Danmarks geologiske Undersøgelse.
II. Række. No. 48.

# Stratigraphical and Paleontological Studies of Interglacial Fresh-water Deposits in Jutland and Northwest Germany

By

Knud Jessen and V. Milthers.

With XXXX Plates in an Atlas.

København.
I Kommission hos C. A. Reitzel
(Indeh. Axel Sandal).
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Andelsbogtrykkeriet i Odense.

*To N. Hartz, the earliest authority on the interglacial bogs of Denmark, these studies are dedicated.*

# Contents.

# Introduction.

With the publication of "Bidrag til Danmarks tertiære og diluviale Flora"[1]), N. HARTZ brought to a conclusion his fundamental investigations of interglacial bogs in Denmark, the bulk of which belongs to the so-called Brörup type; that is to say, interglacial deposits lying in a basin recognisable as such relative to the present surface of the country, and covered by layers of sand, gravel or clay of non-glacigenous origin[2]). For some years after, the questions associated with these formations were regarded as solved in all essentials. Supplementary investigations[3]) of the stratigraphical position of these bogs in relation to the extent of the last ice sheet occasioned no alteration in this view, as regards the deposits themselves. But just at the time when these last investigations were being carried out, a starting point was furnished for those further investigations which will be dealt with in the following pages. The first steps in this direction were taken in 1914, in connection with marl prospecting works in the Herning district, in the course of which, calcareous, stoneless clay, bedded on calcareous moraine clay, was discovered in the clay pit at the Herning brickworks. Above this stoneless clay, V. MILTHERS found plant-bearing beds, which again were covered by strata of clay and sand, and which must be regarded as interglacial. In the course of a subsequent visit paid to the spot by KNUD JESSEN together with V. MILTHERS it was found that the interglacial mud beds contained, in addition to the ordinary characteristical fossils, *inter alia* remarkably quantities of nuts of *Trapa natans* hitherto unknown in Danish interglacial deposits. In addition to this more prominent mud bed, and the subjacent clay with an arctic flora we found also an upper plant bearing stratum, 5 cm thick, which however, was not regarded as of

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1) N. HARTZ: Bidrag til Danmarks tertiære og diluviale Flora. D. G. U. II. R. No. 20. 1909. — In all the publications of D. G. U., R. (Series) I, II and IV, is found a summary of the contents in French or Englihs language.

2) Cf. Chapter III. — By a glacigenous formation is here understood — in accordance with Swedish terminology — beds of gravel, sand or clay formed in direct association with the inland ice.

3) AXEL JESSEN, VICTOR MADSEN, V. MILTHERS et V. NORDMANN: Brörup-Mosernes Lejringsforhold. D. G. U. IV. R. Bd. 1. No. 9, 1918.

great importance, but considered as derived from the mud bed deeper down.

With the intention to ascertain whether the covering stratum above the basin deposits should be classed as a glacigenous formation (fluvioglacial sand), as V. MILTHERS supposed at the time, investigations were set on foot in 1919, under his supervision, and borings were made to show the stratigraphical conditions of the beds in this basin as they occur in the vicinity of the brickworks and pits. These borings, which were carried out by I. C. KALLESTRUP, boring-master of Denmark's Geological Survey, must be said to prove that the interglacial strata had not been covered with ice. KNUD JESSEN's examination of the very numerous samples sent home from the borings showed that the deposits of the interglacial lake at Herning consisted of the following strata, reckoning from below upward. 1) Arctic clay, 2) mud with a rich interglacial flora, 3) stoneless clay with a sub-arctic flora, 4) sandy mud and detritus mud with a flora similar to that of 2), 5) stoneless clay with a sub-arctic flora and 6) stony sand. This was a profile differing essentially from what was previously known, and at once suggested the possibility of finding corresponding lake deposits in basins without outflow in other parts of Jutland, which likewise had not been covered with ice during the last glaciation.

A welcome opportunity of putting this to the test occurred two years later, when the Technical Committee of the Ministry of the Interior had borings made down to the depth of 15 m in parts of western Jutland with a view to possible finds of brown coal, this work being under the direction of V. MILTHERS. In the course of these prospecting operations, in the neighbourhood of Videbæk, midway between Herning and Ringköbing, a preliminary boring was made in the immediate vicinity of Solsö, 4 km north of Videbæk itself. This revealed an interglacial bed with a great number of seeds of *Brasenia purpurea*. A new boring was then made directly after, close beside the first, in the presence of KNUD JESSEN; the result suggested that we had here again two warm interglacial horizons, just as at the Herning brickworks. Some borings made in conjunction with these investigations in enclosed basins at Herborg and Astrup south of Videbæk showed that these basins also contained interglacial bogs covered by beds of sand and gravel.

We had now found, in Ringköbing county, interglacial beds in the bottom of enclosed basins at Astrup, Herborg (two localities), Solsö and Herning, in all cases with from 1—ca. 10 m of stony or stoneless sand above, which could not be regarded as a glacigenous deposit. These interglacial formations thus exhibited similar stratigraphical conditions as those of the Brörup bogs, and were situated under hollows plainly visible as such in the country round. It seemed therefore natural to suppose that we might, by systematic borings in landlocked basins of the great hilly tracts of western Jutland, come upon still further interglacial deposits. Such investigations would be interesting not only as throwing fresh light on the interglacial and post-glacial topography of western Jutland but also for the question as to whether the interglacial profile type located at Herning brick-works, with 2 warm horizons, was of any greater extent, and thus of more general importance.

We could not hope, with the means at the disposal of the Denmark's Geological Survey alone, to accomplish such an extensive programme of work within a reasonable time, and therefore, in 1921, we made application to the Carlsberg Fond. This institution readily granted our request for financial support in the search for new interglacial deposits, with subsequent detailed borings in suitable bogs. In the course of the two next summers, 1922 and 1923, we made, in all, 121 borings in 38 enclosed basins[1]), most of these being indicated beforehand on the General Staff maps. The apparatus used was a well boring apparatus with sand pump and 3-inch iron lead-pipe. These borings were carried out in the district between Solsö in the north and Agerskov in the south (cf. Pl. I), and led to the discovery — apart from the 4 localities found in 1921 — of 17 new sites from the last interglacial period, three of which, viz. Rodebæk, Nörbölling and Brörup, exhibited the Herning profile, while the renewed investigations at Solsö showed that matters here are not so as at first supposed. At the same time, borings were also made in several other interglacial deposits.

From the experience gained in the course of this work it is to be expected that one should, by similar operations, be able to locate new interglacial localities in the corresponding parts of South Sleswic and Holstein, and probably farther to the south and east beyond the limit of glaciation in the last glacial period. On the island of Sylt, at Drelsdorff in South Sleswic, at Nienjahn in Holstein, and in the Hamburg district, a number of interglacial bogs of the Brörup type are already known[2]), but no systematic investigations have been made in those regions. With a view of gaining some idea as to the known interglacial formations of northwest Germany, and making comparison between the topographical features there and in western Jutland, we made a journey through those countries in the autumn of 1923, prosecuting out studies on the spot. We had

1) Five of these were known beforehand to contain interglacial bogs.

2) Cf. Chapter IV.

the good fortunate to enjoy the company of Professor Dr. W. WOLFF throughout the greater part of the journey, and it was thanks to him alone that we were able, in the short time at our disposal, to obtain a good general view of the manner in which the interglacial formations occur in northwest Germany. We have also, in the spring of 1927, made an excursion to some interglacial deposits in the Lüneburger Heide, this time in company with Dr. K. VON BÜLOW. Our observations on these journeys have been dealt with in the Chapter IV—VII, where we also endeavour to draw comparisons between the interglacial formations of Jutland and those of North Germany. Our observations as to the transforming effects of solifluction in the hilly tracts of middle and western Jutland are discussed in Chapter III.

It must, from the nature of the case, be far more expensive to obtain boring profiles through interglacial freshwater deposits, and to determine the extent of these, even approximately, than in the case of alluvial bogs. This is one of the reasons why many of the deposits mentioned in the following may perhaps appear insufficiently investigated, as is often the case for instance with the marginal portions of those very basins in which most borings were made.

As regards the interglacial deposits, we had here to concentrate on the elucidation of their main stratigraphical features with a wiew to closer comparison between these formations and the post-glacial bog and lake deposits. Not only was it necessary to make sure that the contents of the individual beds as regards macroscopic fossils were thoroughly investigated; it was natural here also to apply the pollen statistical method, which has of late years yielded such excellent results in the case of the post-glacial bogs. We found however, that it was not always possible to obtain pollen samples taken at sufficiently short intervals, as the boring appatus used — though doubtless the best for our purpose — did not always admit of altogether precise determination of depth. As a rule therefore, the distance between the pollen samples is greater than we should wish, and we found particular difficulty when boring in sandy, water-bearing lake deposits. Only in places where interglacial marl deposits lay exposed to the air were pollen samples taken directly in sections or by means of the screw-auger.

The samples for pollen counting have been dealt with approximately as suggested by ERDTMAN[1]); we have, however, for further clarification of the pollen itself and fragments of tissue, first subjected the samples to a light boiling in highly diluted nitric acid. In calca-

1) G. ERDTMAN: Pollenanalytische Untersuchungen von Torfmooren und marinen Sedimenten in Südwest-Schweden. Dissertation. Uppsala 1921, p. 16 f.

reous muds, the pollen frequency of the preparations — i. e. quantity of pollen per sq. cm preparation surface (ERDTMAN[1]) — is greatly increased by this process, and the pollen frequency noted in the diagrams from the calcareous strata cannot therefore be compared with that of series where the carbonate of lime is slight in quantity or lacking altogether. We have throughout operated as far as possible with preparations of uniform density. In the pollen diagrams, we have employed the symbols used by L. VON POST, ERDTMAN and other Swedish geologists for designation of the different species, though we have found it advisable to introduce two alterations, viz. for *Carpinus* and *Corylus*.

We are very indebted to Mr. AUG. HESSELBO for the determination of almost all the Moss-species mentioned, to Mr. K. L. HENRIKSEN for the determination of the remains of insects, to Mr. J. BOYE PETERSEN for the determination of Diatoms and to Mr. K. GRAM and Mr. S. BENGTSSON for taking photographs of seeds and fruits. The translation from Danish is due to Mr. W. WORSTER.

We wish to express our respectful thanks to the Carlsberg Fond for the great assistance granted us in this work; the support thus rendered has enabled us to prosecute our operations on such a scale that we have, in several essential respects, succeeded in correcting and adding to what was previously known as to the diluvial period in Denmark and Northwest Germany.

*The Authors.*

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[1]) G. ERDTMAN: Iakttagelser från en micropaleontologisk undersökning av nordskotska, hebridiska, orkadiska och shetlandiska torvmarker. Geol. Fören. Förhandl. Stockholm. 1923, p. 541.

# Interglacial Deposits in Jutland.

## Deposits from the Last Interglacial Period.

In this chapter are to be treated interglacial deposits generally situated in a basin recognisable as such in the precent surface of the ground, lying outside the border line of the last ice sheet, and not covered by glacigenous formations but by "covering sand", which may for the most part be regarded as fossil solifluction material[1]).

In addition to the bogs mentioned in the following pages, this group also comprises the bogs at Bramming[2]), Tuesböl I[3]), Skovlyst[4]), Lundtofte[5]), Emmerlev[6]), Mögeltönder and Spandet[7]; doubtless also the bog in the clay pit belonging to the Brörup Marl Compagny[8]), the lake deposits at Ejstrup and the bog at Rostrup, see p. 196.

### Bogs with two separate Mud beds. The Herning-Type.

### The Interglacial Lake at Herning.

Mention has already been made, in the introduction, of the manner in which our attention was drawn to the interglacial deposits at the Herning brickworks, situated 2 km west of the town of Herning (see Fig. 1), and of how the investigation proceeded. On the site of the interglacial lake there is now a perfectly flat hollow sloping from the southwest to the northeast, with an outflow towards the northwest along the Herning-Holstebro road, to the stream known as Hernings-

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1) Cf. Chapter III.

2) N. Hartz: Bidrag etc. . . . D. G. U. II. R. No. 20, p. 183.

3) D. G. U. II. R. No. 20, p. 160. A. Jessen, Victor Madsen, V. Milthers, V. Nordmann: Brörup-Mosernes Lejringsforhold. D. G. U. IV. R. Bd. I. No. 9, p. 17—22.

4) D. G. U. II. R. No. 20, p. 178. D. G. U. IV. R. Bd. I. No. 9, p. 22—32.

5) D. G. G. II. R. No. 20, p. 191. D. G. U. IV. R. Bd. I. No. 9, p. 32—36.

6) Meddel. fra Dansk geol. Forening, Bd. 6. 1925, p. 35.

7) These two last named bogs situated on the geological map Tönder have not yet been published.

8) D. G. U. IV. R. Bd. I. No. 9, p. 36—40. V. Milthers: Kortbladet Bække. D. G. U. I. R. No. 15. 1925, p. 55—63.

holm Aa. There are however, in this hollow a couple of small areas bounded on the map by closed curves, and in the deeper of these there is some post-glacial peaty soil, cf. Pl. II. The ground surrounding the hollow forms part of the smooth, slightly undulating plateau on the eastern side of Skovbjerg hill island. In the immediate vicinity, the boulder clay crops out at the surface, covered, at the utmost, by a layer of stony sand, which rarely amounts to a meter in thickness. Below the boulder clay lie fluvioglacial sand and gravel, which at several places close by crop out at the surface in patches of more or less extent in which there are several large gravel pits.

The profile which we surveyed in the brickworks pit in 1914 is shown in Pl. III and is further reproduced at the south end of the longitudinal profile, Pl. VIII where the heights are greatly exaggerated. The remainder of this profile was drawn from borings, of which 41 were made in all. Borings Nos. 1—3, 5—9, 19—25, 34—41 are from 1919 (cf. p. 2); the remainder are from the autumn of 1923 and autumn 1924, and were carried out in our presence. The position of the borings and the extent of the lake deposits are noted on the map, Pl. II. The numerical sequence here used for the borings does not correspond to their chronological order, but was chosen on practical grounds. From these borings, and also from the lake deposits in the brickworks pit, about half a ton of samples were collected and sent home. Almost the whole of this mass of earth has been washed, after first cleansing the separate samples by scraping, where they consisted of coherent clay or mud. Special samples were also collected for pollen analysis, these being taken as a rule from the lower portion of the mud or clay brought up by the screw-auger. All the boring profiles will be found on p. 22—46.

We have on several occasions referred to the interglacial lake at Herning. Thus for instance in 1914, V. Milthers made a statement as to the profile here in the Danish Geological Society, and in 1915, I mentioned to the Danish Botanical Society our find of *Trapa natans* in the interglacial strata at Herning; I have also given the profile of the lake deposits in a thesis in my work for the Doctorate in 1920[1]). V. Milthers refers to The Herning profile, in the course of his description of the interglacial bogs of the map-sheet Bække[2]).

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1) Knud Jessen: Moseundersøgelser i det nordöstlige Sjælland, Copenhagen 1920, p. 242. Copy of D. G. U. II. R. No. 34.

2) V. Milthers: Kortbladet Bække. D. G. U. I. R., No. 15. 1925, p. 52.

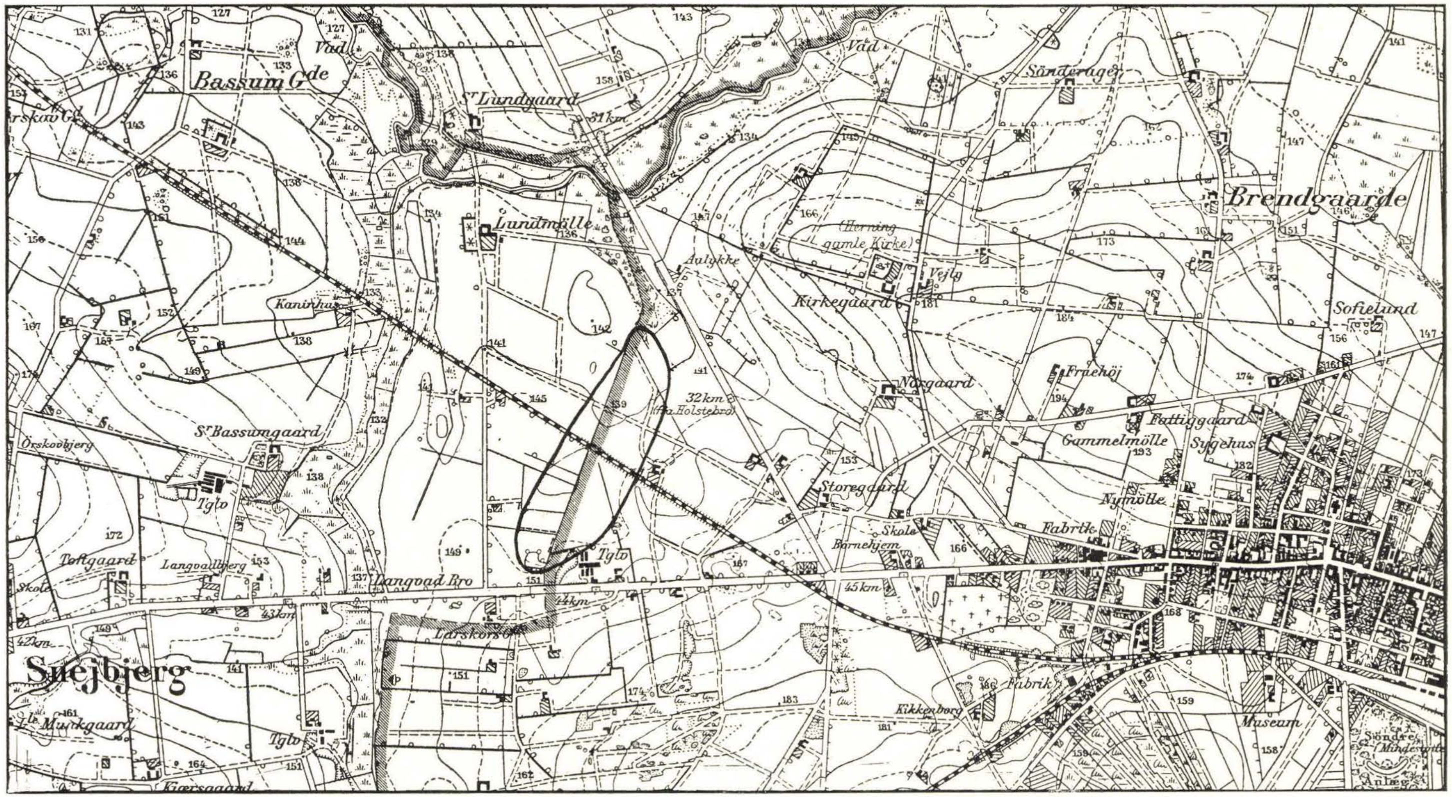


Fig. 1. Map of the district west of Herning (the town is seen to the right in the figure). Position of the interglacial lake is indicated by the enclosed coarse line north of Herning Brickworks (*Tglv.*). Scale 1 : 25000. Contour interval 5 feet = 1.57 m. After the General Staff Map Sheets 2406 and 2506.

## The profile in the Brickworks Pit 1914.

The position of this profile (Pl. III) is shown on the map Pl. II. It was measured for the most part by V. MILTHERS, the botanical collections being undertaken by myself. Of late years, clay has been mostly dug from the ground to the south of the sandy lake deposits, and the profile has now for a long time been almost entirely covered with material fallen from above.

Each bed of the profile from A to O, will be dealt with separately in the following.

A. Sandy, stony Mould, 10—20 cm thick.

B. In a hollow in the subjacent bed, between 8 and 19 m, there was found a layer $^1/_2$ m tick of stoneless, rather fine Sand, which must probably be regarded as wind blown sand.

D. All over the subjacent series of strata extended a bed of stony Sand, the stones as a rule up to the size of hen's eggs. The greatest thickness of this bed was $^3/_4$ m, and for a great part of its extent it was found to be highly contorted, no distinct stratification being otherwise discernible. In the southernmost part, the sand was somewhat mixed with clay, and here the bed might sometimes appear almost of a moraine type.

E. Yellow Sand with scattered stones of the size of eggs; it had distinct stratification, folded and bent at the top, fairly regular and almost horizontal lower down; its total thickness was ca. 1.4 m. South of Point 27 m the beds E and J fused together, and the continuation southward was formed by a sandy, very heterogeneous moraine-like mass with lumps of richer clay kneaded in here and there.

G. A bed of brown muddy Sand, up to 5 cm thick, with numerous rolled sticks in the lower portion; the line of demarcation from the layer below was sharp. This bed could be followed from the northern end of the profile to Point 30 m, where it thinned out. The following determinable vegetable remains were found:

*Betula pubescens*[1], 1 fruit,
*Carex sp.*, a few nuts without utriculus,
*Carpinus betulus*, 1 small nut,
*Salix sp.*, bud scales,
*Trapa natans*, two horns.

*Caliergon stramineum.*

J. Stony non-calcareous Clay up to 0.5 m tick; it had slight stratification, or consisted of small polygonal blocks; its colour was yellowish red at top and bottom, otherwise grey. This bed extended

[1]) The Authors to the systematical names on plants and animals will be mentioned only in the general list in the end of Chapter II.

southward to abt. 27 m, but in the southern portion, it changed character somewhat, appearing in places like stoneless glacial clay, in others more of the moraine type. A large sample from this bed, taken in 1919, yielded on washing only 1 catkin scale of ***Betula nana*** and 4 fruits of ***Empetrum nigrum***.

$K_1$. A bed of rather coarse light Sand, thinning out about point 22 m; greatest thickness $^3/_4$ m. No corresponding bed was found by the borings; it must be regarded as a littoral formation.

$K_2$. The *Trapa* Bed. This was divisible into three distinct zones, merging one into another without marked boundaries. At the top was a weathered horizon consisting of yellow sand mixed with clay and loam, and no fossils; below this the *Trapa* stratum proper, which appeared as a typical shore formation of brown, sandy mud with irregular layers and lenses of light coloured sand. It was rich in fragments of branches, fruits and other vegetable remains; at the bottom was the *Ceratophyllum* Bed. The total thickness was up to 1 m. The lower portion of the *Trapa* stratum proper contained grater numbers of *Trapa* fruits than the upper part, which, on the other hand, yielded more fruits of oak and hazel; otherwise, there seemed to be no difference in the fossil content.

The state of preservation of the vegetable remains was extremely good; they were not rolled, and both *Trapa* and *Ceratophyllum* fruits had the horns as a rule intact; acorn cups were frequently found with the stalk unbroken. *Trapa natans* was found from the north end of the profile to 42.5 m in the south, and afterwards again between 35 and 37 m, but representatives of the "*Trapa* flora" have been met with throughout the whole stratum as far as 27 m, where it thinned out.

The following vegetable remains have been found in the *Trapa* bed:

*Acer campestre*, fruits without wings, seeds (Pl. XXXI, 17–21),
*Alnus glutinosa*, catkin spindles, fruits, pollen, very common,
*Betula sp.*, pollen, scarce,
*Brasenia purpurea*, 9 seeds,
*Carpinus betulus*, 2 grains of pollen,
*Ceratophyllum demersum var. apiculatum*, numerous fruits,
— *submersum*, 2 half fruits,
*Cornus sanguineus*, 1 fruit-stone,
*Corylus avellana*, numerous nuts, some gnawed by mice *(Mus sylvaticus?)*, pollen,
*Frangula alnus*, 1 fruit-stone,
*Fraxinus excelsior*, 1 fruit,
*Ilex aquifolium*, numerous fruit-stones, a fragment of a leaf,
*Najas marina*, several fruits,
*Nuphar luteum*, numerous seeds,
*Nymphaea alba*, several seeds,

*Pinus silvestris*, pollen, not common,
*Polygonum tomentosum*, 1 fruit,
*Potamogeton densus*, 1 fruit-stone,
— *natans*, common,
— *praelongus*, 5 fruit-stones,
— *sp.*, common,
*Quercus robur*, acorns and acorn cups, most common in the upper part of the stratum, pollen,
*Ranunculus repens*, 2 fruits,
*Salix sp.*, some pollen,
*Scirpus lacuster*, numerous fruits,
*Sparganium erectum*, fairly common,
— *minimum*, several fruits,
*Taxus baccata*, 1 seed,
*Tilia platyphylla*, a part of a pyriform *Tilia*-fruit with thick, somewhat spongiouse wall and with keels on the sutures (Pl. XXXIII, 3–5),
*Tilia sp.*, pollen,
*Trapa natans*, numerous fruits, especially in the lower part of the stratum (Pl. XXXI, 1—16),

*Climacium dendroides*,
*Eurynchium praelongum*,
*Homalothecium sericeum*,
*Hylocomium proliferum*,
— *squarrosum*,
*Isothecium viviparum*,
*Mnium stellare*.

*Cenococcum geophilum*, numerous sclerotia.

Mouse *(Mus sylvaticus?)* gnaved hazel nuts.[1])

*Phytoptus laevis*, galls.

*Spongilla lacustris*, spicules.

The *Ceratophyllum* Bed. This consisted of a dark-brown, sandy Mud, the lower portion of which, a thin boundary layer, sharply set off from the underlying clay, was almost black. The stratum filled the cauldron-shaped depressions in the subjacent clay, as described below, and its upward limit was altogether diffuse. It attained a thickness of up to 40 cm, and extended from the northern end of the profile to abt. 43.5 m. South of this point, the *Trapa* stratum rested directly on the arctic clay.

In the black boundary layer adjoining the clay were found:

*Betula pubescens*, 1 catkin scale,
*Ceratophyllum demersum var. apiculatum*, a few fruits,
*Potamogeton sp.*, 2 fruits.

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[1]) Determined by the late Vice-Inspector Herluf Winge.

The remaining portion of the stratum contained.

*Alnus glutinosa*, fruits, catkin spindles, pollen, commen,
*Betula sp.*, pollen, fairly, common,
*Ceratophyllum demersum var. apiculatum*, many fruits,
*Corylus avellana*, 1 nut, abt. 20 cm above the lower edge,
*Dryopteris thelypteris*, spores, sporangium fragments,
*Najas marina*, a few fruits,
*Nuphar luteum*, a few seeds,
*Pinus silvestris*, abundant pollen,
*Potamogeton natans*, numerous fruits,
*Quercus sp.*, fairly abundant pollen,
*Scirpus lacuster*, a few fruits.
*Sparganium affine*, 1 fruit-stone from the bottom of the layer (Pl. XXXIII, 27)
*Trapa natans*, a few horns.

L. The Arctic Clay. A bed up to 2,5 m thick of stratified, calcareous, stoneless clay, dark grey in colour, the southern portion however, — above the dotted line in the profile — weathered and yellow. The clay-content was greatest at the bottom, the upper part being more sandy. It extended from the north end of the profile to Point 10 m, where it thinned out. The boundary surface adjoining the *Ceratophyllum* stratum was highly irregular, especially from Point 33 m northward, forming here cauldron-like depressions in the clay, in which the *Ceratophyllum* stratum was found, Pl. V.

The arctic clay showed in several places numerous remains of plants; this was especially the case in three separate horizons, abt. 30, 52 and 86 cm respectively below the upper surface of the stratum; it was here that most of the fossils were found, and no species other than those found here were met with in any other part of the profile. The lowest of these plantbearing strata contained only a few remains of leaves of *Betula nana* and *Salices*, there were more in the middle stratum, and in the uppermost, the bed was at times altogether covered with remains of leaves. The following species were found in these three strata:

| Species | abt. 30 cm | abt. 52 cm | abt. 86 cm |
|---|---|---|---|
| *Batracium aquatile (coll.)* | + | .. | + |
| *Betula nana* (Pl. XXXV, 11—14, 16—18) | + | .. | .. |
| — *nana* × *pubescens* (Pl. XXXV, 15, 19—20) | + | + | + |
| *Carex spp.* | + | + | + |
| *Hippuris vulgaris* | + | + | .. |
| *Potamogeton filiformis* | + | .. | + |
| *Potentilla palustris* | + | .. | + |
| — *sp.* | + | .. | .. |
| *Salix phylicifolia* (Pl. XXXIV, 5—6) | + | + | + |
| — *herbacea* (Pl. XXXIV, 1) | .. | + | .. |

| Species | abt. 30 cm | abt. 52 cm | abt. 86 cm |
|---|---|---|---|
| *Salix reticulata* (Pl. XXXIV, 9) | .. | + | .. |
| — *cf. repens* (Pl. XXXIV, 7–8) | + | .. | .. |
| *Sparganium sp.* | + | .. | + |
| | | | |
| *Amblystegium polygamum* | + | + | .. |
| — *stellatum* | .. | + | + |
| *Brachythecium albicans* | .. | + | .. |
| *Bryum ventricosum* | .. | + | + |
| *Calliergon giganteum* | .. | + | .. |
| — *sarmentosum* | .. | + | .. |
| — *stramineum* | .. | + | + |
| *Camptothecium trichoides* | .. | + | .. |
| *Dicranum congestum* | .. | + | .. |
| — *scoparium* | .. | + | .. |
| *Gymnocybe palustris* | .. | + | + |
| *Hypnum exannulatum* | + | .. | .. |
| — *revolvens* | + | + | .. |
| — *uncinatum* | .. | .. | + |
| *Lescuraea Breidleri* | + | + | + |
| *Meesea triquetra* | .. | .. | + |
| *Mnium cuspidatum* | + | .. | .. |
| *Philonotis tomentella* | .. | + | + |
| *Polytrichum juniperinum* | .. | + | .. |
| — *strictum* | + | .. | + |
| *Scorpidium scorpioides* | + | .. | .. |
| *Thuidium abietinum* | .. | + | + |
| *Tortula ruralis* | .. | + | .. |

*Betula nana* and *Salix phylicifolia* were found abt. 5 cm below the upper surface of the clay.

M. The arctic clay rested concordantly on a 0.4—0.5 m layer of Sand, gravelly here and there in the lower parts. The boundary surface, adjoining the subjacent glacial clay, was somewhat irregular, the clay sometimes thrusting out like streaks af ooze into the lower portion of the sand. In the upper portion of the sand stratum were found several thin mossy layers between 18 m and 32 m; in these were observed:

*Carex sp.*, 3 nuts without utriculus,
*Potamogeton sp.*, 1 small fruit-stone,
*Salix sp.*, 1 grain of pollen.

*Calliergon giganteum*,
*Hypnum aduncum*,
— *exannulatum*,
— *revolvens*,
*Scorpidium scorpioides*.

*Anchomenus lugens*, 2 wings.

N. Rich Clay, without stones, glacial clay. In the southern part of the brickworks pit, where this clay bed was covered directly by the stony sand (D), no distinct stratification was apparent; farther north, however, where covered by the sand (M), it was handsomely stratified, consisting here of alternating light and dark grey layers, varying in thickness from 0.5—4.0 cm. The dark very fine-grained layers were broken up in small scraps and were as a rule very thin. These minor layers, which were presumably varv had on the whole the same slope as the total stratum, the maximum thickness of which was 1.35 m.

Chemical analysis of the dark and light layers in the varvs taken from samples collected by V. MILTHERS gave the following dertermina-tions of $CaCO_3$ and $MgCO_3$, calculated from the quantity of dry matter:

| | $CaCO_3$ | $MgCO_3$ | Parts $MgCO_3$ pr. 100 parts $CaCO_3$ |
|---|---|---|---|
| Dark strata | 9.82 % | 0.57 % | 5.90 |
| Light strata | 23.20 % | 0.64 % | 2.80 |

From these analyses of the year sheeded clay it appears that there is here a very similar difference between the dark and light layers as regards $CaCO_3$ and $MgCO_3$ content, to that found by A. G. HÖGBOM[1]) between the winter and summer deposits in Swedish late glacial formations of varve clay, the calcium content being considerably higher in the summar layers than in the winter ones, while the relative amount of $MgCO_3$ is highest in the dark winter layers. About 80 varv in alle were counted. Pl. VII.

O. The lowest stratum in the greatest part of the clay pit was Moraine Clay. Where this was not covered by the interglacial strata, it showed a strong yellowish red weathering tinge, the unweathered moraine clay being dark grey, and containing 8.5 % $CaCo_3$. A flake of micaceous clay was found enclosed herein. Of stones from the moraine clay, several of rhombic porphyry were observed, and some of Saltholm chalk, but no Baltic blocks or Dala blocks. At the extreme south in the brickworks pit, the fluvioglacial sand and fluvioglacial gravel cropped out under the moraine clay.

## List of Boring Profiles surveyed in 1919, 1923 and 1924 in the area north of the brickworks pit.

(Cf. Pl. VIII and Pl. IX).

Boring 1.

| | | |
|---|---|---|
| A. | 0 — 0.4 m | Sandy Mould. |
| B. | 0.4 — 1.3 m | Greyish yellow, argillaceous Sand. |
| E. | 1.3 — 1.7 m | Grey Sand. |
| F. | 1.7 — 1.8 m | Yellow Clay. |
| G. | 1.8 — 2.8 m | Uppermost: alternating layers of Sand and Mud, below: brown sandy Mud. |

1) A. G. HÖGBOM. Om relationen mellem kalcium og magnesium karbonat i de qvartäre aflagringarna. Geol. Foren. Förhandl. Vol. II, p. 263 ff. Stockholm 1889.

J. 2.8 — 4.4 m Bluish-grey stoneless Clay; at 3 m a thin layer of sand.
$K_2$ 4.4 — 6.8 m Brown sandy Mud.
L. 6.8 — 7.6 m Dark grey stoneless Clay.
O. Dark grey sandy Moraine Clay.

Boring 2.

A. 0 — 0.6 m Stony sandy Mould.
B. 0.6 — 1.2 m Yellowish-grey argillaceous Sand.
D. 1.2 — 1.7 m Yellow Sand with small stones.
E. 1.7 — 3.1 m Rather coarse, somewhat humous Sand, grey in colour:
*Carex sp.*, 1 fruit.
*Cenococcum geophilum*, several sclerotia.
F. 3.1 — 3.8 m Greyish brown argillaceous Mud, or grey Clay.
Washings from this yielded:
*Arctostaphylus sp.*, $^1/_2$ fruit-stone,
*Batrachium aquatile (coll.)*, 5 fruits,
*Betula nana*, 1 catkin scale,
*Carex sp.*, 2 fruits,
*Compositae*, 1 small fruits,
*Empetrum nigrum*, several fruit-stones,
*Selaginella selaginoides*, 1 spore.

*Calliergon stramineum*, several shoots,
*Hypnum exannulatum*, several shoots.

*Cenococcum geophilum*, several sclerotia.

*Daphnia pulex*, 1 ephippium.
G. 3.8 — 4.0 m Greyish brown sandy Mud, in which were found:
*Ajuga reptans*, 1 nut,
*Alnus glutinosa*, several fruits and catkin spindles,
*Ceratophyllum demersum*, a few fruits,
*Corylus avellana*, 1 nut,
*Najas marina*, $^1/_2$ fruit,
*Potamogeton filiformis*, 1 fruit-stone,
— *natans*, a few fruit-stones,
— *sp.*, several fruit-stones,
*Scirpus lacuster*, several fruits,
*Sparganium minimum*, 2 fruits,
— *sp.*, 1 fruit,
*Trapa natans*, fairly common.
J. 4.0 — 5.5 m Bluish grey stoneless Clay:
*Batrachium aquatile (coll.)*, 2 fruits,
*Betula nana*, 1 fruit,
*Selaginella selaginoides*, 1 spore.

*Cenococcum geophilum*, 1 sclerotium.
$K_2$. 5.5 — 7.7 m Brown Mud:
*Alnus glutinosa*, 1 fruit,
*Betula pubescens*, 2 fruits,
*Carex sp.*, 1 fruit,
*Carpinus betulus*, 1 fruit,
*Ceratophyllum demersum*, 2 fruits,

*Corylus avellana*, 1 nut,
*Potamogeton sp.*, 4 fruit-stones,
*Scirpus lacuster*, 2 fruits,
*Trapa natans*, three fragments of fruits.

L. 7.7 – 8.7 m Greyish blue stoneless Clay:
*Betula nana*, 1 fruit, 1 catkin scale,
*Compositae*, 1 fruit,
*Potamogeton sp.*, several fruit-stones.

O. Moraine Clay.

Boring 3.

A. 0 — 0.5 m Sandy Mould.

B. 0.5 — 1.7 m Yellow Sand.

D. 1.7 — 2.6 m Pale grey stony Sand.

E. 2.6 — 3.3 m Coarse greyish brown Sand, in which were found.
*Hippuris vulgaris*, 1 fruit-stone.
*Cenococcum geophilum*, some sclerotia.

G. 3.3 — 3.5 m Greyish brown argillaceous Mud:
*Betula pubescens*, 1 fruit,
*Carpinus betulus*, 1 fragment of a fruit
*Empetrum nigrum*, 1 fruit-stone,
*Myriophyllum cf. alterniflorum*, 1 nut.

*Cenococcum geophilum*, several sclerotia.

J. 3.5 — 6.2 m Greyish brown, stoneless Clay. A sample from this yielded
*Betula pubescens*, 4 fruits,
*Betula nana*, 1 fruit,
*Empetrum nigrum*, 1 fruits-tone,
*Picea excelsa*, 2 fragments of bud scales,
*Salix sp.*, 1 small bud.

*Cenococeum geophilum*, several sclerotia.

$K_2$. 6.2 — 8.3 m Brown Mud:
*Alnus glutinosa*, 4 fruits,
*Betula pubescens*, 4 fruits,
*Carex sp.*, 1 fruit,
*Lycopus europaeus*, 2 nuts,
*Menyanthes trifoliata*, 1 seed,
*Najas marina*, 1 fruit.
*Potamogeton sp.*, 5 fruit-stones,
*Scirpus lacuster*, 2 fruits.

L. 8.3 — 8.8 m Bluish grey stoneless Clay:
*Betula nana*, 3 fruits,
*Hippuris vulgaris*, several fruit-stones,
*Potamogeton sp.*, several fruit-stones.

M. 8.8 — 9.4 m Grey coarse Sand, which rose up a great deal in the lead pipe.

Boring 4.

(Pollen diagram see Pl. XXXVI, 1).

A. 0 — 0.3 m Mould.

D. 0.3 — 2.1 m Sand with stones up to the size of hen's eggs.

G. 2.1 — 4.0 m Uppermost, alternating layers of S a n d and M u d, rich in small fragtments of wood; below (abt. 0.5 m), brown m u d:
*Alnus glutinosa*, 2 fruits,
*Batrachium sceleratum*, numerous fruits,
*Betula pubescens*, 3 fruits,
— *sp.*, 1 fruit,
*Carex sp.*, several fruits,
*Carpinus betulus*, 1 fruit,
*Dulichium spathaceum*, 1 fruit with the perigonium bristles preserved,
*Empetrum nigrum*, 4 fruit-stones,
*Picea excelsa*, many fragments of wood (uppermost),
*Pinus silvestris*, 1 piece of bark etc. and leaf epidermis,
*Polypodium vulgare*, 3 spores,
*Potamogeton sp.*, 1 fruit-stone.

*Otiorrhynchus dubius*, 1 wing in the top of the bed.

J. 4.0 — 6.9 m Uppermost greyish brown a r g i l l a c e o u s M u d, with stones up to the size of beans, lower down merging into grey—greyish blue, tough non-calcareous C l a y. Vivianit.
*Batrachium sceleratum*, abt. 30 fruits, uppermost, (possibly brought down from G.),
*Batrachium aquatile (coll.)*, 2 fruits,
*Betula pubescens*, 2 fruits,
— *nana*, 1 fruit,
*Empetrum nigrum*, 2 fruit-stones.

*Acrocladium cuspidatum*,
*Bryum sp.*,
*Ceratodon purpureus*,
*Dichodontium pellucidum*,
*Ditrichum flexicaule*,
*Hylocomium proliferum*,
*Hypnum exannulatum*,
— *uncinatum*,
*Philonotis fontana*,
*Pohlia nutans*,
*Rhacomitrium sp.*

*Botryococcus Braunii*,
*Pediastrum integrum*,
— *Kawraiskyi*.

*Spongilla lacustris*.

$K_2$. 6.9 — 9.65 m Brown M u d, argillaceous in the upper part, sandy and distinctly stratified lower down:
*Alnus glutinosa*, 1 fruit,
*Betula pubescens*, 1 fruit,
*Carpinus betulus*, 1 fruit,
*Dryopteris thelypteris*, fairly many spores,
*Nymphaea alba*, intercellular hairs,
*Polypodium vulgare*, 1 spore,
*Sparganium minimum*, 1 fruit-stone.

*Botryococcus Braunii,*
*Staurastrum sp.*

*Spongilla lacustris*, several spicules.

$K_3$. 9.65—10.35 m Grey, sharp Sand, with some few small stones, the lower portion argillaceous.

Boring 5.

A. 0 — 0.2 m Mould.

B. 0.2 — 0.6 m Greyish yellow Sand with a few small stones.

D. 0.6 — 1.6 m Dark grey argillaceous Sand with stones the size of nuts.

G. 1.6 — 2.6 m Brown more or less sandy Mud:
*Alnus glutinosa*, several fruits and branches,
*Betula pubescens*, some fruits,
*Carex vesicaria*, 1 fruit,
— *sp.*, several fruits,
*Carpinus betulus*, fruits,
*Cladium mariscus?*, 2 rhizomes,
*Picea excelsa*, 2 needles, 1 seed, flakes of bark, 1 tip of a shoot,
*Pinus silvestris*, much wood,
*Polygonum tomentosum*, 4 fruits,
*Potamogeton sp.*, fruit-stones rather numerous,
*Rubus idaeus*, some few fruit-stones,
*Sambucus cf. nigra*, 1 small fruit-stone,
*Scirpus lacuster*, some fruits,
*Sparganium erectum*, 3 fruit-stones.

*Hypnum exannulatum,*
*Polytrichum sp.,*
*Sphagnum sp.*

*Cenococcum geophilum*, many sclerotia.

*Phytoptus laevis*, galls.

J. 2.6 — 4.5 m Uppermost, some few decimeters of fine, argillaceous Sand; below this, greyish blue stoneless Clay.
*Batrachium aquatile (coll.)*, 6 fruits,
*Betula nana*, 1 fruit,
*Carex sp.*, 1 fruit,
*Empetrum nigrum*, 1 fruit-stone,
*Salix sp.*, 1 bud, 1.5 cm long.

*Hypnum adnatum,*
— *uncinatum,*
*Meesea triquetra.*

$K_2$. 4.5 — 5.6 m Greyish brown Mud. Washings from the upper portion yielded the following:
*Alnus glutinosa*, 1 fruit,
*Betula pubescens*, 4 fruits,
*Carex sp.*, some fruits,
*Carpinus betulus*, 1 fruit,
*Picea excelsa*, bud-scales,

*Pinus silvestris*, bark,
*Scirpus lacuster*, some fruits.

[*Lescurea Breidleri*, a single specimen of this arctic species in the uppermost part of the stratum, probably derived from J.].

$K_3$. 5.6 — 6.2 m Grey Sand. Two fruits of *Najas marina* were found here.
L. 6.2 — 7.8 m Greyish blue stoneless sandy Clay with thin stripes of sand; slightly calcareous. No fossils in the washing samples.

Boring 6.

A. 0 — 0.3 m Mould.
B. 0.3 — 1.5 m Grey Sand, the upper part at any rate wind blown Sand.
C. 1.5 — 1 6 m Grey, stoneless Clay.
D. 1.6 — 2.7 m Grey, stony Sand.
E. 2.7 — 3.4 m Grey Clay and greyish brown argillaceous Mud kneaded together:
*Batrachium aquatile (coll.)*, 1 fruit,
*Empetrum nigrum*, 1 fruit-stone,
*Potamogeton spp.*, several small fruit-stones.
G. 3.4 — 5.5 m Greyish brown sandy Mud:
*Menyanthes trifoliata*, 1 seed,
*Potamogeton sp.*, 1 fruit-stone.

*Cenococcum geophilum*, several sclerotia.
H. 5.5 — 7.3 m Grey Sand with some plant detritus; between 6.0 and 6.5 stones were rather numerous. Washings from the lower part of this layer yielded:
*Batrachium aquatile (coll.)*, 1 fruit,
*Betula pubescens*, 1 fruit,
*Betula nana*, 1 fruit, 2 catkin scales,
*Carex sp.*, 1 fruit,
*Empetrum nigrum*, several fruit-stones,
*Potamogeton sp.*, 1 fruit-stone,
*Scirpus lacuster*, 1 fruit.
$K_2$. 7.3 —10.5 m Greyish brown Mud.
L. 10.5 — 13.0 m Stoneless Clay.

Boring 7.

A. 0 — 0.3 m Mould.
B. 0.3 — 1.0 m Red Sand (presumably wind blown sand).
D. 1.0 — 4.2 m Grey stony Sand.
F. 4.2 — 4.7 m Uppermost, 10 cm grey argillaceous Sand; grey coarse Sand below.
G. 4.7 — 5.8 m Brown Mud.
J. 5.8 —12.3 m Grey, greyish blue stoneless Clay, with sand streaks in the upper portion.
$K_2$. 12.3 — 13.5 m Brown Mud. This stratum not bored through.

Boring 8.

A. 0 — 0.3 m Mould.
B. 0.3 — 2.0 m Sand without stones.

| | | |
|---|---|---|
| D. | 2.0 — 3.85 m | Sand with stones up to the size of walnuts. |
| D. | 2.85 – 4.0 m | Sand with a few thin streaks of sandy Mud. |
| G. | 4.0 — 5.3 m | Alternating layers of Sand and brown Mud. |
| $H_1$. | 5.3 — 7.4 m | Uppermost, grey sharp Sand with a few small stones; from 6.8 m to 7.4 m, the sand contained a considerable number of stones, up to the size of hen's eggs; abt. 6.3 m below the surface was a thin layer of sandy Mud, washings from which yielded:<br>*Batrachium sp.*, 1 fruit,<br>*Juniperus communis*, 1 small branch,<br>*Selaginella selaginoides*, 1 megaspore. |
| J. | 7.4 — 7.7 m | Grey, sandy mudy Clay; abt. 7.45 m below the surface a fragment of the branch of a conifer was found. This stratum was not bored through. |

Boring 9.

(Pollen diagram, see Pl. XXXVI, 2).

| | | |
|---|---|---|
| A. | 0 — 0.3 m | Mould. |
| B. | 0.3 — 1.3 m | Rather fine Sand, the upper part wind blown sand. |
| $C_1$. | 1.3 — 2.1 m | Uppermost, abt. 5 cm of fresh moss, below this Sand with plant detritus, numerous fruits of *Carex sp.*, and a fruit-stone of *Potamogeton sp.* The moss consisted of the following species:<br>*Amblystegium polyganum*,<br>*Hypnum exannulatum*,<br>— *revolvens*,<br>*Mnium cuspidatum*,<br>*Scorpidium scorpioides*. |
| $D_1$. | 2.1 — 2.95 m | Rather fine Sand with stones. |
| $D_2$. | 2.95 — 3.75 m | Grey, non-calcareous stony Clay. |
| F. | 3.75 — 4.0 m | Greyish brown argillaceous and sandy Mud with a few small stones:<br>*Batrachium aquatile (coll.)*, numerous fruits,<br>*Betula nana*, 1 catkin scale, 2 fruits, several dwarf branches,<br>*Betula sp. (alba?)*, 1 fruit,<br>*Carex sp.*, 3 fruits,<br>*Empetrum nigrum*, 4 fruit-stones,<br>*Salix sp.*, a bud, 2 mm long,<br>*Sparganium sp.*, 1 small fruit.<br><br>*Cenococcum geophilum*, 1 sclerotium,<br><br>*Pediastrum sp.*<br><br>*Spongilla lacustris*, spicules. |
| F. G. | 4.0 — 4.7 m | Stony Sand, gravelly with stones the size of hen's eggs. |
| G. | 4.7 — 7.15 m | At top and bottom some thin layers of Mud, the remainder consisting of stony Sand with stones up to the size of walnuts. For the pollen content of these mud bed see Pl. XXXVI, 2. Apart from tree-pollen, the following were found:<br>*Ajuga reptans*, $1/2$ nut,<br>*Betula pubescens*, 2 fruits,<br>*Dryopteris thelypteris*, spores, |

*Lycopodium annotinum*, 1 spore,
*Nymphaea alba*, intercellucular hairs,
*Polypodium vulgare*, several spores,
*Scirpus lacuster*, 1 fruit,
*Umbelliferae*, 1 grain of pollen.

*Gymnocybe palustris*, fragments of leaves,
*Hypnum uncinatum*,
[*Lescuraea Breidleri*, an arctic species, presumably derived from the beds higher up or lower down].
*Polytrichum sp.*

*Cenococcum geophilum*, some sclerotia.

*Botryococcus Braunii*,
*Pediastrum sp.*

*Spongilla lacustris*, spicules.

H. 7.15— 7.7 m Grey, stony Sand.

J. 7.7 —13.5 m Uppermost, greyish brown, lower down grey and more argillacous Clay Mud: between 11.5 and 11.75 m several stones size of nuts were found. Throughout the entire stratum there occured very thin brown layers rich in plant detritus, but the amount of determinable material was extremely small. Altogether, 9 samples of this stratum, from different depths were washed and examined; the result showed:

| Species | Samples: m below surface | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 7.7—8.0 | 8.0—8.4 | 8.4—8.9 | 8.9–9.4 | 10.1—10.4 | 10.9—11.5 | 11.5—11.8 | 12.4—12.6 | 13.2—13.5 |
| *Batrachium aquatile (coll.)*, fruits | + | + | .. | .. | 2 | 2 | 5 | 2 | .. |
| *Betula pubescens*, fruits | .. | 1 | .. | 4 | 1 | .. | .. | 3 | .. |
| — *nana*, fruits | 3 | 6 | 1 | 2 | 1 | .. | .. | 1 | .. |
| *Carex sp*, fruits | 2 | .. | .. | 1 | .. | .. | .. | .. | .. |
| *Empetrum nigrum*, fruit-stones | 2 | .. | .. | .. | .. | .. | .. | .. | .. |
| *Molinia coerulea?*, shoot base | 1 | .. | .. | .. | .. | .. | .. | .. | .. |
| *Myriophyllum alterniflorum*, pollen | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| — *cfr. spicatum*, pollen | .. | 2 | .. | .. | .. | .. | .. | . | .. |
| *Picea excelsa*, 1 little piece of bark | .. | 1 | .. | .. | .. | .. | .. | .. | .. |
| *Potamogeton spp.*, fruit-stones | 6 | 4 | .. | 1 | .. | .. | 2 | .. | .. |
| *Salix sp.*, buds, 1--3 mm long | .. | + | .. | .. | .. | .. | .. | .. | .. |
| *Amblystegium stellatum* | .. | .. | .. | .. | .. | r | .. | .. | .. |
| *Bryum sp.* | .. | .. | .. | r | .. | r | .. | .. | .. |
| *Cratoneuron filicinum* | .. | .. | .. | .. | .. | r | .. | .. | .. |
| *Hypnum exannulatum* | .. | r | .. | r | .. | .. | .. | .. | .. |
| — *uncinatum* | .. | .. | .. | r | .. | .. | .. | .. | .. |
| *Philonotis fontana* | .. | .. | .. | .. | .. | r | .. | .. | .. |
| *Scorpidium scorpioides* | .. | r | .. | .. | .. | .. | .. | . | .. |
| *Cenococcum geophilum* | + | .. | .. | .. | .. | .. | .. | .. | .. |
| *Diatomaceae* | r | r | .. | .. | r | .. | .. | .. | .. |
| *Pediastrum boryanum* | .. | r | .. | .. | r | .. | .. | .. | .. |

| Species | Samples: m below surface | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 7.7—8.0 | 8.0—8.4 | 8.4—8.9 | 8.9—9.4 | 10.1—10.4 | 10.9—11.5 | 11 5—11.8 | 12.4—12 6 | 13.2—13.5 |
| *Pediastrum Kawraiskyi* | .. | r | .. | r | r | .. | .. | .. | .. |
| — *sp.* | r | .. | .. | .. | .. | .. | .. | .. | .. |
| *Daphnia pulex*, ephippium | .. | .. | .. | r | .. | .. | .. | .. | .. |
| *Spongilla lacustris* | .. | r | r | r | r | r | .. | r | .. |

$K_2$. 13.5 16.8 m Mud, the upper part brown, and somewhat argillaceous; below this, (13.9—16.4 m) it was firm and brittle, containing much vivianit, the lowest portion greenish brown and slightly calcareous. A considerable outstreaming of marsh-gas took place from this stratum. Microscopical examination revealed, apart from pollen of forest trees (see Pl. XXXVI, 2) the following species:
*Dryopteris sp.*, spores,
*Nupar luteum*, 1 grain of pollen,
*Polypodium vulgare*, spores.

*Anabaena sp.*
*Botryococcus Braunii*,
*Staurastrum sp.*

*Spongilla lacustris*.

L. 16.8 —16.9 m Dark grey, calcareous Clay Mud:
*Betula nana*, 2 fruits,
*Potamogeton filiformis*, 10 fruit-stones,
*Sparganium sp.*, 2 fruit-stones.
Owing to heavy welling up of sand in the boring, further operations were discontinued.

Boring 10.

A. 0 — 0.3 m Mould.
B. 0.3 — 0.6 m Sand.
$C_1$. 0.6 — 0.8 m Low-Moor Peat.
$C_2$. 0.8 — 2.25 m Sand without stones.
$D_1$. 2.25— 3.0 m Sand with many stones up to the size of hen's eggs.
$D_2$. 3.0 — 3.4 m Sandy, here and there oozy and brownish Clay with stones.
F. 3.4 — 3.6 m Brown Clay Mud.
F. G. 3.6 — 5.5 m Sand, with stones in several horizons; between 4.60—4.75 was a thin layer of mud.
G. 5.5 — 6.4 m Brown sandy Mud:
*Alnus glutinosa*, 6 fruits, 1 catkin scale,
*Batrachium aquatile (coll.)*, several fruits,
*Betula pubescens*, 3 fruits,
— *nana*, 3 fruits at abt. 6.10 m,
*Carex sp.*, several fruits without utriculus,
*Carpinus betulus*, 2 fruits in the upper portion,

*Ceratophyllum demersum*, 1 fruit,
*Picea excelsa*, 1 needle, upper portion,
*Polygonum tomentosum*, several fruits,
*Potamogeton praelongus*, 4 fruit-stones,
— *sp.*, 3 fruit-stones,
*Rubus idaeus*, 1 fruit-stone,
*Scirpus lacuster*, 3 fruits,
*Trapa natans*, many fragments of fruits, both in the upper and lower portions.

J. 6.40 - 8.15 m Grey to greyish brown sandy Clay Mud, not bored through:
*Batrachium aquatile (coll.)*, several fruits,
*Betula nana*, 4 fruits, 1 catkin scale.
*Carex sp.*, 1 fruit,
*Empetrum nigrum*, some fruit-stones,
*Potamogeton sp.*, 1 fruit-stone.

Boring 11.

A. 0 — 0.4 m Mould, overlying pale brown Low-Moor Peat with rhizomes of reeds and roods of *Alnus glutinosa*.

$C_2$. 0.4 — 0.9 m Greyish brown stoneless Sand.

$C_4$. 0.9 — 2.0 m Sand intermixed with mud, the upper 10 cm however sandy Mud with tree roots.

$D_1$. 2.0 — 2.85 m Grey Sand, rich in stones in the lower portion.

$D_2$. 2.85 — 3.15 m Brown sandy Mud, mixed with Clay, some few small stones. A fruit of *Carex sp.* was washed out from this. A Pollen analysis showed: *Betula* 98 %, *Pinus* 2 %, Pollen frequency 31; also, considerable pollen of *Myriophyllum alterniflorum* was observed; some few specimens of *Botryococcus Braunii* and *Pediastrum integrum*, and numerous spicules of *Spongilla lacustris*.

F. 3.15 — 3.65 m Dark grey sandy Clay. The sample contained hardly any pollen, but:
*Betula nana*, 1 fruit,
*Carex sp.*, several fruits,
*Empetrum nigrum*, 2 fruit-stones,
*Hippuris vulgaris*, 2 fruit-stones,
*Potamogeton sp.*, 13 fruit-stones,
*Potentilla sp.*, 2 fruits.

*Spongilla lacustris*, some spicules.

F. G. 3.65 — 6.0 m Coarse stony Sand with stones the size of hen's eggs.

$G_2$. 6.0 — abt. 6.75 m Brown stratified sandy Mud. Fragments of fruits of *Trapa natans* were common, and 1/2 fruit of *Najas marina*. Also flakes of wood from a conifer, fragments of cones of *Picea excelsa*, and a fruit of *Carpinus betulus* were found.

H. abt. 6.75 — 9.80 m Greyish brown slightly muddy, fine Sand, the lower portion argillaceous. A sample from 6.75—7.50 yielded on washing:
*Betula nana*, numerous fruits, 8 catkin scales,
*Betula cf. pubescens*, 2 fruits.

*Carex sp.*, 3 fruits,
*Picea excelca*, tips of two needles, upper part of the stratum
*Potamogeton sp.*, 1 fruit-stone,
*Sparganium sp.*, 1 fruit-stone,
*Viola palustris*, 1/2 seed.

*Calliergon stramineum*,
*Hypnum uncinatum*,
*Polytrichum strictum*.

Washings from a sample taken at 9.0 – 9.8 m yielded:
*Batrachium aquatile (coll.)*, 1 fruit.
*Empetrum nigrum*, 1 fruit-stone,
*Potamogeton sp.*, 1 fruit-stone,
*Viola palustris*, 2 seeds.

J. 9.8 — 17.20 m Uppermost (abt. 5 m) greyish brown sandy Clay with thin brown streaks of plant detritus. Vivianite. Below this, grey to greyish blue, hard tough clay with fewer detritus streaks. Abt. 16 m below the surface were found numerous stones up to the size of walnuts. The lowest 0.5 m or thereabouts exhibited transition to the subjacent bed. The stratum was extremely poor in determinable vegetable remains, but a number of mosses were found, all from the lowest 2 metres. — 6 samples yielded on washing:
*Batrachium aquatile (coll.)*, 12 fruits,
*Betula alba*, 1 fruit abt. 15 m below surface,
*Scirpus lacuster*, 1 fruit.

*Bryum ventricosum*,
*Calliergon stramineum*,
*Climacium dendroides*,
*Cratoneuron filicinum*,
*Dichodontium pellucidum*,
*Hypnum exannulatum*,
— *intermedium*,
*Mnium cuspidatum*,
*Philonotis fontana*,
*Polytrichum strictum*,
— *sp.*,
*Rhacomitrium canescens*,
*Sphagnum palustre*,
— *sp.*

*Cenococcum geophilum*.

$K_2$. 17.20—18.45 m Brown Mud. Not bored through

Boring 12.

A. 0 — 0.8 m *Amblystegium*-Peat with rhizomes and seeds of *Menyanthes trifoliata;* a few small sticks or twigs.

$C_3$. 0.8 — 1.15 m Greyish brown muddy Sand with layers of moss:
*Batrachium aquatile (coll.)*, 2 fruits,
*Potentilla palustris*, 1 fruit,
*Salix herbacea*, some leaves.

| | | |
|---|---|---|
| | | *Calliergon stramineum*, |
| | | *Gymnocybe palustris*, |
| | | *Hypnum exannulatum*, |
| | | — *uncinatum*, |
| | | *Polytrichum strictum*, |
| | | *Rhacomitrium canescens*, |
| | | *Tortella tortuosa*. |
| $C_4$. | 1.15 — 3.4 m | Alternating layers of Sand and sandy Mud. |
| D. | 3.4 — 3.7 m | Stony Sand: stones up to the size of hen's eggs. |
| G. | 3.7 — 4.5 m | Greyish brown sandy Mud: |
| | | *Batrachium aquatile (coll.)*, fairly many fruits, |
| | | — *sceleratum*, 2 fruits, |
| | | *Betula pubescens*, 2 fruits, |
| | | *Carex sp.*, some fruits, |
| | | *Empetrum nigrum*, 5 fruit-stones, |
| | | *Myriophyllum cf. spicatum*. 2 nuts, |
| | | *Picea excelsa*, 1 needle, |
| | | *Potamogeton cf. filiformis*, 1 fruit-stone, |
| | | *Trapa natans* numerous fragments of fruits. |
| H. | 4.5 — 7.7 m | Greyish brown muddy stratified Sand. Six samples yielded on washing: |
| | | *Batrachium aquatile (coll.)*, fairly many fruits, |
| | | *Betula nana*, numerous fruits, 1 catkin scale, |
| | | — *nana* × *pubescens*, 1 fruit, |
| | | — *pubescens*, 5 fruit, |
| | | *Carex sp.*, a few fruits without utriculus |
| | | *Empetrum nigrum*, some fruit-stones, |
| | | *Picea excelsa*, 1 fragment of bud scale, |
| | | *Pinus silvestris*, 1 small piece of bark, |
| | | *Potamogeton filiformis*, 2 fruit-stones, |
| | | — *sp.*, 2 fruit-stones, |
| | | *Salix sp.*, 1 bud scale, 3 mm long, |
| | | *Scirpus lacuster*, 1 fruit, |
| | | *Sparganium sp.*, 1 fruit-stone, |
| | | *Viola palustris*, 1/2 seed. |
| J. | 7.7 — 8.1 m | Grey Clay Mud not bored through. |

## Boring 13.

| | | |
|---|---|---|
| A. | 0 — 0.4 m | Peat. |
| $C_2$. | 0.4 — 1.0 m | Sand without stones, |
| $C_3$. | 1.0 — 1.5 m | Brown Mud. Pollen spectra see p. 60. Also: |
| | | *Batrachium aquatile (coll.)*, numerous fruits, |
| | | *Carex sp.*, som fruits without utriculus, |
| | | [*Carpinus betulus*, 1/2 fruit][1]), |
| | | *Empetrum nigrum*, 2 fruit-stones, |
| | | *Myriophyllum alterniflorum*, 3 nuts, much pollen |
| | | *Potamogeton alpinus*, 1 fruit-stone, |
| | | — *praelongus*, 14 fruit-stones, |
| | | — *pusillus*, 3 fruit-stones, |

1) Probably derived from an interglacial bed, G or $K_2$.

C4. 1.5 — 5.0 m Sand with layers of Mud:
*Carex sp.*, 1 fruit,
[*Trapa natans*, 2 horns][1]).

D. 5.0 — 5.5 m Sand with stones up to the size of eggs.

G. 5.5 — abt. 6.6 m Grey muddy Sand: several pieces of fruits of *Trapa natans.*

J. abt. 6.5 —13.0 m Uppermost, grey sandy Clay, lower down grey stiff clay with thin streaks of sand. The boring was stopped owing to heavy inflow of sand into the lead pipe.

Boring 14.

A. 0 — 0.3 m Mould.

$C_5$. 0.3 — 2.75 m Sand without stones.

D. 2.75 — 3.8 m Sand with stones up to the size of hen's eggs.

F. 3.8 — 5.15 m Argillaceous, muddy Sand with stones up to the size of eggs in the lower portion. Washings from this lower part yielded some remains of *Trapa natans*, *Ceratophyllum sp.* and *Alnus glutinosa,* here presumably in a secondary position, as Stratum G must be supposed to have been destroyed by solifluction.

J. 5.5 — 7.10 m Loamy, muddy Sand, not bored through:
*Batrachium aquatile (coll.)*, 3 fruits,
*Betula nana*, 4 fruits.

Boring 15.

A. 0 — 0.3 m Mould and humous Peat.

$C_5$. 0.3 — 2.75 m Fine Sand without stones.

D. 2.75 — 3.25 m Stony Sand (Gravel), stones up to the size of a clenched fist.

F. 3.25 — abt. 5.0 m Grey stoneless non-calcareous Clay, thin plant layers:
*Batrachium aquatile (coll.)*, some fruits,
*Betula nana*, 4 fruits,
*Viola palustris*, $^1/_2$ seed.

G. abt. 5.0 — abt. 5.35 m Grey Clay much the same as F.
Several fragments of branches of *Picea excelsa*. The following spectrum was taken from abt., 5.20 m below the surface: *Betula* 19 %. *Pinus* 28 %, *Quercus* 2 %, *Alnus* 19 %, *Carpinus* 4 %, *Picea* 28 %, and *Corylus* taken separately 11 %.

J. abt. 5.35 — 8.35 m Grey Clay with a few thin streaks of plant detritus, in which some vivianite. Merging gradually into the subjacent stratum.

$K_2$. 8.35—11.35 m Brown Mud, crumbling in parts; in the lowest half metre, alternating layers of clay mud, sand, and mud. In the upper half of the stratum, fruits and seeds of *Carpinus betulus* and *Brasenia purpurea.*

L. 11.35—12.35 m Grey, tough stoneless Clay with dark streaks.

N. 12.35—12.45 m Brownish Glacial Clay without stones.

Boring 16.

A. 0 — 0.25 m Mould.

$C_5$. 0.26 — abt. 1.85 m Stoneless Sand.

[1]) Probably derived from an interglacial bed, G or $K_2$.

D. abt. 1.85— 3.0 m Sand with stones up to the size of hen's eggs.
F. 3.0 — 3.95 m Grey non-calcareous stony Clay rather rich in the upper portion, more sandy lower down.
J. 3.95— 4.85 m Brown Clay-Mud.
$K_2$. 4.85— 6.2 m Brown sandy Mud and Sand. In the upper half of this stratum were found: *Brasenia purpurea*, *Trapa natans*, *Scirpus lacuster*, *Carpinus betulus*, *Picea excelsa*. *Rubus idaeus*.
L. 6.2 — 6.9 m Greyish-blue calcareous Clay, the upper part very sandy.

### Boring 17.

A. 0 — 0.3 m Mould.
D. 0.3 — 2.1 m Grey Sand with stones up to the size of a hand; a layer of Gravel at the bottom.
O. 2.1 — 4.0 m Grey sandy calcareous Moraine Clay.

### Boring 18.

A. 0 — 0.4 m Sandy Mould.
D. 0.4 — 2.20 m Stony Sand; at the bottom, Gravel with stones the size of eggs.
O. 2.20— 4.25 m Grey sandy Moraine Clay with limestone.

### Boring 19.

A. 0 — 0.7 m Stony Mould.
D. 0.7 — 1.4 m Yellow Sand with stones.
G. 1.4 — 2.4 m Greyish brown sandy Mud:
*Alnus glutinosa*. 2 fruits,
*Brasenia purpurea*, 1 seed,
*Carex sp.*, 2 fruits,
*Empetrum nigrum*, 2 fruit-stones,
*Salix sp.*, 3 fragments of branches, 2 small buds,
*Cenococcum geophilum*, several sclerotia.
J. 2.4 — 3.8 m Greyish blue Clay with a few small stones:
*Batrachium aquatile (coll.)*, 3 fruits,
*Betula nana*, 3 fruits,
— *pubescens*, 1 fruit,
*Potentilla palustris*, 3 fruits,
*Cenococcum geophilum*, 1 sclerotium.
$K_2$. 3.8 — 5.9 m Brown Mud, rather sandy, especially at the bottom:
*Ajuga reptans*, 1 nut,
*Alnus glutinosa*, fruits and catkin spindles, rather numerous,
*Batrachium aquatile (coll.)*, 1 fruit,
*Carpinus betulus*. 4 fruits,
*Ceratophyllum demersum*, 2 fruits,
*Cladium mariscus*, 2 fruits,
*Corylus avellana*, 1 nut,
*Hippuris vulgaris*, 3 fruit-stones,
*Hydrocotyle vulgaris*, 1 nut,
*Ilex aquifolium*, 1 fruit-stone,
*Lycopus europaeus*, 2 nuts,
*Myriophyllum sp.*, 1 nut,
*Picea excelsa*, several bud scales,

*Potamogeton spp.*, fruit-stones rather numerous,
*Potentilla sp.*, 1 fruit,
*Rubus idaeus*, 3 fruit-stones,
*Scirpus lacuster*, several fruits,
*Trapa natans*, 1 horn,

*Cenococcum geophilum*, several sclerotia,

*Phytoptus laevis*, 1 gall.

L. 5.9 — 8.2 m Bluish grey calcareous Clay without stones:
*Hippuris vulgaris*, 1 fruit-stone,
*Potamogeton spp.*, 2 species, 4 fruit-stones,
*Potentilla cf. erecta*, 1 fruit,
*Salix sp.*, several buds, 1.0—1.5 mm long.

O. 8.2 — 8.5 m Dark grey Moraine Clay.

### Excavation at Point 19.

We dug a pit at Point 19. The profile was as follows.

A. 0 — 0.4 m Stony Mould.

D. 0.4 — 1.3 m Sand; stones rather abundant in the upper part, fewer lower down.

G. 1.3 — 1.35 m Sandy brownish Mud with flakes of wood, twigs and other plant detritus:
*Betula pubescens*, 1 catkin scale,
*Brasenia purpurea*, 2 seeds,
*Carex pseudocyperus*, 1 fruit,
— *sp.*, several nuts,
*Ceratophyllum demersum*, 1 fruit,
*Menyanthes trifoliata*, 1 seed,
*Picea excelsa*, wood,
*Potamogeton sp.*, 1 fruit-stone,
*Rubus idaeus*, 1 fruit-stone,
*Sambusus cf. nigra*, 1 fruit-stone,
*Sparganium minimum*, 1 fruit-stone,
— *erectum*, 2 fruit-stones,
*Trapa natans*, $1^1/_2$ fruits.

*Cenococcum geophilum*, many sclerotia.

$G_2$. 1.35— 1.60 m Sand, the lower part slightly argillaceous.

$G_3$. 1.60— 1.85 m Alternating layers of Clay, Sand and Mud.

$G_4$. 1.85— 2.15 m Sand, with stones up to the size of eggs in the lower portion. Heavy inflow of water prevented further excavation.

### Boring 20.

A. 0 — 0.4 m Sand-Mould.

D. 0.4 — 1.0 m Yellow (lower down grey) stony Sand.

G. 1.0 — 2.8 m Brown, sandy Mud with layers of purer mud. Numerous small fragments of wood:
*Batrachium aquatile (coll.)*, 2 fruits,
*Carex sp.*, 2 fruits,
*Nuphar luteum*, 1 seed,
*Picea excelsa*, pieces of wood.

*Pinus silvestris*, pieces of wood; also charcoal of *Picea* or *Pinus*.
*Salix sp.*, fragments of shoots of a low species.

J. 2.8 — 4.3 m Bluish grey stoneless non-calcareous Clay. The washing sample contained no fossils.

$K_2$. 4.3 — 6.4 m Brown Mud:
*Alnus glutinosa*, 2 fruits,
*Carex sp.*, 1 fruit,
*Carpinus betulus*, 2 fruits,
*Hippuris vulgaris*, 1 fruit-stone,
*Hydrocotyle vulgaris*, 1 nut,
*Picea excelsa*, 8 bud scales,
*Potamogeton spp.*, numerous fruit-stones.

L. 6.4 — 7.2 m Grey, stoneless calcareous Clay with thin streaks of sand.

O. Dark grey Moraine Clay.

Excavation at Point 20.

A. 0 — 0.4 m Stony Mould.

D. 0.4 — 0.9 m Sand with stones up to the size of a hand.

$G_1$. 0.9 — 1.7 m Stratified sandy Mud, the upper part greatly dislocated and containing stones pressed down from above, the lower part (abt. 20 cm) mainly sand with thin layers of mud. Pieces of wood from *Picea excelsa* etc. and birch bark were found throughout the entire stratum. A sample from 1.4—1.5 m below the surface yielded on washing:
*Carex sp.*, some nuts,
*Carpinus betulus*, $^1/_2$ nut,
*Hippuris vulgaris*, 1 fruit-stone,
*Picea excelsa*, 1 needle,
*Quercus sp.*, 1 piece of wood,
*Ranunculus sp.*, 2 fruits.

*Cenococcum geophilum*, sclerotia fairly numerous.

$G_2$. 1.7 — 2.4 m Stratified, sandy Mud with numerous partly rolled pieces of wood and a quantity of birch bark, The sand content of this stratum increased lower down. At abt. 2.25 m below surface a 5 cm layer of clay mud was found. Heavy rise of water in the pit.
A sample taken between 1.7—1.8 m below the surface yielded on washing:
*Betula nana*, 3 fruits,
*Carex sp.*, several fruits,
*Empetrum nigrum*, 4 fruit-stones,
*Ranunculus sp.*, 7 small fruits,
*Scirpus lacuster*, 3 fruits.

*Cenococcum geophilum*, numerous sclerotia.

Boring 21.

A. 0 — 0.4 m Sand Mould.

D. 0.4 — 1.5 m Yellowish-grey, stony Sand.

$O_1$. 1.5 — 1.6 m Dark grey Moraine Clay.

| | | |
|---|---|---|
| $O_2$. | 1.6 — 1.7 m | Water-bearing Gravel. |
| $O_3$. | 1.7 — 2.2 m | Dark grey Moraine Clay. |

Boring 22.

| | | |
|---|---|---|
| A. | 0 — 0.3 m | Mould. |
| D. | 0.3 — 0.9 m | Grey or yellowish Sand, with stones rather few and small. |
| E? | 0.9 — 2.0 m | Grey, stoneless Sand perhaps with a little clay. |
| N. | 2.0 — 5.5 m | Greyish Blue, when dry brownish, Varve Clay with calciumcarbonate; no fossils. |
| O. | 5.5 — 6.5 m | Dark grey Moraine Clay. |

Boring 23.

| | | |
|---|---|---|
| A. | 0 — 0.4 m | Mould. |
| B. | 0.4 — 1.0 m | Sand, yellowish above, grey below. |
| C. | 1.0 — 1.5 m | Grey Sand with thin layers of stoneless Clay. |
| E? | 1.5 — 3.0 m | Grey Sand. |
| L. N. | 3.0 — 6.2 m | Grey, stoneless calcareous Clay, part of which appeared to be varved. |
| O. | | Dark grey Moraine Clay, |

Boring 24.

| | | |
|---|---|---|
| A. | 0 — 0.5 m | Mould. |
| B. | 0.5 — 2.7 m | Grey Sand, the lower part water-bearing. |
| D. | 2.7 — 3.0 m | Grey, stony, water-bearing Sand. |
| L. N. | 3.0 — 6.8 m | Grey, stoneless Clay. |
| O. | | Dark grey Moraine Clay. |

Boring 25.

| | | |
|---|---|---|
| A. | 0 — 0.3 m | Mould. |
| B. | 0.3 — 2.9 m | Sand, reddish at the top, lower down grey and water-bearing. Presumably wind blown sand. |
| D. | 2.9 — 3.7 m | Grey, stony Sand. |
| F. | 3.7 — 4.5 m | Grey, stony Clay [was erroneously regarded as moraine clay in the year 1919, and the boring therefore stopped; cf. Stratum F in Boring 9]. |

Boring 26.

| | | |
|---|---|---|
| A. B. | 0 — 1.0 m | Mould above stoneless Sand. |
| D. | 1.0 — 2.3 m | Stony Sand. |
| L. N.? | 2.3 — 4.75 m | Grey, stoneless calcareous Clay, bedded on a layer af Sand a few cm thick. |
| O. | 4.75— 5.25 m | Grey, calcareous Moraine Clay. |

Boring 27.

| | | |
|---|---|---|
| A. | 0 — 0.2 m | Mould. |
| B. | 0.2 — 1.5 m | Sand without stones, the upper part presumably wind blown sand. |

$D_1$. 1.5 — 2.2 m S a n d, a few stones in the upper part, lover down numerous stones up to the size of a hand.

$D_2$. 2.2 — 3.5 m Coarse, stony S a n d with layers of arenaceous-argillaceous mud. 2 fruits of *Scirpus lacuster*. Wood detritus.

F. G. 3.5 — 3.9 m Sharp S a n d.

G. 3.9 — 4.3 m Sandy D e t r i t u s - M u d, consisting mainly of small twigs and other plant detritus, with seeds and fruits. The following were found:

*Acer campestre*, 3 nuts without wings,
*Ajuga reptans*, 2 nuts,
*Alnus glutinosa*, fruits, catkin spindles, branches, fairly common,
*Arctostaphylus uva ursi*, 1 fruit-stone,
*Batrachium aquatile (coll.)*, 7 fruits,
*Betula pubescens*, 4 fruits without wings,
*Brasenia purpurea*, 3 seeds,
*Carex lasiocarpa*, 1 fruit,
— *rostrata*, 6 fruits,
*Carpinus betulus*, 10 fruits,
*Ceratophyllum demersum var. apiculatum*, numerous fruits,
*Cladium mariscus*, 1 fruit,
*Corylus avellana*, several fragments of nuts,
*Empetrum nigrum*, 5 fruit-stones,
*Hippuris vulgaris*, 1 fruit-stone,
*Hypochoeris radicata*, 1 fruit (Pl. XXXII, 1),
*Litorella uniflora*, 3 nuts (Pl. XXXII, 8—9),
*Menyanthes trifoliata*, 1 seed,
*Myriophyllum spicatum f. muricata*, 1 nut,
— *cf. spicatum*, 2 nuts,
*Nuphar luteum*, 1 seed,
*Picea excelsa*, 1 cone-scale,
*Potamogeton filiformis*, 8 fruit-stones,
— *natans*, 8 fruit-stones.
*Quercus sp.*, 1 fragment of an acorn cup, 1 piece of charcoal.
*Ranunculus lingua*, 1 fruits,
— *repens*, 4 fruits,
*Rubus idaeus*, 1 fruit-stone,
— *sp.*, 1 fruit-stone,
*Scirpus lacuster*, numerous fruits,
*Sparganium erectum*, 11 fruitstones,
— *minimum*, 6 fruit-stones,
*Taxus baccata*, 2 seeds,
*Tilia platyphylla*, parts of 2 fruits (Pl. XXXIII, 1—2),
*Trapa natans*, several whole fruits, numerous horns.

*Calliergon trifarium*,
[ — *Richardsonii*] [1]),
— *stramineum*,
*Philonotis fontana*,
*Scorpidium scorpioides*.

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1) A mainly subalpine species, probably not belonging to this stratum.

J 4.3 — 8.0 m Uppermost, greyish brown, sandy Clay Mud, below this, grey tough Clay, lowest of all brown Clay Mud. Three washing samples yielded:
*Batrachium aquatile (coll.)*, 4 fruits,
*Betula nana*, 7 fruits, 1 catkin scale,
— *nana × pubescens?*, 1 fruit,
— *pubescens*, 2 fruits, abt. 7 and abt. 8 m below the surface respectively,
*Carex sp.*, 1 fruit,
*Compositae?*, 2 fruits,
*Potentilla palustris*, 1 fruit.

*Acrocladium cuspidatum*,
*Encalypta rhabdocarpa*,
*Hylocomium proliferum*,
*Hypnum uncinatum*,
*Paludella squarrosa*,
*Pohlia nutans*,
*Polytrichum juniperinum*,
*Sphagnum sp.*

*Acidota crenata*, a wing.

$K_2$. 8.0 — 8.85 m Brown, brittle Mud:
*Alnus glutinosa*, 1 fruit,
*Lycopus europaeus*, 5 nuts,
*Menyanthes trifoliata*, 1 seed,
*Nuphar luteum*, 1 seed,
*Umbelliferae*, 1 nut.

*Cristatella mucedo*, 2 statoblasts.

L. 8.85— abt. 9.5 m Grey, stoneless, calcareous Clay, the upper portion containing vivianite. Merging gradually into the subjacent. A washing sample yielded the following:
*Batrachium aquatile (coll.)*, 1 fruit,
*Betula nana*, 1 fruit,
*Potamogeton sp.*, 2 fruit-stones.
*Amblystegium stellatum*,
*Camptothecium trichoides*,
*Polytrichum juniperinum*,
*Thuidium sp.*

N. abt. 9.5 —10.0 m Glacial Clay, rather calcareous.

### Boring 28.

A. 0 — 0.3 m Mould.

B. 0.3 — 1.6 m Sand without stones,

D. 1.6 — 2.55 m Sand with stones up to the size of a hand. Between 2.1 and 2.3 m however, greyish blue loamy sand without stones was found.

J. 2.55 - 7.1 m Uppermost, grey, sandy Clay with thin brown streaks of detritus; vinianite; *Batrachium aquatile (coll.)*. Lower down grey to greyish-blue Clay, tougher than that above.

$K_3$. 7.1 — 9.4 m Brown Mud gradually showing transition to the strata above and below. Fruits of *Carpinus betulus* and *Sparganium erectum*.

| | | |
|---|---|---|
| L. | 9.4 —11.75 m | Greyish blue calcareous tough Clay, with stripes and spots of a darker colour. Between 11.6 and 11.7 a layer of yellowish, calcareous Clay Mud from which was washed a catkin scale of *Betula cf. nana* × *pubescens*. |
| N. | 11.75 - 12.0 m | Brownish calcareous Glacial Clay. |

Boring 29.

| | | |
|---|---|---|
| $A_1$. | 0 — 0.6 m | Brown, fairly fresh Low-Moor-Peat. |
| $A_2$. | 0.6 — 1.25 m | Uppermost, sandy Mud, with *Potamogeton sp.*: lower down Sand mixed with mud. |
| D. | 1.25— 1.85 m | Gravel above stony Sand; stones up to the size of eggs. |
| N? | 1.85— 3.15 m | Rich stoneless Clay. |
| $O_1$. | 3.15— 4.0 m | Grey sandy Moraine Clay with limestone. |
| $O_2$. | 4.0 — 4.3 m | Greyish brown stratified calcareous Clay. |
| $O_3$. | 4.3 — 5.15 m | Grey, calcareous Moraine Clay. |

Boring 30.

| | | |
|---|---|---|
| A. | 1 — 1.25 m | Brown fresh Low-Moor-Peat with *Phragmites communis* over brown Mud. |
| D. | 1.25 - 1.65 m | Gravel with stones up to the size of a hand. |
| O. | 1.65— 3.0 m | Grey, sandy calcareous Moraine Clay. |

Boring 31.

| | | |
|---|---|---|
| A. | 0 — 0.4 m | Mould. |
| B. | 0.4 — 0.7 m | Sand without stones. |
| D. | 0.7 — 1.5 m | Stony Sand. |
| O. | 1.5 — 4.1 m | Grey, sandy Moraine Clay with limestone. |

Boring 32.

| | | |
|---|---|---|
| A. | 0 — 0.4 m | Mould. |
| $D_1$. | 0.4 — 1.3 m | Sand with stones up to the size of hen's eggs. |
| $D_2$. | 1.3 — 2.25 m | Greyish brown stony humous sandy Clay:<br>*Batrachium aquatile (coll.)*, 1 fruit,<br>*Hippuris vulgaris*, 1 fruit-stone,<br>*Potamogeton spp.*, 2 species, several fruit-stones,<br>*Potentilla sp.*, 2 fruits. |
| F. G. | 2.25 - 2.8 m | Reddish yellow stony Sand. |
| G. | 2.8 — 5.25 m | Brown, more or less sandy Mud; between 4.4—4.6 Sand with stones the size of walnuts. The following determinable vegetable remains were found:<br>*Brasenia purpurea*, 1 seed,<br>*Menyanthes trifoliata*, 1 seed,<br>*Potamogeton sp.*, several fruit-stones,<br>*Trapa natans*, numerous fragments of fruits. |
| H. | 5.25— 8.0 m | Sand with thin layers of sandy mud and a few small stones; also a few small twigs and fragments of *Trapa natans* fruits, probably brought down by the bore from G. |
| J. | 8.0 —12.1 m | Uppermost, grey sandy Clay with numerous thin brown layers of plant detritus; lower down the stratum became |

more and more argillaceous, and consisted at the bottom of stiff grey-blue clay. 4 washing samples yielded:
*Batrachium aquatile (coll.)*, fruits rather numerous,
*Betula nana*, 32 fruits, 3 catkin scales,
— *cf. nana* × *pubescens*, 3 fruits, uppermost
— *pubescens*, 3 fruits, in the lover Part of the bed,
*Carex sp.*, 4 fruits without utriculus,
*Empetrum nigrum*, 2 fruit-stones,
*Hippuris vulgaris*, 1 fruit-stone,
*Menyanthes trifoliata*, 1 seed,
*Potentilla sp.*, 2 fruits,
*Salix sp.*, 3 buds, 2 mm long,
*Selaginella selaginoides*, 1 megaspore,
*Viola palustris*, 1 seed.

*Amblystegium polyganum*,
— *stellatum*,
*Anisothecium crispum*,
*Bryum sp.*,
*Calliergon stramineum*,
*Climacium dendroides*,
*Cratoneuron filicinum*,
*Dichodontium pellucidum*,
*Hylocomium proliferum*,
*Hypnum uncinatum*,
*Mnium cinclidioides*,
— *cuspidatum*,
*Philonotis fontana*,
*Pohlia albicans*,
*Polytrichum juniperinum*,
*Rhacomitrium canescens*,
*Sphagnum papillosum*,
— *sp.*,
*Tortula ruralis*.

*Otiorrhynchus sp. (ad. rugosostriatus)*, a wing.

$K_2$. 12.1—15.25 m Mud; greyish brown, and somewhat argillaceous, at top and bottom; the remainder brown and brittle.

L. 15.25—15.90 m Greyish blue calcareous Clay, without stones, darker stripes here and there. A washing sample from the lower part of the stratum yielded:
*Batrachium aquatile (coll.)*, 1 fruit,
*Betula nana*, 3 fruits,
— *pubescens*, 7 fruits,
*Potamogeton spp.*, 2 species, 9 fruit-stones,

*Amblystegium stellatum*,
*Ditrichum flexicaule*,
*Hylocomium proliferum*,
*Swartzia montana*.

N. 15.90—16.55 m Brownish calcareous Glacial Clay.

Boring 33.

A. 0 — 0.65 m Mould and Rubbish.
B. 0.65 — 1.1 m Red Sand without stones.
D. 1.1 — 1.5 m Sand with stones up to the size of a hand.
O. 1.5 — 5.85 m Grey, non-calcareous Moraine Clay. Below this, Sand which rose up in the lead pipe.

Boring 34.

A. 0 — 0.3 m Mould.
B. 0.3 — 1.0 m Red Sand.
C. 1.0 — 1.8 m The upper 10 cm reddish Sand mixed with sandy mud: fine greyish yellow Sand below.
D. 1.8 — 3.1 m Grey stony Sand.
G. 3.1 — 4.8 m Uppermost, dark grey Sand, with plant detritus, lower down brown Mud, argillaceous at the bottom.
$J_1$. 4.8 — 5.2 m Bluish grey stoneless Clay; transition to the subjacent stratum.
$J_2$. Grey Sand; the boring was not carried further.

Boring 35.

A. 0 — 0.3 m Mould.
B. 0.3 — 2.0 m Grey Sand.
D. 2.0 — 5.5 m Red, very stony water-bearing Sand.
E. (et sq.?) 5.5 — 8.0 m Grey Sand.

Boring 36.

A. 0 — 0.5 m Sand-Mould.
D. 0.5 — 2.0 m Greyish yellow Sand with stones.
E. 2.0 — 4.9 m Coarse Sand, reddish above, grey lower down.
F. 4.9 — 5.0 m Brown Clay Mud; some small twigs.
G. 5.0 — 5.4 m Fine grey Sand:
*Carex sp.*, 1 fruit,
*Empetrum nigrum*, 1 fruit-stone,
*Sambucus cf. nigra*, 1 fruit-stone.
H. 5.4 — 6.7 m Rather coarse grey Sand; the lower part reddish and water-bearing.
J. 6.7 — 11.9 m Uppermost, grey sandy Clay with thin layers of Sand containing Detritus; a few stones up to the size of nuts; 4 washing samples yielded:
*Batrachium aquatile (coll.)*, fruits fairly numerous,
*Betula nana*, 9 fruits, 1 catkin scale,
— *pubescens*, 1 fruit, 8.9 m below surface,
*Carex sp.*, 2 fruits,
*Potamogeton filiformis*, 1 fruit-stones,
*Salix cf. phylicifolia*, 1 leaf base.

*Dichodontium pellucidum.*

From 9.4 m to the lower margin of the stratum was bluish grey stoneless Clay with thin stripes of Sand. A little vivianite. Three washing samples yielded:
*Batrachium aquatile (coll.)*, several fruits,

*Betula nana*, 14 fruits, 1 catkin scale,
— *pubescens*, 1 fruit, at the bottom,
*Potamogeton filiformis*, 1 fruit-stone.
*Polytrichum juniperinum*,
*Rhacomitrium fasciculare*.

*Cenococcum geophilum*, 2 sclerotia.

$K_2$. 11.9 — 13.6 m Brown Mud, the upper part somewhat argillaceous. This stratum was not bored through. 4 washing samples yielded:
*Acer sp.*, 1 seed,
*Alnus glutinosa*, several fruits,
*Betula pubescens*, some fruits,
*Carex pseudocyperus*, 1 fruit,
— *sp.*, some fruits,
*Dulichium spathaceum*, 1 short fruit,
*Lycopus europaeus*, 4 nuts,
*Picea excelsa*, bud scales fairly numerous,
*Scirpus lacuster*, 1 fruit,
*Selaginella selaginoides*, 1 megaspore, in the upper part of the stratum,
*Sparganium minimum*, some fruit-stones.

Boring 37.

A. 0 — 0.2 m Mould.
C. 0.2 — 1.8 m Grey Sand.
F? 1.8 — 2.4 m Sandy Clay, yellow above, grey lower down. A sample from 2.3—2.4 m yielded:
*Betula nana*, 3 fruits,
— *sp.*, 1 fruit.
H? 2.4 — 4.3 m Pale grey Sand.
$K_2$. 4.3 — 6.4 m Uppermost, greyish brown Clay Mud; lower down brown, stratified sandy Mud, and at the bottom (from 5.0 m) alternating layers of grey Sand with a few small stones, and brown Mud:
*Alnus glutinosa*, 3 fruits,
*Betula pubescens*, several fruits,
*Brasenia purpurea*, 1 seed,
*Carex sp.*, some fruits,
*Lycopus europaeus*, 1 nut,
*Picea excelsa*, 1 needle, bark, cone- and bud scales, especially in the upper part,
*Potentilla sp.*, 1 fruit,
*Potamogeton sp.*, several fruit-stones,
*Scirpus lacuster*, several fruits,
*Sparganium erectum*, 3 fruit-stones,
— *minimum*, 1 fruit-stone,
*Trapa natans*, 1 horn,
*Viola palustris*, 1 seed.
L. 6.4 — abt. 6.6 m Bluish grey Clay.
N. abt. 6.6 — 8.3 m Bluish grey Varve Clay. A washing sample yielded no fossils.
O. 8.3 — 8.6 m Dark grey Moraine Clay.

Boring 38.

A. 0 — 0.3 m Sand-Mould.
D. 0.3 — 1.4 m Grey Sand with stones.
O. 1.4 — 6.6 m Calcareous Moraine Clay, yellow at the top, greyish blue lower down.

Boring 39.

A. 0 — 0.3 m Sand-Mould.
D. 0.3 — 2.0 m Yellow, stony Sand.
G. 2.0 — 2.7 m Grey Sand with layers of brown Mud:
*Betula pubescens*, fruits and catkin scales common,
*Calluna vulgaris*, 2 fragments of branches,
*Dulichium spathaceum*, 1 fruit,
*Menyanthes trifoliata*. 1 seed,
*Myriophyllum verticillatum*, 1 leaf tip,
*Picea excelsa*, wood, bark, needles etc.,
*Pinus silvestris*, flakes of bark,
[*Salix herbacea*, 2 leaves, probably from bed H. Pl. XXXIV 2—3],
*Sparganium erectum*, 1 fruit-stone,
*Trapa natans*, 3 fragments of fruits.

*Hypnum aduncum*.

*Cenococcum geophilum*, many sclerotia.

H. 2.7 — 4.9 m Fine water-bearing Sand, reddish above, grey lower down.
J. 4.9 — 7.2 m Greyish blue, tough Clay:
*Batrachium aquatile (coll.)*, 6 fruits,
*Betula nana*, several fruits and catkin scales,
*Hippuris vulgaris*, 1 fruit,
*Potamogeton sp.*, several fruit-stones.

*Characeae*, some spores.

*Cenococcum geophilum*, some sclerotia.

$K_2$. 7.2 — 8.5 m Brown Mud:
*Alnus glutinosa*, 1 fruit,
*Betula pubescens*, 2 fruits,
*Carpinus betulus*, 2 fruits,
*Picea excelsa*, 1 seed, 1 bud scale,
*Potamogeton spp.*, many fruit-stones,
*Scirpus lacuster*, 3 fruits.

L. 8.5 — 9.8 m Greyish blue tough Clay, rather sandy here and there:
*Carex sp.*, some fruits,
*Potamogeton sp.*, many fruit-stones.

M. Sand. This was not bored through.

Boring 40.

A. 0 — 0.2 m Mould.
D. 0.2 — 1.1 m Greyish yellow stony Sand.
J? 1.1 — 1.3 m Grey Clay, mixed with stones lower down.
$K_2$. 1.3 — 3.1 m Uppermost, greyish brown, sandy Mud, lower down brown Mud. In the uppermost sandy part of the stratum especially the following were found:

*Alnus glutinosa*, 6 fruits, 2 catkin spindles,
*Betula pubescens*, 2 fruits,
*Carpinus betulus*, 10 fruits,
*Ceratophyllum demersum*, 1 fruit,
*Nuphar luteum*, 1 seed,
*Picea excelsa*, 3 needles, 3 seeds, 1 shoot, bud scales,
*Polygonum sp.*, 1/2 fruit.
*Potamogeton sp.*, 4 fruit-stones,
*Quercus sp.*, wood,
*Rubus idaeus*, 3 fruit-stones,
*Scirpus lacuster*, numerous fruits,
*Sparganium erectum*, 2 fruit-stones.

*Phytoptus laevis*, galls.

L? 3.1 — 3.5 m Grey stony Sand.
L. 3.5 — 5.8 m Dark grey, stoneless calcareous Clay.
O. 5.8 — 6.2 m Dark grey Moraine Clay.

Boring 41.

A. 0 — 0.3 m Sand-Mould.
D. 0.3 — 2.4 m Grey stony Sand.
N. 2.4 — 3.0 m Dark grey stoneless Clay.
O. 3.0 — 4.0 m Dark grey Moraine Clay.

## List of the Fossils found in the Lake Deposits at Herning Brickworks.

c common, + fairly common, r rare.

| Species | Sandy Mud | Subarctic Sand and Clay | | Mud | Subarc. Clay The Middle Bed | | Mud | Arctic Clay | Arctic Sand |
|---|---|---|---|---|---|---|---|---|---|
| | C | E | F | G | H | J | K2 | L | M |
| *Acer campestre* (Pl. XXXI, 17-21) | | | | r | | | + | | |
| — *sp.* | | | | | | | r | | |
| *Ajuga reptans* | | | | r | | | r | | |
| *Alnus glutinosa* | | | | +, +[2] | | r[2] | c, c[2] | | |
| *Arctostaphylus uva ursi* | | | | r | | | | | |
| — *sp.* | | | r | | | | | | |
| *Batrachium aquatile (coll.)* | c | | + | + | r | + | r | + | |
| — *sceleratum* | | | | + | | [r][3] | | | |
| *Betula nana* (Pl. XXXV, 11—14, 16—18) | | | r | r[4] | c | c | | + | |
| *Betula nana* × *pubescens*[1] | | | | | r | r | | r | |
| — *pubescens* | | | r | c | + | r | + | r | |
| — *sp.*[2] | | | | + | | r | c | | |
| *Brasenia purpurea* | | | | r | | | + | | |
| *Calluna vulgaris* | | | | r | | | | | |
| *Carex lasiocarpa* | | | | r | | | | | |
| — *pseudocyperus* | | | | r | | | r | | |
| — *rostrata* | | | | + | | | | | |
| — *vesicaria* | | | | r | | | | | |
| — *sp.* | c | r | + | + | r | c | r | + | |
| *Carpinus betulus* | [r][5] | | | +, r[2] | | r[2] | +, c[2] | | |
| *Ceratophyllum demersum* | | | | r | | | r | | |

[1]) See Pl. XXXV, 15. [2]) Pollen. [3]) See p. 25. [4]) See p. 37. [5]) See p. 33.

| Species | Sandy Mud | Subarctic Sand and Clay | | Mud | Subarc. Clay The Middle Bed | | Mud | Arctic Clay | Arctic Sand |
|---|---|---|---|---|---|---|---|---|---|
| | C | E | F | G | H | J | K2 | L | M |
| *Ceratophyllum demersum var. apiculatum* (Pl.XXXI, 26—28) | | | | c | | | c | | |
| *Ceratophyllum submersum* | | | | | | | r | | |
| *Cladium mariscus* | | | | r | | | r | | |
| *Compositae* | | | r | | | ? | | r | |
| *Cornus sanguinea* | | | | | | | r | | |
| *Corylus avellana* | | | | +, +1) | | r1) | c, c1) | | |
| *Dryopteris thelyteris*2) | | | | c | | | c | | |
| — *sp.*2) | | | | | | | r | | |
| *Dulichium spathaceum* | | | | r | | | r | | |
| *Empetrum nigrum* | r | | + | r | + | r | | | |
| *Frangula alnus* | | | | | | | r | | |
| *Fraxinus excelsior* | | | | | | | r | | |
| *Hippuris vulgaris* | | r | r | r | | r | r | + | |
| *Hydrocotyle vulgaris* | | | | | | | r | | |
| *Hypochoeris radicata*3) | | | | r | | | | | |
| *Ilex aquifolium* | | | | | | | c | | |
| *Juniperus communis* | | | | | r | | | | |
| *Litorella uniflora* (Pl. XXXII) | | | | r | | | | | |
| *Lycopodium annotinum*2) | | | | r | | | r | | |
| *Lycopus europaeus* | | | | | | | + | | |
| *Menyanthes trifoliata* | | | | r | | r | r | | |
| *Molinia coerulea?* | | | | | | r | | | |
| *Myriophyllum alterniflorum* | r | | +1) | cf. | | r1) | | | |
| — *spicat.f.muricata* | | | | r | | | | | |
| — *cf. spicatum* | | | | r | | r1) | | | |
| — *verticillatum* | | | | r | | | | | |
| *Najas marina* | | | | r | | | + | | |
| *Nuphar luteum* | | | | r | | | + | | |
| *Nymphaea alba* | | | | + | | | + | | |
| *Picea excelsa* | | | | c, + 1) | r | r, r1) | +, c1) | | |
| *Pinus silvestris* | | | | c, +1) | r | r1) | +, c1) | | |
| *Polygonum tomentosum* | | | | r | | | r | | |
| — *sp.* | | | | | | | r | | |
| *Polypodium vulgare*2) | | | | r | | | r | | |
| *Potamogeton alpinus* | r | | | | | | | | |
| — *densus* | | | | | | | r | | |
| — *filiformis* | | | | + | r | r | | | |
| — *natans* | c | | | | | | c | | |
| — *praelongus* | + | | | | | | + | | |
| — *pusillus* | r | | | | | | | | |
| — *spp.* | r | | + | c | r | + | c | + | r |
| *Potentilla cfr. erectum* | | | | | | | | r | |
| — *palustris* | r | | | | | r | | + | |
| — *sp.* | | | r | | | r | + | | |
| *Quercus robur* | | | | r | | | c | | |
| — *sp.*1) | | | | + | | | c | | |
| *Ranunculus lingua* | | | | r | | | | | |
| — *repens* | | | | r | | | r | | |
| — *sp.* | | | | r | | | | | |
| *Rubus idaeus* | | | | r | | | + | | |
| — *sp.* | | | | r | | | | | |
| *Salix herbacea* (Pl. XXXIV, 1-3) | r | | | [r]4) | | | | + | |
| — *phylicifolia* (Pl.XXXIV, 5-6) | | | | | | r | | c | |
| — *reticulata* (Pl. XXXIV, 9) | | | | | | | | + | |
| — *cf. repens* (Pl. XXXIV, 7-8) | | | | | | | | + | |

1) Pollen. 2) Spores. 3) See Pl. XXXII, 1. 4) See p. 45.

| Species | Sandy Mud | Subarctic Sand and Clay | | Mud | Subarc. Clay The Middle Bed | | Mud | Arctic | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Clay | Sand |
| | C | E | F | G | H | J | K2 | L | M |
| *Sambucus cf. nigra* | | | | r | | | | | |
| *Scirpus lacuster* | | | | c | r | r | c | | |
| *Selaginella selaginoides* | | | r | | | r | r | | |
| *Sparganium affine* (Pl. XXXIII, 27) | | | | r | | | r | r | |
| *Sparganium erectum* | | | | + | | | + | | |
| — *minimum* | | | | + | | | r | | |
| — *sp.* | | | r | | r | r | | r | |
| *Taxus baccata* | | | | r | | | r | | |
| *Tilia platyphylla* (Pl. XXXIII, 1–5) | | | | r | | | r | | |
| *Tilia sp.*[1]) | | | | r | | | r | | |
| *Trapa natans* (Pl. XXXI, 1—16) | [r][2]) | | | + | [r][3]) | | c | | |
| *Ulmus cf. glabra*[1]) | | | | r | | | + | | |
| *Umbelliferae* | r[1]) | | | r[1]) | | | r | | |
| *Viola palustris* | | | r | | r | r | r | | |
| | | | | | | | | | |
| *Acrocladium cuspidatum* | | | | | | r | | | |
| *Amblystegium polygamum* | + | | | | | r | | r | |
| — *stellatum* | | | | | | r | | c | |
| *Anisothecium crispum* | | | | | | r | | | |
| *Brachythecium albicans* | | | | | | | | r | |
| *Bryum ventricosum* | | | | | | r | | r | |
| — *sp.* | | | | | | c | r | | |
| *Calliergon giganteum* | | | | | | | | r | r |
| — *Richardsonii* | | | | [r][4]) | | | | | |
| — *sarmentosum* | | | | | | | | r | |
| — *stramineum* | + | | r | + | r | + | | r | |
| — *trifarium* | | | | r | | | | | |
| *Camptothecium trichoides* | | | | | | | | + | |
| *Ceratodon purpureus* | | | | | | r | | | |
| *Climacium dendroides* | | | | | | + | r | | |
| *Cratoneuron filicinum* | | | | | | + | | | |
| *Dichodontium pellucidum* | | | | | | c | | | |
| *Dicranum congestum* | | | | | | | | r | |
| — *scoparium* | | | | | | | | r | |
| *Ditrichum flexicaule* | | | | | | r | | r | |
| *Encalypta rhabdocarpa* | | | | | | r | | r | |
| *Eurhynchium praelongum* | | | | | | | r | | |
| *Gymnocybe palustris* | + | | | r | | | | r | |
| *Homalothecium sericeum* | | | | | | | r | | |
| *Hylocomium proliferum* | | | | | | c | r | r | |
| — *squarrosum* | | | | | | | r | | |
| *Hypnum aduncum* | | | | r | | r | | | r |
| — *exannulatum* | + | | r | r | | c | | + | r |
| — *intermedium* | | | | | | r | | | |
| — *revolvens* | + | | | | | | | r | r |
| — *uncinatum* | + | | | r | r | c | | r | |
| *Isothecium viviparum* | | | | | | | r | | |
| *Lescuraea Breidleri* | | | | [r][5]) | | | [r][6]) | c | |
| *Meesea triquetra* | | | | | | r | | r | |
| *Mnium cinclidioides* | | | | | | r | | | |
| — *cuspidatum* | + | | | | | + | | r | |
| — *stellare* | | | | | | | r | | |
| *Paludella squarrosa* | | | | | | r | | | |
| *Philonotis fontana* | | | | r | | c | | | |

1) Pollen. 2) See p. 34. 3) See p. 41. 4) See p. 39. 5) See p. 29. 6) See p. 27

| Species | Sandy Mud | Subarctic Sand and Clay | | Mud | Subarc. Clay The Middle Bed | | Mud | Arctic | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Clay | Sand |
| | C | E | F | G | H | J | K2 | L | M |
| *Philonotis tomentella* | | | | | | | | r | |
| *Pohlia albicans* | | | | | | r | | | |
| — *nutans* | | | | | | + | | | |
| *Polytrichum juniperinum* | | | | | | c | | + | |
| — *strictum* | + | | | | r | r | | r | |
| — *sp.* | | | | + | | r | | | |
| *Rhacomitrium canescens* | + | | | | | + | | | |
| — *fasciculare* | | | | | | r | | | |
| — *sp.* | | | | | | r | | | |
| *Scorpidium scorpioides* | + | | | r | | r | | r | r |
| *Sphagnum palustre* | | | | | | r | | | |
| — *papillosum* | | | | | | r | | | |
| — *sp.* | | | | r | | c | | | |
| *Swartzia montana* | | | | | | | | r | |
| *Thuidium abietinum* | | | | | | | | r | |
| — *sp.* | | | | | | | | r | |
| *Tortella tortuosa* | + | | | | | | | | |
| *Tortula ruralis* | | | | | | r | | r | |
| *Cenococcum geophilum* | | + | c | c | | r | c | | |
| *Anabaena sp.* | | | | | | | + | | |
| *Botryococcus Braunii* | + | | r | + | | + | + | | |
| *Characeae* | | | | | | + | | | |
| *Diatomaceae* | | | | | | r | | | |
| *Pediastrum boryanum* | | | | | | r | | | |
| — *integrum* | | | r | | | + | | | |
| — *Kawraiskyi* | | | | | | + | | | |
| — *sp.* | + | | r | r | | r | | | |
| *Staurastrum sp.* | | | | | | | + | | |
| *Mus (silvaticus?)*[1] | | | | | | + | + | | |
| *Phytoptus laevis* | | | | + | | | + | | |
| *Acidota crenata* | | | | | | r | | | |
| *Anchomenus lugens* | | | | | | | | | r |
| *Otiorrhynchus dubius* | | | | r | | | | | |
| — *sp. (ad rugosostriatus)* | | | | | | r | | | |
| *Cladocera* | + | | | | | | | | |
| *Daphnia pulex* | | | r | | | r | | | |
| *Cristatella mucedo* | | | | | | | r | | |
| *Spongilla lacustris* | + | | + | + | | + | + | | |

## Stratigraphy and Geological History of the Interglacial Lake at Herning.

### The Lake Deposits.

The map Pl. II shows the position of all the borings, and of the profile in the brickworks pit from 1914. The approximate extent of the mud beds will appear from this; and it will be noted that the

[1]) Gnawed marks on hazel nuts.

interglacial lake in which these deposits were formed must have been at least 800 m long in the direction from N—S, and up to about 300 m across. The material described in the foregoing, and the profile drawings (Pl. VIII and IX), show how the lake was filled up, and illustrate the climatic conditions under which the contemporary vegetation lived.

The underlying stratum on which the lake deposits were formed consists of moraine clay. This cropped out in the brickworks pit, and has also been found in a great number of the borings, especially along the marginal portions of the lake (Nos. 1, 2, 17—24, 26, 29—31, 33, 37, 38, 40, 41) whereas in most cases, we were unable to get through the basin deposits farther out, where the depth was greater. Moraine clay, which is indeed widely distributed as a surface stratum in the vicinity of the lake though often covered by a layer of stony sand, forms the deep oblong bowl in which the lake deposits rest. The edge of this bowl is highest on the south side, where the moraine clay reaches up over 45 m above sea level, and on the east, where, in Borings 38 and 33, it reaches 45.1 and 43.8 m, whereas on the north, it does not rise beyond 40.3 m (Boring 17). As the lake deposits extend up to abt. 45 m (in the brickworks pit) and were not bored through even at 24 m above sea level in the deepest boring (No 11) the basin must have been over 21 m deep.

On the moraine clay was bedded, in the brickworks pit, a stratum of glacial clay (N) up to 1.35 m thick, appearing as varve clay in the deeper parts (see p. 22); and in many of the borings there was found, below the fossiliferous lake deposits the same kind of clay.

The thickness of this stratum out under the basin is but incompletely ascertained, the stratum either not being reached, or not separated from the superimposed, plant-bearing arctic clay. In Borings 22, 23 and 37, however, the glacial clay appeared to have a thickness of 3.5, 3.2 and 1.7 m respectively. In Boring 26, above the moraine, there was found a bed of clay 2.4 m thick which belongs here. In Borings 1 and 2, the stratum was not located with certainty, whereas it was of considerable thickness in the brickworks pit. The glacial clay appears to be associated with the basin, as it is not known from any level above abt. 45 m, viz. in the pit itself. The map Pl. II shows how the moraine clay lies directly below the stony sand at the surface on the eastern side of the basin, the stoneless clay covering the moraine on the western side of this; its extent here is not known, but its presence shows that the lake must, during the ice recession in the penultimate glacial period when the ice was retreating from this region, have been of considerably greater extent, especially on this side, than the lake in which the mud beds were formed.

In the brickworks pit, profile 1914 (Pl. III), the two clay strata are separated by a layer of sand (M) up to half a metre thick, containing the oldest vegetable remains, especially mosses (p. 21). More characteristic was the flora in the arctic clay (L) which is known partly from the brickworks pit and partly from numerous borings; its thickness might amount to as much as 2 m at least; it contained a quantity of carbonate af lime, and was dark grey or greyish blue in colour. This stratum also reached up to 45 m above sea level on the extreme south, while in the northernmost boring (16) where it was found it only reached 36.5 m and the stratum must thin out at something below abt. 40 m above sea level (boring 17). Most of the vegetable remains from this stratum were found in the brickworks pit 1914 (p. 20). Species such as *Salix herbacea*, *S. reticulata* and the mosses *Calliergon sarmentosum*, *Dicranum congestum* and *Lescuraea Breidleri* belong more particularly to arctic conditions; and the remaining species from this stratum are also on the whole widely distributed at the present day in sub-arctic regions, none of them being associated only with the temperate zones. The fact that the two arctic species of *Salix* were not found in the upper part of the stratum in the brickworks pit 1914 might perhaps be taken as indicating that an improvement in the climate had already set in at the time when this deposit was formed; cf. also the appearance of *Betula nana* × *pubescens* in the upper part of this bed. And in this connection, attention should also be drawn to the finding of a number of fruits of *Betula pubescens* in Stratum L in Boring 32 (p. 42). This species must then be reckoned as belonging to the flora of the arctic clay, always presuming that the fruits in question were not brought down from above by the drill.

The moraine clay which forms the bed of the lake basin, and the oldest of the deposits therein formed, namely the varve clay and the arctic clay go together in the sense that the two latter are washing products of the former. There are no lacunæ between them, and the entire situation clearly shows that the lake deposits were formed in a interglacial period immediately following the glacial period to which the moraine clay belongs.

It has been noted in the foregoing that the *Ceratophyllum* stratum in the brikworks pit 1914 was bedded directly on clay with *Salix phylicifolia* and *Betula nana*, and this possibly means a slight lacuna in the series of strata, as indeed is also suggested by the irregular surface of the arctic clay. At the time when the *Ceratophyllum* stratum was being formed, the environs of the lake were covered with a flora of oak and pine (cf. p. 20), and *Trapa natans* had made its appearance in the lake. The layer of sand ($K_3$) found below the mud bed $K_2$ in borings 4 and 5, and which contained fruits of *Najas* *marina*, is presumably contemporaneous with the lower portion of the *Ceratophyllum* stratum.

The *Trapa* stratum ($K_2$) in the brickworks pit 1914 was discernible in nearly all the borings in which lake deposits were found, and extended with a thickness of up to 3 metres and more, throughout the entire basin. Towards the margins, the stratum consisted of arenaceous or argillaceous mud, often rich in drifted plant remains (detritus mud), whereas out in the deeper parts, it was poorer in mineral constituents, save in the upper and lower portions, where it showed transition to the strata above and below. The greater part of the stratum consisted of dark brown mud, mostly rather brittle and poor in clay, with a fine admixture of sand, assuming a light greyish brown colour when dried. This stratum also reached, on the extreme south, as far up as 45 m above sea level, whereas on the northern end of the profile it was not observed at any higher level than 37.6 and must thin out at something below 40 m.

The rich flora from this stratum (see the list p. 46, f) was found more especially in the marginal portions, close to the shore, e. g. in the brickworks pit 1914, and it shows, *inter alia*, all the characteristic interglacial fossils; also, *Trapa natans* for instance was here found for the first time in Danish interglacial deposits. The two pollen diagrams in Pl. XXXVI show how the development of the forest growth proceeded during the time when this mud bed was in process of formation.[1]) At the bottom, there was a zone of but slight thickness, where *Betula* (surely *Betula pubescens*) and *Pinus silvestris* were almost sole masters of the soil; less than half a metre above the lower edge of this stratum however, we find already up to 35 % oak pollen. The greater portion of the bed was formed at a time when mixed oak forest with *Quercus robur*, *Alnus glutinosa*, *Ulmus cf. glabra* and a abundance of *Corylus avellana* covered the ground surrounding the lake (Zone *f*), and the forest now contained also *Acer campestre*, *Fraxinus excelsior*, *Ilex aquifolium*, *Tilia platyphylla* and *Taxus baccata*. The *Ulmus* curve culminates in the lower third of the stratum with 4—5 %, but in the diagram Pl. XXXVI, 2 it again appears in the upper half with 6 %. *Alnus* and *Corylus* here attain their maxima, with 41 % and 117 % respectively in spectrum 18, while the curve for mixed oak forest (*Quercus* and *Ulmus*) reaches its summit a little higher up, at about the same time when *Betula* and *Pinus* are thrust farthest back. In the upper third of the diagram for the mud bed, the aspect is entirely different, *Picea* and *Carpinus* here making their entry on the scene, and attaining 55 % and 25 % respectively close to the

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1) As for the designation of the floristic zones, see Chapter VII.

upper margin of the mud bed, while at the same time the curves for *Pinus* and *Betula* turn off again to the right, that for mixed oak forest to the left. On the basis of these pollen analyses, we can divide the mud bed into three capital zones comprising, the *Betula-Pinus* zones *c*, *d* and *e* at the bottom, above these a relatively thick Mixed oak forest zone *f;* and uppermost, the *Picea-Carpinus* zones *g* and *h* (cf. Chapter VII).

