SUOMEN GEOLOGINEN TOIMIKUNTA | GEOLOGISKA KOMMISSIONEN I FINLAND

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N:o 81

ON THE DEVELOPMENT OF LAKE HÖYTIÄINEN IN CARELIA AND ITS ANCIENT FLORA

BY

MATTI SAURAMO AND VÄINÖ AUER

WITH 20 FIGURES IN THE TEXT AND 4 PLATES

REPRINTED FROM
COMMUNICATIONES EX INSTITUTO
QUESTIONUM FORESTALIUM FINLANDIAE EDITAE 13

HELSINKI - HELSINGFORS
MARCH 1928

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INTRODUCTION.

Among the thousands of lakes of Finland Lake Höytiäinen in northern Carelia (fig. 1) has aroused greater interest than most other lakes. This lake with an area of 265 square kilometres had a natural outlet westward, into Lake Viinijärvi, past the parish church of Polvijärvi (map, Pl. I), but in 1859 Lake Höytiäinen found a new outlet at the southern end of its basin. Endeavours were made by means of a lock-canal here to connect the said lake with Lake Pyhäselkä across the terminal moraine of Jaamankangas. The lock-contrivances were, however, not strong enough, so the waters of the lake forced themselves through and eroded the canal down to bedrock. Now the outlet of Polvijärvi went dry and the surface of the lake fell in the course of about a month 9.5 metres or from 97 to 87.5 metres above the sea level.

The event was the most striking of its kind in the history of lake-drainage in Finland. A very vivid description of the drainage, its nearest causes and consequences has been given by E. G. PALMÉN (1903). The extensive outlet eroded by the volumes of water and the structure of the soil layers around it, was studied a fresh after the event by A. F. THORELD (1862), and somewhat later by PETER KRAPOTKIN, (1876) the famous Russian geographer.

At present the outlet of Lake Höytiäinen is a rather insignificant river running along the bottom of the ravine that was formed by the catastrophe.

On the sudden fall of the lake a total of 170 square kilometres of lake-bottom, which had formerly been under water, was disclosed. The main part of the alluvial area is situated in the northern part of the basin, the shores of the lake there being gently sloping. The economic profit derived from the drainage of the lake is thus concentrated to this part. There were left considerable areas of meadow, arable land and forest land. In the southern part where the shores are steep there is between the earlier and the present shores of L. Höytiäinen a belt of land from 50 to 100 metres broad covered with barren sand, gravel and accumulations of cobble-stones for the most part. In some places also peat strata with thick stump layers were disclosed. These submerged forests, more than anything have drawn the interest of geologists on L. Höytiäinen.

As an explanation of these forests two theories greatly differing from each other have been presented. THORELD, whose early investigation was mentioned above, and later on A. R. HELAAKOSKI (1915) assume that those tree trunks and peat fragments have been pushed from the shore of the lake into the water, where they were partly covered by the littoral accumulations. The stub layers would after the fall of the lake have glided underneath the old shore line.

R. HERLIN (1896) advanced another hypothesis. He carried out phytopaleontological investigations in great detail and concluded that the peat layers and stubs in question are in their original position. The same opinion was later held by W. W. WILKMAN (1912) who inferred that they had come under water because the uplift of the earth crust in that region had later turned into a sinking of the crust. The upheaval would have progressed in an undulating manner from the periphery of the area of glaciation towards its centre. BLYTT-SERNANDER's theory concerning the variation of dry and moist periods does not suffice, according to WILKMAN, to explain those submerged forests.

Since the appearance of the last-mentioned publication rapid progress has been made in the spheres of investigation concerning the change of level and the peat bogs. The results attained have helped us to see the earlier research made at L. Höytiäinen in a somewhat new light. This lake seemed to represent a case where particularly good results might be expected, as here the earlier submerged areas from which the evidences of transgression can be found have at a later time become disclosed and are therefore much easier to study than in other lake basins where the proofs of transgression must be revealed exclusively by borings under water.

For the purpose of attacking this problem it was agreed between Professor J. J. SEDERHOLM, Director of the Geological Survey, and Professor OLLI HEIKINHEIMO, Director of the Forest Research Institution, that the authors of this publication should together carry out an investigation on L. Höytiäinen, as proposed by Professor WILHELM RAMSAY. The field observations being the basis of our joint publication were made by us in the summer of 1927. In these we were able to draw attention principally to the investigation of the shore peat bogs of L. Höytiäinen, the ancient shores (with the exception of those belonging to the lake stages) having been previously studied by SAURAMO (1928). Under the experienced guidance and collaboration of AUER he had a good opportunity of being acquainted with the methods of peat bog investigation in the field.

He made use of the same advantageous opportunity when the collected material later in the autumn was treated in the laboratory of the Forest Research Institution. The microscopic investigation of the samples of peat was chiefly made by SAURAMO, while AUER in numerous cases checked his determinations and chiefly devoted himself to the history of the development of the flora. The drawing of the plates and maps accompanying our publication have been made at the Geological Survey.

We have thus while working together acquainted ourselves with each other's methods and checked them in the field as well as laboratory work.

THE DEVELOPMENT OF LAKE HÖYTIÄINEN.

By

Matti Sauramo.

TOPOGRAPHIC AND GEOLOGIC FEATURES OF THE REGION.

The neighbourhood of L. Höytiäinen in the northwest, on the northern side of the Polvijärvi church, is for an extent of from 10 to 30 kilometres a low flat country. Farther away the terrain rises 100 or 200 metres above the lake, but in places, e. g. at Martonvaara, the higher land approaches the shore itself. The region is also flat in the east, but it fells plateau-like rather steeply 30 or 40 metres to the lake. The whole southern and southwestern shore up to the neighbourhood of the Polvijärvi church is also steep and high. In the last-mentioned district the shore is more broken than elsewhere, and the land-forms are more uneven.

The form of the basin of Höytiäinen is evidently controlled by the varying character of the bed-rock. It has been excavated in that part of the Carelian schist formation where the soft phyllite is alone prevailing. The high region in the north is built up of quartzites that have better resisted erosion, while in the southeast and southwest the basement of the schist formation, the granite gneiss, reaches the surface and also forms higher lands. Between the two protruding masses of granite gneiss the schist area extends continuously towards the south. Here the ponding of the water in L. Höytiäinen is probably effected only by the Quaternary deposits, namely, the vast masses of glaci-fluvial materials of the Jaamankangas.

Elsewhere the superficial deposits chiefly consist of morainic drift. It is in general fine-grained and sandy.

Assorted glacifluvial gravels build up rows of eskers, mos. abundantly on the western and northwestern coast of the laket Clay and silt occur at levels above the lake surface only in northern part of the lake basin in the surroundings of the long and narrow bays as Rauanlahti (map Pl. I, point 2).

THE OBJECT OF THE INVESTIGATION.

Peat bogs originally formed on land but later drowned have been found in many lakes in Fennoscandia. As an example we may mention Lake Hornborga in Sweden which has been studied in detail by R. SANDEGREN (1912). In Finland we have a similar case in Lake Vanajavesi. It has been thoroughly investigated by VÄINÖ AUER (1924), who ascertains, among other things, that terrestric peats and old dried soils had, farthest in the south-east part of that basin come under a cover of water up to 11.5 metres deep.

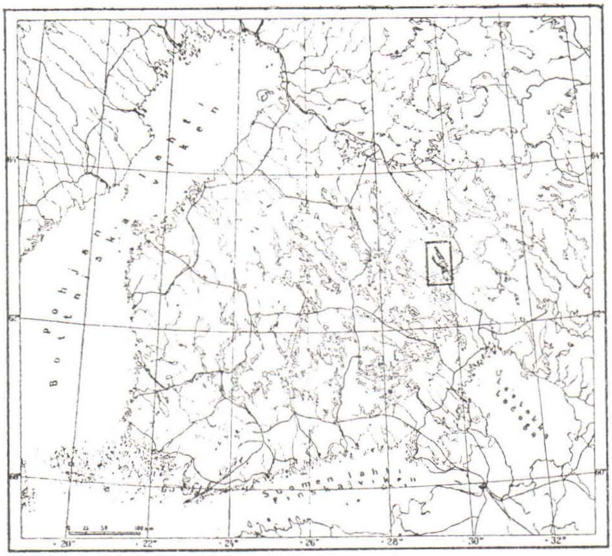

Fig. 1. Location of Lake Höytiäinen.

According to both investigators, the transgression in these cases is due to the regional variation in the amount of upheaval. The threshold of the outlet has risen more than that part of the lake basin which is farthest away from the centre of upheaval. As the height of the threshold determines the water level in the lakes, the water surface has in the said part of the basin been continually rising.

The upheaval has in the whole of Fennoscandia been regionally different. In Carelia the late-Glacial shore levels have warped towards the southeast (SAURAMO 1928). Therefore it was expected that the deformation of the crust would, also during the later part of the Quaternary period, have warped in the same direction, and that this could be demonstrated in the basin of Lake Höytiäinen.

This seemed so much more probable as submerged peat bogs have actually been found only in that part of the lake basin which is on the southeast side of the earlier natural outlet near the church of Polvijärvi. The transgression would thus find an explanation similar to that in the case of L. Vanajavesi.

Taking this probability into consideration the question does not apply only to the structure and conditions of deposit of those problematic shore peat bogs and their later destinies. Our problem widens so as to comprise the development of the whole lake, above all the changes of the shore-lines which have taken place in the basin.

METHODS.

We shall endeavour to explain the shifts of level within the bounds of this area after the Ice Age, and especially those of Höytiäinen during the period of its lake stage. To this end we shall apply the evidence of old shores as well as of the soils, particularly of the peats.

It is not necessary here to deal with the methods concerning the said lines of investigation separately. As regards the investigation of old shore marks we may refer to RAMSAY's last publication (1928), and to the investigations of the present writer concerning Northern Carelia (1928). In the sphere of the investigation of peat bogs the methods generally used in Northern Europe developed by L. v. POST (1909) have been applied in the form they have been adapted, completed and checked by AUER, above all in his investigation on Lake Vanajavesi.

In so far as anything noteworthy in the sphere of the methods of peat bog and shore investigations at Höytiäinen may appear, special mention will be made below. An account of the evidences for the chronology necessary as a frame-work of the history of the development will be given at the proper places.

