SVERIGES GEOLOGISKA UNDERSÖKNING

SER C NR 658 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 65 NR 4

JAN LUNDQVIST

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APPENDIX 1: Investigation of the tills at Leveäniemi, by John Ek

APPENDIX 2: The insects from the interglacial deposits at Leveäniemi, by Carl H. Lindroth and G. Russell Coope

APPENDIX 3: The macroscopic remains of the Eemian interglacial flora of Leveäniemi, by Hans Tralau

APPENDIX 4: Pollenanalytical investigation of the Leveäniemi sediments, by Ann-Marie Robertsson

APPENDIX 5: Diatom floras in the sediments at Leveäniemi, by Urve Miller

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Kartorna, fig. 2 o. 3, är för spridning godkända i rikets allmänna kartverk den 10 februari 1971

C. DAVIDSONS BOKTRYCKERI AB, VÄXJÖ

CONTENTS

Abstract. A deposit of till-covered peat and sediments from the Leveäniemi mine, Swedish Lapland, has been investigated by a number of specialists. Their reports are included in this book as appendices 1–5. The location of the site appears in Fig. 1.

The stratigraphy of the deposit appears in Fig. 9 and on p. 21. The outline implies that a series of peat and sediments is covered by two different till beds, interstratified by thick minerogenic sediments.

The lithology of the tills indicates that they can be referred to the two Würm glaciations identified by Ljungner (1949; See app. 1). The intermorainic sediments may be referred to the Jämtland Interstadial (J. Lundqvist 1967), although evidence is lacking.

The organic beds have been dated by radiocarbon to be > 40 000 years old. They contain a fauna (app. 2) and flora (app. 3, 4 and 5) which clearly indicate even more temperate conditions than during the postglacial climatic optimum (See Figs. 4:1–3). The climate seems to have been more continental than that of the present day (app. 2 and 3). The deposit is interpreted as Eemian. Its stratigraphical position in relation to identified geological stages in adjacent parts of the world is shown in Fig. 12.

Introduction

In connection with the opening of new mines in northern Sweden excavations, which offer especially favourable conditions for study of the stratigraphy of the Quaternary deposits, are often made. One example is the Leveäniemi mine at Svappavaara, situated at Lat. 67°38′N., Long. 21°01′E., 40 km SE of Kiruna centre, and run by the Luossavaara-Kiirunavaara Mining Company (LKAB). Large excavations made to expose the ore as well as for construction purposes have revealed there different till beds and water-deposited sediments below the till.

These deposits were first observed by a Quaternary geologist when the present author together with the geologists Gunnar Nilsson and John Ek from the prospecting division of the Geological Survey visited the site in July 1967. Two till beds, in places interstratified by thin gravel or sand, were at that time visible around the exposed part of the ore. In the vicinity large excavations for the foundation of a new refinery (pelletizing plant) showed thick, sandy sediments covered with till and resting upon another till bed. The problems to be investigated at that time concerned the direction of glacial transportation over the region. Therefore samples were taken (by Ek) to allow a thorough investigation of the lithological composition of the till beds and of their possible content of micro-fossils. As the sediments were much disturbed and with a grain size less suited for micro-fossil analyses, samples, which allowed, e. g., pollen analysis, were unfortunately not taken.

In the late autumn of 1967 finds of tree remnants in the sediments were reported by the mining company. These reports only mentioned isolated finds of wood in the inorganic sediments. By this time it was also reported that finds of wood and peat had been made earlier, although no specialist in Quaternary geology had had the opportunity to examine them. However, these facts were interesting enough, and therefore John Ek visited the locality to take care of the finds. At the time of his visit the whole section shown in Fig. 9 had been exposed. It was immediately evident that the organic sediments were extremely rich in plant fossils. Ek was able to measure the section but snow cover, frozen soil, and much water in the excavation made the sampling conditions very unfavourable. Thus only scattered samples of typical strata were taken.

Somewhat later, however, by courtesy of the LKAB mining company a complete series of samples through the section was taken by the company's own geologist, Jarl von Feilitzen. This series, upon which the pollen analysis in Fig. 4:1 was made, seems to be the most complete and undisturbed of all that has been obtained from the site.

In July 1968 the author again visited the mine in order to examine the new excavations made during the spring, this time together with the geologists Esko

Daniel and Staffan Lundström from the prospecting division. The construction of the refinery now prevented further investigations there and the section sampled by Ek and von Feilitzen had been completely removed. However, some other sections through the organic deposits were well exposed, mainly in pockets in the weathered bedrock. In these sections the beds seemed to be somewhat disturbed along obliquely dipping shear planes. They could thus be supposed to give less reliable results than the first section but two series of samples were taken. Large samples of fossiliferous parts and isolated remnants of wood were also taken from blocks of the sediments removed during the excavation.

The situation under the till as well as radiocarbon dating (St-2533) made on the first samples taken by Ek immediately showed that the sediments must originate from the time before the last glaciation. The dating mentioned gave an age of >40 000 BP for the deposit. The rich flora, including among other things a whole pine stump and cones, and remnants of waterlilies, unmistakebly demonstrated a much warmer climate than the interstadial deposits, earlier known from northern Sweden (cf. J. Lundqvist 1967). In a short preliminary note (J. Lundqvist 1968) the deposit was supposed to be Eemian.

The investigation of the very rich material was entrusted to the present author at the Geological Survey. However, the material had to be investigated by different specialists. Thus the lithological analysis of the till beds was entrusted to John Ek, mainly as a part of the original investigation for prospecting purposes. Professor Carl H. Lindroth, Lund, kindly undertook investigation of the insect fossils. This investigation was performed in cooperation with Dr. G. R. Coope, Birmingham. The diatoms were studied by Mrs Urve Miller, F. L., and the pollen flora by Mrs Ann-Marie Robertsson, F. L. Dr. Hans Tralau was responsible for a preliminary investigation of the plant macro-fossils. The reports of these different collaborators are added *in extenso* as appendices to this article. This procedure has the advantage that it permits each co-author to draw his own conclusions idependently of the others. The present author therefore has only had the task of describing the topography of the locality and combining the different contributions into a conclusive text, placing the find in relation to the earlier known interglacial and interstadial deposits of northern Scandinavia. As the fossil material is very rich much additional work can be done on it. Thus the following report should to a great extent be considered preliminary, only. It is to be hoped that further work in the future will complete our knowledge about this important site.

It is a pleasant duty of the author to thank the contributors mentioned, and thus also the institutions outside that of the Geological Survey which in this way have rendered support to the work, i. e. the Entomological Institute of the University of Lund, the Paleobotanical Department of the Museum of Natural History, Stockholm and the Department of Geology, University of Birmingham. Also most sincere thanks are directed to the Luossavaara-Kiirunavaara Company and their personel, especially Mr. Jarl von Feilitzen and Mr. T. Parak, who have rendered valuable help by providing samples and information. The author is also indebted to Dr. Hans Möller for critical reading of the manuscript and Miss Dorothy Guy, F. L., for checking the language.

Description of the site

General topographic situation

As was mentioned above, the Leveäniemi mine is situated 40 km southeast of Kiruna centre. The topographic situation is on the east-sloping side of the hill Gruvberget about 2 km west of Svappavaara village and half-way between the rivers Torne älv and Kalix älv. The hill slopes eastwards towards a small basin in which the village is situated. This basin, which has a rather hummocky bottom with several tarns, is locally drained northwestwards but the main drai-

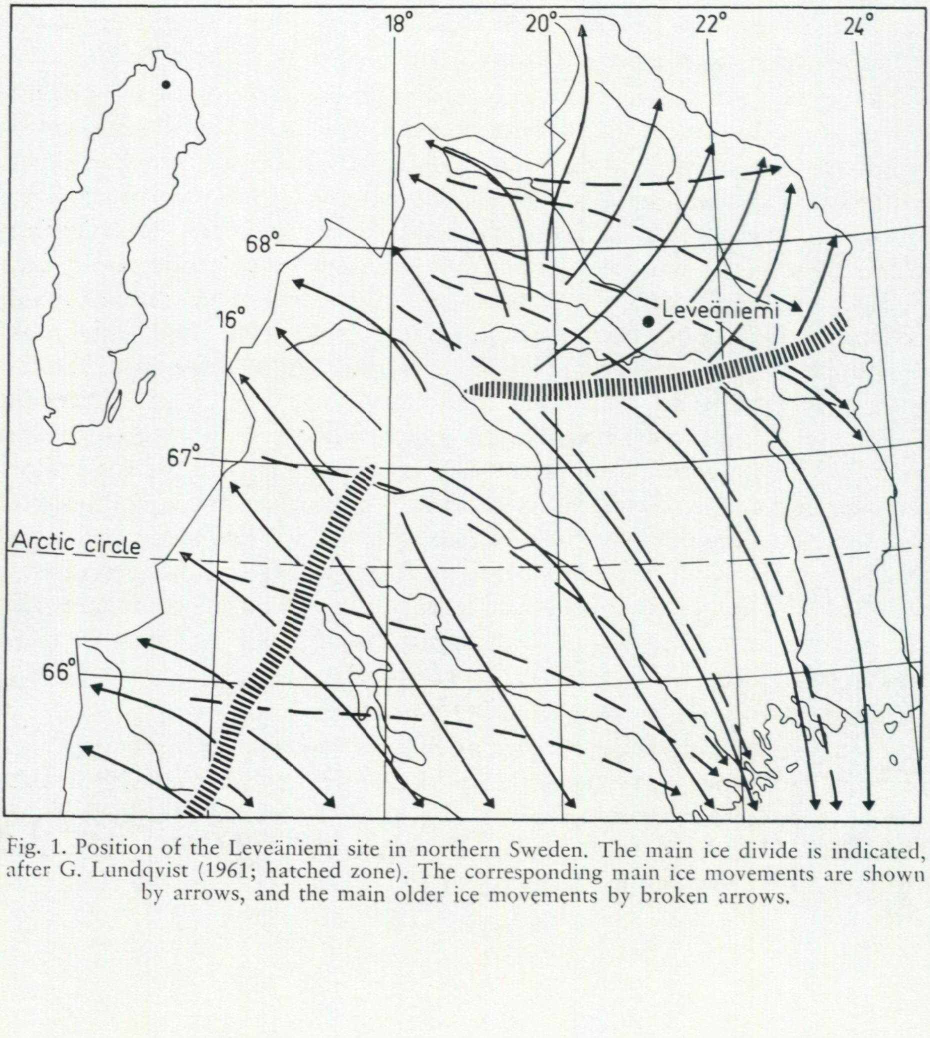

Fig. 1. Position of the Leveäniemi site in northern Sweden. The main ice divide is indicated, after G. Lundqvist (1961; hatched zone). The corresponding main ice movements are shown by arrows, and the main older ice movements by broken arrows.

nage of the area goes northeastwards through the stream Liukattijoki towards the river Torne älv running southeastwards.

The hill Gruvberget reaches a level of about 435 metres above sea-level. The highest observed submorainic sediments, the section at the refinery, reach to about 370 metres. The main sections, i. e., the organic deposits, occur somewhat lower or around the 360 metre-level. The bottom of the basin at the foot of the hillslope is situated at about 320 metres.

These figures also give an impression of the general level of the region. The landscape has a rather flat but slightly rolling surface with scattered mountains reaching from 400 to more than 600 metres above sea-level, that is, even slightly above the tree-line, which is here found between 600 and 650 metres. The distance from the limit of the mountain range in the west, where it reaches a height of more than 2 000 metres above sea-level, is about 60 km.

The area, like the whole of northern Sweden, has been glaciated at least twice. It is situated roughly 35 km north of the ice divide of the last glaciation (cf. G. Lundqvist 1961). The general direction of the corresponding ice movement was towards the northeast. This is demonstrated by numerous striated rocks as well as by well developed drumlin forms (cf. Hoppe 1957). The distribution of marginal deposits, glaciofluvial sediments and sediments deposited in ice-dammed lakes clearly shows that the recession of the last ice took place in the corresponding direction, that is southwestwards or westwards.

On scattered localities in the region Svappavaara–Vittangi there are striae also from the northwest. These evidently represent an older ice movement, possibly an older glaciation. The age relation is demonstrated both by crossings of the two systems of striae and by the lack of glacial morphology in the older direction. The existence of a NW-movement is proved not only by the striae but also by the distribution of boulders from known occurrences of characteristic rocks.

On the exposed ore at Leveäniemi there are surfaces with good striae. The dominating system comes from S30°W. Older, coarse striae from S65°W and younger, very fine ones from S10°W indicate a counter-clockwise turning of the last ice movement. In lee-side positions to these main systems there are scattered striae belonging to an even older system from N40°W. Thus the general picture of ice movement in the region is supported also by observations at the Leveäniemi site itself.

Other deposits than till which represent older glaciations or intervals between glaciations are not earlier known from this part of Sweden. The nearest locality with organic sediments from such an interval was found at Porsi, 135 km southwards from Svappavaara. It was described by G. Lundqvist (1960), who interpreted the sediments as interglacial. Later, J. Lundqvist (1967) reinterpreted them as interstadial, possibly corresponding to the Brörup Interstadial known from Denmark (S. Th. Andersen 1961).

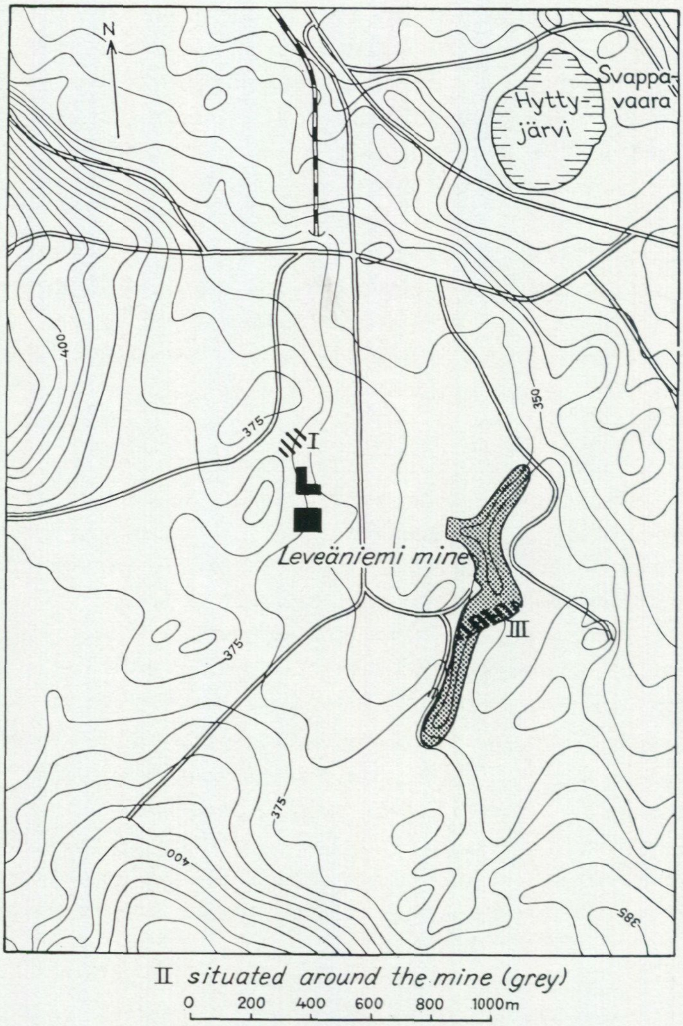

Fig. 2. Contour map (interval 5 m) of the area around the Leveäniemi mine (grey). The positions of the localities I, II and III described in the text are shown. Loc. II comprises the whole scarp around the mine. The hill Gruvberget mentioned in the text is the height northwest of the mine.

The fact that the Leveäniemi deposits occur in a lee-side position in relation to both the known ice movements may help to explain that they have been preserved during at least one glaciation. Ordinarily, such a protected position is not a precondition necessary for the preservation. (Cf. other interstadial sediments in northern Sweden, e. g. Pilgrimstad. See J. Lundqvist 1967.) In the part of northernmost Sweden under consideration, however, the erosive activity of the ice seems to have been rather strong. This is indicated, among others, by the well-developed glacial sculpture of the till surface. These facts

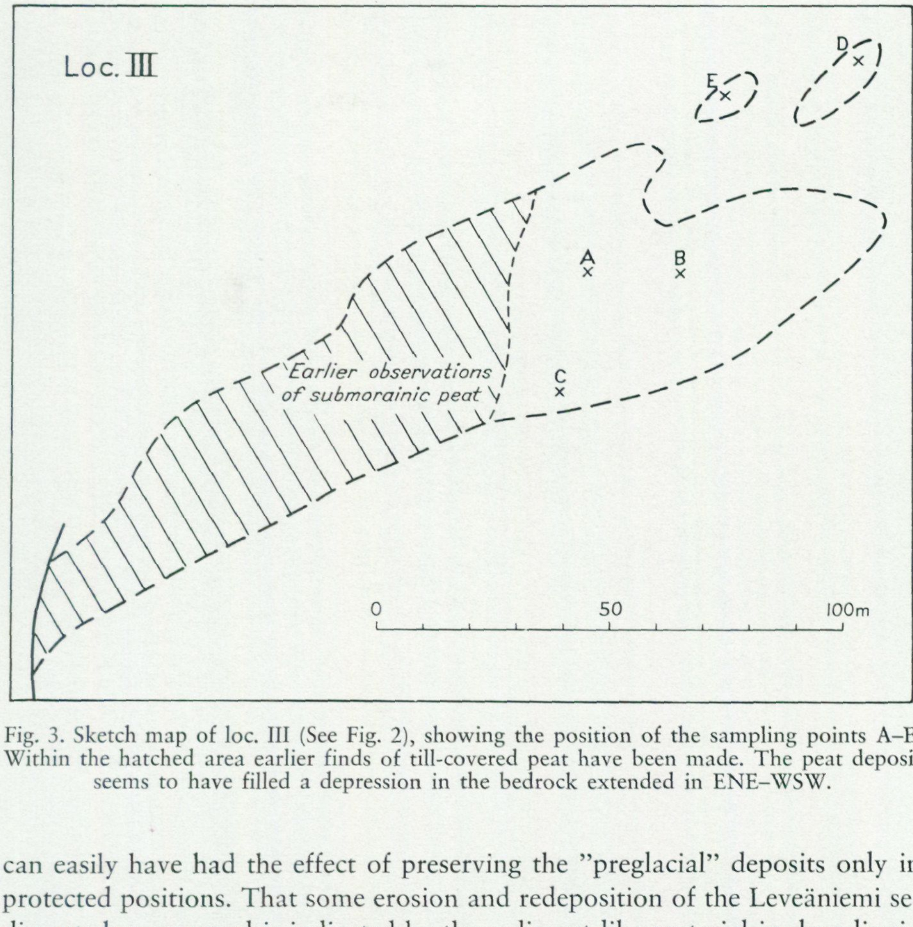

Fig. 3. Sketch map of loc. III (See Fig. 2), showing the position of the sampling points A–E. Within the hatched area earlier finds of till-covered peat have been made. The peat deposit seems to have filled a depression in the bedrock extended in ENE–WSW.

can easily have had the effect of preserving the "preglacial" deposits only in protected positions. That some erosion and redeposition of the Leveäniemi sediments has occurred is indicated by the sediment-like material in drumlinoid moraine hummocks between the mine and the tarn Puttjala at the foot of the hill.

The exposures

As was indicated in the introduction the submorainic sediments were exposed in different places within the Leveäniemi mine area. The large exposure at the refinery (named loc. I in the following, see Fig. 2) clearly differs from the sections with organic deposits upon the ore (loc. III). A third type of exposure is represented by the sections with thin sediments around the exposed ore body (loc. II). It was considered preferable to describe these three types separately.

THE REFINERY SECTION (LOC. I)

The large section which was exposed during the construction of the pelletizing plant reached an altitude of about 375 metres above sea-level. The walls of the excavation showed an uppermost till bed with a maximum thickness of 5–6

Fig. 4. The upper part of the refinery section (loc. I) showing about 5 m till (the upper half of the wall) resting upon sandy sediments. – Photo J. Lundqvist 1967.

Fig. 5. Cross-bedded sand in the refinery section. – Photo J. Lundqvist 1967.

metres (Fig. 4). Down-hill it seemed to be thinner, so that the upper surface of the sediments was more or less horizontal, reaching an approximate altitude of 370 metres. The difference between the till bed and the underlying sediments there was less distinct than up-hill. The main part of the sorted material was probably a kind of ice-contact deposit or sediments reworked by ice. In Ek's profile (app. 1, p. 36) these strata are called "reworked till".

THE UPPER TILL, which here means the typical till above the sorted material, was found by Ek (app. 1, p. 37) to be rich in silt to fine sand, thus being better sorted than ordinary till. The sorting is most probably due to the fact that this till to some extent consists of reworked sediments from the substratum. The second alternative concerning the "reworked till" mentioned above is thus supported.

From Ek's investigation it is quite clear that the upper till has been deposited by ice moving from the southwest.

THE SEDIMENT SERIES in its main, upper unreworked part consisted of sandy sediments with scattered thin gravel beds. The bedding of the sand was of clearly fluvial type, showing numerous discordances, delta bedding, ripples etc. (Fig. 5). Sand of this type reached a thickness of about 4 metres, that is, down to approximately 365 metres. At this level, which was at the base of the large excavation, the sediments became more fine-grained. They graded into a fine, somewhat silty sand and even silt, which was exposed in smaller

Fig. 6. Disturbances of load-cast type in fine-sandy sediments below the sand shown in Figs. 4 and 5 in the refinery section. Thickness of the strata shown is about 1 m. – Photo J. Lundqvist 1967.

pits made for the construction of the foundations of the building. These more fine-grained sediments reached a thickness of about 1 metre. They were rather disturbed through load-cast or glaciotectonic. The beds were torn to lenses and shear planes and other dislocations were frequent (Fig. 6). These sediments rested upon a lower till, exposed to a depth of about 1 metre.

The type of the sediment series clearly indicates fluvial deposition either in a broad stream or, most probably, in a lake or a smooth part in a stream course. The sediments cannot possibly be deposited in a small brook of the type that could now exist in that position. The position at the relatively high altitude of the hill-slope therefore seems rather strange. The existence of such a water body at this level demands either damming by, e. g., ice of a rather large area around the river Torne älv, or a more local damming by rock sills or earth deposits no longer present. The latter alternative demands at least 50 metres thick deposits in the Svappavaara basin, now completely removed in spite of their protected position. The simple fact that the sediments themselves are still preserved make this assumption improbable.

The hypothesis about a damming in the depression where the river flows will imply either a damming by ice of reasonable size or a total damming of the whole region by an overburden of enormous thickness, more than 100 metres, and now completely removed. Such an earth dam is not impossible but the damming by ice appears far more probable. This means that the ice must have been either situated in the lower parts of the whole region, perhaps as dead ice, or formed lobes extending south- or southeastwards from the mountains in the northwest along the flat river "valleys".

The assumption of ice lobes finds some support in the stratigraphy of the sediments, which is reminiscent of the submorainic sediments in Jämtland (J. Lundqvist 1967). The latter begin with extramarginally formed, fine-grained sediments which grade upwards into ice-contact deposits, together indicating an ice advance. The fact that the oldest ice movement in the area did come from the northwest also supports such a theory. However, the morphology of the region is not the one that would give rise to well-defined ice lobes. The rivers, e. g. the rivers Torne älv and Vittangi älv, do not flow in a distinct valley but just follow the lower parts of the landscape in rather winding courses. Distinct valleys of the type characteristic for Jämtland, which will lead to the formation of ice lobes and will be still more accentuated by the glacial erosion, do not occur. Therefore, an advancing ice resulting in a damming of the Svappavaara region more probably must have come from the north or even northeast. This assumption is not impossible, but actually there is no evidence for its support. Striation or other signs of ice movement from this direction are not known and high mountains where glaciation could start are lacking towards the northeast. Also in the north the mountains are rather low and do not seem to be favourable for the formation of an extensive ice sheet.

Thus, the most probable explanation of the sediments seems to be a damming by ice (probably stagnant) in the lower parts of the country. This assumption agrees well with our present opinion about the mode of deglaciation after the last glaciation. According to this large ice bodies were left behind in the inland of northern Sweden while the active ice receded towards the mountains in the west. The stratigraphy of the sediments to some extent contradicts the hypothesis but this evidence is not conclusive. Such a stratigraphy need not necessarily indicate advancing ice. It could as well result from the successive filling up of a small water body, by the shifting of streams or, simply, correspond to an ordinary delta bedding. However, the fact that the sediment is till-covered directly shows that on some occasion ice advanced over it.

At the present stage it is impossible to draw any more definite conclusion as to the formation of the sediments. This would imply too many uncertain assumptions. We can only state that the presence of these sediments under a thick cover of basal till clearly shows that there was an ice-free stage of unknown length during the last glaciation.

THE LOWER TILL was exposed to a depth of about a metre. It was a rather dark, bluish grey, compact basal till with a grain size corresponding to that of an ordinary sandy, poorly sorted basal till. Ek's investigation rather convincingly indicates that it was deposited by ice moving from the northwest. The relatively rich pollen content makes it probable, that its material to some extent also derives from pollen-bearing deposits, possibly the organic sediments described in the following text. The fact that *Pinus* is almost missing in the till is worth noting. It could be an indication that the pollen flora in a removed, uppermost part of the sediments has been of a more subarctic type than is visible in, e. g., the pollen diagram (app. 4, Fig. 4:1).

THE SECTIONS AROUND THE MINE (LOC. II)

In the whole wall surrounding the cleared ore body, especially the western wall, there are two till beds (Fig. 7), in most places covered with fen peat of about 1 metre thickness. The upper surface of the fen is situated at an altitude of about 365 metres and the stratigraphical column reaches down to the surface of the bedrock at 355–356 metres. This makes a total maximum thickness of the beds of about 10 metres, but due to the sloping land surface and irregularities in the bedrock surface the variations towards lower values are great.

THE PEAT is a monotonous sedge peat of the type common in the vast fens of northernmost Sweden. The pollen diagram shown in Fig. 4:6 was made on a sample series from this peat taken near the southwestern end of loc. III (Fig. 3). It thus provides excellent comparison between the flora of the submorainic sediments and postglacial to recent conditions.

Fig. 7. Till at loc. II (See Fig. 2). The upper till is sandy with few stones. It rests upon a more stony and gravelly bed. The contact at the level of John Ek's head is very distinct. The stony bed grades downwards into the lower till. – Photo J. Lundqvist 1967.

THE UPPER TILL bed can be up to 3–4 metres thick. It is a basal till with numerous lenses and thin strata of water-laid sediments. These are rather distorted and not always well separated from the compact till. They might well be to some extent reworked parts of underlying sediments, although they probably mostly are lenses of the type common in most basal till. Ek's investigation (app. 1, p. 37) shows the great similarity between this till and the upper till in the refinery section. No doubt the upper till in both sections represents the same bed. Thus it has a clearly southwesterly origin.

THE SEDIMENTS between the two till beds are rather thin. They consist of sand and gravel of a thickness of only a few decimetres, often much less. The type is not very different from lens material but the extension throughout a large part of the excavation, about 1 km in length, and the difference between the till beds make it clear that the origin is different. It is most improbable that such a layer was formed subglacially like the small lenses. It indicates at least temporary ice-free conditions. Its genesis is not clear, but it could well be a thin shore deposit or, rather, be formed at some distance from a shore by material washed down from it. This explanation is supported by the close resemblance between the two till beds in this section and in the refinery section. The sediments are in this way correlated with the thicker sediments at the somewhat higher level of the pelletizing plant.

THE LOWER TILL clearly differs from the upper bed being more compact and lacking lenses. The thickness is about the same as that of the upper till. From appendix 1 it is evident that the rock material of southwesterly origin is entirely absent in the lower till. This fact agrees well with the striae upon rock surfaces directly underlying the lower till. These rocks are striated only from about N50°W – the strong magnetic deviation over the ore body rendered exact observation difficult. The southwesterly striae mentioned on p. 7 were observed on surfaces overlaid directly by the upper till. The origin of the lower till is most probably from the northwest.

SEDIMENTS below the lower till also occur in these sections but they are insignificant. Between the till and the bedrock there are in some places small patches of gravel (Fig. 8). They occur especially in pockets in the uneven surface of the bedrock. The bedrock is strongly broken and to some extent wea-

Fig. 8. Thin gravel below the lower till in loc. II. The till shows here a well-developed fissility. The gravel is probably formed by weathering and the contact with the underlying disintegrated bedrock is very diffuse. – Photo J. Lundqvist 1967.

thered (Cf. below) and the thin gravel could well be material from the bedrock, reworked, e. g., at a shore. Further interpretation of the gravel has not been possible.

THE SECTIONS WITH ORGANIC DEPOSITS (LOC. III)

The organic, fossil-bearing beds occurred in a lower part of the surface of the bedrock somewhat east of the sections described above. They seem to have formed a long, narrow body extended in about ENE–WSW direction, possibly in a fracture zone in the bedrock where erosion and weathering had lowered the surface of the bedrock (Cf. Fig. 3). The southwestern part of the deposit had been observed as early as in 1963, although the material had not been brought to the knowledge of specialists. The sections studied in 1967 and 1968, were situated in the northeastern part of the sediment body marked on Fig. 3. At point A only scattered samples were taken by Ek. At B 20 metres east of A he measured the following profile (See Fig. 9):

a) Till of a thickness that could not be determined because of the excavation.
b) 20 cm of fine sand with some stones and gravel. It contained scattered twigs and pieces of peat.
c) 70 cm of peat. It contained a whole pine stock and a large amount of smaller pieces of wood and other plant fossils.
d) 7 cm grey fine sand to silt.
e) 30 cm of a material that was originally described as diatomite. Microscopic investigation showed that the bulk of the material was minerogenic although it was rich in diatoms and gyttja. Small plant fossils were frequent.
f) Below the sediments there was material described as till. Water-filling and very unfavourable conditions prevented closer study and the taking of good samples but, from what could be seen and a comparison with the following sections, it is more probable that the material was weathered residual from the underlying bedrock. The thickness is not known but could not possibly be great.

The altitude of the original ground at this place had been 360.5 metres. The bottom of the sediment series was situated at about 346 m.

At point C, 25 m south of A and at a higher level of 2 m, the sample series analyzed in Fig. 4:1 was taken by von Feilitzen. The stratigraphy there seems to have been simpler than at B. Below the till there followed 120 cm of organic matter.

It should be observed that the stratigraphies described here may differ slightly from the ones shown in the diagrams in appendices 4 and 5. This is due to the rather undulating and irregular bedding which results in small differences from one point to another.

In the summer 1968 the part with sections A–C had been completely removed but the sediments were still exposed along a scarp where the upper part of the bedrock was being removed. Two profiles were measured and sampled there,

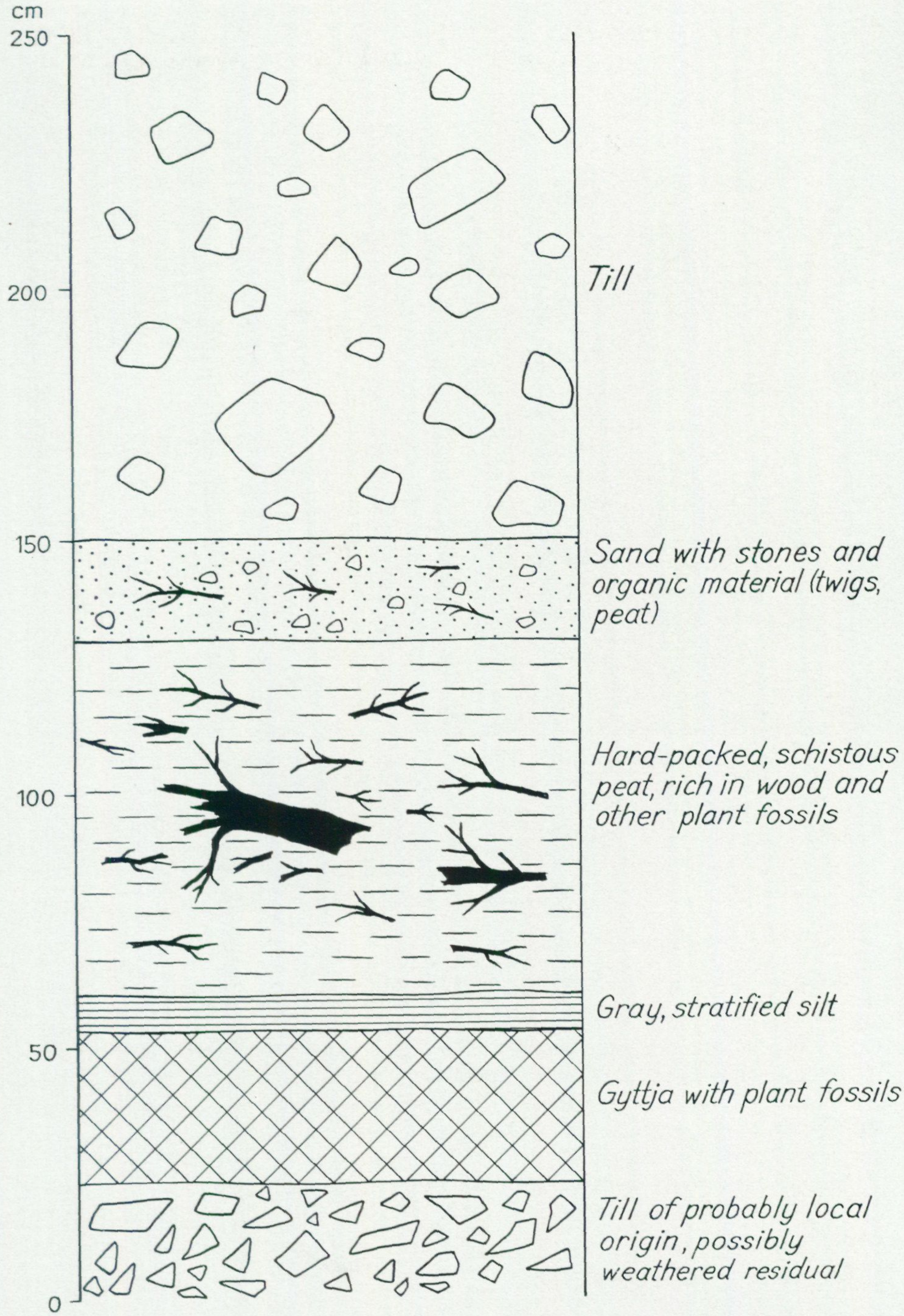

Fig. 9. Section through the interglacial deposits at point B, loc. III (See Figs. 2 and 3), measured by John Ek 1967. At this place the sediments seem to be differentiated best.

Fig. 10. Boulder of the interglacial peat with numerous fragments of pine wood, leaves etc. – Photo J. Lundqvist 1968.

both at an altitude of about 349 metres. Profile D was situated about 60 m northeast of B in a shallow depression in the bedrock. The following stratigraphy was measured:

a) An upper till, almost completely removed and therefore of unknown thickness.
b) 5 cm of clayey sediment with a varve-like bedding.
c) 155 cm peat with frequent wood remnants and plant fossils (Fig. 10). The peat seemed to be pressed, showing a distinct schistosity dipping northwards. Scattered stones occurred in it and especially the uppermost part was very sandy and hard. In the bottom of the peat there was a layer of weathered, angular stones, evidently coming from the underlying bedrock. The huminosity of the peat was very low. The colour was light brown when freshly exposed, but in the air it almost immediately turned dark brown, almost black.
d) 10 cm sand.
e) 5 cm muddy, fine-grained sediment.
f) 5 cm sand.
g) 40 cm sand-stratified, fine-grained sediment with gyttja. Some of the mineral material clearly derived from the underlying ore.

Fig. 11. Pocket in the disintegrated bedrock filled with organic deposits. This is point E, loc. III, where the geologists E. Daniel and S. Lundström take the sample series shown in the pollen diagram, Fig. 4:3. – Photo J. Lundqvist 1968.

h) 5 cm varved, clayey sediment.

i) 5 cm till-like material, probably material derived from the weathered bedrock and redeposited in water.

k) 20 cm very loose, weathered bedrock with angular pieces of better preserved rock. The contact against the underlying bedrock was very indistinct, the bedrock being slightly weathered and disintegrated into pieces by numerous fractures down to at least about 10 metres depth.

Profile E was measured in a pocket in the bedrock 30 m WSW of D (Fig. 11). Another pocket close to E was rather inaccessible in the steep wall but showed a similar stratigraphy. The following stratigraphy was measured in E:

a) Till of unknown thickness of which $^1/_2$ metre remained.

b) 45 cm of peat with very low degree of huminosity.

c) 30 cm more humified peat.

d) 25 cm peat like c but brecciated and showing numerous fractures filled by clayey material. This peat rested directly upon disintegrated bedrock.

Summarizing sections A–E the following can be concluded about the main stratigraphical units (for the till, cf. Ek, app. 1):

THE UPPER TILL is evidently the same as was described as "the lower till" in the section at the refinery and around the mine. It represents the lowest part of the till bed and is separated from the bedrock only by the organic deposits in the lower (crevasse?) zone across the ore body. Therefore it has been mixed with material from the shattered bedrock to a higher extent than in its upper part. Most characteristic is, however, the absence of foreign material from the southwest and the same proportions between Kiruna porphyries and Lina granite. No indisputable solution has been found to explain the total lack of diorite and syenite which are to be found in the surrounding lower till beds but not in the upper till. Probably the two till types represent different stratigraphical parts of the same unit with a somewhat different origin. The organic remnants and the local material directly show that material from the substratum has been included in the till but also the longdistance-transported material could have been derived from different areas, towards the west or northwest.

THE SEDIMENTS have been described above in the profile descriptions. Their fossil content is thoroughly described in appendices 2–5. A general feature is the disturbances in profiles D and E. In D there was a fissility dipping steep northwards or northwestwards but to some extent conforming with the substratum. Most probably the fissility is due to ice pressure from the northwest, although in detail influenced by the morphology of the bedrock surface. The same pressure probably accounts for the brecciation of the bottom layer in profile E. Because the sections at A–C seem to be more undisturbed the pollen diagram in Fig. 4:1 should be considered more reliable than those in Figs. 4:2 and 4:3, as far as concerns the sequence of pollen spectra. The extremely unfavourable sampling conditions while taking series C might, on the other hand, have resulted in some minor contamination from one sample level to another neighbouring one. Important mistakes are, however, excluded, although in this respect sections E and D are more reliable (Cf. p. 5).

Beside the sediment types described above there occur thin layers of a dark reddish, sandy material, especially in the upper and lower parts of the sections. Evidently this material derives from the weathered bedrock of iron and sulphide ore.

The peat is not very different from the ordinary sedge peat in the fen covering the area. A closer examination of its structure gives, however, an impression that some parts of it are of a limnic type rather than terrestrial. The coherent, felty structure of the sedge peat and its rootlets are lacking. The peat seems to consist of fragments of wood, bark, mosses and leaves washed together in water. It is rather similar to such deposits of this material that can be found on recent shores or by material being brought out into a shallow water by brooks, being mixed with detritus from the vegetation growing in the water. Most probably the sedimentation occurred in this way in a shallow tarn, fed by brooklets from the slope towards the southwest. Some parts could well have been formed in a more fen-like, terrestrial or telmatic environment close to the tarn. The diatoms in most of section C indicate that the surface must have been very wet, either situated at the level of the tarn or, at least, fead by water percolating down the slope.

The stones within the peat also contradict a pure fen. They must have been transported either by brooks or rolled down from a shore. Possibly ice pushing or transport by floating ice have contributed to their deposition.

A LOWER TILL seems to be lacking. The redeposited weathered residual forming the substratum of the organic beds in sections D and E contains fine-grained material as well as stones. Most probably the till-like material in profile B is a little thicker deposit of this type. Such negative observations can never be conclusive as they do not exclude the existence of a lowermost till in other places. Yet it is important to observe that there are no signs in the Leveäniemi site of a glaciation before the deposition of the sediments. The surface of the bedrock under the sediments does not show any signs of glacial sculpture or polishing. The deep-reaching disintegration, making the bedrock highly sensitive to glacial erosion, indicates a long period of ice-free conditions before the sedimentation. It is not clear if this means a long interglacial period or preglacial, *s. str.*, conditions.

Summary of the total stratigraphy at Leveäniemi

A correlation of the different sections based on the discussion above and on Ek's discussion in appendix 1 gives the following total stratigraphy:

A) In some parts of the area superficial deposits of postglacial origin represented only by the peat of the thin fens. Pollen analysis (Fig. 4:6) gives the outlines of the climatic evolution since about 6 000 B. C.

B) An upper till with material from the bedrock in the north to west and south. This mixture of rocks can be the result either of a taking up and redeposition of material from the lower till, or of a shifting of the motion within the ice sheet.

C) A series of sediments of glaciofluvial or glaciolacustrine type. These sediments were deposited during an ice-free stage but probably in close connexion with ice thinning out by ablation. There are no signs of temperate conditions or any vegetation during this stage. Glacial, or at least subarctic, conditions have prevailed throughout the stage but it is true that the absence of non-glacial sediments does not exclude the existence also of more temperate conditions. Deposits from such a warmer stage could have been removed by erosion or, locally, never formed.

D) A lower till with material transported only from the northwestern quadrant. Its lowermost part is rich in material of local origin. Where striated bedrock has been observed directly under this till it shows striae only from the northwest.

E) The organic deposit described above. Its type is strictly non-glacial and the fossil content, described in appendices 2–5, indicates climatic conditions milder than the present. The outlines of the evolution during this ice-free stage are indicated by the pollen diagrams, Figs. 4:1–3.

F) Directly under the organic sediments the disintegrated bedrock, locally with insignificant patches of redeposited weathered residual. The weathering must represent a considerable time. There are no signs of a glaciation previous to the deposition of the organic sediments.

Summary of the geological and climatological development at Leveäniemi

The sequence of geological events and the climatological development, as illustrated by the stratigraphy described above and the pollen-analytical investigation by Robertsson (appendix 4), can be summarized as follows.

PRE-INTERGLACIAL STAGE. During a first stage there was a strong disintegration due to weathering of the bedrock. Very little is known about this stage, but the disintegration seems to be of mechanical type, possibly frost-shattering. No signs of chemical weathering have been observed. The weathering could have been of a cold-climate type, perhaps during periglacial conditions. No proofs of a glaciation during this stage have been observed, but the development of the vegetation in the following phase indicates that the vegetational stage was preceded by cold conditions. (Cf. app. 4 and 5.) A possible glaciation in the first stage has either been restricted to the mountain area, or are signs of glacial erosion or accumulation locally absent at Leveäniemi. (Cf., however, Fig. 9.)

INTERGLACIAL STAGE. The second stage, the Interglacial, is characterized by a certain evolution of the vegetation, as is clearly demonstrated by Robertsson's results. In the region an open birch forest with scattered shrubs of juniper and willows constituted the early vegetation. Although the general climatic conditions of that time are probably not directly comparable with postglacial (Cf. especially Lindroth's results in appendix 2) this is a vegetation that seems to indicate cooler conditions than those existing today. The conditions seem to be somewhat similar to those of the Karesuando region farther northwards.

Evidently rather early in the interglacial stage the climate reached its optimum. More thermophilic species invaded the birch forest. Pine, alder, and, according to Robertsson, even hazel replaced the birch as main forest constituents. Spruce forest advanced from the east but without reaching the Leveäniemi area during the optimum (Robertsson's zone b). The climate during the optimum was, according to Robertsson, probably mild enough to allow even the growth of mixed oak forest. Only the existence of a broad inlet between the White Sea and the Baltic (p. 86) prevented such trees extending to the area in question. The climate, according to the insect fauna (Lindroth and Coope, appendix 2), was at this phase of a more continental type, perhaps similar to that of inner, central Finland. This continentality is established also by the flora (See Tralau's discussion in appendix 3). Many species occurring in the Leveäniemi deposit have today a much more southeasterly distribution. Although it is true that some species also occur in the maritime areas along the Atlantic coast, the general impression is that the vegetational zones of the Interglacial were displaced towards the northwest compared to the present conditions. On the other hand, the rather thermophilic flora of Leveäniemi indicates that the winter temperature cannot have been very low. Continental climate implies great difference between summer and winter temperature. Therefore we can conclude, that the general temperature level must have been considerably higher than that of the present day. Thus, the rise of the mean annual temperature was evidently more decisive than the moderate rise of the summer temperature discussed below.

The climatic conditions during the optimum phase are of special importance for comparisons with postglacial and interstadial climates. The dislocation of the plant distribution may give some impression of them, although we must remember that the Leveäniemi finds give only a minimum value of the dislocation. We do not know how far towards the mountains or the north the different plants etc. were distributed.

Lindroth and Coope (p. 54) state that the insects indicate a climate "considerably more temperate and of a pronouncedly continental character with warmer summers" than at the present day. They compare the conditions with those of inner central Finland at the present day. This means a mean annual temperature about 4°C higher, or a mean July temperature about 1°C higher than today. (Cf. Atlas över Finland 1925–28, Östman *et al.* 1953, Ångström 1953.)

Many of the plants, the distribution of which is discussed by Tralau in appendix 3, also indicate a more temperate climate. Comparing with their present area of distribution we can obtain different values for the higher temperature. This of course is due to the fact that Leveäniemi probably does not represent the limit of their growth. The species *Potamogeton friesii* and *Carex pseudocyperus* give the highest values. The mean annual temperature at their present outermost occurrences is about 3.5° and 5.5°C, respectively, higher than the present-day temperature at Leveäniemi. The corresponding difference in summer (July) temperature is only about 1–2°C.

If Robertsson's assumption that the hazel really grew at Leveäniemi is correct it means a considerable displacement of its northern limit. The assumption is not proved by macro-fossil finds but it seems probable, judging from the pollen frequency, that the northern limit of the hazel was situated not far from Leveäniemi. According to Andersson (1902) the present limit of the hazel follows the 12°-isotherm for August-September quite close. Applying this condition at Leveäniemi we find that the interglacial climatic conditions there were comparable with the present conditions in south-central Sweden and the southernmost coast of the Gulf of Bothnia. In terms of mean annual temperature it means a climate 5°C warmer than today and 2.5°C warmer than during the postglacial climatic optimum.

The pollen diagrams (appendix 4, Figs. 4:1–3) are not directly compatible with postglacial diagrams (e. g. those of Granlund 1943, Fromm 1965) and thus they do not permit definite conclusions about the climatic conditions. However, in general the Leveäniemi diagrams are rather similar to the postglacial ones if we consider those parts representing the climatic optima in diagrams from regions along the coast of the Gulf of Bothnia with a mean annual temperature about 5°C higher than in the Leveäniemi area. Thus the pollen diagrams at least do not contradict the evidence of the individual species.

After the most temperate phase the climate became cooler. Pine and spruce replaced the more thermophilic species as main forest constituents. The spruce soon disappeared again, birch together with pine replacing it as forest constituent. According to the vegetation this phase seems to be most similar to the present conditions.

