

## II. On the glacial lakes in the upper part of the Ume-river-valley.

By

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(With map.)

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### Introduction.

Shore-lines, formed by glacial lakes at the end of the Glacial period have for a long time ago been observed by Scandinavian investigators. Noted as early as in the former part of the 18:th century by LINNÉ and BROVALLIUS, formations of this kind are later mentioned in the geological literature by A. E. TÖRNEBOHM (from the region southwest of Lake Fæmund in Norway), by A. G. HÖGBOM (from Jemtland), by D. HUMMEL, F. SVENONIUS, K. A. FREDHOLM and K. PETTERSEN (from Laponia). But it was not until A. M. HANSEN made his careful examination of the shore-lines in the valleys of the upper Glommen and its tributaries, that it was discovered that these formations were records of lakes, dammed up by the receding ice-sheet. HANSEN showed that these shore-lines occur in the parts of the Scandinavian peninsula, in which, according to Professor HÖGBOMS investigations, the ice-movement towards the end of the Glacial period went against the general decline of the land, that is, immediately east of the watershed. HANSEN also showed that the height of such a shore-line in general coincides with the height of a corresponding pass across the watershed, by which the lake, dammed up by the rest of the ice-sheet in the east, had its outlet westwards.

After these investigations of HANSEN, especially the glacial lakes of Jemtland have been examined (by HÖGBOM and G. ANDERSSON), and SVENONIUS has described shore-lines from the upper parts of a great number of river-valleys in Laponia. Finally from the south of Sweden and east of the ice-shed A. HOLLENDER has given a description of two glacial waters, the glacial lakes Stråken and Vettern.

Although glacial lakes evidently have existed also east of the ice-shed, it is, however, the region immediately west of it or between the ice-shed and the waterparting, that shows most traces of them, and here they are so frequent that this region with good reason may be characterized

as the *region of glacial lakes*. This region of glacial lakes, which in Sweden nearly coincides with the mountainous region in a proper sense, occupies a zone east of the watershed of varying breadth from about 150 kilometres (in Jemtland) to only 30—50 kilometres in the northern part of Laponia. At the end of the ice age the ancient river-valleys in that zone were occupied by long, narrow fiord-like lakes which discharged most of their water over the watershed to the west. Only at the end of their existence they might (at least in many cases) have had an outlet of short duration eastward, until the last rest of the ice-sheet was broken through or molten, and the rivers found their natural courses to the Gulf of Bothnia.

During my stay in the mountainous regions of Southern Laponia in the latter part of the summer of 1897 and during my work for the Geological Survey of Sweden in the summer 1898 I devoted myself for some time to an examination of the shore-lines in this region. Although this examination was not so exhaustive as might have been desirable, I have thought it suitable to publish the result, especially as it is impossible for me to complete it this summer.

### General geographic features.

The region in which the traces of glacial lakes to be treated of in this paper are found, comprises chiefly the upper part of the basin of the Ume-river (66° Latit.) and extends as a belt of about 100 kilometres length and 50—60 kilometres width east of the border between Sweden and Norway. It is a very hilly region, the highest summits of which attain an altitude of nearly 1800 meters above the level of the sea and the average height of which in the west may be estimated at about 1000 meters, in the east only at 6—700 metres. In this region the Ume-river and its tributaries have cut very deep valleys. The main valley and its first two tributary valleys on the left, the valleys of Tängvattnet and Jovattnet, attain an altitude of somewhat more than 500 metres, while the Björkvattnet-Abelvattnet valley, still more southward, has a height of nearly 700 metres, and the height of the westward pass of the Tärnariver, joining from the north, is considerably more than 700 m. above the level of the sea.

The direction of the glacial striæ in this region seems to be rather regular from the east-west to E.S.E.—W.N.W. according to the observations being at my disposal.

How far in the east the ice-shed has gone, is not yet to be determined, as no systematical examinations in this respect have been made. For several reasons, however, I think it very probable that it has not been situated more eastward than across the western end of Lake Great Uman, that is one or two miles east of the eastern border of the glacial lake Gäuta, indicated on the map.