TIME BEFORE THE LAKE STAGE.

The writer has carried out investigations on varved sediments in wide tracts of Central Finland, comprising the area now under consideration. According to the results of these chronological studies which have not yet been published the region of Höytiäinen was released from the ice sheet of the Quaternary Ice Age at the beginning of the fini-Glacial epoch, after the Salpausselkä stages. The sandy ridges of Jaamankangas ponding the lake in the south belong to that great series of recessional moraines which run across the whole of Fennoscandia. The Jaamankangas represents, within this belt of slow recession, the third great halt, that one during which the so-called third Salpausselkä was formed in Western Finland. This halt begins about the year 100 counting from the end of the second Salpausselkä stage.

Owing to the scarcity of varved sediments the retreat of the ice sheet cannot be followed in detail at the southern part of the basin of Höytiäinen itself. The edge of the ice sheet arrived at the northern

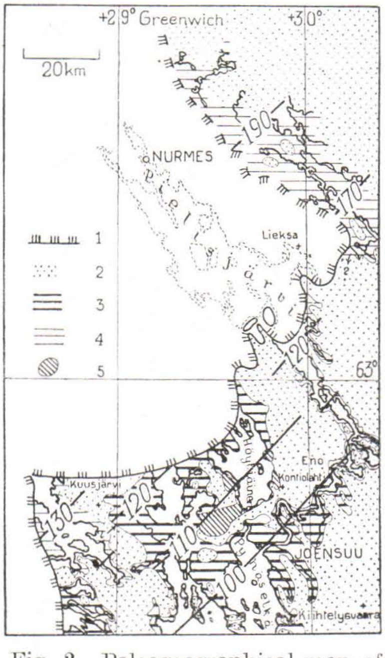

Fig. 2. Paleogeographical map of Northern Carelia at the Yoldia period. 1 Ice edge. 2 Dry land. 3 Yoldia Sea with its isobases 4 Ice-ponded lakes. 5 Dead ice and ablation moraine.

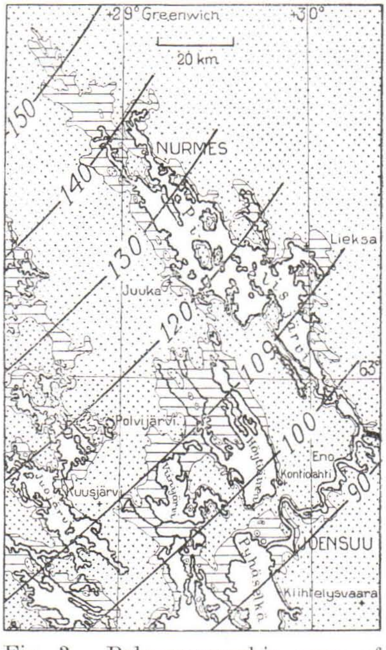

Fig. 3. Paleogeographic map of Northern Carelia at the Ancylus time. The isobases of the Ancylus Lake given in metres. The isobasis of 114 metres represents the zone of the outlet in Central Sweden.

end about the year 450 after the second Salpausselkä stage. But at the same time considerable masses of »dead» ice had remained on the southern side of the coherent, »living» ice sheet, especially on the proximal edge of the recessional moraine of Jaamankangas where there is a belt of typical ablation moraine. Detached masses of ice have remained also on the bottom of special depressions with steep walls. These melted away as late as about the year 500, as may be concluded from the position of the highest shore of the regions in question being here lower than in the surrounding areas (Fig. 2).

As regards the changes of level, the said halt at Jaamankangas represents that important stage when the Baltic ice-lake and the local ice-ponded lakes in the district of the watercourse of Saimaa finally drained to the level of the ocean. The signs of the highest water surface which appear in the basin of Höytiäinen represent the surface of the Yoldia Sea (SAURAMO 1928). Its absolute elevation is at the southern end of the basin 105 metres. Towards northwest the height of the shore level rises 63 centimetres per kilometre and attains a height of nearly 130 metres on the northern half of the basin of L. Höytiäinen (Fig. 2, 4, 5 and 6).

Fig. 4. Shore cliff of the Yoldia Sea. Kinahmi, NW of Höytiäinen. Photo M. SAURAMO.

The levels of the Yoldia Sea and of the other shore surfaces are shown in the graph Pl. II. They have been designated, in a chronological succession, by figures I—IX and their names: Yoldia, Eo-Ancylus 1, Eo-Ancylus 2, Ancylus 1, Ancylus 2, isolation shore of L. Höytiäinen, shore at the time of the arrival of spruce, shore of 1859, and the present shore. Fig. 2 shows sections from slope of the lake basin at certain points where old shores have been observed and levelled.

The Yoldia Sea stage ends in the district of the Baltic basin about the year 400 or 450. The next four lower shores found in the district of the basin of L. Höytiäinen represent the stages of the Ancylus Lake (see fig. 3, 5 and 8) during the time when its outlet was in Närke, in Central Sweden. The immense masses of water that were poured out here with a great fall (MUNTHE 1927) have greatly eroded its channel, so that the water surface in the Ancylus Lake gradually sank.

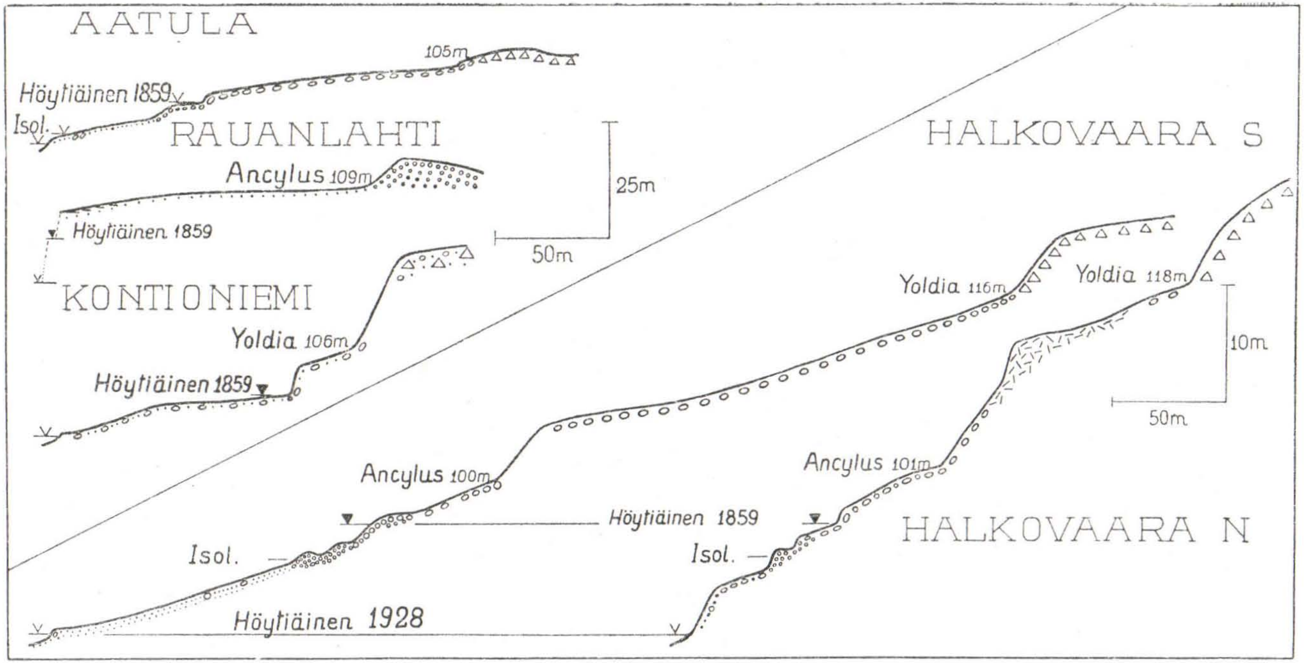

Fig. 5. Selected sections across the slopes of the basin of Lake Höytiäinen showing ancient shores from the lake stage as well as from still earlier times. The highest shore of 105 metres near Aatula represents the Eo-Ancylus.

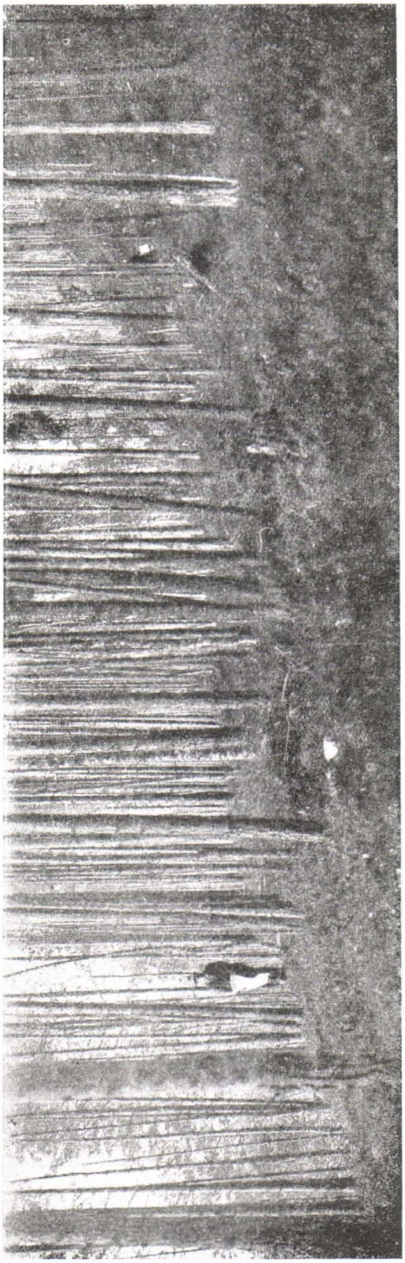

Fig. 6. The Yoldia beach at Kontioniemi, 14, S of L. Höytiäinen. The man to the right stands at the foot of the steep cliff of the Yoldia Sea; another man to the left stands at the crest of the shore cliff of the old Lake of Höytiäinen. Photo M. SAURAMO.