In the profile found in the brickworks pit 1914, the greater part af the *Ceratophyllum* stratum and the whole of the *Trapa* stratum presumably belonged to the mixed oak forest zone, as neither *Picea* nor *Carpinus* were found in the large samples taken from there. The *Picea* zone then was not discernible in the brickworks pit 1914; it has probably been desintegrated, (cf. the yellow sand uppermost in $K_2$, p. 18).

The dark brown mud bed $K_2$ ran through a horizon of lighter, more argillaceous mud, over into the stratum above, the "Middle Bed" (H and J). This consisted, at the bottom, of grey to greyish blue tough clay, rather abruptly separated from the layer beneath, the upper portion being composed of grey to greyish brown clay with a small amount of mud and varying sand content, and in this upper portion of Stratum J were found numerous thin brown streaks of plant detritus, a few millimetres thick. Vivianite was fairly common. This intermediate stratum extended throughout the entire basin from the brickworks pit, where it reached up as far as the 45 m level, to the north end; it was here observed as high as 38.5 m, but thins out at a somewhat higher level. The greatest thickness of the clay stratum, 7.40, was measured in Boring 11, but it is here overlaid by a bed of sand (H) abt. 3 m thick, containing exactly the same flora as the clay itself, and evidently to be included in the horizon of the Middle Bed, the maximal thickness of which thus amounts to 10.40 m. Borings 6, 8, 9 and 12 also contained sand layers which for similar reasons must be ascribed to the Middle Bed, in several of these sand layers were found numerous stones, some as big as hen's eggs.

The Middle Bed was poor in determinable vegetable remains, and altogether but few species were found, despite the fact that the bulk of all the washing samples from the interglacial lake at Herning was from this stratum. Among the aquatic plants may be noted especially fruits of *Batrachium aquatile (coll.)*, *Hippuris vulgaris* and *Potamogeton filiformis*, with pollen of *Myriophyllum alterniflorum* and *M. cf. spicatum*, and from marshes we have *Scirpus lacuster*, *Menyanthes trifoliata*, *Carex sp.*, *Viola palustris* and *Potentilla palustris*, as also a number of mosses. The greater part of these consisted, according to A. HESSELBO, of the Hypnaceae etc., common in sub-arctic swamps, and widely distributed also in the temperate zone. *Hypnum exannulatum*, which at the present day is an extremely common species e. g. in Iceland and Greenland, was found in the Herning material in a number of different forms, one of particular interest, and apparently common at the period, being a type with highly prolonged and undulating leaf nerve (*var. capillifolium*) which is very rare at the present day. The decidedly arctic mosses found in the arctic clay (L) were lacking in the Middle Bed, where on the other hand, a number of species were found which might best be called sub-arctic, and are now rare in Denmark, viz: *Anisothecium crispum*, *Dichodontium pellucidum*, *Ditrichum flexicaule*, *Encalypta rhabdocarpa*, *Meesea triquetra*, *Mnium cinclidioides*. The moss flora from this stratum was thus of a sub-arctic character, in contrast to that found in the mud bed $K_2$, which was drived rather from moist woodland soil under foliage trees.

The sub-arctic character of the Middle Bed was further emphasised by the relatively abundant occurrence throughout its extent of *Betula nana*, which, together with *Empetrum nigrum*, must presumably have been common in the environs of the lake. There is further, a find of *Salix cf. phylicifolia* (Boring 36) and many small buds of *Salix sp.* were found, as also spores of *Selaginella selaginoides*. Occasionally (Borings 3, 9, 11, 12) some macroscopical remains (bud scales, flakes of bark) of *Picea excelsa* and *Pinus silvestris* were found, but only in the upper part of the Middle Bed, and in this horizon, as well as in the lower part of the stratum, some fruits of *Betula pubescens*[1]) were also found. *Juniperus communis* was only observed once in the Middle Bed, viz. in its upper portion (H in Boring 8).

A series of pollen analyses from the Middle Bed afford further data as to the vegetation contemporaneous with this formation in the vicinity of the lake. In the two diagrams Pl. XXXVI, 1—2 it will be seen that the pollen frequency suddenly decreases at the transition from stratum $K_2$ to stratum J, in the lower portion of which only a couple of grains per sq. $cm^2$) preparation surface were found, as against up to abt. 190 in the subjacent mud bed. The very sparsely distributed pollen found in this lower portion of stratum J belonged to *Betula, Pinus, Alnus, Quercus, Carpinus, Picea* and *Corylus*; but of these, *Betula* and

1) With regard to the occurrence of scanty remains of such species as *Betula pubescens*, *Picea excelsa* and *Pinus silvestris*, which are common both in the stratum above and in that below, it should be noted that the boring apparatus used may sometimes bring down vegetable remains from above to strata lower down; moreover, it is not always possible to prevent a collected sample from extending somewhat beyond the limit of the stratum indicated.

2) That this impoverishment need not be due to the altered sedimentation is apparent from the fact that other clay deposits, e. g. postglacial marine fjord clay, can be very rich in pollen.

*Pinus* appear to be rather more common than the remaining species. *Betula* must have been growing about the lake at this period, to wit, *Betula nana*, and presumably also *Betula pubescens* but for the rest, it is likely that the great majority of the pollen in the lower portion of stratum J are due to wind transport from far away. Even in the Færoes we find, in postglacial bogs, a small amount of pollen from forest trees, carried thither by the wind from Norway and Scotland[1]), and it is hardly likely that species such as *Carpinus*, *Corylus* and *Quercus* should have existed here together with the above-mentioned sub-arctic community. In the upper part of Stratum J, the pollen frequency increases somewhat, reaching up to abt. 33; the diagram Pl. XXXVI, 2 shows an altogether regular course in the curves for this portion: *Pinus*, *Picea* and *Betula* dominate in most of the spectra, and these trees probably also stood scattered about in the neighbourhood of the lake, when this upper part of the Middle Bed was deposited. It is rather more doubtful, however, whether the presence of *Alnus* pollen can be due to a local growth of this species, for if it did live by the shores of the lake, then the absence of its fruits etc. in the Middle Bed, when they are of so frequent occurrence in the mud beds above and below, must seem very remarkable. The pollen of *Carpinus*, *Corylus* and *Quercus* and presumably also *Alnus*, must be regarded as brought by the wind from far away, also in the upper portion of Stratum J.

The vegetation round the lake, during the period when the Middle Bed was being formed therein, consisted then of heaths and bogs having a sub-arctic character; for the first part of the time, perhaps, some *Betula pubescens* may have managed to thrive on these heaths, but it was most probably ousted in course of time. The whole of the rich temperate flora found in the lower mud stratum $K_2$ had now disappeared from the district, being replaced by northern species. The paucity of species in the Middle Bed, and the character of those there found, as well as the constitution of the stratum itself, show that it was formed under essentially cooler climatic conditions than those which marked the vegetation of the previous period. In the upper part of the lower mud bed we already find distinct evidence, in the pollen diagrams, that the vegetation is assuming a more northerly character, and this process of development was continued as time went on. Owing to the considerable thickness of the Middle Bed as compared with the total depth of all the strata resting on the moraine in the basin, it must be presumed that the formation of this stratum must have

[1]) Knud Jessen: De færøske Mosers Stratigrafi. Förhandl. 17de Skandinaviska naturforskaremötet. Göteborg 1925, p. 190*. Cf. also L. v. Post: Ur de sydsvenska skogarnas regionala historia under postarktisk tid, Figs. 7—8. Geolog. Fören. Förhandl. Bd. 46. Stockholm. 1924.

lasted a considerable time. The cause of this radical alteration in the nature both of the vegetation and of the sedimentation may be sought in a marked fall of the temperature, although not great enough or of sufficient duration to drive species sensitive to cold as far away as the high-arctic climate of a new glacial period would have done. We must imagine that the temperate species thus driven out found a sojourning place more or less distant from Jutland for the time being, and then returned *en masse* as soon as the climate once more became favourable in those regions whence they had been temporarily evicted. Evidence of the fact that this improvement in the vegetation had commenced even before the Middle Bed was fully formed is afforded by the scattered finds of *Picea excelsa*, *Pinus silvestris* and *Betula pubescens*, and by the increased quantity of pollen from these trees, in the upper part of the intermediate stratum; the forest commenced its advance over the *Empetrum-Betula nana* heaths, which were gradually driven out, the sedimentation of the lake however, alternating its character at the same time.

Stratum G, the Upper mud bed. When we first observed this stratum, viz. in the brickworks pit 1914, we did not consider it as of any particular importance; this was first apparent when subsequent borings had shown that it extended in the form of a coherent horizon, up to abt. 2 m thich, throughout the entire basin. This stratum consisted of several different soils, with all kinds of transition between. For the most part, it was made up of alternating thin layers of sandy mud and mud-blended sand, rich in small sticks and wood detritus; this facies could also appear as a typical drift mud (Schwemmtorf), rich in fruits and seeds (e. g. in the pit at Point 20 and Boring 27). Farther from the shore, out in deeper water, a deposit of brown clay mud or detritus mud was formed (e. g. Boring 4). The south end of the stratum reached up to about 44.5 m in the brickworks pit, but in the northern part of the lake it is never observed at so high a level; as was also noted in the case of Strata J and $K_2$. In Boring 15, the most northerly point at which it was observed, it does not reach beyond 37.6 m, whereas in Boring 12 it reached 38.7 and in Boring 32 (Pl. IX) 40.8 m. The stratum has been located in the following borings: 1—13, 14?, 15, 19, 20, 27, 32, 34, 36, 39 (Pl. II). In Boring 9, the stratum was found to differ from its normal development, being here almost effaced by a layer of stony sand with only thin layers of mud above and below (see Pl. XXXVI, 2). At the time when stratum G was being formed, the lake was of rather smaller extent than when the lower mud bed was laid down, the depth also having appreciably diminished; it was however, doubtless still something approaching ten metres deep. The considerable difference between the composition of the two mud beds G and $K_2$ is due to their having been formed at different depths. The shore facies of the lower mud bed, the *Trapa* layer in the brickworks pit 1914, resembled very closely indeed the most extended facies in the upper mud bed.

The flora of this upper mud bed comprised very much the same species as the lower mud bed $K_2$ e. g. *Brasenia purpurea*, *Dulichium spathaceum*, *Trapa natans*, *Tilia platyphylla*, *Carpinus betulus*, *Taxus baccata*, and others. The vegetable remains from this stratum do not present appearance of having been rolled; they must have been deposited calmly and without disturbance on the floor of the lake together with the masses of mud and sand enveloping them. It has been noticed however, that in the shore facies of the stratum for instance, flakes of wood were sometimes slightly rolled. Stratum G however contained a number of vascular plants, not found in the lower mud bed, firstly some heath species: *Arctostaphylus uva ursi*, *Calluna vulgaris*, *Empetrum nigrum* and *Betula nana* (three fruits of this last were found about in the middle part of the stratum in trench No. 20, p. 37) and further, of forest forms, especially *Sambucus cf. nigra*, also some marsh plants such as *Carex filiformis*, *C. rostrata*, *C. vesicaria*, *Ranunculus lingua* and *Litorella uniflora* and finally *Hypochoeris radicata*. The greater abundance of *Cyperaceae* in this stratum than in the lower mud bed is perhaps connected with the existence of better growth conditions for these plants round the now shallower lake. On the other hand, there are far fewer species known from $K_2$ and not observed in G, viz. *Cornus sanguinea*, *Ilex aquifolium*, *Hydrocotyle vulgaris*, *Lycopus europaeus*,[1]) and *Viola palustris*.

The presumable development of the flora which took place while the upper portion of the Middle Bed was being formed was continued during the period that followed. The heaths were covered with forest growth, but the occurrence of the dwarf bushes above noted suggests that the dwarf-shrub heath was not entirely eradicated. The washing lists show that it was a mixed forest, rich in variety of species, which throve in the vicinity of the lake at this period, and the process of development, with starting-point in the two almost identically pollen spectra uppermost in the Middle Bed, is further illustrated by the pollen diagrams. The pollen frequency increases as we pass to Stratum G, in which it reaches 113; at the same time, the curves for *Betula*, *Pinus* and *Picea* turn off to the left, the first-named however, soon turning back sharply towards the right again; there is a marked in-

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[1]) All three species occured in the upper mud stratum at Nørbølling, p. 74.

crease in the relative frequency of pollen of *Alnus*, *Quercus* (almost the sole constituent of the "mixed oak forest" in this part of the diagrams) and *Corylus*; *Alnus* reaching as much as 37 %, *Quercus* + *Ulmus* 9 %, and *Corylus*, taken separately, 27 %; the curves for *Carpinus* are not particularly characteristic, and only reach 4 %. Spectra 1 in Fig. 1, Pl. XXXV and in Fig. 2, Pl. XXXV answering to the uppermost horizon of stratum G, are very much alike: *Betula* is markedly dominant in both, *Alnus* coming next, while the species of the great forest proper are but poorly represented; evidently the forest was at this stage already feeling the effects of the conditions which led to the formation of the strata above. Unfortunately however, paucity of material prevents further detailed consideration of the forest development in this period of the upper mud bed.

The moss flora in Stratum G is not particularly characteristic; the *Hypnum* species so strongly represented in the Middle Bed J were here rather rare, and the small community observed may be described as temperate — *Lescuraea Breidleri*, found but once (Boring 9) being doubtless an adulteration, as also in $K_2$ (Boring 5). *Calliergon trifarium* is now rare in Denmark, but has, according to AUG. HESSELBO, doubtless been commoner here at any rate in the postglacial period; *C. Richardsonii* is a sub-alpine species, living however, here and there in the lowlands, including Denmark.

Since the mud bed G — being in a primary positon — contains about the same thermophile species as the lower mud bed $K_2$, it must be supposed that the summer temperature, when it was deposited, was approximately the same as in the first warm period. The thick Middle Bed with its sub-artic flora then indicates a hitherto unknown but very considerable oscillation of temperature in the interglacial period represented by the Herning locality — an interglacial period which must, as will be seen from the following, be reckoned as beeing our last.

Between Borings 8, 10, 27 and 32, the mud bed G lay conspicuously deep, and formed a bowl, filled up with stony sand F—G, this being separated only by a thin layer of mud from the sandy portion embedded in Stratum G at Boring 9. Over the sand F—G extended a thin layer of mud-blended sandy clay D, apparently a continuation of the clay stratum above the mud G in Borings 2, 6 and 7 and 14—16. This, between Points 8—11, shows a remarkable interruption in the deposit of stony sand. Those portions of stony sand which were found in Borings 8—11 under this clay horizon, and Stratum H in Borings 8 and 9, must presumably be taken as one unit, and should possibly be regarded as the delta of a stream.

The flora of the clay bed F was of precisely similar character to that of the Middle Bed, consisting of *Betula nana*, *B. pubescens*, *Empetrum nigrum*, *Arctostaphylus sp.*, *Selaginella selaginoides*, and aquatic plants such as for instance *Batrachium aquatile (coll.)*, and *Myriophyllum alterniflorum*. Spectrum 1 in Fig. 2, Pl. XXXVI is from this stratum. The stratum attained a maximal thickness of up to 1.7 m (Boring 15). It was found only in a minority of the borings made, but the stratigraphical conditions of the different portions of this lake deposit show that it must originally have been far more united throughout its extent. Certain portions have doubtless been completely eroded during the formation of the sand stratum above (D); and the stratum of stony, mud-blended clay ($D_2$) which covered it in Borings 9—11, may presumably be regarded as originating from a fusion of the stony sand above (here $D_1$), and the subjacent clay. The pollen spectrum: *Betula* 98 %, *Pinus* 2 % (pollen frequency 31) found on analysis of the stratum in Boring 11, is thus the last reminiscence of interglacial tree vegetation in the district (*Pinus* pollen however, presumably brought by wind transport from far away). For other vegetable finds see Borings 11, 27 and 32. Possibly however, this clay bed may be regarded as fully preserved in Borings 1 and 2, where it is covered by a layer of stoneless, rather humous sand with some few vegetable remains, for this sand stratum E may be regarded as a shore facies to Stratum F. The stratified, contorted, somewhat stony sand stratum observed below the bed D in the brickworks pit 1914 (p. 17) may perhaps partly be a derivate, later affected by solifluction, of this shore facies.

### The Covering Sand and more recent Strata.

Over the lake deposits described in the foregoing, was spread a layer of stony sand (Covering Sand) D, which was observed both in the brickworks pit 1914 and in nearly all the borings, also extending up over the plateau round the lake. The thickness of the layer varied from 0 m (Boring 1) to 3.2 m (Boring 7). No dictinct stratification was observed, either in the brickworks pit or elsewhere where excavations were made. The numerous stones enclosed in the layer were up to the size of a fist, and in many of the borings, especially close to the edge of the northern part of the basin, the layer assumed the character of gravel, the stones here being also somewhat larger than farther out over the basin.

No moraine clay was found anywhere over the basin; the local moraine formations are plainly older than the interglacial lake deposits in this, and the stony sand (D) affords, in its constitution and stratigraphical conditions, no ground for supposing that it should have been deposited by inland ice.[1]) Its lack of stratification shows, on the other hand, that it is not a lake deposit. But we might well suppose that it is an accumulation of flowing earth, crept down from the higher ground round the basin out over the bottom of the lake, (which at that time was almost entirely filled up) under the influence of regelation and of frost in the crust of the earth (Tæl) during an arctic period. The constitution of the stratum, e. g. at the southern end of the brickworks pit, shows that it was here formed by the union of various kinds of earths, and in the course of its progress out over the basin it has partially destroyed the uppermost lake sediment, Stratum F, or an intermingling of this with the stony sand has taken place.

After the formation of the mud bed G, the climate again turned colder; the rich temperate flora known from this stratum once more forsook the district, and a *Betula nana-Empetrum* heath again spread over the ground, the sedimentation in the lake at the same time changing from sandy mud to clay. It is this development of the climate in the direction of arctic conditions which was continued, and attained its culmination, while the stony sand was making its way out over the lake. This covering layer D must then undoubtedly be taken as coeval with the last Scandinavian glacial period, when the inland ice spread out over the greater part of Jutland, though without covering the lake at Herning Brickworks, which lake then dates from the last interglacial period.

After the formation of the stony sand stratum D, the basin was still not quite filled up, there being, more especially, a considerable depression in the northern portion, situated in the profile between Points 7 and 17. In this, fine sand and sandy mud were deposited, the latter often lying in thin streaks in the sand; at the top, a little *Phragmites-Carex* peat was formed. Washings from these sandy lake deposits yielded a poor flora consisting notably of *Batrachium aquatile (coll.)*, *Hippuris vulgaris*, *Potamogeton sp.* and *Myriophyllum alterniflorum*; among land plants, were found *Empetrum nigrum* and *Salix herbacea*. We have also from here a half nut of *Carpinus betulus*, and some few remains of *Trapa natans*, but these fragments may safely be regarded as having occupied a secondary position in the mud, and originating properly from the destroyed ends of the subjacent strata (cf. p. 33 and 34). From the lower part of the sandy mud $C_4$, Boring 13 we have the following spectrum: *Betula* 28 %, *Pinus* 21 %, *Ulmus* 1 %, *Quercus* 12 %, *Tilia* 1 %, *Alnus* 19 %, *Carpinus* 3 %, *Picea*

[1]) In this connection it is of interest that we in the summer 1927 detected a couple of interglacial bogs of the Brörup type ca. 4 km SE of Herning.

15 %, and *Corylus* 14 % (Pollen frequency 30) which is undoubtedly strongly influenced by the intermixture of interglacial material. In the upper part of the mud bed $C_3$, 1.25 below the surface in boring 13, the following late- or early postglacial spectrum was determined: *Salix* 2 %, *Betula* 78 %, *Pinus* 19 % and *Alnus* 1 %. Then in the lowest portion of the area, a stratum, of reed peat was formed, which has since turned into humus, and remains as the last relic of the once deep lake.

It is possible that the argillaceous sand beds covering Stratum D in Borings 1—3 should at any rate to some extent be regarded as washed out material (Schwemmsand), while the surface layer in other parts of the former lake area consists of wind-blown sand, which accounts for the slightly undulating surface of the ground, e. g. between points 5 and 10.

It now remains to consider the peculiar inclined position of the lake deposits, which has been referred to several times in the foregoing. A decisive factor in the determination of the magnitude of this incline is the difference of altitude between the highest level to which the lake deposits reach at the southern end of the basin (abt. 45 m) and the lowest portion of the margin of the interglacial basin on the north. The flat trough which now marks the site of the interglacial lake deposits slopes from south to north with an average fall of 4.5 m in 1000, and merges gradually into the valley followed by the streams, Herningholm Aa and Storaa, on their way to North See. There is nothing in the landscape to show where the northern edge of the basin should be sought; it is only discernible by borings, and appears for instance in Borings 17 and 18 (Pl. VIII) as moraine clay, the surface of which lies above the 40 m level. Its lowest part should doubtless be looked for where the ground lies lowest, or between Borings 28 and 29. The former of these goes down through deeper lake deposits; in the second, no such deposits were found, and the surface of the uppermost stratum ($O_1$), which is undoubtedly older than the lake deposits, lies here about 40 m above sea level. Somewhere near this level we must suppose the threshold of the interglacial basin to lie, and higher than this of course, the lake deposits cannot go. Actually, they have not been observed above 39.5 m (Stratum F in Boring 16). The lake strata have thus at present a fall of at least 5 m in 850, or 5.9 in 1000. The cause of removel of the northern barrier of the lake, together with the upper ends of the strata of the interglacial deposits cannot be sought in ice erosion, since, as already mentioned, the inland ice cannot have extended over the basin during the last glacial period. If running water had cut away a former projecting barrier at this spot, after the formation of the interglacial deposits, then the hollow which these form about

Point 13 would surely have been filled with material of a different character from that met with in the borings. Finally, it might be imagined that the surface of the land as it was at the close of the interglacial period, may have been essentially altered by solifluction (p. 60). As above noted, it must be presumed that this factor *inter alia* is responsible for the formation of Stratum D, the stony sand, but as far as our borings throw any light upon the matter, there does not appear to have been any considerable transport of material out over the northern part of the lake. If large projecting portions of formations from the glacial periods have been removed from the environs at the northern end of the lake, then the transport must have proceeded mainly in a direction away from the lake. It must be borne in mind however, that it is not only the northern edge of the basin which has been worn away by erosion, as the same was undoubtly the case with the ends of strata from the lake deposits projecting up at the southern part, all these being cut down to the same level by the covering layer. These southern ends of the strata doubtless extended higher up originally, how far we cannot exactly say, but if we could add this figure to the difference in height already noted, of 5 m, we should then have a minimum value for the height of the barrier which must have been removed from the northern end of the basin. We must, however, still point out the possibility that the basin itself may have been subjected to an irregular movement of the earth's crust, with the results that the northern end was lowered, though it would carry us beyond reasonable limits were we to attribute the actual slope of the strata to this alone; it is impossible to say how much such a factor may count for in the matter.

## Nörbölling Field.

About 1 km SW of Brörup railway station, on land belonging to farmer Otto P. Ottosen in Nörbölling field, there is a small peat bog, now largely dug away, situated in a distinctly visible enclosed hollow, the maximal extent of which amounts to abt. 260 m (bog no. 5 in Fig. 2). As will be seen from the map however, this basin forms the upper portion of flat a valley, running north and north-west, and opening out at Præstegaard into Holsted River. During the summer of 1922, we succeeded, by means of borings in this hollow, in demonstrating the existence here of interglacial lake deposits of considerable thickness. We therefore continued our investigations during the following summer, making in all 21 borings through these interglacial deposits.

The site of the borings within the margin of the basin will be apparent from Fig. 3, Pl. XI. The postglacial bog was up to 2 m deep

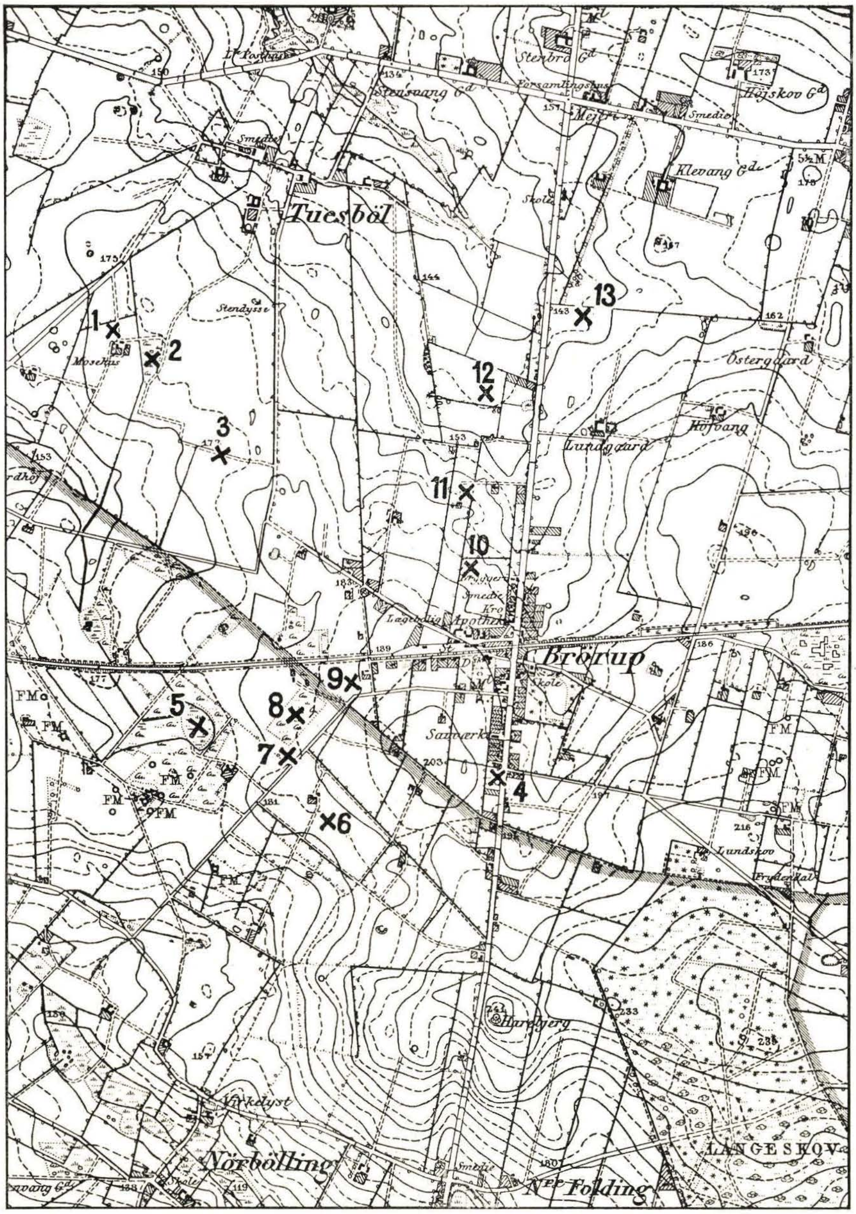


Fig. 2. Neighbourhood of Brörup Railway Station, with the interglacial bogs numbered 1—13. Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. From The General Staff Map Sheet 3406.

(Boring 7), its bottom lying abt. 3 m and abt. 5 m lower than the lowest and highest portions of the margin of the basin. The sides of the basin must, then, prior to the formation of the postglacial bog, have had an inclination of 3—4 m in 100 m, the interglacial basin being originally at least 12 m deep, answering to a gradient for the sides of up to about 18 m per 100 m.

To facilitate an appreciation of the nature and constitution of the strata penetrated, a description of the sequence of strata in some of the borings is here given, together with the results of washings from the samples taken. The stratigraphical division of the profiles will be seen from the terms used for the strata from A—N, the same letter denoting everywhere the same horizon. The two transverse profiles in Pl. XI are designated A and B.

Profile A.

Boring 2.

| | | |
|---|---|---|
| D. | 0 — 1.10 m | Sand with scattered small stones, humous at the top. |
| L. | 1.10— 3.70 m | Top and bottom, muddy Sand, in the middle, sandy Mud; seeds and fruits of *Ceratophyllum sp.*, *Nuphar luteum*, *Potamogeton sp.*, *Menyanthes trifoliata*, *Corylus avellana*, *Quercus cf. robur;* a cone of *Picea excelsa.* |
| M. | 3.70— 5.0 m | Greyish green, sandy Clay without stones. |
| N. | 5.0 — 5.1 m | Sandy Moraine Clay. |

Boring 4. (Pl. XXXVI, 3).

| | | |
|---|---|---|
| A. B. | 0 — 0.9 m | Mould above mud. |
| C. | 0.9 — 1.5 m | Grey Sand. |
| D. | 1.5 — 2.45 m | Grey Sand with stones. Abt. 2.1 m below surface a layer of greyish brown sandy mud, some few cm thick, with some small sticks. |
| E. | 2.45— 2.75 m | Greyish brown, sandy Clay Mud with scattered stones the size of nuts. In this layer were found: *Carex sp.*, 2 fruits without utriculus, *Potentilla sp.*, 1 fruit. |
| F. | 2.75 — 3.65 m | Brown Mud, sandy at the bottom. The following were picked out on the spot:<br>*Brasenia purpurea*, 1 seed,<br>*Carpinus betulus*, 3 fruits,<br>*Nuphar luteum*, several seeds,<br>*Picea excelsa*, fragments of wood,<br>*Potamogeton sp.*, several fruit-stones. |
| G. | 3.65 — 4.30 m | Brown Sand with stones the size of nuts at the bottom. The washing sample yielded:<br>*Alnus glutinosa*, 2 fruits,<br>*Betula nana*, 6 fruits,<br>— *pubescens*, 1 fruit,<br>*Carex sp.*, several fruits,<br>*Empetrum nigrum*, 10 fruit-stones,<br>*Hippuris vulgaris*, several fruit-stones,<br>[*Najas flexilis*, 8 fruits],<br>*Myriophyllum alterniflorum*, several nuts,<br>*Nymphaea alba*, 1 seed,<br>*Picea excelsa*, 1 needle,<br>*Potamogeton filiformis*, 12 fruit-stones,<br>— *praelongus*, 8 fruit-stones. |

*Sparganium minimum*, 3 fruits-tones,
— *sp.*, 1 fruit-stone.

H. 4.3 — 5.5 m Uppermost, grey, rather sandy Clay Mud, with stones the size of nuts here and there. Between 4.9 and 5.05 m a layer of Sand. At the bottom (last 25 cm) brown sandy clay mud. Four samples from different levels between 4.3 and 5.25 m yielded the following vegetable remains:
*Betula nana*, 1 fruit and a small branch abt. 5.10 m below the surface,
*Betula pubescens*, 1 fruit.
— *sp.*, 1 fruit, pollen fairly plentiful,
*Carex sp.*, 2 fruits.
*Empetrum nigrum*, 5 fruit-stones,
*Myriophyllum alterniflorum*, pollen abundant,
*Picea sp*, some pollen,
*Pinus sp.*, pollen rather plentiful,
*Salix sp.*, 4 bud scales, 1 mm long,
*Sparganium minimum*, 2 fruit-stones,
*Viola palustris*, 2 half seeds,

*Cenococcum geophilum*, some sclerotia.

J. 5.5 — 6.5 m Brown *Sphagnum* Peat. Numerous twigs of *Calluna vulgaris*, epidermis of *Eriophorum vaginatum*, leaf fragments of *Gymnocybe palustris*, spores of *Dryopteris cf. spinulosa*. Also abundant pollen of *Picea, Pinus, Betula* and *Alnus*, and *Carpinus* in the lower part.

K. L. 6.5 — 9.35 m Uppermost, brown Mud, between 7.3 - 7.5 m horny mud, below this, paler mud with increasing admixture of sand. In this stratum (K L) were found:
*Alnus glutinosa*, pollen common in the upper part,
*Betula sp.*, pollen common in the lover part,
*Brasenia purpurea*, numerous seeds to abt. 7.5 m below the surface,
*Carpinus betulus*, many fruits and much pollen in the upper part,
*Ceratophyllum demersum var apiculatum*, many fruits,
*Corylus avellana*, pollen common in the midmost part,
*Dryopteris thelypteris*, spores,
*Frangula alnus*, 1 grain of pollen,
*Lycopodium annotinum*, 1 spore,
*Najas flexilis*, epidermis of fruit,
*Nymphaea alba*, pollen and intercellular hairs,
*Picea excelsa*, 1 bud, leaf epidermis, and much pollen, uppermost,
*Pinus silvestris*, leaf epidermis, and much pollen, low down,
*Polypodium vulgare*, spores,
*Potamogeton spp.*, numerous fruit-stones,
*Quercus sp.*, much pollen in the midmost part,
*Typha latifolia*, pollen-tetrads,
*Tilia sp.*, pollen rare,
*Ulmus sp.*, pollen especially in the lower part,

*Rivulariaceae,*

*Botryococcus Braunii,*
*Pediastrum duplex,*

*Spongilla lacustris.*

M. Sand.

Boring 5.

Here, only the upper strata were bored through, as far as the *Sphagnum* peat J. The profile was as follows:

A. 0 — abt. 0.6 m *Sphagnum* Peat.

B. 0.6 — 1.0 m Mud.

C. 1.0 — 1.5 m Sand without stones.

D. 1.5 — 2.95 m Sand with numerous stones up to the size of hen's eggs.

F. 2.95 — 4.50 m Sandy Mud, the upper portion greyish brown, the lower part more brownish. Washings from the upper part of the stratum yielded only 1 fruit-stone of *Empetrum nigrum* and a fruit of *Carex sp.* In the lower portion, the following were found:
*Batrachium aquatile (coll.)*, fruits fairly numerous,
*Brasenia purpurea*, 1 seed,
*Carex sp.*, some fruits without utriculus,
*Empetrum nigrum*, fruit-stones fairly numerous,
*Hippuris vulgaris*, several fruits,
*Hydrocotyle vulgaris*, 1 nut,
*Picea excelsa*, a small piece of wood,
*Potamogeton filiformis*, 16 fruit-stones,
— *sp.*, 8 fruit-stones.

G. 4.5 — 5.8 m Medium fine grey Sand, with some few small stones and a little wood detritus. Also the following:
*Batrachium aquatile (coll.)*, fruits fairly numerous,
[*Brasenia purpurea*, 1 seed, undoubtedly brought down from the stratum above],
*Carex sp.*, some fruits without utriculus,
*Empetrum nigrum*, fruit-stones fairly numerous,
*Hippuris vulgaris*, several fruits,
*Myriophyllum alterniflorum*, 1 nut, in the upper part,
— *cf. spicatum*, 1 nut,
[*Najas flexilis*, 1 fruit],
*Picea excelsa*, a few small pieces of bark,
*Potamogeton filiformis*, 14 fruit-stones,
— *natans*, 1 fruit-stone,
— *praelongus*, 1 fruit-stone,
— *cf. pusillus*, 1 fruit-stone,
— *spp.*, 2 species, 4 fruit-stones,
*Potentilla palustris*, 1 fruit,
*Scirpus lacuster*, 1 fruit.

H. 5.8 — 7.1 m Uppermost, 30 cm of tough stoneless Clay; below this greyish brown Clay Mud, at bottom with transition to the subjacent:
*Betula nana*, 12 fruits, 3 catkin scales,
— *pubescens*, 1 fruit,

*Carex sp.*, 1 fruit without utriculus,
*Empetrum nigrum*, 11 fruit-stones,
[*Najas flexilis*, 1 fruit, in the upper part],
*Potamogeton sp.*, 1 small fruit,
*Salix sp.*, 6 small bud scales, 1—2 mm long,
*Scirpus sp.*, 1 fruit,
*Sparganium cf. affine*, 1 fruit-stone,
*Viola palustris*, $^1/_2$ seed,

*Cenococcum geophilum*, 1 sclerotium.

J. 7.10 — 7.25 m Brown, stratified *Sphagnum* Peat with branches and roots of *Calluna vulgaris*.

Boring 6.

A. 0 — 0.9 m *Sphagnum* Peat.
B. 0.9 — 1.5 m Mud.
C. 1.5 — abt. 1.8 m Sand.
D. abt. 1.8 — 3.3 m Stony Sand.
E. 3.3 — 3.5 m Grey Clay with some plants detritus:
*Batrachium aquatile (coll.)*, 2 fruits,
*Betula pubescens*, 1 fruit,
*Carex sp.*, 4 fruits without utriculus,
*Empetrum nigrum*, 2 fruit-stones,
*Potamogeton spp.*, 3 species, 3 fruit-stones.

F. 3.5 — 4.5 m Brown Mud with a quantity of rotten wood and other vegetable remains:
*Alnus glutinosa*, 2 fruits, 2 catkin spindles,
*Arctostaphylus uva ursi*, 1 fruit-stone,
*Batrachium aquatile (coll.)*, several fruits,
*Betula pubescens*, fruits fairly numerous,
*Brasenia purpurea*, 4 seeds,
*Calluna vulgaris*, a few shoots,
*Carex pseudocyperus*, 3 fruits,
*Dulichium spathaceum*, 4 fruits,
*Empetrum nigrum*, 28 fruit-stones,
*Hippuris vulgaris*, 10 fruit-stones,
*Hydrocotyle vulgaris*, 2 nuts,
*Lycopus europaeus*, 1 nut,
*Myriophyllum alterniflorum*, 3 nuts,
*Najas flexilis*, 11 fruits,
*Nuphar luteum*, 1 seed,
*Picea excelsa*, 1 needle,
*Potamogeton alpinus*, 1 fruit-stone,
— *filiformis*, numerous, fruit-stones,
— *praelongus*, 2 fruit-stones,
— *spp.*, 2 species, 13 fruit-stones,
*Rubus idaeus*, 2 fruit-stones,
— *sp.*, 1 fruit-stone.
*Scirpus sp.*, 1 fruit with bristles,
*Sparganium erectum*, 1 fruit-stone,

G. 4.5 — 5.5 m Fine grey Sand with a thin layers of mud:
*Batrachium aquatile (coll.)*, 6 fruits,

*Carex sp.*, 1 fruit without utriculus,
*Empetrum nigrum*, 2 fruit-stones,
*Potamogeton natans*, 1 fruit,
— *spp.*, 2 species, 3 fruits,

H. 5.5 — 7.0 — Greyish brown sandy Clay Mud. Samples taken with the spiral auger from 5.5—6.2 m depth yielded, besides a number of flakes of wood, the following:
*Arctostaphylus sp.*, 1/2 fruit-stone,
*Armeria vulgaris*, 1 calyx,
*Batrachium aquatile (coll.)*, numerous fruits,
*Betula nana* × *pubescens*, 1 fruit,
*Calluna vulgaris*, 1 shoot,
*Empetrum nigrum*, 4 fruit-stones,
*Myriophyllum alterniflorum*, 1 nut,
*Rubus idaeus*, 1 fruit-stone.
Washing samples taken with the pump and derived mainly from the lowest metre of the stratum yielded the following:
*Andromeda polifolia*, 1 seed,
*Batrachium aquatile (coll.)*, numerous fruits,
*Betula nana*, 1 fruit, 2 catkin spindles,
— *pubescens*, 3 fruits,
*Calla palustris*, 2 seeds,
*Carex cf. pseudocyperus*, 1 fruit,
— *vesicaria*, 1 fruit,
— *sp.*, numerous fruits without utriculus,
*Empetrum nigrum*, numerous fruit-stones,
*Myriophyllum alterniflorum*, 3 nuts,
*Picea excelsa*, 1 needle, 1 piece of bark,
*Potamogeton spp.*, abt. 3 species, a few fruit-stones,
*Rubus idaeus*, 1 fruit-stone,
*Sambucus cf. nigra*, 1 fruit-stone (belonging to stratum H ?).

J. 7.0 — 7.75 m Highly stratified *Sphagnum* Peat with numerous seeds of aquatic plants, quaking-bog-peat; in this were found:
*Alnus glutinosa*, 1 fruit,
*Betula pubescens*, several fruits,
*Brasenia purpurea*, seeds,
*Calla palustris*, 2 ordinary seeds and 2 seeds, 2.4 and 2.5 mm long, 1 mm broad at the pitted end and tapering down to the opposite end,
*Calluna vulgaris*, several fragments of branches, also shoots,
*Carex pseudocyperus*, 2 fruits,
— *rostrata*, 7 fruits,
— *sp.*, numerous fruits without utriculus,
*Ceratophyllum demersum var. apiculatum*, 4 fruits,
*Najas flexilis*, numerous fruits,
*Nuphar luteum*, 1 seed,
*Nymphaea alba*, 3 seeds,
*Potamogeton natans*, numerous fruit-stones,
— *pusillus*, 8 fruit-stones,
— *trichoides*, 1 fruit-stone.

*Hypnum exannulatum*,

*Sphagnum imbricatum,*
— *palustre,*
— *papillosum.*

K. 7.75— 8.70 m Hard, horny Mud:
*Alnus glutinosa*, 1 fruit,
*Betula pubescens*, several fruits,
*Brasenia purpurea*, 6 seeds,
*Calla palustris*, 3 seeds,
*Calluna vulgaris*, 1 piece of a branch,
*Carex sp.*, numerous fruits without utriculus,
*Ceratophyllum demersum var. apiculatum*, 8 fruits,
*Najas flexilis*, several fruits, especially in the upper part,
*Nymphaea alba*, 2 seeds,
*Potamogeton natans*, numerous fruit-stones,
— *pusillus*, 4 fruit-stones,
— *trichoides*, 3 fruit-stones,
*Scirpus lacuster*, 1 fruit,
— *sp.*, 1 fruit with a few bristles.

*Gymnocybe palustris,*
*Hypnum exannulatum,*
*Sphagnum palustre.*

L. 8.70 - 9.85 m Brown, softer Detritus Mud.
*Betula nana* × *pubescens*, 1 catkin scale,
— *pubescens*, numerous fruits, several catkin scales,
*Carex sp.*, fruits without utriculus fairly numerous,
*Ceratophyllum demersum var. apiculatum*, 2 fruits,
*Hippuris vulgaris*, 1 fruit,
*Menyanthes trifoliata*, 1 seed,
*Pinus silvestris*, fragments of bark,
*Potamogeton natans*, 3 fruit-stones,
— *pusillus*, numerous fruit-stones.

M. White Sand.

### Boring 7.

A. 0 — 1.25 m *Sphagnum* Peat.

B. 1.25— 2.0 m Brown Mud.

D. 2.0 — 3.25 m Sand with numerous stones up to the size of a fist.

E. 3.25— 4.25 m Sandy grey Clay, browner lower down, the upper part with some small stones. Small firm fragments of brown mud were common in the clay. A sample from the lower portion of the stratum yielded on washing:
*Batrachium aquatile (coll.)*, 1 fruit,
*Empetrum nigrum*, 1 fruit-stone,
*Potamogeton filiformis*, 6 fruit-stones.

G. 4.25— 5.50 m Grey rather find Sand with a few thin streaks of Clay-Mud. Small pieces of rotten wood. Washing yielded:
*Armeria vulgaria*, 1 calyx,
*Batrachium aquatile (coll.)*, 11 fruits,
*Betula pubescens*, 2 fruits,
*Calluna vulgaris*, 1 shoot tip,

*Carex sp.*, 1 fruit without utriculus,
*Empetrum nigrum*, 1 fruit-stone,
*Picea excelsa*, 1 needle, several pieces of bark,
*Potamogeton alpinus*, 1 fruit-stone,
— *filiformis*, 2 fruit-stones,
*Potentilla erecta*, 1 fruit,
*Rubus idaeus*, 4 fruit-stones,
*Sparganium cf. affine*, 1 fruitstone.

H. 5.50 – 7.00 m Clay Mud, grey and rather sandy at the top, more brownish lower down. Three washing samples yielded:
*Batrachium aquatile (coll.)*, 6 fruits,
*Betula nana*, 7 fruits, 1 catkin scale,
— *pubescens*, 1 fruit,
— *sp.*, a small branch,
*Calluna vulgaris*, 1 tip of a shoot,
*Carex rostrata*, some fruits,
— *sp.*, numerous fruits without utriculus,
*Empetrum nigrum*, numerous fruit-stones,
*Myriophyllum alterniflorum*, 10 nuts,
*Picea excelsa*, 1 needle, 1 small piece of bark,
*Potamogeton natans*, several fruit-stones,
— *sp.*, 1 fruit-stone,
*Viola palustris*, 1 seed.

*Hypnum exannulatum*,
*Sphagnum palustre*.

J. 7.00 – 7.75 m Brown *Sphagnum* Peat with numerous remains of aquatic plants:
*Brasenia purpurea*, 4 seeds,
*Carex rostrata*, several fruits,
— *sp.*, numerous fruits without utriculus,
*Carpinus betulus*, $1/2$ fruit,
*Ceratophyllum demersum*, 1 fruit,
*Empetrum nigrum*, 1 fruit-stone,
*Najas flexilis*, 16 fruits,
*Picea excelsa*, 1 needle,
*Potamogeton natans*, several fruit-stones,
— *pusillus*, 3 fruit-stones.

K. 7.75 – 8.65 m Brown horny Mud. Two samples, one from the top and one from the bottom, yielded:
*Betula pubescens*, 3 fruits,
*Brasenia purpurea*, 13 seeds (top), 3 do. (bottom),
*Carex rostrata*, 3 fruits, from the top,
— *sp.*, numerous fruits without utriculus from the top,
*Carpinus betulus*, $1/2$ fruit,
*Ceratophyllum demersum var. apiculatum*, 2 fruits from the top, many from the bottom,
*Najas flexilis*, numerous fruits,
*Nuphar luteum*, 2 seeds, from the bottom,
*Nymphaea alba*, 1 seed from the top, 3 from below,
*Picea exelsa*, 1 seed.
*Potamogeton natans*, numerous fruit-stones,

*Patamogeton pusillus*, 18 fruit-stones,
— *trichoides*, 1 fruit-stone.

L. 8.65— 9.50 m Brown Mud.
*Betula pubescens*, several fruits,
*Menyanthes trifoliata*, 1 seed,
*Potamogeton natans*, 2 fruit-stones.

M. Grey Sand.

Boring 9.

A. 0 — 0.3 m Peat-Mould.

C. 0.3 — 1.6 m Reddish brown Sand without stones.

D. 1.6 — 2.0 m Gravel with stones the size of hen's eggs.

E. 2.0 — 2.7 m Sandy grey Clay with a few stones and numerous small hard fragments of mud.

H. 2.7 — 3.8 m Greyish brown, more or less argillaceous fine Sand with organic detritus. A washing sample from the upper, argillaceous portion yielded no fossils; in a sample from the lower part the following were found:
*Betula nana*, 4 fruits,
*Carex sp.*, 1 fruit,
*Empetrum nigrum*, 1 fruit-stone,
*Myriophyllum alterniflorum*, 1 nut.

J. 3.8 — abt. 4.6 m Brown *Sphagnum* Peat with branches of *Calluna vulgaris*. Seeds of *Brasenia purpurea*.

K. abt. 4.6 — 5.7 m Brown, horny Mud with thin layers of sand. Fruits of *Najas flexilis* (Pl. XXXIII, 6–9), *Potamogeton natans*, *Corylus avellana* etc.

L. 5.7 — 5.9 m Brown, sandy Mud. Some fruits of *Najas flexilis*, *Ceratophyllum demersum var. apiculatum*, *Carex pseudocyperus* etc.

M. 5.9 — 9.0 m Sand with a few thin layers of clay.

Boring 13.

C? 0 — 0.6 m Yellowish brown argillaceous Sand, the lower part with stones the size of a fist.

D. 0.6 — 1.2 m Pale yellow Gravel, the lower part with greyish brown lumps of Sand (digging was carried to abt. 1.25 m).

E. 1.2 — 1.85 m Pale yellow, argillaceous Sand with small stones.

H. 1.85— abt. 2.0 m Sand.

L.(K). abt. 2.0 — 2.9 m Grey and brown Mud above horny mud:
*Betula pubescens* 2 fruits,
*Brasenia purpurea*, 28 seeds,
*Carex sp.*, numerous nuts,
*Najas flexilis*, numerous fruits,
*Potamogeton natans*, fruits very numerous.
— *pusillus*, numerous fruits,
*Sparganium erectum*, 1 fruit-stone.

M. 2.9 — 3.0 m Coarse Sand.

Profile B.

Boring 15. (Pl. XXXVI, 4).

A. B. 0 — 0.75 m Mould above brown sandy Mud.

C. 0.75 - 1.25 m Greyish brown Sand above greyish blue loamy sand.

| | | |
|---|---|---|
| D. | 1.25 — 2.7 m | Stony Sand interkneaded with lumps of greyish brown clay mud with pollen (spectrum 1); stones the size of a hand at top, the size of nuts at the bottom. Gradual transition to the subjacent. Samples from abt. 2 m below the surface yielded on washing:<br>*Betula sp.*, 1 piece of bark,<br>*Carex sp.*, 1 nut,<br>*Empetrum nigrum*, 1/2 fruit-stone,<br>*Sparganium cf. affine*, 1 fruit-stone,<br>*Viola palustris*, 2 half seeds. |
| F. | 2.7 — 3.1 m | Brown Mud with pollen of *Betula*, *Pinus*, *Alnus*, *Quercus*, *Tilia*, *Corylus*, *Carpinus*, *Picea* (pollen diagram, spectr. 2). |
| H. | 3.1 — 4.0 m | Grey, sharp Sand, with stones, especially at the bottom. |
| $H_1$. | 4.0 — 5.0 m | Uppermost, brown Sand, lower down pale greyish brown Clay Mud. Washings from the upper part of the stratum especially yielded a quantity of vegetable remains, some of which presumably did not properly belong there but were in a secondary position:<br>*Alnus glutinosa*, pollen rare,<br>*Batrachium aquatile (coll.)*, 4 fruits,<br>*Betula pubescens*, 2 fruits,<br>— *sp.*, pollen,<br>*Empetrum nigrum*, numerous fruit-stones,<br>*Hippuris vulgaris*, 1 fruit,<br>[*Najas flexilis*, 1 fruit],<br>*Picea excelsa*, 1 piece of a branch, pollen rare,<br>*Pinus silvestris*, 1 piece of wood, 1 slip of bark, pollen,<br>*Potamogeton filiformis*, numerous fruit-stones,<br>*Ranunculus sp.*, 1 fruit,<br>*Rubus idaeus*, 4 fruit-stones,<br>*Sparganium minimum*, 16 fruit-stones.<br><br>*Cenococcum geophilum*, several sclerotia. |
| J. | 5.0 — abt. 5.4 m | Dark brown Peat or Peat-Mud. |
| L. | abt. 5.4 — 7.0 m | Brown, sandy Mud. |
| M. | 7.0 — 7.1 m | Sand. |

Boring 19. (Pl. XXXVI, 5).

| | | |
|---|---|---|
| A. B. | 0 — 0.3 m | Mould over Mud. |
| C. | 0.3 — 2.0 m | Sand without stones. |
| D. | 2.0 — 2.4 m | Sand with stones. |
| E. | 2.4 — 3.4 m | Alternating layers of Clay Mud and Sand. In the lower part of the stratum, the sand layers contained some fruits of *Empetrum nigrum*, *Carex sp.* and *Potamogeton sp.* |
| F. | 3.4 — 4.85 m | Uppermost, sandy Mud rich in plant detritus; lower down, brown mud. Fossil content approximately the same in both upper and lower portions of the stratum:<br>*Alnus glutinosa*, 5 fruits, much pollen,<br>*Batrachium aquatile (coll.)*, several fruits,<br>*Brasenia purpurea*, 3 seeds,<br>*Betula pubescens*, 3 fruits, much pollen,<br>*Carpinus betulus*, 3 fruits, pollen, |

*Corylus avellana*, pollen fairly abundant,
*Dulichium spathaceum*, 8 fruits, several with the bristles preserved,
*Empetrum nigrum*, 6 fruit-stones,
*Hippuris vulgaris*, 4 fruit-stones.
*Hydrocotyle vulgaris*, 1 nut,
*Myriophyllum alterniflorum*, 1 grain of pollen,
*Najas flexilis*, numerous fruits,
*Nymphaea alba*, 5 seeds,
*Picea excelsa*, 4 needles, much pollen,
*Pinus silvestris*, pieces of wood, pollen fairly abundant,
*Quercus sp.*, some pollen,
*Potamogeton natans*, several fruit-stones,
— *filiformis*, numerous fruit-stones,
— *praelongus*, 2 fruit-stones,
— *pusillus*, 1 fruit-stone,
— *trichoides*, 1 fruit-stone,
— *spp.*, several fruit-stones,
*Rubus idaeus*, 5 fruit-stones,
*Scirpus lacuster*, 1 fruit,
*Sparganium erectum*, 3 fruit-stones,
— *minimum*, 4 fruit-stones,
*Tilia sp.*, pollen rare.

G. 4.85 – 5.15 m Sand.

H. 5.15 — 5.95 m Grey Clay Mud; gradual transition to the subjacent. Fossils found on washing from two samples were as follows
*Arctostaphylus sp.*, 1 fruit-stone,
*Batrachium aquatile (coll.)*, 1 fruit,
*Betula nana*, 2 fruits,
— *sp.*, much pollen,
*Carex sp.*, 1 fruit,
*Empetrum nigrum*, 4 fruit-stones,
*Myriophyllum alterniflorum*, some pollen,
*Picea excelsa*, a little pollen,
*Pinus silvestris*, pollen fairly abundant,
*Viola palustris*, 3 fragments of seeds.

J. 5.95 – 6.40 m Dark-brown *Sphagnum* Peat, twigs of *Calluna vulgaris*, fibres of *Eriophorum vaginatum*.

$J_1$. 6.40 – 6.75 m *Sphagnum* Peat, laminated; the upper part brown, the lower lighter in colour. Twigs of *Calluna vulgaris*.

L. 6.75 — 7.20 m Sandy *Sphagnum* Peat. Seeds of *Brasenia purpurea*, fruits of *Potamogeton sp.*

M. 7.20 – 7.35 m Sand.

### Boring 21.

C. 0 — 1.45 m Mould over reddish brown Sand.

D. 1.45 — 2.1 m Grey, sandy somewhat muddy and stony Clay.

F. 2.1 — 2.6 m Stony Sand with black lumps of mud; some few remains of wood from conifers; also the following:
*Carpinus betulus*, $1/_2$ fruit,
*Empetrum nigrum*, 5 fruits,
*Potamogeton filiformis*, 2 fruit-stones,

*Patamogeton praelongus*, 2 fruit-stones,
— *sp.*, several fruits.

H. 2.6 — 3.0 m Clay Mud, grey at the top, brownish lower down: *Empetrum nigrum*, 1 fruit, *Myriophyllum alterniflorum*, 2 nuts,

*Cenococcum geophilum*, some small sclerotia.

J. 3.0 — 4.75 m Uppermost, dark brown, humous Peat containing white sand; twigs of *Calluna vulgaris*, fruits of *Carex sp.*,, and *Empetrum nigrum*. Lower down, stratified *Sphagnum* Peat, at the bottom of which *Brasenia purpurea*.

K.—L. 4.75— 6.25 m Horny Mud and brown Detritus Mud: *Brasenia purprea*, *Ceratophyllum demersum var. apiculatum*, *Potamogeton sp.*

M. 6.25— 6.35 m Greyish blue argillaceous Sand.

## List of the Fossils found in the Interglacial Bog at Nörbölling.

c common, + fairly common, r rare.

| Species | Clay | Mud | Clay and Sand The Middle Bed | | | Peat | Mud |
|---|---|---|---|---|---|---|---|
| | E | F | G | H | H1 | J | KL |
| *Acer platanoides* (Pl. XXXI, 22) | | | | | | | r |
| *Alnus glutinosa* | | +, c[1] | r | r[1] | r[1] | +, +[1] | +, c[1] |
| *Arctostaphylus uva ursi* | | r | | r | | | |
| — *sp.* | | | | r | | | |
| *Andromeda polifolia* | | | | r | | | |
| *Armeria vulgaris* | | | r | r | | | |
| *Batrachium aquatile (coll.)* | r | + | + | c | r | | |
| *Betula nana* | | | + | + | | | |
| — *pubescens* × *nana* | | r | | r | | | r[3] |
| — *pubescens* | r | + | r | r | r | + | c |
| — *sp.*[1] | | + | | + | r | c | c |
| *Brasenia purpurea* | | + | [r][4] | | | + | c |
| *Calla palustris* | | | | r | | + | r |
| *Calluna vulgaris* | | r | r | r | | c | r |
| *Carpinus betulus* | | c, +[1] | | | | +, +[1] | +, c[1] |
| *Carex pseudocyperus* | | r | | [cf][5] | | r | r |
| — *rostrata* | | | | + | | + | r |
| — *vesicaria* | | | | r | | | |
| — *sp.* | r | | + | c | | c | c |
| *Ceratophyllum demersum var. apiculatum* | | | | | | + | + |
| — *submersum* | | | | | | | r |
| *Corylus avellana* | | +[1] | | | | r[1] | +, c[1] |
| *Crataegus sp.?* | | | | | | | r |
| *Dryopteris filix mas*[2] | | | | | | r | |
| — *spinulosa* | | | | | | r | |
| — *thelypteris*[2] | | | | | | | + |
| — *sp.*[2] | | r | | r | | | |
| *Dulichium spathaceum* | | + | | | | + | r |
| *Empetrum nigrum* | r | c | + | c | c | r | |
| *Eriophorum vaginatum* | | | | | | + | |
| *Frangula alnus*[1] | | | | | | | r |
| *Hippuris vulgaris* | | + | + | | r | r | r |
| *Hydrocotyle vulgaris* | | r | | | | | |

[1] Pollen. [2] Spores. [3] In the lower part of the stratum. [4] See p. 66. [5] See p. 68.

| Species | Clay | Mud | Clay and Sand The Middle Bed | | | Peat | Mud |
|---|---|---|---|---|---|---|---|
| | E | F | G | H | $H_1$ | J | KL |
| *Ilex aquifolium* | | r | | | | | |
| *Isoetes lacustris*[2] | | | | r | | | |
| *Lycopodium annotinum*[2] | | | | | | | r |
| *Lycopus europaeus* | | r | | | | | + |
| *Menyanthes trifoliata* | | r | | | | | r |
| *Myriophyllum alterniflorum* | | + | + | +, c[1] | | | |
| — *cfr. spicatum* | | + | r | | | | |
| *Najas flexilis* (Pl. XXXIII, 6–9) | | c | [r] | [r] | [r] | c | c |
| *Nuphar luteum* | | r | | | | r | r |
| *Nymphaea alba* | | r | r | | | r | r |
| *Picea excelsa* | | +, +[1] | r | r, r[1] | r | c, c[1] | +, +[1] |
| *Pinus silvestris* | | r, +[1] | r | r, +[1] | r, +[1] | +, c[1] | +, +[1] |
| *Polypodium vulgare*[2] | | | | | | | r |
| *Potamogeton alpinus* | | r | r | | | | |
| — *filiformis* | + | c | c | c | c | | |
| — *natans* | | + | r | | | + | c |
| — *praelongus* | | r | r | | | | |
| — *pusillus* | | r | r | | | + | c |
| — *trichoides* | | r | | | | r | r |
| — *spp.* | | c | c | | | | |
| *Potentilla erecta* | | | r | | | | |
| — *palustris* | | r | r | | | | |
| — *sp.* | r | | | | | | |
| *Quercus cf. robur* | | | | | | | r |
| — *sp.*[1] | | + | | r | | r | c[1] |
| *Ranunculus flammula* | | r | | | | | |
| — *sp.* | | | | | r | | |
| *Rubus idaeus* | | r | r | r | r | r | r |
| — *sp.* | | r | | | | | |
| *Salix sp.* | | | | r | | | |
| *Sambucus cf. nigra* | | | | [r][3] | | | |
| *Scirpus lacuster* | | r | r | | | | r |
| — *cf. Tabernaemontani* | | | | | | | r |
| — *sp.* | | r | | r | | + | r |
| *Solanum dulcamara* | | | | | | | r |
| *Sparganium cfr. affine* | | | r | | | | |
| — *erectum* | | r | | | | | r |
| — *minimum* | r | c | | r | r | | |
| *Stratiotes aloides* | | | | | | | r |
| *Tilia sp.*[1] | | r[1] | | | | | r, r[1] |
| *Typha latifolia*[1] | | | | | | | r |
| *Ulmus sp.*[1] | | | | | | | +, +[1] |
| *Umbelliferae*[1] | | | | r | | | |
| *Viola palustris* | | | | r | | | |
| *Gymnocybe palustris* | | | | | | + | + |
| *Hypnum exannulatum* | | | | + | | + | + |
| *Sphagnum imbricatum* | | | | | | c | |
| — *palustre* | | | | + | | c | + |
| — *papillosum* | | | | | | + | |
| *Cenococcum geophilum* | | | | r | + | c | + |
| *Botryococcus Braunii* | | | | + | | c | + |
| *Pediastrum duplex* | | | | | | | r |
| *Rivulariaceae* | | | | | | | + |
| *Spongilla lacustris* | | | | | | | + |

[1] Pollen. [2] Spores. [3] See p. 68.

## General Survey of the Interglacial Bog at Nörbölling.

### The Lake Deposits.

The soil in the immediate vicinity of the interglacial bog at Nörbölling consists mainly of fluvioglacial sand[1]); a little distance off, however, both to the north and south, moraine clay crops out on the surface, and this type of soil has also been found in several places out under the basin (cf. Pl. XI). Resting on the moraine clay in the basin we found either sandy greenish stoneless clay, as in Borings 1 and 2, or a grey sand with thin layers of clay. The samples avaiable for washing from these clay and sand strata yielded no fossils.

Bedded on the sand and clay strata M was a layer, up to 2 m thick, of brown detritus mud (L), the lower part crumbled or rather tough, and containing a quantity of sand, while in the upper portion we found a zone (K) where the mud was hard and coherent, the boring samples coming up in the form of hard lumps of horny mud. Among the numerous vegetable remains washed out from this stratum must be noted *Brasenia purpurea*, *Stratiotes aloides*, *Najas flexilis*, *Dulichium spathaceum*, with *Picea excelsa* and *Carpinus betulus*, all of which were found in the upper portion of the stratum.

Subsequently, the lake became overgrown by an oligotrophic quaking bog in which *Sphagnum*, with the species *palustre*, *imbricatum* and *papillosum*, accompanied by *Hypnum exannulatum* and *Gymnocybe palustre*, played a leading part; to these were added *Calla palustris*, *Carex pseudocyperus*, *C. rostrata*, *Dulichium spathaceum*, and there was also abundance of *Eriophorum vaginatum* and *Calluna vulgaris*; in addition the peat bed contained numerous seeds and fruits of aquatic plants washed ashore in interglacial time, e. g. *Brasenia purpurea* and *Najas flexilis*; as regards forest trees, the only ones of which macroscopic remains were found were *Picea excelsa* and *Carpinus betulus*.

The quaking bog-peat was in its lower portion of a pale brown colour, and was distinctly stratified; the degree of humification increased higher up; the colour became darker, and at the same time, the quantity of *Calluna vulgaris* increased. In the marginal zone of the bog a purely terrestric vegetation has developed in several places; the upper part of the stratum in Boring 21 for instance showed numerous branches of *Calluna*, and fruits of *Empetrum nigrum* and *Carex sp.* while at the top of the stratum in Borings 14 and 17 a forest peat had been formed, in which were found remains of wood and fragments of branches of *Picea excelsa*, fruits of *Alnus glutinosa*, and *Rubus idaeus*, with numerous sclerotia af *Cenococcum geophilum*.

[1]) V. MILTHERS: Kortbladet Bække. D. G. U. I. R. Nr. 15. 1925.

The profiles show that the peat bed does not cover the mud bed throughout; in the north-western part of Profile A especially it might be imagined to have been removed by erosion during the formation of the strata above. The highly curved appearance of the peat stratum in its present state is due to compression of the subjacent mud bed.

It will be seen from the profiles that the peat stratum is everywhere overlain by a layer of clay mud up to 1.5 m thick (H), developed in some places as a grey tough clay, and in the southern part of the Profile A especially it appears as a greyish brown argillaceous fine sand with admixture of organic detritus; here and there the bed contained stones the size of nuts. In the main basin, a thin layer of brown mud was occasinally found between the *Sphagnum* peat and the clay mud (not drawn in the figures), and in the smaller basin fartherst to the NW (Borings 15 and 16) this stratum ($H_1$) which was very sandy, was of considerable thickness. The clay-mud stratum itself (H) on the other hand was quite insignificant in this basin, and almost ewerywhere replaced by a layer of sharp sand with stones. In regard to the flora also, $H_1$ forms a transition to the Middle Bed H and G. Among aquatic plants undoubtedly belonging to this stratum may be noted *Batrachium aquatile (coll.), Hippuris vulgaris* and *Myriophyllum alterniflorum*, with species of *Potamogeton*. Among marsh growths from the Middle Bed may be mentioned *Carex rostrata, Carex vesicaria, Scirpus lacuster, Sparganium cf. affine, S. minimum* and *Viola palustris*. The stock of dry soil plants is characterised by the relatively numerous species from heath and similar formations. Most prominent is *Betula nana*, together with the hybrid form *B. nana* × *pubescens*; then come *Empetrum nigrum* (common), *Calluna vulgaris, Arctostaphylus uva ursi, Armeria vulgaris*, and *Andromeda polifolia. Betula pubescens, Picea excelsa, Pinus silvestris* and *Rubus idaeus* were represented only by very few macroscopical remains.[1]) The flora of the Middle Bed in Nörbölling Bog thus exhibits a character entirely similar to that of the corresponding stratum in the interglacial lake at Herning, but as it is greatly inferior in thickness, we could not, from the boring samples, make any division into zones as in the case of the Herning lake.

Throughout almost the whole of Profile B, and in the deeper parts of Profile A, the Middle Bed was covered by a layer of brown or dark brown, more or less sandy mud, F, which was often very rich in plant detritus, giving the bed the appearance of shore mud deposited

[1]) The few remains of species, such as *Brasenia purpurea, Carex pseudocyperus Najas flexilis* and *Sambucus cf. nigra* found in some boring samples must presumably have been brought down from Stratum F.

i shallow water. The plant remains found presented no appearance of having been rolled; we often found, for instances, the perigonium bristles preserved on fruits of *Dulichium spathaceum*. Among the rich flora in Stratum F — as far as it is represented by macroscopic remains — may be mentioned, in addition to that above noted, ***Brasenia purpurea, Najas flexilis, Carex pseudocyperus, Lycopus europaeus, Hydrocotyle vulgaris***, with ***Alnus glutinosa, Betula pubescens, B. nana*** $\times$ ***pubescens***[1]), ***Carpinus betulus, Ilex aquifolium, Picea excelsa*** and ***Pinus silvestris***, furthermore *Myriophyllum alterniflorum* wich occured also in the upper part (Zone *i*) of the lower mud stratum in Brörup Hotel Bog. The flora was, in the main, of the same temperate character as that of the upper part of the lower mud bed and the lower portion of the peat stratum, differing in an essential degree from the more northerly flora of the Middle Bed, the petrographical constitution of this last also being entirely different from that of the subjacent layers and of the one immediately above. The interglacial bog at Nörbölling is thus in these respects a perfect parallel to the interglacial lake at Herning, and affords the same evidence as the Herning lake of a considerable climatic oscillation during the last interglacial period, to which the bog at Nörbölling, like the other interglacial bogs of the Brörup district, must be said to belong.

Above the upper mud stratum (F) was found, especially in Profile A, a layer up to 1 m thick of grey, sandy clay or greyish brown clay mud (E) enclosing thin layers of sand, and with a considerable number of stones, up to the size of eggs, kneaded into it, especially towards the east. Washing samples from this stratum yielded but a poor and little characteristic flora, consisting mainly of *Batrachium aquatile (coll.), Potamogeton sp., Empetrum nigrum* and *Betula pubescens*. The rich flora found in Stratum F had evidently now been driven out of the locality, this time under the influence of that deterioration in the climate which culminated in the last glacial period. In Stratum E were also found numerous small hard polygonal lumps of a stratified dark brown mud or clay mud, these being evidently in a secondary position there. Microscopical analysis of such fragments from Boring 9 gave the following spectrum: ***Betula*** 48 %, ***Pinus*** 31 %, ***Quercus*** 1 %, ***Alnus*** 1 %, ***Carpinus*** 1 %, ***Picea*** 18 % — with ***Corylus*** 3 % (Pollen frequency 244); the sandy and stony clay in which these lumps were embedded yielded itself no macroscopical plant remains, and but very little pollen. These lumps may have originated from a deposit synchronous with the upper portion of Stratum F (cf. Pl. XXXVI), which

1) Cf. p. 57.

has been disturbed, with the result that parts of it have been introduced into Stratum E. Presumably, this transposition and the introduction of the stone-content in the southern part of Stratum E (Profile A) was due to the same factor, viz. solifluction, and we can in this, in connection with the regelation perhaps also find the cause of the entire absence of the upper mud bed (F) from the south-eastern part of Profile A, where its place is taken by Stratum E, which, containing the mud lumps above mentioned, had evidently taken up portions of earlier sediments. If the mud bed F ever extended south-east of Boring 7, it must presumably have been of but slight thickness (cf. Profile B). That this mud bed, at any rate its more proximal part, must have been affected by regelation is evident from the fact that in Boring 21 we find it represented by a stony sand stratum with lumps of mud, as described on p. 73.

A glance at the accompanying pollen diagrams (Pl. XXXVI, 3—6) will suffice to show the development of the forest growth, during the time when the strata referred to in the foregoing were in process of formation in the lake at Nörbölling.

In the lower part, the zones *c* and *d* of the diagram Pl. XXXVI, 3, *Betula* and *Pinus* predominate, but the curves for these two species soon turn off to the left, and in Spectr. 8 attain only 2 % and 3 % respectively, yielding place to the mixed oak forest *(Quercus + Ulmus)* which culminates in Spectr. 10 (68 %), Zone *f*. The *Ulmus* curve attains a pronounced maximum in Spectr. 11, while the summit of the *Quercus* curve lies in Spectr. 9, *Corylus* culminating at the same time with 175 %. *Corylus* appears to have immigrated into the forest surrounding the lake much later than *Quercus*; *Alnus* is here, as in many other places, still more behinhand; it culminates in Spectr. 8, just when *Tilia* attains its maximum (2 %).

The *Carpinus* curve forms an arc between Spectra 9 and 5 and in the upper part of the mud runs out to 42 % in Spectr. 7, where it is the most frequently occurring species of pollen.

The rational boundary for *Picea* pollen lies between Spectra 8 and 9, approximately in the same horizon as the rational limit[1]) of *Carpinus* pollen, but *Picea* has the later maximum of the two, (41 %) in Spectr. 6, and we have then, in this diagram, a pure *Carpinus* zone (*g*) prior to the *Picea* zone (*h*).

In the diagram, the lower part of the *Sphagnum* peat belongs to this last, in which the *Pinus* curve continues its pronounced move out to the right, commenced in Spectr. 7, at the same time as the

[1]) L. von Post: Skogsträdpollen i sydsvenska torvmosselagerföljder. Forhandlinger ved de skandinaviske Naturforskeres 16. Möte. Kristiania 1918, p. 456.

*Picea* curve moved in the same direction; the pollen species of the mixed oak forest have practically disappeared from the *Picea* zone, as also *Corylus.* The last stage of development shown in the diagram is the *Pinus* zone *i* and the *Betula-Pinus* zone *k* in Middle Bed H. In zone *i Pinus* reaches 54 %. In zone *k Betula* has a considerably higher frequency value than *Pinus,* though the difference is not so great as in the *Betula-Picea* zone which opens the temperated part of the interglacial period; the frequency of *Picea* is reduced to 5—7 %, *Alnus* disappears altogether, and the 1 % noted for *Carpinus* is undoubtedly due to pollen transported by wind from far away.

The three other pollen diagrams, Pl. XXXVI, 4—6 show the course of development through the Middle Bed and the upper mud stratum F. The *Betula* and *Pinus* curves cross in the lower part of the Middle Bed, in Diagrams Pl. XXXVI, 3 and 4, and the *Betula* curve lies hence forward on the outside, as in the two other diagrams. *Picea* has, as in Diagram Fig. 3, a slight frequency value in the spectra of the Middle Bed; *Alnus* does not reach beyond 5 %, *Quercus* attains 2 % in Spectr. 4, Diagram Fig. 5, but considering the course of the curve in the upper part of Diagram Fig. 3, it seems very doubtful whether this 2 % can be due to other than pollen transported by wind from far away. Common to the three diagrams is, further, the fact that the *Pinus* and *Betula* curves turn off sharply to the left at the transition from the Middle Bed to the upper mud stratum; at the same time, the remaining curves turn to the right, this including *Picea,* which attains 23 % (Fig. 5), *Alnus* 40 % (in Fig. 4), *Corylus* (25 % in Fig. 5), mixed oak forest (6 % in Fig. 5) and *Carpinus* (7 % in Fig. 5). The material did not permit of distinction being made between different zones within the mud bed F; it must suffice to point out that both washing samples and pollen analyses agree in showing that a temperate mixed forest, in which practically all the elements from the zones of the lower mud bed and the *Sphagnum* peat are represented, has driven back the sub-arctic heath vegetation, remains of which formed a dominant character of the Middle Bed, during the time when the upper mud bed was forming. As to the destruction of the forest growth involved by the approaching glacial period, our material affords no certain data beyond what can be gathered from the small flora list from Stratum E, cf. p. 78.

### The Covering Sand and more recent Strata.

All the borings were found to contain a stratum of stony sand, D, bedded on Strata E or F, and forming a flat bowl out over the originally far deeper basin. The thickness of the stratum varied greatly in the different borings, but was smallest on the whole in the middle portions of the profiles. The amount of stone in the stratum was often great, so that one might in many cases speak of it as gravel. The stones were as a rule up to the size of a fist. On the site of Borings 11—13, preliminary excavations were carried deep down into, or right throught, the stony sand, and it was here observed, that at the transition from this stratum to the sandy clay below numerous sand-worn stones up to the size of a fist lay scattered about, and in the stony sand itself, the stones were up to the size of a head, viz. at Point 12.

A trench dug at Point 16 afforded further data as to the constitution of the upper strata at this spot. The trench was 2.75 m deep, and 2 m long in the direction of the profile. Its southern wall showed the following profile:

| | | |
|---|---|---|
| A. | 0 — 0.2 m | Mould. |
| C. | 0.2 — 0.7 m | Red Sand with a layer of hard-pan and scattered small stones. |
| D. | 0.7 — 1.85 m | Stony argillaceous Sand, stones the size of a fist; no stratification. |
| F. | 1.85— 2.25 m | Brown Mud. In the midst of the mud lay a lens of stony Sand of the same composition as the stratum above. The mud contained fruits and seeds etc., *inter alia* of *Alnus glutinosa*, *Betula nana* × *pubescens* (2 catkin scales, 3 fruits), *Picea excelsa*, *Brasenia purpurea*, *Carpinus betulus*, *Dulichium spathaceum*, *Ilex aquifolium*. |
| H. | 2.25— 2.45 m | Grey, stony Sand. |
| $H_1$. | 2.45— 2.75 m | Uppermost, a pale greyish brown sandy Clay Mud extending down to 2.55 m; then grey stony Sand to 2.75 m, below this again Clay Mud. |

In the northern wall of the trench, the strata sequence was as follows:

| | | |
|---|---|---|
| A. | 0 — 0.2 m | Mould. |
| C. | 0.2 — 0.95 m | Reddish brown Sand with scattered small stones. |
| D. | 0.95— 1.4 m | Stony argillaceous Sand, without stratification; stones the size of eggs. |
| D.F. | 1.4 — 1.9 m | Grey, lumpy (kneaded) Mud, containing some fruits of *Sparganium minimum* and *Carex sp.* |
| F. | 1.9 — 2.45 m | Brown Mud as in the south wall. |
| H. | | Sand with stones. |

The stony sand (D) was found, in several of the borings, to contain numerous small lumps of mud kneaded into the sand, and large portions or even the whole of the stratum might appear as a greyish brown, humous, stony sand, as for instance more especially in Borings 15 and 17. Spectr. 1 in Diagram Fig. 4 is from material of this nature, and we have here undoubtedly a mingling of lake sediments with stony sand from the vicinity of the lake; in the excavation above mentioned, also, the stony sand stratum was found to have attacked the subjacent bed. The composition of the upper mud bed (F) in Boring 21 has already been referred to. Between Points 17 and 18 indeed, it looks as if the whole of Stratum F had been removed; and here, where Stratum D forms an anticline, owing to the shape of the basin, it would necessarily, when passing in a state of flowing earth out over the basin, bear especially hardly on the underlying bed. In the north-western portion of Profile A, it even seems as if the very oldest strata in the basin had themselves been affected. The Boring profile from Point 1 is as follows:

| | | |
|---|---|---|
| A. | 0 — 0.4 m | Mould and hard-pan with stones. |
| $D_1$. | 0.4 — 0.8 m | Sand with stones the size of a fist. |
| $D_2$. | 0.8 — 1.45 m | Uppermost, stony, sandy Clay, lower down greyish green loamy Sand or sandy, stoneless Clay. |
| $D_3$. | 1.45— 2.1 m | Grey, stony Sand with stones the size of eggs, the lower part somewhat argillaceous. |
| M. | 2.1 — 3.2 m | Grey-greenish, stoneless, sandy Clay. |
| N. | | Moraine Clay. |

This profile is perhaps to be interpreted as meaning that the projecting end of the greenish clay M has been carried along by the solifluction, and, in a partly kneaded form redeposited as Stratum $D_2$ in the profile given above.

The manner in which the stony sand stratum appears above the interglacial bog at Nörbölling affords no ground for the supposition that it should be a moraine formation, whereas on the other hand it corresponds exactly to the ideas of fossil flowing earth obtained from a study of the covering strata above other interglacial bogs, e. g. the lake at Herning, the bogs at Agerskov, Höllund Sögaard etc. Cf. Chapt. III.

Above the stony sand stratum D was found, in nearly all the borings, a layer, up to 1.5 m thick, of sand (C) which as a rule was free from stones, but might occasionally contain a few small ones. In the two northernmost borings of Profile B, this sand stratum contained small lumps of mud, and was there covered by a thin layer of sandy clay with stones, in the lower part, while at the SE end of Profile A it contained thin argillacous streaks. Since it was covered by the postglacial bog, it must presumably be late glacial or even older. The stratum can not be regarded as wind-blown sand, but is presumably deposited chiefly by water. If the stratified portion of the bed at the SE extremity in Profile A was deposited in a lake, then this must probably have been dammed by a barrier later on removed by solifluction, for at Point 13, the stratum reaches nearly 1 metre above the western margin of the basin itself.

## Brörup Hotel Bog.

About two of hundred metres NW of the hotel at Brörup, there is a slight depression in the grund, only abt. 80 m long, and not more than abt. 1 metre deep; Pl. XII. In 1922, two borings were made here (Nos. 3 and 4, Pl. XIII, 1), with our large apparatus, revealing a remarkable interglacial profile. At the same time, we exposed the marginal portion of the interglacial deposit by an excavation in the north-eastern side of the hollow. In the following year we made another boring (5), in this interglacial bog, and ascertained its extent by means of a screw auger; a minor excavation was also made. Pl. XIII, 2 shows the extent of the bog, and its position relative to the boundary of the field, as well as the site of the respective borings. The map in Fig. 2, p. 63 shows how the bog (No. 5) is placed at the edge, and near the upper end, of a shallow, valley-like hollow sloping down towards the north to Holsted River. The bog referred to on p. 162 at Brörup railway station, No. 4 on the map, and the bog marked No. 11, are similarly situated in relation to this valley; the interglacial bogs 12 and 13 lie out in the valley itself. From the geological map Bække,[1]) it will be seen that the moraine clay extends in under the western part of Brörup, but often is found a thin layer of stony sand forming the actual covering material, as is also the case for instance round the two interglacial bogs at Tuesböl.

In the following pages, an account will be given of the strata sequence, as found in the three borings made with the large apparatus, and in the two excavations.

Boring 3.

| | | | |
|---|---|---|---|
| A. | 0 — 0.4 | m | Stony Mould. |
| B. | 0.4 — 1.2 | m | Sand, grey at the top, red lower down. |
| C. | 1.2 — 1.8 | m | Gravel with stones the size of a fist. |
| D. | 1.8 — 2.1 | m | Sand, with a thin layer of sandy mud at the top, in which was found a fruit of *Carex sp.* |
| E. | 2.1 — 3.0 | m | Brown, stratified *Sphagnum* Peat, with some admixture of Mud at the bottom. Among the numerous seeds and fruits contained in this stratum may be mentioned: 7 fruits |

1) V. Milthers: Kortbladet Bække. D. G. U. I. R. No. 15, 1925.

of *Betula nana*, numerous fruits etc. of *Betula pubescens*, a fair quantity of needles, seeds, etc. of *Picea excelsa*, 2 seeds of *Juniperus communis*, fruit stones of *Empetrum nigrum* and *Arctostaphylus uva ursi*.

F. 3.0 — 4.5 m Brown Mud, containing a similar flora to that of E.

G. 4.5 — 5.0 m Sandy Mud, containing *inter alia* a needle tip of *Picea excelsa* and two nuts of *Myriophyllum alterniflorum*.

H. 5.0 — 6.5 m Coarse Sand, with stones the size of nuts at the bottom; in the upper part were found *inter alia* a fruit of *Betula nana* and two nuts of *Myriophyllum alterniflorum*.

J. 6.5 — 9.9 m Brown sandy Detritus Mud especially at the top, full of flakes of wood from foliage trees *(Alnus, Betula)*; the lowest 10 cm with transition to the subjacent. In the upper half metre of the stratum were found 3 fruits of *Betula cf. nana* and 10 nuts of *Myriophyllum alterniflorum*; washings also revealed a number of moss plants, especially of *Scorpidium scorpioides*, but also *Hypnum exannulatum* and *Sphagnum sp.*, other samples included remains of *Picea excelsa* and *Carpinus betulus*, (upper part) and of *Cladium mariscus* (lower part of the stratum), fruits of *Sambucus cf. nigra* and *Ajuga reptans*; also many aquatic plants, e. g. *Ceratophyllum demersum* and *C. submersum*. Cf. flora-list p. 86. For the pollen flora of this and the other strata see p. 88, f.

K. 9.9 —13.25 m Grey, stoneless Clay, calcareous at the bottom; this stratum was not bored through. Calcium analyses of two samples from the lower part of the stratum, were made by JOHS. ANDERSEN, the percentages of $CaCO_3$ being 23.5 and 20.5 respectively in the dried samples. Washing samples revealed a quantity of vegetable remains; a fruit of *Ceratophyllum demersum* was doubtless brought down from the stratum above. There were also numerous remains of aquatic plants, many fruits of *Betula pubescens* and a few remains of *Betula nana*.

### Boring 4.

A. 0 — 0.4 m Mould with stones.

B. 0.4 — 1.0 m Sand with a few stones.

C. 1.0 — 1.2 m Gravel.

D. 1.2 — 1.8 m Grey Sand.

E. 1.8 — abt. 2.3 m Mud-blended Moss-Peat, consisting mainly of *Hypnum exannulatum*; here were found e. g. one fruit of *Betula nana* and numerous needles, seeds and fragments of wood from *Picea excelsa*.

F. abt. 2.3 — 3.35 m Brown Mud, hard and crumblet at the bottom. Besides aquatic plants and marsh growths, were found 4 fruits of *Betula nana*, numerous remains of *Betula pubescens*, 2 seeds of *Juniperus communis* and some few remains of *Picea excelsa*.

G. 3.35— 4.65 m Mud-blended, fine Sand. Fruits of *Betula pubescens*, *Empetrum nigrum* etc.

H. 4.65— 5.9 m Uppermost, very coarse Sand; below this, sand with scattered stones the size of nuts, and thin layers of Clay;

at the bottom, transition to J. 3 fruits and 1 leaf of *Betula nana*, a needle of *Picea excelsa*, etc.

J. 5.9 — 9.0 m In the upper part, brown, Peat-like Detritus Mud, full of wood and branches from *Picea excelsa* and *Alnus glutinosa*, as well as numerous other vegetable remains. Below this, grey Detritus-Mud. In the very uppermost part of the stratum were found a fruit of *Betula nana* and 6 seeds of *Andromeda polifolia*; also in the upper part were found fruits e. g. of *Carpinus betulus*, *Sambucus cf. nigra* and *Stratiotes aloides*; a fruit of *Cladium mariscus* and numerous fruits of *Ceratophyllum submersum* were obtained by washing from the lower part (abt. 8 m) of the stratum.

K. 9.0 — 9.7 m Grey, non-calcareous, stoneless Clay.

L. 9.7 —10.5 m Grey Moraine Clay, non-calcareous.

Boring 5.

A. 0 — 0.3 m Mould.

C. 0.3 — 1.2 m Sand with stones, one the size of a head.

D. 1.2 — 1.85 m Uppermost, grey, reddish flamed Clay with a few small stones; below this, brown, argillaceous sandy Mud containing several fruits of *Empetrum nigrum*, *Potamogeton sp.*, and *Sparganium minimum*; at the bottom, grey Sand.

F. 1.85 - 2.65 m Brown Clay Mud, washings from which revealed e. g. a catkin spindle of *Alnus glutinosa*, 3 needles of *Picea excelsa*, bark fragments of *Pinus silvestris*, 2 fruit-stones of *Sambucus cf. nigra*.

H. 2.65— 4.65 m Uppermost 20 cm: Stony Sand with rolled wood fragments of *Picea excelsa* and lumps of a pale brown, argillaceous Mud containing *Potamogeton sp.*; below this, grey, stony sand with streaks of pale brown, argillaceous sandy mud; the lowest 15 cm. of the stratum contained small lumps of mud from the subjacent stratum, with remains e. g. of *Ajuga reptans*, *Alnus glutinosa* and *Picea excelsa*.

J. 4.65— 5.5 m Dark brown Detritus Mud with a similar flora to that found in the other borings through this stratum; in this case, however, washing samples were found to contain a remarkably large number of fruits of *Ajuga reptans*.

K. 5.5 — abt. 8.0 m Greyish blue Clay with dark stripes, the lowest portion slightly calcareous.

L. abt. 8.0 — 8.4 m Sandy Moraine Clay.

Excavation 1.

6 m south of Boring 4, a shaft was sunk through the upper strata. The profile was as follows:

A. 0 — 0.5 m Mould.

B. 0.5 — 1.15 m Yellow Sand.

C. D. 1.15 — abt. 1.8 m Stony, argillaceous Sand, stones up to the size of a head; the lower surface of the stratum was very uneven, and in other parts of the shaft it lay as much as 2.2 m below the surface of the ground.

F. abt. 1.8 — 2.5 m + Brown, finely arenaceous Mud, not dug through;

this stratum contained, in the upper part, sand lenses. A washing sample from the upper portion yielded *inter alia* fruits of *Betula nana, Empetrum nigrum, Rubus idaeus, Potamogeton natans.*

Excavation 2.

The trench, 2.5 m long, which was dug at the eastern edge of the basin, between Points 6 and 7, see Fig. 1, Pl. XIII, showed, at its north-eastern end, the following profile (the letters indicate the probable connection of the respective strata with those of the borings):

| | | |
|---|---|---|
| A. | 0 — 0.65 m | Mould with small stones. |
| C. | 0.65— 1.15 m | Stony red Sand with hard-pan; the stones up to the size of a man's head, decreasing in number and size towards the west. The stratum gradually merged into the one below. |
| D. | 1.15— 1.40 m | Grey Sand. |
| F. | 1.40— 1.70 m | Greyish black to brownish, argillaceous-arenaceous Mud; at the western end of the trench, the upper part of the stratum consisted of Sand with smears of brown sandy mud, the lower part gradually merging into the subjacent. |
| H? | 1.7 — 2.0 m | Stratified, argillaceous Sand, gradually giving place on the west to pure sand. |
| L. | | Sandy Moraine Clay. |

## List of the Fossils found in the Interglacial Bog at Brörup Hotel.

cc very common, c common, + fairly commen, r rare.

| Species | Sand | Mud and Peat | | | Middle Bed | Mud | Clay |
|---|---|---|---|---|---|---|---|
| | D | E | F | G | H | J | K |
| *Ajuga reptans* | ..... | ..... | ..... | ..... | ..... | cc | ..... |
| *Alnus glutinosa* | ..... | ..... | r, c[1]) | r[1]) | ..... | +, c[1]) | ..... |
| *Andromeda polifolia* | ..... | ..... | ..... | ..... | ..... | r | ..... |
| *Arctostaphylus uva ursi* | ..... | r | r | ..... | ..... | ..... | ..... |
| — *sp.* | ..... | ..... | r | ..... | ..... | ..... | ..... |
| *Batrachium aquatile (coll.)* | ..... | ..... | + | r | r | + | r |
| — *sceleratum* | ..... | ..... | ..... | ..... | ..... | + | ..... |
| *Betula alba* × *nana* | ..... | ..... | r | ..... | ..... | ..... | r |
| — *nana* | ..... | r | r | ..... | r | r | r |
| — *pubescens* | ..... | c | cc | r | r | c | c |
| — *sp.*[1]) | ..... | c | cc | c | ..... | c | c |
| *Carex lasiocarpa* | ..... | r | r | ..... | ..... | ..... | ..... |
| — *pseudocyperus* | ..... | ..... | ..... | ..... | ..... | + | ..... |
| — *rostrata* | ..... | c | + | ..... | ..... | r | ..... |
| — *sp.* | r | c | cc | c | + | c | r |
| *Carpinus betulus* | ..... | r[1]) | ..... | r[1]) | ..... | r | ..... |
| *Caryophyllaceae*[1]) | ..... | ..... | r | ..... | ..... | ..... | ..... |
| *Ceratophyllum demersum var. apiculatum* | ..... | ..... | ..... | ..... | ..... | c | [r][2]) |
| — *submersum* | ..... | ..... | ..... | ..... | ..... | cc | ..... |
| *Cladium mariscus* | ..... | ..... | ..... | ..... | ..... | r | ..... |
| *Cornus sanguinea* | ..... | ..... | ..... | ..... | ..... | r | ..... |
| *Corylus avellana*[1]) | ..... | r | c | r | ..... | c | ..... |

[1]) Pollen. [2]) See p. 84.

| Species | Sand | Mud and Peat | | | Middle Bed | Mud | Clay |
|---|---|---|---|---|---|---|---|
| | D | E | F | G | H | J | K |
| *Cruciferae* | | | | | | + | |
| *Dryopteris thelypteris*[2]) | | | | | | c | |
| *Empetrum nigrum* | r | + | cc | cc | + | + | |
| *Eriophorum vaginatum?* | | | | | | r | |
| *Hippuris vulgaris* | | | | | | r | r |
| *Juniperus communis* | | r | r | | | | |
| *Labiatae* | | | r | | | r | |
| *Lycopodium complanatum*[2]) | | | r | | | r | |
| *Lycopus europaeus* | | | | | | + | |
| *Menyanthes trifoliata* | | c | + | | | r | |
| *Myriophyllum alterniflorum* | | | c | r | r | + | |
| — *cfr. spicatum* | | | r | | | r | |
| *Nuphar luteum* | | | | | | r | |
| *Nymphaea alba* | | | | | | + | |
| *Picea excelsa* | | + | r | r | [r] | + | |
| *Pinus silvestris* | | +[1]) | r, +[1]) | +[1]) | | +[1]) | r[1]) |
| *Polypodium vulgare*[2]) | | | | | | r | |
| *Potamogeton alpinus* (Pl. XXXIII, 14—16) | | | c | | | r | |
| — *filiformis* | | | r | | | + | + |
| — *natans* | | + | cc | c | r | + | + |
| — *praelongus* (Pl.XXXIII,12-13) | | | r | | | | |
| — *pusillus* (Pl. XXXIII, 17 20) | | | c | | r | r | |
| — *sp.* | r | r | | r | c | + | r |
| *Potentilla palustris* | | c | + | | r | r | |
| — *sp.* | | | | | r | | |
| *Quercus sp.*[1]) | | r | + | | | c | |
| *Ranunculus repens* | | | | r | | + | |
| — *sp.* | | | r | | | r | |
| *Rubus idaeus* | | | r | | | + | |
| *Salix sp.* | | | | | r | | |
| *Sambucus cfr. nigra* | | | r | | | + | |
| *Scirpus lacuster* | | | | | | r | |
| — *sp.* | | | r | | | | |
| *Scleranthus perennis?* (Pl. XXXII, 19) | | | | r | | | |
| *Selaginella selaginoides* | | | r | | | | |
| *Solanum dulcamara* | | | | | | r | |
| *Sparganium affine* | | | r | | | | |
| — *erectum* | | | | | | c | |
| — *minimum* | r | + | r | r | + | + | |
| — *sp.* | | r | r | | | r | |
| *Stratiotes aloides* | | | | | | r | |
| *Thalictrum?* | | r | r | | | | |
| *Tilia sp.*[1]) | | | r | | | | |
| *Ulmus sp.*[1]) | | | r | | | + | |
| *Urtica dioeca* | | | | | | c | |
| *Viola palustris* | | r | r | r | | | |
| *Hypnum exannulatum* | | c | | | | r | |
| *Scorpidium scorpioides* | | | | | | + | |
| *Sphagnum sp.* | | c | | | | r | |
| *Cenococcum geophilum* | | r | r | | | | |
| *Amphitrema flava* | | c | | | | | |

[1]) Pollen. [2]) Spores.

## The Development of the Interglacial Bog at Brörup Hotel.

The basin in which the bog at Brörup Hotel is situated, is formed of moraine clay, and must during the last interglacial period have held a small, very deep lake. It is remarkably deep in proportion to its superficial area, and the gradient on the north-eastern slope in the profile plan is abt. 30 in 100, that of the southern slope nearly 40 in 100; it is rare to find anything corresponding to this even in eastern Danish marginal moraine landscapes. At the beginning of the interglacial period, stoneless clay was deposited in the lake, the earliest portion being calcareous (p. 84). No high-arctic plants have been found in this stratum, but, apart from remains of aquatic plants, only *Betula nana* and abundance of *Betula pubescens*. The *Betula* pollen amount to 93 % in Spectr. 19 from the upper part of the stratum, in the pollen-diagram Fig. 7, Pl. XXXVI, whereas *Pinus* has only 4 %. After this, came a deposit of brown, sandy mud, in which all manner of coarse detritus and drifted material, especially from the surrounding forest vegetation, gradually became very prominent; while this was going on, the adjacent forest was going through the usual course of development. Certain peculiarities may however, be noted in the course of the pollen curves.[1] The *Pinus* curve has its most pronounced turn to the right in the mixed oak forest zone, thus the *Betula-Pinus* zone being here very poorly developed and with but a small amount of *Pinus* pollen. *Picea* occurs constantly, but with only a very slight frequency in the lower spectra, just as we find for instances in Starup and Hollerup. Only over Spectr. 13, where the *Quercus* and *Corylus* curves turn to the left, does this species attain a high degree of frequency; at the same time, however, the *Alnus* pollen was still very common. At the boundary between the mud J, and the Middle Bed H, hardly anything but *Betula* and *Pinus* was found; traces of *Corylus* and 1 % *Carpinus* may be due to pollen brought by the wind from far away. *Alnus* was also noted with 3 %.

In the three Borings 3, 4 and 5, the mud J was covered by a layer some 2 m thick of coarse sand, with small stones in places, the Middle Bed, in which were found thin streaks of clay or clay mud, and occasionally lumps of mud from the stratum below. Disregarding the vegetable remains enclosed in such alien components, the flora of this stratum was but poor, the principal forms being *Betula nana*, *Betula pubescens*, *Empetrum nigrum* and *Salix sp.*, with *Myriophyllum alterniflorum*; see also the flora list. Spectr. 11 in the diagram shows that the forests consisted almost exclusively of *Betula* and *Pinus* when

[1] We had, however, too few samples available from the upper part of the stratum to enable us to follow the development in detail.

Stratum H began to form; later on, a heath vegetation undoubtedly played a considerable part in the surroundings of the lake, as at Nörbölling.

It is evident, from the pollen diagram, that the forest development, during the time when the upper series of the essentially organogenetious strata G, F, E, were formed, proceeded to some extent on the lines shown in the lower part of the diagram. We find for instance, in Spectr. 10 (Stratum G) *Betula* and *Pinus* predominant in frequency, with only low values for *Picea*, *Alnus* and *Corylus*; 1 % *Carpinus* may be due to material brought from a distance. In marked contrast to this, we have *Corylus* and *Alnus* altogether predominant in Spectr. 9, with 133 % and 52 % respectively, the mixed oak forest having 15 %; *Betula* and *Pinus* only 14 and 13 %. In the following spectra, the *Betula* curve runs out to 96 %, the other foliage trees disappear almost entirely, while *Picea*, at the top of Stratum E, attains 61 % in Spectr. 1. We have here, then, a *Betula-Pinus* zone (the upper part of *k*), a zone of mixed oak forest, *Alnus* and *Corylus* (*l*), and finally, a zone far exceeding the others in thickness, consisting of *Betula* and conifers, with *Picea* ultimately predominating (*m*). The pollen frequency values lie within about the same limits for both parts of the pollen diagram.

The washing analyses show that vegetation forms of the heath type have throughout held some place in the environs of this bog, at the time when strata G, F and E were being formed, these strata containing *Arctostaphylus uva ursi*, *Betula nana* in stratum E and the upper part of stratum F, *Empetrum nigrum*, *Lycopodium complanatum* and *Selaginella selaginoides*. We also find however, *Alnus glutinosa*, *Betula pubescens*, *Juniperus communis*, *Picea excelsa*, *Pinus silvestris*, *Rubus idaeus* and *Sambucus cf. nigra*, by way of addition to and confirmation of what the pollen analyses show as to the forest growth.

Thanks to the great depth of the basin, it had, even after the Middle Bed Period, still room for the series of strata, up to 3 m thick, which we must, from the foregoing, designate the upper warm horizon, comparing it with the corresponding horizon in the Herning lake deposit, and with that at Nörbölling. From the transition stratum of sandy mud, G, through the formation of the mud bed F, we reach the quaking bog E, composed of *Sphagnum* peat, which finally covered the whole expanse of the lake. This is the only instance hitherto known of a lake overgrown in the period of the upper warm horizon.

As regards the covering sand, we may here separate a lower, stoneless sand stratum D, in the marginal portion of which (Boring 5) patches of clay and sandy mud were found here and there. Above this layer, which was up to 0.6 m thick, was stony sand or gravel

C, to a thickness of more than 1 m in the marginal zone of the basin, the thickness of this stratum dwingling almost to nothing farther out towards the centre, presumably indicating that the effect of the arctic earth-creeping, directed downwards into the basin, was in a relative small degree felt beyond the edges. At the top, we have again sand almost if not entirely devoid of stones; the uppermost portion of this stratum had been transformed into mould.

## Rodebæk I.

About 200 m N of the road between Rodebæk and Faaborg, and hardly 2 km NE of this village, which lies some 17 km ESE of Varde, there is a small pond, which owes its origin to the excavation of a peat bog, now almost completely dug away. Pl. XIV.

In 1923, the water level of the pond was 1—2 m lower than the level of the road south and west of the bog; and if we imagine the postglacial peat, up to $1^1/_4$ m thick, removed, then the completely enclosed hollow would appear very distinctly. The maximal extent of the postglacial bog is abt. 110 m, but the entire watershet area, in the deepest part of which the bog lies, is more than twice that in diameter. Fig. 3 and Pl. XV, 4.

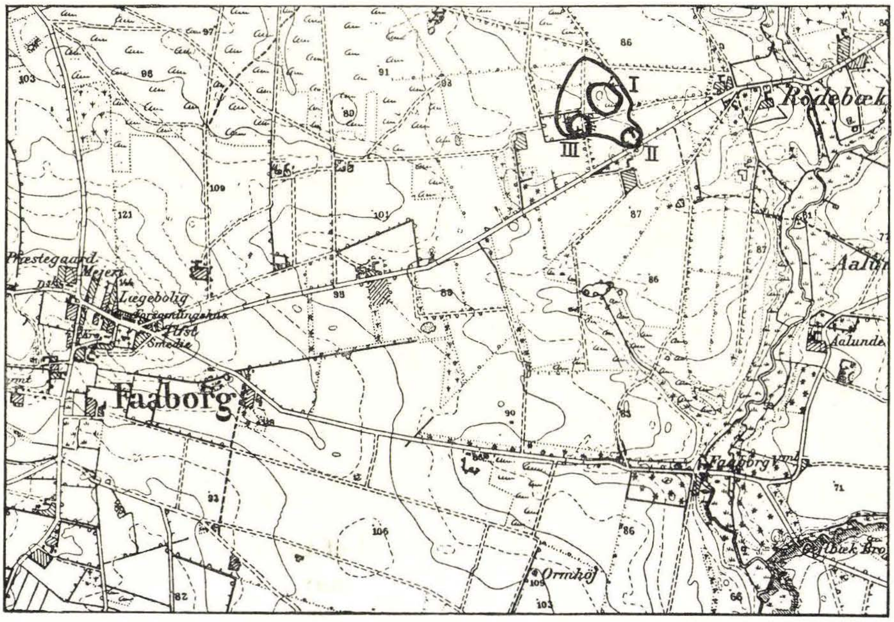


Fig. 3. The Rodebæk district, with the interglacial bogs I, II and III surrounded by the watershet line. Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. From the General Staff Map Sheet 3305.

In 1922, a boring was made in this bog, at point 5, and as the profile thus obtained rather suggested that we had here also an interglacial bog with a profile of the Herning type, we continued our investigations here in the following year. Borings were made at 19 places in all throughout the basin.

Profile A.

Boring 1.[1]

A. 0 — 0.2 m Mould.
B. 0.2 - 1.9 m Uppermost stony Sand with stones the size of eggs; at the bottom, sandy clay with stones.
J. 1.9 — 2.3 m Dark brown Detritus Mud, fruits of *Najas marina* and *Scirpus lacuster*.
K. 2.3 — 2.55 m Dark green Mud.
L. 2.55— 3.0 m Grey, stoneless, sandy Clay; a washing sample yielded nothing determinable.
M. 3.0 — 3.15 m Dark grey, sandy Moraine Clay.

Boring 2.

A. 0 — 0.85 m Sand-Mould with stones (25 cm) over Forest Peat.
B. 0.85— 1.9 m Sand with stones the size of walnuts.
H. 1.9 — 2.4 m Dark, reddish brown Forest Peat with rotten wood and bark.
J. 2.4 — 2.9 m Brown Detritus Mud with fruits of *Ceratophyllum sp.*, *Najas marina* and *Sparganium minimum*.
K. 2.9 — 4.3 m Greyish green, calcareous Mud, lighter in colour and finely sanded lower down:
*Betula pubescens*, several fruits,
*Ceratophyllum demersum var. apiculatum*, 5 fruits,
*Ceratophyllum submersum*, 1 fruit,
*Najas marina*, numerous fruits,
*Nymphaea alba*, 4 seeds.

*Bithynia tentaculata*, several lids.

L. 4.3 — 4.6 m Pale grey, stoneless calcareous Clay:
*Betula pubescens*, numerous fruits and catkin scales,
*Carex pseudocyperus*, 2 fruits,
— *rostrata*, 1 fruit,
*Hippuris vulgaris*, 3 fruits,
*Najas marina*, $^1/_2$ fruit (from Stratum K?),
*Potamogeton filiformis*, 3 fruits,
— *sp.*, 1 fruit.
M. 4.6 — 5.1 m Sandy Moraine Clay.

Boring 3.

A. 0 — 0.3 m Humous Peat.
C.+F.[2] 0.3 — 2.6 m Grey Sand, the lowest 20 cm peaty; washings from this lowest portion yielded several fruits of *Carex sp.*, and *Potentilla sp.*, with one fruit-stone of *Rubus idaeus*.

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1) The borings were not made in the order here given.

2) In borings where strata D and E were not found, the layer of sand above the peat stratum is noted as C+F, cf. Pl. XV, 1—3.

H. 2.6 – 3.7 m Dark brown Forest Peat with numerous remains of wood and branches of *Picea excelsa* etc. Also:
*Ajuga reptans*, 1 nut,
*Betula pubescens*, several fruits,
*Potentilla palustris*, 2 fruits,
*Rubus idaeus*, 1 fruit-stone,
*Urtica dioeca*, 2 fruits.

*Cenococcum geophilum*, sclerotia.

J. 3.7 — 4.6 m Brown, crumbling Detritus Mud with numerous fruits of *Ceratophyllum demersum var. apiculatum.*

K. 4.6 — 6.5 m Dark grey, calcareous Mud, sandy at the bottom; pollen spectr. No. 17 in Pl. XXXVI, 8, from 6.4 m. The following were also found:
*Batrachium sceleratum*, 5 fruits,
*Betula pubescens,* fruits fairly numerous,
*Carex pseudocyperus*, 3 fruits,
— *rostrata*, 1 fruit,
*Ceratophyllum demersum var. apiculatum*, 2 fruits,
*Hippuris vulgaris*, 2 fruits,
*Najas marina*, fruits fairly numerous,
*Nymphaea alba*, 4 seeds,
*Potamogeton natans*, 1 fruit,

*Calliergon stramineum,* forming a thick layer abt. 6.4 m below the surface.

M. 6.5 — 7.0 m Grey, calcareous Moraine Clay.

Boring 4.

A. 0 — 0.5 m *Sphagnum-Betuletum* Peat.
B. 0.5 — 1.25 m Sand with stones the size of a fist.
C.+F. 1.25— 3.9 m Grey Sand without stones.
G. 3.9 — abt. 4.4 m Brown stratified *Sphagnum* Peat.
H. abt. 4.4 — 5.15 m Dark brown Peat with twigs of *Calluna vulgaris* and branches of *Pinus silvestris.*
J. Dark brown Mud. This stratum was not bored through.

Boring 5.

A. 0 — 0.7 m *Sphagnum* Peat.
B. 0.7 — abt. 1.3 m Sand with stones the size of a fist.
C. 1.3 — 2.05 m Sand without stones.
D. 2.05— 2.40 m Brown, finely arenaceous Mud:
*Batrachium aquatile (coll.)*, 4 fruits,
*Betula sp.*, much pollen (cf. Tab. 1, p. 105),
*Carex sp.*, fruits without utriculus,
*Empetrum nigrum*, 5 fruit-stones,
*Myriophyllum alterniflorum*, 7 nuts, much pollen,
*Picea excelsa*, some pollen,
*Pinus silvestris*, much pollen,
*Sparganium minimum*, 2 fruit-stones.
*Sphagnum sp.*, numerous spores.

*Botryococcus Braunii*,
*Pediastrum duplex*.

*Spongilla lacustris.*

E. 2.4 — 3.55 m Pale greyish brown, stoneless Clay, very sandy at the bottom:
*Alnus sp.*, pollen (cf. Tab. 1, p. 105),
*Armeria vulgaris*, 1 calyx,
*Betula nana*, fruits fairly numerous, 7 catkin scales,
— *pubescens*, 1 fruit, at the bottom, pollen,
*Carex pseudocyperus*, 1 fruit, at the bottom,
— *sp.*, some fruits without utriculus,
*Corylus avellana*, pollen,
*Empetrum nigrum*,
*Pinus silvestris*, pollen.

*Amblystegium stellatum*,
*Calliergon stramineum*,
*Hypnum exannulatum*,
*Polytrichum strictum*,
*Rhacomitrium canescens*,
*Sphagnum sp.*

*Cenococcum geophilum*, several sclerotia.

*Cristatella mucedo*, statoblasts.

F. 3.55— 4.65 m Brown, rather fine Sand; a layer of hard pan abt. 2 cm thick at the bottom.

G. 4.65— abt. 5.15 m Strata of brown *Sphagnum* Peat alternating with layers of Sand; a few thin branches of *Betula pubescens*, fruits of *Carex sp.*: twigs of *Calluna vulgaris* at the bottom.

H. abt. 5.15— abt. 6.5 m Dark brown Forest Peat with numerous branches of *Betula pubescens*, *Picea excelsa* and *Pinus silvestris*; a few spruce cones; in the lowest portion of the stratum remains of marsh plants. Gradual transition to the subjacent:
*Ajuga reptans*, 4 nuts,
*Alnus glutinosa*, several fruits, pollen,
*Batrachium sceleratum*, 1 fruit,
*Betula pubescens*, numerous fruits, catkin scales, pollen,
*Carex pseudocyperus*, 3 fruits,
— *sp.*, numerous fruits without utriculus,
*Cirsium palustre*, 3 fruits,
*Dryopteris thelypteris*, spores, sporangia,
*Dulichium spathaceum*, 1 fruit,
*Ericaceae*, pollen tetrads,
*Hydrocotyle vulgaris*, 1 nut,
*Nasturtium aquaticum*, several seeds,
*Picea excelsa*, needles, seeds, pollen, leaf epidermis, branches, cones, 1 root,
*Pinus silvestris*, branches, pollen,
*Polypodium vulgare*, 1 spore,
*Ranunculus repens*, 8 fruits,
*Rubus idaeus*, 15 fruit-stones,
*Sparganium erectum*, 9 fruit-stones,
— *minimum*, 2 fruit-stones,

*Urtica dioeca*, 1 fruit,
*Viola palustris*, 4 seeds.

*Cenococcum geophilum*, numerous sclerotia,
*Puccinia sp.*, one teleutospore.

J. abt. 6.5 — 7.1 m Dark brown Detritus Mud with drifted material above fine Sand; below this, Mud again:
*Alnus glutinosa*, numerous fruits, pollen,
*Arenaria trinervia*, numerous seeds,
*Batrachium sceleratum*, fruits fairly numerous,
*Carex pseudocyperus*, 6 fruits,
— *sp.*, numerous fruits without utriculus,
*Carpinus betulus*, 1 fruit, some pollen,
*Ceratophyllum submersum*, numerous fruits,
*Corylus avellana*, much pollen,
*Dryopteris thelypteris*, spores and sporangia,
*Frangula alnus*, 1 fruit-stone,
*Lycopus europaeus*, 10 nuts,
*Picea excelsa* 1 needle, some pollen,
*Pinus silvestris*, some pollen,
*Quercus sp.*, much pollen,
*Rubus idaeus*, 2 fruit-stones,
*Sparganium erectum*, 1 fruit-stone,
*Ulmus sp.*, much pollen,
*Urtica dioeca*, many fruits.

K. 7.1 — 10.5 m Greenish calcareous Mud, finely arenaceous at the bottom
*Alnus glutinosa*, numerous fruits, pollen,
*Batrachium sceleratum*, 2 fruits,
*Betula pubescens*, fruits fairly numerous, pollen,
*Carex pseudocyperus*, 2 fruits,
*Ceratophyllum demersum var. apiculatum*, 3 fruits at the bottom,
*Ceratophyllum submersum*, numerous fruits, in the upper part,
*Corylus avellana*, much pollen,
*Dryopteris thelypteris*, spores,
*Hippuris vulgaris*, 1 fruit,
*Najas marina*, several fruits,
*Nymphaea alba*, 2 seeds,
*Pinus silvestris*, pollen.
*Potamogeton natans*, 1 fruit,
*Quercus sp.*, much pollen,
*Sparganium cf. affine*, 1 fruit-stone,
— *erectum*, 1 fruit-stone,
*Tilia sp.*, some pollen,
*Ulmus sp.*, much pollen.

*Cosmarium sp.*,
*Diatomaceae*, fairly numerous at the bottom,
*Phacotus lenticularis.*

*Cladocera.*
*Spongilla lacustris*, silica spicules.

M. 10.5 — 10.7 m Calcareous Moraine Clay.

Boring 6.

| | | |
|---|---|---|
| A. | 0 — 1.05 m | Uppermost, 85 cm dark brown *Sphagnum* Peat with roots of *Pinus silvestris*; below this, 10 cm *Phragmites* Peat above 10 cm of Mud. |
| B. | 1.05— 1.35 m | Stony Sand cemented together by rust; stones the size of a fist. |
| C.+F. | 1.35— 2.65 m | Stony Sand, the upper part cemented by rust, the bottom part brown, somewhat argillaceous, and containing root fibres; washing samples from the transition zone to Stratum H yielded 4 fruits of *Carex caepitosa* (Pl. XXXV, 21—22). |
| H. | 2.65— 3.0 m | Dark brown Forest Peat. |
| J. | 3.0 — 3.4 m | Dark Detritus Mud abounding in drifted matters with *Ceratophyllum demersum var. apiculatum.* |
| K. | 3.4 — 5.25 m | Greenish Mud. |
| M. | 5.25— 5.75 m | Greyish blue Moraine Clay. |

Boring 7.

| | | |
|---|---|---|
| A. | 0 — 0.3 m | Mould. |
| B. | 0.3 — 0.7 m | Reddish, stony Sand. |
| M. | 0.7 — 3.5 m | Grey, sandy Moraine Clay. |

Profile B.

