SVERIGES GEOLOGISKA UNDERSÖKNING

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## Abstract

The main purpose of this investigation is to determine the age of a till-covered organic layer found at Skurup, southern Scania. Pollen analyses and radiocarbon datings show that the sediments are of Late-Glacial age, representing a period from the Bölling oscillation about 10 200–9 900 B.C. to the beginning of Younger Dryas 8 900 B.C. (Fig. 4). The minerogenic layer covering the organic sediments probably originates from slumping, which took place in Younger Dryas. The other section examined (Skurup Lms) illustrates the vegetational development during the transition from Late-Glacial to Post-Glacial times (Fig. 6).

Examination of the diatom flora revealed water conditions characterized by high pH-values (constantly alkaline water) during Bölling, Older Dryas and Alleröd, but a lower pH during Younger Dryas (largely neutral-alkaline water) in the Skurup section (Fig. 12). According to halobion-spectra increased evaporation caused a higher salinity and lowering of the water-level in the Skurup lake during Alleröd. The proportions of different living-forms indicate that there was only a low water-depth in both of the small Skurup lakes.

## Preface

In 1966 Svensk Grundundersökning AB, Malmö, made a geotechnical investigation of a building site at Skurup in southern Scania. During the boring organic material consisting of peat and gyttja was found below a till layer. Kaj Nilsson arranged the collection of samples for investigation. The material was then handed over to the author. The purpose was to determine the age of the material by pollen analyses and radiocarbon datings. As the layer was covered by till it could possibly be of interglacial or interstadial age. The pollen content in the overlying and underlying till beds was also examined. Diatom analyses were carried out to determine the conditions of sedimentation (pH, salinity, water-depth). Sediment analyses were made to clarify alternations between organic and inorganic material.

As the peat and gyttja were found to be of Late-Glacial age, a small supplementary series af samples was collected in 1968 at Lantmannaskolan (The Agricultural School) south of Skurup for comparison. Viak AB was making a geotechnical investigation prior to enlargement of the school. The samples of this series were also subjected to pollen, diatom and sediment analyses.

The Late-Glacial history of the vegetation in Scania has been described in the extensive work of T. Nilsson (1935). More recently other vegetational investigations have been made (Magnusson 1962, Welinder 1969, Berglund and Digerfeldt 1970, Berglund 1971).

When in 1965 K. Nilsson and U. Miller began an investigation of age relations between different sediment- and till beds in the Alnarp Valley, southwestern Scania (deep borings at Tofthög, Gärdslöv and Hyby) they thought it would be of interest to clarify the Late-Glacial development of the pollen and diatom floras within their area of investigation. The Alnarp investigation was intended, among other things, to endeavour to distinguish deposits from different ice streams by means of bio- and litho-stratigraphical analyses (Miller 1968, 1969, 1971 b, K. Nilsson 1968, 1971).

*Acknowledgements.* This investigation has been carried out under the guidance of Professor C.-G. Wenner, Head of the Department of Quaternary Geology of the University of Stockholm. I wish to thank him for generous support and critisism in this work.

The Geological Survey of Sweden (SGU) provided material and technical assistance for the investigation. For this I express my gratitude to Mr K. A. Lindbergson, Director General, the late Dr Phil. Fritz Brotzen, previous Director of the Department for Applied Geology, his successor Dr Otto Brotzen and the present Director of this Department, Dr Erik Fromm. I would also like to thank Mr Kaj Nilsson, F. L., Viak AB, for samples and for valuable discussions.

I am specially much indebted to my teacher Mrs Urve Miller, F. L., SGU, for her valuable advice, encouragement and help in the preparation of this publication. She also introduced me how to use the scanning electron microscope and the diatom photos were taken under her guidance.

Valuable information and help were provided by Mr Erik Mohrén, F. L., SGU, and by Mrs Gunnel Linnman, F. L., Museum of Natural History.

I am also grateful to Mr Ernest Magnusson, F.L., SGU, for critical reading of the manuscript.

Professor Björn Berglund, Department of Quaternary Geology, University of Lund, and Dr Henrik Tauber of the Laboratory for radiocarbon datings, Copenhagen, were kind enough to provide information by correspondence.

The samples were prepared in the Micropaleontological laboratory (SGU) by Mrs Georgia Olsson, Mrs Elfriede Gabriel and Miss Berit Henriksson. Mr Bengt Falkenström kindly carried out the size measurements of *Betula* pollen and took the diatom photos in a light microscope.

Thanks also to Miss Ulla Skarin, Mrs Inga Palmaer and Miss Elin Pulkkinen (drawings), Mrs Kerstin Brodén (typing) and Mr Uno Samuelsson (photographical work).

The manuscript has been translated by Mrs Aasa Körgma.

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# INTRODUCTION

## Quaternary geology of the Skurup area — a short review

Skurup is situated in the so-called hillocky moraine landscape south and southwest of Romeleåsen, a ridge in southwestern Scania (Fig. 1).

The hillocky landscape contains a large number of small lakes originating from dead ice hollows. These small, circular to oval lakes, or dried-up overgrown basins, are mostly only about 10 m in diameter. They have been formed by dead ice bodies which have remained in depressions. When the dead ice melted the remaining material collapsed into the water-filled hollows. The till in this area consists of Baltic chalk and Cambro-Silurian material with a high lime and clay content, so-called Baltic till. The Quaternary stratigraphy of the area is very complicated. Several ice streams have passed across this part of Scania (Wennberg 1949, Möller 1959, K. Nilsson 1959, Fig. 22). Where the

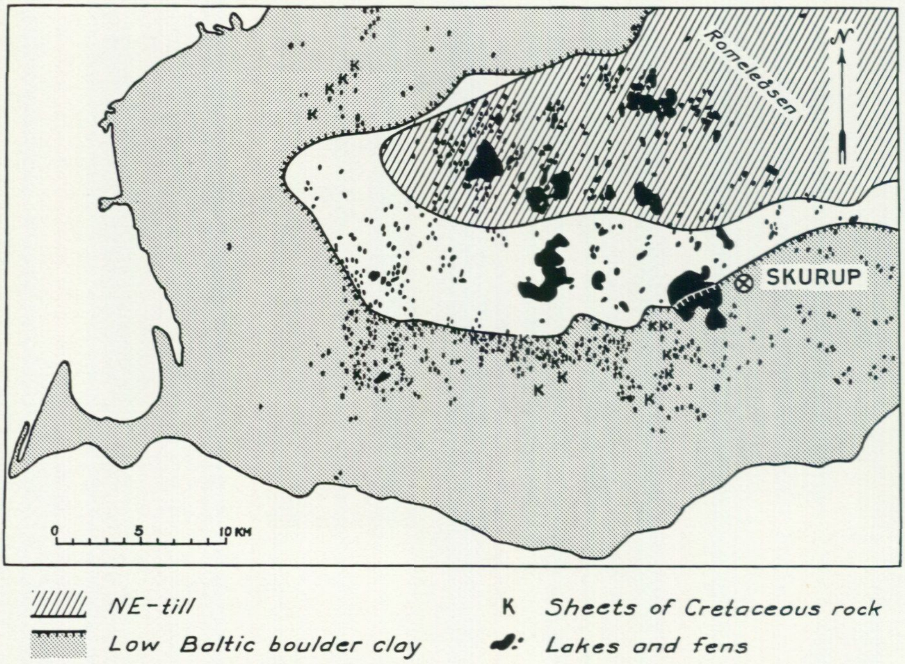


Fig. 1. The hillocky landscape and till types in southwestern Scania. Skurup is situated just south of the northern limit of the Low Baltic boulder clay. After K. Nilsson 1959 and G. Lundqvist 1961.

erosion has not been too strong, a stratification with several till beds and layers of sediments can be found in a series. They represent not only the last ice stream but also earlier ones (cf. sediments and till beds in the Alnarp Valley).

Skurup is situated just south of the northern limit of the Low Baltic boulder clay (see K. Nilsson 1959, Plate 2), in an area where Low Baltic dead ice was isolated. The so-called Low Baltic was the last of the ice streams to cross the area, and deposited its drift about 13 000 to 16 000 years ago. When the higher parts of the landscape were exposed, nunatak lakes were formed in which clay ("platålera") was deposited. The highest shore line was formed very early by the large ice-dammed lakes which covered the low-lying parts of the country to the west and southwest of Romeleåsen and around the present lake Vombsjön (E. Nilsson 1953, 1960, 1968). Along the south coast, however, the highest shore line was formed during one of the Litorina transgressions (T. Nilsson 1935).

## Sampling technique and stratigraphy

The sampling sites are situated at Skurup, south of Romeleåsen about 20 km west of Ystad in southern Scania (Fig. 2). The Fridhem area is in the northern part of this village and Lantmannaskolan (The Agricultural School) in the southern part. The distance between the sampling sites is about 2.5 km. 64 samples from the Fridhem area were taken by a screw sampler, as a layer of till had to be forced through which cannot be done with a usual Hiller sampler.

Before the samples were put into plastic bags they were properly cut clean. In the organic layers the samples were taken at an interval of 5 cm, in the minerogenic sediments at 10 cm at both sections. At Lantmannaskolan 15 samples were directly taken out of the open pit-wall which was first cut clean, whereby a 2–3 dm thick layer was removed. The stratigraphy at Fridhem (called Skurup in the text) is:

| Depth below surface | Stratigraphy |
|---|---|
| 0 –3.10 m | filling |
| 3.10–4.20 m | gravelly-sandy till downwards clayey (solifluction material) |
| 4.20–4.30 m | fen wood peat with minerogenic material |
| 4.30–4.45 m | fen wood peat with twigs and seeds of *Betula* |
| 4.45–4.75 m | clayey gyttja with thin sandlayers |
| 4.75–5.60 m | clayey gyttja–clay gyttja downwards muddy clay |
| 5.60–6.90 m | clayey sandy-silty till |

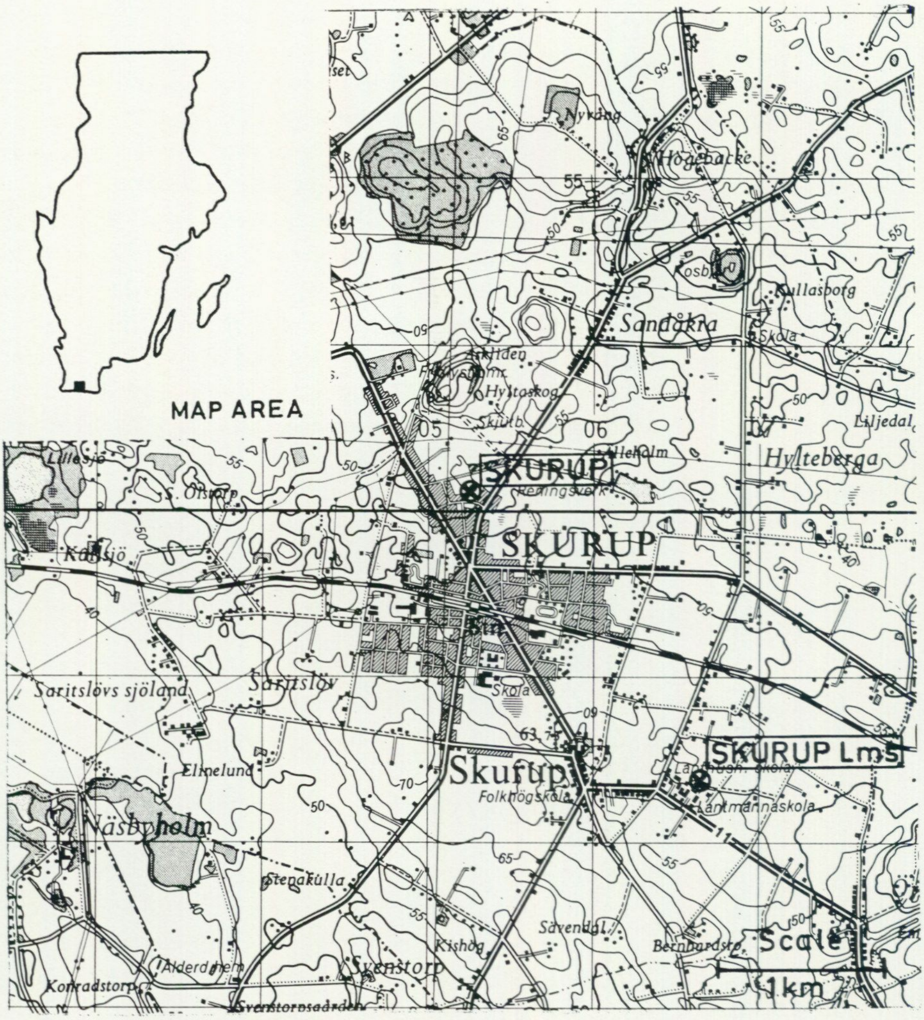


Fig. 2. Part of the topographical map 1 D Ystad NV/2 D Tomelilla SV showing the situation of the Skurup sections.

Lantmannaskolan (in the text called Skurup Lms):

| Depth below surface | Stratigraphy |
|---|---|
| 0 –1.80 m | filling |
| 1.80–2.35 m | *Sphagnum-Carex* peat |
| 2.35–2.55 m | algal gyttja |
| 2.55–2.80 m | clayey gyttja |
| 2.80– | boulder clay |

In the Skurup series the upper layer of minerogenic material (till?) is not in situ. Either it is a solifluction deposit or material brought here to fill the depression where peat and gyttja have been deposited.

During the climatic deterioration in the Younger Dryas frost and solifluction fenomenon were usual in southern Scandinavia. Climate, topography and unstable soil-conditions characteristic of the hillocky landscape around Skurup made it quite probable that slumping might have taken place on the steep slopes around the small dead ice hollows. Similar sections where boulder clay has slided down and covered organogenic sediments have been described from southern Scania (Mohrén 1938, Munthe 1920). Also a lowering of the water-level could have caused an increased erosion of the sediments at the shore (cf. Berglund and Digerfeldt 1970).

## POLLEN

### Preparation of samples and construction of pollen diagrams

About 70 samples from both sampling-series were treated for pollen analysis. 4–5 g material of organic samples and 10–12 g of minerogenic were prepared. First the samples were put into cold HCl to remove calcium carbonate. Almost all samples contained minerogenic material. They were therefore boiled in HF according to Assarsson-Granlund's method, modified by Heinonen (Heinonen 1957). This treatment differs from that of Assarsson-Granlund so far as the boiling in HF is directly done, without any previous treatment with KOH. Heinonen's method is more suitable for minerogenic samples with great amount of fine-material, e. g. boulder clay, because 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 concreted particles remain unhurt and pollen-grains in them disappear by the decanting. HF on the contrary releases organic matter undamaged into the liquid".

The concentration method may be summarized as follows:

1) Boiling 2–5 min. in 30–40 % HF to dissolve silicates.
2) Centrifuging and decanting (after each step in the treatment).
3) Adding of dest. water, vigorous stirring followed by about 10 sec. sedimentation and decanting. Hereby the coarser mineral grains are eliminated. Mom. 1–3 are repeated until the sample is as free from mineral particles as possible.
4) A few minutes heating in 10 % HCl to dissolve colloidal $SiO_2$.
5) Washing with dest. water.

After Heinonen's method the samples were treated according to Erdtman's acetolysis (see Faegri and Iversen 1964, p. 71). Thereby most organic material (cellulose) was eliminated. The organogenic samples from Skurup Lms *(Sphagnum-Carex* peat and algal gyttja) were directly acetolysed after a previous short boiling in KOH.

The remaining material was mounted in glycerin and sealed with wax. Glycerin was thought to be the best mounting medium as a lot of pollen and spores were shrinkled and corroded. In a fluidal medium it is easier to turn the pollen grains if needed for their identification.

A Reichert microscope "Neopan" was used at the analytical work. Objectives for phase contrast and ordinary light were available. The magnifications were 250x, 500x and 1 250x. The 250x was used when analysing till samples which were very poor in pollen. At the identification of pollen and spores reference works of Erdtman (1954), Erdtman and Berglund and Praglowski (1961), Erdtman and Praglowski and Nilsson (1963), Beug (1961), Faegri and Iversen (1964) and others were used.

The pollen frequency is mostly very low in the Late-Glacial minerogenic samples (muddy clay, clayey gyttja). Therefore the number of counted pollen of trees, shrubs and herbs does not exceed 500, but usually is 300–400. In the till samples only about 100 pollen grains were counted.

Pollen of trees, shrubs and herbs, except aquatic plants, comprise the basic sum in the diagrams. The frequencies of all different components occurring are calculated on this basic sum. Thus the sum percentages of trees, shrubs, herbs, aquatic plants, spores, algae *(Pediastrum)*, redeposited pollen and spores, hystrichospheres and dinoflagellates show the frequencies in relation to the basic sum.

*Picea, Alnus, Corylus, Ulmus, Quercus, Tilia, Fagus, Carpinus* and pre-quaternary pollen and spores are considered redeposited and are not included in the basic sum. The only exceptions are the pollen grains of *Alnus* and *QM* found in the 2.20 and 2.30 m samples in the Skurup Lms series. They are thought to be of primary origin.

Zoning of the diagrams was made after the Scanodanian system (Jessen 1935, T. Nilsson 1935, 1961, 1965, Berglund 1966, 1971).

## Pollen zones and development of the vegetation during Late-Glacial and Pre-Boreal times

The Late-Glacial pollen zones were named and described regionally for Scania by T. Nilsson 1935. This zoning was later revised by himself (T. Nilsson 1961 and 1965), as it was partly based on the occurrence of rebedded pollen (T. Nilsson 1935, p. 471).

Description of the Late-Glacial pollen zones for northwestern Scania (Mt Kullen) and Blekinge was made by Berglund (1971 and 1966).

Other pollen-analytical investigations concerning the development of the Late-Glacial vegetation in northwestern Europe are:

| | |
|---|---|
| Faegri 1935, 1953<br>Chanda 1965<br>Hafsten 1960, 1963<br>Mangerud 1970 | Norway |
| Jessen 1935<br>Iversen 1942, 1947, 1954<br>Krog 1954 | Denmark |

| | |
|---|---|
| Averdieck 1957 | northern Germany |
| Behre 1966 | |
| Menke 1968 | |
| van der Hammen 1952, 1957 | Netherlands |
| Casparie & von Zeist 1960 | |
| Wasylikowa 1964 | Poland |
| Ralska-Jasiewiczowa 1966 | |
| Pirrus 1969 | Estonia, USSR |

## Oldest Dryas and Bölling (zones DR 1, BÖ)

In Netherlands the beginning of the Oldest Dryas has been put in the pollen diagrams, where the *Artemisia* curve increases. $C^{14}$-datings have given the age 11 400–11 300 B.C. (van der Hammen 1957, van der Hammen and Vogel 1966). The Bölling interstadial was described and defined by Iversen (1942), in accordance with pollen-analytical investigations of material from Böllingsö, Jylland. Evidence of this climatic oscillation, after the recession of the last ice, has later been revealed by investigations in northwestern Europe concerning changes of the Late-Glacial flora. This climatic amelioration has also been discovered in other parts of North and East Europe as well as in northeastern USA. Interstadial sediments, older than Alleröd have been investigated from Jaeren in Norway. The so-called Bröndmyr interstadial (Bölling?) was described by Faegri (1935) and dated at 13 000 ±400 B.P. (Hafsten 1960). The same section has later been analysed and described again (Chanda 1965). Investigations from Salla in northern Finland show that the Bölling interstadial possibly is registered in pollen diagrams representing Late-Glacial times (Sorsa 1965).

The beginning of the Bölling interstadial is put in the pollen diagrams where the *Betula* curve rises. The arboreal birch spread to northwestern Europe, when the climate improved. The tundra in Denmark, northern Germany, Poland and Netherlands during Oldest Dryas, was replaced by park-tundra with scattered stands of trees. Birch was then the only type of tree. Pine spread to northwestern Europe later during Alleröd.

Except arboreal *Betula*, the vegetation consisted of shrubs like *Salix, Betula nana, Juniperus* and *Hippophaë*. Among the herbs *Gramineae* and *Cyperaceae* dominated. In the field layer there were also growing *Selaginella, Dryas, Saxifraga oppositifolia, Galium, Thalictrum* and *Caryophyllaceae*. Stepp-elements like *Artemisia, Helianthemum, Ephedra* and *Chenopodiaceae* were also included in the light-demanding herb-flora.

