at Skagen in Bø on the west coast of Langøy 35,8 m o. s. l., on Vedøy in the Røst group at 48,7 m, and on Trenyken in the same island group at 39,9 m above sea level, on both these islands at the entrances of caves formed by the sea. The western shores of Flakstadøy have not been surveyed, but it is likely that the n-line will be found also there. On pl. III the most westerly line is intended to show the supposed maximal stage of the ice front of the last ice sheet. When the n-line was engraved the ice front may have retreated somewhat from this border line.

At Toften on Langøy and at Meltefjordnes on Sørøy it is the next younger shore line, the m-line, which is marking the upper marine boundary. At Bleik and Eggum on Vestvågøy the marine boundary is marked by l, at Vik on the same island, at Bø and Risøyhamn on Andøy by k, at Fuglnes near Hammerfest and at Ganslåt on the outer part of Malangen fjord by i_1, at Vengsøy on the western side of Kvaløy by i, at Rekvik on the western coast of Kvaløy and at Finnsæter on the western shore of the Kvæfjord by h_3, at Gresnes farther south on the same shore, at Fritsvoll on Malangenfjord, and in Jøkelfjord by h_2, at Vasstrand and Ersfjordbotn on the west coast of Kvaløy and in Hersfjord on the northern part of Langsund by h_1, at Alteidet by h, at Badderen near the head of Kvænangenfjord by g_4 etc.

According to what has been stated above the shore lines from n to h_3 have only been pointed out from the Lofoten islands northwards. It is therefore reason to believe that while these lines were engraved there was an ice barrier off the coast of Helgeland and Salta. The sea must have washed a continuous ice front all along this stretch, likely forming, by degrees, a wide bay in the Vestfjord where an eventual stream along the ice front had to turn to the northwest for rounding the west point of the Lofoten islands which then stood as a continuous wall to the north. That such a bay must have existed is proved by the fact that at Skagstad on the north coast of Engeløy in Steigen the shore line g_4 has been pointed out as the oldest line on the coast of Nordland, south of Lofoten, 92 m a. s. l.

It must be supposed that the melting of the ice started at the outer border just on account of a relatively warm north-going stream. As long as the sounds between the Lofoten islands were blocked up by the ice this stream must round the outer part of Lofoten. Therefore the front south of Lofoten was more exposed to melting than the ice in sounds and fjords farther north where it was protected against melting by outlying islands and was keeping its ground for a relatively long time. Still farther north there was free front once more between Vannøy and Sørøy, and therefore this part of the open sea and the adjoining sounds and fjord became free from ice as the first ones in Northern Norway as the ice sheet was not so thick there.

In the time next after the engraving of the m-line a melting period seems to have been replaced by a cold period, for on Andøy there have been two stationary stages of the ice front, one along the west coast where highlands did not bare the way to the coast, and another farther to the east, crossing the lowland just west of Bjørnskin chapel, touching the middle mountain party at its eastern projection and continuing northwards west of Dverberg church, there called the Kirkra. At the same time the sea surface seems to have been in eustatic rest, as will be pointed out later. During the engraving of the lines l to k even an eustatic sinking may have taken place. After the ice front had retired from the Kirkra stage the recession must have been continuous for a length of time, for no moraines have been found till in the sounds between the islands and the mainland, and the sea may also have been continuously rising till a new standstill of the ice front took place and with it the engraving of the shore line g_2.

During the melting period just mentioned the Sørøysund, the Rognsund, the Stjernsund, and the Kvænangenfjord became free from ice. The Lyngenfjord got ice free to beyond the Rotsund, the Ulsfjord to Skarmok, likewise the Langsund, the Kvalsund, the Grøtsund, and the Malangenfjord, but the Tromsøysund and the Balsfjord were still filled by the ice. The ice in the sound between Senja and the mainland was melted from the north, from the outer part of the Malangenfjord, and at some later date, near the end of the melting period, the inner part of the Vågsfjord and the Tjellsund seem to have been opened, but not yet the Ofotenfjord. To the south of this fjord the western part of Hamarøy and Steigen may have been free from ice, but from the mouth of the Foldenfjord southwards there was still a continuous ice front off the coast.

5. THE TROMSØ-LYNGEN STAGE OF THE ICE FRONT

The melting period above mentioned was succeeded by a cold period which brought about a stationary stage of the ice front, the Tromsø—Lyngen Stage, marked by the best developed moraine series in Northern Norway. Moraines likely belonging to this series are to be found at the heads of Alta, Kvænangen, and Nordreisa fjords, at Slottet on the Lyngenfjord just south of the Rotsund, and at Skarmok where the moraine is cut by a stream leading from the Ulsfjord to the Sørfjord. A fine terminal moraine crosses the Breivikeid near the Ramfjord as a continuous ridge. On the east side of the Tromsøysund and in the town of Tromsø two ridges are to be found. The foremost ridge can be followed continuously across the Tromsøy. On the east coast of Kvaløy west of the Sandnessund the moraine series is represented by a thick layer of moraine material on the lower part of the mountain side westwards to the Kallfjordeid. Farther south it is once more a single ridge, rising from 50 m to about 200 m above sea level, which can be followed southwards to the Rystrøm (3 og 7). Likely the same series is to be found as a fine terminal moraine at Aspenes on the southern shore of the inner part of Malangenfjord and as fine ridges at the waterfalls Malangsfoss and Bardufoss in the Målselv district. At the head of the Salangenfjord is a great terminal moraine, and a similar ridge is to be found farther east in the Salangsdal. South of the Salangenfjord the moraine series cannot easily be followed, but according to the evidences of the shore lines the ice border must have crossed the Lavangenfjord and the Gratangenfjord at their mouths, and moraines near the head of the Grovfjord and at the mouths of valleys westwards to the Tjellsund are likely belonging to this series. South of the Ofotenfjord no moraines can be pointed out, but according to the shore lines forming the upper marine boundary it must be assumed that the ice front crossed the Ofotenfjord near the southern mouth of the Ramsund and the Tysfjord near its mouth, and from there it likely did pass the outer part of Hamarøy, Steigen, and Leiranger districts to the Brennsundvik on the mainland west of the mouth of the Foldenfjord. The shore lines g_2 and g_1 were engraved during this stationary stage of the ice front. The line g_4 has only been pointed out in a single place in Nordland south of Lofoten, at Skagstad on Engeløy, and on Vega g_1 is forming the upper marine boundary, cut in solid rock 98 m a. s. l., and the same line is surrounding the island Torget at the level of the well-known hole there through the Torghatten mountain. On pl. III the stationary Tromsø—Lyngen stage is named with the line G. From Kvænangen fjord to the Tjellsund the line G has been drawn along the moraine series mentioned above, from Ofotenfjord to the Foldenfjord its direction is based on the shore lines g_2 and g_1 as upper marine boundary lines, but from the Foldenfjord southwards it is only hypothetical. The one thing sure is that the ice front during that stage must have been situated off the coast of the mainland, but whether really stationary cannot be settled.

During the Tromsø-Lyngen stage there was a quite considerable local glaciation outside the stationary ice front. Former local glaciers were increasing, "dead" glaciers once more came in activity and new glaciers grow into being on the north side of the Hadseløy, on the southeastern side of Langøy and Sørøy, all of them places from which the inland ice had receded during the preceding melting period. It is therefore reasonable to suppose that also the inland ice proper was increasing at the same time and possibly in some places advancing.

Before the recession of the ice front from the Tromsø-Lyngen moraines took place a new melting period had set in, for on the east side of the Tromsøsund just opposite to the town of Tromsø a terrasse of glaci-fluvial material had been built 57 m a. s. l. at the right ice border while the ice still lay in the sound. During this melting period the shore lines g, f_1 and f_0 were engraved. In the Lyngenfjord

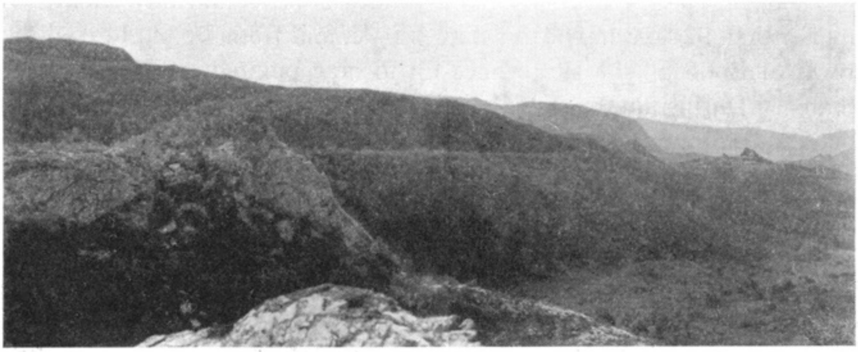

Fig. 18. A shore line in solid rock at Eidet in Vel-fjord
121,6 m a. s. l. Gr. phot.

the ice front seems to have stood firm for some time, for the lines g, f_1 and f_0 have not been found along this fjord, but as the f-line has been pointed out, the ice, however, must have been broken there in the later part of this melting period. The Sørfjord south of Skarmok became completely free from ice and likewise a greater part of the Balsfjord. In the Salta district the Sagfjord and a greater part of the Foldenfjord seem to have been opened. In the southern part of Helgeland the ice front had reached the mainland, for at Malm in Vik g is the uppermost shore line 131,5 m a. s. l., and at Eide on the south side of the outer part of the Velfjord f_1 represent the upper marine boundary. The f_1-line is in that locality sharply engraved in solid rock 121,6 m a. s. l. None of the younger lines below is so distinct and fine, and therefore it is to be supposed that the ice front must have been lying close by while this shore line was engraved. It seems to be a fact that no shore line has been sharply engraved in solid rock far-off an ice front (fig. 18).