Boring 8.

| | | |
|---|---|---|
| A. | 0 — 0.5 m | Peat. |
| B. | 0.5 — 1.8 m | Stony Sand; the stones, up to the size of head, were sand-worn. |
| $J_1$. | 1.8 — 2.2 m | Uppermost, pale brown Clay-Mud; at the bottom, Sand. The washing sample yielded only 1 fruit of *Carex caepitosa.* An analysis of the pollen, which was not well preserved, gave the following spectrum: *Betula* 11 %, *Pinus* 24 %, *Ulmus* 3 %, *Quercus* 4 %, *Alnus* 49 %, *Carpinus* 1 %, *Picea* 8 % — and *Corylus* 27 %. In addition, spores of *Dryopteris thelypteris* and *Polypodium vulgare* were found. |
| $J_2$. | 2.2 — 3.0 m | Brown Mud with *Najas marina.* |
| K. | 3.0 — 4.05 m | Greenish Mud; fruits of *Alnus glutinosa*, *Ceratophyllum sp.*, and *Najas marina.* |
| M. | 4.05— 4.30 m | Greyish blue, sandy Moraine Clay. |

Boring 9.

| | | |
|---|---|---|
| A. | 0 — 0.2 m | Peat which had been dug over. |
| B. | 0.2 — 1.15 m | Sand with stones the size of a fist. |
| B.E? | 1.15— 1.3 m | Grey, sandy Clay with small stones. |
| F. | 1.3 — 3.85 m | Sand without stones. |
| H. | 3.85 – 5.50 m | Dark brown Forest Peat; branches of *Calluna vulgaris* in the upper part. |
| J. | 5.50— 6.1 m | Brown Detritus Mud. |
| K. | 6.1 — 7.9 m | Greenish Mud; *Ceratophyllum sp.* |
| M. | 7.8 — 7.8 m | Moraine Clay. |

Boring 10.

| | | |
|---|---|---|
| A. | 0 — 0.2 m | Peat which had been dug over. |
| B. | 0.2 — 0.8 m | Stony Sand. |
| B.E? | 0.8 — 1.65 m | Grey Clay, with a few stones in the lower part: no vegetable remains. |
| F. | 1.65— 4.0 m | Greyish brown Sand; a thin layer of hard pan at the transition to the subjacent. |
| G. | 4.0 — 4.05 m | Stratified Peat, not bored through. |

Boring 11.

| | | |
|---|---|---|
| A. | 0 — 1.1 m | *Sphagnum* Peat with birch branches, a stump of *Pinus silvestris*. |
| B. | 1.1 — 1.3 m | Brown Sand with stones the size of a fist. |
| C. | 1.3 — 3.6 m | Sand without stones. |
| D. | 3.6 — 3.95 m | Greyish brown, somewhat laminated Mud; for pollen spectrum see Table 1, p. 105. The following were also found:<br>*Arctostaphylus uva ursi*, 1 fruit-stone,<br>*Batrachium aquatile (coll.)*, several fruits,<br>*Betula nana*, 3 fruits,<br>*Carex sp.*, fruits without utriculus,<br>*Dryopteris filix mas*, 1 spore,<br>*Empetrum nigrum*, fruits fairly numerous,<br>*Fraxinus excelsior*, 1 grain of pollen,<br>*Lycopodium annotinum*, 1 spore,<br>*Myriophyllum alterniflorum*, numerous nuts and much pollen<br>*Sparganium minimum*, 3 fruits,<br>*Viola palustris*, 1 seed.<br><br>*Sphagnum sp.*, numerous spores.<br><br>*Botryococcus Braunii*,<br>*Pediastrum boryanum granulatum*. |
| E. | 3.95— 4.2 m | Grey mud-blended Clay; pollen spectrum see Table 1.<br>*Empetrum nigrum*, 5 fruit-stones,<br>*Lycopodium annotinum*, 2 spores,<br>*Myriophyllum alterniflorum*, 1 nut, some pollen.<br><br>*Sphagnum sp.*, numerous spores. |
| F. | 4.2 — 4.9 m | Grey Sand, rather loamy at the bottom; a thin layer of hard pan here. |
| G. | 4.9 — 5.3 m | Stratified *Sphagnum* Peat. |
| H. | 5.3 — 6.0 m | Dark brown Forest Peat. |
| J. | 6.0 — 7.4 m | Dark brown *Ceratophyllum*-Mud; *Sparganium cfr. simplex*. |
| K. | 7.4 —10.4 m | Greenish Mud. |
| M. | 10.4 —10.45 m | Sandy Moraine Clay. |

Boring 12.

| | | |
|---|---|---|
| A. | 0 — 0.3 m | Peat whith had been dug over. |
| B. | 0.3 — 1.2 m | Sand with stones the size of eggs. |
| C. | 1.2 — 1.9 m | Grey Sand without stones. |
| D. | 1.9 — 2.2 m | Brown Mud, pollen spectrum see Table 1, p. 105: |

*Carex sp.*, several fruits without utriculus,
*Empetrum nigrum*, 6 fruit-stones,
*Myriophyllum alterniflorum*, much pollen in the upper part,
*Sparganium affine*, 13 fruit-stones (Pl. XXXIII, 28—31).

*Sphagnum sp.*, numerous spores,

*Botryococcus Braunii.*

| | | |
|---|---|---|
| F. | 2.2 — 2.65 m | Sand. |
| G. | 2.65 — 3.0 m | *Sphagnum* Peat mixed with sand. |
| H. | 3.0 — 4.0 m | Crumbling Forest Peat. |
| J. | 4.0 — 4.9 m | Greenish brown *Ceratophyllum*-Mud. |
| K. | 4.9 — 6.25 m | Pale greyish green Mud. |
| M. | 6.25 — 6.50 m | Slightly argillaceous Sand with small stones. |

Boring 13.

| | | |
|---|---|---|
| A. | 0 — 0.25 m | Mould. |
| B. | 0.25 — 0.7 m | Sand with a few stones. |
| C.+F. | 0.7 — 3.1 m | Sand without stones; some lumps of sandy Mud were brought up from the lowest half metre; the stratum here contained:<br>*Batrachium aquatile (coll.)*, 1 fruit,<br>*Betula nana*, several fruits, dwarf-branches, bark,<br>*Carex sp.*, several fruits without utriculus,<br>*Empetrum nigrum*, numerous fruit-stones,<br>*Myriophyllum alterniflorum*, numerous nuts,<br>*Sparganium minimum*, 4 fruit-stones (Pl. XXXIII, 22—24), |
| H. | 3.1 — 3.6 m | Dark brown Forest Peat. This stratum was not bored through. |

Boring 14.

| | | |
|---|---|---|
| A. | 0 — 0.75 m | Dumped Sand above Forest-Peat. |
| C.+F. | 0.75 — 2.1 m | Uppermost, Sand without stones, in which was a layer of hard pan; from 1.6 downwards, stony sand with stones the size of walnuts. |
| H. | 2.1 — 3.2 m | Dark brown Forest Peat with charcoal; at the top transition to the stratum above. |
| K. | 3.2 — 5.4 m | Mud, greenish brown, then brown, and at the bottom greenish again, the greater part of the stratum highly arenaceous: *Ceratophyllum demersum var. apiculatum*, *Najas marina*, *Potamogeton sp.*, *Scirpus lacuster*, *Betula sp.*, *Cenococcum geophilum.* |
| L? | 5.4 — 6.15 m | Grey Sand, with stones at the top, this stratum was not bored through. |

Boring 15.

| | | |
|---|---|---|
| A. | 0 — 0.3 m | Mould. |
| C.+F. | 0.3 — 1.0 m | Yellow Sand with small stones, slightly argillaceous at the bottom. |
| M. | 1.0 — 3.35 m | Yellow, sandy Clay with a few small stones. |
| $M_1$. | 3.35 — 4.0 m | Yellow, fine loamy Sand, not bored through. |

Profile C.

Boring 16.

| | | |
|---|---|---|
| A. | 0 — 0.95 m | Peat. |
| B. | 0.95— 2.0 m | Stony Sand with stones up to the size of a fist. |
| H. | 2.0 — 2.3 m | Forest Peat. |
| J. | 2.3 — abt. 2.5 m | Brown Mud. |
| K. | abt. 2.5 — 3.3 m | Greenish Mud. |
| M. | 3.3 — 3.4 m | Coarse, stony Sand. |

Boring 17.

A. 0 — 0.85 m Peat.

B. 0.85— 2.0 m Sand with stones up to the size of a fist; the stones were largest in the upper part; a layer of hard pan here.

D. 2.0 — 2.65 m Uppermost, dark brown Clay-Mud, lighter lower down; in this were found two fruits of *Betula pubescens*, a few fruits of *Batrachium sceleratum* and *Carex cf. caespitosa*,[1] much pollen of *Myriophyllum alterniflorum* and *Empetrum nigrum;* some small bud scales of *Salix sp.*, spores of *Sphagnum sp.*, *Botryococcus Braunii.* Cf. also Tab. 1, p. 105.

E. 2.65 — 2.9 m Grey Clay. Pollen of *Myriophyllum alterniflorum*, *Ericaceae* and *Empetrum nigrum;* a few spores of *Dryopteris thelypteris* and *Polypodium vulgare.* Spores of *Sphagnum sp.*

F. 2.9 — 3.9 m Sand with no vegetable remains.

J. 3.9 — 4.3 m Brown coarse Detritus Mud:
*Alnus glutinosa*, 4 fruits,
*Batrachium sceleratum*, 3 fruits,
*Betula pubescens*, 1 fruit,
*Carex pseudocyperus*, 1 fruit,
*Carex sp.*, fruits without utriculus,
*Ceratophyllum submersum*, numerous fruits (Pl. XXXI, 29—32)
*Nasturtium aquaticum*, 1 seed,
*Urtica dioeca*, 2 fruits.

K. 4.3 — 6.2 m Greenish, calcareous Detritus Mud:
*Batrachium aquatile (coll.)*, 1 fruit,
*Betula pubescens*, several fruits, 1 catkin scale,
*Carex rostrata*, 1 fruit,
— *sp.*, fruits without utriculus,
*Hippuris vulgaris*, 1 fruit,
*Najas marina*, 1 fruit,
*Potamogeton sp.*, 1 fruit.

*Calliergon giganteum.*

*Cristatella mucedo* statoblasts.

M. 6.2 — 6.4 m Moraine Clay.

Boring 18.

| | | |
|---|---|---|
| A. | 0 — 0.65 m | Peat. |
| B. | 0.65— 1.6 m | Sand with stones up to the size of a fist; hard pan at the top. |
| C. | 1.6 — 1.95 m | Clay Mud, greyish brown at the top, brown at the bottom. |

[1]) The four fruits found are very much like those shown in Pl. XXXV, 21—22 but all slightly smaller.

| | | |
|---|---|---|
| H. | 1.95— 2.4 m | Dark brown Forest Peat. |
| J. | 2.4 — 3.3 m | Dark brown *Ceratophyllum* Mud. |
| K. | 3.3 — 4.5 m | Greenish Mud, somewhat lighter, and sandy, lower down. |
| M. | 4.5 — 5.2 m | Sand over Moraine Clay. |

Boring 19.

| | | |
|---|---|---|
| A. | 0 — 0.95 m | Forest Peat with stumps of *Pinus silvestris* etc., over amorphous *Sphagnum* Peat. |
| B. | 0.95— 2.9 m | Uppermost, stony, slightly argillaceous Sand, stones the size of goose-eggs; the stones fewer and smaller lower down. |
| C.+F. | 2.9 — 4.75 m | Sand without stones, but containing in the lower part small splinters of charcoal and particules of humus. |
| G. | 4.75— 5.25 m | Brown stratified *Sphagnum* Peat with thin birch twigs and numerous sclerotia of *Cenococcum geophilum*. |
| H. | 5.25— 6.75 m | Dark brown Forest Peat, branches of *Picea excelsa*, a fruit of *Ranunculus repens*. |
| J. | 6.75— 8.0 m | Dark brown *Ceratophyllum* Mud; a fruit of *Alnus glutinosa*. |
| K. | 8.0 - 11.5 m | Greenish, calcareous Detritus Mud: |

*Alnus glutinosa*, 1 fruit at the bottom,
*Batrachium sceleratum*, 1 fruit,
*Betula pendula*, some fruits, 1 catkin scale,
— *pubescens*, numerous fruits, catkin scales,
*Carex pseudocyperus*, 7 fruits,
— *sp.*, fruits without utriculus,
*Ceratophyllum demersum var. apiculatum*, 6 fruits,
— *submersum*, 3 fruits,
*Najas marina*, 8 fruits,
*Nuphar luteum*, 1 seed,
*Nymphaea alba*, 6 seeds,
*Pinus silvestris*, 1 seed, several pieces of bark,
*Potamogeton natans*, 1 fruit,
*Scirpus lacuster*, 1 fruit,
*Urtica dioeca*, 2 fruits,
*Viola palustris*, 1 seed.

| | | |
|---|---|---|
| M. | 11.5 —11.8 m | Sandy Moraine Clay. |

## List of the Fossils found in the Interglacial Bog Rodebæk I.

c common, + fairly common, r rare.

| Species | Mud | Clay Mud | Sand | Peat | | Mud | | Clay |
|---|---|---|---|---|---|---|---|---|
| | D | E | C+F2) | G | H | J | K | L |
| *Ajuga reptans* | | | | | r | | | |
| *Alnus glutinosa* | | +1) | | | + | c | c | |
| *Arctostaphylus uva ursi* | r | | | | | | | |
| *Arenaria trinervia* | | | | | | c | | |
| *Armeria vulgaris* | | r | | | | | | |

1) Pollen. 2) The finds mentioned under this head are from the transition zone to Stratum G.

| Species | Mud | Clay Mud | Sand | Peat | | Mud | | Clay |
|---|---|---|---|---|---|---|---|---|
| | D | E | C+F[3] | G | H | J | K | L |
| *Batrachium aquatile (coll.)* | + | | r | | | | r | |
| — *sceleratum* | r | | | | r | + | + | |
| *Betula nana* | r | + | + | | | | | |
| — *pendula* | | | | | | | r | |
| — *pubescens* | r | | | + | c | | c | + |
| — *sp.* | c | c | | c | + | + | c | |
| *Calluna vulgaris* | | | | + | c | | | |
| *Carex caespitosa* (Pl. XXXV, 21—22) | cf. | | r | | | r | | |
| — *pseudocyperus* | | r | | | + | + | + | r |
| — *rostrata* | | | | | | | r | r |
| — *sp.* | + | r | + | + | c | c | + | |
| *Carpinus betulus* | | | | | | r | | |
| *Ceratophyllum demersum var. apiculatum* | | | | | | c | c | |
| *Ceratophyllum submersum* (Pl. XXXI, 29—32) | | | | | | c | c | |
| *Cirsium palustre* | | | | | r | | | |
| *Corylus avellana*[1] | r | + | | | r | c | c | |
| *Dryopteris filix mas*[2] | r | | | | | | | |
| — *thelypteris*[2] | | r | | | c | c | c | |
| *Dulichium spathaceum* | | | | | | r | | |
| *Empetrum nigrum* | + | c | c | | +[1] | | | |
| *Ericaceae*[1] | + | + | | | | | | |
| *Frangula alnus* | | | | | | r | r[1] | |
| *Fraxinus excelsior*[1] | r | | | | | | | |
| *Hippuris vulgaris* | | | | | | | + | r |
| *Hydrocotyle vulgaris* | | | | | | r | | |
| *Lycopodium annotinum*[2] | r | r | | | | | | |
| *Lycopus europaeus* | | | | | | + | | |
| *Myriophyllum alterniflorum* | + | r | c | | | | | |
| *Najas marina* | | | | | | c | c | [r] |
| *Nasturtium aquaticum* | | | | | | + | | |
| *Nuphar luteum* | | | | | | | r | |
| *Nymphaea alba* | | | | | | | + | |
| *Picea excelsa* | r[1] | | | | c | r | | |
| *Pinus silvestris* | c[1] | +[1] | | c[1] | c | r[1] | c[1] | |
| *Polypodium vulgare*[2] | | r | | | r | | | |
| *Potamogeton natans* | | | | | | | r | |
| *Potamogeton filiformis* | | | | | | | | r |
| — *sp.* | | | | | | | r | |
| *Potentilla palustris* | | | | | r | | | |
| — *sp.* | | | r | | | | | |
| *Quercus sp.*[1] | | r | | | | c | c | |
| *Ranunculus repens* | | | | | + | | | |
| *Rubus idaeus* | | | r | | c | r | | |
| *Salix sp.* | r | | | | | | | |
| *Scirpus lacuster* | | | | | | + | + | |
| *Sparganium affine* (Pl. XXXIII, 28—31) | + | | | | | | cf. | |
| *Sparganium erectum* | | | | | + | r | r | |
| — *minimum* (Pl. XXXIII, 22—24) | r | | r | | r | + | | |
| *Sparganium cf. simplex* | | | | | | r | | |
| *Tilia sp.*[1] | | | | | | | r | |
| *Ulmus sp.*[1] | | | | | | + | r | |

[1] Pollen. [2] Spores. [3] The finds mentioned under this head are from the transition zone to Stratum G.

| Species | Mud | Clay Mud | Sand | Peat | | Mud | | Clay |
|---|---|---|---|---|---|---|---|---|
| | D | E | C+F[2]) | G | H | J | K | L |
| *Urtica dioeca* | .... | .... | .... | .... | .... | c | r | .... |
| *Viola palustris* | r | .... | .... | .... | r | .... | r | .... |
| *Amblystegium stellatum* | .... | + | .... | .... | .... | .... | + | .... |
| *Calliergon giganteum* | .... | .... | .... | .... | .... | .... | + | .... |
| — *stramineum* | .... | + | .... | .... | .... | .... | + | .... |
| *Hypnum exannulatum* | .... | + | .... | .... | .... | .... | .... | .... |
| *Polytrichum strictum* | .... | + | .... | .... | .... | .... | .... | .... |
| *Rhacomitrium canescens* | .... | + | .... | .... | .... | .... | .... | .... |
| *Sphagnum sp.* | c[1]) | +[1]) | .... | c | .... | .... | .... | .... |
| *Cenococcum geophilum* | .... | + | .... | c | c | .... | + | .... |
| *Puccina sp.* | .... | .... | .... | .... | r | .... | .... | .... |
| *Botryococcus Braunii* | + | .... | .... | .... | .... | .... | .... | .... |
| *Cosmarium sp.* | .... | .... | .... | .... | .... | .... | + | .... |
| *Diatomaceae* | .... | .... | .... | .... | .... | .... | c | .... |
| *Pediastrum boryanum* | r | .... | .... | .... | .... | .... | .... | .... |
| — *duplex* | + | .... | .... | .... | .... | .... | .... | .... |
| *Phacotus lenticularis* | .... | .... | .... | .... | .... | .... | .... | + |
| *Bithynia tentaculata* | .... | .... | .... | .... | .... | .... | .... | + |
| *Cladocera* | .... | .... | .... | .... | .... | .... | .... | + |
| *Cristatella mucedo* | .... | + | .... | .... | .... | .... | .... | + |
| *Spongilla lacustris* | + | .... | .... | .... | .... | .... | .... | + |

## Survey of the Filling-up of the Lake Basin.

On the geological map[3]) the region surrounding the interglacial bogs at Rodebæk is noted as sand. The moraine clay however, probably does not lie very far below the surface, and it has been found in nearly all the borings in the basin at Rodebæk I; the basin is hollowed out in moraine clay and it must, at the commencement of the interglacial period, have been abt. 12 m deep, with steep sides; the gradient of the southern slope (Profile C), for instance, would have been abt. 24 : 100.

No deposit with arctic vegetable remains was found in the bottom of the basin. The washing samples from the deepest parts, Stratum L (Profile 1) and from the lower portion of Stratum K, contain species such as *Carex pseudocyperus*, *Ceratophyllum demersum* and *Najas marina*. Analysis of a sample from the lower margin of the series in Boring 3 showed, apart from Spectrum No. 17, Pl. XXXVI, 8 also, *inter alia*, leaf tips of *Ceratophyllum sp.*, spores of *Dryopteris thelyptheris* and pollen of *Frangula alnus*.

1) Spores.

2) The finds mentioned under this head are from the transition zone to Stratum G.

3) AXEL JESSEN: Kortbladet Varde. D. G U. I. R. No. 14.

The sedimentation seems then not to have properly begun until the *Betula-Pinus* period, and opened, either with a deposit of stoneless, calcareous clay (Stratum L) or with greenish calcareous mud (Stratum K), the lower part of which was on the whole richer in sand than the younger parts of the stratum. While this green calcareous mud was formed, cf. the pollen diagram, the *Betula-Pinus* forest was replaced by mixed oak forest; the *Quercus* pollen takes, as usual, the leading place. *Tilia* is very poorly represented, and at its highest frequency attains only 2 % (in Spectr. 12) at the same time as *Ulmus* reaches its second maximum (18 %); this was in the upper part of the mixed oak forest zone; the first maximum for *Ulmus* pollen, here but faintly indicated, must be sought in the lower portion of the diagram, at the transition between the *Betula-Pinus* zone and the mixed oak forest zone.

The rational limit for *Corylus* and *Alnus* lies about Spectr. 15, and the curves for these two species keep together throughout the mixed oak forest zone, the *Corylus* curve, however, turning off to the left before the other. Both these species culminate, as usual, later than *Quercus*. The Pollen of *Corylus* was also here very frequent.

During the last stage of the lake, Stratum J was formed, this consisting of non-calcareous, coarse detritus mud more or less rich in drifted matters containing very numerous fruits of the two *Ceratophyllum* species, as also, by the way, the upper part of Stratum K. In the upper portion of this non-calcareous mud stratum we have the rational limit for *Picea excelsa*, viz. in Spect. 11, and here alone is *Carpinus betulus* represented, by 1 %. Correspondingly, there was found at about this level a nut from this tree, the only one found in all the washing samples. That the upper part of the mud bed in the middle of the lake is synchronous with the shore facies of the stratum, the clay mud $J_1$ in Boring 8, is evident from the essential likeness between the spectrum from this stratum (p. 95) and Spectr. 10 and 11 in the pollen diagram.

After this, the basin was covered by a forest bog vegetation, without previous formation of a quaking bog or marsh-phase, and both *Betula pubescens*, *Alnus glutinosa*, *Picea excelsa*, and *Pinus silvestris* formed part of this vegetation and contributed in an essential degree to the formation of stratum H. In the diagram, this constitutes nearly the whole of the *Picea* zone, in which no pollen of the mixed oak forest species was found, and only very little from *Corylus*; the *Alnus* curve also turns off here sharply towards the vertical axis. The *Pinus* curve, on the other hand, turns to the right, and in the upper part of the stratum, the *Betula* curve follows it, the *Picea* curve at the same time taking the opposite direction, so that the transition to the upper *Betula-Pinus* zone lies near the upper surface of Stratum H.

The state of dryness which marked the bog at the time when the forest peat H was being formed gave place to more humid conditions, under which was formed a layer of fresh, stratified *Sphagnum* peat; in the lower part of this especially were found a number of twigs of *Calluna vulgaris* and *Betula pubescens*. It seems as if there had been thin layers of sand embedded in this stratum, the sand content increasing from below upwards, forming a more or less gradual transition to the sand stratum F above. The spectra from the *Sphagnum* peat G are of precisely the same type as Spectr. 11, Pl. XXXVI, 7 from the upper surface of the mud bed in Brörup Hotel Bog, whereas Spect. 8, Pl. XXXVI, 8 from Rodebæk I answers very well to Spect. 5, Pl. XXXVI, 3 from Nörbölling; the horizons in question from the three deposits may therefore be regarded as synchronous. The lake deposits above them in the basins referred to must thus all date from one and the same part of the interglacial period.[1])

After the formation of the *Sphagnum* peat, the basin once more contained a pond, but the deposit formed in this consisted predominantly of sand. The strata formation was thus altered from mainly organogenic to one of an essentially minerogenic character, just as we find at the same time in the basins of Nörbölling, Brörup Hotel and Herning. The list of washing samples p. 99 shows that *Betula nana* now occured together with *Empetrum nigrum* in the environs of the lake, *Myriophyllum alterniflorum* etc. being found in the water itself. The forest growth was now doubtless to a great extent superseded by heath vegetation. Only *Betula* and *Pinus* pollen play any considerable part in Spectr. 6, Pl. XXXVI, 8 from the boundary between Strata F and G, *Alnus* having here only 4 % and *Picea* 1 %.

In the southern part of the basin however, there was found a small area within which the sand strata C and F enclosed strata of brown mud and more or less muddy clay. The boring made in 1922 (No. 5) just touched this area, and gave us the idea that the interglacial deposit in question must be of the Herning type. Even though the borings and washings carried out during the following year showed that the matter was not so clear in this respect as at first supposed, I am still of opinion that the assumption is correct.

The three profiles in Pl. XV show how the mud bed D reaches

[1]) In the pollen diagrams from Herning, spectra from the upper part of the mud bed $K_2$ are lacking, but Spectr. 6, Pl. XXXVI, 1 corresponds well with Spect. 6, Pl. XXXVI, 3 from Nörbölling and Spect. 14 in Fig. 2, Pl. XXXVI, from Herning seems to have its synchronous level in the Nörbölling diagram between Spect. 6 and 7.

up to abt. 4 m below the 0-line in Borings 5, 12, 15 and 17, whereas in Boring 11 it lies abt. 1.3 lower down. These strata form, it would seem, a rather narrow bowl, the northern margin of which however could not be located, as the lake offered an obstacle to the work; they indicate that there was, approximately above the spot where the original lake basin is deepest, a small water-filled hollow at a time when the great bulk of the sand masses below the stony sand was deposited. The stratification in Boring 17 suggests that these mud and clay-mud beds have been discordantly cut off by the solifluction stratum $B_2$, and there is possibly some connection — as indicated in Profile B, — between the clay bed E in Boring 5 and the clay stratum $B_2$ in Borings 9 and 10, which last has undoubtedly been affected by solifluction.

Washing of samples from Strata D and E revealed, among land plants, especially *Betula nana*, *Betula pubescens*, *Empetrum nigrum*, *Armeria vulgaris* and *Arctostaphylus uva ursi*; of hydrophilous plants, *Batrachium aquatile*, *B. sceleratum*, *Myriophyllum alterniflorum* and *Sparganium spp.*, *Carex pseudocyperus* and *C. caespitosa*.

We have no pollen analyses from the sand stratum F, but Spectr. 5, from the lower portion of Stratum E, shows, in contrast to the analyses from the *Sphagnum* peat G, that the frequency of *Betula* and *Alnus* had increased, while that of *Pinus* had decreased, *Corylus* appearing at the same time with 19 % and *Quercus* with 2 %. Samples 3 and 4 contained practically no pollen. In the anylyses from Stratum D, the *Pinus* curve again lies far to the right, *Alnus* and *Quercus* have disappeared, *Corylus* is reduced to 1 %, and *Picea* appears with 2 %.

Corresponding changes in the frequency of the pollen species within Strata D and E have also been found in the other borings which touched these strata. The analysis material in question is shown in Table 1. From this, in conjunction with the pollen diagram, it will be seen that there are pronounced maxima for *Alnus*, *Corylus* and mixed oak forest in Stratum E, just as in the lower part of the upper warm horizon at Herning and Brörup Hotel bog. At Nörbölling also, we find maxima for these pollen curves in the upper warm horizon of the diagrams for that bog. Referring now to the observations on p. 103 it must therefore be assumed that Strata E and D at Rodebæk are synchronous with the upper warm horizon in the interglacial deposits at Herning, Nörbölling and Brörup Hotel. True, this conclusion is not decisively confirmed by the remaining fossil content of the strata in question; for though *Betula pubescens* and *Carex pseudocyperus* have been found in Strata D and E, the numerous thermophile species otherwise appearing in the washing lists from the upper varm horizon

| Boring: | | *Salix* | | | | *Betula* | | | | *Pinus* | | | | *Ulmus* | | | | *Quercus* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 11 | 12 | 17 | 5 | 11 | 12 | 17 | 5 | 11 | 12 | 17 | 5 | 11 | 12 | 17 | 5 | 11 | 12 | 17 |
| Stratum D | upper part | | | | | 65 | 49 | 84 | 57 | 33 | 42 | 14 | 35 | | 4 | 2 | | | | | |
| | lower — | | | | | 59 | | | 67 | 39 | | | 30 | | | | | | | | 1 |
| Stratum E | upper part | | | | | | 35 | | 60 | | 37 | | 26 | | 1 | | | | 8 | | 2 |
| | lower — | 1 | | | | 76 | | | | 9 | | | | | | | | | | | |

| Boring: | | *Quercus* + *Ulmus* | *Alnus* | | | | *Carpinus* | | | | *Picea* | | | | *Corylus* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 5 | 11 | 12 | 17 | 5 | 11 | 12 | 17 | 5 | 11 | 12 | 17 | 5 | 11 | 12 | 17 |
| Stratum D | upper part | 7 | | 3 | | 3 | | 1 | | | 2 | 1 | | 5 | | 5 | | 4 |
| | lower — | | | | | 1 | | | | | 2 | | | 1 | 1 | | | 2 |
| Stratum E | upper part | 11 | | 15 | | 10 | | 1 | | | | 3 | | 2 | | 47 | | 20 |
| | lower — | | 12 | | | | | | | | | | | | 19 | | | |

Table 1. Rodebæk I. Pollen spectra from Strata D and E.

are here lacking, while on the other hand, *Betula nana* was of frequent occurrence here. With regard to this point, reference may be made to the general remarks on the development of the vegetation in Chapter VII.

After the formation of Stratum D, the deposit of sand in the basin was continued, until the bowl formed by Strata D and E was completely filled up. No vegetable remains are known from this sand stratum (C). As the most recent diluvial stratum we find here also a bed of stony sand, B, forming an almost horizontal covering over the entire basin. Here, then, there can only have been an altogether insignificant compression of the subjacent lake deposit after the deposition of the stony sand. The thickness of this stratum varies somewhat. It is greatest — up to a good 1.5 m — towards south-west, south and north-west, where the margins of the basin are highest, the stratum thinning out towards the north and east, thus indicating from which quarters the transportation of the stony sand out over the basin must principally have taken place.

## Bogs with one Mud or Peat Stratum. The Brörup Type.

## Solsö.

In the course of the borings for brown coal made by the Technical Committee of the Ministry of the Interior in 1921, under the direction of V. MILTHERS, a boring was made on the northern bank of Solsö, which lies 4 km NNW of Videbæk and 22 km W of Herning. A mud bed, bored through at a depth of abt. 8 m, attracted attention on account of its great wealth of vegetable remains, and a sample submitted was found to contain, *inter alia*, numerous seeds of *Brasenia purpuea*, a horn of a *Trapa natans* fruit, a small seed of *Juniperus communis*, and some pieces of wood distinctly green, the culour of

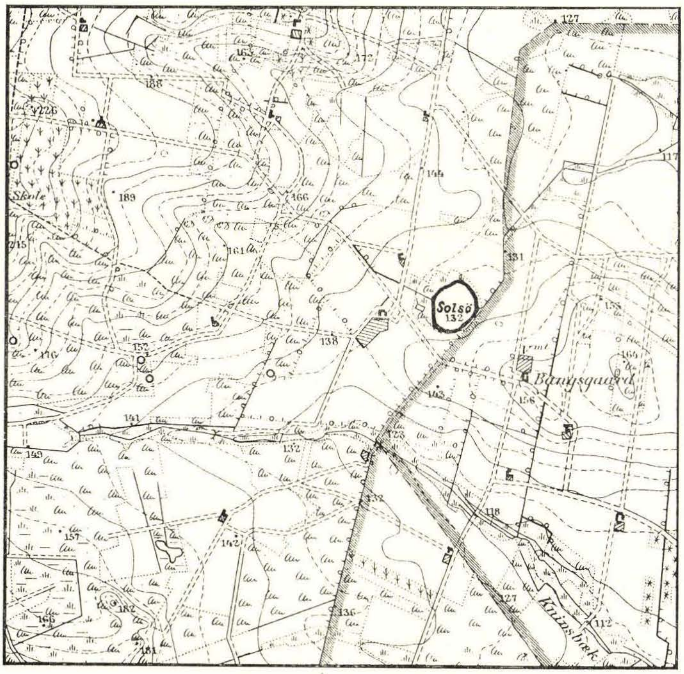


Fig. 4. Solsö and environs. Scale: 1:25000. Contour interval 5 ft. = 1.57 m.
From the General Staff Map Sheet 4504.

recent wood attacked by *Chlorosplenium aeruginosum* (OEDER). It seemed then highly probable that there was an interglacial bog situated under Solsö; and in the same year, this was confirmed by a new boring carried out in the presence of the author; the Profile No. 15 a, described on p. 114. In the upper portion of the bed $H_2$ there was a layer of dark clay mud, and it was suggested that this might also indicate a profile of the Herning type; in the following year therefore, a considerable number of borings were made in the vicinity of the lake. These proved, however, conclusively that there was only the one layer of mud in the interglacial basin.

The little lake, which measured 140 m in its maximum extent, lies in a hollow in the watershed area between the brook Abildaa, which flows into Vorgod River and the brook Knivsbæk, which flows into the brook Abildaa. See Fig. 4 and Pl. XVI and XVII.

The profiles A, B and C, Plate XVII, show these 16 borings together; the description is given in the following pages.

Profile A.

Boring 1.

| | | |
|---|---|---|
| D. | 0 — 1.70 m | Uppermost, 25 cm Mould, below this Sand, the upper part of this latter containing a bed of hard pan, and having a slightly argillacous character abt. 1 m below the surface. |
| F. | 1.70 – 2.30 m | Gravel. |
| G. | 2.30 – 5.60 m | Uppermost, grey Sand with a thin layer of clay, lower down, dark sand with vegetable remains. |
| H. | 5.60 — 6.00 m | Grey, stoneless Clay with dark stripes. |
| J. | 6.00 – 6.25 m | Brown Clay Mud. |
| K. | 6.25 — 6.70 m | Stoneless Clay with dark stripes. |
| L. | 6.70 — 7.00 m | Sand, passing over at the bottom to Boulder Clay. |

Boring 2.

| | | |
|---|---|---|
| D. | 0 — 1.50 m | Reddish brown Sand with a layer of hard pan; at the bottom, grey sand. |
| F. | 1.50 – 2.90 m | Grey Sand with stones, the largest ones, in the upper part of the bed, as big as pigeon's eggs. |
| G. | 2.90 — 3.80 m | Grey Sand, containing a layer of clay at the bottom. |
| H. | 3.80 — 5.60 m | Grey to greyish-brown Clay Mud:<br>*Batrachium aquatile (coll.)*, 1 fruit,<br>*Betala nana*, several fruits,<br>— *pendula*, 2 fruits in the lower part (Pl. XXXV, 1 – 2)<br>— *cf. pendula* × *pubescens*, 1 fruit (Pl. XXXV, 6),<br>— *pubescens*, 2 fruits (Pl. XXXV, 7—8),<br>*Carex sp.*, several fruits without utriculus,<br>*Empetrum nigrum*, several fruits,<br>*Potamogeton sp.*, 1 fruit,<br>*Ranunculus lingua*, 2 fruits in the lower part (Pl. XXXII, 16-17),<br>*Selaginella selaginoides*, several spores.<br><br>*Cenococcum geophilum*, some sclerotia. |
| J. | 5.60 — 6.50 m | Brown Mud:<br>*Batrachium aquatile (coll.)*, 1 fruit,<br>*Betula pendula*, 1 fruit,<br>— *pubescens*, several fruits,<br>*Brasenia purpurea*, 2 seeds,<br>*Cruciferae?* 1 seed,<br>*Litorella uniflora*, 1 seed,<br>*Pinus silvestris*, several flakes of bark,<br>*Ranunculus lingua*, 2 fruits (Pl. XXXII, 18),<br>*Potamogeton natans*, 1 fruit-stone, (Pl. XXXI, 27),<br>*Taxus baccata*, 2 needles. |
| L. | | Dark-grey Boulder Clay. |

Boring 3.

| | | |
|---|---|---|
| A.B. | 0 — 1.00 m | *Sphagnum* Peat covering Mud. |
| C. | 1.00 — 1.15 m | Greyish brown Clay Mud. |

| | | |
|---|---|---|
| D. | 1.15 — 3.55 m | Greyish brown Sand, the lower part containing vegetable remains:<br>*Batrachium aquatile (coll.)*, numerous fruits,<br>*Betula nana*, several fruits,<br>*Carex sp.*, fruits without utriculus,<br>*Empetrum nigrum*, numerous fruits.<br>*Myriophyllum alterniflorum*, several fruits,<br>*Potentilla palustris*, 1 fruit,<br>*Ranunculus sp.*, 2 small fruits,<br>*Salix sp.*, a few small buds,<br>*Selaginella selaginoides*, 1 megaspore. |
| E. | 3.55 — 3.65 m | Grey, sandy Clay. |
| F. | 3.65 — 4.10 m | Brownish Sand, with stones especially at the bottom; thin plant-bearing layers with *Empetrum nigrum* and *Batrachium aquatile (coll.)*. |
| H. | 4.10 — 6.55 m | Uppermost, grey Clay with a few stones, lower down greyish brown Clay Mud. This stratum contained:<br>*Batrachium aquatile (coll.)*, 1 fruit,<br>*Betula nana*, 5 fruits,<br>*Empetrum nigrum*, several fruits. |
| J. | 6.55 — 7.70 m | Brown Mud:<br>*Batrachium aquatile (coll)*., numerous fruits,<br>*Betula pendula*, 2 fruits,<br>— *pubescens*, 3 fruits,<br>*Brasenia purpurea*, 1 seed,<br>*Ceratophyllum demersum var. apiculatum*, 1 fruit,<br>*Pinus silvestris*, two flakes of bark at the bottom,<br>*Potamogeton filiformis*, fruits fairly numerous, at the bottom,<br>*Potamogeton natans*, 1 fruit,<br>*Sparganium erectum*, 1 fruit,<br>— *mininum*, 1 fruit. |
| K. | 7.70 — 7.85 m | Grey Clay. |
| L. | 7.85 — 8.15 m | Sand. |

Boring 4.

| | | |
|---|---|---|
| A.—B. | 0 — 2.05 m | *Sphagnum* Peat with *Scheuchzeria palustris* and *Carex rostrata* above Mud with *Nuphar luteum* and *Nymphaea alba*. |
| C. | 2.05 — 2.55 m | Grey Clay, with transition to the strata above and below:<br>*Batrachium sceleratum*, 1 fruit,<br>*Betula nana*, 2 catkin scales, 3 fruits,<br>*Empetrum nigrum*, 4 fruits,<br>*Potamogeton sp.*, $^1/_2$ fruit,<br>*Selaginella selaginoides*, 1 megaspore. |
| D. | 2.55 — 5.05 m | Greyish brown fine Sand, in the lower part of which numerous vegetable remains were found:<br>*Batrachium aquatile (coll.)*, numerous fruits,<br>*Potamogeton filiformis*, several fruits,<br>— *praelongus*, several fruits,<br>— *pusillus*, 8 fruits,<br>*Selaginella selaginoides*, 2 spores. |
| E. | 5.05 — 5.90 m | Grey, sandy Clay. |
| F. | 5.90 — 6.40 m | Grey Sand with scattered stones the size of pigeons' eggs. |

| | | |
|---|---|---|
| H. | 6.40 – 9.45 m | Uppermost, abt. 1/2 m clayey Sand, below this abt. 1/2 m rich Clay, at the bottom, greyish brown Clay Mud; *Empetrum nigrum*, *Cenococcum geophilum*. |
| J. | 9.45–11.75 m | Brown Mud with vivianite.<br>*Betula pubescens*, 2 fruits,<br>*Brasenia purpurea*, 1 seed,<br>*Potamogeton natans*, 1 fruit. |
| K. | 11.75–13.00 m | Pale grey Clay; the washing sample yielded nothing. |
| L. | | Boulder Clay. |

Boring 5.

| | | |
|---|---|---|
| A. | 0 — 0.25 m | Peat. |
| D. | 0.25— 2.80 m | Sand, the upper part containing hard pan, the lower vegetable remains: *Batrachium aquatile (coll.)*, *Potamogeton praelongus*, *Potamogeton sp.* |
| F. | 2.80— 4.40 m | Sand with many stones, the largest as big as hen's eggs. |
| J. | 4.40— 4.50 m | Sandy Mud with seeds of *Brasenia purpurea*. |
| L. | 4.50— 4.80 m | Boulder Clay. |

Boring 6.

| | | |
|---|---|---|
| A. B. | 0 — 0.70 m | Uppermost, *Sphagnum* Peat above *Magnocaricetum* Peat; below this, sandy Mud with *Nymphaea alba* and *Potamogeton sp.* |
| D. | 0.70— 1.85 m | Sand, with hard pan in the upper part. |
| F. | 1.85— 3.00 m | Stony Sand, the stones as big as pigeon's eggs. |
| L. | 3.00— 4.15 m | Uppermost, Boulder Clay, (0.70 m), below this, micaceous, argillaceous Sand. |

Profile B.

Boring 7.

| | | |
|---|---|---|
| A. | 0 — 0.25 m | Peat. |
| D. | 0.25— 2.00 m | Uppermost, brown Sand with hard pan, lower down yellow sand, and at the bottom grey sand. |
| F. | 2.00 – 2.80 m | Very stony Sand. |
| H. (—J.—K.?) | 2.80— 5.00 m | Uppermost, grey Clay, merging gradually lower down into a brownish Clay Mud; at the bottom again (0.8 m) grey Clay. |
| L. | | Sand. |

Boring 8.

| | | |
|---|---|---|
| A. | 0 — 0.25 m | Mould. |
| D. | 0.25 – 2.75 m | Yellow Sand, grey at the bottom, the upper part containing hard pan. |
| F. | 2.75 – 3.00 m | Sand with stones. |
| L. | 3.00— 3.16 m | Boulder Clay. |

Boring 9.

| | | |
|---|---|---|
| A.B. | 0 — 0.50 m | Mould covering Mud. |
| C. | 0.50— 0.75 m | Clay Mud, in which were found:<br>*Betula nana*, 1 catkin scale, 4 fruits,<br>— *pubescens*, 1 fruit,<br>*Menyanthes trifoliata*, 2 seeds, |

| | |
|---|---|
| | *Potamogeton natans,* 2 fruits. |
| D. 0.75– 4.40 m | Sand, the lower part slightly argillaceous, and here especially containing scattered vegetable remains: |
| | *Batrachium aquatile (coll.),* numerous fruits, |
| | *Betula pendula,* 3 fruits in the lower part (Pl. XXXV, 3–5), |
| | — *pubescens,* 1 fruit, |
| | *Empetrum nigrum,* 2 fruits, |
| | *Potamogeton natans,* 1 fruit, |
| | — *praelongus,* 2 fruits, |
| | — *sp.,* 1 fruit, |
| | *Salix sp.,* 2 buds, 2 mm long. |
| F. 4.40– 4.90 m | Grey stony Sand, stones as big as pigeon's eggs. |
| G. 4.90– 6.50 m | Grey, coarse Sand, the lower part containing some plant detritus, in which were found: |
| | *Batrachium aquatile (coll.),* numerous fruits, |
| | *Empetrum nigrum,* 3 fruits, |
| | *Hydrocotyle vulgaris,* 1 carpel, |
| | *Potamogeton filiformis,* 2 fruits (Pl. XXXIII, 10–11). |
| H. 6.50– 9.10 m | Uppermost, $^1/_2$ m grey Clay with 2 fruits of *Empetrum nigrum*; below this, greyish brown Clay Mud with vivianite, washings from which yielded: |
| | *Arctostaphylus alpina?,* 1 small fruit-stone, |
| | *Betula nana,* 1 catkin scale, 3 fruits, bark, (Pl. XXXV, 9–10) |
| | — *pubescens,* 1 fruit (abt. 8.15 m below surface), |
| | *Carex sp.,* fruits without utriculus, |
| | *Salix herbacea,* 1 leaf, |
| | — *sp.,* several small buds. |
| J. 9.10 – 10.80 m | Brown Mud with vivianite. |
| K. 10.80 – 11.00 m | Greyish brown Clay Mud: |
| | *Arctostaphylus alpina,* 1 fruit-stone, |
| | *Batrachium aquatile (coll.),* 3 fruits, |
| | *Betula nana,* 1 fruit, |
| | — *pubescens,* 1 fruit, |
| | *Dryas octopetala,* leaf fragments, |
| | *Potamogeton filiformis,* 11 fruits, |
| | — *natans,* 1 fruit, |
| | *Potentilla sp.,* 1 fruit, |
| L. | Boulder Clay. |

## Boring 10.

| | |
|---|---|
| A. B. 0 – 1.20 m | Peat covering Mud. |
| C. 1.20– 1.55 m | Clay Mud. |
| D. 1.55– 3.70 m | Greyish brown Sand with much moss in thin, argillaceous layers; stones the size of pigeon's eggs in the lower part of the bed: |
| | *Armeria vulgaris,* 1 calyx at abt. 2.5 m, |
| | *Batrachium aquatile (coll.),* fruits very numerous, |
| | *Betula nana,* several catkin scales and fruits, |
| | — *pubescens,* several fruits in the lower half of the bed, |
| | *Calluna vulgaris,* many carbonified twigs and flowers in the lower part of the bed, |

*Carex sp.*, fruits without utriculus,
*Empetrum nigrum*, several fruits,
*Eriophorum vaginatum*, several fruits,
*Hydrocotyle vulgaris*, 1 nut, lower part of the bed,
*Menyanthes trifoliata*, 3 seeds,
*Myriophyllum alterniflorum*, fruits fairly numerous,
*Nymphaea alba*, several seeds,
*Potamogeton filiformis*, numerous fruits,
— *natans*, 3 fruits,
— *praelongus*, 8 fruits,
— *pusillus*, 1 fruit,
— *sp.*, 5 fruits,
*Potentilla erecta*, 1 fruit, in the lower half,
*Rubus idaeus*, 1 fruit-stone, in the lower half,
*Salix herbacea*, fragments of two leaves, at abt. 2.5 m
*Scirpus palustris*, numerous fruits, at bottom,
*Sparganium minimum*, 1 fruit,
*Viola palustris*, several seeds,

*Characeae*, 2 spores,

E. 3.70 -- 3.90 m Stoneless Clay.

F. 3.90 - 4.60 m Very stony Sand, stones the size of hen's eggs.

G. 4.60—10.40 m The uppermost 0.25 m argilllaceous, sandy material with vegetable remains:
*Batrachium aquatile (coll.)*, several fruits,
*Betula pubescens*, 5 fruits,
*Calluna vulgaris*, carbonified flowers and shoots,
*Carex sp.*, fruits without utriculus,
*Empetrum nigrum*, several fruits,
*Eriophorum vaginatum*, 1 fruit,
*Hippuris vulgaris*, 1 fruit,
*Potamogeton filiformis*, 1 fruit,
— *natans*, 6 fruits,
*Potentilla erecta*, 1 fruit,
— *sp.*, 2 fruits,
*Scirpus palustris*, 8 fruits,
*Viola palustris*, 1 seed.
Below this, grey Sand without vegetable remains, to a depth of 6.0 m; at the bottom, grey Sand with plant detritus:
*Andromeda polifolia*, 2 seeds,
*Betula nana*, several dwarf shoots,
— *nana* × *pubescens*, 1 catkin scale,
— *pubescens*, 2 fruits,
*Carex sp.*, fruits without utriculus,
*Empetrum nigrum*, numerous fruit-stones.
*Potentilla palustris*, 2 fruits,
*Rubus idaeus*, 1 fruit-stone,
*Salix sp.*, several small buds.

*Cenococcum geophilum*.

H 10.40 - 12.85 m Greyish brown Clay Mud·

*Betula nana,* several fruits,
*Carex sp.,* fruits without utriculus,
*Empetrum nigrum,* 2 fruit-stones,
*Picea excelsa,* 1 needle, at abt. 12 m,
*Selaginella selaginoides,* 2 spores.

J. 12.85 – 15.50 m Brown Mud with vivianite: many diatoms at the bottom. This stratum was not bored through. Much pollen of *Alnus cf. glutinosa, Betula sp., Carpinus betulus, Corylus avellana, Picea excelsa, Pinus silvestris* and *Quercus sp.,* also some of *Ulmus sp.,* and *Ilex aquifolium.*

Boring 11.

A. 0 — 0.40 m Grey, oozy Sand.

B. C. 0.40 – 0.85 m Uppermost, Gravel with worn, rounded stones (shore pebbles) up to the size of hen's eggs; lower down, stony sand with stones more angular in shape.

D. 0.85 – 3.45 m Grey Sand, without stones, or with only a few small ones; several thin streaks of Clay; plant detritus was found abt. 1.5 m from the surface:
*Batrachium aquatile (coll.),* 1 fruit,
*Betula nana,* 1 fruit,
— *pubescens,* 1 fruit,
*Carex sp.,* fruits without utriculus,
*Empetrum nigrum,* several fruit-stones,
*Salix sp.,* 1 bud scale.

E. 3.45 – 3.80 m Grey, sandy Clay, with a few fruits of *Betula nana,* and *Empetrum nigrum.*

G. 3.80 – 7.55 m Grey, coarse Sand without plant detritus; a few stones the size of pigeon's eggs between 5 and 6 m.

H. 7.55 — 7.85 m Uppermost, grey, rich Clay, lower down brownish Clay Mud, in which $^1/_2$ seed of *Viola palustris.*

J. 7.85 — 9.00 m Brown Mud with a thin layer of coarse sand abt. 8.8 m *Betula pubescens, Scirpus palustris.*

L. 9.00 — 9.50 m Boulder Clay.

Profile C.

Boring 12.

D. 0 — 2.25 m Sand without stones, the upper part containing hard pan.

F. 2.25 — 2.45 m Sand with numerous stones.

L. 2.45 — 6.00 m Boulder Clay.

Boring 13.

D. 0 — 2.90 m Sand without stones, uppermost reddish brown with hard pan, lower down grey.

F. 2.90 — 3.40 m Stony Sand.

L. 3.40 — 7.40 m Stoneless Clay, the extreme upper part containing some plant detritus, but soon passing over lower down into typical slightly calcareous, stoneless Diluvial Clay.

Boring 14.

A. 0 — 0.25 m Peat.

D. 0.25 — 3.60 m Fine Sand, brownish at the top, grey lower down.

| | | |
|---|---|---|
| F. | 3.60 – 3.85 m | Sand with stones the size of pigeon's eggs. |
| H. | 3.85 – 5.45 m | Grey Clay; washing samples yielded no identifiable vegetable remains. |
| J. | 5.45 – 6.55 m | Sandy Mud with much vegetable detritus, including:<br>*Ajuga reptans*, 1 nut,<br>*Alnus glutinosa*, numerous fruits etc.,<br>*Brasenia purpurea*, numerous seeds,<br>*Corylus avellana*, one nut,<br>*Lycopus europaeus*, 1 nut,<br>*Menyanthes trifoliata*, 1 seed,<br>*Nymphaea alba*, 1 seed,<br>*Nuphar luteum*, 1 seed,<br>*Potamogeton natans*, several fruits,<br>*Ranunculus sp.*, 1 fruit,<br>*Scirpus lacuster*, very common,<br>*Sparganium erectum*, several fruits,<br>*Trapa natans*, 1 horn of a fruit. |
| K. | 6.55 – 7.40 m | Fine Sand. |
| $L_1$. | 7.40 – 8.90 m | Grey, stony Sand. |
| $L_2$. | 8.90 – 13.50 m | Fine brown Sand with mica; a few small stones at the bottom. |

Boring 15.

| | | |
|---|---|---|
| D. | 0 – 4.00 m | Fine greyish brown Sand, with some vegetable remains in the lower part:<br>*Batrachium aquatile (coll.)*, numerous fruits,<br>*Betula nana*, 1 catkin scale,<br>*Calluna vulgaris*, small shoots,<br>*Myriophyllum alterniflorum*, fruits fairly numerous,<br>*Potamogeton filiformis*, numerous fruits,<br>— *praelongus*, 8 fruits,<br>*Salix cf. herbacea*, 1 leaf.<br><br>*Polytrichum sp.* |
| F. | 4.00 – 4.05 m | Sand with stones the size of pigeon's eggs. |
| H. | 4.05 – 6.85 m | Uppermost, grey Clay, lower down greyish brown Clay Mud:<br>*Betula nana*, 3 fruits, in the upper part,<br>— *pubescens*, 1 fruit, lower part,<br>*Empetrum nigrum*, 3 fruit-stones,<br>*Salix sp.*, 1 small bud scale.<br><br>*Cenococcum geophilum*, 1 sclerotium. |
| J. | 6.85 – 8.40 m | Uppermost, brown sandy Mud, greyish green lower down:<br>*Ajuga reptans*, 1 fruit,<br>*Alnus glutinosa*, fruits and catkin scales,<br>*Betula pubescens*, several fruits,<br>*Brasenia purpurea*, numerous seeds,<br>*Ceratophyllum demersum*, 1 fruit,<br>— — *var. apiculatum*, 1 fruit,<br>*Litorella uniflora*, 1 fruit, |

*Menyanthes trifoliata*, 1 seed,
*Myriophyllum cf. spicatum*, 1 fruit,
*Nuphar luteum*, 1 seed,
*Nymphaea alba*, several seeds,
*Picea excelsa*, 1 seed wing,
*Potamogeton spp.*, numerous fruits,
*Ranunculus repens*, several fruits,
*Rubus idaeus*, 2 fruit-stones,
*Scirpus lacuster*, numerous fruits,
*Sparganium erectum*, several fruits,
— *minimum*, 2 fruits.

K. 8.40 – 9.15 m Uppermost, greyish brown Clay Mud, lower down grey Clay:
*Batrachium aquatile (coll.)*, 4 fruits,
*Betula cf. nana*, 1 fruit,
*Potamogeton filiformis*, 1 fruit.

L. 9.15 – 9.40 m Sandy Boulder Clay.

Boring 15, a.

Some few metres from Boring 15, was the boring mentioned on p. 106 as made in 1921; the following profile was noted from here:

D. 0 — 4.25 m Brown Sand uppermost, grey sand lower down; at 3.20 m a thin layer of Clay with fruits of *Batrachium aquatile (coll.)*, and a spore of *Selaginella selaginoides*.

F. 4.25 — 4.55 m Sand with stones the size of hazel nuts.

$H_1$. 4.55 - 6.50 m Stoneless grey Clay:
*Batrachium aquatile (coll.)*, 1 fruit,
*Betula nana*, 1 leaf, several fruits,
*Selaginella selaginoides*, numerous megaspores.

*Cenococcum geophilum*, some small sclerotia.

Also some pollen of *Pinus* and *Betula*.

$H_2$. 6.50 - 7.55 m Clay Mud, more or less argillaceous in alternating layers:
*Alnus cf. glutinosa*, pollen,
*Betula nana*, a leaf fragment and 2 fruits at abt. 6.75 m,
— *sp.*, pollen,
*Callitriche cf. autumnalis*, 1 nut,
*Corylus avellana*, some pollen,
*Dryopteris sp.*, spores,
*Ericaceae*, pollen, common,
*Picea excelsa*, pollen,
*Pinus silvestris*, much pollen,
*Polypodium vulgare*, 1 spore,
*Potamogeton sp.*, 1 fruit,
*Salix sp.*, 1 small bud, 1 mm long,
*Selaginella selaginoides*, 6 megaspores.

*Botryococcus Braunii*,
*Characeae*, several spores at 7.3 m,
*Rivulariaceae*.

*Spongilla lacustris*.

J. 7.55—10.00 m Brown, sandy Mud or muddy Sand, much plant detritus, especially small pieces of wood and bark. Washing samples yielded the following identifiable remains:

*Ajuga reptans,* 1 nut,
*Alnus glutinosa,* numerous fruits at the top, only a few lower down, pollen,
*Batrachium aquatile (coll.),* 2 fruits,
— *sceleratum,* 2 fruits,
*Betula nana,* 1 fruit at 9.25 m
— *pendula,* several fruits,
— *pubescens,* very many fruits, catkin scales.
— *sp.*, much pollen,
*Brasenia purpurea,* numerous seeds in the upper part, about 8.5 m, a few seeds lower down, to 9.6 m,
*Carex pseudocyperus,* 7 fruits,
*Ceratophyllum demersum,* 4 fruits,
— — *var. apiculatum,* 2 fruits,
*Corylus avellana,* 1 nut, much pollen,
*Cruciferae,* 1 seed,
*Dulichium spathaceum,* 1 fruit (abt. 8.5 m),
*Eupatorium cannabinum,* 7 fruits,
*Lycopus europaeus,* 10 nuts,
*Mentha cf. aquatica,* 14 nuts,
*Menyanthes trifoliata,* 1 seed,
*Myriophyllum cf. spicatum,* 1 carpel,
— *verticillatum,* 3 floral leaves (Pl. XXXII, 2—3)
*Najas flexilis,* 1 fruit at abt. 8.50 m,
— *marina,* some fruits throughout the whole bed,
*Nasturtium aquaticum,* 1 seed,
*Nuphar luteum,* 7 seeds,
*Nymphaea alba,* 14 seeds,
*Picea excelsa,* 1 flake of bark, 1 needle, bud scales, abt. 8.5 m,
*Pinus silvestris,* some bark flakes abt. 8.5 m, much pollen,
*Polygonum cf. tomentosum,* one small fruit at abt. 9.6 m,
*Potamogeton densus,* 1 fruit at abt. 9.7 m,
— *filiformis,* 3 fruits, at the bottom,
— *natans,* 16 fruits,
— *trichoides,* 1 fruit at 9.4 m,
— *spp.*, several fruits,
*Potentilla cf. erecta,* 1 fruit with the style base at abt. the middle of the ventral suture,
*Potentilla palustris,* 1 fruit,
— *sp.*, 2 fruits,
*Quercus sp.*, much pollen,
*Ranunculus flammula,* 1 fruit,
— *lingua,* 5 fruits, 9.25—9.6 m,
— *repens,* 1 fruit,
*Rubus idaeus,* 7 fruit-stones,
*Rumex sp.*, 1 perigonium,
*Scirpus lacuster,* fruits very numerous,
— *cf. fluitans,* 4 small fruits,
*Solanum dulcamara,* 3 seeds,

*Sparganium erectum*, 17 fruit-stones,
— *minimum*, 9 fruit-stones,
— *simplex*, 1 fruit-stone (Pl. XXXIII, 21),
*Trapa natans*, fragments of fruits, many at the top (abt. 8.5 m), several at abt. 9 m, a single one at abt. 9.5 m,
*Typha latifolia*, some pollen at 10.0 m,
*Urtica dioeca*, 1 nut,
*Viola palustris*, 1 seed,

*Hypnum fluitans*,[1]) at the top,
*Sphagnum sp.*, at the top.

*Cenococcum geophilum*, some sclerotia,
*Phryganidae*, covers of larva tubes,
*Nephelis octoculata*, coccoons,
*Cristatella mucedo*, statoblasts,

K. 10.00—14.75 m Grey slightly calcareous stoneless Clay, uppermost exhibiting transition to J; a few thin streaks of Sand.
*Batrachium aquatile (coll.)*, some fruits,
*Betula nana*, several fruits and catkin scales,
— *nana* × *pubescens*, 3 fruits at abt. 12.70 m,
— *pubescens*, some fruits throughout the entire bed,[2])
*Dryas octopetala*, 3 leaves at 12.40 m,
*Potamogeton filiformis*, 4 fruits,
*Salix sp.*, 1 small shoot with buds, at abt. 11.5 m.

*Daphnia pulex*, ephippia.

Boring 16.

D. 0 — 1.50 m Reddish brown Sand,
F. 1.50 — 2.95 m Very stony Sand, stones as big as hen's eggs and larger,
G. 2.95— 5.55 m Fine Sand, with a few thin streaks of Clay; a few leaves of *Betula nana*,
H. 5.55 6.95 m Grey, sandy Clay Mud; washings from the upper part of the bed yielded:
*Betula nana*, 2 catkin scales, 2 fruits,
— *pubescens*, 1 fruit,
*Empetrum nigrum*, several fruits,
*Juniperus communis*, 1 small needle,
*Salix sp.*, some small buds.
J. 6.95 — 7.65 m Dark brown Mud.
L. 7.65— 8.00 m Grey Sand.

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[1]) *Hypnum fluitans*, was here found — according to A. HESSELBO — in a peculiar form, with very narrow leaves with extended nerve, which may be most nearly described as a parallel form to *Hypnum exannulatum var. Rotae* (DE NOT) SCHIMPER; it has finely dentate leaves with very long and narrow leaf cells and cells at the basal part of the leaf as in *H. fluitans*.

[2]) Those in the lower part of the stratum possibly carried down by the drill.

# List of Fossils found in the Interglacial, Late-glacial and Post-glacial beds at Solsö.

c = common, + = fairly common, r = rare.

| Species | Post-glacial | Late-glacial | Interglacial | | | |
|---|---|---|---|---|---|---|
| | | | Sub-arctic | | Tempe-rate | Arctic Sub-arctic |
| | A—B | C—E | G | H | J | K |
| *Ajuga reptans* | | | | | r | |
| *Alnus glutinosa* | | | | r[1]) | c | |
| *Andromeda polifolia* | | | r | | | |
| *Arctostaphylus alpina* | | | | cf. | | r |
| *Armeria vulgaris* | | r | | | | |
| *Batrachium aquatile (coll.)* | | c | c | r | c | r |
| — *sceleratum* | | | | | r | |
| *Betula nana* (Pl. XXXV, 9-10) | | + | + | + | [r] | + |
| — — × *pubescens* | | | r | | | r |
| — *pendula* (Pl. XXXV, 1-5) | | | | r | + | |
| — *cf. pendula* × *pubescens* (Pl. XXXV, 6) | | | | r | | |
| — *pubescens* (Pl. XXXV, 7-8) | | r | r | r | c | r |
| *Brasenia purpurea* | | | | | c | |
| *Callitriche cf. autumnalis* | | | | r | | |
| *Calluna vulgaris* | | + | + | | | |
| *Carex pseudocyperus* | | | | | + | |
| — *rostrata* | c | | | | | |
| — *sp.* | | + | + | + | | |
| *Carpinus betulus*[1]) | | | | | c | |
| *Ceratophyllum demersum* | | | | | r | |
| — — *var. apiculatum* | | | | | r | |
| *Corylus avellana* | | | | r[1]) | r, c[1]) | |
| *Cruciferae* | | | | | r | |
| *Dryas octopetala* | | | | | | r |
| *Dryopteris sp.*[2]) | | | | r | + | |
| *Dulichium spathaceum* | | | | | r | |
| *Empetrum nigrum* | | + | + | + | | |
| *Ericaceae*[1]) | | | | + | | |
| *Eriophorum vaginatum* | | + | r | | | |
| *Eupatorium cannabinum* | | | | | + | |
| *Hippuris vulgaris* | | | r | | | |
| *Hydrocotyle vulgaris* | | [r] | [r] | | | |
| *Ilex aquifolium*[1]) | | | | | r | |
| *Juniperus communis* | | | | r | r | |
| *Litorella uniflora* | | | | | r | |
| *Lycopus europaeus* | | | | | + | |
| *Mentha cf. aquatica* | | | | | + | |
| *Menyanthes trifoliata* | | r | | | r | |
| *Myriophyllum alterniflorum* | | + | | | | |
| — *cfr. spicatum* | | | | | r | |
| — *verticillatum* (Pl. XXXII, 2—3) | | | | | r | |
| *Najas flexilis* | | | | | r | |
| — *marina* | | | | | r | |
| *Nasturtium aquaticum* | | | | | r | |
| *Nuphar luteum* | + | | | | + | |
| *Nymphaea alba* | + | + | | | + | |
| *Picea excelsa* | | | | r | +, c[1]) | |
| *Pinus silvestris* | | | | +[1]) | +, c[1]) | |
| *Polygonum cf. tomentosum* | | | | | r | |
| *Polypodium vulgare*[2]) | | | | r | r | |

[1]) Pollen. [2]) Spores.

| Species | Post-glacial | Late-glacial | Interglacial | | | |
|---|---|---|---|---|---|---|
| | | | Sub-arctic | | Tempe-rate | Arctic Sub-arctic |
| | A—B | C—E | G | H | J | K |
| *Potamogeton densus* | | | | | r | |
| — *filiformis* (Pl. XXXIII, 10–11) | | c | r | | + | + |
| — *natans* (Pl. XXXII, 27) | | r | + | | + | r |
| — *praelongus* | | + | | | | |
| — *pusillus* | | + | | | | |
| — *trichoides* | | | | | r | |
| — *sp.* | | + | | r | c | |
| *Potentilla erecta* | | r | r | | cf. | |
| — *palustris* | | r | r | | r | |
| — *sp.* | + | r | r | | r | r |
| *Quercus sp.*[1] | | | | | c | |
| *Ranunculus flammula* | | | | | r | |
| — *lingua* (Pl. XXXII, 16—18) | | | | r | r | |
| — *repens* | | | | | + | |
| — *sp.* | | r | | | r | |
| *Rubus idaeus* | | r | r | | + | |
| *Rumex sp.* | | | | | r | |
| *Salix herbacea* | | cf. | | r | | |
| — *sp.* | | r | r | + | r | r |
| *Scheuchzeria palustris* | c | | | | | |
| *Scirpus lacuster* | | | | | c | |
| — *palustris* | | c | | | r | |
| — *cfr. fluitans* | | | | | r | |
| *Solanum dulcamara* | | | | | r | |
| *Selaginella selaginoides* | | r | | + | r | |
| *Sparganium erectum* | | | | | + | |
| — *minimum* | | r | | | r | |
| — *simplex* (Pl. XXXIII, 21) | | | | | r | |
| *Taxus baccata* | | | | | r | |
| *Trapa natans* | | | | | c | |
| *Typha latifolia*[1] | | | | | r | |
| *Ulmus sp.*[1] | | | | | r | |
| *Urtica dioeca* | | | | | r | |
| *Viola palustris* | | + | r | r | r | |
| *Hypnum fluitans* | | | | | + | |
| *Polytrichum sp.* | | + | | | | |
| *Sphagnum sp.* | c | | | | +[2] | |
| *Botryococcus Braunii* | | | | + | + | |
| *Characeae* | | r | | + | + | |
| *Rivulariaceae* | | | | r | + | |
| *Cenococcum geophilum* | | | + | r | r | |
| *Chlorosplenium aeruginosum* | | | | | cf. | |
| *Phryganidae* | | | | | r | |
| *Daphnia pulex* | | | | | | r |
| *Nephelis octoculata* | | | | | r | |
| *Cristatella mucedo* | | | | | r | |
| *Spongilla lacustris* | | | | + | + | |

[1] Pollen. [2] Spores.

## The History of Solsö and its Environs.

The Solsö basin is hollowed out in boulder clay, and when the last ice-covering of that region had meltet away at the beginning of the last interglacial period, a deposit was formed in the lake, of clay containing remains of a tundra vegetation, *Dryas octopetala*, *Betula nana*, *Arctostaphylus alpina* etc. Soon however, *Betula pubescens* and other forest trees spread, the sedimentation changed to a dark, finely arenaceous mud, and a forest development such as that indicated by the pollen diagram Pl. XXXVII, 7, must be supposed to have taken place in the vicinity of the lake. In the lowest zone of the mud bed, *Betula* is dominant, but *Pinus* here attains its maximum; then comes a zone with maxima for *Corylus* and *Quercus*. In the upper half of the mud bed, pollen of *Carpinus* and *Picea* attain the greatest frequency, the curves for *Quercus* and *Corylus* turning off to the left. The rich aquatic flora belongs to the zones of mixed oak forest and *Carpinus betulus* (Boring 15 a). From the uppermost horizon of the mud bed and through the layer of clay mud above (Boring 15 a), *Pinus* pollen is dominant; *Picea* gradually takes second place in order of frequency, the *Betula* curve turns off to the right at the top, the curves for the other deciduous trees, with exception of *Alnus*, lying close along the vertical axis. A conifer forest of northern character now covered the surroundings of the lake, *Betula nana* at the same time reappearing. A remarkable find of this last-named species is noted on p. 115, bed J; this, if not due to the fruit having been carried down by the drill, indicates that *Betula nana* still stood here — possibly as a relict — during the warmest part of the interglacial period.

The bed H, consisting of more or less muddy clay, and the sandy bed G which goes with it in floristic respects, and occupies the central part of the bowl formed by H, constitute the main part of the material with which the Solsö-basin is filled. Both are lake deposits. The pollen diagram shows the development of the pollen flora in the lower part of the bed H, where the mud content was greatest; the amount of pollen in the remaining part of the bed was extremely small. The flora indicated by washing samples from these two beds is distinctly sub-arctic in character, containing for instance *Betula nana*, *Salix herbacea*, *Andromeda polifolia*, *Empetrum nigrum* and *Selaginella selaginoides*. A few finds of *Betula pubescens*, *Picea excelsa* and *Rubus idaeus* indicate however, that there existed, at any rate from time to time, small patches of forest near Solsö while these strata were forming.[1])

[1]) The finding of *Hydrocotyle vulgaris* in Stratum G, Boring 9, as also the finding of the same species in the similarly sub-arctic Stratum D, Boring 10, may perhaps be best explained as due to carrying down from post-glacial strata; cf. p. 123 and 54.

The sedimentation of the beds G and H was interrupted by the formation of the stony sand bed F. The extent and thickness of this stratum show that the material of which it is composed was brought mainly from the SW, NW and N, the stratum being developed more especially on the western side of the basin, where also it attains its maximum thickness, abt. 1.5 m. The stones were most numerous, and also largest, in the marginal parts of the basin, where some were as big as hen's eggs. It it unlikely therefore that Stratum F should have been formed during a glaciation of the Solsö region, the more so since there is nothing in the least moraine-like about the stratum in question. On the other hand, its genesis as a produkt of solifluction is perfectly clear, *inter alia* from the fact that the lie of the country round the lake points precisely to the part SW, W and N of the lake as that which was exposed to greatest denudation (cf. Chap. III). This denudation must be supposed to have taken place under arctic conditions of climate, and in any case, the bed F is both covered by and bedded on sub-arctic lake sediments, the flora of Strata C, D and E being essentially of the same kind as that of G and H. Stratum F is evidently synchronous with Stratum D in the Herning profile, and may be regarded as dating from the period of the last glaciation at its height.

At the close of the late-glacial period, there was formed the pebble beach observed at the eastern end of Profiles B and C. When this was forming, the water level of the lake came up to abt. 42.75 m, and the upper little terrace-like plane shown in the photos, Pl. XVI was thus produced (cf. Profile C). The approximate extent of the lake at that time is shown in the map, Pl. XVII, 4.

The post-glacial period commenced with the deposit of the mud bed D, which comes to the level of 41.50, presumably answering to a water level reaching to the lower notch in the terrace (41.70 m) shown in Pl. XVI and Profile C, Pl. XVII. When the post-glacial *Sphagnum* bog west of the lake began to form, however, the water level was somewhat below 41,20, for at this level, the peat bed rests on sand, into which roots of *Eriophorum vaginatum* had grown down. Afterwards, the water level rose again somewhat, until artificially lowered to its present position, 41.40 above sea level.

On the site where Solsö now lies there was, then, a lake all through the post-glacial, late-glacial and interglacial periods. The sedimentation in this basin seems to have been interrupted only at one period, namely when the stony sand bed F was formed under the influence of periglacial solifluction. The beds G and H must correspond to the Middle Bed in the Herning profile. It may seem surprising that no certain trace should have been found at Solsö of the upper temperate zones known from the profiles of the Herning type. Here however, it should be noted that the beds corresponding these zones, where hitherto observed, are as a rule of less extent horizontally than the lower temperate beds in the profiles of the Herning type,[1]) and we cannot therefore disregard the possibility that they exist in the deepest parts of the Solsö basin, which is still covered by the lake.

## Herborg I.

At Herborg, abt. 3 km SW of Videbæk and abt. 23 km E a little S of Ringköbing, a couple of borings were made, in October 1921 in two flat hollows, one on either side of the railway line, 1.0 km and 1.5 km respectively SW of Herborg railway station (Hpl.), Fig. 5. Both borings were carried down through interglacial lake deposits. The more easterly site, Herborg I, lies at the upper end of a flattish valley sloping towards the north, and carrying water to Herborg Brook, which again flows into Vorgod River; it appears as a hollow 275 m long by 80 broad, now containing a peat bog. The western site, Herborg II, is likewise situated at the upper end of a gently sloping valley, the slope here however, being towards the west, down to Ganer River, which flows out into Ringköbing Fjord. The place presents the appearance of a small bog and is indicated on the map by a closed curve, marking a hollow having no outflow; its greatest extent is abt. 200 m.

The boring in the more easterly of these two basins, Herborg I, showed the following profile.

| | | |
|---|---|---|
| A. | 0 — 1.5 m | Peat above 1 m fine, slightly argillaceous Sand. |
| B. | 1.5 — 2.8 m | Gravel. |
| C. | 2.8 — 8.0 m | Sand with small stones. |
| D. | 8.0 —11.5 m | Fine Sand and sandy, stratified Mud with vegetable remains. |
| E. | 11.5 12.5 m | Brown sandy Mud. In this were found inter alia many fruits of *Betula nana*, also *Myriophyllum alterniflorum*, *Callitriche cf. autumnalis* etc. |
| F. | 12.5 —12.75 m | Grey, sharp Sand with stones the size of hazel nuts: vegetable detritus, e. g. numerous fruits and catkin scales of *Betula nana* and numerous nuts of *Callitriche cf. autumnalis*. |
| G. | 12.75—13.4 m | Brown sandy Mud with numerous vegetable remains including a seed of *Brasenia purpurea*. |
| H. | 13.4 —15.5 m | Grey Sand with vegetable detritus including a fruit of *Ceratophyllum demersum var. apiculatum*. |
| J. | 15.5 —16.0 m | Grey, coarse Sand with no vegetable detritus. |

Owing to the great amount of sand in the plant-bearing strata, the samples were often brought up in such a state that they could

[1]) e. g. at Herning, Nörbölling and Rodebæk I.

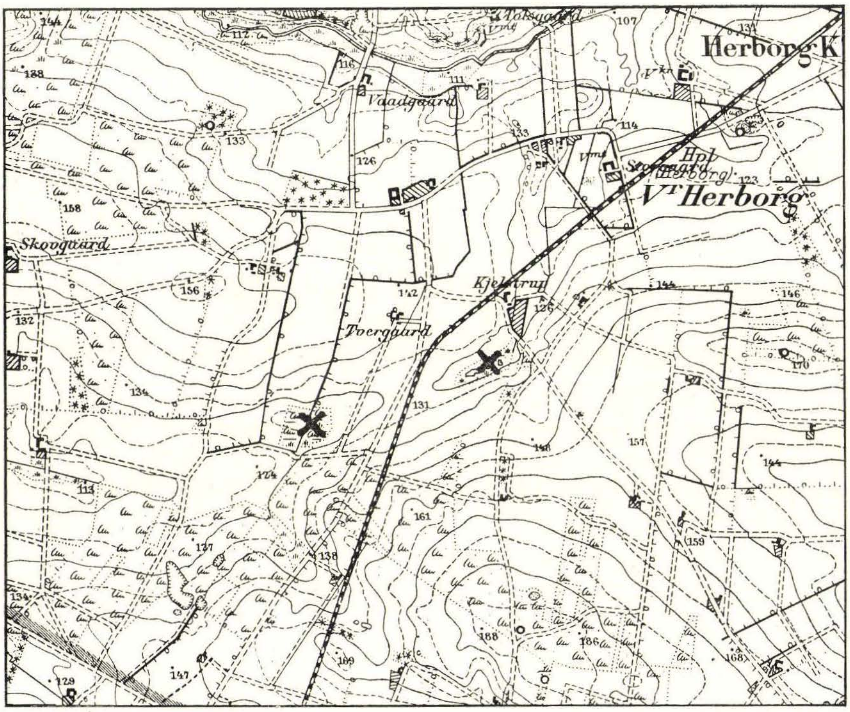


Fig. 5. Map showing the interglacial bogs at Herborg, the eastern cross is Herborg I, the western cross is Herborg II. Scale 1 : 25000. Contour interval 5 ft = 1.57 m. From the General Staff Map Sheet 2604.

not be utilised for pollen analyses, and we can only give three of these:

| No. | Stratum | Depth | *Salix* | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen-frequency | Zones |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | D. | 10.0 - 11.5 m | 2 | 36 | 30 | | 3 | Trace | 16 | Trace | 13 | 7 | 70 | *i* |
| 2 | E. | 11.5—12.5 m | | 38 | 23 | 2 | 2 | | 23 | | 11 | 11 | 52 | *i* |
| 3 | G. | 12.5—13.4 m | 1 | 47 | 10 | 2 | 9 | | 28 | 9 | 2 | 36 | 106 | *f* |

Table 2. Pollen spectra from Herborg I.

On comparing these with pollen diagrams from other interglacial localities it will be seen that samples No.s 1 and 2 are from the *Pinus-Picea* zone, No. 3 being from the close of the mixed oak forest zone. The earlier portions of this, as well as the lower *Pinus* zone, must thus be looked for in Stratum H, where *Ceratopyllum demersum* was found. The washing lists from Stratum G includes several thermophile species such as *Brasenia purpurea*, *Carex pseudocyperus* and *Hydrocotyle vulgaris*; and it must be supposed that the few remains of *Betula nana* (some fruits and a catkin scale) found here are due to intermixture from the Stratum F above in process of boring. *Betula nana* was common both in this and in Stratum E, and must have been a regular component of the vegetation, which was however, unquestionably characterised primarily by the forest growths (Spectr. 2). The material affords but little information as to the state of the vegetation at the time when the upper portion of Stratum D was being deposited, and the finding of a single nut of *Hydrocotyle vulgaris* in this part of the bed seems somewhat remarkable.

## List of the Fossils found at Herborg I.

c common, + fairly common, r rare.

| Species | D | E | F | G | H |
|---|---|---|---|---|---|
| *Alnus glutinosa* | +[1]) | c[1]) | | r, c[1]) | |
| *Arenaria trinervia* | | | | r | |
| *Batrachium aquatile (coll.)* | r | r | r | c | |
| *Betula nana* | | c | c | [r] | |
| — *pendula* | | | | r | |
| — *pubescens* | | | | r | |
| *Brasenia purpurea* | | | | r | |
| *Callitriche cf. autumnalis* | | + | c | r | |
| *Calluna vulgaris* | | r | | | |
| *Carex pseudocyperus* | | | | + | |
| — *rostrata* | | + | c | + | |
| — *sp.* (figured in Pl. XXXV, 23—24) | | c | + | c | r |
| — *sp.* | r | | | | |
| *Carpinus betulus*[1]) | [r] | | | r | |
| *Ceratophyllum demersum var. apiculatum* | | | | | r |
| *Cirsium palustre* | | | | r | |
| *Corylus avellana*[1]) | + | + | | c | |
| *Dryopteris thelypteris*[2]) | | + | | c | |
| *Empetrum nigrum* | r[1]) | r | r | r | r |
| *Hippuris vulgaris* | | + | + | | |
| *Hydrocotyle vulgaris* | r | | | r | |
| *Menyanthes trifoliata* | | | | r | |
| *Myriophyllum alterniflorum* | | r | + | | |
| *Picea excelsa*[1]) | + | + | | r | |
| *Pinus silvestris*[1]) | c | c | | + | |
| *Polypodium vulgare*[2]) | r | | | | |
| *Potamogeton cf. pusillus* | | r | | | |
| — *sp.* | r | | | r | |
| *Quercus sp.*[1]) | r | r | | + | |
| *Ranunculus sp.* | r | | | | |
| *Rubus idaeus* | | | | r | |
| *Salix sp.* | | | | r | r |
| *Selaginella selaginoides* | | r | | r | |
| *Sparganium affine* (Pl. XXXIII, 26) | | | | | r |
| — *erectum* | | | | r | |
| — *minimum* | | | | r | |
| — *sp.* | r | | | | |
| *Tilia sp.*[1]) | [r] | | | | |
| *Ulmus sp.*[1]) | | r | | r | |
| *Viola palustris* | | r | r | + | |

1) Pollen. 2) Spores.

| Species | D | E | F | G | H |
|---|---|---|---|---|---|
| *Hypnum sp.* | ..... | ..... | + | ..... | ..... |
| *Polytrichum strictum* | r | ..... | ..... | ..... | ..... |
| *Sphagnum sp.* | + | + | + | c | ..... |
| *Cenococcum geophilum* | ..... | r | + | ..... | ..... |
| *Botryococcus Braunii* | + | + | ..... | ..... | ..... |
| *Oligochaeta* (a coccoon) | ..... | ..... | ..... | r | ..... |
| *Spongilla lacustris* | r | ..... | ..... | ..... | ..... |

## Herborg II.

For the situation of this bog see p. 121. The Boring profile was as follows:

A. 0 — 1.15 m Uppermost, 40 cm humous Peat; below this, 15 cm of Mud, bedded on 40 cm of fine, slightly argillaceous Sand containing numerous megaspores of *Selaginella selaginoides;* at the bottom, Mud again (20 cm) in which were found *Batrachium aquatile (coll.), Hippuris vulgaris, Myriophyllum spicatum et var. muricata* AHLFVENGR., *Potamogeton sp.*, *Ranunculus cf. flammula* (6 small fruits); *Daphnia pulex.*

B. 1.15— 3.0 m Gravel with stones the size of hen's eggs.

C. 3.0 — 3.25 m Fine Sand with no plant detritus.

D. 3.25— 5.0 m Fine Sand with plant detritus; washing samples yielded inter alia a fruit of *Frangula alnus* and a small fruit of *Potamogeton densus* (Pl. XXXII, 22).

E. 5.0 — 10.0 m Uppermost, 2 m coarse Sand with some vegetable remains *(Cenococcum geophilum)*; then 80 cm Gravel with stones the size of eggs; below this, 2.2 m Sand with some vegetable detritus; abt, 9 m separate, thin layers of sandy Mud.

F. 10.0 —15.5 m Fine Sand, mixed in varying degrees with Mud. Remains of *Betula nana*, including fruits, catkin scales and leaves, were found throughout the entire stratum, but from abt. 11 m downwards there were also remains of several temperate species, such as *Bidens cernuus. Cladium mariscus, Corylus avellana*, a few needles of *Picea excelsa* were likewise found, cf. Table 3 and the list of fossils.

G. 15.5 - 16.0 m Coarse grey Sand, not bored through; some remains of *Batrachium aquatile (coll.)* and *Viola palustris* here found must be regarded as brought down from F.

As at Herborg I, the plant-bearing strata in this profile were so sandy that only a few of the samples were found suitable for pollen analysis; these — three in all — are given below.

| No. | Stratum | Depth | *Salix* | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen-frequency | Zones |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | F | 12.1 - 13.0 m | 1 | 41 | 32 | | 2 | | 8 | 2 | 14 | 10 | 43 | *(g–i)?* |
| 2 | — | 13.6–14.5 m | | 32 | 31 | 1 | 4 | 1 | 17 | 3 | 11 | 13 | 106 | |
| 3 | — | 14.5–15.5 m | Trace | 49 | 20 | | 5 | | 19 | 3 | 4 | 21 | 69 | |

Table 3. Pollen spectra from Herborg II.

No. 3 of these spectra may perhaps be referred to the transition between the mixed oak forest zone and the *Pinus-Picea* zone, while Nos. 1 and 2 belong entirely to the latter. The part of the profile from which these three spectra are taken is altogether synchronous with that portion of the Herborg I profile shown in Table 2. For the rest, our knowledge as to the state and development of the vegetation in and around the two interglacial lakes at Herborg is very uncertain. It must be left for the future to determine whether Strata D *(Frangula alnus* and *Potamogeton densus)* and E can be considered as parallel to the upper warm stratum and the Middle Bed respectively in the lake deposits at Herning.

## List of the Fossils found at Herborg II.

c common, + fairly common, r rare.

| Species | D | F | | | | | |
|---|---|---|---|---|---|---|---|
| | 3.25–5.0 | 10.0–10.5 | 10.5–11.2 | 11.2–12.1 | 12.1–13.0 | 13.6–14.5 | 14.5–15.5 |
| *Alnus glutinosa*[1] | | | | | + | c | c |
| *Armeria vulgaris* | | | | | r | | |
| *Batrachium aquatile (coll.)* | | r | + | + | c | c | c |
| *Betula nana* | | r | r | | c | c | c |
| — *pubescens* | | | | | r | | r |
| — *sp.*[1] | | | | | c | c | c |
| *Bidens cernuus* | | | | | r | | |
| *Callitriche cf. autumnalis* | | | | | | | + |
| *Calluna vulgaris* | | | | | | r | |
| *Carex pseudocyperus* | | | | | r | | |
| — *rostrata* | | | | | | | r |
| — *sp.* (Pl. XXXV, 23 - 24) | | | | | + | c | c |
| — *sp.* | + | + | c | + | + | + | |
| *Carpinus betulus*[1] | | | | | r | r | r |
| *Cladium mariscus* | | | | r | | | |
| *Corylus avellana* | | | | | r, c[1] | +[1] | +[1] |
| *Dryopteris thelypteris*[2] | | | | | | + | + |
| *Empetrum nigrum* | | + | c | + | c | c | c |
| *Frangula alnus* | r | | | | | | |
| *Hippuris vulgaris* | | | | | | | r |
| *Juniperus communis* | | | | | | r | r |

[1]) Pollen. [2]) Spores.

| Species | D | F | | | | | |
|---|---|---|---|---|---|---|---|
| | 3.25—5.0 | 10.0—10.5 | 10.5—11.2 | 11.2—12.1 | 12.1—13.0 | 13.6—14.5 | 14.5—15.5 |
| *Myriophyllum alterniflorum* (Pl. XXXII, 4-6) | | | | | r | r | + |
| *Picea excelsa* | | | | | r, +[1] | +[1] | r, r[1] |
| *Pinus silvestris* | | | | | c | c | + |
| *Polypodium vulgare*[2] | | | | | r | | |
| *Potamogeton densus* (Pl. XXXII, 22) | r | | | | | | |
| — *filiformis* | | | r | | | | r |
| — *pusillus* | | | | | | | r |
| — *sp.* | | | | | | r | |
| *Potentilla palustris* | | | | | | r | |
| — *sp.* | r | | | | | | |
| *Quercus sp.*[1] | | | | | r | r | + |
| *Ranunculus sp.* | | | | | | r | r |
| *Salix sp.* | | | + | | + | | r |
| *Selaginella selaginoides* | | | | | | | r |
| *Sparganium erectum* | | | | | r | | |
| — *minimum* | r | | | | | | r |
| — *sp.* | | | r | | | | |
| *Tilia sp.*[1] | | | | | | r | |
| *Ulmus sp.*[1] | | | | | | r | |
| *Viola palustris* | | | | | | + | r |
| *Hypnum sp.* | | | | | | | c |
| *Polytrichum strictum* | | | | | | | r |
| *Sphagnum sp.* | | | | | c | + | + |
| *Cenococcum geophilum* | | + | c | c | + | + | |
| *Botryococcus Braunii* | | | | | + | | |
| *Pediastrum sp.* | | | | | | r | r |

## Astrup.

A short half-kilometre NE of Astrup, which lies 6 km NW of Borris railway station, there is a *Sphagnum* Bog, now largely dug away, the maximal extent of which, both from NE—SW and NW—SE, is some 200 m or a little more, Fig. 6. The bog was formed by the overgrowing of a lake, and we find here an encloced basin constituting the upper part of one of the minor valleys with which the Slumstrup Mill-brook valley begins, while four enclosed hollows at Klokmose, mentioned on p. 128 lie in the upper portion of another lateral valley running down into the same. Slumstrup Mill-brook is a stream flowing into Kirkeaa River, which again flows into Skjern River.

In the middle portion of this considerable basin at Astrup, we made a boring, in 1921 and obtained the following profile:

[1] Pollen. [2] Spores.

A. 0 — 1.5 m Peat, predominantly *Sphagnum* Peat.
B. 1.5 — 2.25 m Mud.
C. 2.25 — 2.5 m Sandy Clay.
D. 2.5 — 3.0 m Gravel.
E. 3.0 — 3.5 m Sand.
F. 3.5 — 3.6 m Dark brown horny hard Mud in which were found, apart from pollen of trees, the following:
*Batrachium aquatile (coll.)*, 1 fruit,
*Betula pubescens*, 2 fruits, 1 catkin scale,
*Carex sp.*, 1 fruit without utriculus,
*Ceratophyllum sp.*, 1 leaf tip,
*Dryopteris thelypteris*, numerous spores,
*Empetrum nigrum*, 1 fruit-stone,
*Nymphaeaceae*, intercellular hairs,
*Potamogeton praelongus*, 2 fruit-stones,
— *sp.*, 4 fruit-stones.

*Anabaena sp.*,
*Botryococcus Braunii.*

*Spongilla lacustris.*

G. 3.6 — 4.0 m Mud-blended, mossy Sand:
*Batrachium aquatile (coll.)*, 1 fruit,
*Betula pubescens*, several fruits,
*Carex sp.*, several fruits,
*Eriophorum vaginatum*, 3 fruits,
*Gramineae*, pollen,
*Nymphaeaceae*, intercellular hairs,
*Picea excelsa* two needles, plane convex in transverse section, with slightly serrate edge and the stomata on the flat side; primordial leaves,
*Potamogeton filiformis*, 1 fruit-stone,
— *sp.*, 1 fruit-stone,
*Selaginella selaginoides*, 1 spore.

*Hypnum exannulatum*,
*Sphagnum angustifolium*,
— *palustre*,
— *teres*.

*Botryococcus Braunii.*
*Pediastrum Boryanum.*

*Daphnia pulex*,
*Amphitrema flava.*

H. 4.0 —10.0 m Moraine Clay with lumps of brown coal.
J. 10.0 —10.3 m Stony Sand.
K. 10.3 —13.2 m Moraine Clay with lumps of brown coal.

A couple of pollen analyses afford further data as to the section of the interglacial period to which these two mud beds should be ascribed.

| Depth below surface | Stratum | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen-frequency | Zones |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.55 m | F | 4 | 8 | 1 | 51 | | 36 | | | 95 | 267 | *f* |
| abt. 3.80 m | G | 40 | 28 | 2 | 6 | | 4 | | | 20 | 87 | *d* |

Table 4. Pollen spectra from Astrup.

The lower of these spectra dates from the section towards the close of the *Betula-Pinus* period, when *Corylus*, *Quercus* and *Alnus* made their appearance; the upper spectrum probably lies somewhere about the time when *Quercus* and *Corylus* reached their culmination. We thus lack here the upper portions of the interglacial series, which we may presume to have been destroyed during the last glacial period, when the covering strata were in process of formation.

## Duedam I.

At Klokmose, abt. 5 km north of Borris railway station, in the plateau consisting predominantly of fluvioglacial sand and sandy moraine clay, several of the usual small enclosed hollows are found. In two of these, viz. the northern and southern Duedam, interglacial deposits were found, see Fig. 6, whereas none were discovered in two adjacent hollows where borings were also made, south and west of the southern Duedam. The northern Duedam, a pond used for watering cattle, but often dry i summer, lies at the bottom of a deep horseshoe-shaped depression in the southern margin of the heather-clad hills (Pl. XVIII, 1). Its bottom lies up to as much as 3 m below the level of the edge of the surrounding plateau, which slopes down steeply towards it on three sides; on the south, the edge of the basin is but little noticeable, and on this side, the hollow is connected, by a slight depression in the ground, with the southern Duedam, lying 140 m distant, the bottom of this latter pond being abt. half a metre lower than the sourrounding terrain. There was formerly a well here. In both these hollows the bottom is peaty.

The bottom of the northern hollow, which is distinctly apparent in Fig. 6 is abt. 50 m long, in a N—S direction, and abt. 30 m wide. In 1922, a boring was made in the middle of this basin. The profile was as follows:

A. 0 — 0.5 m Peat.
B. 0.5 — 2.2 m Stony Sand, reddish yellow at the top, grey and mixed with humus at the bottom.
C. 2.2 — 4.55 m Dark brown, firm laminated *Sphagnum* Peat, which at the

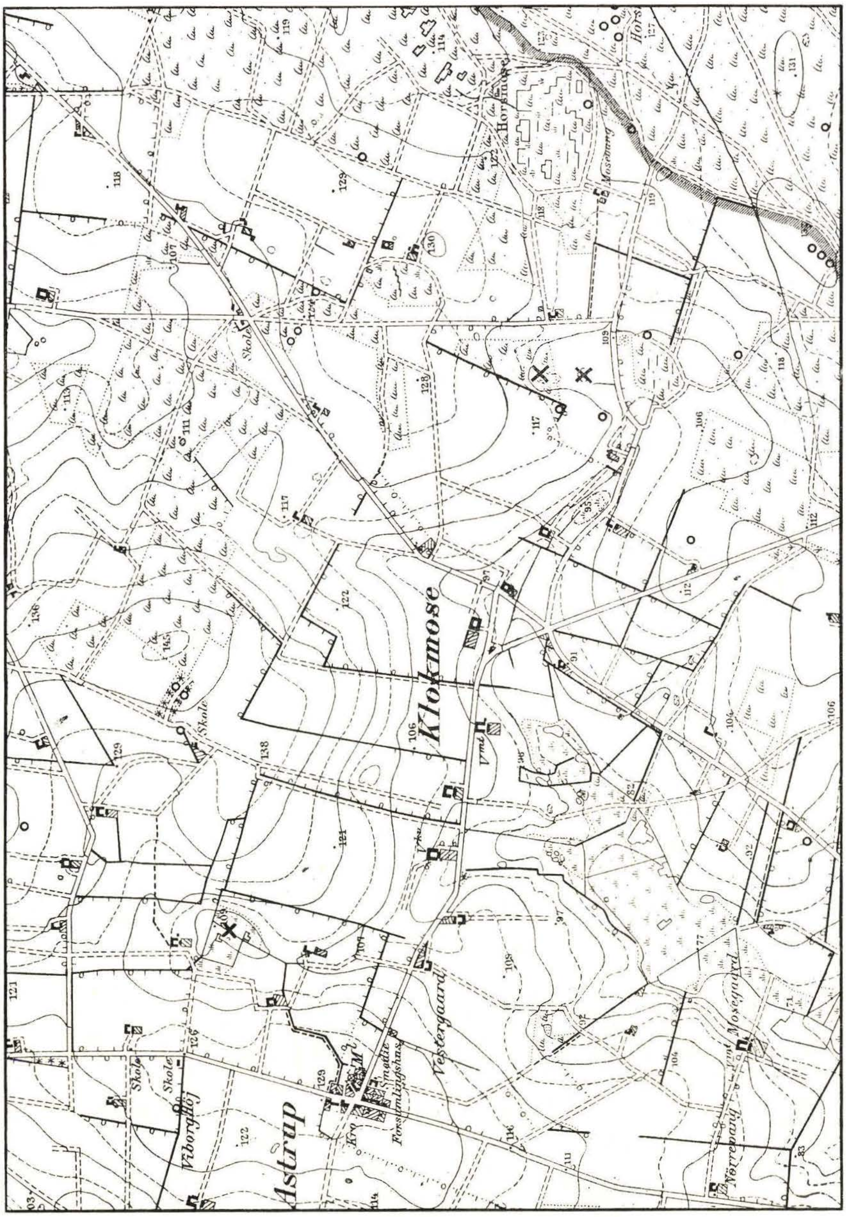


Fig. 6. The Klokmose district with the interglacial bogs, Astrup, marked by the cross to the NW, further Duedam I (north) and Duedam II (south) the crosses in the south-east. Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. From the General Staff Map Sheets 2604 and 2704.

junction with the overlying bed appeared as greyish-brown, sandy Mud; the microscopic analysis revealed numerous of leaves and spores of *Sphagnum*, much pollen of *Ericaceae* and *Empetrum nigrum*, spores of *Dryopteris thelypteris*, epidermis of *Eriophorum vaginatum*, numerous hyphae of fungi. The five samples taken for washing yielded but few determinable vegetable remains:

*Andromeda polifolia*, 4 seeds at the top,
*Betula pubescens*, a few fruits,
*Carex rostrata*, numerous fruits,
*Dulichium spathaceum*, 1 fruit at the bottom,
*Empetrum nigrum*, 1 fruit-stone,
*Hydrocotyle vulgaris*, 1 nut at the bottom,
*Picea excelsa*, a few fragments of bark, both in the upper and lower portions of the stratum,
*Pinus silvestris*, a fair quantity of wood, at the bottom.

D. 4.55— 7.55 m Brown, horny Mud, the upper part with transition to the overlying bed, sandy lower down:

*Alnus glutinosa*, several fruits, branches:
*Arctostaphylus uva ursi*, 2 fruit-stones,
*Betula pubescens*, numerous fruits,
*Brasenia purpurea*, 6 seeds in the lower half,
*Carex sp.*, many fruits without utriculus,
*Carpinus betulus*, 1 nut, 6 m below the surface,
*Ceratophyllum demersum var. apiculatum*, 1 fruit and numerous hairs in the lower part of the stratum,
*Dulichium spathaceum*, 17 fruits throughout nearly the whole of the stratum,
*Empetrum nigrum*, pollen tetrads common in the upper part,
*Hydrocotyle vulgaris*, 3 nuts in the upper and the lower part,
*Ilex aquifolium*, some pollen in the lower part,
*Lycopus europaeus*, 3 nuts,
*Menyanthes trifoliata*, 4 seeds,
*Nuphar luteum*, Pollen and intercellular hairs,
*Picea excelsa*. 1 bud scale, 1 leaf, 1 seed, uppermost,
*Pinus silvestris*, some wood,
*Polypodium vulgare*, 1 spore in the lower part,
*Potamogeton natans*, several fruit-stones,
*Potentilla palustris*, 1 fruit,
*Rubus idaeus*, 1 fruit-stone,
*Scirpus lacuster*, several fruits at the bottom.

*Hypnum exannulatum*,
— *intermedium*,
*Sphagnum sp.*, common in the upper part of the stratum.

*Cenococcum geophilum*, a few sclerotia,
*Fungi*, hyphae common in the upper part.

*Rivulariaceae*.

E. 7.55— 7.95 m Gravel.

F. 7.95—10.0 m Sandy Moraine Clay.

The pollen diagram (Pl. XXXVII, 2) shows roughly the course of development of the woodland during the period when the little pool was being filled up with mud and peat. It would seem as if the sedimentation of mud had only begun at the time when the mixed oak woods were nearing their culmination, as the frequency values for *Ulmus* and *Quercus* in spectrum 9 are 10 % and 51 % respectively, while *Pinus* and *Betula* are but poorly represented in comparison. The curves for these two lastnamed species, and for the mixed oak wood, tend towards the left in the lower portion of the diagram, *Alnus* culminating in Spectr. 6 and 7, with 34 and 33 % respectively. The *Corylus* curve conforms to that for *Alnus*, and reaches its summit, 64 %, in Spectr. 7. The *Ulmus* curve has two summits, beginning with 10 % in Spectr. 9, and falling to 4 % in Spectr. 7, but rising again to 7 % in Spectr. 6, i. e. uppermost in the zone of the mixed oak wood. *Tilia* is represented only in Spectr. 7, with 1 %.

*Carpinus* may be traced in the last part of the mixed oak wood zone, while *Alnus* and *Corylus* are most frequent, and its pollen attains highest frequency i Spectr. 5 (22 %). The curve then turns off to the left, and *Carpinus* can hardly have been of any great importance in the forest growth at the time when the *Sphagnum*-peat was forming.

*Picea* was first noted in Spectr. 5, where it culminates with 38 %; it has evidently made itself master of the forest within a comparatively short time of its arrival on the scene, and shows a fairly high frequency (17—18 %) in the spectra from the *Sphagnum*-peat. In these, the predominant forms are *Pinus* and *Betula*, with *Alnus*; the two former undoubtedly formed the principal constituents of the forest growth at the time when a *Sphagnum*-chamaephyte formation was covering the bog.

At the time when the upper part of Stratum C was forming, a quantity of sand was brought down into the basin from the surrounding hills, and after that, the quantities of sand and gravel brought down from the hills increased to such a degree that the bog no longer served as an indicator of the further development of the surrounding vegetation. Probably in the course of this transportation of material out over the bog, peat or mud from the outcrops of older layers may have been destroyed and blended with the upper part of stratum C, the supposition of which would give os the intelligence why the pollen-curves of *Alnus*, *Corylus*, *Quercus* and *Carpinus* all turn off to the right in this uppermost part of the diagram.

The diagram thus represents the following process of evolution:

*(i)* *Pinus*-zone with much *Betula* (Spect. 4—2),
*(h)* *Picea*-zone (about Spect. 5—4),

*(g)* *Carpinus*-zone (about Spect. 5),
*(f)* Mixed oak forest zone (Spect. 9—6).

The peculiar horseshoe-shaped hollow in the bottom of which our interglacial bog was discovered cannot have arisen from a collapse of the bog itself; it must necessarily be older than the mud and peat beds, and must have been formed at the same time as the surrounding hills. Moreover, it is hardly likely that the inland ice, during the last glacial period, should have extended out over this hollow[1]) and yet have left no trace beyond a thin layer of stony sand; and this even mixed with humus at the bottom. On the contrary, the Duedam basin emphatically shows that it lay outside the margin of the ice during the last glacial period. Arctic conditions then prevailed in western Jutland; and regelation in connection with the action of running water, could easily bring down sand and gravel from the surrounding hills, spreading it out over the little bog, in the enclosed basin of which it would come to rest.

## Duedam II.

In this little hollow (see p. 128 and Fig. 6) a boring revealed the following strata:

| | | | |
|---|---|---|---|
| A. | 0 — 0.9 | m | Mould and sandy Mud. |
| B. | 0.9 — 3.4 | m | Stony Sand. |
| C. | 3.4 — 3.55 | m | Brown, very sandy Mud with a few small sticks. |
| D. | 3.55 — 5.0 | m | Gravel. |
| E. | 5.0 — 6.0 | m | Sandy Moraine Clay. |

No macroscopically determinable vegetable remains were found in Stratum C, but the microscope showed, in samples from here, *Anabaena sp.*, pollen of *Nuphar luteum*, *Typha latifolia* and grass, spores of *Dryopteris thelypteris* and much pollen of forest trees: *Betula* 84 %, *Pinus* 11 %, *Ulmus* 1 %, *Quercus* 3 %, *Alnus* 1 % and *Corylus* 2 %. — *Carpinus* and *Picea* are not represented in this *Betula-Pinus* spectrum, where the species of the mixed oak woods show but slight frequency values. And since there can be no doubt but that the mud bed is interglacial, dating from the same interglacial period as the northern Duedam, it must be referred to a previous section of this interglacial period, viz. the *Betula-Pinus* zone, than Spectr. 9 in the diagram from Duedam I. Spectr. 8 in the pollen diagram from Rodebæk III (Pl. XXXVII, 4) is approximately equivalent to this spectrum from the southern Duedam.

[1]) Comp. p. 136.

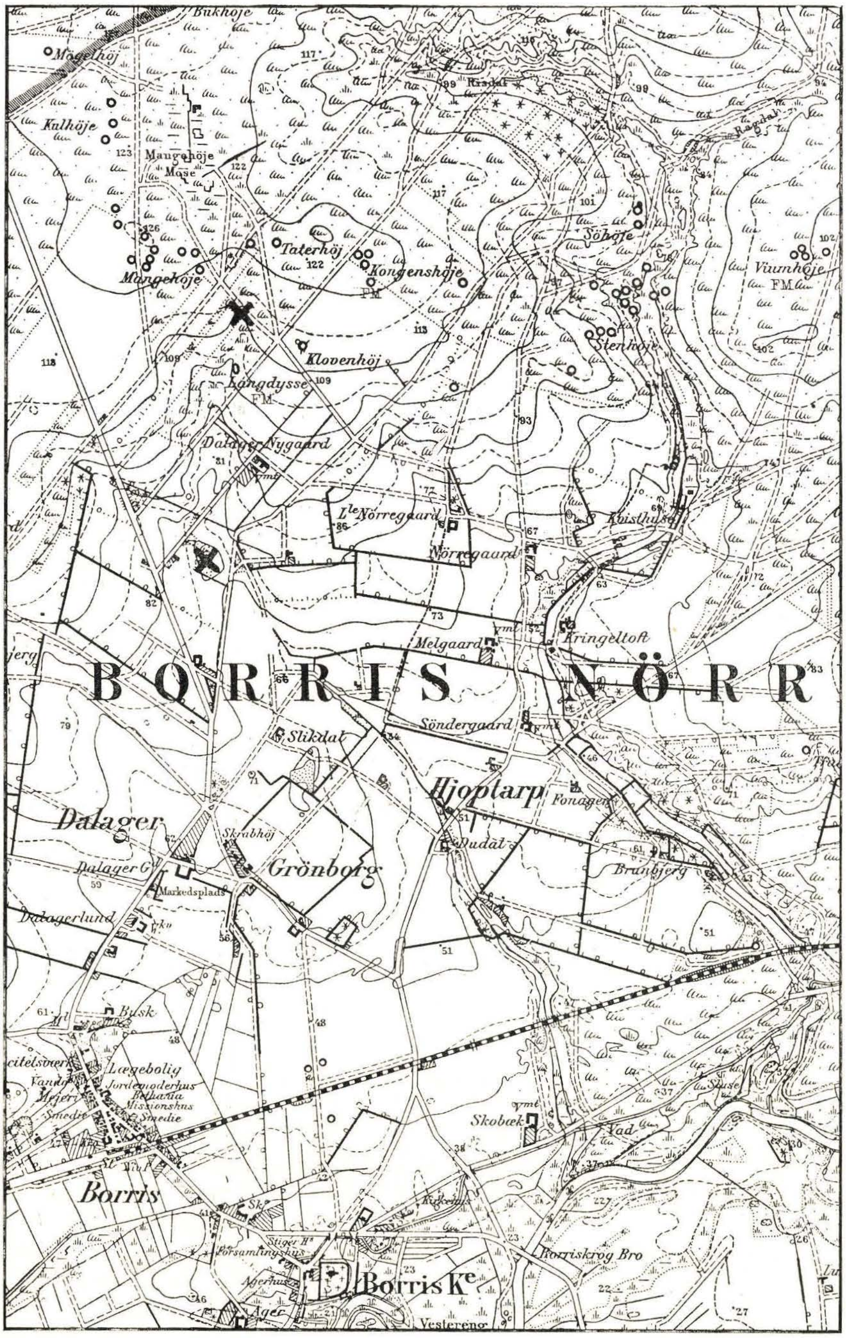

Fig. 7. District north of Borris with the interglacial bogs at Dalager (the cross to the south) and Dalager Nygaard (the cross to the north). Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. From the General Staff Map Sheet 2704.

# Dalager.

Along the southern slope of the great plateau "Skovbjerg Bakkeö", there are numerous small valleys, often cutting down to a considerable depth, now as a rule forming the beds of small streams, which flow down into Skjern River, the part of the valleys situated at higher levels being mostly dry.

In one of these dry valleys we found, in the course of borings made in 1922 and 1923, two interglacial bogs, which we named Dalager and Dalager Nygaard. The former lies 3 km N of the railway station at Borris, the latter 0.8 km farther north again, Fig. 7. The bog at Dalager was found in a fairly large hollow without outlet in the bottom of the valley, and as this is marked on the map with a closed curve, we were inclined to be interested in the site before hand. The maximum diameter of the hollow is abt. 150 m.

In 1923, 4 borings were made in the bog at Dalager, three of which encountered the interglacial mud.

Boring 1 (on the eastern side of the hollow).

| | | |
|---|---|---|
| A. | 0 — 1.25 m | Peat-Mould (0.25 m) above brown loamy, sandy Mud. |
| B. | 1.25— 1.65 m | Uppermost, grey Sand; below, 10 cm grey sandy Clay. |
| C. | 1.65— 2.5 m | Gravel. |
| D. | 2.5 — 3.6 m | Brown Mud with numerous vegetable remains, including seeds of *Brasenia purpurea* both in the upper and lower parts of the stratum. |
| E. | 3.6 — 5.0 m | Grey Moraine Clay without chalk. |

Boring 2 (44 m west of Boring 1).

| | | |
|---|---|---|
| A. | 0 — 0.6 m | Peat-Mould (0.3 m) above brown, loamy, sandy Mud. |
| B. | 0.6 — 1.2 m | Yellow Sand. |
| C. | 1.2 — 2.6 m | Stony Sand above, Gravel below. |
| D. | 2.6 — 6.9 m | Mud; the uppermost 30 cm brown, below this, down to 6.25 below surface, a dark-brown, hard and laminated mud, the lowest portion again lighter in colour; this lowest part especially contained a quantity of vegetable remains. |
| E. | 6.9 — 7.1 m | Non-calcareous Moraine Clay. |

Boring 3 (36 m NW of Boring 2).

| | | |
|---|---|---|
| A. | 0 — 0.25 m | Mould. |
| B. C. | 0.25 — 3.9 m | Uppermost, — down to 1.5 m below surface — Sand and Gravel with stones the size of a fist; below this, gravel with smaller stones; the bottom part of the stratum contained small lumps of Mud. |
| D. | 3.9 — 5.9 m | Uppermost, brown Mud, rather hard at the top; below 5.0 m was lighter-coloured mud. In the upper part of the stratum two leaves of *Taxus baccata* were found, and washings from the middle part yielded one seed of *Brasenia purpurea* and a fruit of *Dulichium spathaceum*. |
| E. | 5.9 — 6.1 m | Grey Moraine Clay. |

Boring 4 (40 m SE of Boring 1).

A. 0 — 0.2 m Sandy Mould.

C. 0.2 — 1.6 m Uppermost (0.2—0.9) Gravel with sand-worn stones the size of head; below this, grey, slightly argillaceous Sand with scattered stones.

E. 1.6 — 3.7 m Grey, non-calcareous Moraine Clay.

| No. | Boring and Stratum | Depth below surface | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen-frequency | Zone |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2, D | ca. 2.75 m | 20 | 16 | | 1 | | 28 | 15 | 20 | 12 | 190 | *g* |
| 2 | 3, D | - 4.20 m | 7 | 6 | 1 | 41 | 2 | 39 | 4 | | 45 | 325 | *f* |
| 3 | - - | - 4.75 m | 2 | 5 | 1 | 41 | | 51 | | | 133 | 220 | - |
| 4 | - - | - 5.45 m | 11 | 16 | 11 | 61 | | 1 | | | 8 | 170 | - |

Table 5. Pollen spectra from Dalager.

## List of Fossils found in the Interglacial Bog at Dalager.

c common, + fairly common, r rare.

| Species | Stratum D | | |
|---|---|---|---|
| | upper | middle | lower |
| *Alnus glutinosa* | c | c | r |
| *Betula pendula* | c | + | c |
| — *pubescens* | + | ..... | r |
| — *sp.*[1] | c | r | + |
| *Brasenia purpurea* | r | r | r |
| *Carex pseudocyperus* | r | ..... | ..... |
| — *sp.* | ..... | ..... | r |
| *Carpinus betulus*[1] | + | ..... | ..... |
| *Ceratophyllum demersum var. apiculatum* | r | ..... | r |
| *Corylus avellana*[1] | + | c | + |
| *Dryopteris thelypteris*[2] | r | r | ..... |
| *Dulichium spathaceum* | ..... | r | ..... |
| *Ilex aquifolium*[1] | r | ..... | ..... |
| *Lycopus europaeus* | r | ..... | ..... |
| *Menyanthes trifoliata* | r | ..... | r |
| *Najas marina* | ..... | ..... | r |
| *Nymphaea alba* | r | r | ..... |
| *Osmunda regalis*[2] | r | ..... | ..... |
| *Picea excelsa*[1] | c | ..... | ..... |
| *Pinus silvestris*[1] | + | r | + |
| *Polypodium vulgare*[2] | r | ..... | ..... |
| *Potamogeton natans* | + | ..... | + |
| — *pusillus* | r | ..... | ..... |
| *Quercus sp.*[1] | r | c | c |
| *Rubus idaeus* | r | ..... | r |
| *Scirpus lacuster* | r | ..... | + |
| *Sparganium erectum* | r | ..... | + |
| — *minimum* | r | ..... | r |
| — *cfr. simplex* | r | ..... | ..... |
| *Taxus baccata* | r | ..... | ..... |

[1]) Pollen. [2]) Spores.

| Species | Stratum D | | |
|---|---|---|---|
| | upper | middle | lower |
| *Tilia sp.*[1]) | r | ...... | ...... |
| *Ulmus sp.*[1]) | r | ...... | + |
| *Umbelliferae*[1]) | ...... | r | r |
| *Cenococcum geophilum* | ...... | ...... | r |
| *Anabaena sp.* | ...... | c | ...... |
| *Botryococcus Braunii* | + | + | ...... |
| *Spongilla lacustris* | + | + | + |

The basin in which the Dalager interglacial lies is formed of moraine clay. The interglacial deposit consists of brown, in parts hard, mud, which was brought up in angular lumps; the greatest thickness of the deposit was 4.3 m (Boring 2). That section of the floristic development covered by our material here extends from the first part of the mixed oak forest period to the beginning of the *Picea* period. *Taxus baccata* was found at about the same level as that from which Spectr. 2 is derived. *Brasenia purpurea* was found both in Zone *f* and Zone *g*, *Dulichium spathaceum* in Zone *f*.

The mud bed was covered by a stratum (C) of sand with sand-worn stones, which, out above the bog itself, were sometimes the size of a fist, but along the edges reached the size of a head; the great quantity of stones present sometimes gave the stratum a gravelly character. The lower portion of this stratum contained here and there small lumps of the mud from below. The thickness of this stratum was, in Borings 1 and 2, 0.85 and 1.40 m respectively; in Boring 3, the determination is somewhat uncertain. Finally, Stratum C, was covered by the stoneless sand stratum B, which in some places attained a thickness of 0.6 m (Boring 2). Presumably, Stratum B must be mainly a late glacial sediment, altered in the course of the postglacial period to mud (Boring 1 and 2). We have then, Stratum C as the only true glacial formation remaining.

The moraine in which the basin was formed must be referred to the penultimate glacial period in Denmark[2]); consequently, Stratum C must be contemporaneous with the last inland ice. This did not extend so far west as Skovbjerg Bakkeö, and the stratum is thus not glacigenous, but should be regarded as a product of solifluction similar to those covering bogs of the Brörup type elsewhere.[3])

[1]) Pollen.

[2]) Victor Madsen: Terrainformerne paa Skovbjerg Bakkeö. D. G. U. IV. R. Bd. 1. Nr. 12, 1921, p. 16 (22). — Axel Jessen: Kortbladet Varde. D. G. U. I. R. Nr. 14, 1922, p. 70 (103).

[3]) Axel Jessen etc: Brörup-Mosernes Lejringsforhold. D. G. U. IV. R. Nr. 9, 1918.

# Dalager Nygaard.

The site of this interglacial bog, 3.8 km N of Borris railway station, in a small erosion valley, was mentioned on p. 134, cf. Fig. 7. It lies at the northern end of the valley, which appears as a horseshoe shaped depression, abt. 60 m across, its margins on the NW, N and SE rising from 1 to 1.5 m above the level of its bottom; on the south however, there is an entrance abt. 30 m wide, through which the bottom runs out gradually into the lower-lying part of the valley. Here, in this hollow, "brown coal" had been found — i. e. interglacial mud — by some workmen engaged in digging a well. This was dry on the occasion of our visit in 1923. Furthermore, persons acquainted with the locality informed us that in the course of draining operations in the bottom of the valley between the interglacial bogs at Dalagar and Dalager Nygaard, peat with a covering layer of sand had been found in several places, presumably indicating further interglacial bogs.