Hydrophytes already occur very early in Bölling. In the Swedish, Danish

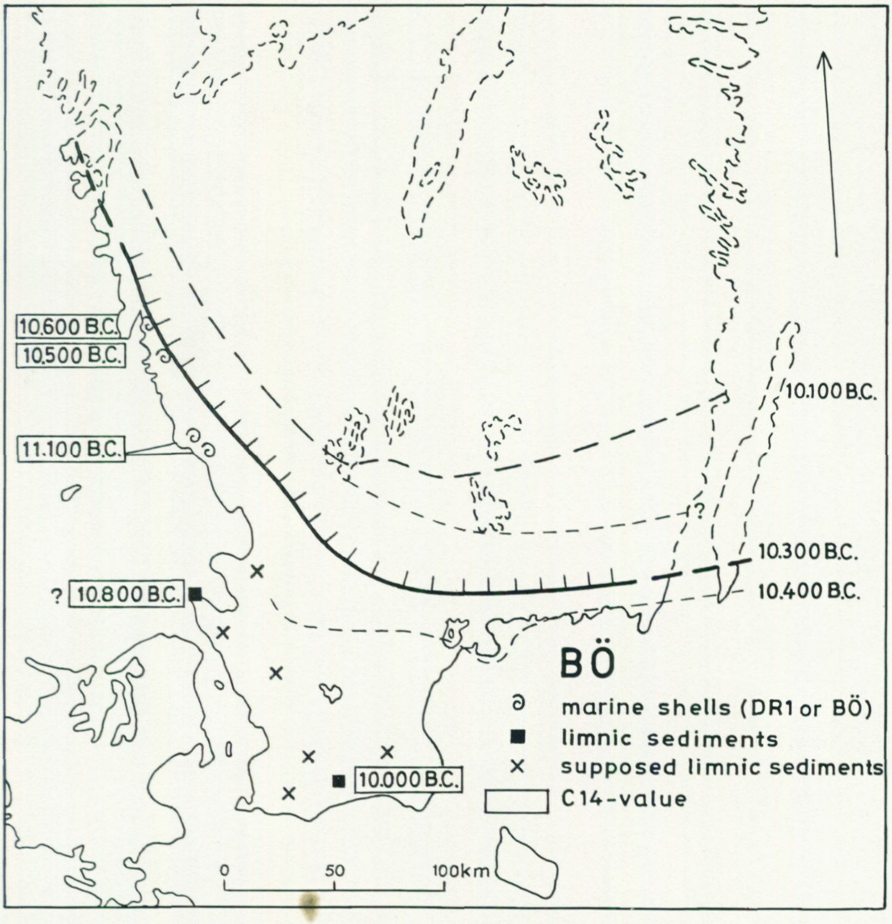


Fig. 3. South Sweden with varve-dated ice margins at the end of the Bölling period. Notes on organic material from the same period or slightly older are indicated. Limnic sediment in southern Scania dated 10 000 B.C. is Skurup. From Berglund 1971.

and Dutch summary diagrams the climatic oscillation during the Bölling period is reflected by the rise of the AP sum from about 30 % in DR 1 to 50–70 % in BÖ (Berglund 1971, Iversen 1954, van der Hammen 1952).

In Sweden the Bölling interstadial has up till now been described with the guidance of pollen diagrams, only in two sections from Mt Kullen, northwestern Scania (Berglund 1971).

During the Bölling oscillation Scania already was ice-free (Fig. 3). But as many depressions were filled with dead ice no pure organic sediments could be deposited. But in some ice-free sedimentation basins undoubtedly an organic production began and muddy clays and clayey gyttjas were formed.

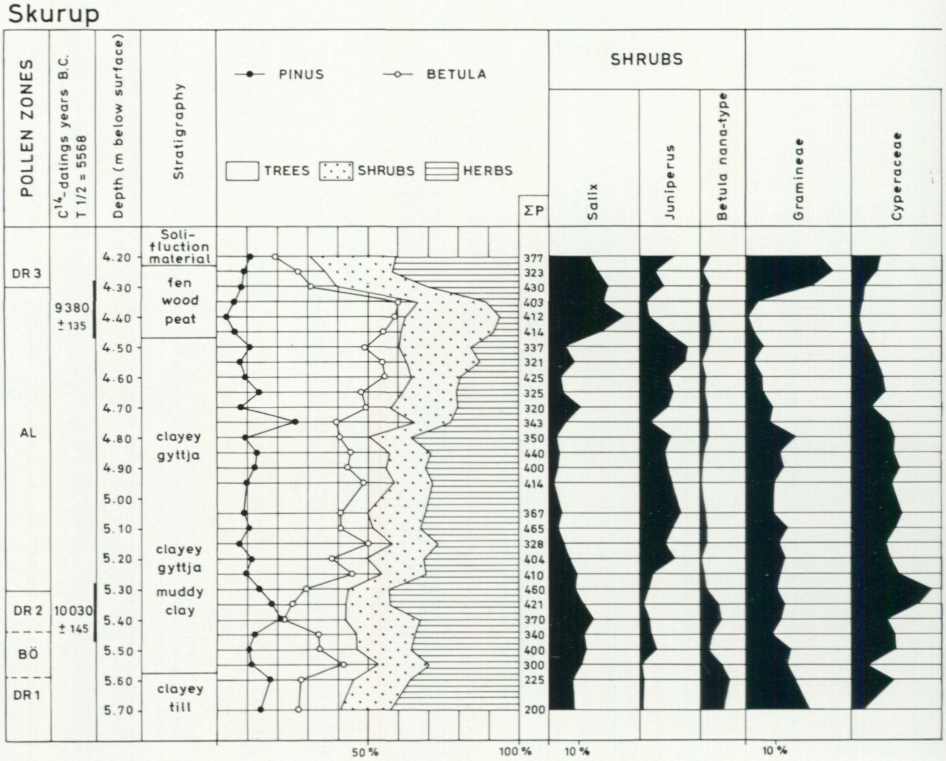
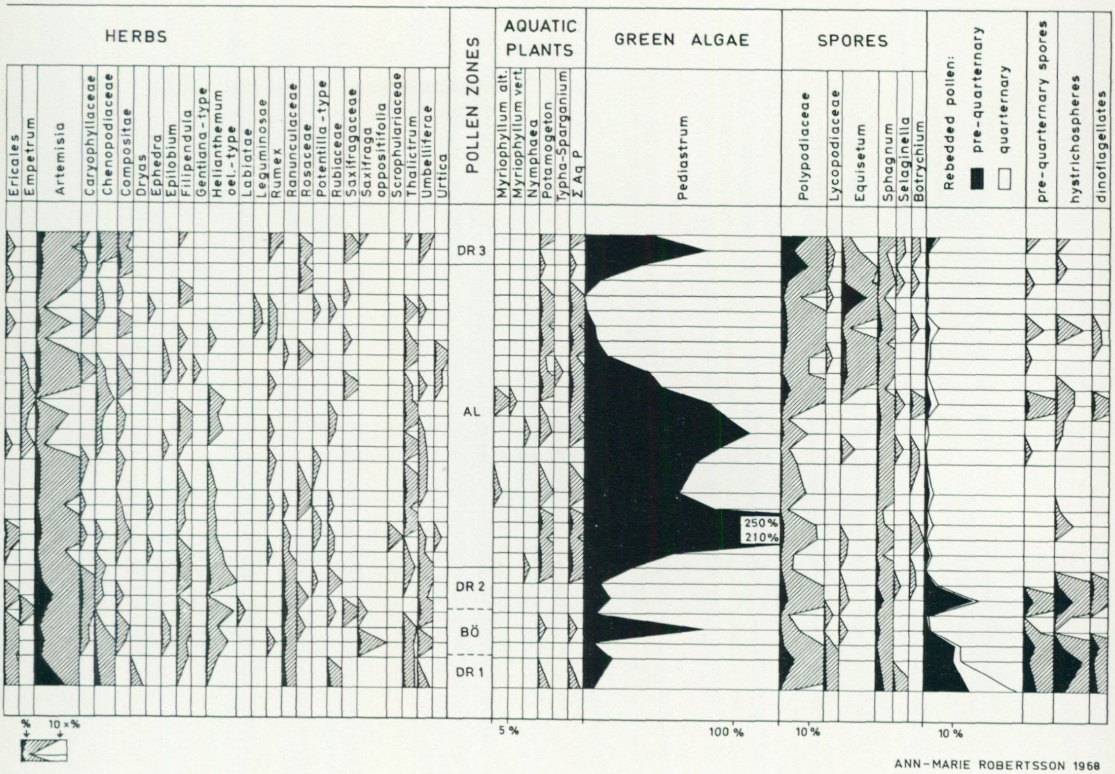


Fig. 4. Pollen diagram from the Skurup section.

*Skurup.* The pollen diagram from Skurup is shown in Fig. 4. Probably the Bölling interstadial is represented at 5.45–5.55 m. There is a rise of the *Betula* curve also after the correction for secondary pollen in the samples from the lower part of the series (Fig. 8 and p. 23). The size measurements of *Betula* pollen show that *Betula nana* and *Betula pubescens* (also *Betula tortuosa* is included) are represented at 5.50 m (see p. 28 and Fig. 9).

*Betula verrucosa* immigrated later to Scania during the Alleröd period. Even if *Betula pubescens* did not grow in the Skurup area, it would have occurred at favoured places in the vicinity so quite a lot of pollen has been transported to the sedimentation basin by wind or/and water. With the exception of some scattered *Betula pubescens* the arctic or sub-arctic park-tundra consisted of *Salix*, *Betula nana*, and possibly of scattered *Juniperus* stands. Among the herbs there were *Gramineae*, *Cyperaceae*, *Artemisia*, *Caryophyllaceae*, *Compositae*, *Filipendula* and *Ranunculaceae*. No pollen of aquatic plants have been noted, but on the other hand there are green algae like *Pediastrum* and *Botryococcus*,



ANN-MARIE ROBERTSSON 1968

richly at 5.50 m (*Botryococcus* is not shown in the diagram). This production of green algae may indicate a climatic amelioration. The supply of minerogenic material is reduced, as the organic production is rising which is also reflected in the sediment-analytical diagram (Fig. 10). As an alternative these changes can be regarded as fixed organic productivity but reduced supply of minerogenic material.

### Older Dryas (zone DR 2)

During Older Dryas the climate became more severe and the recession of the ice was stopped. In Sweden the glacial frontier was in the beginning situated not far from the western coast and kept an west-eastern course south of Bolmen and towards Kalmar (Moslätt-Berghemlinjen, see Mörner 1969, p. 128).

In the pollen diagrams the cooler climate is reflected by a dislocation southwards of the so-called park-tundra. It was replaced in southern Scandinavia and northwestern Europe by a treeless tundra with shrubs and herbs. Among others higher values of *Salix* and *Juniperus* show a more open vegetation. Minima of *Juniperus* in the Late-Glacial zones may be interpreted in two ways (Iversen 1954):

a) when the vegetation is getting more dense *Juniperus* due to its great demand of light is suppressed by trees;
b) if the climate is getting cooler and the snow-sheet deeper, *Juniperus* becomes sterile and does not produce any pollen.

The NAP curve of the total diagram is rising during the Older Dryas, whereas AP is decreasing.

*Skurup.* The Older Dryas is represented by muddy clay at 5.30–5.45 m. *Betula pubescens* type decreases at the same time as *Salix, Betula nana* type and *Artemisia* increase somewhat. At the same time the curves of redeposited pollen, spores, hystrichospheres and dinoflagellates rise. No aquatic pollen have been observed in the samples below 5.35 m. The relatively high age of the $C^{14}$-dating of the muddy clay at 5.30–5.45 m, 10 030 ±145 B.C., shows that Older Dryas and also the Bölling oscillation are represented in the lower part of the Skurup section.

### Alleröd (zone AL)

The Alleröd interstadial, described for the first time by Hartz and Milthers 1901, has later been registered in many pollen diagrams from southern Scandinavia, other European countries and the USA. The rise of temperature, which characterizes the beginning of Alleröd, caused that the almost treeless tundra in southern Sweden and adjacent areas gradually was replaced by scattered woods. Small tree-stands mainly consisting of birch made it possible for light-demanding shrubs and herbs to thrive. The pine was immigrating to Sweden from southeast and thus first occurred in Blekinge and southeastern Scania, before spreading westwards. In Denmark (except Bornholm) and in the main part of Scania the birch was the only tree growing during the Alleröd period (Iversen 1947, 1954, Krog 1954, se also Fig. 5). Pollen diagrams from Poland, Bornholm and Blekinge show however that *Pinus* immigrated to these areas during the Alleröd. Towards the east and southeast (Poland and the Baltic states) *Pinus* was the dominating tree during the latter part of Alleröd, at least within areas with sandy dry soils (Pirrus 1969, Ralska-Jasiewiczowa 1966, Wasylikowa 1964). During the whole Alleröd *Betula* has much higher values than *Pinus* in pollen diagrams from the following investigated sites (see Fig. 5):

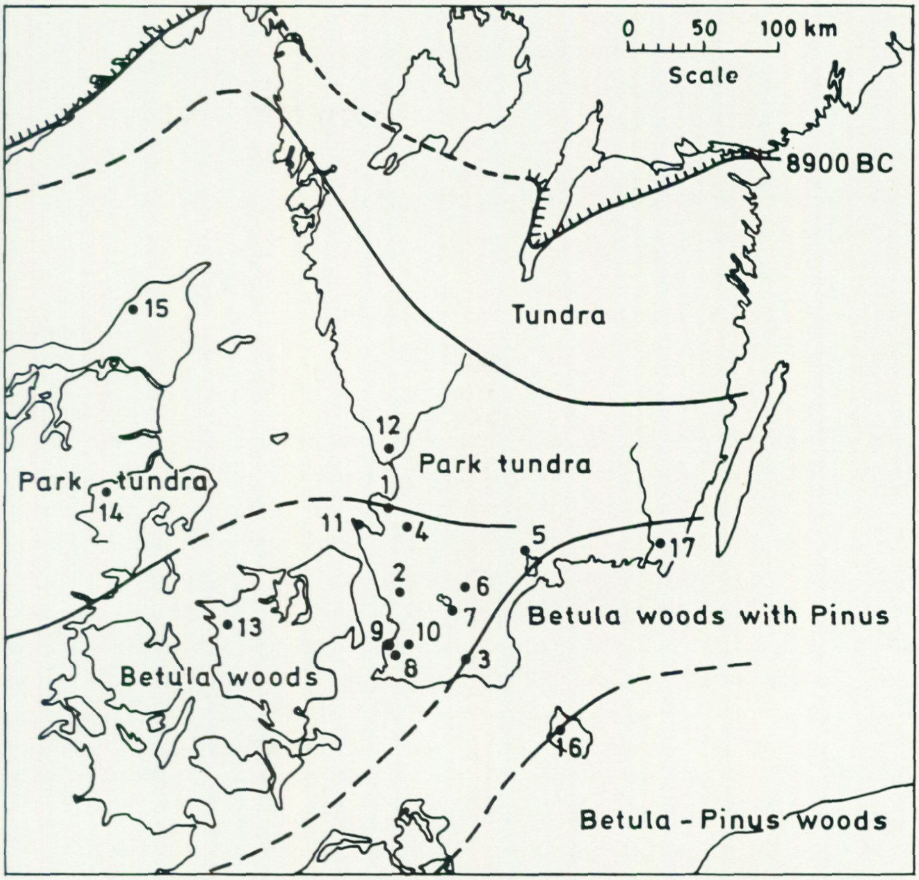


Fig. 5. Survey map of the vegetation during the Alleröd period. After Berglund 1966. The sites numbered are referred to in the text (p. 17).

Scania:
1. Stora Ellemossen (T. Nilsson 1935)
2. Baremosse (T. Nilsson 1935)
3. Bjärsjöholmssjön (T. Nilsson 1935)
4. Ramnasjön (T. Nilsson 1935)
5. Kaffatorps mosse (T. Nilsson 1935)
6. Store mosse (T. Nilsson 1935)
7. Lyby mosse (Magnusson 1962)
8. Ö. Grevie (Berlin and Mohrén 1942)
9. Hindby mosse (Welinder 1969)
10. Torreberga (Berglund and Digerfeldt 1970)
11. a) Mölle mosse (Berglund 1971)
    b) Håkulls mosse (Berglund 1971)
    c) Björkeröds mosse (Berglund 1971)

Halland: 12. Danstorpsmossen (Linnman 1966)
Denmark: 13. Ruds Vedby (Krog 1954)
14. Böllingsö (Iversen 1954)
15. Nörre Lyngby (Iversen 1942, 1954)

*Pinus* has higher values than *Betula* during the latter part of Alleröd in the following diagrams:

Denmark/
Bornholm: 16. Vallensgård mose (Iversen 1954)
Blekinge: 17. Lösensjön (Berglund 1966)

A division of the Alleröd into three subzones (a, b and c) was made by Iversen 1954 (see also Krog 1954) and represents two warmer phases (a, c) separated by a cooler one (b). Several facts show that the rise of temperature during Alleröd did not go on unceasingly. The *Betula* curve has in most Danish diagrams two maxima separated by a minimum. The maximum of the temperature occurred during the latter part of Alleröd in subzone c. The typical so-called fork-formed *Betula* curve is also found in some Swedish diagrams, e. g. Hindby mosse (Welinder 1969). The Danish trisecting of Alleröd has not been recognized in the northern German and Polish pollen diagrams. There are instead two phases during Alleröd: at first *Betula* is dominating, then *Pinus* is represented by higher values than *Betula* (Overbeck 1949, Averdieck 1957, Ralska-Jasiewiczowa 1966, Wasylikowa 1964).

*Skurup. Betula* occurs during the whole Alleröd period with high values (40–60 %). The maximum at 4.35–4.45 m depth may partly be due to local pollen production from birches growing within the semi-terrestrial zone where the fen wood peat was formed. *Pinus* does not reach above 26 % but is on the average represented by about 10 %. These values are so low that it is considered to be long-distance pollen. In pure birch wood *Pinus* pollen may be found in soil samples with values up to 25 %, without any pine growing within the wood (Aario 1940). Above 25 % *Pinus* in the pollen spectra means that some single pines could have grown within the woods. The birch wood around the sedimentation basin in Skurup has probably been rather open as *Juniperus* is represented with relatively high values (10–15 %).

*Salix* occurs with considerably lower values during Alleröd than during Older and Younger Dryas. *Empetrum*-heaths which are characteristic for leached soils (poor in lime) seem to have had subordinate extension in southwestern Scania during Late-Glacial times. Same conditions were prevailing also in the part of Denmark with calcareous soils (Krog 1954). On Mt Kullen in northwestern Scania *Empetrum* occurred as an element of the lower shrub vegetation during the latter part of Alleröd and above all, during Younger

Dryas and the transition zone DR 3/PB (Berglund 1971). In Skurup relatively thermophilous herbs occur during Alleröd and e.g. *Filipendula* has a more or less continuous curve. Pollen of Late-Glacial stepp-elements like *Ephedra, Helianthemum, Artemisia* and *Chenopodiaceae* occur in the Skurup series and reach their maxima during Older Dryas and the first part of Alleröd. Their presence also clearly indicate that no closed forests existed during Alleröd. Green algae, e. g. *Pediastrum* and *Botryococcus,* were richly represented in the clayey gyttja. Also aquatic plants like *Potamogeton, Myriophyllum, Nymphaea* and *Typha-Sparganium* were found in the Alleröd samples. The frequency of green algae and diatoms decreases when peat is formed (Fig. 4 and 10).

Another possible interpretation of the Skurup series is that the sediments between 4.30–5.60 m are of Alleröd age. Then 5.45–5.55 m should represent subzone a, 5.30–5.45 m subzone b, and 4.30–5.30 subzone c of the Alleröd interstadial. In this case the cooler part (subzone b) coincides with the so-called Taberg advance of the ice-sheet. This oscillation has been dated at about 9 200 B.C. (E. Nilsson 1968). Then, however, the two $C^{14}$-datings have given too high ages (800–900 years too old for the lower sample and 300–400 years too old for the upper, see p. 31). This may be caused by Mesozoic and Palaeozoic lime present in the sediments at the beginning when the lake was formed.

### Younger Dryas (DR 3)

The recession of the ice-sheet retarded during DR 3 and the composition of the terminal moraines in central Sweden took place. The colder climate was reflected by a dislocation southwards of the vegetational zones. In the pollen diagrams this clearly appears as lower values for AP *(Betula)* and increasing percentages for NAP. Concerning climate and vegetation the conditions remind of those during DR 2. The sediments are generally more minerogenic during DR 3 than during Alleröd due to slumping or solifluction (see p. 9).

*Skurup*. In the Skurup section only the beginning of Younger Dryas is represented. The content of minerogenic material in the fen wood peat increases at 4.20–4.30 m. Arboreal birch decreases to 30 ⁰/₀. *Salix* and *Betula nana* type increase while *Juniperus* decreases. Among herbs the values of *Gramineae, Cyperaceae, Caryophyllaceae* and *Chenopodiaceae* are higher than during Alleröd.

*Skurup Lms*. Younger Dryas is represented by clayey gyttja at the bottom of the analysed sample series (Fig. 6). Arboreal birch has low values. Shrubs like *Salix* and *Betula nana* type as well as some herbs, e. g. *Gramineae, Cyperaceae* and *Artemisia* occur with rather high percentages.