During the melting period here mentioned the Velfjord became free from ice as the first fjord in Helgeland. With the then existing relative stand of the sea level this part of the coast lay open against the sea, and the ice in the Velfjord was therefore attacked in three places, at the mouth of the fjord, through a sound at Eide, and through a sound stretching northeast from Ursfjord to Hommelvik. From the mouth of the Vistenfjord northwards the ice front must still have been situated off the coast, for no one of the shores lines g, f_1 and f_0 are there to be found, and even on Dønna neither Vogt and

Rekstad nor the present writer have been able to find any shore line higher than 92—93 m which satisfies f—e, and from Dønna to past the town of Bodø all the shore lines up to now pointed out are younger than f. During the engraving of f—e there must therefore still have been a continuous ice front off the coast on this stretch. The lines f—e have formerly been supposed to be identical with the M-line in Troms fylke. This line was assumed to have been engraved during a stationary stage of the ice front or the fjord glaciers represented by a series of terminal moraines called the M-moraines (3). On Dønna the M-line (f—e) is strongly engraved in solid rock 92 m a. s. l., indicating that the ice front must have been close by while it was formed, but in Helgeland I do not know moraines belonging to this stage, and therefore the accurate course of the ice front cannot be fixed. The stage is designated by the line M on pl. III. This line is only to be regarded as a rough estimate as to its course within Nordland fylke. In Troms, however, its course follows the M-moraine series, which, however, ought to have been gone over once more in the field.

During a melting period following the stationary M-stage the inner part of the Lyngenfjord and the Balsfjord became free from ice. The ice melted away in the stem of the Ofotenfjord but not in its branches. It further melted away in the Sørfoldenfjord, in the Salta-Skjerstadfjord system, in the Ranafjord to about 8 km past Hemnesberget, and in the Vefsenfjord to past the present head of this fjord. The inland ice had during that period been reduced to isolated valley glaciers which at the end of the period by degrees passed into a new stationary stage at a moraine series called the M′-moraines (3), on pl. III noted M′. In Troms fylke a shore line engraved during the stationary M′-stage was called the M′-line and there believed to be a single line at a level about 83 % of that of M, but in Nordland this line seems to divide into a diverging bundle of at least three lines with d_2 as the middle line. The ice front stage M′ is more distinctly fixed than the M-stage.

During a new melting period the valley glaciers receded to a last stationary stage noted M″. Also to this stage a distinct moraine series can be pointed out corresponding with a sea level at about 64 % of that of M (f), in Troms fylke represented by one line called M″ which in Nordland fylke was substituted by a bundle of three lines with d at the middle.

After the M″ time the climatic conditions seem to have so much ameliorated that likely all ice melted away on our side of the frontier. It is the b o r e a l time. Before this time the valley glaciers in Troms fylke seem to have been fed from the east through passes in the frontier, while in Nordland fylke the ice had been broken at an earlier date.

From the boreal time some finds of shells may be of interest. At Mælen near the head of the Balsfjord great specimens of *Cardium echinatum,* Lin. and *Zirphœa crispata,* Lin, have been found about 40 m above sea level. These two species are no longer living in sounds and fjords in this part of Norway, and the three living specimens of Cardium echinatum found by Sparre Schneider at Hillesøy were quite small. At Laberg on the southern shore of Gratangen fjord *Cardium edule,* Lin. has been found to 50 m a. s. l. and at the head of Balsfjord at 40 m a. s. l. In the valley of Trøsen river south of Skånland on the east side of the Tjellsund 30 m above sea level have been found among other shells *Homalogyra atomus* and *Cardium echinatum, abundantly* of *Macoma fabula* and some specimens of *Periploma prœtenuis,* the last species only found in this locality in Northern Norway. In this place the b-line is situated 26 m a. s. l. It is likely that *Pinus silvestris* has immigrated to Northern Norway during this warm period. On Tromsøy roots and pollens of pine have been found in bogs, and in the Tromsdal on the east side of Tromsøysund I have found trunks and bark pieces of pine to between 250 and 300 m a. s. l. though at present not a single living tree of this species is to be seen there.

The boreal time seems to have been followed by a cold period in Northern Norway, at all events in Troms fylke. It is a fact that the shore line or bundle of shore lines called the Tapes level is so sharply engraved that this level was one of the two levels measured by Helland in Troms fylke. I have on a former occasion (7) drawn attention to two moraine series in some elevated valleys near the frontier in Troms, likely deposited by glaciers coming into being after the last inland ice had melted away. One of these moraine series was supposed to have been deposited in the a t l a n t i c time, described as a warm and humid period in temporate latitudes farther south. A humid period in the northern parts of our country would likely have had abundant snowfall in winter and wet summers without sunshine and warmth even if the middle temperature of the year was not exceptionally low. The said younger moraine series have not only been found west of the frontier, for Sjøgren has also found them within the mountains south and southwest of lake Torneträsk. Lofty cirques on the islands from Lofoten northwards are also pointing in the same direction. By examining fossiliferous shell material from occurrences on the Tjellsund, especially from the shell banks at Evenskjær, about three metres thick, I found in material from the lowest layers a fossiliferous mollusc fauna composed of about 60 % arctic species and 40 % boreal and lusitanic species whereas the upper layers had a fauna composed of about 60 % boreal and lusitanic species and only 40 % arctic species. There did not seem to be any discontinuance in the deposition, for samples taken from the middle of the banks had a fauna of transitional character (4). I have mentioned these facts in the hope that some one will be interested in these questions which ought to be more closely studied.

The shore lines c and b are nearly one in Troms fylke, the b-line, however, being the higher line in the greater part of the district, but c-line the higher line near the heads of the fjords. The c-line may have been engraved during the atlantic time contemporarily with the deposition of the lower layers of the shell banks. Then a warm period set in, the s u b b o r e a l time. Glaciers melted away, a warm stream was running along the coast and a boreal-lusitanic fauna immigrated. A strong melting of the ice took place all over the globe, and the level of the sea rose quickly till the rising faded away near the level of the former c-line, and the b-line was engraved. This movement of the sea level is the T a p e s t r a n s g r e s s i o n. In the b-line then lived a boreal-lusitanic littoral fauna, and the upper layers of the shell banks were deposited. In that way I believe that the observed facts are to be explained, and Tanner seems to have followed a similar course of thinking when dealing with the said transgression.

On the mainland south of the Ofotenfjord the b-line is everywhere situated above 27,5 m, and therefore c and b never coincide as the c-line is the upper one. None of them is so sharply engraved or so different from other lines that they easily can be identified there. Nor have moraines supposed to have been deposited in the atlantic time been found except in the vicinity of the Svartis. From the central part of this area a valley stretches in north westerly direction to the Beiarfjord, the Arstad- or Dokmodal. At the mouth of this valley is a terminal moraine with the form of an arch 30 m a. s. l. Far south in the Beiardal about 50 km from the head of the fjord some small moraines are also to be found likely of the same age as the Dokmo moraine. These moraines have been locally fed and must be younger than the M″-moraines, and therefore they may have been deposited in the humid atlantic time by advancing glaciers from the Svartis area.

In Troms is further a shore line which has been correlated with the younger one of the two moraine series above mentioned. In the northern part of Troms fylke it is the sole line below the b-line which is so sharply engraved that it cannot be easily overlooked during the field work. It is to be found at a level about 37 % of that of b, and would approximately correspond to a_3—a_4 in the diagram. More closely it cannot be indicated, for in Troms the said line no doubt is a double line, and the material from Nordland respecting the a-lines is not yet worked out sufficiently in detail. This line or bundle of lines has formerly been called T′ and the corresponding moraine series the T′-moraines, supposed to date from the subatlantic period (3). From Nordland fylke no moraines from this period are known.