With increasing paludification, lasting up to the subsequent glacial stage, birch and willows gradually replaced the conifers. An increase of *Alnus* and *Pinus* pollen towards the end of the Interglacial could be interpreted as an amelioration of the climate before the definite end of the Interglacial (Robertsson, p. 88). It is perhaps more natural to interpret it as an increased influence of long-transportation when the birch forest lost its importance towards the beginning of glacial conditions. If, however, we tentatively correlate the Leveäniemi Interglacial with the Mikulino Interglacial of the USSR, as known from, e. g., the Kola Peninsula (Armand *et. al.* 1969), the increase could be correlated with the final climatic optimum of that period.

If there was such an amelioration it was certainly of short duration. The pollen diagrams indicate that the birch forest soon (in Robertsson's zone f) disappeared due to increased glacial conditions. A tundra zone probably extended in front of the advancing ice.

The local conditions at the Leveäniemi site during the interglacial stage are indicated especially by the diatom flora and insect fauna (appendices 5 and 2). The sediments seem to have been deposited in one or more small ponds, fed by brooks from the adjacent height. This agrees very well with the general topographic conditions. If we do not assume very large – and very hypothetical – changes of the topography during the subsequent glacial and interstadial periods, the situation does not allow the existence of large streams or water bodies. Also the fact that the pond in which the sediments were deposited seems to have been dried out in zone c (Robertsson, p. 87, Miller, p. 120) indicates that it was small and susceptible to variations of the water level.

FIRST GLACIAL STAGE. In the glacial stage following the Interglacial the ice advanced over the region from approximately northwest. This is important, because the direction of the ice movement indicates, that the ice did not necessarily originate in the highest mountains in the west. As there are no deep valleys or other morphological features in the landscape to force an ice stream from the west towards the southeast, the direction of the movement indicates a strong influence of a glaciation centre to the northwest of Leveäniemi. In that area the mountains are lower and situated rather close to the Atlantic coast. The general lowering of the firn and glaciation lines towards the north has resulted in an ice cap, the movement in which was directed radially from the glaciation centre irrespective of the steeper or gentler slope of the landscape from the centre. It could otherwise easily be expected that the much steeper gradient from west to east than from northwest to southeast over the Leveäniemi region would have forced the ice stream in a more easterly direction.

A lowering of the glaciation limit a certain amount must result in a more coherent ice cover in the flatter landscape of northernmost Scandinavia than in the more dissected regions farther southwards. The fact that this ice cover in the north was able to maintain its separate direction of movement towards the southeast can be interpreted as a northerly orientation of the ice sheet. The orientation farther southwards could be described as westerly and more influenced by the local morphology. These facts should not be further discussed here, but are briefly mentioned because they are of great importance considering Ljungner's (1949) discussion of the balance of the Quaternary ice caps.

INTERSTADIAL STAGE. The glaciation described was followed by an ice-free interval, that could best be described as an Interstadial. We do not know anything about the climatic conditions in this interval or its duration. It is represented only by glacial sediments. This could be taken as a proof that glacial or periglacial conditions prevailed throughout the interval, but we must admit that we cannot expect other deposits in the site in question.

The sediments from the interval are glacial, and their type indicates that they were formed in a water body that cannot have been too insignificant. It must have been considerably larger than the pond(s) in which the interglacial sediments accumulated. This immediately follows from their type and thickness, and the situation higher up on the slope. Such a water body demands –

if we shall not construct a too speculative hypothesis – a surrounding ice sheet to account for the damming. Probably the pond can be described as a nunatak lake extending around or, at least, on the lee-side of the hill, Gruvberget.

It is quite clear, that whether there was a continued deglaciation after the existence of the ice-lake or a readvance of the ice, conditions only allowed sedimentation at the site during the nunatak stage. After this the pond was either emptied or overridden by ice.

If, however, we consider only the facts available and make no speculations about missing strata, we can conclude that only glacial conditions are known from the interval.

SECOND GLACIAL STAGE. After the ice-free interval there was a new glaciation. We do not know how it began. Theoretically it could have begun in the same way as the earlier glaciation. The petrographic composition of the till (Ek, appendix 1) could be interpreted as proof of an ice movement from the northwest also in this stage. However, the same material in the till could be derived from reworking of the older till. What we know for sure is that the second glaciation either began with or developed into a strong dependence of the mountain range. The ice was centred at the eastern side of the mountains which is in agreement with our general opinion about the last glaciation. This easterly orientation could be developed only where there was a high range with a distinct slope towards the east. Such conditions are found only southwards from the area northwest of Leveäniemi, and become more pronounced southwards. The effect of such an easterly orientation upon the ice movement over the Leveäniemi region would be a turning towards the northeast. When the ice divide moved eastwards from the mountains (according to, i. a., Ljungner 1949) this effect increased.

On maps showing the ice movements during the last glaciation the ice divide is usually drawn as an east-westerly zone somewhat south of Leveäniemi (See Fig. 1 and, e. g., G. Lundqvist 1961). It is not quite certain if such an ice divide is a reality or just a construction due to the difficulty in correlating striae from different localities. Perhaps it represents only the central line of an area with divergent ice movement, the visual impression of which is increased by the occurrence of other generations of striae. This question shall not be further discussed here. The only essential fact is that such a zone, whether it is a true ice divide or not, will result in a northeasterly ice movement at Leveäniemi.

POSTGLACIAL STAGE. After the retreat of the last ice sheet about 6 000 B. C. the postglacial climate developed through an optimum, as is well-known from other areas, towards the present conditions. The outlines of the development are indicated by a pollen diagram (Fig. 4:6). They will not be discussed in detail here. It should only be emphasized that the postglacial conditions seem to have been rather different from the interglacial. The much less differentiated flora and the curves of the diagram indicate a climate much cooler in postglacial than in interglacial time. This is true also for the climatic optimum. As far as we know from other regions the optimal postglacial climate was about 2–3°C warmer than the present. This warmer climate, however, is not very clearly reflected by the pollen curves. They show together a very indistinct optimum of slightly warmer conditions at a time about 2 000–4 000 B. C. The warmest conditions in the Leveäniemi area seem to have been somewhat similar to the present conditions nearer the Baltic coast (Cf. the diagrams of Fromm, 1965). In very general terms this difference between present and optimal postglacial climatic conditions at Leveäniemi indicates a temperature difference of the order mentioned above.

Discussion of the age of the Leveäniemi deposits

Outlines of the Quaternary development in adjacent regions

Correlation between the Leveäniemi sediments and earlier known interglacial and interstadial periods is complicated by the large distance to other known deposits. Within Sweden we know a number of sites with organic and minerogenic sediments older than the last glaciation but these seem to be entirely different from the main Leveäniemi deposit in having a colder flora and fauna. Sediments showing more temperate conditions are unknown from Scandinavia and Finland with very insignificant exceptions to the north of Denmark. The nearest comparable deposits are known from the Kola Peninsula and eastern Karelia. The flora of remote interglacial localities south and east of the Baltic is characterized to a large extent by such thermophilic species *(Carpinus* and other broad-leaf trees) that we cannot expect to find in the Leveäniemi region, not even under the rather favourable climatic conditions described above. A brief summary of what is known about different glacial and interglacial (interstadial) stages in the area northern Sweden–Finland–Kola Peninsula may, however, facilitate a tentative correlation or, at least, exclude some possibilities of correlation.

SWEDEN

According to J. Lundqvist (1967) very few, if any, true Eemian deposits are known from northern Sweden. Possibly the Bollnäs sediments described by Halden (Eriksson 1912, Halden 1915, 1948) have this age, which was discussed by J. Lundqvist (1967, p. 236 ff.). A more thermophilic flora than in the interstadial sediments described below, in which *Corylus* plays a notable role, makes an Eemian age possible. However, the Bollnäs sediments are very fragmentary and possibly to some extent redeposited (See Halden 1915) and the importance of the pollen diagram (Halden 1948, Figs. 9 and 10) is therefore reduced. The Bollnäs flora is discussed by Robertsson in appendix 4. Because of this uncertainty the Bollnäs deposit does not allow conclusive correlation with Leveäniemi.

The Würm glaciation in Sweden, according to Ljungner (1946, 1949) was divided in two parts, separated by an Interstadial. During the first glacial stage, the Prime Glaciation, the ice cap had a northerly orientation with its ice divide situated close to the mountain range. The ice divide had a pronounced northerly culmination. In consequence the movement of the ice was directed towards the southeast in northernmost Sweden and more towards the east over the southern parts of the country. (Cf. Ljungner 1949, Fig. 35.)

Deposits from this glacial stage are probably – although conclusive proofs are lacking – a dark, bluish, clayey till, which is known from scattered localities in Sweden. It has been described from Värmland (J. Lundqvist 1958), the County of Gävleborg (G. Lundqvist 1963) and the Stockholm region (Möller 1965). Similar observations have been made in many places along the Baltic coast in the counties of Västernorrland and Västerbotten (J. Lundqvist, unpublished).

After the Prime Glaciation there was an Interstadial, during which most of the intermorainic deposits of central Sweden were accumulated.

In the second glacial stage, the Posterior Glaciation, the ice divide moved eastwards from the mountain range. During the glacial maximum it was situated far east of it, perhaps even over the Gulf of Bothnia. In northern Sweden this must have resulted in an ice movement directed more or less towards the north.

J. Lundqvist (1967) showed that, as had been supposed by Ljungner (1946), most of the till-covered sediments in the province of Jämtland had been deposited during an Interstadial, evidently the one defined by Ljungner. From the same Interstadial also almost all other known organic, till-covered deposits of northern and central Sweden derive. In one instance (Gallejaure) the interstadial age had been proposed by Magnusson (1962), but G. Lundqvist (e. g. 1964) and many others interpreted all these deposits as interglacial, Eemian. As J. Lundqvist showed, however, their fossil content indicated much cooler conditions than are known from the Eemian. The Interstadial defined was shown to have had a climate about 2 or 3°C cooler than today at its optimum which is not in accordance with interglacial conditions. The conditions agree much better with those described by S. Th. Andersen (1961) for the Brörup Interstadial of Denmark and the northern European continent. The Interstadial defined in Sweden was called the Jämtland Interstadial because of the fact that its characteristic feature is the wide distribution of sediments within the province of Jämtland. J. Lundqvist (1967, p. 228) considered a correlation between the Brörup and Jämtland Interstadials as probable, although by no means proved. (Cf. below.)

FINLAND

More certainly the Swedish interstadial sediments could be correlated with the Peräpohjola deposits of northern Finland (Korpela 1969). Korpela's description and deductions make it quite clear that they represent the same period. His correlation, however, makes a correlation with Brörup less probable. Brörup is dated with radiocarbon at about 59 000 B. P. (S. Th. Andersen 1961). From the Peräpohjola sediments one radiocarbon dating, from the site Kostonjärvi, has given the age 45 400 ±2 000 B. P., which is not in agreement with the age of Brörup. It is true that dating of such old material demands extreme purity of the sample and is very readily affected by even the slightest contaminations. Thus this single dating does perhaps not definitely exclude a correlation with Brörup, but Korpela's (1969, p. 93) correlation with the Upton Warren Interstadial Complex (Coope a. Sands 1966), that is, a Middle Würm Interstadial, seems so far to be the most probable. In reality this question is a question about the age of the first main glacial advance. If this is placed a f t e r Brörup, as was done by Coope a. Sands (1966, Fig. 2) and Korpela (1969, Fig. 47), the correlation between the Brörup and Jämtland Interstadials is impossible – provided the Kostonjärvi date is correct. If, on the contrary, the main glacial phase is placed b e f o r e Brörup, this can be considered one of the different phases making up the Upton Warren Complex. The correlation Jämtland–Peräpohjola–Upton Warren leaves at least one important question open: the lack of Upton Warren deposits above Brörup in Denmark. This absence is an embarrassing fact speaking against the correlation mentioned. The question ought to be elucidated with more radiocarbon datings of Jämtland and Peräpohjola fossils. Fig. 12 gives an impression of the problematic point in the correlation.

These problems have but little importance for the main Leveäniemi deposit. It is essential that we know only one large Interstadial from northern Scandinavia and that this Interstadial was characterized by a cooler climate than the present. According to J. Lundqvist (1967) the interstadial climatic conditions in the Leveäniemi region must have been of periglacial type. The vegetation, if there was any, must have been a tundra or mountain heath. Glaciated areas cannot have been distant. This is clearly demonstrated by the climatic zonation deduced from the Jämtland and Peräpohjola fossil floras.

The glaciations before and after the Peräpohjola Interstadial have developed somewhat differently and resulted in different till types. Before the Interstadial the ice movement over northern Finland was directed from northwest towards southeast (Korpela 1969, Fig. 46). The deposit accumulated during this stage was a dense till containing weathered residual and some organic material, derived from interglacial sediments. In the second glaciation the ice moved from west to east over northern Finland. The deposit from this time is the common greyish-brownish, sandy till of these regions.

True interglacial, that is Eemian, deposits in Finland are even more fragmentary than in Sweden. The only sediments that, according to Korpela (1969), can be interpreted as interglacial, are the Rouhiala finds from southeastern Finland, described by Brander (1937, 1943). These finds only consist of boulders of sediments within a lateglacial glaciofluvial deposit. The fossils of the sediments indicate a climate even warmer than at the postglacial optimum, showing a dominance of broad-leaf trees over coniferous ones. Even *Tilia* pollen occur and a relatively large amount of *Carpinus* makes a correlation with the Eemian probable. Unfortunately no stratigraphy is known, which makes correlation with, e. g., Leveäniemi difficult, but it is important enough that the climate was warm and the broad-leaf tree forest reached at least that far northwards.

KOLA PENINSULA

In the Kola Peninsula there occur in many places different till-covered sediments and till beds. These have been interpreted in somewhat different ways by different authors. A short summary of the stratigraphy according to the review by Armand *et al.* (1969), which follows here, seems to give the most probable interpretation of the Kola deposits.

A lowermost till, which is described as reddish brown and clayey, derives from an early glaciation and is by Armand *et al.* (1969) assigned to the Moscow Glaciation, correlated with the Riss Glaciation of Central Europe.

After the Moscow Glaciation followed the Mikulino Interglacial, correlated with the Eemian, and in Kola represented by sedimentary beds. Fossil content and pollen diagrams indicate the following development during the Mikulino stage. Birch forests and tundra were invaded by pine and spruce during an optimum phase, after which there was again a colder phase with birch–tundra vegetation. There seems to have been a second climatic optimum in this Interglacial, which in the Kola region is marked by invasion of pine and spruce before the onset of the final deterioration. This second optimum is better developed in more southern areas. According to Grave *et al.* (1969) it can not be traced in Kola. During the first and warmest optimum the climate was warmer than today with a sea-water temperature about 3–4°C higher than the present. Thermophilic trees could grow not far away and are represented up to 6 per cent *(Corylus* +QM) in the pollen diagrams. The northern limit of the mixed oak forests was displaced about 800 km north of its present position. The water-level of the sea was at times much higher than today. Two transgressions can be traced at an early and a late phase of the Interglacial.

The Mikulino Interglacial was followed by the Valdai Glaciation, which was evidently divided in two parts. Valdai I is represented by a characteristic bluish till and Valdai II by the ordinary wide-spread till of these regions.

Between Valdai I and II there was an ice-free stage, an Interstadial. This

Kola Interstadial is by the Russian geologists correlated with the Mologo-Sheksna[1] Interstadial of other parts of the Soviet Union and the Paudorf Interstadial of Central Europe. The latter fact places it within the Upton Warren Complex, that is, the Middle Würm Interstadial. The vegetation during this Interstadial developed from tundra to birch forest, which at the climatic optimum to some extent was invaded by pine. Towards the end of the period this succession was reversed. Thus the climate was evidently notably colder than today. Also the sea-water was cold, as is shown by the fauna and diatom flora. During some phase of this short Interstadial the water-level of the sea was considerably higher than that of the present day.

Stratigraphic position of the Leveäniemi deposits

The stratigraphic position of the main unit at Leveäniemi, the organic beds, is probably rather clear from what has already been written. Thus it is evident that these deposits cannot be correlated with other till-covered, organic deposits in Sweden, perhaps with exception of Bollnäs. The much more temperate climate during the formation of the Leveäniemi sediments is not compatible with the cold climate of the Jämtland Interstadial. It conclusively shows that the period in question must be considered a true Interglacial irrespective of the unclear distinction between the terms interglacial and interstadial.

Thus we can most probably correlate the Leveäniemi ice-free stage with the Eemian (Mikulino) Interglacial. Conclusive proof of this correlation is lacking because of the great distance to other well-defined Eemian deposits. However, the probability of the correlation decreases with increasing age of the Interglacial assumed. Therefore we must thus, in so far as is possible, consider the correlation Leveäniemi–Eemian as the most plausible. Some positive evidence is the following:

1. The temperature conditions, that is a maximum mean annual temperature roughly 5°C higher than today, agree with what is known about the Eemian, and Mikulino, stages. (Cf. above and, e. g., J. Lundqvist 1967, p. 208.)

2. The pollen flora at Leveäniemi agrees with the assumption of a position of the vegetational limits some 800 km more to the north than the present ones (cf. p. 30). This displacement brings the limit of the hazel up to the interior of Lapland. The mixed oak forest should not have been far away but, as Robertsson (appendix 4) pointed out, its immigration could have been prevented by the broad inlet between the White Sea and the Baltic.

3. The fact that only one ice-free stage is known after the formation of the organic beds at Leveäniemi correlates well with our knowledge about Würm Interstadials in these regions. This evidence is, of course, not conclusive, since

[1] According to Serebryanny *et al.* (1970) the Mologo-Sheksna sediments have recently been redated to the Mikulino Interglacial. The name, Mologo-Sheksna Interstadial, should therefore according to them be changed to Karuküla Interstadial after the new type site.

other beds may have been removed by glacial erosion. The glacial character of the interstadial sediments above the organic beds agrees, however, very well with what we know about the conditions in this region during the Jämtland Interstadial, the only ice-free period known after the Eemian that could possibly have affected this area. Since no fossils are known from the upper sediment series at Leveäniemi this part of the discussion is rather speculative, although reasonable.

4. The directions of ice movement in the glacial epochs after the Interglacial agree well with the known directions of ice movement during the two Würm glacial stages.

5. Also the character of the till (compact, dark, bluish) stratigraphically overlying the organic beds at Leveäniemi agrees well with the type of the supposed early-Würm till in other parts of Sweden and the Valdai I till of the Kola Peninsula. (Cf. pp. 28 and 30.)

The stratigraphic position of the Leveäniemi deposits, the main, organic series and the upper, minerogenic series, as it seems most probable, is illustrated in Fig. 12. Here we also see the problematic relationship between the Jämtland, Peräpohjola and Brörup Interstadials. The correlation there is evidently much dependent on the way we draw the glaciation curve around the Brörup interval.

A feature of the Leveäniemi deposits that causes some problem is the continentality of the climate (Cf. appendices 2 and 3, and p. 23). Very generally, a displacement towards the north or northwest of the climatic limit would mean that the continental climate of eastern Europe would affect more northwesterly regions. The fact that, at least during some part of the Interglacial, the sea-level was much higher than today will, however, bring the surface of the Baltic much closer to the Leveäniemi region than it is today. Therefore, also considering the widened surface of the Baltic, it is somewhat astonishing that the effect was not a shifting towards maritime conditions at Leveäniemi. It is not clear how this fact should be explained. It is true, that today there is an area with locally continental climate southeast of the Leveäniemi region (See Ångström 1953, Fig. 5). The explanation may simply be that this area was forced northwestwards during the higher stage of the sea, but the effect of the higher sea-level also in the west would probably eliminate this effect by forcing the area of maritime climate in the mountain region southeastwards.

The conditions at Leveäniemi *could be* interpreted as an indication that the sea-level in the west was lower and a landmass extended outside the present coast of northern Norway. We know that the sea-level in the Mikulino Interglacial was high in the Kola region (p. 30). We also know that it was probably high in the Baltic area (Cf. Brander 1937, Fig. 7), but according to Brander's construction of the extension of the Portlandia Sea it could be ex-

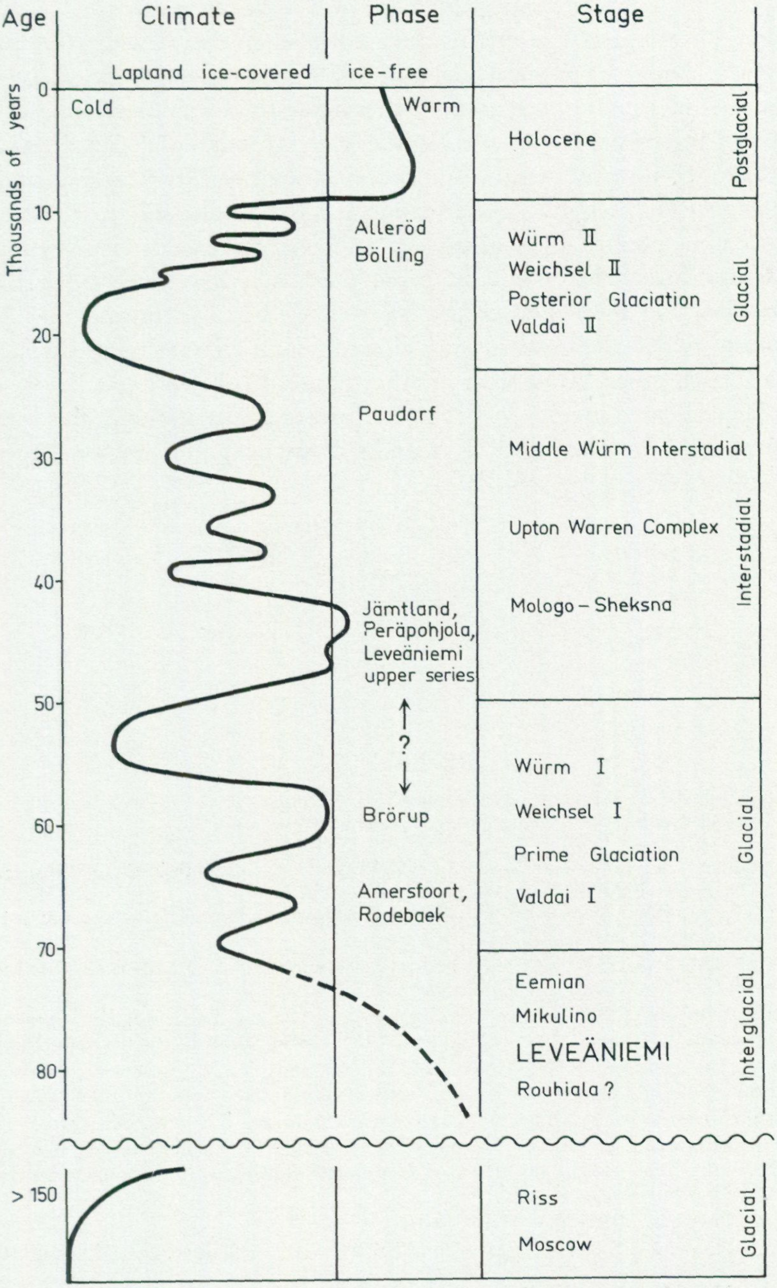

Fig. 12. Diagram of the glacial development during Late Pleistocene, mainly from Coope a. Sands (1966) and Korpela (1969). The curve to the left gives an impression of the course of the glaciations. The phases represented by the Jämtland and Peräpohjola sediments should perhaps be correlated with Brörup, but this assumption is contradicted by Korpela's (1969) radiocarbon dating. The organic Leveäniemi deposits are considered to belong to the Eemian. Concerning the name, Mologo-Sheksna, see p. 31, footnote.

pected, that its shore-line was gradually lower towards the west. It is true that there are indications of a higher Eemian sea-level on the western coast of Norway (See B. Andersen 1964, Mangerud 1970) but this evidence is somewhat uncertain. Andersen's observations either refer to a very early phase of the Riss-Würm Interglacial or to the Middle Würm Interstadial (See B. Andersen 1965). Mangerud's observations are more difficult to interpret and may anyway indicate only a slightly raised sea-level. We must also admit that we know very little about the changes of the sea-level and the earth's crust in this part of the world during the time in question. There may have been more than one transgression and regression of the sea (Cf. p. 30), and during the climatic optimum to which the observations of continental climate refer, the sea-level may have been much lower than in other phases of the Interglacial.

The Leveäniemi deposits do not allow further speculations in this question. The purpose of these concluding remarks is just to point out some problems which still remain to be solved.

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Appendix 1

INVESTIGATION OF THE TILLS AT LEVEÄNIEMI

by

John Ek

Geological Survey, Prospecting Division

CONTENTS

Collection of samples

Till samples from the three localities I–III (Fig. 2, p. 8) were taken during the summer 1967 by the authors (Lundqvist, Ek).

Locality I was situated about 500 m northwest of the open pit. There the mining company was building a new pelletizing plant at that time. It was possible, because of excavations for the constructions, to study profiles of the glacial deposits of a vertical length of about 10 m. The following profile was noticed:

a: 1 m till. Sample 1
b: 6 m reworked till
c: 2 m silt
d: 1 m till. Sample 2

Sample 1 was taken from the upper till near the contact to the reworked till. Sample 2 was taken from the lower till at the bottom of a pit dug for concrete pillars. Unfortunately the bedrock was not exposed in any of the pits, which made an estimation of the thickness of the lower till impossible.

The second locality was situated at the western side of the open pit (within II in Fig. 2, p. 8). At this side of the excavation one could study a vertical section of the glacial overburden along a stretch of about 500 m. The following profile was measured:

a: 2 m till. Sample 3
b: 0.5 m pebble-rich layer
c: 2 m till. Sample 4

It was possible to distinguish between two till layers in most parts of this section. The upper till had a thickness of about 2 m and contained fine layers of silt and sand. It rested upon a gravel-rich bed about 0.5 m thick. Under this bed followed the lower till. It differed from the upper till in being more consolidated and of darker brown-gray colour. It was also richer in the coarser fractions than the upper till. One sample was taken from each till layer, sample 3 from the upper till and sample 4 from the lower till.

Locality III was identical with the place where the peat was found (Fig. 3, p. 9). It was situated in the central part of the open pit. The bedrock surface (iron ore) there formed a depression, which resulted in greater thickness of the glacial deposits. The mining started in this part in 1967, which made it necessary to remove all the glacial deposits. During this work the peat was discovered at the bottom of the depression. The following profile, also shown in Fig. 9, p. 17, was measured:

a: > 5 m till (the exact thickness impossible to estimate because of excavation of the surface layer). Samples 5, 6, 7
b: 20 cm sand and silt. Sample 8
c: 70 cm peat
d: 7 cm fine silt. Sample 9
e: 30 cm gyttja. Sample 10
f: Bedrock (iron ore)

Three samples were taken from the till (nos. 5, 6 and 7); one from the sand and silt layers (no. 8), one from the fine silt layer (no. 9) and one from the gyttja (no. 10). However, only sample 5 was subjected to a complete investigation, the other samples being investigated only with pollen analysis.

Grain size of the till beds

The SGU laboratory made the particle size determinations using dry sieving and hydrometer analysis. The results were plotted in the laboratory directly on a semilogaritmic diagram on which the size distribution is presented as a cumulative curve.

The results are presented in Fig. 1:1. The two upper till samples (1 and 3)

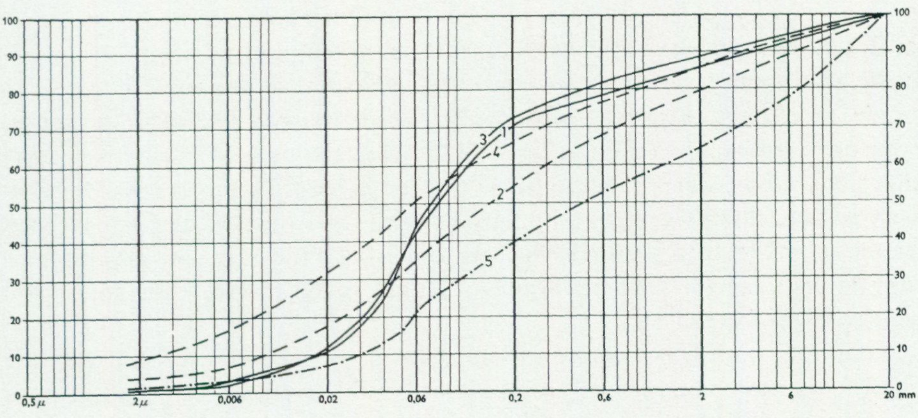

Fig. 1:1. Cumulative-frequency curves for the till samples 1–5.

are dominated by the silt fraction. The cumulative curves for the two samples are very similar, having a typical S-shaped form.

The curves of samples 2 and 4 representing the lower till have a quite different form. They form more or less straight lines, which means that no size fraction tends to dominate. The grain size of these samples indicates that they represent normal basal tills.

The grain size of sample 5 (taken above the peat) is characterised by a dominance of the coarser fractions (sand and pebbles). The frequency of the finest fractions is low, giving the cumulative curve a concave (upwards) form.

Petrographic investigation of the pebbles

In order to determine some possible relationships between the different till layers petrographic determinations were made on the five samples. The fraction 4–8 mm was chosen and 250–330 grains were obtained from the different samples. The identification of the rock types was made with a binocular microscope after removing the finer fractions by washing.

It was possible to refer all the grains to six different groups of rocks. These are: 1) porphyry, 2) granite, 3) mica schists, 4) dark rock types as diorites, gabbros and amphibolites, 5) local rock types, 6) magnetite ore. (For the Precambrian geologi of northern Sweden see Ödman 1957 and Fig. 1:3.)

The results of the petrographic investigation are shown in Fig. 1:2. In the following the probable geographic origin of the different rock components in the gravel fraction will be discussed.

The pebbles of the porphyry group involve grains of liparitic, keratophyric and andesitic composition. They were easy to distinguish from the other rock types because of the plagioclase phenocrysts. Some grains could be identified as belonging to derivatives of the Kiruna porphyries. These rocks occur to the north and northwest of Leveäniemi as can be seen in Fig. 1:3.

The pebbles of the granite group involve types with typical holocrystalline texture. However, probably not all pebbles are of granitic composition. Some of them might be of syenitic, granodioritic or even of dioritic composition. Because of the uncertainty in identifying pebbles of this size some might even originate from gneissic rocks, which occur in two massives southeast and southwest of Leveäniemi. Certain differences between the pebbles in the two upper till samples (nos. 1 and 3) and those in the two lower till samples (nos. 2 and 4) were noticed. In the former group most pebbles show the typical characteristics of the so-called Lina granite, which is a late orogenic Svionian granite. It is very widespread in northern Sweden, mainly to the north, east, south and southwest of Leveäniemi.

Samples 2 and 4, on the other hand, are dominated by pebbles with the characteristics of the perthite granites and perthite syenites. The nearest massive of these is located about 15 km northwest of Leveäniemi. Pebbles of the

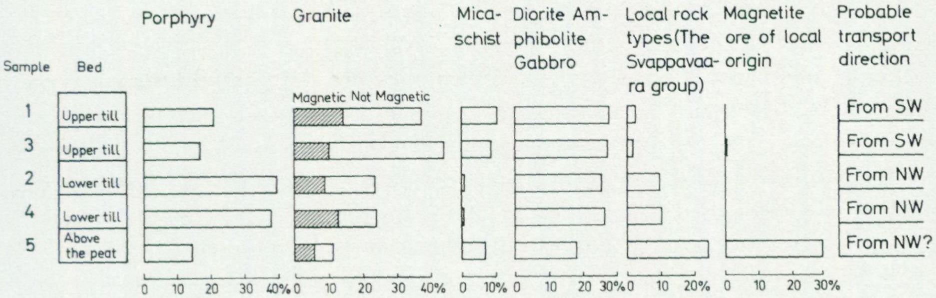

Fig. 1:2. Lithologic composition of the fraction 4–8 mm in the till samples 1–5.

Lina granite type are subordinate. In the two lower till samples a few pebbles very similar to the early orogenic Svionian granite were identified. Their probable origin is the big massives 50 km northwest of Leveäniemi.

The pebbles of the mica schist group are fissile, which probably means that they are under-represented in the gravel fraction. Having dark colours because of abundance of mica (mainly biotite) they are easy to identify. They probably originate from basic derivatives of gneisses. Such rocks occur in a couple of big massives to the south and southwest of Leveäniemi as mentioned above (Fig. 1:3).

Pebbles of the group diorites, amphibolites and gabbros are characterized by dark minerals, such as amphibole, basic plagioclase, pyroxene and biotite. The grains are dark, often magnetic, and originate from basic rocks of medium grain size. Rock types with these characteristics occur within the gneissic rocks to the south and southwest, but they are also common around Leveäniemi.

The rocks comprising the group of local types are very similar to those belonging to the so-called Svappavaara group, described by Frietsch (1966). They are dense and grey, probably of both volcanic and sedimentary origin.

The magnetite pebbles, finally, most probably originate from some of the iron ore bodies in the vicinity.

The samples from localities I and II include the two samples from the upper till (nos. 1 and 3). As can be seen, granite is the dominant rock type in the two upper till samples, while porphyry dominates in the two lower till samples.

Mica schists are much more abundant in the upper till than in the lower till (around 10 per cent and less than 1 per cent respectively).

The contents of diorites, amphibolites and gabbros, however, are about the same for the four samples (25–28 per cent), not indicating any difference between the two till beds.

Local rock types of the Svappavaara group, however, show different proportions with respect to the two till beds. The upper till has contents of 2–3 per cent and the lower till around 10 per cent.

The contents of magnetite ore, finally, are less than 1 per cent in the four samples.

The results show, that the upper till samples are dominated by rock types occurring to the south and southwest (granites and mica schists). They also show (as was expected) very low contents of local rock types.

The two lower till samples, on the other hand, are dominated by porphyry, indicating a transport direction of the till from the north, northwest or west.

The results fit very well with the directions of the glacial striae in the area. They indicate two glacial transport directions, an older one from the northwest (that probably deposited the lower till) and a younger one from the southwest (that probably deposited the upper till).

It is not possible to correlate sample 5 (taken above the peat) with any of the two till beds on the basis of the rock composition of the gravel fraction. The reason is the large proportions of local rock types (more than 50 per cent). However, some conclusions can be drawn. First, the gravel fraction in this sample has a higher percentage of porphyry than of granite. Secondly, the granitic grains in this sample are more similar to those in the lower till samples with respect to the magnetic characteristics. About 50 per cent of the granite pebbles could be separated from the others using a hand magnet. About the same results were obtained for the two lower till samples. The upper till samples, on the other hand, have much smaller proportions of magnetic granite pebbles (around 30 per cent).

On the basis of these statements we can conclude, that the till at locality III has been subjected to the same glacial transport as the lower till of localities I and II (i. e. from the northwest).

Pollen analysis of the till samples

The till samples were treated according to the HF method as described by Heinonen (1957) and then pollen-analysed (Cf. Robertsson, p. 82). The analyses were made by Miss Karin Bengtsson, F. K. The results are presented in Fig. 1:4.

Besides samples 1–5 also samples 6–10, from the section with the peat, were analysed. The location of these samples is shown on p. 37.

The results from samples 1 and 3 indicate that the upper till is almost without pollen. In spite of several preparations only 8 pollen grains were obtained from sample 1 and 2 pollen grains from sample 3.

The two lower till samples (3 and 4) were richer in pollen (100–200 counted grains). Among these dominated *Betula* (about 80 per cent in sample 2 and 55 per cent in sample 4). The percentage of *Pinus* was low (1 per cent and 8 per cent respectively). Also the percentage of *Alnus* pollen was low (around 1 per cent). The most frequent pollen species from shrub is *Corylus* (around 3 per cent).

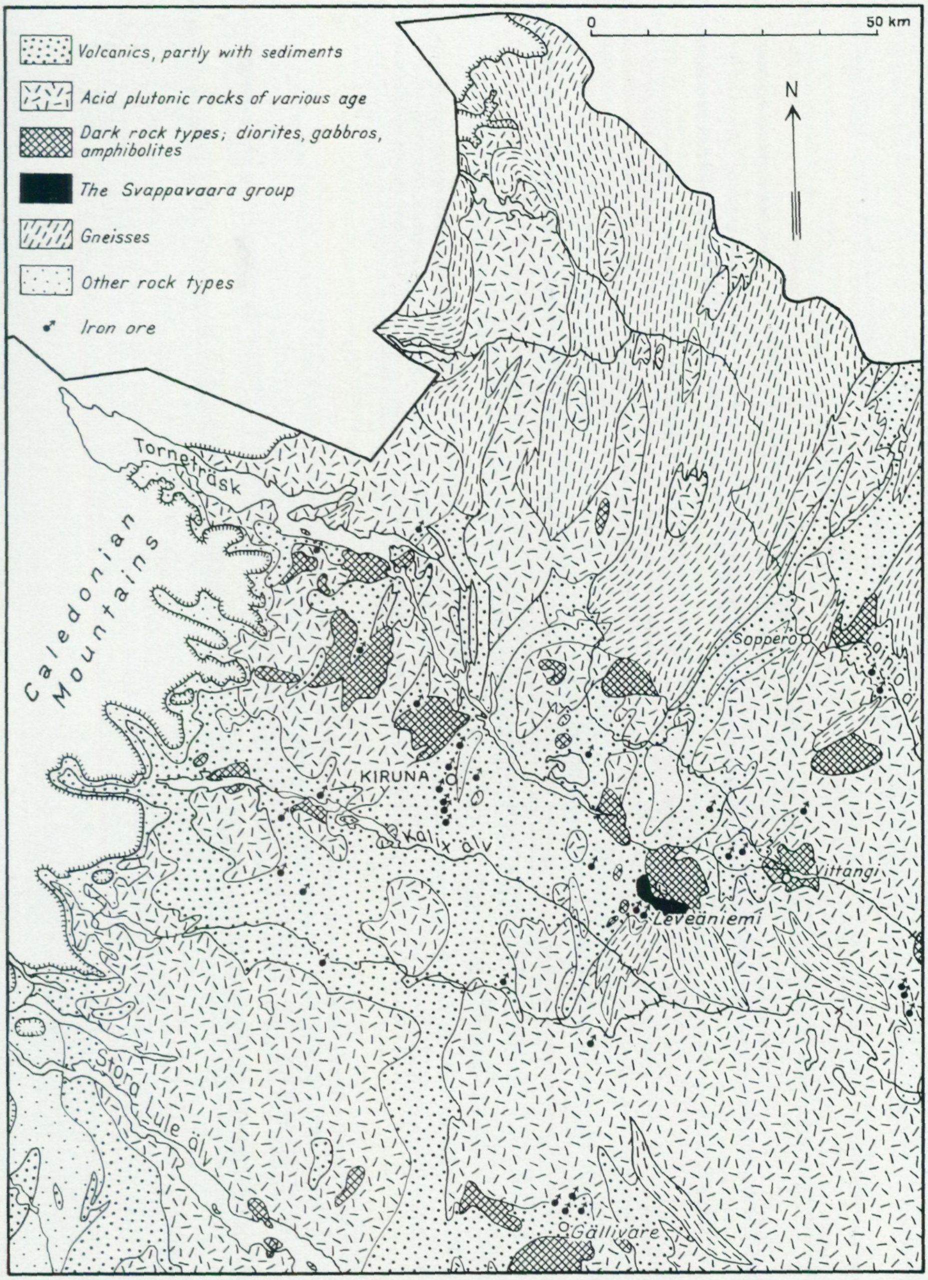

Fig. 1:3. Precambrian rocks of northernmost Sweden. The hatched line in the western part of the map shows the eastern border of the Caledonian nappes. – Simplified after Magnusson *et al.* (1960).

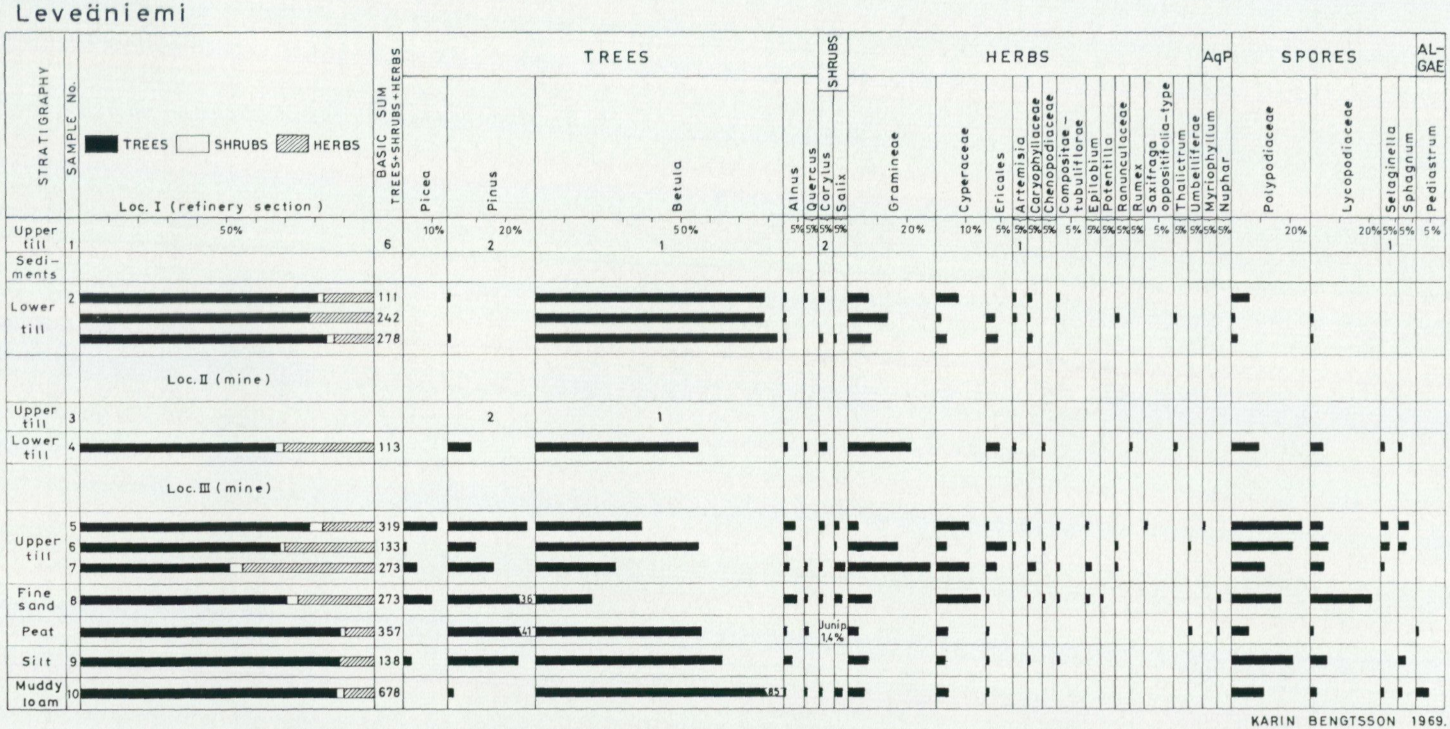

Fig. 1:4. Pollen flora of the different till beds. For comparison also a few analyses of the interglacial sediments are included. The results should be further compared with the pollen diagrams in appendix 4.

The NAP-flora is dominted by pollen from *Gramineae, Cyperaceae* (only in sample 2) and *Ericales*. Also some other species were present, but only in small amounts.

On the whole, the results indicate that samples 2 and 4 are similar as far as the pollen flora is concerned.

All samples from locality III (i. e., the place where the peat was found) contained a considerable amount of pollen. The pollen flora in the till samples 5–7 is dominated by *Betula,* but in a smaller amount than in samples 2 and 4. Instead, these samples were richer in *Pinus* (10–28 per cent) and *Picea* (2–12 per cent) pollen. Also the content of *Alnus* was higher than in the samples from localities I and II (max. 5 per cent in sample 5). Shrubs are represented by *Salix* and *Corylus* (max. 5 per cent for both). The NAP flora, finally, has roughly the same composition as in the two lower till samples (2 and 4).

The remaining samples were taken from a) a sandy and silty bed resting upon the peat (no. 8), b) a silty layer immediately under the peat (no. 9), and c) a bed of gyttja below the silt layer (no. 10).

As can be seen in Fig. 1:4 the pollen content of sample 8 is very similar to that of the samples from locality III (5, 6, 7). The same also applies to sample 9 except for the content of *Betula,* which is higher in this sample (65 per cent).

Sample 10, finally, showed much higher contents of pollen than the others, with *Betula* as the main component.

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Appendix 2

THE INSECTS FROM THE INTERGLACIAL DEPOSITS AT LEVEÄNIEMI

by

Carl H. Lindroth and G. Russell Coope

University of Lund University of Birmingham

CONTENTS

Introduction

We received from Dr. Jan Lundqvist parts of samples (1–7) from the interglacial peat and gyttja layers at Leveäniemi (near Svappavaara, Swedish Lapland). The remains of insects were extracted at the Department of Geology, University of Birmingham, by means of the "kerosene method" previously described (Coope 1968, p. 426). A few additional fragments were found during the botanical examination by Dr. H. Tralau.

Although several remains of Chironomid, Trichoptera and *Sialis* larvae, as well as ephippia of *Daphnia* and statoblasts of *Cristatella* were found, only some of the beetle fragments could be identified to species. Most of them were incomplete but otherwise in good shape, little distorted as a rule, often with colours and even scale structures preserved.

The preliminary identifications were made by Coope, then checked by Lindroth. We are thus mutually responsible for the result.

Of the 7 numbered samples, to which most of the fossils could be referred, identifiable insects were absent from the two deepest and oldest, nos. 6 and 7, close to the beginning of the organic sedimentation. Samples 1–5, judging from the beetles, were formed during uniform climatic conditions. Samples 1–3 were taken at point A (Fig. 3, p. 9). Samples 4–7 all derive from point B. No. 4 was taken in the middle part of the peat (see Fig. 9, p. 17), no. 5 close above the bottom of the peat, no. 6 in the silt below the peat, and no. 7 in the lowermost organic bed, the gyttja.

Identified Coleoptera

Fam. *CARABIDAE*

Bembidion doris Panz. – Sample 2. Left elytron except apex (but preapical pale spot clearly visible). On the intervals are single rows of small punctures, a common postmortal change in fossil Carabids.

DISTRIBUTION. Palaearctic. Generally distributed and common in Europe, except the southernmost parts. In Fennoscandia north to Petsamo (and with a single locality in northern Norway); scarce on the west-coast and absent from the mountains.

ECOLOGY. Very hygrophilous, at the margin of oligo- or dystrophic waters and in marshes, with Carices, mosses, & c. Not known from arctic or subarctic country but reaching the upper parts of the *regio coniferina.*

DYNAMICS. The wings are constantly full and the beetle is a regular flier.

Patrobus septentrionis Dej. – Sample 2. Anterior third of left elytron with inner intervals missing but shoulder region complete. Intervals with irregularly arranged, apparently postmortal punctures.

It cannot be decided whether the specimen belongs to the *forma typica* or to the southern sbsp. *australis* J. Sahlb. (See below).

DISTRIBUTION. Circumpolar. The *forma typica* of Europe is boreo-alpine, on the continent inhabiting the Alps only. In Britain it is confined to the north. In Fennoscandia south to Central Finland, northern prov. Dalarna, Sweden, and the mountains of southern Norway. – Sbsp. *australis* in Central Europe and western Siberia; north to Central Finland, Scania and Denmark.