Remarkable enough, these events are quite plainly registrered by the ancient shores here in Carelia, so far away from their actual scene. A detailed account of these relations has been given in another paper (SAURAMO 1928).

At the same time a powerful transgression took place in the Baltic basin southeast of that isobasis which runs over the threshold in Närke. The region of Central Sweden had ultimately risen so much that the Ancylus Lake found for itself a lower outlet through the straits of Denmark. This happened about the year 900 when the edge of the ice sheet had retreated to East-Bothnia. When a new outlet thus opened far south, transgression in almost the whole of the Baltic basin, and also in Northern Carelia, turned into regression. The water surface continued to sink and ultimately sank underneath the surface of that strait which has connected the basin of L. Höytiäinen with the Ancylus Lake. Höytiäinen was cut off into an independent lake, which from that time onward had a special development of its own.

L. HÖYTIÄINEN AS LAKE.

THRESHOLD AND ISOLATION.

According to our observations, the neighbourhood of the parish church of Polvijärvi is the only place that can be considered as a point of isolation of Höytiäinen, or, in other words, the place where its natural outlet was situated until the year 1859.

In the deeper depressions of the outlet there are two narrow, long ponds, Polvijärvi and Mertajärvi. The last-mentioned, the

Fig. 7. The same terraces as in fig. 6 seen from a distance. Photo V. AUER.

Fig. 8. Shore cliff and terrace of the Ancylus Lake cut in an esker. Rauanlahti NW of Lake Höytiäinen. Photo V. AUER.

more eastern one, is only 1.6 metres lower than the surface of the old Höytiäinen. The pond in the south, the highest point of the outlet, may be considered as the real threshold of the old Höytiäinen (map Pl. I, point 1). Its height from the present Höytiäinen is 8.1 metres.

The outlet has at this point gently sloping shores cut in a hard stony morainic drift. Erosion has not been able to deepen it much, evidently in consequence of the small fall, nor has in all probability the surface of Höytiäinen in the course of thousands of years appreciably sunk owing to the wear and tear of its threshold.

This position of the threshold influenced the development of Höytiäinen in a decisive manner, as, judging by the position of the shore surface of Yoldia and Ancylus, the earth crust has warped towards the southeast. The line running through the threshold in the direction of the isobases of the said shore surfaces divides the lake into two parts, in which the later events were very different. Regression still continued in the northwest part, although much more slowly than previously; in the southeast part the earlier regression turned into transgression.

The cutting of the basin as an independent lake thus means in itself a change, and in the southern part a direct turning-point in the changes of level that took place within the boundaries of the basin. The beginning of the lake stage should be registered by a specially developed s h o r e o f i s o l a t i o n. Its surface should be inclined towards the southeast, just as that of the Ancylus Lake, but less so. It should cut the shore surface of L. Höytiäinen of 1859 along the isobasis running through the threshold. On the northwestern side of the same isobasis, the shore surface of isolation should rise above the ancient shore, on the southeastern side again it should sink underneath, the more so the farther we go.

It might be expected that the shore of isolation should be best developed on the southeastern half of the lake. It there represents that limit, below which the water surface can never have been after the Ice Age. Beneath this lowest shore one cannot expect to find any kind of shores. It is also the lowest limit of the spreading of dry-land deposits, especially of the oldest terrestric and telmatic peat. These peats as well as the shore marks have, owing to the transgression that has taken place afterwards been later submerged, but through the fall of the surface of the lake in 1859 become again exposed, though it is likely that they have to some extent changed.

These two theoretical postulates: that of the existence of an absolutely lowest shore, and that of the lowest appearance of the terrestric peat may possibly be verified and ascertained by actual observations. Of these the appearance of peat bogs and stumps is, no doubt, the most palpable evidence and undisputably permits but one interpretation. Therefore it is most convenient to commence the search of the isolation shore by means of an investigation of the peat bogs.

It is worth mentioning that the layers of peat below the ancient shore are very scarce, so scarce in fact that the end aimed at can barely be reached.

RECORD OF THE PEAT BOGS.

Kunnasniemi, Mustonen, point 2. Close to the farm of Mustonen, a narrow depression in the direction of the shore under a steep cliff belonging to the shore of L. Höytiäinen of 1859, where there is a peat stratum 1 ½ metres thick. The borings show the structure of the peat bog to be such as shown in fig. 9. Lowest there is a rather thin telmatic *Carex* and brushwood peat, and upon it also a telmatic layer of *Carex-Phragmites* peat. The main part of the peat bog comprises, however, terrestric *Sphagnum* and forest peat, and a layer of stumps occurs in the surface part of the last-mentioned. The uppermost of these pine-stumps »in situ» rise from the surface of the peat bog and they have been greatly worn by the abrasion of the water (Fig. 10).

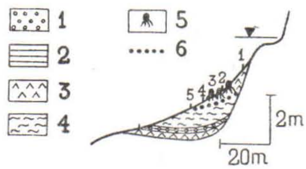

Fig. 9. Section across the shore peat bog near Mustonen, 21. Shore of 1859 is designated by ▼ 1 *Phragmites.* 2 *Carex.* 3 Forest peat. 4 *Sphagnum.* 5 Stubs. 6 Limit of *Picea.*

The regular structure of this peat bog shows this deposit to be in its primary position and to have formed from the beginning above the surface of L. Höytiäinen. It has afterwards submerged. The shore of isolation must therefore be at a lower level than the bottom of this peat bog, or more than 4.5 metres lower than the shore of Höytiäinen of 1859.

Kunnasniemi, Lahdenpohja, 22. A coherent peat bog on even ground, the main part beneath the shore of 1859. The greatest thickness of the peat is 3 or 3.5 metres. The sequence of layers along the section fig. 11 is overall the same: In the main part of the real peat bog there is, lowest, a layer of peat from 1 to 1.75 metres thick, which is very rich and of a special kind composed chiefly of *Carex* with *Phragmites* and *Equisetum.* The composition indicates a telmatic origin. Higher up follows a pure *Carex* peat and then a *Sphagnum* peat from 1 to 2 metres thick with thick layers of stumps.

On the lake side one meets with a telmatic *Amblystegium* peat and a thin purely limnic stratum under the afore-said *Phragmites* peat. The basement of the last-mentioned coherent peat deposit

Fig. 10. Stub layer on the surface of peat bog near Mustonen, 21, Kunnasniemi, W of Höytiäinen. Before 1859 submerged below the lake water, in that year disclosed at the sudden fall of the lake.
Photo M. SAURAMO.

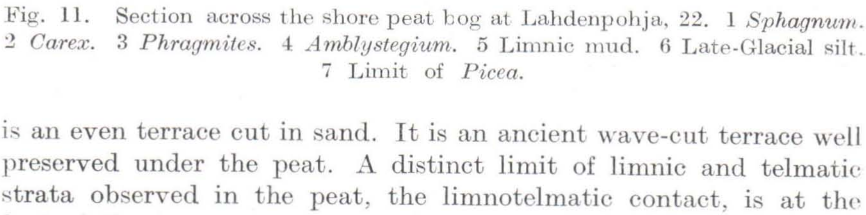

Fig. 11. Section across the shore peat bog at Lahdenpohja, 22. 1 *Sphagnum*. 2 *Carex*. 3 *Phragmites*. 4 *Amblystegium*. 5 Limnic mud. 6 Late-Glacial silt. 7 Limit of *Picea*.

is an even terrace cut in sand. It is an ancient wave-cut terrace well preserved under the peat. A distinct limit of limnic and telmatic strata observed in the peat, the limnotelmatic contact, is at the foot of the terrace, 4.10 metres above the present Höytiäinen and 5.40 metres beneath the shore of 1859. The peat stratum as well as the shore terrace afford definite evidence permitting no other interpretation but that at the said height the water line of the oldest stage of L. Höytiäinen, or the s h o r e o f i s o l a t i o n, has been found.

Another shore cliff has been cut into the peat itself somewhat beneath the contact of *Phragmites*- and *Carex*-peats and the limit of common spreading of spruce pollen. The peat bog has formerly

Fig. 12. Alluvial land at Lahdenpohja, Kunnasniemi, W of Lake Höytiäinen. Photo V. AUER.

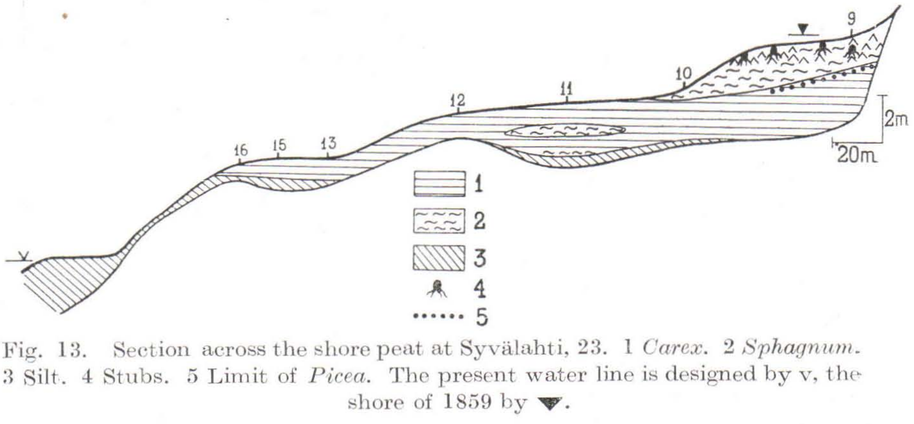

Fig. 13. Section across the shore peat at Syvälahti, 23. 1 *Carex*. 2 *Sphagnum*. 3 Silt. 4 Stubs. 5 Limit of *Picea*. The present water line is designed by v, the shore of 1859 by ▼.

extended farther, but wave erosion has worn off a great deal of it, almost to the original limnotelmatic contact.

K u n n a s n i e m i, S y v ä l a h t i, 23. A peat bog in the farthest corner of the Syvälahti bay, the main part beneath the shore of 1859 (fig. 13 and 14). The thickness of the peat layer is in some places nearly 4 metres. The upper part of this consists of *Sphagnum* peat with stump layers, the lower part chiefly of telmatic *Carex* peat. The limit of the common spreading of spruce pollen lies here also at the contact. At the bottom there is a thin limnic stratum of ooze. The limnotelmatic contact is in that part which is perfectly open towards the lake 3.4 metres above the present Höytiäinen and 6.10 metres beneath the shore of 1859. It evidently shows the waterline at the time of the isolation. Even from this peat bog wave erosion has, during the time of transgression, worn off the surface layers on the lake side.