### The glacial lake Tärna.

Shore-lines in this region are for the first time mentioned in 1894 by Dr. SVENONIUS, who in his journal describes from the eastern slope of Gabbie a well developed shore-line, which seemed to continue far down the wide and comparatively flat valley, at the bottom of which the present lake Tärnajaur is situated. According to a barometrical determination the height of this shore-line on Gabbie was found to be about 732 metres above ocean level. Even I have in many places observed this shore-line, which seems to be best developed in the northern parts of the valley, on the mountains Gabbie, Mesket, Laivatjåkko, and up the valley of the Älts-creek. Further to the south it is more indistinct, but in many places well traceable, as for instance on the eastern slopes of the mountains Rasjetjåkko and Skirasnuortje, where I have observed and measured roughly formed but indubitable terraces. Unfortunately my aneroid measurements are here as well as in some other places, where I have been able to observe this shore-line, performed in an unfavourable state of weather and taken from starting points, not thoroughly determined as to their height. Moreover, it appears not to be so distinctly developed that a careful determination of the water level where it has been formed is always possible, at least not in the same degree as the shore-line, along the main valley of the Ume-river, which is to be described below. Although no terraces situated above one another have been observed here, it is, finally, not quite impossible that some of the measured terraces belong to different shore-lines. Under these circumstances I shall not give any figures referring to the heights of the terraces in the Tärna-valley, only remarking, that they vary between 700 and about 760 m. above the sea level.

As far to the south as Gurk-brook north of Gurk Mountain I have observed plateaus of well sorted sand and gravel, cut to pieces by a later erosion, about 720 m. above ocean level. As far as I could gather by a rapid survey of the region, the plateaus do not occur at a greater height. They are probably to be regarded as deltas of this glacial lake, whose greatest extent to the south they in this case nearly indicate. In the north parts of Bång Mountain and Njeritjåkko less conspicuous terraces have been observed, which, according to an aiming by levelling-mirror from Gurk Mountain, is probably situated about 700 m. above ocean level. The fact that records of this glacial lake, which may be called the glacial lake Tärna, are found so far to the south, seems to indicate, that a mighty ice-rest still remained in the valley of Lajsan and very likely a good bit of way up the valley of the Tärna-river, after the mountains east and west of the Tärna-valley had been cleared from their ice-cover.

The glacial lake Tärna had probably throughout its existence its outlet westward across the Älts-valley. However, it is not quite impossible that in a later phase it communicated by the valley north of Ammar Mountain with the system of ice-dammed lakes which occupied the upper

Vindel-valley and discharged itself westward through the Vindelpass, probably somewhat less than 700 m. above the sea level.

## The glacial lake Gäuta.

### General Description.

*Extent of the lake.* As the damming ice-barrier in the southeast gradually uncovered the Tärna-valley in the region of Solberg (immediately south of Gurk Mountain), the glacial lake Tärna was poured into a lake, which occupied the main valley of the Ume-river to the northwest and from which two important bays stretched westward along the valleys of Tängvattnet and Jovattnet. Near Solberg there is also an ose-like formation. The manner in which it occurs is such as to indicate that it has, in all probability, been formed in connection with this draining process, while an ice-rest, more than 100 m. thick, still remained in the Tärna-valley south and southeast of Solberg, forcing the water of the glacial lake Tärna to find its way out into the valley of Ume-river along the northern border of the ice. This lower glacial lake, which may be named the glacial lake Gäuta after Gäutajaur in its centre, has been more carefully studied, in as much as its shores have been surveyed from 20 localities, well distributed in the region. There are, however, still several parts of it that are imperfectly known, especially the northwestern part of the lake around Lake Upper Uman and its outlet across it westward, further the bay of Jovattnet and, finally, the eastern and southeastern parts of the glacial lake.

As a glance at the accompanying map will show, the glacial lake Gäuta formed, when at its largest extent, a narrow, long extended lake, the greatest length of which in the direction northwest-southeast to a certainty was more than 100 kilometres and the width of which varied between 2 to 6 à 9 km. Two bays of considerable length stretched westward along the valleys of Tängvattnet and Jovattnet. Probably the lake extended so far to the southeast that also the valley of Björkvattnet was occupied by a similar fiord. As, however, I have no observations from here, I have not indicated this bay on the map.

In despite of its inconsiderable width, the part hitherto known of the glacial lake Gäuta occupied an area of about 600 square-kilometres. The greatest depth was in the eastern part between 150 and 200 metres.

*Outlet.* It lies very near to assume that the glacial lake Gäuta had its outlet across the pass west of Great Umevatten. I have not myself visited this locality, but Dr. SVENONIUS states in his journal of 1894 that it is about 10—12 metres above the level of Great Umevatten, and as the latter is 520,1 metres above the sea, the height of the pass consequently is about 530 metres above the level of the sea. I am certainly of opinion that the glacial lake Gäuta had its main outlet here, but I think it probable that at least at its highest watermark there was

a somewhat shallower outlet over the pass of Tängvattnet and that for the following reasons.