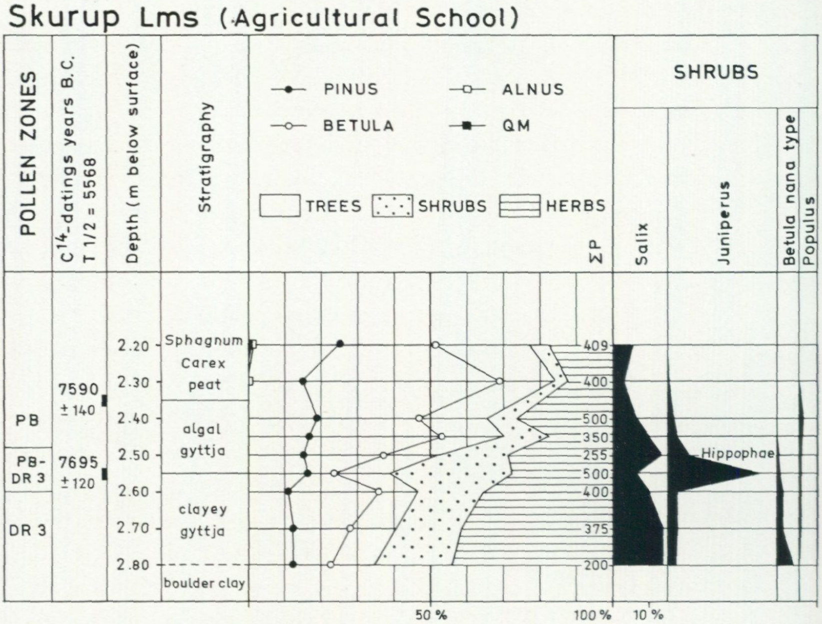
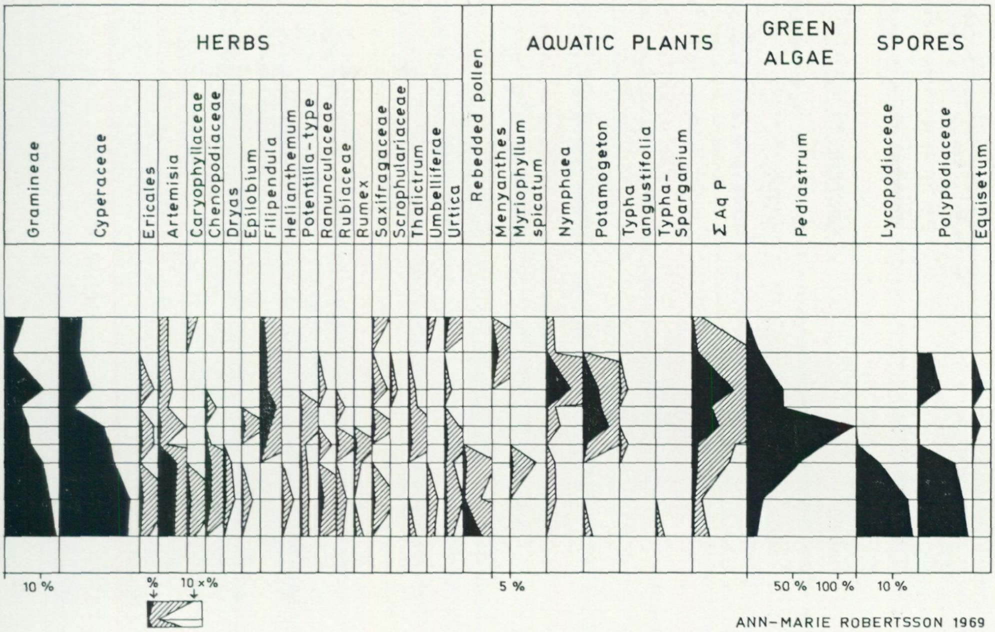


Fig. 6. Pollen diagram from the Skurup Lms section.

### Transition zone Younger Dryas/Pre-Boreal (DR 3/PB) and Pre-Boreal (PB)

The boundary of Younger Dryas/Pre-Boreal is very clearly identified by means of varve-chronology. Also biostratigraphically the boundary is usually easy to recognize in southern Scandinavia. In fresh-water deposits it appears as a transition from more or less minerogenic to purely organogenic sediments (T. Nilsson 1935, 1961, 1965, and others). In the pollen diagrams the lower boundary of the Pre-Boreal is characterized by reduced NAP values and increasing AP values. During Pre-Boreal time arboreal birch mostly reaches its highest values, at least in southern Sweden and in Denmark. Among the herbs *Artemisia* decreases together with *Helianthemum* and other light-demanding plants. Iversen, in his Late-Glacial diagrams, distinguished a special transition zone between Younger Dryas and Pre-Boreal (Iversen 1954). There was a short period when open plant communities with shrubs and scattered trees turned into closed forests. A certain delay of the expansion of woods in proportion to the sudden rise of the temperature can be traced in the beginning of the Pre-Boreal: "The forest development could not keep step with the climatic improvement" (Iversen 1954, p. 98). This transition zone, DR 3/PB, has been described from eastern Blekinge, northwestern Scania (Berglund 1966, 1971) and southwestern Scania (Digerfeldt 1971). The climate in Scania changed from sub-arctic during Younger Dryas to a coolish temperated one in the Pre-Boreal.



*Skurup Lms.* To get a detailed picture of the transition zone when more or less woodless vegetation was replaced by *Betula* forest (DR 3/PB) the intervals of the samples analysed should be short. In the Skurup Lms section only two samples, 2.50 and 2.55 m, represent the zone mentioned (Fig. 6). Herbs and shrubs dominate the pollen spectrum. There is a distinct *Juniperus* maximum at 2.55 m, and also some pollen of *Populus* were found. The *Juniperus* maximum shows that a change from a treeless or dispersedly wooded vegetation to a dense forest is taking place. *Artemisia, Betula nana* type, *Salix* and *Gramineae* together with *Cyperaceae* decrease upwards. The rising temperature is reflected also by higher frequencies for relatively thermophilous plants such as *Filipendula*. The deposition of algal gyttja begins with the expansion of different aquatic plants. In turn, *Myriophyllum spicatum, Pediastrum, Potamogeton, Nymphaea* and *Menyanthes* have distinct maxima. Except *Pediastrum* also other green algae (like *Tetraëdon)* were present but have not been included in the pollen diagram. Their occurrence is evident from the sediment-analytical diagram (Fig. 11). According to the two $C^{14}$-datings the algal gyttja has been deposited within about 100 years (7 695–7 590 B.C.). The age is probably somewhat too young when taking into consideration that the boundary Younger Dryas/Pre-Boreal is fixed at 8200–8100 B.C. (see p. 31) according to varve-chronology and radiocarbon datings (Tauber 1970).

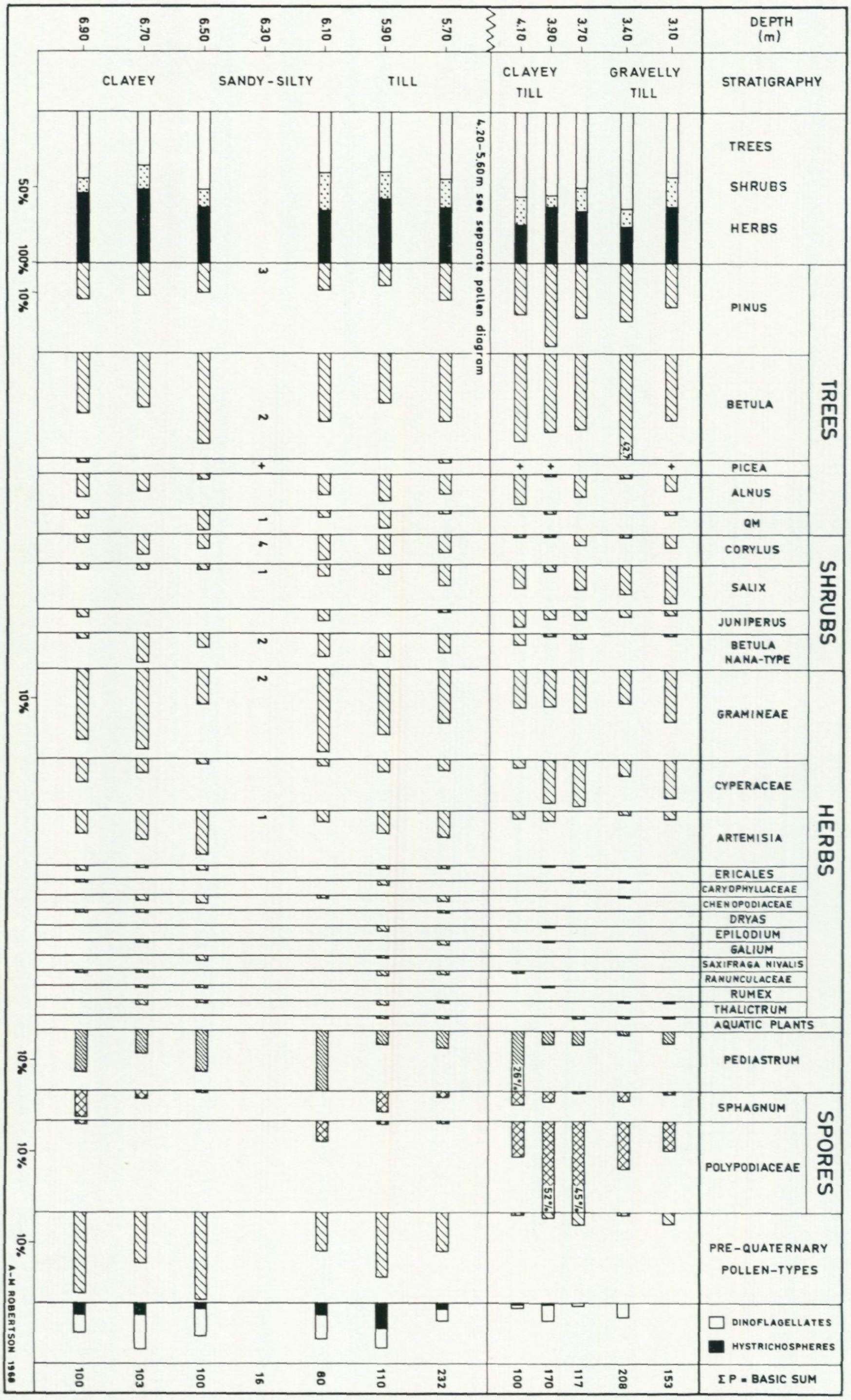


Fig. 7. Pollen analyses of till samples from the Skurup section.

## Pollen analyses of till samples

In the Skurup section pollen analyses of samples of (clayey) gravelly till at 3.10–4.20 m as well as of clayey (sandy-silty) till at 5.70–6.90 m were made for the following reasons:

a) to correct the lower part of the pollen diagram regarding redeposited pollen;
b) to see if the till layers were homogeneous as to the contents of pollen and spores both within and between the two layers.

The results of the analyses are represented in Fig. 7 and Table 1. The basic sum is the sum of pollen from all trees, shrubs and herbs (consequently also of trees like *Alnus*, *QM*, *Picea* and *Corylus)*. On the other hand pollen of aquatic plants and pre-quaternary species are not included, nor spores, hystrichospheres and dinoflagellates.

a) Correction of redeposited pollen in the lower part of the Skurup series at 5.30–5.60 m depth has been carried out according to Iversen (1936, 1942). This method is based on the hypothesis that the secondary pollen flora in more or less minerogenic sediments, for example clayey gyttja and muddy clay, is thus to be found in the till, out of which the minerogenic material originates. After the correction (see Fig. 8) the *Betula* maximum at 5.55 m is somewhat more accentuated. Likewise the decrease of the *Betula* curve appears more

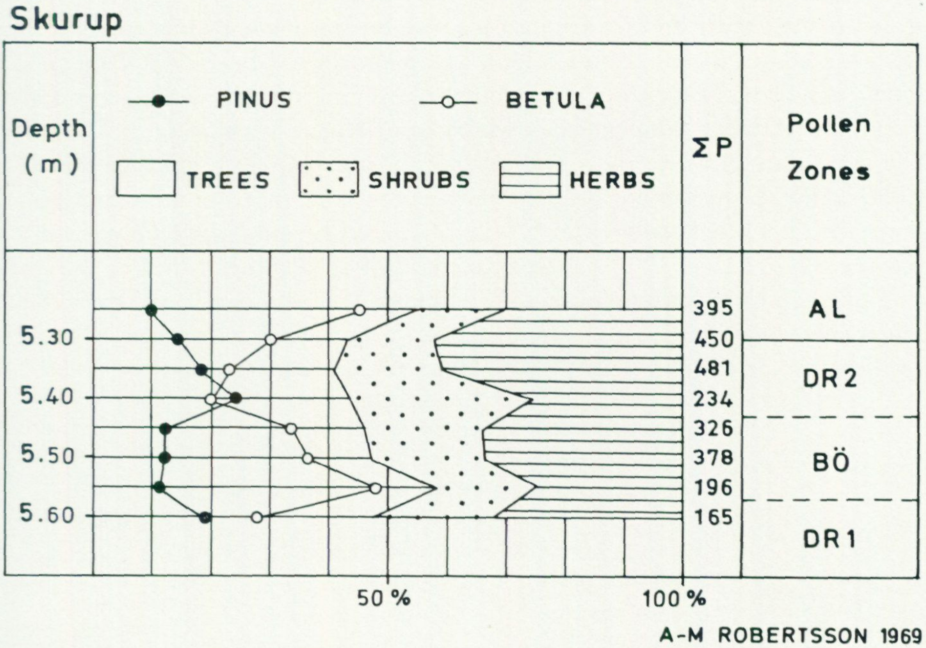


Fig. 8. Part of the Skurup pollen diagram after subtraction of redeposited pollen.

clearly at the 5.40 m sample. Higher up in the series (above 5.30 m) there are very low frequencies of redeposited pollen (see Fig. 4). The curves of the Late-Glacial flora elements do not change very much after a recalculation.

b) The homogenity within the respective till layers is relatively great. Also between themselves the two till layers show rather similar spectra. The greatest differences are as follows:

| | clayey till 5.70–6.90 m average value (%) | gravelly till 3.10–4.10 m average value (%) |
|---|---|---|
| *Betula nana* type | 6.8 | 1.2 |
| *Salix* | 4.1 | 8.3 |
| *Artemisia* | 8.8 | 2.2 |
| *Cyperaceae* | 4.0 | 10.5 |
| *Compositae* | – | 1.7 |
| dinoflagellates | 3.7 | 0.3 |
| hystrichospheres | 6.7 | 2.9 |
| pre-quaternary pollen types | 19.8 | 2.4 |
| *Polypodiaceae* spores | 1.2 | 26.6 |

Pollen and spores found in the clayey till but not in the gravelly till are represented by *Dryas* and *Saxifragaceae.* Species registered in the gravelly till but not noted in the clayey till belong to *Compositae, Filipendula, Potentilla, Botrychium* and *Selaginella.* The contents of micro-fossils within the two layers are relatively homogeneous which can be seen in the diagram, Fig. 7. The confirmity between these two layers is also great which sustains the hypothesis that the material is originating from the same till from the very beginning. The rather high values of e. g. *Salix, Cyperaceae* and *Polypodiaceae* show that the till at 3.10–4.20 m has been exposed after the withdrawal of the ice, for plants which first immigrated to the tundra. It is also confirmed by higher pollen frequencies in the gravelly till (3.10–4.20 m) with an average value of 6 pollen/turn. In the clayey till (5.70–6.90 m) the average frequence was only 2.

**Table 1. Comparison between the micro-fossil contents of the two till layers at Skurup**

| | clayey till 5.70–6.90 m | | gravelly till 3.10–4.20 m | |
|---|---|---|---|---|
| | variation: lowest and highest value % | average value for all samples % | variation: lowest and highest value % | average value for all samples % |
| AP (Trees): | | | | |
| *Picea* | 0 – 1.0 | 0.4 | 0 – 0.2 | 0.1 |
| *Pinus* | 7.4–12.0 | 10.8 | 14.4–27.1 | 19.5 |
| *Betula* | 16.5–32.0 | 22.0 | 22.2–42.7 | 31.1 |
| *Alnus* | 2.0– 9.2 | 6.2 | 0.6–10.0 | 4.1 |
| *QM (Quercus, Ulmus, Tilia)* | 0 – 7.0 | 2.9 | 0 – 1.3 | 0.5 |
| Sum | 35.0–51.0 | 42.3 | 43.3–64.0 | 55.3 |
| Shrubs: | | | | |
| *Corylus* | 3.0– 8.7 | 6.2 | 0.6– 4.6 | 2.0 |
| *Betula nana* type | 2.0– 9.5 | 6.8 | 0.6– 4.0 | 1.2 |
| *Salix* | 1.8– 6.9 | 4.1 | 2.4–13.1 | 8.3 |
| *Juniperus* | 0 – 3.8 | 1.1 | 2.0– 6.0 | 3.2 |
| Sum | 10.0–25.0 | 18.2 | 7.7–20.2 | 14.7 |
| NAP (Herbs): | | | | |
| *Gramineae* | 12.0–27.5 | 20.5 | 11.5–17.6 | 13.5 |
| *Cyperaceae* | 2.0– 8.0 | 4.0 | 3.0–15.4 | 10.5 |
| *Ericales* | 0 – 2.0 | 1.1 | 0 – 0.9 | 0.3 |
| *Artemisia* | 3.8–15.0 | 8.8 | 0 – 3.5 | 2.2 |
| *Caryophyllaceae* | 0 – 1.8 | 0.5 | 0 – 0.9 | 0.3 |
| *Chenopodiaceae* | 0 – 3.0 | 1.4 | 0 – 0.5 | 0.1 |
| *Compositae** | – | – | 0 – 2.9 | 1.7 |
| *Dryas* | 0 – 1.0 | 0.3 | – | – |
| *Epilobium* | 0 – 1.8 | 0.3 | 0 – 0.6 | 0.1 |
| *Filipendula** | – | – | 0 – 1.0 | 0.3 |
| *Galium* | 0 – 1.3 | 0.4 | 0 – 0.6 | 0.1 |
| *Potentilla* type* | – | – | 0 – 0.6 | 0.1 |
| *Ranunculaceae* | 0 – 1.8 | 1.0 | 0 – 1.0 | 0.1 |
| *Rumex* | 0 – 1.0 | 0.3 | 0 – 0.6 | 0.1 |
| *Saxifragaceae* | 0 – 2.0 | 0.5 | – | – |
| *Thalictrum* | 0 – 0.4 | 0.3 | 0 – 0.6 | 0.1 |
| *Umbelliferae** | 0 – 0.4 | 0.1 | 0 – 0.3 | 0.5 |
| Sum | 35.0–49.0 | 39.5 | 22.5–37.5 | 30.0 |
| Extraneous to the basic sum: | | | | |
| Spores: | | | | |
| *Sphagnum* | 0 – 9.0 | 3.7 | 0.9– 5.0 | 3.0 |
| *Polypodiaceae* | 0 – 7.5 | 1.2 | 9.8–51.8 | 26.6 |
| *Lycopodiaceae** | 0 – 2.0 | 1.1 | 0 – 1.0 | 0.4 |
| *Bothrychium** | – | – | 0 – 2.0 | 0.5 |
| *Selaginella** | – | – | 0 – 0.6 | 0.1 |
| *AqP* (aquatic plants) | 0 – 2.0 | 0.7 | 0 – 0.9 | 0.4 |
| *Pediastrum* (green algae) | 8.0–21.3 | 9.8 | 1.4–26.0 | 6.7 |
| Pre-quaternary pollen types | 12.5–29.0 | 19.8 | 1.0– 4.3 | 2.4 |
| dinoflagellates | 2.0– 7.3 | 3.7 | 0 – 0.9 | 0.3 |
| hystrichospheres | 3.8–12.0 | 6.7 | 0 – 5.9 | 2.9 |

* = not represented in the diagram.

## Size measurements of Betula pollen

There have been many investigations made to separate pollen of *Betula nana* from the other *Betula* species by means of size measurements. Both recent and fossil material have been used (Faegri 1935, Eneroth 1951, Iversen 1954, Wenner 1947, 1953, Andersen 1961, Birks 1968, Florin 1969, Berglund and Digerfeldt 1970). On account of different concentration methods and embedding media various average values of the size of different *Betula* species have been achieved. Careful comparisons between the size variations of fossil and recent *Betula* pollen have been carried out by Berglund (1970). He assumes that the dislocation of the size frequencies of *Betula* pollen to a smaller average size in Younger Dryas sediments compared with Alleröd, is due to the increase of *Betula nana* during DR 3. Birks (1968) has tried to separate *B. nana* from the other species by the ratio grain size/pore depth. This method makes it difficult to separate *B. nana* from *B. tortuosa.* Morphologically there are differences between *B. nana* and *B. pubescens,* as well as between *B. verrucosa* and *B. tortuosa.* Both size measurements and pollen-morphological observations were made at the analyses of the Skurup series.