Fig. 14. Peat bog at Syvälahti, W of L. Höytiäinen. Disclosed from water in 1859. After this time forest has grown on the bog which now again becomes deforested and cultivated (in the fore-ground). Photo M. SAURAMO.

J o u t s e n n i e m i, 19. The peat bog spreads on the bottom of the valley above and below the shore of 1859. (Fig. 15.) Its thickness in some places is up to 5 metres. It reminds one of the former as to structure, but the limnic strata are completely lacking. It represents a case where the peat bog or at least the remaining part of it has formed rather high above the shore of isolation, and only later partly come under water through transgression.

P u n t a r k o s k i, 17. Sohlman's house. Peat layers spread below the shore of 1859 and have partly been brought under cultivation, (Fig. 16). Stumps and tree-trunks stick out from the surface. The peat here evidently represents remains of thicker peat layers preserved from wave erosion and partly detached from their original position. The layers were formed before the arrival of spruce.

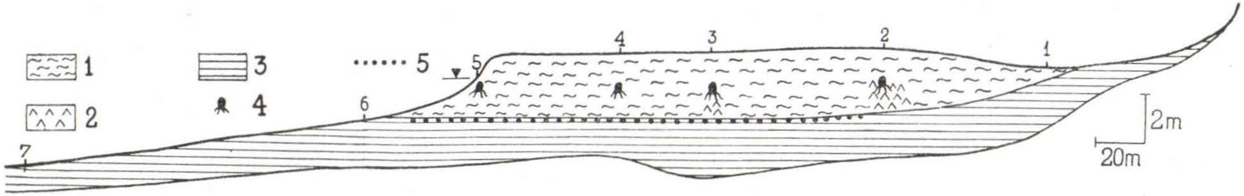

Fig. 15. Section across the peat bog at Joutsenniemi, 19. 1 *Sphagnum.* 2 Forest peat. 3 *Carex.* 4 Stubs. 5 Limit of *Picea.* The shore of 1859 designated by ▼.

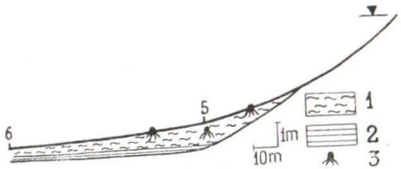

Fig. 16. Section across the shore peat bog at Puntarkoski, 17. 1 *Sphagnum.* 2 *Carex.* 3 Stubs. The shore of 1859 designated by ▼.

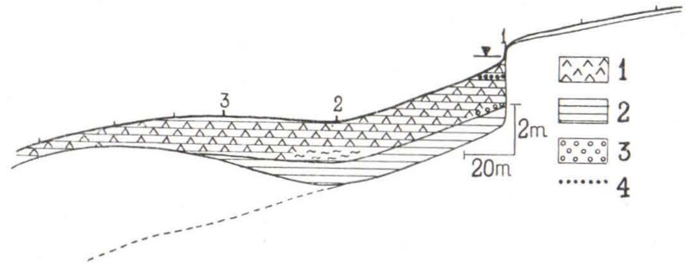

Fig. 17. Section across the shore peat bog at Paskonpohja, 16. 1 Forest peat. 2 *Carex.* 3 *Phragmites.* 4 Limit of *Picea.* The shore of 1859 designated by ▼.

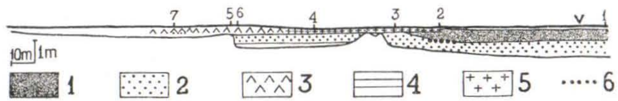

Fig. 18. Section across the shore peat bog at Kontiolahti, 15. 1 Ooze. 2 Accumulation peat. 3 Forest peat. 4 *Carex.* 5 *Amblystegium.* 6 Limit of *Picea.* The present water surface designated by v.

Paskonpohja, 18. As regards its structure and position to the shore of the Höytiäinen of 1859 this peat bog (Fig. 17) is most similar to the peat bog of Joutsenniemi. It differs only in so far that here also *Phragmites* peat occurs below the limit of spruce pollen. Deepest there is a layer of peat bog covered with fine-grained sand and silt. The basement is evidently a shore terrace, at a height which belongs to the shore surface of the Ancylus Lake.

Kontiolahti, 15. A low corner of the bay is in its lowest part at great length covered with a thin peat, which represents old preabiegnic remains of a thicker series of peat strata, all that has been preserved from wave erosion. Upon a sandy bottom there are (Fig. 18) first limnic strata and ooze, and above these a layer of telmatic sedge peat and another of terrestric forest peat. The limnotelmatic contact between these is throughout clear and at the same height, on a level with the present surface of the water. On the area covered with water there is recent ooze upon old preabiegnic formations and telmatic brown moss peat at the water line.

According to the observations described above there are below the shore of 1859 thick and very old peat strata »in situ» at the southern end of L. Höytiäinen. These have formed on dry ground, others at the very oldest water line. During the time that followed the common spreading of spruce the peat bogs were covered with a rich forest vegetation. Later on the transgression of water has covered and to a large extent destroyed these organogenic terrestric deposits.

At Kunnasniemi, 22, Syvälahti, 23 and Kontiolahti, 15 the formation of peat has from the outset taken place on the shore of the lake on the water line and a little above and below the water. In these places the lowest water limit of the lake may be determined from the limnotelmatic contact. This surface corresponding to the shore of isolation, is in the corner of the bay of Kunnasniemi 4.10 metres, in the peat bog of Syvälahti 3.30 metres above the present lake surface and at Kontiolahti on a level with it.

RECORD OF THE SHORES.

The lowest water limit ascertained at Kunnasniemi by means of terrestric peat gave a clue as to the height at which the lowest shore was to be sought. It was not in vain that it was sought for. In the belt of land between the old and the new shore an upper and a lower zone may be distinguished which very markedly differ from each other.

In the upper belt there are apparent signs of the geological agents that once worked upon the shores. The ancient shore line is in a striking manner indicated by boulders that were pushed by the ice in wintertime and which are in an upright position, leaning somewhat inland. In some places the boulders have accumulated to form a coherent ice rampart. At the foot of the ice rampart there extends a terrace surface densely paved with stones. Still lower down the bottom is very stony, in many places arranged into rows of stones and somewhat like embankments.

Fig. 19. Ice rampart of the isolation shore at Mustonen, 21, Kunnasniemi, W of Lake Höytiäinen.
Photo V. Auer.

In the lower belt the ground is usually sandy or consisting of a still finer soil. A few stones may occur, but their position indicates no push of the ice. In short: signs of the geological agents indicating the shore are lacking.

The limit of these two belts is usually marked by a distinct and coherent row of stones which remain strictly at the same level. It is a well-marked ice rampart; the stones, however, especially large flat-shaped boulders, do not stand upright as on the shore of 1859, but have fallen down and are partly buried under finer soil. Apparently the push of the ice has turned them over at the beginning of the transgression and at the shift of the shore line, but during the continued rise of the water they have stayed where they were.

This lowest shore below which the ground has never been laid bare after the Ice Age, in a way forms a counterpart to the highest shore, above which the land has never been covered with water. Between these most extreme shores is the zone where the changes of water level in the lake basin have taken place.

The measurings show that the lowest, somewhat deformed, shore lies from 0.3 to 0.5 metres higher than the limnotelmatic contact on the same isobasis. It is close to Mustonen (21) 4.2 metres above the water surface of L. Höytiäinen, on the northwest shore of Kunnasniemi 5 metres and in the south at the mouth of the Kunnaslahti bay it is 3.3—3.5 metres high. The shore surface is consequently warped towards the southeast as much as the plane of the limnotelmatic contact.

The ice rampart has formed above the medium water line; the limnotelmatic contact again shows the lowest level of the water. To this is due the difference of height between the said levels. Thus completing each other they together distinctly show the shore of isolation of L. Höytiäinen.

In the same way we were able to determine the shore of isolation in almost any place in the southern part of Höytiäinen. The observations have been marked on the map, pl. I, and also on the graph pl. II. The surface of isolation is represented by the levels going through all the observed shores as well as the limnotelmatic contacts. The threshold at Polvijärvi finds its place in this level, as could be expected. Continued on the northwestern side of the threshold it meets with a couple of distinct old shore marks, the one at Rauanlahti, 4, the other at Martonvaara, 5. The discontinuity in the rate of regression, due to its retardation at the time of isolation, has accordingly registered itself on the northwestern side of that isobasis which runs through the threshold.

The isolation shore is best preserved between the isobases of 90 and 94 metres. Within this belt, approximately midway in a vertical direction between the shore of 1859 and the present water line, the ancient shores have most thoroughly escaped the destructive agents before and after 1859.

The gradient of warped shore surfaces affords a means of determining the age of the shore by applying a diagram constructed by Ramsay (1926) the abscissa representing time, the ordinate the gradients in centimetres per kilometre. In the present case the gradient of the isolation shore surface is 39 cm/km. Plotted on Ramsay's diagram this value determines the time of isolation of L. Höytiäinen at about 6 800 or 6 900 B. C., or at the close of the Ice Age.

SHORE MARKS BETWEEN THE SHORE OF 1859 AND THAT OF ISOLATION.

The afore-said zone between the shore of isolation and the surface of the Höytiäinen of 1859 has developed in a special manner in those places where the inclination is greater and the belt thus narrower than usually.

In such places there are a number of stony embankments beside and above each other and at nearly equal distances both in a vertical and horizontal direction. The narrow zone of Halkovaara affords room for only two embankments (fig. 5); where there is more room, more of them will be found, even as many as five or six.

A. R. Helaakoski (1915) has described these embankments on the island of Jouhteninen, stating their lowest limit to be 2.5—3 metres above the present Höytiäinen. They are thus exactly at the above-mentioned shore of isolation. As far as I have understood his paper they are classed as primary formations belonging to the esker of which the island is part. The evident fallaceousness of this conclusion is shown by the fact that they are not to be found in the esker above the shore of 1859.