A Boring about the middle of the horseshoe gave the following profile:

| | | |
|---|---|---|
| A. | 0 — 0.75 m | Mould and Rubbish. |
| B. | 0.75 — 1.0 m | Yellow, loamy Sand. |
| C. | 1.0 — 2.5 m | Yellow, loamy Sand with stones. |
| D. | 2.5 — 3.0 m | Yellowish-brown, somewhat loamy Sand without stones. |
| E. | 3.0 — 3.4 m | Grey stony Sand. |
| F. | 3.4 — 5.2 m | Dark brown Mud, in which were found: |

*Alnus glutinosa*, numerous fruits, especially in the upper part; pollen,
*Arenaria trinervia*, 1 seed, uppermost,
*Betula pubescens*, fruits and catkin scales very common; pollen,
*Brasenia purpurea*, 1 seed,
*Carex pseudocyperus*, 7 fruits,
— *sp.*, fruits without utriculus,
*Ceratophyllum demersum*, some fruits (Pl. XXXI, 23—25),
— — *var. apiculatum*, many fruits,
*Corylus avellana*, some pollen,
*Frangula alnus*, 2 fruit-stones,
*Hypochoeris radicata*, 1 fruit (recent?),
*Lycopus europaeus*, nuts fairly numerous,
*Menyanthes trifoliata*, seeds fairly numerous,
*Najas marina*, 4 fruits,
*Nuphar luteum*, several seeds,
*Nymphaea alba*, several seeds,
*Picea excelsa*, some pollen,
*Pinus silvestris*, much pollen,
*Polypodium vulgare*, 1 spore,
*Potamogeton natans*, numerous fruit-stones,
— *praelongus*, many fruit-stones,

*Potamogeton sp.*, many fruit-stones,
*Potentilla sp.*, 1 fruit,
*Quercus sp.*, much pollen,
*Rubus idaeus,* 2 fruit-stones,
*Rumex sp.*, 3 fruits with perigonium,
*Scirpus lacuster,* 1 fruit,
*Sparganium erectum*, fruit-stones fairly numerous,
*Typha latifolia,* 1 pollen tetrad,
*Ulmus sp.*, some pollen,
*Urtica dioeca,* 3 fruits.

G. 5.2 — 8.2 m Grey stoneless Glay without chalk, some Mud in the upper part:
*Batrachium aquatile (coll.),* numerous fruits,
— *sceleratum,* 1 fruit, in the upper part of the stratum,
*Betula nana*, many fruits, 1 catkin scale,
— *pubescens*, some fruits,
*Carex sp.*, 1 fruit without utriculus,
[*Ceratophyllum demersum var. apiculatum*, a few fruits doubtless brought down from Stratum F],
*Hippuris vulgaris,* 2 fruits,
*Potamogeton filiformis,* several fruit,
— *praelongus,* 1 fruit,
*Potentilla cf. erecta,* many fruits, with very slightly wrinkled surface,
*Salix sp.*, several buds, 1—2 mm long,
*Scirpus lacuster,* 1 fruit, in the upper part,
*Sparganium erectum*, 1 fruit-stone.

*Calliergon Richardsonii*,
— *stramineum*,
*Helodium lanatum*,
*Hypnum aduncum*,
— *exannulatum*,
*Isothecium myosuroides*,
*Mnium cuspidatum*,
*Philonotis fontana*,
*Swartzia montana*,
*Thuidium delicatulum*.

H. 8.2 — 8.5 m Grey sandy Moraine Clay.

The flora of Stratum G suggests that this stratum was formed in a climate essentially colder than that of Denmark at the present day, in as much as we find not only *Betula nana* abundantly represented there, but also several mosses of decidedly northern character such as *Calliergon Richardsonii, Helodium lanatum* and *Swartzia montana*. The flora was, however, hardly altogether arctic at the time when this stratum was being formed.

Among the numerous species in the mud stratum F should be specially noted *Brasenia purpurea* and *Najas marina*. This stratum was formed during the *Betula-Pinus* zone of the last interglacial, and a part of the zone characterized of the mixed oak forest, as a spectrum from the upper part of the mud shows consisted of the following: *Betula* 12 %, *Pinus* 19 %, *Ulmus* 1 %, *Quercus* 58 %, *Alnus* 9 %, *Picea* 1 %, *Corylus* 2 %. The *Carpinus* and *Picea* zones were not present here, and if formed at all, must have been carried away by solifluction over the southern margin of the basin during the glacial period.

## Sandfeld.

In the course of the borings for brown coal made in 1921 by the Technical Committee of the Ministry of the Interior, under the superintendance of V. MILTHERS, a boring was made 850 m S of the farmstead of Sandfeld Gaard, which lies abt. 17 km nearly S of Herning. The site is on the late glacial sand plain (Sandr) south of Skjern River, at the north-eastern corner of a small lake, see Fig. 8. The following profile is quoted from the boring journal:

| | | |
|---|---|---|
| A. | 0 — 9.35 m | Alternating layers of stoneless and stony Sand. |
| B. | 9.35 – 10.0 m | "Black clay with vegetable remains« Mud, (greyish brown at the top, lower down brown and finely arenaceous); vide infra. |
| C. | 10.0 —10.2 m | Grey, calcareous Clay without stones. In a sample from here was found a fruit of *Potamogeton cf. natans* and some pollen of *Alnus glutinosa*, *Betula sp.*, and *Pinus silvestris*. |
| D. | 10.2 —10.8 m | Dark Sand, stoneless at the top, coarse and stony at the bottom. Below this again was pale stoneless, calcareous Clay, bedded at 15 m depth on dark stoneless Sand (tertiary). |

There were two small samples from Stratum B; these contained, apart from pollen of forest trees (see Table 6) the following:

*Alnus glutinosa*, fruits, 1 catkin, at the bottom,
*Carex sp.*, fruits without utriculus,
*Ceratophyllum sp.*, hairs,
*Cornus sanguinea*, 1 fruit-stone,
*Dryopteris thelypteris*, numerous spores,
*Najas marina*, several fruits, at the bottom,
*Nuphar luteum*, 1 seed,
*Potamogeton sp.*, 1 fruit-stone,
*Polypodium vulgare*, several spores,
*Trapa natans*, 10 horns of fruits, at the bottom.

*Sphagnum sp.*, numerous spores.

*Spongilla lacustris*, silica spicules.

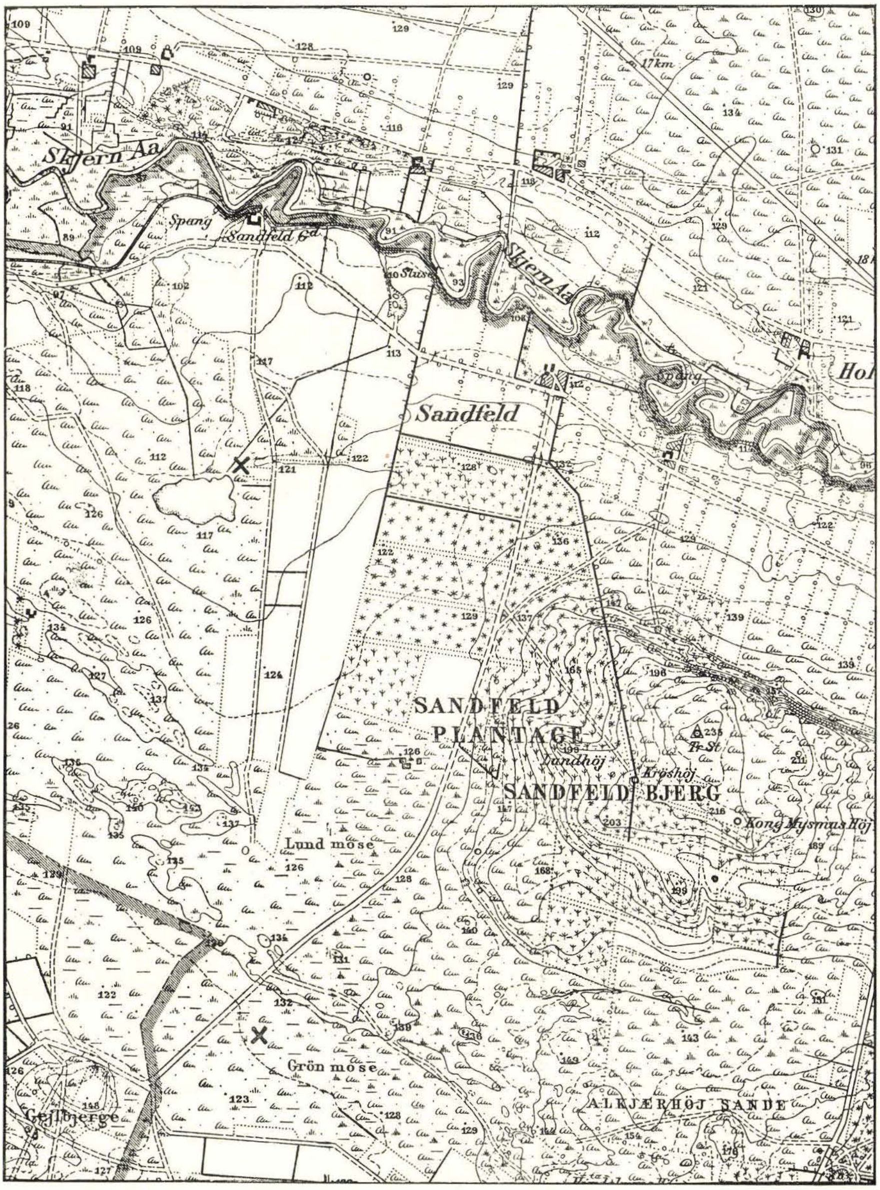


Fig. 8. Map showing position of the interglacial bogs at Sandfeld (cross to the north) and Grönmose (south). Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. From the General Staff Map Sheets 2706 and 2707.

The following pollen spectra were determined from the two samples from Stratum B: No. 1 uppermost, No. 2 below, see p. 141.

The profile shows that the fossiliferous strata, which are bedded on and covered by quaternary fluviatile material, must be still in

| No. | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Fraxinus?* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen-frequenay | Zones |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 20 | | 4 | | | 35 | 2 | 33 | 8 | 56 | *h* |
| 2 | | 6 | 2 | 25 | | 1 | 65 | | 1 | 16 | 90 | *f* |

Table 6. Pollen spectra from Sandfeld.

their primary position, and must be interglacial; this last is also confirmed by the presence of 33 % *Picea* pollen in Spectr. 1. The strata are covered by late glacial melting water sand and date presumably from the last interglacial period.

## Grönmose.

At this locality, which lies 1.9 km S of the boring at Sandfeld, interglacial lake deposits were likewise met with in the course of the borings for brown coal in 1921. The ground here is perfectly flat, presumably in this case also a late glacial sand plain (Sandr), and the spot lies abt. 0.6 km SW of Sandfeld Bjerg, Fig. 8. The following profile is taken from the boring journal:[1])

A. 0 — 8.0 m Sand.

B. 8.0 — 8.5 m "Black clay with vegetable remains" (greyish brown finely arenaceous Mud); vide infra.

C. 8.5 — 9.25 m Fine Sand.

D. 9.25—10.6 m Alternating layers of sandy Clay and coarse, quaternary Sand.

E. 10.6 —10.9 m "Black clay with plants" (grey muddy Sand with wood and small pieces of charcoal and other vegetable remains); vide infra. Below this, alternating layers of "micaceous clay" and sandy clay — possibly quaternary material — throughout the rest of the boring to a depth of 15 m.

Some small samples were obtained for examination from Strata B, C and E. Sample C contained no vegetable remains; the two others yielded the following:

Stratum B.

*Empetrum nigrum*, 1 fruit-stone,
*Picea excelsa*, several pieces of wood,
*Potentilla palustris*, a few fruits,
*Salix sp.*, a few buds.
Also some pollen of *Alnus*, *Betula*, *Picea* and *Pinus*.

Stratum E.

*Alnus glutinosa*, several fruits and catkins,
*Carex sp.*, fruits without utriculus,

1) Here so well as at Sandfeld the boundaries of strata cannot be stated with absolute precision.

*Lycopus europaeus*, 2 nuts,
*Ranunculus repens*, 2 fruits,
*Urtica dioeca*, 6 fruits.
The sample contained a considerable amount of pollen, and the following spectrum was arrived at: *Betula* 5 %, *Pinus* 16 %, *Quercus* 23 %, *Alnus* 54 %, *Picea* 2 % and *Corylus* 30 %; Zone *f*.

These fossiliferous interglacial strata should doubtless also be referred to the last interglacial period. It is remarkable that the two plant-bearing strata B and C are separated by abt. 2 m of sand and sandy clay, which appear to be non-fossiliferous.

## Tiphede.

In the course of the borings for brown coal which in 1921 led to the discovery of the interglacial deposits at Solsö, Sandfeld and Grönmose, a plant-bearing, unquestionably interglacial stratum was also found at Tiphede, abt. 5 km N of Solsö. The site is 900 m W of Tiphede Church, in a small valley running down towards Abild Brook, and 450 m E of this. According to the boring journal, the profile here was as follows:

| | | |
|---|---|---|
| A. | 0 — 1.25 m | Peat. |
| B. | 1.25 - 6.0 m | Gravel. |
| C. | 6.0 — 6.5 m | "Clay with wood", i. e. Mud with numerous vegetable remains. |
| D. | 6.5 —10.0 m | Clay with mica. |

A small sample from Stratum C yielded the following vegetable remains:

*Alnus glutinosa*, fruits and catkins, also numerous fragments of wood and pieces of branches with bark,
*Batrachium aquatile (coll.)*, 1 fruit,
*Corylus avellana*, 1 nut,
*Mentha cf. aquatica*, 1 nut,
*Montia lamprosperma*, 1 seed,
*Ranunculus lingua*, several fruits,
 - *repens*, 1 fruit,
*Urtica dioeca*, 8 fruits.

This plant-bearing deposit seems to be situated in a similar manner to that of the peat strata found in the valley between the interglacial bogs at Dalager Nygaard and Dalager (p. 137) and may probably be referred to the last interglacial period.

## Ringdal.

South of the road between Rousthöje and Roust, abt. 1.2 km west of the latter village, lies a small lake, near the farm of Ringdal, 10 km SE of Varde. The lake measures abt. 150 m from north to south, is nearly 40 m broad, and lies in a kind of gully between hills rising

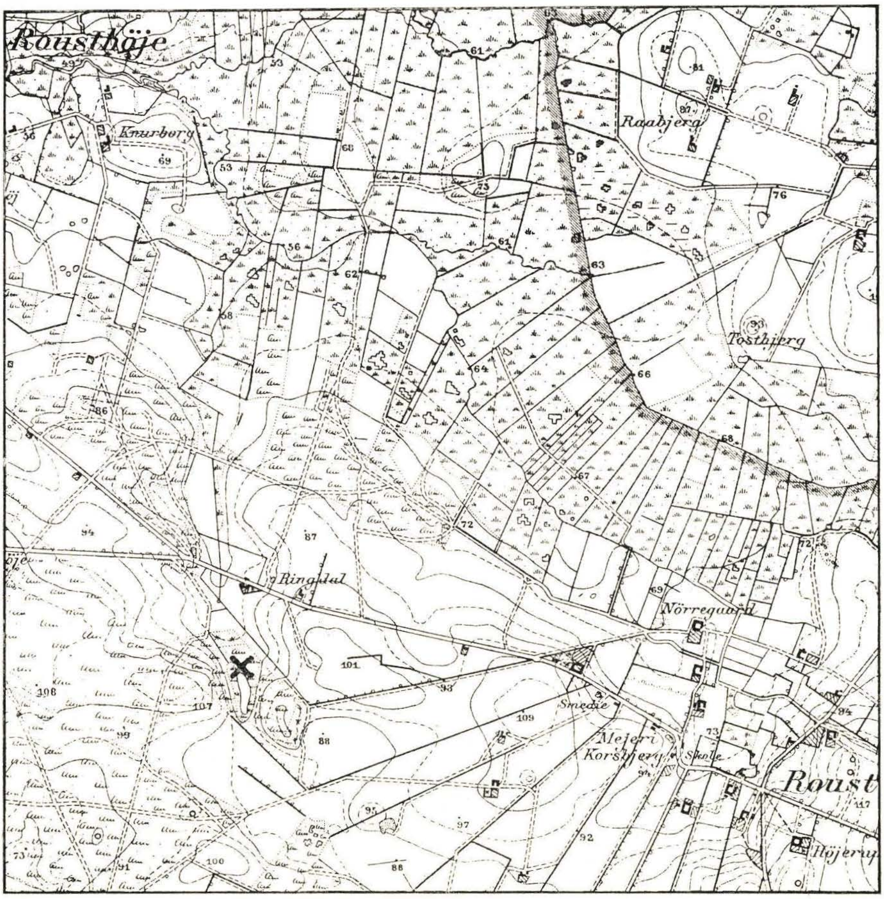


Fig. 9. Map showing position of the interglacial bog at Ringdal (×). Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. The General Staff Map Sheet 3304.

east and west of the lake to about 9 m above its water level; it is surrounded by a narrow border of meadowland, and is drained by a ditch which follows the valley-like continuation of the above-mentioned gully, northward to the great peat-filled shallow basin east of Rousthöje, where Alslev Brook has its source. Cf. Fig. 9. The surface formation round the lake is fluvioglacial sand.[1])

1) AXEL JESSEN: Kortbladet Varde. D. G. U. I. R., Nr. 14. 1922.

In 1922, we made a boring at the northern end of the lake with the following result:

| | | |
|---|---|---|
| A. | 0 — 0.3 m | Peat. |
| B. | 0.3 — 2.1 m | Stony Sand; stones the size of hen's eggs. |
| C. | 2.1 — 6.25 m | Greyish stoneless or almost stoneless Clay with a slight admixture of Mud components. The stratum was non-calcareous for about the upper metre, the remainder but slightly calcareous; some vivianite was present.<br>Five washing samples yielded but few vegetable remains, viz.:<br>*Batrachium aquatile (coll.)*, 2 fruits,<br>*Betula pubescens*, 2 fruits,<br>*Carex sp.*, 1 fruit without utriculus,<br>*Ceratophyllum submersum*, $1/2$ fruit at the bottom of the stratum,<br>*Corylus avellana*, 1 grain of pollen, at the bottom,<br>*Pinus silvestris*, some pollen, at the bottom,<br>*Potamogeton filiformis*, numerous fruits,<br><br>*Catoscopium nigritum*, in the upper part of the bed,<br>*Hypnum exannulatum*,<br>*Scorpidium scorpioides*,<br>*Sphagnum sp.*,<br>*Thuidium sp.* |
| D. | 6.25— 6.75 m | Sandy Moraine Clay. |

*Catoscopium nigritum* is a decidedly northern species, no longer found in Denmark; it was here discovered in the upper portion of Stratum C, while the relatively southern form *Ceratophyllum submersum* was found near the lower margin of the stratum. This suggests that the clay-mud belongs to the last part of the interglacial period. The clay-mud was very poor in pollen.

## Rodebæk II.

About 125 m SE of the interglacial Bog Rodebæk I and just north of the road between Rodebæk and Faaborg, there is a bog situated in a small hollow measuring abt. 75 m in diameter. See Fig. 3, p. 90 and Pl. XVIII, 2. The maximal extent of the bog is abt. 50 m. The surface layer in the ground surrounding this bog, and the adjacent Rodebæk I and Rodebæk III, consists of fluvioglavial sand.[1])

About the middle of the basin was made our Boring 1.

Boring 1.

| | | |
|---|---|---|
| A. | 0 — 1.25 m | Post-glacial Peat. |
| B. | 1.25— 5.1 m | Sand, the upper part with a few small stones, the lower half-metre with stones the size off eggs: at the top, 30 cm |

1) Axel Jessen: Kortbladet Varde. D. G. U. I. R., Nr. 14.

sand with hard pan. Between 4.25 and 4.45 a layer of greyish-brown sandy Mud in which were found a few seeds of *Menyanthes trifoliata*.

| | | |
|---|---|---|
| D. | 5.1 — 5.65 m | Mud, the upper part rich in plant detritus, the lower part sandy, with considerable abundance of vegetable remains, see p. 146. |
| F. | 5.65— 6.15 m | Gravel, with stones the size of eggs; the lead pipe could not be carried deeper than 5.65 m but the sand pump was abt. $1/2$ m farther down. As it was uncertain whether this gravel bed represented the bottom of the bog, or possibly an intermediate stratum, a Middle Bed, covering over another bed of mud below, another boring (2) was made 8 m north of Boring 1. |

Boring 2.

| | | |
|---|---|---|
| A. | 0 — 1.45 m | Peat above Mud, the latter making a stratum 15 cm thick. |
| B. | 1.45— 4.35 m | Sand with stones the size of eggs, the lower part gravelly. |
| C. | 4.35 — 5.65 m | Brown Muddy Sand. In the upper portion of the stratum were found a couple of fruits of *Batrachium sceleratum*, *Empetrum nigrum* and *Carex sp.*; among the species found in washing samples from the lower portion of the stratum, as shown in the table, should be noted especially *Ajuga reptans*. |
| D. | 5.65— 7.55 m | Coarse Detritus Mud, brown at top and bottom, greenish in the middle, and here with vivianite. The lower part of the stratum contained shell fragments of *Unio sp.* and lids of *Bithynia tentaculata*. |
| E. | 7.55 - 8.20 m | Greyish green, sandy, slightly calcareous Mud. |
| F. | 8.20— 9.00 m | Sandy Moraine Clay. |

The two last-named mud beds especially contained numerous seeds and fruits. Particularly interesting was the finding of a couple of large *Najas* fruits, 5.5 mm long and 3 and 2.5 mm broad respectively. *Ceratophyllum demersum* with powerfully developed lateral horns on the fruits was rare, but the form *apiculatum* Cham, distinguished by wart-like lateral horns, was common. This form of fruit constitutes a transition to the — post-glacial — southern species *C. submersum*, of which many good fruits were found.

The pollen diagram (Pl. XXXVII, 3) shows the development of the forest growth. The *Betula-Pinus* zone reaches as far as Spectr. 7, the mixed oak forest covers Spectr. 6—4. *Carpinus* is poorly represented, only attaining 2 % in Spectr. 3. In the upper part of the diagram, *Pinus* and *Picea* are, with *Betula*, the predominating species of forest trees.

In the upper part of the mud bed (D) in Boring 1, there was but very little pollen, but in the lower portion, the following spectrum was found: *Betula* 12 %, *Pinus* 14 %, *Ulmus* 3 %, *Quercus* 48, *Alnus* 23 % and *Corylus* 86 %. This fits in very well in the pollen diagram between Spectr. 4 and 5, save as regards *Corylus* but the maximum for this in the diagram has undoubtedly not been reached, and presumably lies between the two spectra mentioned. The lower part of the mud stratum D in Boring 1 is thus synchronous with the upper half of Stratum D in Boring 2. Otherwise, nothing is known as to the relation between the gravel bed F and the sedimentation in the little lake.

## List of the Species found in Rodebæk II.

cc very common, c common, + fairly common, r rare.

| Species | Boring 1 | | Boring 2 | | | |
|---|---|---|---|---|---|---|
| | D Upper | D Lower | C | D Upper | D Lower | E |
| *Ajuga reptans* | | | r | | | |
| *Alnus glutinosa* | c | cc | c | c | | r |
| *Arenaria trinervia* | | | r | | | |
| *Batrachium sceleratum* | + | c | + | r | r | |
| *Betula pendula* | | | | | + | |
| — *pubescens* | | c | | + | cc | c |
| *Carex pseudocyperus* | + | c | c | + | + | + |
| — *rostrata* | + | r | | r | r | r |
| *Carpinus betulus*[1] | | | r | r | | |
| *Ceratophyllum demersum* | | | | | | r |
| — *demersum var. apiculatum* | r | + | | r | + | c |
| — *submersum* | | | cf. | | c | r |
| *Cladium mariscus* | | + | | | | |
| *Corylus avellana* | | + | | c | | |
| *Dryopteris thelypteris*[1] | c | | + | + | + | + |
| *Empetrum nigrum* | | | r | | | |
| *Eupatorium cannabinum* | + | r | | r | r | |
| *Hippuris vulgaris* | + | r | | | r | |
| *Lampsana communis?* | | r | | | | |
| *Lycopodium annotinum*[1] | | | | | r | |
| *Lycopus europaeus* | | r | | r | | r |
| *Mentha cf. aquatica* | | r | | | | |
| *Menyanthes trifoliata* | | | | r | | + |
| *Myosoton aquaticum* (Pl. XXXII, 15) | | r | | | r | |
| *Myriophyllum cfr. spicatum* | | r | | r | r | r |
| *Najas marina* | | + | | r | c | + |
| *Nasturtium aquaticum* (Pl. XXXV, 26—28) | r | c | | | | r |
| *Nuphar luteum* | | + | | | | r |
| *Nymphaea alba* | | r | c | + | + | c |
| *Picea excelsa* | | | r?, +[1] | | | |
| *Pinus silvestris*[1] | | | c | + | c | c |
| *Polygonum tomentosum* | | | r | | | |
| — *sp.* | | r | | | | |
| *Potamogeton natans* | | | r | r | r | + |
| *Quercus sp.* | | | r | c | + | |
| *Ranunculus cf. repens* | r | | | | | |
| *Rubus idaeus* | r | r | r | | + | |
| *Salix sp.*[1] | | | | | r | r |
| *Scirpus lacuster* | + | cc | c | r | r | r |
| *Sparganium erectum* | | | | r | r | r |

[1] Pollen. [2] Spores and Sporangia.

| Species | Boring 1 | | Boring 2 | | | |
|---|---|---|---|---|---|---|
| | D Upper | D Lower | C | D Upper | D Lower | E |
| *Sparganium minimum* | ..... | r | ..... | ..... | ..... | r |
| *Stachys silvaticus* | ..... | ..... | ..... | r | ..... | ..... |
| *Typha latifolia* | ..... | ..... | ..... | ..... | r | r |
| *Ulmus sp.*[1]) | ..... | ..... | ..... | + | + | r |
| *Urtica dioeca* | + | + | c | r | r | r |
| *Viola palustris* | ..... | ..... | ..... | ..... | ..... | r |
| *Sphagnum sp.* | ..... | ..... | ..... | ..... | + | r |
| *Characeae* | ..... | ..... | ..... | ..... | ..... | r |
| *Diatomaceae* | ..... | ..... | ..... | ..... | r | ..... |
| *Botryococcus Braunii* | ..... | ..... | ..... | ..... | r | ..... |
| *Rivulariaceae* | ..... | + | ..... | ..... | ..... | ..... |
| *Cladocera* | ..... | ..... | ..... | ..... | + | + |
| *Spongilla lacustris* | ..... | ..... | ..... | ..... | + | + |

# Rodebæk III.

About 100 m SW of Rodebæk I the map Fig. 3 shows a farmstead, lying in a hollow distinctly noticeable in the landscape, the deepest part being directly N of the house, in the fowl run. On the west especially, the basin is bounded by a considerable slope, planted with spruce.

A boring carried out in 1923 in the fowl run, abt. 20 m W of the road, gave the following profile:

A. 0 — 0.4 m Rubbish with Mould below.

B. 0.4 — 1.9 m Stony Sand, with egg-sized stones.

C. 1.9 — 2.8 m Brown stratified Forest Peat with much wood and bark, the uppermost part chiefly Birch Wood Peat with numerous spores of *Sphagnum sp.*, and epidermis of *Eriophorum vaginatum*; also a flake of the bark of *Picea excelsa*, a fruit and some pollen of *Empetrum nigrum*, a fruit of *Carex-pseudocyperus* and some of *Carex sp.* — In a preparation made for pollen analysis 2, numerous fragments of leaves were found with the characteristic hair-fringes of *Trichocolea tomentella* (Pl. XXXV, 29—30). This plant is now very rare in Denmark but is found, e. g. on swampy forest soil.[2])

The bottom of the layer had developed like Alder Wood Peat; here, *inter alia*, a fruit of *Batrachium sceleratum*, numerous spores of *Dryopteris thelypteris*, a spore of *Polypodium vulgare* and leaf epidermis of *Pinus silvestris* were found.

[1]) Pollen. [2]) C. JENSEN: Danmarks Mosser, I, Copenhagen 1915, p. 173 f.

D. 2.8 — 3.5 m Mud, brown and free from chalk:
*Alnus glutinosa*, several fruits,
*Batrachium sceleratum*, fairly many fruits,
*Carex pseudocyperus*, several fruits,
— *sp.*, several fruits without utriculus,
*Ceratophyllum demersum* mainly *var. apiculatum*, several fruits,
*Ceratophyllum cf. submersum*, 1 fruit,
*Dryopteris thelypteris*, numerous spores,
*Najas marina*, 1 fruit,
*Nymphaea alba*, 1 seed,
*Picea excelsa*, 1 bud scale,
*Polypodium vulgare*, 1 spore,
*Potamogeton sp.*, 1 fruit,
*Prunus sp.*, fragment of a fruit-stone,
*Scirpus lacuster*, several fruits,
*Typha latifolia*, a few pollen tetrads,
*Urtica dioeca*, several fruits.

*Spongilla lacustris*, siliceous spicules.

E. 3.5 — 5.3 m Greyish green somewhat calcareous Mud:
*Betula pubescens*, many fruits,
*Carex sp.*, several fruits without utriculus,
*Ceratophyllum sp*, 1 fruit, many leaf tips
*Dryopteris thelypteris*, spores,
*Nuphar luteum*, pollen,
*Nymphaea alba*, 1 seed,
*Pinus silvestris*, flakes of bark,
*Scirpus lacuster*, some few fruits.

*Cladocera*,
*Spongilla lacustris*, siliceous spicules.

F. 5.3 — abt. 6.15 m Grey, sandy, rather chalky argillaceous Mud, in which were found:
*Betula pubescens*, many fruits,
*Carex sp.*, 1 fruit without utriculus,
*Hippuris vulgaris*, 3 fruits,
*Myriophyllum sp.*, 1 grain of pollen,
[*Najas marina*, 1 fruit, presumably derived from E or D]
*Potamogeton cf. praelongus*, 1 fruit,
*Umbelliferae*, 1 grain of pollen,
*Urtica dioeca*, 1 fruit.

*Spongilla lacustris*, silica spicules.

G. abt. 6.15— 7.10 m Grey, sandy micaceous Clay (diluvial clay).

The Pollen diagram (Pl. XXXVII, 4) shows the distribution of the different species of pollen in the 9 spectra. The deepest sample (9) was very poor in pollen (frequency 8); the mixed oak forest is represented here only by *Quercus*. *Betula* and *Pinus* predominate in the lower part of E and the upper portion of C. *Quercus* and *Ulmus* occur in Spectr. 8, each with 1 %, the former culminating in Spectr. 6 with

44 %, while *Ulmus* shows almost uniform frequency throughout the three spectra 5, 6, 7 (4—6 %). The empirical limit of *Corylus* pollen lies deep down in the profile (Spectr. 8) but its rational limit is first reached at the point where *Quercus* culminates, and *Alnus* occurs for the first time. The culmination of *Alnus* falls somewhat later than that of *Corylus*. *Carpinus* is represented by 1 % in Spectr. 5, where the rational limit for *Picea* may be fixed and by 3 % in Spectr. 3; *Picea* has its maximum in Spectr. 3. We can here then, from the material available, draw up 5 horizons, connected by gradual transition, and designated in the pollen diagram with the letters, *d*, *e*, *f*, *gh* and *i*; see Chapter VII.

The amount of calcium carbonate contained in the ground within the narrow limits of the watershed enclosing this little pool has been sufficient to set its mark on the sedimentation there throughout a considerable period, during which time the mixed oak forest culminated, whereas the curves for *Picea* and *Pinus* first attain their maximum up in the non-calcareous strata; this is a feature which recurs in several of the other diagrams, and will be mentioned later on.

## Höllund Sögaard.

The interglacial bog at Höllund Sögaard, which lies abt. 16 km north of Brörup railway station, has been known since the excavations made there by N. HARTZ in 1903.[1]) Since then, the bog has been repeatedly subjected to investigation[2]) and in 1922, V. MILTHERS made a boring there in order to obtain further data as to the substratum of the bog. This boring was made in the north-eastern part of the bog, and 7.5 m NW of the well which stands in the bog itself, whereas the diggings previously made had been situated in the south-western part. The surface of the ground above the bog, the extent and position of which are shown on the map Fig. 19, p. 192 in the work of N. HARTZ, presents the usual appearance of a shallow depression, the lowest portion lying 2.35 m below the surrounding country.

The profile revealed by the boring was as follows:

A. 0 — 2.0 m Sand, the upper part containing a bed of stones, the lower part argillaceous.

B. 2.0 — 2.1 m Pale grey Clay.

C. 2.1 — abt. 3.25 m Brown (uppermost greyish brown) sandy, presumably redeposited Peat, in which were found *inter alia* fruits of *Betula nana*, some fragments of bark from *Picea excelsa*, and the pollen species noted in the pollen diagram Pl. XXXVII, 5.

1) N. HARTZ. Bidrag etc. D. G. U. II. R. No. 20. 1909, p. 193 f.

2) AXEL JESSEN, VICTOR MADSEN etc.: Brörup-Mosernes Lejringsforhold. D. G. U. IV. R. No. 9, 1918, p. 14 f.

D. abt. 3.25 – 5.0 m Brown, mouldlike Peat; the lower part highly humified *Sphagnum*-Peat. The stratum contained *inter alia* fruits of *Betula pubescens*, needles of *Picea excelsa*, leaf epidermis of *Pinus silvestris*, a catkin scale of *Populus tremula*, (in the upper part), leaf sheaths of *Eriophorum vaginatum*, branches of *Calluna vulgaris*, seeds of *Andromeda polifolia* etc. Spectr. 4–7.

E. 5.0 – 5.75 m Brown, stratified fresh *Sphagnum-Eriophorum vaginatum* Peat with thin layers of hard brown Mud. Among the flora may be mentioned: three seeds of *Brasenia purpurea*, several fruits of *Potamogeton natans*, a fruit of *Carex pseudocyperus*, 3 nuts of *Lycopus europaeus*, 2 fruits of *Rhyncospora alba*, a few needles of *Picea excelsa*, leaf epidermis of *Pinus silvestris*. Spectr. 8–9.

F. 5.75 – 6.4 m Rather fine Sand, enclosing a thin layer of finely arenaceous brown Mud. Spectr. 10.

G. 6.4 – 7.2 m Uppermost, brown Clay Mud, lower down, alternating with layers of Sand. Only in the lowest portion were any identifiable plant remains found, among which may be mentioned fruits of *Betula pubescens* and flakes of bark from *Pinus silvestris*.

H. 7.2 – 10.0 m Grey Sand without stones, 10 cm hard pan at the top.

J. Gravel with large stones.

For comparison with this profile, we give here that described by Hartz (l. c.) from the southern part of the bog:

0.50 – 0.75 m Sand with a few small sand-worn stones.

1.50 – 1.75 m Stratified Sand without stones.

0.80 – 1.00 m "Transition stratum" (brown Loamy Sand) containing *Betula nana*.

1.35 m Compressed *Sphagnum* Peat. Throughout the upper metre of the stratum were found *Betula nana* with *Picea excelsa* and *Vaccinium uliginosum*. The peat also contained *Dulichium spathaceum*, *Oxycoccus palustris* and a leaf fragment of *Quercus sp.*

Coarse Sand.

## List of the Fossils found in the Interglacial bog at Höllund Sögaard, Boring 1922.

c common, + fairly common, r rare.

| Species | C | D | E | F | G |
|---|---|---|---|---|---|
| *Alnus glutinosa*[1] | + | + | c | r | .... |
| *Andromeda polifolia* | r | + | .... | .... | .... |
| *Betula nana* | + | .... | .... | .... | .... |
| — *pubescens* | .... | + | + | .... | r |
| — *sp.*[1] | c | c | + | + | .... |
| *Brasenia purpurea* | .... | .... | r | .... | .... |
| *Calluna vulgaris* | r | r | r | .... | .... |

[1]) Pollen.

| Species | C | D | E | F | G |
|---|---|---|---|---|---|
| *Carex pseudocyperus* | ..... | ..... | r | ..... | ..... |
| — *sp.* | r | c | + | ..... | r |
| *Carpinus betulus*[1] | [+] | + | r | ..... | ..... |
| *Corylus avellana*[1] | [+] | r | c | r | ..... |
| *Dryopteris thelypteris*[2] | ..... | ..... | c | r | ..... |
| *Empetrum nigrum* | + | + | ..... | ..... | ..... |
| *Ericaceae*[1] | c | c | + | ..... | ..... |
| *Eriophorum vaginatum* | ..... | + | c | ..... | ..... |
| *Gramineae*[1] | ..... | r | r | r | ..... |
| *Ilex aquifolium*[1] | r | ..... | r | ..... | ..... |
| *Lycopus europaeus* | ..... | ..... | r | ..... | ..... |
| *Menyanthes trifoliata* | ..... | ..... | + | ..... | ..... |
| *Nymphaeaceae* (intercell. hairs) | ..... | ..... | + | ..... | ..... |
| *Osmunda regalis*[2] | r | r | r | ..... | ..... |
| *Picea excelsa* | r, +[1] | r, +[1] | r, r[1] | ..... | ..... |
| *Pinus silvestris*[1] | c | c | + | c | r |
| *Polypodium vulgare*[2] | r | ..... | ..... | ..... | ..... |
| *Populus tremula* | ..... | r | ..... | ..... | ..... |
| *Potamogeton natans* | ..... | ..... | + | ..... | r |
| *Potentilla palustris* | ..... | ..... | r | ..... | ..... |
| *Quercus sp.*[1] | r | r | c | + | ..... |
| *Rhyncospora alba* | ..... | ..... | r | ..... | ..... |
| *Sparganium minimum* | ..... | ..... | ..... | ..... | r |
| *Tilia sp.*[1] | ..... | ..... | r | ..... | ..... |
| *Ulmus sp.*[1] | r | r | r | r | ..... |
| *Umbelliferae* | ..... | ..... | r | ..... | r |
| *Sphagnum sp.* | c | c | c | ..... | ..... |
| *Cenococcum geophilum* | r | ..... | r | ..... | ..... |
| *Tilletia sphagni* | ..... | r | ..... | ..... | ..... |
| *Amphitrema flava* | ..... | ..... | c | ..... | ..... |

There is no pollen spectrum from Stratum G, but from the flora list for the lower part of this stratum, together with Spectr. 10 from the covering layer (Pl. XXXVII, 5), it must be presumed that the greater portion of Stratum G belongs to zones *c* and *d*. No "lower arctic flora" is known from Höllund Sögaard. Spectrum 10 should presumably be referred to zone *e*, where *Pinus* often has its lower maximum. Stratum F must be regarded as w a t e r-b o r n e sand (Schwemmsand), and since we may take it that the boring was made somewhere near the deepest part of the lake, the formation of this deposit suggests that the water in the lake was at a very low level at that time. We can however, in the $^3/_4$ m of Stratum E above, trace an alternation between limnian stages, when the lake produced *Brasenia purpurea* and *Potamogeton natans*, and semi-limnian stages, when quaking bog like formations with *Rhyncospora alba*, *Carex pseudocyperus* and *Lycopus europaeus* encroached over the lake. This shows that even in the period of mixed oak forest (Zone *f*) there was still much moisture

[1] Pollen. [2] Spores.

remaining in the basin. Within this zone we have, as usual, the culmination of the mixed oak forest, *Alnus* and *Corylus*, but the sequence here differs from the usual, *Alnus* culminating first. Stratum E may be regarded as synchronous with the lower part of the *Sphagnum* peat stratum in HARTZ's profile.

After this, the former lake was covered over with a bog of *Sphagnum*-peat, giving rise to the formation of the highly humified peat Stratum D. The boundary between Strata E and D coincides with the transition from mixed oak forest to conifers. The diagram exhibits a *Carpinus* maximum (Spectr. 7) preceding that of *Picea*, which is distinctly apparant in Spectr. 6. The *Pinus* pollen is predominant throughout all spectra from 7—1. The second conifer period commenced with the arrival of the relatively dry conditions which led to the formation of Stratum D. In Stratum C the amount of sand gradually increases. This stratum, especially as regards its upper part, was presumably formed during a partial transposition of older material originating from the upper part of Stratum D and the lower part of Stratum C. Taking this to be the case, we cannot, then, from the section of the diagram in question, venture upon any determination of the composition of the forest, as a great part of the pollen from here may perhaps have been shifted from its original position. But the fact that Stratum C contains *Betula nana* shows that a new, northerly element had now been added to the flora; the course of development now is marked by the approaching sub-arctic period. Stratum C in the 1922 profile is evidently synchronous with the "transition stratum" and probably the uppermost part of the *Sphagnum*-peat in HARTZ's profile.

The deposit of predominantly organogenic material terminated here with the formation of the clay stratum B, which gradually gave place to the sand stratum A, the lower part of this being argillaceous, and the upper part contained a few small stones. Just as Stratum C, in its upper portion, bears witness to increased influence of the water notifyed by the transposition of the peat, so also Stratum B and the lower part of A show that the basin could, at any rate from time to time, accomodate a shallow lake.

In a section through the marginal zone of the bog in the southern part of the basin, the covering strata above the bog appeared — save for a thin layer of wind blown sand — as products of solifluction, consisting mainly of a sandy, moraine-like stratum, "which, farther north out over the bog gradually gives place to sand with a very few small stones, and finally, in the deepest parts of the bog, to stoneless, stratified, distinctly water-sorted sand".[1]) It is this distal, water-sorted

[1]) AXEL JESSEN, VICTOR MADSEN etc.: Brörup-Mosernes Lejringsforhold. D. G. U. IV. R., No. 9, 1918, p. 15.

derivate of the moraine-like solifluction deposit from the marginal zone which is comprised by Stratum B and the lower part of Stratum A in the 1922 profile. The upper part of Stratum A, consisting of sand with small stones, thus represents the last phase in the filling-up of the basin, when the solifluction extended right out over the former lake.

## Fövling.

About 2 km NE of Fövling Church and abt. 6 km SW of Brörup railway station, there is a bog, which in rainy periods becomes flooded and turns into a small pond. This emphasises very nicely the character of the basin, as that of a depression without outlet, Fig. 10 and Pl. XIX, 1.

In 1922, a boring was made on the north side of this water-filled bog-hole, giving the following profile:

| | | |
|---|---|---|
| A. | 0 — 2.5 m | Fine Sand without stones. Gradual transition to the layer below. |
| B. | 2.5 — 4.7 m | Fine Sand, with a quantity of plant detritus, mainly crumbled wood, with seeds and fruits. The quantity increases from above downwards. In the lower portion, some few muddy strata. |
| C. | 4.7 — 6.0 m | Hard brown Mud separated by thin layers of Sand; numerous vegetable remains. |
| D. | 6.0 — 6.2 m | Brown sandy Mud with stones up to the size of nuts; much wood detritus and other vegetable remains. |
| E. | 6.2 — 6.7 m | Gravel. |
| F. | 6.7 — 6.8 m | Sandy Moraine Clay. |

The samples collected from B, C and D yielded after washing numerous determinable remains of plants, as noted in the accompanying list. We may note especially *inter alia* the typical interglacial forms such as *Brasenia purpurea*, *Picea excelsa*, *Carpinus betulus* and *Ilex aquifolium*; these finds show that we have here again indubitable interglacial deposits despite the fact that the stoneless, fine-grained covering sand as found in the bore, does not *eo ipso* point to glacial origin. Among the plants we must also especially note the rare forms *Trapa natans*, of which fairly many flattened fruits were found, *Najas flexilis*, *Hydrocotyle vulgaris* and *Montia lamprosperma*, represented only by a few fruits or seeds.

Fig. 1 on Pl. XXXVII shows 6 pollen analyses; on comparing these with the results of the washing as noted in the list, it will be seen that several of the macroscopic plant remains must doubless have been carried down by the process of boring (for which the pumping method was used) to a level below that where they certainly belong (*Picea*, *Carpinus*). This warns us to be careful in employing the washing-lists here as in other cases.

The pollen diagram shows that the alterations in the forest vegetation known also in other regions took place in the neighbourhood of Fövling while the interglacial lake deposits were in process of formation. *Betula* and *Pinus* were unquestionably the most prominent species in the oldest vegetation, which has left any trace here. Then

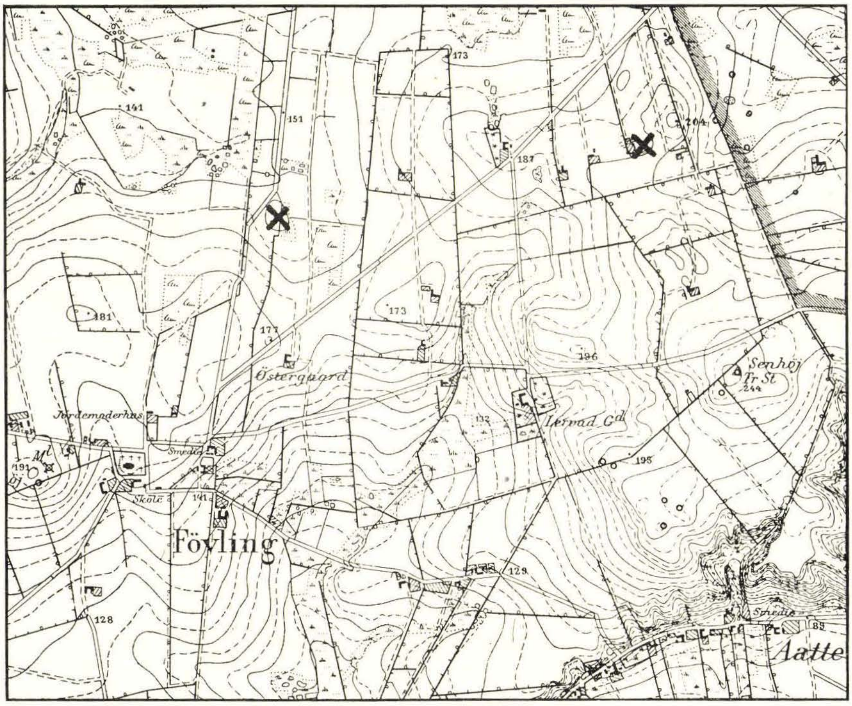


Fig. 10. District SW of Brörup with the interglacial bogs at Fövling (cross to the west) and Lervad (cross to the east). Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. From the General Staff Map Sheet 3506.

a mixed growth of foliage trees took possession of the ground, with successive culmination of the different species *Ulmus* (12 %), *Quercus* (46 %), *Corylus* (138 %) and *Alnus* (54 %). *Tilia* was here evidently but of altogether subordinate importance; we have 1 % of *Tilia* pollen in Spectrum 2, and answering to this, 1 *Tilia* fruit found in the same horizon. At the time when the sedimentation in the lake was changing its character, from mud to sand at the spot where our boring was made, *Picea*-pollen became common, *Pinus* and *Betula* also making progress. *Alnus* still shows a frequency of 34 % in spectrum 1, but has fallen off considerably. And while the conifers were thus advancing at the expence of the foliage trees, there was evidently also a spread of certain dwarf bushes, such as *Arctostaphylus uva ursi*, *Calluna vulgaris* and *Empetrum nigrum*, while layer B was being formed.

Simultaneously with the predominance of the mixed foliage trees on the land surrounding the lake, *Brasenia purpurea* and *Trapa natans* attained their highest frequency in its waters.

## List of the Fossils found in the Interglacial bog at Fövling.

c common, + not uncommon, r rare.

| Species | B | C | | | | D |
|---|---|---|---|---|---|---|
| | 2.5—4.7 m | 4.7—5.2 m | 5.2—5.5 m | 5.5—5.7 m | 5.7—6.0 m | 6.0—6.2 m |
| *Alnus glutinosa* | r, c[1]) | +, c[1]) | c[1]) | +, +[1]) | r[1]) | .... |
| *Arctostaphylus uva ursi* | r | .... | .... | r | .... | .... |
| *Betula pubescens* | c | c | r | + | + | c |
| *Brasenia purpurea* | r | c | + | + | .... | .... |
| *Calluna vulgaris* | + | r | .... | r | r | .... |
| *Carex lasiocarpa* | .... | .... | .... | .... | r | .... |
| — *pseudocyperus* | r | r | .... | .... | .... | + |
| — *rostrata* | .... | .... | .... | r | .... | .... |
| — *sp.* | c | + | + | r | + | .... |
| *Carpinus betulus* | r | r | .... | [r] | .... | .... |
| *Ceratophyllum demersum var. apiculatum* | r | + | + | + | .... | c |
| *Cladium mariscus* | r | + | .... | r | r | .... |
| *Corylus avellana*[1]) | r | c | c | c | r | r |
| *Dryopteris thelypteris*[2]) | + | + | + | + | + | + |
| *Empetrum nigrum* | c | r | r | r | r | r |
| *Frangula alnus* | .... | r | .... | .... | .... | .... |
| *Hippuris vulgaris* | .... | .... | .... | .... | .... | + |
| *Hydrocotyle vulgaris* | .... | .... | .... | r | .... | .... |
| *Ilex aquifolium* | .... | r | .... | .... | .... | .... |
| *Lycopodium sp.*[2]) | .... | .... | .... | .... | r | .... |
| *Lycopus europaeus* | .... | .... | .... | .... | .... | + |
| *Menyanthes trifoliata* | .... | r | .... | r | + | + |
| *Montia lamprosperma* (Pl. XXXII, 7) | .... | .... | r | .... | .... | .... |
| *Najas flexilis* | .... | r | .... | r | .... | .... |
| — *marina* | .... | r | r | .... | .... | .... |
| *Nuphar luteum* | .... | r | r | .... | r | + |
| *Nymphaea alba* | .... | r | r | r | r | + |
| *Picea excelsa* | c, c[1]) | + | r, r[1]) | [r] | [r] | [r] |
| *Pinus silvestris*[1]) | + | r | r | + | c | c |
| *Polypodium vulgare*[2]) | r | .... | .... | .... | .... | .... |
| *Potamogeton natans* | r | r | r | r | r | + |
| *Quercus sp.*[1]) | r | c | c | c | c | r |
| *Ranunculus cfr. flammula* | r | .... | r | .... | .... | .... |
| *Rubus idaeus* | + | .... | r | r | .... | r |
| — *sp.* | .... | .... | .... | .... | .... | r |
| *Salix sp.*[1]) | .... | .... | .... | r | .... | .... |
| *Sambucus cfr. nigra* | r | r | .... | r | .... | r |
| *Scirpus lacuster* | r | c | c | c | + | + |
| *Sparganium erectum* | .... | + | r | .... | r | .... |
| — *minimum* | r | .... | .... | .... | r | r |
| *Tilia cfr. cordata* | .... | r | .... | .... | .... | .... |
| *Trapa natans* | r | + | r | r | r | r |
| *Typha latifolia* | .... | .... | .... | .... | .... | r |
| *Ulmus sp.*[1]) | r | + | r | + | + | + |

1) Pollen. 2) Spores.

| Species | B | C | | | | D |
|---|---|---|---|---|---|---|
| | 2.5–4.7 m | 4.7–5.2 m | 5.2–5.5 m | 5.5–5.7 m | 5.7–6.0 m | 6.0–[illegible].2 m |
| *Hypnum exannulatum* | ..... | ..... | + | ..... | ..... | ..... |
| — *intermedium* | + | + | ..... | ..... | ..... | ..... |
| — *lycopodioides* | ..... | ..... | ..... | + | ..... | ..... |
| — *uncinatum* | ..... | ..... | ..... | ..... | ..... | + |
| *Meesea longiseta* | + | ..... | ..... | ..... | ..... | ..... |
| *Paludella squarrosa* | ..... | ..... | ..... | ..... | ..... | + |
| *Scorpidium scorpioides* | + | ..... | + | ..... | ..... | + |
| *Sphagnum sp.* | ..... | ..... | + | ..... | ..... | ..... |
| *Botryococcus Braunii* | r | ..... | ..... | r | ..... | r |
| *Pediastrum sp.* | r | ..... | ..... | ..... | ..... | ..... |
| *Rivulariaceae* | + | ..... | ..... | ..... | ..... | ..... |
| *Cenococcum geophilum* | + | ..... | r | + | ..... | ..... |

## Lervad.

N. HARTZ[1]) mentions an interglacial bog at Lervad Gaard, 4 km SW of Brörup, characterised by the usual slight depression in the ground, see Fig. 10. He had a couple of trenches made here in 1898, and gives the following profile:

| | | |
|---|---|---|
| 0 — 2.60 m | Sand. |
| 2.60— 2.90 m | "Black, rich Sand", "transition stratum". |
| 2.90— 3.05 m | Sphagnum Peat. |
| 3.05— 3.20 m | Sandy Mud. |
| 2.20— 4.50 m | Sand. |

Among the numerous vegetable remains which he found in the different strata of the bog may here be noted the following: *Calla palustris, Cornus sanguinea, Dulichium spathaceum, Fraxinus excelsior, Picea excelsa, Potamogeton densus, P. trichoides (condylocarpus), Taxus baccata* and *Viscum album.*

No climatic difference was apparent in the flora of the different strata.

In 1922, I made a boring in the same bog, in the course of which I came upon a stratum sequence evidently nearer the middle of the basin than that observed by HARTZ. The profile was as follows; the species found by me are noted in the list p. 157.

A. 0 — 0.45 m Mould.
B. 0.45— 1.35 m Argillaceous Sand with many stones up to the size of a head.

[1]) N. HARTZ: Bidrag . . . D. G. U. II. R. No. 20, 1909, p. 181.

| | | |
|---|---|---|
| C. | 1.35 – 1.95 m | Sand with numerous stones up to the size of a fist. |
| D. | 1.95 – 2.55 m | Argillaceous Sand with many small stones. |
| E. | 2.55 – 3.15 m | Black sandy Mud, brown when dry (HARTZ' "transition stratum"). It will be seen from Table 7 p. 158 that Spectr. 1 from here shows dominance of *Picea* and *Carpinus* together with *Betula* and *Alnus*. |
| F. | 3.15 – 4.15 m | Brown detritus Mud, very rich in wood fragments of some deciduous tree (*Betula*). Washings revealed an abundant flora, among which may be specially noted the southern forms *Potamogeton trichoides*, *Ceratophyllum submersum* and *Cornus sanguinea*. In the upper part of the stratum, the pollen from mixed oak forest is fairly well represented, (23 %), while *Corylus* has 54 %; the *Corylus* maximum, 150 %, falls about the middle of the stratum, in Spectr. 3. In the lower part of the stratum, *Betula* pollen was, strangely enough, almost sole prevailing, despite the fact that washings from this horizon also yielded fairly numerous fruits of *Potamogeton trichoides* as well as fruits of *Cornus sanguinea*, *Ceratophyllum demersum*, *Carex pseudocyperus*, *Lycopus europaeus* etc. |
| G. | 4.15 – 4.40 m | Brown, finely arenaceous argillaceous Mud. The flora approximately as in Stratum F, and the sample from here also exhibited a remarkably one-sided pollen spectrum (90 % *Betula*). The remaining species, represented in this spectrum as well as in Spectr. 4, were undoubtedly present in the vicinity of the lake (excepting perhaps *Picea*); presumably an extensive growth of *Betula pubescens* surrounded the site at the time. |
| H. | 4.40 – 4.75 m | Grey, stoneless non-calcareous Clay; flora approximately as in Stratum G. |
| J. | 4.75 – 5.25 m | Sand with numerous stones. |
| K. | 5.25 – 5.60 m | Sandy, stony Moraine Clay. |

## List of the Species found in the bog at Lervad in 1922.

c common, + not uncommon, r rare.

| Species | E | F | G | H |
|---|---|---|---|---|
| *Alnus glutinosa*[1] | c | c | | |
| *Arenaria trinervia* | | r | | |
| *Batrachium sceleratum* | | r | | |
| *Betula pendula* | | r | | |
| — *pubescens* | | c | c | r |
| — *sp.*[1] | c | c | c | |
| *Carex pseudocyperus* | | + | | r |
| — *sp.*[1] | + | | | r |
| *Carpinus betulus*[1] | c | r | | |
| *Ceratophyllum demersum var. apiculatum* | | r | r | |
| — *submersum* | | r | | |
| *Cornus sanguinea* | | r | r | |
| *Corylus avellana*[1] | + | c | r | |

[1]) Pollen.

| Species | E | F | G | H |
|---|---|---|---|---|
| *Dryopteris thelypteris*[2] | + | + | .... | .... |
| *Empetrum nigrum* | .... | .... | r | .... |
| *Eriophorum vaginatum* | .... | r | .... | .... |
| *Frangula alnus*[1] | r | .... | .... | .... |
| *Lycopus europaeus* | .... | r | r | r |
| *Cf. Origanum vulgare* (Pl. XXXIV, 10—11) | .... | r | .... | r |
| *Menyanthes trifoliata* | .... | c | r | r |
| *Nuphar luteum* | .... | r | r | .... |
| *Nymphaea alba* | .... | r | .... | .... |
| *Oenanthe phellandrium* | .... | r | .... | .... |
| *Osmunda regalis*[2] | c | r | .... | .... |
| *Picea excelsa*[1] | c | r | (r) | .... |
| *Pinus silvestris*[1] | r | r | r | .... |
| *Polypodium vulgare*[2] | r | .... | .... | .... |
| *Potamogeton filiformis* | .... | .... | + | r |
| — *natans* | r | + | r | r |
| — *trichoides* (Pl. XXXII, 23–26) | .... | + | + | r |
| — *spp.* | .... | + | .... | r |
| *Potentilla cfr. erecta* | .... | r | .... | .... |
| — *palustris* | .... | r | .... | .... |
| *Quercus sp.*[1] | r | + | r | .... |
| *Rubus idaeus* | r | r | .... | .... |
| *Salix sp.* | r | .... | .... | .... |
| *Scirpus lacuster* | .... | + | .... | .... |
| *Sparganium minimum* (Pl. XXXIII, 25) | r | r | .... | .... |
| *Tilia sp.*[1] | r | r | .... | .... |
| *Typha latifolia*[1] | .... | r | .... | .... |
| *Ulmus sp.* | r | r | r | .... |
| *Umbelliferae*[1] | .... | r | .... | .... |
| *Viola palustris* | .... | r | .... | .... |
| *Sphagnum sp.* | + | + | .... | .... |
| *Cenococcum geophilum* | c | + | .... | r |
| *Tilletia sphagni* | + | r | .... | .... |
| *Botryococcus Braunii* | .... | + | .... | .... |
| *Rivulariaceae* | .... | + | .... | .... |
| *Amphitrema flava* | .... | r | .... | .... |

| No. | Stratum | Depth | *Salix* | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen-frequency | Zone |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | E | Middle | | 26 | 6 | 1 | 3 | 1 | 24 | 19 | 20 | 21 | 237 | *g* |
| 2 | F | Upper | | 40 | 8 | 4 | 18 | 1 | 23 | 1 | 5 | 54 | 112 | *f* |
| 3 | F | Middle | 1 | 47 | 4 | 1 | 19 | | 27 | 1 | | 150 | 97 | *f* |
| 4 | F | Lower | 0.4 | 94.4 | 4 | 0.4 | 0.4 | 0.4 | | | | ? | 262 | ? |
| 5 | G | Middle | | 90 | 6 | 2 | 1 | | | | 1 | 1 | 143 | ? |

Table 7. Pollen spectra from the bog at Lervad.

1) Pollen. 2) Spores.

The stratum of "black, rich sand" which N. HARTZ called the "transition stratum", in which he found sclerotia of *Cenococcum geophilum*, appeared in the 1922 boring as a sandy Mud containing *inter alia Potamogeton natans*. The boring showed however no *Sphagnum* peat, this being presumably restricted to the margin of the basin. On the other hand, there was a comparatively thick layer of shore mud (see Chap. IV) and this Stratum F, together with Stratum G corresponds to the "sandy mud" mentioned by HARTZ. It is less certain however, whether the clay stratum H corresponds to the lower stratum of "sand" observed by him. This clay stratum H has a temperate flora, and is a formation analogous to the lower part of the clay bed at Ringdal.

The object of the boring made in 1922 was to ascertain whether the basin at Lervad, in which the glacigenous bottom was not reached by N. HARTZ, contained a bog of the Herning type. The finding of the moraine (Stratum K) shows that this interglacial deposit belongs to the bogs of the Brörup type.

## Tuesböl II.

Directly SE of the interglacial bog at Tuesböl Mark, mentioned by N. HARTZ 1909, p. 160 f. ("Tuesböl I"), and 1.1 km NW of the railway station at Brörup, there is a small postglacial peat bog, measuring abt. 100 m in its greatest extent. The site is that marked as No. 2 on the map Fig. 2. At the present day, as will be seen, the ground presents the appearance of a small hollow without outlet, which, like most of the other interglacial basins at Brörup, lies high up on a flat plateau, not in valley as for instance the bog at Nörbölling (5 on the map fig. 2) and so many of the other bogs described in the present work from the last interglacial period.

In 1922, a boring was made at Tuesböl II by V. MILTHERS. The profile was as follows:

A. 0 — 1.0 m Peat and Mud.
B. 1.0 — 1.9 m Sand, yellow at the top, grey at the bottom.
C. 1.9 — 2.3 m Sand with numerous vegetable remains, thin strata of sandy mud. For pollen of the usual forest trees in this and the following strata see the pollen diagram Pl. XXXVII, 10.
*Acer campestre*, 1 fruit with seed, at the bottom,
*Alnus glutinosa*, numerous fruits, also pollen,
*Batrachium sceleratum*, 1 fruit,
*Betula pubescens*, some fruits, also pollen,
*Carex pseudocyperus*, numerous fruits,
— *sp.*, fruits without utriculus,
*Carpinus betulus*, some pollen,
*Corylus avellana*, much pollen,
*Dryopteris thelypteris*, numerous spores,

*Dulichium spathaceum*, 3 fruits, at the top,
*Eriophorum vaginatum*, epidermis,
*Ilex aquifolium*, some pollen,
*Lycopus europaeus*, numerous nuts, especially at the bottom
*Mentha cf. aquatica*, 2 nuts, at the bottom,
*Menyanthes trifoliata*, numerous seeds,
*Najas flexilis*, several fruits, especially at the top,
*Osmunda regalis*, some few spores,
*Oxalis acetosella*, 1 seed at the bottom,
*Picea excelsa*, some pollen,
*Pinus silvestris*, some pollen,
*Pinus* or *Picea*, 1 fruit, at the bottom,
*Potamogeton filiformis*, several fruit-stones,
— *natans*, numerous fruit-stones,
*Quercus sp.*, pollen,
*Rhyncospora alba?*, 1 fruit,
*Rubus idaeus*, fruit-stones, fairly numerous,
*Scirpus sp.*, several small fruits with perigonium bristles,
*Sparganium erectum*, several fruits,
*Stratiotes aloides*, 2 seeds, at the top,
*Tilia sp.*, some pollen,
*Ulmus sp.*, much pollen.

*Sphagnum sp.*, leaf fragments, spores.

*Phytoptus laevis*, galls, very common.

D. 2.3 – 4.0 m Peat-like Detritus Mud, the bottom part of the stratum, however, had developed into a hard and laminated mud. Numerous vegetable remains:
*Alnus glutinosa*, fruits, etc. very numerous throughout the greater part of the stratum,
*Batrachium sceleratum*, 2 fruits, at the top,
*Betula pubescens*, numerous fruits, much pollen at the bottom
*Carex diandra*, 1 fruit,
— *pseudocyperus*, numerous fruits throughout the greater part of the stratum (Pl. XXXV, 25),
— *sp.*, fruits without utriculus,
*Ceratophyllum cf. submersum*, 2 fruits, at the bottom,
*Corylus avellana*, much pollen at the top,
*Drosera cf. rotundifolia*, a pollen tetrad,
*Dryopteris thelypteris*, rhizomes, leaf fragments and spores,
*Eriophorum vaginatum*, epidermis,
*Frangula alnus*, 6 fruits,
*Ilex aquifolium*, 1 grain of pollen, spectr. 4,
*Lycopus europaeus*, nuts very numerous in the upper half of the stratum,
*Lysimachia vulgaris*, 1 seeds, at the top,
*Mentha cf. aquatica*, 7 nuts in the upper half,
*Menyanthes trifoliata*, numerous seeds,
*Myriophyllum cf. spicatum*, 1 nut,
*Najas flexilis*, 1 fruit, at the top,
*Nuphar luteum*, 1 seed, pollen,

*Nymphaea alba*, 1 seed,
*Osmunda regalis*, some spores at the top,
*Pinus silvestris*, some pollen at the bottom,
*Potamogeton natans*, 1 fruit-stone,
— *sp.*, 2 fruit-stones,
*Quercus sp.*, much pollen,
*Ranunculus flammula*, 1 fruit,
*Rubus idaeus*, 3 fruit-stones,
*Solanum dulcamara*, 1 seed,
*Sparganium erectum*, several fruit-stones,
*Tilia sp.*, some pollen,
*Typha latifolia*, some pollen tetrads,
*Ulmus sp.*, pollen,
*Urtica, dioeca*, 5 fruits.

*Gymnocybe palustris*, leaf fragments,
*Hypnum sp.*, leaf fragments,
*Sphagnum sp.*, spores, leaf fragments,

*Phytoptus laevis*, numerous galls.

E. 4.0 — 4.75 m Grey, stoneless Clay, in which were found:
*Alnus glutinosa*, some pollen,
*Batrachium aquatile coll.*, 1 fruit,
*Betula sp.*. much pollen,
*Corylus avellana*, some pollen,
*Dryopteris thelypteris*, some spores,
*Picea excelsa*, some pollen,
*Pinus silvestris*, much pollen,
*Potamogeton filiformis*, many small fruit-stones
— *cf. natans*, 2 fruit-stones,
*Potentilla palustris*, 3 nuts,
*Sparganium minimum*, 3 fruit-stones,
— *affine*, 1 fruit-stone,
*Ulmus sp.*, much pollen,

*Spongilla lacustris.*

F. 4.75— 5.0 m Grey Moraine Clay.

The interglacial basin at Tuesböl II is, like its neighbour on the NW, hollowed out in moraine clay, and in both cases the oldest stratum deposited in the two small lakes was mainly composed of clay. At Tuesböl II, the older part of the lower stratum (E) was not examined, Spectr. 6 (Pl. XXXVII, 10) shows dominance of *Pinus* and *Betula*, but the mixed oak forest species have nevertheless left their mark on this horizon. From the remaining portion of the pollen diagram it will be seen how the pollen first of *Betula*, then of *Alnus*, occurs in altogether predominating quantity; this is evidently due to local influences from the forest bog formations along the margins of the basins. The lower margin for the mixed oak forest zone (*f*) may be set a little above Spectr. 5 in the lower part of Stratum D.

The *Corylus* maximum lies in the upper half of this stratum, and the uppermost spectrum still belongs to zone *f*. Only a few grains of pollen of *Carpinus* and *Picea* were observed. Stratum C must be supposed to date from the hottest part of the interglacial period, as we found here species such as *Stratiotes aloides*, *Acer campestre* and *Dulichium spathaceum*. These species, together with *Najas flexilis*, give the interglacial character of the flora. Despite careful, search, we failed to find here *Aldrovanda vesiculosa* which, under the name of *Hydrocharis morsus ranae*, is noted in the washing list from Tuesböl I[1]) by HARTZ, 1909 p. 173.

The strata sequence from E to C shows a steadily advancing filling up of the basin from sedimentation of clay and laminated mud via detritus mud to sand; the transition between C and B is very gradual, and the mud formation in the basin probably came to an end, owing to the depth of water being insufficient. Answering to the whole of the long period from the last time of the mixed oak forest in the last interglacial period to the commencement of the postglacial period, we have, in the profile from Tuesböl II, only the stratum of stoneless sand (B) 0.9 m thick, which can hardly be a true product of solifluction, but should rather be regarded, at any rate for the greater part, as washed down sand (Schwemmsand). Is is possible, on the other hand, that excavations in the marginal zone of the bog might bring to light folds and interkneadings due to solifluction, of the type known from Tuesböl I.[2])

## Bog at Brörup Railway Station.

N. HARTZ gives (l. c. 140 ff.) a thorough description of an interglacial bog at Brörup, a station on the railway line between Esbjerg and Kolding, (cf. Fig. 2, bog No. 4). The account includes a list of the strata with plant remains found therein, etc. The profile he gave of this deposit was as follows:

| | | |
|---|---|---|
| (A.) | 0 — 0.6 m | Rubbish. |
| (B.) | 0.6 — 5.6 m | Greyish white Sand, with a few stones, faintly stratified. |
| (D.) | 5.6 — 5.9 m | Humous, light greyish-brown argillaceous Sand, a "transition stratum". Presumably formed by sand and clay becoming kneaded together with the subjacent peat. |

1) E. M. REID and M. E. J. CHANDLER: The Bembridge Flora, British Museum Catalogue of Cainozoic plants in the Departm. of Geology. Vol. I, p. 112. London 1926.

2) AXEL JESSEN, VICTOR MADSEN etc.: Brørup-Mosernes Lejringsforhold. D.G.U. IV. R., No. 9, 1918, p. 17 f.

(E.–G.) 5.9 — 7.9 m "Peat": the upper 25 cm (E) was "altogether earthy and transformed into mould" the rest of the stratum consisted of firmly compressed *Sphagnum* Peat.

(H.) 7.9 — 8.5 m Mud, horny when dry, and splitting up into lamellae no thicker than paper.

(J.) 8.5 — 9.0 m Fresh-water Sand, water-bearing. This stratum was not dug through.

N. Hartz did not thus penetrate right through the interglacial strata in this bog, and the possibility of finding "two warm horizons" here, as at Nörbölling for instance, was not altogether excluded. We therefore, in 1922, made a boring here, and arrived at the following results, cf. Fig. 11:

A. 0 — 1.3 m Rubbish.

B. 1.3 — 4.1 m Reddish yellow Sand with stones especially at the top; at 2.25 m below the surface, the implement struck a large block of flint, which had to be broken up.

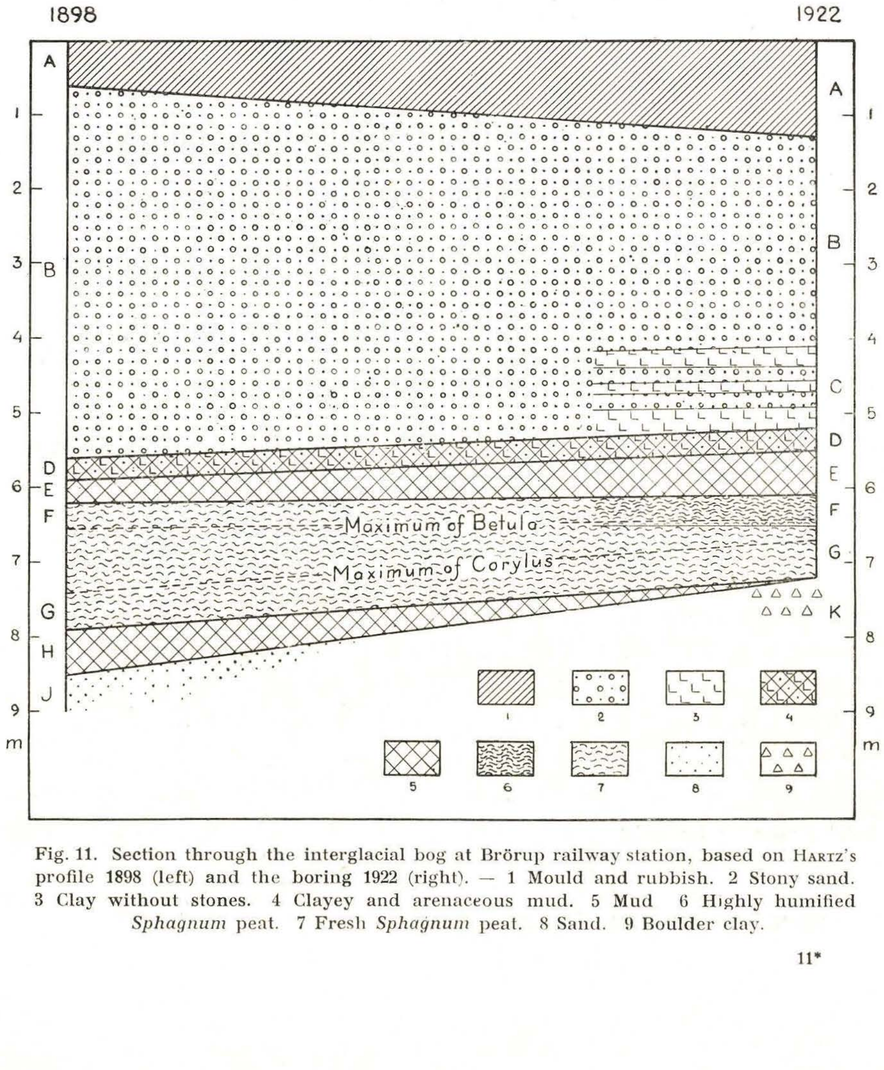


Fig. 11. Section through the interglacial bog at Brörup railway station, based on Hartz's profile 1898 (left) and the boring 1922 (right). — 1 Mould and rubbish. 2 Stony sand. 3 Clay without stones. 4 Clayey and arenaceous mud. 5 Mud 6 Highly humified *Sphagnum* peat. 7 Fresh *Sphagnum* peat. 8 Sand. 9 Boulder clay.

| | | |
|---|---|---|
| C. | 4.1 — 5.2 m | Pale-grey Clay without stones, and Sand with stones, in alternating strata; the stones up to the size of nuts. |
| D. | 5.2 — 5.5 m | Pale greyish-brown, arenaceous-argillaceous Mud; portions of older strata presumably kneaded in, see the pollen diagram, Pl. XXXVII, 8. |
| E. | 5.5 — 6.1 m | Brown, finely sandy Mud with birch bark and charcoal; fruit-stones of *Empetrum nigrum*. This stratum was rich in well-preserved pollen; besides the items noted in Spectr. 2 and 3[1]) also some of *Ericaceae* and numerous *Sphagnum* spores; *Botryococcus Braunii*, was very common. |
| F. | 6.1 — abt. 6.5 m | Dark-brown, considerably humified *Sphagnum* Peat with abundant remains of *Eriophorum vaginatum*, branches and bark of *Betula sp.*, branches of *Calluna vulgaris* etc. Merges gradually into the layer below. |
| G. | abt. 6.5 — 7.2 m | Lighter brown, fairly fresh "foliated" *Sphagnum* Peat with numerous leaf-sheaths of *Eriophorum vaginatum*. The stratum contained here and there thin streaks of Sand, and a few flakes of horny Mud came up with it from the lower part of the stratum. |
| J. | 7.2 — 8.0 m | Boulder Clay. |

The distance between the pit dug by N. HARTZ and our boring cannot have been great, hardly more than abt. 10 m. The accompanying sketch, Fig. 11, shows how the two profiles may be combined on the assumption that their summits lay at the same level. The pit of 1898 was doubtless carried down somewhat farther from the margin of the bog than the boring of 1922, as HARTZ found a layer over 1 m thick of lake deposits, whereas Stratum G in the boring must be regarded as a quaking bog-formation resting on the firm bottom. In the profile of 1922, the peat layer terminated at the top in a considerably humified layer of *Betuleto-Sphagnetum* peat, covered by finely sanded mud. N. HARTZ's layer, E, referred to as "earthy and transformed into mould", which formed the upper termination of the peat deposit in the pit 1898, is doubtless identical with this fine sandy mud stratum E, which certainly may resemble mould, but, *inter alia* by the presence of the fresh-water alga *Botryococcus Braunii*, reveals its origin from a little shallow lake or pond with much humus in the water. A decisive point in the identification of the two strata is that their lower margins lie at the same distance from, and close above, the upper *Betula* maximum noted in both profile and that the mud stratum E (1922) lay on a level with, or rather, a little above, the contemporaneous "mouldy" stratum E in the pit 1898. This upper *Betula* maximum in the 1922 profile (Spectr. 4) lies in Stratum F, answering to the

[1]) The sample brought home consisted of portions of light and darker mud kneaded together; Spectr. 2 is determined from the light part, Spectr. 3 from the dark (Pl. XXXVII, 8). The latter is undoubtedly older than the former, and has been drawn in the lower margin of Stratum E.

fact that while this was in process of formation, a birch vegetation was colonising on the marginal zone of the bog. The birches do not appear to have reached as far as the 1898 profile, where HARTZ makes no mention of birch scrubs; the level corresponding to this in point of time is here marked by the very pronounced course of the *Betula* curve in Fig. 9, Pl. XXXVII (Spect. 5).

In the pollen diagram from the 1922 profile *Pinus* is but slightly prominent in the lower portion, where Spect. 7 shows a pronounced *Betula* maximum; then culminate, in the order here given: mixed oak wood (*Quercus* and *Ulmus*), *Corylus*, *Alnus* and *Betula*, *Carpinus*, *Picea* and *Pinus*. Spect. 1 is drawn without connection with Spect. 2, as it is evidently affected by the intermixture of older deposits (possibly from the upper portion of F).

In the lower part of the pollen diagram, Fig. 9 in Pl. XXXVII, will be seen 6 spectra from the soil samples preserved in the collections belonging to Denmark's Geological Survey from the excavations by N. HARTZ; above have been added Spectr. 1—3 from the pollen diagram Fig. 8. The 1898 diagram agrees very nicely with that from the contemporaneous strata in the boring of 1922; certain discrepancies are however, to be found (e. g. the *Alnus* curve) the cause of which lies doubtless mainly in the fact that the intervals of the spectra are too long, so that the curves found give but an imperfect reproduction of the actual state of things.

Following the course of the curve in the pollen diagram Fig. 9, we notice that the inferior rational limit for *Carpinus* may be set at Spectr. 7, and that the species has its maximum in Spectr. 4, at the upper edge of the *Sphagnum* peat. The rational lower limit for *Picea* on the other hand lies in Spectr. 6, this species only attaining its maximum at the top of the series (Spectr. 2). In this, the upper part of the diagram, the curves for *Pinus* and *Betula* also turn off sharply to the right, while those for *Alnus* and *Carpinus* turn to the left. *Corylus*, *Quercus* and *Ulmus* have, from Spectr. 5 inclusive and upwards — or since the birch colonisation of the bog — shown very low frequency values. The two pollen diagrams taken together show the following pollen floristic zones: *d*, *e?*, *f*, *g*, *h*, *i*, *(k)*, cf. Chapter VII.

On comparing the diagrams with the table given by HARTZ (l. c. p. 159) for distribution of the principal species from macroscopic finds in strata D—H[1]) (his Zones I—X, cf. the texte to Fig. 9 Pl. XXXVII) according to which none of the more thermophile species were found in Zone IV and above that beyond *Acer sp.* ("some few seeds") and

[1]) The frequency noted in HARTZ's table for *Picea excelsa* does not agree with his find of this tree mentioned p. 143 - 147; the dark line in the table should include Zones III—VI.

*Carpinus*, which still yielded numerous fruit in zone III, we find that the pollen diagrams confirm the conclusion arrived at by HARTZ, that it is the "middle parts of the bog which represent the temperature maximum of the interglacial period".

N. HARTZ records, both from the upper and lower parts of his profile, finds of numerous fruits etc. of *Betula nana* and *B. nana*-hybrids, also *Betula subalpina* (LARSS. LÆST.) determined by Dr. L. M. NEUMAN.[1]) My washings of peat samples from the profile of 1922 revealed only *Betula pubescens* (common) and *B. pendula*.

Otherwise, my washings of peat samples from this bog yielded no finds of particular interest beyond 1 nut of *Urtica urens*, which has not hitherto been found in Danish interglacial bogs. It was found in Stratum G, at the bottom, together with *Betula pubescens*, *Carex lasiocarpa*, *Lycopus europaeus*, *Menyanthes trifoliata* and *Viola palustris*.

## List of the Species found in the Interglacial bog at Brörup railway station in 1922.

c common, + not uncommon, r rare.

| Species | D | E | F | G |
|---|---|---|---|---|
| *Alnus glutinosa*[2]) | + | + | c | + |
| *Betula pendula* | ..... | ..... | ..... | r |
| -- *pubescens* | ..... | ..... | + | c |
| — *sp*[2]) | c | c | c | c |
| *Calluna vulgaris* | ..... | ..... | + | + |
| *Carex lasiocarpa* | ..... | ..... | ..... | r |
| *Carpinus betulus*[2]) | + | c | r | r |
| *Corylus avellana*[2]) | r | r | c | c |
| *Dryopteris thelypteris*[3]) | ..... | ..... | r | + |
| *Empetrum nigrum* | ..... | + | ..... | r |
| *Eriophorum vaginatum* | ..... | ..... | c | c |
| *Fraxinus excelsior*[2]) | ..... | ..... | r | ..... |
| *Lycopus europaeus* | ..... | ..... | r | r |
| *Menyanthes trifoliata* | ..... | ..... | ..... | c |
| *Osmunda regalis*[3]) | ..... | ..... | + | r |
| *Polypodium vulgare*[3]) | ..... | r | r | ..... |
| *Picea excelsa*[2]) | + | c | r | r |
| *Pinus silvestris*[2]) | + | c | r | + |
| *Quercus sp.*[2]) | r | r | + | c |
| *Tilia sp.*[2]) | ..... | ..... | r | ..... |
| *Ulmus sp.*[2]) | ..... | r | r | + |
| *Urtica urens* | ..... | ..... | ..... | r |
| *Viola palustris* | ..... | ..... | r | r |
| *Sphagnum sp.* | ..... | c[3]) | c[3]) | c |
| *Botryococcus Braunii* | ..... | c | ..... | ..... |
| *Amphitrema flava* | ..... | ..... | + | c |
| *Assulina sp.* | ..... | ..... | ..... | + |

[1]) These birch remains are no longer in the collections of Denmark's Geological Survey. [2]) Pollen. [3]) Spores.

## Other Interglacial Bogs at Brörup.

In addition to the interglacial bogs in the vicinity of Brörup noted by N. HARTZ[1]), V. MILTHERS[2]) and in the foregoing (see Fig. 2), brief mention should here be made of four such bogs discovered in 1923 from the shallow depressions above the sites. In each of them, only a single boring was made, with the spiral auger, by J. C. HANSEN. They are indicated by the numbers 6, 7, 8 and 9, and will be found so marked on the map Fig. 2.

Bog No. 6.

A. 0 — 1.0 m Mould above red Sand with hard pan.
B. 1.0 — 2.0 m Grey Sand with stones.
C. 2.0 — 2.5 m Mud.
D. 2.5 — 4.4 m Peat, the upper part mixed with sand.
Boring was not carried further.

Bog No. 7.

A. 0 — 1.2 m Mould above red Sand with hard pan.
B. 1.2 — 1.5 m Grey watery Sand.
C. 1.5 — 2.3 m Sandy Peat and Mud.
D. 2.3 — 3.6 m Greyish blue Clay with vegetable remains.

Bog No. 8.

A. 0 — 2.0 m Mould above grey Sand with stones.
B. 2.0 — 4.4 m Peat and Mud, not bored through.

Bog No. 9.

In this hollow, an excavation was made, revealing Peat below 1.3—2.0 m Sand.

## Over Gestrup.

On a stretch of heath belonging to Over Gestrup in the parish of Agerskov, in South-Jutland, west of the oak thicket at Gestruplund, there is a remarkable and very conspicuous hollow with steep sides. The bottom lies up to 2 m lower than the surrounding plateau, which is perfectly flat, and its greatest breadth is abt. 50 m from edge to egde (cf. map Fig. 12 and Pl. XIX, 2).[3]) Shortly before our visit to the spot in 1922, a well had been dug in the northern part of the hollow, where it is deepest, and peat had on that occasion been found, under a layer of sand. We found small pieces of highly compressed *Sphagnum* peat lying about among the excavated sand,

1) N. HARTZ: Bidrag . . . . D. G. U. II. R. No. 20, 1909, p. 190.
2) V. MILTHERS: Kortbladet Bække. D. G. U. I. R. No. 15, 1925, p. 51, f.
3) This hollow is locally known as "Soverkulen".

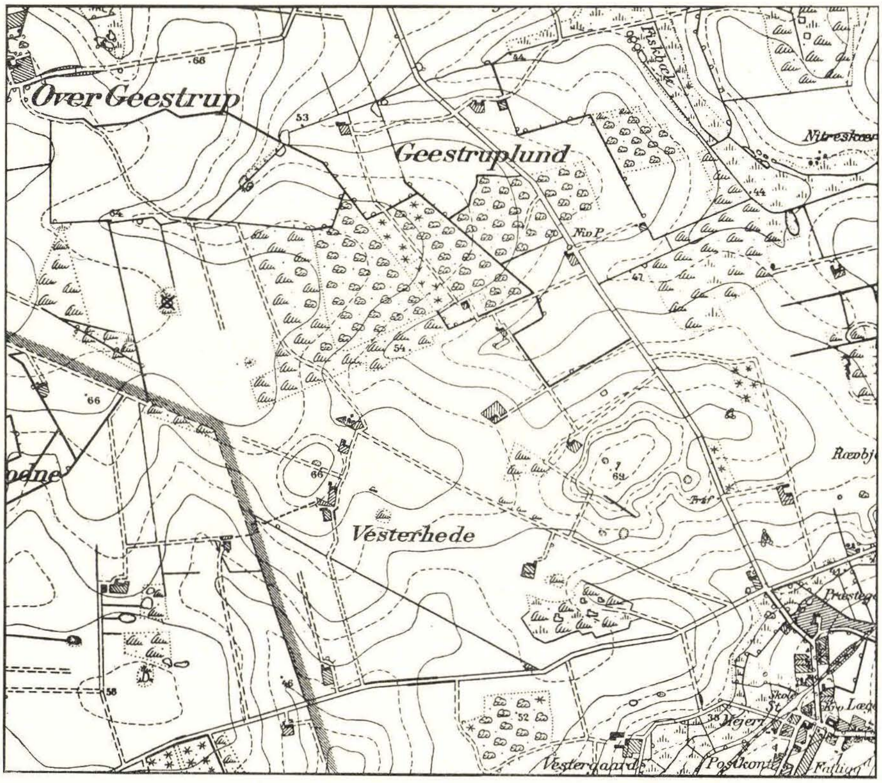


Fig. 12. Map showing position of the interglacial bog at Over Gestrup (cross South of Over Gestrup). Scale 1 : 25000. Contour interval 2,5 m. The General Staff Map Sheet 3907.

and with a view to further investigation of the position, we made a boring in the bottom of the hollow, close to the well: the result was as follows:

A. 0 — 2.35 m Slightly argillaceous Sand, grey at the top, reddish brown lower down. In the upper half metre of this stratum were a few scattered stones up to the size of hen's eggs; otherwise it was practically stoneless.

B. 2.35— 3.55 m Grey stoneless Clay. The washing sample yielded no determinable vegetable remains.

C. 3.55 – 3.8 m Brown Mud; here were found a fruit of *Betula nana*, a fruit of *Betula pubescens*, and some pieces of charcoal from a conifer; a spore of *Lycopodium annotinum*, a spore of *Osmunda regalis*, and a few spores of *Dryopteris thelypteris;* pollen of *Empetrum nigrum*, as well as that noted in the Diagram Fig. 6, Pl. XXXVII.

D. 3.8 — 6.7 m Brown *Sphagnum* Peat. In the upper metre of the stratum especially were found a quantity of wood detritus and numerous small sticks; otherwise, it consisted mainly of fairly fresh, stratified *Sphagnum* peat. Eight washing samples from various depths yielded the following:

*Alnus glutinosa*, 4 fruits, bottom,
*Andromeda polifolia*, 2 seeds, uppermost,
*Betula nana*, 3 fruits, uppermost,
— *pubescens*, fruits and small branches,
*Calluna vulgaris*, numerous fragments of branches and leaf shoots, especially in the upper part,
*Empetrum nigrum*, several fruit-stones, uppermost,
*Eriophorum vaginatum*, remains of leaf sheaths fairly numerous,
*Picea excelsa*, a few needles abt. 6.0 m down,
*Pinus silvestris*, a needle, a piece of root wood (abt. 6.2 m),
*Polypodium vulgare*, some spores,
*Rhyncospora alba*, numerous fruits, lower part (Pl. XXXII, 21).

*Calliergon stramineum*,
*Gymnocybe palustris*,
*Hylocomium parietinum*,
*Hypnum exannulatum*,
*Sphagnum palustre*, in samples from the lower part of the stratum,
*Sphagnum papillosum*, from the upper part.

*Cenococcum geophilum*, sclerotia,
*Tilletia sphagni*, spores.

E. 6,7 — 7.7 m Brown Mud, the lower part split by very fine layers of sand. Two washing samples yielded:
*Alnus glutinosa*, several fruits,
*Betula pubescens*, numerous fruits,
*Brasenia purpurea*, seeds very numerous,
*Carex lasiocarpa*, 1 fruit,
— *pseudocyperus*, several fruits,
*Ceratophyllum demersum*, 1 fruit,
*Dryopteris thelypteris*, rhizomes and leaf stalks,
*Dulichium spathaceum*, 7 fruits,
— *sp.*, 1 fruit,
*Lycopus europaeus*, 4 nuts,
*Menyanthes trifoliata*, several seeds,
*Myriophyllum sp.*, some pollen,
*Nymphaea alba*, numerous seeds,
*Oenanthe sp.*, 1 nut, (Pl. XXXII, 20).
*Potamogeton natans*, numerous fruit-stones,
*Rhyncospora alba*, numerous fruits, upper part,
*Scirpus lacuster*, some fruits,
*Sparganium erectum*, 2 fruits,
— *minimum*, 4 fruits,

*Castor fiber*, excrements?

*Amphitrema flava*, fairly common.

F. 7.7 — 8.0 m Stratified, brown Clay-Mud:
*Betula pubescens*, numerous fruits,
*Carex lasiocarpa*, 1 fruit,
— *pseudocyperus*, 2 fruits,

*Lycopus europaeus*, 4 nuts,
*Menyanthes trifoliata*, 2 seeds,
*Nymphaea alba*, 2 seeds,
*Potamogeton natans*, several fruit-stones,
*Scirpus lacuster*, 1 fruit-stone,
*Sparganium minimum*, 1 fruit-stone.

G. Moraine Clay.

The pollen diagram (Pl. XXXVII, 6) gives an idea of the forest history of the district during the period occupied by the formation of the bog.

The oldest spectrum — from the clay-mud F — belongs to the first part of the mixed oak forest zone; *Betula*, it is true, dominates with 58 %, but *Pinus* has only 13 %, and *Quercus* + *Ulmus* together amount to 26 %; *Alnus* and *Corylus* were here still rare. The species indicated in the washing lists from this stratum also suggest that it was formed in a temperate climate; there does not appear to have been any sedimentation taking place in the basin during the first part of the interglacial period. During the time when the mud layer E, 1 m thick, was being formed, the foliage trees round the lake attained their highest development, to judge from the pollen diagram. *Ulmus*, *Quercus*, *Corylus* and *Alnus* culminate here in the order named; the *Tilia* curve lies in about the same position in Spectra 9—11 i. e. abt. 6—7 %, but this species of pollen can hardly be traced at all above and below these. Here also the *Ulmus* curve appears with a faint double summit, the latter one in the upper part of the zone. Simultaneously with this development of the forest vegetation, we have *Brasenia purpurea* and *Dulichium spathaceum* in the lake itself.

The rational limit for *Carpinus* lies between Spectr. 10 and 11, and this species attains 20 % in Spectr. 9. Even in Spectr. 7, where *Picea* culminates, *Carpinus* can still show 16 %, after which its curve turns off abruptly to the left.

The rational limit for *Picea excelsa* lies between Spectr. 9 and 10 in the lower part of the *Sphagnum* peat D, which was here developed as a quaking bog. In Spectr. 8, *Picea* has already 42 %, and through the entire upper part of the profile, up to and including Stratum C, the *Picea* pollen is very common. In this upper part of the diagram the elements of the mixed oak forest, as well as *Corylus* and *Carpinus*, are very poorly represented, and the greater part of the pollen of these species may doubtless be taken as brought from far away by the wind as far as most of the spectra in question are concerned. It is a remarkable fact that the *Carpinus* curve runs out to 8 % in Spectr. 2 from Stratum C, which, like the upper portion of Stratum D, contained remains of *Betula nana*. As to the cause to this compare the corresponding facts in the diagrams from for example Duedam p. 131 and Höllund Sögaard p. 152.

*Alnus* maintains an almost constant frequency from Spectr. 7 upwards. The *Betula* curve turns off well to the right after its minimum in the lower part of the *Picea* zone, in Spectr. 7. In this latter, *Pinus* is altogether lacking, after which the curve for this species likewise runs out well to the right and in Spectr. 4 even out-distances the *Picea* curve. I think the spectra 2—4 belong to the Zone *i*, in which the *Pinus* pollen is very common and the *Picea* pollen reaches its second maximum.

About the time when the comprehensive change from foliage trees to conifer forest was taking place, the *Sphagnum* bog altered its character, changing from a quaking bog overgrown with *Rhyncospora alba* and other *Cyperaceae* to a heath bog with trees in varying quantity, where *Betula pubescens*, *Pinus silvestris* and perhaps also *Picea excelsa* throve side by side with *Calluna vulgaris*, *Empetrum nigrum*, *Andromeda polifolia*, and (uppermost) *Betula nana*. This dry and firm bog then became covered with water, and the mud stratum C was formed. The climate has gradually become cooler — to judge from the evidence of the vegetation in the *Picea* zone — and in the course of its subsequent development towards the approaching subglacial period, the sedimentation changed from mud to clay and sand, which was washed out from the lands, now probably poor in vegetation, surrounding the little lake. Here, as above other interglacial bogs, outside the limit of the last glaciation in Jutland, the climax of arctic conditions was indicated by the formation of the stony sand deposit in the uppermost part of the profile.

## Agerskov.

According to a statement in the "Flensborg Avis" dated $^{14}/_{7}$ 1905, brought to the notice of Denmark's Geological Survey by J. P. J. Ravn, men digging in a field belonging to the farmer P. Rosenblad, of Östergaard near Agerskov, in South-Jutland, found peaty soil with tree roots under an eight foot thick layer of sand and gravel. In the same year, Axel Jessen made a closer examination of the place, and writes to us in this connection as follows:

"The site[1]) is a little to the SW of Östergaard in the parish of

[1]) The situation will be seen from the map Fig. 13. The site, which lies abt. 56 m above sea level, is in a flat, valley-like depression sloping towards the NW, between the hilly ground up to 75 m high.

Agerskov, 1400 m ENE of Agerskov Church. The land slopes down from a fairly high hill in a gradual incline towards the highroad on the north. It is sour, tufty, heath soil, containing hard pan, the vegetation consisting of *Calluna*, *Empetrum*, *Erica* and grass. In the dry part of the heath there is stony sand with stones as big as a man's hand or larger. Several were worn by the action of sand; I did not however, notice any good facetted pebbles.

The hollow in which the excavation was made is but little noticeable in the surroundings, measuring hardly more than 20—30 paces across.

The hole dug was 2.5—3.15 metres square, and of like depth.

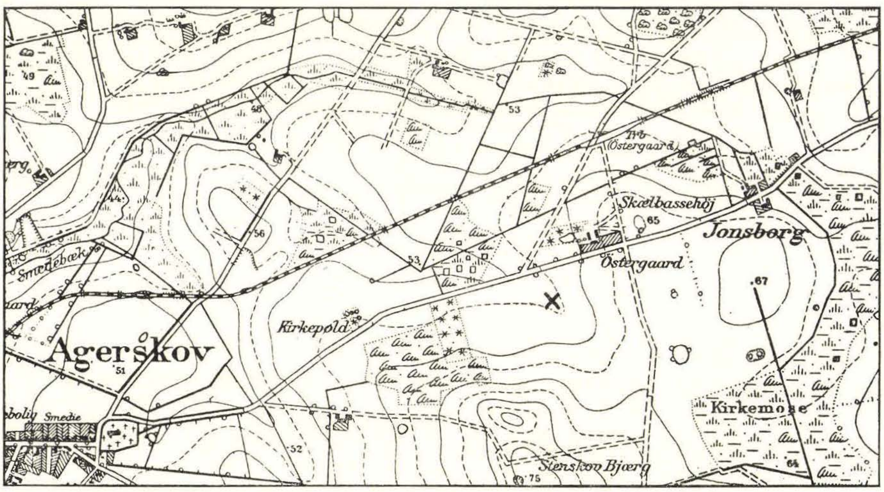


Fig. 13. District East of Agerskov with the interglacial bog (x). Scale 1 : 25000. Contour interval 2.5 m. From the General Staff Map Sheet 3907.

The profile is as follows: 13—16 cm heather turf merging below into black humous sand with many stones ranging from the size of nuts to the size of hen's eggs; flints are particularly frequent, and often polished by the action of sand. 47 cm below the surface, this layer ends in a 16 cm thick layer of sandy hard pan. Below this, yellow sand without stratification, with some few stones from the size of nuts to the size of eggs. These last are often accumulated in gravelly lumps.

From 1.57 m below the surface and downwards the sand becomes purer, almost free from stones, almost devoid of structure, with but a slight suggestion of horizontal stratification.

2.5 m below the surface there is a layer of blachish brown Mud, varying in thickness from 2.5 to 21 cm. The upper part is sandy, brownish, the lower portion darker in colour and more peaty. At several places in the mud bed there are streaks of sand a couple of cm thick, rather like the thinning out of the mud streaks of Ejstrup.[1]).

Below the mud there is 0.63 m of Sand, without stones, the upper portion perfectly white, the lower grey and coarser.

Below this, Peat. In the upper part of the peat, small veins of sand were found. At the top — to a foot down — the peat contained wood, bark and small twigs; deeper down it became firmly compressed moss peat.

The water stood at the surface of the peat, and flowed out strongly when we dug in the peat. Tried then to bore with a marl drill, but the peat was too hard, we could make no progress. It must however, be at least 1.1 m thick. Subjacent stratum unknown."

A number of samples from the various strata in the bog were collected by AXEL JESSEN:

I. The Mud layer, sandy, argillaceous mud, greyish brown in colour; this contained no determinable vegetable remains.

II. Brown, stratified Detritus Peat (forest peat with a touch of the low-moor type), with a quantity of birch bark and numerous rhizome fragments and fruits of *Carex sp.;* also several charred needles of *Picea excelsa* and sclerotia of *Cenococcum geophilum.*

III. Brown, stratified Birch Forest Peat, very rich in flattened branches, flakes of bark and fruis of *Betula pubescens*, some few branches of *Calluna vulgaris* and carbonified needles of *Picea excelsa* with large sclerotia of *Cenococcum geophilum.*

IV. Brown, foliated fairly fresh *Sphagnum* Peat, very rich in tufts of *Eriophorum vaginatum* etc. In this were found:

*Alnus glutinosa*, 2 fruits,
*Betula pubescens*, fruits and catkin scales, with some branches,
*Carpinus betulus*, 6 fruits,
*Eriophorum vaginatum*, leaf sheaths in tufts, several fruits (Pl. XXXII, 10—12),
*Oxycoccus palustris*, several shoots with leaves, large seeds (Pl. XXXII, 13–14),
*Picea excelsa*, needles and seeds,
*Sparganium minimum*, several fruit-stones.

*Cenococcum geophilum*, numerous sclerotia.

In 1914, attention was again drawn to the interglacial bog at Agerskov, and another excavation was made there in order to include it in the series of investigations of the deposits in the "Brörup Bogs", published by AXEL JESSEN, VICTOR MADSEN, V. MILTHERS and V. NORDMANN.[2]) At the same time, the investigation was extended to

[1]) N. HARTZ: Bidrag . . . . D. G. U. II. R. No. 20, p. 207.
[2]) D. G. U. IV. R. No. 9, 1918.

embrace some interglacial bogs at Westerland, on the island of Sylt; these are dealt with in a separate publication[1]) whereas the bog at Agerskov has not yet been mentioned, as the final examination of the ground here was hindered by the outbreak of war.

AXEL JESSEN had an excavation made in the bog close to the hole made in 1905. The trench was 2 m wide and 7 m long, running N—S; the survey of the strata exposed was made by AXEL JESSEN

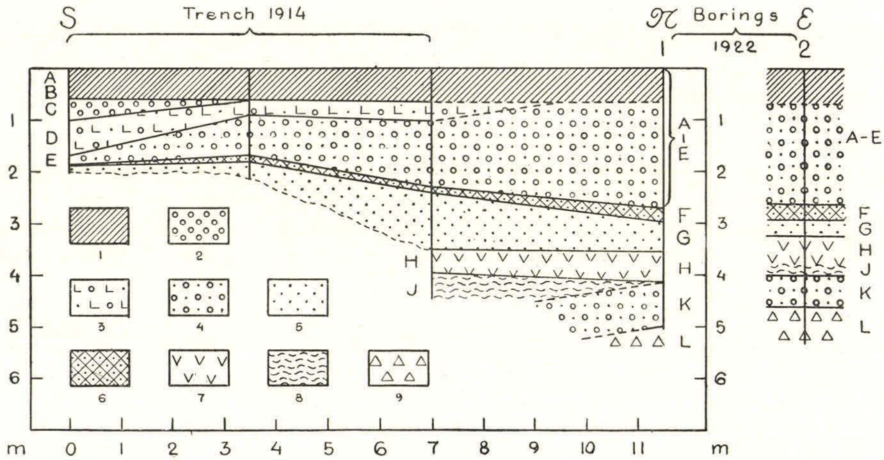


Fig. 14. The interglacial bog at Agerskov, with covering strata. 1 Podsol soil. 2 Gravel. 3 Clayey, stony sand. 4 Sand with stones. 5 Sand without stones. 6 Arenaceous mud, "the black bed". 7 Birch forest peat. 8 *Sphagnum* peat. 9 Moraine clay.

in conjunction with the gentlemen above mentioned and KNUD JESSEN. Cf. Fig. 14.

The profile at the southern end of the trench was as follows:

A. 0.50 m Raw Humus and bleached Sand.
B. 0.10 m Hard Pan.
C. 0.40 m Gravel and Sand cemented together with hard pan.
D. 0.70 m Argillaceous Sand with scattered stones.
E. 0.20 m White Sand with stones, sometimes many, sometimes few.
F. Fragments of the "black streak" (this is the mud bed met with in the excavation of 1905).

The profile midway along the trench was as follows:

A. 0.50 m Raw Humus and bleached Sand.
B. 0.10 m Hard pan.
D. 0.30 m Sand, slightly argillaceous in parts, and with numerous small stones.
E. 0.85 m Yellow Sand, with comparatively few stones.

1) V. NORDMANN, KNUD JESSEN & V. MILTHERS: Quartärgeologische Beobachtungen auf Sylt. Medd. fra Dansk geol. Foren. Bd. 6. No. 15, 1923.

F. 0.04 m "The black streak".
G. 0.30 m Sand without stones (stones are only found in and immediately below the black streak).

Both the gravel deposit (C) and the argillaceous, stony, moraine-like sand (D) which characterised the southern end of the profile, had here thinned out, and D assumed an altogether different character. Here, in the middle of the trench, several streaks of hard pan were found, sloping down towards the north, 1.55 m below the surface.

The profile at the north end of the trench was as follows:

A. 0.40 m Raw Humus and bleached Sand.
B. 0.30 m Hard Pan.
D. 0.30 m Slightly argillaceous, stony Sand, here and there with smears of the same argillaceous sand ("Moraine sand") as at the south end.
E. 1.35 m Grey Sand with some few stones up to the size of hen's eggs, lying here and there.
F. 0.04 m "The black streak", which is broken by several faults and divides up into several strata.
G. 1.15 m Sand, with no stones, or very few. Immediately below the black streak lie several stones of the size of hazel nuts. The sand shows distinct stratification, falling away towards the north (or NNE) alternating between more sandy and more argillaceous strata (almost entirely clay, in which there may be not a few small stones).
H.J. 1.00 m Peat; the upper portion amorphous peat with wood; lower down, moss peat in thin flakes.

In the upper layer, (A), there were many stones, one of them 40 cm in diameter, another 35 cm, and another 30 cm. Below this was hard pan which had to be broken up. The upper stony strata were from 1 to about 2 m thick, the thickness being greatest at the south end towards the hill, where also the largest stones were found. Here at the south end, i. e. nearest the hill, the substratum underlying the gravel and hard pan was greyish-yellow, argillaceous sand with small stones (D), resembling moraine sand; farther out in the basin, this moraine-like character of the sand became more effaced, and the stones in the subjacent stratum were far fewer.

In the discussion held on the spot, the investigators failed to agree as to whether the upper strata, and the series generally above the black stratum, represented a sandy, gravelly moraine, or should be regarded as a product of solifluction over a water-filled depression in the ground.

In 1922, when we had completed our preliminary investigation of the Brörup bogs, we made more borings in the interglacial deposit at Agerskov, viz:

1. 4.5 m north of the northern end of the trench dug in 1914, which was still visible, and
2. 17 m E of the north end of this trench, and
3. 19 m N of the north end of the trench. In the two first borings we encountered the interglacial deposits (see Fig. 14), the last one however, fell outside the basin of the bog, and we found here below 1.5 m of stony sand, only sandy yellow moraine clay.

Boring 1.

| | | |
|---|---|---|
| A.—E. | 0 — 2.65 m | Stony Sand, many stones especially in the upper metre, where some as big as a man's head were found. |
| F. | 2.65 — 2.90 m | Greyish brown, sandy Clay mixed with humus ("the black streak). No vegetable remains here. |
| G. | 2.90 — 3.55 m | Grey, sharp Sand with stones as big as nuts. |
| H. | 3.55 — 4.1 m | Dark brown Detritus Peat with much birch bark, partly, and presumably at the bottom, muddy. Washings from this yielded:<br>*Betula pubescens*, numerous fruits,<br>*Carex pseudocyperus*, 4 fruits,<br>— *sp.*, numerous fruits without utriculus,<br>*Ceratophyllum submersum*, 8 fruits,<br>*Cladium mariscus*, 5 fruits,<br>*Menyanthes trifoliata*, seeds very numerous,<br>*Sparganium erectum*, 2 fruits,<br>*Viola palustris*, 1 seed. |
| K. | 4.1 — 5.0 m | Grey stony Sand with a few thin stripes of loamy sand; stones up to the size of hen's eggs. |
| L. | 5.0 — 5.5 m | Grey Moraine Clay. |

Boring 2.

| | | |
|---|---|---|
| A. E. | 0 — 2.6 m | Stony Sand. |
| F. | 2.6 — 2.9 m | Greyish brown, sandy Clay, with humus, no stones ("the black streak"); no vegetable remains. |
| G. | 2.9 — 3.2 m | Sharp Sand with some few, very small stones. |
| H. J. | 3.2 — 4.0 m | Dark brown Detritus Peat with no determinable macroscopic plant remains; below this, a thin layer of foliated *Sphagnum* Peat, in which were found *Carex pseudocyperus*, and *Menyanthes trifoliata*. |
| K. | 4.0 — 4.6 m | Stony Sand. |
| L. | 4.6 — 3.0 m | Moraine Clay. |

Circumstances did not permit us to make a more detailed investigation of the extent of this little basin; on the south, towards the hills, it hardly runs much beyond the southern end of the trench from 1914, cf. the thinning out of the black stratum, while on the north, the margin of the basin lies between Borings 2 and 3; on the east also, its extent is very limited. Only the slight depression in the soil, barely visible above the bog, here reveals the presence of the interglacial basin beneath the floor of the valley, which otherwise slopes gradually to the north.

The bottom of the basin is formed of a stratum of stony sand, bedded on moraine clay. No typical mud deposits have been found in the bog, but the finding of *Ceratophyllum submersum* shows nevertheless that there must at some time have been open water there. This was then later covered over by a *Sphagnum-Eriophorum vaginatum* bog, which was soon taken possession of by birch thicket, under which the deposit of "detritus peat" was formed. On this bed of peat lay stratified sand (G) which must presumably have been deposited in a lake or pond, in which also the muddy clay of the black streak must have been deposited. The forces which subsequently carried material of the covering strata, consisting of sand, clay and stones, out over the basin, seem, from the profiles, to have moved from south to north, the quantity of stones decreasing out towards the middle of the basin, the character of moraine sand at the same time becoming effaced, just as we have observed in several other cases of interglacial bogs of the Brörup type.[1]) Here also then, we may take it that the covering layer was formed mainly by solifluction, in the course of the last glacial period, and that the bog at Agerskov lay at that time outside the margin of the ice.

## The Limnean Horizon of the Eem Strata.

In several of the localities with dislocated Eem strata in the western parts of the Baltic region there are, as we know, fresh-water formations lying below the marine deposits. As a type of the strata sequence in these formations, we give here, after VICTOR MADSEN[2]) the profile of the cliff at Stensigmose, in Broagerland:

Diluvium from the last glacial period.
*Tapes* sand.
Argillaceous marine sand.
*Cyprina* clay with *Cyprina* etc.
*Cyprina* clay with *Mytilus* etc.
Brackish water deposit?
Fresh-water clay.
Calcareous mud.
Thin layer of peat.
Fresh-water (?) sand.
Fluvioglacial deposits.

[1]) AXEL JESSEN, VICTOR MADSEN etc.: Brörup-Moserne. D. G. U. IV. Række, No. 9, 1918, p. 15, 24 f.

[2]) VICTOR MADSEN, V. NORDMANN & N. HARTZ: Eem-Zonerne. D. G. U. II. Række, No. 17, 1908, p. 87.

The stratigraphical and faunistic investigations of the Eem strata has shown that the *Cyprina* clay with the *Tapes* sand were formed during a submergence and subsequent upheaval of the land, whereby the freshwater formations were covered by marine deposits, and that both these alterations of level took place under temperate conditions of climate (l. c. p. 87). From the latest investigations made by V. Nordmann[1]) as to the age of the Eem deposits, it must be regarded as certain that they were formed in the course of the last interglacial period, and the flora lists given by N. Hartz (l. c. p. 106 f) from the limnean horizon of the Eem zones in different localities in Ærö and Horneland and at Stensigmose, show that they must belong to the first part of this interglacial period. For *Picea* has not been found in these deposits, neither macro- nor microscopically, and *Carpinus* is similarly lacking, whereas *Pinus*, *Quercus*, *Ulmus*, *Tilia*, *Fraxinus* and *Crataegus* occur, as well as species as *Limnanthemum nymphaeoides* and *Najas marina*, which at the present day have a southerly extension.

The absence of *Picea* and *Carpinus* in the fresh water deposits at Stensigmose is confirmed by my pollen analyses of two samples from these beds, preserved in the collections of the D. G. U. viz. 1) fresh-water clay, abt. 40 cm below the *Mytilus* bed in Gottsche's profile, answering to Column V in the table given by Hartz l. c. p. 110, and 2) "the grey bed", diatomaceous earth just above the peat in Gottsche's profile.[2])

| No. | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen-frequency | Zone |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 45 | 2 | 41 | | | | | 2 | 26 | *d&e* |
| 2 | 54 | 30 | 8 | 8 | | | | | 1 | 146 | |

Table 8. Pollen spectra from the fresh-water beds at Stensigmose.

1) V. Nordmann: La position stratigraphique des dépôts d'Eem. D. G. U. II. R. No. 47. 1928.

2) Besides the pollen mentioned, the clay sample yielded also: *Pediastrum Boryanum* and *P. Kawraiskyi*, *Melosira arenaria* and *Spongilla lacustris*, and the diatomaceous mud contained species of the genera *Cymbella*, *Epithemia*, *Fragilaria*, *Melosira* and *Synedra*, as well as hairs of *Ceratophyllum sp.* and silica spikes of *Spongilla lacustris*. Furthermore, Mr. Carl Loewe, of Flensburg, states, in a letter to Dr. Nordmann, that he has found *Batrachium sp.*, *Menyanthes trifoliata*, *Scirpus lacuster* and *Cenococcum geophilum* in the fresh water deposits at Stensigmose; these species were not previously known from there.

Some samples of fresh-water clay from Vejsnæs Nakke (Ærö) were also investigated, but nothing was found here beyond a little *Pinus pollen*, some of *Chenopodiaceae* and silica spikes of *Spongilla lacustris*.

Spectr. 2 belongs most properly to the *Betula-Pinus* zone. The proportion of mixed oak forest to *Pinus* is 0.53, whereas it has risen to 0.96 i Spectr. 1, which originates from the upper portion of the fresh-water deposits and lies at the junction between the *Betula-Pinus* and mixed oak forest zones. Similar spectra to these appear in the diagrams from Nörbölling (Fig. 3, Pl. XXXVI, Spectr., 12), Fövling (Fig. 1, Pl. XXXVII, Spectr. 6) and Kollund (Fig. 2, Pl. XXXIX, Spectr. 4 and 5). A characteristical feature is the absence of *Alnus* and the low frequency values for *Corylus*; correspondingly, N. HARTZ does not mention macroscopic remains of these genera.

The transgression of the Eem sea over the fresh water beds in Stensigmose cliff, must then have taken place in the time of the mixed oak forest, during the last interglacial period. At the time when a lusitanian mollusc fauna was moving in to the Baltic basin by way of the sounds that cut diagonally through the southern portion of the Cimbrian peninsula, and the summer temperature, according to V. NORDMANN (l. c. 125 and 247) was a couple of degrees above that of Denmark at the present day, the rich flora of the mixed oak forest spread over Denmark, thrusting out the boreal *Betula* and *Pinus* forests. It is impossible to determine, by pollen statistics, when the upheaval of land which again shut off the Baltic from the Eem sea occured, as no bogs resting on deposits from that sea are known. But since the upheaval took place while the mild climate still prevailed, it must be supposed that the marine zone of the Eem beds is contemporaneous with the mixed oak forest zone and the *Carpinus* zone, in the interglacial bogs, while their upper strata, the *Picea* and *Pinus-Betula* zones, with the Middle Bed and overlying strata of the Herning profile, must be younger than the Eem sea deposits (cf. Chapter VII).