It has been proved that the size of the same *Betula* species varies quite a lot due to the type of sediment in which the pollen grains have been embedded. From a general point of view it seems that the pollen in pure peat (highly humified) have a bigger average size than those in more or less muddy and minerogenic sediments (Wenner 1947, 1953, Florin 1969). As a comparison there may be mentioned M.-B. Florin's average values for *B. nana* and *B. pubescens* in fossil minerogenic material (Younger Dryas/Pre-Boreal). The samples have been treated with HF and acetolysis and embedded in glycerin (the same treatment as carried out with the Skurup samples):

| | | |
|---|---|---|
| *B. nana* | 20–23 | (16–26) microns |
| *B. pubescens* | 24–28 | (23–31) ,, |

(M.-B. Florin 1969, p. 146).

The treatment of the sample effects the size of the pollen grains. Boiling in HF affects the pollen grains to decrease in size, while the acetolysis makes the pollen grains swell. Measuring *Corylus* pollen in algal gyttja Christensen obtained the following results (Christensen 1946, p. 17):

Hydrofloric acid treatment: "As to be expected, the result was that the size of pollen grains had diminished a little but not so much as might perhaps been assumed after the experience of others. It may turn out that the pollen grains in clayey gyttja are smaller than in other gyttjas and peats, so that treatment with HF may perhaps be only partly to blame for the familiar small size of pollen in analyses of this kind".

Acetolysis after HF treatment: ". . . naturally caused the pollen to swell

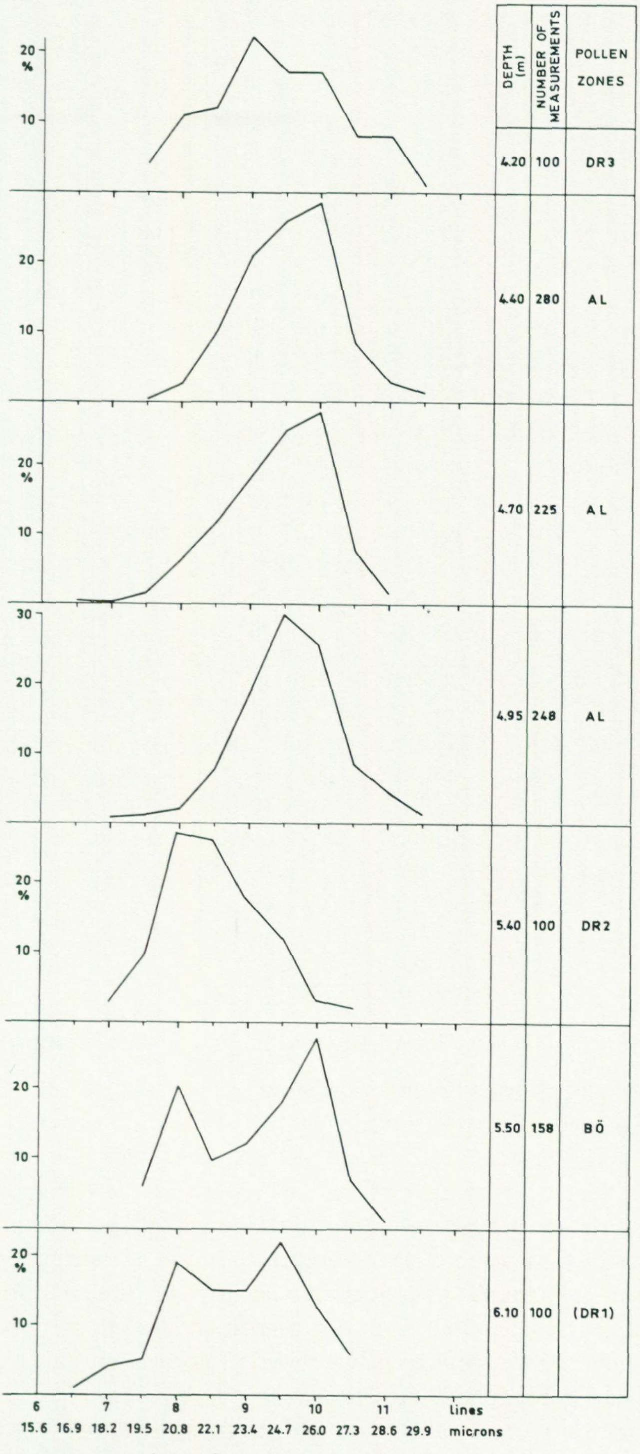


Fig. 9. Size measurements of *Betula* pollen. Distribution of size frequencies calculated as % of the number of measurements.

again, but not to the same size as the pollen from the sample acetolysed on the ordinary basis. The increase in size was also relatively smaller, which means that the HF treatment endowed the pollen grains with a certain intensivity to acetolysis almost the same as was described above in respect of the recent samples".

Results of the size measurements of the Skurup samples: As it appears from the curves of Fig. 9 there is a very remarkable dislocation of the size distribution at 5.50–5.40 m. The top at 26 microns, which is to be found at the 5.50 m sample, is missing at 5.40 m. Even if it is difficult to state any average size for *B. nana, B. pubescens* and *B. tortuosa* (the only species concerned during Older Dryas and Bölling) the curve of the 5.50 m sample indicates that different *Betula* species could have been growing around the lake. The maximum at 20.8 microns of the 5.40 m sample certainly consists mostly of *B. nana* even if there may be some percentage redeposited older *Betula* pollen. During Older Dryas the climatic deterioration caused a dislocation southwards for arboreal birch which had immigrated to Scania during the Bölling interstadial (see p. 16). *B. nana,* on the other hand, plays a more important role during Older Dryas and is included in the tundra vegetation which at that time occupied southern Scandinavia. During Alleröd (represented by the 4.95, 4.70 and 4.40 m samples) *B. pubescens* and *B. tortuosa* were spread to this area. In the 4.20 m sample (Younger Dryas) the distribution of size frequencies is characterized by lower average values again. The explanation is that the subarctic elements in the flora had increased. The deterioration of the climate during Younger Dryas lasted 700–800 years. In the Skurup diagram, however, only the first part of this period is represented. *Betula* pollen of size 20.8 microns increase from 5.0 % to 15 %. The results of the size measurements are confirmed by the frequencies of pollen of *B. nana* type noted at the pollen analyses (see Fig. 4).

## SPECIAL ANALYSES

### Sediment analyses ("strukturanalys") and loss on ignition

As a complement to the ocular classification of the sediments, "strukturanalys" was carried out according to G. Lundqvist 1927 (p. 21), to show the variations of organic material contra inorganic in the samples. This method is relative and gives no exact values either of volume or weight of the different components. Therefore also determination of loss on ignition was made. At the sediment analyses first some slides were prepared with a suspension of sediment in water and glycerin to see if there was any humus left in the samples. As this was not the case, about 5 mm$^3$ of the material was dissolved in 10 % KOH and boiled a few minutes in water-bath. Thereafter followed washing with dest. water, centrifuging and decanting. Two drops of the remaining material were put on an object glass together with a drop of glycerin. At the microscopical analyses a 250x magnification was used. A measuring-scale, divided into 50 lines, was used, every line corresponding to about 6 microns. With the aid of the cross-board the slides were divided into a certain number of squares evenly distributed on the cover glass. 1 000 lines of minerogenic and organogenic particles were counted. A division of different components was made in the following way:

a) mineral particles smaller than 6 microns = clay and fine silt
6– 20 „ = medium silt
20–100 „ = coarse silt and fine sand
b) coarse detritus = plant fragments with recognizable cell structure
c) fine detritus = unidentifiable small plant remains
d) mosses
e) pollen and spores
f) diatoms
g) algae
h) chitin

When summing up the diagrams (see Fig. 10 and 11), one signature was used for the minerogenic material (the three different size groups were added). Mosses and chitin were so rare that they were not included in the diagram.

*Skurup*. The minerogenic matter is dominating except in the fen wood peat at 4.30–4.45 m depth (Fig. 10). There is a maximum for fine detritus at 5.50 m, coinciding with the Bölling interstadial (see pollen diagram Fig. 4 and p. 15). During the climatical improvement the supply of minerogenic material diminished and the organic content rised from 7 to 14 %. The percentages of pollen, spores and diatoms also rise. Furthermore, the richness of diatom species is striking at the 5.50 m sample (see Table 6). During Alleröd the distribution between organogenic and minerogenic material is relatively constant. In Younger Dryas the supply of minerogenic matter is increasing again.

*Skurup Lms*. The results of the sediment analyses and loss on ignition are shown in Fig. 11. In the clayey gyttja at 2.55–2.80 m the minerogenic material is dominating. The algal gyttja at 2.35–2.55 m consists of different *Scenedesmus, Pediastrum* and some *Desmidiaceae* species. At low magnification the algae were sometimes difficult to separate from the fine detritus and may be represented with somewhat too low values in the diagram. At 2.35 m the gyttja changes into *Sphagnum – Carex* peat. In the peat the coarse detritus consists of stems and leaves of *Sphagnum, Amblystegium* and *Carex*. It is quite remarkable that *Sphagnum* has grown in such a lime-rich area as Skurup. Gertz has investigated a small fen near the church of Skurup about 1 km west of Lantmannaskolan (Gertz 1927). The stratigraphy included a 40 cm thick layer of *Vaucheria* gyttja containing relics of *Sphagnum*. Gertz explains the possibility of *Sphagnum* to grow within the Skurup area by assuming that

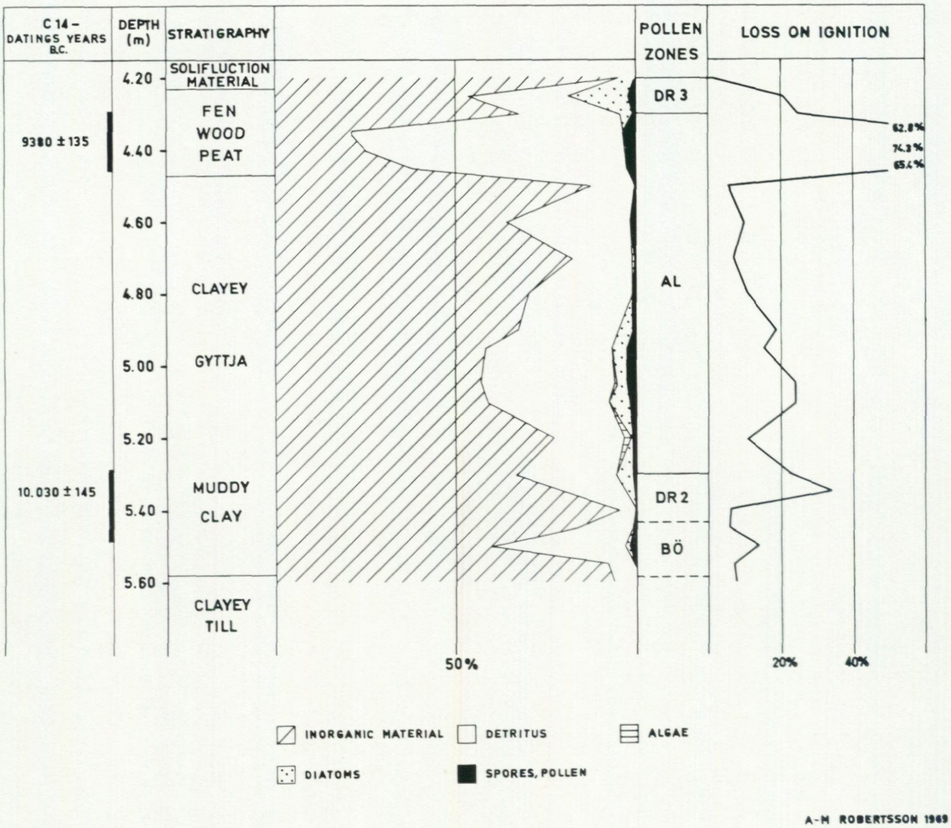


Fig. 10. Sediment analyses of the Skurup section.

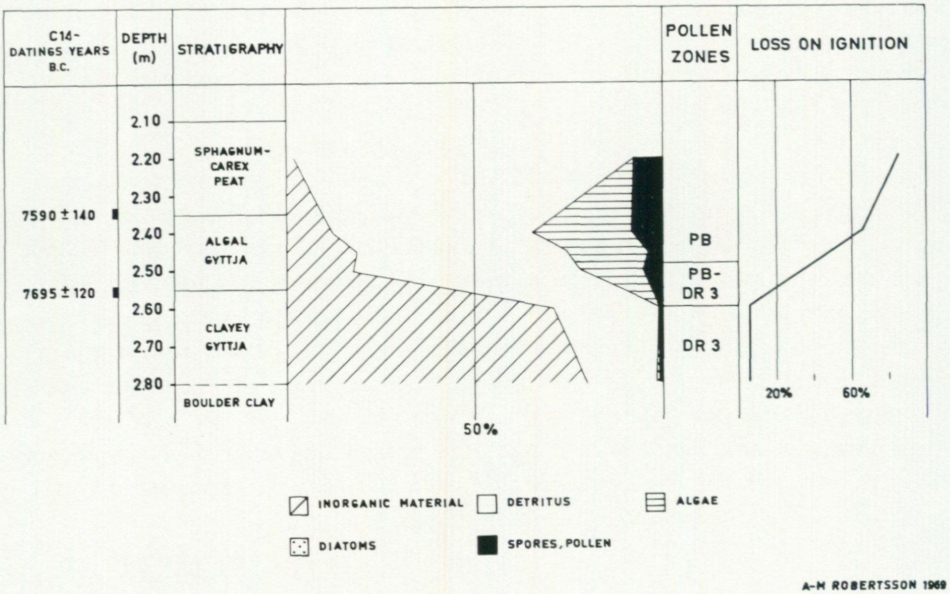


Fig. 11. Sediment analyses of the Skurup Lms section.

water from Romeleåsen with nearly no content of lime had overflowed this area, and contributed to that these mostly lime-avoiding mosses could grow there. The same may be the case with several other small fens within this area, for example at Lantmannaskolan.

## Radiocarbon datings

Two samples from the Skurup section have been $C^{14}$-dated with the following results (half-life 5 568 years):

St 2547 4.30–4.45 m fen wood peat 9 380 ± 135 B.C.
St 2548 5.35–5.50 m muddy clay 10 030 ± 145 B.C.

The high age of the sample at 5.35–5.50 m (4 samples added at the $C^{14}$-analyses) sustains the hypothesis that the Bölling oscillation is represented in the series. When comparing varve-chronological data with $C^{14}$-values (conventional dates), it appears that the boundaries of the Bölling interstadial and other Late-Glacial zones are stated as follows (Tauber 1970, Table 5):

| pollen zone | varve-chronological data | $C^{14}$-datings ($T^{1/2} = 5\ 568$ years) |
|---|---|---|
| BÖ | 10 200–9 900 B.C. | 10 400–10 000 B.C. |
| DR 2 | 9 900–9 700 „ | 10 000– 9 800 „ |
| AL | 9 700–8 900 „ | 9 800– 9 000 „ |
| DR 3 | 8 900–8 100 „ | 9 000– 8 200 „ |

Tauber has calculated these boundaries by means of E. Nilsson's values for the mean rate of ice recession (Tauber 1970, p. 183 and Table 3). The boundaries have been put where the recession has a marked increase or decrease. Furthermore, there are many $C^{14}$-dated Late-Glacial samples from northwestern Europe, where except Alleröd also Bölling is well represented in the pollen diagrams, e. g. Usselo in Netherlands (van der Hammen 1952, 1957, Tauber 1960, 1961) and Witow in Poland (Wasylikowa 1964, Tauber 1966).

If the above mentioned values are to be used, it would mean that Scania and a great part of the Swedish west-coast have been ice-free during Bölling (see Fig. 3). The sedimentation must then have started in many depressions where dead ice was not present. As the minerogenic part of these sediments is dominant (muddy clays and clayey gyttjas mostly) it will be difficult to get suitable material for $C^{14}$-datings. Shells of molluscs however from e. g. Fjärås bräcka have been dated to 10 600 B.C. (Wedel 1969).

The age of the upper $C^{14}$-sample of the Skurup series is probably somewhat too high if counted with the fact that the peat was formed during the warmest part of Alleröd (subzone c).

At Skurup Lms two samples have been $C^{14}$-dated, the lower and the upper boundary of the algal gyttja:

| | | | |
|---|---|---|---|
| St 3007 | 2.35 m | *Sphagnum-Carex* peat and algal gyttja | 7 590 ± 140 B.C. |
| St 3008 | 2.55 m | algal gyttja and clayey gyttja | 7 695 ± 120 B.C. |

According to the pollen analyses the algal gyttja should have been deposited at the beginning of the Pre-Boreal period 8 200–8 000 B.C. It is likely that a change from minerogenic to purely organogenic sediments already occurred during the first part of the Pre-Boreal. Thus the $C^{14}$-datings have stated a too low age of the algal gyttja.

**Table 2. Swedish $C^{14}$-datings of Late-Glacial sediments ($T^{1}/_{2}$ = 5 568 years)**

| Datings | Site | Material | Age B.C. | |
|---|---|---|---|---|
| Oldest Dryas and Bölling: DR 1, BÖ | | | | |
| Lu 270 | Grimbo, Bohuslän<br>(Hillefors 1969) | *Balanus* shells,<br>exterior fraction | 11 010 ± 135 | |
| Lu 270 | ” | interior ” | 10 930 ± 125 | |
| Lu 165–169 | Fjärås bräcka, Halland<br>(Wedel 1969) | *Mytilus* and *Balanus* shells,<br>exterior and interior fractions | 10 360 ± 650<br>11 140 ± 130 | |
| Lu 337 | Björkeröd, NW Scania | clayey calcareous gyttja | 11 430 ± 120 | DR 1 |
| Lu 338 | ” | | 10 820 ± 135 | BÖ |
| Lu 339 | ” | | 10 750 ± 110 | |
| | (Berglund 1971) | | 10 780 ± 135 | |
| Older Dryas: DR 2 | | | | |
| Lu 340 | Björkeröd, NW Scania<br>(Berglund 1971) | calcareous clay gyttja | 10 760 ± 90 | |
| St 2548 | Skurup, S Scania<br>(Robertsson 1973) | clay gyttja–muddy clay | 10 030 ± 145 | BÖ/DR 2 |
| St 2508 | Klinehögkärret, Halland<br>(Mörner 1969) | clayey silty mud | 9 820 ± 200 | |
| Alleröd: AL | | | | |
| St 341 | Toppeladugård, S Scania<br>(T. Nilsson 1959) | peat (Alleröd mould) | 10 040 ± 200 | |
| St 345 | ” | clay gyttja | 9 940 ± 180 | |
| St 1683 | Lösensjön, Blekinge<br>(Berglund 1966) | ” | 9 790 ± 170 | |
| Lu 200 | Hjärtum, Bohuslän<br>(Hillefors 1969) | *Mya* shells, exterior fraction | 9 640 ± 110 | |
| Lu 199 | ” | ” interior fraction | 9 590 ± 100 | |
| St 2547 | Skurup, S Scania<br>(Robertsson 1973) | fen wood peat | 9 380 ± 135 | |
| St 2168 | Lökeberga mosse, Bohuslän<br>(Mörner 1969) | muddy clay | 9 285 ± 235 | |
| St 2163 | Hålsjön, Halland<br>(Mörner 1969) | clay gyttja, muddy clay | 9 220 ± 240 | |
| St 2528 | Älgare mosse, Blekinge<br>(Berglund 1966) | clay gyttja | 8 965 ± 230 | |
| St 1420 | Igelsjön, Blekinge<br>(Berglund 1966) | ” | 8 850 ± 220 | |

# DIATOMS

## Review of diatom-analytical investigations of Late-Glacial fresh-water sediments

Already in 1906 a Late-Glacial series of samples from Toppeladugård in southwestern Scania was analysed in diatoms (Holst 1906, 1908). Later T. Nilsson investigated the same profile by pollen analyses (1935, p. 430 and 1959). The stratigraphy is:

| Holst 1906 | T. Nilsson 1935 | 1959 |
|---|---|---|
| 1. Late-Glacial clay, fresh-water deposit | clay | Younger Dryas clay |
| 2. a) "white" gyttja | clay gyttja | calcareous gyttja |
| b) „ clayey gyttja | muddy clay | clay gyttja – clayey gyttja |
| c) „ shell gyttja | clay gyttja | clay gyttja |
| 3. peaty layer or peat | peat | "Alleröd mould" |
| 4. sand | sand | sand |
| 5. till, low content of stones, upper part so-called "tärningslera" | boulder clay | boulder clay |

There are different opinions about the age of the sequence (T. Nilsson 1935, 1959, E. Nilsson 1968). Diatoms in the Toppeladugård section were identified by Östrup and Cleve-Euler in the layers 2a, 2c and 4 (Holst 1906, p. 11–13). Most species were noted in the shell gyttja (2c – 40 species) and the "white" gyttja (2a – 32 species), while in the sand layer (4) only 8 species were identified. Most diatom species found at Toppeladugård have also been noted in the Skurup sections (see Table 6).