6. CORRELATION BETWEEN NORTHERN NORWAY AND THE OSLO DISTRICT

To correlate the quaternary conditions of Northern Norway with those of the southern part of our country is not easily done and must in many ways be uncertain. As for the latitude, Bodø lies 7 degrees and Tromsø nearly 10 degrees farther to the north than Oslo. During the melting of the last inland ice the west and northwest coast must have been washed by the Gulf stream drift as now, while Kattegat, the Oslofjord, and Skagerak for a greater part lay outside this stream system and had a more or less rapid currant from southeast, a Baltic stream. Stationary stages of the ice front or periods of recession did not therefore of necessity be contemporaneous in so distant places as Oslo and Tromsø. Moraine series are especially difficult to correlate as they often partly owe their site to local conditions. Vogt, Tanner and the present author have been of opinion that the Tromsø-Lyngen stage was identical with the Ra stage in Southern Norway. This was possibly going too far, but it must, however, be reasonable to think that in spite of distance and local conditions an interplay between north and south had existed while the moraines were deposited even if some shifting of phases must be expected. To correlate the shore lines must, however, be safer because their forming was not only owing to the submergence of the land but still more to the eustatic stand of the sea level which was independent of local conditions and latitude. In order to find a connection between Southern and Northern Norway I have therefore inserted some measurements from the Oslo districts in my diagram. Pl. IV is only a direct prolongation to the right of pl. II in the same scale, and only lines of some interest have been drawn. In a paper by Holtedahl (12) a summary is given of the marine stages as follows according to Øyen: 1. The Mytilus stage from 220 m a. s. l. 2. The Portlandia stage from 205 m. 3. The Littorina stage at 175 m. 4. The Pholas stage at 142 m. 5. The Mactra stage at 95 m. 6. The Tapes stage at 70 m. 7. The Trivia stage at 47 m. 8. The Ostræa stage at 22 m and The Mya stage, the present stage. When these figures are inserted in the diagram where the b-line lies 70 m above the present sea level, then the 220 m line coinsides with f′, the Portlandia level is to be found between f° and f, the Littorina level coinsides with a line next below d_4, the Pholas level with d or close upon this line, the Mactra level with c_1, the Trivia level with a_7, the Ostrea level I with a_4, and the Ostrea level II with a_2. In spite of the fact that the levels by Øyen are not shore lines proper they still coinside fairly well with fixed shore lines except the Portlandia level. While the sea stood at that level *Portlandia arctica* was living near the ice front at the head of the fjord of that time.

In Northern Norway the climatic conditions were not fully arctic for there all sounds were open for passage of Gulf Stream water, but within the fjords glaciers were for a time stationary at the M moraines.

Holtedahl has studied the recession of the ice front on Romerike and he has pointed out the following stages: The Hauersæter stage, corresponding to a sea level at 205 m, The Dal stage, corresponding to a shore line at 202 m, and the Minnesund stage with a shore line at 194 m. The 205 m line seems to be identical with the f-line, the 202 m line with e, and the 194 m line with d_4. The Minnesund stage may thus be contemporaneous with the Littorina stage at Oslo. As the b-line has not been measured in the locality just named the figures cannot be inserted with absolute certainty but the error cannot be great.

The diagram pl. IV has been drawn in order to show how measurements from Southern Norway fit in a diagram only based on material from Northern Norway, but for closer discussing of these things the material at hand is too scanty.

IV. Equations of the Lines in the Shore Line Diagram. The Eustatic Stand of the Sea Level.

In order to fix the lines in the shore line diagram mathematically I have used a coordinate system with the zero line, representing the present sea level, as axis of abscissas. The vertical line limitting the diagram to the right cuts the b-line 59 mm above the zero line. Five hundred mm to the left of this vertical line another vertical line has been chosen as ordinate axis. In this coordinate system all the lines in the diagram are then represented by an equation of the form

$$y = kx + b.$$

The two vertical lines named above are cut by all the lines in the diagram which represent former sea levels. If the ordinates of the two cutting points are called y'' and y' then $k = \frac{y'' - y'}{500}$ and $b = y'$ and accordingly

$$y = \frac{y'' - y'}{500} x + y'.$$

y'' and y' can be taken out of the diagram with an exactitude of between 0,1 and 0,2 mm. By representing the lines in the diagram with equations it has been made possible to find cutting points between the lines by calculation instead of extending the lines to cutting and then measure the coordinates. The calculating method will give a safer result than the graphic method, for the lines are often cutting each other at a very acute angle and then it is difficult to measure the coordinates accurately.

For the n-line $y' = 122{,}7$ mm and $y'' = 305$ mm. The equation of this line is therefore

$$y = \frac{305 - 122{,}7}{500} x + 122\ 7$$

$$y = \frac{182{,}3}{500} x + 122{,}7$$

$$y = 0{,}3646\, x + 122{,}7$$

In the same way the equations of the other lines in the diagram have been found as the following table will show.

Line	y″	y′	Equation	Distance from the zero line
n	305	122,7	y = 0,3646 x + 122,7	−100
m	299,9	119,9	y = 0,3600 x + 119,9	−100
l	284,5	111,4	y = 0,3462 x + 111,4	− 99,8
k_2	277	107,3	y = 0,3394 x + 107,3	− 99,7
k_1	273	105,3	y = 0,3354 x + 105,3	− 99,3
k	269,5	103,2	y = 0,3326 x + 103,2	− 99,8
i_3	265	101,1	y = 0,3278 x + 101,1	− 98,7
i_2	259,4	98,3	y = 0,3222 x + 98,3	− 98,3
i_1	250,4	94,2	y = 0,3124 x + 94,2	− 96,6
i	243,9	90,3	y = 0,3072 x + 90,3	− 97,1
h_3	234,2	86,5	y = 0,2945 x + 86,5	− 93,5
h_2	224,5	83	y = 0,2828 x + 83	− 89,3
h_1	219	79,6	y = 0,2788 x + 79,6	− 90,7
h	211,2	76,6	y = 0,2692 x + 76,6	− 87,8
g_4	207	74,5	y = 0,2650 x + 74,5	− 87,5
g_3	203	73,2	y = 0,2596 x + 73,2	− 85,3
g_2	200,3	71,2	y = 0,2582 x + 71,2	− 86,7
g_1	197,8	70	y = 0,2556 x + 70	− 86,3
g	191	66,9	y = 0,2482 x + 66,9	− 84,8
f_1	184	63,3	y = 0,2414 x + 63,3	− 84,3
f_0	177	61	y = 0,2320 x + 61	− 80,8
f	173	59	y = 0,2280 x + 59	− 80,5
e	167,8	57	y = 0,2216 x + 57	− 78,5
d_5	163,3	55,2	y = 0,2162 x + 55,2	− 77,3
·	159	53,5	y = 0,2110 x + 53,5	− 75,6
d_4	155,5	52	y = 0,2070 x + 52	− 74,7
·	150,5	50,3	y = 0,2010 x + 50,3	− 72,7
·	148,5	49,7	y = 0,1976 x + 49,7	− 71,2
d_3	146,3	48,3	y = 0,1960 x + 48,3	− 71,2
·	144,3	47,7	y = 0,1932 x + 47,7	− 70,6
·	141,7	47,1	y = 0,1892 x + 47,1	− 68,7
d_2	139,1	46,5	y = 0,1852 x + 46,5	− 67
·	137,1	45,7	y = 0,1828 x + 45,7	− 66,2
·	134,5	43,5	y = 0,1818 x + 43,5	− 67,8
·	131,8	42,5	y = 0,1786 x + 42,5	− 66,8
d_1	129,6	41,3	y = 0,1766 x + 41,3	− 66,8
·	127,4	40,2	y = 0,1744 x + 40,2	− 66,6
·	122,8	39,6	y = 0,1664 x + 39,6	− 62,4
·	121,6	39,2	y = 0,1648 x + 39,2	− 61,8
·	119	38,2	y = 0,1616 x + 38,2	− 61,7
·	117	37,5	y = 0,1590 x + 37,5	− 60
d	113,2	36,6	y = 0,1536 x + 36,6	− 57,4
·	111	35,5	y = 0,1510 x + 35,5	− 57
·	109	34,4	y = 0,1492 x + 34,4	− 57
c_4	106,8	33,4	y = 0,1468 x + 33,4	− 56,5
·	102,6	32,5	y = 0,1402 x + 32,5	− 53,4
·	100	32	y = 0,1360 x + 32	− 51,4
c_3	95,5	31,6	y = 0,1278 x + 31,6	− 46,7
·	90,5	30,3	y = 0,1204 x + 30,3	− 43,5
c_2	89,3	29,5	y = 0,1200 x + 29,5	− 44
·	87	28	y = 0,1180 x + 28	− 44,3
·	84	27	y = 0,1140 x + 27	− 42,8
·	81	26,5	y = 0,1090 x + 26,5	− 40,3

Line	y″	y′	Equation	Distance from the zero line
c_1	78	25,3	y = 0,1054 x + 25,3	− 39,4
·	74,5	24,2	y = 0,1006 x + 24,2	− 37,4
·	72,4	23	y = 0,0988 x + 23	− 37,6
·	71	21,7	y = 0,0964 x + 21,7	− 37,4
c	68,8	21,2	y = 0,0952 x + 21,2	− 37,1
b	59,5	22,5	y = 0,0740 x + 22,5	− 22,9
·	55,2	21,4	y = 0,0676 x + 21,4	− 20
a_9	53,5	20,8	y = 0,0654 x + 20,8	− 19
·	50	20	y = 0,0600 x + 20	− 16,6
a_8	46,7	19,4	y = 0,0546 x + 19,4	− 13,9
·	44,4	18,2	y = 0,0524 x + 18,2	− 13,8
a_7	41	17	y = 0,0484 x + 17	− 12,3
·	37,9	17	y = 0,0418 x + 17	− 8,6
·	36,4	16,5	y = 0,0398 x + 16,5	− 7,8
·	33,7	15	y = 0,0374 x + 15	− 7,8
a_6	31,3	14,2	y = 0,0342 x + 14,2	− 6,6
a_5	26	13,5	y = 0,0250 x + 13,5	− 1,7
·	23,7	12,8	y = 0,0218 x + 12,8	+ 0,5
·	21,3	12	y = 0,0186 x + 12	+ 1,3
a_4	19,8	11,7	y = 0,0162 x + 11,7	+ 1,4
·	18,1	10,2	y = 0,0156 x + 10,2	+ 1,3
·	15,8	9,5	y = 0,0126 x + 9,5	+ 2,4
a_3	14,6	9	y = 0,0112 x + 9	+ 2,7
·	13	8,3	y = 0,0094 x + 8,3	+ 3,2
·	10,7	7,5	y = 0,0084 x + 7,5	+ 2,5
a_2	9,2	6	y = 0,0064 x + 6	+ 2,6
·	7,7	5	y = 0,0054 x + 5	+ 2,6
a_1	5,5	3,6	y = 0,0038 x + 3,6	+ 1,6
·	4	2,5	y = 0,0030 x + 2,5	+ 1,3
·	3	2	y = 0,0020 x + 2	+ 1,4
·	1,5	1	y = 0,0010 x + 1	+ 1
a_0 The present sea level				0