In our effort to understand the origin of these embankments we shall, no doubt, get upon the right track by taking into consideration their position between the shore of 1859 and the shore of isolation. They have formed while the water rose from the level of isolation to the level of the shore of 1859.

G. K. Gilbert (1883—1884) has, in his classical treatise on lake shores, demonstrated that a rhytm is introduced in the construction of embankments, on shores where transgression is going on. When the water surface has risen a certain amount, the embankment that had formed earlier, is submerged and escapes total destruction, while a new one is being built up at a new shore line above.

It could be supposed that some of these embankments might depict some special stage in the shifts of level in connection with the variations of drier and moister periods which will be discussed below. It is not possible more accurately to explain them on the basis of the present material. This task as well as a description of the shore of 1859 in its entirety will be a special and a very grateful subject for a future investigation. In this connection also the shores of the corresponding time in the area of regression as well as analogical features in other lake-basins should be taken into consideration.

THE COURSE OF DEVELOPMENT.

THE CHRONOLOGY.

According to the above result, the lake stage of Höytiäinen comprises about 9 000 years or nearly the whole post-Glacial time. The development has gone, in general, in the same manner as we concluded at the outset on the basis of facts previously known. Some idea as to the many special events which have taken place during that long period will be afforded us by the study of the shore peat bogs, their structure and the subfossil flora which they contain as well as by the whole vegetation from which the peat has been formed.

For such a history of development we first need a chronological frame-work in which we can place the data concerning the varying events. In the stratigraphy of the peat bogs the chronologically corresponding points can be ascertained by means of the variations of the amount of pollen of certain plant species, which variations are synchronous at least on a limited area. In drawing up correlations the starting points in the case in question are: (1) The time of arrival of *Picea* and (2) that of *Alnus,* as also (3) the maximum of *Betula.* Between and near the horizons of peat thus connected parallels may further be drawn by means of (4) the maximum occurrence of *Picea* and (5) that of *Alnus,* as also (6) the general occurrence of noble foliaceous trees. The pollen diagrams are reproduced in plates III and IV, and the connections are schematically shown in fig. 20, p. 37.

The pollen diagrams thus indicate the relative ages. There are, however, two points in the peat bogs which can quite satisfactorily be fixed also in the absolute chronological scale: The one is the horizon corresponding to the epoch when spruce became common, in the early part of the period of development of L. Höytiäinen; the other is the drying of peat bogs towards the end of the lake stage, which is followed by a moist period.

THE POLLEN LIMIT OF SPRUCE.

The discontinuity in the pollen curve indicating the common spreading of spruce may be considered as a very synchronous horizon in the southern part of L. Höytiäinen. During the spreading of pollen the surface of the peat bogs was, of course, at different height in different places. For this reason the pollen limit is not always on the same level in the graph demonstrating the changes of level. But to the extent the position of the water surface at the common spreading of spruce is ascertained, to the same extent its age can be determined according to the gradients.

The ancient water surface can be ascertained in the peat bogs which at the time of the common spreading of spruce has been on the water limit, by following the course of the pollen limit at the limnotelmatic contact in the manner which has been explained in detail by AUER (1924). The scarce peat bogs of Höytiäinen do not permit the determination of this limit so well as for example at Lake Vanajavesi. Lahdenpohja, 22, is the only peat bog usable for this purpose. Here the limit of spruce lies at a hight of 5.7 metres above the present water surface. It gives us about 34 centimetres per kilometre as the gradient of the level in question, which means a common spreading of spruce about the year 6 500 B. C.

This determination may from a methodical point of view be considered as reliable, for L. Höytiäinen is situated on the very zone of those isobases, for which the curve used (RAMSAY 1926) has been drawn up. On the other hand it should be noticed that the pollen limit may, owing to the compression of the subjacent peat, to some extent have sunk below its original position. For example a fall of 0.5 metres which may be considered as maximum, would shift the time of the common spreading of spruce about 800 years nearer to the present time.

The determination of the time is influenced in another direction by the fact that the height of the pollen limit has been measured in a telmatic and terrestric peat, thus above the surface of water, and not in the limnotelmatic contact, which has been destroyed by wave erosion. The determination of time here presented may thus be correct.

OTHER POLLEN LIMITS.

The chronological limit of *Alnus* may, in the same manner as that of the common spreading of spruce, be ascertained in the pollen diagrams, which indicate its arrival at the place. It, as well as the still older maximum of *Betula*, places itself in the bottom layers of the peat bogs and is to be found only in those places where the disclosure of dry ground has first rendered paludification possible. Such a place is Paskonpohja, 16, where paludification might have begun immediately after the transgression of the Ancylus Lake, about the year 7 500 B. C., when the edge of the ice sheet was on Suomenselkä in East-Bothnia at a distance of 200 kilometres. This date and the still older time corresponds to the maximum of birch, the limit of *Alnus* being probably a little later, at highest a few centuries.

In the occurrence of *Alnus* there is a double-crested maximum below the limit of the common spreading of spruce. Their chronological importance is emphasized by the fact that two separate occurrences of spruce previous to its common spreading are located at the same point in the graph. It may further be observed that also the pollen of the noble foliaceous trees concentrates at the same point. The whole zone of occurrence of foliaceous trees forms a special horizon, which according to AUER (see page 36 below) is synchronous in the whole southern half of Finland. Its upper limit is close to the maximum of spruce.

THE HISTORY PREVIOUS TO THE MAXIMUM OF SPRUCE.

On the basis of the results presented above conclusions may be drawn regarding the intensity, modes and causes of paludification during different periods. From this point of view attention is first drawn to the limit of the common spreading of spruce. It divides the whole cover of peat into two horizons. The lower preabiegnic horizon is nearly as thick as the amount of peat formed after the arrival of spruce. Of the time of paludification after the Ancylus period, from 1 000 to 1 500 years fall to the lot of the lower layer, from 8 500 to 8 000 years to the lot of the upper one. Paludification has thus at first been many times as intense as it was later.

This result fully agrees with similar observations made elsewhere. In the shore bogs of Höytiäinen paludification has, no doubt, been accelerated by transgression which earlier was more rapid than later. The upheaval has on this zone in the early part of the Ancylus period been about 10 metres per century (SAURAMO 1928), during the period of the Litorina maximum about 1.5 metres (RAMSAY 1926), at present only 0.45 metres per century (WITTING 1918). A greater moisture is indicated by the very luxuriant *Phragmites* peat. Vegetation has in those early days been favoured not only by this local factor but also by the general factors, the virgin soil and the favourable climate. The peat has grown very rapidly even outside the sphere of influence of the lake water, representing even there a more hygrophilous facies than during later periods.

The change of the peat vegetation into more xerophilous takes place after the common spreading of spruce, or during the first thousand of years following the Ice Age. From this time onwards the growth of peat is greatly retarded. To the three or four thousands of years following the common spreading of spruce, corresponds stratigraphically only that thin peat layer which remains between the pollen limit of spruce and its maximum. The lastmentioned point, no doubt, chronologically corresponds to the sub-Boreal period, as we shall see later on. The thinness of the said layer is in harmony with its facies; it is much decayed, real mold, so its formation may easily have extended to a great length of time. Whether thereare in this horizon embracing such a long epoch, signs of general climatic changes is a question to be solved by future, more extensive nvestigations.

THE LAST EVENTS IN THE HISTORY OF LAKE HÖYTIÄINEN.

Upon the maximum of spruce a change universally observed takes place in the mode of paludification. The rather hygrophilous vegetation previously prevailing passes over into a xerophilous forest peat. Especially a certain definite level is rich in heavy stubs among which individual tree stumps more than 40 cm thick were observed. (Fig. 10, page 18.) A splendid forest was thus thriving on the peat bogs; forests like these are no more seen on the peat bogs in Finland.

This can hardly mean anything else than that the climate had been considerably drier than earlier and than it is at present. Especially on shore peat bogs threatened by transgression drought and hence a prevailing low water is a necessary condition for the spreading of forest. The wave-cut terrace in the peat bog of Lahdenpohja, 22, (page 18) points to the same conclusion. This terrace is evidently synchronous with the stub-bearing peat layers having formed at a time when the water surface remained long at the same place. On shores where transgression was actually going on this could only happen when the water surface in the whole lake remained low for climatic reasons.

After this stage the water has rapidly risen and all the shore peat bogs have in consequence thereof become submerged at a surprisingly quick rate. Now it has no mere been possible for the terrace in question to wear to its former low level. On the northwestern half of the lake, in the area of regression, this general rise of the water surface has kept the shore longer than usual at the same line. Thus e. g. we could understand the origin of the well-formed and well-preserved ice rampart at the foot of Martonvaara, 5, a couple of metres above the shore of 1859.

This sequence of events clearly illustrates the characteristic features of the dry sub-Boreal period and the subsequent moist sub-Atlantic epoch. Quite the same development is seen in Finland, for example, in the submerging of the shore peat bogs and forests of Vanajavesi and Puulavesi, in the downward shift of the forest boundary in Lapland and in the sharp limit between the decayed and the raw peat of Hochmoors throughout Northern Europe. This sudden deterioration of the climate dates, chronologically, according to Swedish investigations, back to about the year 500 B. C. The most remarkable and in some respects the most fatal stage in the long development of Höytiäinen, thus dates to a comparatively late period.

THE ANCIENT FLORA.

By

VÄINÖ AUER.

In the microscopical investigations of the profiles of the shore peat bogs of Höytiäinen the same methods have been followed as those used in the earlier pollen investigations in Finland. Thus endeavours have been made to ascertain the relation of the amount of pollen to the character of peat and the degree of decay. In this respect the results have been in general in accordance with those obtained in the peat bog layers of the Kuusamo and Kuolajärvi hilly areas and also in those of the watercourse area between Tampere and Hämeenlinna. The least amount of pollen was found in the *Amblystegium* peat layers and in the layers rich in *Vaginatum* as also in certain accumulation peat layers of coarse material. Limnic layers such as ooze and mud, are very rich in pollen, also a certain kind of grass-herb forest peat occurring near the farm of Vaskela. It is the residue of a rather large peat bog which was eroded by the rising water during the transgression of Höytiäinen. The place has evidently been a watery herb marsh in which pollen could stratify very abundantly so that slides of 8×8 mm in size can contain some 2 000 or 4 000 particles of pollen. The pollen concentration of the *Carex* and *Sphagnum* peat appears, as a rule, to be such that the more decayed peats are richer than the raw varieties.