The height of the waterparting in the pass is, according to my measurements, about 534—535 metres; there are in the pass as well as immediately east of it sand and gravel plateaus evidently formed at a waterlevel coinciding with the height of the pass, and, finally, no indubitable shore-marks are found above the shore of the glacial lake Gäuta around the lake Tängvattnet.

It is evident that, if the glacial lake Gäuta had not reached the level of the pass, there would be above the shore of the lake Gäuta a shoreline (perhaps somewhat more indistinct) corresponding to the shore-marks of the pass and dating from the stage of the receding ice when it did not yet allow the dammed Tängvattnet any outlet over the pass of Lake Upper Uman.

*Shore-marks.* In most places where I have studied and measured the shore-marks of the glacial lake Gäuta, these have consisted of tolerably well developed *cliffs* (or *wave-cut terraces*) cut out in the till. Less frequent are accumulation terraces or *deltas*. In despite of the wood- and bush-vegetation that hides them, these formations show very distinctly that they originate from a water-surface which for some time reached this level. It is, certainly, rather rare that the shore-line is observed at any considerable distance as a strongly marked horizontal line or shelf on the slope of a mountain. On the contrary, it is in most cases hidden by the wood-vegetation and is in general revealed by cuts in promontories and in such places where brooks flow down slopes of the proper steepness. There is, however, seldom any difficulty in finding the ancient shore. Ascending a moderately steep slope, exposed to the wave-action of the glacial lake, you will almost always find a conspicuous terrace, which in horizontal direction is traceable over long stretches.

On a typical wave-cut terrace the width of the terrace-level varies from a few to 10—30 metres. Wider terraces may be found, but as a rule the most conspicuous are about 10 metres wide. The terrace-level is in general almost horizontal or declines only 2 to 5 à 10 degrees at most, while the slope above as well as below the terrace may decline several tens of degrees. In general the most conspicuous terraces are to be found where the declivity of the ground is about 20—30 degrees; where the declivity is much stronger or weaker, the shore-line is more indistinctly developed. In exposed places the base of the cliff is often found to be marked by a girdle of washed stones and blocks, which are sometimes somewhat rounded, but very rarely show any certain traces of the wave-action. In such places bare rocks also often protrude at the base of the cliff, while they are, above as well as below, almost perfectly hidden by the thick till. In one place protruding rocks of this kind (consisting of a loose mica-slate) have evidently been worn by the waves.

Indubitable terraces cut by the waves in the rock were never observed.

Plateaus of more or less distinctly stratified sand and gravel were observed in many places, especially in the narrowest part of the Ume-river-valley, that is between Klippen and Upper Uman. The slopes are here on both sides of the river in general so steep and the situation so little exposed that no wave-cut terraces are developed, but important quantities of sand and gravel were carried down by the numerous brooks and deposited as deltas in the glacial lake. Where sections were observed, these sand and gravel plateaus were found to be well stratified. At Umfors I observed, that these plateaus reach a level well corresponding to that of the glacial lake Gäuta and that they cease above it (see page 238).

The shore-line is generally wider and more conspicuous near brooks, where during the existence of the glacial lake important deltas were formed. On moderately steep slopes these seem to indicate the ancient water-level as distinctly as the wave-cut terraces into which they pass at some distance from the brooks. On flat slopes accumulation terraces no doubt occur, the crests of which lie a little above the ancient water-level, but these have not been studied.

#### Details.

*Björkfors.* From the hills west of the Ume-river at Björkfors a conspicuous horizontal offset is easily traceable on the slope just above the village. This offset is very conspicuous for a stretch of 5 kilometres at least and the most eastern settlement is situated on it. By a levelling-mirror (ELFVING'S construction) cuts in the promontories further to the north and to the south are easily observed at the same level. At a closer examination of this offset it is found to be a well formed terrace, 10—30 metres broad. The terrace-level is almost horizontal or declines only a few degrees, while the slope above and below has a declivity of several tens of degrees. The base of the cliff is mostly very conspicuous and can be followed long stretches, the barometer indicating no deviation from the horizontal level. Bare rocks sometimes lie at the base of the cliff. The terrace becomes perceptibly broader where the »Great-brook» rushes down the slope: During the existence of the glacial lake considerable quantities of debris have here been carried down and deposited into a delta which is now for the most part destroyed by the eroding action of the brook in postglacial time. This delta consists of conspicuously sorted material which is not or only rudely stratified. According to 3 aneroid measurements the height of the terrace was found to be 46, 46 +, 43 metres above a little rickle, quite adjacent, with a height of 499 metres above the sea. Aiming with the levelling-mirror, the height was found to be 48 metres. The two 46-values are obtained under the most favourable circumstances and are therefore the most correct. The altitude of the

shore-line here is consequently 545 metres above the level of the sea<sup>1</sup>. Aiming with the levelling-mirror from here, I found the shore-line marked in many places on the opposite side of the valley.