ECOLOGY. The *f. typ.* is most abundant in arctic-subarctic regions and is very eurytopic there. In the conifer region distinctly hygrophilous, occurring on river banks, in *Sphagnum,* & c. – Sbsp. *australis* usually at the margin of standing waters in somewhat shaded places.

DYNAMICS. The wings are constantly full and spontaneous flight has been observed in Norway (Lindroth 1945, p. 589).

Fam. *DYTISCIDAE*

Unidentifiable fragments of *Hydroporus* and *Ilybius.*

Fam. *GYRINIDAE*

Gyrinus marinus Gyll. – Sample 3. Entire left elytron (flattened and somewhat wrinkled). The microsculpture, according to Mr. Bo Svensson, Lund, is stronger than in normal *marinus* but otherwise typical.

DISTRIBUTION. Palaearctic, south to the Mediterranean. In Fennoscandia north to Finnish Lapland (prov. Li), northern Swedish Lapland (T. Lpm.); only in southern Norway.

ECOLOGY. Almost exclusively in stagnant waters, usually pools and dystrophic lakes. Not found in arctic-subarctic regions.

DYNAMICS. The wings are full and functionary.

Gyrinus natator L. or *substriatus* Steph. – Sample 3. About one third, from just behind middle, of right elytron; shoulder and apex lacking but entire width present from suture to side-margin. According to Mr. Bo Svensson, Lund, who based his judgment on the microsculpture, only either of the two above mentioned species (with slightly higher probability for *natator)* are concerned.

In northern Fennoscandia both species are restricted to the forested parts *(regio coniferina).*

Fam. *HYDROPHILIDAE*

Hydraena riparia Kug. – Number of sample unknown. Entire right elytron, in good shape. The choice is between this species and *britteni* Joy. A distinctive character, not found in the literature but visible at high magnification (about 200×) in the ultropaque microscope, is that in the centre of each serial puncture of the elytra, at the base of the seta, *riparia* possesses a broad, scale-like structure which is lacking in *britteni.* The fossil specimen shows clear vestiges of such "scales" (notably medially in the anterior part).

DISTRIBUTION. Almost entire Europe (doubtful in Asia). In Fennoscandia north to central Finland, prov. Hälsingland in Sweden, Trondheim district in Norway.

ECOLOGY. Aquatic; usually, but not exclusively, in running waters. Occurs submerged, attached to stones, twigs, & c.

DYNAMICS. The wings are full and no doubt functionary.

Chaetarthria seminulum Hbst. – Sample 1. Left elytron without apex (deformed). – Sample 2. Left elytron without shoulder region (deformed). –Sample 3. Left elytron (in excellent condition). – Sample 4. Two left elytra (one in excellent condition).

All the fossil elytra deviate from recent specimens by more or less stronger punctuation. This, however, is not unusual in fossil beetles; and recent specimens are also somewhat variable in this respect.

DISTRIBUTION. Palaearctic; widely distributed. In Fennoscandia barely reaching the Polar Circle, both in Finland, Sweden and Norway.

ECOLOGY. Very hygrophilous, almost amphibious. On soft mud at the margin of standing waters. Not above the conifer region.

DYNAMICS. Wings full and no doubt functionary. Several specimens were found among shore-drift in Finland (Palmén 1944).

Fam. *STAPHYLINIDAE*

Olophrum consimile Gyll. – Sample 1. Entire left elytron and apex of another. – Sample 2. Five prothoraces.

DISTRIBUTION. Circumpolar. In Europe northern but occurring south to northern Germany and in Great Britain. It is generally distributed in Fennoscandia but rare and local in southern Sweden.

ECOLOGY. Among moss and dead leaves on moist places, often under *Salix* bushes. Found in the lower *regio alpina* both in Sweden and Norway.

DYNAMICS. The wings are very large, reaching well behind apex of abdomen; so, in spite of the stout, clumsy appearance of the beetle it is probably able to fly.

Acidota crenata F. – Number of sample unknown. Entire left elytron (well preserved). Darker than usual, almost pure black, but punctuation normal.

DISTRIBUTION. Circumpolar. Generally distributed in Europe (except southern peninsulas) and in Fennoscandia.

ECOLOGY. Rather eurytopic. Often among mosses on moist ground, both in open country and thin forests. In the *regio alpina* probably established only in the lower part, occurrences from higher elevations apparently being temporary.

DYNAMICS. A regular flier with almost migratory tendencies. Often found in large numbers on snowfields in the mountains as well as among drift material on lake and sea shores.

Lathrobium sp. – Sample 2. Two prothoraces and one elytron.

Fam. *PSELAPHIDAE*

Bryaxis sp. (*Bythinus* auctt.). – Sample 1. One prothorax. One species of the genus, *B. bulbifer* Reich., is generally distributed in Fennoscandia and the fossil is indistinguishable from this species.

Fam. *HELMIDAE* (Elminthidae)

Riolus nitens Müll. – Sample 5. Entire left elytron; main part of right elytron; base of left elytron. The complete elytron is distinctive: the 7. interval is strongly carinate but intervals 3 and 5 not elevated.

DISTRIBUTION. Restricted to Europe and predominantly southern. In Scandinavia confined to Sweden south of Lat. 58° N, but in Finland and northwestern Russia to approximately 65° N.

ECOLOGY. Aquatic. It seems to be confined to sandy river banks.

DYNAMICS. The wings are full and the beetles are often seen swarming in the evening.

Oulimnius sp. *(Limnius* auctt.). – Sample 1. Median part of anterior half of right elytron. The innermost of the three lateral, strongly crenulate longitudinal ridges is clearly visible. A decision in favour of either *tuberculatus* Müll. or *troglodytes* Gyll., the only species of northern and central Europe, cannot be made.

ECOLOGY. Both species are aquatic and usually occur in lakes, sometimes also in running waters.

DYNAMICS. *O. tuberculatus* has been observed swarming in the evening.

Fam. *PHALACRIDAE*

Phalacrus caricis Sturm *(nigrinus* auctt.). – Sample 2. Two right elytra and anterior part of one left elytron; one of the former with attached abdominal segments including an almost complete oedeagus. The microsculpture is strong, isodiametric. One of the elytra is very well preserved and shows the elongate, only moderately convex shape characteristic of the species. This elytron, as in recent specimens, has faint suggestions of striae between the seriate punctures; in the two others, more deformed, these striae are more incised, probably a postmortal change. The parameres of the aedeagus are perfectly preserved and agree completely with those of a ♂ from Uppland, Sweden (See also drawings by Palm 1947, p. 181; Thompson 1958, p. 10). In *championi* Guill. *(suecicus* Palm), the only other north European species with reticulate elytra, the parameres are quite different.

DISTRIBUTION. Europe (except southernmost parts), western Asia. In Scandinavia restricted to southeastern Sweden (north to approximately Lat. 62° N), in Finland north to approximately Lat. 66° N.

ECOLOGY. The species feeds upon brand fungi on Carices and is restricted to marshes and moist meadows.

DYNAMICS. The beetle is an excellent flier.

Fam. *CHRYSOMELIDAE*

Unidentifiable fragments of *Donacia.*

Fam. *CURCULIONIDAE*

Otiorrhynchus dubius Ström *(nodosus* auctt.). – Sample 2. Head and fragments of prothorax. – Sample 4. Fragments of elytra. – Unknown sample: fragments of prothorax.

DISTRIBUTION. Strictly European but extending westward to Greenland and eastward to the Petshora River. Boreo-alpine but with only narrow gap in northern Central Europe (map, see Holdhaus & Lindroth 1939). Generally distributed in Fennoscandia, but very rare in southern Sweden.

ECOLOGY. Rather eurytopic though usually most abundant in open, dry country. A polyphagous plant-feeder. In the mountains the species ascends to the *regio alpina superior*.

DYNAMICS. The beetle is flightless but, since it is constantly parthenogenetic (tetraploid) in northern Europe, its powers of dispersal are considerable.

Notaris aethiops F. – Number of sample unknown. Apical half of right elytron (well preserved).

DISTRIBUTION. Almost circumpolar. In Europe mainly in the north but also in mountainous districts of the central parts. In Fennoscandia generally distributed (except on the west-coast of Norway between Lat. 58° and 63° N).

ECOLOGY. On moist ground with thin vegetation, often on lake shores and in fens. It has been found feeding on *Sparganium* but is probably rather polyphagous.

DYNAMICS. The wings are full. A few specimens have been found in drift material in Finland (Palmén 1944).

Eubrychius velutus Beck (*velatus* auctt.). – Sample 1. Lateral third of left elytron with many scales preserved. These have a characteristic mosaic pattern visible at a magnification of 400 times.

DISTRIBUTION. Most of Europe (the records from North America require confirmation). Southeastern Sweden, north to Uppland; one locality in Norway (Trondheim district); bicentric in eastern Fennoscandia: in the south but also between the Polar Circle and approximately Lat. 68° N. – Due to the concealed habitat of the species, its distribution is no doubt incompletely known.

ECOLOGY. Aquatic. The only foodplant seems to be genus *Myriophyllum*.

DYNAMICS. The wings are well developed and no doubt functionary.

Apion sp. – Sample 2. One left elytron.

General character of the fauna

Disregarding the numerous fragments that were too nondescript to be named with certainty even to genus, 20 different taxa of beetles were identified, 12 of which could be determined to species. These latter are summarized in Table 2:1, where some of their characteristics in ecology and geography are given in a condensed form.

From the data in Table 2:1, certain general features of the Leveäniemi assemblage of beetles and inferences concerning the contemporary environment become apparent.

(1) The high proportion of aquatic or hygrophilous forms is striking. Of the 12 identified species, 4 are aquatic during their entire life cycle, and amongst the

Table 2:1. Certain ecological and geographical features of the interglacial beetles from Leveäniemi that could be specifically identified.

	Moisture	Dynamics	Geography	Zonation					
				Regio alpina			Regio betul.	Regio conif.	Regio querc.
				superior	media	inferior			
Bembidion doris	h	m	(S)	–	–	–	–	+	+
Patrobus septentrionis	(h)	m	(N)	+	+	+	+	+	–
Gyrinus marinus	a	m	O	–	–	–	–	+	+
Hydraena riparia	a	m	S	–	–	–	–	+	+
Chaetarthria seminulum	h	m	S	–	–	–	–	+	+
Olophrum consimile	(h)	m	(N)	–	–	+	+	+	(+)
Acidota crenata	m	m	O	(+)	(+)	+	+	+	+
Riolus nitens	a	m	S	–	–	–	–	+	+
Phalacrus caricis	h	m	S	–	–	–	–	+	+
Otiorrhynchus dubius	m	b	(N)	+	+	+	+	+	(+)
Notaris aethiops	h	m	O	–	–	+	+	+	+
Eubrychius velutus	a	m	S	–	–	–	–	+	+

Abbreviations:

MOISTURE. a = aquatic. h = hygrophilous. m = mesophilous. (No xerophilous form present.)
DYNAMICS. b = brachypterous (with reduced wings, flightless). m = macropterous (fully winged and no doubt able to fly).
GEOGRAPHY. (General distribution in Fennoscandia.) N = northern. S = southern. O = generally distributed.
ZONATION. (In Fennoscandia.) Crosses in brackets indicate accidental or relict occurrence.

8 taxa named to genus only, 4 also belong to this biological group (to which *Donacia* which has aquatic larvae could be added). Since, in a normal beetle fauna of temperate regions, truly aquatic forms amount to only 6 or 7 per cent of the species, these are clearly significantly abundant in the samples. There can be little doubt that the deposit accumulated in a pond or lake and the rarity of terrestrial species may indicate that the contemporary shore line was some distance away.

(2) In keeping with this interpretation is the preponderance of flying forms, only one species *(Otiorrhynchus dubius)* being incapable of flight. As a whole the Leveäniemi samples provide an assortment of the vagile elements of the fauna.

(3) Though the sample of the total fauna of the time is obviously small, the complete absence of any obligate forest species may indicate that the pond or lake was in relatively open country.

(4) There is little evidence from the beetles of the character of the flora. The occurrence of *Carex* and *Myriophyllum* is indicated by *Phalacrus caricis* and *Eubrychius velutus,* respectively.

(5) Most important is the evidence of the climatic conditions provided by the fossil insects. Table 2:1 shows that out of 12 identified species, 7 may be termed "southern", judged from the position of the northern limits of their

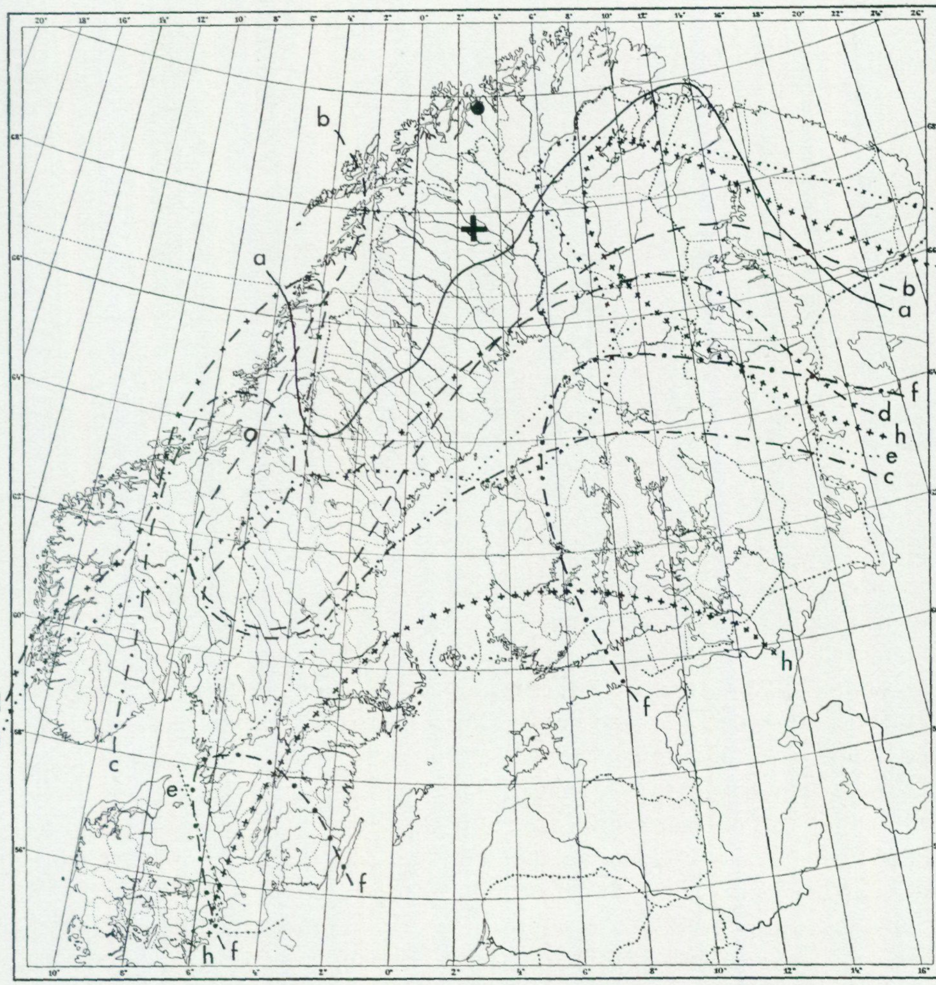

Fig. 2:1. Approximate northern limit of "southern" species or groups of species represented in the interglacial Leveäniemi deposits, Swedish Lapland. The site is marked with a cross.
(a) *Bembidion doris* Panz. (isolated locality as dot).
(b) *Gyrinus natator* L. + *substriatus* Steph. (collective limit).
(c) *Hydraena riparia* Kug.
(d) *Chaetarthria seminulum* Hbst.
(e) *Phalacrus caricis* Sturm.
(f) *Riolus nitens* Müll.
(g) *Oulimnius tuberculatus* Müll. + *troglodytes* Gyll. (collective limit).
(h) *Eubrychius velutus* Beck (isolated locality as ring).

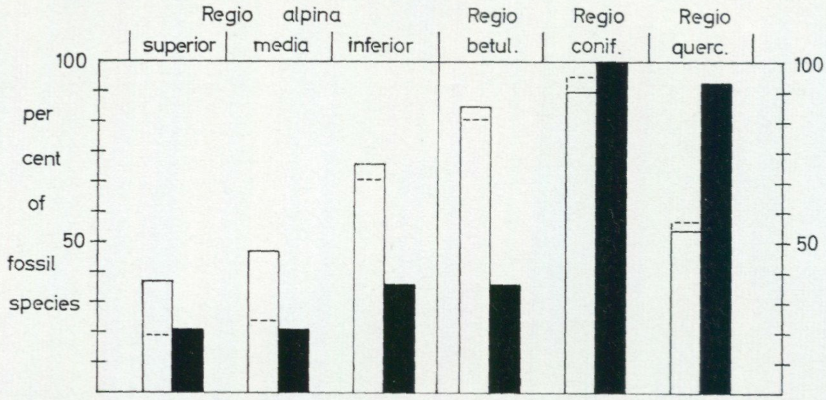

Fig. 2:2. Zonation spectrum – according to present distribution – of the interstadial (white) and interglacial (black) fossil beetles from Sweden (41 and 14 species or species groups, respectively). See also Table 2:2. It should be observed that the comparison is not between quite equivalent units. The list of "interstadial" species is a conglomerate of fossils from four different deposits formed during rather different climatic conditions. Therefore the figures for the Långsele site are inserted as broken lines.

present day distributions (Fig. 2:1). Their zonation in the mountains of Fennoscandia gives a similar picture (Table 2:2, Fig. 2:2). Only 5 species are known to occur today in the *regio alpina* (2 of these only in the lower parts of the region) and 7 species are not even recorded from the *regio betulina (subalpina, subarctica)*. If the present northern limits of the southern forms are regarded as governed by climatic (and not dynamic) factors – which in most cases they no doubt are – then it may be inferred that only 6 species represented in this deposit would be able to live in the Leveäniemi district under present conditions. More than half the fauna, 8 species or species-groups *(Gyrinus natator-substriatus, Oulimnius tuberculatus-troglodytes,* Fig. 2:1), indicate a m i l d e r c l i m a t e than present day. Some of these 8 forms, whose northern limits are illustrated on the map, Fig. 2:1, belong to a c o n t i n e n t a l element of the present Fennoscandian fauna; their range extends farthest north to the east of the Baltic. Most pronounced in this respect are *Phalacrus caricis* and *Riolus nitens* which reach as far north as Lat. 65–66° N in Finland but are entirely absent from Norway. The only part of Fennoscandia where all 14 species (or species-groups) of the Leveäniemi fauna live together at the present day is the inner central area of Finland, between approximately Lat. 64° and 66° N.

Discussion of the fauna

Insect fossils from deposits thought to be interglacial in age have already earlier been reported from Scandinavia, from four sites in Central Sweden (Lindroth 1948; Sundius & Sandegren 1948; G. Lundqvist 1964). They indicated a

Table 2:2. Zonation of the fossil beetles — according to present distribution — of interstadial and interglacial deposits in Sweden

The "warmest" interstadial sample, from Långsele, prov. Ångermanland, is also recorded separately.

	Regio alpina superior	Regio alpina media	Regio alpina inferior	Regio betul.	Regio conif.	Regio querc.
Interstadial fossils (41 species) No. of species	15	19	31	35	37	22
Per cent	*37*	*47*	*76*	*85*	*90*	*54*
Långsele (21 species) No. of species	4	5	15	17	20	12
Per cent	*19*	*24*	*71*	*81*	*95*	*57*
Interglacial fossils (14 species) No. of species	3	3	5	5	14	13
Per cent	*21*	*21*	*36*	*36*	*100*	*93*

wide spectrum of climatic conditions, from arctic (Härnön) to temperate (Långsele). The methods used for their dating were summarized by G. Lundqvist (1964, p. 42 a.f.); their age is beyond the reach of radiocarbon age determination as practiced in Sweden.

Based on a thorough analysis of the so-called "interglacial" deposits in prov. Jämtland, among these the famous Pilgrimstad site, J. Lundqvist has recently (1967) arrived at the conclusion that all previously recorded "interglacial" finds from Sweden must be referred to an "Interstadial" early in the Last Glaciation, possibly equivalent to the Brörup Interstadial in Denmark. There is nothing in the composition of the fossil insect fauna contradicting this conclusion except, perhaps, that two beetles from Långsele indicate a climate about as warm as now (Lindroth 1948, p. 24) hinting, that the deglaciation of Scandinavia during the optimum of this interstadial period must have been almost total (also, however, inferred by J. Lundqvist 1967, p. 261).

It is most welcome that now, through discovery of the Leveäniemi site, Scandinavian deposits of an apparently undisputable interglacial (Eemian) age have been brought to light. And it is tempting to make a comparison between the two stories told by the fossil insects from the two different periods, about 50 000 and, perhaps, 80 000 years ago, respectively, notably with regard to the climatic conditions indicated.

There are only four species of beetles in common, represented in the deposits from both periods, namely *Patrobus septentrionis, Acidota crenata, Otiorrhynchus dubius*, and *Notaris aethiops*, and these, characteristically enough, are the geographically most wide-spread members of the Leveäniemi fauna and belong to the few that penetrate into the present *regio alpina*. Their common occurrence in the interglacial and interstadial faunas is thus of little climatic significance.

As a background for a general comparison between the interstadial and interglacial faunas a "zonation spectrum" has been compiled (Table 2:2, Fig. 2:2), based on present distribution of the species (or species-groups) concerned.

In both cases the maximum of species (90 and 100 per cent, respectively) is in the conifer zone; but there is little other similarity between the two groups of samples. Those from interstadial deposits are markedly well represented on the colder side of the diagram. This holds true even for the sample from Långsele, the "warmest" of them, which indicates a climate of present type (Table 2:2). Thus the interglacial fauna from Leveäniemi undoubtedly indicates more temperate conditions than do any of the known interstadial faunas in Fennoscandia (See also Korpela 1969, Lindroth 1969).

Conclusions

The identifiable insects from the Leveäniemi deposits, all of them beetles, constitute a rather uniform assemblage that could have lived under the same climatic conditions.

The majority of species are foreign to the district today which lies in the uppermost part of the *regio coniferina*. They indicate that the climate at the time was considerably more temperate and of a pronouncedly continental character with warmer summers than those of the present day in Swedish Lapland.

The insect fossils from the interstadial deposits of Sweden indicate colder conditions than those at Leveäniemi. Even the site at Långsele whose insect fauna indicated a climate warmer than subarctic, did not contain as many "southern" species as that from Leveäniemi.

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Appendix 3

THE MACROSCOPIC REMAINS OF THE EEMIAN INTERGLACIAL FLORA OF LEVEÄNIEMI

by

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CONTENTS

Introduction

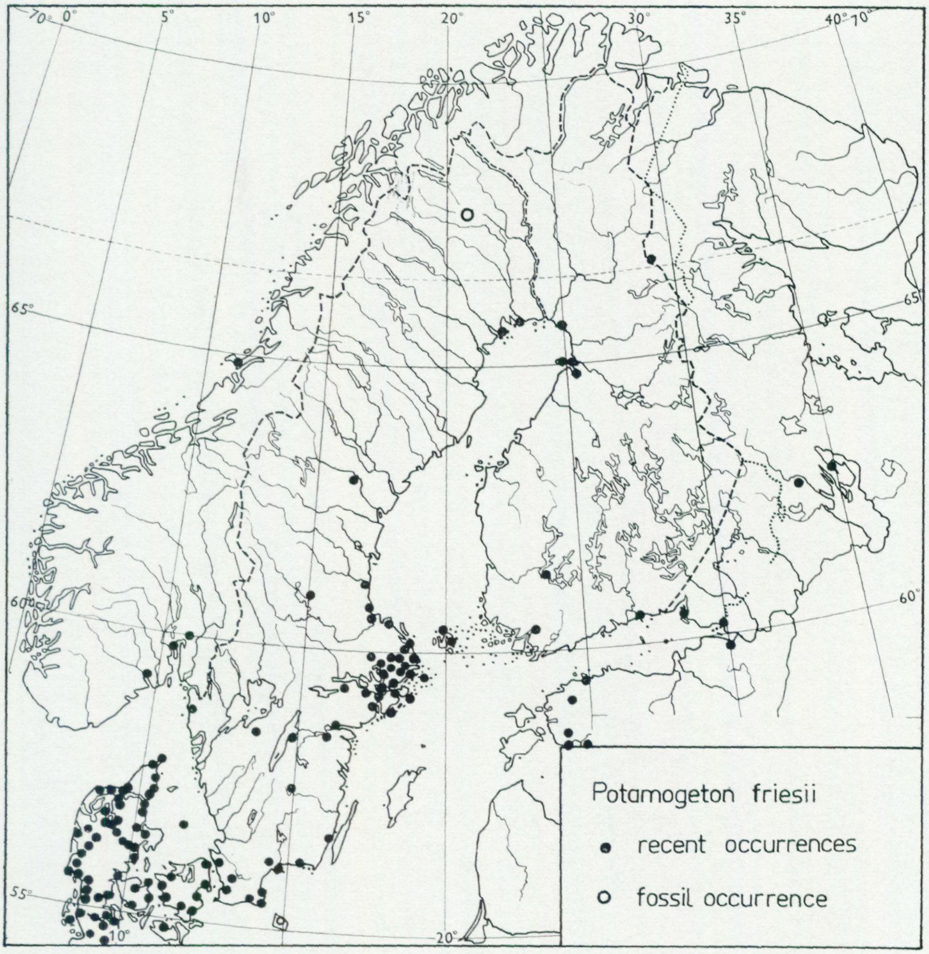
The fossil flora of Leveäniemi, Svappavaara, contains a remarkable number of carpological remains most of which are seeds of aquatic plants. The samples investigated are obtained from large blocks of the sediments in order to give as rich material as possible. Therefore they can unfortunately not be correlated with the material used for the pollen diagrams in app. 4. For this reason and because of the author's wish to collect samples at closer intervals at the site in order to obtain more detailed information on the ecological development of the fossil lake, this contribution has to be considered preliminary. It is to be regretted that it has not been possible to give a more detailed description of the environmental evolution of this most remarkable flora. The macroscopic components hitherto found promise impressive future possibilities in reconstructing the fossil flora, which hardly can be done by a standard pollen diagram. Still, the facts obtained so far are of considerable significance and shall therefore be outlined below. The most outstanding features are phytogeographical ones. Therefore maps of distribution are used to show these characteristics. The recent distribution of plants shown in the maps are chiefly taken from Hultén's atlas (1950). The *Carex* species have partly been determined by aid of a seed atlas of Scandinavian seeds (Greta Berggren 1969).

Description of the fossils

Fam. *PINACEAE*

Pinus silvestris L. (Plate 3:I, Fig. 1)

One seed only was found, although the pollen diagrams contain a considerable percentage *Pinus* pollen. The seeds of other European species of *Pinus*, for instance *P. cembra,* are different. The present seed is therefore attributed to *P. silvestris*. Cones and trunks of pine were frequent.

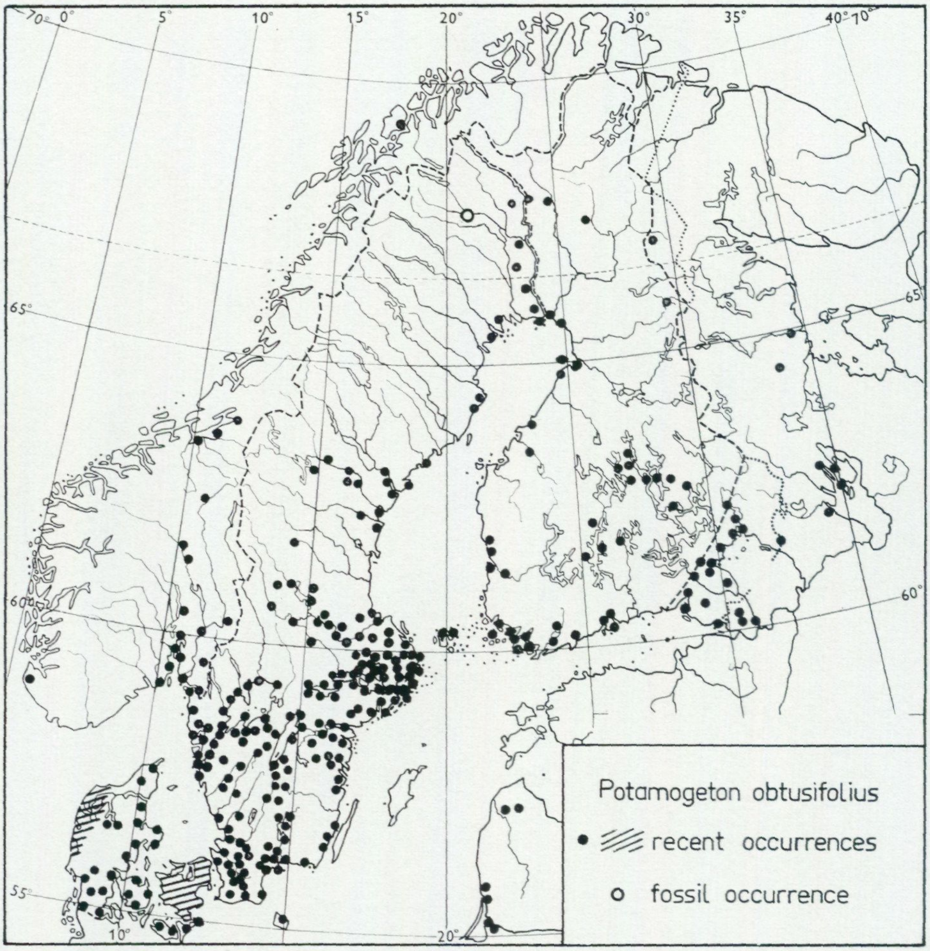


Map 3:1. The recent and fossil distribution of *Potamogeton friesii* in northern Europe.

Fam. *POTAMOGETONACEAE*

Potamogeton friesii Rupr. (Plate 3:I, Fig. 2, map 3:1)

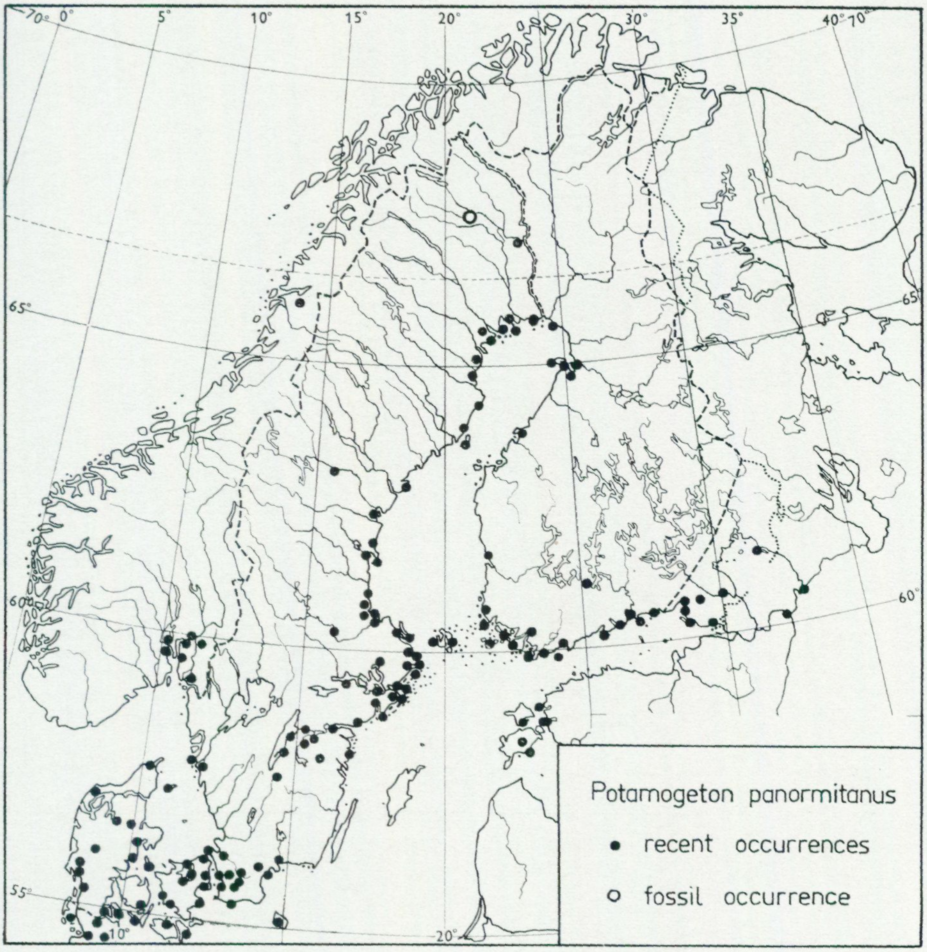
Two fruits of this species were found. It is a plant of shallow waters and it is rare in the present-day vegetation of Scandinavia. *P. friesii* is absent from the recent flora of the area in question. The nearest recent occurrences are to be found along the coast area of the Gulf of Bothnia in Sweden and in Finland.



Map 3:2. The recent and fossil distribution of *Potamogeton obtusifolius* in northern Europe.

Potamogeton obtusifolius M. et K. (Plate 3:I, Fig. 3, map 3:2)

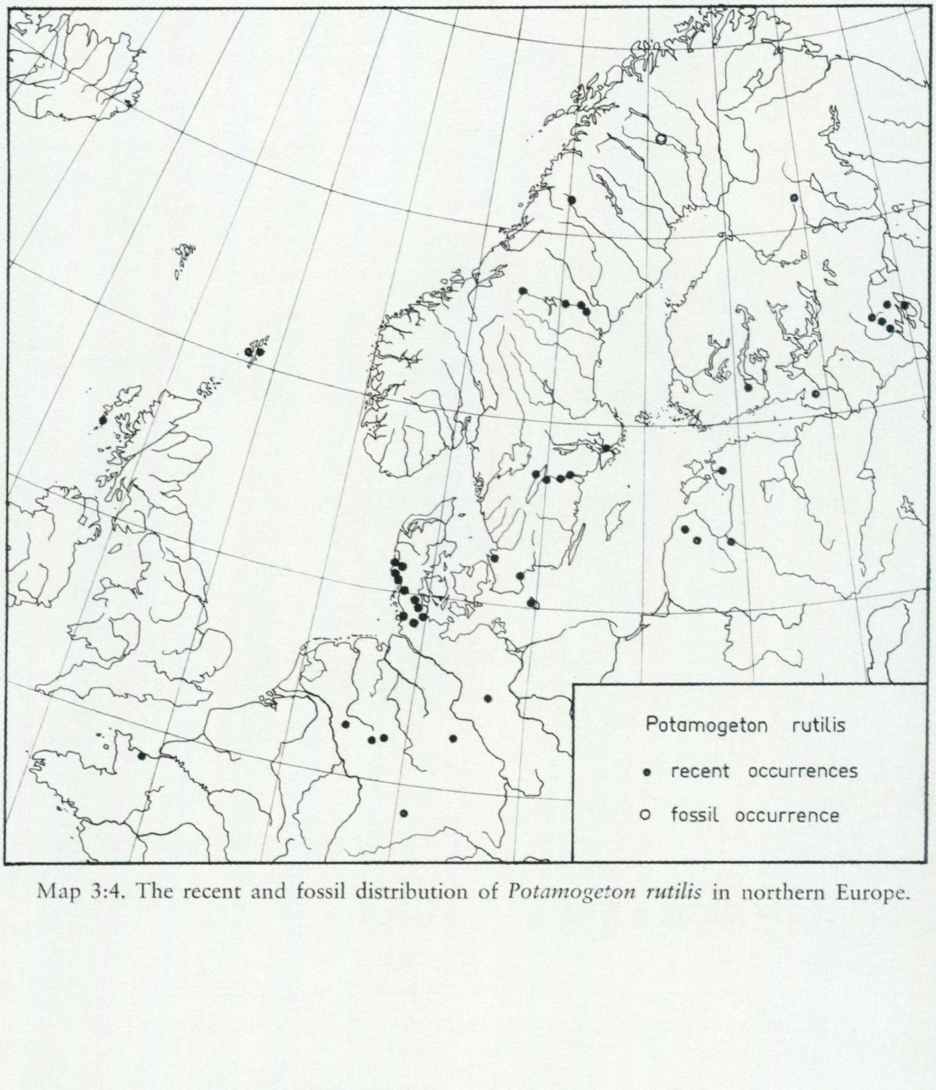
A total of 9 fossils belonging to this species have been encountered. *P. obtusifolius* occurs in the deeper water of small rivers and in lakes. In the present-day vegetation of northern Scandinavia the species is rare and it is now lacking in the area of the fossil flora.



Map 3:3. The recent and fossil distribution of *Potamogeton panormitanus* in northern Europe.

Potamogeton panormitanus Biv. (Plate 3:I, Fig. 6, map 3:3)

One endocarp of this species was found. *P. panormitanus* is a species of brackish waters although it also occurs in fresh water. Nowadays this species does not occur in the neighbourhood of the fossil flora.



Map 3:4. The recent and fossil distribution of *Potamogeton rutilis* in northern Europe.

Potamogeton rutilis Wolfg. (Plate 3:I, Fig. 4, map 3:4)

One endocarp of *P. rutilis* was found. This fossil is of particular interest as the northernmost recent occurrence of this species is in the province of Jämtland. Furthermore the species is extremely rare in the present-day flora of Scandinavia, probably because of it's peculiar ecological requirements. The species occurs in shallow lakes.

Potamogeton alpinus Balb. (Plate 3:I, Fig. 5)

About 30 per cent of the carpological remains belonging to the genus *Potamogeton* are made up of this species. In the present flora *P. alpinus* is common over vast areas of northern Europe. The presence of this species is thus of little significance.

Potamogeton praelongus Wulfen (Plate 3:I, Fig. 7)

More than 14 fruits of this species have been found among the fossil material. Although *P. praelongus* is not common anywhere in northern Europe nowadays the species occurs in almost all parts of the region. It is still found in the neighbourhood of the fossil flora.

Potamogeton natans L. (Plate 3:I, Fig. 8)

The number of specimens belonging to this species exceeds 100 which makes the species a common one in the material investigated. Except for the mountain range and the northernmost part of Scandinavia the species is commonly found in the recent flora.

Potamogeton perfoliatus L. (Plate 3:II, Fig. 1)

More than 30 specimens have been encountered. The species occurs in lakes and in slightly brackish waters. It is rather common in the flora of present-day Fennoscandia.

Potamogeton berchtoldii Fieber in Berch. and Fieber (*P. pusillus* L.)

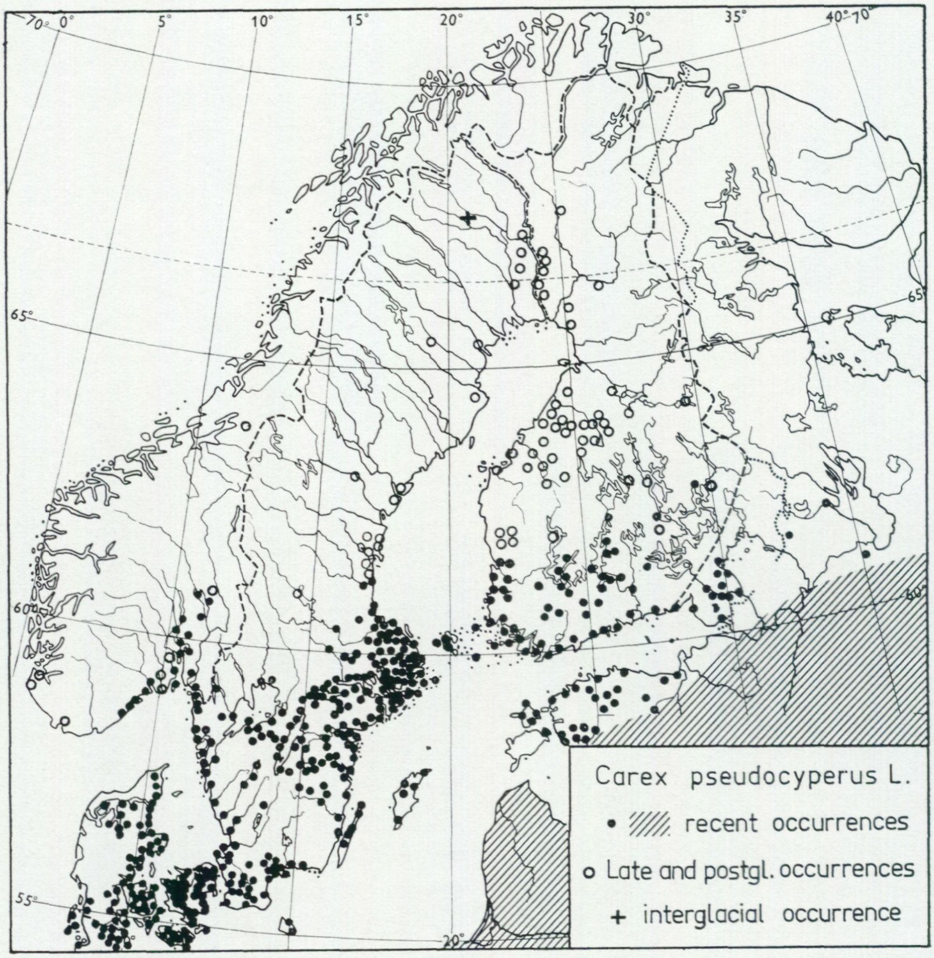
(Plate 3:II, Fig. 2)

P. berchtoldii is a species of shallow waters and is rather rare in the recent flora of northern Scandinavia.

Fam. *CYPERACEAE*

Carex lasiocarpa Ehrh. (Plate 3:II, Fig. 6)

A common species of swamps and bogs all over northern Europe. The species is therefore of little interest.



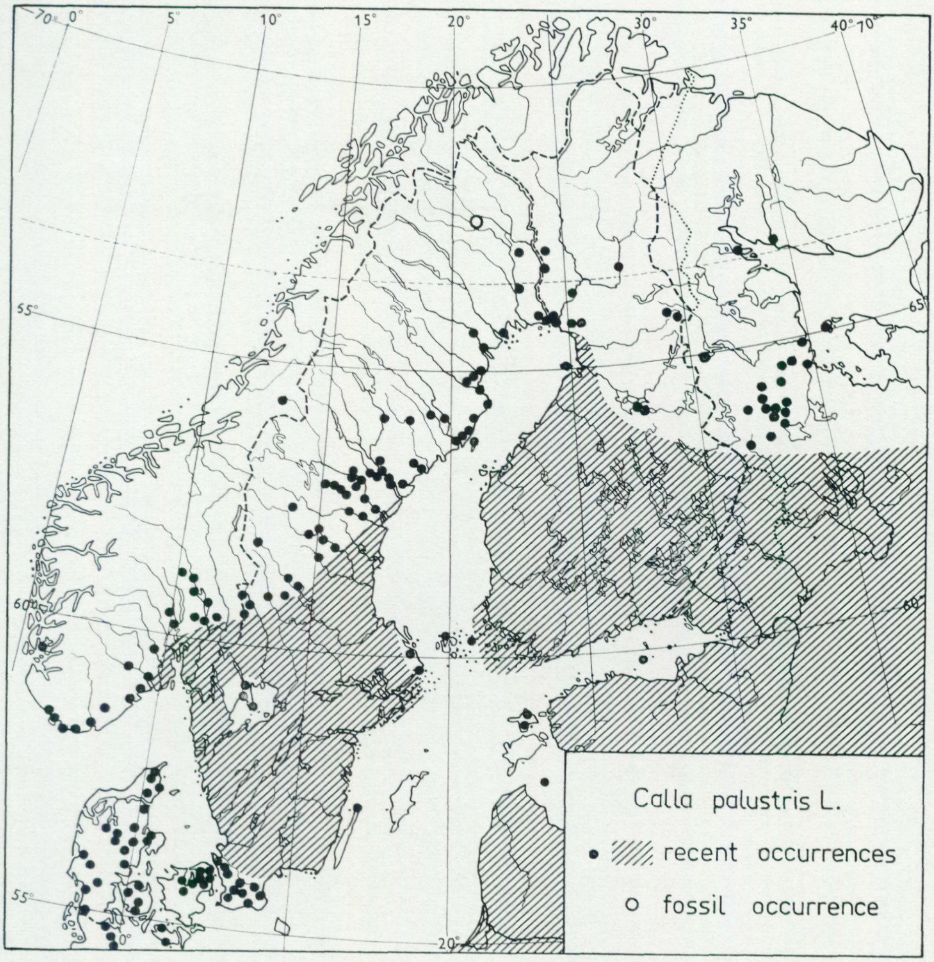
Map 3:5. The recent and fossil distribution of *Carex pseudocyperus* in northern Europe.

Carex pseudocyperus L. (Plate 3:II, Fig. 3, 4, 5, 7, map 3:5)

An infrequent but remarkable fossil. Both perigynia and achenes were recognized. *C. pseudocyperus* occurs on shallow shores of fresh-water lakes and in the recent flora it belongs to southern elements. During the Late- and especially Postglacial period the species was widely distributed in northern Scandinavia.

Scirpus lacustris L. (Plate 3:III, Fig. 1)

A species of shallow waters and lake beaches. Its present distribution is mainly southeastern in Scandinavia. In northern Scandinavia the species is rare.



Map 3:6. The recent and fossil distribution of *Calla palustris* in northern Europe.

Fam. *ARACEAE*

Calla palustris L. (Plate 3:III, Fig. 6, map 3:6)

Two seeds were found of this species, which is a species of forest swamps and of shallow shores of fresh water lakes. In the present flora of Scandinavia *C. palustris* has a southeastern distribution being absent from the area in which the fossil flora under consideration is found.

Fam. *BETULACEAE*

Betula cf. *pubescens* Ehrh. (Plate 3:III, Fig. 3, 4)

One winged nutlet and one scale was found only, although the genus *Betula* was a predominant element in the flora in question according to the pollen diagrams. A size statistical analysis was therefore impossible to make owing to the restricted number of the macro-fossils obtained. The general features of the two fossils, however, seems to indicate the presence of *B. pubescens*. From the ecological point of view these remains are of restricted interest.

Fam. *CHENOPODIACEAE*

Cf. *Chenopodium* spec. (Plate 3:III, Fig. 5)

A considerable number of small seeds, all less than 1.0 mm in diameter, were obtained. Their closest affinity is with the genus *Chenopodium*, although I was unable to make a definite generic determination. The state of preservation of the seed surface was too bad even for the scanning electron microscope. In the pollen diagrams pollen of *Chenopodiaceae* occur sporadically throughout the sediments.

Fam. *NYMPHAEACEAE*

Nymphaea cf. *alba* L. (Plate 3:IV, Fig. 4)

Although there seems to be a remarkable number of pollen referred to *Nymphaea*, and even some referred to *N. alba*, there is only one seed so far belonging to this genus. There is some reason to refer this seed tentatively only to *N. alba*. The shape and the surface of the seed resembles this species. *N. alba* is a plant of lakes and small rivers.