## Deposits from the Penultimate Interglacial Period.

Under this heading are included interglacial lake deposits lying outside the main stationary line of the last glaciation, but covered with moraine clay or typical fluvioglacial sand, or on other grounds presumably older than the last interglacial period (Starup). Included here are also the peat at Vejen, which, though lying a little to the east of the limit of the last glaciation, must nevertheless be reckoned as belonging to the older interglacial, owing to the depth at which they occur, viz. as far as 37.5 m below the surface.

## Rind.

West of the highroad running south from Herning, at a distance of 4.8 km from the town, marl is obtained from an interglacial deposit of calcareous mud, which came to the notice of V. MILTHERS after the publication of his "Mergelaflejringerne i Hammerum Herred".[1])

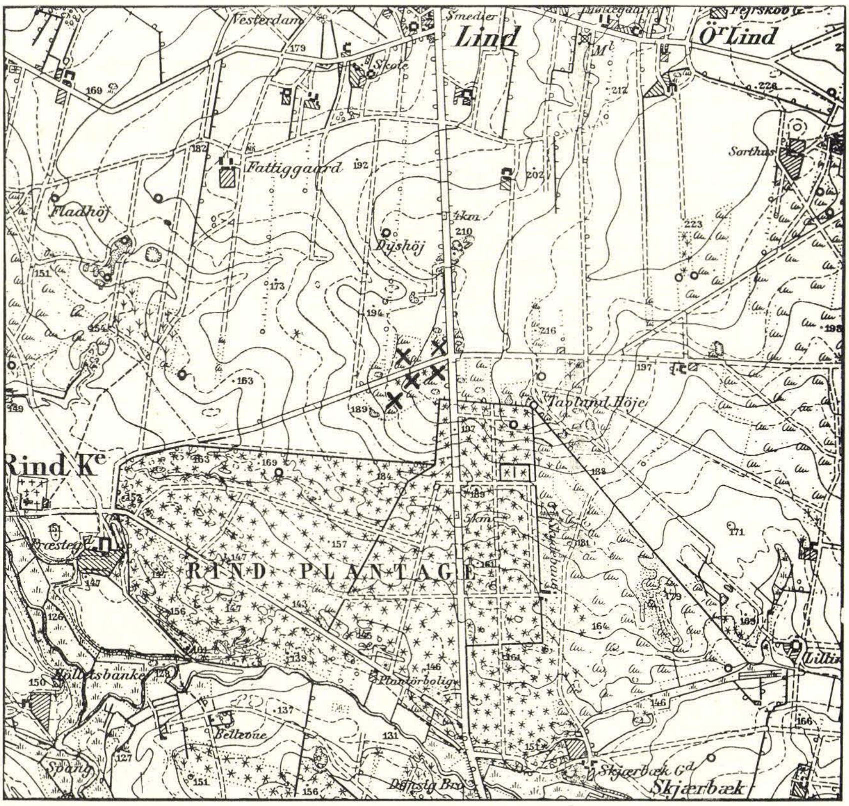


Fig. 15. Map showing position of the marl pits in the interglacial calcareous mud at Rind, the five crosses. Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. The Generel Staff Map Sheet 2506.

The mud is covered by a deposit, up to 5 m thick, of stratified gravel and sand, on the western declivity and near the top, of the gravelly plateau which slopes down towards Fjederholt River in the south and east, and towards Rind River on the west. Farther north, towards the village of Lind, the fluvioglacial gravel, in which there are several pits in the area surrounding the marl deposit, is covered by moraine clay, and this has been followed as a surface formation, as far as to the brickworks at Herning, where it forms the foundation

1) D. G. U. III. R. No. 13. 1916.

of the interglacial lake deposits there found. This moraine at Herning must be presumed to date from the same glacial period as the typically fluvioglacial, stratified gravel and sand beds which cover the Interglacial at Rind, and then this belongs to an earlier interglacial period than the lake deposit at Herning, or in other words, dates from the penultimate interglacial period.

The marl pits recently worked at Rind all lie south of the road leading from the highroad running west to the village of Rind, and there are old and new pits here covering an area of abt. 3 hectares. According to information furnished by the owner, AUG. DYNESEN, of Lind, marl has been drawn from this deposit during the past fifty years. The same type of marl however, is said to have been found north of the Rind road, in place quite close to the road, and also south of Dyshøj, abt. 400 m farther north. See Fig. 15.

In 1923, we noted the following profile in one of the western pits south of the Rind road:

Profile 1.

| | | |
|---|---|---|
| A. | 0 — abt. 2.0 m | Stratified Gravel, with stones the size of eggs. |
| B. | 2.0 — 5.0 m | Stratified Sand. Both the sand bed and the gravel bed fell away 30°—40° towards the east. |
| D. | 5.0 — 5.15 m | Reddish-brown, loamy Disintegration Strata. |
| E. | 5.15— 6.15 m | Pale grey Calcareous Mud (Marl) without stratification. The surface slopes concordantly with the stratification of A and B. The mud was full of fine fissures, irregular in their course and covered with rust on the sides. The subjacent bed was not reached. |

Profile 2.

In 1925, I found a very similar profile in another pit close by. The upper portion of the mud bed could be discerned directly in the pit itself; the spiral auger was used for boring down through the deeper portion of the stratum to the sand beneath.

| | | |
|---|---|---|
| A. | 0 — 0.7 m | Mould and stony Sand without stratification (above these, refuse from previous operations). |
| B. | 0.7 — 2.0 m | Irregularly stratified Sand and Gravel. A kind of chimney, rich in rust, ran down through the whole of this bed. |
| C. | 2.0 — 2.35 m | Grey, non-calcareous Clay with a few small stones. No stratification. |
| D. | 2.35— 2.5 m | Reddish brown, ochreous Clay containing 3.35 % carbonate of lime in a dry state. |
| E. | 2.5 — 4.2 m | Grey calcareous Mud (Marl) as Stratum E in Profile 1. The lower 10 cm of the stratum contained rather more clay than the upper part. Besides pollen of forest trees, a pollen tetrad of *Typha latifolia* was observed, and also a considerable quantity of the calcareous alga *Phacotus lenticularis*. The carbonate of lime content was determined |

by JOHS. ANDERSEN in three samples (dry matter) viz. from the upper portion of the mud 89.8 %, from the lower portion (4.0—4.15 cm below the surface) 58.8 %, and from a heap already dug out 92.9 % $CaCO3$ respectively.

F. Red sharp Sand.

The direction of the profile wall was approximately North-South. The mud bed cropped out along a range of abt. 2 m, and exhibited a highly upward curwing surface (see Pl. XX, 1), Strata D and C being stratified concordantly therewith; it was observed, however, that the thickness of the ochreous layer was about 15 cm, where the marl bed projected farthest, growing thicker down to the sides (20 cm). According to information from the owner of the property, the marl deposit lies altogether very irregularly, often forming banks like the ridge of a roof, a few metres wide, or sticking up in peaks; where the marl bed is thin, the ochreous layer is thickest.

Profile 3 (50 m E of Profile 2).

| | | |
|---|---|---|
| A. | 0 — 0.6 m | Mould and stony Sand without stratification. |
| B. | 0.6 — 1.75 m | Stratified Gravel. |
| C. | 1.75— 3.75 m | Stratified Sand. Discordance between B and C. |
| D. | 3.75— 4.05 m | Reddish-brown, ochreous Clay. |
| E. | | Calcareous Mud of unknown thickness. |

Profile 4 (50 m E of Profile 3).

| | | |
|---|---|---|
| A. | 0 — 0.4 m | Gravel, without stratification. |
| B. | 0.4 — 1.1 m | Gravel with horizontal stratification. |
| D. | 1.1 — 1.7 m | Reddish brown ochreous Clay. |
| F. | 1.7 — 1.8 m | Grey Sand. |

Strata D and F were investigated by boring. In this profile, the calcareous mud was lacking, whereas the ochreous layer was thicker than observed anywhere else in the area; at a little distance off, however, in various directions, lay pits, now fallen in, where marl was said to have been found. The ochreous stratum is probably a relict of disintegration of the calcareous mud, arising from the action of water oozing down through covering strata, and a closer acquaintance with the structure of these than the small and casual profiles could afford would probably explain the peculiar surface form of the marl bed.

No macroscopic vegetable remains were found on washing the marl samples from Rind Marl pits; a somewhat better result was obtained from the microscopic analyses of samples from Profile 2, though the pollen frequency was very slight; where it was lowest, the percentage frequency of the species was not calculated, but a + in the accompanying table indicates the presense of the pollen species in question.

| No. | Depth below surface | Stratum | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Zone | Pollen-frequency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.4 m | D | + | .. | .. | .. | .. | + | .. | .. | + | .. | 4 |
| 2 | 2.6 m | E | 18 | 4 | .. | 38 | 28 | 12 | .. | .. | 15 | *f* | 13 |
| 3 | 2.8 m | — | 14 | 12 | .. | 24 | 18 | 32 | .. | .. | 27 | *f* | 19 |
| 4 | 3.05 m | — | 12 | 2 | 8 | 26 | 14 | 38 | .. | .. | 35 | *f* | 23 |
| 5 | 3.35 m | — | .. | + | + | + | + | + | .. | .. | + | .. | 6 |
| 6 | 3.6 m | — | .. | + | .. | + | .. | .. | .. | .. | + | .. | 4 |
| 7 | 3.8 m | — | + | + | .. | + | .. | + | .. | .. | .. | .. | 6 |
| 8 | 4.05 m | — | + | .. | .. | + | + | + | .. | .. | .. | .. | 6 |
| 9 | 4.15 m | — | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0 |

Table 9. Pollen spectra from Rind.

Despite the paucity of vegetable remains in the mud bed, the view afforded by the table above as to the vegetation contemporaneous with the formation of the deposit is nevertheless clear enough. *Picea* and *Carpinus* were not found, but *Quercus* and *Alnus* appear nearly in all the samples, while *Pinus* is but poorly represented in proportion. *Alnus* and *Corylus* attain their highest frequency in Sample 4, *Quercus* and *Tilia* in Sample 2. Even in the deepest of the samples in which pollen was found, both *Tilia* and *Quercus* were present. The formation of the calcareous mud in the interglacial lake at Rind must then have taken place during the period of the mixed oak forest, simultaneously with the deposit of calcareous mud in the lake at Harreskov. Here, the series of strata preserved terminates in a *Picea* zone with much *Pinus* and *Betula*; nothing of this has been found in the Rind interglacial, but this may be due to the fact that the upper part of the lake deposit has in this case been transformed, and its possible fossil-content destroyed by the process of disintegration which led to the formation of the ochre bed.

## Harreskov.

In 1916, V. Milthers mentioned[1]) a peculiar occurrence of interglacial lake marl at Harreskov, abt. 4 km almost due east of Kibæk railway station, at the source of Harreskov Brook (Fig. 16). With a view to ascertaining the extent and thickness of the deposit, and its value for the extraction of marl on a large scale, V. Milthers had, in 1914 made, for Denmark's Geological Survey, 13 borings in the neighbourhood of some marl pits on the spot, north of the farmstead to which the marl deposit belongs (see Pl. XXI). It was then found

1) V. Milthers: Mergelaflejringerne i Hammerum Herred. D. G. U. III. R., No. 13, p. 19 f., 1916.

that the stratum extended for several hundred metres in a NE-SW direction, on the south side of the stream that flows through the valley.

The interglacial lake deposits found in these borings consist partly of pale grey calcareous mud (marl), partly of dark brownish-green, non-calcareous mud, with finally, diatomaceous earth; they were found to contain abundant pollen of *Betula*, *Alnus*, *Pinus*, *Picea*, *Tilia* and *Corylus*.

The calcareous mud was from 1—3 m thick, with from 70—80 % carbonate of lime; this percentage was however, not infre-

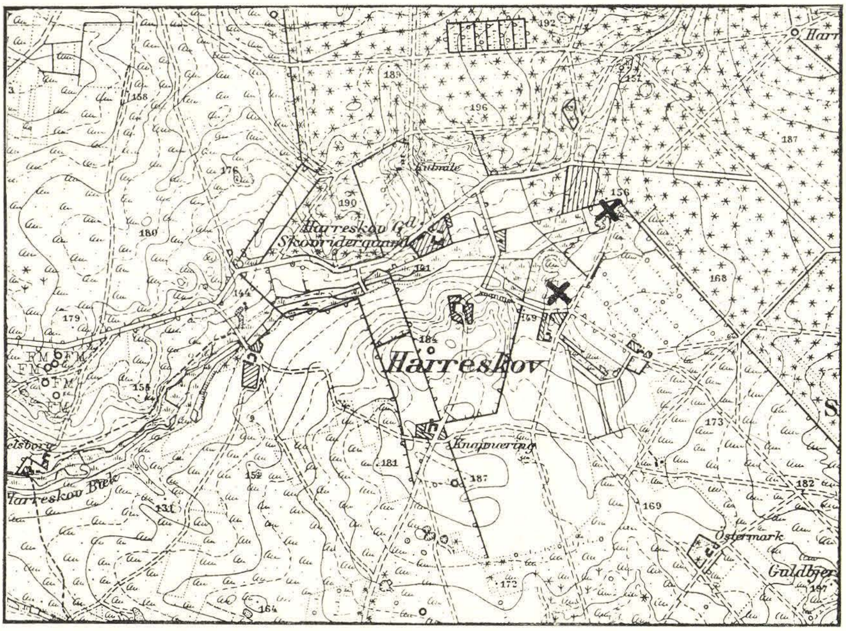

Fig. 16. Map showing the position of the interglacial lake deposits at Harreskov, between the two crosses, Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. The General Staff Map Sheet 2606.

quently lower, especially in the upper part of the stratum; the lowest figure for content of carbonate of lime in the boring samples was 57.5 %. The calcareous mud was found in all the borings except 2 and 13. In this last boring, which was made down in the meadow at Harreskov Brook, the interglacial strata were not met with at all.

The marl was generally both covered by and bedded on the dark, non-calcarous mud (cf. Pl. XXI, 1). The subjacent layer of this was however, often quite thin, while that above was considerably thicker. The thickness of this covering layer varied in the different borings from 0.3 to 3.4 m, and in five of the 11 in which it was found, it was over 1 m thick.

In Boring 8, this mud stratum was not found, but its place above the calcareous mud was occupied by a layer of fairly pure grey diatomaceous earth 1.1 m thick.

The total thickness of the lake deposits found in the borings might amount to 4.7 m. The surface of the mud reached, at the utmost, to abt. 49 m above see level, viz. in Borings 1, 2, 3 and 11; in the remainder, it was considerably lower — down to 45.4 m. The mud surface preserved is thus hardly the original surface; it must be presumed that a more or less considerable portion of the deposit was removed at different places during the deposition of the covering sand; this view is supported by the fact that in the lower parts of this sand stratum, lumps, and at times folded smears, of a mud resembling brown coal were found, this evidently being derived from the upper mud stratum.

The substratum for this coherent deposit of marl and dark mud was Sand, while the covering strata consisted mainly of stony sand and moraine clay. Wind-blown sand and peat may also be found at the top. At one of the borings, the thickness of these covering strata was only 2.2 m, but in 6 of the 11 borings it was over 3 m, and in one place it amounted to 6.1 m. The moraine clay was enclosed in the stony sand, and formed a lens-shaped layer up to 3.7 m thick, apparently enclosing in itself a smaller lump of sand (see Pl. XXII). The moraine clay was found in Borings 5, 9, 10, 12 and 13.

As mentioned above, the stony sand contained lumps of mud; these are stated as having been found especially in that part of the sand stratum which lies below the moraine clay, but interkneaded particles of mud were found in the sand also beyond the edges of this stratum, as was observed in 1925, in the profile described below, from one of the marl pits in the north-easterly part of the locality. Here also, it was noticed that the sand was sometimes stratified; as a rule however, there is no distinct stratification to be seen in the covering sand above the interglacial strata in the marl pits. The profile was as follows:

| | |
|---|---|
| 0 — 0.4 m | Mould. |
| 0.4 — 0.9 m | Highly folded strata of Sand with smears of Mud. |
| 0.9 — 1.4 m | Irregularly colliding blocks of non-stratified Sand. Below this was horizontally stratified Sand, abt. 0.5 m, above masses of fallen material, (cf. Pl. XX, 2). |

The land above the interglacial deposits lies almost throughout in a gentle slope to the NW down towards Harreskov Brook. Great portions of the surface are also curiously pitted, as is faintly indicated, in the profile shown in Pl. XXII. We found, especially in the south-western part of the area included in the plan, (Pl. XXI, 2) numerous small enclosed hollows, up to 1 m deep and abt. 10 m across. There does not appear to be any relation between the occurrence of these pits in the surface and the subjacent lake deposits, and they can hardly be regarded as subsidences occasioned by compression of the interglacial strata (cf. the profile). They must presumably have been formed during the glaciation which deposited sand and moraine clay above the lake basin. It cannot have been in the last glacial period, that the inland ice extended so far west as to Harreskov (cf. p. 59) but in the foregoing, and the temperate lake deposits here must therefore be ascribed to the penultimate glacial period.

With a view to obtaining a closer acquaintance with the development of the forest flora also in one of these western interglacial deposits covered by glacigenous formations, I meassured, in 1925, the following profile in a marl pit in the eastern part of the interglacial lake area, collecting samples for pollen analysis at the same time. The lowerlying strata were investigated by borings with the spiral auger.

| | | |
|---|---|---|
| A. | 0 — 1.5 m | Stony Sand with no distinct stratification. |
| B. | 1.5 - 3.0 m | Greenish brown non-calcareous Mud; spicules of *Spongilla lacustris,* diatoms, spores of *Dryopteris thelypteris* and *Sphagnum sp.* |
| C. | 3.0 — 5.05 m | Pale grey calcareous Mud. Numerous diatoms, pollen of *Nuphar luteum* and *Typha latifolia*, spores of *Dryopteris thelypteris* and *Lycopodium cf. complanatum.* |
| D. | 5.05— 5.40 m | Dark grey finely sanded non calcareous Clay-Mud. |
| E. | 5.40— 5.60 m | Sharp Sand, reddish above, grey lower down. |

The pollen diagram (Pl. XXXVIII, 2) is drawn from 13 pollen analyses from Strata B, C and D in this profile.

The profile itself is divided into three zones, characterised by the presence or absence of carbonate of lime; so also the diagram falls into three sections, changing its character at the transition from calcareous mud to the strata of non-calcareous mud above and below.

In the lowest portion of the diagram, we find the uppermost portion of a *Pinus* zone in Spectr. 13, which shows 62 % *Pinus,* 14 % *Betula,* 10 % *Alnus,* 7 % mixed oak forest, and — a remarkable feature — 7 % *Picea.* The pollen frequency was only 13. But even at the lower margin of the calcareous mud, C, we find already a very different state of things. In Spect. 12 for instance, the mixed oak forest predominates with 56 %, while *Pinus* has dropped to 20 % and *Betula* to 5 %; the curve for mixed oak forest lies on the extreme right throughout the whole of Stratum C without any essential or lasting move to the left; in Spectr. 6, at the upper edge of the calcareous mud, it lies out at 46 %. The *Ulmus* curve culminates in Spectr. 12 with 38 %, attains a secondary maximum of 22 % in Spect. 9, and then falls gradually away towards the left. The *Tilia* curve lies remarkably far to the right, and runs up to 13 % in Spectr. 6 and 7; then this too turns off to the left. The curves for *Alnus* and *Corylus* show relatively low values at the upper and lower margins of the stratum, and culminate in the middle. The curves for *Betula* and *Pinus* run almost parallel with the vertical axis throughout the greater part of the stratum, but with a rising tendency in the upper part; Spectr. 6 shows *Pinus* 14 % and *Betula* 16 %. After *Picea* has attained 7 % in Spectr. 13, its pollen amounts to 1—2 % of Spectr. 11—7, the curve running out to 8 % in Spectr. 6.

The diagram in the upper non-calcareous mud, B, is characterised especially by the curves for mixed oak forest, *Corylus* and *Alnus* running to the left, and those for *Pinus* and *Picea*, partly also *Betula*, to the right. In Spectr. 5, the pollen of the mixed oak forest is still predominant, but the *Pinus* curve, with its marked trend to the left, entirely dominates the 4 upper spectra, attaining 70 % in Spectr. 1. The *Picea* curve has two summits, the first in Spectr. 5 (14 %) the upper in Spectr. 2 (28 %) and there is no pronounced *Picea* zone here, but the *Picea* pollen reaching its highest frequency in the upper *Pinus* zone. No *Carpinus* pollen was found in any of the analyses.

The pollen diagram shows that the conifers found the most favourable conditions of life at the time when the non-calcareous mud was being deposited in the lake, while a mixed oak forest, with abundance of *Corylus* and *Alnus*, reigned unchallenged as long as calcareous mud was being deposited in the lake. This combination — transition from calcareous to non-calcareous sedimentation about at the same time as mixed oak forest gives place to conifers — has also been noted in other cases, more or less complete, as for instance at Hörup, Hollerup and Rodebæk III; also at Egtved, though the paucity of carbonate of lime in the upper part of the mud in this profile perhaps in only secondary. An exception is formed, however, by the Starup mud, where the transition from calcareous to non-calcareous mud is not reflected in the diagram (cf. Pl. XXXVIII, 1).

## Starup.

In 1910, Poul Harder made, on behalf of Denmark's Geological Survey, a boring in a marl pit at Starup, near Tofterup railway station, attention having been drawn to this site by V. Milthers the year before. The marl deposit, in which there is a big pit, lies 700 m SE of Starup Church, at the eastern edge of a small erosion valley, which, sloping down to the northward, has cut its way through the surface of the plain along Holme River (Fig. 17). The boring


Fig. 17. Map showing the marl pit at Starup, the black area. Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. The General Staff Map Sheet 3205.

was made "on the eastern side of the marl pit just in front of the drive leading up to the farmhouse close by". The profile is here given as noted in POUL HARDER's Journal.

Boring 1910.

| | | |
|---|---|---|
| A. | 0 — 0.8 m | Sand (late glacial melting water sand). |
| B. | 0.8 — 1.9 m | Non-calcareous, very dark rather greenish Mud. The surface of this bed is somewhat uneven, with hollows resembling "giants' kettles" and stream beds. |
| C. | 1.9 — abt. 6.0 m | Calcareous grey Mud dark at top and bottom, lighter in the middle. |
| D. | abt. 6.0 —13.9 m | Lighter, faintly greenish, blue and rather stiff Clay Marl, glacial clay merging at the top into the mud above. |

POUL HARDER took 8 samples, the contents of which in carbonate of lime, sulphur, nitrogen and phosphoric acid were determined.

| | 2.0—2.9 m | 2.9—4.0 m | 4.0—4.8 m | 5.0—6.0 m | 6.0—7.0 m | 7.0—8.15 m | 8.15—9.3 m | 9.3—10.5 m | 10.5—12.2 m | 12.2—13.9 m |
|---|---|---|---|---|---|---|---|---|---|---|
| % Carbonate of lime ($CaCO_3$) | 47.6 | 60.0 | 62.2 | 35.6 | 5.5 | 1.9 | 4.3 | 4.8 | 7.6 | 6.1 |
| % Sulphur (S) .......... .. | 1.43 | 0.90 | 1.06 | 1.48 | 0.39 | | 0.15 | | | |
| % Nitrogen (N) ......... . | 0.18 | 0.11 | 0.01 | 0.11 | 0.09 | | 0.06 | | | |
| % Phosphoric acid ($P_2O_5$) . | 0.09 | 0.13 | 0.13 | 0.11 | 0.09 | | 0.14 | | | |

**Table 10.** Determination of lime, sulphur, nitrogen and phosphoric acid in the marl from Starup.

No sharply defined boundary was found between the different strata, and the glacial clay merged without any distinct break into the mud above. Axel Jessen refers to the mud at Starup in his description of Varde geological map sheet[1]) and states that it contains fish scales and small vegetable remains (e. g. fruits and catkin scales of *Betula sp.*). "The upper part of the mud bed, which is dark grey or brownish and free from lime, has no distinct stratification, whereas the calcareous mud shows a distinct horizontal or slightly basin-like stratification". His Fig. 14 shows the situation. Axel Jessen considers it certain that the glacial clay below the mud at Starup is identical with the glacial clay found in undisturbed beds in the immediate neighbourhood. As the stoneless glacial clay of this district is situated between the strata of moraine clay from the first glacial period and the second glacial period (the last glaciation of western Jutland) he considers — and doubtless correctly — that the Starup mud bed should be referred to the penultimate interglacial period.

In 1922, I made a boring on the eastern edge of the marl pit at Starup, abt. 50 m north of the spot where Poul Harder had worked. The profile and fossil contents were as follows:

Boring 1922.

A. 0 — 1.2 m Stony Sand.

B. 1.2 — abt. 7.5 m Non-calcareous Mud, the upper part (abt. 1.3 m) reddish-brown to dark grey, lighter brown lower down, and at the bottom (4.4 to abt. 7.5 m) dark greenish:
*Alnus glutinosa*, numerous fruits,
*Batrachium aquatile (coll.)*, 1 fruit,
*Betula pubescens*, several fruits,
*Ceratophyllum sp.*, 1 leaf-tip,

1) Axel Jessen: Kortbladet Varde. D. G. U. I. R. No. 14, 1922, p. 68 f. Axel Jessen prefers to fix the boundary between diluvial clay and mud at 9 m below the surface; he gives, erroneously, the contents of carbonate of lime in the glacial clay as 22 %.

*Hydrocotyle vulgaris*, 1 nut (abt. 3 m down),
*Lycopus europaeus*, 2 nuts,
*Najas flexilis*, 5 fruits (4 were found 3—4 m, 1 abt. 7 m below the surface),
*Nuphar luteum*, pollen, intercellular hairs,
*Rumex maritimus*, 1 fruit with perigonium (abt. 4 m down),
*Scirpus lacuster*, 2 fruits.

C. abt. 7.5 – 12.5 m + Greyish brown chalky M u d, lighter grey in colour when dry. Determinations of $CaCO_3$ were made in the following samples examined in a dry state by JOHS. ANDERSEN:

| 8—10 m | 11 m | 12 m |
|---|---|---|
| 59.6 % | 62.3 % | 62.0 % |

In the lower portion of the bed, below abt. 11 m fruits of *Betula pubescens* were fairly frequent; the upper portion yielded:
*Alnus glutinosa*, several fruits,
*Betula pendula*, 2 fruits,[1])
— *pubescens*, many fruits,
*Lycopus europaeus*, 1 nut,
*Mentha cf. aquatica*, 1 nut,
*Rumex sp.*, 1 fruit with perigonium.

Not until the samples brought home had been investigated was it discovered that the boring had not penetrated the interglacial lake deposits; the bottom of the basin however, can hardly have lain much farther down, as is evident from Spectr. 18 and 19 in the pollen diagram Pl. XXXVIII, 1.

With a view to procuring better material for pollen analyses, I made yet another boring through the Starup mud in 1925. As however, only a spiral auger was used on this occasion, it was impossible to get farther down than 9.4 below the surface. This profile also, which is shown in Fig. 18 was surveyed on the eastern side of the marl pit, but between the two previous borings, abt. 15 m S of the 1922 site.

Boring 1925.

A. 0 — 1.1 m Stratified S a n d.

B. 1.1 abt. — 6.0 m M u d, reddish greyish brown at the top, lighter greyish brown lower down, turning darker again however, at the bottom, to greenish brown. This stratum was free from carbonate of lime in the upper portion, but with a very small amount at the bottom, e. g. 2.8 % at 4.8 m, and 4.8 % at 5.8 m.[2]) The mud contains a considerable quantity of D i a t o m s, e. g. *Cyclotella comta*, *Cymbella cf. lanceolata*, *Epithemia cf. Hyndmanni*, *Fragilaria sp.*, *Melosira arenaria*,

[1]) These fruits of *Betula pendula*, together with some of *Alnus glutinosa* and 1 perigonium of *Rumex sp.*, were washed out from some samples of chalky mud collected by V. MILTHERS in the marl pit at Starup in 1909.

[2]) Analyses by JOHS. ANDERSEN.

*Melosira sp., Synedra ulna;* in addition to which there were found *Anabaena sp., Botryococcus Braunii, Pediastrum clathratum, Rivulariaceae,* pollen of *Nuphar luteum* and *Umbelliferae,* hairs of *Ceratophyllum sp.,* spores of *Dryopteris thelypteris* and *Lycopodium clavatum;* silika spikes of *Spongilla lacustris* and *Ephidatia Mülleri.*

C. Abt. 6.0 — 9.4 m + Light grey to greyish-brown finely sandy Mud, rather argillaceous especially at the bottom. —
JOHS. ANDERSEN determined the $CaCO_3$ content in the following samples (in a dried state):

| 6.8 m | 7.8 m | 8.8 m | 9.4 m |
|---|---|---|---|
| 22.0 % | 40.8 % | 59.0 % | 63.0 % |

The bottom of the bed in particular was rich in Diatoms: *Cymatopleura elliptica, C. Solea, Cymbella Ehrenbergii, Epithemia Hyndmanni, E. sorex, E. zebra, Fragilaria mutabilis, Melosira arenaria, Melosira sp.,* also present: *Botryococcus Braunii, Pediastrum boryanum, Phacotus lenticularis, Revulariaceae,* intercellular hairs of *Nymphaeaceae,* spores of *Dryopteris thelypteris.* Silica spikes of *Spongilla lacustris.*

Fig. 18 illustrates the approximate relative position of the three borings and the surface of the chalky mud in the southern portion

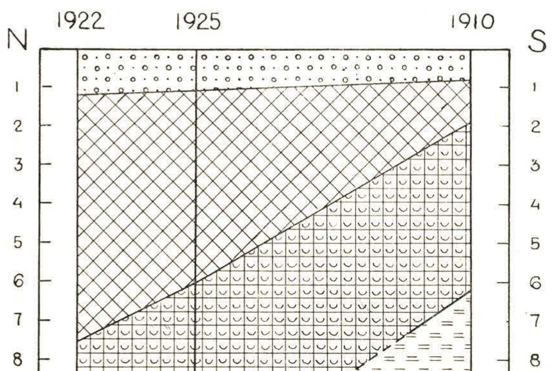


Fig. 18. Section through the interglacial lake deposits at Starup, drawn on the basis of the 1910, the 1922 and the 1925 boring. 1 Melting water sand from the last glaciation. 2 Non-calcareous mud. 3 Calcareous mud. 4 Glacial clay.

of the basin. The bottom of the basin itself slopes gently down towards the north, the south side of the marl pit being presumably not far from the edge of the basin. Nothing more is known as to the maximal depth and extent of the interglacial lake. We do know, however, from AXEL JESSEN's geological survey of the district, that the glacial clay crops out in marl pits situated respectively some 500 m N and NW of the interglacial site, and it was probably also glacial clay which was dug in a small marl pit 160 east of this. These measurements must give the maximum for the extent of the lake in the directions noted.

The pollen diagram Pl. XXXVIII, 1, gives the pollen-floristic sequence in the series bored through in 1925, as shown in Spectra 1—17. Below the double line will be found two Spectra, 18 and 19, from 12 m and 12.5 m below the surface respectively in the boring of 1922. From the profile sketch Fig. 18 it will be seen that the synchronous horizons in the mud have a pronounced incline between the two boring profiles of 1922 and 1925; the table below shows more precisely the difference in level between the synchronous sections of these boring profiles, for Spectr. 20 indicates a horizon situated between Spectr. 16 and 17, and nearest the latter. Setting it at 9.25, this would mean that Spectr. 18, (12.0 m below the surface in Boring 1922) is synchronous with the 10.25 m level in the profile of 1925.

| Spect. No. | Boring-Profile Depth | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Alnus* | *Picea* | *Corylus* | Pollen-frequency |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 1925, 8.8 m | 12 | 31 | 24 | 2 | | 24 | 4 | 1 | 139 |
| 20 | 1922, 11.0 m | 41 | 36 | 8 | | | 9 | 6 | | 125 |
| 17 | 1925, 9.4 m | 41 | 51 | 1 | | | 2 | 5 | 1 | 133 |

Table 11. Pollen spectra from Starup.

The pollen diagram from Starup differs in several respects from the remaining interglacial diagrams. The three lowest spectra give a *Pinus-Betula* zone, *Ulmus* is represented by 1 % in these spectra, and *Corylus* and *Alnus* may be traced with 1 % and 2 % respectively in Spectr. 17, *Picea* is found both in these and the following spectra, up to Spectr. 13, reaching its highest in Spectr. 17 and 18 with 5 % (in Spect. 20 6 %). Even in Spectr. 15 and 16, *Pinus* still has the highest frequency value, but the mixed oak forest runs it very close; after this, the *Pinus* curve turns off to the left, and reaches a minimum of 4 % in Spectr. 9, winding then, in the upper part of the diagram, somewhat to the right, to reach a secondary maximum of 28 % in Spectr. 2; above this, it lies once more outside the curve for mixed oak forest. The *Betula* curve on the other hand makes no such marked divergence, but after turning in towards the axis in the lower part of the figure, never attains any higher frequency than 9 % throughout the rest of its course. Almost the whole of the diagram for the 1925 profile belongs to the mixed oak forest zone, although, as mentioned, with a relatively high value for *Pinus*; *Ulmus* culminates in the lower part of the zone with 29 % in Spectr. 14, its curve then turning to the left and keeping more or less to the 10 % line throughout the upper portion of the figure from Spectr. 11, in Spectr. 4 however, it runs out to 14 % (the secondary maximum) and drops to 6 % in Spectr. 1. *Quercus* was first noted in Spectr. 16 (2 %), the curve then rising to a maximum in Spectr. 9 (31 %) and falling to 10 % in Spectr. 1. The earliest find of *Tilia* pollen is noted in Spectr. 13 (1 %) and this species of pollen occurs with frequency values below 4 % in spectra 11—2, but reaches 6 % in Spectr. 1. The curve for the sum of the frequency values of these three species lies not lower than 28 % in Spectra 16—2, and culminates with 46 % in Spectr. 9. The *Alnus* curve soon swings out to high figures, attaining 40 % in Spectr. 14 (first maximum) culminating as late as Spectr. 5 with 47 %, and lies moreover, farthest to the right throughout the greater part of the diagram for 1925. Particularly conspicuous is the *Corylus* curve, which, from Spectr. 17 to the summit of the figure never reaches more than 9 % (Spectr. 2). *Picea*, having just shown itself in the lower part of the figure, appears with 1—2 % in Spectr. 9 and 8, and from Spectr. 6 to 2 has never more than 3 %, while in Spectr. 1 it reaches 11 %. *Carpinus* never attains more than 1 %, in Spectr. 6 and 2.

The course of development thus ranges from a *Pinus Betula* zone, a zone with maximum of *Ulmus* and that of the mixed oak forest, while the beginning of a *Picea* zone is indicated in the uppermost spectrum of the diagram. Younger beds of mud together with the covering strata from the penultimate glacial time may have been removed of the melting water rivers from the last glacial time, which at last deposited the stratum A. In contrast to what we find in other diagrams, the transition from calcareous to non-calcareous mud is not reflected here in the course of the pollen curves.

## A Peat Bed at Tirslund.

A boring at Tirslund, east of the railway station of Holsted, in the southern part of Jutland, revealed a layer of fresh *Sphagnum* peat at a depth of 37.5 m below the surface.[1]) The covering strata consisted

[1]) V. Milthers: Kortbladet Bække. D. G. U. I. R., No. 15. 1925, p. 89.

predominantly of sand. Analysis of the peat sample gave the following spectrum: *Betula* 22 %, *Pinus* 69 %, *Quercus* 1 %, *Alnus* 2 %, *Picea* 6 %; also pollen tetrads of *Ericaceae* and spores of *Sphagnum sp.*; and further, *Amphitrema flava* and *Assulina sp.* The spectrum seems to show that the peat bed dates from the later part of the interglacial period, Zone *i*.

## Deep-lying Interglacial Bog Formations at Vejen.

In 1909, N. HARTZ published[1]) the profiles of a number of borings made near the town of Vejen, in the south of Jutland, where several peat and mud beds were found at a considerable depth, covered with moraine clay and sand. The beds were from 13 to 37.5 m, below the surface. Vejen lies a little to the east of the western boundary[2]) of the last glaciation, but from the depth at which the interglacial bog formations were found, it is reasonable to regard them as older than the adjacent Brörup bogs, which are covered only by some few metres of sand. V. MILTHERS, who (l. c. p. 89 ) mentions these borings together with several new ones made in 1924 near the Alfa margarine factory, sums up his view of the strata as follows: "The strata, which were bored through at the spots indicated, and which lie surrounded by sand beds, can perhaps be regarded as lying here on the site of their original formation. It is, however, more likely that they are flakes of a coherent deposit. The strata must at any rate be considered as having originated in an interglacial period earlier than the glacial strata which constitute the upper strata in the western plateaus of the map area."

The flora found in the small boring samples is very poor, and much alike in the different strata. Pollen analyses showed that the formations were more or less synchronous, dating from the last part of the interglacial period, like the *Sphagnum* peat at Tirslund. *Carex pseudocyperus* and *Rubus idaeus* were found in the *Dryopteris thelypteris*-peat at the Alfa margarine factory in 1924. The accompanying table gives the results of the pollen analyses. In the last column are noted the zones of the temperate strata from the penultimate interglacial period to which the respective samples probably belong, cf. Chapter VII.

On comparing the zones indicated with the depths from which the samples in question were derived in the separate borings, the impression that the deposits consist of loose flakes is further emphasised.

1) N. HARTZ: Bidrag. . . . D. G. U. II. R., No. 20. 1909, p. 185 -190.

2) V. MILTHERS: Kortbladet Bække. D. G. U. I. R.. No. 15, 1925, p. 89 - 90 and Plan 1.

| No. | Site of Boring | Nature of Sample | Depth below surface m | *Betula* | *Pinus* | *Quercus* | *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen-frequency | Zone |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Vejen Fishery Co. 1903. H. 4.5[1]) ..... | Sandy mud ...................... | 17.0 – 18.2 | 54 | 45 | | | | | 1 | | 69 | *k* |
| 2 | — — — ..... | Mud .......................... | 19.8 – 21.0 | 43 | 53 | 1 | | | 1 | 2 | | 71 | *i* |
| 3 | — — — ..... | Mud? .......................... | 21.0 – 21.7 | 53 | 43 | | | 2 | Trace | 2 | | 65 | *k* |
| 4 | — — — ..... | Forest peat ...................... | 26.4  26 9 | 27 | 52 | Trace | 1 | 1 | | 19 | | 33 | *i* |
| 5 | Vejen Dairy. 1907. H. 4.8[1]) .......... | Sandy mud ...................... | 31.4 – 32.0 | 41 | 38 | 1 | | 12 | | 8 | | 36 | *i* |
| 6 | — — .......... | — — ...................... | 32.0 – 32.7 | 33 | 37 | 1 | 4 | 9 | | 16 | 2 | 79 | *i* |
| 7 | Vejen Margarine factory. 1913. H. 4.10[1]) | Sandy mud ...................... | 34.5—36.1 | 21 | 61 | | | 4 | | 14 | | 202 | *i* |
| 8 | Vejen Margarine factory. 1898. H. 4.1[1]) | Sandy low-moor peat ............ | 36.7 – 37.7 | 9 | 38 | | 2 | 29 | | 22 | 1 | 20 | *i* |
| 9 | Vejen Margarine factory. 1924 ...... | *Dryopteris thelypteris*-peat .......... | 32 | 17 | 53 | | | | | 30 | | 25 | *i* |
| 10 | — — — ...... | Sand with some detritus .......... | 33 | | | | | | | | | 0 | |
| 11 | — — — ...... | Low-moor peat .................. | 34 | 15 | 45 | 5 | | 7 | 2 | 26 | | 44 | *i* |
| 12 | — — — ...... | Sand and *Dryopteris thelypteris*-peat | 35 | 39 | 34 | 1 | | 3 | | 23 | | 41 | *i* |

Table 12. Pollen analyses of the interglacial bog deposits at Vejen.



1) Refer to Archives of the Mineralogical Museum, where these samples are preserved.

# Interglacial Lake Deposits covered by Young Glacial Material.

In all the diluvial fresh-water deposits of Jutland lying east of the limit of last glaciation, the stratification affords as a rule no further information as to age of the strata than that they are interglacial, then the possibility may often be present that they two times have been surpassed by the ice. They are covered as a rule by moraine clay or fluvioglacial sand. Their fossil content yields no information on which to distinguish between them in point of age. The most western of them, especially the lake deposits at Ejstrup,[1]) covered by late-glacial river sand, and the peat deposit at Rostrup[2]), lying near on the limit of the last glaciation and covered by only a few metres of sand and moraine clay, may be referred to the last interglacial period. As to the other of these deposits we must be content to define them as probably originating from the last interglacial period, though older formations also may be taken into consideration.

Apart from the deposits of this group noted in the following so well as Ejstrup and Rostrup, we may here mention the occurrence of diatom muds at Vellev,[3]) Trelde,[4]) Fredericia[5]) and Vejle,[6]) and the peat beds at Kolding[7]).

## Hörup.

The interglacial fresh-water deposits here crop out on either side of a restricted area in the small erosion valley which, running from NNW to SSE, opens out into the valley of the Skals River, near the village of Hörup, 16 km NNE of Viborg, see Fig. 19. The site has already found mention in the litterature, N. V. Ussing, in 1907, writing as follows:[8]) "At Hörup, in 1903, the following profile was seen (N-S wall of the marl-pit, which lies on the western slope of an erosion gully opening out into the valley of the Skals River ): at the bottom, grey,

1) N. Hartz: Bidrag. . . . D. G. U. II. R. No. 20, 1909, p. 205—231.

2) V. Milthers: Kortbladet Bække. D. G. U. I. R., No. 15, 1925, p. 77—82.

3) N. Hartz og E. Östrup: Danske Diatoméjord-Aflejringer og deres Diatoméer. D. G. U. II. R., No. 9, 1899, p. 13. — V. Milthers og Th. Claudi Westh: Viborg Egnens Mergellag. D. G. U. III. R., No. 9, 1913, p. 59. Tavle I.

4) N. Hartz og E. Östrup: D. G. U. II. R., No. 9, 1899, p. 19—23.

5) Ibidem, p. 14—19.

6) Ibidem, p. 24.

7) N. Hartz: Bidrag . . . D. G. U. II. R. No. 20. 1909, p. 232—236.

8) N. V. Ussing: Om Floddale og Randmoræner i Jylland. Oversigt. Kgl. danske vidensk. Selsk. Forh. 1907. No. 4, p. 207. — Handbuch der regionalen Geologie, 1. Bd. 2. Abth. 1910, p. 20.

laminated chalky marl, rich in vegetable remains (*Quercus*, *Alnus*, *Picea* etc.); it was said to be 3 m thick, bedded on gravel with much water; above the marl, abt. $1^1/_2$ m diatomaceous earth. Above these interglacial strata, which slope slightly inwards, lay abt. 4 m of fine white sand in beds sloping sharply (abt. $30^0$) outwards; above this again


Fig. 19. Map showing position of the two marl pits at Hörup, the black areas. Scale 1 : 25000. Contour interval 5 ft. = 1,57 m. The General Staff Map Sheet 1810.

at least 6 m sand and gravel, for the most part in almost horizontal strata; in this however, there were some subordinate streaks of moraine clay; the top is moraine sand with large to very large stones, (partly removed for convenience in cultivation)". In addition to the finds mentioned by Ussing, V. Nordmann[1]) mentions the find of a stag's antler (*Cervus elaphus*) and three molars of the elk (*Alces machlis*)

1) V. Nordmann: On Remains of Reinder & Beaver. D. G. U. II. R. No. 28, 1915, foot note 3, p. 5.

from the interglacial lake deposits at Hörup. Later, however, it would seem that yet another species of deer has been found here. There is in the Mineralogical Museum at Copenhagen, as J. P. J. RAVN kindly informs me, a small bone, found in the interglacial marl at Hörup in 1913 by N. LAUSTSEN, on the label of which HERLUF WINGE has written: "apparently part of the radius of a young doe (*Cervus dama*), but this may possibly be erroneous".

This deposit is also referred to, in conjunction with similar formations at Hollerup and Vellev, in V. MILTHERS' and TH. CLAUDI-WESTH's account of the marl beds of the Viborg district.[1])

The interglacial deposits at Hörup have since been visited by VAGN PETERSSON in 1922 and by me in 1925. VAGN PETERSSON has very kindly presented his material to D. G. U., and we take this opportunity of expressing our cordial thanks for the same. These new investigations of the interglacial formation at Hörup will be described in the following pages.

In 1922, the digging of marl had practically ceased on the western side of the valley, the thickness of the covering strata was too great to render it worth while. This western marl pit measures abt. 250 m from north to south, cf. Fig. 19. On the eastern side of the valley, VAGN PETERSSON saw a profile in the interglacial deposits on the north side of the marl pit indicated on the map, nearest the road, where the thickness of the strata was at a minimum. Here lay abt. 3 m stratified fluvioglacial sand with small stones, and with some few thin layers of glacial clay above the lake deposits. The upper $^{3}/_{4}$ m of these consisted of a bed of diatomaceous earth, in the lower part of which a deposit of iron dioxide had formed, producing a couple of layers of ochre 3—4 cm thich above and below a 4—5 cm thick layer of sand. Below the lower ochre bed was 1.5 m of chalky mud, marl with 72.0—85.8 % carbonate of lime; below this again was a thin layer of low moor peat bedded on gravel.

When I visited the spot in 1925, marl was being dug on the eastern side of the valley, about midway along the north end of the pit, and thus probably somewhat to the east of VAGN PETERSSON's profile point. Only the top of the interglacial series was exposed. The layer of diatomaceous earth however, was lacking here, but was said to occur farther to the east, abt. 1 m thich. The sample of this stratum was collected from the heaps dug up. The preserved surface of the lake deposits is evidently very uneven, the upper portions of the interglacial strata being here and there eroded away by the subglacial currents of water which deposited the fluvioglacial sand

1) V. MILTHERS og TH. CLAUDI-WESTH: Viborg Egnens Mergellag. D. G. U. III. R., No. 9, 1913, p. 58.

above, this here constituting a stratum nearly 5 m thick, with almost horizontal stratification. It contained comparatively few stones. The thickness of the mud beds was determined by boring, and samples were taken at the same time for pollen analysis. Subsequently, I received from the owner of the property, ANDERS VESTER, a couple of samples of mud, taken at the upper edge of the marl bed, and below the diatomaceons earth, not far from the spot where the boring was made. The upper sample consisted of black non-calcareous mud representing a bed abt. 5 cm thick, the other sample, which consisted of yellow mud, was taken directly below this, i. e. from the upper surface of the ochreous mud. The profile of the intergacial lake deposits at Hörup is thus as follows, cf. Pl. XXXIX, 4.

B. abt. 1 m White to light grey Diatomaceous Earth. — No macroscopic vegetable remains or pollen were found in this stratum, but with the kind assistance of BOYE PETERSEN, the following diatoms have been determined: *Caloneis silicula. Cyclotella comta, Cymatopleura elliptica, Diploneis elliptica, D. ovalis, Epithemia sorex* (common), *E. turgida* (common), *Fragillaria brevistriata, F. construens, F. parasitica, Gyrosigma attenuatum* (common), *Melosira arenaria, Navicula oblonga, Pinnularia mesolepta, Stephanodiscus astraea* (very common), *Surirella sp.* Numerous silica spicules of *Spongilla lacustris* were also found.

C. abt. 0.05 m Black, non-calcareous Mud.

D. abt. 1.10 m Chalky Mud, the upper part red, the lower a lighter reddish brown, rich in ochre, with thin streaks and flames of pale grey mud throughout. At the top, where it joins C, a thin layer of yellow mud. I found no macroscopic vegetable remains in this stratum, but a sample of brown non-calcareous mud collected by VAGN PETERSSON, presumably from the upper edge of this stratum, yielded on washing:
*Alnus glutinosa*, 8 fruits,
*Betula pubescens*, 4 fruits,
*Carpinus betulus*, 1 fruit,
*Potamogeton sp.*, 5 small fruits,
*Picea excelsa*, several needles, 1 seed wing, 1 seed.

E. abt. 2 m Dark, greyish-green calcareous Mud which when dried assumes a lighter colour, the upper part, which was less easy to split, and was rather poor in macroscopic vegetable remains, becomes a pale grey-blue, the lower, which splits easily and is rich in leaf impression, fish scales etc. pale grey. In this stratum were found:
*Alnus glutinosa*, catkins, fruits,
*Betula pubescens*, fruits and catkin scales,
*Corylus avellana*, 1 nut,
*Najas marina*, 2 half fruits; one of the pieces, which was complete, measured 6 mm by 2.3 mm,
*Picea excelsa*, 1 seed wing, 2 fragments of cone scales,

*Pinus silvestris*, fairly many flakes of bark,
*Potamogeton sp.*, 3 small fruits,
*Quercus robur*, fairly many leaves.

*Amblystegium stellatum*,
*Calliergon stramineum*,
— *giganteum*,
*Camptothecium trichoides*,
*Hypnum exannulatum*,
— *intermedium*,
*Scorpidium scorpioides*,
*Sphagnum sp.*

*Anabaena sp.*,
*Pediastrum boryanum*,
— *duplex*,
— *clathratum*,
*Phacotus lenticularis*.

*Esox lucius*, many scales, 1 tooth,
*Perca fluviatilis*, many scales,

*Bithynia tentaculata*, 1 shell cower.
*Ostracods*.

F. abt. 0.1 m Dark greyish brown muddy Low Moor Peat. In this were found:
*Betula pubescens*, fairly many fruits,
*Carex pseudocyperus*, 7 fruits,
*Cladium mariscus*, 3 fruits,
*Juniperus communis*, 1 small seed,
*Menyanthes trifoliata*, fairly many seeds,
*Sparganium cf. minimum*, 1 fruit-stone,
*Typha latifolia*. 1 grain of pollen.

G. Sand with stones.

Johs. Andersen has made analyses for determination of carbonate of lime, potassium and sulphur, from three samples in a dry state from the marl on the eastern side of the valley (cf. the analysis given on p. 198).

| | Carbonate of lime ($CaCO_3$) | Potassium ($K_2O$) | Sulphur (S) |
|---|---|---|---|
| Stratum D, reddish yellow marl | 90.0 % | 0.01 % | 0.06 % |
| — E, blue — | 84.0 % | 0.02 % | 0.09 % |
| — E, grey — | 73.0 % | 0.04 % | 0.15 % |

The extent of the lake deposits is only known from the marl workings, and the map Fig. 19 shows the extent of these. The eastern pit however, is somewhat larger than here indicated, and reaches on the south as far as the spruce plantation N of the house. Here, abt. 1.5 m of sand, with few stones, covered abt. 1 m ochreous chalky mud bedded on sand, and it seems thus as if we were here approaching the southern limit of the lake deposits. The deposits on both sides of the valley are undoubtedly parts of one and the same interglacial formation. The greatest known extent of this lake as far as hitherto known, from NE to SW is abt. 400 m.

While F, the peat bed, was being formed, on the bottom of the basin which later became filled with water, it was undoubtedly for the most part *Betula pubescens*, with some *Pinus silvestris*, which grew on the surrounding hills, where *Juniperus communis* also throve at the time; of other trees, *Corylus avellana* is the only one that makes itself apparent, in Spectr. 12 (Pl. XXXIX, 4), and then only to the amount of 1 %. In Spectr. 11, *Ulmus* and *Quercus* appear, making 3 % together, and this latter species with *Corylus* and *Alnus*, soon attains high frequency values in the following spectra. In the lower half of E, the *Pinus* curve lies a little to the right of that for mixed oak forest, but turns then towards the vertical axis as far as Spectr. 3 inclusive. It is thus the mixed oak forest in conjunction with *Corylus* and *Alnus* which dominate the spectra from almost the whole of the marl deposit. Not until Spectr. 2 is reached does the *Pinus* curve swing off to the right, and attain a higher frequency value than the mentioned species. At the same time, *Picea* now appears, and in the non-calcareous, dark mud up above (Spectr. 1), *Picea* and *Pinus* are the predominant species; the conifer spectra in this diagram are thus more particularly associated with the non-calcareous strata. The non-calcareous diatom earth must also be presumed to be mainly derived from the younger conifer period, but we have, as mentioned, no pollen from this stratum. *Carpinus* was only found in the two youngest spectra, and attains its greatest frequency (8 %) in Spectr. 2.

As it is shown in the pollen diagram (Pl. XXXIX, 4) we here have the following pollenfloristic zones, *c*, *de*, *f*, *g* and *h*; see Chapter VII.

## Lövskal I.

K. Rördam once drew the attention of V. Milthers to a deposit of ochre at the village of Lövskal, abt. 19 km W of Randers, and in 1926, V. Milthers visited the locality and found that the deposit in question was an interglacial formation of ochre deposited in a lake basin. In the same year, I made a survey of that portion of the deposit which was visible in an excavation made in the bed, and collected samples for a botanical investigation of the ochre formation etc.

With the permission of the Director of The Federation of Danish Industries, G. E. Hartz, we give here some main points in the report on the constitution of the Lövskal ochre bed, with the stratification conditions, as drawn up by the orders of The Federation in 1918. As will be seen from the map Fig. 20, the ochre bed lies in a hollow in the young-diluvial plateau on the eastern side of the valley of Skals River. Numerous borings showed the greatest extent of the deposit as abt. 250 m, the area involved being 1.6 hectares. The thickness of the ochre bed along the edges is only very slight, but soon attains considerable magnitude in towards the middle, in places as much as 5 m or over. The covering material is stated in the report to consist of sand, gravel and clay, attaining a total thickness varying between 0.5 m and 6.5 m. The ochre itself is throughout bedded on sand.

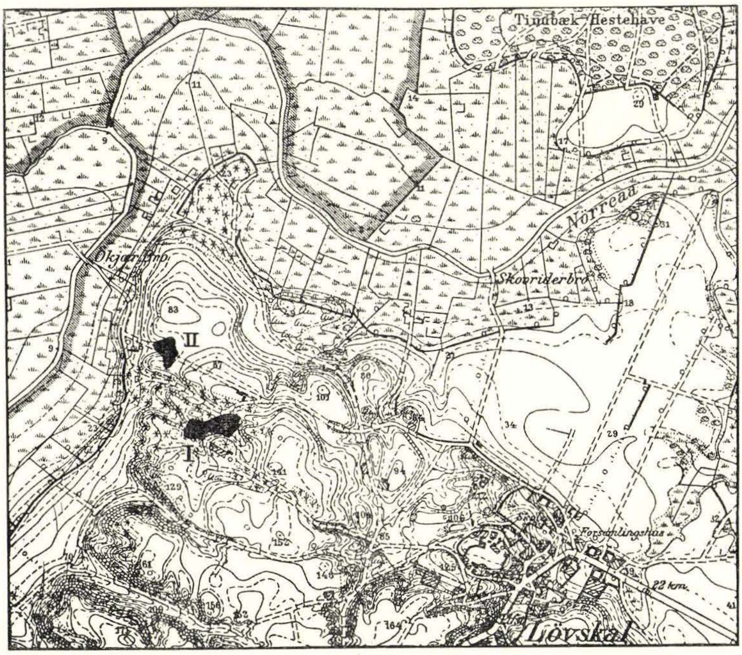


Fig. 20. Map showing position of the ochre bed at Lövskal I and the marl pit Lövskal II; the black areas. Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. The General Staff Map Sheet 2011.

K. Rördam analysed for The Federation 10 different samples of ochre from Lövskal. The result of this investigation was, briefly, that the samples contained from 16.9 % to 68.5 % $Fe_2O_3$ from 0.174 % to 0.839 % $P_2O_5$ and from 0.004 % to 0.104 % $SO_3$. Only two of the samples were calcareous, containing respectively 22.37 % and 64.70 % $CaCO_3$. The loss of material by heating after drying of 100° fluctuated between 3.33 % and 24.40 %, showing that the percentage of humus (+ water chemically bound) was on the whole but slight throughout the deposit. The amount of sand present varied as a rule between 10.17 % and 30.55 %.

The ochre is dug for the use of the gas works, and it was from the northern wall of the pit thus made that the survey was taken in 1926, as shown in the western part of the profile given in Table XXIII, 1, the eastern part being constructed on the basis of some borings made on behalf of The Federation. All observations as to the position of the ochre bed show that we have here a lake deposit in its primary situation in a basin. Only the upper horizon of the ochre bed showed traces of erosion and a little folding. The covering strata, from the last glacial period, consisted, as regards the western end of the northern wall of the pit, of stratified fluvioglacial sand, the stratification being approximately horizontal in the western part of the profile, but running concordantly with the eastward sloping strata of the ochre in the eastern part. The sand contained a few large stones. On the extreme east, alternating strata of sand and stoneless clay were observed, and a lens of sandy moraine clay. At the top was a thin layer of wind-blown sand.

In the western end of the pit, a layer of black, finely arenaceous humus was observed, up to 10 cm thick, lying between the ochre and the bottom of the basin, which consists of fluvioglacial sand, separated from the bottom however, in places, by a layer of sandy ochre abt. 1 cm thick. The greater part of the ochre deposit appeared in the pit as a reddish brown, greasy mass with indistinct stratification. In the uppermost metre however, the stratification was very distinct, as a rule almost concordant with the surface of the deposit, the ochre here being more sandy, while at the same time thin streaks of sand with small stones appeared. Here also were found veins and lenses of pure light coloured sand.

The samples taken for washing analyses, partly from the black humus and partly from the ochre itself, contained no macroscopic vegetable remains, and even the microscopical examination of numerous samples from this lake deposit revealed only very few determinable plant remains — apart from pollen of forest trees — viz. a couple of grains of pollen of *Nuphar luteum* and *Nymphaea alba,* with two specimens of *Pediastrum boryanum* and some threads of a *Rivulariaceae.* The interglacial lake here seems to have been very poor in plant life of the higher classes; possibly the water may have been poisoned by the great amount of iron oxides present.

The samples used for pollen analysis[1]) were taken from the eastern end of the pit, some few m south of Point 6 in the profile shown,

[1]) The $Fe_2O_3$ contained in the samples was dissolved by boiling with dilute hydrochloric acid; the pollen was washed in a filter and treated with KOH, the grains of pollen showing no trace of yellow; they were afterwards stained a bright red with erythrocine liquid.

i, e. from about the middle of the interglacial basin. Here, partly from the wall of the pit and partly by boring, the following profile was measured:

| | | |
|---|---|---|
| A. | 0 — 2.5 m | Fluvioglacial Sand, stratified almost horizontally, with stones the size of fist. |
| B. | 2.5 — 3.4 m | Alternating strata of reddish-brown sandy Ochre and greyish brown Sand with scattered stones the size of beans. |
| C. | 3.4 — 4.15 m | Pale reddish brown rather flamed calcareous Ochre; 20 cm below the upper surface of the stratum was an undulating bed of sand 4 cm thick. |
| D. | 4.15— 7.87 m | Darker reddish brown, horizontally stratified Ochre, the upper part rather dry and crumbling, that below the bottom of the pit moister and of a greasy consistency. |
| E. | | Greyish brown sharp Sand. |

The 17 spectra of the pollen diagram cover only 3 of the floristic zones which are distinguished in the interglacial pollen diagrams (cf. Chap. VII), and the unusually varied curves in zones *e* and *f* must doubtless be considered in connection with this.

In the lower spectra of the pollen diagram in Fig. 1, Pl. XXXIX the dominant forms are *Betula*, with a falling tendency, and *Pinus*, with a corresponding tendency to rise, whereas *Quercus*, *Corylus* and *Alnus* show only 1—2 %. Then comes a zone with pronounced *Pinus* maximum (57 %), *Betula* falling off to a marked extent, while *Corylus*, *Quercus* and *Ulmus* have become far more frequent than at the base of the diagram; the two later pollen species have, in Spectr. 13, relative maxima; *Alnus* is still less common. In Spectr. 5—12, *Corylus* contributes in most cases more than half the total amount of pollen, attaining indeed a frequency of 227 % and 226 % in Spectr. 9 and 10; the *Alnus* pollen also now becomes gradually more frequent, and culminates about the same time as, or a little later than, *Corylus*, with 74 % in Spectr. 9. Here at Lövskal also we find an *Ulmus* maximum in the upper part of zone *f* (18 % in Spectr. 4) about the same time as *Tilia* makes itself apparent (3 %). An uncommon feature is the pronounced movement of the *Quercus* curve in the upper spectra of the *f* zone, from 4 % to 59 % in Spectr. 2; something similar was however, noted at Hörup and Hollerup for instance, but it is only here, in the Lövskal diagram, that we find the *Quercus* curve lying to the left of the *Pinus* curve in the middle part of the *f* zone, though the *Pinus* pollen is also highly prominent in this zone in the deposits at Hörup and Hollerup. In each of the spectra 2, 3 and 13 a pollen grain of *Ilex* was found. The rational limit for *Carpinus* pollen may be fixed at Spectr. 4, but if a true *Carpinus* zone ever developed in this basin, it must have been destroyed during the glaciation of the site in the following glacial period. *Picea* pollen was only found in isolated grains, and was doubtless all brought by the wind from far away. Stratum B, which consisted of alternating beds of sand and displaced ochre, was not subjected to pollen analysis.

As in many of our interglacial basins elsewhere, a formation of chalk took place in Zone *f*, but in contrast to what is usually found, only the upper part of the zone is here calcareous.

## Lövskal II.

About 250 m NW of Lövskal I, on the edge of the plateau looking out towards the valley of the River Nörreaa, there is a large marl pit, now disused (Fig. 20). According to information received by V. MILTHERS from the proprietor, the marl formerly dug here was of a highly calcareous sort, and covered with sand. This suggested that there might here be another interglacial lake deposit, and the supposition was confirmed in 1926, when I visited the spot, inasmuch as the marl was found to consist of a yellowish calcareous mud, covered by 3—4 m of fluvioglacial sand and bedded on sand again. An air-dried sample from the site, analysed by JOHS. ANDERSEN, was found to contain 85.7 % $CaCO_3$.

A boring made in the lower part of the eastern slope of the marl pit, now overgrown with grass, abt. 3 m below the surface of the field, showed the following profile:

| | | | |
|---|---|---|---|
| A. | 0 — 1.4 | m | Fluvioglacial Sand. |
| B. | 1.4 — 2.0 | m | Yellowish calcareous Mud. |
| C. | 2.0 — 2.5 | m | Grey sandy calcareous Mud. |
| D. | 2.5 — 3.0 | m | Mud-blended Sand. |
| | | | Sharp Sand. |

A sample from the lowest part of Stratum C contained only a little pollen, chiefly of *Quercus* and *Pinus*; a sample from 1.95 below the surface showed the following pollen spectrum: *Betula* 22 %, *Pinus* 31 %, *Alnus* 2 %, *Ulmus* 2 %, *Quercus* 42 %, *Picea* 1 % and *Corylus* 3 %. Some pollen of *Gramineae* was found, also a spore of *Lycopodium selago*.[1])

Here, as in other interglacial localities, the calcareous mud belongs to the mixed oak forest zone, the pollen spectrum above noted being from the lower part of this.

1) The appearance of the spore corresponded to Fig. 37, Taf. 1 in G. ERDTMAN (Beitr. zur Kenntnis der Microfossilien in Torf und Sedimenten. Archiv f. Botanik, Bd. 18, No. 14, Stockholm 1923), but measured only 24 $\mu$ in diameter.

# Hollerup.

The researches of N. Hartz and E. Östrup, published in 1899, on Danish diatomaceous earths and their diatoms,[1]) laid the foundations of our knowledge as to the stratigraphical conditions and fossil content of the Hollerup Interglacial. It was desirable however, to make


Fig. 21. Position of the diatomaceous earth at Hollerup, the black areas. The profiles surveyed are from the western pit. Scale 1 : 25000. Contour interval 5 ft = 1.57 m. The General Staff Map Sheet 2112.

thorough pollen investigations also in this locality, so as to permit of more detailed stratigraphical comparison between this and, primarily, the other Danish interglacial deposits of calcareous and diatom mud. This was the more to be wished for, as the finds of higher plant forms from Hollerup hitherto published were derived almost exclusively from a single horizon in the calcareous mud (l. c. p. 9); I therefore

[1]) N. Hartz og E. Östrup: Danske Diatoméjord-Aflejringer og deres Diatoméer. D. G. U. II. R., No. 9, 1899.

visited the spot in 1925, and collected the necessary samples throughout the whole of the formation. The collection was made in the western part of the great pit, which has shifted appreciably towards the north since N. HARTZ took his profiles here. (Fig. 21). The 1925 profile was as follows.

Under a layer of fluvioglacial Sand (A), horizontally stratified and abt. 7 m thick, lay the following strata:

| | | |
|---|---|---|
| B. | 0 — 0.15 m | Greyish brown, sandy Clay with thin streaks of Sand and a few small stones. |
| C. | 0.15— 2.50 m | "White Diatomaceous Earth", white to pale yellow, almost entirely pure bedded with a gradual transition on Stratum D. The upper $1^1/_2$ m of the layer contained a quantity of fine sand. The following were found: *Pediastrum boryanum, Anabaena sp., Rivulariaceae*, numerous spicules of *Spongilla lacustris*. Also many pollen tetrads of *Ericaceae* and *Empetrum nigrum*, pollen of *Nuphar luteum* and a spore of *Lycopodium clavatum*. For pollen of the forest trees in this and the other strata see the pollen diagram Pl. XXXIX, 5. |
| D. | 2.50— 4.35 m | "Black Diatomaceous Earth", i. e. a dark greyish brown mud when damp, but producing when burnt a pure white product. The microscope revealed intercellular hairs of *Nymphaeaceae* (very common); also *Pediastrum boryanum, Tetraedron minimum, Anabaena sp., Rivulariaceae, Cladocera, Spongilla lacustris* and leaf epidermis of *Pinus silvestris* and *Picea excelsa*, with some few pollen tetrads of *Empetrum nigrum*. |
| E. | 4.35 — 4.95 m | Greyish brown, rather sharp Sand, containing vivianite. This stratum, which slopes from west to east, like the upper and under surface of the diatom earth, thinning out in the same direction, presumably indicates that the western margin of the interglacial basin lies not far from the western end of the present pit. |
| F. | 4.95— 6.45 m | Pale greyish brown, finely sanded calcareous Mud, (Marl): Hairs of *Nymphaeaceae*, pollen tetrads of *Typha latifolia*, 2 pollen grains of *Chenopodiaceae*, leaf epidermis of *Pinus silvestris*; also *Anabaena sp., Cosmarium spp.* (2 species), *Euastrum (binale)?, Pediastrum clathratum?, Phacotus lenticularis, Rivulariaceae, Tetraedron minimum*, — *Spongilla lacustris*. |
| G. | 6.45— 6.70 m | Coarse Sand, red at the top, grey lower down. |

Strata A—D were observed directly in the north wall of the pit; E—G were investigated with the spiral auger.

The sand stratum E constitutes a sharp boundary line between the marl bed and the non-calcareous layer of diatomaceous earth; it also provides a similarly difinite boundary between the foliage tree zone and that of the conifers. In this profile, we have no non-calcareous deposit of mud or peat below calcareous mud, such as is found in the profiles at Hörup and Harreskov; we also lack here the lower *Pinus-Betula* zone proper. True, *Pinus* attains a considerable frequency in the two lower spectra, 39 % in Spectr. 17, and 48 % in Spectr. 16, and indeed, does not fall below 14 % in any part of the figure; *Betula*, however, in the two spectra named, has only 7 % and 6 % respectively, while the mixed oak forest amounts to 28 % and 34 %. The lower portion of the typical interglacial pollen diagram is here lacking. Within the horizon of the calcareous mud, the mixed oak forest attains its culmination, with 37 % in Spectr. 13 (*Quercus* 29 % in Spectr. 16, 13 and 12, *Ulmus* 8 % in Spectr. 14, and *Tilia* 3 % in Spectr. 13), *Corylus* with 79 % in Spectr. 14, and *Alnus* with 33 % in Spectr. 13.

Immediately above the sand stratum E, at the lower edge of which there may perhaps be a lacuna due to erosion of the calcareous mud, the pollen frequency of the mixed oak forest and hazel dwindles to altogether insignificant figures, and it is probably for the most part pollen due to wind transport from far away which represents these groups in the upper spectra. The *Alnus* curve likewise turns off sharply to the left in Spectr. 11, but in the next two, Spectr. 10 and 9, *Alnus* at once attains a secondary maximum at the bottom of the *Picea* zone, and we find something of the same sort in the case of other diagrams (Duedam I, Brörup). The rational limit for *Carpinus* lies at Spectr. 13, and the *Carpinus* zone reaches to Spectr. 11, culminating with 19 % in the lower part of the diatom earth. *Picea* also culminates in the same spectrum, (48 %); the *Picea* zone proper embrases only Spectra 10 and 11. For the rest, it seems as if *Picea excelsa* had been represented by some scattered growth in the vicinity of the lake all the time the calcareous mud was forming; its pollen was found therein with a frequency of up to 5 % (Spectr. 17), and N. Hartz records (l. c. p. 11) the finding of a needle and a couple of winged seeds of *Picea excelsa* from the greyish blue marl. After its first culmination, (Spectr. 11) the frequency of *Picea* falls rapidly — having a secondary maximum in Spectr. 3 and 4 — and that of *Pinus* rising rapidly at the same time; the curves for these two species lie on the extreme right as far as Spectr. 2, where the *Picea* curve is intersected by the curves for *Betula* and *Alnus* turning to the right. The curve for pollen frequency makes a decided turn to the right at Spectr. 4, where we have 330 pr. sq. cm, in Spectr. 1 only 49 per sq. cm appeared, and in the samples from the upper part of the "white diatomaceous earth" pollen was almost entirely lacking.

# Frausing.

After the greater part of the present work had gone to press, I examined some samples of diatomaceous earth and ochre sent to Denmark's Geological Survey by KRISTIAN STORGAARD, from a deposit at Frausing, 11 km N of Silkeborg. These showed that the fresh-water deposit in question was interglacial. From information communicated by the contributor it appears that this bed of diatomaceous earth crops out on the steep slope on the western side of the deep, late-glacial erosion channel which opens out into the valley of Alling River, 2 km E of Hinge. The site is 300 m N of the northern edge of the Alling River valley.

The thickness of the stratum is described by the contributor as varying greatly, from a very thin layer to over 4 m. At the spot where the samples were taken, the profile is noted as follows:

A. Sand (fluvioglacial sand).

B. 0.7 m Ochre, sandy at the top, with a thin layer of diatomaceous earth at the bottom.

C. 1.05 m Yellow, light brown or perfectly white, flamed Diatomaceous Earth, non-calcareous, the upper $^2/_3$ of the deposit distinctly stratified; the lower part, which contained much vivianite, showed hardly any stratification.

D. Firm Sand.

Chemical analysis of the samples from Strata B and C was made by JOHS. ANDERSEN, with the result shown in Table 13.

| | Samples | % Organic matter and water chemical bound | % $SiO_2$ Mainly as diatom scales) | % $Fe_2O_3$ | % $Al_2O_3$ and $P_2O_5$ |
|---|---|---|---|---|---|
| Ochre.................. | 1 | 10.8 | 37.8 | 45.9 | 4.9 |
| Diatomaceous earth .... | 2 | 10.2 | 50.7 | 27.7 | 11.1 |
| — .... | 3 | 5.7 | 78.0 | 9.3 | 6.5 |
| — .... | 4 | 6.3 | 59.1 | 26.7 | 7.3 |

Table 13. Chemical analyses of ochre and diatomaceous earth from Frausing.

The following table shows the result of the pollen analyses of the samples received:

| No. | Stratum | Depth below surface of B | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Ulmus* + *Quercus* + *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen frequency | Zone |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B | 0.85 m | 4 | 1 | 2 | 2 | 1 | 5 | 52 | 34 | 4 | 14 | 107 | *g* |
| 2 | C | 1.20 m | 5 | 10 | 1 | 4 | 1 | 6 | 53 | 19 | 7 | 31 | 82 | - |
| 3 | - | 1.55 m | 2 | | 1 | 6 | 3 | 10 | 59 | 29 | | 87 | 122 | - |
| 4 | - | 1.90 m | 6 | 8 | 9 | 10 | 3 | 22 | 60 | 4 | | 69 | 238 | *f* |

Table 14. Pollen spectra from Frausing.

From these analyses it appears that the diatomaceous earth is interglacial (*Carpinus, Picea*) and that the lower part of it was formed during the latter part of the mixed oak forest period in the interglacial period in question, the upper parts of the deposit belonging to the *Carpinus* zone. *Ulmus* exhibits, here as elsewhere, considerable frequency in the upper part of Zone *f*. The minimum for *Pinus* and *Betula* lies in the lower part of Zone *g*. *Picea* immigrated to the Frausing district at a time essentially later than *Carpinus* during the interglacial period in question. *Corylus* here displays an unusually high frequency even in the lower part of the *Carpinus* zone.

## Egtved.

In the geological description accompanying the map sheet Bække, V. MILTHERS notes[1]) an occurrence of interglacial freshwater beds in the sharply defined erosion valley of Ballehule N of Egtved and 1200 m W of the parish road leading across the valley, cf. Fig. 22. The formation crops out in the stream that runs through the valley, and has also been located, by digging and boring, some way up in the northern slope of the valley itself. In the bottom of the valley, the interglacial strata cropped out to the surface, or were covered by a thin layer of stony sand. In the side of the valley also, the covering layer of sand was as a rule but of slight thickness, attaining however, a thickness of 6 m in the highest of the borings in which the interglacial deposit was encountered. In this, ist surface was abt. 16 m above the level of the stream, which at this point is 28 m above sea level (cf. MILTHERS, l. c. Fig. 12). The deposit consisted of fresh-water mud, the lower strata of which are calcareous. In the bottom of the valley, along the foot of the hill, the calcareous mud was found to be covered here and there by a thin layer of diatom earth; higher up in the slope, the calcareous mud was covered by a layer of non-calcareous mud, and this again by a bed of sandy clay abt. 1 m thick. The mud was very handsomely stratified, and in a trench exposing the upper 2 m of the mud, it was noticed that the upper strata sloped in the same direction as the surface, the lower being nearly horizontal (MILTHERS l. c. Fig. 14). The mud bed was up to 7.8 m thick.

Here especially in the calcareous (foliated) mud and in the diatom earth, plant remains were fairly numerous; we may note here *Picea excelsa, Pinus silvestris, Quercus robur, Acer platanoides, Taxus baccata, Ilex aquifolium*. For the rest, the flora of this formation will be found described at greater length in the following.

In the autumn of 1925, Denmark's Geological Survey received

[1]) V. MILTHERS: Kortbladet Bække. D. G. U. I. R., No. 15, 1925, p. 66—77.

from J. O. BRANDORFF of Kolding, large portions of the skeleton of a fallow-deer, found while digging for marl in the interglacial deposit at Egtved. I therefore made a renewed examination of the


Fig. 22. Map showing position of the interglacial locality at Egtved (x). Scale 1 : 25000. Contour interval 5 ft. = 1.57 m. The General Staff Map Sheet 3208.

locality, which now, thanks to the marl workings which had been commenced in the same year, offered better opportunities for investigation of those parts of the formation situated in the bottom of the valley than had previously been available. The profile Fig. 2, Pl. XXIII shows the survey of the beds as observed, partly in the northern wall of the marl pit, (the approximate size of this is indicated by a dotted line on the profile) partly by borings. The 5 observation points marked in the figure lie in a straight line along the foot of the northern slope of the valley. V. MILTHERS' profile line 2—9 (l. c. Fig. 12) intersects this profile at about point 4.

The profiles surveyed by boring or directly in the wall of the pit at these five points were as follows, (cf. Pl. XXIII, 2):

Point 1.

A. 0 — 2.8 m Greyish brown River-Sand consisting of alternate layers of sand and sandy mud with vegetable remains.

B. 2.8 — 3.3 m Grey Moraine Clay.

Point 2.

A. 0 — 1.1 m Sand with stones up to the size of hen's eggs; these were found more especially at the bottom, where the bed assumed the character of a gravel bed.

B. 1.1 — 1.35 m Reddish brown, here and there white Diatomaceous Earth, which, especially in the lower part, was cemented together in hard crusts resembling hard pan, and in little veins of ochre. Apart from the diatoms, (see MILTHERS l. c. p. 75) and pollen of forest trees, (see Pl. XXXIX, 3) the lower portion of this bed contained spores of *Dryopteris thelypteris*, *Osmunda regalis* and *Polypodium vulgare*, a pollen tetrad of *Typha latifolia* and pollen of *Nymphaea alba*.

C. 1.35— 4.35 m Greyish green, finely stratified calcareous Mud. Diatoms were very common, especially at the top; also *Anabaena sp.*, *Botryococcus Braunii*, *Chroococcus turgidus*, *Cosmarium sp.*, *Euastrum cf. binale*, *Pediastrum boryanum*, *P. duplex*, *Rivulariaceae*, *Tetraedon minimum* — leaf tips of *Ceratophyllum sp.*, Pollen of *Nuphar luteum*, *Typha latifolia*, *Chenopodiaceae*, (1 grain of pollen in sample 12), *Ilex aquifolium*, (Spectr. 7 and 10) spores of *Dryopteris thelypteris*, *Osmunda regalis* (Spectr. 4 and 12) and *Polypodium vulgare*.

D. 4.35— abt. 5.0 m Sandy, lighter grey calcareos Mud, richest in sand at the bottom, spores of *Dryopteris thelypteris*, leaf epidermis of *Pinus silvestris*.

E. abt. 5.0 — 5.15 m Fine sharp Sand.

Point 3.

A. 0 — 0.2 m Mould and stony Sand.

B. 0.2 — 1.8 m Greyish yellow to reddish yellow Diatomaceous Earth. Only in the lower 40 cm or thereabout was well preserved pollen found in any considerable quantity (cf. the pollen diagram); in the upper part very little was observed and in a poor state of preservation. V. MILTHERS (l. c. p. 75) mentions a number of diatoms from the diatom earth at Egtved; in addition to these, a few other species may here be noted, found by BOYE PETERSEN in samples of the bed from Point 3: *Cymbella cistula*, *Fragillaria brevistriata*, *F. construens*, *F. intermedia*, *F. mutabilis*, *Melosira granulata*.

C. 1.8 — 5.05 m Greyish-green calcareous Mud (Marl).

D. 5.05— 7.45 m Light grey calcareous Mud; the boring samples yielded on washing several fruits of *Betula pubescens* and one of *Cladium mariscus* (abt. 7.35 m below the surface).
E. Sand.

Point 4

The boring was made at the side of the stream, where the calcareous mud crops out in the channel, about Point 2 in MILTHERS' profile (l. c. Fig. 12).

A. 0 — 0.5 m Stony Sand.
B. 0.5 — 2.0 m Dark green-greyish calcareous Mud.
C. 2.0 — 2.6 m Lighter grey calcareous Mud.
D. 2.6 — 2.7 m Coarse Sand.

Point 5.

A. 0 — 1.1 m Sand with small stones.
B. 1.1 — 1.6 m Dark greenish Mud.
C. 1.6 — 1.9 m Lighter grey calcareous Mud.
D. 1.9 — 2.0 m Sharp Sand with a few small stones.

Point 6.

The boring was made in the middle of the valley, 22 m S of Point 5, the ground here lying abt. 0.75 m higher than at that point.

A. 0 — 1.80 m Reddish Sand with stones.
B. 1.80— 2.10 m Grey, stony, sandy calcareous Mud.
C. 2.10— 2.65 m Light grey calcareous Mud.
D. 2.65— 3.10 m Grey, sandy argillaceous Mud.
E. 3.10— 3.65 m Grey Sand.

The following determinations of $CaCO_3$ content in samples of mud from Egtved were made by JOHS. ANDERSEN.

| No. | Depth below surface | Point | % of $CaCO_3$ in dried sample |
|---|---|---|---|
| 1 | 1.50 m | 2 | 4.0 % |
| 2 | 2.15 — | - | 23.0 — |
| 3 | 2.65 — | - | 30.3 — |
| 4 | 3.15 — | - | 13.0 — |
| 5 | 3.35 — | - | 47.5 — |
| 6 | 4.65 — | - | 55.3 — |
| 7 | 4.25 — | - | 50.8 — |
| 8 | 7.35 — | 3 | 56.5 — |

Table 15. Determination of $CaCO_3$ from Egtved.

The mud, which was calcareous throughout the entire profile, was bedded on sand which contained small stones here and there. The available data as to the extent of these lacustrine beds, and their stratification, suggest that they were deposited in a rather small but deep basin, the vertical distance between the highest point at which they have been observed (MILTHERS l. c. Point 8, Fig. 12) and the lowest similar point (Point 3 in Fig. 2, Pl. XXIII) being abt. 22 m. They are undoubtedly still in their primary position. At the bottom, on the sandy floor, a layer of pale grey calcareous mud up to 2.4 m thick had been formed, sometimes much mixed with sand out towards the edge. Above this was up to 4 m of dark greyish-green calcareous mud, handsomely stratified in almost horizontal lines. In the north wall of the marl pit, this mud is covered by a layer of diatomaceous earth up to 1.6 m thick, likewise apparent in the adjacent boring made by V. MILTHERS (l. c.) as well as farther down the hill at his Point 1. In a pure state, this diatom earth was pale grey, but often exhibited a reddish tinge, due to a strong formation of ochre, which, especially lower down towards the dark mud, sometimes formed thin layers like hard pan, or crusted concretions. As the profile shows, the boundary line between these two strata was highly irregular. Both diatomaceous earth and mud were stratified almost horizontally in thin, distinct layers, and in places where no ochre intervened between the two strata, it was noticed that the transition from one to the other was gradual and "flamed". Where the boundary was steep or vertical, it cut through the horizontal stratification, which continued uninterruptedly from diatomaceous earth to mud. It was also noticed that where taps of ochre, which might be some few cm thick, projected down into the dark mud, the latter was discoloured near the tap assuming the appearance of diatomaceous earth. The bed of diatomaceous earth appeared as an upper weathering zone of the diatomaceous dark mud, the content of lime in which was very slight in the upper portions. In connection with this it should be noted that the diatomaceous earth seems only to occur under the floor of the valley, where the covering layer above the interglacial lake deposits is of very slight thickness. In under the north side of the valley, where the position of the bed had to be sought between the calcareous mud ("foliated mud") and the clay bed below the covering sand, it was not found (cf. MILTHERS l. c. p. 68 f.).

The stony sand bed, covering the diatomaceous earth and the mud, was on the whole of but slight thickness, and consisted for the most part doubtless of masses which had slipped down from the steep side of the valley, like the covering sand above the mud in the profile given by MILTHERS. In the western part of the profile Fig. 2, Pl, XXIII it will be seen that the covering sand is thicker here, while at the same time, parts of the lake deposit have been cut away. In the lower portion of the covering sand here, a bed of gravel was found a couple of decimeters thick; this bed could be traced along the western wall of the marl pit under the floor of the valley, where also it rested directly on the mud; here, it was up to $^{1}/_{2}$ m thick, containing also large stones up to 4 dcm diameter. This gravel bed must doubtless be regarded as a watercourse from the late-glacial period, when the narrow valley in which the interglacial deposits occur was formed by the erosion of running water. It must be presumed that the southern ends of the strata in the interglacial deposits, which must have projected up as far as those on the north (cf. V. MILTHERS' Fig. 2), were carried away, together with the highest situated strata out under the floor of the valley, in the course of this erosion, the northern part of the lake basin being sheltered from the most powerful action of the water. The erosion-cut seen in the profile west of point 2 is of post-glacial date, like the sand of the river bed found in Boring 1. This sand also cropped out in the western wall of the marl pit above the late-glacial gravel.

The pollen diagram (Pl. XXXIX, 3) comprises almost exclusively calcareous mud; only at the top of the diagram, about as far as Spectr. 4 there are deposits free from or poor in lime. Here also, the mixed oak forest zone in the diagram is developed in the calcareous part of the profile. The lower *Pinus-Betula* facies for instance is almost entirely lacking; only Spectr. 16 can be referred to the upper part of this with its 57 % *Pinus*, 23 % *Betula*, but even here, *Quercus* already amounts to 20 and *Corylus* 3 %. Close to the lower edge of Stratum D again, at Point 3, i. e. 7.35 m below the surface, there was found a spectrum analogous to this, its composition being: *Betula* 15 %, *Pinus* 59 %, *Ulmus* 2 %, *Quercus* 20 %, *Alnus* 1 %, *Carpinus* 1 %, *Picea* 2 % and *Corylus* 3 %. Among the exceptions must be noted more especially the finds of *Carpinus* and *Picea*; pollen of the latter has however also been found elsewhere, in small quantities, near the base of the interglacial profiles.

In Spectr. 15, *Pinus* and *Betula* are present with 14 % and 9 % respectively, and in the following spectra, as far as 5 inclusive, the frequency value for *Pinus* lies between 4 and 10 %, while for *Betula*, it is between 3 and 7 % throughout the remaining portion of the pollen diagram.

Among the mixed oak forest species, *Quercus* is here also by far the most important; its maximum (54 %) is very soon reached, viz. in Spectr. 14. *Ulmus* pollen was extremely common in the calcareous mud at Egtved. The *Ulmus* curve, has in several of the diagrams from the interglacial deposits, a more or less distinct double summit, the earlier maximum lying in the lower part of the mixed oak forest zone, and the later one in the upper portion. The earlier of these two maxima in the Egtved diagram only amounts to 4 % (Spectr. 14 and 15); the later one however, is remarkably highly developed, the curve running out to 23 % in Spectr. 9. Here also we have the culmination of *Tilia* (4 %) the curve for which extends from Spectr. 13 to Spectr. 6, while the *Ulmus* curve runs from Spectr. 15 to Spectr. 3. After its culmination in Spectr. 14, (58 %) the mixed oak forest curve proceeds on a somewhat wavering course to 53 % in Spectr. 9, then turning off to the left until, in the two upper spectra of the diagram — in the diatomaceous earth — it is represented only by 2 % *Quercus*. ***Corylus*** is here, as in most of the other interglacial diagrams, earlier present than *Alnus*; both culminate in Spectr. 13, ***Corylus*** with 117 %. Both pollen species are still very common up to Spectr. 7, above this their curves turn suddenly off to the left, the ***Alnus*** curve however exhibiting a secondary maximum in Spectr. 7 and 8. ***Corylus*** as usual, has lower frequency values than *Alnus* in the upper part of the diagram.

The rational limit for ***Carpinus*** lies at Spectr. 10, but as far as Spectr. 7 inclusive the species does not attain greater frequency than 8 %. After this the curve turns off sharply to the right, and *Carpinus* is the dominant species as far as Spectr. 2 inclusive, where its frequency amounts to 60 %. The ***Carpinus*** zone embraces Spectr. 2—6. The rational limit for *Picea* lies at Spectr. 7, and from here, the frequency of this species of pollen is on the increases, with a deviation conforming to that of *Pinus*, in Spectr. 2 to the upper edge of the diagram.

The upper part of the *Carpinus* zone from Spectr. 4 inclusive, forms a transition to the *Picea* zone proper to which in this case, only Spectr. 1 from the lower part of the diatomaceous earth at Point 3 belongs. In the samples from higher up in the strata than this spectrum and spectr. 2 at Point 2 no pollen was found, or very little and poorly preserved; it must be presumed however, that the diatomaceous earth here belongs entirely to the *Picea* zone, or as regards the upper portion, perhaps to the *Pinus-Betula* zone. To this must undoubtedly be referred the brown non-calcareous mud which rests on the calcareous mud, and which was previously found a little way up on the north side of the valley, under sand and clay (Profiles 5 and 6 by V. MILTHERS l. c. p. 68 f.).

As already mentioned, the workmen found the remains of a doe (*Cervus dama*) in the calcareous mud at Egtved. The skeletal parts were found 3.3 m below the surface, on the north side of the pit; the site is indicated by a cross in Fig. 2 Pl. XXIII. On my visit to the spot, a few more bones of the animal were found. Pollen analysis of a mud sample, from the doe's horizon, gave this spectrum: *Betula* 6 %, *Pinus* 2 %, *Ulmus* 6 %, *Quercus* 15 %, *Alnus* 29 %, ***Carpinus*** 41 %, *Picea* 1 % and *Corylus* 21 %. This spectrum corresponds fairly closely to Spectr. 6 in the pollen diagram and thus indicates the position of this doe in the strata, viz. the lower portion of the *Carpinus* zone.

## Kollund.

On the slope of the northern bank of Flensborg Fiord, 750 m SW of Kollund Badested (Fig. 23), we observed, in the summer of

1923, the following profile under a bed (A) of fluvioglacial sand some 20 m thick, horizontally stratified, and with very large stones at the top:

C. 1.05 m Brown, hard Mud which on washing yielded:
*Alnus glutinosa*, pollen,
*Betula pendula*, 2 catkin scales,
— *sp.*, pollen,
*Corylus avellana*, pollen,
*Najas marina*, $1/2$ fruit,
*Pinus silvestris*, pollen,
*Potamogeton sp.*, 1 fruit-stone,
*Quercus sp.*, pollen,
*Scirpus lacuster*, 4 fruits,
*Tilia sp.*, 1 flower stem, pollen,
*Ulmus sp.*, pollen.

D. 0.3 m Grey, rich stoneless Clay containing many fruits and much pollen of *Betula pubescens*, pollen of *Pinus silvestris* and statoblasts of *Cristatella mucedo*.

The upper portion of the mud bed lay abt. 5.5 m above sea level. It was for the most part covered with material fallen from above, but could be discerned at several points for a stretch of over 50 m along the fiord. Farthest to the east, beyond the gully, the mud was lighter in colour and contained numerous diatoms.

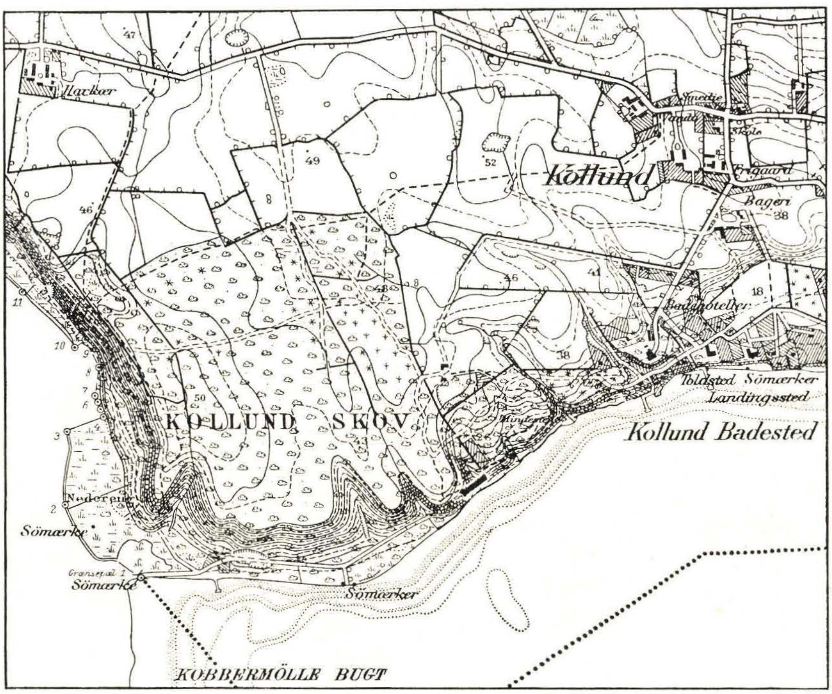


Fig. 23. Map showing position of the interglacial bog at Kollund, the thick line near the coast SW of Kollund Badested. Scale 1 : 25000. Contour interval 2.5 m. The General Staff Map Sheet 4409.

In addition to the mentioned interglacial deposits, fragments of a bed (B) of low moor peat were also observed, consisting mainly of *Hypnum aduncum*, which had been dug up together with mud from a shaft subsequently destroyed by blasting.

In this low moor peat, which undoubtedly had been bedded on the mud, the following plant remains were found:

*Alnus glutinosa*, several fruits, pollen,
*Betula pubescens*, 1 fruit,
— *sp.*, pollen,
*Carex pseudocyperus*, several fruits,
— *cf. rostrata*, 1 fruit,
— *sp.*, some fruits without utriculus,
*Carpinus betulus*, several fruits, pollen,
*Corylus avellana*, pollen,
*Dryopteris thelypteris*, several rhizomes,
*Picea excelsa*, several seeds, pollen,
*Scirpus sp.*, some few fruits,
*Ulmus sp.*, pollen.

*Hypnum aduncum*, very common.

This interglacial deposit at Flensborg Fjord was known to MEYN, and has previously been mentioned by W. WOLFF[1]). It is well-known to the local inhabitants. Mr. TEICHGRÄBER, for instance, a former Member of the Town Council of Flensburg, informed us that 20—30 years back, endeavours had been made to dig "brown coal" at Kollund, and that a new attempt had been made in 1919, when a 10 m shaft was put in. Both attempts were soon relinquished.

The pollen diagram Pl. XXXIX, 2 shows the order in which the forest trees immigrated in the forest at Kollund, and their pollen attained the highest frequency. The Birch (*Betula pubescens*) has an overwhelming majority in Spectr. 5 (91 %) but *Pinus* is however represented, and this species attains its maximum (33 %) in Spectr. 4, in the lower part of the mud bed. *Corylus* is here found together with *Quercus* and *Ulmus*, culminating, indeed, with 255 % in Spectr. 3, where the curves for *Alnus* and *Quercus* also turns off farthest to the right, while the curve for mixed oak forest, thanks to an unusually high value for *Tilia* (32 %), attains its highest (42 %) in Spectr. 2. In none of the other interglacial pollen diagrams hitherto available does *Tilia* show such a high percentage as here; this is perhaps an easterly touch in the composition of the interglacial mixed oak forest. In the spectrum from the low moor peat, *Quercus*, *Corylus* and *Pinus* show but slight frequency values, whereas *Betula* and *Picea* for instance, are more numerously represented than in Spectr. 2, and

1) W. WOLFF: Erdgeschichte u. Bodenaufbau Schleswig-Holsteins. Hamburg. 1922, p. 46.

*Carpinus* attains a value of 24 %. Both from the appearance of the spectrum and also on stratigraphical grounds, the low moor peat must be supposed to rest on the mud, but the depth of the stratum is not known.

# List of Flora and Fauna.

This list includes the species of vascular plants and mosses mentioned by N. HARTZ 1909[1]) besides all the species referred to by V. MILTHERS 1925[2]) and in the foregoing. For the animals, the algæ and fungi it appears only as a supplement to the list given by N. HARTZ.

The following have been omittet:

a) The flora found in the quaternary strata at Skærumhede in Vendsyssel.[3]) All the vegetable remains from these strata lay in glacial clay and fluvioglacial sand, or in the strata of the *Portlandia arctica* zone, viz. in a secondary or tertiary situation, so that it in some cases may be difficult to distinguish species originating from the amber-pine-beds as compared with those from the last part of the interglacial period.

b) The diatomaceous flora from Hollerup, Fredericia and Trælle.[4])

c) The diatomaceous flora of the Eem Strata.[5])

d) The flora of the mud blocks found in a secondary position near Copenhagen, which are considered by N. HARTZ and V. MILTHERS[6]) as pre-quaternary, but should presumable be assigned to the penultimate interglacial period.[7])

Several alterations have been made in the nomenclature of the list given by N. HARTZ; this applies more especially to the mosses, where the terminology employed by C. JENSEN[8]) has been followed.

The localities at Höllund Sögaard, Lervad, Brörup railway station and Hollerup are also included in the list given by HARTZ; from these localities therefore, only species found by me and new to the respective localities are noted.

1) N. HARTZ: Bidrag .... D. G. U. II. R. Nr. 20. 1909, p. 256—265.

2) V. MILTHERS: Kortbladet Bække. D. G. U. I. R. Nr. 15. 1925, p. 83—89. The localities Brörup marl pit, Egtved and Rostrup.

3) A. JESSEN, V. MILTHERS o. s. v.: En Boring gennem de kvartære Lag ved Skærumhede. D. G. U. II. R. Nr. 25. 1910, p. 93—109.

4) N. HARTZ og E. ÖSTRUP: Danske Diatomèjord-Aflejringer og deres Diatoméer. D. G. U. II. R. Nr. 9. 1899, p. 61—65.

5) VICTOR MADSEN, V. NORDMANN og N. HARTZ: Eem-Zonerne. D. G. U. II. R. Nr. 17. 1908, p. 107—108, 112—113.

6) V. MILTHERS: Nordøstsjællands Geologi. D. G. U. V. R. Nr. 3. 1922, p. 40, 173.

7) KNUD JESSEN: Nematurella-Leret ved Gudbjerg og Gytjeblokkene i Københavns Frihavn i pollenfloristisk Belysning. Meddelelser fra Dansk geol Forening. Bd. 7. 1927, p. 142.

8) C. JENSEN: Danmarks Mosser. I, 1915. II, 1923. Köbenhavn.

| Flora and Fauna | The last i | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | HARTZ 1909[1] | Herning | Nörbölling | Brörup Hotel | Rodebæk I | Solsö | Herborg I | Herborg II | Astrup | Duedam | Dalager |
| **Plantae vasculares.** | | | | | | | | | | | |
| *Acer campestre* L. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *platanoides* L. | ... | ... | + | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Ajuga reptans* L. | + | + | ... | + | + | + | ... | ... | ... | ... | ... |
| *Aldrovanda vesiculosa* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Alnus glutinosa* (L.) GAERTNER | + | + | + | + | + | + | + | × | ×[4] | + | + |
| *Andromeda polifolia* L. | ... | ... | + | + | ... | + | ... | ... | ... | + | ... |
| *Arctostaphylus alpina* (L.) SPR. | ... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... |
| — *uva ursi* (L.) SPR. | ... | + | + | + | + | ... | ... | ... | ... | + | ... |
| — *sp.* | ... | + | + | + | ... | ... | ... | ... | ... | ... | ... |
| *Arenaria trinervia* L. | ... | ... | ... | ... | + | ... | + | ... | ... | ... | ... |
| *Armeria vulgaris* WILLD. | + | ... | + | ... | + | + | ... | + | ... | ... | ... |
| *Batrachium aquatile* (L.) *coll.* | +[5] | + | + | + | + | + | + | + | + | ... | ... |
| — *cfr. confervoides* FR. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sceleratum* (L.) LANGE | ... | + | ... | + | + | + | ... | ... | ... | ... | ... |
| *Betula alba* (L.) *coll.* | + | × | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *nana* L | + | + | + | + | + | + | + | + | ... | ... | ... |
| — *nana × pubescens (alba × nana)* | ... | + | + | + | ... | + | ... | ... | ... | ... | ... |
| — *pendula* ROTH. | + | ... | ... | ... | + | + | + | ... | ... | ... | + |
| — *cf. pendula × pubescens* | ... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... |
| — *pubescens* EHRH. | + | + | + | + | + | + | + | + | + | + | + |
| — *subalpina* LARSS., LÆST. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Bidens cernuus* L. | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... |
| — *tripartitus* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Brasenia purpurea* MICH | + | + | + | ... | ... | + | + | ... | ... | + | + |
| *Butomus umbellatus* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Calla palustris* L. | + | ... | + | ... | ... | ... | ... | ... | ... | ... | ... |
| *Callitriche cf. autumnalis* L. | + | ... | ... | ... | ... | + | + | + | ... | ... | ... |
| *Calluna vulgaris* (L.) SALISB. | + | + | + | ... | + | + | + | + | ... | ... | ... |
| *Carex caespitosa* L. | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... |
| — *diandra* SCHRANK | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *lasiocarpa* EHRH. | + | + | ... | + | ... | ... | ... | ... | ... | ... | ... |
| — *pseudocyperus* L. | + | + | + | + | + | + | + | + | ... | ... | + |
| — *riparia* CURT. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *rostrata* STOKES | + | + | + | + | + | + | + | + | ... | + | ... |
| — *cf. stellulata* GOOD | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *vesicaria* L. | ... | + | + | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | + | + | + | + | + | + | + | + | + | + | + |
| *Carpinus betulus* L. | + | + | + | + | + | × | + | × | ... | + | × |
| *Carum carvi ?* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Caryophyllaceae* | + | ... | ... | × | ... | ... | ... | ... | ... | ... | ... |
| *Ceratophyllum demersum* L. | + | + | ... | ... | ... | + | ... | ... | ... | ... | ... |
| — *dem. var. apiculatum* CHAM. | ... | + | + | + | + | + | + | ... | ... | + | + |
| — *submersum* L. | ... | + | + | + | + | ... | ... | ... | ... | ... | ... |
| — *sp.* | ... | ... | ... | ... | ... | ... | ... | ... | + | + | ... |
| *Chenopodiaceae* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Cicuta virosa* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Cirsium lanceolatum* (L.) SCOP. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

[1]) The Brörup bogs, the lake deposits at Ejstrup, cf. p. 196 and the Eem b
lokalities. [4]) A × indicates that only pollen or microscopical spores

| l period | | | | | | | | | | | | The penultimate interglacial period | | | | Interglacial deposits covered by young-glacial formations | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ringdal | Rodebæk II | Rodebæk III | Höllund Sögaard | Fövling | Lervad | Tuesböl II | Brörup railway-station | Brörup marl pit | Over Gestrup | Agerskov | Rostrup[2]) | Rind | Harreskov | Starup | Vejen, Tirslund | HARTZ 1909[3]) | Hörup | Lövskal I, II | Hollerup | Egtved | Kollund |
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e p. 196, also HARTZ 1909, p. 236. [3]) Kolding, Hollerup and other eastern
rved. [5]) By N. HARTZ *Batrachium sp.*

| Flora and Fauna | The last in[…] | | | | | | | | | | | |
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| | HARTZ 1909 | Herning | Nörbölling | Brörup Hotel | Rodebæk I | Solsö | Herborg I | Herborg II | Astrup | Duedam | Dalager | [illegible] |
| *Cirsium cf. oleraceum* (L.) SCOP. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *palustre* (L.) SCOP. | ... | ... | ... | ... | + | ... | + | ... | ... | ... | ... | ... |
| *Cladium mariscus* (L.) R. BR. | + | + | ... | + | ... | ... | ... | + | ... | ... | ... | ... |
| *Compositae* | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Cornus sanguinea* L. | + | + | ... | + | ... | ... | ... | ... | ... | ... | ... | ... |
| *Corydalis cava* (L.) SCHW. & K. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Corylus avellana* L. | + | + | + | × | × | + | × | + | × | × | × | × |
| *Crataegus monogyna* JACQ. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | + | ... | ? | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Cruciferae* | ... | ... | ... | + | ... | + | ... | ... | ... | ... | ... | ... |
| *Drosera rotundifolia* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Dryas octopetala* L. | + | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... |
| *Dryopteris cristata* (L.) GRAY | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *filix mas* (L.) SCHOTT | × | ... | × | ... | × | ... | ... | ... | ... | ... | ... | ... |
| — *spinulosa*(O.F.MÜLL.)KUNTZE | × | ... | × | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *thelypteris* (L.) GRAY | + | × | × | × | × | ... | × | × | × | × | × | ... |
| — *sp.* | ... | × | × | ... | ... | × | ... | ... | ... | ... | ... | ... |
| *Dulichium spathaceum* PERS. | + | + | + | ... | + | + | ... | ... | ... | + | + | ... |
| *Empetrum nigrum* L. | + | + | + | + | + | + | + | + | + | + | ... | ... |
| *Equisetum sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Ericaceae* | + | ... | ... | ... | + | × | ... | ... | ... | × | ... | ... |
| *Eriophorum vaginatum* L. | + | ... | + | ? | ... | + | ... | ... | + | + | ... | ... |
| *Eupatorium cannabinum* L. | + | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... |
| *Frangula alnus* MILLER | + | + | + | ... | + | ... | ... | + | ... | ... | ... | + |
| *Fraxinus excelsior* L. | + | + | ... | ... | × | ... | ... | ... | ... | ... | ... | ... |
| *Gramineae* | + | ... | ... | ... | ... | ... | ... | ... | × | ... | ... | ... |
| *Hippuris vulgaris* L. | + | + | + | + | + | + | + | + | ... | ... | ... | + |
| *Hydrocotyle vulgaris* L. | ... | + | + | ... | + | + | + | ... | ... | + | ... | ... |
| *Hypochoeris radicata* L. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Ilex aquifolium* L. | + | + | + | ... | ... | × | ... | ... | ... | × | × | ... |
| *Iris pseudacorus* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Isoetes lacustre* L. | ... | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Juniperus communis* L. | ... | + | ... | + | ... | + | ... | + | ... | ... | ... | ... |
| *Labiatae* | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | ... | ... |
| *Lampsana communis* L. ? | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Limnanthemum nymphaeoides* (L.) | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Litorella uniflora* (L.) ASCHERSON | ... | + | ... | ... | ... | + | ... | ... | ... | ... | ... | ... |
| *Lycopodium annotinum* L. | × | × | × | ... | × | ... | ... | ... | ... | ... | ... | ... |
| — *clavatum* L. | × | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *complanatum* L. | ... | ... | ... | × | ... | ... | ... | ... | ... | ... | ... | ... |
| — *selago* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Lycopus europaeus* L. | + | + | + | + | + | + | ... | ... | ... | + | + | + |
| *Lysimachia vulgaris* L. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Mentha cf. aquatica* L. | ... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... |
| *Menyanthes trifoliata* L. | + | + | + | + | ... | + | + | ... | ... | + | + | + |
| *Molinia coerulea* (L.) MOENCH | + | ? | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Montia lamprosperma* CHAM. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Myosoton aquaticum* (L.) MOENCH | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Myriophyllum alterniflorum* D. C. | ? | + | + | + | + | + | + | + | ... | ... | ... | ... |
| – *spicatum f. muricata* AHLFVENGREN | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *cf. spicatum* L. | + | + | + | + | ... | + | ... | ... | ... | ... | ... | ... |

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| Rodebæk II | + | | | + | | | + | + | | + | | | | | X | | | + | | | | | | | | + | | | | + | | | | + | | | X | | | | | | | | | X | | | | + | | | |
| Rodebæk III | | | | | | | | | | | | | | | | | | | | | | | | | | + | | | | | + | | | + | | | X | | | | | | | | | X | | | | | | | |
| Höllund Sögaard | | | | | | | + | | | + | | | | | | | | | | | | | X | | | | X | | | | + | X | | + | | | X | | | | | | | | | X | | | | | | | |
| Fövling | | | | | + | | + | | | + | X | | | | | | | | | | | | + | | + | + | | | + | | | | | + | | | X | | | | | | | | | X | | | | + | | | |
| Lervad | | | | | | | + | | | + | | | | | | | | | | | | | | | | | | | X | | + | | | + | | | X | | | | | | | | | X | | + | | | | | |
| Tuesböl II | + | | | | | | + | + | + | + | | | | | | | | | | | | | X | | | | | | + | | + | | | | + | | + | | | | | cf | | | | X | | | | | | | |
| Brörup railway-station | | | | | | | + | | | + | | | | | | | | | | | | | | | | | | X | | | + | | | + | | | X | | | | | | | | | + | | | | | | | |
| Brörup marl pit | + | | | | | | + | | | + | | | | | | | | | | | | | | | | + | | | | | | | | | | | X | | | | | | | | | | | | | + | + | + | |
| Over Gestrup | | | | | | | + | | | + | | | | | X | | | | | | | | | | | | | | | | + | | | + | + | | + | | | | | | | | | X | | | | | | | |
| Agerskov | | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | + | | | | | | | | | | | | | | | | | | | + | | | |
| Rostrup | | | | | | | | | | + | | | | | | | | | | | | | | | | | | | | | + | | | | | | X | | | | | | + | | | + | | | | | | | |
| Rind | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | The penultimate interglacial period |
| Harreskov | | | | | | | | | | | | | cf | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | X | | | | | | | |
| Starup | | | | | | | | + | | + | | | | X | | | | | | | | | | | + | | | | | | | | | | | | | | | | | | | | | X | | | | | | | |
| Vejen, Tirslund | | | | | | | + | | | | | | | | | | | | | | | | | | | + | | | | | + | | | | | | + | | | | | | | | | X | | | | | | | |
| Hartz 1909 | | | ? | | | | + | | | | | | | | | | | | | + | + | | + | | | + | | + | | | | | | | | | | | | | + | | | | | + | | | | + | | | Interglacial deposits covered by young-glacial formations |
| Hörup | | | | | | | + | | | | | | | | | | | | | + | | | | | | | | | | | | | | | | | | | | | | | | | | + | | | | + | | | |
| Lövskal I, II | | | | | | | | | | | | X | | | | | | | | | | | X | | | | X | | | | | | | | | | | | | | | | | | | X | | | | | | | |
| Hollerup | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | | | X | | | | | | | |
| Egtved | | | | | | | + | | | + | | | | | | | | | ? | | ? | | + | | | + | | + | | | + | | + | + | | | X | | | | | | | | | + | | | | + | | | |
| Kollund | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | | | | | | | | | X | | | | | | | |

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| | Hartz 1909 | Herning | Nörbölling | Brörup Hotel | Rodebæk I | Solsö | Herborg I | Herborg II | Astrup | Duedam | Dalager |
| *Myriophyllum verticillatum* L. | ... | + | ... | ... | ... | + | ... | ... | ... | ... | ... |
| *Najas flexilis* (Willd.) Rostk. & Schm. | ... | ... | + | ... | ... | + | ... | ... | ... | ... | ... |
| — *marina* L. | + | + | ... | ... | + | + | ... | ... | ... | ... | + |
| *Nasturtium aquaticum* (L.) Karst. | ... | ... | ... | ... | + | + | ... | ... | ... | ... | ... |
| *Nuphar luteum* (L.) Sm. | + | + | + | + | + | + | ... | ... | ... | + | ... |
| *Nymphaea alba* L. | + | + | + | + | + | + | ... | ... | ... | ... | + |
| *Nymphaeaceae* | ... | ... | ... | ... | ... | ... | ... | ... | + | + | ... |
| *Oenanthe aquatica* (L.) Lam. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Ophioglossum vulgatum* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Origanum vulgare* L. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Osmunda regalis* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | × |
| *Oxalis acetosella* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Oxycoccus palustris* Pers. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Phragmites vulgaris* (Lam.) Crép. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Picea excelsa* (Lam.) Link | + | + | + | + | + | + | × | + | + | + | × |
| *Pinus silvestris* L. | + | + | + | + | + | + | × | + | × | + | × |
| *Polygonum tomentosum* Schrank | + | + | ... | ... | ... | cf. | ... | ... | ... | ... | ... |
| — *sp.* | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Polypodium vulgare* L. | × | × | × | × | × | × | × | × | ... | × | × |
| *Polystichum lobatum* (Huds.) Presl. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Populus tremula* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Potamogeton alpinus* Balbis | ... | + | + | + | ... | ... | ... | ... | ... | ... | ... |
| — *acutifolius* Lk. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *compressus* Schum. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *densus* L. | + | + | ... | ... | ... | + | ... | + | ... | ... | ... |
| — *filiformis* Pers. | + | + | + | + | + | + | ... | + | + | ... | ... |
| — *Friesii* Rupr. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *gramineus* L. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *natans* L. | + | + | + | + | + | + | ... | ... | ... | + | + |
| — *obtusifolius* M. & K. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *perfoliatus* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *polygonifolius* Pourret | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *praelongus* Wulfen | + | + | + | + | ... | + | ... | ... | + | ... | ... |
| — *pusillus* L. | + | + | + | + | ... | + | cf. | + | ... | ... | + |
| — *trichoides* Cham. & Schl. | + | ... | + | ... | ... | + | ... | ... | ... | ... | ... |
| — *spp.* | + | + | + | + | + | + | + | + | + | ... | ... |
| *Potentilla anserina* L.? | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *erecta* (L.) Dalla Torre | ... | cf. | + | ... | ... | + | ... | ... | ... | ... | ... |
| — *palustris* (L.) Scop. | + | + | + | + | + | + | ... | + | ... | + | ... |
| — *sp.* | ? | + | + | + | + | + | ... | + | ... | ... | ... |
| *Prunus padus* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Pteris aquilina* (L.) Kuhn | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Quercus robur* (L.) | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | ... | × | + | × | × | × | × | × | × | × | × |
| *Ranunculus flammula* L. | ... | ... | + | ... | ... | + | ... | ... | ... | ... | ... |
| — *lingua* L. | ... | + | ... | ... | ... | + | ... | ... | ... | ... | ... |
| — *repens* L. | + | + | ... | + | + | + | ... | ... | ... | ... | ... |
| — *sp.* | ... | + | + | + | ... | + | + | + | ... | ... | ... |
| *Rhyncospora alba* (L.) Vahl | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Rubus idaeus* L. | + | + | + | + | + | + | + | ... | ... | + | + |

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| | Hartz 1909 | Herning | Nörbölling | Brörup Hotel | Rodebæk I | Solsö | Herborg I | Herborg II | Astrup | Duedam | Dalager |
| *Rubus saxatilis* L. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | + | + | + | ... | ... | ... | ... | ... | ... | ... | ... |
| *Rumex maritimus* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | + | ... | ... | ... | ... | + | ... | ... | ... | ... | ... |
| *Sagittaria sagittifolia* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Salix cfr. caprea* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *herbacea* L. | ... | + | ... | ... | ... | + | ... | ... | ... | ... | ... |
| — *phylicifolia* L. | cf. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *polaris* Wbg. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *cf. repens* L. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *reticulata* L. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | ... | + | ... | + | + | + | + | + | ... | ... | ... |
| *Sambucus cf. nigra* L. | ... | + | + | + | ... | ... | ... | ... | ... | ... | ... |
| — *sp.*[1]) | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Scirpus cf. fluitans* | ... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... |
| — *lacuster* L. | + | + | + | + | + | + | ... | ... | ... | + | + |
| — *palustris* L. | ... | ... | ... | ... | ... | + | ... | ... | ... | ... | ... |
| — *cf. Tabernaemontani* Gmel. | ... | ... | + | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | + | ... | ... | + | ... | ... | ... | ... | ... | ... | ... |
| *Scleranthus perennis* L.? | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | ... |
| *Selaginella selaginoides* (L.) Link | ... | + | ... | + | ... | + | + | + | + | ... | ... |
| *Solanum dulcamara* L. | ... | ... | + | + | ... | + | ... | ... | ... | ... | ... |
| *Sparganium affine* Schnizlein | .. | + | + | + | + | ... | + | ... | ... | ... | ... |
| — *erectum* L. | + | + | + | + | + | + | + | + | ... | ... | + |
| — *minimum* Fr. | ... | + | + | + | + | + | + | + | ... | ... | + |
| — *simplex* Hudson | ... | ... | ... | ... | cf. | + | ... | ... | ... | ... | cf. |
| — *sp.* | + | + | ... | + | ... | ... | + | + | ... | ... | ... |
| *Stachys silvaticus* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Stratiotes aloides* L. | + | ... | + | + | ... | ... | ... | .. | ... | ... | ... |
| *Taxus baccata* L. | + | + | ... | ... | ... | + | ... | | ... | ... | + |
| *Thalictrum* ? | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | ... |
| *Tilia cordata* Mill. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *platyphylla* Scop. | + | + | ... | ... | ... | ... | ... | ... | ... | ... | .. |
| — *sp.* | ... | × | × | × | × | ... | × | × | ... | × | × |
| *Torilis anthriscus* (L.) Gmelin | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Trapa natans* L. | ... | + | ... | ... | ... | + | ... | ... | ... | ... | ... |
| *Typha latifolia* L. | + | ... | × | ... | ... | × | ... | ... | ... | ... | ... |
| — *sp.* | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Ulmus sp.* (*cf. glabra* Huds.) | + | × | × | × | × | × | × | × | × | × | × |
| *Umbelliferae* | + | + | × | ... | ... | ... | ... | ... | ... | ... | × |
| *Urtica dioeca* L. | ... | ... | ... | + | + | + | ... | ... | ... | ... | ... |
| — *urens* L. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Vaccinium uliginosum* L. | + | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... |
| *Viburnum opulus* L. | + | ... | ... | ... | ... | .. | ... | ... | ... | ... | ... |
| *Viola palustris* L. | + | + | + | + | + | + | + | + | ... | ... | ... |
| *Viscum album* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Zannichellia sp.* | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **Bryophyta.** | | | | | | | | | | | |
| *Acrocladium cuspidatum* (L.) Lindb. | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Amblystegium confervoides* (Brid) Br.eur. | ... | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... |

[1]) Identical with *Sambucus cf. nigra*.