*Majsor.* East of the little lake Majsor there are deposits of sand and gravel which doubtless are in genetic relation to the glacial lake Gäuta. The highest limit of these formations, however, has not been determined.

*Tängvattnet.* On the eastern slope of Mount Kamheden towards the lake Tängvattnet and somewhat northeast of the settlement of the same name a conspicuous terrace was found, which was followed long stretches without greater deviation from the horizontal level, than locally one or two metres. Some metres above the conspicuous shore-level indistinct and irregular terraces, probably accumulation terraces, were observed in a few places. By aid of the levelling-mirror I observed on the southern side of the lake a well marked terrace-level just at the same height. — Two barometer measurements indicated the height of the ancient shore to be 67, 67,5 metres above the lake Tängvattnet (471 metres above sea), that is 538 metres above ocean level — probably a very good value, in as much as the atmospheric pressure was almost unchanged under the measurements.

*Rönnäs.* On the slope towards Tängvattnet somewhat east of the settlement of Rönnäs there is a conspicuous terrace cut in the till. In spite of the rich bush-and herbe-vegetation this terrace was followed for a long stretch eastward without interruption. Near the great Ruttje-brook, immediately east of the settlement, this terrace passes into an accumulation terrace at the same height. — The altitude of the terrace was determined to be 66 metres above Tängvattnet, that is 537 metres above the sea.

Only about 1—2 kilometres east of the waterparting of the Tängvattenpass there are sand and gravel plateaus, partly destroyed by a later erosion, that attain to the height of about 534—535 metres above the level of the sea.

On the steep northern slope of the hill about 2 kilometres northwest of Drift Mountain there is a well developed wave-cut terrace with a breadth of about 10 metres. At the well marked base of the cliff bare rocks often protrude. The altitude of the terrace was determined to be resp. 538, 537, 537, 536 metres above the sea. By a rapid levelling the height was also found to be 537 metres — probably a very good value.

*Umasjö.* Here are on each side of the brook, rushing down between the farms, horizontal accumulation terraces which at a greater distance from it pass into more indistinct cut terraces at the same height. — Two aneroid measurements indicate the height of the terraces to be 22 metres above Lake Upper Uman (520,1 metres above the sea). A levelling undertaken in stormy and rainy weather gave 21 (+) metres. The shore-line is

<sup>1</sup> On the map the height of the shore-line is indicated by figures leaning backward.

here consequently 542 metres above the sea. — From the remaining stretch around Lake Upper Uman there are no observations.

*Umfors.* Along the narrow valley between Lake Upper Uman and the settlement of Klippen the sides of the mountains are too steep and the situation too little exposed to admit the development of any conspicuous wave-cut terraces. Instead, there are at the bottom of the valley and on the slopes of the sides, where these are not too steep, deposits which in the sections observed consist of sorted, more or less distinctly stratified, sand and gravel. These plateaus attain at Klippen and next west of it only 500—525 m, that is several tens of metres above the level of the river, and they rise gradually along the river up to Lake Upper Uman without reaching the height of the glacial lake Gäuta. Somewhat south east of Umfors, near the brook flowing from North Great Mountain, sand and gravel plateaus were found, which are evidently the deltas of the brook in the glacial lake. They seem to cease at the height of 543 metres above the sea. This was, namely, the altitude of the highest terrace I have been able to observe. But I had no time to make more careful observations, and, therefore, I cannot affirm, that nowhere in the valley such plateaus reach higher, although it seemed to me to be so. The figure indicating the height agrees, at any rate, with that of the shore-line of the glacial lake at Umasjö and Björkfors.

*Lajsholm.* 3—4 kilometres WNW from Lajsholm a conspicuous terrace was found, stretching in horizontal direction several kilometres with only a few local deviations from the horizontal level. The terrace is chiefly a wave-cut terrace with well developed base of the cliff. — According to three barometer measurements the height of the shore-line was found to be resp. 97, 94 +, 96 metres above Lake Lajsan (452,1 above the sea) that is, on an average 548 metres above the sea.