In Denmark Iversen's Late-Glacial profiles from Böllingsö were studied with regard to their content of diatoms (Fjerdingstad 1954). There, as well as in the Skurup material, the genus *Fragilaria* is dominating during all Late-Glacial zones. At Böllingsö *Fragilaria* is represented as follows: DR 1: 77 %, BÖ: 96–98 %, DR 2: 84–86 %, AL subzone a: 54–95 %, DR 3: 33–86 % (valves in % of the total sum). At Skurup there are higher percentages of *Fragilaria* (see Table 3 and Table 6) in all the zones. During Late-Glacial times the lake at Böllingsö has, according to Fjerdingstad, been a constant alkaline water body, first of oligotrophic later of eutrophic character. The lake was eutrophic only during the warmer part of Alleröd (Alleröd in Böllingsö is divided into two subzones: a and b). These conditions appear from the proportional representation of diatoms and other algae and also from the proportions of different living-forms among the diatoms.

A Late-Glacial profile with fresh-water sediments from Fyn in Denmark was investigated by Foged (1965). During Alleröd the conditions of the water were oligotrophic-mesotrophic. Here *Fragilaria* occurs with very low frequencies while *Gomphonema* and *Cymbella* are represented by many species. Foged finds it impossible to date the profile only by means of diatom analysis. Furthermore, he considers it doubtful to make conclusions about climatic oscillations due to the fact that the composition of the diatom flora is changing. If water conditions (pH-value, supply of nutrients, alkalinity, water-level) are altered, also the composition of the diatom flora will change.

In northern Germany (Holstein) Late-Glacial lake deposits were studied by Dahm (1959, 1961) and Simonsen (1957). They both make the conclusion that Bölling and Alleröd are reflected by variations of the diatom flora, as the so-called boreo-alpine forms have their minimum in these periods. The occurrence or absence of boreo-alpine forms is not caused by climatical oscillations, but reflects certain trophic conditions.

Marciniak (1969) carried out diatom analyses of Late-Glacial sediments from the Mikolajki Lake in northeastern Poland. She found that the Bölling interstadial in the Mikolajki Lake was characterized by a diatom flora, dominated by plankton *(Stephanodiscus astraea* v. *minutulus, Cyclotella comta, Melosira ambigua, M. granulata* v. *angustissima)* and *Fragilaria brevistriata.* During DR 2 *Fragilaria* was represented by high values. At the boundary DR 2/AL the number of diatom species increased and plankton like *Cyclotella, Stephanodiscus* and *Melosira ambigua* became predominant. In DR 3 *Fragilaria* again was represented with high values (Marciniak 1969, Fig. 1). This change from a rich plankton flora (represented by *Stephanodiscus* and *Melosira)* during BÖ to dominance of epiphytes *(Fragilaria)* in DR 2 was probably partly connected with reduced water-depth of the lake.

In Lithuania investigations of the Late-Glacial diatom flora were made by Kabailiene (1968). The Late-Glacial diatom flora in sediments from three lakes was examined and the following assemblages of diatoms were predominant during Late-Glacial times:

| | |
|---|---|
| BÖ: | *Fragilaria pinnata, F. brevistriata, Gyrosigma attenuatum* |
| DR 2<br>AL<br>DR 3 | *Cyclotella comta, C. kützingiana, C. meneghiniana, Fragilaria construens, F. lapponica, F. brevistriata, Synedra ulna, Navicula oblonga, Amphora ovalis, Melosira arenaria, M. italica, Stephanodiscus astraea* |

The composition of the Late-Glacial diatom flora in the Lake District, England, was studied by Round 1957.

In northeastern USA (Kirchner Marsh, southeastern Minnesota) the development of the Late-Glacial diatom flora was investigated by M.-B. Florin

(Florin and Wright 1969, Florin 1970). This material, however, represents quite different water conditions and changes of the diatom flora, compared with above mentioned investigations. Citing the author: "The sequence of diatom zones records the development of a small superglacial lake on the slightly reworked plant debris of a superglacial forest soil. Zone 1 is represented by euterrestrial forms, zone 2 is dominated by benthic aquatic forms. Zone 3 contains benthic aquatic forms representing the first truly limnic stage. Zone 4 is represented by pelagic species, as water depth increased in the basin" (Florin 1970 p. 667).

## Methods of concentration and preparation

All 64 samples from the Skurup section and 7 from the Skurup Lms section were treated with chemical and mechanical methods for diatom analysis. The method of concentration was as follows (see Miller 1964, p. 13):

1) Lime was removed by treating the samples with cold 10 % HCl.
2) Boiling with 10 % $H_2O_2$ in water-bath to bleach and destroy the organic matter.
3) Repeated suspension in destilled water, sedimentation (about 2 hours) and decanting the wash water to eliminate the colloidal clay.

At the preparation of slides Caedax (synthetic Canada balsam) was used as embedding medium (refraction index = 1.55 at 20° C.).

Samples for studies in the scanning electron microscope (SEM) were prepared in accordance with Miller (1969, p. 8). The photo-micrographs were taken with a small film camera both in the light microscope and SEM. The film used was Kodak Plus X, panchromatic, 22° Din. Some of the most common species occurring in the Skurup section are represented on Plate I–VIII.

## Analyses and distribution of species

By the identification of diatoms general reference works of Cleve-Euler (1951–1955), Hustedt (1930, 1927–1966), Patrick and Reimer (1966) and van der Werff and Huls (1958–1970) were used.

First a qualitative preliminary analysis was made on slides from all the samples. At the interval 4.35–4.95 m in Skurup no diatoms were found. In the other samples the frequencies were varying. The quantitative examination was made of the following nine samples which were most abundant in diatoms: 4.25, 4.30, 4.95, 5.05, 5.10, 5.20, 5.35, 5.45, 5.50 m. In the Skurup Lms series no diatoms were observed in samples from the peat and the algal gyttja at 2.20–2.55 m. Two samples, 2.55 and 2.80 m, contained sufficiently diatom valves for a quantitative examination. All these 11 samples from both sections had a mass-occurrence of *Fragilaria* with 83.0 to 99.1 % of all counted valves (Table 3). Also *Amphora ovalis* varr. *pediculus* and *libyca* were present with quite high values (up to 10.3 %). The number of counted valves in most samples exceeded 600. As *Fragilaria* occurred abundantly it was necessary to count at least 200 valves of other taxa to get a view of the total diatom flora. Exception was the 5.10 sample where *Fragilaria* constituted 99.1 % of all counted diatoms and only 50 valves of other taxa could be noted.

**Table 3. Diatom analysis from Skurup**

| | A | | | B | C |
|---|---|---|---|---|---|
| Depth m | *Fragilaria* % | *Amphora* % | Other taxa % | Basic sum (valves counted) | Number of taxa |
| Skurup: | | | | | |
| 4.25 | 83.5 | 5.6 | 10.9 | 600 | 30 |
| 4.30 | 96.5 | 1.7 | 1.8 | 1 450 | 30 |
| 4.95 | 94.0 | 2.5 | 3.5 | 442 | 34 |
| 5.05 | 83.0 | 10.3 | 6.7 | 603 | 35 |
| 5.10 | 99.1 | 0.1 | 0.8 | 1 010 | 19 |
| 5.20 | 87.5 | 10.2 | 2.3 | 800 | 25 |
| 5.35 | 92.7 | 5.2 | 2.1 | 755 | 39 |
| 5.45 | 95.7 | 3.6 | 0.7 | 1 150 | 33 |
| 5.50 | 95.3 | 3.8 | 0.9 | 420 | 43 |
| Skurup Lms: | | | | | |
| 2.55 | 96.8 | 1.7 | 1,5 | 936 | 33 |
| 2.80 | 93.2 | 4.4 | 2.4 | 710 | 45 |

A. The distribution in % between *Fragilaria, Amphora* and other taxa.
B. Basic sum for the percentages of A.
C. The number of taxa in the samples.

## pH-spectra

The diatoms were grouped together according to the pH-system employed by Hustedt (1938):

Alkalibiontic, occurring at pH values above 7;

Alkaliphilous, occurring at pH about 7 and with the greatest distribution at pH above 7;

Indifferent, equable occurrence at pH about 7 (pH neutral);

Acidophilous, occurrence at pH about 7, but with the greatest distribution at pH below 7;

Acidobiontic, occurrence at pH values below 7, widest distribution at pH values of 5.5 and lower.

Information about the pH-demands of the different species has been obtained from Hustedt (1927–1966, 1938, 1957), Jörgensen (1948), Cholnoky (1968) and Foged (1964, 1965). No acidobiontic diatoms were noted at the analyses (see Table 6). The alkaliphilous diatoms were dominating in all samples (Table 4 and Fig. 12).

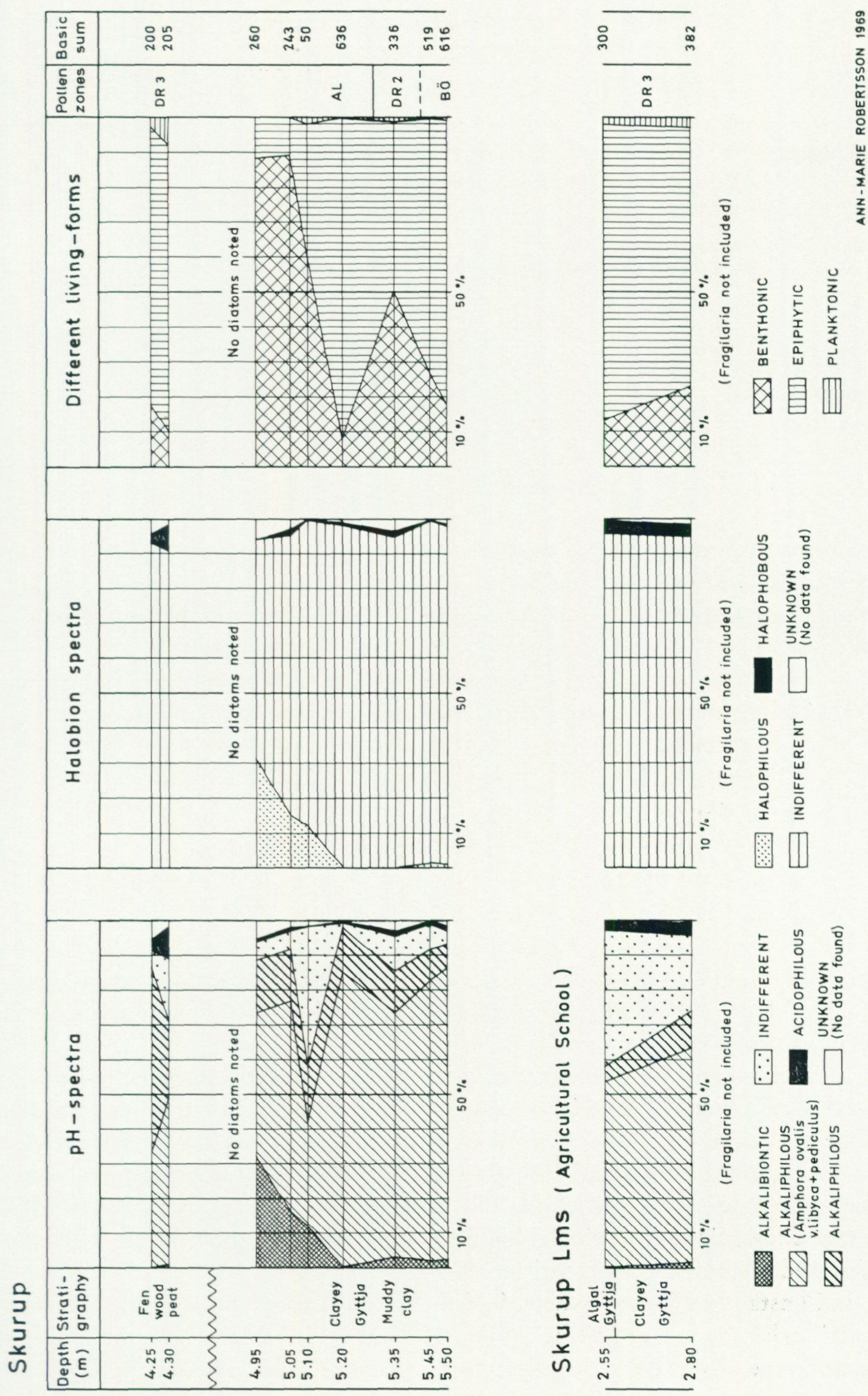


Fig. 12. pH-spectra, halobion-spectra and proportions of different living-forms of diatoms in the Skurup sections.

**Table 4. The percentages of different pH-groups (Fragilaria excluded)**

| depth m | alkalibiontic % | alkaliphilous % | indifferent % | acidophilous % | pH unknown % |
|---|---|---|---|---|---|
| Skurup: | | | | | |
| 4.25 | – | 86.5 | 4.5 | 4.5 | 4.5 |
| 4.30 | 0.5 | 70.6 | 18.1 | 8.8 | 2.0 |
| 4.95 | 32.6 | 54.6 | 7.4 | – | 5.4 |
| 5.05 | 16.3 | 74.3 | 6.1 | 0.4 | 2.9 |
| 5.10 | 12.0 | 40.0 | 46.0 | – | 2.0 |
| 5.20 | 1.0 | 95.6 | 2.5 | 0.2 | 0.7 |
| 5.35 | 3.4 | 81.6 | 10.7 | 0.9 | 3.4 |
| 5.45 | 2.4 | 89.1 | 8.4 | 0.2 | – |
| 5.50 | 2.8 | 91.2 | 3.7 | 0.6 | 1.7 |
| Skurup Lms: | | | | | |
| 2.55 | 0.3 | 58.0 | 39.1 | 2.3 | 0.3 |
| 2.80 | 0.8 | 73.7 | 22.0 | 3.0 | 0.5 |

Information about pH-demands is uncertain as regards the following species (see also ecological notes p. 50): *Cymbella brehmii, C. parva, C. parvula, Fragilaria virescens, Navicula hustedtii, N. järnefeltii* (probably indifferent – alkaliphilous), *Pinnularia cuneata, P. latevittata, P. stauroptera.*

As *Fragilaria* species found are alkaliphilous, with some uncertainty for *Fragilaria lapponica* (indifferent?), the alkaliphilous group dominates still more, if *Fragilaria* is included.

When *Fragilaria* is included in the basic sum the percentage of the alkaliphilous group of the Skurup series will range from 97.5 % (4.95 m) to 99.1 % (5.10 m) and at Skurup Lms from 98.3 % (2.80 m) to 98.7 % (2.55 m).

By means of the pH-spectra the following types of Danish waters have been distinguished (Fjerdingstad 1954, p. 19):

1. Constantly acid waters, in which the percentages for the acidophilous and acidobiontic individuals combined constitute 70 % or more; the number of indifferent individuals may vary from 0–30 %. Alkaliphilous individuals occur in few acid waters, and if so, in inconsiderable numbers.

2. Alternately acid and alkaline waters can be divided into two groups: a) Largely acid waters, in which the acidobiontic individuals are almost absent, while the acidophilous individuals constitute 45–70 % and the indifferent and the alkaliphilous individuals usually make 20–50 %. b) Largely neutral-alkaline waters. This group is readily distinguishable from the others, the indifferent and the acidophilous individuals together constituting 25–50 %, while the alkaliphilous individuals constitute 45–70 %.

3. Constantly alkaline waters, in which the alkalibiontic and alkaliphilous individuals together constitute around 90 %. But the alkalibiontic individuals do not generally present the distribution that might be expected. It does not

seem possible, therefore, solely on the basis of the diatoms to distinguish between slightly alkaline waters with a maximum pH-value under 9.0 and highly alkaline waters with a maximum pH-value about or above 9.0.

The lake at Skurup may, according to Table 4, have had a constantly alkaline water during BÖ, DR 2 and AL with a pH-value above 7. In the samples at 4.95–5.50 m the alkalibiontic and alkaliphilous diatoms make more than 90 % together. The only exception is at 5.10 m, but there only 50 valves of other species than *Fragilaria* could be counted in three slides. It is difficult to judge if this change depends on a real lowering of the pH-value in the water, or is a statistical error. In the sample mentioned, nevertheless, *Fragilaria* constitutes 99.1 %, which results in the dominance of the alkaliphilous diatoms. When *Fragilaria* was excluded *Achnanthes conspicua* and *Amphora ovalis* v. *libyca* occurred with 30 % and *Anomoeoneis sphaerophora* v. *sculpta* with 12 % at 5.10 m.

During DR 3 (4.25–4.30 m) the indifferent as well as the acidophilous taxa increased. The sediment did no longer consist of clayey gyttja but of fen wood peat. The formation of peat started during the latter part of Alleröd. As the dispersion of lime out of the surrounding minerogenic sediments diminished, the pH-conditions of the sedimentation basin grew somewhat more acid (cf. Berglund and Malmer 1971). The pH-value of the water was probably still about 7 (surely above 6). Even if the milieu was no longer constantly alkaline, it should be considered as mainly neutral-alkaline. The group of acidophilous taxa is represented by *Cyclotella antiqua, Eunotia pectinalis* v. *minor, E. valida* and *Tabellaria flocculosa.* Of *Tabellaria flocculosa* only internal septa were found in the 5.10 and the 4.30 m samples so this species was not included in the basic sum.

At Skurup Lms the water was constantly alkaline during the sedimentation of clayey gyttja (2.80 m). Since the formation of algal gyttja the pH-conditions were somewhat changed and the water became more of the type "largely neutral-alkaline" during Pre-Boreal times (Fig. 12). The explanation here should be that the thickening of the vegetation around the lake and its siltening up made the alkalinity of the water steadily diminish. The pH-value has been considered to be about 7 (not below 6).

## Halobion-spectra

Grouping of the diatoms according to different salt-ecological conditions (Fig. 12), has been carried out with reference to a. o. Hustedt (1930, 1927–1966, 1938, 1948, 1957), Petersen (1943), Foged (1964, 1965), Cleve-Euler (1951–1955, Miller (1964, 1971 a) and Florin (1944).

| | | |
|---|---|---|
| mesohalobes: | brackish diatoms, salinity range | 5–20 ‰ Cl |
| halophilous: | slightly brackish diatoms to fresh-water diatoms, salinity range | 2– 5 ‰ |
| indifferent: | fresh-water diatoms, salinity range | 0– 2 ‰ |
| halophobous: | fresh-water diatoms, no salinity | |

**Table 5. The percentages of different salt-ecological groups (Fragilaria excluded).**

| depth m | mesohalobes % | halophilous % | indifferent % | halophobous % | unknown % |
|---|---|---|---|---|---|
| Skurup: | | | | | |
| 4.25 | – | – | 91.0 | 4.5 | 4.5 |
| 4.30 | – | + | 89.2 | 8.8 | 2.0 |
| 4.95 | 0.4 | 31.1 | 63.1 | – | 5.4 |
| 5.05 | – | 15.5 | 80.8 | 0.8 | 2.9 |
| 5.10 | – | 12.0 | 86.0 | – | 2.0 |
| 5.20 | – | 0.2 | 99.0 | – | 0.8 |
| 5.35 | 0.3 | + | 95.5 | 0.9 | 3.3 |
| 5.45 | – | 1.6 | 98.2 | 0.2 | – |
| 5.50 | – | 0.8 | 96.9 | 0.8 | 1.5 |
| Skurup Lms: | | | | | |
| 2.55 | – | – | 95.8 | 3.6 | 0.6 |
| 2.80 | – | – | 95.7 | 2.7 | 1.6 |

Species about which the information of the salinity range is uncertain or unknown are: *Cymbella brehmii, C. parvula, Fragilaria virescens, Navicula hustedtii, Pinnularia cuneata, P. latevittata, P. stauroptera.*

The indifferent diatoms (fresh-water species) are dominating in all samples in both series. *Fragilaria,* which also belongs to the indifferent group, makes the dominance still larger for this group if they are included in the basic sum. The mesohalobous species, found in two samples, are *Navicula digitoradiata* and *N. peregrina*. The high percentages of halophilous diatoms at 5.10–4.95 m are due to one species, namely *Anomoeoneis sphaerophora* v. *sculpta,* which is a lagoon form. It usually occurs at the isolation of a basin from the sea together with the so-called *Clypeus* or lagoon flora. In the Skurup section this species appears with over 10 % between 4.95 and 5.10 m. The probable explanation of the occurrence of *Anomoeoneis sphaerophora* v.*sculpta* may be increased evaporation due to the rise of temperature during AL. The increased evaporation, in turn, has caused a concentration of clorids in the small lake and made it possible for *Anomoeoneis sphaerophora* v. *sculpta* to develop. Some halophilous diatoms are also able to survive in dry habitats as they endure changes in the osmotic pressure (Cholnoky 1968). Analysing the diatoms in Alleröd material from Fyn Foged observed the same phenomenon (Foged 1965). In his material the mesohalobous species *Mastogloia elliptica* v. *dansei* was represented with high values.