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| Ringdal | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | l period |
| Rodebæk II | . | . | . | . | + | . | . | . | + | . | X | . | X | . | . | . | . | . | . | . | . | + | . | . | + | + | . | . | . | . | . | . | . | + | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | |
| Rodebæk III | . | . | . | . | . | . | . | . | + | X | X | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Höllund Sögaard | . | . | . | . | . | . | . | . | . | + | X | . | . | . | . | X | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Fövling | . | . | . | . | . | . | . | . | . | . | X | . | X | + | . | X | . | cf | . | . | . | . | . | . | + | + | . | . | . | . | . | . | . | + | . | . | + | X | . | . | . | . | . | . | . | . | . | + | . | |
| Lervad | . | . | . | . | + | . | . | . | . | X | X | . | X | . | . | X | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | + | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | |
| Tuesböl II | . | . | . | . | . | . | . | + | + | . | X | . | X | . | . | X | . | . | . | . | + | . | + | . | + | + | + | + | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Brörup railway-station | . | . | . | . | + | . | . | + | . | . | X | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Brörup marl pit | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Over Gestrup | . | . | . | . | . | . | . | . | . | + | X | . | . | . | . | X | . | . | . | . | . | . | . | . | + | + | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Agerskov | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Rostrup | . | . | . | . | . | . | . | . | + | . | X | . | X | . | . | X | . | . | . | . | . | . | . | . | . | + | . | . | . | . | + | + | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | |
| Rind | . | . | . | . | . | . | . | . | . | . | X | . | X | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | The penultimate interglacial period |
| Harreskov | . | . | . | . | . | . | . | . | . | . | X | . | X | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Starup | . | . | . | . | . | . | . | . | . | X | X | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | + | + | . | . | |
| Vejen, Tirslund | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Hartz 1909 | + | . | + | + | . | . | . | . | . | . | . | + | . | . | . | . | . | ? | . | + | . | . | ? | . | . | . | . | . | . | . | ? | . | . | + | . | + | . | . | + | . | + | + | . | . | . | . | + | . | + | Interglacial deposits covered by young-glacial formations |
| Hörup | . | . | . | . | . | . | . | . | . | . | X | . | X | . | . | X | . | . | . | . | . | . | . | . | cf | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Lövskal I, II | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Hollerup | . | . | . | . | . | . | . | . | . | . | X | . | X | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Egtved | . | + | . | . | . | . | . | . | + | . | X | . | X | . | . | X | cf | cf | . | + | . | . | + | . | . | . | . | . | + | . | + | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| Kollund | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |

| Flora and Fauna | The last | | | | | | | | | | |
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| | Hartz 1909 | Herning | Nörbölling | Brörup Hotel | Rodebæk I | Solsö | Herborg I | Herborg II | Astrup | Duedam | Dalager |
| *Amblystegium Juratzkanum* Schimp. | | | | | | | | | | | |
| — *polygamum* Br. eur. | + | + | | | | | | | | | |
| — *Sommerfeltii* (Myr.) | | | | | | | | | | | |
| — *stellatum* (Schreb.) Lindb. | | + | | | + | | | | | | |
| *Anisothecium crispum* (Schreb.) Lindb. | | + | | | | | | | | | |
| *Anomodon viticulosus* (L.) Hook & Tayl. | + | | | | | | | | | | |
| *Antitrichia curtipendula* (L.) Brid. | + | | | | | | | | | | |
| *Barbula rubella* (Hoffm.) Mitt. | | | | | | | | | | | |
| *Brachythecium albicans* (Neck.) Br. eur. | | + | | | | | | | | | |
| — *plumosum* (Huds.) | | | | | | | | | | | |
| — *rutabulum* (L.) Br. eur. | + | | | | | | | | | | |
| — *velutinum* (L.) Br. eur. | + | | | | | | | | | | |
| — *viride* (Lam.) | + | | | | | | | | | | |
| *Bryum ventricosum* Dicks. | | + | | | | | | | | | |
| — *sp.* | | + | | | | | | | | | |
| *Calliergon cordifolium* (Hedw.) Kindb. | + | | | | | | | | | | |
| — *giganteum* (Schimp.) Kindb. | + | + | | | + | | | | | | |
| — *Richardsonii* (Mitt.) Kindb. | | + | | | | | | | | | |
| — *sarmentosum* (Wahlenb.) Kindb. | | + | | | | | | | | | |
| — *stramineum* (Dicks.) Kindb. | | + | | | + | | | | | | |
| — *trifarium* (Web. & Mohr) Kindb. | | + | | | | | | | | | |
| *Camptothecium lutescens* (Huds.) Br. eur. | + | | | | | | | | | | |
| — *trichoides* (Neck.) | | + | | | | | | | | | |
| *Catoscopium nigritum* Hedw. Brid. | | | | | | | | | | | |
| *Ceratodon purpureus* (L.) Brid. | ? | + | | | | | | | | | |
| *Climacium dendroides* (L.) Web. & Mohr | | + | | | | | | | | | |
| *Cratoneuron filicinum* (L.) Loeske | | + | | | | | | | | | |
| *Dichodontium pellucidum* (L.) Schimp. | | + | | | | | | | | | |
| *Dicranum Bojeani* De Not | + | | | | | | | | | | |
| — *congestum* Brid. | | + | | | | | | | | | |
| — *scoparium* (L.) Hedw. | + | + | | | | | | | | | |
| *Ditrichum flexicaule* (Schleich.) Hamp. | | + | | | | | | | | | |
| *Encalypta rhabdocarpa* Schwägr. | | + | | | | | | | | | |
| *Eurhynchium praelongum* (L.) Hock. | + | + | | | | | | | | | |
| — *striatum* (Schreb.) Schimp. | + | | | | | | | | | | |
| — *strigosum* (Hoffm.) Br. eur. | | | | | | | | | | | |
| — *Swartzii* (Turn.) Curnow | + | | | | | | | | | | |
| *Gymnocybe palustris* (L.) Fries | | + | + | | | | | | | | |
| *Helodium lanatum* (Ström) Broth. | + | | | | | | | | | | |
| *Homalothecium sericeum* (L.) Br. eur. | + | + | | | | | | | | | |
| *Hylocomium parietinum* (L.) Lindb. | + | | | | | | | | | | |
| — *proliferum* (L.) Lindb. | + | + | | | | | | | | | |
| — *squarrosum* (L.) Bruch & Sch. | + | + | | | | | | | | | |
| — *triquetrum* (L.) Bruch & Sch. | + | | | | | | | | | | |
| *Hypnum aduncum* Hedw. | ? | + | | | | | | | | | |
| — *exannulatum* Gümb. | + | + | + | + | + | | | | + | + | |
| — — *var. Rotae* (De Not) Schimp. | | | | | | | | | | | |
| — *fluitans* L. | + | | | | | + | | | | | |

| …al period | | | | | | | | | | | | The penultimate interglacial period | | | | Interglacial deposits covered by young-glacial formations | | | | | |
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| Ringdal | Rodebæk II | Rodebæk III | Höllund Sögaard | Fövling | Lervad | Tuesböl II | Brörup railway-station | Brörup marl pit | Over Gestrup | Agerskov | Rostrup | Rind | Harreskov | Starup | Vejen, Tirslund | HARTZ 1909 | Hörup | Lövskal I, II | Hollerup | Egtved | Kollund |
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| Flora and Fauna | The last i | | | | | | | | | | |
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| | Hartz 1909 | Herning | Nörbölling | Brörup Hotel | Rodebæk I | Solsö | Herborg I | Herborg II | Astrup | Duedam | Dalager |
| *Hypnum intermedium* Lindb. | ... | + | ... | ... | ... | ... | ... | ... | ... | + | ... |
| — *lycopodioides* Neck. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *revolvens* Sw. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *uncinatum* Hedw. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| *Isothecium myosuroides* (L.) Brid. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *viviparum* (Neck.) Lindb. | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Lescuraea Breidleri* (Kindb.) Arn. et Jensen | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Marchantia polymorpha* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Meesea longiseta* Hedw. | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *triquetra* (L.) Ångstr. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Mnium cinclidioides* (Blytt) Hüb. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *cuspidatum* (L.) Neck. | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *medium* Bruch & Sch. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *pseudopunctatum* Bruch & Sch. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *punctatum* (L.) Reich. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *silvaticum* Lindb. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *stellare* Reich. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *undulatum* Neck. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Neckera complanata* (L.) Hüb. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *crispa* (L.) Hüb. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Paludella squarrosa* (L.) Brid. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Philonotis fontana* (L.) Brid. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *tomentella* Mol. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Pohlia albicans* (Wahlenb.) Lindb. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *nutans* (Schreb.) Lindb. | ? | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Polytrichum attenuatum* Menz. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *commune* L. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *juniperinum* Willd. | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *strictum* Banks | + | + | ... | ... | + | ... | + | + | ... | ... | ... |
| — *sp.* | ... | + | ... | ... | ... | + | ... | ... | ... | ... | ... |
| *Porotrichium aloperurum* (L.) Mitt. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Rhacomitrium canescens* (Timm.) Brid. | ... | + | ... | ... | + | ... | ... | ... | ... | ... | ... |
| — *fasciculare* (Schrad.) Brid. | .. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Scleropodium purum* (L.) Limpr. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Scorpidium scorpioides* (L.) Limpr. | + | + | ... | + | ... | ... | ... | ... | ... | ... | ... |
| *Sphagnum acutifolium* Ehrh. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *angustifolium* C. J. | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... |
| — *imbricatum* Hornsch. | ... | ... | + | ... | ... | ... | ... | ... | ... | ... | ... |
| — *palustre* L. | + | + | + | ... | ... | ... | ... | ... | + | ... | ... |
| — *papillosum* Lindb. | + | + | + | ... | ... | ... | ... | ... | ... | ... | ... |
| — *teres* (Schimp.) | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... |
| — *sp.* | + | + | ... | + | + | + | + | + | ... | + | ... |
| *Stereodon cupressiformis* (L.) Brid. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Swartzia montana* (Lam.) Lindb. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Thuidium abietinum* (L.) Br. eur. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *delicatulum* (L.) | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *tamaricifolium* (Neck.) Lindb. | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Tortella fragilis* (Drumm.) Limpr. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *tortuosa* (L.) Limpr. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |

| al period | | | | | | | | | | | | The penultimate interglacial period | | | | Interglacial deposits covered by young-glacial formations | | | | | |
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| Ringdal | Rodebæk II | Rodebæk III | Höllund Sögaard | Fövling | Lervad | Tuesböl II | Brörup railway-station | Brörup marl pit | Over Gestrup | Agerskov | Rostrup | Rind | Harreskov | Starup | Vejen, Tirslund | Hartz 1909 | Hörup | Lövskal I, II | Hollerup | Egtved | Kollund |
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| Flora and Fauna | The last i | | | | | | | | | | |
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| | Hartz 1909 | Herning | Nörbölling | Brörup Hotel | Rodobæk I | Solsö | Herborg I | Herborg II | Astrup | Duedam | Dalager |
| *Tortula ruralis* (L.) Ehrh. | ... | + | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Trichocolea tomentella* (Ehrh.) | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **Thallophyta.** | | | | | | | | | | | |
| *Cenococcum geophilum* Fr. | ... | + | + | + | + | + | + | + | ... | + | + |
| *Chlorosplenium aeruginosum* (Oeder) | ... | ... | ... | ... | ... | cf. | ... | ... | ... | ... | ... |
| *Puccinia sp.* | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... |
| *Tilletia sphagni* Nawasch | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Anabaena sp.* | ... | + | ... | ... | ... | ... | ... | ... | + | ... | + |
| *Amphora ovalis* Kütz. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Botryococcus Braunii* Kg. | .. | + | + | ... | + | + | + | + | + | ... | + |
| *Caloneis silicula* Ehrb. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Characeae* | ... | + | ... | ... | ... | + | ... | ... | ... | ... | ... |
| *Chroococcus turgidus* Naeg. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Cocconeis sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Cosmarium spp.* | ... | ... | ... | ... | + | ... | ... | ... | ... | ... | ... |
| *Cyclotella comta* (Ehrb.) Kütz. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *Kützingiana* Thw. *var. planetophora* Fricke | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Cymatopleura elliptica* Bréb. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *solea* Bréb. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Cymbella cistula* Hempr. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *Ehrenbergii* Kütz. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *lanceolata* Ehrb. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Diploneis elliptica* Kütz. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *ovalis* Hilse | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Epithemia Hyndmanni* W. Sm. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sorex* Kütz. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *turgida* Ehrb. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *zebra* Ehrb. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Euastrum cf. binale* (Türp.) Ralfs | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Fragilaria brevistriata* Grun. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *construens* (Ehrb.) Grun. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *intermedia* Grun. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *mutabilis* (W. Sm.) Grun. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *parasitica* W. Sm. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Gomphonema constrictum* Ehrb. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Gyrosigma attenuatum* Kütz. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Melosira arenaria* Moore | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *crenulata* Kütz | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *varians* Ag. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Navicula bacillum* Ehrb. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *dicephala* W. Sm. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *elliptica* Kütz. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *oblonga* Kütz. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| — *scutelloides* W. Sm. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Nitella sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Nitzschia sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

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| | Rodebæk II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | | + | | | | | | | | |
| | Rodebæk III | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | |
| | Höllund Sögaard | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | + | | |
| | Fövling | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | | | | | | + | | |
| | Lervad | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | | | X | | | + | | |
| | Tuesböl II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Brörup railway-station | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | | | | | | | | |
| | Brörup marl pit | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | | | | | | | | | | |
| | Over Gestrup | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | + | | |
| | Agerskov | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | | |
| | Rostrup | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| The penultimate interglacial period | Rind | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Harreskov | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Starup | | | | | | | | + | | | + | | | + | | + | | | | | + | | + | + | | | cf | cf | | + | + | | + | | | | | | + | | + | | | | | | |
| | Vejen, Tirslund | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | | |
| Interglacial deposits covered by young-glacial formations | Hartz 1909 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Hörup | | | | + | | | | | | | + | + | | | + | | | + | + | | | + | + | | + | + | | | | | + | | + | | | | | + | | | + | | | | | | |
| | Lövskal I, II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Hollerup | | | | | | | | | | | | | | | | | | | | + | | | | | | | | | | | | | + | | | | | | + | | | | | | |
| | Egtved | + | + | + | + | + | + | + | | + | + | | | + | | | + | + | + | + | + | + | + | | | | | + | + | + | + | | + | + | + | + | + | + | | + | + | + | | | | + | | |
| | Kollund | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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| | Hartz 1909 | Herning | Nörbölling | Brörup Hotel | Rodebæk I | Solsö | Herborg I | Herborg II | Astrup | Duedam | Dalager |
| *Pediastrum boryanum* (Turp.) Men. | | + | | | + | | | | + | | |
| — *clathratum* (Schroet.) Lem. | | | | | | | | | | | |
| — *duplex* Meyen | | | + | | + | | | | | | |
| — *integrum* Naeg. | | + | | | | | | | | | |
| — *Kawraiskyi* Schmidle | | + | | | | | | | | | |
| — *sp.* | | + | | | | | | + | | | |
| *Phacotus lenticularis* Stein | | | | | + | | | | | | |
| *Pinnularia mesolepta* Ehrb. | | | | | | | | | | | |
| *Pleurosigma sp.* | | | | | | | | | | | |
| *Rhopalodia gibba* (Ehrb.) O. Müll. | | | | | | | | | | | |
| *Rivulariaceae* | | | + | | | + | | | | + | |
| *Staurastrum sp.* | | + | | | | | | | | | |
| *Stephanodiscus astraea* (Ehrb.) Grun. | | | | | | | | | | | |
| *Surirella sp.* | | | | | | | | | | | |
| *Synedra ulna* (Nitsch) Ehr. *var. danica* (Kütz.) | | | | | | | | | | | |
| — *cfr. ulna* | | | | | | | | | | | |
| — *vaucheriae* Kütz | | | | | | | | | | | |
| *Tetraedon minimum* A. Br. | | | | | | | | | | | |
| **Vertabrata.** | | | | | | | | | | | |
| *Alces machlis* Ogilby | | | | | | | | | | | |
| *Castor fiber* L. | | | | | | | | | | | |
| *Cervus dama* L. | | | | | | | | | | | |
| — *elaphus* L. | | | | | | | | | | | |
| *Elephas sp. (primigenius)* Blum[1]) | | | | | | | | | | | |
| *Mus (silvaticus L.?)* | | + | | | | | | | | | |
| *Esox lucius* L. | | | | | | | | | | | |
| *Perca fluviatilis* Rond. | | | | | | | | | | | |
| **Arthropoda.** | | | | | | | | | | | |
| *Agelastica alni* L. | | | | | | | | | | | |
| *Acidota crenata* Fabr. | | + | | | | | | | | | |
| *Anchomenus lugens* Duft | | + | | | | | | | | | |
| *Hydroporus sp.* | | | | | | | | | | | |
| *Otiorrhyncus dubius* Ström | | + | | | | | | | | | |
| — *sp. (ad rugosostriatus)* | | + | | | | | | | | | |
| — *sp.* | | | | | | | | | | | |
| *Phryganidae* | | | | | | + | | | | | |
| *Strangalia sp.* | | | | | | | | | | | |
| *Phytoptus laevis* Nal. | | + | | | | | | | | | |
| *Cladocera* | | + | | | + | | | | | | |
| *Daphnia pulex* aut. | | + | | | | + | | | + | | + |
| *Ostracoda* | | | | | | | | | | | |

1) From the interglacial lake deposits at Ejstrup (V. Nordmann: Nyere Fur
1921. — N. Hartz (1909) states *Homo sp.* (eoliths) from a couple of local

| …l period | | | | | | | | | | | | The penultimate interglacial period | | | | Interglacial deposits covered by young-glacial formations | | | | | |
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| Ringdal | Rodebæk II | Rodebæk III | Höllund Sögaard | Fövling | Lervad | Tuesböl II | Brörup railway-station | Brörup marl pit | Over Gestrup | Agerskov | Rostrup | Rind | Harreskov | Starup | Vejen, Tirslund | Hartz 1909 | Hörup | Lövskal I, II | Hollerup | Egtved | Kollund |
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| ... | + | ... | ... | + | + | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... | + | + | + | ... |
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| Flora and Fauna | The last | | | | | | | | | | |
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| | Hartz 1909 | Herning | Nörbölling | Brörup Hotel | Rodebæk I | Solsö | Herborg I | Herborg II | Astrup | Duedam | Dalager |
| **Mollusca.** | | | | | | | | | | | |
| *Bithynia tentaculata* L. | ... | ... | .. | .. | + | ... | ... | ... | .. | ... | ... |
| *Limneae sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Pisidium sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Unio sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | . . |
| **Annelida.** | | | | | | | | | | | |
| *Nephelis octoculata* Bergm. | ... | ... | ... | .. | ... | + | ... | ... | ... | ... | ... |
| *Oligochaeta* | ... | .. | ... | ... | ... | ... | + | ... | ... | ... | ... |
| *Cristatella mucedo* Cuv. | ... | + | ... | ... | + | + | ... | ... | ... | ... | ... |
| **Coelenterata.** | | | | | | | | | | | |
| *Ephydatia Mülleri* Liebk. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| *Spongilla lacustris* L. | ... | + | + | ... | + | + | + | ... | + | ... | + |
| **Protozoa.** | | | | | | | | | | | |
| *Amphitrema flavum* Archer | ... | ... | ... | + | ... | ... | ... | ... | + | ... | ... |
| *Assulina sp.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

| l period | | | | | | | | | | | | The penultimate interglacial period | | | | Interglacial deposits covered by young-glacial formations | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ringdal | Rodebæk II | Rodebæk III | Höllund Sögaard | Fövling | Lervad | Tuesböl II | Brörup railway-station | Brörup marl pit | Over Gestrup | Agerskov | Rostrup | Rind | Harreskov | Starup | Vejen, Tirslund | Hartz 1909 | Hörup | Lövskal I, II | Hollerup | Egtved | Kollund |
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# III. The Covering Strata of the Bogs from the Last Interglacial Period and the Interglacial Landscape.

## Historical Introduction.

It is, as a rule, a distinctive feature in interglacial bogs of the Brörup type, that their presence is revealed superficially in the landscape by the basin-like depression formed above them in the terrain. It is this which has led to the systematic search for such bogs, the results of which are stated in the present work. The fact that the bogs so reveal themselves is connected with the fact that they have not, since their formation, been directly covered by inland ice, which would have effaced the interglacial features of the landscape. The depressions above these interglacial bogs my be regarded as relics from the pitted ground of the interglacial period, in the hollows of which the bogs themselves were formed.

As regards the manner in which the covering strata were carried out over the bogs, various opinions have been advanced. As stated in the historical section of the present work (p. 266) writers in the early days of the interglacial theory held that a covering of moraine was essential if a deposit were to be called interglacial.

The term "interglacial" was thus originally a stratigraphical term pure and simple; in course of time, however, the vegetation of the strata being considered, it came to be a determination of the date of formation, so that the cover above need not have been deposited there by inland ice or melting water from the same, but might have been carried out over the bogs from their surroundings by other agencies.

N. Hartz,[1]) in his publications dealing with the investigations he made in 1898 and after, among the interglacial bogs of the Brörup district and at Höllund Sögaard, takes the view that these bogs must have been covered by the ice of the last glacial period, "even if the ice-sheet has only lain here a relatively short time and had a relatively small thickness." According to Hartz, the covering layer above the

[1]) N. Hartz: Bidrag ... D. G. U. II. R. No. 20. 1909.

bogs was composed of fluvioglacial sand and a superimposed "thin (ca. $^1/_2$ m) deposit of stony sand," which, from its general appearance and composition "(scattered, unsorted stones, contents of fine material in larger quantities than in the underlying sand, the wanting stratification)" he regarded "to be a ground moraine of a thin ice-sheet which has been of short duration", (l. c. p. 291).

HARTZ however, was here largely intent on the fact that the bogs in the hilly ground lie "under hollows easily distinguishable in the landscape". He states that he learned, in course of time, "to see from the type of landscape whether there was likelihood of finding an interglacial bog below the sand." "For the peat has, in course of time, been highly compressed by the weight of the diluvial strata above, producing a flattish, basin-like depression in the landscape above the interglacial bog" (l. c. p. 139).

That the depressions — from HARTZ's point of view — must have been produced by this means, i. e. by compression, is evident enough. On the other hand, granted that the bogs have not been covered by inland ice, it is not so certain that the depressions were due to compression of the peat.

The statement that these bogs had been covered by the inland ice was challenged by AXEL JESSEN,[1]) who firmly maintained that the covering material had been carried out over the bogs from the surroundings. He writes in this connection: "The diluvial bogs lie, as we have seen, up on the hilly island sites . . . and are formed in small, deep holes, only 30—50 m across; these depressions are still distinctly visible in the landscape, . . the peat, which has been compressed by the weight of the strata above, is covered by 2—6 m stratified sand, some of it coarse, some fine, and more or less argillaceous, and with a few small stones scattered about here an there. The boundary between peat and sand however, is by no means sharply defined, the peat at the top merging into a dark ooze, which becomes more and more sandy higher up, and — like the covering sand — with a few small stones here and there; the transition zone itself consists of alternating strata of pale, clean sand and dark, oozy sand. The upper portion of the sand, below the mould, may contain more small stones, but may also be practically stoneless; this upper sand can certainly not be classed as any kind of moraine or remain of such, and is not to be taken as a parallel to our "stony sand" (Geschiebesand, Decksand). The sand immediately above the peat shows, moreover, a stratification so undisturbed, that it could hardly have been submitted to the passage of inland ice . . ."

[1]) AXEL JESSEN: Kortbladene Aalborg og Nibe. D. G. U. I. R. Nr. 10 p. 85—87. 1905.

"The argillaceous sand above the diluvial peat must be a secondary deposit, washed down in course of time over the bog, carried also, to some extent, by the wind, or slidden down from the slopes surrounding the bog. This movement from the surroundings down over the bog must probably have been most pronounced during the advance of the inland ice which followed the formation of the bogs . . . the climate at that time being most favourable to such transport of material. The great accumulations of snow in winter, and the sudden thaws of spring would free such quantities of water on the surface of the soil that the latter would become soft and gruelly, especially if the strata a couple of metres farther down were still frozen hard. Forthermore, the constant and rapid alternations of frost and thaw in the upper, saturated soils would occasion contractions and expansions which, except on perfectly level ground, would help to set the whole mass in motion down over the bog."

"In course of time, as the sand was washed down over these diluvial bogs, the peat became compressed, and so it comes about that we now find all these bogs lying beneath small round or elongated depressions, still conspicuous and easily recognisable in the landscape. This is a further proof that the inland ice can never have covered these tracts since the bogs were formed, for if it had, the ice would have compressed the peat, and the depressions would at once have been filled up with moraine material or fluvioglacial deposits."

That the present hollows should be due exclusively to compression of the peat is not proved. True, in the "Brörup Mosernes Lejringsforhold",[1]) where the grounds for supposing that these bogs can never have been covered by the inland ice are given (cf. p. 309), it is stated that the hollows "are evidently due to collapse or compression of the originally sodden peat" but no foundation is given for this view. The statement expressed however, the opinion which the writers of the work in question unanimously held to be correct.

## Formation of the Covering Strata by Subaërial Denudation.

When the presence of a covering stratum above a bog of the Brörup type cannot be due to the whole having been covered by inland ice, it is obvious that the covering material must have been brought down from the higher ground adjacent. The area from which it can be derived is thus restricted to these portions of the sourrounding country which slope down towards the bog, and the movement out

1) A. Jessen, V. Madsen, V. Milthers og V. Nordmann: Brörup-Mosernes Lejringsforhold. D. G. U. IV. R. Bd. I. Nr. 9, 1918, p. 4.

out over the bog must then have taken place either in the form of solifluction due to the causes associated therewith — plasticity at a given water-content, regelation (repeated frost and thaw) in conjunction with permanent frost in the ground — or by the action of running water. As there are but very few localities from which we have anything like adequate profiles through these strata, it is difficult, in the various cases under consideration, to determine under what conditions and in what precise manner, the transport and deposition of the material took place. Judgement in such cases must depend to a considerable extent on whether the soil shows evidence of sorting and stratification or not. Sorting and stratification will, normally, indicate that the transport and deposition of the material where errected through the agency of running wather, and took place in water. On the other hand, where the covering soil shows no stratifications or sorting, the deposit may have come into its place through the action of solifluction, and in the form of a coherent mass. The movement can have taken place either owing to release of inherent plasticity on saturation, when the soil ceases to hold together as a solid and becomes a fluid mass, or to the alternation of frost and thaw, which is especially the case in arctic conditions.

## The dynamics of Solifluction.

In the cases here concerned, the deposition of covering material over interglacial bogs by landslide proper can hardly be entertained, at any rate only in rare instances. The slopes are for the most part not sufficiently steep. Solifluction due to saturation alone — i. e. excluding the effect of frost — can only take place in the case of soils capable of attaining sufficient plasticity to render the mass incapable of supporting its own weight, so that it must slip away in the direction of the slope. This calls for a certain degree of fineness in the grain. SIMON JOHANSSON states[1]) that the coarsest soil of this character ("Flydejord") in ATTERBERG's collection was composed of the following:

| | | | |
|---|---|---|---|
| Sand | 2.0 —0.2 | mm | 0.1 % |
| "Mo" | 0.2 —0.02 | mm | 73.3 % |
| "Schluff" | 0.02 —0.002 | mm | 19.2 % |
| Clay | < 0.002 | mm | 7.2 % |
| Humus | | mm | 0.2 % |

Two samples of "Flydejord" which J. G. ANDERSSON[2]) has had analysed, consisted of:

[1]) SIMON JOHANSSON: Die Festigkeit der Bodensorten bei verschiedener Wassergehalt. S. G. U. Årsbok 7. 1913. Nr. 3, p. 91—92. Stockholm 1914.

[2]) Schwed. Südpolar-Exp., Bd. II. Lief. 2. Stockholm, 1907.

| | | |
|---|---|---|
| Gravel | 1.3 % | — % |
| Sand | 2.7 % | 37.0 % |
| "Mo" | 22.5 % | 14.8 % |
| "Schluff" | 20.2 % | 9.3 % |
| Clay | 42.0 % | 29.1 % |
| Lost by heating | 11.0 % | 9.3 % |

S. JOHANSSON however, does not consider either of these two samples as belonging to the true solifluction types, i. e. those which become fluid solely by the plasticity derived from saturation. Since they have nevertheless given rise to solifluction phenomena on a grand scale, there must have been some particular factors contributing to the effect. Frost is regarded as capable of acconting for this. S. JOHANSSON explains this as follows: The volume of water increases, as we know, on freezing, and the frost thus serves to decompose the particles of the soil; also, when freezing is taking place, there is a pronounced influx of water from below into the freezing strata, so that the water content of these frozen strata greatly exceeds what it could normally attain; the subjacent strata are correspondingly deprived of their water, though in this case, the contribution is levied over a greater volume. In order to illustrate this, S. JOHANSSON had a column of earth containing 31.6 % of water subjected to frost from the upper end. After one day's frost, the humidity of the column at different levels was measured, and found to be as follows:

| | |
|---|---|
| 0— 3 cm from the upper end, frozen | 46.0 % |
| 3— 6 cm — — | 28.3 % |
| 10—13 cm — — | 28.9 % |
| 20—23 cm — — | 29.6 % |

Again, when a frozen stratum of earth, which was saturated with water prior to freezing, is thawed from above ,the thawed stratum will be highly super-saturated with water, and far more liable to solifluction than under ordinary conditions. If at the same time, the surplus water be prevented from scaping out of the stratum owing to the surface being watered by the melting of snow, or by the formation of a fresh crust of frost, the likelihood of solifluction is still further increased. The layer of frozen soil below the thawed, the "tæl", prevents the water from percolating down from the supersaturated layers above, and thus again serves to encourage solifluction. On the other hand, the frozen subsoil will not serve as a gliding surface, being too uneven. The actual effects of frost also help to increase the plasticity, as the disruption produced gives finer particles, and in arctic regions, where the ground is always frozen, we find, in conjunction with solifluction, a great number of surface phenomena, which can hardly be fully explained save by the action of alternating frost and thaw, and the consequent repeated alterations in state, and internal dislocations, of the separate parts of the soil.[1])

Apart from dislocations produced by the action of frost and thaw alone, there are also movements which arise in the sodden, easily fluent strata resting on the frozen subsoil, owing to the difference in specific gravity of water $0^{0}$ C and at $4^{0}$ C.[2])

Some arctic writers consider frost and thaw as of decisive importance in the solifluction which takes place under arctic or sub-arctic conditions of climate; others, again, do not regard this factor as directly active in producing arctic solifluction. JOHN FRÖDIN, in "Några Bidrag till flytmarkens dynamik",[3]) which forms part of a larger work, states that the water content is more important as a factor in solifluction than the alternation of frost and thaw. The water content is high immediately after a thaw, but decreases in the course of the summer, so that when frost again sets in, the upper parts of the soil may have dried up considerably. On the other hand, the saturated stratum immediately above the frozen part is held to provide the gliding surface for the material above. "Först när detta plastiska lager blir för obetydligt i förhallande till den övre fastare, transporterade massan, torde glidningen upphöra". (Only when this plastic stratum becomes too insignificant in proportion to the upper, firmer, transported mass, will the gliding cease). The position of the frozen stratum below the surface of the soil is therefore of great importance, as the mobility of the earth mass must decrease as the surface of the frozen soil moves lower down. In a thawed solifluction field in Swedish Lapland, a little below the boundary line of the melting snow, and with a slope of abt. 1 : 17, the gradient of the frozen stratum was abt. 1 : 11 throughout a range of abt. 20 m from the snow-line downwards.[4])

Before we can arrive at a fuller understandig of the dynamics of arctic solifluction, a far greater number of systematic observations and

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1) B. HÖGBOM: Einige Illustrationen zu den geol. Wirkungen des Frostes auf Spitzbergen. Bull. of the Geol. Inst. of Upsala, Vol. 9. 1910. — Über die geol. Bedeutung des Frostes. Bull. Geol. Inst. Upsala, Vol. 12, 1914. — A. HAMBERG: Zur Kenntnis der Vorgange im Erdboden beim Gefrieren und Auftauen. Geol. Fören. Förh. Vol. 37. Stockholm. 1915.

2) A. R. LOW: Instability of Viscous Fluid Motion. Nature, vol. 115, p. 299. 1925.

3) JOHN FRÖDIN: Geogr. Studier i St. Lule Älvs Källområde. Sveriges geolog. Undersökning. Årsbok 7 (1913) Nr. 4, 1914, p. 235 ff. Cf. same writer: Über das Verhältnis zwischen Vegetation in den alpinen Regionen des Schwedischen Lappland. Lunds Univ. Årsskr. N. F. Avd. 2 Vol. 14, No. 24, 1918, p. 24—25.

4) JOHN FRÖDIN: Geogr. Studier, p. 240, Fig. 62.

measurements will be needed than are at present available. This applies both to the magnitude of the solifluction and the mechanical constitution of the material concerned, its composition and structure, the incline of the site, water content of the material transported, position of the frozen stratum, and alternation of frost and thaw in the thawed earth.

As the conditions requisite for repeated freezing and thawing of the upper soils are found most abundantly in the arctic regions, where the frozen subsoil hardly if ever thaws completely, it is easy to understand that there is here a frequent occurrence of soliflution in such strata as are capable of attaining the required plasticity. Even in those which are not themselves capable of solifluction, however, the action of frost and thaw may produce movements in the direction of the surface incline, these being due solely to the expansion and contraction of the upper levels occasioned by the frost. As already mentioned, the water content of a saturated stratum can, on freezing, be increased by about 50 %. This increase in the water content must result in an increase of the volume of the stratum, answering at least to the volume of the additional water. To this must be added the increase of volume produced in the stratum itself on passing into the frozen state, i. e. abt. 10 %.[1]) As the expansion can, generally speaking, only proceed in an upward direction, the rise in the level of the ground produced by freezing must amount to abt 1 : 10th of the thickness of the frozen stratum, supposing the soil to be saturated with water before freezing. If now the surface be not horizontal, but somewhat inclined, then the upward movement occasioned by the frost will be in a direction at right angles to the plane of the incline; the fall occasioned by thaw, on the other hand, will be vertical. The outward movement of a particle of soil and its subsequent return will therefore not coincide in direction, but form an angle answering to that of the surface incline. If, for instance, the ground has a fall of $5^{0}$ (1 : 11.5), and the surface of the frozen stratum has been raised 10 cm, then we can reckon that when both frost and thaw have taken place, there will have been a horizontal movement of the mass mounting to 0.8 cm. The actual movement is thus in the form of a zigzag; a creeping rather than a flow.[2])

Whichever of the two forms of movement it may be, the solifluction or the earth creeping, the mass of earth in question — compared with washed or water-sorted deposits — will to a certain extent move

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1) Axel Hamberg, l. c.

2) Cf. G. Götzinger: Beiträge zur Entstehung der Bergrückenformen. Geogr. Abh. Vol. IX. Leipzig. 1907. Comprehensive references are here given as to the term »creeping of earth« in earlier worcks. — Cf. Paul Kessler: Das eiszeitliche Klima. Stuttgart 1925.

as a compact mass. In both cases, however, the movement will be greatest in the upper portions, decreasing from the surface downvards until a level is reached at which the particles are entirely unaffected by the action produced by frost in the upper strata.

There is yet a further effect of frost which should be noted, though it does not directly concern the movement of soil in a horizontal direction. And this is, the constant uplift of stones. When the ground freezes, the stones follow the upward movement of the soil in which they lie. With the subsequent thaw, the finer parts of the soil gradually sink down again as the thaw proceeds. The larger stones however, which have their lower parts in the frozen subsoil, are kept in position thereby, maintaining their previous rise in level, and cannot commence to partake of the downward movement until the surrounding frozen mass has thawed entirely. The soil proper thus sinks back to its former level after frost followed by thaw, whereas the stones remain in their higher positions; they "grow". The effect is greatest while the stones reach down to the greatest depth in the frozen stratum, decreasing as they rise or reach but a slight depth below the surface. The total effect of this phenomenon is to bring about an accumulation of stones in the upper soil.

## Thickness of the covering strata above the bogs.

We now know, in Jutland, some 32 localities, or more, as to which it may be assumed that the mineral covering mass above the bogs was deposited by solifluction or by the action of running water. Of these, only a few have been bored through to such an extent as to provide adequate information concerning the quantity of mineral earth so deposited. In most cases, we have only a single boring or excavation, or a few such, these being, however for the most part in the lowest portions of the hollow, and thus on the whole presumably indicating a thickness exceeding the average.

The thickness of the covering strata below the alluvial.

I. Bogs with only one or a few borings or shafts.

| | Depth in metres | Thickness of covering strata | Thickness of interglacial strata |
|---|---|---|---|
| Herborg I | 1.50–11.50 | 10.00 m | 4.00 m |
| — II | 1.15–10.00 | 3.25 - | - |
| Astrup | 2.25– 3.50 | 1.25 - | 0.10 - |
| Duedam I | 0.50– 2.20 | 1.70 - | 5.35 - |
| — II | 0.90– 3.40 | 2.50 - | 0.15 - |

| | Depth in metres | Thickness of covering strata | Thickness of inter-glacial strata |
|---|---|---|---|
| Dalager 1 | 1.25— 2.50 (1.25) | | |
| — 2 | 0.60— 2.60 (2.00) | 2.20 m | |
| — 3 | 0.0 — 3.90 (3.90) | | |
| — 4 | 0.0 — 1.60 (1.60) | | |
| Dalager Nygaard | 0.0 — 3.40 | 3.40 - | 4.80 m |
| Ringdal | 0.30— abt. 6.25 | 5.95 - | |
| Rodebæk II, 1 | 1.25— 5.10 (3.85) | 3.40 - | 0.55 - |
| — II, 2 | 1.45— 4.35 (2.90) | | 3.85 - |
| — III | 0.40— 1.90 | 1.50 - | 4.25 - |
| Höllund Sögaard | 0.0 — 2.10 (2.10) | | 5.10 - |
| — — (HARTZ[1]), p. 193) | 0.0 abt.3.00 (3.00) | 2.45 - | |
| — — ( — , p. 199) | 0.0 — 2.00 (2.00) | | |
| Bramminge ( — , p. 184) | 0.0 — 1.00 | | |
| — ( — — ) | 0.0 — 2.00 | 1.80 - | |
| — (A. JESSEN[2])) | 0.0 — 2.50 | | |
| Lundtofte (D. G. U. IV. R. Nr. 9) I. | 0.0 — 1.10 (1.10) | | |
| — ( — ) II. | 0.4 — 1.50 (1.10) | | |
| — ( — ) IV. | 0.3 — 1.60 (1.30) | | |
| — ( — ) V. | 0.0 — 1.15 (1.15) | 1.15 - | |
| — ( — ) VI. | 0.5 — 1.70 (1.20) | | |
| — ( — ) VII. | 0.4 — 1.00 (0.60) | | |
| — ( — ) VIII. | 0.3 — 1.95 (1.65) | | |
| Fövling | 0.0 abt.3.50 | abt.3.50 - | abt 2.70 - |
| Lervad | 0.0 — 2.55 (2.55) | 2.70 - | 2.20 - |
| — (HARTZ, p. 181) | 0.0 — 2.90 (2.90) | | |
| Tuesböl I (HARTZ, p. 161) I | 0.0 — 1.60 (1.60) | | |
| — - ( — , p. 166) II | 0.65— 1.65 (1.00) | | |
| — - ( — , p. 168) III | 0.0 — 2.00 (2.00) | 1.45 - | |
| — - ( — , p. 171) IV | 0.0 — 1.10 (1.10) | | |
| — - (D. G. U. IV. R. Nr. 9, p. 21). | 0.0 — 1.54 (1.54) | | |
| — II | 1.0 — 1.90 | 0.90 - | 2.85 - |
| — (HARTZ, l. c. p. 190) | 0.0 — 1.30 | 1.30 - | 2.00 - |
| Bog at Brörup, Nr. 11, Fig. 2 | 0.0 — 1.90 | 1.90 - | |
| Bog SW of Brörup St. No. 6, Fig. 2 | 0.0 — 2.00 | 2.00 - | |
| — — No. 7, Fig. 2 | 0.0 — 1.50 | 1.50 - | |
| — — No. 8, Fig. 2 | 0.0 — 2.00 | 2.00 - | |
| Bog at Brörup railway station | 1.30— 5.20 (3.90) | 4.60 - | |
| — — — (HARTZ, p. 140) | 0.6 — 5.90 (5.30) | | |
| Bog S of — — ( — , p. 190) | 0.0 — 6.30 | 6.30 - | |
| Skovlyst (HARTZ, p. 177) | 0.0 — 2.20 | | |
| — (D. G. U. IV. R. Nr. 9) | 0.0 — 1.85 | | |
| — ( — ) | 0.0 — 1.35 | | |
| — ( — ) | 0.0 — 1.80 | | |
| — ( — ) | 0.0 — 1.95 | 1.90 - | |
| — ( — ) | 0.0 — 1.95 | | |
| — ( — ) | 0.0 — 1.85 | | |
| — ( — ) | 0.0 — 2.19 | | |

1) N. HARTZ: Bidrag . . . D. G. U. II. R. No. 20. 1909.

2) A. JESSEN: Kortbladet Varde. D. G. U. I. R. Nr. 14, 1922, p. 74.

| | Depth in metres | Thickness of covering strata | Thickness of inter-glacial strata |
|---|---|---|---|
| Agerskov | 0.0 — 3.55 | 3.40 m | 0.55 m |
| — | 0.0 — 3.20 | | 0.80 - |
| Over Gestrup | 0.0 — 3.55 | 3.55 - | 4.45 - |

II. Bog in which systematic boring has been carried out.

At Solsö, the thickness of the covering material, from the average of 13 borings (3.85–8.85) is 6.00 m.

III. Bogs with two separate mud strata.

| | | | |
|---|---|---|---|
| Rodebæk I | 16 borings | (1.05–3.80 m) | 2.35 m |
| Nörbölling | 16 — | (1.35–5.10 m) | 3.00 m |
| Brörup Hotel | 3 — | (3.55–3.80 m) | 3.65 m |

For the average thickness of mineral earths deposited after the close of the lower warm period — apart from the Middle Bed in the bogs with two separate mud beds — we find the value 2.99 m, a figure which, however, would in all probability be considerably reduced if we could make a thorough investigation of the average thickness in the different localities.

We have then the Interglacial Lake at Herning, where, owing to the extent and depth of the lake, special conditions prevailed, and where the average thickness of the mineral earths deposited is considerable, but most difficult to determine, as the strata are so greatly mixed with mud. If on the other hand, we take only that portion which has been carried out over the lake area by solifluction or washing in the last glacial period, then the mean thickness will amount to abt. 3.0 m, if anything, a little less.

## Evidence of Solifluction and Earth-creeping.

In determining the manner in which the covering material was deposited above the bogs, we have to take into consideration the composition of the soil shown by borings and profiles of incisions, and the disturbances which the peat beds have undergone during the deposition of the covering soil.

The following borings show strata which from their constitution might appear to have been deposited by solifluction.

| | | | |
|---|---|---|---|
| Herning No. 9 | 2.95–3.75 m | Grey, non-calcareous stony clay. |
| — 25 | 3.7 –4.5 m | Stony clay. |

| | | |
|---|---|---|
| Rodebæk I, No. 1 | 1.75—1.90 m | Sandy, stony clay, the lower part very sandy. |
| — No. 15 | 0.30—1.00 m | Yellow sand with small stones, slightly argillaceous at bottom. |
| | 1.00—2.60 m | Yellow, sandy clay with a few small stones, richer in the lower part. |
| Lervad | 0.45—135 m | Argillaceous sand, many stones up to the size of a head. |
| — | 1.35—1.95 m | Sand with many stones, up to the size of a fist. |
| Nörbölling 3 | 1.40—1.70 m | Argillaceous, stony sand or sandy clay. Stones like pigeon's eggs. |
| — 7 | 3.25—4.05 m | Sandy grey clay with a few stones, more brownish lower down. Small lumps of hard, dark grey mud. |
| — 10 | 1 00—1.75 m | Argillaceous sand, with more clay in the lower portion. |
| | 1.75—1.90 m | Sandy grey clay. |
| | 1.90—2.10 m | Brownish sandy clay. |
| — 11 | 0.90—2.00 m | Stony sand, with sand-worn stones in the upper part; small lumps of brown, sandy mud lower down. |
| | 2.0 —2.30 m | Sandy, argillaceous mud with interkneaded stones. |
| — 16 (pit) | 0.70—1.85 m | Stony, argillaceous sand, stones the size of a fist, cf. p. 81. |
| | 1.85—2.25 m | Mud. Midway down in this bed a lens 40 m long of material like the stratum above. |
| — 18 | 1.0 —1.60 m | Sand with lumps of mud and interkneaded small stones. |
| — 21 | 1.45—2.10 m | Grey, sandy, rather muddy, stony clay. |
| Brörup Hotel Bog, No. 5. | 0.30—1.20 m | Sand with stones here and there; one was bigger than a man's head. |
| | 1.20—1.55 m | Grey, reddish flamed clay with a few small stones. |
| — Excavation 1 | 1.15—1.80 m | Stony, argillaceous sand; stones up to the size of a head. |
| Agerskov (trench, p. 174) | 0 —0.70 m | Argillaceous, stony sand. |

I the profiles of incisions, we have in several places observed material and forms of stratification which might be regarded as due to solifluction. This is the case, for instance, at Herning, Höllund Sögaard, Tuesböl, Skovlyst and Lundtofte.

In the profile at Herning Brickworks pit we found in 1914, farthest to the south, and at the top, a sandy, very heterogeneous moraine-like layer of soil, containing interkneaded lumps of richer clay. Farther north in the profile — i. e. out towards the lake — this merged into yellow, stratified sand with stones here and there; at the bottom, the stratification was fairly regular, the strata above were bent or even folded, and this strata series terminated at the top in stony sand without stratification, and containing small stones, as a rule up to the size of hen's eggs. The heads of the subjacent strata, which belonged to the interglacial lake deposit, showed that these strata farthest to the south must, prior to the deposition of the covering material, have been subjected to denudation, which had presumably removed a layer of 2 metres' thickness or more. The plane of denudation cut across strata from both the temperate horizons, and seemed, as far as could be judged to lose itself in the sand above mentioned, the strata of which were curled at the top, but lay undisturbed lower down. Cf. Pl. III. These last were presumably deposited by running water in the lake basin at the close of the interglacial period. The denudation surface is thus synchronous with the last glaciation, and probably due to solifluction.

At Höllund Sögaard, excavations in the marginal zone of the bog, to the south of it, gave a profile with "argillaceous strata like moraine sand, which farther north out over the bog gradually gives place to sand with a very few small stones, and finally, in the deepest parts of the bog, to stoneless, stratified, distinctly water-sorted sand".[1]) The strata above are richer in stones, but the quantity of stones here also decreases as we approach the middle of the bog.[2]) The beds lacking stratification must be presumed to have been deposited by solifluction (cf. p. 152).

At Tuesböl, the peat in several of the pits dug for HARTZ was highly folded, and "the folding was evidently most pronounced . . . at the edge of the bog".[3]) A profile taken when investigating the stratification of the Brörup bogs[4]) showed that a portion of the moraine clay below the peat was folded up over a flake of peat. This profile was found on the eastern side af the bog; on the western side also however, a folding of the strata was observed, in this case from the west, i. e. as in the former case, out towards the bog from the surrounding country. The most natural explanation of these folds then is that they are due to solifluction proceeding from the sides out over the former lake.

In the bogs at Skovlyst, south of Brörup, HARTZ found[5]) that the peat was "very much folded" and that the covering or transition layer was of brownish argillaceous sand, mixed with smears of peat and a few small stones up to 3—4 cm." On investigating the stratification of the Brörup bogs[6]) beds resembling moraine sand were also

1) D. G. U. VI. R. Bd. 1. No. 9, p. 15.
2) — — — p. 15.
3) — II. R. No. 20, p. 172.
4) — IV. R. Bd. 1, No. 9, p. 20.
5) — II. R. No. 20, p. 178.
6) — IV. R. Bd. 1, No. 9, p. 23—31.

found here, with many stones at the top, and folds in the subjacent beds of mud and interglacial peat.

In the interglacial bog at Lundtofte, 3 km SW of Holsted Station, highly folded peat strata were likewise observed, undoubtedly folded by solifluction.[1])

From these profiles it seems that we may reasonably expect to find solifluction and its attendant phenomena through the marginal zones of these bogs.

## Sorted and stratified covering material.

Side by side with solifluction and "creeping", we have running water as a main factor in the deposition of the covering layers above the interglacial bogs not covered by ice. The evidence of water as the agency appears in the profiles of incisions in the stratifiation of the material, whereas in the borings, we have to be content with the indications afforded by the sorting of the material. Founds of stratified material has been mentioned before. Sorted material seems to occur in the great majority of the localities investigated, as far as we can judge from the results of the borings.

Most of the bogs investigated seem to have been in the form of lakes at the close of the interglacial period. Several were lakes throughout the entire interglacial period, while others have at some time or other presented a dry surface, with a subsequent return to the lake form, before the interglacial gave place to a colder climate. Finally, there are some where the bog-surface has lain in more or less dry state immediately before the glacial period set in and water-borne or slidden sandy material was deposited above them.

Stony sand, gravel, or pure sand directly above the interglacial mud have been found at the following localities:

Herborg I: Sand — mud.
— II: Sand — mud.
Astrup: Gravel — sand — mud.
Duedam II: Stony sand — mud.
Dalager: Gravel — mud.
Dalager Nygaard: Stony sand — mud.
Rodebæk II, Boring 1: Sand — mud.
Fövling: Sand — mud.

A somewhat greater variety of material is shown by the borings in the following bogs:

Ringdal: Stony sand — stoneless clay.
Lervad: Argillaceous sand — stony sand — loamy sand — mud.

[1]) D. G. U. IV. R. Bd. 1. No. 9, p. 34—35.

Höllund Sögaard: Sand — clay — peat.
Brörup railway station: Stony sand — stoneless clay and stony sand — mud — peat.
Over Gestrup: Sand — stoneless clay — mud — peat.
Rodebæk II, Boring 2: Gravel — sandy mud — peaty mud.

Strata of purer mineral earth directly above the peat have been found at the following.

Duedam I: Stony sand — peat — mud.
Rodebæk III: Stony sand — peat — mud.
Höllund Sögaard (HARTZ l. c. p. 194): Sand — transition layer — peat.
Brörup railway station (HARTZ l. c. 141): Sand — argillaceous sand — peat.
Tuesböl I (HARTZ, p. 166): Sand — peat — mud.
Brörup Hotel Bog, Boring 3: Stony sand — sand — peat — mud.
— — Boring 4, 2: Stony sand — sand — peat — mud.

Borings from the various bogs which have been subjected to detailed investigation reveal the following features:

Solsö: The interglacial strata, which are here exclusively of lacustrine origin, consist, at the top, of argillaceous mud or stoneless clay. Above this is sand, and gravel beds, or again with beds of stoneless clay. That these are mainly watersorted strata can hardly be doubted.

Rodebæk I: The detailed borings in this bog show that we have here a throughout peat horizon which at the close of the older warm period was covered over with mud. After the formation of this lake deposit, stoneless sand was washed out into the basin. After the close of the younger warm period, the deposition of sand in the lake was continued, and terminated at the top with stones up to size of a fist. This horizon over the central portion of the lake, is abt. 1/2 m thick, whereas the stony sand in the marginal zone is considerably thicker, and on the west and south sides of the bog is bedded directly on the interglacial lower mud: this stony sand, at the SW corner of the lake, is somewhat argillaceous as regards its lower part, which might suggest solifluction as its origin.

Nörbölling. After the close of the older warm period, there has been a lake here all the time until the formation of the postglacial peat bog. In the time of the Middle Bed, it was more especially stoneless clay, but also sand, and — at the northern end — sharp, stony sand, which was washed out into the lake. After the close of the younger warm period, sandy clay was washed down into the lake from the SE; higher up towards land, this seems to give place to a solifluction product (see p. 95, Borings 6 and 7); above this stratum are more stony strata, of gravel or stony sand. The borings in the other parts of the lake show that there must have been stony sand or gravel immediately above the lacustrine mud of the warm period, some of it possibly deposited by solifluction (indicated by interkneaded lumps of mud), while in other parts it was deposited by running water. Above this stony horizon comes one with fewer stones, indicating that a certain degree of sorting has taken place; this horizon however, also bears, in places, indications of having been deposited by solifluction (see p. 248, Boring 10).

## Importance of the Watershed surrounding the interglacial bogs.

Whichever of the actions indicated may be responsible for the covering material above the interglacial bogs, it is obvious that the source of origin of this material must lie within the watershed which has always enclosed these bogs. Observations showing that the covering strata are on the whole poorer in stones in the central part of the bogs than at the sides are among the arguments which may be adduced against the theory of deposition of the covering beds by the passage of inland ice. They also argue against the view that bogs where such conditions prevail should have been traversed solely in one direction by the covering strata, even though the causes of deposition are other than inland ice. On the whole, we may take it that *the covering material has been deposited by radial movements down towards the bogs hollows*, though there may, in some few cases, have been a transverse movement out across the bogs. This we may suppose to have been the case for instance at Dalager Nygaard, where the bog does not now appear as an enclosed hollow, but lies under a small sloping valley.

In all bogs where the covering soil was deposited by radial movement in towards the bogholes due to solifluction or the action of running water, such movement naturally requires that the surface of the ground should have sloped at the time down towards the bog from the surrounding country. During the deposition of sand strata above the beds of mud and peat, these latter strata must from time to time have been crushed together, and the original boghole still appeared as a depression in the surface of the ground. The hollow has never been filled up to level with its surroundings. The movement towards the bog must have stopped before this, in all the localities where the the transport of material has not reached the stage of a complete traversing of the bog from one side to the other. Only in bogs where this last can be shown to have taken place, and where there is nevertheless still a perceptible depression above the bog, can we safely conclude that the depression is due solely to compression of the subjacent peat and mud by the material above. As a rule, however, the presence of the hollows will be an indication of incomplete filling up of the basins in which the bogs were formed.

The correctness of this view is supported, *inter alia*, by the boring profiles from Rodebæk I, where we have at the top a horizon of stony sand, its surface lying almost horizontal, whereas the strata of interglacial mud and peat lower down show a decidedly basin-like form, cf. Pl. XV. The horizon of stony sand in question seems to have maintained approximately the same surface form as it had when the deposit was formed, and there is no indication of any subsequent sinking, which would have been most apparent in the central part of the basin. That it is not mainly compression of the mud and peat beds, but lack of filling material which is responsible for the visible depressions above the bogs is also shown by the fact that such depressions occur whether the interglacial beds of peat and mud are thick, or relatively insignificant compared with the covering material. We may in this connection refer more especially to the two localities: Astrup and Duedam II, at Klokmose, where only 10 and 15 cm of mud were found below the hollows here observed, though the one at Astrup contains a post-glacial peat bog. Furthermore — as we shall discuss in detail later on — we find, at several places in south-west Jutland, similar depressions in the landscape, though no trace has been found of any interglacial deposit beneath.

## Enclosed hollows without interglacial strata.

In the summer of 1922, when we commenced our boring investigations, we were acting on the basis of experience gained during the previous autumn, when we had found interglacial bogs in all the enclosed hollows we had bored. We therefore sought out, with the assistance of the General Staff Map (1 : 20000) such hollows as we had reason to believe might indicate the occurrence of subjacent interglacial deposits. In this, we were guided by the consideration that such hollows, when they had lain outside the limits of the ice-sheet during the last glaciation, and been exposed to such levelling of the ground and filling up of hollows as then took place, without being themselves effaced, must, prior to this glaciation, have been even more prominent and probably filled with water, or have contained beds of mud and peat. A number of these sites disappointed us however, by exhibiting no trace of such deposits. The localities are noted in the following:

Troldsö, 500 m S of Troldhede railway station; a hollow which is left uncultivated (probably covered with water in winter).

| | |
|---|---|
| 0 — 0.25 m | Peat. |
| 0.25— 1.00 m | Grey, humous Sand, rather loamy at the bottom. |
| 1.00— 4.00 m | Coarse Sand and Gravel with stones. |
| 4.00— 7.90 m | Fine, micaceous Sand, loamy lower down, the bottom part more of a sandy clay. |
| 7.90— 8.10 m | Fine, micaceous, sandy Clay. |
| 8.10—12.20 m | Fine micaceous Sand. |

Bog at Over Tarp, 6 km SE of Troldhede.

| | |
|---|---|
| 0 — 0.90 m | Peat. |
| 0.90— 2.70 m | Fine Sand, the upper part rather loamy. |
| 2.70—18.00 m | Sand with small stones; Gravel with stones the size of pigeon's eggs, some brown-coal-wood. From abt. 11 m downwards some lumps of loamy sand or sandy clay were brought up with the rest. |

Skarrild Bog, 6 km ESE of Troldhede.

| | |
|---|---|
| 0 — 2.00 m | Peat. |
| 2.00— 2.50 m | Fine Sand. |
| 2.50— 3.00 m | Gravel. |
| 3.00— 4.00 m | Greyish blue Boulder Clay. |

Klapbæk, in Klokmose, 4.4 km N of Borris railway station.

| | |
|---|---|
| 0 — 0.30 m | Peat (bog dug away). |
| 0.30— 0.70 m | Pale brown sandy Mud, very firm. |
| 0.70— 1.20 m | Fine grey Sand. |
| 1.20— 3.65 m | Grey Sand with stones, the size of a fist in the upper parts, lower down, the size of pigeon's eggs. |
| 3.65— 4.05 m | Sandy Clay strongly stained with rust; fragments of hard pan. |
| 4.05— 7.00 m | Stony Sand and sandy Boulder Clay. |

Barbara's Hule, 3 km SSE of Varde.

| | |
|---|---|
| 0 — 0.90 m | Peat and Mud. |
| 0.90— 1.20 m | Gravel. |
| 1.20— 5.00 m | Fine Sand. |

This little lake was shut in by mounds of wind-blown sand on the east and south. The basin itself may perhaps have been hollowed out by the gradual removal of sand carried away by the wind, and may thus be of late glacial or even more recent origin.

Röverkælderen, 4.5 km SE of Varde.

| | |
|---|---|
| 0 — 0.90 m | Peat. |
| 0.90— 3.00 m | Gravel. |
| 3.00— 7.40 m | Sand with a few stones in the upper part, many lower down. |
| 7.40— 8.40 m | Very fine Sand. |
| 8.40—12.00 m | Sandy Clay, reddish brown at the top, otherwise greyish blue. |
| 12.00—13.00 m | Coarse Sand. |

Hegnshus Hedesö, 6 km SE of Varde.

Boring 1. 4–5 m from the edge of the moor.

0 — 0.60 m Water and Ooze.
0.60— 0.80 m Stone beds.
0.80 – 3.20 m Sand with stones.
3.20 – 5.90 m Fine Sand.
5.90— 6.10 m Gravel beds.
6.10 – 15.20 m Sharp white Sand.

Boring 2. 5 m from the edge of the moor.

0 — 0.10 m Water.
0.10— 0.30 m Root felt from marsh plants.
0.30 – 0.50 m Sand with a few stones.
0.50— 0.55 m Brown firm Mud.
0.55 – 0.65 m Brown soft Mud.
0.65 – 5.00 m Gravel.

Boring 3. In the lake, 5 m from the edge of the water.

0 — 0.60 m Water.
0.60— 0.95 m Dark, greyisk brown, sandy, stony Ooze with stones the size of pigeon's eggs.
0.95 – 1.20 m Pale brown, finely sanded Mud.
Below this, firm stony bottom.

In order to ascertain whether the mud beds encountered in the borings below stony sand could be traced beyond the lake, a ditch was dug from the water's edge up along the slope and the following measurements were noted:

Point 1. At the waterside.

0 — 0.15 m Raw humus.
0.15— 0.35 m Grey Sand with stones.
0.35 – 0.43 m Dark brown Humus with stones; at the bottom, 1 cm hard pan. Below this, reddish brown Sand.

Point 2. 4 m from the waterside.

0 — 0.10 m Raw humus.
0.10 – 0.20 m Grey Sand.
0.20— 0.26 m Dark brown Humus. Red Sand below.

Point 3. 26 m from the waterside and 1.9 m above the surface of the lake.

0 — 0.08 m Raw humus.
0.08 – 0.16 m Grey Sand.
0.16 – 0.20 m Humus. Red Sand below.

Lifstrup Moor. Northern Pit.

0 — 1.20 m Peat.
1.20— 1.40 m Peat with sand and stones.
1.40— 5.20 m Gravel.
5.20— 5.50 m Dark Boulder Clay.

Lifstrup Moor. Middle Pit.

0 — 0.20 m Root felt.
0.20— 8.80 m Red sandy Clay.
8.80 - 12.20 m Red Sand.

Cauldron-shaped hollow, abt. 1 km N of Rousthöje, 8 km SE of Varde.

| | |
|---|---|
| 0 — 0.70 m | Peat. |
| 0.70— 3.00 m | Sand with many stones. |
| 3.00— 5.00 m | Grey Boulder Clay. |

Skovsende Heath, near Trindhöj, 3.2 km E of Starup Church, which lies 29 km ENE of Varde. Boring made in a small basin-like depression.

| | |
|---|---|
| 0 — 0.50 m | Sand. |
| 0.50— 2.50 m | Stoneless, micaceous Glacial Clay. |

Skovsende Heath, N of Trindhöj, 3.4 km NE of Starup Church. Excavation at the bottom of a cauldron-like hollow near the lake, 125 ft above sea level:

2 metres of stoneless Sand. The surface strewn with stones.

Skovsende Heath, S. of Æskehöje, 2.3 km NE of Starup Church. Boring made in "the lake", N of Cote 132 ft. above sea level.

| | |
|---|---|
| 0 — 3.50 m | Sand with a few stones. On digging down through the upper metre, balls of stony Moraine Sand were found. |
| 3.50— 4.20 m | Sand with many stones; at 4.20 m a thin layer of sandy, stoneless Clay. |
| 4.20— 6.40 m | Stony Sand; abt. 6.30, it was stained a bright reddish yellow. |
| 6.40— 6.50 m | Dark grey Glacial Clay. |

Bog 400 m NE of Hovborg Church, 11 km N of Holsted.

| | |
|---|---|
| 0 — 2.00 m | Peat. |
| 2.00— 2.50 m | Gravel. |
| 2.50— 9.00 m | Sand with a single layer of gravel. |

Bog a little E of the road to Hovborg, 1.2 km N of Holsted.

| | |
|---|---|
| 0 — 3.00 m | Peat with numerous stubs of pine. |
| 3.00— 3.75 m | Pale brown Mud. |
| 3.75— 6.50 m | Stony Sand, reddish at the top, grey lower down. |
| 6.50— 9.00 m | Reddish brown Sand with stones; at 8 m, some thin reddish brown to grey beds of stratified Clay. |
| 9.00—11.40 m | Reddish brown (lower down greyish) sharp Sand with few stones. |

Tirslund Bog, SE of Raskenborg, 3.6 km WSW of Brörup railway stn.

| | |
|---|---|
| 0 — 1.90 m | *Sphagnum* Peat. |
| 1.90— 2.50 m | Brown, sandy Mud. |
| 2.50— 2.90 m | Pale, greyish yellow Clay Mud. |
| 2.90— 5.50 m | Stratified micaceous sandy Clay. |
| 5.50— 6.00 m | Grey Boulder Clay. |

Bog 1.2 km W of Brörup stn., north of the railway line.

| | |
|---|---|
| 0 — 1.10 m | Loam (the peat removed). |
| 1.10— 1.15 m | Finely sanded Mud with moss. |
| 1.15— 3.00 m | Sand and Gravel. |
| 3.00— 4.00 m | Calcareous Boulder Clay. |

Though the time occupied in these and a few other negative borings might be regarded as wasted as far as the finding of interglacial strata is concerned, we cannot regard these borings as altogether valueless. They show, for instance, that such depressions in the soil as are found above bogs of the Brörup type are not infallible signs of the existence of interglacial bogs beneath. The depressions in themselves are but instances of cases where the levelling of the ground has not advanced far enough to fill up the hollows completety, with a subsequent passage of denudation material across the site. In other words, the levelling process has not succeed in producing a perfect levelled slope in these localities, and there are still faint indications remaining of the original pitted and irregular surface of the glacial terrain.

Beyond this, the borings in question do not seem to afford any positive answers to questions at issue, but rather to raise new problems. As will be seen, in several places the borings only revealed sandy and gravelly deposits, even when carried to a considerable depth, as for instance at Troldsö and Over Tarp, Hegnshus Hedesö, the bog at Holsted and perhaps elsewhere. In such cases as these, where no water-stopping strata occur for many metres' depth, it is easy to understand that even hollows of considerable depth may have remained in a dry state throughout the interglacial period, so that no mud or peat was formed there, and that we were unable to trace, by borings in the hollows not levelled up, the land surface of the interglacial period in the former deeper hollows. True, in a case like that of the bog at Holsted, with close on 4 m of mud and peat, showing that there was a lake there during the postglacial period, it was natural to suppose that the interglacial period should have afforded even better conditions for the formation of a lake than the postglacial, since the hollow then must have been deeper in proportion to its surroundings, but the climate may have been of such a character that the possibility of lake formation was correspondingly reduced. This applies more particulary if, during the last glacial period, only the very smallest quantities of soil were carried out into the hollows, so that their depht would be almost the same in both interglacial and postglacial periods. We also find, in several of the postglacial bogs and adjacent dry hollows, that, as regards the depht of the hollow themselves, quite accidental circumstances may have determined whether conditions favourable to the formation af lake or peat bog should arise there.

## Extent of the subaërial denudation after the interglacial epoch.

The denudation of the landscape which accompanied the covering over of the bogs with sand and clay, must, one is inclined to believe, have been very extensive when we compare the forms left by the last glacial period with those which occur outside of the area of the last glaciation. The differences are at times highly conspicuous. The much-pitted landscape of the region of the last glaciation has no parallel in the nonglaciated areas of the same period. The levelling here has been so complete that only such small depressions as those above the Brörup bogs show traces of the deeper pits which existed in earlier times. But if the extent of denudation be taken as indicating a great and general removal of material from the landscape, then our observations in bogs of the Brörups type would seem to insolve a certain revision of this conception.

Given such conditions as at Brörup, with the many small hollows where there were originally deep holes with bogs formed therein, we may take it as highly probable that no great amount of material can have been removed from this area. A movement has taken place, from higher to lower levels within the area, but the levelling process has not gone so far as to fill up the hollows completely, nor attained the stage where passage from one side to the other of the hollows could take place. The same will apply to those other sites where such basin-like depressions are found. Where these are entirely lacking, there is reason to conclude that the denudation has passed this limit, and in such case, it will be difficult to give any measure of its extent. If, on the other hand, unfilled hollows still remain in the landscape, it is evident that the denudation material deposited in these affords an indication as to how much has been carried away from the denuded portion of the landscape which formed the source of supply.

Taking the thickness of the covering strata above the bogs as a starting point for determination of the extent of denudation as shown on p. 245 f. it will be seen that this value fluctuates very considerably. In the 32 localities noted from SW Jutland, the thickness of the covering material varies from 1.15 m to 10.0 m. One of the causes of this variation may be the difference in the nature of the soil, another cause may lie in the difference in the surface-forms of the land. Obviously, in an area with great differences of level and steep slopes between, denudation would be relatively more intensive than in a landscape where the starting point consists of fairly level moraine surfaces.

## Calculation of the amount of material transported at Solsö and Rodebæk.

In order to estimate the thickness of the material which have been removed by denudation in different places to provide the covering material above the bogs, we have made some calculations from a few of the bog areas investigated.

One of the areas where this calculation could be made with the highest degree of accuracy was that of Solsö, where the bog itself and its immediate surroundings were thoroughly investigated by borings, affording a good survey of the distribution of the covering material. Moreover, the area of precipitation — or of supply — is in this case a simple, isolated tract, the boundaries of which are easily defined, see Pl. XXIV.

In the basin at Solsö, borings were made at 16 different spots. The greatest thickness of the covering material above the interglacial deposits was 8.9 m. Borings above the bog and others outside the area of the bog proper show that the thickness of the covering strata decreases from the deepest part of the basin toward the edges. We may take it as fairly probable that the strata deposited by denudation extend out, with diminishing thickness, far enough to cover about the lower half part of the total area of precipitation, i. e. abt. $15^1/_2$ ha. (The total area of precipitation round Solsö is abt. $31^1/_4$ ha). The total volume of this mass of deposited material is reckoned at abt. 435.000 cubic metres. The method of calculation is a follows: curves indicating thickness of the covering material, based partly on the borings, partly on the contours of the landscape, are drawn, and from these, the area, and so the volume, subsequently calculated. The surrounding circular portion of the precipitation area of the bog amounts to abt. $15^3/_4$ ha. The average thickness of soil removed by denudation from this area will then be approximately $2^3/_4$ m.

Similar calculations have been made in the case of three bogs at Rodebæk, taken together in conjunction with the precipitation area surrounding the whole group (see Fig. 3). Only one of the three bogs was subjected to detailed boring investigation, and we have here reckoned with the average thickness of the covering strata obtained from the 16 borings made in the central part of the basin. In the case of the others, we have reckoned with the thicknesses noted for the two borings at Rodebæk II and the one at Rodebæk III. The true average thickness is probably considerably less than that arrived at by this method. The result of the calculation will be seen from the following table:

| Accumulation area | Thickness of covering material | Volume of soil deposited |
|---|---|---|
| Rodebæk I abt. 10.400 m² | 2.35 m | 24.440 m³ |
| — II - 3.600 - | 4.00 m | 14.400 - |
| — III - 3.200 - | 1.50 m | 4.800 - |
| 17.200 m² | | 43.640 m³ |

Table 16. Amount of material transported at Rodebæk.

The total precipitation area is at least 51600 sq. m, the area of denudation (51600 ÷ 17200) = 34400 sq. m. The average thickness of the soil removed by denudation will thus be $\frac{43640}{34400}$, or 1.27 m.

In a case like this, it is inevitable that some degree of uncertainty and arbitrary determination should exist, in estimating the area of accumulation and the total area of denudation. The areas have perhaps been reckoned a little too smal; on the other hand, the values for average thickness of covering strata above the bogs are certainly too high, and would be further reduced by reckoning with a larger accumulation area. There seems then not reason to believe that the calculated value for average thickness of soil carried away by denudation abt. 1¼ m, is reckoned too low in this area.

We have not made any similar calculations for other areas where borings have been carried out. In order to provide the necessary basis of fact for such calculations, we should require a greater number of observations than we have in any one case. There is however, a sufficient foundation for some general remarks on this head.

The known values for thickness of covering strata above the bogs (see p. 245 f.), refer, as already mentioned, mainly to the central portions of the hollows. The average thickness of the accumulated stratum can therefore be taken as rather less than indicated on p. 247 abt. 3¼ m, when noted for all the 32 localities together. Assuming that the denudation areas for the separate basins were of the same extent as the accumulation areas, it follows that the stratum removed by denudation must have had an average thickness of 3¼ m at the outside. But we must here again point out that the covering strata of the various bogs differ very considerably in thickness, so that the results from one area cannot by any means be applied to another indiscriminately. Moreover, we cannot know anything to begin with as to the relative extent of the accumulation and the denudation areas on the different sites. On the other hand, in those areas where no essential *removal of material* has taken place, it is obvious that the *average heigh* must be essentially the same before and after the transposition of material effected by denudation within the boundaries of the area itself. It is this fact that forms the basis of our calculations in the case of the Solsö and Rodebæk areas.

## Imaginary transformation of a young-glacial landscape by subaërial denudation.

The above mentioned fact also furnishes a possibility of approaching the question as to the effect of arctic denudation on a landscape from another side. The method would be as follows: taking a landscape consisting of broken ground of young-glacial origin, with many enclosed hollows, a cartographical levelling experiment should be carried to a stage where the hollows are all but filled up, leaving just sufficient to indicate their presence in the landscape. The result will then give the same stage of development as has been reached in several of the groups of interglacial bogs known from SW Jutland. An experiment of this nature finds its justification more especially in the peculiarity that these bogs frequently occur in groups. Instances of this are seen in the areas of Brörup, Rodebæk and Klokmose. This group formation probably indicates that the country was originally very broken ground, at any rate with numerous small, enclosed bog-holes. From this we may conclude that by subaërial denudation, it should be possible to transform a young-glacial landscape of this irregular type into a levelled landscape such as we find now for instance in the Brörup district. A description is given in the following pages of an experiment designed to give an idea as to how a Sealand landscape, abunding in hills and enclosed basins, might be supposed to be transformed by extra-glacial levelling, such as the hilly ground of SW Jutland has undergone during the last glacial period.

The area chosen for the purpose lies a little north of Ledreborg, 9 km SW of Roskilde (Pl. XXV, 1). On the north, it comprises the southern portion of Gevninge Oredrev, extending up on the south to Herthadal and on the west to Slorup forest. It forms part of a terminal moraine landscape the extreme edge of which lies at Skullerupholm, abt. $2^1/_2$ km farther to the west. From the General Staff Map, scale 1 : 20.000 with 5 ft. contour lines a section measuring 10 cm from N—S and $8^1/_2$ cm from W—E, was photographically enlarged to the scale of 1 : 4000, and this enlarged map was used for the experiment.

First of all, the area selected was divided up into small parts by lines drawn along the watersheds. The average height was calculated for each part; this will, of course, be the same before and after the levelling process, as long as no material is actually removed from, or introduced into, the induvidual area. The determination of mean level will thus serve as a test as to whether such processes has taken place. Removal of material will reduce the mean level, introduction of material from without will increase it. In determining the mean level of these small subdivisions, it is possible, before commencing the experiment, to obtain a view as to the direction in which any possible shift of material will take place.

A guiding principle in the supposed transformation is also that the lie of the land after levelling must not in any spot exhibit a fall exceeding 1 : 30. Such a gradient can occur in the area to which the interglacial bogs round Brörup station belong, but as a rule, it is less than this. On the other hand, the transformed countryside must not have become so flat as to exclude the preservation, as far as possible, of a few basin-like depressions like those found in the Brörup area. The two tests: mean level and magnitude of the surface gradient, have been applied throughout drawing up the map (Pl. XXV, 3) with the altered contours produced by the levelling process.

After this second map was produced, a third (Pl. XXV, 4) was drawn on the basis of the two sets of contour lines (Pl. XXV, 2 and 3), with Isopachytes showing the thickness of the strata shifted, both those removed from the denudation area and those deposited within the area of accumulation. The mean thickness of the stratum carried away from the denudation area was then calculated.

We have thus arrived at the various elements required to give an estimate of the effect of a denudation such as here supposed. In so far as the experiment is actually carried out in accordance with what must have taken place during subaërial levelling of the extra-glacial landscape in the last glacial period, it will also serve as a guide as to the original form of the landscape in question, and the thickness of soil which would have to be removed from its higher levels to give the present levelled terrain.

The following figures are here given by way of illustration of the experiment at Ledreborg, showing the influence of the transformation in this area.

| | | | |
|---|---|---|---|
| Total area involved | | 176 ha. | |
| Mean level prior to transformation | | 61.0 m | (194.4 ft.) |
| Mean level after transformation | | 60.7 m | (193.5 ft.) |
| Maximum altitude prior to transformation | abt. | 79.0 m | (252 ft.) |
| Minimum altitude prior to transformation | abt. | 48.0 m | (152 ft.) |
| Maximum altitude after transformation | abt. | 68.5 m | (218 ft.) |
| Minimum altitude after transformation | abt. | 52.0 m | (166 ft.) |
| Total area of denudation | | 91 ha. | |
| Mean thickness of material removed | | 3.3 m | ( 10.5 ft.) |
| Greatest thickness of material removed | | 13.0 m | ( 41 ft.) |
| Total area of accumulation | | 85 ha. | |
| Mean thickness of material deposited | | 3.0 m | ( 9.5 ft.) |
| Greatest thickness of material deposited | abt. | 8.5 m | ( 27 ft.) |

A study of the maps, and of the values noted for thickness, shows that the thickness of soil carried out over the hollows in the experiment agrees well with that of the covering strata above the interglacial bogs of Western Jutland. In some places, enclosed hollows have been conserved, so that the surface of the transformed landscape above the bogholes of the original ground correspond entirely to the basin-like depressions above the interglacial bogs of the Brörup type. It will also be seen however, that in some places, gently sloping valleys with no particular indication of basin-formation appear above the bogs and original basins. Should such a basin-formation occur in such places, it must be caused by collapse of the subjacent peat. But the basin-like depressions above the interglacial bogs of the Brörup type must, as has been shown in the foregoing, as a rule be regarded as due to incomplete filling-up of the originally deeper basins; not to a subsequent collapse of the interglacial mud and peat beds below. The compression to which these last have been subjected, and their consequent reduction in thickness, must rather have taken place gradually, while the covering sand was being deposited. Therefore, when we now find basin-like depressions of this kind above interglacial bogs of the Brörup type, it is most likely that perceptible hollows have always existed on the sites in question, throughout the whole of the time which has elapsed since the last interglacial period, and that the depth of the hollows in relation to their surroundings has steadily decreased all through the glacial period.

## General results of the levelling experiment.

The levelling experiment shows however, that sites where bogholes and enclosed hollows existed in the original terrain may also be found to have developed gentle slopes entending right out across the depression beneath. The ultimate result of levelling in such cases will depend on the differences of level existing within the area prior to the transformation, and during its course. There seems no reason to doubt that the same conditions must have prevailed in the subaërial levelling which took place during the last glacial period, whereby the bogs of the previous interglacial period became covered over by masses of slidden down or water-borne soil. But if this be so, then it should also be possible, in suitable localities, to find interglacial bogs showing transition to the Brörup type, apart from the spots where the basin-like depressions in the hilly country of Western Jutland and corresponding landscapes indicate the presence of such bogs. The cartographical levelling experiment thus gives us a hint as to the types of landscape in which there is any likelihood of finding interglacial bogs, but where there are no basin-like depressions giving informations.

The subaërial denudation which has taken place in the form of solifluction must presumably have effected a near connection of the valley-like depressions in the levelled ground with those tracts of the original landscape where hollows with peat bogs or small lakes existed. The experiment above described seems to indicate that this must be the case, and indeed it is only reasonable to assume that such was also the case with the transformation that actually took place in Western Jutland and elsewhere. There would, then, be some likelihood of finding, in these tracts, remains of interglacial bogs along such valleys save where subsequent water erosion has taken place to such an extent as to cut through and carry away not only the covering material but also the subjacent interglacial strata. We should not, however, here expect to locate our bogs with the same certainty as when guided by the basin-like depressions. In the valleys, the surface of the ground has been to a greater extent produced by direct passage of transported soil than is the case with the basins. And there is therefore no single point which should be selected in preference to all others in the search; the bogs would however, most probably lie in a belt along the bottom line of the valley. But the search for sand-covered interglacial bogs and land surfaces needs not even be restricted to a very narrow belt along the bottom of the valleys; there is also the possibility of finding them below the highlands sloping down towards the valleys. The Ledreborg experiment gave some indication of this, and thus furnished the key to understanding of a problem

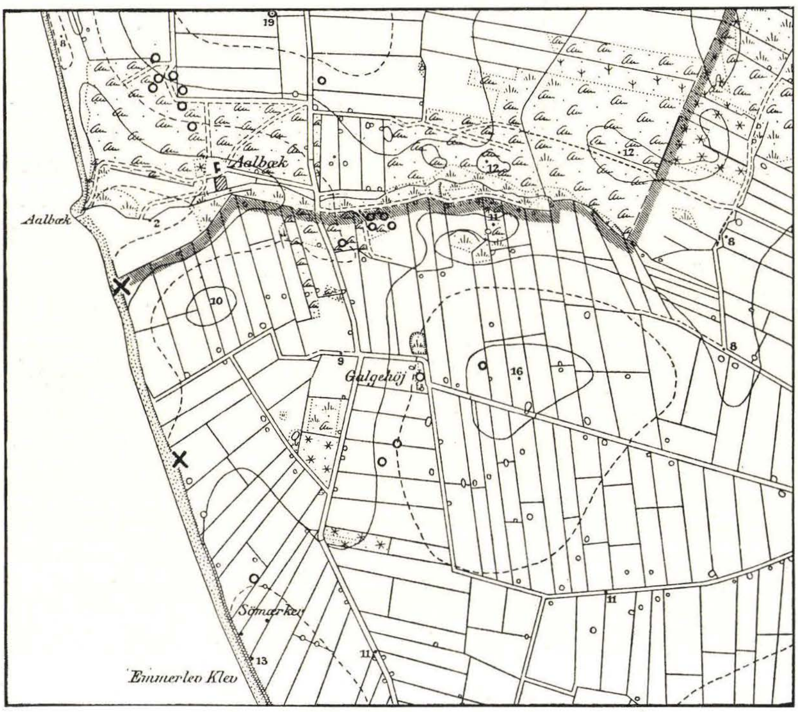


Fig. 25. Map of the shore at Emmerlev Cliff NW of Tönder. The situations of the two interglacial fresh-water deposits is marked by the crosses. 1 : 25000. Contour interval = 2.5 m. The General Staff Map Sheet 4104.

which otherwise appeared difficult to explain. The case in question is that of the northernmost part of Emmerlev Cliff, NW of Tönder. In the autumn of 1923, we visited the spot, in company with V. NORDMANN, in order to inspect an interglacial bog which had previously been located in the cliff (the southern cross on the map Fig. 25), and was supposed to contain two warm horizons, like a number of the interglacial bogs in Western Jutland.[1]) And we found then, at the northernmost end of the cliff about 500 m in north of the above mentioned bog, a profile abt. 100 m long in the southern part of which, at the foot of the cliff, was the remain of an interglacial land surface (cf. Fig. 26). The covering material, consisting at the bottom of stratified sand and at the top of unsorted

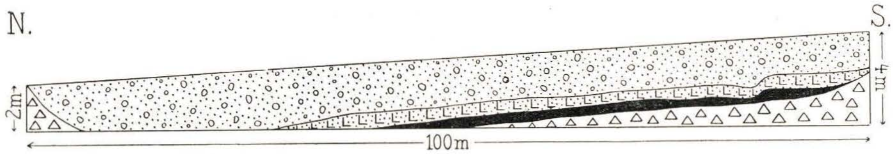


Fig. 26. The northern bog in Emmerlev Cliff. At the basis boulder clay, above this a peat bed (black) covered by a bed of arenaceous clay without stones. Contorted, stony sand in the upper part of the profile.

solifluction soil (and contorted sand) with stones, was up to ca. 3 m thick. The upper edge of the cliff runs in a gentle slope from south to north down towards the meadows of Aalbæk Brooke. The ground inland from the cliff edge likewise slopes down gently towards Aalbæk and towards the cliff face, the general appearance of the land affording no direct indication of any interglacial deposit, or of any transposition or movement of the soil having taken place. The cliff face however, shows plainly that such is the case, and the experiment made at Ledreborg points the direction in which we should look for the explanation. In places where the original glacial landscape was very much broken, and exhibited marked differences of level, it is perfectly possible for a powerful and far-reaching levelling movement to spread the material removed by denudation out over adjacent lower tracts of land, producing there a new land surface with a slight gradient, and merging gradually and imperceptibly into the new surface of the denudation area.

1) V. NORDMANN: Interglaciale Moser i Emmerlev Klint i Vestslesvig. Medd. fra Dansk geol. Forening, Vol. 6, 1925. Møder og Ekskursioner p. 35.

# IV. Interglacial Deposits in Northwestern Germany.

## Development of the Interglacial Theory in Northern Europe.

Long ere the study of the ice age had furnished a basis for stratigraphical division of the Quaternary formations in northern Europe by means of interglacial deposits, investigators in North Germany had already, on practical grounds, introduced a distinction between upper and lower drift. The upper drift consisted mainly of the "upper boulder-clay" and contained no fossils, the lower comprising all subjacent quaternary deposits of sand, clay or marl, and containing here and there shells of marine and fresh-water molluscs (among them *Paludina diluviana)*, together with remains of mammals. In 1883, F. KLOCKMANN[1]) held that the limit of the upper drift could be drawn west of the Oder, along the Baruther Valley and the lower valley of the Elbe. This line coincided with the boundary of the lake area in North Germany; beyond it lay the Altmark and the Lüneburger Heide, without lakes.

Once the glacial theory had come to the front in Germany, which was in 1875, it was not long before the view gained ground that the glacial period consisted, not of a single cold period, but of several — two or three — glaciations, with intervals of warmer climate, the interglacial periods. Among the deposits from these warm periods, the fresh-water formations soon took a prominent place. Nevertheless, it was held that in order to merit the name of a true interglacial formation, the deposit in question should be both bedded on and overlain by boulder-clay. As a result of this, K. KEILHACK, writing in 1882[2]), reckoned a number of interglacial fresh-water deposits, inclu-

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1) F. KLOCKMANN: Die südliche Verbreitungsgrenze des oberen Geschiebemergels und deren Beziehung zu dem Vorkommen der Seen und des Lösses in Norddeutschland. (Jahrb. d. K. Pr. Geol. Landesanstalt f. 1883).

2) K. KEILHACK: Ueber präglaziale Süsswasserbildungen im Diluvium Nordwestdeutschlands. (Jahrb. d. K. Pr. Geol. L. f. 1882).

ding beds of fresh water marl and kieselguhr (diatomaceous earth) from several parts of the Lüneburger Heide, as preglacial, these deposits being bedded on diluvial sand of Scandinavian origin, but without any known subjacent moraine formation.

Another effect of this view as to the true interpretation of the term "interglacial" was seen in the important part played by the interglacial peat beds at Kuhgrund, near Lauenburg, in the discussion of the question. These beds, which had been known since 1766, were described by K. KEILHACK in 1884[1]). The interglacial peat deposits crop out in two places, under identical conditions, on the northern bank of the Elbe west of Lauenburg (cf. p. 277). In both cases, the peat lies in a basin-like depression in the boulder-clay, and is covered by sand (up to 12 m deep) which extends right up to the surface. When KEILHACK put forward his first account of the beds, he considered their interglacial character proved by the fact that he had found, as he considered, in one place, the sand above the peat covered again itself by boulder-clay. Later, it was found[2]) that this was not correct; the sand above the peat must have been carried from its surroundings out over the peat basin without any direct action of inland ice. The peat itself was regarded as postglacial, in the sense of alluvial, which, in the then state of knowledge as to the flora of the beds, agreed with the fact that all the plants there in found "sich auch heutzutage in der weiteren Umgebung Lauenburgs finden". In spite of this, KEILHACK[3]) held fast by his view as to the interglacial origin of the peat, arguing particularly from the character of the covering layer, while his opponents[4]) maintained their own theory, and asserted that the covering layer had nothing to do with any second glacial invasion, but owed its origin to "postglacial Aufarbeitung der darunter liegenden weissen Muldensande bei gleichzeitiger Vermischung mit Material, welches von anzugrenzende Geschiebemergel-Rücken herabführt worden ist".

The interglacial origin of the Kuhgrund deposits was however, fully established by the presence among the flora of *Brasenia purpurea*[5]). This however, has not put an end to the dispute regarding the po-

1) K. KEILHACK: Ueber ein interglaziales Torflager im Diluvium bei Lauenburg a. d. Elbe. (Jahrb. d. K. P. Geol. Landesanstalt f. 1884).

2) H. CREDNER, E. GEINITZ und F. WAHNSCHAFFE: Ueber das Alter des Torflagers von Lauenburg an der Elbe. (N. Jahrb. f. Min. etc. 1889).

3) K. KEILHACK: Ueber das Alter des Torflagers von Lauenburg an der Elbe. (N. Jahrb. f. Min. etc. 1892).

4) H. CREDNER, E. GEINITZ und F. WAHNSCHAFFE: Ueber das Alter des Torflagers von Lauenburg an der Elbe. (N. Jahrb. f. Min. etc. 1893).

5) A. NEHRING: Über Wirbeltierreste von Klinge. (Neues Jahrbuch f. Min. u. Geol. 1895).

sition of the deposits, which has since been resumed, and carried on into quite recent times (cf. p. 270).

A similar and very comprehensive discussion arose out of the discovery of the interglacial peat beds at Klinge, near Kottbus, described in 1892 by A. NEHRING. The effect of these discussions was to produce a gradual alteration in the view as to what could properly be said to constitute a true interglacial deposit.

Up to this time, it had been held essential that the deposit should lie, in its primary position, between two moraines, and that the flora and fauna of the bed itself should be of a temperate character. This was now altered, and the qualifications required [1]) to give a deposit the character of interglacial, were formulated as follows: Firstly, the deposit must be bounded above and below by glacial deposits of some kind or other; secondly, the plants must have grown on the spot or in the vicinity, and in a climate not constantly glacial, and finally, the covering glacial strata must not have been brought to the spot later on, by secondary agency (earth slide or washing down) and so spread out over the plant-bearing stratum. The term "interglacial" was thus, to a certain extent, if not entirely, altered from a stratigraphical to a chronological term.

With this altered view as to the meaning of "interglacial" it necessarily followed that the above mentioned deposits in the Lüneburger Heide, which KEILHACK had regarded as preglacial, must now be considered interglacial. As these deposits were covered by strata supposed to belong to the "lower diluvium", they must date from the first of the two interglacial periods which were now beginning to be reckoned with. For the same reason, C. A. WEBER referred the interglacial deposits at Honerdingen, near Walsrode, SE of Bremen, described by him in 1896, to the first interglacial period. To the later interglacial was ascribed the so-called Rixdorf fauna, with bones of large mammals, e. g. *Elephas primigenius*, which had been found in the environs of Berlin, in numerous sand and gravel pits, between upper and lower boulder-clay. The strata of the earlier interglacial period, below the lower boulder-clay, were characterised *inter alia* by the occurrence of *Paludina diluviana*. At Rüdersdorf, both the two interglacial horizons have been found in one and the same boring, with boulder-clay both above and below. To the older is ascribed a deposit containing both marine and plant-bearing strata, situated a little north of Lauenburg, under the same "lower" moraine horizon as forms the bed below the peat at Kuhgrund. To the same horizon

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1) C. A. WEBER: Zur Kritik interglazialer Pflanzenablagerungen. (Abh. d. Naturw. Ver. zu Bremen 1896).

are referred the marine strata investigated by C. GOTTSCHE, in the subsoil at Hamburg and at several places in Holstein.

The manner in which the deposits here mentioned, and some few others, were placed among the various sections of the glacial period will be seen from the table p. 276.

KLOCKMANN, in 1883, had advanced the opinion that the "upper" diluvium was bounded on the south-west by the lower Elbe valley; WAHNSCHAFFE[1]) and others, however, maintained that the formations of the last glacial period extended farther to the south, and regarded "die oberen Geschiebesande der Altmark und Lüneburger Heide" as "sandige Æquivalent des oberen Geschiebemergels". The view that the Elbe had not by any means formed the boundary of the last glaciation gained more and more support as time went on, *inter alia* from observations in connection with the interglacial deposits of the Lüneburger Heide.

In 1902, two horizons of boulder-clay with an intermediate one of stratified clay (Bänderton) were discovered by H. MONKE[2]) in the region of the Ilmenau valley. The interglacial fresh-water marl at Westerweyhe, near Ülzen, being regarded as belonging to the same horizon as this stratified clay, a boring was made, which showed that the interglacial horizon was here not only overlain by glacial diluvial deposits, but was also bedded on boulder clay (48 m) below 28 m sand and gravel. As the upper diluvium was here involuntary regarded as originating from the last glaciation, the interglacial marl was thereby automatically shifted from the first interglacial period, where it had always been held to belong, into the second.

In 1905[3]), H. SCHRÖDER and J. STOLLER published a preliminary account of their observations at Unter Glinde, NW of Hamburg, where interglacial peat lies below a thin covering of boulder-clay, supposed to date from the last glaciation. They gave a more detailed description of the conditions in 1907.[4])

In several clay pits here, the interglacial peat is found bedded on stoneless clay, with marine fossils in the lower part, and is covered by sand, which again is covered by moraine clay or moraine sand. The peat beds on the bank of the Elbe at Schulau, W of

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1) WAHNSCHAFFE: Die Ursachen der Oberflächengestaltung des norddeutschen Flachlandes, 1891. Ibid. 2 Ed. 1901.

2) H. MONKE: Zweimalige Vereisung und Interglazial südlich der Elbe. (Jahrb. d. K. Pr. Geol. L. f. 1902, p. 625).

3) H. SCHRÖDER und J. STOLLER: Marine und Süsswasser-Ablagerungen im Diluvium von Ütersen-Schulau. (Jahrb. d. K. Pr. Geol. L. f. 1905).

4) H. SCHRÖDER und J. STOLLER: Diluviale marine und Süsswasser-Schichten bei Ütersen-Schulau. (Jahrb. d. G. Pr. Geol. L. f. 1906).

Hamburg, which had been known from earlier times, were regarded by these writers as belonging to the same interglacial period. The subjacent layer is a thin bed of sand resting on moraine clay; the peat is covered by a deposit, up to 3½ m thick, of stratified, stoneless sand and stony moraine-like sand of heterogeneous character.

In 1905, C. GAGEL claimed [1]) to have proved that the upper ground moraine in the Lauenburg region could be traced from the north to the Elbe valley and out over this; he also considered that the last glaciation must have extended to the western parts of Holstein. In the same year, W. WOLFF [2]) expressed similar views, pointing out that "das Elbthal keineswegs die Südgrenze der letzte Vereisung war, sondern dass dieselbe auch in Lüneburger Heide noch ihre Ablagerungen hinterlassen hat; unter denen die dortigen lakustren Interglacialschichten von Ülzen, Oberohe, usw. lagern". As a possible boundary for the last ice-sheet, WOLFF suggested the valley of the Weser and the Bremen district, though he considered it not impossible that the same young glaciation which could be traced through Holstein might be identical with that which had produced the glacial surface of Oldenburg and Eastern Friesland.

Theories as to the extent of the last glaciation reached their extreme point, however, in O. TIETZE's "Geologisches mittleren Emsgebiete" [3]) wherein he declared that no one could deny the possibility "dass die jüngere Vereisung die Hauptvereisung war, und unsere Grundmoräne sowie ein Produkt der jüngeren Vereisung ist". Nevertheless, the view most generally held was that expressed in the third edition of WAHNSHAFFE's "Oberflächengestaltung" of 1909, and KEILHACK's "Begleitworte zur Karte der Endmoränen und Urstromtäler Norddeutschlands" of the same year [4]), viz. that the boundary of the latest glaciation followed the line of the Breslau-Magdeburg "Urstromtal", extending through the Lüneburger Heide out over the western part of Holstein and Slesvic.

The consequences arising out of these researches and opinions as to the extent of the last ice-sheet, as regards the view of the interglacial problem, became apparent in the third edition of WAHNSCHAFFE: "Die Oberflächengestaltung des norddeutschen Flachlandes" (1909, p. 305). We read here: "Da nun Gagel durch die Verfolgung der oberen Geschiebemergels nach Süden zu dem Resultat gelangt ist,

1) C. GAGEL: Über die südliche und westliche Verbreitung der Oberen Grundmoräne in Lauenburg. (Zeitschr. d. d. geol. Ges., M-B., p. 434—45, 1905).

2) W. WOLFF: Bemerkungen über die holsteinische Glaciallandschaft. (Zeitschr. d. d. geol. Ges., M-B. p. 395—400, 1905).

3) Jahrb. K. Pr. Geol. L. f. 1906.

4) Jahrb. K. Pr. Geol. L. f. 1909.

das der im Liegende des Torflagers am Kuhgrund in Lauenburg auftretende, von G. Müller als unterdiluvial kartierte Geschiebemergel mit dem Oberen Geschiebemergel ident ist, so entsteht die Frage, ob nicht trotz des Vorkommens der *Brasenia purpurea* das Lauenburger Torflager als postglacial anzusehen werden muss, eine Frage, die auch schon Wolff aufgeworfen hat".

The question had, indeed, been raised by WOLFF in 1906 [1]) in connection with his own investigations and those of GAGEL, with regard to the extent of the youngest moraine towards the south in Holstein and Lauenburg, and was here followed up in its logical course. According to the explanation given, the interglacial deposits at the brickworks north of Lauenburg and at Ütersen-Glinde and Hummelsbüttel near Hamburg, correspond exactly one to another as regards their internal composition; the investigations show that they are covered by the same moraine, viz. that of the last glacial period. As the beds in the Hamburg region must belong to the interglacial period immediately preceding, this must also be the case with the deposits at Lauenburg. And since, according to the investigations, it is the moraine of the last glacial period which underlies the peat bed at Kuhgrund, WOLFF is naturally led to ask, with regard to this: "Ist es also doch postglazial?"

Renewed investigation of the Kuhgrund deposits was made by J. STOLLER [2]), with a view to providing a sound paleontological basis for consideration of the question. STOLLER established the paleontological interglacial character of the deposits, and their position in a basin of "lower boulder-clay"; the covering sand, up to 12 m thick, above the peat, was regarded either as meltingwater sand from the fresh advance of the inland ice, or sand deposited in an ice-dammed lake (the Lüneburg Eis-Stausee), which had been tapped by the breaking through of the Elbe valley. No boulder-clay, however, was found above the peat.

In the same year, W. WOLFF states [3]) his reluctance to regard the covering layer above the long-known peat of the Elbe bank at Schulau, and of other places near Hamburg (Bahrenfeld, Winterhude, Ohlsdorf, Altwahlstedt, Glinde bei Reinbek) and Kuhgrund near Lüneburg, as remains of a moraine. He considers that they may be "Gehängeschutt". The occurrences noted "lassen die Vermutung aufkom-

[1]) W. WOLFF: Ein Nachwort zur Interglazialfrage. Z. d. d. geol. Ges. M-B., p. 329—32, 1906.

[2]) J. STOLLER: Beitrage zur Kenntnis der diluvialen Flora Norddeutschlands. II. Lauenburg a Elbe (Kuhgrund). (Jahrb. d. K. Pr. Geol. L. f. 1911).

[3]) W. WOLFF: Die Torfflöze im Schulauer Elbufer bei Hamburg. (Zeitschr. d. d. geol. Ges., M-B., p. 406—10. 1911).

men, dass die Postglazialzeit für diese Gegenden in eine sehr alte und eine junge Torfbildungsperiode zu teilen ist, zwischen die sich eine (vielleicht trockenere?) Zeit der Sedimentation und der Gehängesschuttbildung einschaltet".

Interesting in this connection is a discussion which took place shortly after[1]) concerning a sand-covered, fossilbearing fresh-water deposit in Winterhude Stadtpark, near Hamburg. One party (MENZEL, KOERT and GAGEL) maintained that the flora and fauna of the deposit were interglacial, and that the covering layer could not have been brought to the spot in postglacial times, but was a moraine deposit. As against, E. HORN, supported by W. WOLFF, contended that the covering sand above the fossiliferous strata, which constituted a basin, was not a moraine at all, but material carried out over the peat bed from the margins of the basin itself. HORN stated that the stratigraphical conditions corresponded entirely to those at Kuhgrund and Schulau; the fossiliferous strata he regarded as alluvial; and he protested against their being considered interglacial, "ohne dass bis jetzt an irgendeiner Stelle durch der Nachweis einer Grundmoräne über den Torfen den Beweis für eine neue Vereisung erbracht wäre".

The first attempt at distinction between the deposits here concerned — which had been regarded as interglacial, and belonging to one and the same interglacial period — by placing them in each of two interglacial periods, was made by W. WOLFF in his survey: "Über Glazial und Interglazial in Norddeutschland".[2]) After a preliminary reference to the "old" interglacial peat beds at Ütersen (u. Glinde), Prisdorf, Hummelsbüttel, Flottbeck, Lauenburg and other places in the vicinity of Hamburg, where fresh-water deposits are found together with marine "Flachseesedimenten", he proceeds to note the "zahlreiche limnische Ablagerungen" . . . "ausserhalb der circumbaltischen Blockmoränen", "die faunistisch und floristisch von den sicheren Postglazialbildungen abweichen und sowohl deshalb wie wegen ihrer Lagerungsverhältnisse als eine jüngeres, zweites Interglazial angesehen werden. Faunistisch sind sie gekennzeichnet durch grosse diluviale Säugetiere wie Mammut, Wollnashorn und Riesenhirsch, sowie durch einige Binnenmollusken wie *Paludina Duboisii* und gewisse *Belgrandia* Arten; floristisch nehmen sie eine Sonderstellung ein durch die Führung von *Picea excelsa* in jetzigen Föhrengebieten sowie von *Brasenia purpurea* und *Dulichium spathaceum*". And he then goes on to say:

"Dennoch ist die Frage offen, ob alle diese "jüngere Interglazial-

1) E. HORN: Die geologischen Aufschlüsse des Stadtparkes in Winterhude und des Elbtunnels und ihre Bedeutung für die Geschichte des Hamburger Gegend in postglazialer Zeit. (Zeitschr. d. d. geol. Ges., M-B., p. 130. 1912).

2) Congrès géologique internationale, Canada 1913.

bildungen“ zusammengehören. Im südlichen Jütland (Brörup) am Kaiser Wilhelms Kanal (Beldorf, Bornholt) und bei Schulau, Ohlsdorf, Winterhude, Steinbeck und Lauenburg in der Hamburger Gegend liegen über den fraglichen Torfschichten lediglich Sande oder Kiese, niemals echte Grundmoränen. In einigen Fällen, z. B. bei Schulau, enthalten die Sande viele Steine bis zu Kopfgrösse, aber keine Grossgeschiebe; an andern Orten, z. B. bei Beldorf, Bornholt und Winterhude, enthalten sie nur Kies und feines Geröll. Ist es demgemäss schon fraghlich, ob sie überhaupt von einem Gletscher überschritten sind, so ist es vollends undenkbar, dass dieser Gletscher mächtig und ausgedehnt genug gewesen sei, um die Elbe zu überschreiten, und das 100 Meter hohe Plateau der Lüneburger Heide bis in die Nähe des Aller-Weser-Talzuges zu bedecken. Nun kommen aber in der Lüneburger Heide bedeutende Sedimente von Süsswasserseen (Kalk, Kieselguhr) vor, die zwar ebenfalls keine typische Grundmoränedecke, aber dock mächtige Geschiebesande mit grösseren Blöcken tragen; während an den südholsteinischen Torfen, nur geringe Lagerungsstörungen zu beobachten sind, die durch das Gewicht der Decksande hervorgebracht sein können, zeigen sich an den Kieselguhrlagern Stauchungen von grösseren Ausmass und glazialem Habitus. Ich kann mir deshalb nicht vorstellen, dass diese mit jenen gleichzeitig entstanden sind, und habe den Eindruck, dass die nördlichen und die südlichen ”Interglazialschichten“ verschiedenen Schwankungen angehören“.

Wolff however, adopted a firmer standpoint in regard to the consequences of such distinction in his work: ”Das Diluvium der Gegend von Hamburg“ [1]). In this, he distinguishes sharply between two sections of the interglacial in the Hamburg district. To the one section, which has a covering ground moraine belongs Ütersen-Glinde, which ”stimmt faunistisch völlig überein mit dem älteren Interglazial von Rissen, Dockenhuden, Nienstedten, Othmarschen, Hamburg, Billwerder, Hummelsbüttel u. s. w.“. The other section, which has no covering ground moraine, but ”Gehängeschutt“ instead, brought to the spot during the last glacial period, originated in an interglacial period which for the Hamburg region amounted to ”den ältesten Abschnitt der Postglazialzeit“, insofar as this region lay beyond the limit of the last glaciation. Such peat beds, with remains of plants, foreign to the alluvium of the region *(Picea excelsa, Taxus baccata, Abies pectinata, Tilia platyphylla, Carpinus betulus, Ilex aquifolium, Najas marina)*, and covered by layers of sand and gravel up to several metres thick, have been found for instance at Eimsbüttel, Winterhude Stadtpark, Barmbek, Ohlsdorf churchyard, all in the northern part of Hamburg. Here to

1) Jahrb. d. K. Pr. Geolog. Landesanstalt. 1915.

belong also occurrences of a similar character at Öjendorf, Ost-Steinbeck, Domhorst, Glinde and Witzhove east of Hamburg, and the oft-mentioned peat bed on the bank of the Elbe at Schulau. This last, as already mentioned (p. 270) was regarded by SCHRÖDER and STOLLER as belonging to the same interglacial period as the moraine-covered beds at Unter Glinde; WOLFF showed, however, that they did not belong to the same period at all. The moraine covering the peat at Unter Glinde is, according to his investigations, identical with that on which the peat at Schulau rests. The covering layer above the Schulau peat on the other hand, is only a locally developed "Gehängeschutt", having the same extent along the slope as the peat basin itself.

From the stratigraphical conditions on the sites in question WOLFF now concludes, with regard to the extent of the ice-sheet, "dass das jüngste Inlandeis nirgends den Elbstrom überschritten hat. Dieser mächtigste und ehrwürdige Urstrom Norddeutschlands hat den ganzen Zeitenwechsel vom Spätstadium der zweiten Vereisung bis zur Gegenwart unverrückbar überdauert".

WOLFF however, seems to have been almost the only North-German geologist, down to comparatively recent times, to hold this view as to the extent of the last ice-sheet; the works noted below[1]) give it as WAHNSCHAFFE and KEILHACK had done in 1909. Even SCHUCHT, writing in 1921, does not, apparently, neglect the possibility that the peat bed at Kuhgrund — despite its flora and position — might date from the postglacial period. "Als Zeit seiner Entstehung würde dann das Ende der Ancyluszeit und die erste Hälfte der Litorinazeit in Betracht kommen".[2])

We have in the foregoing almost superabundant proof that great divergency and uncertainty of opinion has existed, during the period considered, as to the position of the deposits in question within the glacial period. There is but one point on which the German geologists are agreed, viz. the setting of three glaciations and two interglacial periods. Whether the matter answers to this setting we shall consider later on.

Among the interglacial but not moraine-covered bogs mentioned by WOLFF in 1913, were also the Danish "Brörup bogs", which had been investigated about the turn of the century by N. HARTZ.[3]) The

1) K. KEILHACK: Die Nordgrenze des Löss in ihren Beziehungen zum norddeutschen Diluvium. (Zeitschr. d. d. geol. G., M-B., p. 77. 1918).
J. STOLLER: Geologischer Führer durch die Lüneburger Heide. 1918.
F. WAHNSCHAFFE: Geologie und Oberflächengestaltung des norddeutschen Flachlandes, 4 Auflage, neubearb. von F. SCHUCHT. 1921.

2) l. c. p. 325.

3) N. HARTZ: Bidrag til Danmarks tertiære og diluviale Flora. (D. G. U. II R. No. 20, 1909).

flora of these bogs, with *Picea excelsa*, *Carpinus betulus*, *Brasenia purpurea*, *Dulichium spathaceum* etc. characterised them as unquestionably interglacial, despite the fact that the strata were not covered by any ground moraine, but only by layers of sand. There was no difference of opinion among Danish geologists as to the interglacial origin of these plant-bearing strata; the question as to the character and origin of the covering sand was, however, debated, the point at issue here being more especially whether the covering sand originated directly from the melting water of the last ice-sheet, or had been carried to the spot by being washed down, or slipping down, from the sides of the peat basin. HARTZ (l. c.) held the former to be the case, whereas A. JESSEN[1]) maintained the latter — and A. JESSEN's view was supported by other Danish geologists in a common investigation of the stratigraphical conditions of the Brörup Bogs[2]), where the different opinions are stated. It was thus evident that the last ice-sheet had not extended over Brörup in southern Jutland.

The same stratigraphical position as that of these non-moraine-covered peat deposits is also found by the interglacial Tuul on the island of Sylt[3]), this deposit being situated in a valley, "postglacial" as far as Sylt is concerned, in the village of Westerland. The same applies to an interglacial peat deposit at Nienjahn, near Hohenwedstedt in Holstein, mentioned by W. WOLFF[4]). We shall later revert to the consequences which follow from the facts here noted in conjunction with other investigations in North-west Germany.

* * *

In the previous account of our investigations in Jutland, we have pointed out the importance of the enclosed hollows (Mulden) in landscapes lying beyond the limit of the last glaciation, a very great number of these sites having been found to contain interglacial bogs covered by solifluction, i. e. bogs of the Brörup or Herning type from the last interglacial period.

Our search for such localities gave positive results all through the west of Jutland down to the southern frontier, and on our journey in 1923 in company with Professor, Dr. W. WOLFF (see p. 12) we found that the interglacial bogs at Drelsdorf in South Slesvic and at Nienjahn in Holstein for instance, probably belonged to the same type as the Brörup Bogs. So also, as far as can be seen from the literature on the subject, do several of the interglacial bogs at Hamburg.

1) A. JESSEN: Kortbladene Aalborg og Nibe. D. G. U. I R. No. 10. 1905, p. 85—87.

2) Brörup-Mosernes Lejringsforhold. D. G. U. IV. R., Vol. I, No. 9. 1918.

3) V. NORDMANN, K. JESSEN und V. MILTHERS: Kvartärgeologische Beobachtungen auf Sylt. Dansk geol. Foren. 1923.

4) Zeitschr. d. d. geol. Ges., M.-B., p. 68—71. 1922.

| | Keilhack | | Wahnschaffe | | Wahnschaffe | | Gagel | | Wolff | | Menzel | | Wahnschaffe–Schucht | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1897 | | 1901 | | 1909 | | 1913 | | 1913–15 | | 1915 | | 1921 | |
| Paludina horizon (Berlin a. o.) | I | | I | | I | | I | | I | | I | | I | |
| Ober Ohe a. o. | I | | I | | | II | | II | | | | | | II |
| Luhetal | | | | | | | | II | | | | | | II |
| Westerweyhe at Ülzen | I | | I | | | II | | II | | $II_1$ | I | | | II |
| Honerdingen | I | | I | | | | | II | | | | | | II |
| Unter Glinde at Ütersen | | | | | | II | | II | I | | | | | II |
| Lauenburg (Brickworks) | I | | | | I | | I | | I | | I | | I | |
| Rixdorf horizon (Motzen) | | II | | II | | II | | II | | II | | II | | II |
| Römstedt at Bevensen | | | | | | | | II | | | | | | |
| Fleestedt at Harburg | | | | | | | | II | | | | | | |
| Kuhgrund at Lauenburg | | II | | II | | II | | II | | $II_2$ | | II | | II |
| Schulau | | | | II | | II | | II | | $II_2$ | | | | II |
| Winterhude at Hamburg | | | | | | | | | | $II_2$ | | | | II |
| Ohlsdorf at Hamburg | | | | | | II | | | | $II_2$ | | | | II |
| Tuul, Sylt | | | | | | | I | | | | | | | II |
| The Brörup Bogs | | | | | | | | II | | $II_2$ | | | | |

Table 17, illustrating the different views of the age of some interglacial deposits in Northern Germany. I) the first, II) the second (last) interglacial period. $II_1$ and $II_2$ cf. p. 273.

During our visit to the Lüneburger Heide in company with Professor Dr. W. WOLFF we realized that the enormous deposits of kieselgur and calcareous mud there found, which, as noted by J. STOLLER in his excellent "Geologischen Führer durch die Lüneburger Heide" had been covered by the inland ice, must be older than the bogs of the Brörup type in Jutland, Slesvic and Holstein. This was fully confirmed when we again visited North-west Germany in the spring of 1927, this time accompanied by Dr. K. VON BÜLOW, of the Preussische Geologische Landesanstalt in Berlin.

On visiting the kieselgur pits at Ober Ohe and Neu-Ohe, we found, on this occasion, further evidence that an inland ice of considerable importance in its activity had traversed these deposits; this ice could not however, have belonged to the last Scandinavian glaciation, as was shown by the discovery of several interglacial bogs farther to the NE, answering in every respect to the Brörup type now so well known to us.