About 5 kilometres further eastnortheastward there are very conspicuous terraces the height of which, according to two aneroid measurements, is 98—99 metres above Lake Lajsan, that is 550—551 metres above the sea. From here I also observed that this shore-line is distinctly marked up the Jovatten valley. Aiming at Lax Mountain south of Lajsan, I found a well developed system of terraces at the same height.

*Solberg.* The shore-level of the glacial lake is here well marked and is distinctly seen as far as from Lax Mountain and the western slope of Gäutavardo. On the southwestern slope of Sol Mountain (South of Gurk Mountain) there are conspicuous cut terraces, which, according to aneroid measurements, lie 100 metres above Lajsan, that is 552 metres above the level of the sea. Somewhat southwest of the settlement a conspicuous accumulation terrace of same height was observed. It consists, at least in its lower peripheral parts, of sand distinctly stratified. Somewhat northeast of the settlement there is a broad plateau, reaching in some places about 10—12 metres higher and without interruption passing into the oseformation, mentioned above (page 234). By aid of a levelling-



mirror the shore-line is traceable from here along the western slope of Gäutavardo and north of Oltokjaur.

*Lax Mountain.* The shore-line is easily followed around the beautiful Lax Mountain, which during the existence of the glacial lake was an isle in it. Especially on the southern slope of the mountain a conspicuous terrace, cut out in till, was found and followed at the same height more than one kilometre. At the base of the cliff a zone of blocks and stones is found, sometimes richly covering the whole terrace-level. Bare rocks also often protrude at the base of the cliff. According to two aneroid measurements the height of the shore-line on the southern slope of the mountain above Tärna chapel was indicated to be 114,5 metres above Gäutajaur (438,4 m. above the sea), that is 553 metres above ocean level.

In the northeastern part of Lax Mountain a conspicuous terrace was measured, Gäutajaur as well as Lajsan being starting points. In both cases the height was found to be 552—553 metres above the sea. By aid of the levelling-mirror I observed corresponding terraces at Solberg and Lajsholm and on the northwestern slope of Gäutavardo.

*Tärnafors.* In the NW part of Gäutavardo, immediately east and northeast of Tärnafors, there are well developed terraces cut out in till. The terrace-level here is often very narrow — from a few to 10—12 metres wide — with a declivity of only a few degrees. The base of the cliff is often particularly well marked by blocks and bare water-worn rocks. — Several barometer measurements indicate the altitude of the terrace to be 556 metres above the sea.

On the NE slope of Gäutavardo towards Oltokjaur distinct wavecut terraces were found, which by aid of the levelling-mirror were shown to lie at about the same height as conspicuous horizontal terraces east and north-east of Oltokjaur. According to two aneroid measurements (lake Oltokjaur, 481,7 metres, being starting point) the height of the terraces was found to be resp. 557, 560 metres, on an average 558 metres above the level of the sea.

*Björkbacken.* Immediately above the settlements of Björkbacken, situated east of the lake Oltokjaur, there is a very conspicuous terrace. According to an aiming with the levelling-mirror from the lake, this terrace was found to be about 560 metres above the sea.

From the eastern part of Gäutavardo I observed that the ancient shore-line continues to the east along the valley, at the bottom of which the lake Jokksjaur is situated. According to information, given me by Mr O. Pettersson, there are also conspicuous, horizontal terraces around the lake Boksjön, but I have had no opportunity of making any direct observations and measurements here.

*Stalofjället.* On the western slope of Stalo Mountain towards the little lake Blattnikselet I have from the lake observed a terrace which is probably the continuation of the shore-line of the glacial lake. By levelling-mirror the height of the terrace was found to be between 562 and 569, at a medium about 565 metres above the sea.

*Brakk Mountain.* On the SE slope of Brakk Mountain, some kilometres SW of the settlement of Rödingsfors, I observed rather indistinct terraces, the height of which, according to an aneroid measurement, was found to be about 562 metres above the sea. By aid of the levelling-mirror a terrace on the mountain east of Ajaur was observed at nearly the same height.

On the mount Bratikken, situated about 2 miles further to the southeast, I observed in the twilight at probably the same height a horizontal line, which may possibly be the continuation of the shore-line of the glacial lake. — At the time of my visit, there was no topographical map with figures indicating altitudes of this region, and therefore I could not examine it.