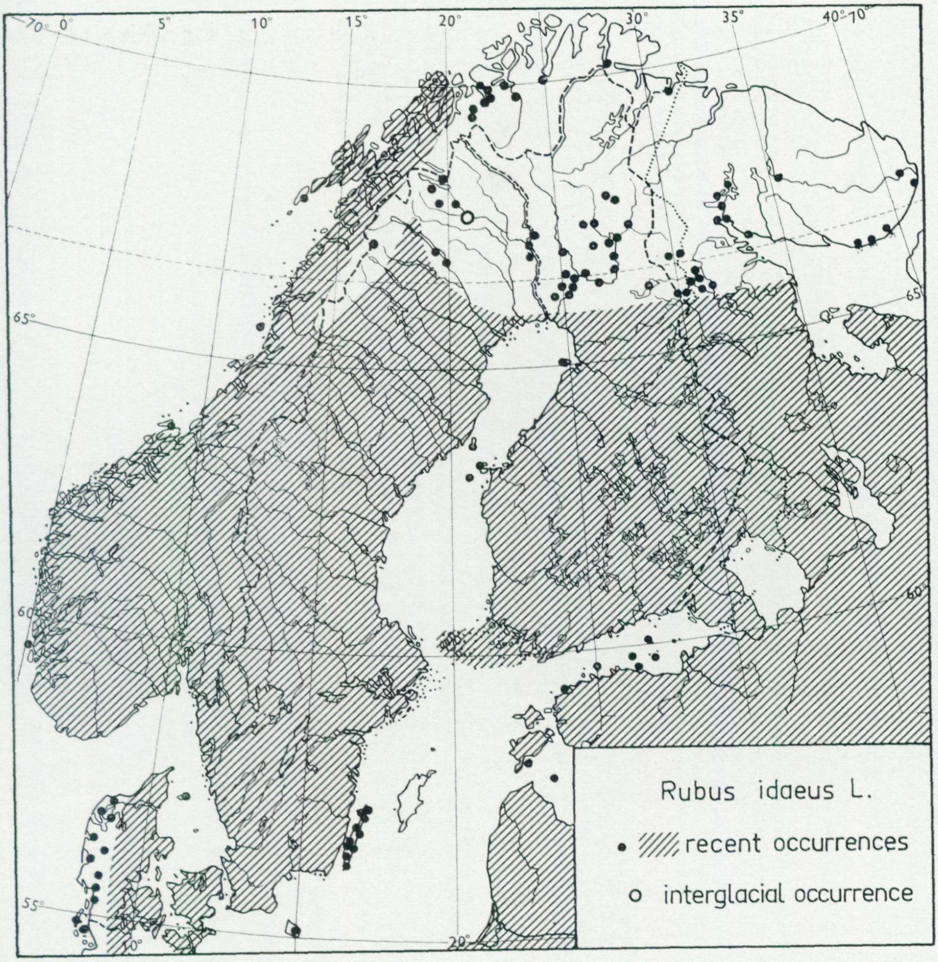
Nuphar spec. (Plate 3:V, Fig. 1)

Two seeds of a *Nuphar* species have been found although the content of *Nuphar* pollen in the sediments indicates a higher frequency of this genus. The limited number of specimens makes a specific determination of the fossils impossible. Both *Nuphar pumilum* and *N. luteum* may be considered. The two species occur in lakes and small rivers.

Fam. *RANUNCULACEAE*

Batrachium spec. (Plate 3:IV, Fig. 1–3)

A relatively limited number of seeds belonging to *Batrachium* have been found. In the pollen diagrams the *Ranunculaceae* are not infrequent. *Batrachium* species are found in very different water environments and the fossils are therefore from the ecological point of view of restricted interest.



Map 3:7. The recent and fossil distribution of *Rubus idaeus* in northern Europe.

Fam. *ROSACEAE*

Rubus idaeus L. (Plate 3:IV, Fig. 5, map 3:7)

Two seeds of this rather ubiquitous species were found among the material investigated. Still the fossil occurrence of this species is somewhat outside its present range, being perhaps of some climatological significance. A considerable amount of pollen referred to the *Rosaceae* in the pollen diagrams can be suspected to belong here.

Rubus chamaemorus L. or *R. saxatilis* L. (Plate 3:IV, Fig. 6)

Both species are common all over present-day Scandinavia. Their ecological requirements are, however, quite different. Size and shape of the fossil seed found resembles types of seeds observable in both species, for which reason a definite species determination seems to be impossible with only one fossil seed at hand.

Comarum palustre L. (Plate 3:V, Fig. 2)

Only one seed of this species was found. It is now common in almost all parts of Scandinavia and it is of little ecological significance in the fossil flora.

Fam. *HALORRHAGIDACEAE*

Myriophyllum alterniflorum DC (Plate 3:V, Fig. 3, 4)

Two very typical seeds of this species were found. The pollen diagrams contain pollen grains referred to this species. *M. alterniflorum* occurs in stagnant fresh-water pools and lakes in most parts of Scandinavia.

Myriophyllum spicatum L. (Plate 3:V, Fig. 5)

Besides the pollen grains attributed to this species some seeds belonging to this species have been encountered. *M. spicatum* occurs sporadically all over present-day Scandinavia in fresh-water lakes but even in brackish waters. These two species of *Myriophyllum* are foodplants of *Eubrychius velutus* (Cf. Lindroth and Coope, app. 2, p. 49).

Fam. *HIPPURIDACEAE*

Hippuris vulgaris L. (Plate 3:V, Fig. 6)

Seeds of this species occur in tremendous quantities in the sediments investigated. However, the species is of limited significance from the ecological and climatological point of view as it is ubiquitous in the present flora of northern Europe. It is found in shallow waters and moist places.

Fam. *PRIMULACEAE*

Lysimachia (Naumburgia) thyrsiflora (L.) Rchb.

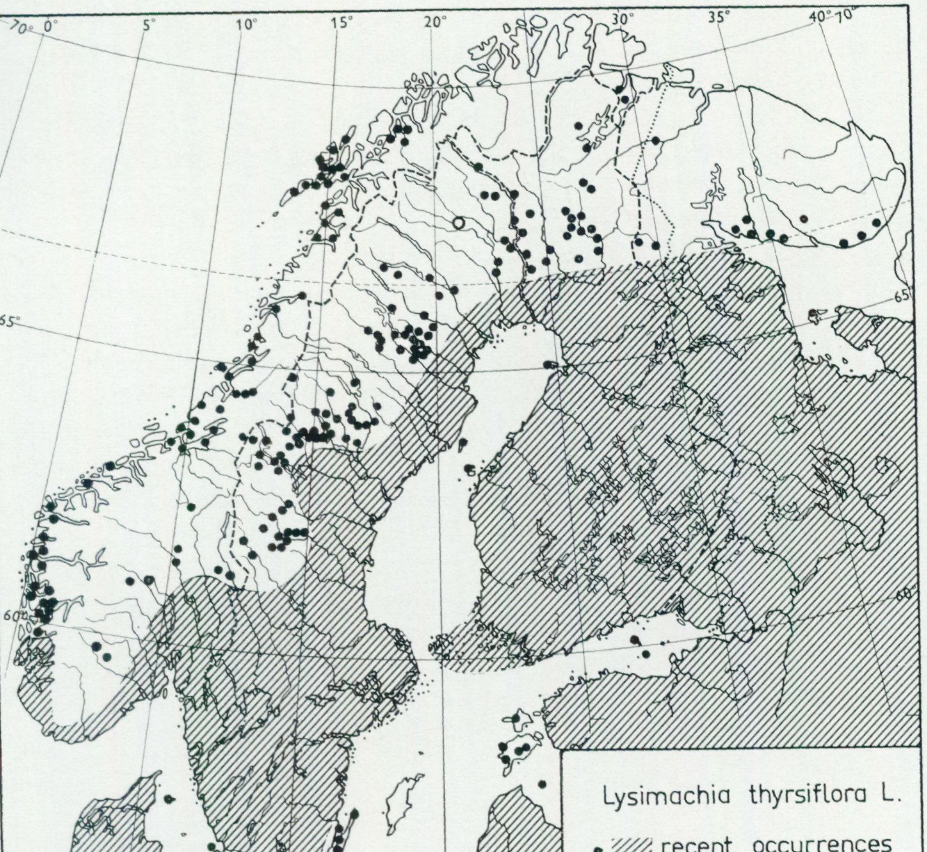
(Plate 3:VI, Fig. 1, 2, map 3:8)

A restricted number of seeds of this species was found. The species is common in shallow waters with a predominantly southeastern distribution in northern Europe.

SPEC. INCERT. SEDIS

Carpolithus spec. 1, 2, 3 (Plate 3:VI, Fig. 3–6)

Three very distinct carpological remains have been found of which C. spec. 1 is rather frequent. C. spec. 2 reminds of seeds of *Cornus*, but no definite generic determination could be made.



Map 3:8. The recent and fossil distribution of *Lysimachia thyrsiflora* in northern Europe.

Conclusions

This fossil flora – obviously Eemian in age – is remarkable from different points of view, though only 27 types of remains could be attributed to genera or species. Nevertheless, some of the species occur far beyond the northern border of their present range, as for instance *Potamogeton friesii, P. panormitanus, P. rutilis, Carex pseudocyperus,* and *Calla palustris.* Others have their present northern border range within the very area of the fossil flora, while their main distribution is more or less further south or southeast, as in *Lysimachia thyrsiflora.* Therefore it seems evident from the maps of distribution shown here, that most of the species found have their northern optimal growth area between latitudes 61° N (the *Carex pseudocyperus* type of distribution) and 66° N (the *Lysimachia thyrsiflora* type of distribution). It can thus hardly be doubted that the general climatic conditions under which the fossil flora grew must have been more favourable than they are at present. Phytogeographically the fossil flora seems to have its modern equivalent in the coastal areas of northern Sweden and Finland.

There is also, however, a remarkable indication of special ecological conditions in the fossil flora. The sediments in question have been deposited in shallow waters, probably in a relatively small lake. Plant species typical for eutrophic lakes dominate the fossil flora.

Potamogeton friesii, P. obtusifolius, P. rutilis, and *P. panormitanus* are generally considered to be indicators of highly eutrophic environments. Some of the species are said to occur exclusively in areas extremely rich in limestone with alkaline waters. *Potamogeton praelongus* seems to be another remarkable member of this flora. In the Lateglacial and Preboreal flora of northern Europe it is a typical and frequently found species (Iversen 1954, Sorsa 1965). The eutrophic character of the fossil lake is furthermore indicated by the presence of *Myriophyllum spicatum* and *M. alterniflorum.*

Although the information obtained from the macro-fossils as yet is scarce, there is a definite trend concerning its phytogeographic and ecologic significance. This is evident from the facts pointed out above. Nevertheless, it is impossible to trace any vegetational development of the flora whatsoever. Further investigations with samples taken at close intervals from the fossil site will be carried out by the author and it can be hoped that this material may give more information than the material available at present.

ACKNOWLEDGEMENTS

I have had the pleasure of co-operating with several persons during the investigation of this material. Preliminarily determinated *Potamogeton* remains were sent to Dr. Marjatta Aalto of Helsinki, who kindly carried out a thorough examination of the material sent to her. I tender my sincere thanks to her for her kindness in determining the species of this genus. Miss Greta Berggren has kindly discussed different aspects during the work with the fossil remains and has made valuable suggestions. Mr. K. E. Samuelsson has taken the photographs. The scanning EMGs were taken by the author himself with a scanning electron microscope, which is a donation of the Wallenberg Foundation of Stockholm to the Swedish Museum of Natural History and the Geological Survey of Sweden.

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Plate 3:I. Fig. 1: *Pinus silvestris,* 9×. Fig. 2: *Potamogeton friesii* 11×. Fig. 3: *Potamogeton obtusfolius,* 11×. Fig. 4: *Potamogeton rutilis,* 11×. Fig. 5: *Potamogeton alpinus,* 11×. Fig. 6: *Potamogeton panormitanus,* 11×. Fig. 7: *Potamogeton praelongus,* 11×. Fig. 8: *Potamogeton natans,* 11×.

PLATE 3:I

Plate 3:II. Fig. 1: *Potamogeton perfoliatus,* 11×. Fig. 2: *Potamogeton berchtoldii,* 11×. Fig. 3: *Carex pseudocyperus,* achenes. Fig. 4: *Carex pseudocyperus,* exocarp of achene, scanning EMG 1100×. Fig. 5: *Carex pseudocyperus,* surface of pericarp, EMG 1100×. Fig. 6: *Carex lasiocarpa,* 11×. Fig· 7: *Carex* pseudocyperus, 11×.

PLATE 3:II

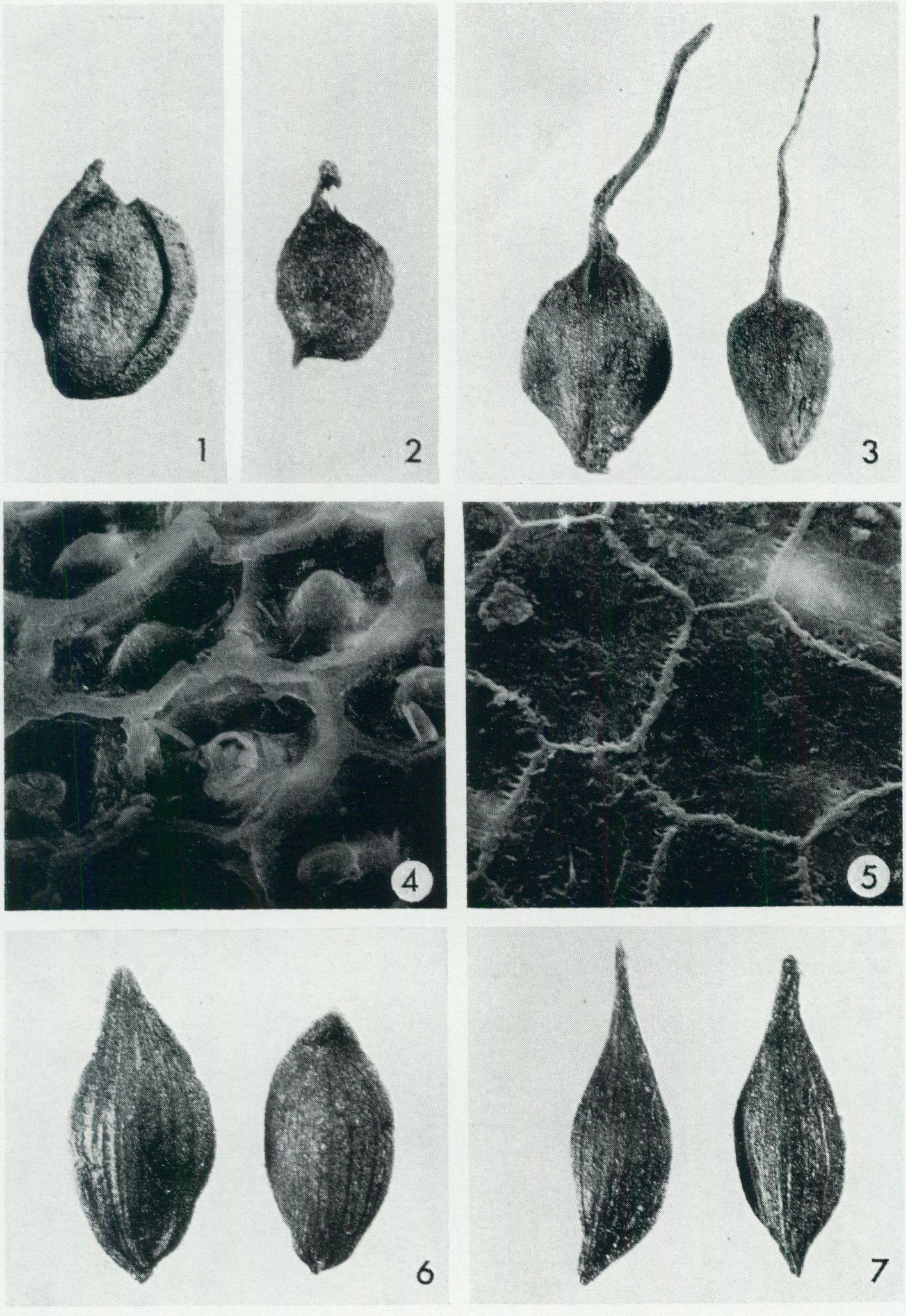


Plate 3:III. Fig. 1: *Scirpus lacustris,* 14×. Fig. 2: *Scirpus lacustris,* exocarp, scanning EMG 1200×. Fig. 3–4: *Betula* cf. *pubescens,* 14×. Fig. 5: cf. *Chenopodium* spec., 30×. Fig. 6: *Calla palustris,* 9×.

PLATE 3:III

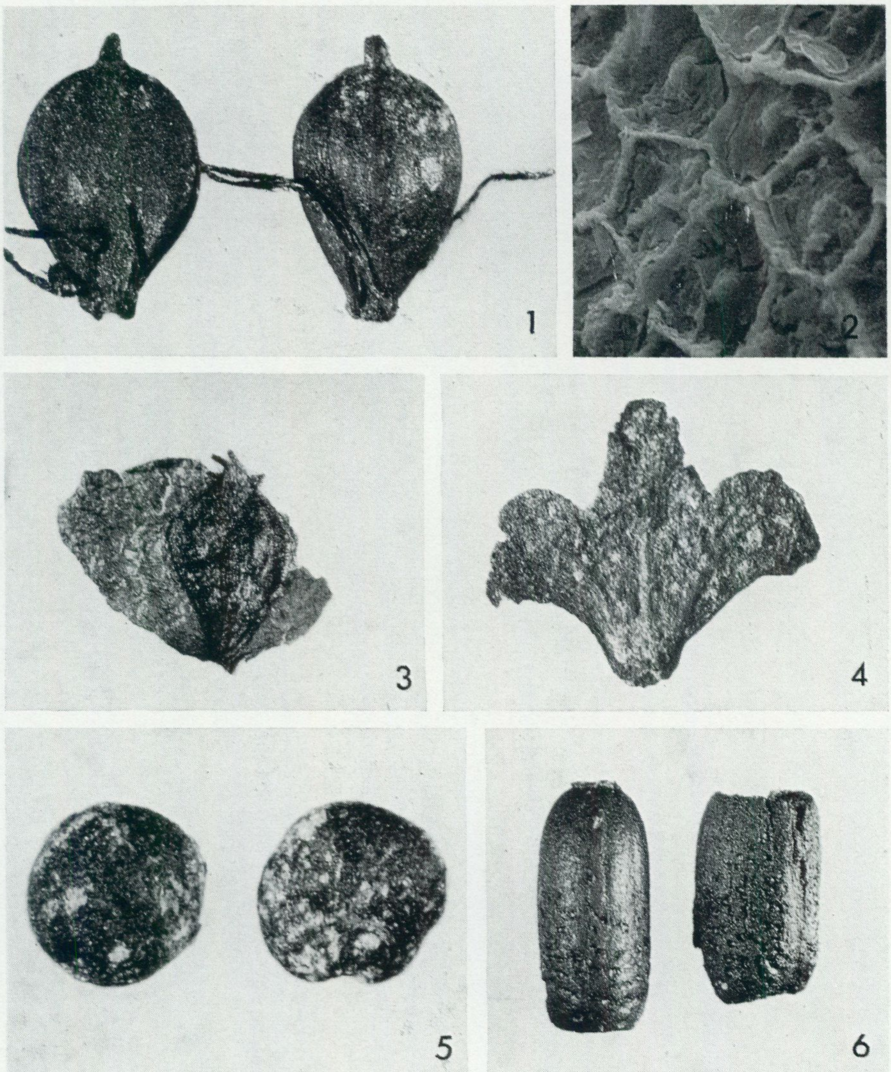


Plate 3:IV. Fig. 1–3: *Batrachium* spec., Fig. 1: 20×, Fig. 2: scanning EMG 500×, Fig. 3: 25×. Fig. 4: *Nymphae* cf. *alba*, 13×. Fig. 5: *Rubus idaeus*, 14×. Fig. 6: *Rubus chamaemorus* or *R. saxatilis*, 10×.

PLATE 3:IV

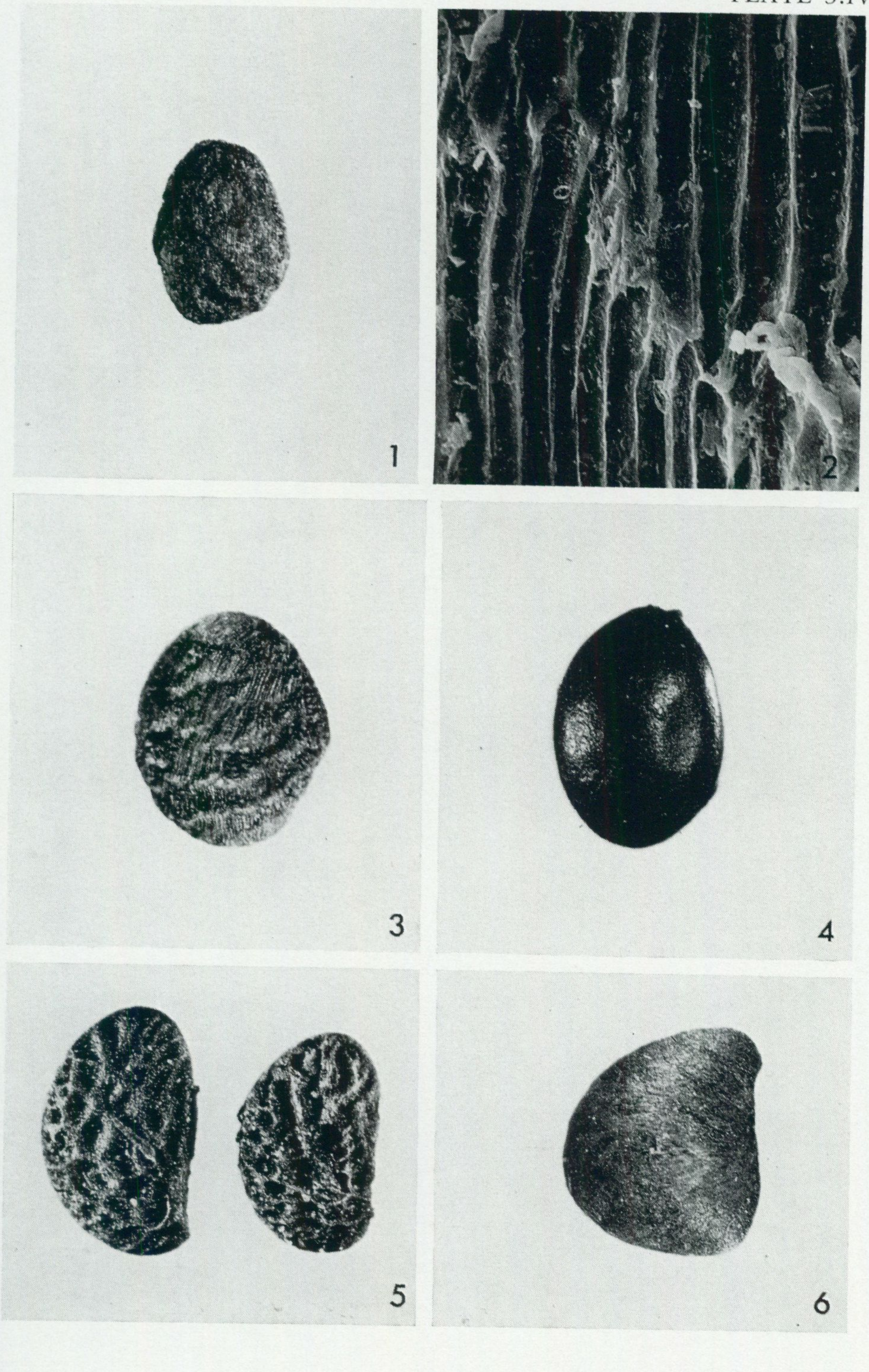


Plate 3:V. Fig. 1: *Nuphar spec.*, 9×. Fig. 2: *Comarum palustre*, 27×. Fig. 3: *Myriophyllum alterniflorum*, 30×. Fig. 4: *Myriophyllum alterniflorum*, surface of pericarp, scanning EMG 1200×. Fig. 5: *Myriophyllum spicatum*, 20×. Fig. 6: *Hippuris vulgaris*, 20×.

PLATE 3:V

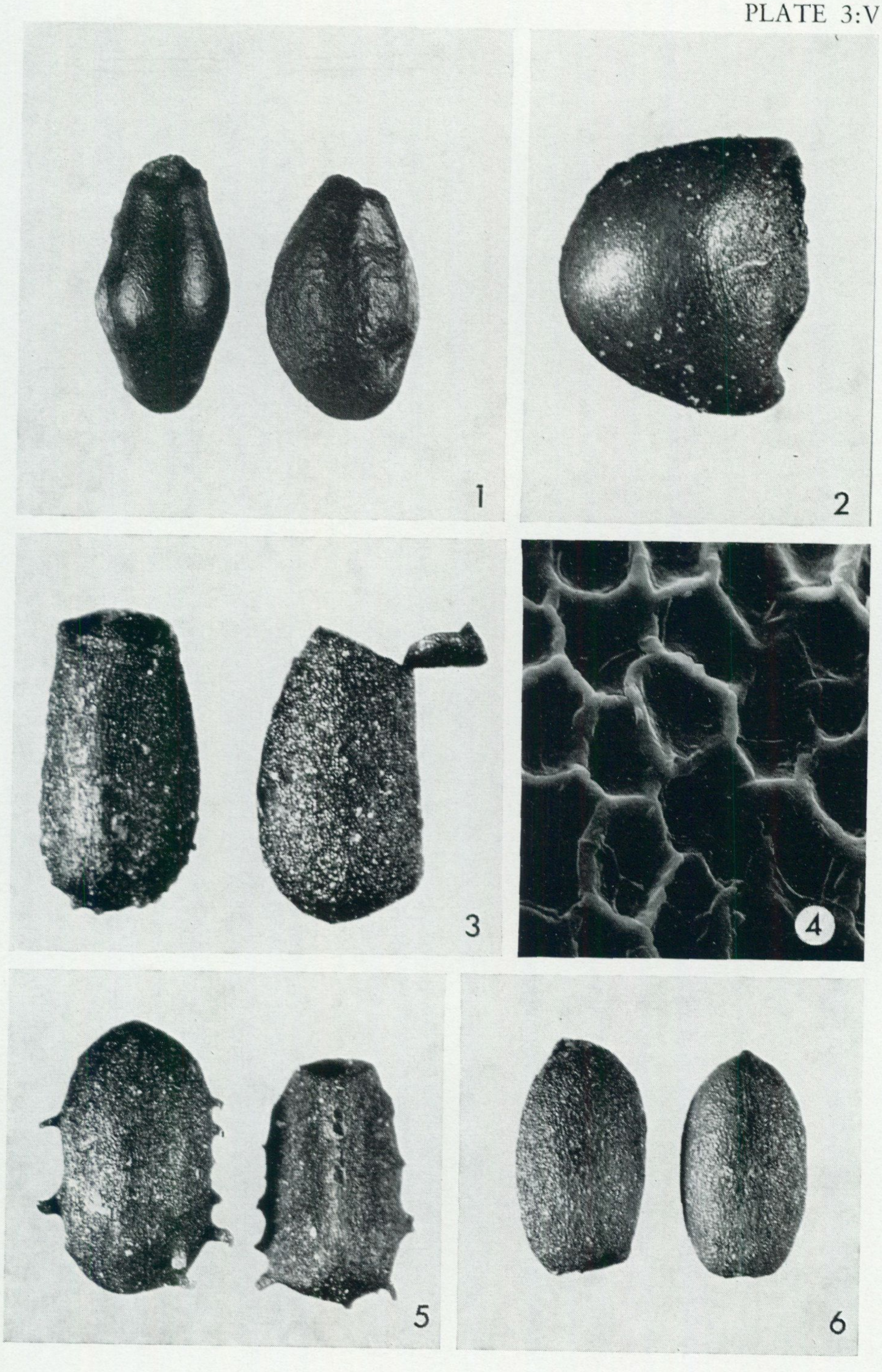
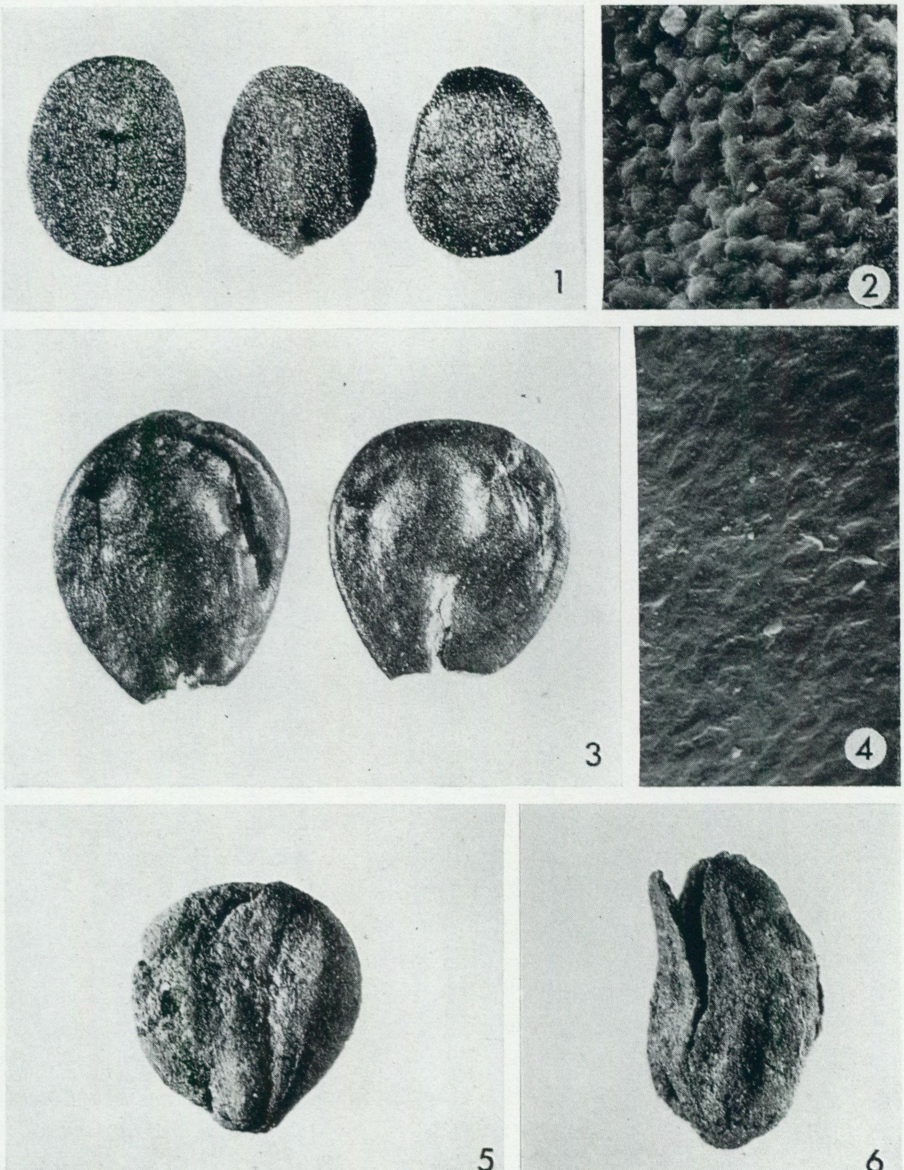


Plate 3:VI: Fig. 1: *Lysimachia thyrsiflora*, 20×. Fig. 2: *Lysimachia thyrsiflora*, surface of pericarp, scanning EMG 200×. Fig. 3–4: *Carpolithus* spec. 1, Fig. 3: 8×. Fig. 4: scanning EMG 1300×. Fig. 5: *Carpolithus* sp. 2 (cf. *Cornus?*) spec., 9×. Fig. 6: *Carpolithus* spec. 3, 8×.

PLATE 3:VI



Appendix 4

POLLEN-ANALYTICAL INVESTIGATION OF THE LEVEÄNIEMI SEDIMENTS

by

Ann-Marie Robertsson

Geological Survey, Micropaleontological Lab.

CONTENTS

Methods

The pollen-analytical investigation was carried out on three submorainic sections within loc. III (Fig. 2, p. 8). These are points C, D and E (Fig. 3, p. 9). The samples consist of somewhat clayey and silty carr (fen) peat, and gyttja. Samples from the lower and upper till beds and a postglacial peat profile were also treated and analysed (Cf. appendix 1).

All samples containing inorganic material were treated according to the HF method described by Heinonen (1957). This method slightly differs from the HF treatment usually used (Assarsson & Granlund 1924). The samples are heated and boiled directly with HF after treatment with cold HCl to remove calcium carbonate in the samples. Assarsson and Granlund first used KOH for deflocculation and decanting in destilled water, when sand was present. But according to Heinonen "the decanting of greater amounts of material with mere water in the beginning is not suitable because the clay crust of larger granules and the concentrated particles remain unhurt and pollen grains in them disappear by the decanting. HF on the contrary releases organic matter undamaged into the liquid." After boiling 2–3 minutes in HF the material was heated with HCl (10 per cent) to remove colloidal SiO_2 and silicofluorids. To eliminate organic material the method of acetolysis according to Erdtman, as described by Faergi & Iversen (1964) was used. The material was mounted in glycerol. The analyses were made by Miss Karin Bengtsson, F. K., and Miss Inger Österman.

Pollen analyses were made using a Reichert microscope "Neopan". A magnification of × 320 was generally used, and × 800 (immersion oil) for special identifications of different species. 300–350 pollen grains of trees (AP) were counted and used as basic sum for the percentages of other components of the flora, such as shrubs, herbs, aquatic plants, spore plants and green algae *(Pediastrum)*. In the diagrams there are different columns for trees, QM-components *(Quercus, Ulmus, Tilia, Fraxinus)*, shrubs, herbs, sum of aquatic plants, *Pediastrum* and a total diagram. The basic sum in the total diagram is the percentage of trees + shrubs + herbs. The values of herbs with low frequencies, different aquatic plants and spores are to be found in Tables 4:3–6.

The micrographs (Pl. 4:I) were taken with an automatic microphoto camera on the Reichert microscope "Zetopan".

Description of pollen zones and development of vegetation

The development of the vegetation in the different pollen zones defined appears from the following, Figs. 4:1–3, and Tables 4:2–5.

ZONE a: *Betula (– Juniperus – Salix)*
Section C: 120–130 cm?
,, D: 130–220 cm
,, E: 40– 90 cm

Betula occurs with very high percentages, generally over 90. *Pinus* and some pollen of *Alnus*, QM and *Picea* also occur. *Quercus* is present in sections D and E with a continuous curve. The percentages of shrubs *(Salix* 4 and *Juniperus* 7) are highest in zone a. A few pollen of *Corylus* were also found. Among the herbs *Gramineae* and *Cyperaceae* are abundant. *Pediastrum* is frequently represented and has a maximum in the lower part of the zone in sections D and E. Aquatic plants are represented by *Nuphar* and *Potamogeton*.

The vegetation consisted of *Betula* forest with scattered shrubs *(Salix, Juniperus)*. As *Salix* and *Juniperus* have small maxima in zone a, they indicate a rather open *Betula* forest with light demanding shrubs in the open areas. Small stands of *Populus* also existed (pollen identified in section E). The low values of *Pinus* in zone a depend on the fact that *Pinus* did not grow in the neighbourhood. The pollen grains have been transported by wind or/and water to the sedimentation area. The few pollen of QM, *Alnus* and *Picea* may also be wind-transported or rebedded, judging from the mineral content in the samples. The most common herbs are *Gramineae, Cyperaceae, Ericales* (section D) and *Artemisia* (section E). Concerning herbs with irregular and low values see Tables 4:3–5.

In the sedimentation basin the temperature and the transparency of the water as well as the supply of nutrients must have been favourable. (Cf. Miller, p. 116.) It is indicated by the peak of *Pediastrum* in sections D and E and the diatom flora. The succession of the aquatic plants was *Potamogeton, Typha-Sparganium, Nuphar, Nymphaea* and *Myriophyllum alterniflorum*. (Cf.

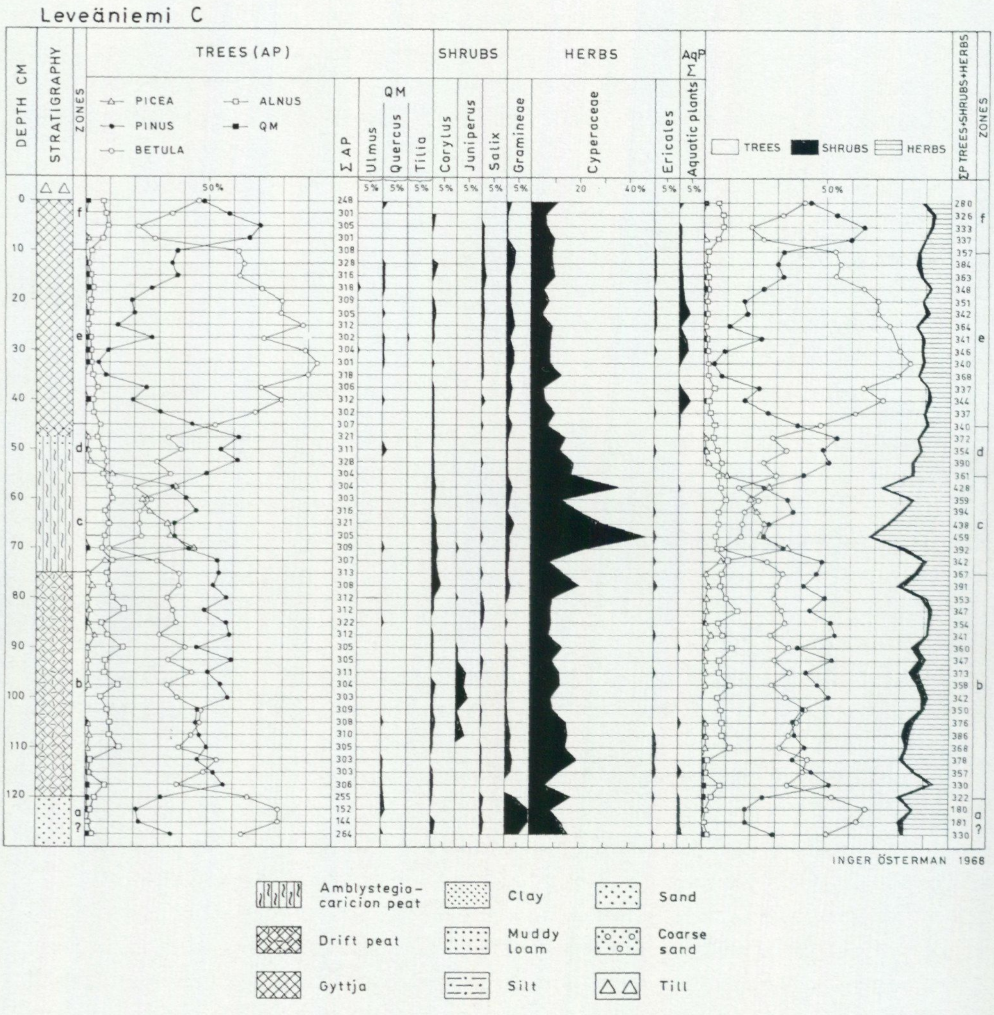


Fig. 4:1. Pollen diagram from loc. III, point C. (Cf. Figs. 2 and 3.)

Tralau, app. 3.) Several hairs of *Nymphaceae* (Pl. 4:I, Fig. 2) were also noted in the slides and leave tips of *Ceratophyllum* (Pl. 4:I, Fig. 1). The pollen of *Ceratophyllum* have no exine, so they will be destroyed instead of fossilized and embedded in the sediments.

ZONE b: *Pinus – Betula – Alnus*

Section C: 75–120 cm
,, D: 0–130 cm
,, E: 30– 40 cm

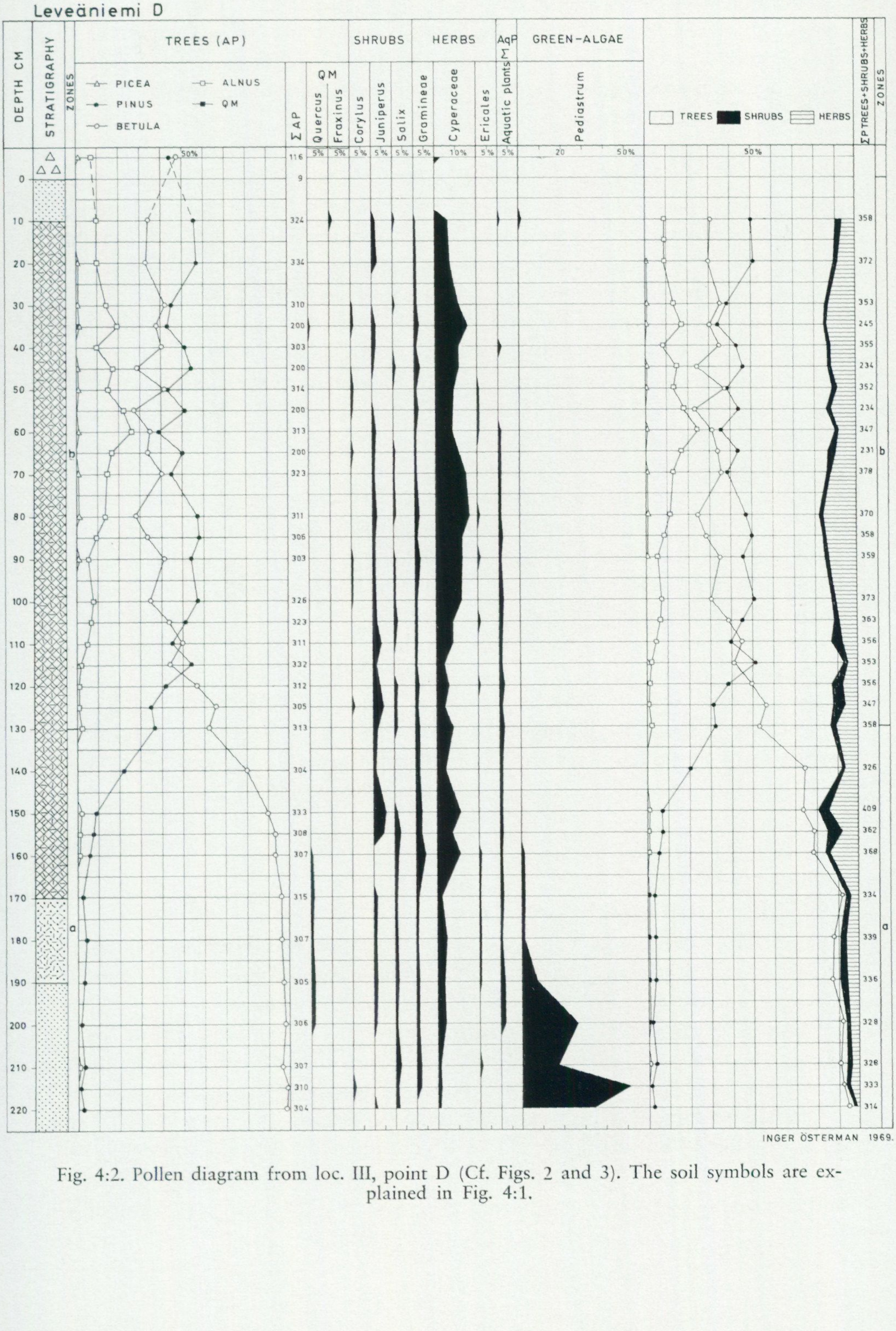


Fig. 4:2. Pollen diagram from loc. III, point D (Cf. Figs. 2 and 3). The soil symbols are explained in Fig. 4:1.

Pinus increases and *Betula* decreases (crossing curves). The *Alnus* curve rises. Shrubs are represented by *Juniperus, Corylus* and *Salix*. *Corylus* has a little maximum at 77.5 cm in C before the rise of the *Picea* curve. *Salix* has lower values than in zone a. Herbs decrease. *Pediastrum* disappears in sections D and E and the sum of aquatic plants decreases.

When the climate improved, *Pinus, Alnus* and, to some extent, *Corylus* replaced *Betula* as dominant forest component. *Picea* expanded from the east, now growing at not too far a distance. Some pollen of *Picea* occur in zone b. They are probably wind-transported. *Juniperus* and *Salix* are still present. *Polypodiaceae* and *Lycopodiaceae* do not decrease, except *Polypodiaceae* in section E. Zone b is represented by a very thin layer (20 cm) in section E and by thicker layers in sections C and D (45 and 130 cm). It is obvious that the warm-temperate broad-leaf forest with *Quercus, Ulmus, Tilia* and *Carpinus* never expanded as far towards the north and west as to the Leveäniemi area. The reason was probably the existence of a broad inlet from the White Sea to the Baltic, which separated Scandinavia from the continent (Zāns 1936, Frenzel 1968, Gross 1967). The altitude (350 m above sea-level) and the northerly position also prevented the warm-temperate forest to expand so far. Zone b must be considered to represent the warmest stage during the interglacial vegetational development. The climate must have been more temperate than during the postglacial optimum (Cf. p. 96 and Fig. 4:6) judging from pollen-analytical investigations of postglacial sections in the Leveäniemi area and adjacent localities. *Alnus* and *Corylus* are the most temperate forest elements. Northern Scandinavia and the Kola peninsula belonged to the same floristic region as northwestern USSR with coniferous forests. It is therefore difficult to compare the Leveäniemi diagrams in detail with the vegetational development shown by pollen diagrams from Poland, Germany, Denmark and Holland, which represent the district of broad-leaf thermophilic forests (Cf. p. 94).

ZONE C: *Picea – Pinus (– Betula – Alnus)*

Section C: 55–75 cm
„ E: 0–30 cm

Picea has a very sudden increase and reaches its maximum in this zone. Other forest components are *Pinus, Betula* and *Alnus*. *Corylus* is still present with low frequencies. The shrubs decrease when *Picea* increases in zone c. The percentages of *Cyperaceae* increase rapidly especially in section E (80 per cent), perhaps because of local reasons, connected with the formation of the peat. In section C *Polypodiaceae* decrease. Pollen of aquatic plants are rare.