As before said the cutting points can be found between two consecutive lines in the diagram by extending the concerned lines to cutting and then measure the coordinates of the cutting point, but these coordinates can be found more accurately by calculation when the equations of the lines are given. I have made such a calculation for all the lines of the diagram here reproduced, but a curve through the cutting points is crenelated and irregular and therefore it is not taken into nearer consideration. Some of the cutting points are, however, of interest. The coordinates of the cutting point (n, m) between n and m have been found to be (-608, 7, -99, 2), the cutting point (n, l) to be (-614, 1, -101, 2) (n, k_2) to be (-611, 1, -100, 1) and (n, k) to be (-609, 4, -100). The arithmetic medium of these figures is (-610, 8, -100, 1). A greater exactitude was not to be expected, and the coordinates of the point (n, m) has therefore been fixed to (-610, -100). This result transfered from the diagram to the map shows that the cutting line between the former sea levels n and m may be situated at about 100 m below the present sea level and between 72 and 80 km west of Andøy.[1]

Geologists studying the quaternary geology seem to agree that the forming of shore lines was owing to a cooperation between the isostatic movement of the land and the eustatic movement of the sea level. In a system of shore lines- and then also in a shore line diagram — the result of these two different movements must be enrolled as the sum of an isostatic and an eustatic component. The isostatic movement in the peripheric part of a depression must be to comprehend approximately as a rotation round a line, an axis — in a diagram round a point —, while the sea surface whether in rest or in movement must have been, broadly speaking, always parallel to the present surface. The isostatic movement was caused by alterations of the ice masses which lay over a depression, while the eustatic movements were due to climatic changes within all the glaciated parts of the earth, and they were, therefore, of a more general character. But since the result of the said movements has been registered as shore lines, in many places finely developed, it must be possible to find the approximate stand of the sea level while a former shore line was engraved, if only the search can be based on reasonable suppositions.

In conformity with the diagram pl. II the following suppositions have been made: The n-line is the oldest late glacial marine shore line and the m-line the next oldest shore line. The movement of the land surface in the peripheric part of the depression was a rotation round the point (n, m) = (-610, -100), regarded as a fixed point for some length of time. The former levels of the sea surface were always parallel to the present sea level. If the movement of the land had only been a rotation round (n, m) and no eustatic movement of the sea level had taken place all the lines in the diagram would have

[1] In a diagram drawn after the method of Tanner the ordinates of the cutting points between lines only depend on the vertical scale of the diagram. If for instance a length of 1 chosen at will is inserted in the equations of the lines n and m instead of the 500 mms used between the two vertical lines y′ and y″ 1 is not to be found in the expression of the ordinate y of the cutting point, as it has passed out during the calculation.

gone through the point (n, m). When not so doing it is due to the eustatic movement of the sea level.

One may then get an idea of the approximate stand of the sea level while the different shore lines younger than m were ingraved in the following ways:

1) By measurement on the diagram.

The diagram can be made to turn round an axis through the point (n, m), and the position of the zero line is fixed by a stretched thread before turning of the diagram. If then the different lines in due order are set parallel to the thread by turning round the point (n, m) the distance of the line from the thread in mm is the distance in meter of the former sea level from the present sea level. A line set parallel to the thread cuts the perpendicular line from (n, m) on the thread at a right angle, and the distance between the line and the thread is most easily measured on this perpendicular line.

2) By calculation.

The distance of a former shore line from the present shore line while formed can also be found by calculation. The equations of the lines in the form $y = kx + b$ must then be transformed to the form $\frac{y - kx - b}{\sqrt{1 + k^2}} = 0$. If the coordinates of the point (n, m) (- 610, -100) are inserted in this formula for x and y then the quantity

$$\frac{-100 + 610\,k - y'}{\sqrt{1 + k^2}} = a$$

where a is the distance of the line from (n, m). k and y′ are taken from the equation of the line in question. The distance of a line from the zero line (the thread), d, can be found by the formula

$$d = a - 100.$$

All the figures inserted in the last column of the table on page 54—55 have been found in that way, calculated by the aid of a sliding rule. On pl. V a point marks the stand of the sea level while the corresponding shore line was engraved. The horisontal distance between these points ought to have been in ratio with the lapse of time between concecutive shore lines, but as this time is unknown the distances have been chosen alike.

The curve pl. V shows that the sea level was nearly constant while the shore lines n to k were engraved. During this time the ice front was slowly receding across Andøy where two terminal moraine series were deposited, one along the west coast and another farther east of which the Kirkra is a part. The climate must therefore have been arctic with faint melting of the ice not only in Northern Norway but everywhere. After the ice had receded from Andøy there seems to have been a continuous melting period with a rise of sea level to g_3. While the ice front was stationary at the Tromsø-Lyngen moraines there was a sinking of the sea level from g_3 to g_1. After that time the rise of sea level has for the most part been even only with standstills from d_2 to d and from c_3 to c_1. From c to b is a considerable rise from -37 to -22 m, the Tapes transgression. During the sub-boreal time the sea level was once more quickly rising and reached the present level in the time between a_5 and a_4. From a_4 till the present time it seems always to have been situated higher than now but with a little sinking between a_3 and a_2 which may correspond to the sub-atlantic time.[1]

The curve pl. V shows what can be found by studying a shore line diagram and is in the first instance an attempt at bringing to light an eustatic component in a graphic reproduction and finding a method for isolating it. But if the graphic method is to be trusted,

[1] As formerly mentioned the measuraments concerning the lines p to n_1 are deficient, either taken in places where the lines were indistinct from weathering or doubtful as measured with aneroid. If good shore lines they, moreover, ought to have been found in such places as Hasvåg, Skagen in Bø and on the islands within the Røst group, but no such lines have there been found above the n-line. Of that account I have not taken them into consideration as marine shore lines. But for making the account of the lines in the diagram as complete as possible the following remarks will be added:

Equation of the	p-line:		$y = 0{,}426\ x + 167$
—»—	o_2	»	$y = 0{,}410\ x + 155$
—»—	o_1	»	$y = 0{,}396\ x + 147{,}7$
—»—	o	»	$y = 0{,}387\ x + 141{,}5$
—»—	n_3	»	$y = 0{,}381\ x + 136{,}5$
—»—	n_2	»	$y = 0{,}3746\,x + 132{,}7$
—»—	n_1	»	$y = 0{,}3672\,x + 127{,}4$

The cutting point (p, o_2) has the coordinates (-750, -152,5). The distances of the lines o_1 to n_1 from this point are as follow: o_1 -3,0, n_3 -3,5, n_2 -3,1, n_1 -4,2 m. The arithmetic means is -3,3.

then the result must be to extend to the very system of shore lines. In a diagram each line represents a former sea level now brought out of its originally horizontal position by the rise of the land. The point (n, m) represents the boundary line of the depression. It is of some interest in this connection to note that the depth found for this point is of the same size as assumed by Tanner, -100 m.

It is likely that the sea bottom west of the said boundary line had been pressed somewhat up above its present level during the sinking of the land below the ice sheet. Such a ridge would then move eastwards again when the pressure within the depression decreased, and when approaching the boundary line then the sea bottom there would be rising and then once more sinking when the wave of uplift had passed. Such an uplift can, however, scarcely have taken place during the earlier part of the melting period as no irregularities have been found in the older part of the shore line system. When a wave of uplift had passed it must therefore have taken place while the later d-lines or c-lines were engraved, but this part of the diagram has not been so detailed worked out that any thing more positive can be said.

V. Connection between the Depth of a Depression and the Thickness of the Depressing Ice Sheet.

If supposed that the depressions of formerly glaciated parts of the surface of the earth were called forth by the weight of the ice masses which once lay over them it is evident that there must have been a certain ratio between the thickness of the ice and the depth of the depressions in case of equilibrium.

When the last Fennoscandian ice sheet had reached its maximal thickness the western ice border may have extended to the outmost line on pl. III. A greater part of the continental shelf was then, at all events, covered by the ice and therefore the sea had no touch with the land, and no shore lines could be engraved till the ice barrier had been broken somewhere or other. The uppermost shore line at Hasvåg, supposed to be the oldest late glacial marine shore line, could not, therefore, be formed till some time after the melting, of the ice along the ice border had set in. It is not necessary, however, to suppose that any rising of the land ere this had taken place, for it is likely that the inner masses which were to be pressed outwards during the sinking of the land surface offered so great a resistance that the subsoil had not come to rest till some time after the melting of the ice had set in and the recession of the ice front had started. Nor is it necessary to suppose that the sea level had moved off from its lowest stand essentially, for inferring from the present conditions it is likely that the melting of the ice set in at first just off the Norwegian coast.