In the examination of the pollen diagrams and the curves of different tree species occurring in them the most convenient starting point is the spruce pollen limit which, in the basin of the lake, is a synchronous point on the series of the peat strata. With regard to this limit the following regularities occur in the course of the different curves and the occurrence of pollen in general.

Pine pollen is very scarce in the oldest bottom layers. From this minimum the pine curve suddenly rises to its maximum, from where it begins to fall again so that a new minimum is near to the limit of the spruce pollen. Afterwards a rise takes place again towards the surface. In other diagrams the culmination beneath the limit of the spruce pollen forms in its middle part a small fall towards the ordinate.

The curves of the birch in the diagrams are in general contrasts to the previous one. Thus in the oldest layers there is a great abundance of birch and from this maximum it falls rapidly and rises again, so that at the spruce limit or somewhat below the same it attains a new maximum, from which it gradually falls towards younger layers.

In the curves of spruce pollen attention is first called to the fact that single, and often isolated occurrences of pollen are found much below the limit the common spreading of spruce pollen. This is so much more remarkable as the samples for example in profile 2 have been taken from the wall of a pit dug in the peat where, no doubt, isolated samples have been obtained. Incoherent occurrences of pollen below the limit of the common spreading of spruce are really primary. In this manner they have now been found also in Finnish Lapland, in parts of the shores of Lake Puulavesi in Central Finland and in the peat strata of Pohjankangas in southwestern Finland.

It is difficult to say to what extent the incoherent occurrence is substantial, for the amount of pollen of such separate pollen occurrences is in general so small that an interruption of the curve can casually occur anywhere. Two distinct isolated pollen occurrences below the limit of common spreading can, however, be clearly ascertained in most diagrams. In those cases where four isolated pollen occurrences are met with in the diagrams they should, in all probability, be understood thus that the two upper ones correspond to one single upper occurrence in other diagrams and the two lower ones to the lower single occurrence in the others.

The curves of the spruce pollen begin, at the limit of their common spreading, gradually to rise attaining soon their maximum, from where it gradually falls. The curve of maximum is, however, not regular, but a small depression is usually found in it.

In the diagrams of alder pollen the lower parts of the oldest layers contain remarkably enough no alder at all. In eastern Finland we can thus clearly distinguish peat layers which were formed previous to the arrival of alder. This is the second distinct pollen limit, which can now be distinguished in Finland, the first one being that of spruce, which has been well known long ago. The limit of alder pollen, again, has not been ascertained earlier in Finland. The same was found to be the case in the layers of the oldest shore peat bogs in L. Puulavesi, the bottom parts of which are without alder pollen.

The alder curve rises from its pollen limit to about 10—30 per cent and somewhat before the pollen limit of spruce it begins to fall and does so up to the surface. It may therefore be determined with certainty, that in the amount of alder pollen there is a maximum of long duration up to the common spreading of spruce. When the curves are carefully compared with each other, the maximum is, however, found to be divided into two small culminations. These two culminations may be seen in most diagrams.

The pollen amounts of noble foliaceous trees *(Quercus, Tilia, Ulmus)* are conspicuously large as compared with those found at the investigations carried out elsewhere in Finland. This fact apparently means that in the basin of Höytiäinen or in its neighbourhood there have, at an earlier period, been luxuriant groves. This supposition is supported by the existence of the grass herb forest peat at Vaskela previously mentioned, in which there is an exceptional abundance of pollen of the noble foliaceous trees, so that in the same slide of 8 × 8 mm there may be, on one single line (magnification: 300 ×) 20 or 30 pollen particles of these trees.

The pollen particles of *Tilia* are not found quite in the bottom layers. They appear very early, but only in so small an amount, that it is impossible to define any pollen limit. In some places the curve breaks off and somewhat above the limit of the common spreading of spruce *Tilia* is very rare.

The pollen of *Ulmus* is found in the oldest bottom layers of the peat bogs. In general it is very scarce, so that no definite idea can be formed as to the actual appearance of this tree and its arrival at the place. The pollen of *Ulmus* occurs most abundantly close to the limit of spruce, being concentrated on both sides of it.

The oak, is likewise scarce, and it is difficult to give any accurate information of its occurrence. Quite evidently, however, the first pollen of oak are found below the limit of the common spreading of spruce, but not in the oldest layers and certainly above the pollen limit of alder. The pollen limit of oak is thus decidedly at hand, though owing to the scarcity of pollen it is difficult to determine accurately its location. The pollen of this tree species is most abundantly found close to the limit of the common spreading of spruce, below it or a little above.

Of other micro-subfossils the following may be mentioned.

Pollen of plant species of the *Ericaceae* family are to be found in all layers of peat bogs.

The *Polypodiaceae* family is also abundantly represented. In addition to *Athyrium* at least a couple of other spores of species belonging to the same family are found of which there is a very great abundance in the grass herb forest peat close to the farm of Vaskela. Several hundreds per slide could be counted.

Lycopodium is apparently represented by two species of which the one is almost certainly *L. selago*.

The pollen of *Graminaceae* and *Cyperaceae* plants are rather scarce throughout the whole series of peat layers.

The pollen of *Typha* is found in the oldest layers of ooze and mud.

The *Compositae* family is represented in the peat beginning from the bottom layers.

The pollen of the species of *Salix* have been found in the very oldest layers in the same horizon as where *Betula* has its maximum and pine has its minimum. In the youngest layers they are not to be found to any considerable amount.

Of *Myriophyllum* one pollen particle has been found in the oldest bottom layers at Vaskela.

Of *Ceratophyllum* only one leaf-thorn has been found in a peat bog situated in the southwestern part of Höytiäinen in a layer formed previous to the common spreading of spruce.

The pollen of *Rhamnus* was found in the grass herb forest peat at Vaskela a little below the limit of the common spreading of spruce.

We may also mention the two big and remarkable-looking pollen particles of *Epilobium palustre* which were found one at Vaskela and the other in the Porttikallio peat bog north of Höytiäinen, in each case close to the limit of the common spreading of spruce.

The curves of the pollen diagrams of the shore peat bogs of Höytiäinen are not so regular as those obtained in connection with earlier investigations. To all appearance local factors have played a great part in the composition of the vegetation, for it is otherwise difficult to explain such a great difference as that between the very luxuriant layer of grass herb forest peat at Vaskela and the *Sphagnum* strata being of the same age, the vegetation of which must have been very barren. Notwithstanding the capricious loca .variations the curves can, however, be connected between one an other by means of the spruce.

We shall now examine by means of the pollen connection in what relation the aforesaid regularities are to one another in the different curves.

The first isolated occurrences of spruce pollen, of which two are very clearly distinguished, are in the closest relation also to other pollen occurrences. It is thus evident that in the pollen curves of alder there is a rise at level with each of those isolated occurrences of spruce and there is, in general, an abundance of pollen of noble foliaceous trees and hazel just at these points. This shows that the isolated pollen occurrences of spruce are synchronous in the peat bog layers.

As mentioned earlier, similar isolated occurrences have been found in Lapland, in the neighbourhood of L. Puulavesi and in the peat bogs of Pohjankangas. Considering, however, that the limit of the common spreading of spruce is of different age on all these areas, the isolated occurrences in question obviously are not of the same age in the aforesaid regions. Thus we have here to do with some special feature connected with the first spreading of spruce, for it has been certainly in a significant manner influenced by local factors.

At the same time that the curves of *Betula* and *Pinus* as to percentage are each other's contrasts, the courses of the curves show reversed amounts of pollen. This means that the periods when spruce and pine were in power have mutually changed places.

The amount of the *Alnus* pollen begins to diminish somewhat previous to the limit of common spreading of spruce. As the question is of the diminution of the amount of pollen at a time when the spruce has no influence whatever upon the percentages of pollen in the peat bogs, the diminution of alder has, to all appearance, taken place independently of the arrival of spruce. On the other hand, the fact that everywhere in Finland the curve of alder falls somewhat previous to the arrival of spruce, would show that, after all, spruce has perhaps played some part in the occurrence of alder.

As mentioned above, the occurrence of the pollen of *Quercus* in the peat bogs is so small that it is not possible exactly to define its pollen limit. It is worthy of note in any case that the pollen of *Quercus* is in general more abundant just at those points where the two isolated occurrences of spruce and the two maxima of alder are found. The percentage of *Quercus* is high enough to grant the assumption that this tree had grown in the tract of Höytiäinen.

Likewise we can assert with certainty that hazel *(Corylus)* has grown in this region, because there is an abundance of its pollen in the peat layers. Its pollen, too, is especially abundant at the abovementioned points of the isolated occurrences of spruce and the two maxima of alder. The amount of pollen of *Ulmus* shows that that tree has also grown much further north than its present area.

As is evident from this report, the pollen of the noble foliaceous trees and the hazel are exceedingly abundant in the layers formed before the common spreading of spruce but after the arrival of alder. This abundance extends somewhat above the limit of common spreading of spruce. The investigation carried out in Häme shows that the abundant occurrence of noble foliaceous trees in that region begins at the bottom layers extending to about the pollen limit of spruce and even somewhat above it. The same regularity is noticeable in the investigations carried out in the heaths of Pohjankangas in the province of Satakunta. Under these circumstances there has in Finland evidently been a period favourable to the growth of the noble foliaceous trees. The age of this period can be ascertained on the basis of the age of the pollen limit of spruce.

As shown by the investigations the spruce arrived at eastern Finland about the year 6 000 B. C., somewhat previous to the isolation of Lake Vanajavesi. At the lastmentioned lake, again, it arrived about 1 000 years later. As, thus, the occurrence of the noble foliaceous trees extends at Höytiäinen a good deal above the limit of common spreading of spruce, but in the neighbourhood of Vanajavesi ends near to the pollen limit of spruce, it is natural under these circumstances that the period of the noble foliaceous trees has been almost simultaneous in eastern Finland.