The temperature was already falling when coniferous forests of *Pinus* and *Picea* dominated the vegetation in zone c. Among the herbs *Cyperaceae* increase and *Rubiaceae (Galium* type) have a little maximum. *Polypodiaceae* decrease distinctly when *Picea* immigrates. The sedimentation basin probably

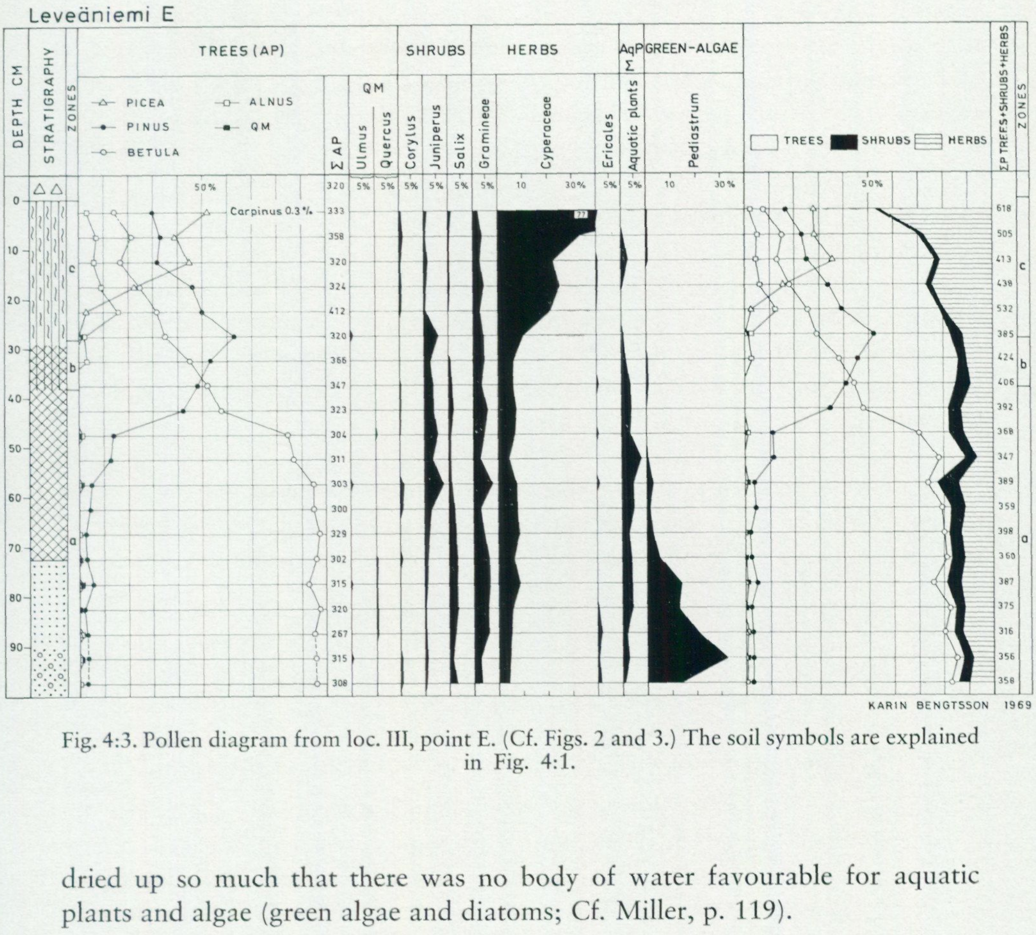


Fig. 4:3. Pollen diagram from loc. III, point E. (Cf. Figs. 2 and 3.) The soil symbols are explained in Fig. 4:1.

dried up so much that there was no body of water favourable for aquatic plants and algae (green algae and diatoms; Cf. Miller, p. 119).

ZONE d: *Pinus – Betula (– Alnus)*
Section C: 45–55 cm

Pinus reaches high values (60 per cent), *Alnus* decreases and *Picea* disappears. Some *Quercus* pollen were found. *Corylus* is still present and *Salix* returns. *Cyperaceae* dominate among the herbs. No aquatic pollen were observed in this zone.

When *Picea* disappeared as the main forest component *Betula* took its place.

ZONE e: *Betula (– Pinus)*
Section C: 10–45 cm

Betula replaces *Pinus* and has a peak at 30–35 cm with 92 per cent. *Pinus* and *Alnus* consequently decrease. *Salix* is more frequent than in the preceding zone, and *Corylus* has no continuous curve as in zone c and d. The low vegetation is dominated by *Cyperaceae* and *Gramineae*. Aquatic plants like *Nuphar, Typha latifolia* and *Nymphaea* occur again in the gyttja.

The dominance of *Betula* and the rising *Salix* values indicate a falling temperature. The return of aquatic plants as well as the diatoms shows a rise of the water level (Cf. Miller, p. 119).

ZONE f (?): *Pinus – Betula (– Alnus)*
Section C: 0–10 cm

Pinus and *Alnus* increase and *Betula* decreases. It is possible that the pollen frequencies are influenced by rebedded pollen which have been embedded in the upper part of the section by the advancing ice. Otherwise the *Pinus* and *Betula* increase could mean a small climatic improvement before the final deterioration.

We do not know for how long the sedimentation of organic sediments continued before the ice advanced at the beginning of the last glaciation. Probably the upper part of the gyttja was removed and embedded in the till.

Soil development and its relation to vegetational changes

Changes in vegetation are due to not only climatical fluctuations but also to soil development (Andersen 1964, 1969). Andersen proved that there is a certain development in the vegetational succession during interglacial periods (Table 4:1). First, light demanding, quickly spreading trees and shrubs occupy the virgin, often calcareous soils rich in mineral salts. As a consequence, formation of mull begins at favourable climatic conditions and characteristic so-called mull plants immigrate. Mull plants are, for example, *Quercus, Ulmus, Tilia, Corylus* and *Carpinus.* In areas too wet (and cold) for mull formation, *Alnus* often replaces the mull plants, but like the mull plants, according to Andersen, it requires a soil influenced by mineral salts. The third phase begins when the soils are leached due to decreasing temperature and increasing precipitation. Then acid humus plants like *Picea, Ericales* and *Sphagnum* occur. An attempt was made to illustrate the soil development at Leveäniemi with diagrams of the three characteristic groups of plants (Fig. 4:4):

Light plants = *Betula, Pinus, Salix* and *Juniperus* (light demanding herbs are also present, but with such low percentages that they could be neglected in these diagrams)
Acid humus plants = *Picea, Ericales* and *Sphagnum*
Mull plants = *Alnus, Corylus, Quercus, Ulmus* and *Tilia*

The basic sum is light plants + acid humus plants + mull plants.

Table 4:1. Comparison between interglacial vegetational stages (after Iversen and Andersen) and the pollen zones at Leveäniemi

Stage	Vegetation	Zone
protocratic stage	open forest	a
mesocratic	mull forest	b
oligocratic	open forest and heath	c
telocratic	paludification increase	d, e, f

The development at Leveäniemi, according to Fig. 4:4, was the following:

ZONE a: Open forest of light plants (95 per cent) like *Betula, Salix* and *Juniperus.*

ZONE b: Forest of the light plants *Pinus, Betula, Salix, Juniperus,* and mull plants like *Alnus* and *Corylus.* Temperature optimum with mull plant maximum of 10–15 per cent.

ZONE c: Coniferous forest of acid character with *Picea* but also *Pinus, Betula* and *Alnus.* No real heath vegetation with *Ericales* and *Sphagnum* developed. Light plants 50–60 per cent, acid humus plants 30–40 per cent and mull plants 5–10 per cent.

ZONE d: *Pinus – Betula* forest with some *Alnus.* Light plants 90–95 per cent, mull plants 5–10 per cent and acid humus plants 1–2 per cent.

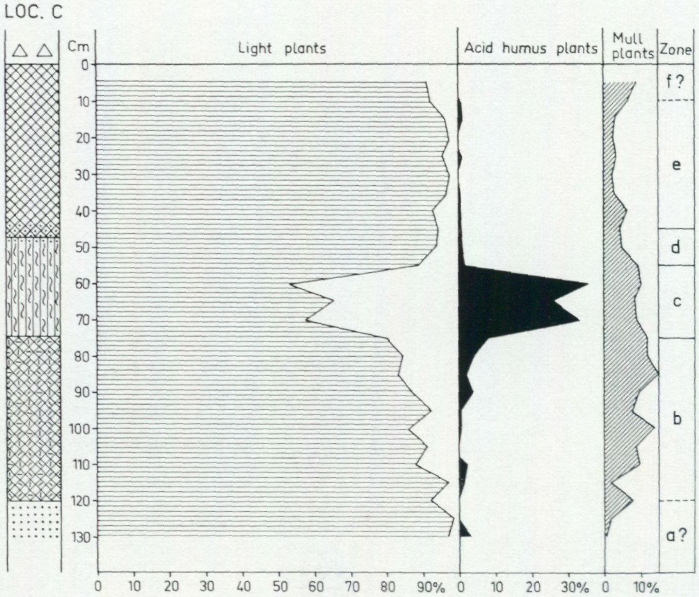
ZONE e: Dominated by *Betula* with some *Pinus, Alnus* and *Corylus,* and *Salix.* This stage was probably cooler than zone d and the following zone f. *Alnus* decreased markedly while *Betula* has a pronounced maximum. Light plants about 95 per cent and mull plants 5 per cent.

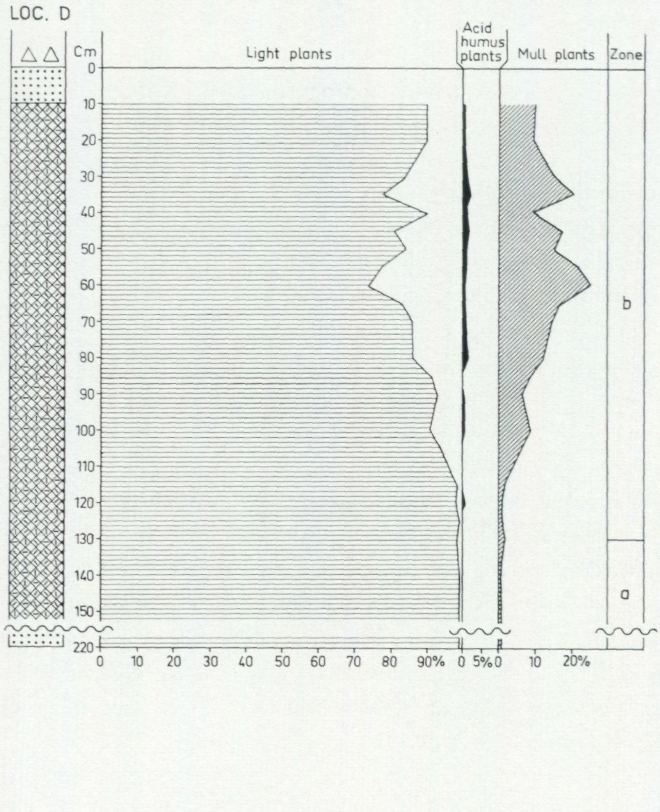
ZONE f (?): Increasing *Alnus* and decreasing *Betula.* Light plants constitute 90–95 per cent and mull plants 5–10 per cent.

Comparison with other interglacial and interstadial deposits

Northern and Middle Sweden

Many of the so-called interglacial deposits in northern and middle Sweden have been scrutinized and discussed by G. Lundqvist (1964) and J. Lundqvist (1967). According to, among others, pollen-analytical and macrofossil investigations J. Lundqvist concluded that many of the deposits earlier considered to be of Eemian age could be correlated with the Jämtland Interstadial and possibly Brörup in Denmark (Andersen 1961).


LOC. C
Cm
Light plants
Acid humus plants
Mull plants
Zone
f?
e
d
c
b
a?
0 10 20 30 40 50 60 70 80 90 100 110 120 130
0 10 20 30 40 50 60 70 80 90%
0 10 20 30%
0 10%


LOC. D
Cm
Light plants
Acid humus plants
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b
a
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0 10 20 30 40 50 60 70 80 90%
0 5%
0 10 20%

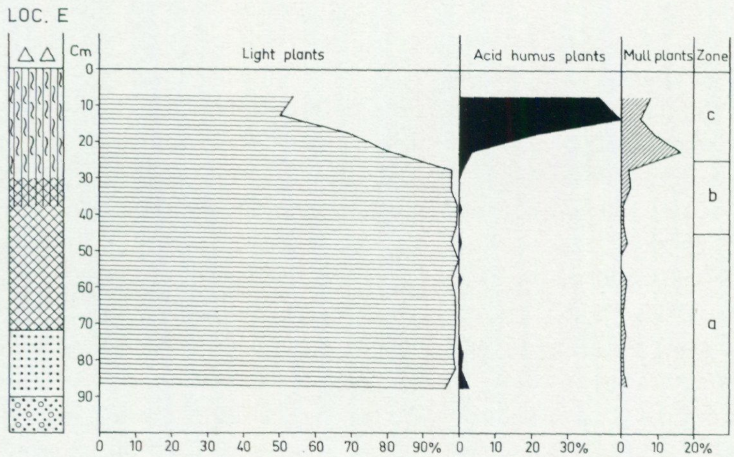

Fig. 4:4. Diagrams showing the soil development as deduced from the pollen diagrams, Figs. 4:1–4:3.

The four sites Porsi, Ale, Gallejaure, and Boliden (G. Lundqvist 1960, Fromm 1960, Magnusson 1962, Grip 1949, J. Lundqvist 1955), are the most northerly situated, and of primary interest in connection with Leveäniemi. Development and composition of the vegetation as shown in pollen diagrams and of macrofossil remains have an arctic to subarctic character at these four localities. There are no indications of temperate vegetation like QM-components, *Alnus* or *Corylus* (except of Boliden where some wood and pollen of *Alnus* were found). If the submorainic deposits at Porsi, Ale, Gallejaure or Boliden should be of Eemian age, they only represent the beginning or the end of the interglacial period (G. Lundqvist 1964). At Gallejaure the herbs constitute 30–50 per cent of the total pollen sum. At Leveäniemi the average percentage of herbs is 10–15 per cent. Subarctic elements like *Artemisia, Betula nana* and *Salix* are represented with high values at Gallejaure, but never exceed 5 per cent at Leveäniemi. Moreover, at Leveäniemi the vegetation seems to have been moderate-temperate during the climatic optimum in the Interglacial, as trees like *Alnus* and *Corylus* could immigrate as far north (300 km north of Gallejaure) and at an altitude of 360 m above sea-level.

More southern localities, like Långsele and Härnön, can be correlated with the Jämtland Interstadial (Cf. J. Lundqvist 1967, p. 232–235). Some of the deposits in central Sweden may be of Eemian age but the material is so fragmentary (mammoth teeth or *Picea* wood in mineral sediments) that it is impossible to determine whether they are interstadial or interglacial.

The most complete investigation was made on submorainic peat from Bollnäs. The pollen diagrams indicate a flora more temperate than nowadays with high frequencies of *Alnus* (max. 40 per cent) and *Corylus* (max. 8 per cent) but show no continuous curve for the QM-components. It is, however, strange that no pollen of other broad-leaf trees (mull plants) than *Corylus* (also present at Leveäniemi) were found in the Bollnäs sediments. Bollnäs is situated about 750 km south of Leveäniemi so climatical conditions must have been more favourable during the Eemian, even suitable for trees like *Quercus, Ulmus, Tilia* and *Carpinus*. It seems queer that *Betula* dominates the pollen spectra in all the samples except one (Cf. Halden 1948, Fig. 9). We do not know how much of the Interglacial is represented in the Bollnäs diagram, but as *Alnus, Corylus* and *Picea* each show maxima it may represent a time of about the same duration as the Leveäniemi diagrams. The retarded immigration of more temperate forest elements may be caused by the isolation of Scandinavia from the continent during the transgressions of the sea in the Eemian. To compare the Bollnäs and Leveäniemi sections, a diagram was constructed showing the development and relation of light plants, acid humus plants and mull plants. In this diagram (Fig. 4:5) as distinguished from Fig. 4:4, only percentages of trees were used:

Light plants = *Betula, Pinus* and *Salix*
Acid humus plants = *Picea*
Mull plants = *Alnus* and *Corylus*

The following correlation was found:

Bollnäs, sample nr		Leveäniemi pollen zone
1	corresponds to	d (e, f)
2	,,	c
3, 4, 5	,,	b
6, 7, 8	,,	a

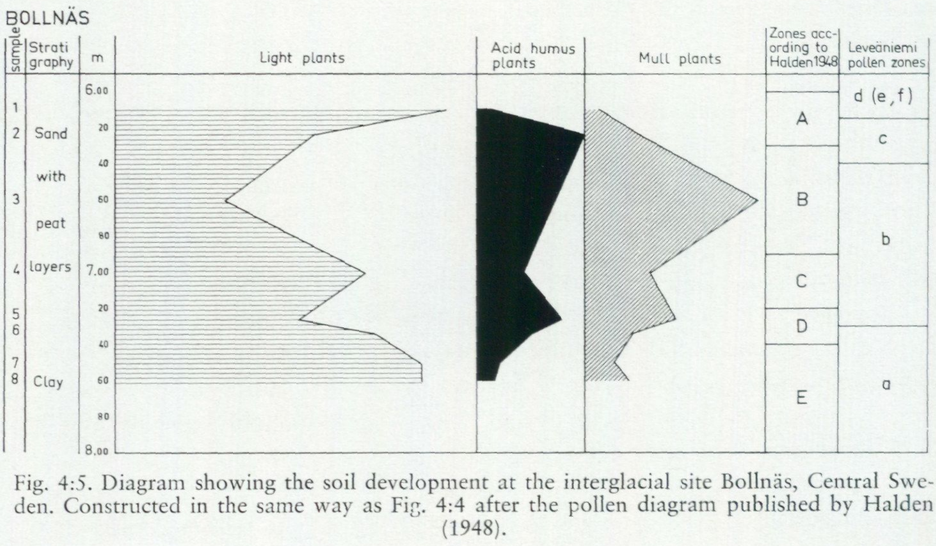

Fig. 4:5. Diagram showing the soil development at the interglacial site Bollnäs, Central Sweden. Constructed in the same way as Fig. 4:4 after the pollen diagram published by Halden (1948).

Most important at Leveäniemi are the indications that the climate was warmer during the interglacial optimum than in postglacial time in the same area (Cf. p. 96).

USSR (Kola Peninsula and European USSR)

Many studies dealing with the vegetational development in glacial, interglacial and interstadial periods in northern Eurasia have been carried out in USSR and Europe. Gritchuk (1964) has set up a scheme of the climatic rythm within an interglacial–glacial period, valid for Eurasia (continental climate; Cf. Gritchuk 1964, Fig. 5):

glacial	cryoxerotic stage	cold and dry
inter-	thermoxerotic	warm and dry
glacial	thermohygrotic	warm and moist
	cryohygrotic	cold and moist
(glacial	cryoxerotic	cold and dry)

In pollen-analytical investigations carried out on material from the south-eastern Kola Peninsula (Grave *et al.* 1969) the palynologists stated that Gritchuks stages are represented as follows:

CRYOXEROTIC STAGE: tundra and north boreal flora elements like *Betula nana, Dryas octopetala, Botrychium boreale, Lycopodium alpinum, L. apressum, L. pungens, Selaginella selaginoides*

THERMOXEROTIC STAGE: absent

THERMOHYGROTIC STAGE: *Betula* sect. *alba, Pinus, Picea, Alnus,* traces of QM and *Corylus*. Moderate-thermophilic aquatic plants like *Alisma, Myriophyllum verticillatum* and *Typha angustifolium*

CRYOHYGROTIC STAGE with three subzones:

1) forest of a thermohygrotic stage with traces of *Quercus, Ulmus, Carpinus* and *Corylus*

2) tundra and north boreal elements more frequent. Pollen of thermophilic species badly preserved, possibly because of rebedding

3) compared with subzone 2 higher values for tundra elements.

In a section from the Strelna river two climatic optima are separated by a cooler stage with higher percentages of *Betula nana* and *Artemisia*, and decreasing *Alnus*. (Cf. Leveäniemi, zone e in section C.)

There are, however, some difficulties in correlating these profiles from the Kola Peninsula with Leveäniemi, because:

a) The material from Kola consists of inorganic sediments. The Leveäniemi material is limnic and organic. The pollen spectra will not be comparable, as marine and lacustrine inorganic sediments will give a picture of the vegetation covering a larger surrounding area than the spectra in a peat bog.

b) Rebedded pollen play a great role in mineral sediments. It is more difficult to determine how much of the pollen content shows the real composition of the vegetation. On the other hand, in inorganic sediments local over-representation of pollen is avoided.

c) Not only temperature and humidity confine the succession of plants within an Interglacial, but also the degeneration of soils from unstable bare soils to mull or/and leached soils (podsol) influences the vegetational changes (Andersen 1969). In northern Scandinavia and on the Kola Peninsula a warm-temperate mull forest with broad-leaf deciduous trees, like *Ulmus, Quercus, Tilia* and *Carpinus* never developed in the Interglacial. But during the optimum there was a small admixture of *Corylus* and QM (?) in the *Pinus – Betula* forest.

Finland

Hitherto no pure limno-telmatic organic sediments comparable with Leveäniemi and representing a longer sequence of the last Interglacial have been found in Finland. Most submorainic sediments that were earlier considered interglacial can probably be correlated with the Peräpohjola Interstadial (Korpela 1969) and the Jämtland Interstadial in Sweden (J. Lundqvist 1967). The vegetation was dominated by *Betula* and had a subarctic character during the Peräpohjola Interstadial. Korpela (1969, p. 23, 40, 43, 62) stated that the clay pieces found in glaciofluvial material at Rouhiala (southeastern Finland) could be of Eemian age. The pollen flora in the marine clay found at Rouhiala shows the following percentages: *Pinus* 10, *Betula* 15, *Alnus* 70, *Carpinus* 2, QM 2, *Salix* 1 and *Corylus* 37 (not included in the basic sum). This warm-temperate forest flora consisting of mostly broad-leaf trees represents a warm maritime climate (Eemian climatic optimum). The plant-geographical conditions (Cf. Frenzel 1968, Fig. 7) during the warmest phase of the Eemian were the following.

Picea – Pinus – Larix forests covered the coast of Norway, northern Sweden (east of the alpine region), northern Finland and the Kola Peninsula. Southern Norway, central Sweden and central Finland were covered by *Pinus – Picea* forests with a small admixture of QM. In southern Sweden and Denmark the main forest components were QM with *Carpinus.*

Norway

Near Bergen in southwestern Norway, Eemian marine sediments covered with till have been found (Mangerud 1970). Three samples were pollen-analysed. The pollen spectrum of the clay gyttja shows high percentages of *Pinus* and *Picea,* but only 4 per cent NAP. Mangerud stated that the great amount of *Picea* (together with *Ilex)* is of special interest since spruce has not grown in the area after the last glaciation. In comparison with Leveäniemi one may point out that the forest at Bergen during the Eemian consisted of more thermophilic and oceanic species. Frenzel (1968, Fig. 7) placed southern Norway in the zone of coniferous forest with a small admixture of QM during the *Tilia* phase of the Eemian.

Postglacial development of the vegetation at Leveäniemi

Today the Leveäniemi area is situated in the boreo-montane coniferous forest zone. The development of the forest after the last deglaciation, as illustrated by the pollen diagram, Fig. 4:6, can be divided into three parts (Cf. Fromm 1965):

132.5–150 cm: *Betula*-dominated forest with *Salix*. Zone I
57.5–132.5 cm: *Pinus – Betula* forest with some *Alnus*. Zone II
0 – 57.5 cm: *Pinus – Betula – Picea* forest. Zone III

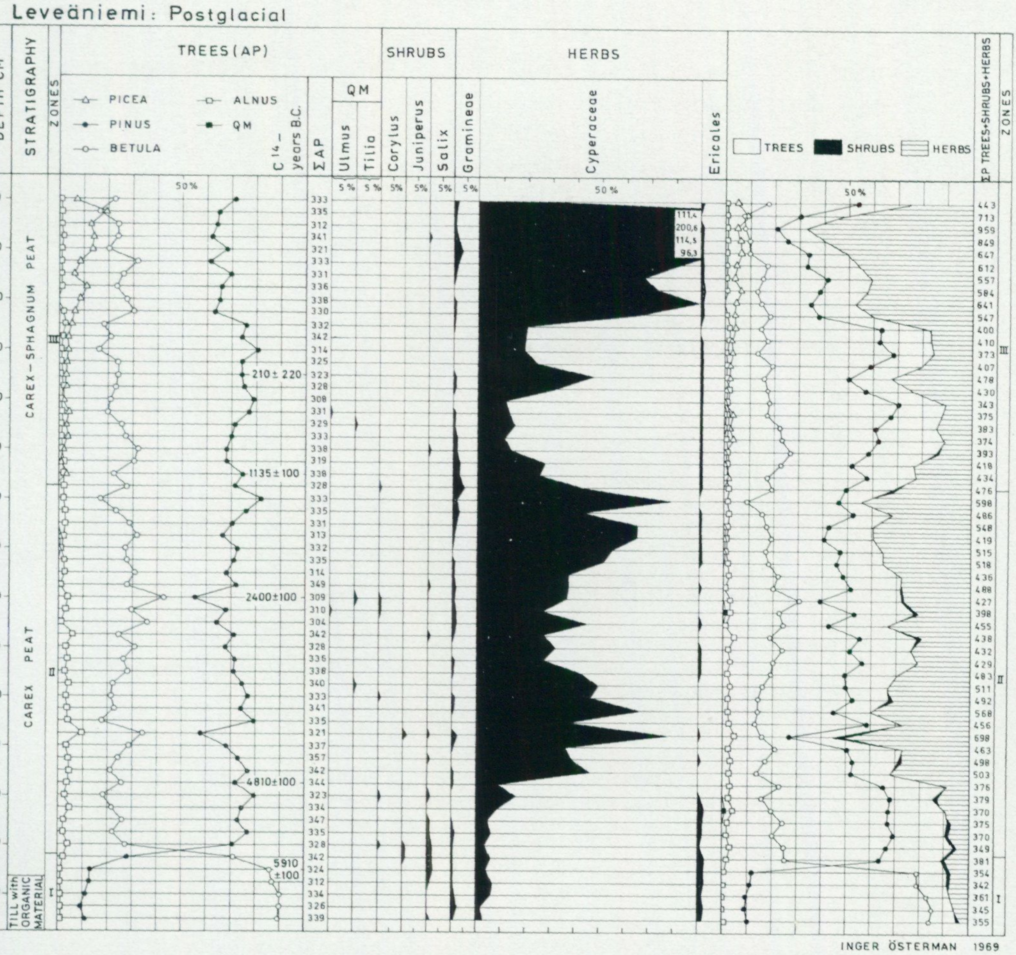

Fig. 4:6. Pollen diagram from the postglacial peat resting upon the till beds above the interglacial sediments at Leveäniemi. The sample series was taken in the northern side of the western part of loc. III. (Cf. Figs. 2 and 3.) The radiocarbon datings have been made at the Stockholm Dating Laboratory.

The postglacial climatic optimum can be placed between 75 and 110 cm. In this northern area it is only reflected by a very slight increase of the *Alnus* curve and traces of *Corylus, Tilia* and *Ulmus*. At the same time there is an almost continuous *Filipendula* curve indicating more favourable climatic conditions. By means of the postglacial diagram from Leveäniemi (Fig. 4:6) and several pollen-analysed sections from the county of Norrbotten (Fromm 1965) it is obvious that the climate must have been warmer and more favourable in the interglacial zones b, c and f (?) than during the postglacial optimum (p. 86).

Five C14-datings were made on the postglacial section. The lowermost, 5 910 B. C., shows that organic sedimentation started shortly after the deglaciation of the area (6 500–6 000 B. C.). The assumption that the postglacial climatic optimum may be placed as mentioned above is confirmed by the two datings at 117.5 and 80 cm. The ages were 4 810 and 2 400 B. C. The beginning of the continuous *Picea* curve is dated at 1 135 B. C. which is in very good agreement with other determinations of the spread of *Picea* in northern Scandinavia (G. Lundqvist 1957, Fromm 1965, Moe 1970).

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GFF = Geologiska Föreningens i Stockholm Förhandlingar
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Table 4:2. Main character of the vegetational zones in the sections of Leveäniemi

Section (depth below upper till bed in cm)			Pollen zone	Vegetation	
D	E	C		Forest (trees and shrubs)	Aquatic plants (AqP)
		0– 10	f ?	*Pinus – Betula – Alnus*	*Nuphar, Typha latifolia*
		10– 45	e	*Betula – Pinus, Salix*	max. of AqP with *Nuphar Typha latifolia, Nymphaea*
		45– 55	d	*Pinus – Betula – Alnus Salix, Corylus*	*Nuphar*
	0–30	55– 75	c	*Picea – Pinus – Betula Alnus, (Corylus)*	min. of AqP
0–130	30–40	75–120	b	*Pinus – Betula – Alnus Juniperus, Corylus, Salix*	decreasing AqP
130–220	40–90	120–130 ?	a	*Betula, Juniperus, Salix*	first max. of AqP with *Pediastrum, Nuphar, Potamogeton, Nymphaea*

Table 4:3. Frequenzy of pollen and spores in the series Leveäniemi C, not included in the diagram

In Tab. 4:3–6 1 = 0–1 per cent, 11 = 1–5 per cent, 111 = more than 5 per cent.

Pollen zone:	a (?)	b	c	d	e	f (?)
Herbs (NAP):						
Artemisia	–	1	1	1	1	–
Caryophyllaceae	–	–	–	1	–	–
Chenopodiaceae	–	1	1	–	1	–
Compositae	–	–	1	–	1	–
Epilobium	–	1	1	–	1	–
Filipendula	1	–	–	–	1	–
Leguminosae	–	–	–	–	–	–
Lysimachia-type	–	1	–	–	–	–
Potentilla-type	1	1	11	–	1	1
Ranunculaceae	1	–	–	–	11	–
Rosaceae	–	1	1	–	1	–
Rubiaceae	–	1	11	–	1	1
Rumex	1	1	–	–	1	1
Thalictrum	–	1	–	–	1	1
Umbelliferae	1	11	1	1	1	–
Valerianaceae	–	–	1	1	1	–
Aquatic plants (AqP):						
Nymphaea	–	–	–	–	1	–
Nuphar	1	1	–	1	11	1
Potamogeton	–	–	1	–	–	–
Typha-Sparganium	–	1	–	–	1	–
Typha latifolia	1	1	–	–	1	1
Spores:						
Lycopodiaceae	111	11	11	11	11	11
Lycopodium selago	–	1	–	1	1	–
Polypodiaceae (average percentage)	15.4	17.0	6.9	10.1	24.6	17.1
Selaginella	–	1	1	–	–	1
Sphagnum	1	1	1	–	11	–

Table 4:4. Frequency of pollen and spores in the series Leveäniemi D, not included in the diagram

Pollen zone:	a	b
Herbs (NAP):		
Artemisia	1	1
Caryophyllaceae	1	1
Chenopodiaceae	–	1
Compositae	1	–
Epilobium	1	1
Filipendula	1	1
Lysimachia-type	1	1
Plantago	1	1
Polygonaceae	1	–
Potentilla-type	1	11
Ranunculaceae	1	1
Rhamnaceae	–	1
Rosaceae	1	1
Rubiaceae	–	1
Rumex	–	1
Scrophulariaceae	–	1
Thalictrum	–	1
Umbelliferae	11	11
Aquatic plants (AqP):		
Nymphaea	1	–
Nuphar	111	11
Potamogeton	1	1
Typha-Sparganium	–	1
Spores:		
Equisetum	–	11
Lycopodiaceae	11	111
Lycopodium selago	–	1
Polypodiaceae (average percentage)	15.3	18.9
Selaginella	–	11
Sphagnum	1	11

Table 4:5. Frequency of pollen and spores in the series Leveäniemi E, not included in the diagram

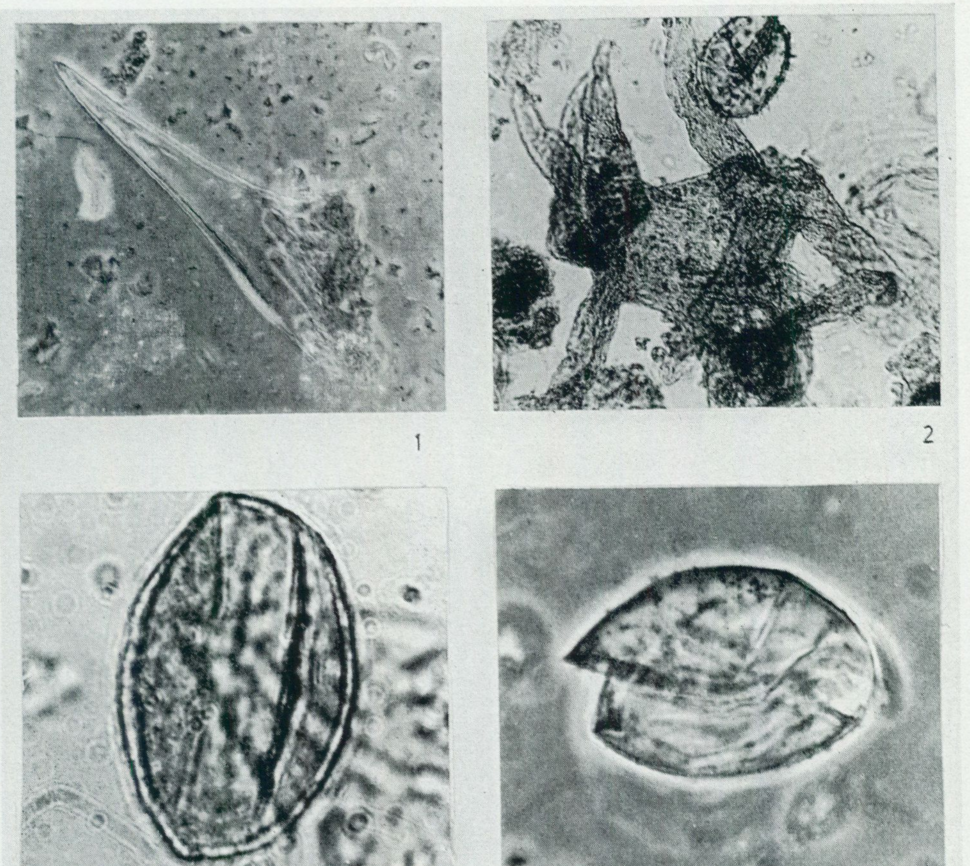
Pollen zone:	a	b	c
Herbs (NAP):			
Artemisia	1	–	1
Caryophyllaceae	1	–	1
Chenopodiaceae	1	–	–
Compositae	1	1	1
Epilobium	–	–	1
Filipendula	1	–	–
Lysimachia-type	1	1	–
Plantago	–	–	1
Potentilla-type	1	1	11
Ranunculaceae	11	1	1
Rosaceae	1	–	–
Rubiaceae	1	–	11
Rumex	1	–	1
Scrophulariaceae	–	–	1
Umbelliferae	11	–	1
Shrubs:			
Myrica	1	–	1
Populus	11	11	1
Viburnum	1	–	–
Aquatic plants (AqP):			
Menyanthes	1	1	1
Myriophyllum alterniflorum	1	–	–
M. spicatum	–	–	1
Nymphaea	1	–	–
Nuphar	11	11	–
Potamogeton	11	1	–
Typha-Sparganium	11	1	1
Typha latifolia	–	1	–
Spores:			
Equisetum	11	11	111
Lycopodiaceae	111	1	11
Polypodiaceae (average percentage)	14.5	2.1	2.0
Selaginella	1	–	11
Sphagnum	1	–	–

Table 4:6. Frequency of pollen and spores in the postglacial Leveäniemi series, not included in the diagram

Pollen zone:	I	II	III
Herbs (NAP):			
Artemisia	–	1	1
Chenopodiaceae	1	–	1
Compositae	–	1	1
Filipendula	–	11	1
Potentilla-type	1	1	1
Rosaceae	1	11	1
Rubiaceae	–	1	1
Thalictrum	–	1	–
Spores:			
Lycopodiaceae	11	11	1
Lycopodium selago	–	1	–
Polypodiaceae (average percentage)	11.7	1.9	0.4
Selaginella	–	111	11
Sphagnum	11	11	1

Plate 4:I. Fig. 1. Leave tip of *Ceratophyllum,* 260×. Fig. 2. Hair of *Nymphaceae* and *Nuphar* pollen, 260×. Fig. 3. *Quercus* pollen, 1250×. Fig. 4. *Juniperus* pollen, 1250×. Fig. 5. *Umbelliferae* pollen, 1250×. Fig. 6. *Rosaceae* pollen, *Potentilla*-type, 1250×.

PLATE 4:I



Appendix 5

DIATOM FLORAS IN THE INTERGLACIAL SEDIMENTS AT LEVEÄNIEMI

by

Urve Miller

Geological Survey, Micropaleontological Lab.

CONTENTS

Material

The material analysed originates from 5 submorainic sediment sections, called section A, B, C, D and E, one Postglacial peat section and different lower and upper till beds in connection with the sediment sections. (Cf. Figs. 2 and 3, pp. 8 and 9.)

The samples from the lower parts of the submorainic sections mainly consist of mineral material – sand, silt, muddy loam and clay – with some contents of organic matter and plant remains.

The organic sediment samples from the middle and upper parts of the sections consist of gyttja, drift peat and fen peat. Carex peat and Carex-Sphagnum peat occur only in the Postglacial section. The submorainic organic sediments are partly mixed with some silt and loam.

98 samples were prepared for diatom analysis.

Submorainic sediments

Section	A:	1 sample	collected by J. Ek, summer 1967
„	B:	5 „	(no more samples available)
„	C:	20 „	from material collected by J. v. Feilitzen, autumn 1967
„	D:	25 „	from material collected by J. Lundqvist, summer 1968
„	E:	15 „	„

Postglacial section: 17 samples

Upper and lower till beds in the sections: 8 samples

Till beds, separate samples collected by J. Ek, summer 1968: 7 samples

Methods

Preparation

The preparative work was carried out at the Micropaleontological laboratory, SGU. The samples prepared for diatom analysis were first concentrated by boiling in 10 % H_2O_2 (2 hours in a water bath) to bleach and destroy the organic matter.

To eliminate the colloidal clay the samples were washed repeatedly by suspending and dispersing the material in distilled water, followed by decanting the wash water after at least two hours sedimentation.

Sand was separated by rapid sedimentation (about 5 sec.) and decanting the suspended sample.

The samples prepared for studies in the scanning electron microscope (SEM) were concentrated by boiling in conc. H_2SO_4, with addition of $NaNO_3$ and $CuSO_4$, and finally washed repeatedly in distilled water.

The diatom slides used for analysing in light microscope were prepared by mounting the dried sample concentrate in Caedax (refractive index = 1.55). This mounting medium is especially suitable for microscopical work (analysing and photographing) in phase contrast.

The sample concentrates used for studies in SEM were prepared as described by Miller (1969).

Analysis

The microscopical analyses were made using Reichert Zetopan and Reichert research light microscopes in phase contrast with 100/130 oil immersion at 1 000 × magnification. The main part of the analytical work and the diatom identifications were carried out by Mr Bengt Falkenström, Micropaleontological lab., SGU.

The number of counted diatom valves per sample (basic sum) generally varies between 250 and 350. (The often mass occurring *Fragilaria* valves are not included in the basic sum.) In many samples poor in diatoms the number of counted valves is lower. These analyses must be considered more or less uncertain, only showing a tendency of the character of the diatom flora.

The diatoms were mainly identified after Hustedt (1930, 1927–66), Cleve-Euler (1951–55), van Heurck (1880–85), Schmidt *et al.* (1874–1959), Pantocsek (1903–05), van der Werff & Huls (1958–70) and Patrick & Reimer (1966).

Photomicrography

Most of the diatom forms (taxa) found in the Leveäniemi sediments were photographed in the light microscope by B. Falkenström and the author (with a Reichert research microscope with photo automatic or with a Reichert Zetopan microscope with camera adapted). Generally the micrographs were taken both in ordinary light and in phase contrast.

5 samples from sections B, D and E together were also studied in the scanning electron microscope (SEM). The species noted were photographed with polaroid camera and with a small film camera. The film used both for light micrographs and for SEM micrographs was Kodak Plus X, panchromatic, PX, 410, 22° din.

A selection of the most common or otherwise remarkable species from the Leveäniemi sediments is reproduced on the plates 5:I–XI.

The lay-out work of these plates was carried out with valuable assistance of Mrs Inga Palmaer, SGU.

Construction of diagrams

Three different diagram types for each section were constructed to give a general impression of

1) the composition and succession of diatom associations,
2) the ecology of the biotope: The living form (biological group) and
3) pH-requirement of the components.

The first diagram type shows the succession of the main components, arranged according to their vertical distribution and order of dominance. In cases of genera where the (main part of) species have the same requirement of biotope and almost the same vertical distribution, the taxa are summed up to one component *(Eunotia, Achnanthes, Navicula, Nitzschia, Tabellaria, Pinnularia)*. The basic sum of calculations is the number of diatom valves counted, excluding *Fragilaria*. The distribution and approximate frequency of *Fragilaria* species are shown in connection to the succession diagrams.

The second diagram type illustrates so-called "living forms" – biological groups of the components. The taxa are combined according to their preferred biotope. The groups used here are: benthonic (bottom living), benthonic-epiphytic (living attached at bottom), epiphytic (attached mainly to higher algae and aquatic plants), epiphytic-planktonic (facultative pelagic or attached) and benthonic-planktonic (floating near bottom).

The grouping in living forms is mainly after Cleve-Euler (1951–55), Foged (1964), Florin (1957, 1970), Mölder (1943a, b, 1944a, b).

The third diagram type shows the pH-requirement of the diatom floras presented as pH-spectra of the sediments. The taxa were grouped together according to the known pH-requirement of recent diatoms. The information is taken mainly from Hustedt (1957), Foged (1953, 1955, 1958, 1964), Cholnoky (1969), Mölder & Tynni (1967, 1968–69, 1970), Meriläinen (1967, 1969).

The taxa were classed after the following pH-values:

>8 and 8–7.5	alkaliphilous diatoms (mainly alkalibionts)
7.5–6.5	indifferent or neutral diatoms (including slightly alkaliphilous and slightly acidophilous diatoms and diatoms of unknown and uncertain pH-requirement)
6.5–6 and <6	acidophilous diatoms (mainly acidobionts).

The calculation of pH-spectra was based on two different basic sums. The first corresponds to the number of valves counted, excl. *Fragilaria*. The second corresponds to valves counted, excl. *Fragilaria, Melosira, Tabellaria* and *Epithemia*. These genera belong to the epiphytic and planktonic groups and can appear more or less allochtonous or otherwise occur in misleading frequencies. *Fragilaria* spp. (mainly *F. construens)* has mass occurrence in almost all the samples. *Melosira* spp. (mainly *M. distans* and *M. italica* v. *valida* et v. *italica "laevis")* dominate in the middle and upper parts of the sections. The taxonomical and ecological data on *Melosira italica* subspp. and varr. are very confusing (see notes p. 125). *Tabellaria* and *Epithemia* will often be overrepresented in the analysis as they are easily recognized. They were excluded to give a better picture of the pH-requirement of the remaining species and to control the pH-spectra calculated in the first pH-diagram.

The ecological data used for each taxa are given in the alphabetic lists (p. 132–140) together with the approximative frequency and the vertical distribution.

The diagrams were drawn by Mrs Greta Hellström, SGU.

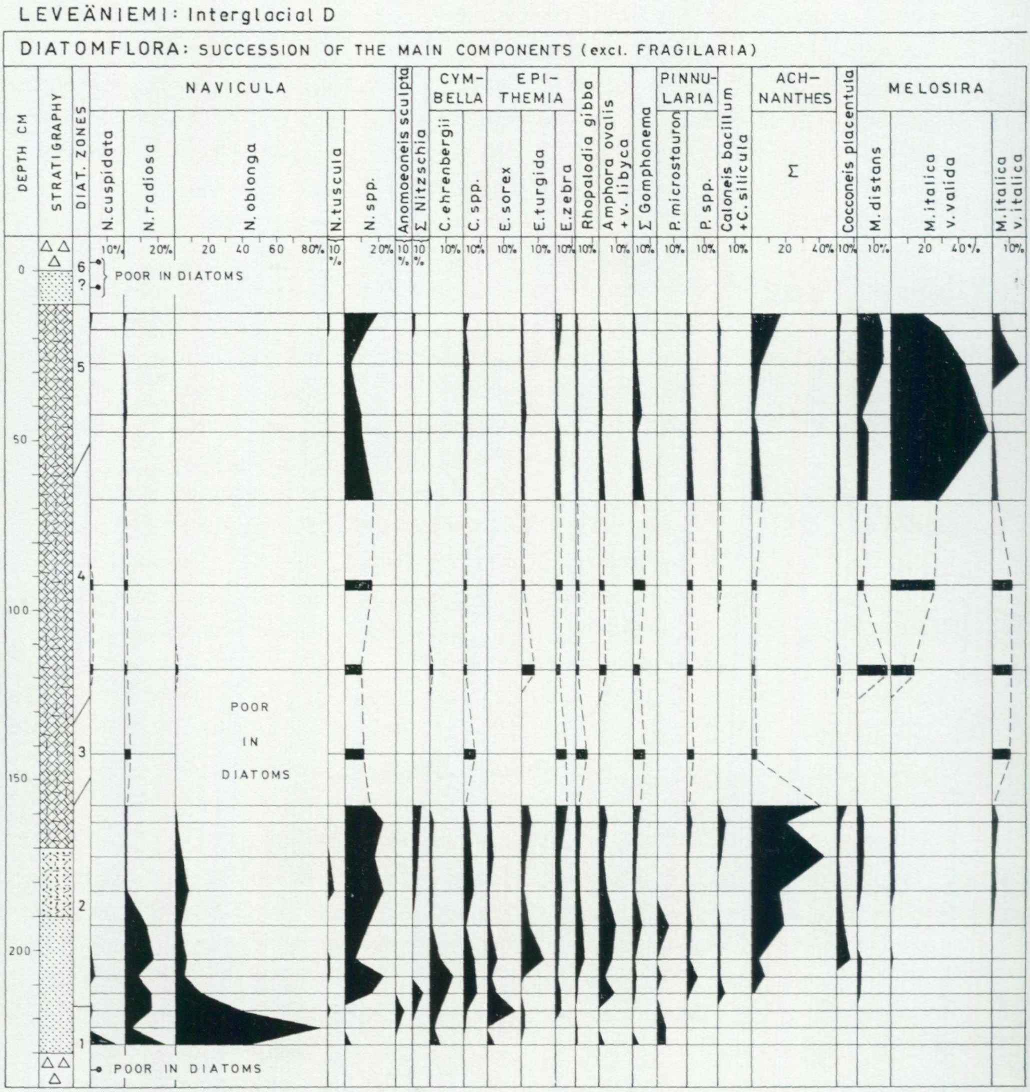


Fig. 5:1a. Succession of the main components of the diatom flora at loc. III, point D. (Cf. Figs. 2 and 3, pp. 8 and 9.) For explanation of the signs, see Fig. 4:1.

General character of the diatom floras and their succession in the submorainic sediment sections

General character

About 300 taxa belonging to 224 species and 30 genera were found in the submorainic sediments (Cf. alphabetic list of diatom species, p. 132). All diatoms noted are fresh-water forms – oligohalobes – of slightly brackish (halophilous), indifferent or halophobous character.