If assumed as approximately correct that the n-line was engraved during the lowest stand of the sea level and the maximal depression of the land surface, the veritable depth of the depression in any place will be found by adding together the height of the uppermost shore line above the present sea level and the stand of the sea level at the time when this shore line was engraved.

If the thickness of the ice sheet in a place be H, the speciphic gravity of the ice 0,9, the height of the shore line in the same place is h, the isostatic component be q and the speciphic gravity of the inner masses be 3, the following equation of equilibrium can be used:

$$0{,}9\,H = 3\,(h + q)$$

$$H = \frac{10}{3}(h + q)$$

If now the stand of the sea level while passing from sinking to rising was 100 m below the present sea level and n the oldest shore line then the thickness of the last ice sheet during its maximum should be to calculate by aid of the formula

$$H = \frac{10}{3}(h + 100)$$

where h is taken out of the diagram in the place in which the thickness of the ice sheet is to be found. At Hasvåg h = 51,8 m and accordingly

$$H = \frac{10}{3}(51{,}8 + 100)$$

$$= 506 \text{ m}$$

In this way H can be found in other localities of interest. For some localities H is found as follows: Nyksund 437 m, Eggum 448 m, Værøy 497 m, Vengsøy 520 m, Greipstad on Malangenfjord 625 m, Strømsbukt near the Rystrøm 633 m, Vika on Vega 873 m, Bjørn on Dønna 920 m, Skagstad on Engeløy in Steigen 823 m and North Fugløy in Gildeskål 953 m. Most of these localities lie outside the inshore channel, the ordinary fairway. From these figures may be concluded that the thickness of the last ice sheet on the continental shelf off the coast of Helgeland and Salta was between 800 and 900 m. If the present depth of the part of the shelf then covered by ice is supposed to be on an average 250 m the ice sheet should have risen to between 550 and 650 m above the present sea level. North of Lofoten the thickness was less, between the islands in Troms fylke only between 500 and 600 m, 250 to 300 m above the present sea level.

From the main territory of accumulation to the east of the frontier the ice was pressed in westerly and northwesterly direction over Northern Norway where it filled up the valleys and flowed over the mountain wilds. There the ice had its greatest velocity and made its most important eroding work, but off the coast the partially separated ice streams merged together to a more or less continuous ice plateau or ice barrier of decreasing thickness and motion westwards. The continental shelf was in that way a secondary area of accumulation for ice and loose material where the ice must be a dead mass from the moment when the ice flow from the east no longer could overcome the friction within the mountainous inland.

A calculation similar to that above concerning the islands can also be carried out for localities on the mainland on fjords and in valleys. The figures found are for some localities the following: At Eidstrand near the north point of the Lyngen peninsula 653 m, at Skarmok 763 m, at Målsnes in Malangen 760 m, at Heldal in the Folla district 960 m, at the mouth of Bindalsfjord and at Eidet on the south side of Velfjord 1033 m, at the head of Leirfjord in Folla 1103 m, at Søfting on the north side of the Vefsenfjord 1117 m, at Børjeør at the head of one of the inner branches of Velfjord 1123 m, at the head of Elsfjord in the Rana district 1187 m, at Setså on the east side of the inner part of Skjerstadfjord 1190 m and at Bergulnes in the Saltdal 1323 m. All these localities are situated within the part of the land where the erosion took place and where the real thickness of the ice was very much varying on account of the unevenness of the ground below the ice. The figures found, therefore, do not have the same value as figures from localities on the continental shelf but they may still give a faint idea of the elevation of the ice surface within the mountainous districts. An attempt at finding a probable value of the depression at the centre and the thickness of the ice there has given as result a depression of about 700 m and a thickness of the ice of between 2300 and 2400 m.

The calculations dealt with above do not as a matter of course pretend to be something more than a rough approximation based on suppositions more or less questionable. It is supposed that the n-line is accurately fixed and is the oldest late glacial shore line, and can be lengthened outside districts where measurements had been carried on. It is further supposed that the eustatic stand of the sea level was about 100 m below the present level when the m-line was engraved, that the speciphic gravity of glacier ice is 0,9 and of the inner masses equal to 3, every one of them being more or less disputable. It is therefore of rather great interest that the calculated figures, despite so many suppositions, are, however, of the same order according to size as the figures found either by field work or by looking over the maps. I should therefore be inclined to think that the thickness of the last ice sheet has hitherto been underrated especially from the Lofoten islands southwards. A concave bending of the ice front off the said part of the coast as seen on some maps showing the extension of the ice, for instance the map by Granlund in Sveriges geologi, p. 139, cannot be correct. A straight course or a convex bulging out of the ice front is more likely as it is in accordance with the direction of the isobases along this part of the coast. This part of the ice front lay, moreover, nearer to the centre of the glaciation than any other part of the front. The extension of the ice sheet to the south and southeast in Germany and Russia may also give a hint of the dimensions which ought to be taken into consideration. The ice masses moving westwards had, it is true, a mountain ridge to pass, but this hindrance was compensated for by a shorter distance from the ice divide to the outer border.

A calculation similar to that carried out above concerning the supposed uppermost shore line and the lowest stand of the sea level cannot as a matter of course be carried out for younger levels and give results of the same value, for it is but a minute probability for a balance between load and depression after the melting period had set in with full strength. In warm periods the melting would be so quick that the rise of the land surface could not keep up to it. The rise would be retarded as seen in the present time, for the land is even now rising though the ice sheet has melted away long time ago.

But during the melting period, however, once the ice front was stationary for some length of time at the Tromsø-Lyngen stage. The ice front rose then rather steeply from the level of the sea to above 200 m, and at the same time the level of the sea seems to have been in relative rest. By counting alternate layers of coarse and fine loose material on the Breivikeid about 5 km outside the former ice front about 600 double layers have been found, and if supposed that each double layer represents the deposition of loose material in a year, then the melting was reduced for so long a time that balance between load and depression once more may have taken place. It is also likely that the thickness of the ice sheet had been increasing which the strong local glaciation on the islands outside the ice front seems to indicate. During the stationary stage the shore lines g_2 and g_1 were engraved but when the next line, the g-line, was engraved a new and strong melting period had started. In the diagram the n-line at Bergulnes lies 297 mm above the zero line and the g-line 186 mm above the same line. To the former figure corresponds an eustatic stand of -100 m and to the latter -84,8 m. The depth of the depression was therefore in the time of the n-line 397 m and in the time of the g-line 270,8 m or 68,2 %. In case of equilibrium between the thickness of the ice and the depth of the depression in the latter time the thickness of the ice should then have been 68,2 % of 1323 equal to 902 m. As formerly mentioned a melt water river once made its way across the present divide from the Saltdal to the Bjellådal at a level of 844 m. This river, no doubt, only existed in a melting period and most likely at the beginning of such a period as was the time of the g-line. The surface of the Saltdal glacier was then situated at about 900 m above the present sea level, and it fits quite well after all. It must here be put in mind that the oldest ice dammed lake in the Bjellådal lay 765 m above the present sea level. This fact shows that also in the Dunderlandsdal a valley glacier must have existed at that time of similar dimensions as the glacier in the Saltdal.

In the Signaldal 25 km from the head of the Lyngenfjord is the great canyon, fig. 11, cut in the eastern mountain side. The bottom of the canyon lies about 550 m a. s. l. In the diagram the n-line there lies 209,5 mm and the g-line 126,5 mm above the zero line. The depression was therefore in the n-time 309,5 m and in the time of the g-line 211 m or 68,2 %. The corresponding thickness of the ice sheet was for the n-time 1032 m and for the g-time 703,8 m. The upper wall of the canyon is about 50 m high and therefore the cutting of the canyon in the solid rock must have started while the border of the valley glacier lay above 600 m above the present sea level, and the calculation is in accordance with this fact. The canyon has, no doubt, been cut by a rapid river abounding with water which proves that there must have been an intense melting on the surface of the ice. The cutting of the canyon must therefore have taken place in the time of the ice dammed lakes in the Bjellådal.

In the northern part of the Lønsdal and in Dypenådal heavy masses of sand and gravel have been deposited in an ice dammed lake between the mountain side to the east and glacier ice in the Lønsdal and the Saltdal to the south and north. The deposition has taken place in three steps 713, 670 and 640 m above the present sea level, showing three different levels of the ice dammed lake (19). This lake is of a later date than the ice dammed lakes in the Bjellådal. Of special interest is that the existence of this lake clearly proves that the ice sheet now was broken at the frontier or was about to be broken. It is likely that so was the case all along the frontier northwards to the Tysfjord district, while farther to the north the valley glaciers still were supplied from the east through defiles on the frontier.

After partition of the ice cover along the frontier had taken place our valley glaciers would be "dead" if not sufficiently fed from locally glaciated areas, but such a supply may not often have been of any importance.

Norsk resymé.

Innledning.