The moraine-covered kieselguhr and marl deposits of Lüneburger Heide must therefore necessarily be an interglacial period older than these bogs, which were never covered by the inland ice, just as the moraine-covered marine deposits at Hamburg (Ütersen-Glinde etc.) are older than the bogs at Kuhgrund and Schulau, and as the Danish moraine-covered marl deposits at Rind and Harreskov are older than our bogs of the Brörup and Herning type. The effect of this on the general view of the last glaciation, as regards its extent and position in North-west Germany, will be discussed later on.

Finally, there are in North-west Germany several deposits which must be referred to our third group, being covered by the moraines of the last diluvium.

The same divisional arrangement as used in describing the interglacial deposits of Jutland will therefore be employed in the following survey of the interglacial deposits in North-west Germany. In this, only localities known to us from personal inspection will be dealt with at length.

## Deposits from the Last Interglacial Period.

### Kuhgrund II.

In company with Professor Dr. W. WOLFF, of Berlin, V. MILTHERS and I, in 1923, visited a profile in interglacial fresh-water formations on the steep bank of the Elbe at Kuhgrund, in Lauenburg — the same profile which had been investigated the year before by the two

Hamburg geologists, M. BEYLE and E. KOCH. This was Kuhgrund II[1]), an interglacial bog lying abt. 800 m west of the classical interglacial deposit Kuhgrund I, which is likewise situated on the bank of the Elbe, and has been dealt with by KEILHACK, CREDNER, GEINITZ & WAHNSCHAFFE, STOLLER, and others[2]).

In a slightly receding niche in the steep northern bank of the Elbe valley, M. BEYLE had rediscovered the previously known freshwater deposits at Kuhgrund II, and was able to study them in a couple of newly dug profiles, exhibiting approximately the same strata sequence; viz. (Profile I):

1.0 m Sand.
0.9 m Peat, sandy in the upper part.
1.0 m Humous Sand with three streaks of Peat.
Grey Clay with a slight amount of Mud (Sapropel).

The lowest portion of the peat stratum was composed mainly of *Phragmites communis* and *Scheuchzeria palustris;* above this was a layer consisting chiefly of birch residue, the uppermost portion being sandy mould.

Several borings showed that the lake deposits in question lie in a basin, the bottom of which slopes towards the south; and from these borings E. KOCH states that the peat stratum of Kuhgrund II is not covered by strata of unquestionably glacial origin but by a layer some 1—2.9 m thick which, apart from humus formations and "Gehängeschutt" from the slope consisted of more or less fine sand or sandy clay; "selbst der fast faustgrosse Feuerstein in 1.6—1.9 m Tiefe (Boring 3) kann sehr wohl von den benachbarten Höhen stammen" (BEYLE, l. c. p. 6); for the present, however, says KOCH, "wird man — kaum eine in allen Einzelheiten befriedigende Erklärung für die Uberschüttung der Torflager am Kuhgrund geben können". (l. c. p. 7).

The most important result of these borings was thus, that Kuhgrund II was not covered by ice during the last glacial period. E. KOCH is here in agreement with W. WOLFF[3]), who arrives at the same result in the case of Kuhgrund I, and considered the covering sand as a product of melting water from the last glacial period. STOLLER's view, that the last glaciation extended out over the Lüneburger Heide, can, as shown in Chapter V, not be a correct one, and his view of

1) M. BEYLE: Über einige Ablagerungen fossiler Pflanzen der Hamburger Gegend. III. Aus den Mitteil. a. d. Mineralog.-Geolog. Staatsinstitut. H. IV. Hamburg, 1924.

2) Respecting this literature see M. BEYLE, l. c. — Cf. also p. 267.

3) W. WOLFF: Erdgeschichte und Bodenaufbau Schleswig-Holsteins. Hamburg, 1922, p. 45.

the covering sand above Kuhgrund as deposited in an ice-dammed lake (Stausee) is not yet fully proved (cf. E. KOCH by M. BEYLE, p. 7).

In his detailed treatment of the flora of Kuhgrund II, M. BEYLE notes from here a series of species, e. g. *Picea excelsa*, *Taxus baccata*, *Najas marina*, *Carpinus betulus*, *Brasenia purpurea*, *Ilex aquifolium*, *Tilia platyphyllus* and *Trapa natans*, which also occur in several other clay- and sand-covered bogs in the neighbourhood of Hamburg; as for instance Schulau, Ohlsdorf and Winterhude, but are not found "in ähnlichen Ablagerungen aus zweifellos jüngerer postglazialer Zeit" (l. c. p. 11). As a result of his deliberations as to the age of the bog at Kuhgrund II he assumes that it was formed during a period "die für die Hamburger Gegend der älteste Abschnitt der Postglazialzeit ist" (l. c. p. 14). This must undoubtedly be taken as meaning that he refers the bog to the last interglacial period, where GAGEL[1]), STOLLER[2]) and W. WOLFF[3]) also place the deposit at Kuhgrund I, which BEYLE rightly regards as synchronous with Kuhgrund II. For we can safely, with STOLLER[4]) consider *Brasenia purpurea* as a type fossil for the interglacial deposits of Europe. In Jutland also, this plant is known only from the interglacial bogs[5]), where it is of common occurrence, and appears in very similar company to that with which it is found at Kuhgrund. It belongs to a floristic evolution cycle now completed, and which, commencing with arctic strata, passes through the temperate stages, to which *Brasenia* belongs together with *Dulichium spathaceum*, *Trapa natans*, *Najas marina*, *N. flexilis*, the flora of the mixed oak forest, *Carpinus betulus* and *Picea excelsa*, terminating with subarctic strata containing *Betula nana*. The whole of this series — which is further developed in the Herning profile — is, normally, separated by strata of sand and clay several metres thick, not glacigenous, but mainly due to glacial solifluction, from the postglacial cycle appearing in the peat and mud beds of the recent bogs. In these, neither *Brasenia purpurea* nor *Dulichium spathaceum*[6]) have ever been found in Denmark; nor, indeed, anywhere else in Europe.

Seeds of *Brasenia purpurea* have however, occasionally been found together with *Ceratophyllum demersum* and rolled fruits of *Carpinus*

1) GAGEL: Die Beweise . . . Geolog. Rundschau. Bd. 4. 1913, p. 342 f.

2) J. STOLLER: Beit. z. Kenntnis d. diluv. Flora Norddeutslands II. Lauenburg a. Elbe (Kuhgrund). Jahrbuch d. Preuss. Geolog. Landesanstalt, XXXII, 1. Berlin 1911, p. 142.

3) W. WOLFF, l. c.

4) J. STOLLER: Über die Zeit des Aussterbens der *Brasenia purpurea* MICHX. in Europa. Jahrb. d. Preuss. Geolog. Landesanstalt, XXIX, I, Heft. 1. Berlin 1908.

5) *Brasenia purpurea* has not hitherto been found in Danish deposits from the penultimate interglacial period.

6) N. HARTZ; Meddelelser fra Dansk geologisk Forening Nr. 10. Köbenhavn, 1904. J. STOLLER; Jahrb. K. Preuss. Geolog. Landesanstalt, XXX, 1909, p. 157 ff.

*betulus*, in company with the late-glacial arctic *Dryas*-flora in Denmark.[1]) These temperate species can, in such strata, only be regarded as lying in a secondary position, and the finds in question thus afford further support for the view that *Brasenia purpurea* is older than the last glacial period.

We have laid stress on this point here once more because it is still possible to find, in modern German literature, and in a prominent place, the view expressed that a deposit such as the interglacial at Kuhgrund must be postglacial (cf. the citations from WAHNSCHAFFE: "Die Oberflächengestaltung des norddeutschen Flachlandes", 1909, p. 305, and the last edition 1921, p. 325 on p. 270 and p. 274).

Such a determination of the age of the bog strata at Kuhgrund II would agree but ill with the facts noted above; equally so with the development of the forest vegetation which took place during the period of formation of the strata in question. This is plainly apparent from M. BEYLE's flora lists; and by way of supplement to his very fine treatment of the flora in question we give here a pollen diagram from approximately the same profile as that investigated by him. We found, on our visit in 1923[2]) the following strata sequence:

| | | |
|---|---|---|
| A. | | Sand, some few metres. |
| B. | 0 — abt. 0.4 m | Dark-brown *Betuleto-Sphagnetum* Peat with numerous remains and stumps of *Betula pubescens*. |
| C. | abt. 0.4— 0.75 m | Light-coloured *Scheuchzeria palustris* Peat. |
| D. | 0.75— 1.75 m | Greyish brown sandy Mud. |
| E. | | Grey, stoneless Clay. |

It will be seen from the pollen diagram, Pl. XXXX, Fig. 5, in agreement with BEYLE's lists, and our table of washing samples given below, that the sedimentation of the sandy mud commenced in the mixed oak forest period about the time of the *Corylus* maximum, but with *Pinus* still providing an essential part of the total pollen. Later, the *Carpinus* pollen began to dominate (Spectr. 3) and when the *Scheuchzeria* peat was forming *Picea excelsa* took the leading place, while *Pinus* and *Betula* predominate in Spectr. 1, answering to the uppermost part of the forest stratum.

Thanks especially to the untiring researches of C. A. WEBER[3]) of

1) N. HARTZ; D. G. U. II R. Nr. 11, 1902, S. 77. — Cf. J. STOLLER; Jahrb. XXIX, 1908, p. 72.

2) The site lay 400 m east of Cote 39.7. The bog profile investigated was abt. 10 m long, but 15 -20 m farther east, another similar bog profile was found.

3) C. A. WEBER: Die Geschichte der Pflanzenwelt des norddeutschen Tieflandes seit der Tertiärzeit. Résult. sc. du Congrès intern. de Botanique. Wien 1905. Jena 1906. — Cf. also H. A. WEBER: Ueber spät- und postglaziale lakustrine und fluviatile Ablagerungen etc. Kap. 4, p. 236 ff., and Anmerkungen von C. A. WEBER, p. 254—261. Abhandl. Nat. Ver. Bremen

the postglacial bogs in this part of north-west Germany, we may take it for granted that the upper half of the Kuhgrund pollen diagram, with its pronounced maxima for *Carpinus* and *Picea*, and its lack of *Fagus*, reveals no postglacial associations whatever. True, the pollen diagram does not comprise a complete cycle, but there is nevertheless enough of the upper portion of the bog preserved to realize, also here, the course of development as far as the stage of dominant *Betula-Pinus*, which normally terminates a pollen diagram of the Brörup type. No such development is known from postglacial bogs in the Baltic area. The pollen diagram, affording as it does a mean of direct comparison with the other deposits mentioned in the present work, shows that the profile at Kuhgrund II cannot be postglacial, but exhibits complete agreement with interglacial diagrams. The bog at Kuhgrund II dates from the last interglacial period.

H. MENZEL[1]) indicates the possibility that the peat deposit at Kuhgrund represents an interstadial; such a supposition however will not agree very well with the idea of an interstadial given in Chapter VII.

## List of the Fossils found at Kuhgrund II, in 1923.

c common, + fairly common, r rare.

| | B | C | D | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| *Acer campestre* L. | ..... | ..... | r | ..... | ..... |
| — *platanoides* L. | ..... | ..... | r | ..... | ..... |
| *Alnus glutinosa* GAERTN. | r[2]) | r, +[2]) | +[2]) | r, +[2]) | +[2]) |
| *Arenaria trinervia* L. | ..... | ..... | ..... | ..... | r |
| *Batrachium sceleratum* (L.) LGE. | ..... | ..... | ..... | r | r |
| *Brasenia purpurea* MICH. | ..... | ..... | c | ..... | ..... |
| *Betula pubescens* EHRH. | c | ..... | r | ..... | ..... |
| — *sp.*[2]) | c | r | r | r | r |
| *Carex spp.* | ..... | + | r | ..... | ..... |
| *Carpinus betulus* L. | ..... | +, c[2]) | c, c[2]) | Trace | ..... |
| *Ceratophyllum sp.* | ..... | ..... | ..... | r | ..... |

XXIX, 1918, — A pollen diagram which is likewise of considerable interest in this connection is published by K. VON BÜLOW (Jahrb. Preuss. Geolog. Landesanstalt XLVIII, 1927, p. 269), from Labamoor, in Pomerania. It shows, inter alia a value for *Carpinus* remarkably high for North-European postglacial bogs; the *Carpinus* maximum however (12 %) is here found in the upper part of the bog, only 2 dcm from the surface. — Cf. also FRITZ KOPPE und ERICH KOLUMBE: Über die rezente und subfossile Flora des Sandkatener Moores bei Plön. Bericht d. D. Bot. Gesellsch. Bd. XLIV, p. 549-598, Tafel XV. Berlin 1926, und GUNNAR ERDMAN: Pollenstatistische Untersuchungen einiger Moore in Oldenburg und Hannover. Geolog. Föreningens i Stockholm Förhandlingar, Vol. 46, p. 272 f., 1924.

1) Naturwissensch. Wochenschrift. N. F. XVI. No. 15, 1917, p. 200.

2) Pollen.

| | B | C | D | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| *Corylus avellana* L. | r[1]) | +[1]) | r, +[1]) | r, c[1]) | r, c[1]) |
| *Dryopteris sp.*[2]) | | | | | r |
| *Fraxinus excelcior* L.[1]) | | | | | r |
| *Ilex aquifolium* L.[1]) | | | r | | |
| *Lycopus europaeus* L. | | | | | r |
| *Menyanthes trifoliata* L. | | r | | | |
| *Najas marina* L. | | | + | | r |
| *Nuphar luteum* SM. | | | + | + | c |
| *Picea excelsa* LK. | +[1]) | +, c[1]) | r, c[1]) | | r[1]) |
| *Pinus silvestris* L. | +, c[1]) | +[1]) | +[1]) | c[1]) | c[1]) |
| *Potamogeton natans* L. | | | + | | |
| *Potentilla palustris* (L.) SCOP. | | + | | | |
| *Quercus sp.*[1]) | r | r | r | c | c |
| *Scheuchzeria palustris* L. | | c | | | |
| *Scirpus lacuster* L. | | | r | | |
| — *sp.* | | r | | | |
| *Sparganium erectum* L. | | | | r | |
| *Tilia platyphylla* SCOP. | | | r | r | r |
| — *sp.*[1]) | | r | r | r | r |
| *Typha latifolia* L.[1]) | | | | | r |
| *Ulmus sp.*[1]) | | r | r | + | r |
| *Urtica dioeca* L. | | | | r | r |
| *Sphagnum sp.* | + | | | | |
| *Cenococcum geophilum* FRIES | r | | | | |
| *Tilletia sphagni* NAWASH | + | | | | |
| *Botryococcus Braunii* KG. | | + | | | + |
| *Pediastrum boryanum* (TURP.) MENEGH | | r | | | |

## Römstedt I.

In studying the literature of the interglacial deposits of the Lüneburger Heide, we soon came to regard two localities as occupying an exceptional position, to wit, a bog at Römstedt, E of Bevensen, described by J. STOLLER, and a bog at Fleestedt, S of Harburg, described by W. KOERT and C. A. WEBER. Both these bogs differ greatly from the other interglacial deposits of the Lüneburger Heide, not only as regards the constitution of the interglacial strata, but also as to the nature and thickness of the covering material. We therefore made a point of becoming further acquainted with these by personal inspection.

Before proceeding to describe our investigation of the bog at Römstedt, it may be as well to quote J. STOLLER's description[3]) of the site. The Römstedt interglacial lies abt. 1200 m W of the village of

[1]) Pollen.

[2]) Spores.

[3]) H. MONKE und J. STOLLER: Erläuterungen zur Geologischen Karte von Preussen. Lief. 156. Blatt Bevensen. Gradabt. 25, Nr. 56, Berlin 1911, p. 19—20.

Römstedt, and abt. 400 m N of the road to Bevensen "auf einer schwachen Anhöhe von 66 m Meereshöhe" (l. c. p. 19). J. STOLLER bored through the deposit in two places:

Am Südende des Torflagers, direkt an dem vorbeiführenden Feldweg, wurde 1906 folgendes Profil festgestellt:

| | | |
|---|---|---|
| Obere Grundmoräne. | 1.4 m | schwach lehmiger bis lehmiger, eisenschüssiger Geschiebesand. |
| | 0.5 m | sehr sandiger Geschiebelehm. |
| | 0.3 m | stark humoser Sand, schwach tonig, kalkfrei, fein- bis mittelkörnig. |
| | 0.4 m | schwach toniger, kalkfreier, mittelkörniger Sand. |
| Untere Grundmoräne. | 0.6 m | sandiger Geschiebelehm. |
| | 1.0 m | blauer Geschiebelehm. |

80 m nördlicher ergab eine Bohrung in nächster Nähe der Stelle, wo der Besitzer das "Braunkohlenlager" früher bloszgelegt hatte, folgendes Profil:

| | | |
|---|---|---|
| Obere Grundmoräne. | 1.0 m | Schutt (sandiger Geschiebelehm). |
| | 0.6 m | sandiger Geschiebelehm. |
| | 0.3 m | stark humoser Sand, schwach tonig, kalkfrei, mittel- bis feinkörnig. |
| | 1.0 m | schwach sandiger, tonig-erdiger Humus, ohne figurierte Pflanzenteile. |
| | 0.8 m | + schwarzer, schlemmiger Torf mit wenigen Wurzelfasern, z. T. Moostorf, in welchem einzelne Blättchen von Sphagnen beobachtet wurden. |

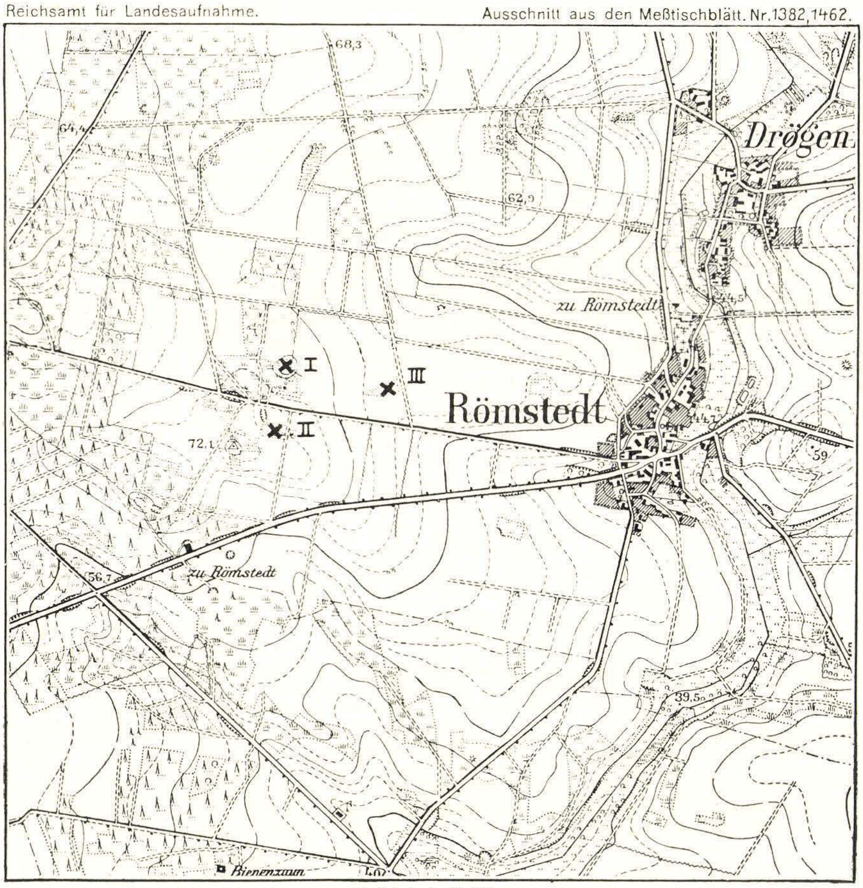
Borings could not be carried beyond this point, as the drill continually encountered wood; it was stated however, that the peat bed was understood to be more than 10 ft. (Fuss) thick, and contained a lot of wood. The humous sand was encountered in several borings "in den näheren Umgebung des Torflagers". Botanical analyses of the small peat samples revealed *inter alia* pollen of *Pinus (silvestris* L.), *Picea (excelsa* LK.), *Alnus (glutinosa* GAERTNER), *Betula (alba* L.), *Corylus (avellana* L.) and *Quercus sp.*

In the spring of 1927, we visited this locality in company with Dr. K. VON BÜLOW, and found, on the plateau W of Römstedt, at the spot indicated (Fig. 27), a small hollow, occupied partly by cultivated meadow land, partly by uncultivated bog, together with a small pool (Pl. XXVI, 1). The depression extended for abt. 100 m from E to W, and abt. 125 m from N to S, the margins appearing in places as short but steep slopes where excavations for attempts at cultivation had been made. It will be seen from the sketch in Fig. 3 in Pl. XXVII that the surface of the water in the pool lies abt. 1.7—5.0 m lower than the surrounding plateau on the west, south and east sides of the basin, the country on the northern side being somewhat lower. Cf. Fig. 1 in Pl. XXVI.

From the geological map of Bevensen it appears that the ground surrounding Römstedt I and II consist mainly of argillaceous sand, with boulder clay jutting out here and there in several very restricted parts.

With the aid of a spiral auger we made 5 borings in the basin, the positions being as noted in Fig. 3, Pl. XXVII. On the basis of

Reichsamt für Landesaufnahme. Ausschnitt aus den Meßtischblätt. Nr.1382,1462.




Maßstab 1 : 25 000

Fig. 27. The Römstedt district. Position of the interglacial bogs I, II, III indicated by crosses. Contour interval for the fully drawn curves = 5 m.

these, we were able to draw up a transverse profile as shown in Fig. 1, Pl. XXVII. The profiles of the respective borings were as follows:

Boring 1.

| | | |
|---|---|---|
| B. | 0 — 0.5 m | Greyish brown Sand with scattered stones up to the size of a nut. |
| C. | 0.5 — 1.5 m | Grey, argillaceous Sand without stones, the lower part merging into the subjacent stratum. |
| F. | 1.5 — 1.9 m | Brown, finely arenaceous Mud, with presumably almost pure, fine Sand at the bottom. |

G. 1.9 — 2.4 m Greyish green, sandy Clay, more sandy at the bottom.
H. Firm stony Sand.

Boring 2.

A. 0 — 0.2 m Peat.
B. 0.2 — 0.5 m Greyish brown, argillaceous Sand with a few stones the size of nuts.
C. 0.5 — 1.85 m Sandy Clay without stones, greyish brown at the top, more greyish lower down.
E. 1.85 — 2.4 m Dark brown Peat.
F. 2.4 — 3.0 m Uppermost, brown, fresh, mud-blended *Hypnum* Peat; below, greyish brown sandy Mud.
H. Stony Sand.

Boring 3.

B. 0 — abt. 1.4 m Uppermost, Sand of medium fineness, (abt. 1 m), below this, somewhat coarser sand with thin streaks of humous sand.
D abt. 1.4 — 3.2 m Uppermost (abt. 0.7 m) alternating layers of Sand and Clay Mud. The latter contained, besides the pollen noted in Spectr. 1 and 2, (Pl. XXXX, 1) also some of *Ericaceae*, spores of *Sphagnum sp.*, needles of *Spongilla lacustris*. — Below this, 2.1 m dark greyish brown Clay Mud, the percentage of clay decreasing downwards. Pollen of forest trees *Pinus*, *Betula*, *Picea* and *Alnus*, with traces of *Quercus*, *Corylus* and *Carpinus*; see the pollen diagram. In addition epidermis with stomata of needles of *Pinus* were found, with pollen of *Ericaceae* and *Empetrum nigrum*, a few spores of *Osmunda regalis*, numerous *Sphagnum* spores, *Botryócoccus Braunii*, *Pediastrum sp*,, *Spongilla lacustris*.
E. 3.2 — 5.0 m Dark brown, highly humified *Sphagnum* Peat with much *Eriophorum vaginatum*, some wood detritus, e. g. of conifers, branches of *Calluna vulgaris*. Numerous pollen tetrads of *Ericaceae* and *Empetrum nigrum* and spores of *Sphagnum sp.*, a spore of *Osmunda regalis* at the bottom; *Tilletia sphagni*; *Amphitrema flava*. Pollen of forest trees: *Pinus*, *Picea*, *Carpinus*, *Corylus*, *Alnus*, *Betula*, *Tilia*, *Ulmus* and *Quercus*; see the pollen diagram.
F. 5.0 — 5.5 m Alternating layers of brown, fresh *Hypnum-Sphagnum* Peat and brown sandy Mud. Uncertain whether the bottom of the basin was reached. The mud yielded a seed of *Brasenia purpurea*. Pollen of forest trees, the same species as in E.

Boring 4.

A. 0 — 0.3 m Sand (recently deposited for attempts at cultivation).
B. 0.3 — 0.7 m Reddish, argillaceous Sand, with sandy Clay lower down, scattered small stones.
C. 0.7 — 1.3 m Stoneless Clay, the upper part rust-coloured, the lower part grey.
D. 1.3 — 2.3 m Uppermost (0.4 m) grey sandy Clay with thin streaks of clay mud, below this, greyish brown Clay Mud.
E. 2.3 — 3.4 m Dark brown Peat, with much rotten wood at the top,

lower down, highly humified *Sphagnum* Peat with *Eriophorum vaginatum.*

F. 3.4 — 4.1 m Uppermost fresh, brown *Hypnum-Sphagnum* Peat, containing seeds of *Brasenia purpurea*, pollen of *Nuphar luteum*, *Alnus*, *Betula*, *Carpinus*, *Corylus*, *Ilex*, *Picea*, *Pinus*, *Quercus*, *Tilia* and *Ulmus*. *Amphitrema flavum*. — The lowest 20 cm dark brown hard Mud, consisting largely of leaf-remains of *Ceratophyllum sp.*, also intercellular hairs of *Nymphaeaceae*, some pollen of *Myriophyllum cf. spicatum*. Also pollen of *Alnus*, *Betula*, *Corylus*, *Pinus*, *Quercus*, *Tilia* and *Ulmus*. *Botryococcus Braunii* and *Rivulariaceae*.

H. Sand.

Boring 5.

A. 0 — 0.3 m Sand, recently deposited for attempts at cultivation.

B. 0.3 — 0.85 m Uppermost, abt. 20 cm reddish grey Sand, slightly argillaceous lower down; below this, reddish brown argillaceous sand with a few small stones.

D. 0.85— 1.1 m Dark grey sandy Clay.

F. 1.1 — abt. 1.35 m Dark brown, slightly argillaceous Mud.

G. abt. 1.35— 1.85 m Grey Clay.

H. Sand.

From Borings 3 and 2, we collected 16 samples for pollen analysis, and it is from these that the pollen diagram in Fig. 1, Pl. XXXX is drawn. A glance at the figure shows that in the first place, it is similar in principle to the pollen diagrams already given for the interglacial bogs of Jutland, and further, that the earliest portions of the interglacial periods in question are not represented, the lowest spectra showing dominance of mixed oak forest and *Corylus*, Zone *f*. The *Corylus* maximum is here conspicuously high, Spectr. 16 showing about 5 times as much hazel pollen as of all the other species together. It is uncertain whether the oldest interglacial beds may perhaps be found in other parts of the bog, or whether mud and peat formation did not set in until the mixed oak forest period. This was followed by a period when *Carpinus* was dominant, this species of pollen showing no less than 59 % in Spectr. 13, Zone *g*. *Picea* is dominant in Spectr. 10, Zone *h*, but throughout all the rest of the diagram, the *Pinus* pollen is absolutely predomiant, Zone *i*. In the lower part of this, the curves of *Picea* and *Betula* meet and cross. *Picea* disappears almost entirely in Spectr. 7 and 8, but shows some advance again in the upper part of the diagram. At the time when Zone *i* was forming, the forest consisted doubtless mainly of *Pinus silvestris*, *Betula pubescens* and *Picea excelsa*, while *Alnus glutinosa* may also be supposed to have been present; it is doubtful however, whether the remaining pollen found in this part of the diagram actually indicates the presence of the respective species, or it was probably brought by the wind from far away.

The fossil content of the lower beds point to a mild climate and luxuriant vegetation, but the course of development can be followed to a later forest growth of decidedly northern character. Both the finding of *Brasenia purpurea* and the pollen diagram plainly show that the bog in question is interglacial.

The organogenic filling of the basin commenced with a mud formation, but the lake was soon covered over with a limnian *Sphagno-Hypnetum* (lower part of Zone *g*) and this again was transformed into a *Sphagnum-Eriophorum vaginatum* bog, which presumably soon assumed the character of a forest bog. While the upper part of Zone *i* was forming, the bog was transformed to a lake and Stratum D, a sandy-argillaceous mud — answering to STOLLER's "humoser Sand", was deposited.

In both sides of the profile, the clay mud merges gradually into a sandy stoneless clay, which, like the clay mud itself, was doubtless deposited in a lake. The inflow of inorganic material increased as the climate grew more arctic.

This supply of material from the surroundings reached its height with the formation of Stratum B, stony clay now slipping over the margin of the basin, the middle portion at the same time being filled up with sand, which can at any rate for the most part be regarded as Schwemmsand. There seems no reason to regard the argillaceous sand or sandy clay, with but few stones in a some few dcm thich layer in the marginal zone of the bog, as moraine clay; on the other hand, with the abundant testimony furnished by the covering strata of the interglacial bogs in Jutland it is natural to regard it as a solifluction product of the last glacial period.

As a result of our investigations of the interglacial bog Römstedt I, the strata of which undoubtedly lie undisturbed, we consider ourselves justified inasserting that is has never been covered by any inland ice but that the covering strata was formed under the influence of arctic solifluction, and that the bog, in its stratigraphical features, corresponds entirely to an interglacial bog of the Brörup type, and is to refer to the last interglacial period.

## Römstedt II.

About 100 m south of Römstedt I, south of the road across the fields (see Fig. 27), there is another basin without outlet, measuring abt. 100 m from E—W and abt. 60 m from N—S. Fig. 3 in Pl. XXVII shows the position relative to Römstedt I and the form of the groud, the basin being enclosed in a loop of the 5 m isohypse on the map.

The bottom of the basin, which now appears as ill-cultivated meadow land, lies abt. 3.5 m above the level of the water in the pool at Römstedt I. Here also preparatory steps towards cultivation have been taken, by dumping material dug out from the sides of the basin, these now appearing in consequence as short, steep slopes.

Five borings were made in this basin, as shown in Fig. 2 and 3, Pl. XXVII but as the borings had to be carried through very wet sand, it was not possible in all cases to reach down through the interglacial strata.

Boring 1.

| | | |
|---|---|---|
| A. | 0 — 0.95 m | Humous Sand, with some few stones (recently deposited). |
| B. | 0.95 -- 1.5 m | Grey, stoneless, rather fine Sand (Schwemmsand). |
| C. | 1.5 — 2.4 m | Grey, argillaceous rather fine Sand without stones |
| F. | 2.4 — 3.6 m | Dark brown Mud. |
| G. | 3.6 — 3.8 m | Brown firm *Hypnum* Peat. |
| H. | 3.8 — 3.9 m | Sand. |

Boring 2.

| | | |
|---|---|---|
| A. | 0 — 0.6 m | Stony Sand, (recently deposited). |
| B. | 0.6 — 1.5 m | Stoneless, rather fine Sand, (Schwemmsand), yellow at the top, grey lower down. — Owing to the water in the sand, the boring could not be carried further. |

Boring 3.

| | | |
|---|---|---|
| A. | 0 — 0.6 m | Stony Sand, recently deposited. |
| B. | 0.6 — 2.0 m | Grey, rather fine Sand without stones, much water (Schwemmsand). |
| D. | 2.0 — 2.2 m | Grey, argillaceous, rather fine Sand. |
| E. | 2.2 — 2.5 m | Greyish brown, finely arenaceous Clay Mud; many pollen tetrads of *Ericaceae*, numerous spores of *Sphagnum sp.*, *Botryococcus Braunii*, *Spongilla lacustris*. Pollen especially of *Pinus* and *Betula*, see the pollen diagram Pl. XXXX, 2. |
| F. | 2.5 — 6.05 m | Dark brown, slightly argillaceous Mud; from 5.8 m downwards the stratum contained fine sand; this stratum was not bored through. The microscope showed forest pollen especially of *Pinus*, *Picea* and *Betula*, with some of *Alnus* and other species, see the pollen diagram; also radicles of *Carex*, epidermis of *Eriophorum vaginatum*, pollen of *Empetrum nigrum*, *Ericaceae* (common), spores of *Osmunda regalis*, *Polypodium vulgare* and *Sphagnum sp*,, (common), *Botryococcus Braunii*, *Pediastrum Kawraiskyi*, *Spongilla lacustris*. |

Boring 4.

| | | |
|---|---|---|
| A. | 0 -- 0.60 m | Stony Sand (recently deposited). |
| B. | 0.60 – 1.4 m | Pale grey stony Sand, the lower part a faint reddish brown (Schwemmsand). |
| D. | 1.4 – 1.7 m | Grey, argillaceous Sand. |
| E. | 1.7 — 2.5 m | Greyish brown, tough Clay Mud. |
| F. | 2.5 – 3.9 m | Dark brown detritus Mud. |

G. 3.9 — 4.7 m Brown firm *Hypnum* Peat.
In boring samples from here, the following species were identified by AUG. HESSELBO:
*Calliergon stramineum* (DICKS) KINDB.,
*Hylocomium proliferum* (L.) LINDB.,
*Hypnum exannulatum* GÜMB.,
— *intermedium* LINDB.,
— *Sendtneri* SCHIMP.,
*Meesea triquetra* (L.) ÅNGSTR.,
*Paludella squarrosa* (L.) BRID.,
Pollen of the following species was also found: *Carpinus, Picea, Corylus, Pinus, Alnus, Betula, Ulmus, Quercus* and *Tilia,* likewise radicles of *Carices* and a few spores of *Dryopteris thelypteris* and *Polypodium vulgare.* — Below this was presumably the solid bottom of the basin; boring could not be carried beyond this point.

Boring 5.

A. 0 — 0.6 m Stony Sand recently deposited.
B. 0.6 — 1.0 m Rather coarse Sand.
C. 1.0 — 1.6 m Coarse Sand with scattered small stones. — Boring had to be stopped here owing to the abundance of water in the sand.

The pollen diagram from Römstedt II is of exactly the same type as that from Römstedt I, save that the upper part of Zone *f*, which is there present, is here lacking; Spect. 17 Römstedt II, thus corresponds precisely to Spectr. 14 Römstedt I. In both diagrams we find a highly developed ***Carpinus*** zone, a less marked ***Picea*** zone, and above this the extraordinarily developed zone with ***Pinus*** greatly predominant and a very even course in the curves for the other pollen species, the curves for ***Picea*** and ***Betula*** crossing each other several times. The type of forest development indicated by these two diagrams is only known from the interglacial period and even without the finds of ***Brasenia*** and ***Dulichium,*** the bog at Römstedt II must therefore be regarded as interglacial.

The strata sequence in Römstedt II begins with the peculiar feature of a bed of *Hypnum* peat below a thick layer of mud, Zones *g* and *h*. There is here no development of semiterrestrial and terrestrial beds as in Römstedt I. This mud bed merges gradually into the clay mud E above, which again, passes gradually via D into the Schwemmsand stratum B. Here, as in Römstedt I, the supply of inorganic material gained the upper hand as compared with the sedimentation of organic detritus in the upper part of the strata sequence, so that in both basins, we have something unknown in North-german post-glacial bogs, to wit, a considerable layer of basin-sand and clay covering organogenic beds which show traces of a forest development ranging from temperate deciduous trees to conifers of northern character. This covering undoubtedly took place at the same time in both basins, and was due to the same climatic cause, the approach of the colder period. In Römsted II again, no trace of any moraine was to be found; the slightly stony sand stratum in Boring 5 may be regarded as a product of solifluction, which here again is only discernible in the marginal zone of the basin, the major part of the covering material consisting of outwashed clay and sand. Römstedt II is thus also an interglacial bog of the Brörup type, from the last interglacial period.

## Römstedt III.

About 400 m E of Römstedt I there is a meadow, abt. 80 m long by 50 m broad, situated in an enclosed basin in the otherwise level ground of the plateau (cf. Fig. 27), the surface formation of which here consists of moraine clay[1]). Unfortunately, we were only able to make a very incomplete investigation of this locality, and an inadequate collection of samples from the fossiliferous strata. Three borings were carried out, giving profiles as follows:

Boring 1 (10 m from the western end of the basin).

| | | |
|---|---|---|
| A. | 0 — 0.8 m | Uppermost reddish-flamed, lower down grey non-calcareous stony sandy Clay, more sandy towards the bottom. |
| F. | 0.8 — 1.65 m | Sandy yellow Clay with stones (Moraine Clay). |

Boring 2 (about the middle of the bssin).

| | | |
|---|---|---|
| A. | 0 — 0.6 m | Grey, argillaceous, rather fine Sand, the top part, abt. 0.2 m, sand recently deposited. |
| B. | 0.6 — 1.0 m | Dark, greyish brown finely arenaceous non-calcareous Clay Mud; more sandy lower down. Pollen of the following forest trees was found: *Corylus*, *Pinus*, *Quercus*, *Betula*, *Alnus*, *Tilia*, *Ulmus* and *Picea*; also especially *Spongilla lacustris*. |
| C. | 1.0 — abt. 1.8 m | Grey, stoneless rather fine Sand, slightly muddy in the middle. |
| D. | abt. 1.8 — 2.3 m | Greyish brown Clay Mud. Besides forest pollen (*Betula*, *Pinus* and *Corylus*), were found spores of *Dryopteris thelypteris*, a grain of pollen of *Myriophyllum sp.*, likewise *Pediastrum boryanum* and *Spongilla lacustris*. |
| E. | 2.3 — 3.5 m | Greyish blue, calcareous rich stoneless Clay; the small samples produced contained no identifiable organic remains. |
| F. | 3.5 — 5.8 m | Calcareous Moraine Clay, grey and sandy at the top, brownish and more argillaceous lower down. |

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[1]) H. MONKE und J. STOLLER: Erläut. Geolog. Karte. Lief. 156. Bevensen.

B o r i n g 3 (20 m from the eastern end of the Basin).

| | | | |
|---|---|---|---|
| A. | 0 — abt. 0.8 | m | Reddish sandy C l a y without stones. |
| B. | 0.8 — 1.2 | m | Dark grey sandy and argillaceous M u d. |
| C. | 1.2 — 1.7 | m | Grey S a n d without stones. |
| D. | 1.7 abt. — 2.8 | m | Brown argillaceous M u d, the lower part greyish green. Forest pollen of *Betula*, *Pinus*, *Corylus*, *Quercus*, *Ulmus*, *Alnus* and *Picea*; also pollen of *Myriophyllum sp.*, *Nuphar luteum* and *Chenopodiaceae*, numerous spores of *Dryopteris thelypteris*, also *Pediastrum boryanum*. *P. duplex* and *Rivulariaceae*. |
| E. | 2.8 — 4.3 | m | Greyish blue, calcareous rich stoneless C l a y, slightly sandy at the bottom. Two fruits of *Potamogeton sp.* |

The profiles and pollen diagrams (Pl. XXXX, 3 and 4) show that we had here come upon the older portion of the cycle of development within which the bog was formed. The clay bed E may be presumed to contain an arctic or sub-arctic flora, and the lower spectra in the two diagrams represent the ***Betula-Pinus*** forest which then grew up. Between Spectr. 2 and 3 in both diagrams, the ***Betula*** and ***Pinus*** curves intersect, and in the two uppermost spectra, the mixed oak forest is apparent, while at the same time, ***Alnus*** and especially ***Corylus*** increase in frequency. Here also the first traces of ***Picea*** are found. A similarity in principle is discernible between Spectr. 1 in Fig. 4, Pl. XXXX and Spectr. 5 in the pollen diagram from Kuhgrund (Fig. 5).

The pollen diagrams suggest that there is synchronism between Stratum B in the profile Römstedt III, 2, and the upper portion of Stratum D in the profile Römstedt III, 3. If this be the case, then Stratum A in the former profile must correspond to Strata A-C in the latter. Unfortunately, we have no pollen analyses from Stratum B in this last.

It will be apparent from our investigations that determination on the basis of pollen analyses as to whether a deposit is interglacial or post-glacial can be made when the upper part of the cycle of development concerned is available. Where this is lacking, as in the present case, and the usual interglacial type fossils are likewise absent from the flora[1]) or fauna lists, only unquestionable stratification conditions can decide. If the deposits at Römstedt III are post-glacial, it must seem curious that only sand and clay should have been deposited in this basin, without any peat formation, throughout the whole of the

[1]) The occurrence of *Picea* pollen with a frequency of 3 % does not here prove with certainty that the deposit is interglacial, though *Picea excelsa* seems not to have appeared as an immigrant in these parts of Germany in the post-glacial period before in the atlantic period. (H. A. Weber, Abh. Nat. Ver. Bremen. 1918. Bd. XXIX, p. 249).

atlantic, sub-boreal and sub-atlantic periods. Assuming that the deposits are interglacial, the difficulty lies not so much in the nature, and the slight thickness, of the covering strata, since in this respect, Römstedt III does not seem to differ decisively from Römstedt I and II; it is surprising however, that the sedimentation of mud should have ceased at so early a stage in the period. We have, nevertheless, an analogous case from a bog of unquestionable interglacial origin, viz. Tuesböll II (p. 159), and the explanation suggested by the profile there may perhaps also hold good in this instance. Only after complete investigation of the basin at Römstedt III will it be possible to decide the age of the fresh-water deposits there found; from the stratigraphical conditions however, we may already regard it as most probable that we have here again a formation from the last interglacial period.

## Fleestedt.

In the descriptive text to the geological map sheet Harburg, by W. KOERT and C. A. WEBER [1]), mention is made of an interglacial bog situated in a small wood 600 m S of the village of Fleestedt, and 5.5 km S of Harburg. Excavations and borings made in 1901 in this bog gave the following profile, here somewhat abbreviated:

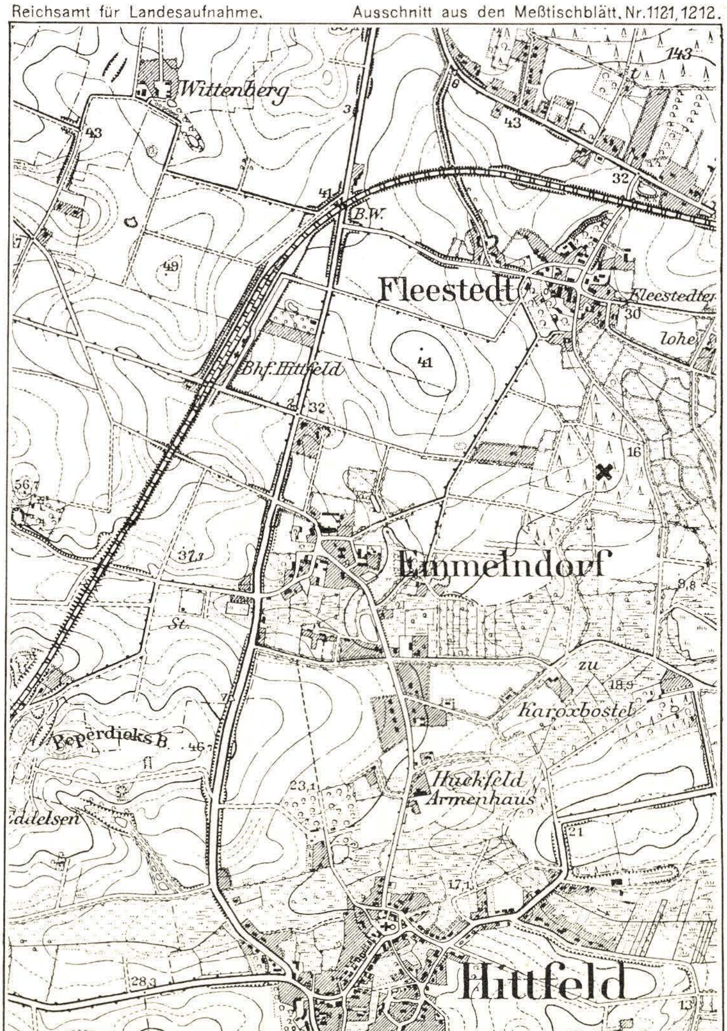
| | | |
|---|---|---|
| a. | 1 — 1.2 m | Schwach eisenschüssiger toniger Feinsand bis Sand. |
| b. | 0.3 — 0.5 m | Gewöhnlicher Diluvialsand. |
| c. | 0.4 m | Kiespackung mit lehmigem Bindemittel, zum Teil sandiger Geschiebelehm, der torfstreifiges Material, offenbar aus zerstörten Teilen des Torflagers herrürend, enthielt. |
| d. | 1 — 1.2 m | Stark zusammengepreszter Torf, in dem folgende Abschnitte unterschieden werden konnten: |
| | | 0.35—0.65 m Bruchwaldtorf. |
| | | 3.35 m Moostorf. |
| | | 0.2 —0.25 m Limnischer Torf. |
| e. | | Über 2 m stark humoser toniger Feinsand. |

C. A. WEBER found a large number of plant-species in Stratum d. Conifers in particular were dominant, especially *Pinus silvestris* but also *Betula alba; Picea excelsa* seems to have been somewhat rare, while the two lowest zones (Abschnitte) were in process of formation, but take a more prominent place in the forest peat. *Alnus* and *Tilia* were not observed, and only four grains of pollen of *Quercus;* but as fruits of a so comparatively southern species as *Carex pseudocyperus* were found, WEBER presumes that the climate during

[1]) Erläuterungen zur Geolog. Karte v. Preussen. Lief. 155, Gradabt. 24, Nr. 34, Berlin 1910, p. 12—17.

the period in question must have answered to "denen des mittlern Finlands oder etwa denen des schwedischen Ångermanlandes bezw.

Reichsamt für Landesaufnahme. Ausschnitt aus den Meßtischblätt. Nr. 1121, 1212.




Maßstab 1 : 25 000

Fig. 28. The Fleestedt district. Position of the interglacial bog marked by a cross. Contour interval for the fully drawn curves = 5 m.

der Hochlande von Dalarne und Wermland". "Wie man sich aber das Klima in einzelnen auch vorstellen mag, auf keinen Fall entspricht die Vergesellschaftung der Pflanzen, wie sie der diluviale Torf von Fleestedt darbietet, irgendeiner Entwickelungsstufe der Flora Norddeutschlands seit dem Ende der Eiszeit, soweit wir diese Geschichte an der Hand paläontologischer Funde bisher haben feststellen können. Denn danach sind die Erle und die Eiche in allen Teilen dieses Gebietes früher vorhanden gewesen als die Fichte, und wo ich die letztgenannte Art bisher in sicher postglazialen norddeutschen Lagerstätten gefunden haben, waren stets daneben die Spuren der beiden anderen, wenigstens ihre Blütenstaubkörner, reichlich forhanden".

We ourselves were struck by the fact that so few diluvial peat bogs were known in north-west Germany south of the Elbe; and having become acquainted with the conditions by personal inspection at Römstedt, we also made an excursion to Fleestedt, in 1927. Here, we found, there was no enclosed basin (Mulde) above the diluvial bog, which lay beneath a surface sloping slightly towards the east (see Fig. 28). This surface however, was not flat, but showed a slight depression. In this we made our boring, as far as could be judged from the map, quite close to the site of the 1901 profile — and obtained the following:

A. 0 — 0.2 m Peat.

B. 0.2 — 1.7 m Uppermost, 0.3 m grey, then 1.2 m reddish, stoneless sandy Clay, the percentage of sand increasing downwards.

C. 1.7 — 2.0 m Uppermost, 0.1 m reddish, argillaceous Sand with a few stones; lower down, argillaceous sand with scattered stones the size of beans; the dark colouring of the lower part due to admixture of humous material.

D. 2.0 — 2.2 m Dark, greyish brown sandy Clay Mud, containing pollen especially of *Pinus*, *Picea* and *Betula*; also numerous *Sphagnum* spores.

E. 2.2 — 2.75 m Dark-brown crumbling Forest Peat with much rotten wood. Abt. 2.65 m a thin layer of brown, fairly fresh *Sphagnum* Peat. Epidermis with stomata of needles of *Pinus*, a single grain of pollen of *Abies pectinata* and numerous *Sphagnum* spores; forest pollen approximately as in Stratum D. See also the pollen diagram Pl. XXXX, 6.

F. 2.75 — 3.4 m Dark brown crumbling finely arenaceous Mud; in which were found, abt. 3 m below surface, a quantity of *Hypnum sp.*, and seeds of *Menyanthes trifoliata*. In addition to forest pollen as in the strata above, the microscope here also showed some of *Umbelliferae* and *Chenopodiaceae*, tetrads of *Ericaceae* and spores of *Sphagnum*.

G. 3.4 — 5.7 m Greyish-brown, non-calcareous finely arenaceous Clay Mud; the stratum was not bored through. Pollen of the above named forest trees was found, also of *Alnus*, *Corylus* and some *Quercus*; furthermore, *Botryococcus Braunii*, *Pediastrum boryanum*, *P. Kawraiskyi*, a leaf-tip of *Ceratophyllum sp.*, (in the upper part of the bed), a pollen tetrad of *Typha latifolia*, several of *Ericaceae*, a few spores of *Dryopteris thelypteris*, *Osmunda regalis*, *Polypodium vulgare* and *Sphagnum sp.*

The great similarity between our profile and that of KOERT and WEBER is at once conspicuous; there are however, certain points of difference not without importance. Corresponding to Stratum e ("stark humoser toniger Feinsand") is our Stratum G; the thickness of this stratum, as well as of what lies below, is unknown. The mud above (limnischer Torf) showed a thickness of 0.65 m in the 1927 profile, but is given as only 0.25 m in 1910; on the other hand, the peat stratum proper (Bruchwaldtorf and Moostorf) in this latter profile is thicker (up to 1.0 m) than in our profile, where Stratum E is 0.55 m thick. Furthermore, it is only in our profile that the forest peat is covered by 20 cm of clay mud. This difference in the profiles, which are otherwise uniform, is doubtless due to the fact that our profile point lies farther from the margin of the diluvial basin than the profile point from 1901.

As regards the covering strata above the bog, the essential difference here between the two profiles is that in the 1927 profile, there is no Kiespackung, Stratum b answering presumably to our Stratum C. We did not find any boulder clay (Geschiebelehm), whereas the 0.4 m thick bed c in the 1901 profile was regarded as consisting partly of boulder clay. It is hardly likely however, that there should be so much difference between the covering strata at points so close together as here in question, and from the modern point of view it seems also more natural to regard the stratum in question (c) as arctic flow-earth, and the description given would be excellently applicable. This would also give a nice agreement between the covering strata in the two profiles, as Stratum C in our profile can be regarded as the more distal facies of a solifluction stratum, the proximal part of which (Strata b and c 1901) would naturally be more stony, as well as containing more interkneaded material from the subjacent strata. The absence of the clay mud stratum D above the forest peat in 1901 may be due to the very fact of its having been destroyed during the formation and deposition of the covering stratum. Incomplete as it is, our knowledge of the covering strata of the Fleestedt bog yet enables us to discern a great resemblance to the covering strata of the bogs at Römstedt I and II, in that we have in all three cases a proximal stony zone in the covering strata, the more central portions consisting almost entirely of stoneless sand or sandy clay. The covering strata of the interglacial bog at Fleestedt thus seem, from the foregoing, to afford no support for the view that the last glaciation should have extended to this region. As with the Römstedt bogs, the fossiliferous strata are here covered by solifluction and washed down material, and the deposit may be regarded as one of the transversally overflowed bogs from the last interglacial period (cf. p. 263 f.).

Thirteen samples were collected for pollen analysis from the different strata of this bog; the pollen diagram is shown in Fig. 6, Pl. XXXX. It will be seen at a first glance that it corresponds very closely to the upper part of the diagrams from Römstedt I and II. The spectra from Strata D and E agree well with the picture of the forest vegetation drawn by WEBER, whereas in the lower part of the diagram we find rather a large amount of *Alnus* pollen, up to 22 %, with a fairly constant, although slight amount of *Corylus avellana*, *Quercus sp*, and *Carpinus betulus*. How much of the pollen of these three species may have been brought by the wind from far away is uncertain, but its presence suggests that the lower part of the diagram must constitute the lower part of Zone *i*, and that Zone *h* might be looked for a little deeper down. It is thus only a little part of the last interglacial period that is here represented.

# Deposits from the Penultimate Interglacial Period.

## Lauenburg.

The profile shown by G. MÜLLER[1]) in 1904 from the Elb-Trave Canal N of Lauenburg, which he himself regarded, although with some hesitation, as mainly preglacial, was built up as follows:

Diluvial Sand
*Cardium* Sand, 5–8 m
*Mytilus* Clay, 2–3 m
Peat, abt. 1 m
*Anodonta* Mud } 1.5 m
Diatomaceous Mud }
Sand
Lauenburgerton.

Since then, most of the North-German geologists have agreed in referring its marine and limnian strata to the penultimate interglacial period, the covering diluvium being regarded as synchronous with that underlying the interglacial at Kuhgrund[2]). G. MÜLLER mentions leaves of *Potamogeton sp.* from the *Anodonta* mud and from the peat,

1) G. MÜLLER: Erläuterungen z. Geolog. Karte von Preussen. Lief. 108. Berlin 1904. See also G. MÜLLER: Jahrb. K. P. Geolog. Landesanstalt für 1899.

2) C. GAGEL: Die Beweise. . . . Geolog. Rundschau, Bd. 4. Berlin 1913, p. 342. J. SCHLUNCK: Das Diluvialprofil von Lauenburg a. d. Elbe. Jahrb. Kgl. Preuss. Geol. Landesanstalt. Bd. XXXV. I. Berlin 1914, p. 603 f.

remains of rodents (Nagern) and fishes, as well as several of the outer wings of beetles, as described by MEUNIER [1]. W. BÜNTE [2] has dealt with the diatoms. Furthermore, W. GOTHAN [3] has found branches of *Pinus silvestris* in this peat bed in the brickworks pits on the western margin of the Stecknitz valley, east of Lauenburg.

In 1923, we had occasion to visit, in company with W. WOLFF, the northernmost of the brickworks situated south of Buchhorst in the edge of the Stecknitz valley where the uppermost of the strata mentioned above, as well as the peat bed, could be observed. We took with us a small sample of the peat. This consisted of highly compressed, very muddy peat containing numerous small branches, fragments of bark, fruits and catkins of *Alnus glutinosa*, a seed of *Pinus silvestris*, fruits of *Carex sp.*, seeds of *Nuphar luteum*, and a fruit of *Potamogeton sp.* In addition, the following pollen spectrum was found: *Betula* 4 %, *Pinus* 21 %, *Quercus* 3 %, *Alnus* 67 %, *Picea* 5 %, traces of *Tilia*, and *Corylus* 4 %.

The peat stratum at Lauenburg must then be regarded as consisting in whole or in part of Schwemmtorv, deposited in a basin surrounded by an *Alnetum*, the adjacent hills being forest clad, with *Pinus silvestris* at any rate for some time as the most important species, and some *Picea*, birch, oak and hazel in addition.

## Ober Ohe.

In the course of our visit in 1927 in company with KURD VON BÜLOW to the kieselgur pits at Neu-Ohe and Ober Ohe (cf. Fig. 29) we also collected a series of samples for pollen analysis from the pit at Ober Ohe, some from the bed abt. 7 m thick midway down the western wall of the pit, and some from the lower part at the entrance to the pit in the south-western corner. The abundance of fossils is shown by the flora list according to J. STOLLER [4]: *Polypodiaceae*, *Abies pectinata*, *Picea excelsa*, *Pinus silvestris*, *Typha sp.*, *Myrica gale*, *Betula pubescens*, *B. pendula*, *Alnus glutinosa*, *Fagus silvatica* [5], *Quercus robur*,

1) F. MEUNIER; Jahrb. K. P. Geolog. Landesanstalt für 1900, p. 51.

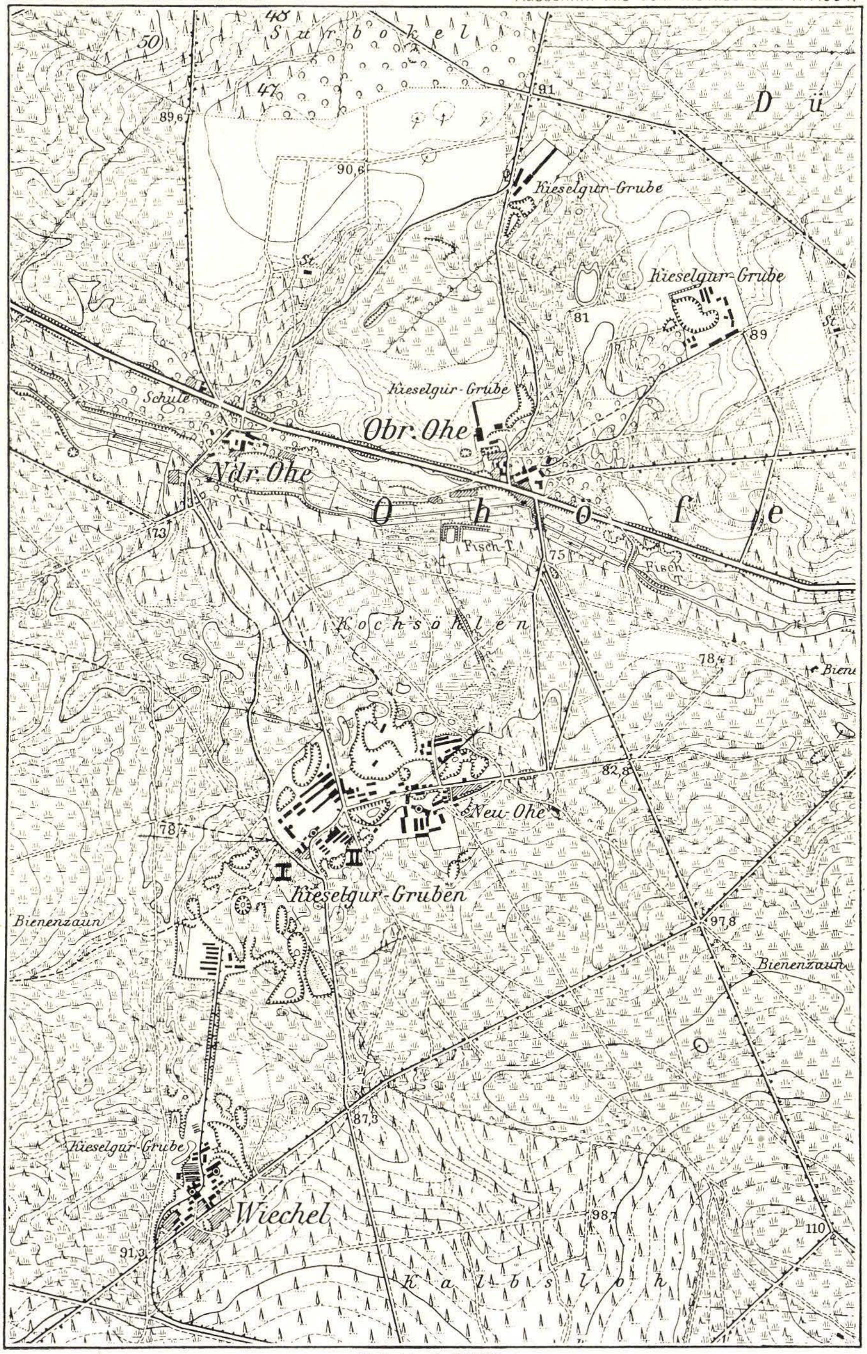
2) W. BÜNTE: Die Diatomeenschichten von Lüneburg, Lauenburg, Boizenburg und Vendisch-Wehningen. Dissertation. Güstrow 1901.

3) See SCHLUNCK: Das Diluvialprofil von Lauenburg a. d. Elbe. Jahrb. K. P. G. Landesanstalt. Bd. XXXV. I. Berlin 1914, p. 608.

4) J. STOLLER: Geolog. Führer durch die Lüneburger Heide. 1918, p. 120; — The same: Festschr. vereinigte deutsche Kieselgurwerke. Hannover 1925, p. 21; for the diatoms see B. HEIDEN, ibidem p. 27.

5) The finds of *Fagus silvatica* here noted are challenged by F. FIRBAS: Beihefte zum Bot. Centralbl. Bd. XLI. 1925. Abt. II, p. 307, cf. Chapter VII of the present work.

Reichsamt für Landesaufnahme. Ausschnitt aus dem Meßtischblatt Nr. 1604.




Maßstab 1 : 25 000

**Fig. 29.** The Ober Ohe and Neu-Ohe district. The pits at Neu-Ohe mentioned in the text are marked I and II. Contour interval for the fully drawn curves = 5 m.

*Q. sessiliflora, Ilex aquifolium, Acer platanoides, A. campestre, Tilia parvifolia, Andromeda polifolia, Vaccinium uliginosum, Utricularia minor,* cf. *Neckera sp.* Also skeletal impressions of small carp-like fishes.

Midway along the western wall, the following profile was measured, the kiselgur (diatomaceous earth) here forming a great anticline:

A. Covering Stratum here dug away (cf. Pl. XXVIII).
B. White Kieselgur with thin streaks of Sand, abt. 3 m.
C. Grey Kieselgur with thin streaks of Sand, abt. 2 m.
D. Green Kieselgur, abt. 2 m, merging gradually below into
E. Sand of medium fineness without stones.

It was found however, that the pollen flora was ill preserved in all the samples from the white and the grey strata, which together made up the greater part of the deposit, and it was only from the lower part of the profile that a reliable pollen diagram could be obtained. This was found to agree in the main with that shown in Fig. 7, Pl. XXXX as noted for the green kieselgur in the profile from the entrance to the pit.

All these pollen spectra (20) exhibit a marked predominance of *Pinus* and *Alnus* throughout the entire series of strata. Of the other *Corylus* only attains any high frequency (24 % utmost) in the lower part of the diagrams. *Betula* is insignificant and does not exceed 12 %. The mixed oak forest *(Quercus* + some *Ulmus* and a very little *Tilia)* attains its maximum almost at the same time as *Corylus,* running out to 12 % in spectr. 5 and 7. In both diagrams, *Picea* attains its greatest frequency, up to 8 %, in the lower part; it appears however, in all spectra. *Carpinus* is lacking in the lower part of the diagrams, its highest frequency (11 %) being noted in Spectr. 3. About at the same time as *Carpinus,* we find *Abies,* the highest value for this last (6 %) being recorded in Spectr. 1.

The uncertain analyses available from the grey and white kieselgur show but very slight relative frequency for *Abies, Picea, Carpinus, Betula* and *Corylus,* while the mixed oak forest species are not found there. By way of example we may note the pollen spectrum from 0.5 m below the surface of the kieselgur stratum in the profile from the anticline: *Betula* 3 %, *Pinus* 45 %, *Alnus* 50 %, *Picea* 1 %, *Abies* 1 % and *Corylus* 3 %.

Among microfossils were also found: some pollen of *Fraxinus sp* , many pollen tetrads of *Ericaceae,* spores of *Dryopteris thelypteris,* (also sporangia), *Osmunda regalis* and *Polypodium vulgare;* also of algæ: *Anabaena sp., Botryococcus Braunii* and *Pediastrum borganum. Spongilla lacustris.*

From the foregoing, we may take it that *Alnus glutinosa* was common along the shores of the lake throughout the whole of the period when the diatomaceous mud was forming there. At the same time, *Pinus silvestris* played a very important part in the forests of the surrounding plateau, which must presumably have been exceptionally favourable ground for the growth of conifers, just as the Lüneburger Heide is at the present day. Other species attained relatively inconsiderable maxima at different times. We can distinguish for instance, a zone with mixed oak forest and *Corylus*, within which the sedimentation of kieselgur began, a *Carpinus* zone following on this, and uppermost an *Abies* zone.

It should no doubt be possible to procure material for a more thorough pollen analysis from the western pit at Neu-Ohe (Pl. XXIX) where the green kieselgur constitutes a comparatively large portion of the organogenic strata.

## Westerweyhe.

On the occasion of our visit to this classical site in 1923 together with W. Wolff, (cf. p. 318) we collected a sample of a greyish brown, stratified, sandy, non-calcareous mud, bedded directly beneath the covering of sand, and resting on the marl. The profile was otherwise covered by fallen masses of Sand etc. A pollen analysis of the mud showed: *Betula* 30 %, *Pinus* 48 %, *Picea* 13 %, *Abies* 2 %, *Alnus* 7 %, *Corylus* 4 %. This mud stratum above the marl is well known and J. Stoller[1]) herein previously found remains of *Pinus silvestris*, *Betula alba* and *Menyanthes trifoliata*. The marl bed, in which were found, inter alia bones of *Rhinoceros Merckii*, *Bos priscus* or *primigenius* and *Cervus elaphus*, appears to be poor in vegetable remains, and J. Stoller notes from here only branches and pieces of trunk and pollen of *Pinus silvestris*, with pollen of *Picea excelsa*.

## Nedden-Averbergen.

This deposit of interglacial fresh-water lime SE of Verden, which, from its situation and composition must likewise be refered to the penultimate interglacial period, has previously been mentioned by J. Stoller[2]) and is noted of p. 322 of the present work on occation

1) J. Stoller: Geolog. Führer, p. 58 f. The same: Erläut. Geolog. Karte. Lief. 156, Blatt Ebstorf. Berlin. 1911, p. 22 f.

2) J. Stoller: Spuren des diluvialen Menschen in der Lüneburger Heide. Jahrb. K. P. Geolog. Landesanstalt für 1909, Bd. XXX. II, p. 448 f. — The same: Geologisch-agronomische Karte d. Gegend östlich von Verden a. d. Aller nebst Erläuterungen. Berlin. 1910, p. 5 f.

of our visit there in 1923 with W. WOLFF. J. STOLLER gives the following finds of vegetable material from the marl: *Picea excelsa, Pinus silvestris, Najas marina, Cladium mariscus, Phragmites communis, Corylus avellana, Carpinus betulus, Ceratophyllum demersum, Betula alba, Alnus glutinosa, Nuphar luteum, Nymphaea alba, Scirpus lacuster* and *Tilia platyphyllus*; to which I am able to add *Najas flexilis*. In addition to this STOLLER mentions a rich mollusc-fauna and of vertebrate animals *Rhinoceros sp., Cervus elaphus, Bos (Bison?) sp., Castor fiber* and other.

From a newly dug heap of marl we obtained two samples, No. 1 of very humous grey calcareous mud, and No. 2 of almost white calcareous mud almost devoid of humus. The pollen analyses of these samples gave the following spectra:

| Nr. | *Betula* | *Pinus* | *Ulmus* | *Quercus* | *Tilia* | *Alnus* | *Carpinus* | *Picea* | *Corylus* | Pollen-frequency |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 2 | 3 | 5 | 1 | 18 | 57 | 10 | 8 | 126 |
| 2 | 5 | 12 | 8 | 13 | 11 | 47 | 1 | 3 | 53 | 195 |

Table 18. Pollen spectra from Nedden-Averbergen.

Of these, No. 2 shows 32 % mixed oak forest *(Quercus + Ulmus + Tilia)* while *Corylus* makes up over half the total amount of pollen found. In No. 1, *Carpinus* is dominant, *Picea* is more common, than in Spect. 2, and the mixed oak forest, as well as *Corylus*, far more sparsely represented, so that we may presume that this sample was derived from a higher level in the profile than No. 2.

# Interglacial Deposits covered by Young-glacial Material.

## Loopstedt.

On the eastern side of Hadeby Nor, near the town of Slesvic in the german province of that name, there appears, in the high cliff looking out towards the frith, an interglacial deposit which is named after the adjacent village of Loopstedt.[1]) We visited this locality in 1923, and measured the profile given below, taking also some small

[1]) W. WOLFF: Erdgeschichte u. Bodenaufbau Schleswig-Holsteins. Hamburg 1922, p. 46.

samples of the different strata. The surface of the subjacent moraine lay approximately at sea level at the spot where the profile was taken; for the rest, this was covered by fallen material. Our profile will be found to differ in some respects from the sketch of the strata sequence as given in the Städtisches Museum at Altona; this must be mainly due to the fact that the two measurements were made at different points of the section cut by the cliff through the interglacial lake deposit.

A. Younger Diluvium, several m thick, consisting mainly of horizontally stratified Fluvioglacial Sand, this however containing a bank of Moraine Clay abt. 1 m thick above the interglacial profile.

B. 0 — 0.4 m Brown, fresh, Mud-blended Peat, consisting mainly of *Hypnum aduncum* HEDW. The following were also found:
*Alnus glutinosa* GAERTN., 1 catkin, much pollen,
*Batrachium aquatile* L. *(coll.)*, 2 fruits,
*Betula pubescens* EHRH., 5 fruits,
— *sp.*, much pollen,
*Carpinus betulus* L., some pollen,
*Ceratophyllum demersum* L., 3 fruits,
— — L., *var. apiculatum* CHAM., 3 fruits,
*Corylus avellana* L., two grains of pollen,
*Myriophyllum cf. spicatum* L., 1 fruit,
*Najas flexilis* (WILLD.) ROSTK. & SCHM., 5 fruits,
*Nuphar luteum* SM., 3 seeds,
*Nymphaea alba* L., 1 seed,
*Picea excelsa* LK., 3 needles, 1 seed wing, much pollen,
*Pinus silvestris* L., pollen fairly abundant,
*Polypodium vulgare* L., 3 spores,
*Potamogeton natans* L., 1 fruit (Pl. XXXII, 28),
— *praelongus* WULFEN, 1 fruit,
— *cf. pusillus* L., 1 fruit,
*Quercus sp.*, 2 grains of pollen.

*Botryococcus Braunii*,
*Pediastrum boryanum*, common,
— *Kawraiskyi*,
*Rivulariaceae.*

*Cladocera*,
*Oligochaeta*, coccons.

C. 0.4 — 0.9 m Greyish brown, finely arenaceous Mud:
*Alnus glutinosa* GAERTN., 2 fruits, 2 twigs, much pollen,
*Betula pubescens* EHRH., 1 fruit,
— *sp.*, some pollen,
*Carpinus betulus* L., pollen fairly abundant,
*Ceratophyllum sp.*, leaf tips,
*Corylus avellana* L., some pollen,
*Dryopteris thelypteris* (L.) GRAY, 1 sporangium, some few spores,
*Picea excelsa* LK., 3 needles, 1 seed wing, much pollen,

*Pinus silvestris* L., some pollen,
*Polypodium vulgare* L., some spores,
*Potamogeton sp.*, 1 fruit,
*Quercus sp.*, much pollen,
*Scirpus sp.*, 1 fruit,
*Tilia sp.*, 2 grains of pollen.

*Botryococcus Braunii*,
*Pediastrum boryanum*, very common,
— *clathratum*,
— *Kawraiskyi*.

D. 0.9 — 2.1 m Dark brown, non-calcareous Detritus Mud:
*Acer campestre* L., 1 fruit in the lower part of the stratum,
*Alnus glutinosa* GAERTN., 3 fruits, much pollen,
*Betula sp.*, pollen fairly abundant,
*Carpinus betulus* L., much pollen in the upper part,
*Ceratophyllum sp.*, leaf tips,
*Corylus avellana* L., much pollen in the lower part,
*Najas marina* L., 5 fruits,
*Nuphar luteum* SM., pollen,
*Picea excelsa*, LK., 2 seed wings, pollen especially in the upper part,
*Quercus sp.*, pollen fairly abundant,
*Salix sp.*, 1 grain of pollen,
*Scirpus lacuster* L., 3 fruits,
*Tilia sp.*, fragments of a fruit, some pollen,
*Ulmus sp.*, some amount of pollen.

*Botryococcus Braunii*,
*Rivulariaceae*.

E. 2.1 — 2.6 m Greyish brown, calcareous Mud:
*Alnus glutionosa* GAERTN., 3 catkins, 1 fruit, much pollen,
*Betula pubescens* EHRH., some fruits,
— sp., some pollen,
*Carex sp.*, 1 fruit without utriculus,
*Cladium mariscus* (L.) R. BR., 1 fruit,
*Corylus avellana* L., much pollen,
*Dryopteris thelypteris* (L.) GRAY, spores,
*Najas marina* L., 2 fruits,
*Picea excelsa* LK., 2 grains of pollen,
*Pinus silvestris*, L., pollen fairly abundant, leaf epidermis,
*Quercus robur* L., a leaf,
— *sp.*, much pollen,
*Tilia sp.*, 1 grain of pollen,
*Ulmus sp.*, much pollen.

F. 2.6 — 2.7 m Dark brown almost non-calcareous Mud rich in drifted matters, numerous small twigs. A lid of *Bithynia tentaculata* L. The following were also found:
*Betula pubescens* EHRH., 2 catkin scales, several fruits,
— *sp.*, much pollen,
*Carex rostrata* STOKES, many fruits,
*Ceratophyllum demersum* L., 1 fruit,

*Ceratophyllum demersum* L., *var. apiculatum* CHAM., 6 fruits,
— *submersum* L., (partly f. *muricata* LGE.,) 14 fruits,
*Najas marina* L., 1 small fruit,
*Pinus silvestris* L., much pollen,
*Potamogeton natans* L., many fruits,
*Quercus sp.*. much pollen,
*Salix sp.*, 1 grain of pollen,
*Typha latifolia* L., several pollen tetrads,
*Ulmus sp.*, much pollen,
*Urtica dioeca* L., 5 fruits.

*Botryococcus Braunii.*

G. Moraine Clay.

The oldest portion of the interglacial pollen diagram is not represented in the diagram from Loopsted (Fig. 8, Pl. XXXX). Even in the lowest spectrum (6), the mixed oak forest has already 34 % against ***Pinus*** 27 %. The zone for mixed oak forest *(f)*, with the culmination of ***Quercus*** 31 % and ***Corylus*** 146 % in Spectr. 5, ***Alnus*** with 51 % and ***Tilia*** with 9 % in Spectr. 4, thus runs through Strata F and E, with the lower portion of D. The rational boundary for ***Carpinus*** must be looked for in the lower portion of D, and this species of pollen dominates in Spectr. 3 with 35 %. The rational boundary for ***Picea*** is here at about the same level as that for ***Carpinus***, but the ***Picea*** maximum occurs in Spectr. 2 with 52 %, and even in the uppermost spectrum, ***Picea*** is still dominant, though ***Pinus*** and ***Betula*** have now again attained higher figures, their minima lying in Spectr. 3 and 2 respectively. In that part of the interglacial lake deposits embraced by the diagram, we have thus an indication of a forest development which must be regarded as in all essentials similar to that known from the interglacial bogs of Jutland. The deposit may likely be refered to the last interglacial period.

# V. Stratigraphy of the Interglacial Deposits and the Landscape in the Lüneburger Heide and Western Jutland.

## The Morphological Landscape Boundary and the Limit of last Glaciation.

The difference between the types of landscape from the last glaciation and the older glacial forms is on the whole conspicuous, and has for many years been noticed by geologists. In the case of Jutland, N. V. Ussing, in 1907[1]) mentions the difference between the form of the hills in front of and behind the "main stagnation line" of the last glacial period, throughout Jutland. Later, Victor Madsen[2]) has dealt at greater length with the difference in the type of landscape between the young-glacial tracts in eastern Jutland and the older, flattened and levelled terrain in the highlands of western Jutland. Ussing considers that the difference is "naturally explained" by the fact that "the hill-islands of western Jutland stood free of ice in the stagnation period", he does not, however, discuss the question as to whether western Jutland is a glacial period older than the eastern side of the peninsula. Madsen points out that "the present surface-forms of the hill-islands have but little connection with the original forms" but is "due to the general erosion throughout the long period which elapsed after the ice had melted away from western Jutland at the close of the penultimate glacial period", (l. c. p. 15—16).

P. Woldstedt[3]) in his "Beiträge zur Morphologie von Nordschleswig" likewise notes the great difference between the eastern hilly country "the Baltic area" and the Geest, the "pre-Baltic surface". As regards the manner in which the forms of this "pre-Baltic" area were produced, Woldstedt keeps mainly to the theories advanced by Ussing. True, there is some difference of age apparent, but this is considered as lying within the limits of one and the same glacial period, viz.

1) N. V. Ussing: Om Floddale og Randmoræner i Jylland. Overs. Vid. Selsk. Forh.

2) Victor Madsen: Terrænformerne paa Skovbjerg Bakkeö. D. G. U. IV. Række. Bd. 1, Nr. 12. 1921.

3) Mitt. der Geogr. Ges. in Lübeck. 1913. — Cf. Jahrb. P. G. Landesanstalt f. 1921. Bd. XLII, II, p. 789.

the last, and is best understood "wenn man für das baltische Stadium einen besonderen Vorstoss nach einem Zurüchweichen des Eises annimmt" (p. 91).

Farther south again, through Holstein, the difference in landscape is very pronounced. W. Wolff, in his paper "Das Diluvium der Gegend von Hamburg"[1]) points out that "diese ganze nordelbische Gebiet ist durch ein ausgebildetes natürliches Entwasserungssystem, durch reife, alte Landschaftsformen . . . gekennzeichnet". But on reaching the neighbourhood of Ahrenburg, between Hamburg and Lübeck, there is a sudden change in the aspect of things. "Hier tritt an Stelle der wellenförmige Ebene eine unruhige, hügelreiche Landschaft mit offenen Seen", and numerous enclosed cauldrons and bogs. An important geological boundary line has been passed; we have come from the area of the older glacial period into that of the last. Wolff thus considers the difference of landscape as closely related to the difference in age of the two areas of glaciation.

C. Gagel, in a paper published in the same year[2]) points out that "in der Umgebung des Baltishen Höhenrücken zeigt das Diluvium die typischen Formen der Glaziallandschaft: frische, schroffe, steil abgeböschte Landschaftsformen mit sehr vielen, abflusslosen Vertiefungen, während südlich und westlich davon die Landschaft viel ruhigere, sanftere, unverkennbar stark eingeebnete ("greisenhafte") Formen aufweist und meist völlig abdrainert ist." Gagel considers however both types as lying within the limits of the last glaciation, saying that: "das junge Diluvium zwar den Ostrand von Föhr, nicht aber mehr Sylt erreicht hat; das es die Unterelbe NW von Stade etwas überschreitet, in der Lüneburger Heide, wenn auch nur als dünne Decke, erheblich nach Südwestern vorstosst, vielfach von älteren, denudierten (Rumpf-) Endmorainen durchbrochen wird und sich in seinen letzten, schleierhaft dünnen Ausläufern bis and den Rand des oberen Allertales erstreckt."

Karl Gripp,[3]) on the other hand, in his "Über die äusserste Grenze der letzten Vereisung in Nordwest-Deutschland", lays stress on the morphological boundary between the younger landscape with predominant accumulation forms, and the older type, where the surface is chiefly characterised by erosions; he regards this boundary as marking the limit of the last glaciation. In agreement with Wolff, he declines to believe that the ice of the last glacial period crossed the Elbe and reached the Lüneburger Heide. He is here, like Wolff,

[1]) Jahrbuch der Kgl. Pr. Geol. Landesanstalt f. 1915.

[2]) Die letzte grosse Phase der diluvialen Vergletscherung Norddeutschlands. Geologische Rundschau 1915.

[3]) Mitt. der Geogr. Ges. in Hamburg. 1924.

in opposition to J. STOLLER, whose "Geologischer Führer durch die Lüneburger Heide" is based on the assumption that the last glaciation also reached this region; STOLLER however, regards the southern portion of the Lüneburger Heide as an "alte ausgereifte Erosionslandschaft" in contrast to the country farther north.

Autorities on the Quaternary period are thus — as the examples quoted above show — agreed that the indicated morphological difference in landscape does on the whole connote a difference of age. But when it comes to determining when the levelling of the older landscape took place, and what length of time should be assigned for the difference in age, there is an end af unanimity. The question cannot be fully decided by the degree or character of the levelling which has taken place, but calls for evidences of a purely geological nature. As long as the morphological features are judged by themselves, without any confirmation from other sources, it will hardly be possible to arrive at anything beyond a subjective estimate, dependent to some extent upon the view already held by the investigator beforehand.

We have, however, means for determining the difference in question, as regards the Cimbrian Peninsula, in the interglacial deposits of the Brörup and Herning types. The occurrence of such deposits under the same or corresponding stratigraphical conditions here affords a maximum limit for the extent of the inland ice in the last glacial period; the ice-sheet of the last glaciation did not reach beyond the sites of their occurrence. The country at Brörup, in southern Jutland, is typical in this respect; and it has its counterpart in the country round Hamburg, where — as WOLFF has shown — there are a great number of interglacial fresh-water deposits occurring under the same stratigraphical conditions as the Jutland bogs of the Brörup type. These deposits mark the farthest limit of extent of the last glaciation in this region.

It has been possible, then, to determine, by the aid of such interglacial deposits, the maximum extent of the last ice-sheet; on the other hand, there can hardly be any doubt but that the Baltic lake area represents the minimum extent of the ice-cover in question. And in this connection, the so-called "tunnel valleys", formed subglacially, with the associated long-lakes and chains of lakes, are of considerable importance. VICTOR MADSEN, in the paper quoted above on the types of landscape at Skovbjerg Bakkeö, states as his opinion that "the inland ice of the last glacial period only embraced those tracts of land where tunnel valleys are found". He thus considers it possible, by this means, to determine not only the minimum but also the maximum limit of glaciation. Similarly, GRIPP regards the morphological landscape boundary as coinciding absolutely with the limit of the last ice-sheet. This however, has been found not to hold good, as regards southern Jutland — east of Brörup. We have here an area where the occurrence, in remarkable abundance, of the otherwise rare boulders of Scanian basalt, lying on the surface or in a thin superficial layer of stony sand, shows that the last glacial period must have spread a thin cover of ice some 10—15 km farther west than the subglacial valleys, with their accompanying ridges, or than the most pronounced morphological boundary extend. Following the traces of these numerous basalt boulders towards the north, we find that the belt in which they occur belongs to the same area as the subglacial valleys of the last glacial period. From this also it is evident that it must be the inland ice of the last glacial period which brought the boulders to the region east of Brörup, where, by the way, the landscape is, morphologically speaking, quite in accordance with the older, highly levelled type. We cannot therefore consider the morphological boundary without reserve as synonymous with the extreme limit of the last glaciation. Just as the interglacial bogs of the Brörup type only afford the means of determining the maximum limit, so again, the morphological boundary only serves to indicate the minimum limit of the last glaciation.

This being understood, we shall now proceed to consider the Lüneburger Heide and the occurrence of interglacial freshwater deposits there in comparison with those of western Jutland, And it will be seen that there are several points of agreement between the two areas, both as regards the occurrence of these deposits and the character of the landscape itself.

## Bogs of the Last Interglacial Period and Surface of the Older Landscape.

In both regions we find bogs of the Brörup type. As will be apparent from the foregoing, these are reckoned as belonging to the last interglacial period, in contradistinction to a series of other interglacial deposits, which are either an interglacial period older or cannot be completely determined stratigraphically. This age of the bogs of the Brörup type and their importance in determining the age of the surrounding landscape is evident from the stratigraphical conditions in which these bogs occur. It is therefore important to be quite clear as to what it is that proves that these bogs have not been traversed by inland ice, and that the covering strata above them is not glacigenous, but deposited by other means during the last glacial period.

As mentioned frequently in the foregoing, it is a typical feature of these bogs that the landscape above them is hollowed out like a bowl, either with dry bottom, or forming the site of a postglacial bog. The interglacial bog itself, with the covering layer of sand, appears as the filling of a still deeper basin (cf. Profiles on Pls. XI, XIII, XV, XVII, XXVII); the interglacial strata are thickest in the middle of the basin, thinning out in all directions up towards the uppermost part of the sides. This typical occurrence of the peat beds — as a bowl — shows in itself distinctly enough that the bogs must be younger than the surrounding highlands in which the basins lie, and that it cannot therefore have been traversed by any ice-sheet since the formation of the bogs; this was recognised as far back as 1903 by A. JESSEN.[1]) The proof that this view of the relative ages is correct is further confirmed by considering the composition of the covering layer above the bogs, both in itself and in comparison with the surrounding surface soil.

The mineral covering strata above the bogs consist of stoneless clay or sand, sand with stones varying from quite small to the size of a clenched fist or seldom more, and gravel. The covering layer above the marginal parts of the basins is as a rule rather more argillaceous than in the middle of the basins, and not infrequently contains lumps of the same material as the subjacent interglacial mud, or smears of the same. Where gravel or very stony sand appear in the covering strata, they are generally thicker at the edge than in the middle of the basin. The total thickness of the covering strata is greatest in the middle, but the material itself is here as a rule of finer grain than at the edges, and in many cases consists of stoneless sand and strata of stoneless clay, whereas finely sorted, precipitated strata of this sort are not found at the edge of the same bogs. In the bog at Höllund-Sögaard[2]) the profiles show distinctly the difference between the coarse, nonstratified material at the edge of the basin and the fine, partly stratified deposit in the deeper central parts.

In connection with the more stony and argillaceous material at the edges of the basins, we find, as mentioned, interkneaded lumps and lenses of interglacial mud and peat. Instances of this are met with at Skovlyst.[3]) From this last-named locality, as also from Tuesböl I[4]) near Brörup, it is likewise known that the peat and mud strata of the marginal portions are folded up towards the middle of the basin, not only on the eastern but also on the western side of the bog.

[1]) AXEL JESSEN, VICTOR MADSEN, V. MILTHERS og V. NORDMANN: Brörup-Mosernes Lejringsforhold. D. G. U. IV. R. Bd. 1. No. 9. 1918, p. 11—12.

[2]) l. c. p. 11 f.

[3]) l. c. p. 22 f.

[4]) l. c. p. 17 f.

No cover of moraine clay has ever been found above bogs of this type. Noting in this connection the marked difference between the nature of the covering stratum at the edges and in the middle of the basins, we have here sufficient assurance that the covering material was not deposited by the inland ice. This would in most cases, have levelled the basins almost entirely, and would in any case have left a covering layer the composition of which was uniform throughout, without regard to whether it was deposited at the edges or in the middle of these small basins.

The connection thus discernible in many places between the composition of the covering stratum and the position relative to the basin itself, shows a dependent relation between the mode of deposition and the basins which can only be explained by supposing that the covering material must have been deposited by subaërial means, viz. by solifiuction and washing down from the higher surroundings of the basin. The appearance of the basins themselves in the landscape points in the same direction. This is due, in the first place, to the fact that the original, deeper basins were not completely filled up by the masses of soil washed down and otherwise carried down during the last glacial period. Had the inland ice traversed the sites, then their present appearence could only be due to subsequent compression of the plant-bearing strata, which would only in extremely few cases suffice to explain the presence of the basins as the are now.

Since the bogs of this type have thus not been traversed by the inland ice of the last period, they serve, as already mentioned, as a basis for determination of the maximal extent to which this ice cover can have reached. And we can thus make certain that the last inland ice reached as far as the innermost — which in Denmark and north-west Germany means the easternmost — occurrences of the deposits of the Brörup type and the Herning type. Through the Cimbrian peninsula from Herning southwards, this maximal boundary can be indicated by the following localities: Herning, Brörup, Agerskov (cf. Pl. I), Nienjahn, the Hamburg district. The investigations in the Lüneburger Heide show that the maximum boundary can be drawn further towards the south-east, viz. east of Kuhgrund near Lauenburg and Römstedt near Bevensen, and Fleestedt near Harburg (cf. Fig. 30).

As the interglacial deposits at Kuhgrund are no longer regarded as having been traversed by the inland ice in the last glacial period, and there is no principal divergence as to the nature of the covering stratum, this locality need not be mentioned here; there are however, two other occurrences of interglacial bogs, viz. at Römstedt, 4 km NE

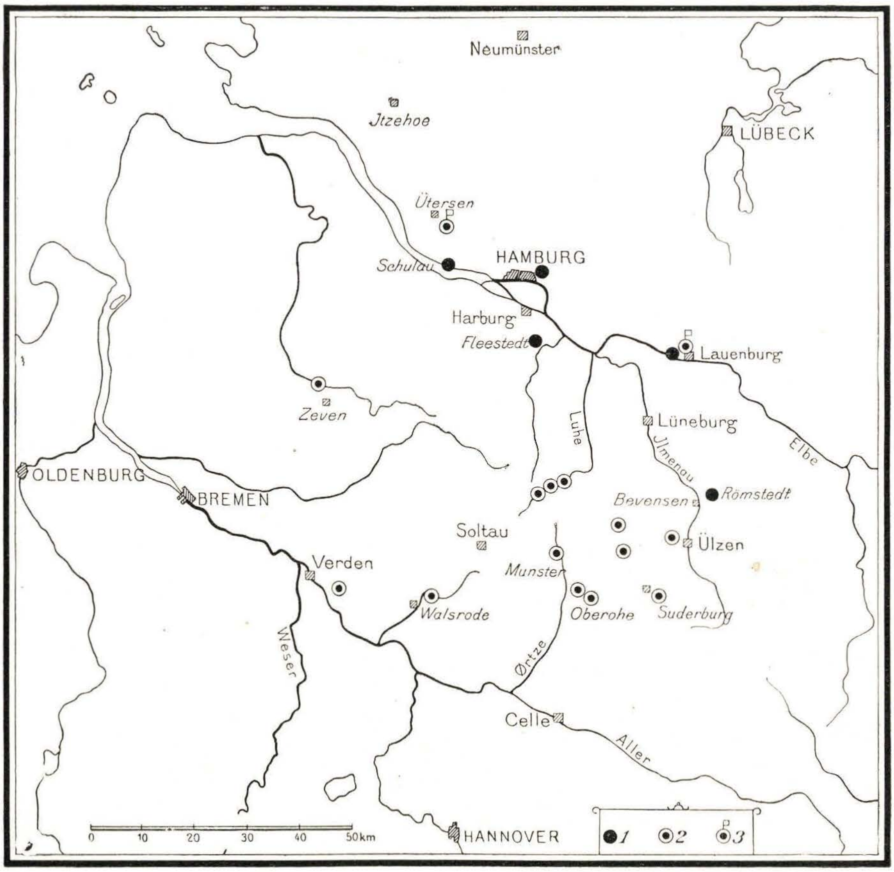



Fig. 30. Map showing position of some interglacial fresh-water deposits in NW Germany. *1*. Deposits from the last interglacial period. *2*. Deposits from the penultimate interglacial period. *3*. Fresh-water deposits covered by marine deposits from the penultimate interglacial period.

of Bevensen, and 22 km SE of Lüneburg, and at Fleestedt, 5,5 km S of Harburg, which call for further consideration in this connection.

At Römstedt, we found, in the course of our investigations in the spring of 1927, three interglacial bogs of the Brörup type (p. 282 f.). Two of these lie 1200 m W of Römstedt and the third nearly 400 m farther east. All present the appearance of shallow depressions in a landscape (cf. Pl. XXVI, 1 and XXVII) whose contour lines have otherwise a very much levelled and conformed shape. Apart from the erosion valleys, the landscape is very slightly undulating, with a maximum gradient of 1 : 60. The surface strata are on the whole of a moraine-like composition; we find however, abt. 100 m west of the most south-westerly bog, hills consisting of fluvioglacial sand and with a surface gradient somewhat exceeding that above noted. The profile sections (see Pl. XXVII) drawn throught the two western bogs show that the covering layer in the middle of the basin is stoneless sand: at the edges, howewer, it can be more or less stony or argillaceous. The thickness both of the covering soil and of the interglacial strata is greatest in the central parts of the basin, decreasing out towards the sides. The stratification thus shows that these bogs at Römstedt, as regards their position in the ground, correspond exactly to the Jutland bogs of the Brörup type. Like these, they have never been traversed by inland ice, and thus afford conclusive proof that the inland ice of the last glacial period did not extent as far to the south-west as Römstedt, and therefore cannot have touched those parts of the Lüneburger Heide which lie farther west. The glacial surface here dates from the penultimate glacial period.

In 1906, J. STOLLER[1]) discovered, by boring, the northernmost of these interglacial bogs at Römstedt. Borings were then carried out in southernmost offshoot "direkt an den vorbeiführenden Feldweg" and "80 m weiter nördlich", probably near the western edge of the bog basin not far from our borings 4 and 5 (Pl. XXVII, 3). In both of STOLLER's borings, some of the upper soil was described as "sandiger Geschiebelehm". It seems however, far more natural to regard this argillaceous covering layer here as a product of solifluction, since the covering soil in the central part of the basin consists of sand, completely free from stones or clay. The result of STOLLER's borings thus disagrees with our results, insofar as he comes to the conclusion that the bog must bave been ice-covered, which proves not to have been the case.

The interglacial bogs at Römstedt are, as regards their stratigraphical features and occurrrence in the landscape, entirely in agreement with the majority of the Jutland bogs of the Brörup type. The interglacial bog at Fleestedt, on the other hand, takes a somewhat different position, inasmuch as the surface above this bog does not present the appearance of an enclosed basin, but of a slightly valley-shaped slope. In this respect, however, it resembles the interglacial bog at Dalager Nygaard (see p, 137) and recalls the situation of the interglacial land surface observed at Emmerlev Cliff, NW of Tönder, which is covered with stony sand and lies below a sloping land surface (see p. 265).

The interglacial bog at Fleestedt lies in the southern part of a small wood, 600 m south of the village of Fleestedt, 5.5 km south of Harburg. The country slopes gently down towards the east, to some meadows. The occurrence here is marked by the fact that the surface

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1) Erläut. z. Geol. Karte v. Preussen. Lieferung 156. Blatt Bevensen. 1911.

is rather swampy, the soil on either side of the slight depression being perfectly dry. The bog was discovered by W. KOERT[1]) in 1901. An excavation was then made, showing the following profile:

1 —1.2 m Schwach eisenschüssigiger toniger Feinsand bis Sand.
0.3—0.5 m Gewöhnlicher Diluvialsand.
0.4 m Kiespackung mit lehmigem Bindemittel, zum Teil sandiger Geschiebelehm, der torfstreifiges Material, offenbar aus zerstörten Teilen des Torflagers herrürend, enthielt.
1 —1.2 m Stark zusammengepreszter Torf.
über 2 m Stark humoser toniger Feinsand.

The boring we made ourselves on the occasion of our visit in the spring of 1927, was, as far as we could judge, made somewhat nearer the centre of the basin that the excavation above mentioned (cf. p. 295). The following covering strata were found above the bog:

0.2 m Peat.
0.3 m Grey, sandy Clay without stones.
1.2 m Reddish, sandy, stoneless Clay; more sand in the lower part.
0.1 m Reddish argillaceous Sand with a few stones.
0.2 m Grey to greyish brown humous stony Sand, stones to size of beans. Below this, Mud (see also p. 294).

Nothing was found in any of the strata here which could be regarded as moraine clay or as evidence that the site had been covered by inland ice after the deposition of the interglacial strata. The covering material must be regarded as having slipped down from the higher surroundings. W. KOERT, in the work above mentioned, gives the following description of the general conditions in connection with this bog: "Das Torflager war mit Hilfe des Handbohrers von 2 m Länge nach Südosten vom Schurf nur noch auf etwa 4 m Entfernung nachzuweisen, nach Südwesten dagegen noch auf etwa 20 m. Aus den zahlreichen Bohrungen ergab sich ferner, dass die über dem Torflager befindlichen Geschiebelehmreste zwar hier und da fehlen können und dann offenbar durch Sande unter der Schleppsanddecke vertreten werden, das diese Reste andererseits aber sich in geringer Entfernung zu einer ausgedehnten Geschiebemergelfläche zusammenschliessen, welche die Karte dort verzeichnet. Wir haben also an diesem Torflager das für die Stratigraphie des Harburger Diluviums wichtige Ergebnis gewonnen, dass der Geschiebemergel und gewisse ihn vertretende Sande mit Geschiebelehmresten ein interglaciales Torflager bedecken."[2])

[1]) Erläut. zu Geol. Karte von Preussen. Lief. 155. Blatt Harburg. 1910.

[2]) The "zahlreiche Bohrungen" cannot, from the context have been carried out on the small patch of ground embraced by the interglacial bog, but must have been made in the environs. These are, in the immediate vicinity of the bog, noted as consisting of "Schleppsand" above Diluvialsand, but west of there as "Schleppsand" above moraine clay.

At this time (1901—1910) it was very natural to advance the view here expressed by KOERT, that the stony, argillaceous strata consisted of moraine clay. But when we consider how thin the stratum here in question is (0.4 m at the outside), and that this is, moreover, only supposed to consist in part of moraine clay, there is no longer any reason to maintain KOERT's view. With our present knowledge of the fact that a stratum such as that here in question can naturally be regarded as a product of solifluction, there is no reason to consider any of the strata concerned as consisting of moraine clay. The stony, argillaceous strata with embedded streaks of peat may correspond entirely to the solifluction strata found in the marginal parts of the Jutland bogs, which not at all are of glacigenous origin. This view is supported by the evidence of the interglacial strata sequence at Fleestedt. This terminates at the top with the customary fir horizon forming the transition to the deposits of the later subarctic period. In the transition from the plant-bearing to the mineral strata, there is no trace of any ice erosion, as we should have expected if the land surface of the site, which slopes towards the east, had been formed by the inland ice from the eastward after the formation of the plant-bearing strata in question. The site must therefore be regarded as not having been covered by inland ice in the last glacial period.

We have, then, as already mentioned, in the line Herning — Brörup — Hamburg — Lauenburg — Römstedt, a means of determining, by the aid of the interglacial bogs and their stratification, the maximum limit for the extent of the inland ice in the last glacial period. In the landscape outside the limit of this glaciation, the details of the young-glacial accumulation forms have been effaced by the subaërial denudation and erosion to which the land surface was exposed.[1]) The projecting hills and slopes were thus flattened down, the enclosed hollows more or less filled up, levelled and obliterated, in some cases even to such a degree that we find, on the site of the original depressions, flat valley-slopes (Emmerlev Cliff, Dalager Nygaard, Fleestedt). The levelling which has taken place in the form of denudation owing to solifluction, has been especially powerful in those areas where the strata were comparatively argillaceous and impervious to water, so that the could easily attain the degree of plasticity which would, under arctic condi-

[1]) J. STOLLER, in his Geol. Führer durch die Lüneburger Heide p. 29, writes, apropos Lindenberg, 4 km SW of Bevensen: "Man geniesst hier auf einen wunderbaren Rundblick über den ganzen Reichtum der Oberflächenformen den eine jungdiluviale Morainenlandschaft aufzuweisen hat.“ The map hovever, gives the impression of conformity in the course of the curves, such as produced by powerful subaërial forces, a conformity which hardly is characteristic of the typical young-glacial moraine landscape.

tions, lead to solifluction. As far as we can judge from the conditions in the vicinity of the Jutland bogs of the last interglacial period, this comprehensive solifluction can hardly have occasioned any great and general reduction in the average height of the landscape concerned. The primary effect of the solifluction was a levelling of the landscape, the relatively higher parts being lowered and the lower parts raised, so that the differences of level which existed in the original young-glacial landscape have been obliterated or reduced. The extent of this levelling is perhaps most distinctly apparent from the fact that all the small but pronounced irregularities which a young-glacial landscape can exhibit, and which find expression in the more or less irregular and much meandrous course of the contour lines, can be altogether effaced in a landscape which has been subjected to thorough denudation, and the contour lines exhibit a striking degree of conformity, very unlike that which marks the typical young-glacial landscape. This levelling of minor landmarks, and obliteration of the highly differentiated character of the young-glacial landscape, is one of the most characteristic features in the highland of south-west Jutland and also in the Lüneburger Heide. At several places in south-western Jutland we find features of the landscape forming a perfect counterpart to those in the country near Römstedt SE of Lüneburg.

Among the most characteristic features of the young-glacial landscape is the great number of enclosed hollows in the ground. In the levelled landscape, these enclosed basins are in many places almost entirely lacking. Sites which in the interglacial period appeared as lake and bogs have become partly filled with plant-bearing material, mud and peat. In the subsequent glacial period, when the landscape formed a periglacial area, the hollows were further filled up by arctic solifluction and the accompanying deposition of washed-down material. This process we may suppose, as already mentioned, to have been more particulary active in regions with relatively high clay content in the soil. On the other hand, in relatively high districts with sandy or gravelly soil, through which the water would pass more readily, and with the ground-water level deeper down, there would not be the same facilities for the formation of lakes and bogs in the interglacial period. In the subsequent glacial period, the more pronounced downward draining would perhaps also serve to hinder the filling up of hollows to the same extent as in more argillaceous soils, where the surface water was less easily absorbed. We must regard this a the explanation of the numerous pronounced depressions in the sandy country of western Jutland, which present no indication whatever of any interglacial bog formation having taken place there, (see p. 253 f.). Neither in the interglacial nor in the subsequent glacial period where there the requisite conditions for the filling up and levelling of these pits in the ground.

Precisely similar features were noted in the course of our investigations in compagny with K. von Bülow in the spring of 1927 in the Lüneburger Heide. The map for Unterlüss (Messtischblatt Nr. 1604) shows close on 20 enclosed hollows, one with a depth of over 10 m, the majority being only 2—5 m deep. The diameter varies between abt. 50 and abt. 200 m. In connection with our visit to the kieselgur quarries at Ober Ohe and Neu-Ohe near Unterlüss, we made experimental borings in three of these enclosed but perfectly dry-bottomed basins near Unterlüss, viz. two of them 0.6 and 1 km respectively SE of the town, and the third 2 km east of it. Diggings and borings with the spiral auger were carried to depths of 4.95, 4.00 and 3.10 m respectively in the three basins, but without finding anything beyond yellow sand. The upper part of the sand contained a number of stones, some of which were sand-worn or polished; the lower portion was almost devoid of stones. There is every reason to believe that investigation of the other basins in this relatively high and very sandy, dry area would be similary fruitless as regards any finds of interglacial freshwater deposits. The position in this respect may probably be taken as altogether parallel to that of the many sites in western Jutland where such deposits have been sought for in vain. If then, it is desired to proceed further on the lines of the systematic search for and investigation of bogs of the Brörup type, which we have carried out in Jutland (and in the Lüneburger Heide), hollows and landscapes of the type mentioned should be avoided, and the bogs sought for preferably in more clayey regions, where there is far more prospect of arriving at positive results. The visible basins here are rather shallow, and rarely of the funnel-shaped type characteristic of many of the empty hollows in the sandy country.

## Stratification of Interglacial Deposits from the Penultimate Glacial Period.

The three interglacial deposits from the penultimate glacial period in south-west Jutland which have been investigated and described in previous sections, viz. Harreskov (p. 183), Rind (p. 180) and Starup (p. 187), all differ in stratigraphical respects. They therefore present, when taken together, a good foundation for comparison with corresponding deposits in the Lüneburger Heide.

The deposit at Harreskov, 4 km E of Kibæk, appears in a valley, but extends into the adjacent glacial highland, where it is covered partly by diluvial sand and partly by moraine clay (see

Pls. XXI and XXII). The surface of the landscape above the deposit is of a remarkable, pitted character, the origin of which has not yet been explained. The stratigraphical position of the beds shows that they are older than the surrounding glacial highland, and must date from the penultimate interglacial period, since the ice-cap of the last glacial period did not extent as far as here.

The same applies to the interglacial deposit at Rind, 5 km S of Herning. The marl layer here presents a very uneven surface and is covered by diluvial sand and gravel. The surrounding land is a plateau, and the strata of sand and gravel which crop out on it are entirely of glacial origin, and cannot, from their position relative to Herning, be younger than the penultimate glacial period.

The interglacial deposits at Harreskov and Rind are covered by moraine clay or by sand and gravel, which must have been deposited in direct connection with the ice-sheet of the penultimate glacial period; the corresponding beds at Starup (21 km E of Varde), on the other hand, are covered directly by late glacial melting water sand from the close of the last glaciation. We cannot therefore conclude, from the age of the covering stratum, that the interglacial calcareous mud here dates from the penultimate interglacial period. This is however, apparent from the fact that it forms a close continuation of the diluvial clay which appears in the surrounding highland as and extensive horizon, covered by moraine clay, sand and gravel from the penultimate ice-sheet.[1]) There is on the contrary, a discordance between the calcareous mud and the covering sand. The late glacial melting water streams which deposited this sand, has probably worn away the upper strata of the interglacial mud deposit, possibly together with an earlier covering of glacial material from the penultimate glacial period. The absence of any marked *Picea* and *Pinus* horizon in the upper part of the calcareous mud might suggest that such erosion had taken place (see p. 193).

Turning from Jutland to the Lüneburger Heide, we find, in several places, deposits of fresh-water lime and diatomaceous earth (Kieselgur) the stratigraphical position of which corresponds to that of Jutland deposits just mentioned. They occur in the glacial highlands, and are entirely covered by diluvial sand and moraine clay, just in the same way as the other diluvial deposits older than the youngest glacial strata of the surrounding country. We find interglacial beds with much disturbed stratification, and other evidences of ice pressure and interferences to which they have been exposed. Or we may find deposits lying, it is true, in what are present valleys, but where the thickness and depth

1) Cf. p. 199.

of the strata, or flakes embedded in the moraine clay of the adjacent highlands, show that the interglacial strata are older than the surface strata of the highland themselves. The stratigraphical conditions under which these interglacial deposits occur are therefore very different from those of the interglacial bogs at Römstedt and Fleestedt.

In the following pages, mention will be made of the stratigraphical positions of some of the interglacial deposits, taking for consideration only those where we have, by personal investigation, studied the occurrences in question and their surroundings.

West of Westerweyhe[1]), 5 km NW of Ülzen, there are large excavations (see Fig. 31), now abandoned, in interglacial fresh-water lime. The deposit extends from N—S for abt. 500 m, and from W—E for abt. 300 m. The ground has a gradient of 1 : 50, sloping down to the south towards the upper end of a small erosion valley, which has its outflow towards Ilmenau River on the east. The marl is covered by diluvial sand up to 8 m thick, this being for the most part stratified and containing but few stones, and these are only small. The upper part of the sand is moraine sand, and contains a number of stones up to the size of a head. The upper surface of the lime bed is very uneven, with a difference of level amounting to as much as 2 m and cauldron-shaped depressions up to 3 m deep have been found in the lime, filled with gravel and ooze. The stratum itself has been up to 10 m thick.

In the Melzinger Heide (Fig. 31), 1 km SW of these pits, there are old excavations where interglacial fresh-water lime has been found, under precisely similar stratigraphical conditions. The spot lies on the gently sloping plateau, near one of its summits. On the surface of the ground in the immediate in vicinity there are many stones, a cubic feet in bulk, lying about, and several with a diameter of 50—50 cm. In the Ülsener Stadtforst, 3 km NW of Ülzen, S of Westerweyhe, there is a lime deposit of the same type with the same stratigraphical features. We find here, in parts, between the fresh-water lime and the superimposed diluvial sand, a thin bank of moraine marl.[2]) As will be seen from the accompanying map, the contours of the landscape are very much levelled, with the conformity characteristic of an old glacial landscape. But the occurrence of the lime is not associated with such basins in the landscape as for instance the bogs at Römstedt. The stratigraphical positions of these bogs on the one hand, and of lime beds at Westerweyhe and Melzinger Heide on the other, are decidedly different, and argue

[1]) J. Stoller: Geolog. Führer durch die Lüneburger Heide. 1918, p. 57.

[2]) G. Berendt: Über Riesentöpfe und ihre allgemeine Verbreitung in Norddeutschland. Zeitschr. d. Deutschen Geol. Ges. 1880.

Reichsamt fur Landesaufnahme.

Ausschnitt aus den Meßtischblätt. Nr. 1461/62, 1534/35.


Maßstab 1 : 25 000

Fig. 31. The Westerweyhe district with the Melzinger Heide. Contour interval for the fully drawn curves = 5 m.

strongly against the supposition that the plant-bearing strata of the two regions should date from the same interglacial period.

Of the many other deposits of interglacial fresh-water lime we mention two, where the strata occur at the bottom of alluvial river beds, to wit those through which now flow the Schwienau at Wriedel[1]) 18 km NNW of Ülzen and the Gerdau at Eimke[2]) 15 km W of Ülzen.

In the Schwienau valley S of Wriedel, fresh-water lime occurs in many places. In the middle of the valley, 1400 m SE of Wriedel, an experimental boring was carried down to a depth of 28 m, without getting through the interglacial marl. In the Gerdau valley, the interglacial lime deposits occur along a range from 14—1800 m NE of Eimke. That the present strata at this spot are only the remains of a larger deposit is evident from the fact that we find, both NE and NW of Eimke, moraine clay with embedded flakes (Schollen) of fresh-water lime of the same character as the other. A single piece of these found NW of Eimke measured 4 × 10 m in horizontal extent. The lime strata are thus older than the last glaciation here.

Far to the west of here, viz. at Walsrode, midway between Bremen and Ülzen, lies the classical locality for interglacial fresh-water deposits, Honerdingen. The locality is immediately south of the railway, 2.5 km NE of Walsrode, in a shallow depression with outflow through a ravine towards the north, to the valley of the river Böhme, 100 m N of the railway line. The height of the surface above sea level at the interglacial deposit is 42—45 m, that of the valley of the Böhme here being 33 m. The depression named is intersected by a watershed 400 m south of the railway, and cannot be regarded as having originated by any late-glacial erosion (in relation to the inland ice last covering the site). A profile taken in 1923 showed, on the other hand, that the depression was probably partly filled up with sand in this late-glacial period.

According to this profile, and some borings made previously, on the eastern side of the hollow, the interglacial lime beds here slope from SW to NE. The thickness of the strata increases in the same direction. Quite close to the railway, 12 m of marl was found, with 11 m of sand above; at the SW end of the 120 m long profile the lime tinned out at a depth of abt. 3 m below the surface. Throughout the whole extent of the profile, the lime stratum was covered by a layer of peat about a metre thick. Above this is stratified sand, finely

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1) H. Monke und J. Stoller: Erläut. z. Geol. Karte v. Preussen, Lief. 188, Bl. Wriedel. 1912.

2) H. Monke und J. Stoller: Erläut. z. Geol. Karte v. Preussen, Lief. 188, Bl. Eimke. 1913.

grained and with very few stones, the strata sloping as much as 45° toward the E, i. e. obliquely in towards the highlands. These sloping sand beds are covered by abt. 1 m gravelly material with stones up to 2 dcm, and on the surface of the uncultivated ground close by a few large stones up to 1 m diameter were lying about. On the extreme NE of the profile was found, at the top, horizontally stratified

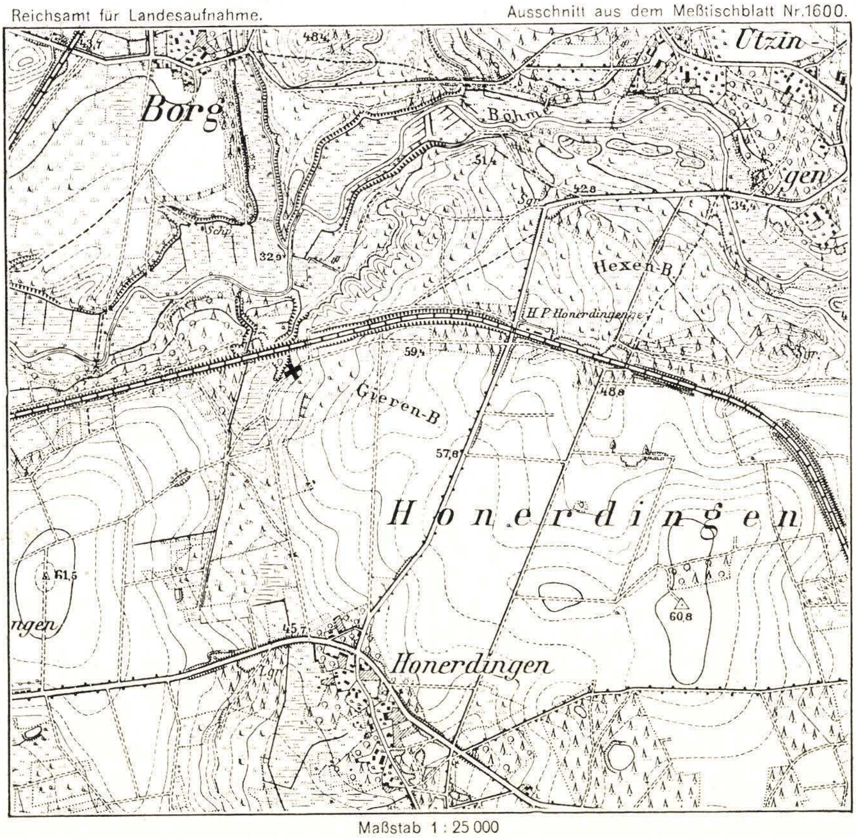


Fig. 32. The district North of Honerdingen. Position of the interglacial deposit marked by ×. Contour interval for the fully drawn curves = 5 m.

sand (Talsand), which, as the filling of a basin, was bedded discordantly on the sloping strata of fluvioglacial sand.

This fine-grained fluvioglacial sand is very much like the almost stoneless sand so commonly found in the hills of the Lüneburger Heide, and must be regarded as belonging to the upper glacial strata of the highlands. The oblique position of the strata of this sand shows that it has been exposed to disturbance, probably due to the passage of ice across the site after is was deposited. The subjacent interglacial strata must date from the previous, i. e. the penultimate interglacial period.

At Nedden-Averbergen, 16 km W of Walsrode, in a valley W of that town, there are extensive strata of interglacial fresh-water lime, covered by up to 3 m of sand or even more. The lime, which attains a thickness of several metres, lies evidently in small, separate basins, of up to at least 2—300 m diameter. In the marl pit at Lehringen, SE of Nedden Averbergen (according to verbal communication from the teacher Mr. HOLSTE of Nedden-Averbergen) occur below the lime a layer of peat 25 cm thick, with tree stumps, bedded on sand. The lake formation must thus here have opened with a swamp formation.

In a tract extending in a curve 50 km long from Suderburg (on the railway line Lüneburg—Celle) S of Ülzen, via Ohe and Munster to Luhetal (between Lüneburg and Soltau) we find the other type of interglacial lake deposit, the kieselgur, which is so abundant in the Lüneburger Heide (cf. Fig. 30). The localities lie in that part of the Lüneburger Heide which has on the whole the greatest heights, and which includes the watershed between the lateral tributaries of the Elbe and the Aller.