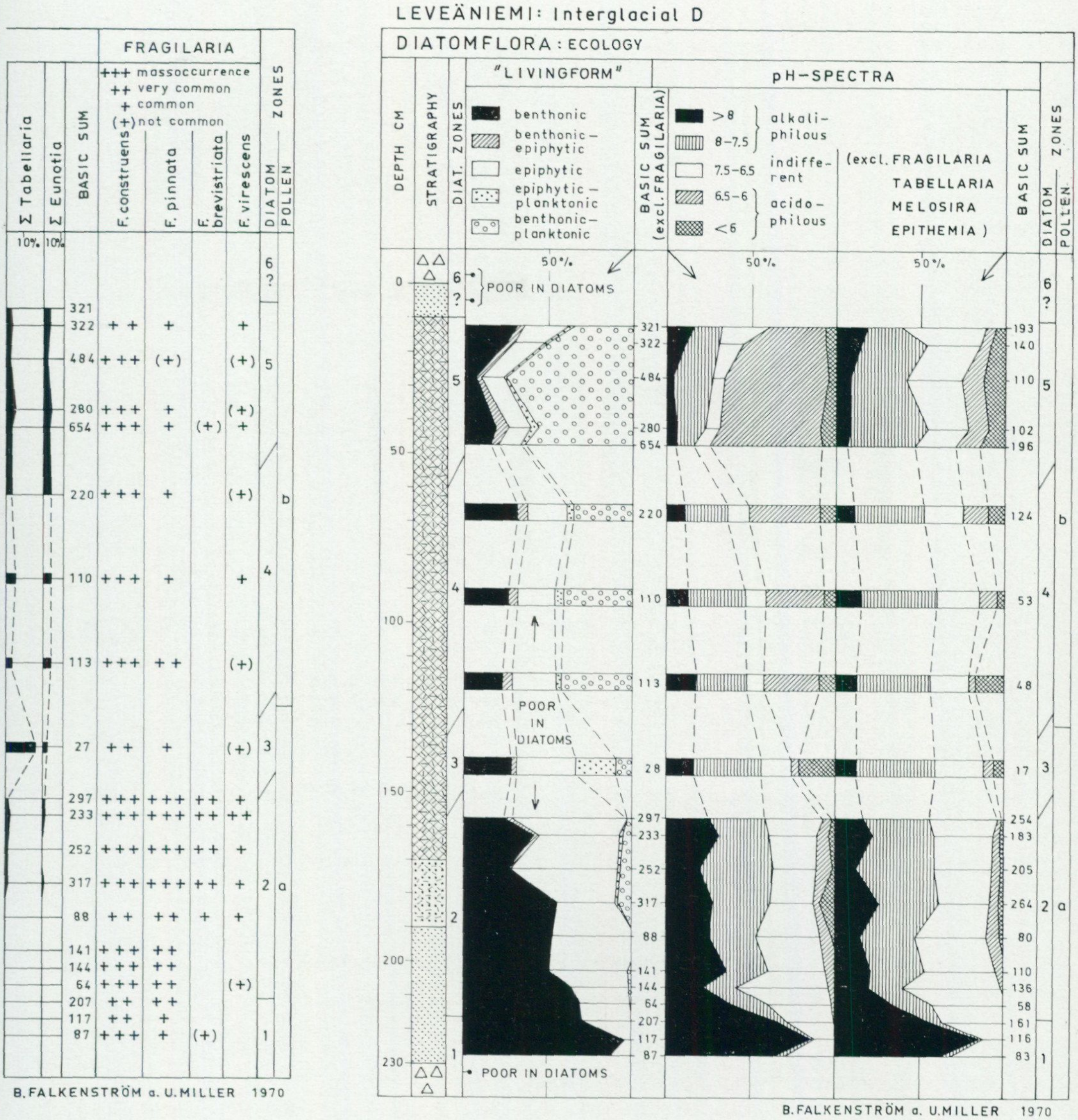


Fig. 5:1b. Diagram showing the ecological development of the diatom flora at loc. III, point D. For explanation of the signs, see Fig. 4:1.

The genera *Fragilaria (F. construens* and *F. pinnata)* and *Melosira (M. distans, M. italica* v. *valida* and *M. italica* v. *italica* f. *laevis)* are the most common ones, often mass occurring. The genera represented by the highest numbers of species are: *Navicula* (50 spp.), *Cymbella* (29 spp.), *Pinnularia* (26 spp.), *Eunotia* (18 spp.), *Achnanthes* (14 spp.), *Gomphonema* (14 spp.) and *Nitzschia* (13 spp.).

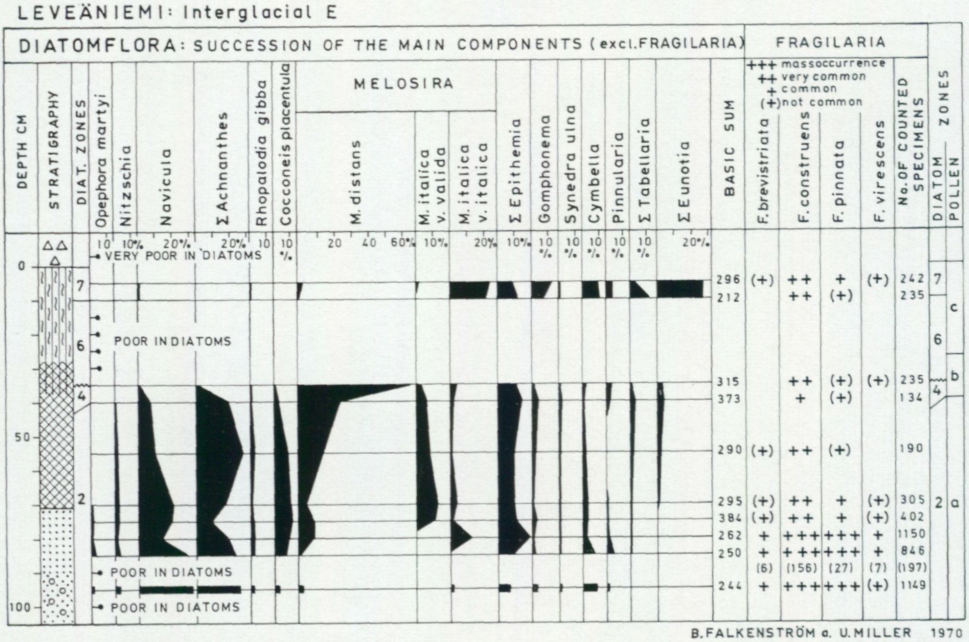


Fig. 5:2a. Succession of the main components of the diatom flora at loc. III, point E. (Cf. Figs. 2 and 3, pp. 8 and 9.) For explanation of the signs, see Fig. 4:1.

Of the five submorainic sections C, D and E were the closest studied ones, while sections A and B represent a few samples only. They were included in the present study to get a better view of the stratigraphy and to check the diatom zones.

Diatom succession in the sediment sections

SECTION D (Fig. 5:1, a and b)

This is the longest section with sediment layers of 230 cm thickness. The succession of diatom floras can be divided in 5 (6?) zones.

The lowest part, ZONE 1 (230–215 cm), consists of clayey sediments and contains an alkaline, slightly brackish diatom flora of mainly benthonic species with *Navicula oblonga* as the guide form ("Leitform").

ZONE 2 (215–150 cm) consists of muddy loam and contains a slightly alkaline to circumneutral diatom flora of bottom forms and epiphytes, with *Fragilaria, Navicula, Achnanthes, Epithemia* and *Nitzschia* as characteristic genera.

ZONE 3 (150–130 cm) corresponds to a silty layer, poor in diatoms, showing a mixed flora with the genus *Tabellaria (T. fenestrata*-type) as main component.

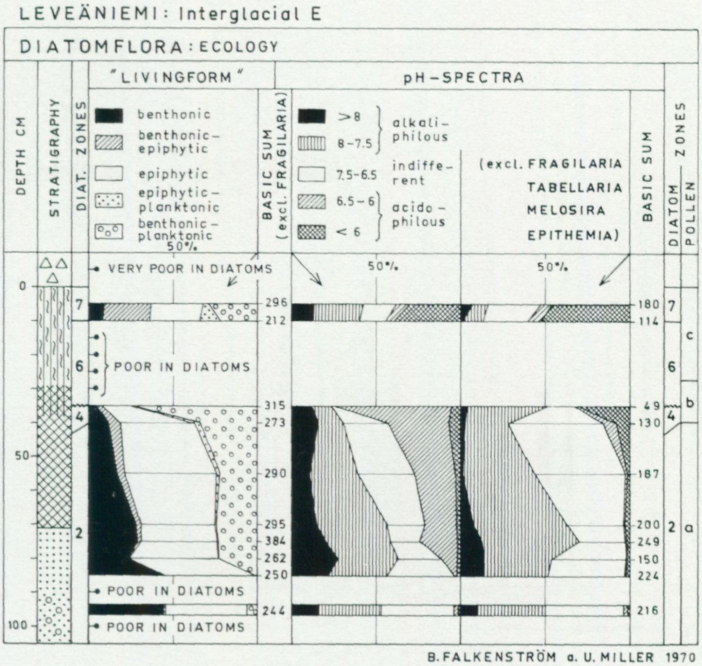


Fig. 5:2b. Diagram showing the ecological development of the diatom flora at loc. III, point E. For explanation of the signs, see Fig. 4:1.

ZONE 4 (130–50 cm) consists of drift peat with a rather poor and uniformely mixed benthonic, epiphytic and planktonic diatom flora. *Fragilaria construens, Melosira distans, M. italia* v. *valida* and v. *italica* f. *laevis* are characteristic components.

ZONE 5 (50–10 cm). Drift peat continues. Diatom flora of acidophilous character with a distinct dominance of planktonic species. *Melosira italica* v. *valida* is guide form ("Leitform").

ZONE 6 ? (10–0 cm) consists of sandy drift peat, poor in diatoms. The specimens occurring are very fragmentary, mainly of the genera *Pinnularia, Melosira, Navicula* and *Anomoeoneis.*

It should be noted that the genus *Fragilaria* is very well represented in section D. *F. construens* has mass occurrence in most of the samples. *F. pinnata* is dominant mainly in the upper part of zone 2, together with *F. brevistriata* (80–50 cm).

SECTION E (Fig. 5:2, a and b)

The thickness of the sediments is about 1 m. The succession of the diatom floras can be divided into 4 main phases. Two of them nearly correspond to the zones 2 and 4 of section D. The third phase may be correlated with zone 6. The fourth phase is called zone 7.

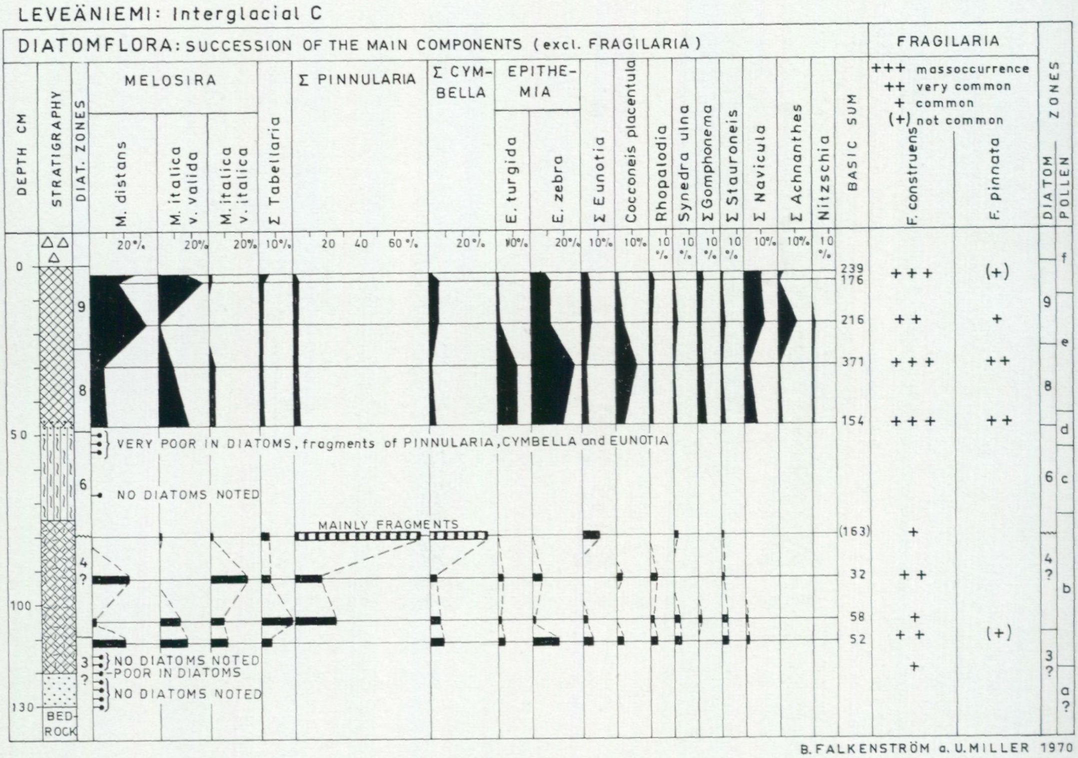


Fig. 5:3a. Succession of the main components of the diatom flora at loc. III, point C. (Cf. Figs. 2 and 3, pp. 8 and 9.) For explanation of the signs, see Fig. 4:1.

ZONE 2. The sediments between 100 and 35 cm consist of clayey sand in the bottom, then muddy loam and gyttja upwards mixed with fen peat. Diatoms are mainly bottom forms and epiphytes of alkaline–circumneutral character *(Navicula–Achnanthes–Epithemia* zone), with some admixture of acidophilous *Melosira* plankton above 80 cm. *Fragilaria construens* and *F. pinnata* are mass occurring in the lower part (100–80 cm).

ZONE 4. Between 35 and 30 cm the sediments consist of mixed gyttja and fen peat of drift character. The diatom flora changes its character to a more planktonic-epiphytic and more acidophilous type. Guide form is *Melosira distans*.

ZONE 6. The fen peat between 30 and 10 cm is very poor in diatoms, mainly fragments of *Pinnularia, Tabellaria* and *Cymbella*. This part has a distinct acidophilous-terrestrial character.

In the uppermost part (10–0 cm) the diatom frequency in the fen peat increases. The composition of the diatom flora has a mixed character with components from all biological groups, indicating an acid milieu *(Eunotia, Tabellaria, Pinnularia)* but also alkaliphilous *Epithemia, Melosira italica* v. *italica*

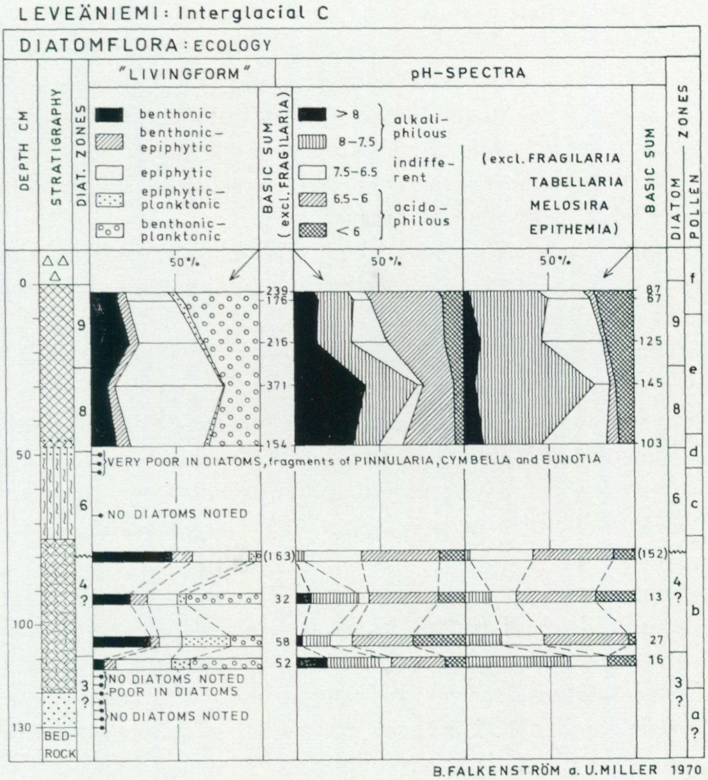


Fig. 5:3b. Diagram showing the ecological development of the diatom flora at loc. III, point C. For explanation of the signs, see Fig. 4:1.

and alkaline-neutral *Fragilaria, Cymbella* and *Gomphonema* species occur in this sediment layer (zone 7).

SECTION C (Fig. 5:3, a and b)

The succession of diatom floras was divided into 5 phases. The three lowest can be correlated with zones 3, 4 and 6 of sections D and E. The two upper phases are called zones 8 and 9.

The thickness of the sediment layers is 130 cm. The section begins with mineral sediment (sandy silt) between 130 and 120 cm. No diatoms were noted in this part. Between 120 and 105 cm a transition from sandy silt to fen peat takes place. The diatom flora is poor, almost lacking in some samples. The composition shows a mixture of alkali- and acidophilous species, mainly plankton and epiphytes (zone 3).

The poor diatom flora continues in the lower part of the fen peat (105–80 cm). The flora is composed of mainly planktonic and benthonic forms of acidophilous character *(Melosira distans, Tabellaria, Pinnularia)* somewhat mixed with *Melosira italica* v. *italica, Epithemia* and *Cymbella. Fragilaria construens* is common, but shows no mass occurrence (zone 4).

The sample from 77.5–80 cm contains a very fragmentary diatom flora with *Pinnularia* and *Cymbella* fragments as main components, some *Eunotia* and *Tabellaria.* Benthonic and epiphytic species of distinctly alkaliphilous-neutral character dominate (beginning of zone 6).

In the fen peat between 77.5 and 50 cm diatoms are almost lacking. Only a few fragments of *Pinnularia, Cymbella* and *Eunotia* were noted from this part (zone 6).

Between 50 and 45 cm the fen peat ends with a silty layer, and the sediments above consist of gyttja (45–0 cm).

In the diatom flora between 50 and 25 cm *Epithemia turgida* and *E. zebra, Cocconeis placentula, Melosira distans* and *M. italica* v. *valida* dominate. *Fragilaria construens* is mass occurring and *F. pinnata* common. The flora has a mixed character with some dominance of epiphytic alkaliphilous diatoms (zone 8).

Also the uppermost gyttja sediments (25–0 cm) contain a mixed diatom flora with mainly *Melosira distans, M. italica* v. *valida, Epithemia zebra, Navicula* and *Achnanthes. Fragilaria construens* is dominant to mass occurring and *Fragilaria pinnata* decreasing. pH-spectra show a mixture of species with all pH-requirements. There is a weak dominance of acidophilous-circumneutral planktonic and epiphytic species (zone 9).

SECTION B (Fig. 5:4)

The five samples analysed can be correlated with zones 2, 3, 4 and 6 (?).

Thickness of the sediments is about 130 cm. The lower part (130–97 cm) consists of muddy loam with organic drift material. The two samples analysed show a dominance of the genera *Achnanthes, Navicula, Epithemia* and mass occurrence of *Fragilaria pinnata* and *F. construens.* The composition of the flora indicates an alkaline-circumneutral milieu with mainly epiphytes and bottom forms typical for zone 2.

Between 97 and 90 cm more silty sediments with a very poor diatom flora of mixed character (zone 3) occur.

The sediments between 90 and 20 cm consist of mixed gyttja–drift peat (drift sediments). One diatom analysis from the middle part shows a composition, dominated by *Melosira distans, M. italica* v. *valida, Amphora ovalis, Navicula, Epithemia zebra, E. turgida* and *Nitzschia.* It is a mixture of both acidophilous and alkaliphilous species, with a weak dominance of acidophilous plankton. *Fragilaria* is noted, but not dominant (zone 4).

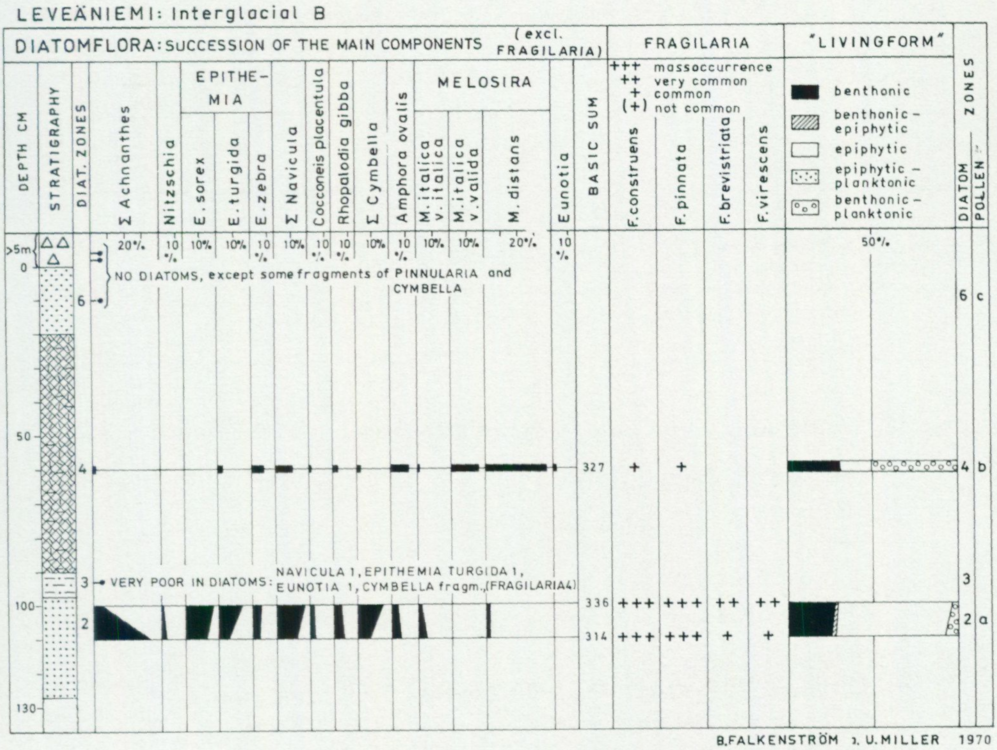


Fig. 5:4. Succession of the main components of the diatom flora at loc. III, point B. (Cf. Figs. 2 and 3, pp. 8 and 9.) For explanation of the signs, see Fig. 4:1.

The uppermost sediments of the section consist of (silty) sand (20–0 cm) very poor in diatoms. Only one *Pinnularia borealis* and some fragments of *Cymbella aspera* and a large *Pinnularia* sp. were noted (beginning of zone 6?).

SECTION A

Section A is situated in the close neighbourhood of section B (see Fig. 3, p. 9) and represents almost the same stratigraphy. The only sample analysed consists of drift sediments from the middle part of the section, and contains a diatom flora corresponding to diatom zone 4. The main components of the diatom flora are: *Melosira distans, M. italica* v. *valida, Epithemia zebra, E. turgida, Rhopalodia gibba* and *Amphora ovalis. Fragilaria construens* is common but not mass occurring. The flora has a mixed character with both acidophilous and alkaliphilous representants. There is a slight dominance of acidophilous plankton over alkaliphilous epiphytes (zone 4):

Biological groups (living forms)	per cent	pH-requirement		per cent
benthonic diatoms	7.5	>8	alkaliphilous diatoms	33
benthonic-epiphytic diatoms	2.5	8 –7.5		9
epiphytic diatoms	41	7.5–6.5	neutral (indiff.) diatoms	6.5
epiphytic-planktonic diatoms	1	6.5–6	acidophilous diatoms	48
benthonic-planktonic diatoms	48	<6		3.5
Basic sum: 600	100.0			100.0

Diatom zones and a correlation with pollen zones

The succession of diatom floras in all the submorainic sections together is divided into nine zones.

ZONE 1

Section D: 230–215 cm, 3 samples, 27 taxa, 411 specimens, excl. *Fragilaria*

Main components: *Fragilaria construens, Navicula oblonga, Epithemia sorex, Fragilaria pinnata, Navicula radiosa, Navicula cuspidata, Pinnularia microstauron, Anomoeoneis sculpta, Cymbella ehrenbergii* var. *hungarica, Epithemia turgida, E. zebra.*

Ecology: Eutrophic, littoral milieu with slightly brackish, cold, transparent water.

ZONE 2

Section	Depth	Samples	Taxa	Specimens
D:	215–150 cm,	10 samples,	136 taxa,	1 536 specimens
E:	100– 35 cm?,	9 „ ,	152 „ ,	2 025 „
B:	110–100 cm,	2 „ ,	76 „ ,	650 „
		21 samples		4 211 specimens

Main components: *Fragilaria construens, F. pinnata, F. brevistriata, F. virescens, Achnanthes exigua, A. lanceolata, Epithemia sorex, Navicula radiosa, N. oblonga, N. tuscula, Cymbella ehrenbergii* var. *hungarica, Epithemia turgida, Amphora ovalis* et var. *libyca, Cocconeis placentula, Opephora martyi, Nitzschia* spp.

Ecology: Eutrophic to mesotrophic, littoral milieu with slightly brackish to fresh, quite cold and transparent water.

Section E has in this zone a somewhat mixed flora of drift character. *Melosira italica* v. *italica* et v. *valida* and *M. distans* compose about 25 per cent of it. (In sections D and B about 10 per cent.) Possibly only the lowest part of section E (100–80 cm) corresponds to zone 2.

On the contrary the rich occurrence of species of genera *Achnanthes, Navicula Nitzschia, Epithemia, Cocconeis placentula* and *Opephora martyi* indicates zone 2 up to 35 cm.

ZONE 3

Section D:	150–130 cm,	1 sample,	22 taxa,	28 specimens
C:	130–110 cm,	8 „ ,	22 „ ,	52 „
B:	97– 90 cm,	1 „ ,	6 „ ,	8 „
		10 samples		88 specimens

Main components: *Fragilaria construens, Tabellaria flocculosa, T. fenestrata, Epithemia zebra, Rhopalodia gibba.* (In section C also *Melosira distans* and *M. italica* v. *valida.)*

Ecology: Diatom flora poor, mixed, with mainly epiphytes and plankton. Drift character. Aquatic littoral milieu.

ZONE 4

Section D:	130–50 cm,	3 samples,	74 taxa,	443 specimens
C:	110–80 cm,	2 „ ,	21 „ ,	90 „
B:	60 cm,	1 „ ,	50 „ ,	327 „
E:	35–30 cm,	1 „ ,	37 „ ,	315 „
A:	?	1 „ ,	56 „ ,	600 „
		8 samples		1 775 specimens

Main components: *Fragilaria construens, F. pinnata, Melosira distans, M. italica* v. *valida* et v. *italica* f. *laevis, Epithemia zebra, E. turgida.*

Ecology: Diatom flora rather poor, uniformely mixed. Aquatic conditions. Increasing values of benthonic plankton *(Melosira* spp.), mainly *Melosira distans* indicate more oligotrophic–dystrophic conditions caused by peaty water (see notes, p. 125), while *Epithemia* spp. and *Fragilaria* spp. reflect an alkaline-neutral, eutrophic-mesotrophic milieu. Changes in water level?

ZONE 5

Section D: 50–10 cm, 8 samples, 148 taxa, 2 061 specimens

Main components: *Melosira italica* v. *valida, Fragilaria construens, F. pinnata, Melosira distans, M. italica* v. *italica* f. *laevis.*

Ecology: Acid oligotrophic to dystrophic milieu mixed with a more neutral to slightly alkaline one. Periodically higher water level? In the uppermost samples (20–10 cm) return to more alkaline-eutrophic conditions with species of genera *Navicula* and *Achnanthes* increasing.

ZONE 6

Section D:	10– 0 cm?,	1 sample,	6 taxa,	12 specimens	
E:	30–10 cm,	3 „ ,	15 „ ,	30 „	
C:	80–50 cm,	5 „ ,	12 „ ,	175 „	(most fragments)
B:	20– 0 cm?,	1 „ ,	3 „ ,	5 „	
		10 samples		222 specimens	(most fragments)

Main components: Fragments of *Pinnularia* spp., *Cymbella aspera* and *Eunotia* spp.

Ecology: Very poor in diatoms, mainly fragments. A terrestrial stage.

ZONE 7

Section E: 0–10 cm, 2 samples, 71 taxa, 477 specimens

Main components: *Fragilaria construens* dominant, but not mass occurring. *Eunotia* spp. *(E. praerupta, E. mondon, E. pectinalis), Melosira italica* var. *valida* f. *laevis, M. distans, Epithemia turgida, E. zebra, Fragilaria pinnata, Gomphonema angustatum, Pinnularia* spp., *Tabellaria fenestrata, Diploneis ovalis* var. *oblongella, Cymbella aspera, C. ventricosa.*

Ecology: Mixed diatom flora. Facultative terrestrial-aquatic conditions. Acid milieu with admixture of slightly alkaline water. Characteristic species in common with the Postglacial flora (See p. 122).

ZONE 8

Section C: 50–25 cm, 2 samples, 64 taxa, 525 specimens

Main components: *Fragilaria construens* mass occurring, *F. pinnata* common. *Epithemia zebra, E. turgida, Cocconeis placentula, Melosira italica* var. *valida, M. distans.*

Ecology: Aquatic slightly alkaline conditions with admixture of more oligotrophic water. Littoral milieu. Many alkaliphilous species in common with diatom zone 2.

ZONE 9

Section C: 25–0 cm, 3 samples, 101 taxa, 621 specimens

Main components: *Fragilaria construens* dominating, *Melosira distans, M. italica* var. *valida, Epithemia zebra, Navicula* spp. *(N. dicephala, N. levanderi, N. pupula), Fragilaria pinnata, Achnanthes* spp. *(A. lanceolata, A. linearis, A. minutissima, A. suchlandti).*

Ecology: Mixed aquatic conditions. The influence of oligotrophic to dystrophic water increases. Milieu similar to diatom zone 4, with an admixture of species characteristic for zone 2.

CORRELATION WITH POLLEN ZONES

A correlation with the pollen zones (Robertsson, p. 83) shows the following: Pollen zone a *(Betula – Pinus* zone) corresponds to diatom zones 1 and 2 (alkaline to circumneutral, slightly brackish littoral milieu).

The transition from pollen zone a to b corresponds to diatom zone 3 and the beginning of diatom zone 4 (increasing influence of oligotrophic conditions, the eutrophic clear-water forms disappear).

Pollen zone b corresponds to diatom zones 4 and 5 (with mixed conditions. Alkaline-circumneutral fresh water mixed with oligotrophic-dystrophic water).

Pollen zone c, the *Picea* zone, is comparable with diatom zone 6, the terrestrial stage.

The end of zone c corresponds to diatom zone 7 (section E) with moister conditions, acid milieu with some admixture of alkaline-neutral water. In section C pollen zone d has continuing terrestrial conditions and corresponds to diatom zone 6. Pollen zones e and f (section C) correspond to the diatom zones 8 and 9 with aquatic conditions and increasing influence of acid, oligotrophic-dystrophic water.

Changes in the sedimentation milieu and geological conditions

According to the diatom succession the interglacial sedimentation at Leveäniemi had no marine phase or conditions of great-lake character. The water body was more of small-lake type with shallow water. The littoral diatom flora in the beginning of the sedimentation indicates aquatic conditions with eutrophic sedimentation milieu rich in mineral salts (alkaline, slightly brackish, transparent, cold water and clayey to loamy sediments). This sedimentation phase is interrupted by deposition of a silty layer with plant remains containing a poor diatom flora, probably formed at the beginning of a rapid drainage and accumulation of drift sediments. The following sedimentation phase shows a slowly increasing influence of more oligotrophic-dystrophic conditions, depending on the continued drainage of the area and the beginning of more acid conditions with peat formation. The transition phase from aquatic to terrestrial milieu, according to the pollen diagrams, represents the warmest phase of the interglacial development. Also in the diatom floras it is indicated by the absence of forms of transparent, eutrophic water. In the thinner sediment sections a terrestrial phase is fully developed, while in the deepest part (section D) the diatom flora shows a phase with marked increase of oligotrophic-dystrophic acidophilous bottom plankton before the drier conditions.

After the terrestrial phase with *Picea* wood the climatic conditions must have been moister. In a thin sediment layer (10 cm) between the terrestrial sediments and upper till in section E, the diatom flora has almost the same mixed composition as in Lateglacial sediments of Kirchner Marsh, southeastern Minnesota, discussed by M.-B. Florin (1970). According to Florin this flora with mainly facultative terrestrial diatoms is characteristic for moister conditions in the surface of humified litter from a *Picea* wood growing on silt-mantled dead ice.

The circumstances must have been partly the same during the end of the interglacial period in the Leveäniemi area. Even here the diatom flora of facultative terrestrial acidophilous diatoms mixed with a more alkaliphilous-circumneutral diatom flora occurs in connection with the sediments of the *Picea* zone.

The origin of the alkaline water at Leveäniemi was not a melting down of a dead-ice block, but probably seasonal melt water from higher ground.

In section C a new aquatic stage with gyttja sediments containing mixed diatom floras of slightly alkaline and acid, peaty waters confirms the more humid conditions at the end of the sedimentation.

In the sediments formed after the terrestrial stage (diatom zones 7, 8 and 9) many of the typical forms of zone 2 return (zones 8 and 9) and diatom species more characteristic for the Postglacial peat section immigrate (zone 7).

Comparison with the till beds and a Postglacial peat section

THE TILL BEDS

In the seven separate moraine samples collected by John Ek no diatoms were noted.

Also the moraine samples connected with the sections (so-called upper and lower till beds) were very poor in diatoms. The number of the few species found are shown in Table 5:2. It should be observed that the terms upper and lower till beds in this connection refer to the strata above and below the organic beds and not to the till beds discussed by Lundqvist in the main text and by Ek in appendix 1.

Most diatoms were found in the upper till bed of section A and in the lower till bed of section D, with diatom associations of quite different composition. In the sample from the upper till bed of section A, the diatoms occur mainly as fragments. The species identified represent a mixed flora characteristic for a terrestrial phase.

The sample from the bottom bed of section D seems to contain a more autochthonous diatom flora of slightly alkaline character, related with the diatom zones 1 and 2.

THE POSTGLACIAL PEAT SECTION

The diatom flora in the Postglacial sediments is developed only in pollen zone II, approximately corresponding to the Postglacial climatic optimum. (Fig. 5 a, b, and Fig. 4:6; cf. Robertsson, p. 95).

From the underlying till no diatoms were noted. The pollen zone I is very poor in diatoms. The few diatoms noted were mainly of genus *Eunotia* (part A 137.5–120 cm.)

Between 120 and 100 cm (part B) an acidic flora occurs with *Eunotia* spp., *Anomoeoneis serians, Tabellaria* spp., *Frustulia rhomboides* v. *saxonica, Gomphonema augustatum* and *Cymbella incerta* as main components (belonging to benthonic and epiphytic living forms).

From 100 to 70 cm (part C) the diatom flora slowly gets a more circumneutral to slightly acidic character. *Eunotia* spp. decrease (from 30 per cent to almost 0).

Species as *Caloneis obtusa, Anomoeoneis zellensis, Cymbella norvegica, C. obtusa* and *C. aspera* immigrate, that is mainly epiphytic and benthonic forms. In the uppermost sample counted (70 cm) most of the acidophilous species disappear. The diatoms occurring are fragmented and represented by *Cymbella, Tabellaria* and *Caloneis obtusa,* indicating the beginning of a terrestrial phase (*Picea* zone).

The following samples analysed (part D 70–40 cm) are very poor in diatoms, only a few fragments of *Cymbella* and *Tabellaria* were found.

The succession of diatoms in the Postglacial section shows a development reverse to the Interglacial. The Postglacial diatom flora was most acid in the beginning, became somewhat more circumneutral during the very climatic optimum, and disappeared at the transition to terrestrial conditions.

The Postglacial diatom flora contains no centric diatoms nor any pelagic forms (except *Tabellaria,* facultative epiphyt–plankton). The main Interglacial components of genera *Fragilaria, Melosira* and *Epithemia* are almost lacking. (Only two *Fragilaria construens* valves and one *Epithemia argus* fragment

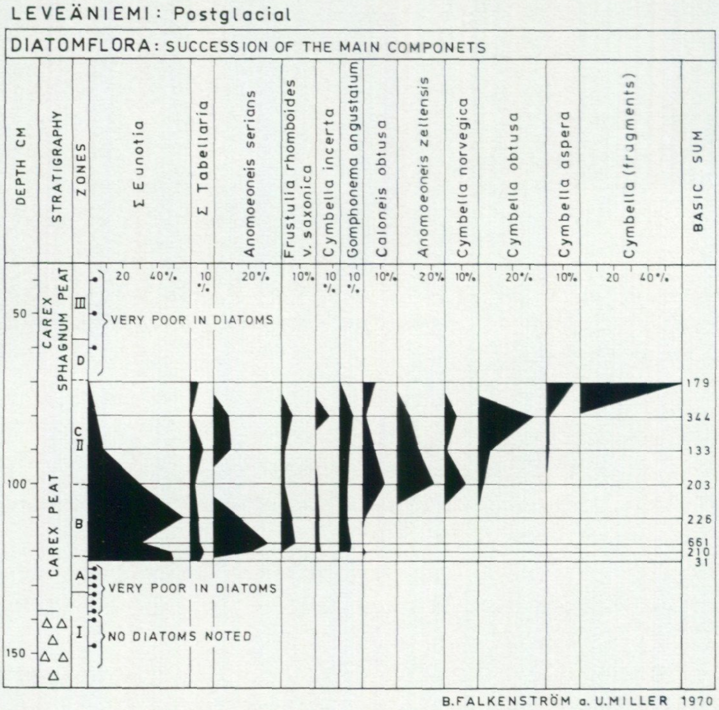


Fig. 5:5a. Succession of the main components of the Postglacial diatom flora at Leveäniemi.

were found in the whole section.) The only Interglacial zones, which in their composition are reminiscent of the Postglacial, are zones 6 and 7. Zone 7 is the most acidic of the Interglacial zones. It has in common with the Postglacial section (part B and C) the high content of *Eunotia* and immigration of many new acidic species (genera *Pinnularia, Eunotia* and *Cymbella)* in combination with the low values of genera *Navicula* and *Achnanthes*. The greatest difference is the occurrence of genera *Melosira, Fragilaria* and *Epithemia* in the submorainic zone.

Zone 6 has in common with the Postglacial (part D) the transition to a terrestrial phase *(Picea* zone), reflected in the beginning by fragmented diatom valves followed by infrequence of diatoms.

The number of taxa noted in the Postglacial section is 82, representing 73 species of 15 genera. The dominating genera are *Eunotia*, *Cymbella* and *Anomoeoneis*.

A complete alphabetic list of diatoms found in the Postglacial section, their distribution and ecology are shown in Tab. 5:3. The taxa found merely in the Postglacial section are:

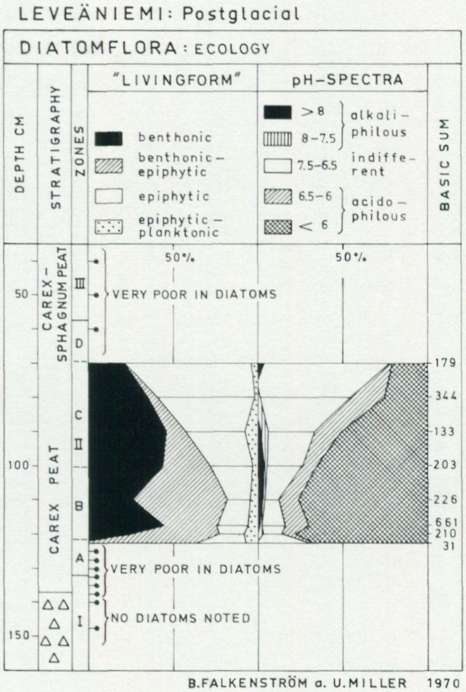


Fig. 5:5b. Diagram showing the Postglacial ecological development of the diatom flora.

Achnanthes flexella
Anomoeoneis exilis
„ *styriaca*
Caloneis obtusa
Cymbella moellerina
Eunotia diodon v. *dovreensis*
„ *exigua*
„ *parallella*
„ *sarekensis*
„ *tenellum*
Pinnularia cf *intermedia*
„ *maior*
Stauroneis cf *norvegica*
„ cf *pusilla*

Comparison with other Interglacial and Interstadial deposits

Concerning the succession of fossil diatom floras of fresh-water origin a comparison with other deposits will be of interest to see if there have been similar conditions of sedimentation. Of greatest importance is the chemistry of water, dependent on surrounding bedrock, soils and vegetation; then water depth, height above sea level, viscosity and transparency of the water. Of secondary importance are the climatic conditions. In most of the Interglacial deposits known from northern Europe the diatom floras indicate at least some phase with marine conditions. A summary of the marine deposits in northern USSR and the Baltic basin has been published by Zāns (1936). Complementary later investigations of new deposits found, or modern studies of the earlier known deposits are: Brander (1937, 1943, Rouhiala in Finland); Brander (1937), Cheremisinova (1959, Mga-sediments in NW USSR); Cheremisinova (1961, Island of Pragli, N Estonia). Hitherto the only deposit known in Sweden that contains marine Interglacial sediments is Bollnäs (Halden 1915, 1948).

In NW Europe, NW Germany, Holland and Belgium the marine Eemian deposits are quite common. All these marine deposits represent a sedimentation milieu different from Leveäniemi.

The large Interglacial fresh-water deposits of diatomite in Denmark (Foged 1954, 1960, 1962, Östrup 1910, Harts & Östrup 1899, Andersen 1966) and northern Germany (Hustedt 1954, 1957, Heiden 1925) are sediments formed during quite different conditions, often in great fresh-water basins. Planktonic forms dominate in them.

The Interstadial deposits in northern Sweden are summarized and discussed by J. Lundqvist (1967), and the deposits in northern Finland by K. Korpela (1969). These Interstadial sediments are mostly of fresh-water origin, but the diatom floras are either of great lake character or in case of small lake of facultative terrestrial character. The composition and succession remind more of Postglacial conditions (Sundius & Sandegren 1948, Munthe 1904, 1946, Fromm 1960, Magnusson 1962, G. Lundqvist 1960, Korpela 1969).

An important question is if the submorainic diatom floras of Leveäniemi can indicate an Interglacial sedimentation.

According to Hustedt (1954) it is necessary to analyse through the whole probable Interglacial sediment section from the bottom to the top, to get a complete picture of the changes in the sedimentation milieu and climatic conditions.

The development of higher vegetation is dependent on the climate. In a pollen diagram of Interglacial sediments it shows the characteristic changes of cold–warm–cold conditions. The aquatic micro-flora, especially diatoms, is more dependent on chemical conditions of the water than on the climate.

The submorainic diatom floras at Leveäniemi indicate in the beginning of the sedimentation an eutrophic, slightly brackish clear-water milieu, not influenced by the terrestrial vegetation. The sedimentation milieu reflects conditions with unleached soils after the earlier glaciation, and clear (cold) melt water from the glaciers (zones 1 and 2).

The warmest phase of the Interglacial period is reflected in the development of diatom floras at Leveäniemi by increasing influence of the land vegetation, drift conditions and inflow of acidic peaty water (zones 3, 4, 5) and transition to a terrestrial phase with diatoms disappearing (zone 6).

The uppermost sediments confirm more humid and probably colder conditions with return of diatom species characteristic for zone 2 and immigration of more acidophilous components of Postglacial character (zones 7, 8, 9).

According to Hustedt these acidophilous diatom species, when occurring in the upper part of Interglacial sediments, are the best indicators of a coming glaciation. Quoting Hustedt (1954, p. 434): "Wenn aber in der Oberflächenschicht der Gur nordischen Formen in mehr oder weniger grosser Anzahl auftreten, ist das der sicherste Beweis, dass ihre Entstehung mit dem sich nähernden Eisrand in unmittelbarem Zusammenhang steht".

Taxonomical and ecological notes. By B. Falkenström and U. Miller

MELOSIRA Agardh

M. distans (E.) Kützing et varr. (Plate 5:I)

In the littoral (as benthonic plankton) of oligo- and dystrophic lakes.

Saproxene, acidophilous, halophobous. Main distribution in northern mountain regions. "Diluvial relikt" in NW Germany (Hustedt 1957).

In the littoral of fresh water in the oligotrophic lakes of Finland. Seldom in plankton and then near the shore (Mölder & Tynni 1967).

Not common in the sediments of recent English lakes. An indicator of more extreme acidic, peaty water (Round 1961).

M. distans is a very old species. Shows mass occurrence in the Upper Miocene sediments in Hessen (Hustedt 1954).

M. italica (E.) Kützing et subspp. et varr. (Plate 5:II)

The determination in the present work is made according to Hustedt (1930) and Huber-Pestalozzi (1942) and not according to Cleve-Euler (1951–55).

The taxonomy and ecology of *M. italica* is very confusing. A photomicrograph in Mölder & Tynni (1967: Taf. 1:12) is called *M. italica* ssp. *subarctica* but represents *M. italica* var. *valida* according to Hustedt (1930). Another photomicrograph in the same work, Taf. 1:13, is by the authors called *M. italica* var. *valida*, but is impossible to recognize as it represents a chain in ± optical cross-section.

Concerning *M. italica* ssp. *italica* the agreement is better in the taxonomy, but not in the ecology. According to Hustedt (1957) *M. italica* ssp. *italica* is an alkaliphilous, pH-indifferent littoral form. According to Huber-Pestalozzi the nomenclatural type (Hauptform) of *Melosira italica* is common in the benthos of eutrophic water and distributed throughout Central Europe, whereas

M. italica var. *valida* and ssp. *subarctica* mainly are ± pelagic forms from alpine mountains and northern areas (Huber-Pestalozzi 1942, Hustedt 1930).

Mölder & Tynni on the other hand are of the opinion that *M. italica* ssp. *italica* is particularly common in the littoral of the oligo- and dystrophic lakes, and in slightly brackish water of river estuaries as plankton, too. *M. italica* ssp. *subarctica* (= *M. italica* var. *valida* Grunow – sensu Hustedt 1930) is a cold-water diatom, recent mass occurring in oligotrophic waters in Lapland (Mölder & Tynni 1967).

According to Lund (1954, 1955) *M. italica* ssp. *subarctica* has a seasonable cyclic variation between benthonic and pelagic "livingform".

In several publications of Lund and Round regarding fossil and recent diatoms of the English Lake District it appears clearly that ssp. *subarctica* is the only form of *Melosira italica,* which in Late- and Postglacial times played any role at all. Any other form of this species is never mentioned by them.

Melosira italica has been regarded as characteristic of lakes rich in dissolved organic matter (Macan 1970, Pennington 1943). No particular ssp. of *italica* is mentioned by Macan. Pennington in her turn refers to Pearsall (1932).

In the samples from Leveäniemi *M. italica* ssp. *italica* is the least common of the *Melosira* species. It almost always occurs together with the acidophilous *M. distans* and *M. italica* var. *valida* (except in zone 7 where it dominates).

It is remarkable that *M. italica* ssp. *italica* mostly was noted as separate valves or in short chains in ± complete "Dauersporbildung", so-called forma *laevis* Grunow.

Concerning these circumstances we are not fully convinced that the species determined really corresponds to *Melosira italica* ssp. *italica*. It may be a phase change of *Melosira italica* var. *valida* before the formation of "Dauerspores".

SPECIAL NOTE

We were confronted with similar problems in samples from Eocene "moler" from Limfjorden, Denmark. There the long chains of *Hemiaulus* at the formation of "Dauerspores" change from one species to another, before the final emanating of the spore. At least twice this phenomenon was noted with 4 different so-called species involved (in manuscript).

According to O. Müller (1906) the forma *laevis* occurs together with *Melosira italica*. But Müller does not mention any subspecies or varieties. Probably he means the nomenclatural type form because it was in this very work which he established the ssp. *subarctica* and was thus well aware of the different types existing.