I de senere år har flere forfattere behandlet Nord-Norges kvartærgeologi mere eller mindre inngående, og blandt disse især Tanner, Nordhagen og Undås. Da nærværende forfatter i årenes løp har samlet materiale av forskjellig slag vedkommende dette emne, har han funnet det riktig å fremlegge den del av materialet som nogenlunde er gjennemarbeidet og gi en foreløpig redegjørelse for de resultater han er kommet til.

I. Den store istid.

Det er hittil i Nord-Norge bare påvist spor efter to nedisninger, en første større og en siste mindre nedisning. Den store innlandsis var så mektig at den dekket fastlandet, så det neppe fantes en eneste nunatak der, men det er sannsynlig at der var nunatakker i den vestlige del av Langøy i Vesterålen og i Lofoten. Det er denne store innlandsis som har utført det vesentlige erosjonsarbeide både inne i landet og på øyene, planert fjellviddene, rundet de fleste topper og rygger og gravet ut de dype traug inne i fjordene. Den har lagt igjen store flyttblokker i store høider ikke bare inne i landet, men også på øyene langt ute. Således finnes det flyttblokker på Kvaløy til over 600 m, på Hadseløy til 450 m og på Værøy til 400 m o. h. Også øyene innen Røstgruppen synes å ha vært oversvømmet av isen under denne nedisning. Det er sannsynlig at den utenfor hele kysten av Nordland gikk helt ut til eggen og der stod med loddrett vegg mot dyphavet vestenfor. Vest for Senja er hele bunnen utover til eggen dekket av store kuppelstein, overveiende vel rundede, av eruptive bergarter.

II. Den siste istid.

Langs fjordene og dalene er det en mere eller mindre skarp skillelinje mellem en nedre del av fjellsiden som er konkav og en øvre del som er konveks og opover går over i de flate fjellvidder. Langs den nevnte skillelinje finner man nu ofte moreneterrasser, steinrekker, tørre elvefar m. m. som må antas å skrive sig fra stasjonære stadier av en innlandsis under avsmelting. Flere sådanne linjer over hverandre viser at det med mellemrum må ha vært flere sådanne stasjonære stadier under avsmeltingen.

En del sådanne morenelinjer og andre randfenomener gjennemgåes. Av større interesse vilde det være om man kunde finne ut den maksimale mektighet av denne innlandsis, og på grunnlag av dels arbeide i marken og dels gjennemgåelse av de topografiske kart blir det sannsynliggjort at den siste innlandsis har hatt en mellem 400 og 500 m mindre mektighet enn den store innlandsis. Følgen av denne mindre mektighet var at der i det indre av landet nu stakk op en hel del høie topper som nunatakker. De indre fjellvidder var nok også da dekket av is, men isdekket var ikke så tykt og hastigheten ikke så stor at der blev utført noget betydelig erosjonsarbeide. Dertil kom at den siste innlandsis vesentlig måtte arbeide i friskt berg. Alle daler og fjorder var fulle av is, og det var disse breer som gav dal- og fjordsider den siste utformning. Utenfor kystlinjen fløt fjordbreene sammen til et isplatå som dekket en stor del av den kontinentale platform. Utenfor Nordlandskysten hadde dette isplatå sin største mektighet, over 800 m med avtakende mektighet vestover. På pl. III er den antakne ytre rand avsatt som en sammenhengende linje. Sannsynligvis endte den med en kalvingsfront mot havet i vest.

Nu er det et spørsmål om ikke den siste nedisning bare var et avsmeltingsstadium av den store istid. Mot dette taler et funn av skjell presset inn mellem steinheller i et steinbrudd i Tromsø by, likeså et avtrykk av et olderblad, funnet på samme sted. Dette funn kan vanskelig forklares på annen måte enn som interglacialt. Men det beste bevis for en interglacial tid mellem de nevnte innlandsiser er dog de fjellplanter som Nordhagen nevner både fra det nordlige og det sydlige Norge, som han kaller interglaciale overvintrere, og som må være innvandret i en interglacial tid (14 og 15).

III. De senglaciale strandlinjer.

I tabellen over målematerialet er foreløpig bare egne målinger brukt, fordi disse for det meste er nivellementer og lokalitetenes beliggenhet og verdi var kjent fra arbeidet i marken. Av de 320 lokaliteter som er tatt med er 312 fra Nord-Norge og 8 fra Novaja Semlja. I den grafiske fremstilling er abscissene proporsjonale med stigingshastigheten og ordinatene er i en bestemt lengdemålestokk. Mitt diagram, pl. II, er både horisontalt og vertikalt omtrent så stort som Tanners diagrammer fra 1930, altså vertikalt 1 : 1000, 1 mm pr. m, horisontalt 1 : 200 000, 1 mm pr. 200 m. Likesom Tanner har jeg brukt Tapes-linjen (b-linjen) som styrelinje, og for å sikre den best mulige bestemmelse av denne linje, har jeg med anvendelse av hele mitt målemateriale utarbeidet et isobasekart for dette nivå, pl. I.

De øverste linjer p til n_1, i diagrammet, pl. II, er bygget på lite og usikkert materiale, og da de ikke er påvist som marine grenser på de ytterste øyer kan de ikke være marine strandlinjer. Den øverste sikre marine strandlinje er n, den nest øverste m. For ikke å bringe inn nye vanskeligheter med betegnelsen har jeg stort sett brukt de samme bokstaver som Tanner på linjer som var identisk med hans. Tvilsomme linjer eller linjer som ikke finnes igjen i Tanners diagrammer har jeg derfor bare betegnet med et punkt.

Ved å følge strandlinjene fra de ytterste kyststrøk østover viser det seg at stadig yngre strandlinjer markerer den øverste marine grense. På den måte gir strandlinjene beskjed om isfrontens tilbakerykking under avsmeltingen, og for en del mere eller mindre stasjonære stadier kan derfor isfrontens stilling så nogenlunde fikseres. Sikrest kan dette gjøres for Tromsø—Lyngen stadiet, da isfronten i Troms fylke lå i ro i flere hundre år og svære morener blev avsatt. I Nordland fylke kan imidlertid heller ikke dette stadium med nøiaktighet bestemmes, da isfronten der enda lå utenfor kystlinjen og neppe var helt stasjonær. Yngre stasjonære stadier som mere eller mindre nøiaktig kan fikseres er i pl. III merket med M, M' og M''.

Som et tillegg til dette avsnitt er tatt med en sammenstilling av Nord-Norge og Oslofeltet på grunnlag av strandlinjediagrammet. Denne sammenstilling gjør ikke fordring på å være av nogen stor nøiaktighet og er derfor ikke underkastet nærmere diskusjon.

IV. Ligninger for linjene i et strandlinjediagram. Den eustatiske stand av havnivået.

Linjene i strandlinjediagrammet kan uttrykkes ved ligninger av formen $y = kx + b$. Kalles den vertikale linje som begrenser diagrammet til høire y'' og en annen vertikal linje 500 mm til venstre for denne y', så er

$$k = \frac{y'' - y'}{500} \text{ og } b = y'$$

hvorfor ligningen blir

$$y = \frac{y'' - y'}{500} x + y'$$

Da alle linjer i diagrammet skjærer disse to vertikale linjer, kan y'' og y' for hver linje tas ut av diagrammet med en nøiaktighet som avhenger av diagrammets vertikale målestokk. For n-linjen er $y'' = 305$ og $y' = 122{,}7$ mm. Derfor blir for linjen

$$n: \; y = \frac{305 - 122{,}7}{500} x + 122{,}7 = \frac{182.3}{500} x + 122{,}7 = 0{,}3646\, x + 122{,}7$$

På samme måte finnes ligningen for næste linje

$$m: \; y = 0{,}3600\, x + 119{,}9.$$

Skjæringspunktet mellem disse to linjer er ca. (- 610, - 100). På grunn av diagrammets egenskaper er ordinaten bare avhengig av den vertikale målestokk. Om man således lar avstanden mellem de to vertikale linler y'' og y' være en vilkårlig lengde l i stedet for 500 mm, vil det ikke ha nogen innflytelse på ordinatene for skjæringspunktene mellem linjer, da l faller bort under beregningen av y. Linjen m blev efter dette innskåret under en havstand ca. 100 m under den nuværende. Finnes på samme måte skjæringen mellem n og de nærmest følgende linjer k_2 og k får man på det nærmeste de samme verdier, og det skulde tyde på en nokså liten bevegelse av havnivået under den første del av landets stiging. Det er forutsatt at skjæringspunktet mellem n og m lå på den vestre grenselinje for depresjonen, at landets stiging stort sett foregikk som en dreiing om dette punkt og at havets eustatiske bevegelse foregikk i parallelstilling til det nuværende nivå. Man kan nu tenke sig diagrammet dreibart om punktet (n, m) og diagrammets 0-linje fiksert ved hjelp av en spent tråd. Dreier man nu diagrammet om (n, m) så de forskjellige linjer efter tur kommer i parallelstilling til tråden, kan man direkte ved måling finne ut stillingen av det havnivå i hvilket hver enkelt linje blev inngravet. Større nøiaktighet vil man opnå ved å overføre ligningene for linjene i diagrammet til normalformen

$$\frac{y - kx - y'}{\sqrt{1 + k^2}} = 0$$

og så sette inn koordinatene for skjæringspunktet mellem n og m i ligningen i stedet for x og y. Man finner ved denne regning de forskjellige linjers avstand fra dette punkt og forutsettes det at det lå i ro i forhold til 0-linjen, kan deres avstand fra denne lett beregnes. Ved en sådan regning er kurven, pl. V, funnet.