At 5.10 m in Skurup the diatom valves were very fragmented which indicates more terrestrial conditions. There are also typical aerophilous diatoms occurring at 5.10 m like *Hantzschia amphioxys* and *Navicula mutica.*

The halophobous species which occur in the Skurup series are: *Cyclotella antiqua, Eunotia pectinalis* v. *minor, E. valida, Navicula bacilliformis, N. hustedtii, Neidium iridis* v. *firmum, Pinnularia brébissonii, P. mesolepta, Tabellaria fenestrata* and *T. flocculosa.* Foged (1965) also regards *Achnanthes conspicua* as halophobous while Hustedt (1938) considers it indifferent. In the Skurup section *A. conspicua* occurs with high frequencies at 5.10 m and 4.30 m. As the halophilous species *Anomoeoneis sphaerophora* v. *sculpta* makes 12 % at 5.10 m it is not likely that a halophobous species should be represented by 30 % within the same sample. According to Kolbe (1927) *Fragilaria leptostauron* and *F. virescens* are halophobous. Petersen (1943) is more hesitant and sustains Hustedt's hypothesis that they are oligohalobes (see ecological notes p. 50). *Fragilaria leptostauron* is represented with high percentages in the lower part of the Skurup section and decreases upwards. It has been placed in the indifferent group.

Fragments of marine plankton such as *Melosira sulcata, Stephanopyxis turris, Coscinodiscus* spp., and *Hemiaulus* spp. were found in all nine samples in the Skurup section and the 2.80 m sample in the Skurup Lms section (see Table 6). They originate from the minerogenic material in the sediments and are redeposited. These species are of lower Tertiary (eocene) age (Cleve-Euler and Hessland 1948, Miller 1966, 1971 b).

The salinity of the Skurup lake has probably fluctuated somewhat during Alleröd in connection with the changes of temperature and related higher evaporation. The salinity has probably not exceeded 2 or 3 ‰. Later the concentration of chlorids sunk in connection with the peat-formation during the last phase of AL and was probably 0–1 ‰ during DR 3. During the relatively short period represented at the Skurup Lms there was no salinity.

## Proportions of different living-forms of diatoms

Fig. 12 shows the proportions of different living-forms, that is, planktonic, epiphytic and benthonic forms. In the Skurup section the epiphytes are dominating except between 5.10–4.95 m, where the benthonic forms rise to almost 90 %. Planktonic forms occur very sparsingly and are represented by *Cyclotella antiqua, C. stelligera* f. *tenuis, C. comta, Melosira islandica* ssp. *helvetica* and *Stephanodiscus astraea.* Among the epiphytes *Amphora ovalis* v. *pediculus* is dominating. According to Jörgensen (1948) *A. ovalis* v. *pediculus* is very common on stones in the littoral zone of eutrophic waters, together with *Fragilaria construens* v. *venter.* The *Fragilaria* species occurring are all epiphytes. *Fragilaria pinnata* and *F. brevistriata* may also live as epiphytes on plankton.

The proportions of different living-forms of diatoms show a great dominance for epiphytes *(Fragilaria, Amphora ovalis* v. *pediculus)* and only small quantities of plankton, indicating a low water-depth in the quite small Skurup lakes during Late-Glacial times.

## Proportional representation of diatoms and Pediastrum, and nutrient conditions in the Skurup lakes

Fjerdingstad (1954), investigating material of Alleröd age, found that the production of plankton changed during the warmest phase of the interstadial. The diatom production ceased (at least there were no valves noted in the slides) and instead such green algae as *Pediastrum* and *Tetraëdon* were frequent together with blue-green algae, e. g. *Gloeotrichia.* In the sediments from a Late-Glacial deposit in Blekinge (Lösensjön), Berglund (1966) found that during the latter part of AL and DR 3 the diatoms dominated while the frequencies of green and blue-green algae decreased. The lower part of Alleröd was not represented in his diagram. The blue-green algae occurred at the boundary DR 3/PB and the green algae only reached about 5 % in the upper part of subzone a and 2–3 % at the lower part of subzone c in Alleröd (Berglund 1966, Fig. 25). The division of Alleröd differs in the two investigations of Fjerdingstad and Berglund. Fjerdingstad used Iversen's division of Alleröd in a cooler and warmer phase (subzone a and b, Iversen 1942), while Berglund has three subzones: a, b and c (see p. 18). Zone b is characterized by a lower temperature compared with the other two. In the Skurup series there were great quantities of both *Pediastrum* and diatoms during DR 2, the first part of AL and DR 3 (Fig. 4 and 10). But during the latter part of Alleröd, when peat was formed, there was small production of diatoms and *Pediastrum.* The supply of nutrients decreased as also the evaporation lowered the water-level.

At Skurup Lms *Pediastrum* was frequent when the supply of minerogenic material had ceased. The algal gyttja mainly consists of green algae *(Pediastrum, Tetraëdon).* Either on account of competition of nutrients or a dissolution of diatom frustules, there were only a few diatoms found in the algal gyttja at 2.40–2.55 m.

According to Hustedt (1948) conclusions about fossil water milieus may be drawn, if there is a mass-occurrence of diatoms with well-known demands of living conditions. When the Skurup lakes were formed after the recession of the ice the supply of nutrients (above all calcium carbonate) was good. The lakes were surrounded by bare soils, which were gradually leached. The transparence of the water increased when the supply of clayey material decreased at the formation of the sediments.

The fact, that *Fragilaria* and *Amphora* have mass-occurrence in all samples analysed, indicates mesotrophic to europhic water-conditions (Jörgensen 1948, p. 48).

Similar diatom flora and water-conditions were found in the interglacial section at Leveäniemi. There zone 2 was characterized by mass-occurrence of *Fragilaria* and many other species in common with the Skurup section (Miller 1971 a).

Plankton forms which are characteristic for large eutrophic lakes, are lacking, due to the small size of the Skurup lakes. Diatoms, usually occurring in oligotrophic lakes, e. g. *Eunotia, Neidium* and *Pinnularia,* are represented with low values in all Skurup samples analysed (see Table 6).

## The diatom succession in the Skurup series

The diagram, Fig. 13, illustrates the succession of diatoms occurring with frequencies above 1.0 % in the samples. Many species are present in all samples while some disappear or immigrate, in the upper part of the section. *Fragilaria lapponica, F. construens* varr. *triundulata* and *binodis* have not been observed in the two upper samples (4.25 and 4.30 m). Species of *Nitzschia, Cocconeis, Opephora, Stephanodiscus, Campylodiscus, Gyrosigma, Mastogloia, Cymatopleura, Rhopalodia* and *Stauroneis* are not represented in the two upper samples. On the other hand, *Cymbella* and *Gomphonema* are however represented by 4–5 new species at 4.25 and 4.30 m.

| | |
|---|---|
| 4.25 m | *Fragilaria* spp. – *Gomphonema intricatum* v. *pumilum* – *Cymbella* spp. |
| 4.30 m | *Fragilaria* spp. – *Amphora ovalis* v. *pediculus* – *Achnanthes conspicua* – *Cyclotella antiqua* – *Gomphonema* spp. – *Cymbella* spp. |
| 4.35–4.95 m | No diatoms noted |
| 4.95–5.10 m | *Fragilaria* spp. – *Amphora ovalis* v. *libyca* – *Anomoeoneis sphaerophora* v. *sculpta* – *Diploneis ovalis* – *Achnanthes conspicua* – *Navicula pupula* – *N. dicephala* – *N. gastrum* |
| 5.20–5.50 m | *Fragilaria* spp. – *Amphora ovalis* v. *pediculus* – *Achnanthes exigua* – *Cymbella ventricosa* |

The succession shows that changes in the composition of the diatom flora do not coincide with climatic variations. Thus the diatom associations of Bölling and Alleröd do not differ much from those of Older and Younger Dryas.

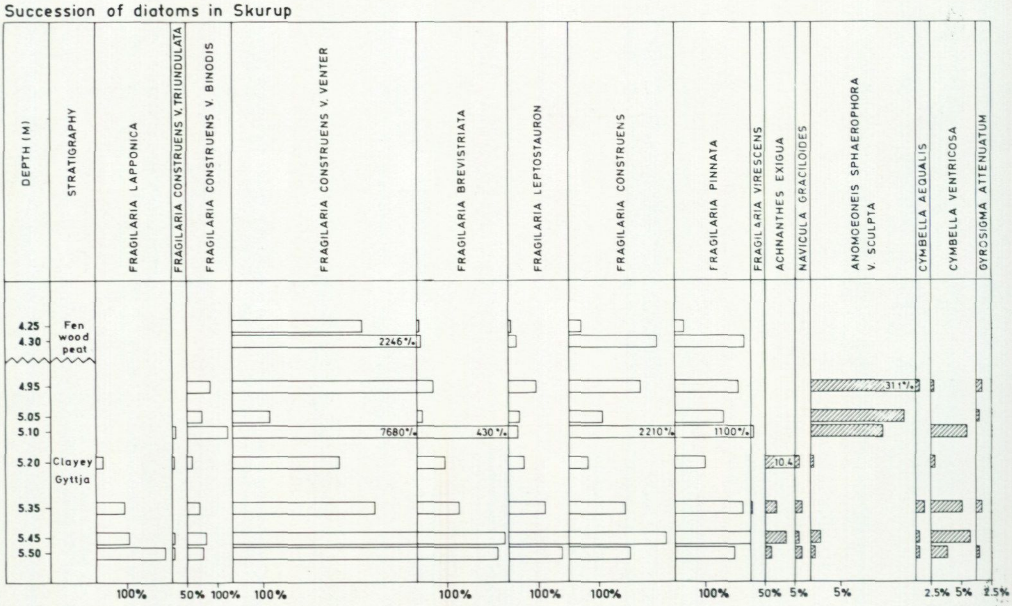
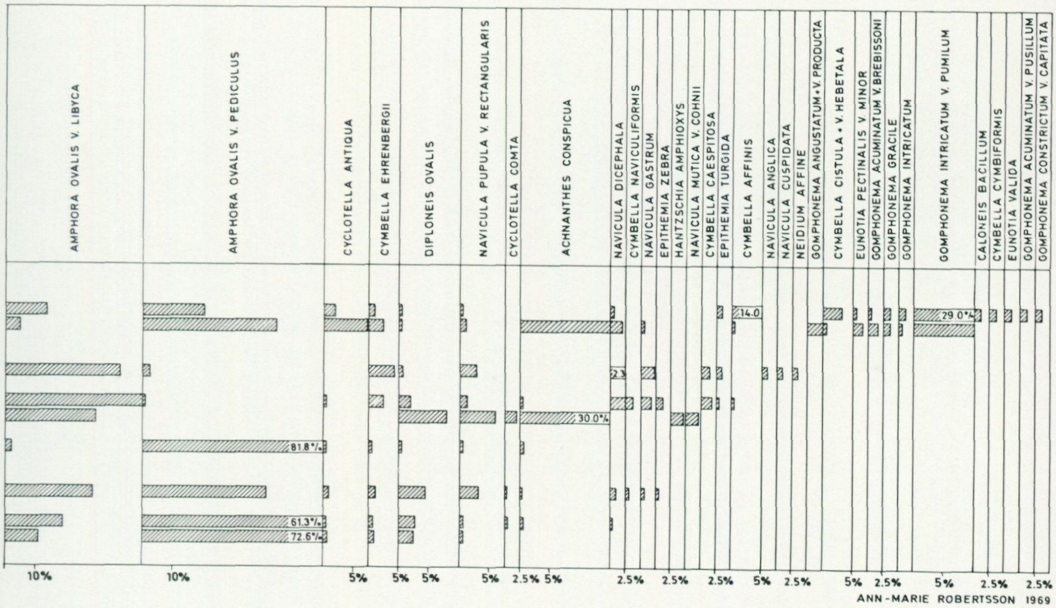


Fig. 13. Succession of diatoms in the Skurup section.

## Remarks on the Late-Glacial diatom flora

Some diatomologists have considered certain diatom species like *Cyclotella antiqua, C. distinguenda* and *Gomphocymbella ancyli* to be typical for Late-Glacial sediments (Hustedt 1948, Simonsen 1957 and Dahm 1959, 1961). No typical diatom flora, comparable with the Late-Glacial pollen flora, has been found. A zoning as regards the diatom flora, like the one within the higher vegetation, cannot be done for southern Scandinavia, northern Germany, the Netherlands as well as England. The lists of diatoms published in investigations concerning the Late-Glacial fresh-water diatom flora show that almost the same flora occurs in the mentioned countries during DR 2, AL and DR 3 (Table 6). This means that the diatoms hardly reacted primary to the temperature oscillations during Late-Glacial times but to variations in pH-conditions, salinity, supply of nutrients, water-depth and transparence of the water they lived in. Changes of the chemical conditions in the water are to a certain extent regulated by temperature, but it is not the main factor to cause variations of the composition of the diatom flora (Fjerdingstad 1954, Round 1957 and Foged 1965).



In the diatom list (Table 6) taxa in common with the Skurup sections found at the diatom analyses of the Late-Glacial sections in Scania and northwestern Europe are noted.

| | |
|---|---|
| Scania: | Toppeladugård (Holst 1906, 1908) |
| Denmark: | Fyn (Foged 1965) |
| Northern Germany: | Holstein (Simonsen 1957) |
| | „ (Dahm 1961) |
| England: | Kentmere valley, Lake District (Round 1957) |

## SUMMARY

The pollen diagrams from Skurup (Fig. 4 and 6) show that the vegetation during Late-Glacial times first had an arctic–subarctic character, consisting of shrub- and herb-tundra. The first immigration of arboreal birch during the Bölling oscillation was registered in the lowermost part of the organogenic sediments at 5.50 m (size measurements of *Betula* pollen, Fig 9). A $C^{14}$-dating, sediment analyses and loss on ignition (Fig. 10) sustain the hypothesis that sediments older than Alleröd are included in the Skurup section.

During Alleröd there were no closed forests but only scattered stands of trees (mostly *Betula)* together with a field layer consisting of light-demanding shrubs and herbs. The typical stepp-elements of the Late-Glacial flora were also present. The climatic deterioration during Younger Dryas was reflected by an increase of shrubs and herbs while *Betula* decreased. The size measurements of *Betula* pollen show to some extent the variations between *Betula nana* and arboreal *Betula* species in Late-Glacial times. The pollen diagram of the Skurup section has been corrected with regard to redeposited pollen with the aid of pollen analyses of till samples (Fig. 7 and 8).

At Skurup Lms the transition between the park-tundra existing during Younger Dryas and the immigration of *Betula – Pinus* forest during Pre-Boreal is noted by reduction of shrubs and herbs (Fig. 6).

The diatom analyses indicate that the water conditions of the two lakes have been "constantly alkaline" to "largely neutral-alkaline" corresponding to pH-values about or above 7. The increased evaporation during Alleröd caused drier conditions and somewhat higher salinity, registered by high values of *Anomoeoneis sphaerophora v. sculpta,* usually occurring in brackish water.

Drier conditions are also indicated by the occurrence of some aerophilous species which live in a more or less terrestrial milieu. No diatom valves were noted in the sediments between 4.30 and 4.95 m. Mass-occurrence of *Fragilaria,* registered in all samples analysed of both sections, shows that the lakes must have been of eutrophic character during the Late-Glacial periods. The proportions of different living-forms with the dominance of epiphytes and only low frequencies of plankton indicates quite low water-depth in the small Skurup lakes (Fig. 12).

## LITERATURE

DGU = Danmarks geologiske undersøgelse
GFF = Geologiska Föreningens i Stockholm Förhandlingar
KVA = Kungliga Vetenskapsakademien
MDGF = Meddelelser fra Dansk Geologisk Forening
SGU = Sveriges geologiska undersökning

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# Appendices

## Ecological notes on diatoms

*Achnanthes conspicua* Mayer (Plate IV, Fig. 3–5)
Living conditions badly known.

Hustedt 1957: Halophobous, alkaliphilous.
– 1959: Rare, observed in littoral fresh-water sediments.
Foged 1965: pH – acidophilous ?, halobion – halophobous?
Cholnoky 1968: *A. conspicua* probably has a high pH-optimum.

*Amphora ovalis* Kütz. v. *pediculus* Kütz. (Plate V, Fig. 1–3)
Planktonic and benthonic.

Jörgensen 1948: Character species in stone scrappings on bottom at shore and less on bottom in deeper water in large eutrophic lakes, in small numbers in lesser lakes and ponds.

*Caloneis silicula* (Ehr.) Cl ssp. *limosa* (Kütz.) Mayer
v. d. Werff 1958–1970: pH-alkalibiontic.

Patrick & Reimer 1966: Prefer a fair amount of calcium, also found in brackish water.
Jörgensen 1948: In small quantities in bottom samples in eutrophic lakes and ponds – alkaliphilous.

*Campylodiscus noricus* Ehr. v. *hibernica* (Ehr.) Grun.

Hustedt 1957: pH-alkalibiontic.
v. d. Werff 1958–1970: pH 6.4–8.5, alkaliphilous.

*Cymbella affinis* Kütz. (Plate VIII, Fig. 7)

Cholnoky 1968: pH-optimum about 8, alkalibiontic?
Jörgensen 1948: Common in small eutrophic lakes, pH 7.4–9.0, alkalibiontic.
Foged 1964: Alkaliphilous.
Hustedt 1957: Alkaliphilous.

*Cymbella brehmii* Hust. (Skurup Lms)
Living conditions badly known.

Hustedt 1930: Rare, perhaps ignored due to its small size.
Foged 1964: In samples from Spitsbergen. pH in the samples 5.0–7.8 pH-indifferent?
Miller 1971 a: Noted in zone 2 at Leveäniemi. Seldom (0.5–1.0 ‰). Zone 2 is characterized by eutrophic to mesotrophic conditions, litoral milieu with slightly brackish to fresh, quite cold and transparent water.

*Cymbella cistula* (Hemp.) Grun. (Plate VIII, Fig. 6)
v. d. Werff 1958–1970: pH 3.5–9.0.

Jörgensen 1948: In most eutrophic lakes and ponds. Most frequent in small lakes and ponds. pH 6.2–9.0 alkaliphilous.
Foged 1964: Alkaliphilous.
– 1965: pH-indifferent.
Hustedt 1957: Alkaliphilous.

*Cymbella ehrenbergii* Kütz. (Plate VI, Fig. 1–3)
Jörgensen 1948: Alkaliphilous.
v. d. Werff 1958–1970: pH-optimum 7.0–8.5 alkalibiontic?
Foged 1965: Alkaliphilous.
Hustedt 1957: Alkalibiontic.

*Cymbella parvula* Krasske.
v. d. Werff 1958–1970: Fresh-water diatom.
Cleve-Euler 1955: Rare, found in lake sediments.

*Diploneis subovalis* Cl.
Cholnoky 1968: pH-optimum at 7.3–8.0, alkalibiontic?
Hustedt 1938: Oligohalobous. Mostly occurring in alkaline waters. Alkaliphilous? Alkalibiontic?

*Eunotia pectinalis* (Kütz.) v. *minor* f. *impressa* (Ehr.) Hust.
Hustedt 1938: Not so pronounced halophobous as the other Eunotia species.
– 1957: Acidophilous.
Petersen 1943: Presumably halophobous.
Foged 1964: pH-indifferent and halophobous.
Cholnoky 1968: pH-optimum at 6.5 acidophilous?

*Fragilaria lapponica* Grun.
Cholnoky 1968: pH-optimum about 8, alkaliphilous?
Foged 1964: pH-indifferent?
Hustedt 1959: Common in stagnant water.
Patrick & Reimer 1966: Seems to prefer circumneutral water of low mineral content.

*Fragilaria leptostauron* (Ehr.) Grun. (Plate III, Fig. 1–4)
Kolbe 1927: With doubt halophobous.
Hustedt 1939: Oligohalobous.
– 1957: Halophobous?, alkaliphilous.
Petersen 1943: Halophobous?
Cholnoky 1968: pH-optimum probably about 8.
Patrick & Reimer 1966: Common in fresh-water, usually in shallow water, often on mud surfaces.
Foged 1965: Alkaliphilous, halophobous.

*Navicula hustedtii* Krasske.
Cholnoky 1968: pH-optimum about or under 6.
Cleve-Euler 1953: Fresh-water species.
Patrick & Reimer 1966: Brackish water?