If the forma *laevis* in Leveäniemi samples corresponds to the nomenclatural type of *Melosira italica,* the frequency of "Dauerspores" may depend on the character of the sedimentation milieu. Probably the biotope was not suitable which resulted in the formation of "Dauerspores".

PROPOSED CHANGE IN COMBINATION OF NAME

The existing difficulties among the diatomologists to distinguish between *Melosira italica* (E.) Kützing subspecies *italica* var. *valida* Grunow and *M. italica* (E.) Kützing subsp. *subarctica* O. Müller, clearly reveals an indication of larger affinity between these taxa than between the nomenclatural type *(M. italica* subspecies *italica)* and its var. *valida.*

We therefore propose the latter to be removed from subspecies *italica* and with retained status as varietas to be transferred to the subspecies *subarctica* O. Müller.

Its complete new name thus will be:

Melosira italica (E.) Kützing subsp. *subarctica* O. Müller var. *valida* (Gr.) Miller et Falkenström comb. nov.

Basionym: *Melosira italica* (E.) Kützing, ssp. *italica* var. *valida* Grunow: V. H. 1881–85, Synops, Taf. 88, Fig. 8.

CYMBELLA Agardh

C. brehmi Hustedt, Bac. 1930, p. 363, Fig. 673, v. ”*medio-paucistriata*”

(Plate 5:VI, Fig. 10)

Striking at the first sight are the extremely sparsely placed transapical striae on both sides of the central node. The dorsal side has one coarse stria straight in the front of the central area. The coarseness of this central stria may be an optical delusion caused by the distance to the next striae.

On the ventral side of the valve the middle stria may be either weaker developed, shorter or lacking. It may be difficult to see on account of the reflexes caused by the rounding of the ventral margin. The specimens of the ”*medio-paucistriata*”-type were always noted as whole thecas.

The raphe seems to be situated somewhat more on the ventral side than it appears in the figure and in the description of the species (Hustedt 1930). The polar fissures are deflected towards the ventral margin, as it appears from the figure in Hustedt (not mentioned in the description). Also the specimens in Foged (1955, Pl. 12:6 and 1964, Pl. XVII:1) have polar fissures deflected towards the ventral margin.

The size of the ”*medio-paucistriata*” is somewhat smaller than the medium size of the species. Length 8–10 μ, breadth 4–4.5 μ (Hustedt reports 13–16 μ in length and 5 μ in breadth).

In the Leveäniemi material the ”*medio-paucistriata*”-type of *C. brehmi* was noted in the Interglacial zones 2 and 9.

The same type of *C. brehmi* has also been noted by Ann-Marie Robertsson, SGU, in the Lateglacial material from Skurup (Robertsson in manuscript).

C. *incerta* Grunow in Hustedt 1930, p. 360, Fig. 665, v. ”*interglacialis*”?
(Plate 5:VI, Fig. 7, 8)

The new varietas ”*interglacialis*” is separated from the species on account of considerable differences in the size.

The specimens of the ”*interglacialis*”-type were mostly noted as whole thecas of the length 65–85 μ and the breadth 11.5–15 μ. Hustedt reports for the species 40–70 μ in length and 7–9 μ in breadth.

According to the rules known, the diatom cell decreases with every division more in length than in breadth (Kolbe 1927, Hustedt 1929, 1955, 1968). This excludes the possibility of having to deal with large sporongial cells of the species, as the ”*interglacialis*” thecas are strikingly larger in breadth and only slightly larger in medium length.

Thecas of the ”*interglacialis*”-type were noted in the Interglacial zone 7. One specimen of the species C. *incerta* was noted in the same zone and is reproduced on Plate 5:VI, Fig. 9.

In the Postglacial section the species C. *incerta* Grunow is one of the main components in some of the samples analysed (Fig. 5:5 a).

STAURONEIS Ehrenberg

S. aff. *lapidicola* Boye Petersen in Hustedt 1927–66, Kies. II, p. 797, Fig. 1144, size 6.6×3.1

The species noted in Leveäniemi material is reproduced on Plate 5:X, Fig. 1. Size: length 7 μ, breadth 3.2 μ.

Transapical striae 50–55 in 10 μ. The characteristic central area of stauros-type appears as the thickened part of the valvar interior.

Noted both in Interglacial and Postglacial sediments in the Leveäniemi area.

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SGU = Sveriges Geologiska Undersökning

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Tables 5:1—3: Lists of diatom species

Abbreviations used of the author's names:

A. Cl.	=	Cleve, Astrid, resp. Cleve-Euler, Astrid
Ag.	=	Agardh, C. A.
B. Pet.	=	Boye Petersen, J.
Bréb.	=	Brébisson, A. de
Cl.	=	Cleve, P. T.
Dipp.	=	Dippel, L.
E.	=	Ehrenberg, C. G.
Gr.	=	Grunow, A
Greg.	=	Gregory, W.
Grev.	=	Greville, R. K.
Hérib.	=	Héribaud, J.
Hust.	=	Hustedt, F
Krieg.	=	Krieger, W.
Krsk.	=	Krasske, G.
Kz.	=	Kützing, F. T.
Lgrst.	=	Lagerstedt, N. G. W.
May.	=	Mayer, A.
O. Müll.	=	Müller, O.
Pant.	=	Pantocsek, J.
Rbh.	=	Rabenhorst, L.
V. H.	=	Van Heurck, H.
W. Sm.	=	Smith, W.

TABLE 5:1

LEVEÄNIEMI: Interglacial

ECOLOGY — Living-form: b = benthonic, e = epiphytic, p = planktonic. pH-request: alk. (>8, 8–7.5), neutral (+?) (7.5–6.5), ac. (6.5–6, <6); >8, 7, 6>

DIATOMS IN THE SUBMORAINIC SECTIONS A, B, C, D, E — ALPHABETIC LIST OF SPECIES

/ = rare (<0.5 %)
× = seldom (0.5–1 %)
○ = common (1–5 %)
● = very common (5–20 %)
◉ = dominate (20–50 %)
⬤ = massoccurrence (>50 %)
+) = illustrated

Living-form	pH-request	Species	A	B			C					D					E			
		ZONE	4	2	3	4	3	4	6	8	9	1	2	3	4	5	2	4	6	7
		DEPTH cm		100–110			130–110	110–80	80–50	50–25	25–0	230–215	215–150	150–130	130–50	50–10	100–35	35–30	30–10	10–0
		No. of samples	1	2	1	1	8	2	5	2	3	3	10	1	3	8	9	1	3	2
		No. of taxa	56	76	6	54	22	21	12	64	101	27	136	22	74	148	152	37	15	71
		<u>*Achnanthes* Bory</u>																		
e		*conspicua* May.	–	○	–	–	–	–	–	–	–	–	○	–	–	–	×	–	–	–
e	?	*didyma* Hust.		–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
e		*exigua* Gr. s.l. +)	–	●	–	○	–	–	–	/	/	–	●	–	–	–	○	○	–	–
e		v. *heterovalvata* Krsk.	–	○	–	–	–	–	–	–	/	–	–	×	–	–	–	–	–	–
e		cf. *hauckiana* Gr.	–	/	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–
e		*kryophila* B. Pet.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–
e		*lanceolata* (Bréb.) Gr. et varr. +)	/	●	–	/	–	–	–	×	○	–	●	–	○	○	●	/	–	–
e	?	*laterostrata* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
e		cf. *levanderi* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
e		*linearis* (W. Sm.) Gr.	/	–	–	–	–	–	–	–	○	–	○	–	○	○	●	/	–	–
e		*marginulata* Gr. et varr.	–	–	–	–	–	–	–	–	–	–	–	–	×	/	–	–	–	–
e		*minutissima* Kz. et varr.	–	/	–	–	–	–	–	–	○	–	×	–	×	○	○	–	–	–
e		*oestrupi* (A. Cl.) Hust.	/	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–
e		*peragalli* Brun.	–	/	–	–	–	–	–	–	–	–	×	–	–	–	/	–	–	–
e		*suchlandti* Hust.	/	–	–	–	–	–	–	–	○	–	/	–	/	/	○	–	–	–
		<u>*Amphora* E.</u>																		
b		*ovalis* Kz. v. *ovalis* +)	/	/	–	/	–	–	–	–	/	–	/	–	×	/	/	–	–	–
b		v. *libyca* (E.) Cl. +)	○	○	–	●	–	–	–	○	×	–	●	–	○	/	○	×	–	/
b e		v. *pediculus* Kz.	–	○	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–
		<u>*Anomoeoneis* Pfitzer</u>																		
b		*serians* (Breb.) Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/
b		v. *brachysira* (Breb.) Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b		*sculpta* (E.) O. Müll. +)	–	/	–	–	–	–	–	–	–	○	/	–	–	–	–	–	–	–
b		*zellensis* (Gr.) Cl. f. *difficilis* (Gr.) Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	×
		<u>*Caloneis* Cl.</u>																		
b		*bacillum* (Gr.) Mereschkowsky	×	–	–	×	–	–	–	/	–	–	×	–	/	/	–	–	–	–
b		*silicula* (E.) Cl.	/	–	–	–	–	–	–	–	–	–	/	–	/	/	–	–	–	–
b		ssp. *limosa* (Kz.) May.	–	○	–	–	–	–	–	×	–	–	–	–	–	/	/	–	–	–
b		ssp. *ventricosa* (Donkin) May.	–	/	–	○	–	–	–	–	–	–	–	–	–	/	/	–	–	–
		<u>*Cocconeis* E.</u>																		
e		*placentula* E. +)	○	○	–	×	×	/	–	●	○	–	○	–	○	○	●	○	–	–
e		cf. *hustedti* Krsk.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
		<u>*Cymatopleura* W. Sm.</u>																		
b		*solea* (Breb.) W. Sm.	–	–	–	/	–	–	–	–	–	/	/	–	/	/	/	–	–	–
		<u>*Cymbella* Ag.</u>																		
e		*affinis* Kz. (sensu Hust. 1955)	–	/	–	/	/	–	–	–	/	–	/	×	/	/	/	×	–	/
e		*aspera* (E.) Cl.	×	/	–	×	/	○	◉	×	○	/	×	–	×	×	×	×	×	○
e	?	cf. *brehmi* Hust. +) v. "*medio-paucistriata*" v. nov?	–	×	–	–	–	–	–	–	/	–	×	–	–	–	×	–	–	–
e	?	*caespitosa* Kz.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
e		*cesati* (Rbh.) Grun.	/	–	–	–	–	–	–	–	–	/	/	–	–	/	/	/	–	–
e		*cistula* (Hemprich) Gr.	○	○	–	○	/	–	–	/	/	×	×	–	–	/	/	–	–	×
e		*cuspidata* Kz.	–	/	–	–	–	–	–	–	–	–	/	–	/	/	–	–	–	/
e		*cymbiformis* (Ag? Kz.) V. H.	–	–	–	–	–	–	–	/	/	–	–	–	–	–	/	–	–	–
e		*ehrenbergii* Kz. +)	/	–	–	–	–	–	–	/	/	–	/	–	/	–	/	×	–	–
e		v. *hungarica* Pant.	–	●	–	/	–	–	–	–	/	○	○	–	–	–	/	–	–	–
e		*gracilis* (Rbh.) Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
e	?	*helvetica* Kz. v. *compacta* (Östrup) Hust. 1955	–	–	–	–	–	–	–	×	–	–	–	–	–	–	–	–	–	–
e		*heteropleura* E. et. v. *minor* Cl.	–	–	–	×	–	–	–	–	–	–	/	–	–	/	–	–	–	/
e	?	cf. *hungarica* (Gr.) Pant. v. *grunowi* A. Cl.	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–	–
e		*incerta* Gr. +)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/
e	?	v. "*interglacialis*" v. nov? +)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	○

TABLE 5:1 (CONT.)

ECOLOGY: LIVING-FORM (b e p)	ECOLOGY: pH-REQUEST (>8 7 6>)	DIATOMS IN THE SUBMORAINIC SECTIONS A, B, C, D, E — ALPH. LIST (contin.)	DISTRIBUTION																	
		SECTION	A	B			C					D					E			
		ZONE	4	2	3	4	3	4	6	8	9	1	2	3	4	5	2	4	6	7
		<u>*Cymbella* Ag. (contin.)</u>																		
e	?	cf. *kerkevarensis* A.Cl.	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-	-	-	-
e		cf. *laevis* Naegeli	-	-	-	-	-	-	-	-	-	-	/	-	-	-	/	-	-	-
e		cf. *lanceolata* (E.) V. H.	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-
e		*leptoceros* (E?) Gr. s.l.	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-	-	-	-
e		v. *rostrata* Hust.	/	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-
e		*microcephala* Gr.	-	-	-	-	-	-	-	-	-	-	/	-	-	/	×	-	-	-
e		"*navicule-diluvianoides*"	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-
e		*naviculiformis* Auerswald	-	-	-	-	-	-	-	○	/	-	/	-	×	×	/	-	-	-
e		*norvegica* Gr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	×
e	?	c.f. *obscura* Krsk. 1938	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-
e		*obtusa* Greg.	-	/	-	-	-	-	-	-	/	-	×	-	-	/	/	-	-	×
e		*perpusilla* A.Cl.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	/
e		cf. *reinhardti* Gr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-
e		*sinuata* Greg.	-	-	-	-	-	-	-	-	○	-	/	-	-	-	/	-	-	/
e		*turgida* (Greg.) Cl.	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-	-	-	/
e		*ventricosa* Kz. s.l.	-	-	-	-	/	-	-	/	×	-	/	×	-	/	/	-	-	○
e		v. *groenlandica* Foged 1959 et 1964	-	-	-	-	-	-	-	-	-	-	-	-	/	/	-	-	-	-
e		v. *paucistriata* A. Cl.	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-	-
e		spp.	-	-	/	-	-	-	-	-	-	-	/	-	-	-	-	-	-	-
		<u>*Diatoma* De Candolle</u>																		
p		*anceps* (E.) Gr.	-	-	-	-	-	-	-	-	/	-	/	-	-	/	-	-	-	-
p		*elongatum* (Lyngbye) Ag.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-
		<u>*Diatomella* Grev.</u>																		
e		*balfouriana* Grev.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-
		<u>*Diploneis* E.</u>																		
b		*ovalis* (Hilse.) Cl. *ovalis*	-	-	-	-	-	-	-	-	/	-	-	-	-	-	/	-	-	/
b		v. *oblongella* (Naegeli) Cl.	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-	○
b		*peterseni* Hust.	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-
b		cf. *subovalis* Cl.	-	-	-	-	-	-	-	/	/	-	-	-	-	-	-	-	-	-
b	?	sp.	-	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-
		<u>*Epithemia* Breb.</u>																		
e		*argus* Kz.	-	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
e		cf. *muelleri* Fricke	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	/
e		*sorex* Kz. et v. *lapponica* Hust. +)	-	●	-	-	-	-	-	×	-	●	○	-	-	-	○	-	-	-
e		*turgida* (E.) Kz. +)	●	●	/	○	×	×	-	●	○	○	○	/	○	/	○	○	-	○
e		*zebra* (E.) Kz. +)	●	○	-	◍	●	×	-	◉	◍	○	○	×	○	◍	●	◍	-	○
e		spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-
		<u>*Eunotia* E.</u>																		
b e		*arcus* et v. *fallax* Hust.	-	-	-	/	-	-	-	-	/	-	-	-	-	-	-	-	-	/
b e		*diodon* E.	-	-	-	-	-	-	-	-	/	-	-	-	-	×	-	×	-	×
b e		*faba* (E.) Gr.	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-	-
b e		*flexuosa* Kz.	/	-	-	-	-	-	-	-	-	-	-	-	/	/	/	/	-	/
b e		*formica* E. +)	×	-	-	-	×	-	-	○	/	-	/	-	-	-	-	-	-	/
b e	?	*glacialis* Meister	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-
b e		*lapponica* A.Cl.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	/
b e		*lunaris* (E.) Gr. s.l.	-	-	-	-	-	-	-	-	/	-	-	-	/	/	/	-	-	-
b e		v. *falcata* (Breb.) A. Cl.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-
b e		*monodon* E. v. *monodon* + f. *curta* V. H.	-	-	-	-	-	-	-	-	/	-	-	-	-	-	-	-	-	○
b e		v. *maior* (W.Sm.) Hust.	-	-	-	-	-	-	-	-	/	-	-	-	-	-	-	-	-	○
b e		*pectinalis* (Kz.) Rbh. v. *pectinalis*	-	-	-	-	-	-	-	×	/	-	/	-	/	/	/	-	-	○
b e		v. *minor* (Kz.) Rbh. f. *impressa* Hust.	×	-	-	-	/	-	-	-	-	-	-	-	-	-	/	-	-	-
b e		v. *minor* (Kz.) Rbh. f. *intermedia* Krsk.	-	-	-	-	-	-	-	-	-	-	/	-	-	/	-	-	-	/
b e		*praerupta* E. v. *praerupta*	-	-	-	-	-	-	/	/	/	-	/	-	/	/	-	/	/	●
b e		v. *bidens* Gr.	-	-	-	-	-	-	-	-	/	-	-	-	-	/	-	-	-	×
b e		*pseudopectinalis* Hust.	/	-	-	-	-	-	-	-	/	-	-	-	-	/	-	-	-	×
b e		*robusta* Ralfs v. *tetraodon* (E.) Ralfs	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-
b e	?	*scandinavica* A.Cl. f. *angusta* Font.	-	-	-	/	-	-	-	×	○	-	/	-	○	×	/	-	-	/
b e		*septentrionalis* Östrup	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-
b e		*sudetica* O.Müll.	-	-	-	-	-	-	-	/	×	-	/	-	○	×	/	×	-	/
b e		*valida* Hust.	/	-	-	×	-	-	-	/	/	-	-	-	/	/	-	-	-	/
b e		*veneris* (Kz.) O. Müll.	/	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	×
b e		spp.	×	-	/	-	-	○	●	-	-	-	/	×	-	/	/	-	×	-

TABLE 5:1 (CONT.)

ECOLOGY: LIVING FORM (b, e, p)	ECOLOGY: pH-REQUEST (>8, 7, 6>)	DIATOMS IN THE SUBMORAINIC SECTIONS A, B, C, D, E — ALPH. LIST (contin.)	A 4	B 2	B 3	B 4	C 3	C 4	C 6	C 8	C 9	D 1	D 2	D 3	D 4	D 5	E 2	E 4	E 6	E 7
		Fragilaria Lyngbye																		
e p		*bicapitata* May.	–	–	–	–	–	–	–	–	–	–	/	–	–	/	–	–	–	–
p		*brevistriata* Gr. +)	/	●	–	/	–	–	–	–	○	/	◉	–	–	/	•	–	–	×
e p		*capucina* Desmazières	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
e p		*construens* (E.) Gr. s.l. +)	◉	●	×	◉	●	•	○	●	◉	●	●	◉	●	●	●	●	–	◉
e p		*inflata* (Heid.) Hust.	–	○	–	–	–	–	–	/	–	–	/	–	–	–	–	–	–	–
e p		*lapponica* Gr. +)	/	•	–	/	–	–	–	/	○	–	○	–	–	–	○	–	–	/
e p		*pinnata* E. et v. *intercedens* Gr. +)	○	●	/	•	×	–	–	◉	•	•	●	○	◉	•	●	○	–	○
e p		*vaucheriae* (Kz.) B. Pet. s.l.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–
e p		v. *continua* A. Cl.	–	–	–	–	–	–	–	–	–	/	/	–	–	–	–	–	–	–
e p		*virescens* (Kz) O. Müll. s.l. +)	/	●	–	/	–	–	–	–	○	–	•	×	○	○	○	○	–	/
		Frustulia Ag.																		
b		*rhomboides* (E.) De Toni v. *saxonica* (Rbh.) DeToni	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
		Gomphonema Ag.																		
e		*acuminatum* E. s.l.	–	/	–	–	–	–	–	/	/	–	/	–	–	/	/	–	–	/
e		v. *brebissoni* (Kz.) Cl.	/	/	–	×	–	–	–	–	–	–	–	–	–	–	/	/	–	–
e		v. *coronatum* (E.) W. Sm.	/	×	–	–	–	×	–	×	/	–	×	–	○	/	/	–	–	×
e		v. *pusillum* Gr.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
e		*angustatum* (Kz.) Rbh.	/	–	–	–	–	–	–	○	×	–	×	–	×	○	/	/	–	•
e	?	*bipunctatum* Krsk.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
e		*constrictum* E.	–	/	–	×	–	–	–	/	/	–	/	–	×	–	/	–	–	/
e		*gracile* E.	–	–	–	–	–	–	–	–	–	–	/	–	–	/	–	–	–	–
e	?	*intricatum* Kz. s.l. et cf. v. *dichotoma* (Kz.) Gr.	/	–	–	–	–	–	–	–	–	–	/	×	–	–	/	–	–	/
e		v. *pumilum* Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
e		cf. *lanceolatum* E. s.l.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
e		cf. v. *affine* (Kz.) A. Cl.	–	–	–	–	–	–	–	×	–	–	–	–	–	–	–	–	–	–
e		*longiceps* E. s.l.	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–	–
e		v. *montanum* (Schuman) Cl.	–	–	–	–	–	–	–	–	/	/	–	–	–	/	/	–	–	–
e		f. *suecicum* Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	/	–	–	–	–
e		*mustela* E.	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–
e		*olivaceum* (Lyngb.) Kz. v. *tenellum*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
e		*parvulum* Kz.	/	/	–	–	–	–	–	/	×	–	/	–	○	/	×	/	–	×
e	?	cf. *sphaerophorum* E.	–	/	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
e		cf. *tenellum* Kz.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	/	–	–	–
e	?	cf. *tackei* Hust.	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–
e	?	spp.	–	–	–	–	–	/	–	×	–	–	–	–	–	–	–	–	–	–
		Hantzschia Gr.																		
b		*amphioxys* (E.) Gr.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	/	/
b		cf. *elongata* (Hantzsch) Gr.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
		Melosira Ag.																		
b p		*arenaria* Moore	/	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b p		*distans* (E.) Kz. s.l. (v. *lirata* et v. *pfaffiana* +)	◉	○	–	◉	•	•	–	•	◉	–	○	–	•	◉	•	●	×	○
b p	?	*italica* (E.) Kz. ssp. *italica* et f. "*laevis*" +)	×	○	–	○	○	•	/	○	○	–	○	○	○	•	○	○	/	•
b p		v. *valida* Gr. (sensu Hust.) +)	•	–	–	•	•	○	/	•	•	–	○	–	◉	◉	○	○	/	/
b p	?	spp. *subarctica* O. Müll. (sensu Hust.)	–	–	–	–	–	–	×?	–	○	–	–	–	○	/	–	–	–	–
		Meridion Ag.																		
c?		*circulare* Ag.	/	–	–	–	–	–	–	–	/	–	/	–	/	/	/	–	–	–
		Navicula Bory																		
b	?	*abiskoensis* Hust.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	/	–	–	–
b	?	*acceptata* Hust.	–	–	–	×	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b		*americana* E. +)	–	–	–	–	–	–	–	–	/	–	/	–	×	/	/	/	–	–
b		*anglica* Ralfs	–	–	–	×	–	–	–	–	–	–	/	–	–	/	–	–	–	–
b		*bacillum* E.	–	–	–	–	–	–	–	–	–	/	/	–	–	/	–	–	–	–
b		*cari* E.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	/	–	–	–
b		*cocconeiformis* Greg.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b		cf. *confervacea* (Kz.) Gr.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–

TABLE 5:1 (CONT.)

ECOLOGY: LIVING FORM b	e	p	pH-REQUEST >8		7		6>	DIATOMS IN THE SUBMORAINIC SECTIONS A, B, C, D, E — ALPH. LIST (contin.)	DISTRIBUTION — SECTION A, ZONE 4	B 2	B 3	B 4	C 3	C 4	C 6	C 8	C 9	D 1	D 2	D 3	D 4	D 5	E 2	E 4	E 6	E 7
								Navicula Bory (contin.)																		
b				—				*cryptocephala* Kz. s.l.	–	/	–	–	–	–	–	–	–	–	–	–	–	/	×	–	–	–
b				—				v. *intermedia* Gr.	–	/	–	–	–	–	–	–	–	–	/	–	/	/	○	–	–	–
b				—				v. *veneta* (Kz.) Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	/	×	–	–	–
b			—					*cuspidata* Kz.	/	×	–	/	–	–	–	/	–	○	×	–	×	/	×	–	–	–
b				—				*dicephala* (E.) W. Sm. s.l.	–	/	–	○	–	–	–	/	○	–	○	×	○	○	/	–	–	×
b				—				v. *constricta* A. Cl.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b				—				v. *neglecta* (Krsk.) Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b			—	—	? - -	- -		*disjuncta* Hust.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b					?			aff. *fennica* Hust.	–	–	–	–	–	–	–	–	/	–	/	–	–	–	/	–	–	–
b			—	—				*gastrum* E.	–	/	–	×	–	–	–	–	–	–	×	×	–	–	×	–	–	–
b			—	—				v. *signata* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b						—	—	*hassiaca*	–	–	–	–	–	–	–	–	/	–	–	–	–	/	–	–	–	–
b			—	—				*hungarica* Gr. v. *capitata* (E.) Cl.	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–	–
b						—	—	*hustedtii* Krsk.	/	–	–	–	–	–	–	–	/	–	/	–	–	/	–	–	–	–
b						—	—	v. *obtusa*	–	/	–	○	–	–	–	–	–	–	○	–	–	–	○	–	–	–
b							—	*krasskei* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b			—	—				*laterostrata* Hust.	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–
b					—			*levanderi* Hust.	–	–	–	×	–	–	–	/	○	–	/	–	×	/	/	–	–	–
b			—	—				*mayeri* A. Cl. v. *mayeri*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b				—				*minima* Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b					?	- -	- -	cf. *molesta* Krsk.	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–
b					?			cf. *muralis* Gr.	–	/	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b			—					*mutica* Kz.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	/	–
b			—					*oblonga* Kz. +)	/	○	–	×	–	–	–	/	/	●	○	–	/	–	×	–	–	–
b			—	—				*placentula* (E.) Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b			—	—				v. *rostrata* May.	–	–	–	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b					—			*pseudocryptocephala* Foged	–	/	–	–	–	–	–	–	–	–	/	–	/	–	/	/	–	–
b					—			*pseudoscutiformis* Hust.	–	/	–	–	–	–	–	/	/	–	×	–	○	/	×	–	–	/
b			—	—				*pupula* Kz.	–	○	–	×	/	–	–	○	○	/	○	–	○	○	○	–	–	–
b					?			*pusio* Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	○	–	–	–	–
b					— - -			*radiosa* Kz.	/	○	–	×	–	–	–	×	×	●	○	×	○	×	○	–	–	/
b					?			cf. *recondita* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b					?			cf. *rotunda* Hust.	–	/	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b				—	—			*rhyncocephala* Kz.	–	–	–	–	–	–	–	–	/	–	×	–	–	×	/	/	–	–
b				—	—			v. *amphiceros* V. H.	–	–	–	–	–	–	–	–	–	–	/	–	/	–	–	–	–	–
b			—					*salinarum* Gr.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–
b			—					*seminulum* Gr.	/	–	–	–	–	–	–	–	×	–	–	–	–	○	○	–	–	–
b							—	*similis* Krsk.	–	–	–	–	–	–	–	–	–	–	/	–	–	/	–	–	–	–
b					?			*siofokensis* Pant. v. *rostrata* A. Cl.	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–	–
b					?			cf. *soehrensis* Krsk.	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–
b						—	—	*subatomoides* Hust.	–	–	–	–	–	–	–	–	–	–	/	–	–	/	–	–	–	–
b					?			*subseminulum* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b						—	—	cf. *tantula* Hust.	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–
b						—	—	cf. *tenuicephala* Hust.	–	–	–	–	–	–	–	–	–	–	/	–	–	/	/	–	–	–
b				—				*tuscula* (E.) Gr. +)	×	–	–	/	–	–	–	×	×	×	×	–	–	/	○	–	–	/
b				—	—			*viridula* Kz. +)	–	–	–	–	–	–	–	–	–	–	/	–	–	–	/	–	–	–
b				—	—			v. *capitata* May.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b				-	—			*vitabunda* Hust.	–	/	–	–	–	–	–	/	/	–	×	–	–	/	×	–	–	–
b					—	- -	-	*wittrockii* (Lgrst.) A. Cl.	–	○	–	/	–	–	–	–	/	/	○	–	○	×	○	–	–	–
b			—	—				*vulpina* Kz.	–	○	–	/	–	–	–	/	–	–	○	–	/	/	○	–	–	–
b					?			spp. (sect. *Minusculae* Cl.)	–	×	–	–	–	/	–	–	–	–	–	–	–	○	–	–	–	–
								Neidium Pfitzer																		
b						—	—	*affine* (E.) Cl. s.l.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b							—	*bisulcatum* (Lgrst.) Cl.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	/
b							—	*hitchcockii* (E.) Cl.	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–	–
b						—	—	*iridis* (E.) Cl. s.l.	–	/	–	–	–	–	–	–	–	–	/	–	–	/	–	–	–	–
b					?			cf. *perminutum* A. Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b						—	—	*productum* (W. Sm.) Cl.	–	/	–	/	–	–	–	–	/	–	–	–	–	/	–	–	–	–
b					?			spp.	×	–	–	–	–	/	–	/	–	–	–	–	–	/	/	–	–	×
								Nitzschia Hassall																		
b			—					*amphibia* Gr.	–	/	–	–	–	–	–	/	–	–	/	–	–	–	–	–	–	–
b			—					v. *fossilis* Gr.	–	/	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b			—					*angustata* (W. Sm.) Gr. v. *acuta* Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–

TABLE 5:1 (CONT.)

ECOLOGY: LIVING FORM (b e p)	ECOLOGY: pH-REQUEST (>8 7 6>)	DIATOMS IN THE SUBMORAINIC SECTIONS A, B, C, D, E — ALPH. LIST (contin.)	A 4	B 2	B 3	B 4	C 3	C 4	C 6	C 8	C 9	D 1	D 2	D 3	D 4	D 5	E 2	E 4	E 6	E 7
		***Nitzschia* Hassall (contin.)**																		
b		cf. *communis* Rbh. s.l.	–	/	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b		cf. v. *abbreviata* Gr.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b		*denticula* Gr.	/	/	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b		*dissipata* (Kz.) Gr. v. *media* (Hantzsch) Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b		*frustulum* Kz. s.l.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	/	–	–	–
b		v. *perminuta* Gr.	–	–	–	–	–	–	–	–	/	–	/	–	–	–	/	–	–	–
b		v. *perpusilla* Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	/	–	–	–
b p		cf. *holsatica* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–
b		*kuezingiana* Hilse	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b		cf. *palea* (Kz.) W. Sm.	–	–	–	–	–	–	–	–	–	–	×	–	–	/	/	–	–	–
b		*paleaceae* Gr.	–	/	–	–	–	–	–	–	/	–	/	–	–	–	/	–	–	–
b		cf. *radicula* Hust.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b		*sinuata* (W. Sm.) Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b		v. *tabellaria* Gr.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b		cf. *thermalis* Kz. v.?	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b	?	sect. *Linearis* (Gr.) Hust.	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–	–
b	?	spp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
		***Opephora* Petit**																		
e		*martyi* Hérib.	–	○	–	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–
		***Pinnularia* E.**																		
b		*acrosphaeria* W. Sm.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b		*biceps* Greg.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b	?	*biclavata* A. Cl.	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–	–
b		*borealis* E.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	×	/
b		*brauni* (Gr.) Cl. s.l.	–	–	–	–	–	–	–	–	–	–	/	–	/	/	–	–	–	–
b		*brevicostata* Cl.	–	–	–	–	–	–	–	–	/	–	–	–	–	/	/	–	–	–
b		*cardinalis* (E.) W. Sm.	/	–	–	–	–	–	×	–	/	–	/	–	–	–	/	○	○	/
b	?	*cuneata* (Östr.) A. Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/
b	?	*debilis* (Pant.) A. Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b		cf. *distinguenda* Cl.	–	/	–	/	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b		*gibba* E. v. *gibba*	–	–	–	–	–	–	–	–	–	/	–	–	–	/	–	–	–	–
b		v. *linearis* Hust.	–	–	–	×	/	–	–	–	–	–	/	–	–	–	/	–	–	–
b		*gibba* E. s.l.	–	/	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b		*interrupta* W. Sm.	–	–	–	–	–	–	–	–	/	–	×	–	–	/	/	–	–	–
b	?	*legumen* E.	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–
b	?	cf. *leptosomoides* A. Cl. v. *smolandica* A. Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/
b		*mesolepta* (E.) W. Sm.	–	/	–	–	–	–	–	/	/	–	/	–	/	/	/	/	–	–
b		*microstauron* (E.) Cl.	–	–	–	–	–	–	–	–	–	●	×	–	/	–	/	–	–	–
b		*neglecta* (May.) Å. Bg.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/
b	?	*nobilis* E. +)	–	–	–	×	–	–	–	–	–	–	–	–	–	–	–	–	–	/
b		*nodosa* E. +)	/	–	–	×	–	–	–	×	○	–	/	–	×	/	/	–	–	–
b		*stauroptera* Gr.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b		v. *minuta* May.	–	–	–	–	–	–	–	–	–	–	/	–	/	/	/	–	–	–
b		v. *parva* Gr.	–	–	–	–	–	–	–	/	/	–	–	–	–	–	–	–	–	–
b		v. *stauroptera*	–	–	–	–	–	–	–	/	–	–	–	–	/	–	–	–	–	–
b		*stomatophora* Gr.	–	–	–	–	–	–	–	–	–	–	/	–	–	/	–	–	–	–
b		*streptoraphe* Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	×
b	?	*subborealis* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b		*subcapitata* Greg. v. *lapponica* A. Cl.	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–
b		*viridis* (Nitzsch) E. v. *viridis*	–	–	–	–	–	–	–	×	/	–	/	×	×	/	/	–	–	–
b		v. *minor* Cl. (= *P. aestuari* Cl.)	–	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	×
b		v. *rupestris* (Hantzsch) Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b		v. *sudetica* (Hilse) Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	/	–	–
b	?	spp.	–	/	–	–	/	●	◉	–	/	–	–	–	–	/	–	–	◉	●
		***Rhoicosphenia* Gr.**																		
e		*curvata* (Kz.) Gr. f. *fracta* Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
		***Rhopalodia* O. Müll.**																		
e		*gibba* (E.) O. Müll. +)	○	○	–	○	/	×	–	○	×	/	○	×	○	×	○	×	–	/
e		*gibberula* (E.) O. Müll.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/
e		*parallella* (Gr.) O. Müll.	–	–	–	–	–	–	–	–	×	–	–	–	–	–	–	–	–	–

TABLE 5:1 (CONT.)

ECOLOGY: LIVING-FORM (b c p)	pH-REQUEST >8	7	6>	DIATOMS IN THE SUBMORAINIC SECTIONS A,B,C,D,E — ALPH. LIST (contin.)	A 4	B 2	B 3	B 4	C 3	C 4	C 6	C 8	C 9	D 1	D 2	D 3	D 4	D 5	E 2	E 4	E 6	E 7
				<u>*Stauroneis* E.</u>																		
b		?—	–	*acuta* W.Sm. +)	–	–	–	/	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b		—		*anceps* E. s.l.	–	–	–	–	/	–	–	–	–	–	/	×	–	/	/	–	–	/
b		—		v. *siberica* Gr.	–	–	–	–	–	–	–	–	–	–	–	–	/	/	/	–	–	–
b		?		*kriegeri* Patrick	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b		-?-		aff. *lapidicola* B. Pet. +)	/	/	/	–	–	–	–	–	×	–	○	–	–	×	○	–	–	–
b		—		*legumen* E.	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–
b			—	*obtusa* Lgrst.	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–
b		?		cf. *palustris* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b		—		*phoenicenteron* (Nitzsch) E. s.l. +)	○	○	–	○	/	/	×	○	○	–	○	–	/	×	/	/	–	×
b		—		f. *brevis* ?	–	–	–	/	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b		—		v. *gracilis* (E.) Dippel	–	/	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
b	—			*smithii* Gr.	–	–	–	/	–	–	–	–	/	–	–	–	×	/	–	–	–	–
b		?		spp.	–	–	–	–	–	×	–	–	–	–	–	–	–	–	–	–	–	–
				<u>*Surirella* Turpin</u>																		
b	—			*elegans* E.	–	–	–	/	–	–	–	/	–	–	–	–	–	/	/	–	–	–
b		?		spp.	/	–	–	–	–	–	–	–	/	–	–	–	–	–	–	–	–	–
				<u>*Synedra* E.</u>																		
b e		—		*amphicephala* Kz.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–
b e	—			*capitata* E.	–	–	–	–	–	–	–	–	/	–	/	–	–	–	–	–	–	–
b e		?		*filiformis* Gr. v. *exilis* A. Cl.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b e	—			*parasitica* W. Sm.	–	–	–	–	–	–	–	–	–	–	–	–	–	/	/	–	–	–
b e	—			*ulna* (Nitzsch) E. s.l.	/	○	–	/	×	×	×	×	×	×	×	○	○	/	×	–	×	×
b e	—			v. *amphirhyncus* (E.) Gr.	–	–	–	–	–	–	–	–	–	–	–	×	–	–	/	–	–	–
b e	—			v. *biceps* (Kz.) von Schönfeldt	–	–	–	–	–	–	–	–	/	–	/	–	–	/	/	×	–	–
b e	—			v. *danica* (Kz.) Gr.	–	×	–	–	–	–	–	×	×	/	×	×	/	×	/	–	–	/
b e		?		cf. *utermöhli* Hust.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–
				<u>*Tabellaria* E.</u>																		
e p		- -	—	*fenestrata* (Lyngbye) Kz. +)	×	/	–	–	○	●	○	/	○	–	×	/	○	○	×	×	○	○
e p			—	*flocculosa* (Roth) Kz.	/	/	–	–	–	×	–	/	×	–	/	●	×	×	×	/	/	×
				<u>*Tetracyclus* Ralfs</u>																		
b			—	*emarginatus* (E.) W. Sm.	–	–	–	–	–	–	–	–	/	–	–	–	–	/	–	–	–	–
b			—	*lacustris* Ralfs	–	–	–	–	–	–	–	–	–	–	–	–	–	/	–	–	–	–
b			—	v. *strumosus* (E.) Hust.	/	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

LEVEÄNIEMI: Till beds

TABLE 5:2

DIATOMS FOUND IN THE LOWER AND UPPER TILL BEDS	A	B	C	D	E
Till bed	upper	upper	upper	lower	upper
No. of samples	1	2	1	2	1
No. of taxa	8	1	3	7	2
Achnanthes exigua Gr.	1	–	–	–	–
Amphora ovalis v. *libyca* (E.) Cl.	–	–	–	1	–
Epithemia turgida (E.) Kz.	–	–	–	–	1
Ep. spp. (fragm.)	–	–	–	1	1
Eunotia pectinalis (Kz.) Rbh.	2	–	–	–	–
Fragilaria construens (E.) Gr.	5	–	3	–	–
v. *binodis*	–	–	–	3	–
v. *venter*	–	–	–	5	–
Fr. pinnata E.	–	–	–	1	–
Melosira italica (E.) Kz. v. *italica*	3	–	–	–	–
Navicula cuspidata Kz.	–	–	1	–	–
Nav. radiosa Kz.	–	–	–	1	–
Nav. sect. *Minusculae*	4	–	–	–	–
Pinnularia (large) spp. fragments	2	–	–	–	–
Pinnularia (small) spp. fragments	2	1	–	–	–
Stauroneis phoenicenteron (Nitzsch) E.	–	–	–	1	–
Synedra ulna v. *danica* (Kz.) Gr.	–	–	1	–	–
Tabellaria flocculosa (Roth) Kz.	2	–	–	–	–
Varia diatom fragments	(138)	(+)	(+)	–	(+)
No. of valves found	21	1	5	13	2

Note that upper and lower till bed here refer to the strata above and below the organic beds and not to the till beds described in app. 1.

TABLE 5:3

LEVEÄNIEMI: Postglacial

ECOLOGY: LIVING-FORM (b, e, p)	ECOLOGY: pH-REQUEST (alk. >8, neutral (+?) 7, ac. 6>)	DIATOMS IN THE POSTGLACIAL SECTION: ALPHABETIC LIST OF SPECIES	DISTRIBUTION: DEPTH cm 0–65	70	80	90	100	110	117.5	120	122.5	125–137	137–150
		Total counted	—	179	344	133	203	226	661	210	31	17	—
		No. of taxa	—	11	33	36	25	30	46	28	8	4	—
			only a few fragments	%	%	%	%	%	%	%	No.	No. poor in diatoms	only a few fragments
		Achnanthes Bory											
e		*flexella* (Kz.) Brun		1.1	—	5.3	—	0.9	—	—	—		
e		*minutissima* Kz.		—	—	0.7	—	—	—	—	—		
		Anomoeoneis Pfitz.											
b		*exilis* (Kz.) Cl.		—	—	3.0	—	—	—	—	—		
b		cf. *follis* (E.) Cl. v. *fossilis*		—	—	—	—	—	0.1	—	—		
b		*serians* (Bréb.) Cl. v. *brachysira* (Breb.) Cl.		—	9.0	12.8	—	14.1	32.3	21.8	—		
b		*styriaca* (Gr.) Hust.		—	2.5	0.7	1.0	—	—	—	—		
b		*zellensis* (Gr.) Cl.		—	6.5	10.6	21.4	—	—	—	—		
		Caloneis Cl.											
b		*obtusa* W. Sm.		16.8	2.0	6.8	12.2	0.5	—	0.5	—		
		Cymbella Ag.											
e		*aspera* (E.) Cl.		14.0	1.1	1.5	—	—	—	—	—		
e		*cesati* (Rbh.) Gr.		—	—	0.7	—	—	—	—	—		
e		*cuspidata* Kz.		—	—	—	—	—	—	0.5	—		
e		*cymbiformis* (Ag.? Kz.) V.H.		—	—	1.5	—	0.9	—	—	—		
e		*gracilis* (Rbh.) Cl.		—	0.3	1.5	—	1.8	1.5	2.8	—		
e		*incerta* Gr. v. *incerta* et. v. *linearis*		—	7.9	—	1.0	—	2.1	2.4	—		
e		*moelleriana* Gr.		—	0.6	—	—	—	—	—	—		
e		*naviculiformis* Auersw.		—	—	—	—	—	0.3	1.0	—		
e		*norvegica* Gr.		—	6.2	0.7	12.2	—	—	—	—		
e		*obtusa* Greg.		—	32.2	10.6	2.9	—	—	—	—		
e		*perpusilla* A. Cl.		—	0.6	—	2.0	—	1.2	—	—		
e		*turgida* (Greg.) Cl.		—	0.6	—	—	0.9	0.8	—	—		
e		*ventricosa* Kz.		—	1.4	3.0	—	2.2	2.4	1.9	1		
e		v. *groenlandica* Fog.		—	—	—	0.5	0.5	—	—	—		
e		spp. (fragments)		57.4	—	—	—	—	—	—	—		
		Diploneis E.											
b		*ovalis* (Hilse) Cl. v. *ovalis*		3.9	—	0.7	3.4	2.7	0.3	—	—		
b		v. *oblongella* (Naegeli) Cl.		—	—	—	—	—	0.3	0.5	—		
		Epithemia Bréb.											
e		*argus* Kz.		—	—	+	—	—	—	—	—		
		Eunotia E.											
b e		*arcus* E.		—	0.3	0.7	1.5	0.5	0.1	—	—		
b e		*diodon* E.		—	1.1	—	2.0	0.9	0.1	—	—		
b e		v. *dovreensis* A. Cl.		—	—	1.5	—	—	—	—	—		
b e		*exigua* (Bréb.) Gr.		—	—	—	—	0.9	—	—	—		
b e		*faba* (E.) Gr.		—	—	—	—	0.9	—	—	—		
b e		*flexuosa* Kz.		—	—	0.7	—	0.5	1.2	1.0	—		
b e		*formica* E.		—	—	—	0.5	—	—	—	—		
b e		*lapponica* A. Cl.		—	—	0.7	0.5	1.3	1.7	1.4	—		
b e		*lunaris* (E.) Gr.		—	—	—	1.0	0.5	—	—	—		
b e		*monodon* E. v. *maior* (W. Sm.) Hust.		—	—	—	—	—	0.5	1.9	—		
b e		*parallella* E.		—	—	—	—	—	0.1	—	—		
b e		*pectinalis* (Kz.) Rbh. v. *pectinalis* et v. *minor*		—	—	—	—	0.9	0.1	1.0	—		
b e		*praerupta* E. v. *praerupta*			2.0	1.5	2.9	22.0	11.1	20.0	16	5	
b e		v. *bidens* Gr.		—	—	0.7	—	0.9	2.1	1.9	2		
b e		*pseudopectinalis* Hust.		—	—	—	—	0.9	0.9	2.4	—		
b e		*sarekensis* Å. Berg		—	—	—	—	—	—	1.0	—		
b e		*scandinavica* A. Cl. f. *angusta* Font.		—	—	—	—	3.5	0.8	—	—		
b e		*septentrionalis* Östr.		—	—	—	—	—	0.1	—	—		
b e		*sudetica* (O. Müller) Hust.		—	—	2.3	—	1.8	3.8	13.8	—		
b e		*tenella* (Gr.) Hust.		—	—	—	—	—	0.8	—	—		
b e		*valida* Hust.		—	1.4	1.5	20.4	20.7	7.5	3.8	1		
b e		spp. (fragments)		+	—	—	—	—	0.3	—	1	10	

TABLE 5:3 (CONT.)