V. Forholdet mellem størrelsen av en depressjon og tykkelsen av den iskappe som fremkalte den.

Det må antas at der i de områder som engang var belastet med is var størrelsen av den depressjon som iskappene forårsaket avhengig av vekten av den ismasse som fremkalte den. Da de hevede strandlinjer innen sådanne områder blev innskåret under en annen og i alminnelighet lavere havstand enn nu, må den virkelige størrelse av en depressjon bli å finne ved å legge sammen høiden av den øverste strandlinje og avstanden av det tilsvarende havnivå til det nuværende. Ifølge det foregående var linjen n i diagrammet den eldste senglaciale strandlinje, og til samme tid skulde ifølge kurven, pl. V, for den eustatiske stand havnivået ha ligget omtrent 100 m under det nuværende havnivå. Var nu disse antakelser riktige, skulde man kunne beregne tykkelsen av den ismasse som fremkalte depressjonen tilnærmet ved hjelp av følgende likevektsligning:

$$0{,}9\,H = 3\,(h + q),\; H = \frac{10}{3}(h + q)$$

hvor H er istykkelsen, h er strandlinjehøiden på samme sted, 0,9 isens specifike vekt, 3 den specifike vekt av de indre masser som var blitt trykket til side under depressjonen og q havets stand under nuværende nivå. Ved å sette q = 100 og så regne ut den istykkelse som skulde svare til en depressjon til linjen n er funnet henimot 900 m utenfor kysten av Helgeland og noget mindre lengere nord. Depressjonen inne ved grensen skulde svare til en vekt av ca. 1400 m iskappe. De verdier som er funnet er av samme størrelse som de man kommer til ved direkte undersøkelse og er derfor rimelige.

Foruten denne beregning av isens maksimale tykkelse er der også foretatt en beregning for den tid da isranden antokes å ligge ved Tromsø—Lyngen morenene, da det var en mulighet for at isen dengang var så lenge stasjonær at der atter blev likevekt mellem depressjon og belastning. Regningen gir sannsynlige resultater.

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EXPLANATION OF THE PLATES

Pl. I. The isobases of the b-level in Northern Norway.
Pl. II. Diagram of the shore lines » » »
Pl. III. Some supposed stands of the ice front during the melting of the last inland ice.
Pl. IV. Diagram of some levels in the Oslo-Romerike district.
Pl. V. A curve showing the eustatic stand of the sea level while the shore lines we.e engraved during the melting period of the last inland ice.

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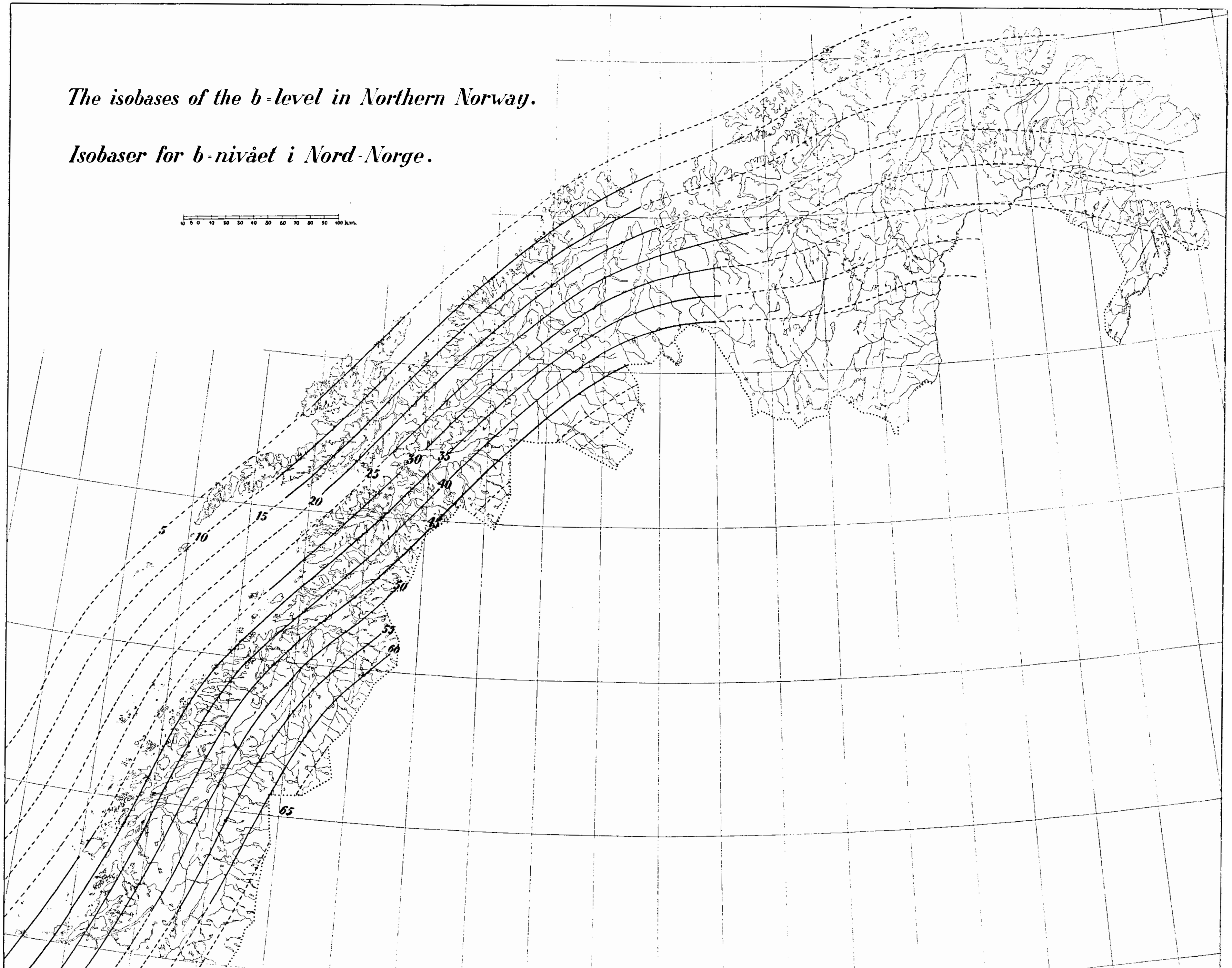
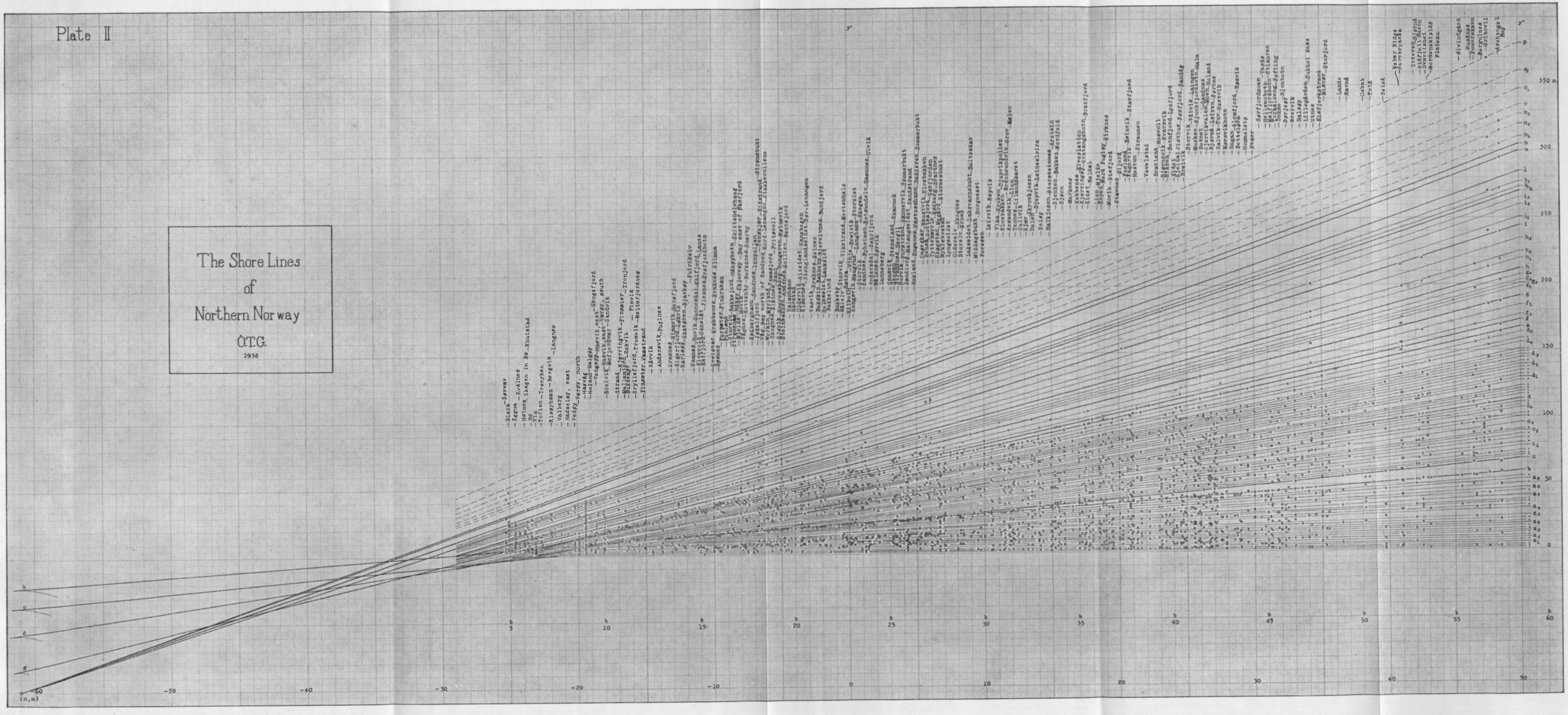
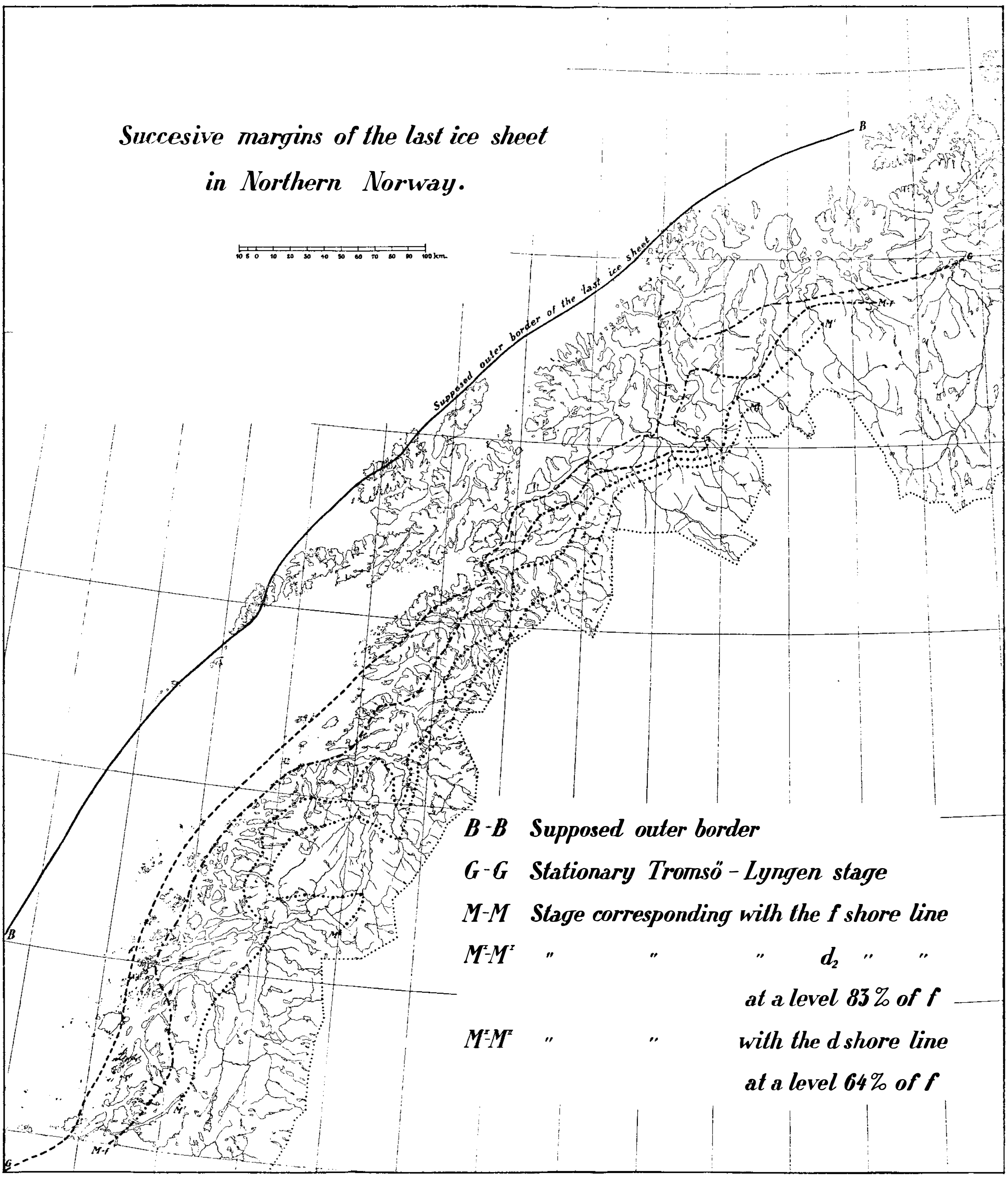
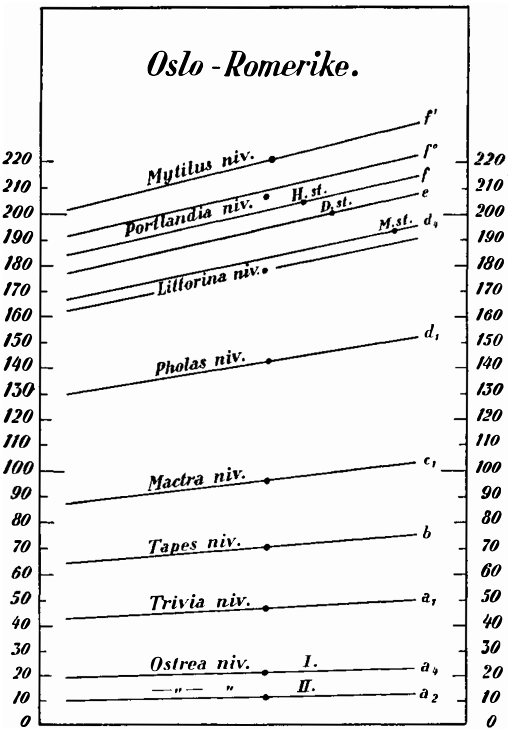