The fact that oak, elm and hazel have then grown so much farther north than they at present do, goes to show that the climate must then have been specially favourable. This period being simultaneous in different parts of southern Finland the assumption of a climatic cause is so much more justified. We would therefore call it the *period of the noble foliaceous trees in the post-Glacial epoch of southern Finland.*

According to BLYTT-SERNANDER's formula of climatic variations the periods of the noble leaf-trees in question has begun in the early Boreal period and during the Atlantic period attained its optimum, ending at the beginning of the sub-Boreal period.

The pollen of the hazel is already found in the oldest layers of the peat bogs immediately above the maximum of birch. In some places hazel pollen is met with very abundantly, which goes to show that hazel groves have grown in the neighbourhood or possibly at the same place. We have, however, not succeeded in finding any hazel nuts. Even hazel pollen occurs most abundantly before spruce and extends somewhat after the arrival of spruce.

The investigations concerning the ancient shore-surfaces in the basin of Höytiäinen form the back-ground to the history of the flora. As ancient lakes whose limnic layers are usually rich in megascopic remains of ancient plants, have not been found in the basin of this lake, the history of its flora is chiefly based upon those remains which could be found by the aid of microscope in the layers of its peat bogs.

As appears from the profile, peat-bogs have originated at least on the terraces of the Ancylus stage and probably even in the Yoldia period. These are the oldest peat layers in this area, and their botanical structure shows the conditions prevailing at those times. During the early stages of the Ancylus period *Phragmites*, *Equisetum* and *Carex* species and *Typha* grew on the shores, the floras of which

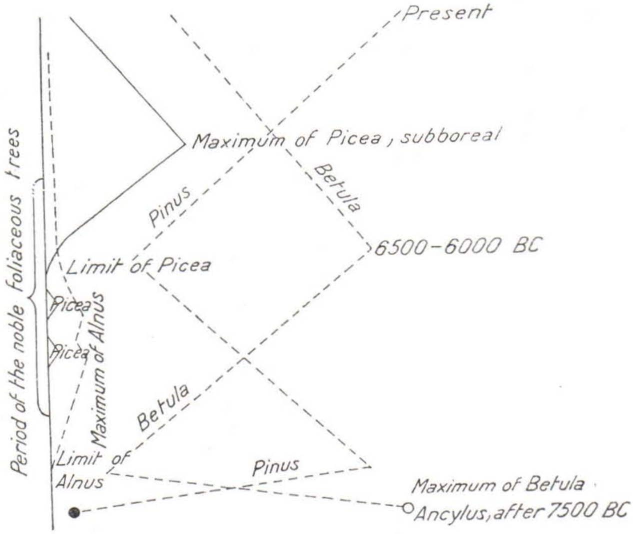

Fig. 20. Diagram showing schematically the pollen curves of certain tree species.

caused the overgrowth of the then existing small ponds. At that time *Myriophyllum*, probably *M. spicatum*, was common, and at about the same time there probably occurred *Ceratophyllum* of which only one leaf-thorn has been found.

According to Sauramo the edge of the continental ice sheet was still situated in the neighbourhood of Suomenselkä, when the great fini-Glacial improvement of climate took place. The ice sheet vanished rapidly and the climate as well as the soil disclosed by the withdrawal of the watero ffered extraordinarily favourable conditions for the spreading of flora. The great pollen amount of *Betula* appearing in the oldest layers of the area shows that birch was for a short time the prevailing tree species and the *Salix* vegetation was also very rich. By this time *Corylus* was spreading on shore-zones and luxuriant depressions. Pine grew on dry ground, but was still rather scarce.

But the dominance of birch did not last long, for pine soon began to occupy ever larger areas, and the sudden rise in the curve of its pollen goes to show that the period when pine predominated was of a very considerable length and its spreading very rapid. The first residues of the species of *Ulmus* and *Tilia* are found in early layers; together with *Corylus* they grew on luxuriant moist habitats when birch already predominated.

When pine began to predominate, *Alnus* appeared for the first time. It began to dominate chiefly shore-areas near to water and at the same time the luxuriant habitats of ancient lakes and depressions. HERLIN (1896) has in the soil-layers of Höytiäinen found megascopical remains of *Alnus glutinosa* and *A. incana*. While alder begins to appear abundantly, noble foliaceous trees and *Corylus* show two minor maximums and together with these the first signs of the arrival of spruce also make their appearance.

The arrival of spruce is a very noteworthy feature in the history of Finnish flora and particularly in the basin of Höytiäinen its arrival is remarkable in so far that it is at present the oldest formation where spruce has occurred in Finland.

The fact that two separate occurrences of spruce pollen previous to its common spreading are found, proves that the migration of spruce really was at that time making progress. It is remarkable that at the time of the first occurrence of spruce there was still continental ice in the northern parts of Finland and that the sea-shore had changed from the transgression-shore of the Ancylus lake.

After the arrival of alder and before the arrival of spruce *Quercus* migrated to this tratc. The regular occurrence of its pollen, although irather small n amount, shows that this tree actually grew in this region. The period of heat of the late Quaternary time which prevailed during the Anculys period, gave the opportunity of rapid spreading for plants and the occurrence of noble foliaceous trees is very considerable especially at those times when spruce became common. During the period of noble foliaceous trees *Trapa natans* (BACKMAN und CLEVE-EULER 1922, p. 21) spread as far as Maaninka which is the northernmost place where this plant, now extinct in the northern countries, has grown. Somewhat previous to the isolation of Vanajavesi spruce finally dominated habitats in the neighbourhood of L. Höytiäinen probably struggling for place with alder and the noble leaf trees. As a biotically powerful species spruce soon appropriated extensive areas spreading quietly to the north and west, so that somewhat later it spread to the region of Puulavesi.

The isolation of Höytiäinen which happened about the year 6 900 B. C. at the end of the Ice Age was obviously apt to influence the composition of the shore flora. *Phragmites* which lived on the coast of Ancylus, grew also along the shores of Höytiäinen after its isolation so abundantly that it could be preserved for a long time as a relict, in the course of transgression, occurring in *Carex* peat. This *Carex-Phragmites* peat is characteristic of the bottom strata of the shore peat bogs of Höytiäinen previous to the formation of terrestric peat.

Of the species of the shore vegetation of Höytiäinen, found as megascopic remains, we will mention *Carex rostrata*, *C. riparia*, *C. limosa* coll., *Scirpus lacustris* and a certain small species of *Scirpus (Sc. paluster)*, as well as *Menyanthes trifoliata* and *Comarum palustre*, the two last mentioned being abundantly represented. The shore meadows were luxuriant and rich in *Ranunculus*, *Epilobium*, *Hippuris* etc. *Potamogeton* was very common in open water, and in some places on the shores there existed luxuriant groves with plentiful specise of *Polypodiaceae*. Some species of *Myrtillus* existed already during the time of isolation as seeds of them have been found in the peat.

The occurrence of the noble leaf trees lasts for some time after the common spreading of spruce when owing to the drought of the sub-Boreal period the surface of the lake was very low so that peat bogs became wooded and large pines grew on them, the stumps of which have now been disclosed. Noble foliaceous trees and *Corylus* became considerably scarcer about the same time. After the sub-Boreal period the surface of the basin of Höytiäinen rose so rapidly as to leave the peat bogs under water. The history of its flora has certainly been powerfully influenced by the afore-said sub-Boreal, and afterwards by the sub-Atlantic, period. After the sub-Boreal period the northern limits of the noble foliaceous trees began to retreat to the south. Thus *Quercus* receded to the shores of the Gulf of Finland and *Ulmus* and *Corylus* to the northern coast of Lake Laatokka. During later times in the sub-Atlantic period the luxuriant floras of the shore areas have disappeared from the southeastern part of the lake. In the northwest part of the lake where the surface has slowly retreated the shore floras formed by alder and noble leaf-trees have been better preserved.

Since the surface of the lake fell suddenly in 1859 leaving extensive alluvial soils behind it, a new stage has again commenced in the flora. In the northwestern part extensive areas of fields have opened out where broadleaf trees are spreading while, on the contrary, on those areas where heaths occur, as in the southeastern part, pine forest begins to re-occur on the ancient bottom of Höytiäinen. The importance of the last mentioned stage for the spread of flora is a question which might offer new and interesting points of view for plant-biological investigation.

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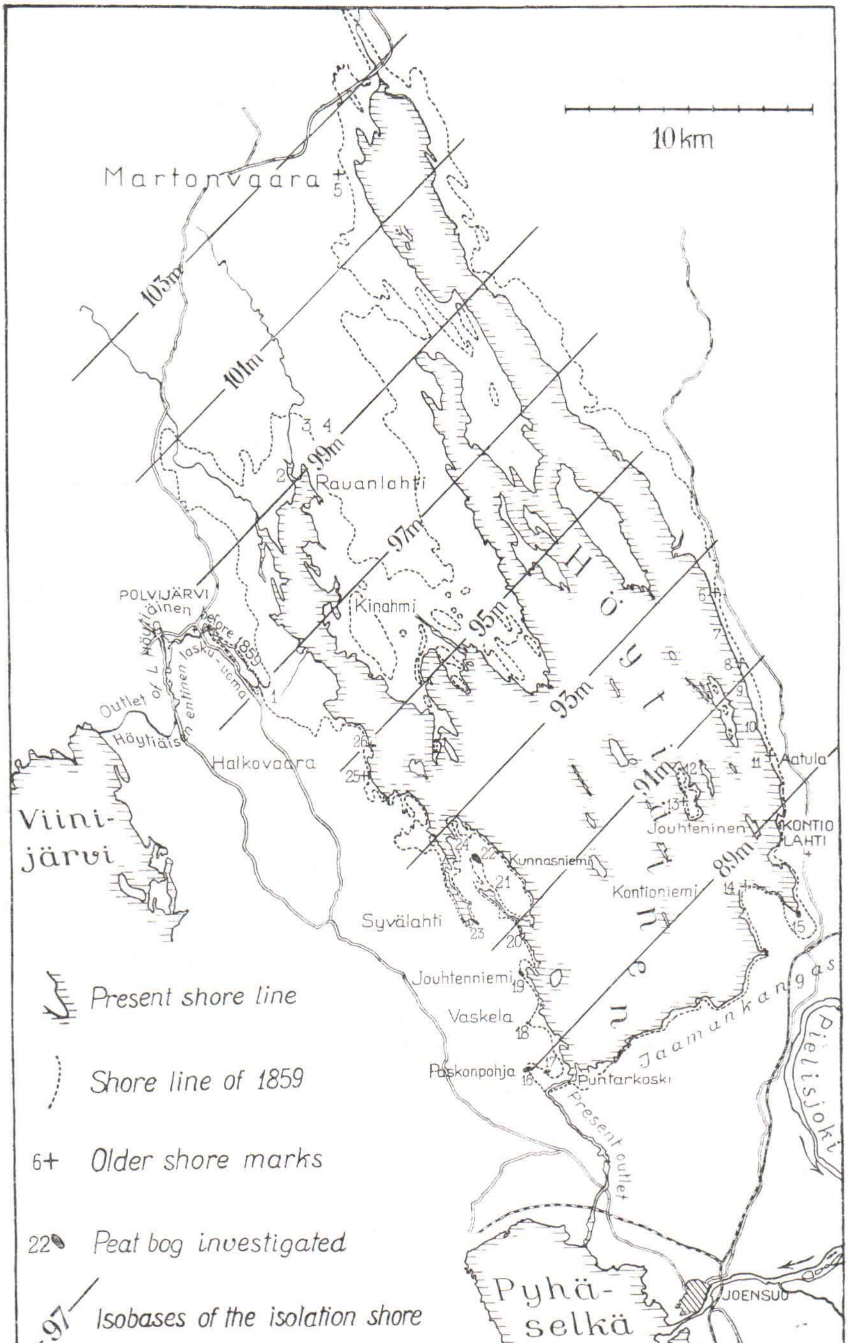