*Upper Jovattnet.* Along the Jovattnet-bay I have had no opportunity of performing any measurements. From Lajsholm and Lax Mountain I could distinctly see that the shore-line of the glacial lake Gäuta continues up the valley. From the upper part of it, south of the lake Upper Jovattnet, Mr O. P. P.—n speaks of »a conspicuous shore-line at a height of about 40 metres above the lake» (See: Svenska Turistföreningens årsskrift för år 1898, page 330.) This shore-line lies consequently about 526 metres above the sea — a figure which, being only approximate, is almost what was to be expected here.

### Remarks on the unequal uplift of the ancient shore-lines.

The study of the shore-lines of the ice-dammed lakes is of very great importance, when the question is how to determine the differential elevation which the interior parts of Scandinavia experienced in postglacial time. For that end it is, of course, necessary to know that the shore-marks, levelled in different places are really formed just at the same water surface, and that the figures indicating the altitudes are as exact as possible. In the mountainous regions of Scandinavia several different shore-levels occur at comparatively small vertical distances from each other, owing to the frequent change of outlet, the blocking up of it by a glacier and so on. Careful examinations are, therefore, sometimes required, when the same shore-line is to be followed for a long stretch. — Attention is also to be given to the state of the shore-marks because (as especially Prof. HÖGBOM has shown) accumulation terraces mostly reach considerably above the surface at which they have been formed. — Especially the glacial lake Gäuta seems in these respects to be fit for the study of level-changes. Firstly, on my examination of this shore-line I never found any conspicuous shore-level either above or below it. Moreover, from almost all points of observation I have been able to ascertain that the same shore-line has been measured in the different places. Finally, almost all shore-marks that I have measured are conspicuous erosion terraces and consequently the ancient water surface is, no doubt, rather accurately indicated. As for the determination of altitudes, all the figures are, except at Umasjö and north-

west of Drift Mountain, where I also levelled the shore, obtained by aneroid measurements. In almost all places more than one determination (sometimes 4—5) were made, all with entirely or very nearly the same result. As the distances of the points of observation from the levelled surfaces from which I started, are very small and the barometer used was very good, I think the figures obtained have no greater errors than about one or two metres, in most cases probably less.

If the localities are arranged from west to east, the following table indicating the height of the shores of the glacial lake Gäuta is obtained.

Locality.	Height above the sea in metres.
The pass west of the lake Upper Uman . . . . .	530±
» » in the Tängvattnet-valley . . . . .	534+?
Ca 1 km east of the pass in Tängvattnet-valley . . . . .	534—535
Rönnäs . . . . .	537
Northwest of Drift Mountain . . . . .	537
Tängvattnet . . . . .	538
South of the lake Upper Jovattnet . . . . .	526+
Umasjö . . . . .	542
Umfors . . . . .	543
Björkfors . . . . .	545
West of Lajsholm . . . . .	548
East of Lajsholm . . . . .	550
Solberg . . . . .	552
Southern slope of Lax Mountain . . . . .	553
Northwestern slope of Lax Mountain . . . . .	552
Tärnafors . . . . .	556
West of the lake Oltokjaur . . . . .	558
East of the lake Oltokjaur . . . . .	560+
Blattnikselet . . . . .	565
Brakk Mountain . . . . .	562+

A glance at this table will be sufficient to show that the shore-line rises remarkably and on the whole regularly eastward and southeastward. In the direction of the stretch that was most carefully examined (Rönnäs—Oltokjaur) that is westnorthwest—east-southeast, the gradient is somewhat greater than 1:2000, whereas in the direction of the main valley (from Umasjö to Lax Mountain), that is in south-southeastern direction, it is about 1:3000.

It is perhaps somewhat unexpected that the gradient is so great, more especially as Dr G. ANDERSSON did not find any similar inclination in the shore-lines of the glacial lakes of Jemtland. It was, indeed, to be expected that the gradient of the shore-lines of the icedammed lakes should be less than the one indicated by the highest shoremarks of the Yoldia-sea, because the elevation probably began, before the glacial lakes

came into existence and then continued without interruption during their life. — Possibly a more careful examination of the northwestern and most southeastern parts of the glacial lake Gäuta and its numerous bays will modify the figures I have obtained for the gradient; in any case, it will no doubt more carefully indicate the process of elevation in the region. I hope to come back to this question another time.

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# MAP OF THE GLACIAL LAKE GÄUTA.

0 5 10  
Kilometres