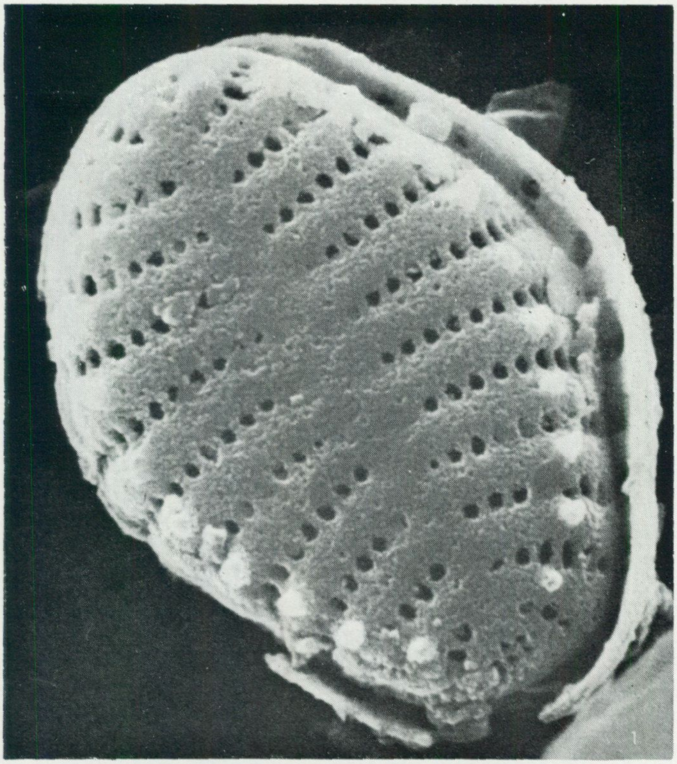
*Navicula järnefeltii* Hustedt.
Hustedt 1930: Fresh-water species.
Cleve-Euler 1953: Fresh-water species, occurs in lakes, ponds and brooks.

*Neidium affine* (Ehr.) Cl v. *amphirynchus* (Ehr.) Cl.
Petersen 1943: Somewhat but not markedly halophobous.
Jörgensen 1948: pH 5.4–9.0 indifferent.
Foged 1964: pH-alkaliphilous.
– 1965: pH-indifferent.
Cholnoky 1968: pH-optimum about 6.0, indifferent.

## Plates I—VIII. Photo-micrographs

Plate I. 1: *Fragilaria construens* v. *venter*. Valvar exterior. SEM 11 000x.
2: „ „ „ „ Phase contrast. LM 1 000x.
3: „ „ „ „ Ordinary light. LM 1 000x.
4: *Fragilaria construens* v. *binodis*. Valvar interior. SEM 5 500x.
5: „ „ „ „ Phase contrast. LM 1 000x.
6: „ „ „ „ Ordinary light. LM 1 000x.

LM = light micrograph
SEM = Scanning electron micrograph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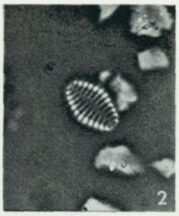
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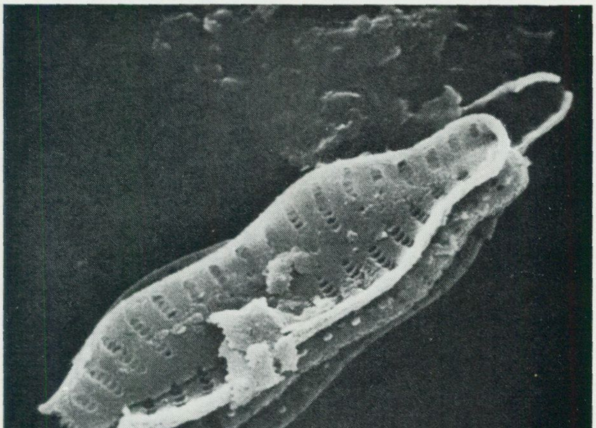
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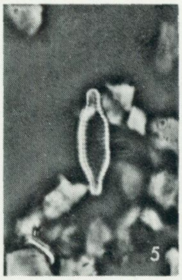
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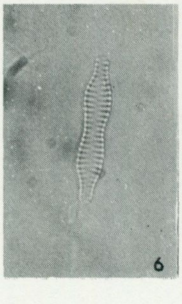
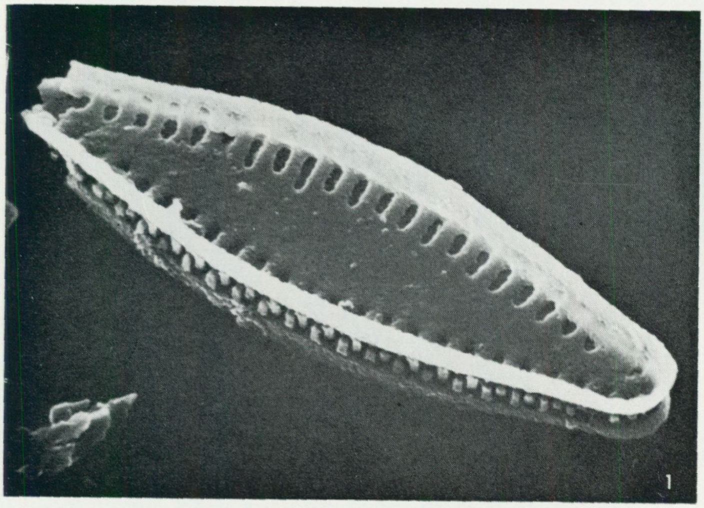

6

Plate II. 1: *Fragilaria brevistriata*. Valvar interior. SEM 5 600x.
2: „ „ Phase contrast. LM 1 000x.
3: *Fragilaria pinnata*. Valvar interior. SEM 5 100x.
4: „ „ Phase contrast. LM 1 000x.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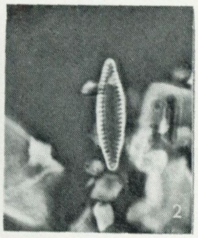
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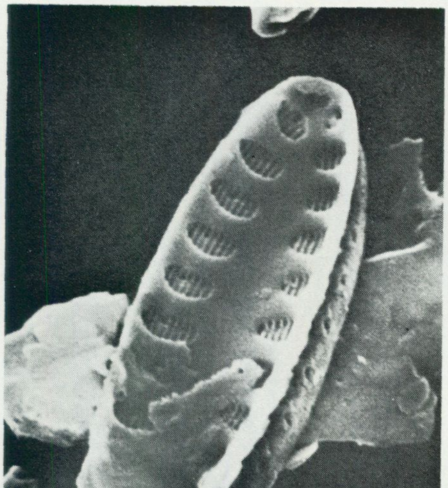
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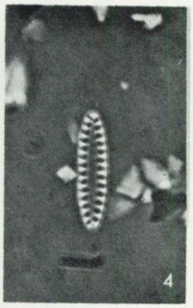
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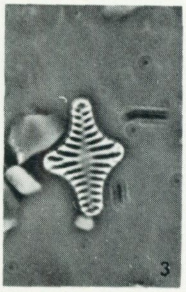
Plate III. 1: *Fragilaria leptostauron*. Valvar exterior. SEM 5 500x.
2: „ „ Valvar interior. SEM 5 500x.
3: „ „ Phase contrast. LM 1 000x.
4: „ „ Ordinary light. LM 1 000x.


1


2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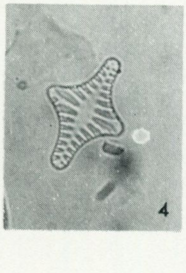
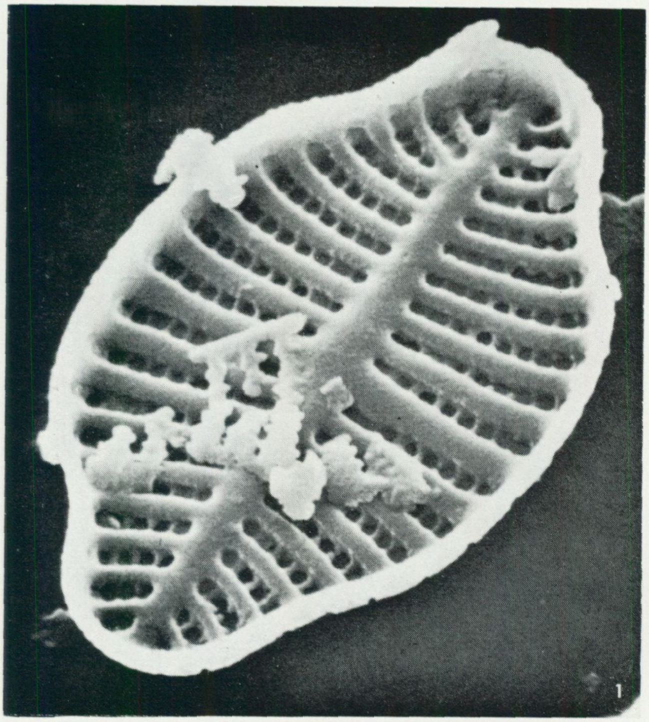

4

Plate IV. 1: *Achnanthes exigua*. Rapheless valve interior. SEM 11 000x.
2: „ „ Phase contrast. LM 1 000x.
3: *Achnanthes conspicua*. Rapheless valve interior. SEM 5 000x.
4: „ „ Phase contrast. LM 1 000x.
5: „ „ Ordinary light. LM 1 000x.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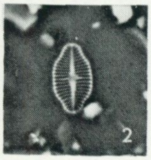
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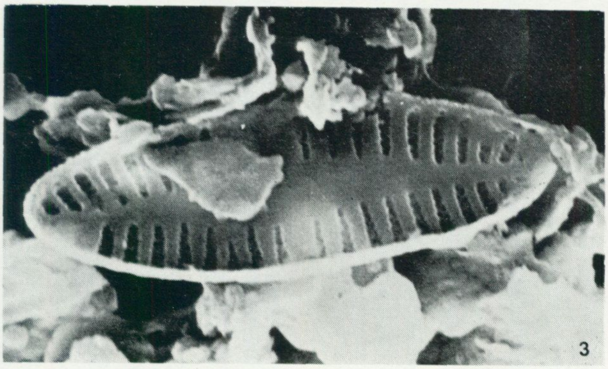
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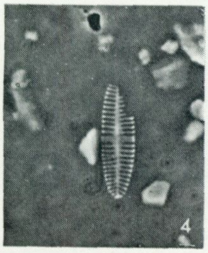
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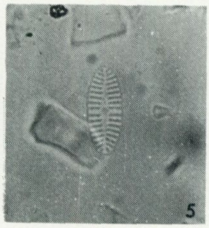
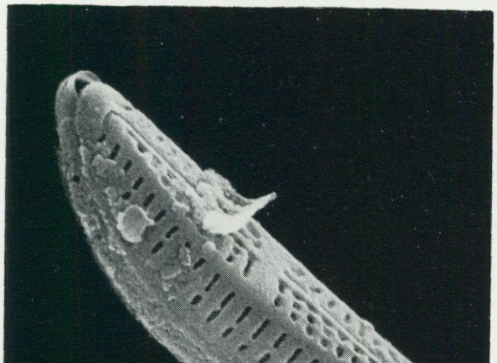

5

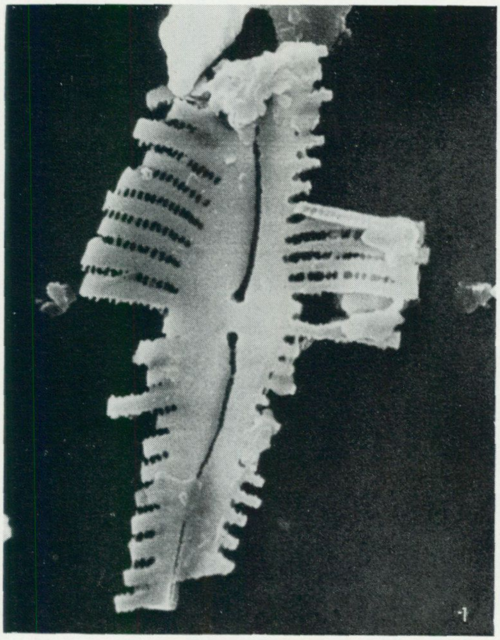
Plate V. 1: *Amphora ovalis* v. *pediculus*. Valvar interior. SEM 11 100x.
2: „ „ „ „ Valvar exterior. SEM 5 500x.
3: „ „ „ „ Phase contrast. LM 1 000x.


1


2


3

Plate VI. 1: *Cymbella ehrenbergii(?)*. Corroded valve, detail of central part. SEM 5 400x.
2: „ „ Valvar interior. Phase contrast. LM 1 000x.
3: „ „ Valvar exterior. Ordinary light. LM 1 000x.
4: *Anomoeoneis sphaerophora* v. *sculpta*. Phase contrast. LM 1 000x.
5: *Diploneis ovalis*. Phase contrast. LM 1 000x.
6: *Navicula graciloides*, right, and *Fragilaria brevistriata*, left. Phase contrast. LM 1 000x.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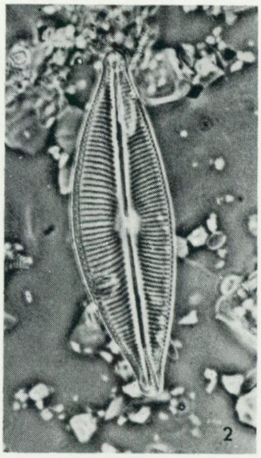
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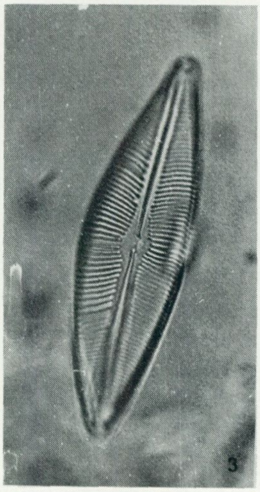
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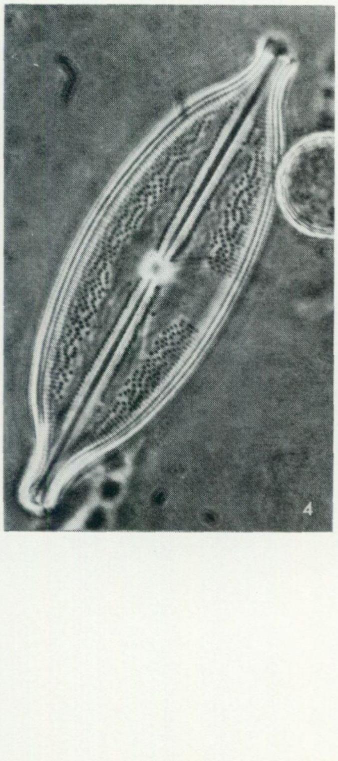
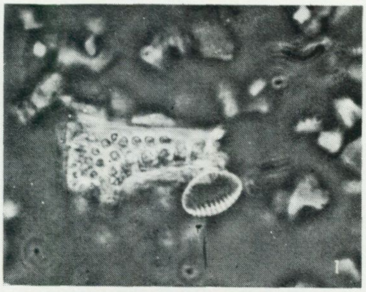

4


5


6

Plate VII. 1: Fragment of tertiary diatom. *Hemiaulus* sp. Phase contrast. LM 1 000x.
2: „ „ „ „ *Hemiaulus* sp. Phase contrast. LM 1 000x.
3: „ „ „ „ *Stephanopyxis* (?). Phase contrast. LM 1 000x.
4: Silicoflagellate: *Ebria antiqua*. SEM 5 500x.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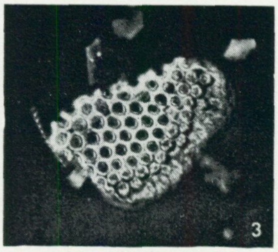
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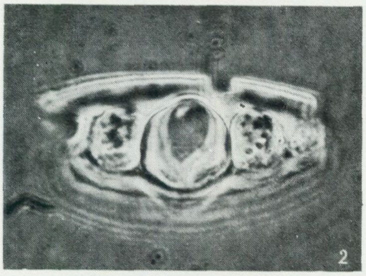
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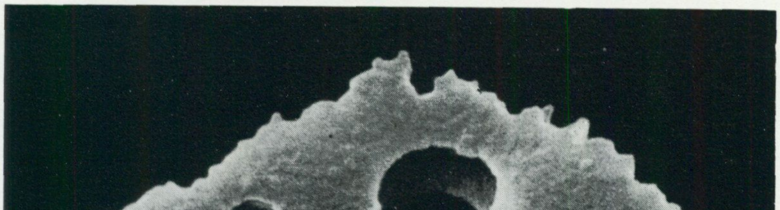
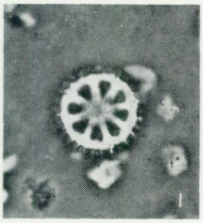

4

Plate VIII. 1: *Cyclotella antiqua,* corroded valve. Phase contrast. LM 1 000x.
2: „ „ , „ „ Ordinary light. LM 1 000x.
3: *Gomphonema intricatum* v. *pumilum*. Phase contrast. LM 1 000x.
4: *Amphora ovalis* v. *libyca*. Phase contrast. LM 1 000x.
5: *Navicula dicephala*. Phase contrast. LM 1 000x.
6: *Cymbella cistula*. Phase contrast. LM 1 000x.
7: *Cymbella affinis*. Phase contrast. LM 1 000x.
8: *Cymbella caespitosa*. Phase contrast. LM 1 000x.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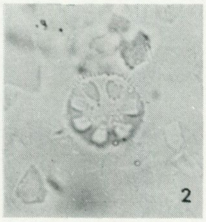
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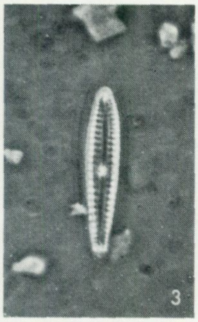
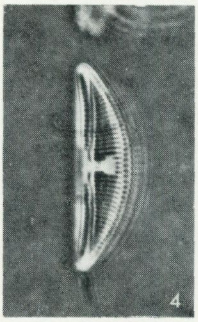

3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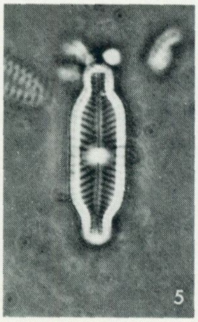
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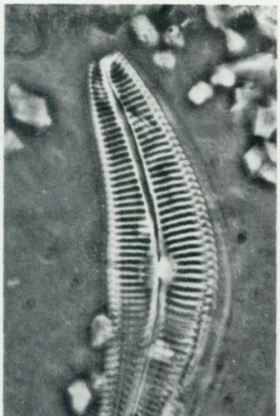
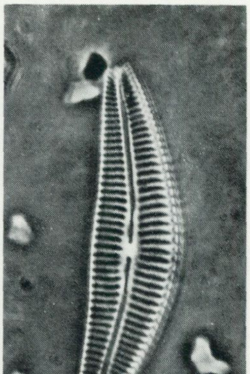
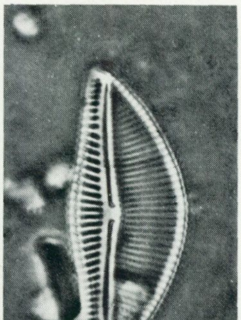

6


7


8

## Diatoms occurring in the sections of Skurup and Skurup Lms

**TABLE 6:1**

| | | | | | SKURUP | | |
|---|---|---|---|---|---|---|---|
| Photo | | pH | hal | | m: 4.25 % | 4.30 % | 4.95 % |
| × | Achnanthes conspicua Mayer | ind. | ind. | e | | 15.1 | |
| × | Achnanthes exigua Grun. | alkf. | ind. | e | | | |
| | Achnanthes lanceolata (Breb.) Grun. | alkf. | ind. | e | | | |
| | Achnanthes lanceolata v. rostrata (Östr.) Hust. | alkf. | ind. | e | | | |
| | Achnanthes östrupii (A. Cleve) Hust. | ind. | ind. | e | | | |
| | Achnanthes spp. | | | | | 0.5 | |
| × | Amphora ovalis Kütz. v. libyca (Ehr.) Cl. | alkf. | ind. | b | 13.5 | 4.9 | 38.3 |
| × | Amphora ovalis Kütz. v. pediculus Kütz. | alkf. | ind. | e(b) | 20.5 | 44.3 | 2.3 |
| | Amphora spp. | | | | | 0.5 | 0.4 |
| × | Anomoeoneis sphaerophora (Kütz.) Pfitz. v. sculpta (Ehr.) O. Müller | alkb. | hfil | b | | | 31.1 |
| | Caloneis bacillum (Grun.) Meresch. | alkf. | ind. | b | 1.0 | | |
| | Caloneis schumanniana (Grun.) Cl. | alkb. | ind. | b | | | |
| | Caloneis silicula (Ehr.) Cl. ssp. limosa (Kütz.) Mayer | alkb. | ind. | b | | | |
| | Campylodiscus noricus Ehr. v. hibernica (Ehr.) Grun. | alkf. | ind. | b | | | |
| | Cocconeis placentula (Ehr.) v. euglypta (Ehr.) Cl. | alkf. | ind. | e | | | 0.4 |
| × | Cyclotella antiqua W. Smith | acf. | hfob | p | 2.0 | 7.3 | |
| | Cyclotella comta (Ehr.) Kütz. | alkf. | ind. | p | | | |
| | Cyclotella stelligera (Cl & Grun.) f. tenuis Hust. | ind. | ind. | p | | | |
| | Cyclotella spp. | | | | 0.5 | | |
| | Cymatopleura elliptica (Breb.) W. Smith | alkf. | ind. | b | | | |
| | Cymatopleura solea (Breb.) W. Smith | alkf. | ind. | b | | | |
| | Cymbella aequalis W. Smith | alkb. | ind. | e | | | 0.4 |
| × | Cymbella affinis Kütz. | alkf. | ind. | e | 14.0 | 0.5 | |
| | Cymbella aspera (Ehr.) Cl. | alkf. | ind. | e | 0.5 | + | |
| | Cymbella brehmii Hust. | ind.? | ind.? | e | | | |
| × | Cymbella caespitosa (Kütz.) Grun. | ind. | ind. | e | | | 1.5 |
| | Cymbella caespitosa v. hybrida (Grun.) A. Cleve | ind. | ind. | e | | | |
| × | Cymbella cistula (Hemp.) Grun. | ind. | ind. | e | 3.0 | | |
| | Cymbella cistula v. hebetala (Pant.) A. Cleve | ind. | ind. | e | | 0.5 | |
| | Cymbella cuspidata Kütz. | ind. | ind. | e | | 0.5 | |
| | Cymbella cymbiformis (Ag. ? Kütz.) v. Heurck | alkf. | ind. | e | 1.0 | | |
| × | Cymbella ehrenbergii Kütz. | alkf. | ind. | e | 1.0 | 2.4 | 4.2 |
| | Cymbella leptoceros (Ehr. ?) Grun. | alkf. | ind. | e | | | |
| | Cymbella naviculiformis Auerswald | ind. | ind. | e | | | |
| | Cymbella parva (W. Smith) Cl. | ? | ind. | e | | | |
| | Cymbella parvula Krasske | ? | ? | e | | | |
| | Cymbella prostrata (Berkeley) Cl. | alkf. | ind. | e | | | |
| | Cymbella sinuata Greg. | ind. | ind. | e | | | 0.4 |
| | Cymbella ventricosa Kütz. | ind. | ind. | e | | | 0.4 |
| | Cymbella spp. | | | | 1.0 | 0.5 | |