The isobases of the b-level in Northern Norway.
Isobaser for b-nivået i Nord-Norge.
5
10
15
20
25
30
35
40
45
50
55
60
65

Plate II




Succesive margins of the last ice sheet
in Northern Norway.
10 5 0 10 20 30 40 50 60 70 80 90 100 km.
Supposed outer border of the last ice sheet
B
G
M-f
B-B Supposed outer border
G-G Stationary Tromsö-Lyngen stage
M-M Stage corresponding with the f shore line
M'-M' " " " d2 " "
at a level 83 % of f
M''-M'' " " with the d shore line
at a level 64 % of f


Oslo - Romerike.
f'
f°
f
e
d4
d1
c1
b
a1
a4
a2
Mytilus niv.
Portlandia niv.
H. st.
D. st.
M. st.
Littorina niv.
Pholas niv.
Mactra niv.
Tapes niv.
Trivia niv.
Ostrea niv.
I.
II.
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

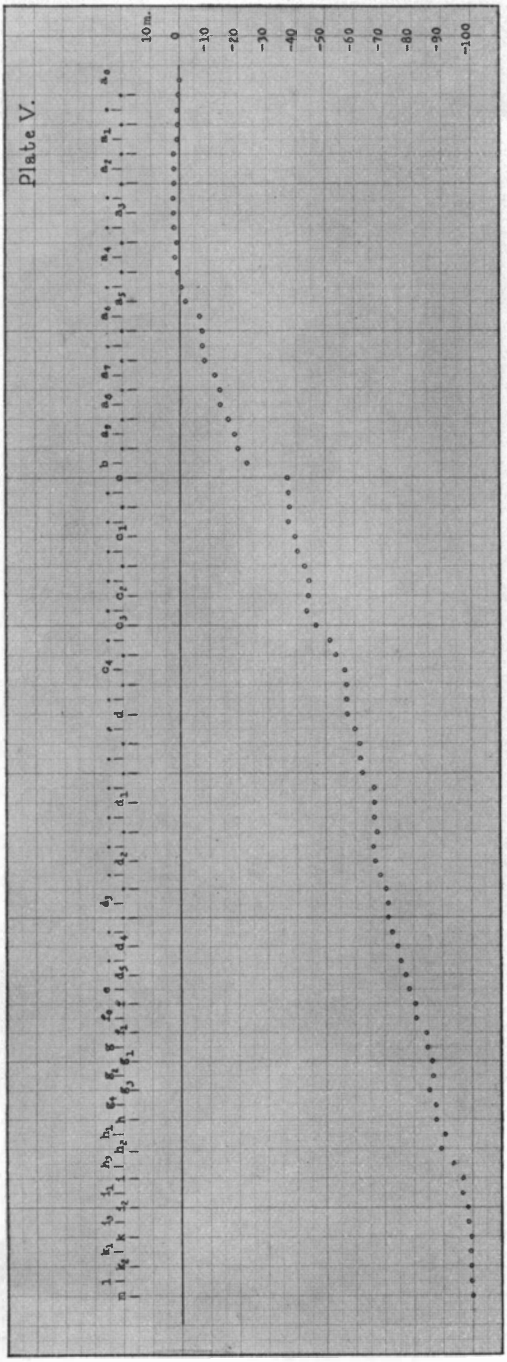


Plate V.
10 m.
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100