LAKE HÖYTIÄINEN

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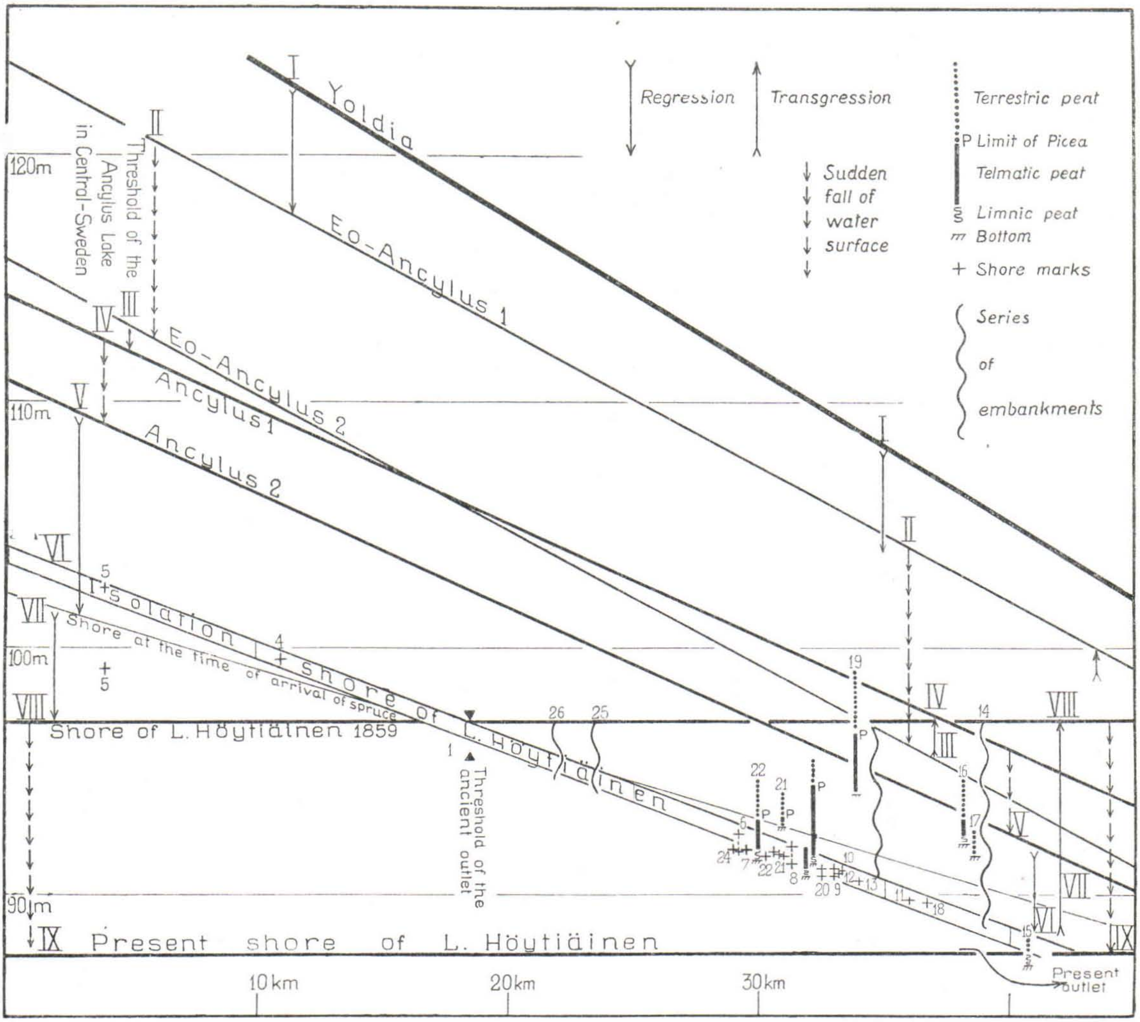

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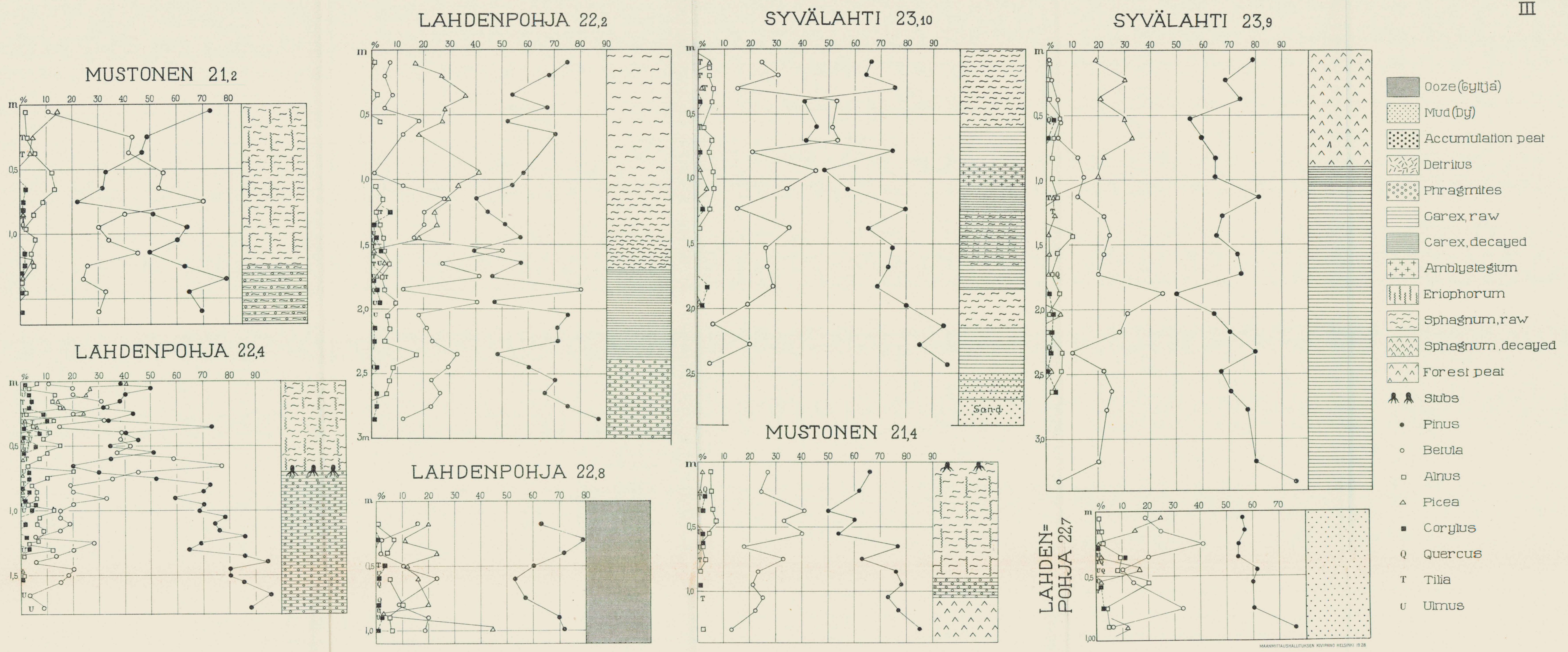
MUSTONEN 21,2
LAHDENPOHJA 22,4
LAHDENPOHJA 22,2
LAHDENPOHJA 22,8
SYVÄLAHTI 23,10
MUSTONEN 21,4
SYVÄLAHTI 23,9
LAHDEN=POHJA 22,7
Sand
Ooze (Gyttja)
Mud (Dy)
Accumulation peat
Detritus
Phragmites
Carex, raw
Carex, decayed
Amblystegium
Eriophorum
Sphagnum, raw
Sphagnum, decayed
Forest peat
Stubs
Pinus
Betula
Alnus
Picea
Corylus
Quercus
Tilia
Ulmus
MAANMITTAUSHALLITUKSEN KIVIPAINO HELSINKI 1928

RAUANLAHTI 4
KONTIOLAHTI 15,2
PUNTARKOSKI 17,5
JOUTSENNIEMI 19,3
JOUTSENNIEMI 19,2
PASKONPOHJA 16,3
PASKONPOHJA 16,1
PASKONPOHJA 16,4
VASKELA 18
Sand
Ooze (Gyttja)
Mud (Dy)
Accumulation peat
Detritus
Phragmites
Carex, raw
Carex, decayed
Amblystegium
Eriophorum
Sphagnum, raw
Sphagnum, decayed
Forest peat
Stubs
Pinus
Betula
Alnus
Picea
Corylus
Quercus
Tilia
Ulmus

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