× = photo

acf. = acidophilous
ind. = indifferent
alkf. = alkaliphilous
alkb. = alkalibiontic

hal. = halobion
hfob = halophobous
ind. = indifferent
hfil = halophilous
mesoh. = mesohalobous

b = benthonic forms
e = epiphytic forms
p = planktonic forms

\+ = fragments

| SKURUP | | | | | | SKURUP Lms | | Scania (Holst 1906) | Denmark (Foged 1965) | Germany (Simonsen 1957) | Germany (Dahm 1961) | England (Round 1957) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.05 % | 5.10 % | 5.20 % | 5.35 % | 5.45 % | 5.50 % | 2.55 % | 2.80 % | | | | | |
| 0.4 | 30.0 | 0.8 | 0.3 | 0.6 | | 1.3 | 2.3 | | × | | | |
| | | 10.4 | 1.8 | 3.6 | 1.0 | 1.0 | 1.3 | | × | × | × | × |
| | | 0.5 | 0.3 | | 0.3 | | | | × | × | × | × |
| | | | | | 0.3 | | | | | | | |
| | | | | | | | 0.5 | | | | | |
| | | | | | 0.3 | | | | | | | |
| 59.6 | 30.0 | 2.0 | 29.0 | 19.3 | 11.2 | 5.3 | 6.7 | × | × | × | × | × |
| 1.2 | | 81.8 | 41.0 | 61.3 | 72.6 | 48.1 | 55.3 | × | × | × | × | × |
| | | 0.3 | 1.2 | | | | | | | | | |
| 15.5 | 12.0 | 0.2 | + | 1.6 | 0.8 | | | | | | | |
| | | | | | | | | | × | × | × | × |
| | | | | 0.2 | | | | | | × | | |
| 0.4 | | | | | | | 0.5 | × | × | × | × | × |
| | | | 0.3 | | 0.2 | | | × | × | × | | × |
| | | | | | 0.2 | | | × | × | × | × | × |
| 0.4 | | 0.2 | 0.9 | 0.2 | 0.6 | 1.7 | 1.3 | × | × | × | | × |
| | 2.0 | | 0.3 | 0.4 | + | 0.3 | 1.3 | × | × | × | | × |
| | | | | | | | 0.3 | | | | | |
| | | + | 0.6 | | 0.2 | | | | | | | |
| + | | | 0.3 | | | | | × | × | × | | × |
| + | | | | | | | | × | × | × | × | |
| | | | 1.2 | 0.2 | 0.3 | | 0.3 | | | × | | |
| 0.4 | | | | | | | | | × | | | |
| | | | | | | 0.3 | 1.1 | × | × | × | × | |
| | | | | | | 15.8 | 5.7 | | | | | |
| 1.7 | | | | | | | | | | | | |
| | | | | | | 0.3 | | | × | × | × | × |
| | | | | | | | | | × | × | × | |
| | | | | | | | | × | | × | | |
| 2.5 | + | 0.2 | 1.2 | 0.6 | 1.0 | 0.3 | 0.3 | × | × | × | × | × |
| | | | | | | 1.7 | 1.8 | | | | | |
| 1.2 | | | 0.6 | | | | | | × | × | | × |
| | | | | | 0.2 | | | | | | × | |
| | | 0.3 | | | 0.3 | | | | | | | |
| | | | | | | | 0.3 | | | | | × |
| | | | | | | 14.1 | 1.1 | | | × | | |
| | 6.0 | 0.8 | 5.3 | 6.4 | 2.8 | 1.0 | 0.8 | × | × | × | × | × |
| 0.4 | 2.0 | 0.2 | 0.3 | | | | | | | | | |

**TABLE 6:2**

| | | | | | SKURUP | | |
|---|---|---|---|---|---|---|---|
| Photo | | pH | hal | | m: 4.25 % | 4.30 % | 4.95 % |
| × | Diploneis ovalis (Hilse) Cl. | alkf. | ind. | b | 0.5 | 0.5 | 0.8 |
| | Diploneis subovalis Cl. | alkf. | ind. | b | | | |
| | Diploneis spp. | | | | 0.5 | | |
| | Epihemia argus Kütz. | alkf. | ind. | e | | | |
| | Epithemia sorex Kütz. | alkf. | ind. | e | | 0.5 | |
| | Epithemia turgida (Ehr.) Kütz. | alkf. | ind. | e | 1.0 | | 0.8 |
| | Epithemia zebra (Ehr.) Kütz. | alkf. | ind. | e | | | |
| | Epithemia sp. | | | | | | 0.8 |
| | Eunotia pectinalis (Kütz.) Rabh. v. minor f. impressa (Ehr.) Hust. | acf. | hfob. | e | 0.5 | 1.5 | |
| | Eunotia valida Hust. | acf. | hfob. | e | 1.0 | | |
| | Eunotia sp. | acf.? | | | 1.0 | | |
| | Gomphonema acuminatum Ehr. v. brébissonii (Kütz.) v. Heurck | alkf. | ind. | e | 0.5 | 1.5 | |
| | Gomphonema acuminatum v. pusillum Grun. | alkf. | ind. | e | 1.0 | | |
| | Gomphonema angustatum (Kütz.) Rabh. | alkf. | ind. | e | | 1.0 | |
| | Gomphonema angustatum v. producta Grun. | alkf. | ind. | e | | 1.9 | |
| | Gomphonema angustatum v. sarcophagus (Greg.) v. Heurck | alkf. | ind. | e | | | |
| | Gomphonema constrictum Ehr. | alkf. | ind. | e | 0.5 | | |
| | Gomphonema constrictum v. capitata (Ehr.) Cl. | alkf. | ind. | e | 1.0 | | |
| | Gomphonema gracile Ehr. | ind. | ind. | e | 1.0 | 1.0 | |
| | Gomphonema intricatum Kütz. | alkf. | ind. | e | 1.0 | 0.5 | |
| × | Gomphonema intricatum v. pumilum Grun. | alkf. | ind. | e | 29.0 | 10.2 | |
| | Gomphonema parvulum (Kütz.) Grun. | ind. | ind. | e | | | |
| | Gomphonema spp. | | | | 2.0 | 0.5 | |
| | Gyrosigma attenuatum (Kütz.) Rabh. | alkb. | ind. | b | | | 1.1 |
| | Gyrosigma spp. | | | | | | |
| | Hantzschia amphioxys (Ehr.) Grun. | ind. | ind. | b | | | |
| | Mastogloia grevillei W. Smith | alkf. | ind. | e | | | |
| | Melosira islandica ssp. helvetica O. Müller | alkf. | ind. | p | | | |
| | Navicula anglica Ralfs | alkf. | ind. | b | | | 0.8 |
| | Navicula bacilliformis Grun. | ind. | hfob | b | | | |
| | Navicula bacillum Ehr. | alkf. | ind. | b | | | |
| | Navicula cuspidata Kütz. | alkf. | ind. | b | | | 0.8 |
| × | Navicula dicephala (Ehr.) W. Smith | alkf. | ind. | b | 0.5 | 1.9 | 2.7 |
| | Navicula cf. digitoradiata (Greg.) A. Schmidt | alkf. | mesoh. | b | | | 0.4 |
| | Navicula exigua (Greg.) O. Müller | alkf. | ind. | b | | | |
| | Navicula gastrum Ehr. | alkf. | ind. | b | | 0.5 | 2.3 |
| × | Navicula graciloides Mayer | alkb. | ind. | b | | | |
| | Navicula hustedtii Krasske | acf.? | ? | b | | | |
| | Navicula järnefeltii Hust. | alkf.? | ind. | b | | | |
| | Navicula minima Grun. v. atomoides Cl. | ind. | ind. | b | | | |
| | Navicula mutica Kütz. v. cohnii (Hilse) Grun. | ind. | ind. | b | | | |
| | Navicula oblonga Kütz. | alkf. | ind. | b | | | 0.8 |
| | Navicula peregrina (Ehr.) Kütz. | alkf. | mesoh. | b | | | |
| | Navicula pseudoscutiformis Hust. | ind. | ind. | b | | | 0.4 |
| | Navicula pupula Kütz. v. rectangularis (Greg.) Grun. | ind. | ind. | b | 0.5 | 1.0 | 2.7 |
| | Navicula radiosa Kütz. v. acuta (W. Smith) v. Heurck | ind. | ind. | b | | | |
| | Navicula tuscula (Ehr.) Cl. v. capitata Fontell | alkb. | ind. | b | | 0.5 | |
| | Navicula spp. | | | | 0.5 | | 1.5 |

| SKURUP | | | | | | SKURUP Lms | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.05 % | 5.10 % | 5.20 % | 5.35 % | 5.45 % | 5.50 % | 2.55 % | 2.80 % | Scania (Holst 1906) | Denmark (Foged 1965) | Germany (Simonsen 1957) | Germany (Dahm 1961) | England (Round 1957) |
| 2.1 | 8.0 | 0.5 | 4.4 | 2.7 | 2.4 | 0.7 | 0.3 | | × | × | | × |
| | | | | | 0.2 | | | | | | | |
| | | | | | 0.2 | | | | | | | |
| 0.4 | | | | | | | | × | × | × | × | |
| | | | | | | | | × | × | × | × | × |
| 0.4 | | | | | | | | | × | × | × | × |
| 1.2 | | | 0.3 | | | | | | × | × | × | × |
| | | | | | | | | | × | × | | |
| | | | | | | | 0.3 | | | | | |
| | | | | | | | | | | × | × | × |
| | | | | | | | | × | × | × | | |
| 0.4 | | | | | | | | | | | | |
| 0.8 | | | | | + | + | | × | × | × | × | × |
| | | | | | | | | | | | | × |
| | | | | | | | | | | × | | × |
| | | | | | | | 1.8 | | × | × | × | |
| | | | | | | | | × | × | × | | |
| | | | | | 0.2 | | | × | × | × | | |
| 0.4 | | | 1.0 | | 0.2 | 0.3 | 0.5 | × | × | × | × | × |
| | + | + | | | | | | | | | | |
| | 2.0 | | | | | | 0.3 | × | | × | | |
| | | | 0.3 | | | | | | | × | | |
| | | | | 0.2 | | | | | | | | |
| | | | | | | | | | × | × | | |
| 0.4 | | | | | | | | × | × | | | |
| 0.8 | | | | 0.2 | 0.3 | | 0.3 | | | × | × | |
| | | | | | + | 0.3 | | | × | | × | × |
| 2.4 | | | 0.9 | 0.4 | | | | | × | | × | |
| | | | | 0.2 | 0.3 | | | | | × | | |
| 1.7 | | | 0.6 | | | | | | | × | × | |
| | | 0.8 | 0.9 | 0.4 | 1.1 | | | | × | × | × | |
| | | | | | | 0.3 | 1.1 | | | | | |
| | | | | | | | 0.5 | | | | | × |
| | | | | | | 1.3 | 1.3 | | | | | |
| | 2.0 | | | | | | | | × | | | |
| 0.4 | | 0.2 | | | 0.2 | | 0.3 | × | × | × | × | × |
| | | | 0.3 | | | | | | | × | | |
| | | 0.2 | | 0.2 | 0.3 | 1.7 | 2.9 | | | × | | × |
| 1.2 | 6.0 | 0.5 | 3.3 | 0.6 | 0.6 | 1.3 | 0.8 | | × | × | | × |
| 0.4 | | | | | | | 0.3 | | × | × | × | × |
| | | | | | 0.2 | | | × | × | × | × | × |
| 0.4 | | | 0.6 | | 0.5 | 0.3 | 0.5 | | | | | |

## TABLE 6:3

| Photo | | pH | hal | | SKURUP | | |
|---|---|---|---|---|---|---|---|
| | | | | | m: 4.25 % | 4.30 % | 4.95 % |
| | Neidium affine (Ehr.) Cl. v. amphirhynchus (Ehr.) Cl. | ind. | ind. | b | | | 0.8 |
| | Neidium iridis (Ehr.) Cl. v. firmum (Kütz.) Mayer | acf. | hfob | b | | | |
| | Neidium sp. | | | | | | 0.4 |
| | Nitzschia denticula Grun. v. curta Grun. | alkf. | ind. | b | | | |
| | Nitzschia frustulum (Kütz.) Grun. v. perpusilla (Rabh.) Grun. | ind. | ind. | b | | | |
| | Nitzschia sinuata (W. Smith) Grun. | ind. | ind. | b | | | |
| | Nitzschia spp. | | | | | + | |
| | Opephora martyi Heribaud | alkf. | ind. | b | | | |
| | Pinnularia brébissonii Kütz. | acf. | hfob | b | | | |
| | Pinnularia cuneata (Östr.) A. Cleve | ? | ? | b | | | 0.4 |
| | Pinnularia gentilis (Donk.) Cl. | ind. | ind. | b | | | |
| | Pinnularia latevittata Cl. | ? | ? | b | | | |
| | Pinnularia mesolepta (Ehr.) W. Smith | ind. | hfob | b | | | |
| | Pinnularia microstauron (Ehr.) Cl. | ind. | ind. | b | | | 0.4 |
| | Pinnularia stauroptera (Rabh.) Cl. v. parva Grun. | ? | ? | b | | | 0.4 |
| | Pinnularia viridis (Nitzsch) Ehr. | ind. | ind. | b | | | 0.8 |
| | Pinnularia spp. | | | | | | 1.5 |
| | Rhopalodia gibba (Ehr.) O. Müller | alkf. | ind. | e | | | |
| | Stauroneis phoenicenteron Ehr. | ind. | ind. | b | | | |
| | Stephanodiscus astraea (Ehr.) Grun. | alkb. | ind. | p | | | |
| | Synedra capitata Ehr. | alkf. | ind. | e | + | | |
| | Synedra ulna (Nitzsch) Ehr. | alkf. | ind. | e | | + | + |
| | Synedra sp. | | | | | | |
| | Tabellaria fenestrata (Lyng.) Kütz. | ind. | hfob | e(p) | | | |
| | Tabellaria flocculosa (Roth) Kütz. | acf. | hfob | e(p) | | + | |
| | Not included in the basic sum: | | | | | | |
| × | Fragilaria brevistriata Grun. | alkf. | ind. | e(p) | 3.0 | 12.0 | 53.5 |
| | Fragilaria construens (Ehr.) Grun. | alkf. | ind. | e | 39.0 | 288.0 | 234.0 |
| × | Fragilaria construens v. binodis (Ehr.) Grun. | alkf. | ind. | e | | | 71.5 |
| | Fragilaria construens v. triundulata Reichelt | alkf. | ind. | e | | | |
| × | Fragilaria construens v. venter (Ehr.) Grun. | alkf. | ind. | e | 424.0 | 2246.0 | 824.0 |
| | Fragilaria lapponica Grun. | alkf. | ind. | e | | | |
| × | Fragilaria leptostauron (Ehr.) Haust. | alkf. | ind. | e(b) | 3.0 | 24.0 | 89.0 |
| × | Fragilaria pinnata Ehr. | alkf. | ind. | e(p) | 30.0 | 228.0 | 210.5 |
| | Fragilaria virescens Ralfs | ind. | hfob | e | | | |
| | Fragilaria spp. | | | | 1.0 | 2.0 | 0.5 |
| | Redeposited tertiary (eocen) marine diatoms: | | | | | | |
| | Coscinodiscus spp. | | | | | + | |
| × | Hemiaulus spp. | | | | + | + | + |
| | Melosira sulcata (Ehr.) Kütz | | | | | + | + |
| × | Stephanopyxis turris (Greville & Arnott) Ralfs | | | | | + | |
| | Stephanopyxis spp. | | | | | | |
| | Redeposited Silicoflagellatae: | | | | | | |
| × | Ebria antiqua | | | | | + | |
| | Ebria tripartita | | | | | | |

| SKURUP | | | | | | SKURUP Lms | | Scania (Holst 1906) | Denmark (Foged 1965) | Germany (Simonsen 1957) | Germany (Dahm 1961) | England (Round 1957) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.05 % | 5.10 % | 5.20 % | 5.35 % | 5.45 % | 5.50 % | 2.55 % | 2.80 % | | | | | |
| | | | | | | | | | × | | | |
| | | | | | | | 0.3 | | | | | × |
| | | + | + | | + | | | | | | | |
| | | | | 0.2 | 0.3 | | | | × | × | | × |
| | | | | | | 0.7 | 4.9 | | | | | |
| | | | 0.6 | 0.2 | | | | | × | | | |
| + | + | + | 0.3 | | | | | | | | | |
| | | | | | 0.3 | | | | × | × | × | |
| | | | | | | | 0.3 | | | | | |
| | | | 0.3 | | | | | | × | | | |
| | | | 0.3 | | | | | | | | | |
| | | | | | 0.2 | 1.3 | 0.8 | | | | | × |
| | | 0.2 | | 0.4 | | | | | | × | × | × |
| 0.4 | | | | | | | | × | × | × | × | × |
| 2.1 | + | + | | | | | | | | | | |
| | | | 0.3 | | | | | | × | × | × | × |
| 0.4 | | | 0.3 | | + | + | | × | × | × | × | × |
| | | | 0.3 | + | 0.2 | + | | | × | × | | |
| | | | + | + | + | | | × | × | × | × | × |
| | | | 0.3 | | | | | × | × | × | × | × |
| | | | + | | | | | | | | | |
| | | | | | | 0.3 | | × | | | | |
| | + | | + | + | | 0.3 | + | | × | × | | × |
| 19.5 | 430.0 | 96.0 | 140.0 | 291.0 | 266.0 | 26.7 | 28.0 | × | × | × | × | × |
| 109.0 | 2110.0 | 64.0 | 185.5 | 320.0 | 202.0 | 80.0 | 74.0 | × | × | × | × | × |
| 47.5 | 130.0 | 15.0 | 40.0 | 62.0 | 50.0 | 6.7 | 10.0 | | × | × | × | × |
| | 10.0 | 1.0 | | 6.0 | 4.0 | | | | | | | |
| 121.0 | 7680.0 | 350.0 | 465.0 | 752.0 | 848.0 | 266.7 | 122.0 | | × | × | | × |
| | | 20.0 | 93.0 | 104.0 | 224.0 | | | × | × | × | | |
| 35.3 | 30.0 | 51.0 | 120.0 | 200.0 | 175.0 | 3.3 | 4.0 | × | × | × | | × |
| 157.7 | 1100.0 | 100.0 | 224.0 | 504.0 | 194.0 | 2936.7 | 1082.0 | × | × | × | × | × |
| | 10.0 | 1.0 | 3.5 | | | | 2.0 | | | | | |
| | | 2.0 | | 1.0 | 1.0 | | 2.0 | | | | | |
| | + | | + | | | | | | | | | |
| + | + | | 0.3 | + | | | + | | | | | |
| | + | | | | + | | | | | | | |
| | | | + | | | | | | | | | |
| | + | | + | + | | | + | | | | | |
| | + | + | | | | | | | | | | |
| | | | | | + | | | | | | | |

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