ECOLOGY: LIVING-FORM (b c p)	DIATOMS IN THE POSTGLACIAL SECTION: ALPHABETIC LIST OF SPECIES	DISTRIBUTION: DEPTH cm 0–65	70	80	90	100	110	117.5	120	122.5	125–137	137–150
	Total counted	—	179	344	133	203	226	661	210	31	17	—
	No. of taxa	—	11	33	36	25	30	46	28	8	4	—
		only a few fragments	%	%	%	%	%	%	%	No.	No. poor in diatoms	only a few fragments
	Fragilaria Lyngbye											
e p	*construens* (E.) Gr.		–	0.3	–	–	–	–	–	–	1	
	Frustulia Ag.											
b	*rhomboides* (E.) De Toni v. *saxonica* (Rbh.) De Toni		–	6.9	2.3	2.0	6.2	7.8	1.0	–		
	Gomphonema Ag.											
e	*acuminatum* E. v. *coronatum* (E.) W.Sm.		–	0.3	1.5	1.0	–	–	–	–		
e	*angustatum* (Kz.) Rbh. et v. *undulatum*		0.6	7.6	6.0	5.4	5.3	6.5	6.2	8		
e	*gracile* E.		–	–	–	–	–	0.5	–	–		
e	*intricatum* Kz. v. *intricatum*		–	–	–	–	–	1.5	1.0	–		
e	*longiceps* E. v. *longiceps*		–	–	1.5	–	–	–	–	–		
e	v. *montanum* (Schum.) Cl.		–	–	–	–	–	0.9	–	–		
e	spp. (fragments)		1.7	–	–	–	–	0.6	–	–		
	Navicula Bory											
b	*bacillum* E.		–	–	–	0.5	–	–	–	–		
b	*hassaica* Krsk.		–	–	3.0	0.5	–	–	–	–		
b	*levanderi* Hust.		–	0.6	3.0	–	–	0.3	–	–		
b	*radiosa* Kz.		–	1.4	–	–	–	0.1	–	–		
b	spp. (fragments)		–	0.8	–	–	–	–	–	–		
	Pinnularia E.											
b	*borealis* E.		–	–	–	–	–	–	0.5	–		
b	*gibba* E. v. *linearis* Hust.		–	1.4	2.3	0.5	1.3	0.1	0.5	–		
b	cf. *intermedia* (Lgrst.) Cl.		–	–	–	–	–	–	0.5	–		
b	*interrupta* W.Sm.		–	0.3	–	–	–	–	–	–		
b	*maior* Kz.		–	0.3	–	–	–	–	–	–		
b	*mesolepta* (E.) W.Sm.		–	0.3	–	–	–	–	–	–		
b	*microstauron* (E.) Cl.		–	–	–	–	–	0.5	–	–		
b	*stomatophora* Gr.		–	–	–	–	–	1.1	–	–		
b	*streptoraphe* Cl.		–	1.7	–	–	–	–	–	–		
b	*subcapitata* Greg.		–	–	–	–	–	0.3	–	–		
b	*undulata* Greg.		–	–	–	–	–	0.1	–	–		
b	*viridis* (Nitzsch) E. v. *viridis*		0.6	0.3	0.7	1.5	0.9	0.1	–	–		
	Stauroneis E.											
b	aff. *lapidicola* B. Pet.		–	–	1.5	–	–	0.1	–	–		
b	cf. *norvegica* Hust.		–	–	–	–	–	0.1	–	–		
b	cf. *pusilla* A.Cl. v. *elliptica* (Östr.) A.Cl.		–	–	–	–	–	–	1.0	–		
b	*phoenicenteron* E.		–	1.1	–	–	–	–	–	–	1	
	Synedra (Nitzsch) E.											
b e	cf. *tenera* W.Sm.		–	–	–	–	–	0.1	–	–		
b e	*ulna* (Nitzsch) E. v. *danica* (Kz.) Gr.		–	–	+	–	0.5	1.2	1.4	–		
	Tabellaria E.											
e p	*fenestrata* (Lyngbye) Kz.		1.7	0.6	6.0	1.5	4.0	2.4	2.4	1		
e p	*flocculosa* (Rbh.) Kz.		2.2	0.6	2.3	1.0	1.3	3.2	6.2	1		
	Σ %	—	100.0	100.1	99.8	99.3	100.2	100.0	100.3	—	—	—

Plates 5:I—XI

Diatoms illustrated

Marked with *) in the list of diatom species.

Achnanthes exigua Gr.	Pl. 5:IX, Fig. 7
Achnanthes lanceolata (Bréb.) Gr.	Pl. 5:VI, Fig. 4
Amphora ovalis v. *libyca* (E.) Cl.	Pl. 5:VIII, Figs. 1–4
Anomoeoneis sculpta (E.) O. Müll.	Pl. 5:VII, Figs. 5–7
Cocconeis placentula E.	Pl. 5:VI, Figs. 1–5
Cymbella brehmi Hust. v. "*medio-paucistriata*" v. nov?	Pl. 5:VI, Fig. 10
Cymbella ehrenbergii Kz.	Pl. 5:VI, Fig. 6
Cymbella incerta Gr.	Pl. 5:VI, Fig. 9
Cymbella incerta Gr. v. "*interglacialis*" v. nov.?	Pl. 5:VI, Figs. 7, 8
Epithemia sorex Kz.	Pl. 5:XI, Figs. 7, 8
Epithemia turgida (E.) Kz.	Pl. 5:XI, Figs. 9–11
Epithemia zebra (E.) Kz.	Pl. 5:XI, Figs. 5, 6
Eunotia formica E.	Pl. 5:V, Figs. 6–8
Fragilaria brevistriata Gr.	Pl. 5:IV, Figs. 1, 2
Fragilaria construens (E.) Gr.	Pl. 5:III, Figs. 4,5. 5:IV, Figs. 3–6. 5:IX, Fig. 7
Fragilaria lapponica Gr.	Pl. 5:III, Fig. 10
Fragilaria pinnata E.	Pl. 5:III, Figs. 3, 8, 9. 5:IV, Fig. 1. 5:IX, Fig. 7
Fragilaria virescens (Kz.) O. Müll.	Pl. 5:III, Figs. 1, 2, 6, 7
Melosira distans (E.) Kz.	Pl. 5:I, Figs. 1–8
Melosira italica (E.) Kz. ssp. *italica*	Pl. 5:II, Fig. 7
Melosira italica (E.) Kz. f. *laevis*	Pl. 5:II, Figs. 8–10
Melosira italica v. *valida* Gr.	Pl. 5:II, Figs. 1–6
Navicula americana E.	Pl. 5:IX, Figs. 8, 9
Navicula oblonga Kz.	Pl. 5:IX, Figs. 4–6
Navicula tuscula (E.) Gr.	Pl. 5:VIII, Fig. 5–9
Navicula viridula Kz.	Pl. 5:IX, Fig. 7
Pinnularia nobilis E.	Pl. 5:X, Figs. 2a–6
Pinnularia nodosa E.	Pl. 5:IX, Figs. 1–3
Rhopalodia gibba (E.) O. Müll.	Pl. 5:XI, Figs. 1–4
Stauroneis acuta W. Sm.	Pl. 5:VII, Fig. 1
Stauroneis aff. *lapidicola* B. Pet.	Pl. 5:X, Fig. 1
Stauroneis phoenicenteron (Nitzsch) E.	Pl. 5:VII, Figs. 2–4
Tabellaria fenestrata (Lyngbye) Kz.	Pl. 5:V, Figs. 1–5

Plates I–XI contain 84 micrographs of 33 diatom taxa. Abbreviations used in the descriptions of plates are: LM = light micrograph, SEM = scanning electron micrograph.

PLATE 5:1

Melosira distans (E.) Kz.

Fig. 1. Girdle view of one and a half theca attached. Low focus. LM 750×.
Fig. 2. Do. High focus. LM 750×.
Fig. 3. Half a theca. Mantle and discus in exterior view. SEM (45°) 3 000×.
Fig. 4. Discus exterior. SEM (0°) 3 000×.
Fig. 5. Half a theca. Mantle and discus in exterior view. SEM (45°) 2 000×.
Fig. 6. Mantle and neck (collum) with interior ledge (septum) and exterior and interior mantle structure. SEM (45°) 3 000×.
Fig. 7. One and a half theca loosely attached by a row of teeth. Down to the right the collum with incision (sulcus) and interior with septum. SEM (45°) 3 000×.
Fig. 8. Two halves of different thecas attached by a row of teeth in zip-like construction. (Miller 1969, Plate 12). Down to the right the collum with sulcus and interior with septum. SEM (45°) 3 250×.

PLATE 5:I

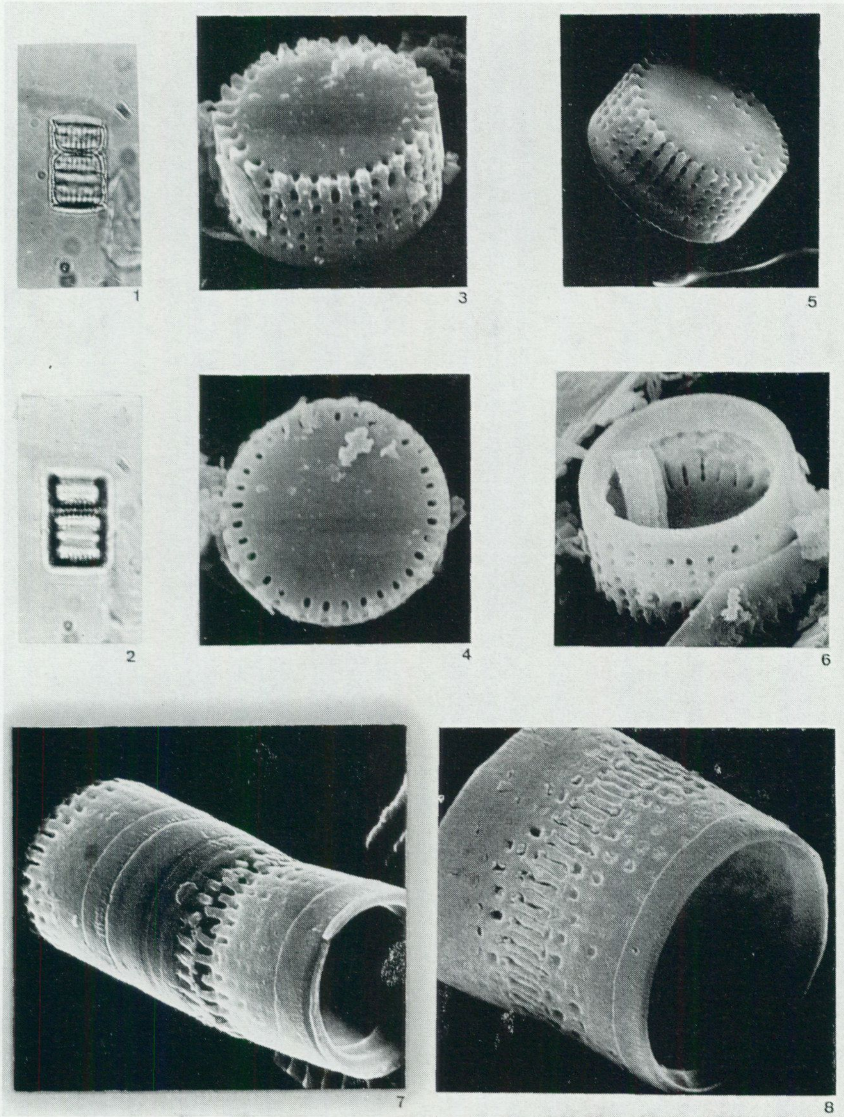

PLATE 5:II

Melosira italica (E.) Kz.

Fig. 1. *M. italica* v. *valida* Grun. Two halves of different thecas attached by teeth. Girdle view. Low focus. LM 750×.

Fig. 2. Do. High focus. LM 750×.

Fig. 3. Half a theca. Mantle and discus in exterior view. SEM (45°) 2 500×.

Fig. 4. Exterior mantle structure of two different thecas attached by zip-like teeth, partly covered by an old girdle band. SEM 2 500×.

Fig. 5. Half a theca with exterior and interior mantle structure and column with septum. SEM 2 500×.

Fig. 6. Do. Detail of the exterior mantle structure. SEM (45°) 10 000×.

Fig. 7. *M. italica*. Column opening. LM 750×.

Fig. 8. *M. italica* (ssp. *italica)* f. *laevis*. Girdle view with "Dauerspor" formation. Low focus. LM 750×.

Fig. 9. Do. High focus. LM 750×.

Fig. 10. *M. italica* (ssp. *italica)* f. *laevis*. Two halves of different thecas attached by zip-like teeth construction. Down to the right a frayed girdle band. SEM (45°) 2 750×.

PLATE 5:II

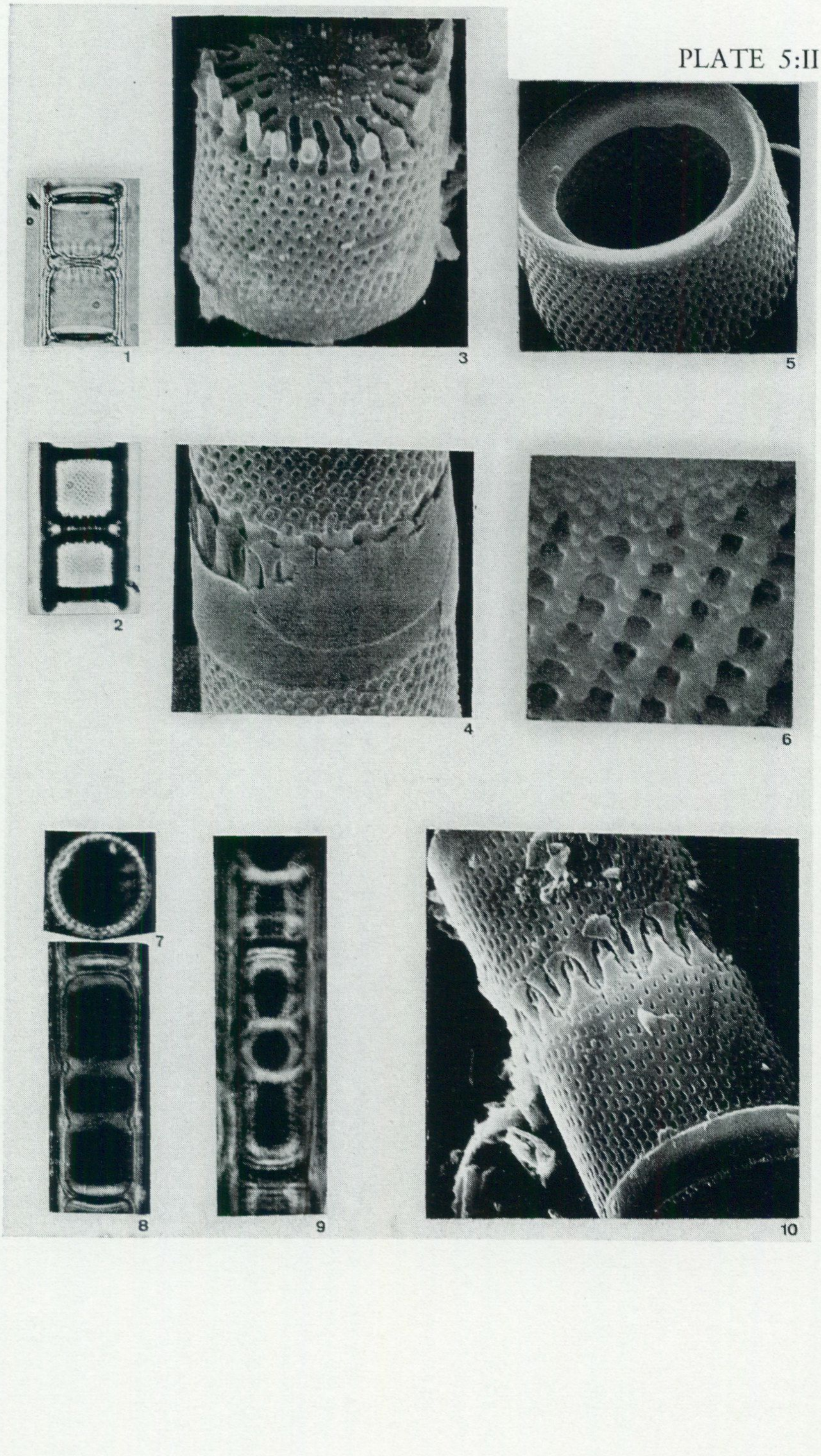

PLATE 5:III

Fragilaria Lyngbye

Fig. 1. *F. virescens* Ralfs. A ribbon colony in girdle view. LM 750×.
Fig. 2. *F. virescens* Ralfs. Valvar view. LM 750×.
Fig. 3. *F. pinnata* E. Valvar view. LM 750×.
Fig. 4. *F. construens* (E.) Grun. v. *venter* (E.) Grun. Valvar view. LM 750×.
Fig. 5. *F. construens* (E.) Grun. Valvar view. LM 750×.
Fig. 6. *F. virescens* Ralfs. Valvar view of the interior side. SEM (0°) 1 250×.
Fig. 7. Do. Detail of the middle part. SEM (0°) 6 200×.
Fig. 8. *F. pinnata* E. Two halves of different thecas attached. Above the interior view of the valve. SEM (45°) 3 250×.
Fig. 9. *F. pinnata* E. Two valves from the exterior side. SEM (45°) 5 000×.
Fig. 10. *F. lapponica* Grun. Valvar view. LM 750×.

PLATE 5:III

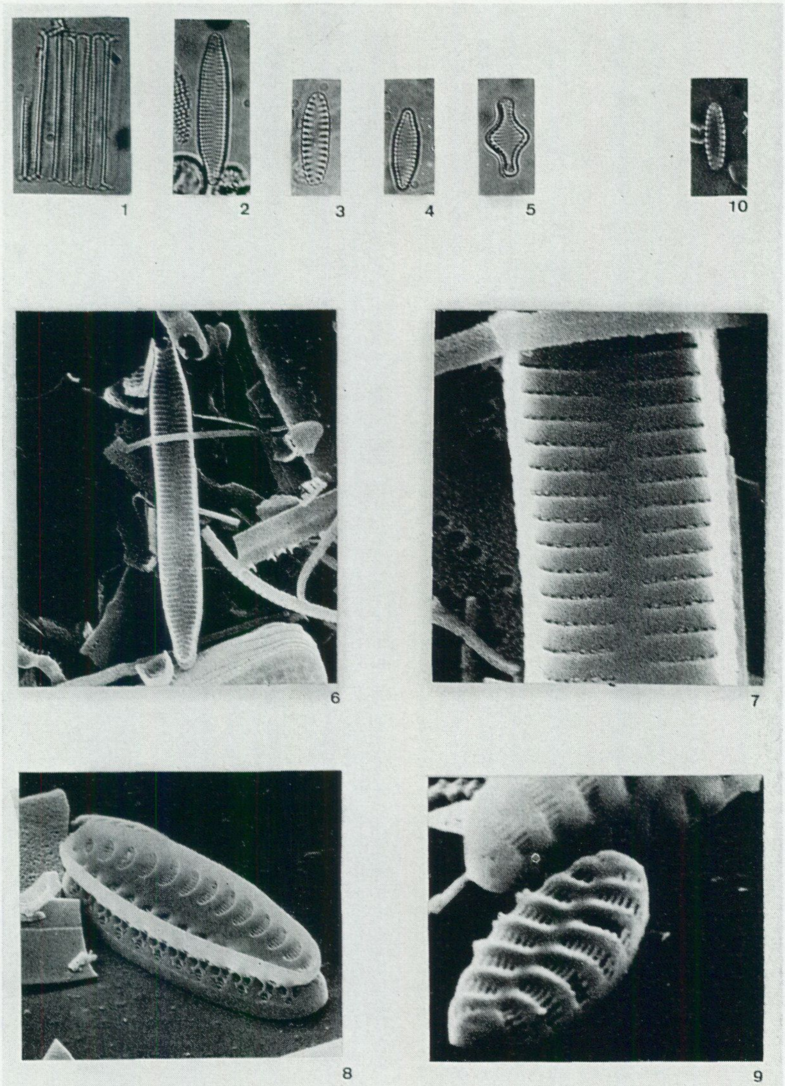

PLATE 5:IV

Fragilaria Lyngbye

Fig. 1. *F. construens* (E.) Grun., left, *F. pinnata* E., above, and *F. brevistriata* Grun., lower right. Valvar exteriors. SEM (0°) 3 200×.

Fig. 2. *F. brevistriata* Grun. Valvar exterior. SEM (45°) 5 350×.

Fig. 3. *F. construens* (E.) Grun. Girdle view of attached thecas. SEM (45°) 3 400×.

Fig. 4. *F. construens* (E.) Grun. Valve and mantle in exterior view. SEM (45°) 5 000×.

Fig. 5. *F. construens* (E.) Grun. Theca with intercalary bands and valvar exterior. SEM 3 200×.

Fig. 6. Do. Detail of the upper part. SEM 6 400×.

PLATE 5:IV

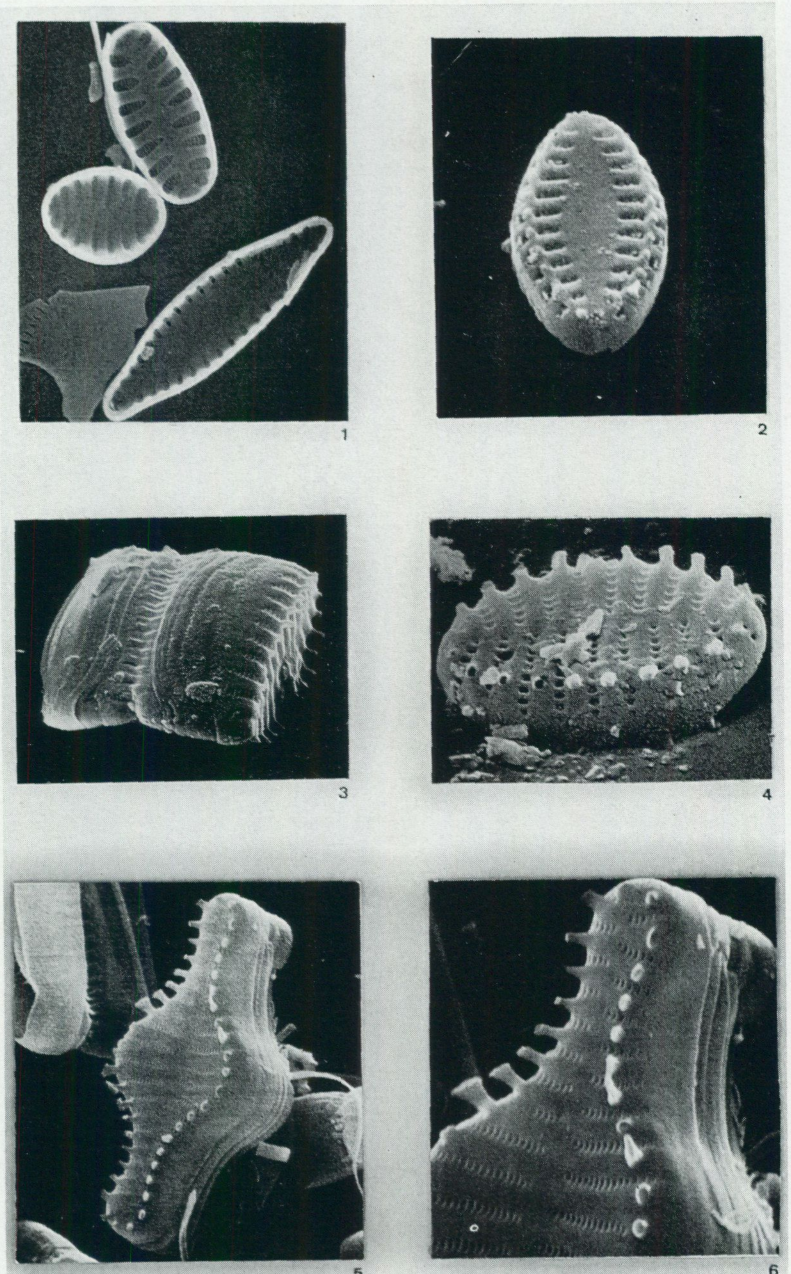

PLATE 5:V

Fig. 1. *Tabellaria fenestrata* (Lyngbye) Kz. Valvar view. LM 750×.
Fig. 2. *T. fenestrata* (Lyngbye) Kz. Valvar exterior. SEM (45°) 1 150×.
Fig. 3. Do. Detail of the central part. SEM 5 750×.
Fig. 4. Do. Detail of the polar part. SEM 5 750×.
Fig. 5. Group-picture with *Tabellaria fenestrata* ("fenestra band") in the centrum surrounded by *Melsosira italica* v. *valida, M. distans, Fragilaria* spp., *Epithemia zebra* et al. SEM (45°) 1 250×.
Fig. 6. *Eunotia formica* E. Valvar view. LM 500×.
Fig. 7. *E. formica* E. Valvar interior. SEM (0°) 625×.
Fig. 8. Do. Detail of the polar part. SEM 3 250×.

PLATE 5:V

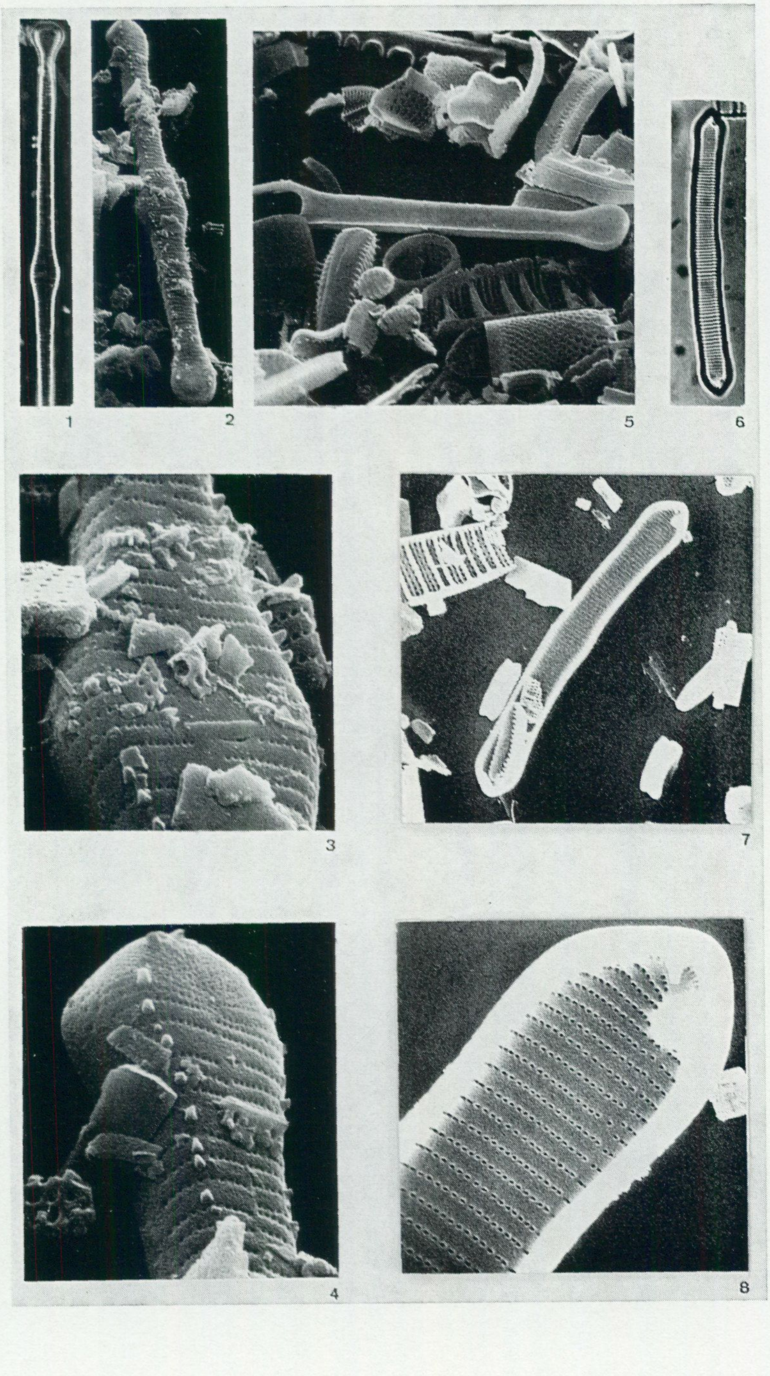

PLATE 5:VI

Fig. 1. *Cocconeis placentula* (E.) Raphe valve. LM 1 500×.
Fig. 2. *C. placentula* (E.) Raphe valve in exterior view. SEM (45°) 2 150×.
Fig. 3. *C. placentula* (E.) Rapheless valve. LM 1 500×.
Fig. 4. *C. placentula* (E.) Rapheless valve in interior view. SEM (45°) 1 225×. (Lower right *Achnanthes lanceolata* Bréb. Rapheless valve in interior view.)
Fig. 5. Do. Detail of the interior valvar structure. SEM 12 250×.
Fig. 6. *Cymbella ehrenbergii* Kz. Valvar view. LM 750×.
Fig. 7, 8. *Cymbella incerta* Grun. v. *"interglacialis"*? Valvar view. LM 750×.
Fig. 9. *Cymbella incerta* Grun. Valvar view. LM 750×.
Fig. 10. *Cymbella brehmi* Hust. v. *"medio-paucistriata"*? Valvar view. LM 1 500×.

PLATE 5:VI

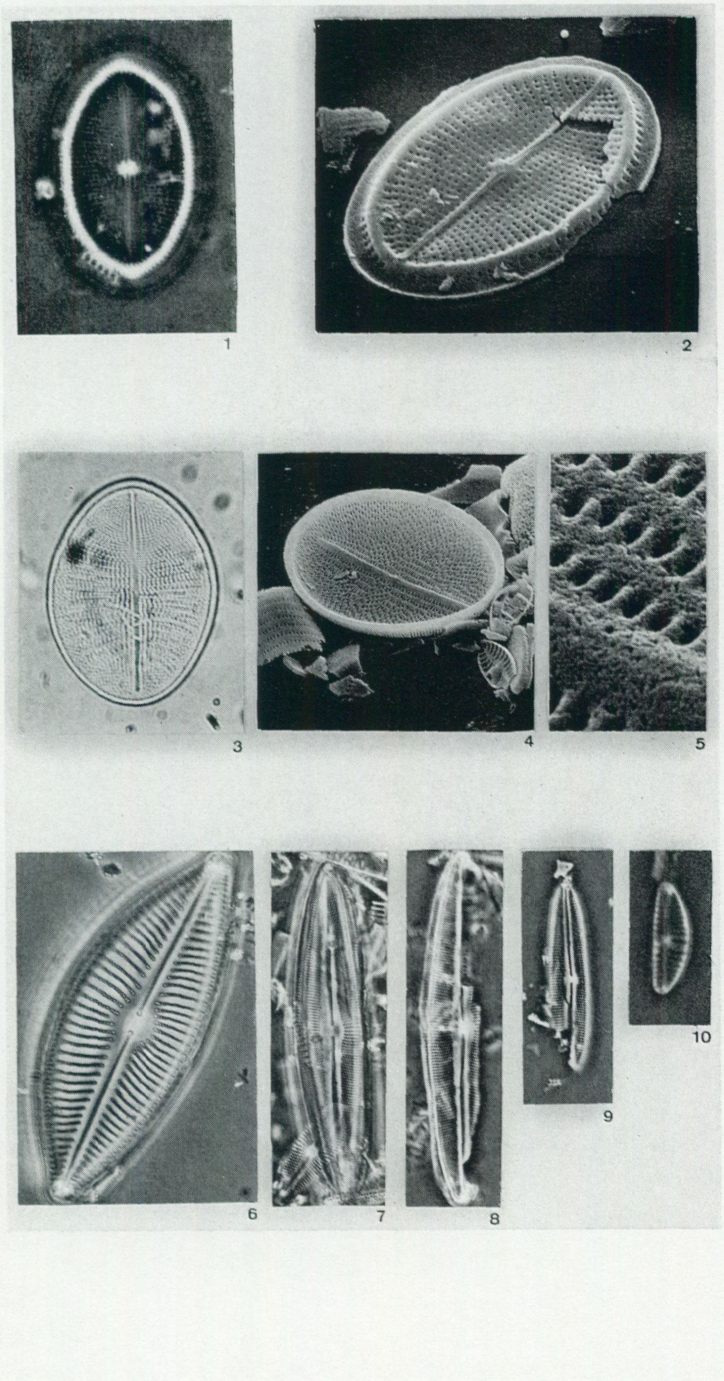

PLATE 5:VII

Fig. 1. *Stauroneis acuta* W. Smith. Valvar view. LM 500×.
Fig. 2. *S. phoenicenteron* E. Valvar view. LM 400×.
Fig. 3. *S. phoenicenteron* E. Valvar view of the interior side. SEM 625×.
Fig. 4. Do. Detail of the stauros from the interior side. SEM 3 100×.
Fig. 5. *Anomoeoneis sculpta* (E.) O. Müll. Valvar view. LM 400×.
Fig. 6. *A. sculpta*. Valvar exterior. SEM (45°) 625×.
Fig. 7. Do. Detail of the middle part. SEM 1 200×.

PLATE 5:VII

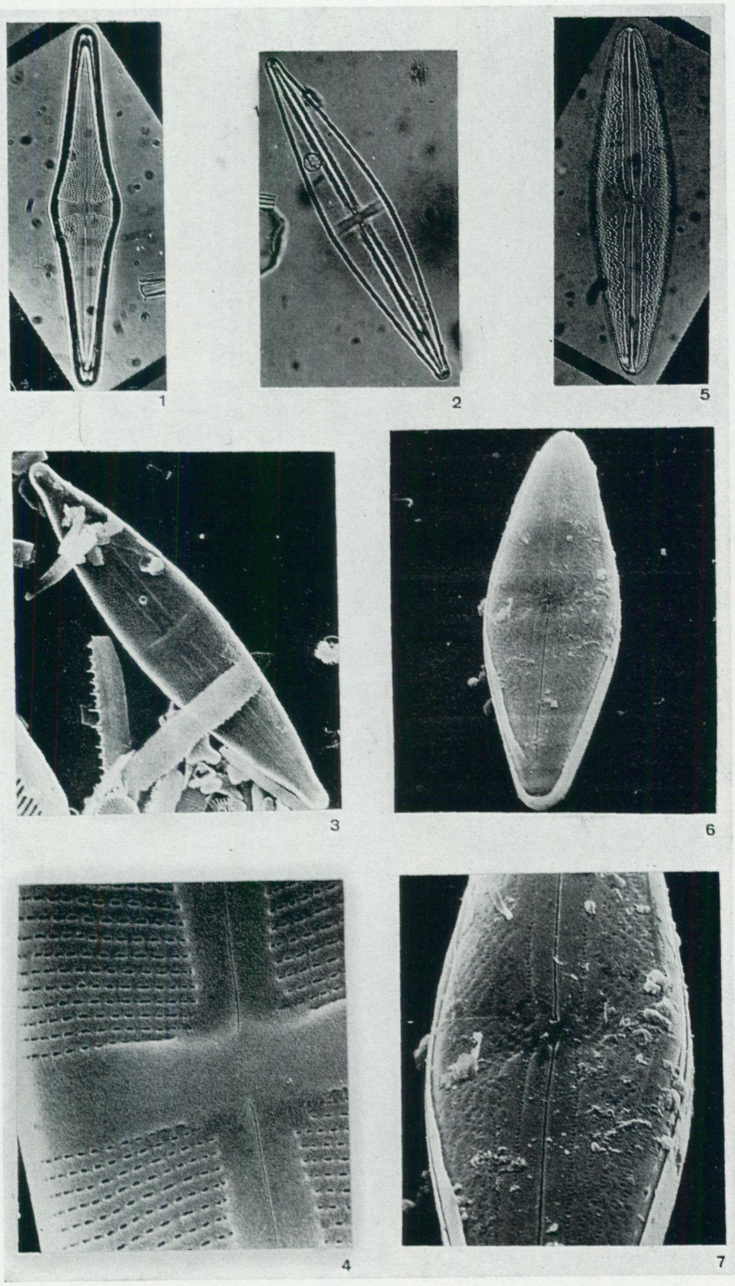

PLATE 5:VIII

Fig. 1. *Amphora ovalis* Kz. v. *libyca* (E.) Cl. Valvar view. LM 750×.
Fig. 2. *A. ovalis* Kz. v. *libyca* (E.) Cl. Valvar exterior. SEM 1 400×.
Fig. 3. *A. ovalis* v. *libyca*. Theca in ventral view. SEM 1 400×.
Fig. 4. *A. ovalis* v. *libyca*. Theca in dorsal view. SEM 1 400×.
Fig. 5. *Navicula tuscula* (E.) Grun. Valvar view. LM 750×.
Fig. 6. *N. tuscula*. Valvar exterior. SEM (45°) 750×.
Fig. 7. *N. tuscula*. Do. Detail of the exterior margin structure. SEM 5 500×.
Fig. 8. *N. tuscula*. Valvar interior. SEM (45°) 750×.
Fig. 9. Do. Detail of the central interior. SEM 5 500×.

PLATE 5:VIII

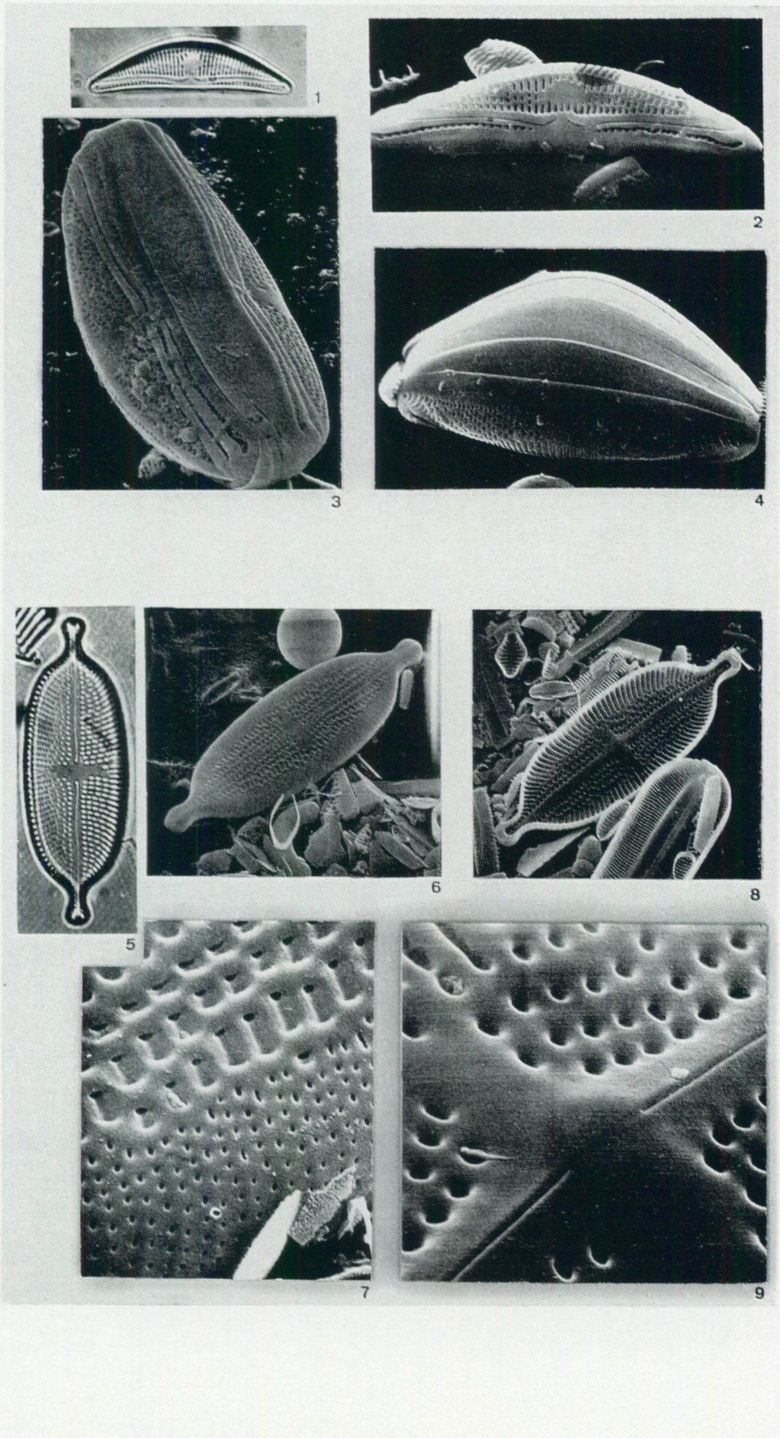

PLATE 5:IX

Fig. 1. *Pinnularia nodosa* E. Valvar view. LM 750×.
Fig. 2. *P. nodosa*. Valvar exterior. SEM (45°) 900×.
Fig. 3. Do. Detail of the valvar exterior structure. SEM 13 000×.
Fig. 4. *Navicula oblonga* Kz. Valvar view. LM 750×.
Fig. 5. *N. oblonga*. Valvar interior. SEM (45°) 700×.
Fig. 6. Do. Detail of the interior polar part. SEM 3 000×.
Fig. 7. *Navicula viridula* Kz. f. *capitata* Mayer. Valvar exterior. SEM (45°) 1 100×. (Upper left *Achnanthes exigua* Grun. in valvar exterior and a colony of *Fragilaria construens*. To the right *Fragilaria pinnata* in valvar exterior.)
Fig. 8. *Navicula americana* E. Valvar view. LM 750×.
Fig. 9. *N. americana*. Valvar exterior. SEM 1 100×.

PLATE 5:IX

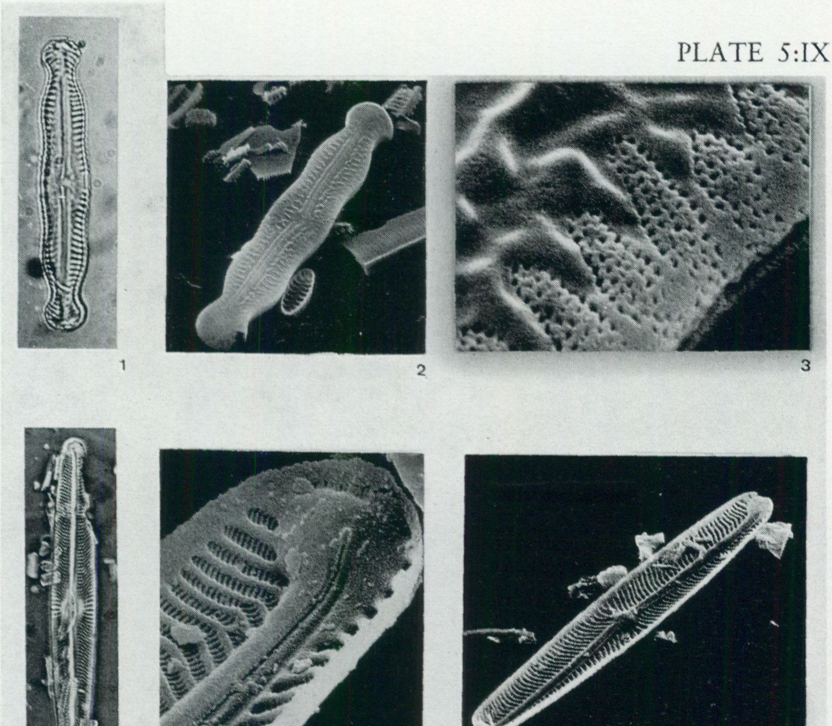

PLATE 5:X

Fig. 1. *Stauroneis* aff. *lapidicola* Boye Petersen. Valvar interior. SEM (45°) 6 500×.
Fig. 2a. *Pinnularia nobilis* E. Valvar view. LM 140×.
Fig. 2b. *P. nobilis*. Valvar view. LM 320×.
Fig. 3. *P. nobilis*. Valvar interior. SEM (0°) 125×.
Fig. 4. Do. Central part of the valvar interior. SEM 625×.
Fig. 5. Do. Polar part of the valvar interior. SEM 1 250×.
Fig. 6. Do. Detail of the interior valvar structure. SEM 6 250×.

PLATE 5:X

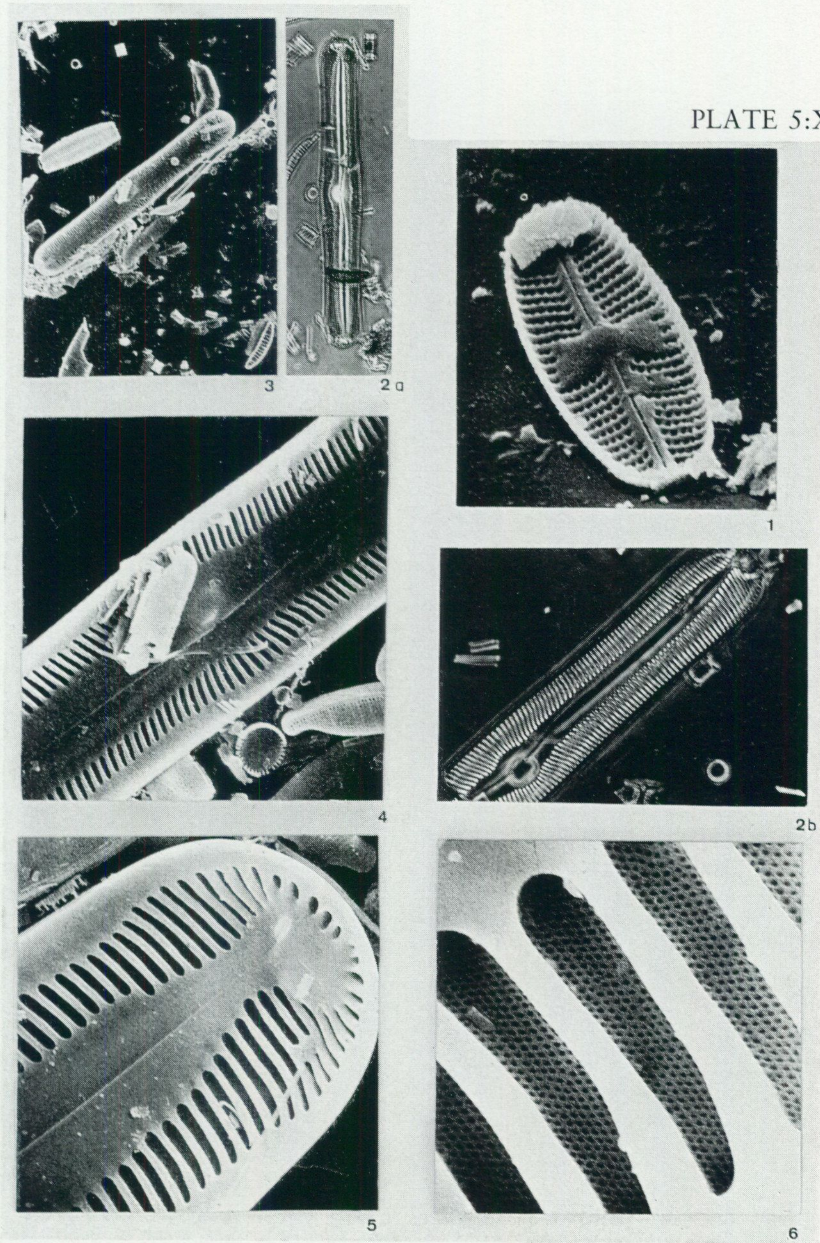

PLATE 5:XI

Fig. 1. *Rhopalodia gibba* (E.) O. M. Valvar view. LM 750×.
Fig. 2. *R. gibba*. Valvar exterior. SEM (45°) 550×.
Fig. 3. *R. gibba*. Valvar interior. SEM (45°) 550×.
Fig. 4. Do. Detail of the interior valvar structure. SEM 5 500×.
Fig. 5. *Epithemia zebra* (E.) Kz. Valvar view. LM 750×.
Fig. 6. *E. zebra*. Valvar interior. SEM (45°) 1 100×.
Fig. 7. *Epithemia sorex* Kz. Valvar view. LM 750×.
Fig. 8. *E. sorex*. Valvar exterior and intercalary bands. SEM (45°) 2 250×.
Fig. 9. *Epithemia turgida* (E.) Kz. Valvar view. LM 500×.
Fig. 10. *E. turgida*. Valvar exterior. SEM 625×.
Fig. 11. *E. turgida*. Valvar interior of the central part with the central node above to the left. SEM (45°) 2 250×.

PLATE 5:XI

PRISKLASS F

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