At Ober Ohe, Neu-Ohe and Wiechel, 6 km NW of Unterlüss, there is one of the largest known collective areas for kieselgur. The tract in question extends to abt. 4 km from NE—SW, and is about 1 km across. The kieselgur, which is up to 13 m thick, or more, is covered throughout by stratified sand, likewise up to 13 m thick. The lovest part of the sand has no stones, or very few; the upper part contains stones or gravel beds, and exhibits a transition to the moraine sand. Between Neu-Ohe and Wiechel also, it is said, moraine clay has in one place been found above the kieselgur, and on the fields beside the pits, large stones are found in several places, all showing that the area must have been covered with ice after the kieselgur was deposited.

The deposit lies east of the broad, extramarginal, glacial valley of Örtzetal, in a hollow of the highlands through which runs the little stream of the Sothrieth with is accompanying alluvial valley and adjacent "Talsand" surface. Ober Ohe lies north of the Sothrieth, Neu-Ohe and Wiechel lie sout of it.

The stratification of the kieselgur and of the covering sand strata take very different forms. In the upper part of the kieselgur we may find an alternation between strata of sand and of kieselgur, lying undisturbed. The covering strata of stoneless sand, which attain thicknesses of over 10 m, can run quite concordantly above these alternating layers, so that the sand must evidently have been deposited without any previous erosion or other disturbance of the strata. In other places we find that the strata have been exposed to powerful erosion or violent folding which can only be supposed to have been produced by the pressure of inland ice passing over the ground.

The stratification produced by these disturbances appears in very different forms, and is appearently very complicated. This was particulary noticeable in the spring of 1927, in the southern pits at Neu-Ohe, as will be seen from the Plates XXIX and XXX, cf. Fig. 29, p. 298.

In the pits at Neu-Ohe I, and in one pit west of there, belonging to Wiechel, it is a noticeable feature that long trough-like depressions ("Täler") run from NE to SW through the upper part of the kieselgur, with interjacent projecting ridges ("Köpfe") of kieselgur. It is natural to regard these elongated hollows as due to water erosion, and this is undoubtedly also the case with many of them, e. g. that running roughly parallel with the SSE wall of the western pit, as shown in Pl. XXIX. This is especially conspicuous in the western part of the wall. Below a layer of dark kieselgur there is another with beds of sand, exhibiting in one place a decided fold, as shown in the figure. Before the basin sand (Beckensand) on the left of this whirl was deposited, there must have been an erosion, cutting away more or less considerable quantities of the kieselgur. Similar features are seen in the eastern part of the profile. On the extreme left of the figure however, we find folded strata of kieselgur with sand strata against which the basin sand is bedded apparently without any considerable erosion of these strata (Pl. XXVI, 2). The folding of the kieselgur strata must have taken place before the erosion in question, i. e. before the deposition of the stoneless basin sand. It is otherwise with the relative ages of the bassin sand and the folds in the eastern of the two pits (Pl. XXX). Here the covering sand, together with the kieselgur itself, has been much folded upwards, so that the profile, in places, looks as if there were loose fragments of kieselgur high up in the sand, whereas in reality, these are kieselgur strata which have been pressed violently upward. In the figure these upturned strata of kieselgur and sand were very conspicuous. The folds here are thus more recent than the deposits of stoneless basin sand. The "Täler" and "Köpfe" running NE—SW must here, it would seem, be taken as connected with the folds, and not due to water erosion.

Whatever may have been the course of these processes: the production of the long "Täler" and interjacent "Köpfe", the water erosion, the deposition of the stoneless sand, and the considerable folds in the strata, it is evident that they must have taken place in connection with the passage of inland ice over the site after the formation of the interglacial strata. The actual beds of stratified, stony sand and gravel, or of moraine sand, above the stoneless sand strata are on the whole of but slight thickness, a couple of metres at the outside; the profiles in the western pit show that they may even be lacking altogether, the present surface being solely and entirely due to denudation. We have thus no decisive factors here for determining the extent of the inland ice in the glacial period following on the interglacial of the kieselgur formation.

J. STOLLER,[1]) in various works on the Lüneburger Heide and the geological features of the kieselgur, has, on the basis of his investigations in this region, pointed out that the last ice-cover of the Lüneburger Heide had its extreme limit in the vicinity of Aller. This view agrees well with the results arrived at by investigation of the stone-content of the upper glacial strata, with regard to the direction of movement of the inland ice in these parts.[2]) That this limit of glaciation does not — as STOLLER considers — indicate the limit of the last Scandinavian glaciation, but that of the last but one, does not in itself affect this fact. As will presumably be apparent from the present work (cf. p. 305 f.), the inland ice of the last glacial period did not extend so far to the SW as the Lüneburger Heide. Nor does there seem much likelihood that the inland ice which last covered the Lüneburger Heide (where older interglacial strata so frequently appear) should be identical with that which extended over the western parts of Germany and Holland, having its extreme limit here in the vicinity of the Rhine. The view that the Aller (and the Weser) should be taken as a kind of boundary rivers for an independent glaciation seems nearer reality.

At a distance of 17 km NW of Ohe, between Munster and Breloh (cf. Fig. 30), there is another area with numerous deposits of kieselgur, some at a considerable depth below the surface. Ten kilometres further to the NNW again, between Bispingen and Hützel, we find the westernmost of a series of deposits cropping out along a range of some 8 km between Bispingen and Schwindebeck, along the upper portion of the Luhetal; this valley is here cut down to a depth of 30—40 m below the level of the adjacent highlands.

The kieselgur at Luhe lies in separate basins, and attains a thickness of up to 10 m; it shows fewer signs of disturbance, than the strata at Ohe. It is covered with sand, some of it stoneless (marlsand) and stoneless clay marl, partly fluvioglacial sand with false

[1]) J. STOLLER: Die Landschaftsformen der südlichen Lüneburger Heide. 2. Jahresber. d. Niedersächs. geol. Ver. Hann. 1909. — Spuren des diluvialen Menschen in der Lüneburger Heide. Jahrb. Kgl. Pr. Geol. L. f. 1909. — Blatt Unterlüss, Lief. 188, 1912. — Blatt Eschede, Lief. 191, 1915. — Geol. Führer durch die Lüneburger Heide 1918. — Die Kieselgur ihre Entstehung und ihre Lagerstätten. Festschrift, Vereinigte Deutsche Kieselgurwerke. Hannover. 1925.

[2]) V. MILTHERS: Ledeblokke i de skand. Nedisningers sydvestlige Grænseegne (Resumé in der deutscher Sprache: Leitgeschiebe in den südwestlichen Grenzgebieten der skandinavischen Vereisungen). Dansk. geol. Foren. 1913.

bedding. In the pit at Schwindebeck, we find above the kieselgur and a thin layer of stoneless clay marl, also a stratum of moraine clay 1—1.3 m thick. The sand horizon to which the marl-sand above the kieselgur belongs is, according to J. STOLLER, at Hützel 20—30 m thick. It is not quite clear whether the deposits of kieselgur here are restricted to the Luhetal, or whether such may also be found in the adjacent highlands, At any rate, the stratification shows that the deposits must be older than the uppermost glacial strata of the surrounding country, just as with the kieselgur in the southern parts of the Lüneburger Heide.

Summing up what has been set fort in the foregoing as to deposits of interglacial fresh-water lime and kieselgur in the Lüneburger Heide, we find that they have this in common: the belong to an interglacial period preceding the last ice-covering of this region. The fact that the inland ice did not extend to this region in the last glacial period proves conclusively that the deposits must belong to the penultimate, and not to the last, interglacial period. KARL GRIPP,[1]) who has with great acumen emphasised the morphological landscape boundary as the limit of last glaciation, has not, strangely enough, drawn from this the natural conclusion as to the interglacial deposits of the Lüneburger Heide here referred to, viz. that they must belong to an interglacial period earlier than that of the bogs of the Brörup type. The same may be noted in W. WOLFF's "Ueber einen Interglazialtorf aus Holstein"[2]), where he compares the deposits of kieselgur at Luhetal, the lime formations at Honerdingen and other places in Hannover, with the interglacial deposits of the Brörup type in Jutland, at Nienjahn near Hamburg etc., despite the fact that he has himself, in earlier works,[3]) expressly separated them. GRIPP lays particular stress on the fact that many of the deposits occur in connection with valleys, but he has not devoted the same attention to the relative ages of the deposits and the valleys in question. The occurrence of an interglacial deposit in a valley does not necessarily imply that the deposit is of more recent date than the valley; it may also be due to the fact that the valley has been worn down by erosion to, or into, the interglacial strata. These may thus very well be older than the valley in the bottom or sides of which they occur, and older than the highland adjacent. This is actually the case with all the deposits of fresh-water lime and kieselgur here dealt with in the area between Ülzen, Unterlüss,

1) KARL GRIPP: Über die aüsserste Grenze der letzten Vereisung in Nordwest-Deutschland. Mitt. d. Geogr. Ges. in Hamburg 1924.

2) Zeitschr. d. Deutschen Geol. Ges. 1922. Monatsber.

3) Congrès géologique internationale. Canada 1913.

Luhetal and Walsrode. They belong therefore from their stratification, to the interglacial period prior to the last covering of the area with inland ice, i. e. the penultimate interglacial period. How far this age determination may be extended to cover all the other lime deposits in the Lüneburger Heide must be left undecided; it seems, however, a priori, likely enough.

The following Table shows schematically the interglacial periods to which the deposits here dealt with have been ascribed (cf. p. 276). Save for the deposits at the brickworks north of Lauenburg, all have in course of time come to be regarded as belonging to the second (or last) interglacial period. The Rixdorf horizon has always maintained a definite

| | A[1]) | | | B | |
|---|---|---|---|---|---|
| | Interglacial period | | | Interglacial period | |
| Paludina horizon near Berlin | I | ...... | ...... | I | ...... |
| Tegelenstufe | I | ...... | ...... | I | ...... |
| Rixdorf horizon | ...... | II? | ...... | ...... | II |
| Kieselgur at Ober Ohe etc. | ...... | II | ...... | I | ...... |
| — in Luhetal | ...... | II | ...... | I | ...... |
| Fresh-water lime near Westerweyhe etc. | ...... | II | ...... | I | ...... |
| Honerdingen | ...... | II | ...... | I | ...... |
| Glinde (Ütersen) | ...... | II | ...... | I | ...... |
| Lauenburg Brickworks | ...... | II | ...... | I | ...... |
| Römstedt | ...... | ...... | III | ...... | II |
| Kuhgrund | ...... | ...... | III | ...... | II |
| Fleestedt | ...... | ...... | III | ...... | II |
| Winterhude and other bogs near Hamburg | ...... | ...... | III | ...... | II |
| Schulau | ...... | ...... | III | ...... | II |
| Westerland (Sylt) | ...... | ...... | III | ...... | II |
| Brörup bogs | ...... | ...... | III | ...... | II |

position in the arrangement as belonging to Interglacial II. The deeper *Paludina*-horizon near Berlin has represented Interglacial I, to which also the deposits at Tegelen and other places in the neighbourhood of Nijmegen (Nimwegen) have been attributed as certain. The strata of kieselgur and fresh-water lime in the Lüneburger Heide have in course of time come to be regarded as belonging to Interglacial II, like the Rixdorf Horizon, partly on account of their fossil content,

1) During recent years, various North German geologists dealing with the quaternary period have also put forward suggestion as to the existence of 4 glacial periods. These considerations have, however, been based almost exclusively on features well known already for some time past, e. g. the conditions observed at Rabutz, east of Halle a/S, and no new finds or other essentially new material have been produced to throw light on the question.

partly from their stratification. To this also, all the other younger interglacial deposits have been ascribed. But since our investigations here show, that the interglacial fresh-water lime and kieselgur of the Lüneburger Heide cannot date from the last glacial period in northern Europe, it is obvious that an alteration must be made in the placing of the interglacial horizons here referred to. As far as can be judged, there is the choice of two alternatives, noted in the table as A and B. We shall not here discuss which seems the more likely in each case.

# VI. Character of the Interglacial Fresh-water Deposits.

Since 1898, when N. HARTZ commenced his investigations of the interglacial flora of Denmark, a considerable number of interglacial fresh-water deposits have been brought to light. They are found more particulary in Jutland, for in the eastern parts of Denmark the erosive action of the last inland ice has almost entirely obliterated the fresh-water deposits of the interglacial periods.

East of the Little Belt, they are found more especially in conjunction with the dislocated Eem strata[1]) of the last interglacial period, viz. in Ristinge Cliff on the island of Langeland, Vejsnæs Nakke on Ærö, Horneland in Fyn; here also belong the mud beds in Stensigmose Cliff at Broager (cf. p. 177 f.). We may further mention a mud bed in the dislocated diluvium at the Cliff of Möen[2]) and finally, some formations which have however, been generally regarded as preglacial, to wit, the plant-bearing mud- and clay blocks in the lower moraine in the free port of Copenhagen and in Valby Hill in that town,[3]) the *Corbicula* stratum at Förslevgaard, South Sealand,[4]) and the *Nematurella* stratum at Gudbjerg,[5]) East Funen. The mud blocks and the *Nematurella* clay however may perhaps date from the penultimate interglacial period.[6]) In all these deposits, animal and vegetable remains are found in their primary position, though the actual deposits themselves are in most cases dislocated, differing in this respect from the amber-pine-beds in which the vegetable remains

1) VICTOR MADSEN, V. NORDMANN og N. HARTZ: Eem-Zonerne. D. G. U. II. R. No. 17. 1908.

2) N. HARTZ: Bidrag . . . D. G. U. II. R. Nr. 20. 1909, p. 246.

3) V. MILTHERS: Nordöstsjællands Geologi. D. G. U. V. R. Nr. 3. 1922, p. 37 f. and p. 173.

4) A. C. JOHANSEN: Om den fossile kvartære Molluskfauna i Danmark . . . København 1904, p. 56. — V. NORDMANN: Danmark Pattedyr i Fortiden. D. G. U. III. R. Nr. 5. 1905, p. 112.

5) VICTOR MADSEN og V. NORDMANN: Det interglaciale Nematurella Ler ved Gudbjerg paa Fyn. Meddel. fra Dansk geol. Foren. Bd. 8. København 1901, p. 20. — A. C. JOHANSEN, l. c. p. 55.

6) KNUD JESSEN: Nematurella-Leret ved Gudbjerg og Gytjeblokkene i Köbenhavns Frihavn i pollenfloristisk Belysning. Meddel. fra Dansk geolog. Foren. Bd. 7. København 1927, p. 139 f.

lie in secondary or tertiary position. The flora in these is perhaps preglacial[1]); though it has — apart from a slight admixture of tertiary species — an interglacial appearance.

The interglacial fresh-water deposits of Jutland, with which we are here more especially concerned, consist in the great majority of cases of basin fillings, the deposits being in their primary position. Dislocation is doubtless restricted to such thin flakes of peat as have been found in moraine deposits, e. g. at Lyngs Odde[2]) and Silkeborg[3]); also for instance the deposits of diatomaceous earth and calcareous mud at Fredericia and Trælle[4]) and possibly a few more of the interglacial fresh-water deposits lying below the deposits of the last ice-sheet.

The interglacial fresh water deposits of Jutland are to be considered as bogs produced by overgrowing of lakes, or as lake deposits which have not attained the stage of peat formation. Bogs as one finds associated with the streams in the valleys and spring-bogs, are unknown. Such forms of bogs, not enclosed by an encircling basin wall, must be expected to have become entirely done away with the influence of water- and wind-erosion, together with solifluction in the last glacial period. Peat formation in the enclosed basins often terminated with the formation of a new lake in the basin, and the peat strata were thus protected against the erosive action of the wind.

Up to the present, only a comparatively small portion of the organogenic formations and other kind of basin-fillings known from the alluvium has been located in the Danish interglacial fresh-water deposits. One of the reasons for this has already been noted above, and in addition, the state of the samples of the interglacial beds does not always admit of so sure a diagnosis as in the case of the fresh-water alluvium. Referring to L. von Post's arrangement[5]) of the organogenic formations we may draw attention to the following:

## I. Sediments.

Profundal mud with its variants, clay-mud and fine detritus-mud have been found in many cases, especially at the base of a strata series. A great portion of the mud deposits from the interglacial lake at Herning come under this head. The clay-mud can appear in the form of a grey clay almost devoid of mud, and is then found either at the

1) V. Milthers, l. c.

2) N. Hartz: Bidrag ... D. G. U. II. R. No. 20. 1909, p. 236.

3) — — — — — — p. 238.

4) N. Hartz og E. Østrup: Danske Diatoméjord-Aflejringer. D. G. U. II. R. No. 9. 1899, p. 14 og 19.

5) L. von Post: Das genetische System der organogenen Bildungen Schwedens. Comité internat. de Pédologie 1924.. IV. Commission Nr. 22, p. 293 ff. Helsingfors.

bottom of the strata, at Herning, Brörup Hotel Bog, Starup etc.; or it may for instance form the lover part of the Middle Bed in Herning interglacial lake. Such clay is occasionally found also in the upper part of the profile (Over Gestrup etc.).

Calcareous Mud. Dark-coloured, slightly greenish, calcareous muds have been found in some localities at the bottom of the strata series in bogs from the last interglacial period (the bogs at Rodebæk). Light-coloured, highly calcareous mud ("lake lime") is found in the lake deposits at Rind, Harreskov and Starup, Westerweyhe, Honerdingen, Nedden-Averbergen etc., which date from the penultimate interglacial period; also from several deposits covered by deposits of the last ice-sheet (Hollerup, Vellev, Hörup, Lövskal II, Egtved, Trælle).

Ochreous mud (siderite), reddish brown to yellowich red, with up to 69 % of $Fe_2O_3$ has been found as a sediment only at Løvskal I.

Diatomaceus mud, diatomaceous earth (Kieselgur). The calcareous muds often contain numerous diatoms (e. g. Harreskov, Starup), and the sedimentation has in such cases changed its character, producing pure, non-calcareous diatomaceous muds. This is best seen among the lake deposits covered by the latest diluvium (Hollerup, Hörup, Vellev, Frausing, Trælle, Fredericia), but is known also from the penultimate interglacial period (Lüneburger Heide). At Egtved, the diatomaceos earth appears to have been formed by decalcification of the calcareous mud rich in diatoms.

The Litoral mud or Coarse Detritus mud is the commonest type of sediment in the bogs of the last interglacial period; there is often a considerable amount of colloidal formations in the mass ("Dy"). The strata of detritus mud are, as regards their upper parts, often developed as "drift mud" (Schwemmtorf).

Sand (Schwemmsand). The "drift mud" is often more or less mixed with sand (the *Trapa* bed at Herning, p. 18) and may merge into pure sand with no vegetable content. This formation generally completes the sedimentation of the basins (Rodebæk I, Fövling, Agerskov); or the sand may exhibit a more or less rich admixture of clay (Over Gestrup, Herning).

## II. Sedentary Formations (Peat).

### The Swamp Peat-Series. (Die Sumpftorfreihe).

*Thelypteris*-Peat is locally developed at Tuesböl[1]) and Vejen.

*Hypnum* Peat etc. (Braunmoostorf), with transition to magnocaricetum peat has been found at several places in thin layers in the quaking bog formations with which the small lakes of the last inter-

1) N. HARTZ: Bidrag ... D. G. U. II. R. No. 20. 1909, p. 169, 170.

glacial period were overgrown. *Hypnum-praelongum* peat[1]) is recorded from Tuesböl, *Hypnum aduncum* peat with *Phragmites communis, Carex lasiocarpa* and *pseudocyperus*, *Dryopteris thelypteris* etc. at Skovlyst[2]) and *Hypnum aduncum* peat with a similar community at Kollund (p. 218).

Forest-Swamp Peat. The *Alnetum* peat (Erlenbruchwaldtorf) constitutes the lower portion of the peat at Rodebæk III (p. 147).

The *Sphagnum*-Peat series. (Die Moortorfreihe).

*Sphagno-Caricetum* Peat was undoubtedly often developed as facies by the overgrowing of the lakes.

*Sphagnum* Peat, stratified, and with a rich admixture of *Eriophorum vaginatum*, is of frequent occurrence. *Sphagnum* peat is generally found in the form of dwarf-bush peat with remains of *Calluna vulgaris, Empetrum nigrum, Andromeda polifolia, Betula nana.*

*Betuleto-Sphagnetum* Peat is noted e. g. from Rodebæk III (p. 147) and from Agerskov (p. 173).

*Betuleto-Piceto-Pinetum* Peat has been formed e. g. at Rodebæk I (Bed H).

*Calluna-Turf* (Heidemoder) has been found at Nörbölling (p. 74, Bed J).

In the fresh-water interglacial deposits of Jutland and North Germany, we can distinguish between two principal types[3]) (connected with transition-stages) representing two different modes of filling up the basins concerned.

1) Deposits of dark, humous, generally non-calcareous mud, often with oligotrophic peat strata above.

2) Calcareous, light-coloured muds (lake lime, marl), sometimes with diatomaceous earth above, or diatomaceous earth constituts the whole deposit.

To the former group belong nearly all the deposits from the last interglacial period within the area in question. The basins here are generally small, and the water would thus more easily develop humic acid than in larger lakes, the deposit of lime being thus restained or prevented[4]). The great Herning lake, however, belongs to this group, and on the other hand, we find that in small basins like the three

[1]) N. HARTZ, 1909, p. 163, 170. There must be an error here, as *H. praelongum* (L) (cf. l. c. p. 229) = *Eurhynchium praelongum* (L) HOLK. does not form peat. Cf. C. JENSEN: Danmarks Mosser, II., p. 164. København. 1923.

[2]) N. HARTZ, 1909, p. 178.

[3]) Fresh-water strata formed in association with marine deposits are here disregarded.

[4]) C. WESENBERG-LUND: Studier over Sökalk, Bönnemalm og Sögytje i danske Indsöer. Meddel. fra Dansk geol. Forening, No. 7, p. 18. Köbenhavn. 1901.

at Rodebæk, calcareous, though dark, mud could be deposited throughout a lengthy period; in the considerable interglacial basin at the Winterhude Stadtpark, Hamburg, lake lime (Seekalk) was deposited before the peat formation took place.[1])

In contrast to this we find nearly all the older interglacial deposits here under consideration in the second group. Thus the calcareous muds at Rind, Harreskov and Starup in Jutland, Honerdingen, Nedden Averbergen, Westerweyhe in the Lüneburger Heide; the kieselgur formations at Ober Ohe, Neu-Ohe, Wiechel etc. and others, also in the Lüneburger Heide. At Honerdingen however, there is a layer of peat above the marl-layer, while at Harreskov we find dark, non-calcareous mud above and below the calcareous mud, and there is a thin layer of peat below the marl beds at Hörup and Nedden Averbergen (see p. 322). The calcareous muds at Harreskov and Starup are very rich in diatoms forming transition stages to true diatomaceous mud, and at the former locality, there is still preserved a little of a deposit of diatomaceous earth above the marl. At Steinbeck in Luhetal[2]) also, for instance and probably also at Hamerstorf near Suderburg[3]) in the Lüneburger Heide, calcareous mud is found below the diatomaceous earth (Kieselgur), and both diatomaceous calcareous mud and calcareous diatomaceous mud is known from this region.[4])

Considering the large number of fresh-water deposits from both interglacial periods known to us in Jutland and North-west Germany, this distribution of the two principal types of formation may seem remarkable. In particular it is surprising that among the numerous non-moraine-covered interglacial deposits outside the limits of last glaciation, no typical examples of the second type should be known.

Finally, looking at the interglacial fresh-water deposits situated east of the limit of the last ice-sheet, we find here both types of formation. Kollund, Loopstedt, Fahrenkrug etc. are rich in humic acid, only slightly calcareous or actually non-calcareous, whereas the deposits at Hörup, Hollerup, Vellev, Lövskal II, Trælle, Fredericia and Egtved consist of light-coloured strata of diatomaceous marl or non-calcareous diatomaceous earth. It would however, doubtless be premature, on these grounds alone, to attempt a distribution of these eastern formations between the two interglacial periods.

1) E. Horn: Die geolog. Aufschlüsse des Stadtparkes in Winterhude. Zeitschr. Deutsch. geolog. Gesell. Monatsber. Berlin 1912, p. 130.

2) Laufer: Jahrb. K. Preuss. Geolog. Landesanstalt. 1883.

3) J. Stoller: Festschr. Vereinigte Deutsche Kieselguhrwerke. Hannover 1925. Sonderabdruck p. 15.

4) B. Dammer: Über einige neue Fundpunkte interglazialer Ablagerungen in der Lüneburger Heide. Jahrb. K. Preuss. Geolog. Landesanstalt. Bd. XXVIII., p. 659 f. 1907.

An essential condition for the formation of diatomaceous mud is, according to WESENBERG-LUND (l. c. p. 119) that the lakes shall be deep, clear and cold; the bottom temperature must, even at the warmest season of the year, never exceed 7—8° C. It seems however necessary to assume that other factors have also to be considered, as the high diatom maxima in the plankton of the lakes did not occur until the later part of the interglacial period concerned. This question may by elucidated by the researches of G. LUNDQUIST and H. THOMASSON, who have studied corresponding profiles in the alluvium of southern Sweden[1]); they consider that the washing down of lime from the surrounding country is of the greatest importance to the nature of the sedimentation in a lake, and that the deposits of lime in the Swedish lakes were formed in the first part of the postglacial period, whereas the formation of diatomaceous ochre belongs to the subatlantic period, when the washing down of lime had ceased.

In the interglacial profiles where the relative ages of the calcareous mud on the one hand and the diatomaceous earth or other non-calcareous muds or peats on the other have been arrived at by pollen statistics, we find, in analogy with what has been stated above, that the sedimentation of the calcareous muds took place more especially during the mixed oak forest period (Zone *f*), while the diatomaceous earth-beds, as also the oligotrophic upper strata in the bogs, where the older strata are calcareous, date from the upper conifer-period (Zones *h* and *i*). First in an advanced period of the interglacial time concerned, when the climate had grown cooler and the washing down of lime in the basins had ceased, the conditions for the great diatom maxima in the lake plankton in Jutland was realized. The connection in time between the sedimentation of calcareous muds and the diatomaceous earth in NW Germany is not yet evident.

The peculiar feature noted at Harreskov and Hörup, of non-calcareous, or but slightly calcareous, humus-stained strata lying below the calcareous muds, and dating from the earlier conifer period, in the interglacial in question (cf. also Nedden-Averbergen) is known in but a few cases, not sufficient to warrant our considering it of general importance; it is evident however, that at these localities, the heavy washing down of the lime did not set in until the opening of the atlantic climate, answering to Zone *f*.

[1]) G. LUNDQUIST: Limnisk Diatoméockra. Sveriges geolog. Undersökning. Årsbok 17 (1923), No. 1. Stockholm 1924. Deutsche Zusammenfassung p. 17. — Utvecklingshistoriska insjöstudier i Sydsverige. Årsbok 18 (1924), No. 2. Stockh. 1925, p. 114. Deutsche Zusammenfassung, p. 125.

# VII. Floristic and Climatic Development in Jutland and North-west Germany during the Interglacial Period and the Paleolithic Chronology.

## Flora and Climate.

Having in the foregoing sections dealt with a series of interglacial deposits in Jutland and North-west Germany, with their distribution as regards the two interglacial periods, we will now endeavour to give a general survey of the floristic and climatic development indicated by a study of the fossil content of the deposits in question.

A survey of this nature should commence with the last interglacial period, as being the better known, not least in the region (Jutland) where these investigations first began. Our account of the development which has taken place will therefore be based primarily on the Danish deposits, synchronous formations in North-west Germany being kept in view throughout for purposes of comparison or reference.

### The last Interglacial Period.

In addition to deposits actually dating from the last interglacial period, we shall also include here deposits covered by material from the last ice-sheet, as these afford — apart from the question of age — together with the former an excellent basis for the consideration of an interglacial flora and its general development.

The entire fossil material procured from the interglacial freshwater deposits of Jutland is — subject to certain limitations — noted in the lists p. 220 f. Apart from animal and lower vegetable forms we have here 99 species of mosses and abt. 165 species of vascular plants. 40 % and abt. 30 % respectively of these two groups represent new acquisitions to the Danish interglacial flora since 1909. Particularly interesting among the finds of vascular plants since that date are those of *Acer campestre*, *Andromeda polifolia*, *Aldrovanda vesiculosa*, *Ceratophyllum submersum*, *Litorella uniflora*, *Myriophyllum alterniflorum*, *Najas flexilis*, *Rhyncospora alba* and *Trapa natans*.

A general view of the floristic and climatic development which took place in north-western Europe during the last interglacial period, as indicated by literature, and by the analyses given in the present work, may be summarised as in the table given below (p. 336). It will be seen that the lake deposits at Herning Brickworks alone embrace all the five stages of the interglacial period, whereas the remaining deposits cover only portions of more or less considerable extent.

## Stage I. Arctic and Subarctic Flora.

Only in some few parts of Jutland have arctic vegetable remains been found in clay or mud-like strata lying under temperate interglacial fresh-water deposits.[1]) Thus at Herning, Solsö and Ejstrup, from the last interglacial period, and Skovmöllen, near Kolding.[2]) The interglacial stratum in this last mentioned locality lies covered by the youngest diluvium, but may be synchronous with the corresponding strata at Herning. There is also a *Betula-nana* flora, which is presumably synchronous with the sub-arctic flora uppermost in the "arctic clay" at Herning (p. 20), viz. from Solsö, Dalager Nygaard, and Brörup Hotel Bog; cf. also the upper portion of the clay at Ringdal. The arctic flora from Herning and other localities is reckoned as belonging to the first of the floristic zones in the interglacial period, Zone *a*. and the sub-arctic flora Zone *b*. The most important elements in this arctic and sub-arctic flora are: *Arctostaphylus alpina*, *Betula nana*, *Dryas octopetala*, *Salix herbacea*, *S. phylicifolia*, *S. polaris*, *S. reticulata*, together with the mosses *Calliergon sarmentosum*, *Catoscopium nigritum*, *Dicranum congestum* and *Lescuraea Breidleri*, to which must be added a number of other species of more or less common northerly distribution, as for instance *Armeria vulgaris*, *Batrachium (cf. confervoides)*, *Hippuris vulgaris*, *Potamogeton perfoliatus*, *P. pusillus*, *Potentilla palustris*, *Amblystegium stellatum*, *Calliergon giganteum*, *C. Richardsonii*, *Hypnum exannulatum*, *H. revolvens*, *Swartzia montana* (see also flora lists p. 220 f.). Most of these species are known from the late glacial *Dryas* clay, which, since the first find of this flora by A. G. Nathorst, has been met with in numerous localities within the areas of Europe affected by the inland ice; they show that these areas were at that time marked by tundra-like conditions. Such

1) In the diluvial strata at Skærumhede, a considerable arctic flora was found together with thermophile species; this however, either in a secondary position in sand and clay or in the marine *Portlandia arctica* zone. D. G. U. II. R. No. 25, 1910, p. 93—109.

2) See p. 196 and D. G. U. II. R. No. 20, p. 233 ff. Only a thin stratum of mud was here found, containing *Salix polaris*, *Betula nana*, *B. alba* etc.

| Stages | Character of the Flora and the Strata | | Immigration and Extinction of some principal species | Zones | Climatic conditions Changes of Level | | Climate-Curve (cold) (warm) |
|---|---|---|---|---|---|---|---|
| V | Arctic Flora, not discovered. Clay with Sub-arctic Flora | Only known in Jutland | *Betula nana*-heaths, *B. pubescens*, Poor aquatic flora | *n* | The last Scandinavian ice sheet advancing | The Skærumhede series | |
| IV | The upper Mud and Peat beds with Temperate Flora | | *Betula pubescens, Pinus silvestris, Picea excelsa, Betula nana* | *m* | The ice-front again retreats | | July abt. 12° C |
| | | | Maximum of deciduous trees *Brasenia purpurea, Dulichium spathaceum, Trapa natans* | *l* | Temperate climate in Jutland | | July abt. 18° C. |
| III | Clay and Sand with Sub-artic Flora (The Middle Bed) | | *Betula nana*-heaths and sub-arctic swamps. Uppermost a little *Betula pub., Pinus silv., Picea excelsa* and *Juniperus communis*, Poor, northerly aquatic flora | *k* | Great advance of the ice-front on the Scandinavian Peninsula Sub-arctic climate in Jutland | | July abt. 12° C |
| II | The lower Mud and Peat beds with Temperate Flora | Forests mainly of — Conifers | *Pinus silv., Picea excelsa, Betula pubescens, Populus trem.* — *Betula nana* immigrates | *i* | Swamping of forest- and high-moors | | |
| | | | *Picea excelsa* dominant, *Pinus silv.* and *Betula pub.* more common, *Carpinus* disappears, *Dulichium spath.* and *Brasenia purp.* rare | *h* | Land probably rising. Climate of a continental character; temperature gradually decreasing | | |
| | | Deciduous trees | *Carpinus bet.* culminates, *Picea* often common; the mixed oak forest retreats | *g* | | | |
| | | | Mixed oak forest — *Alnus, Corylus, Quercus, Tilia* culminates. — *Carpinus bet.* and *Picea excelsa* immigrate. — *Pinus silv.* and *Betula pub.* retreat. — *Brasenia purpurea, Dulichium spathaceum, Trapa natans* | *f* | Eem subsidence. Atlantic climate Temperature optimum | | July abt. 18° C. |
| | | Conifers | *Pinus silv.* and *Ulmus cf. glabra* culminate. *Betula pub.* common. Thermophile aquatic plants immigrate | *e* | Cooler in the first time, gradually milder climate of continental type. The Eem fresh-water beds | | |
| | | | *Pinus silv.* and *Betula pub.* dominant, *Populus trem.* The species of the oak forest immigrate. Pollen of *Picea excelsa* rare in *c*, *d* and *e* | *d* | | | |
| | | | *Betula pubescens* and *Pinus silvestris. Betula nana* disappears | *c* | | | |
| I | Clay with { Sub-arctic Flora | | *Betula nana, Salix phylicifolia.* | *b* | Penultimate ice sheet melts away | | July abt. 12° C |
| | Arctic Flora | | *Dryas octopetala, Salix herbacea, S. reticulata* Arctic moss species | *a* | | | |

Development of the last Interglacial Period in Jutland and NW Germany. (Depth of sections does not correspond to duration of the stages indicated).

conditions also prevailed in Jutland at the commencement of the last interglacial period, and probably also at the same time in great parts of Central Europe, as several occurrences of diluvial arctic plant-bearing beds are known from those regions,[1]) though it has not always been possible to determine the age of the deposits in question.

## Stage II. The Lower Temperate Flora.

In the pollen diagrams covering this period we find the same constellations in the course of the curves, and since these constellations appear in a definite sequence, they may be taken as characteristic of a certain number of zones. In the present material, we can distinguish between 7 such zones, each corresponding to one particular stage in the development of the interglacial forest growth in Jutland and — as far as our material enables us to judge — also in North-west Germany. These zones are designated by the letters from *c—i.*

The present finds of macroscopic plant remains from the interglacial bogs afford support for such a division into zones; it would, however hardly be possible, on the basis of this material alone, to carry out the arrangement so completely for each individual profile as by means of the pollen analyses. This will be apparent from any consideration even of the most thorough investigations, as for instance those of M. BEYLE, J. STOLLER and C. A. WEBER.

Zone *c*. The interglacial Tundra vegetation gradually gave place to forests, in which *Betula pubescens* and *Pinus silvestris* probably constituted the principal elements: *Betula* pollen especially was here predominant, and is represented by up to 93 % of the total pollen and *Pinus* pollen up to 43 %. In addition to macroskopic remains of *Betula pubescens,* we find in this zone also some fruits of *Betula nana,* which here appears as a survivor from the tundra period. A number of aquatic plants were also found, especially *Batrachium aquatile (coll.), Hippuris vulgaris, Potamogeton filiformis, P. natans.*

In the Hörup interglacial, which, like the other deposits of its group (see p. 196) exhibits the same zone formation as those which can be referred with certainty to the last interglacial period, Zone *c* consists of a stratum of marsh peat, the flora of which is noted on

[1]) C. A. WEBER: Versuch eines Ueberblicks über die Vegetation der Diluvialzeit in den mittleren Regionen Europas. Berlin 1900. C. A. WEBER: Die Mammuthflora von Borna. — Abh. Nat. Ver. Brem. 1914, Bd. XXIII, H. 1. Bremen. — After the apprehension of C. A. WEBER the arctic Mammut-bed at Borna near Dresden dates from the late-glacial period of the Riss Glaciation.

p. 200. We found here, *inter alia* fruits of *Carex pseudocyperus* and *Cladium mariscus*. The stratum in question lies at the point of transition to zone *d*, in which the species of the mixed oak forest etc. are beginning to appear as immigrants (see Fig. 4, Pl. XXXIX), but the northern limit of distribution for *Carex pseudocyperus* and *Cladium mariscus* in Scandinavia during the postglacial period lies a little south of the northern limit of the oak forest.

Zone *d*. The next stage in the evolution of the vegetation is marked by the appearrance of immigrant species belonging to the mixed oak forest group. The order of precedence was as a rule *Ulmus*, *Quercus*, *Corylus*, *Alnus*, *Tilia*, the first three generally appearing already in Zone *d*, *Alnus* for the most part not until somewhat later, in Zones *e* or *f*, and *Tilia* in zone *f*. For the rest, the diagrams show *Betula* and *Pinus* as constantly dominant in Zone *d*. The *Betula* pollen is, as in the zones just above and below, generally more frequent than that of *Pinus*.

Zone *e*. Here also *Betula* and *Pinus* pollen will be found dominant, the latter species indeed often attaining its first maximum here — at Höllund Sögaard up to 63 %. At the same time the *Ulmus* curve also is often seen to cultimate — with as much as 17 % at Nörbölling — the Quercus pollen also showing greater frequency. *Ulmus* pollen was somewhat more frequent in the bogs from the south-east of Jutland than in the regions farther north and west; it has however, a frequency of 10 % in Duedam I.

Survey of Zones *c*, *d* and *e*. These zones were deposited during the first conifer period of the interglacial period. The distribution of land and sea in north-western Europe at that time was different from that which prevailed later on in the interglacial period, when a considerable shifting of the shore line in a positive direction took place. The Eem strata show this in South Jutland, and, if the Eem strata represent one and the same horizon throughout the whole of northern Europe, as has been emphatically maintained, for instance by V. Nordmann[1]), then this incursion of the sea must have been a phenomenon of far-reaching extent. The fresh-water deposits under the marine Eem strata at Stensigmose belong to the older part of the interglacial period, Zones *d* and *e*, consequently the transgression of the Eem Sea took place at the beginning of the mixed oak forest period (Zone *f*), cf. p. 178.

This Eem subsidence was undoubtedly accompanied by a corresponding alteration in the climatic conditions, so that at the close of

[1]) V. Nordmann: La position stratigraphique des dépôts d'Eem. D. G. U. II. R. No. 47. 1928.

the first conifer period a more atlantic type of climate was setting in, the deciduous trees at the same time gaining the upper hand. We have here then a close analogy to the well known transition from conifers to deciduous trees in the post-glacial period, which was likewise accompanied by a transition from "boreal"[1]) to atlantic climate, at the commencement of the *Tapes-Litorina* subsidence. In Europe of the present day, as we know, the continental climate is most frequently characterised by the growth of conifers, and the atlantic climate mainly by that of deciduous trees[2]); the same feature is here expressed in Denmark and NW Germany during the interglacial and post-glacial periods.

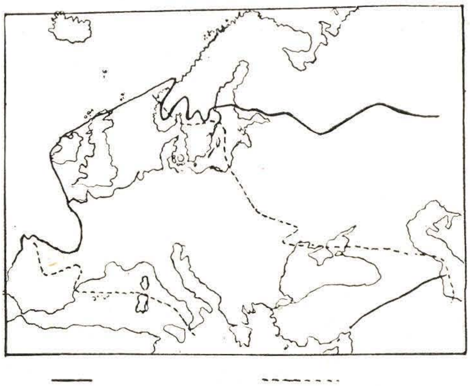

Fig. 33. Boundary lines for the present distribution of *Quercus robur* (the fully drawn line) and *Q. sessiliflora* (the stippled line). After KIRCHNER, LOEW and SCHRÖTER by EUG. WARMING (Botanisk Tidsskr. Bd. 35. Copenhagen 1919, p. 43).

During the first conifer period, conditions of temperature changed from sub-arctic to temperate, immigrant species of more thermophile character making their appearance. This has already ben touched on in the foregoing; it may here be added however, that before the period came to an end, species such as *Ceratophyllum demersum*, *Naias marina* and even *Trapa natans* presumably entered on the scene, the oldest remains of this last being found in the washing samples from Stratum D in the deposit at Fövling (cf. p. 155 and Pollen diagram XXXVII, 1). At the time when the oak *(Quercus robur)* immigrated, it may be supposed that the climatic conditions of Jutland were similar to those now prevailing at the northern limit of the oak in Sweden or Finland (Fig. 33), whereas prior to that event, the climate must have been like that of somewhat more northerly regions at the present day.

A feature of interest is the occurrence of a small percentage (1—5 %) of *Picea* pollen in these zones (answering to the first conifer

[1]) L. v. POST maintains that the climate of the boreal period in Sweden should be characterised as a kind of "atlantic climate" (Gotlands-agen (*Cladium mariscus* R. BR.) i Sveriges postarcticum. Ymer 1925, p. 308 f.). The climate of this period in Denmark hower, is marked not only by a frequently noted occurrence of drying up strata in bogs and deposits of calcareous tufa, but also by the presence of large forest of the continental *Pinus silvestris* out to the west coast of Jutland.

[2]) Cf. BROCKMANN-JEROSCH: Baumgrenze und Klimacharacter. Beitr. zur geobotan. Landesafnahme. 6. Zurich 1919, p. 205 f.

period) in several of the diagrams, viz. for Rodebæk III, Brörup Hotel Bog, Tuesböl II and Kuhgrund II, to which may be added Hörup, Hollerup, Egtved and Kollund among deposits covered with young-glacial strata, whereas in the lower part of Zone *f*, this species of pollen is as a rule altogether lacking. Attention must here also be called to the fact that macroscopical remains of *Picea excelsa* are found in the bog at Astrup from the earliest part of the interglacial period (see p. 127) as well as in the calcareous mud at Hollerup (cf. p. 208). This suggests that *Picea excelsa* occurred quite sporadically in Jutland in the earliest part of the interglacial period. From the post-glacial period such a feature is unknown as far as Denmark is concerned,[1]) but it is a well-known fact, though to a far greater degree, from more easterly regions, viz. Russia,[2]) where *Picea* pollen is sometimes fairly common in the boreal strata of postglacial bogs. The occurrence of *Picea* pollen in the lower part of the interglacial strata sequence seems then to be an eastern feature, and confirms the supposition that the general character at the time in question was continental. We do not know why *Picea excelsa* did not then succeed in the competition with other forest trees, but this may perhaps be explained to some extent by the fact that the climate of northern Europe soon became decidedly atlantic, and thus relatively unfavourable for *Picea excelsa*, cf. p. 360.

Zone *f*. It will be seen from what has already been stated on p. 179 as to the Eem strata, that the marine deposits of these, with *Tapes aureus var. eemiensis* etc. must be synchrounous with zone *f* in bogs of the Brörup and Herning type. The warm Eem sea transgressed great portions of the Cimbrian Peninsula, and other coastal regions of NE Europe, and a Lusitanian fauna immigrated into the Baltic, while at the same time the flora of the rich mixed oak forest superseded the former conifer growth. This alteration of the coastline must have caused, or at any rate furthered, an alteration of the climate of NW Europe in an atlantic direction. The West-European character of the forests in the period answering to Zone *f* is apparent from the flora list and pollen diagrams: deciduous trees almost without or

[1]) Among tens of thousands of pollen grains from Danish postglacial bogs, not twenty of *Picea excelsa* were found except at Femsölyng in North Sealand, where the pollen appears in the upper part of the strata sequence. (L. VON POST: Skogsträdpollen . . . Skandinav. Naturforskeres 16de Möte 1916. Kristiania 1918, p. 459. — KNUD JESSEN: Moseundersögelser . . . D. G. U. II. R. No. 34. 1920, p. 74).

[2]) D. A. GERASSIMOW: Westnik torfjanowo djela (Moore in Gouvernement Kaluga). Nr. 12. Moskou 1924, p. 6. In Russian, with a summary in German. — W. S. DOCTUROWSKY: Über die Stratigraphie der russischen Torfmoore. Geolog. Fören. Förhandl. Bd. 47. 1925, p. 100. — Cf. PETER STARCK: Der gegenwartige Stand der pollenanalytische Forschung. Zeitschr. f. Botanik. 17. Jahrg. 1925, p. 100 f.

with but a little of conifers. Particularly characteristic in this respect is the distribution of the now decidedly atlantic species *Ilex europaea*, which was common in northern Europe during the deciduous forest period of the last interglacial, and reached farther east than at the present day (cf. Fig. 34). It is noted, for instance from Motzen, near Berlin, in a deposit referred to the last interglacial period,[1]) and was also a constituent part of the flora at Klinge, near Kottbus,[2]) the age of which however, has hardly yet been finally determined. There

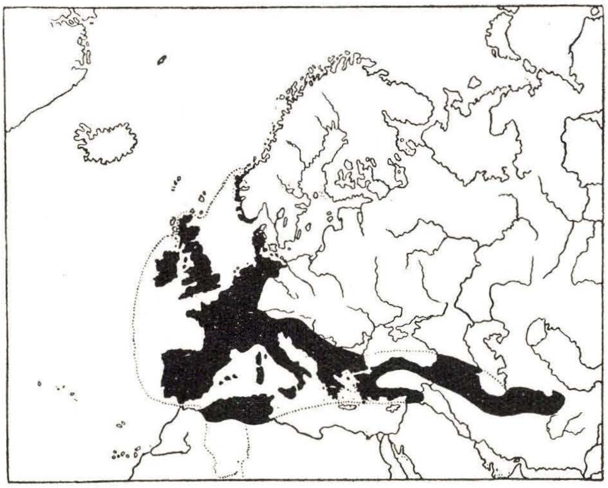

Fig. 34. Map shoving the present distribution of *Ilex aquifolium*. After J. Holmboe: Bergens Museums Aarbok 1913, p. 84.

were however, also other atlantic species living in NW Europe at that time, as for instance *Taxus baccata, Cladium mariscus*[3]), *Hydrocotyle vulgaris, Litorella uniflora, Potamogeton densus;* and it seems from this, and from what is noted in the following that the climate of Jutland and NW Germany in that part of the interglacial period which answers to Zone *f* was no less atlantic in character than the climate of the Litorina period in post-glacial time.

In Zone *f*, which often embraces a relatively considerable portion

1) J. Stoller: Beitr. z. Kenntnis d. diluvialen Flora (besonders Phanerog.) Norddeutschlands. I. Jahrb. Kgl. Preuss. Geolog. Landesanst. Bd. XXIX, 1. Berlin 1908.

2) C. A. Weber: Ueber die diluviale Vegetation von Klinge in Brandenburg und ihre Herkunft. Eng. bot. Jahrb. Bd. XVII. Leipzig. 1893.

3) J. Stoller: Beitr. z. Kenntnis d. diluvialen Flora von Norddeutschland. III. Phöben, Kohlhasenbrück, Quakenbrück. Jahrb. Preuss. Geolog. Landesanstalt. Bd. XLVII, 1. 1926, p. 333. *(Cladium mariscus* at Berlin in the last interglacial period).

of the pollen diagrams, we find the culmination of the curves for mixed oak forest (*Qercus* + *Ulmus* + *Tilia*), *Corylus* and *Alnus*, answering, according to the washing lists, to the species *Quercus robur*, *Tilia cordata*, *T. platyphylla*, *Ulmus glabra*, *Corylus avellana* and *Alnus glutinosa*. In addition to these, however, there were several other trees and shrubs, especially *Acer campestre*, *A. platanoides*, *Fraxinus excelsior*, *Ilex aquifolium*, with *Cornus sanguinea*, *Crataegus sp.*, *Prunus sp.* (plum), *Sambucus cf. nigra*, *Taxus baccata*, *Viburnum opulus* and *Viscum album*; furthermore, *Pinus silvestris* was stil of some importance during the first part of the time, *Carpinus* and *Picea* immigrated during the latter part. This varied wealth of species is in itself an indication that an oceanic climate prevailed at the time, a climate of this sort allowing room for species with a wide diversity of requirements, whereas the continental climate is strictly selective.[1])

The pollen diagrams indicate a certain rhythm in the forest development during the period answering to Zone *f*. In the lower part of this zone, for instance, we have the culmination of the *Quercus* pollen, which attained as much as 65 % (Over Gestrup) and indeed often made up over 50 % of the total pollen in the spectra apart from *Corylus*. It rather seems, from the material, that the oak was about evenly distributed throughout the area under consideration.

Almost simultaneously with *Quercus*, comes the maximum of frequency for *Corylus avellana*, this species often showing a higher frequency of pollen than all the others together. This *Corylus* maximum represents an episode in the time of the mixed oak forest, prior to, synchronous with or subsequent to the date of culmination for the *Quercus* pollen. The highest frequencies for *Corylus* pollen in Jutland was noted at Brörup railway station (233 %), Over Gestrup 186 %, and Lövskal 227 %, Kollund 285 %. At Römstedt I in the Lüneburger Heide, it actually amounted to 492 %.

*Corylus avellana* must at that time have been extraordinarily common as undergrowth under the oaks; in places, perhaps, there would have been something approaching the formation of whole groves of hazel. This interglacial *Corylus* maximum is thus in so far analogous to the post-glacial *Corylus* maximum observed in great parts of Northern and Central Europe, since it was first noted by L. von Post in the bogs of south-western Sweden.[2]) But in the interglacial period, the

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[1]) Brockmann-Jerosch: Baumgrenze und Klimacharakter. Beitr. z. geobotan. Landesaufnahme. 6. Zürich. 1919, p. 200.

[2]) The literature of the postglacial *Corylus* maximum is quoted in G. Erdtman: The Journal of Botany 1926, p. 73. The danish postglacial bogs also exhibit a similar high *Corylus* maximum, often higher than one hundred. That this is not so prominently apparent in the investigations hitherto

*Corylus* pollen attains its maximum rather later in regard to the general forest development than is the case in the post-glacial, in which it is referred to the close of the boreal period, when *Pinus* still predominated over the mixed oak forest, at any rate in the south-western Baltic regions. L. VON POST[1]) regards the post-glacial *Corylus* maximum, which occurs normally in the lower part of the strata sequence of the bogs within the regions of southern Sweden exposed to the influence of the sea, as indicating the presence of hazel woods, which he compares with the hazel groves on the west coast of Norway north of the limit of occurrence for oak. According to this view, it would be a reaction from the atlantic influence on the flora, and this idea is supported by the actual geographical distribution of the localities where the post-glacial *Corylus* maximum is observed; viz. Western Europe and the mountains of Central Europe. Possibly the interglacial *Corylus* maximum in NW Europe may be regarded as indicating the reaction of the forest vegetation from the atlantic climate of the Eem Sea period, though there is hardly any analogy to find at the present day in northern Europe south of the northern limit for oak. The fact that the interglacial *Pinus-Betula* period (Zone *c*, *d*, *e*) which forms a parallel to the post-glacial boreal period, did not suffice for the development of a *Corylus* maximum, may doubtless be taken as emphasising the presence of a climatic difference between these two temperate portions of the Quaternary period.

*Alnus* pollen attains its highest frequency in nearly all diagrams somewhat later than *Quercus* and *Corylus* (except at Höllund Sögaard), and is then in many cases the dominant species; the highest figure is reached at Brörup Hotel bog, which shows 87 %. Post-glacial pollen diagrams from northern Europe show a similar advance of *Alnus* pollen, viz. from the atlantic stage, and the cause lies undoubtedly in the extreme moisture of this type of climate, occasioning an increased distribution of the eutrophic *Alnus* growth on swampy ground, and generally favouring *Alnus glutinosa,* even where it had to compete with the oak forest. By analogy then, we can imagine that it is under the influence of the atlantic climate which set in with the Eem subsidence that the *Alnus* curve shows its pronounced turn to the right in the interglacial pollen diagrams' *f*-zone. The fact that this general increase of moisture does not appear to have favoured

published (D. G. U. II. R., No. 34, 1923, and Mémoires de la Soc. Roy. des antiqu. du nord, 1926–27, p. 25) is due to the employment of a somewhat different method of calculation for the frequency of *Corylus* pollen (D. G. U. II. R., No. 34, p. 9).

1) L. VON POST: Postarktiska klimattyper i södra Sverige. Geol. Fören. Förhandl. Bd. 42. Stockholm. 1920, p. 239.

the birch — the *Betula* curve in the pollen diagrams indicates a minimum for this species of pollen at the time when *Alnus* culminates — must be due to the edaphic conditions, which were still at that time favourable to eutrophic formations.

The *Tilia* pollen, as was to be expected from the macroscopic finds of the species *T. cordifolia* and *T. platyphylla*, appears for the most part with but very low figures for frequency; it is rarest in the western part of Jutland, more common in the east and south. Our material does not allow us to state with complete certainty when the *Tilia* maximum occurred, but for most of the localities where this species was most abundant — Over Gestrup, Römstedt I and II, as also Hörup, Egtved, Kollund, Loopstedt, it would seem to have occured somewhere towards the close of the *f*-Zone period. At the same time, the *Ulmus* curve can indicate a generally slight secondary maximum for this species, which has been somewhat moore poorly represented in the time immediately preceding. In the Egtved diagram, this secondary *Ulmus* maximum amounted to as much as 23 %.

Both the interglacial and the post-glacial pollen diagrams thus show the presence of a mixed oak forest having much the same composition in both periods, indicating that the forest development and the various causes on which it depended were in the main uniform for both these sections of the Quaternary period. Nevertheless, it is evident from the foregoing that there are differences in detail. L. VON POST first pointed out, and others have since confirmed, that after the *Corylus* maximum in the post-glacial forests of northern Europe, first *Ulmus* and then *Tilia* and last of all *Quercus* attained their respective maxima. The corresponding order of precedence for the last interglacial period in Jutland and probably also in NW Germany, on the other hand, was *Ulmus* (during the *Pinus* period) — *Quercus* as a rule a little before *Corylus* — *Tilia*, *Ulmus*. Such differences may possibly afford a key to more thorough understanding of the causes underlying such successions, when the interglacial deposits of Central Europe are also subjected to pollen analysis on the lines adopted for those of Northern Europe.

The curves for mixed oak forest, *Corylus* and *Alnus* attain their maxima in the *f* Zone; those for *Pinus* and *Betula*, on the other hand, have their minima here in nearly all pollen diagrams from the last interglacial period and those of uncertain age; in some cases however, not until the *g*-zone. A survey of the pollen diagrams for these two groups shows that the minimum frequency for *Pinus* pollen in these zones lies between 0 % and 13 %, the avetage (out of 15 cases) being 4.3 %. The *Betula* minima fall about the same time between 2 % and 24 %, average 6.5 %. In the mixed oak forest zone of the Danish bogs of the post-glacial period, the figures for frequency of *Pinus* pollen show altogether similar values, and it is likely then that *Pinus silvestris* was during the portion with deciduous forests of the last interglacial period, reduced to a similarly insignificant position in the forests of north-western Europe, after having been the most important of the forest trees. The causes which led to this may presumably be expressed, as regards the last interglacial period, in approximately the same words as used by E. HEMBERG,[1]) in conformity with the general view, as to the history of *Pinus silvestris* in southern Scandinavia during the latter part of the post-glacial period viz., that the factors mainly responsible for the decline of this species were: successive changes of climate from boreal and northern-temperate to oceanic, the immigration of the oak, and the destructive influence of mankind — save that manking was not one of the factors in the interglacial period.

It seems as if *Fagus silvatica* might have found suitable conditions in Denmark in the last interglacial period; in spite of this however, there is not a single find of this species recorded in this country, not even of its pollen, in the deposits hitherto investigated. Jutland deposits from the penultimate interglacial likewise shown no trace of beech, and the recorded finds of beech at Honerdingen and Ober Ohe, also from the penultimate interglacial period, have not been confirmed.[2]) Within the area under consideration, interglacial beech has only been observed at Fahrenkrug,[3]) in Holstein, in a deposit which, lying below the younger diluvium, most likely must be plaed in the group of "uncertain age", and in an interglacial bog at Bergedorf[4]) near Hamburg, the description of which leaves the question of its age open. Of beach only pollen is found here. The interglacial history of the beech in Europe is however, but very inadequately known, and not until systematic pollen analyses have been carried out can we look for any improvement in this respect. F. FIRBAS (l. c.) has noted this fact, and mentions the various finds of interglacial beech. His statement that *Fagus silvatica* appears to be lacking at any rate during one interglacial period in Central Europe, but to belong, firstly to old quaternary deposits — (Cromer forest bed, Tegelen etc.) — and further to younger quaternary deposits, — occurrences of

1) E. HEMBERG: Skogsvårdsföreningens Tidskrift. Stockholm. 1904, p. 124.

2) FRANZ FIRBAS: Zur Waldentwicklung im Interglazial von Schladming an der Enns. Beih. z. Bot. Centralbl. Bd. XLI. 1925. Abt. II. Dresden, p. 306 f.

3) C. A. WEBER: Über die diluv. Flora von Fahrenkrug in Holstein. Englers bot. Jahrb. XVIII B. 1893, Beiblatt 43, (Separat-Abdruck, p. 9).

4) W. KOERT und C. A. WEBER: Erläuterungen z. Geolog. Karte v. Preussen. Lief. 176. Blatt Bergedorf. Berlin 1912, p. 22.

Schiefekohlen in Switzerland and in the East Alps[1]) — is, as regards the last interglacial period, in marked contrast to what has here been noted in NW Europe. Altogether, the history of the beech in Europe seems to exhibit a doubtless important though hitherto inexplicable difference in geographical respects between interglacial and post-glacial periods.

A similar difference between the two periods is apparent in the occurrence of *Abies pectinata*, which was, in the interglacial period, distributed throughout the lowlands of NW Germany, whereas at the present day, its northern limit lies along the northern margin of the mountains of Central Germany.[2]) This tree is noted from the last interglacial period in NW Germany at Winterhude[3]) near Hamburg, and at Nienjahn near Hohenwedstedt[4]) in Holstein. In the deposit at Godenstedt[5]) near Bremen, and Bergedorf[6]) near Hamburg (only pollen), it is perhaps contemporary with the occurrences at Honerdingen (see p. 370) and in other similar deposits in the Lüneburger Heide and at Seelze at Hannover.[7]) The bogs at Winterhude and Nienjahn must be referred to the Brörup type. From the first of these localities there are finds recorded of macroscopic remains of *Abies pectinata*, whereas from Nienjahn, only pollen is mentioned, according to the analysis by C. A. WEBER: "Unter 1000 Blutenstaubkörneren von Bäumen waren durchschnittlich 866 von *Picea*, 34 von *Pinus*, 56 von *Betula*. Der Rest [4,4 %] verteilt sich auf *Carpinus*, *Populus* und *Abies*" (l. c. p. 69). This is the most northerly locality for interglacial *Abies pectinata*, as the species was not found in any of the numerous Danish interglacial deposits, neither in the form of macroscopic nor microscopic remains.[8])

1) FRANZ FIRBAS: Beiträge zur Kenntnis der Schieferkohlen des Inntals und der interglacialen Waldgeschichte der Ostalpen. Zeitschrift für Gletscherkunde. Bd. XV. 1927.

2) K. RUBNER: Die pflanzengeograph. Grundlagen des Waldbaues. Neudam 1924. Karte III.

3) M. BEYLE in E. HORN: Die geolog. Aufschlüsse des Stadtsparkes in Winterhude. Zeitschr. d. Deutschen Geolog. Gesellschaft. Bd. 64. Monatsber. Berlin 1912.

4) W. WOLFF: Zeitschr. d. Deutschen Geolog. Gesellsch. Bd. 74, Jahrg. 1922. Monatsber. Nr. 3—4, p. 68 f.

5) FR. SCHUCHT: Die diluviale Ablagerungen von Godenstedt bei Zewen. "Auf der Heimat, für die Heimat". N. F. 11.

6) W. KOERT and C. A. WEBER: Erläuterungen z. Gelog. Karte von Preussen. Lief. 176. Blatt Bergedorf. Berlin. 1912, p. 21.

7) J. STOLLER: Über altdiluviale Leineschotter bei Isernhagen und das altdiluviale Torflager bei Seelze in der Umgebung von Hannover. 11. Jahresber. d. Niedersächs. Geol. Verein. z. Hannover. 1919, p. 66.

8) The most important difference between pollen of *Picea excelsa* and *Abies pectinata* lies in the size of the grains; and in none of the Danish interglacial deposits has any conifer pollen been found with a lenght exceeding

*Abies pectinata* is a species requiring much moisture, and it is very susceptible to night frosts. It is cultivated successfully in many places with a decidedly atlantic climate,[1]) but in Denmark one it not sure of its value as a forest tree on a large scale.[2]) RUBNER maintains that the conspicuous absence of this tree in NW Germany is due to incomplete immigration. It is regarded as an indication of atlantic climate, when met with in post-glacial deposits in Central Europe.[3]) Its occurrence in the interglacial deposits of NW Germany together with the species of the oak forest agrees well with the above noted evidence of a mild climate in a portion of the last interglacial period in Northern Europe.

The view expressed by J. STOLLER[4]) that *Abies pectinata*, in its distribution in the diluvial period north of its present northern limit, seems to have taken a different course in the last interglacial period from that followed in the penultimate interglacial, is based mainly on the assumption that the interglacial deposits in the Lüneburger Heide containing *Abies pectinata* must be ascribed to the last interglacial period. According to the classification of the NW Germany interglacial deposits arrived at from the results of the present work however, the northern limit of occurrence for *Abies pectinata* in the penultimate interglacial period must be drawn across Honerdingen and Ober Ohe to Tempelhof near Berlin, where J. STOLLER l. c. has found this species,

that of recent *Picea excelsa* pollen, i. e. up to 139 $\mu$. The table below shows thet there is a distinct difference between the lengths for pollen of *Picea excela* and *Abies pectinata* from different parts of Europe (racial difference?), Only such conifer pollen as exceeds 139 $\mu$ in length can as a rule — at any rate in western Europe — be ascribed to *Abies pectinata*.

| | *Picea excelsa* Lenght in $\mu$ | *Abies pectinata* Length in $\mu$ |
|---|---|---|
| DOCTUROWSKY & KUDRJASCHOW (Geologisches Archiv. III. Königsberg 1924, p. 181) | 90—104 | 100—120 |
| SELMA RUOFF (ibidem p. 181, footnote) | 95—120 | 130—150 |
| KNUD JESSEN (Denmark) | 100—139 | 128—178 (195) |

1) K. RUBNER: l. c. p. 233 f.

2) A. OPPERMANN: Ædelgranens Vækst paa Bornholm (Le sapin pectiné à l'ile de Bornholm). Det forstlige Forsögsvæsen i Danmark. IV, p. 26—39. Kbhvn. 1912. — L. A. HAUCH: Danmarks Trævækst. I. Kbhvn. 1919, p. 117 f.

3) P. STARK: Pollenanalytische Untersuchungen an zwei Schwarzwaldhochmooren. Zeitschr. f. Botanik, 16. Jahrg. 1924, p. 611. — The same: Der gegenwärtige Stand der pollenanalytischen Forschung. Ibidem, 17. Jahrg. 1925, p. 107 f. — H. GAMS & R. NORDHAGEN: Postglaziale Klimaänderungen .... Landeskundl. Forschungen d. geogr. Ges. München. 25, 1923. Vergleichstabelle.

4) F. KAUNHOWEN und J. STOLLER: Neuere Aufschlüsse im Berliner Diluvium. Jahrb. Preus. Geol. Landesanstalt. Bd. XLVI. Berlin. 1926, p. 625.

while in the deposits from the last interglacial period, it has been traced as far as Holstein.

The mildness of the climate, and especially the warmth of summer in that part of the interglacial period which answers to the *f*-Zone, is also seen from the flora lists. The facts in this connection have frequently been touched upon by previous writers, especially C. A. WEBER and J. STOLLER.

*Brasenia purpurea*, which has been found in a considerable number of interglacial deposits in NW Germany, the most of them at any rate from the last interglacial,[1]) was hitherto known in Jutland only from a single locality, viz. Tuesböl.[2]) The recent investigations, however, have shown that this plant was fairly common in Jutland during the last interglacial period, 11 finds from different localities being now recorded. The seeds were found especially in Zone *f* but also in the Zones *g* and *h*. J. STOLLER points out (1908, l. c. p. 72) that *Brasenia purpurea* was able to seed abundantly in a climate where the mean temperature during the vegetation period of the higher plant forms was at least 12 $^0$ C, and the winter temperature did not fall below ÷ 5 $^0$ G; that is, where the summer was a least as warm as in Denmark at the present day.

As with *Brasenia purpurea*, so also *Dulichium spathaceum* proves to have been common in the last interglacial period, 11 finds being now recorded from Jutland of this Cyperacea; it belongs especially to Zone *f*, partly also to Zone *g*, and *h*, and its requirements as to site and climatic conditions[3]) were presumably similar to those of *Brasenia purpurea*. In the interglacial deposits of NW Germany it is recorded especially from Kuhgrund I and Westerland, on the island of Sylt.

*Trapa natans*. This species is known from the NW German interglacial deposits from 4(5) localities in all, viz. Kuhgrund I,[4]) Kuhgrund II,[5]) Hamburg-Barmbech[6]) from the last interglacial period,

1) J. STOLLER: Über die Zeit des Aussterbens der *Brasenia purpurea* MICHX. in Europa, speciell Mitteleuropa. Jahrb. Kgl. Preuss. Geolog. Landesanstalt XXIX, I. Berlin 1908, p. 83. — M. BEYLE: Über einige Ablagerungen fossiler Pflanzen der Hamburger Gegend. I. Jahrb. d. Wissenschaftl. Anstalten, XXX. Hamburg 1913, p. 84. — M. BEYLE: Über einige Ablagerungen . . . III. Ibidem, 1924, p. 19. — V. NORDMANN, KNUD JESSEN und V. MILTHERS: Quartärgeolog. Beobachtungen auf Sylt. Medd. Dansk geolog. Foren. Bd. 6. No. 15. 1923, p. 25.

2) N. HARTZ: Bidrag . . . D G. U. II. R. Nr. 20, p. 176.

3) J. STOLLER: Über das fossile Vorkommen der Gattung Dulichium in Europa. Jahrb. Kgl. Preuss. Geolog. Landesanst. XXX, I. Berlin 1909

4) J. STOLLER: Beiträge z. Kenntnis d. diluvialen Flora Norddeutschlands. II. Lauenborg a. Elbe (Kuhgrund). Jahrb. Kgl. Preuss. Geolog. Landesanst. XXXII, I. Berlin 1911, p. 128.

5) M. BEYLE: Über einige Ablagerungen fossiler Pflanzen d. Hamburger Gegend. 3. Mitt. a. d. Mineral.-Geolog. Staatsinstitut. IV. Hamburg 1924, p. 10.

6) M. BEYLE: Über einige Ablagerungen . . . 1. Ibidem. 6. Beiheft. 1913, p. 87 f.

Seelze at Hannover[1]) *(forma laevigata)* from "Interglacial I", and Grünenthal in Holstein[2]) the age of which perhaps is more uncertain. To these must now be added four localities in Jutland, viz. Herning, Solsö, Fövling and Sandfeld. In all these localities, *Trapa natans* is found more particulary in zones where remains of deciduous trees

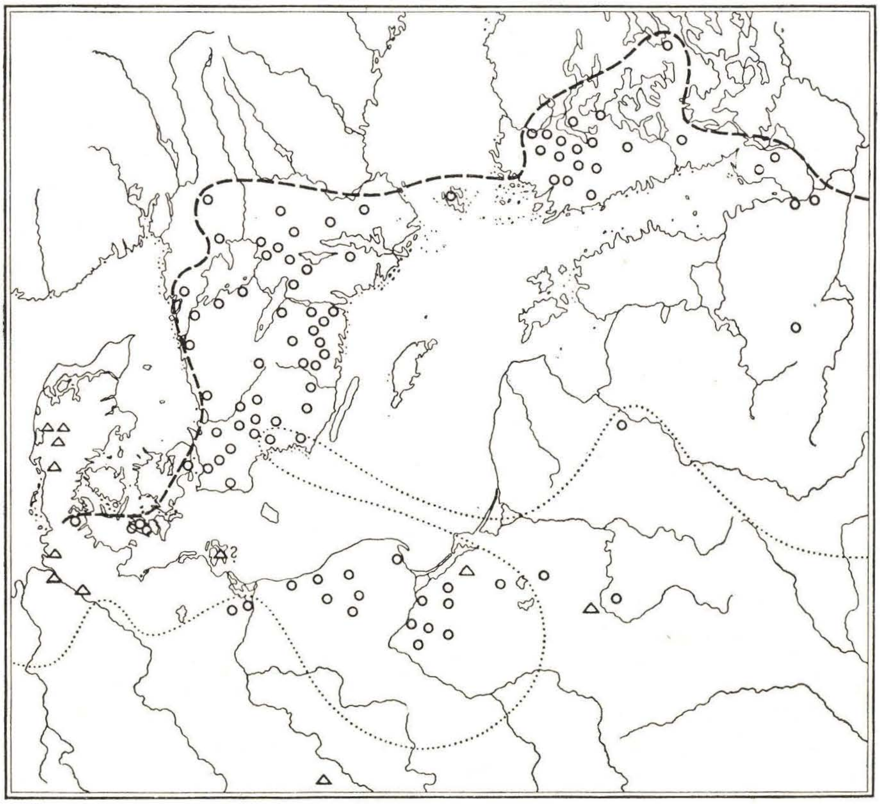

Fig. 35. Distribution of *Trapa natans* in northern Europe: △ finds from the interglacial period; as regards the Cimbrian peninsula at any rate from the last interglacial period. ○ finds from post-glacial times. — — — — northern limit of occurrence for the species during the post-glacial climatic optimum. ·············· northern limit of the species in historical times. (After H. GAMS: Die Gattung Trapa L. Die Pflanzenareale. I. R. H. 3. Karte 25. 1927. With alterations for Denmark).

are most abundant. This frequent occurrence in the north-western part of the northern European lowlands is in marked contrast to the

1) J. STOLLER: Über altdiluviale Leineschotter bei Isernhagen und das altdiluviale Torflager bei Seelze in der Umgebung von Hannover. 11. Jahresber. d. Niedersächs. geol. Ver. z. Hannover. 1919, p. 67.

2) C. A. WEBER: Versuch eines Ueberblicks über die Vegetation der Diluvialzeit. Allgem. verständl. naturwissensch. Abh. 22. Berlin 1900, p. 20.

post-glacial distribution of this species (cf. Fig. 35).[1]) The extreme limit of occurrence of the species in northern Europe during the varm part of the postglacial period runs NE—SW; this can hardly be taken as indicating that the species schunned an atlantic climate, but the fact must rather be that it requires summers of a certain fairly high temperature in order to bear fruit. H. GAMS (l. c.) points out that the diluvial, postglacial and present distributions of *Trapa natans* are alike determined by three factors, viz. that it shuns the lime, but requires much nourishment and much heat. We find also that its nuts occur in non-calcareous, highly humous mud (Dy) together with numerous other aquatic plants; and as regards its termophile character, it may be noted that the northern limit for occurrence in historical times in north Germany[2]) more or less coincides with the July isotherm for 18° C.

The interglacial summers in western Jutland must then undoubtedly have been varmer than those of the present day, and quite as warm as in the south-eastern Baltic regions during the days of the postglacial heat optium, i. e. with a mean temperature for July at about 2° C above that of the present day.[3])

Washing from the excavation at Herning Brickworks yielded, from the *f* zone, a total of 238 whole or nearly whole fruits of *Trapa natans*. These were not large on the whole; they were much compressed, and rather thin-walled, with pointed spines, the basal part of which as a rule was but poorly developed; there were however, some specimens with 2 pairs of powerful excrescences from the region between the spines. The fruits differ greatly in shape, but can be fairly easily divided into a series of forms similar in constitution to many of those described by A. G. NATHORST and GUNNAR ANDERSSON.[4]) In the fruits from Herning, the part situated above the spines is fairly uniform and poorly developed. The shape of the oral part includes all stages from the *laevigata* type, which lacks neck and corona entirely, via the *sub-rostrata* forms and *rostrata* forms to the fully developed *coronata* type with distinct neck and well developed corona. See

1) The map of the distribution of *Trapa natans* published by H. GAMS (Die Pflanzenareale, I. Reihe, Heft. 3, Karte 25. Jena 1927) gives, erroneously, after GUNNAR ANDERSSON, a postglacial find of *Trapa natans* in Jutland; cf. KNUD JESSEN: "Naturens Verden." Copenhagen 1918, p. 448.

2) H. GAMS, l. c. Karte 27.

3) GUNNAR ANDERSSON: Sveriges geolog. Undersökning. Ser. Ca No. 3. Stockholm 1902, p. 165. — Cf. GUNNAR SAMUELSSON: Bull. of the Geol. Instit. of Upsala. Voll. XIII. Upsala 1915.

4) A. G. NATHORST: Bih. K. Svenska Vet. Akad. Handlingar. Bd. 13. Afd. III. No. 10. Tab. I–III. Stockholm 1887. — GUNNAR ANDERSSON: Bulletin de la Commission geologique de Finlande. Nr. 8. Helsingfors 1898, p. 201 f. Tab. III, IV. For postglacial *Trapa natans* in Denmark see KNUD JESSEN: D. G. U. II. R. No. 34, p. 30 f. 1920.

Fig. 1—16, Pl. XXXI. The 238 fruits found are distributed between these four forms as follows:

| | | | | |
|---|---|---|---|---|
| *f. coronata* ...... | 87 | 36.5 % | *coronata*-type ..... | 36.5 % |
| *f. rostrata* ....... | 81 | 34.0 % | | |
| *f. sub-rostrata* ... | 54 | 22.7 % | *laevigata*-type ..... | 63.4 % |
| *f. laevigata* ...... | 16 | 6.7 % | | |
| | 238 | 99.9 % | | 99.9 % |

The occurrence of *Stratiotes aloides* in the interglacial fresh-water deposits likewise testifies to particulary mild summers during the warmest portion of the interglacial period, the time of the mixed oak forest and that immediately following. Finds have been made at Ejstrup, Tuesböl I, Tuesböl II, Nörbölling and Brörup Hotel, all in the southern part of Jutland. The species is also known in NW Germany, especially from Grühnental,[1]) Kuhgrund I,[2]) several localities near Hamburg,[3]) and from Fahrenkrug in Holstein.[4]) In the present day, only the female plant is found N of the frontier river Krusaa and Sundeved, in the south-eastern part of South Jutland.

*Aldrovanda vesiculosa.* N. HARTZ[5]) found in a washing sample of mud from the interglacial bog at Tuesböl I *inter alia* the following species: ***Picea excelsa, Taxus baccata, Alnus glutinosa, Brasenia purpurea, Carpinus betulus, Ceratophyllum demersum, Dulichium spathaceum, Fraxinus excelsior,*** *"Hydrocharis morsus ranae" (8 seeds),* ***Najas marina, Quercus robur, Stratiotes aloides.*** The seeds noted as *Hydrocharis morsus ranae* are now by W. S. DOCTUROWSKY, E. M. REID and M. E. J. CHANDLER recognised as seeds of *Aldrovanda vesiculosa.*[6]) This revision also applies to the find recorded by N. HARTZ 1909, p. 120 of *Hydrocharis morsus ranae* from the amber-pin-beds at Copenhagen, which are perhaps preglacial[7]) E. M. REID and M. E. J. CHANDLER also note *Aldrovanda vesiculosa* from the interglacial deposit at Galitsch near Moscow, and M. BEYLE tells me kindly that the seeds hitherto known

1) C. A. WEBER: Versuch eines Ueberblicks ... Berlin 1900, p. 19.

2) J. STOLLER: Beiträge ... II Lauenburg a. Elbe (Kuhgrund). Jahrb. Kgl. Preuss. Geolog. Landesanstalt. XXXII. I. 1911, p. 120.

3) E. HORN: Die geolog. Aufschlüsse des Stadtparkes in Winterhude ... Zeitschr. d. Deutschen Geolog. Gesellsch. B. Monatsberichte. Berlin 1912, p. 132. — M. BEYLE: Über einige Ablagerungen fossiler Pflanzen d. Hamburger Gegend. 1. Jahrb. d. Wissenschaftl. Anstalten. XXX. Hamburg 1913, p. 81 and 89. — Über einige Ablagerungen. 3. Mitteil. a. d. Mineralog-Geolog. Staatsinstitut. Heft. VI. Hamburg 1924, p. 18.

4) C. A. WEBER: Über die diluviale Flora von Fahrenkrug in Holstein. Beibl. zu den Botanischen Jahrbüchern XVIII. 1893, p. 6.

5) N. HARTZ: Bidrag ... D. G. U. I. R. Nr. 20. 1909, p. 172.

6) E. M. REID and M. E. J. CHANDLER: The Bembridge Flora. British Museum, Catalogue of cainozoic Plants. Vol I. London 1926, p. 112. Plate VI.

7) V. MILTHERS: Nordöstsjællands Geologi. D. G. U. V. R. 1922, p. 39 and 173.

as *Hydrocharis morsus ranae* from Schulau[1]) and Kuhgrund I[2]) near Hamburg are identical with seeds of *Aldrovanda vesiculosa.* Also the seeds of *Hydrocharis morsus ranae* from Klinge[3]) and Samostrzelniki[4]) at Grodno will likely proove to be of *Aldrovanda vesiculosa.* This plant is now met with in Europe only in a few scattered localities

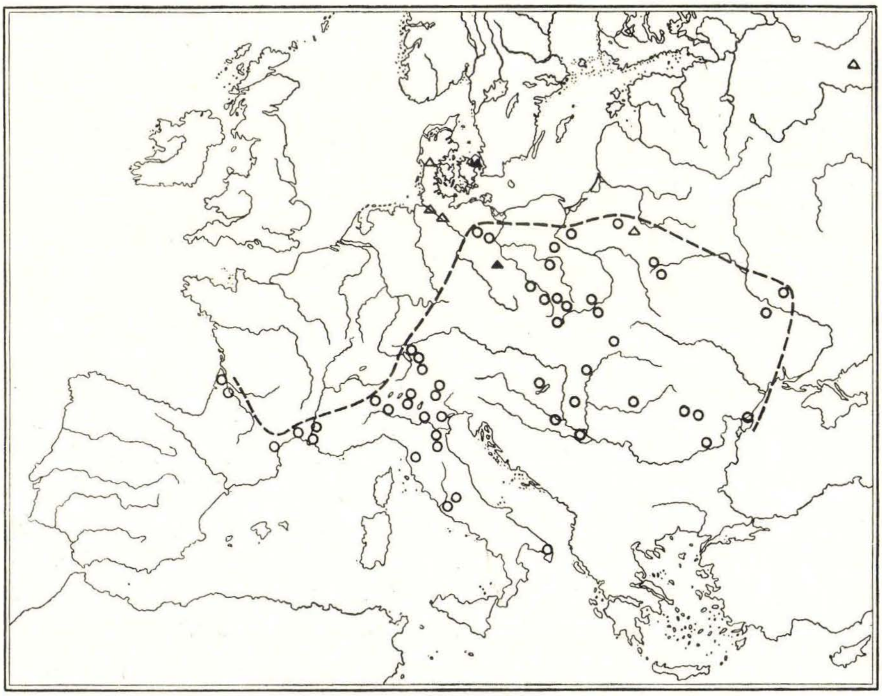

Fig. 36. *Aldrovanda vesiculosa* in Europe. ○ Localities where the species lives at the present day. (G. Hegi: Illustrierte Flora von Mittel-Europa. IV. Bd., 2. H., Fig. 895, p. 507). — — — — Approximate northern, eastern and western limits of the species. △ Localities where this species has been found in deposits from the last interglacial period (Tuesböl, Schulau, Kuhgrund, Samostrzelniki at Grodno, Galitsch). ▲ Localities from older diluvial fresh-water beds (Copenhagen, Klinge). Cf. the text.

1) M. Beyle: Über ein altes Torfmoor im hohen Elbufer vor Schulau. Verh. d. Vereins f. naturwissensch. Unterhaltung zu Hamburg. XI. 1901.

2) J. Stoller: Beiträge zur Kenntnis d. diluvialen Flora Norddeutschlands. II. Lauenburg a. Elbe (Kuhgrund). Jahrb. Kgl. Preuss. Geol. Landesanst. XXXII, I. Berlin 1911, p. 120. — Also from Schmalenbeck near Hamburg. M. Beyle: (Über einige Ablagerungen fossiler Pflanzen . . . Jahrb. Hamburg. Wissensch. Anstalten. XXXVI, 1919, p. 44) mentions *Hydrocharis morsus ranae*, here probably also identical with *Aldrovanda vesiculosa.*

3) C. A. Weber: Versuch eines Überblicks . . . Algemeinverständliche naturwissenschaftliche Abhandlungen. Heft. 22. Berlin. 1900, p. 10.

4) W. Szafer: Über den Charakter der Flora und des Klimas der letzten Interglacialzeit bei Grodno in Polen. Bulletin intern. de l'Academie Polonaise. Cl. d. sci. mathem. et natur. Sér. B. Anné 1925. Cracovie. 1926, p. 294.

(Fig. 36) and has not been observed in flower in north-eastern Germany[1]). The species must thus have been distributed farther to the north during the last interglacial period as is the case now, which also suggests that the climate then, at any rate in summer, was milder than at the present day.

*Acer campestre* and *Tilia platyphylla* were, during the last interglacial period, distributed throughout Jutland and NW Germany; both have now their northern limit of occurrence in southern Denmark, on the islands. *Acer campestre* is also met with in SW Scania; *Tilia platyphylla* is now lacking in the NW of Germany with Sleswic and Holstein as a wild tree.

It is evident then, from what has been stated in the foregoing as to the flora of the *f* zone in the interglacial fresh-water deposits of Jutland and NW Germany, that the climate during the period in question may be characterised as a mild atlantic climate with summers essentially warmer than those of the present day, having presumably a mean temperature 2° C higher in the hottest month. A similar result was arrived at by V. NORDMANN from investigation of the Eem fauna of the same period, see p. 179.

Zone *g*. This, which may be termed *Carpinus* zone, forms the transition between the mixed oak forest zone and the upper conifer zones *h* and *i*. Fruits of *Carpinus betulus* were prominent among the species which from the first characterised the interglacial bogs of northern Europe in paleontological respects, as compared with the post-glacial bogs. In several of the profiles only examined by washing analyses, it was already found that *Carpinus betulus* fruits occurred in a limited zone (e. g. Kuhgrund I and II) and in most of the pollen diagrams, this *Carpinus* zone is also very distinctly apparent. The fruits of *Carpinus* have only very rarely been met with in the post-glacial deposits in the Baltic regions, and where its pollen has been found in these parts, it is nearly always only in small quantities in the most recent strata, mostly in the southern and eastern sections of the area in question, with up to 10 % in southern Sweden and 12 % in Pomerania.[2]) *Carpinus betulus* can hardly have been regularly distributed in Jutland in the last interglacial period, for some deposits were found to contain only very small quantities of this species of pollen, as for instance the bogs at

[1]) ASCHERSON & GRAEBNER: Flora des Nordostdeutschen Flachlandes. Berlin. 1899, p. 376.

[2]) L. VON POST: Ur de sydsvenska skogarnas regionala historia under postarktisk tid. Geol. Fören. Förhandl. Bd. 46. Stockholm. 1924, p. 128. — K. VON BÜLOW, F. KOPPE and KOLUMBE: As noted p. 281, the footnote.

Rodebæk. In other cases however, *Carpinus* pollen attains the absolute frequency in the *g* zone, e. g. Herning, Nörbölling, Kuhgrund II, Römstedt I and II — and Egtved and Loopstedt; the highest maximum, 59 %, was noted at Römstedt I, Nörbölling showing 42 % and Egtved 47 %. This interglacial maximum for *Carpinus* pollen is a phenomenon without parallel in post-glacial finds from northern and central Europe, and shows that *Carpinus betulus* was, at any rate in some places, the dominant species of the forest.

The rational limit[1]) for *Carpinus* pollen lies in the upper part of the *f* zone. At about the same level we find also in many cases the rational limit for *Picea* pollen,[2]) though this often occurs somewhat higher up, viz. in Zone *g*, In other words, *Carpinus betulus* and *Picea excelsa* immigrated to the different localities at about the same time, the former species, however, being in many cases a little ahead of the latter. But the *Picea* pollen often shows a considerable frequency in the *g* Zone, and it is by no means unusual to find it commoner there than the *Carpinus* pollen (Duedam I, Höllund Sögaard, Brörup railway station, Hörup, Hollerup) and it sometimes attains its first maximum here. In such cases, distinction between Zones *g* and *h* may be difficult when dealing with the present material.

In certain cases, the *Pinus* curve first attains its minimum in Zone *g* (p. 344) but as a rule it begins to turn off to the right here. *Pinus silvestris* again began to make headway in the forest at the same time as *Picea excelsa* and *Carpinus betulus*, the *Betula* pollen then also as a rule showing greater frequency. The curves for the mixed oak forest, *Corylus* and *Alnus*, show an essentially different course in this zone, turning off sharply to the left, the mixed oak forest (*Quercus* and *Ulmus)* for instance often from abt. 20 % to 2 %, *Corylus* from as much as 51 % (Nörbölling) to 0 % (Rodebæk III). The *Alnus* pollen — accompanied by fruits and other macroscopic remains of *Alnus glutinosa* — plays an essentially greater part in the upper portion of the pollen diagrams than the pollen of the mixed oak forest; and correspondingly, we find a few exceptions from the rule in the course of the *Alnus* curves. The maximum for *Alnus* pollen in Zone *g* is abt. 50 %, the minimum 11 %.

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1) L. von Post: As noted p. 79.

2) The rational limit for *Picea* pollen is, in the few cases where this species of pollen was found throughout the entire zone *f*, reckoned to lie at that level where its frequency again increases. This position of the *Picea* limit in the interglacial profiles is to a certain extent analoguous to the lower limit of *Picea* pollen in post-glacial bogs of the Lüneburger Heide. (H. A. Weber: Ueber spät- und postglaziale lacustrine und fluviatile Ablagerungen . . . Abh. Nat. Ver. Bremen. Bd. XXIX. 1918, p. 249).

Of thermophile species, noted in the foregoing, *Brasenia purpurea, Ceratophyllum submersum, Dulichium spathaceum, Najas flexilis, Stratiotes aloides, Trapa natans* and *Ilex aquifolium* have also been found in the *Carpinus* zone in Jutland. M. BEYLE[1]) mentions a very interesting flora from the interglacial bog at Winterhude in Hamburg, the greater part of which most likely dates from the *Carpinus* zone. It is about the same species as mentioned above from Jutland but in addition also *Tilia platyphyllus* and *Abies pectinata*. Also *Cervus dama* is to be quoted here. Remains of the fallow deer have repeatedly been found in Danish interglacial deposits, as a rule however, the zone could not be stated. But at Egtved, it has been definitely ascertained that the excavated skeleton of the deer lay in the *g* zone. At the present day, *Cervus dama* is a Mediterranean species.

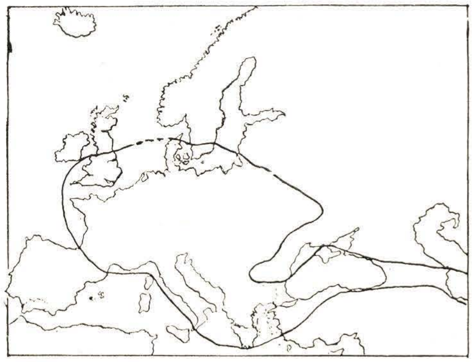

Fig. 37. Map showing the present distribution of *Carpinus betulus* in Europe. (The species is presumably not spontaneous in northern Jutland, and it is lacking in western Jutland). After KIRSCHNER, LOEW and SCHRÖTER by EUG. WARMING (Botanisk Tidsskrift. Bd. 35. Copenhagen 1919, p. 78).

These finds show that the favourable climatic conditions of the interglacial period lasted into the time of the *g*-zone; and this also agrees with the occurrence of *Carpinus betulus*, the most important species in this zone. Its distribution in Europe at the present day will be seen from Fig. 37; it should be noted however, that the species is hardly spontaneous in the northern part of Jutland, and is found more especially in the fertile eastern tracts of the peninsula. Only in the southernmost and warmest part of Denmark does this tree show any tendency to form pure stocks;[2]) otherwise, it appears mainly as a subordinate constituent of the deciduous forests. KIRSCHNER, Loew and SCHRÖTER[3]) note certain regions of Central Europe where the species occurs in pure communities, e. g. Upper Rhine, Danube, and and southern Hungary.

On the other hand, the *g*-zone is the last one in Stage II where

1) M. BEYLE in E. HORN: Die geolog. Aufschlüsse des Stadtparkes in Winterhude und des Elbtunnels . . . Zeitschr. d. Deutschen Geolog. Gesellschaft. Monatsber. Berlin 1912, p. 132.

2) E. ROSTRUP: Lollands Vegetationsforhold. Vidensk. Meddel. Nat. Foren. Köbenhavn 1864. Separate, p. 20. — EUG. WARMING: Dansk Plantevækst. 3. Skovene. Botanisk Tidsskr. Bd. 35. Köbenhavn 1917, p. 77.

3) KIRSCHNER, LOEW & SCHRÖTER: Lebensgeschichte d. Blütenpflanzen Mitteleuropas. Bd. II. 1913, p. 169.

the thermophile species are strongly represented. Here we find the turning point between the climatic optimum and the subsequent cooler conditions. As a general definition of the climate in the time of the *g*-zone we may say that the summers were still warm, but the winter nevertheless cold enough to favour the conifers at the expence of deciduous trees; it is of the nature of a transitional period, as shown by the fact that species such as *Ilex aquifolium, Picea excelsa* and *Trapa natans* were living simultaneously in Jutland at this time immediately before the more thermophile species were exterminated altogether from the region in question. Such a coincidence is not known from regions so far north in post-glacial times.

Zone *h*. After the immigration of *Picea excelsa* during the period answering to the upper part of Zone *f* and Zone *g*, in which latter its pollen often attains great frequency (cf. p. 354) followed Zone *h*, which is characterised by the fact that the *Picea* curve now attains absolute dominance for a more or less considerable time, and reaches its maximal figures for frequency, lying between 23 % (Rodebæk III) and 64 % (Over Gestrup). We are now in the Second Conifer Period, which in some places must be said to have commenced as early as the time of the *g*-zone. The *h* zone shows its finest development in the diagrams from Herning, Nörbölling, Rodebæk I and III, Duedam, Höllund Sögaard, Brörup railway station, Over Gestrup, Kuhgrund II, Römstedt I and II — and Loopstedt. At the same time also, the *Pinus* curve turns off sharply to the right, attaining values lying as a rule between 10 % and 20 %; the highest frequency for *Pinus* in this zone (37 %) is recorded from Höllund Sögaard. The curve for *Betula* often shows more or less of a tendency to follow the two conifers, and in zones *g* and *h* it turns as a rule to the right in conformity with that for *Pinus*. It is otherwise with *Alnus glutinosa*; the curve for this species as a rule keeps on to left, so than in Zone *h* it is for the most part below 12 %; in exceptional cases, as at Brörup Hotel Bog, it may show 39 %. As a rule, this curve has even lower values in zones *i* and *k*, and it is only in a few cases, such as Rodebæk III, Duedam and Höllund Sögaard that the curve is found to move a little to the right again in the upper part of the diagrams. The *Quercus* and *Corylus* pollen are represented in Zone *h* by only a few percent at the utmost, and this may well have been brought by the wind from far away. The *Carpinus* pollen likewise showes a great decrease, but has nevertheles from 6—11 % at several localities in Jutland and as much as 16—27 % in NW Germany, simultaneously with the culmination of *Picea*. Here, in the most southerly part of the area, this tree did best, and we find here at the same time up to 8 % *Quercus* and *Ulmus*, with 13 % *Corylus* (Kuhgrund II).

In addition to the trees mentioned, the following species may be noted from this zone: *Ajuga reptans*, *Batrachium sceleratum*, *Brasenia purpurea* (Duedam I, Nörbölling), *Carex pseudocyperus*, *Ceratophyllum demersum*, *Dryopteris thelypteris* (spores), *Dulichium spathaceum* (Duedam I), *Najas flexilis* (Loopstedt, Nörbölling), *Polygonum tomentosum* (Rodebæk II), *Rubus idaeus*, *Scheuchzeria palustris* (Kuhgrund II), *Urtica dioeca*. The species of the mixed oak forest have in the main disappeared, whereas the characteristic forms of the northern forest, *Picea excelsa*, *Pinus silvestris* and *Betula pubescens*, are advancing. Apart from the *Scheuchzeria palustris*, which is only found in the extreme south, the present northern limits of occurrence in Scandinavia for the most southerly of the aquatic plants and marsh growths above noted coincide approximately with the northern limit of *Quercus rubur* in Sweden (Fig. 33). And it is the mid-Swedish regions in question which may perhaps be regarded as corresponding in climatic respects to NW Europe in the time of the *h* zone.

Zone *i*. The impoverishment of the forest growth which marks Zone *h* as compared with those immediately preceding is also a characteristic of the next zone, *i* which is found developed in the diagrams from Nörbölling, Rodebæk I,[1]) Duedam, Höllund Sögaard, Rodebæk III, Brörup railway station, Over Gestrup, Kuhgrund II, Römstedt I, II, Fleestedt and Hollerup. This zone, which often covers a very essential part of the diagrams, is distinguished from the previous ones by the fact that the *Pinus silvestris* pollen is here the dominant species, its lowest maximum being 34 % (Rodebæk I) and highest maximum 86 (Römstedt I). The *Picea* curve lies now still far to the left, but in certain cases, a secondary maximum has been recorded for *Picea* in the *i* zone, between 15 % and 32 % (Höllund Sögaard, Over Gestrup, Römstedt I and II, also Hollerup). The *Picea* curve has thus two summits in these pollen diagrams, presenting a formal likeness to the *Picea* curve in post-glacial pollen diagrams from northern Sweden[2]). The general tendency of the *Betula* curve is also towards the right; it begins in the lover part of the zone with figures for frequency varying between 10 % and 26 %, and reaching as much as 39 % in the upper part. *Quercus*, *Corylus* and *Carpinus* show on the whole

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1) In the profiles from Herning and Brörup Hotel Bog also this zone must have been develoved, but was not pointed out there owing to lack of sufficient material,

2) L. von Posr: Ur de sydsvenska skogarnas regionala historia . . . Geol. Fören. Förhandl. Bd. 46. Stockholm 1924, p. 95, 123.

but small percentages also in this zone; the *Alnus* pollen is often somewhat more frequent than the pollen of these trees[1]).

The list of other species known from Zone *i* is affected by the fact that the zone is often developed in the form of *Sphagnum* peat; we may here note *Andromeda polifolia*, *Betula nana*[2]) (from Höllund Sögaard and Over Gestrup), *Calluna vulgaris*, *Empetrum nigrum*, *Eriophorum vaginatum*, with several spores of *Osmunda regalis*, especially in the deposits at Römstedt and Fleestedt, *Populus tremula*. — Compared with Zone *h*, the northern character of the flora is now further emphasised.

Survey of Zones *g*, *h* and *i*. Corresponding to the first of the interglacial conifer period herein described, and to the greater part of the subsequent period of deciduous trees, we find definite periods in the post-glacial forest development. We have in the foregoing made certain comparisons between these analogous series of stages. The *Carpinus* maximum in Zone *g* is a phenomenon by itself, with no known parallel in north-western Europe, and from this point onwards, the interglacial forest development in NW Europe followed a line differing widely from that known from the same regions in the later part of the post-glacial period, having, however, certain parallels in the subboreal and sub-atlantic zones of eastern Europe and northern Sweden.[3]) Nevertheless, these cover only the first part of the interglacial development in question, and it is a question of the utmost importance, whether the forest development of northern Europe is to follow the interglacial paradigm through its last stages as well.

The first principal tree in the younger interglacial conifer group was *Picea excelsa*, and if the meteorological constants limiting the distribution of this tree at the present time in north-western Europe were known, the facts would probably be of the greatest importance in leading to a fuller understanding of the climatic conditions during the time of the *h* zone. The discussion regarding the understanding of the western limit of distribution for *Picea excelsa* in Europe, as carried on between A. DENGLER and P. E. MÜLLER shows where the difficulty

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1) The movement to the right often observed in the pollen curves for these species in the upper parts of the diagrams for bogs of the Brörup type is probably due to the fact that the strata in question have been shifted, and mixed with material from earlier deposits, cf. Duedam and Höllund Sögaard.

2) Fruits etc. of *Betula pubescens* are common, and it is undoubtedly this species which has yielded by far the greater part of the *Betula* pollen found in Zone *h*.

3) Cf. P. THOMSON's Pollen diagrams from the bogs of Latvia (Geolog. Fören. Förhandl. Stockholm 1926, p. 489–96) and L. VON POST's pollen diagrams of "the northern type" and the "inland type" (Geol. Fören. Förhandl. Bd. 46, 1924, p. 95 and 89).

lies. DENGLER[1]) regards the western limit of *Picea excelsa* as a winter heat limit, the species thriving best where the winter temperature is low: according to DENGLER, below ÷ 1 ° C in February.[2]) P. E. MÜLLER[3]) is strongly opposed to this view, and maintains that the non-immigration of *Picea excelsa* to North-west Germany and Denmark in the post-glacial period is more especially due to the edaphic conditions, the species being unable to make its way over the great expanses of heath, while the more fertile ground was taken possession of by the beech, which *Picea excelsa* was unable to displace.[4]) He sums up his opinion in a modified utterance of RAMANN'S: In the centre of distribution of a plant species, climatic conditions mainly determine the occurrence of the species; on the margins, however, the occurrence is determined by the various factors which decide the result of the species' struggle for existence with its rivals. But as *Picea excelsa*,

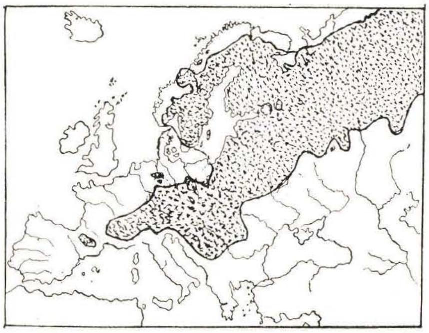

Fig. 38. Natural occurrence of *Picea excelsa* in Europe. After HOLMBOE and DENGLER by EUG. WARMING (Botanisk Tidsskr. Bd. 35. Copenhagen 1919, p. 59).

towards the close of the second stage in the interglacial period became the most important forest tree in Denmark and North-west Germany[5]), this must mean that the "centre of distribution" of the species, its optimal area, had then shifted westwards, to regions where it could not find, either in the first part of the interglacial or in the post-glacial period, the conditions requisite for succes in competition with rival species. Our plantations in Denmark at the present day show that the climate in many parts of the country is of such a character that *Picea excelsa* sickens at a too early age, and the flourishing of the species in various parts of the country is dependent on how far the climate approaches the continental.[6])

1) A. DENGLER: Die Horizontalverbreitung d. Fichte. Mitt. a. d. forstl. Versuchswesen Preussens. Neudam. 1912, p. 99 f.

2) K. RUBNER: l. c. 1925, p. 214, supports DENGLER in this view.

3) P. E. MÜLLER: Rödgranen som Skovtræ i de midtjydske Heder. Det forstlige Forsögsvæsen i Danmark. III. København. 1910, p. 228 f. — The same: Om Vilkaarene for Granens naturlige Forekomst. Ibidem. III. 1913, p. 382 f.

4) DENGLER: l. c. p. 103 quotes against this C. A. WEBER's demonstration of the fact that *Picea excelsa* immigrated to the southern part of the Lüneburger Heide at an earlier date than the beech.

5) *Picea excelsa* is also known from an interglacial deposit in Essex in England (E. M. REID & M. E. J. CHANDLER: The Fossil Flora of Clacton-on-Sea. Quarterly Journal of the Geolog. Soc. LXXIX, parts 4, 1923, p. 619).

6) L. A. HAUCH: Danmarks Trævækst. I. København. 1919, p. 95.
A. OPPERMANN: La Santé de l'Épicéa en Danemark. Det forstlige Forsögsvæsen. VI. 1922, p. 83 f.

"Denmark has no conifer climate". Our winters are too mild both for *Picea excelsa* and *Pinus silvestris.* The fact that *Picea excelsa* likewise failed to thrive well in NW Europe in the first interglacial conifer period (cf. p. 340) is hardly due to the conditions of soil, which appear to have been favourable for the flourishing of the forest both in NW Germany and Denmark at that time, and it was not required to enter into competition with the beech. And it could hardly have been because the species was lower in its advance than those of the mixed oak forest group; on the contrary *Picea excelsa* migrates comparatively rapidly. The cause of the late occurrence as a common forest tree of *Picea excelsa* on the Cimbrian peninsula in the last interglacial period must probably be viewed in the atlantic climate, with its mild winters, which accompanied the Eem subsidence.

The rise of the land which followed the Eem subsidence commenced when the climatic optimum was still prevailing (cf. p. 179) that is, presumably, at latest simultaneously with the formation of the *g* zone in the interglacial bogs and lakes. And this would undoubtedly effect an alteration of the climate of the Cimbrian peninsula and NW Germany in the continental direction. The rise evidently assumed considerable dimensions in course of time, so that — according to G. DUBOIS[1]) the Channel between England and France was dried up, together with great parts of the southern North Sea when the maximum was reached, probably during the last glacial period.[2])

These facts make it probably that in the later part of the interglacial stage II, a relatively continental type of climate prevailed in Jutland and North-western Germany.

Previously temperate, the climate gradually became cooler, and forests of *Betula-Picea-Pinus* covered the area in the latter part of the second stage of the interglacial Period, while at the same time, the *Betula nana* moors, afterwards so prominent, had begun to spread. The polar forest limit, moving south, was already nearing our territory.

The overgrowing of the interglacial lake basins took place at very different times, as will be seen from the table below. Often however, the lakes appear to have had no formation of peat worth mentioning. From the close of the II stage, we have evidence of marked

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1) D. DUBOIS: Recherces sur les terrains quaternaires du nord de la France. Mém. de la Société geologique du Nord. Tome VIII. I. Lille 1924, p. 276, 321.

2) We do not know however whether the rise of the land after the Eem subsidence continued unbroken until the maximum mentioned was reached. Probably the Skærumhede-transgression i Vendsyssel is contemporaneous with the stages IV and V of last interglacial period, (cf. p. 336).

S v a m p i n g s (Versümpfungen) in all basins containing peat strata[1]) save where these were covered over immidiately by sand. Where this is the case it may be presumed that the swamping strata were annihilated during the formation of the covering strata,

| | Overgrowing of the Lake by | | Nature of Swamping | |
|---|---|---|---|---|
| | Zone | Peat | Zone | Sequence of Strata |
| Duedam ........... | *i* | *Sphagnum* peat | .. | ........................... |
| Fleestedt .......... | *i* | Forest peat | *i* | Clay mud<br>Forest peat |
| Nörbölling......... | *h* | Fresh *Sphagnum* Peat | *i* | Clay mud<br>*Sphagnum* peat |
| Rodebæk I ........ | *h* | Forest peat | *k*<br>*i* | Sandy *Sphagnum* peat<br>Forest peat |
| Loopstedt ......... | *h* | *Hypnum* peat | .. | ........................... |
| Kollund .. ........ | *g* | *Hypnum* peat | .. | ........................... |
| Kuhgrund ......... | *g* | *Scheuchzeria* peat | .. | ........................... |
| Rodebæk III....... | *f* | *Alnetum* peat | .. | ........................... |
| Over Gestrup...... | *f* | Fresh *Sphagnum* peat | *i* | Mud<br>Highly humif. *Sphagnum* peat |
| Römstedt I. ...... | *f* | *Sphagnum-Hypnum* peat | *i* | Clay mud<br>Highly humif. *Sphagnum* peat |
| Höllund Sögaard... | *e* | Fresh *Sphagnum* peat | *i* | Sandy Detritus peat<br>Highly humif. *Sphagnum* peat |
| Brörup railway stn. | *d* | Fresh *Sphagnum* peat | *h*<br>*g* | Mud<br>Highly humif. *Sphagnum* peat |
| Römstedt II ....... | .. | Peat bed rests on bottom of basin | *i*<br>*h* | Mud<br>*Hypnum* peat |
| Hörup ............. | .. | Peat bed rests on bottom of basin | *c* | Calcareous mud<br>*Hypnum* peat |

The overgrowing of interglacial lakes and the following swamping.

Disregarding Hörup, where unusual conditions prevail, we learn from the table that the moisture in the soil must altogether have increased greatly during the closing part of the II stage, and it must be presumed that the same factors are responsible for this marked increase of humidity in the different basins. This may be due to increased precipitation, or to hindrance of evaporation. It would seem most likely that both factors contributed.

The inverse sequence of strata shown in the swamping of the bogs presents a certain formal similarity to the post-glacial, sub-boreal sub-atlantic strata sequence, but this last was completed within the

1) As a rule, only a single profile from each bog was subjected to pollen analysis; this may be taken as from the middle of the basin in question. It follows then, that the date of overgrowing will be a minimum determination, that for the swamping a maximum.

latitudes here concerned under a temperate climate — in Denmark and NW Germany favourable to the growth of deciduous trees — whereas the interglacial swamping occurred after the regions in question had acquired a conifer forest growth of northern character, i. e. at a period probably later in relation to the forest development. But, as the sub-boreal sub-atlantic transition is regarded as indicating a change of climate during which the thermophile species were forced southward, followed by northern forms (*Betula nana*), the glaciers pushed forward and the forest limit was lowered in Scandinavia and on the Alps, so also, the interglacial swamping, viewed in the light of the general character of the preceding and accompanying flora accentuates the impression that the polar-climatic zone had now come closer to us. But the swamping in Zone *i* appears to us only as an introduction to the conditions which attained their full development in the subsequent stage; it is but a single item in the series of effects which gradually led to a complete alteration in the character of the vegetation in Denmark, and entirely changed the sedimentation in the lakes.

## Stage III. The Sub-arctic Flora in the Middle Bed.

Zone *k*. In the basins containing bogs of the Brörup type, fossilless clay and sand strata — the so-called covering strata — lie directly on mud and peat beds from the II stage of the interglacial period. Only in bogs of the Herning type (Herning, Nörbölling, Brörup Hotel Bog and Rodebæk I) were the basins sufficiently spacious for continued registration of the floristic and climatic development for a considerable further period of time. There is however, no very clear contrast between the two types, but rather a suggestion of transitional forms, such as in the bogs at Solsö, Höllund Sögaard, Over Gestrup, Tuesböl, Föyling and Brörup railway station, where sedimentary strata of clay and sand are found bedded on the mud or the peat. There is hardly a lacuna of any extent in this part of the strata series, this is first met with above the clay and sand strata in question, which were probably, at least in part, synchronous with the Middle Bed in the bogs of the Herning type.

The sub-arctic character of the Middle Bed has been pointed out when dealing with the individual localities, see especially p, 53, 77 and 88. *Betula nana — Empetrum nigrum* heaths and bogs now took the place of the rich forests, and poor communities of aquatic plants with northern forms, such as *Myriophyllum alterniflorum*, *Potamogeton filiformis* and *Sparganium cf. affine*, superseded the luxuriant *Trapa-*

*Brasenia* flora. In course of time, however, scattered stocks of *Betula pubescens* made their appearance, — this species is likewise noted from the very lowest part of the zone — as also *Pinus silvestris, Picea excelsa* and *Juniperus communis.*

In the pollen diagrams from Nörbölling, Rodebæk I and Brörup Hotel, Zone *k* is characterised by the dominance of *Betula* over *Pinus* and only a little *Picea*, but in most spectra from Zone *k* in the pollen diagram Herning 9, we find a different state of things (cf. Pl. XXXVI, 2). In considering the spectra from the Middle Bed however, we must bear in mind that in regions with a small production of pollen of its own, the effect of alien pollen brought by the wind from far away on the pollen diagrams will be relatively great, cf. for instance the pollen diagrams published by L. v. POST [1]) from late-glacial *Dryas* clay in Scania and Gothland; also, that in regions near the forest limit, where the few species can be heterogeneously dispersed in small groups, the local pollen production would presumably differ greatly from place to place as regards percentages in its composition.

In the pollen diagrams from Nörbölling and Rodebæk I (Pl. XXXVI) especially it will be seen that the lower limit of the Middle Bed is not drawn coincident with the zone limit *i—k*. This is due to practical considerations: The Middle Bed appears in the profiles as a petrographical unit, which, in contrast to the far more organogeneous strata above and below, is composed mainly of inorganic matter. The Middle Bed denotes, in hydrographical respects, a continuation of the state of humidity which set in, and occasioned the swamping in the latter part of the II stage, and the enormous amount of inorganic material which it contains, washed down from the surrounding soil, may — in comparison with the older sediment types of the same basins — be regarded as indicating that the ground no longer possessed a complete cover of vegetation with ability to regenerate, and that the production of organic matter in the lakes themselves was very slight.

From the Herning profile especially it appears that the sub-arctic character of the Middle Bed was most pronounced in the first part of this stage, but it must here be borne in mind that the whole of that development which attained its climax in the Middle Bed is already traceable far earlier (from Zone *h)* through the gradually accentuated paucity of species in the flora, and the dominance of northern types. It is first in the later part of the Middle Bed period that we can again discern progress in the vegetation.

During the first part of the Middle Bed time, the polar forest

1) L. VON POST: Ur de sydsvenska skogarnas regionala historia under postarktisk Tid. Geol. Fören. Förhandl. Bd. 46. Stockholm 1924, p. 102—103.

limit lay undoubtedly south of Herning, whereas in the later part of the period it again moved northward. According to BROCKMANN-JEROSCH [1]) the present polar forest limit lies south of the isotherm for 10 ⁰ C mean temperature in July in regions with oceanic climate, while in regions with continental climate, forest can still thrive at this mean temperature, e. g. in northern Siberia. Jutland can hardly have had such a pronounced continental climate as there prevails, as it had even then the North Sea for a neighbour, though this may perhaps have been of less extent then than at the present time (cf. p. 360). On the other hand, we do not find such evidence of atlantic influence as might be supposed to be furnished by a pure *Betula* zone in the upper part of the Middle Bed period, — cf. the *Betula* zone at the forest limit on the sea coasts of northern Europe [2]). The suggestion that the July temperature during the latter part of the Middle Bed period was abt. 12.7 ⁰ C, as it is nowadays at the northern limit for conifer forests at Kola, is thus hardly putting it too low. During an earlier part of the Middle Bed period, the summer temperature was probably even lower than this.

From the climatic optimum (Zone *f*) of the interglacial period to the sub-arctic climate of the Middle Bed period, climatic development is in the main as might be expected during the closing part of an interglacial period, when the approaching inland ice, or the climatic conditions for its approach, became more and more marked in the effect on the regions lying ahead of the ice itself. Moreover, a considerable number of profiles (see p. 361) present an unmistakable impression of the increasing humidity, which must be supposed to precede a glaciation. We must therefore conclude that the Middle Bed in the interglacial bogs of Jutland indicates that at the time of its formation, a marked advance of the inland ice from the Scandinavian highlands was taking place. During the climatic optimum, the inland ice in those highlands can hardly have been of the same extent as the glaciers of the present day[3]). The question as to how far the ice advanced can hardly be answered; it is evident however, that it did not advance so far as

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1) BROCKMANN-JEROSCH: Baumgrenze und Klimacharackter. Beitr. z. geobot. Landesaufnahme. Zürich. 1919, p. 195.

2) A. OSW. KIHLMAN: Pflanzenbiolog. Studien aus Russisch Lappland. Acta Societatis pro Fauna et Flora Fennica. T. VI, No. 3. Helsingfors. 1890, p. 22, Übersichtskarte. — ROLF NORDHAGEN: Kalktufstudier i Gudbrandsdalen. Videnskapsselskapets Skrifter. I. Mat.-naturv. Klasse. 1921. No. 9. Kristiania. 1921, p. 122.

3) Cf. the high "fossil" forest limit of the Scandinavian highlands from the period of the climatic optimum. (Th. E. FRIES: Botanische Untersuchungen im nördlichsten Schweden. Dissertation. Upsala 1913, p. 203).

under the last glaciation in NW Europe, which covered the greater part of Jutland (see Pl. I) as no trace of flow earth formation from the Middle Bed period has been found.

## Stage IV. The Upper Temperate Flora.

The improvement in climate noticeable in the upper part of the Middle Bed period was not in itself unessential, but formed the introduction to that complete alteration in the climatic conditions which marks the IV stage of the interglacial period, during which the upper temperate flora developed, while at the same time a great change took place in the conditions affecting the sedimentation in the basins. The extensive washing lists from this part of the profiles, Herning Stratum G (p. 46 f.), Nörbölling Stratum F (p. 74 f.), Brörup Hotel bog Strata E, F, G (p. 86 f.), indicate the character of the contemporary flora, while the pollen diagrams for all the profiles of the Herning type (Pl. XXXVI) afford a basis for division of the strata into 2 zones. In a lower zone *l*, we find a considerable frequency value for the pollen of deciduous trees, those of the mixed oak forest for instance (almost exclusively *Quercus)* from 7 to 15 %, *Alnus* from 39—52 %, *Carpinus* 5—7 %, and *Corylus* from 20—57 % while the *Pinus* and *Betula* curves turn off to the left at the same time; the tendency of the *Picea* curve differs in the various diagrams.

In an upper zone *m*, the pollen curves for deciduous trees turn off to the left, though *Alnus* can still show up to 30 %, but the mixed oak forest has only 5 %, *Carpinus* 3 %, *Corylus* 9 % (Herning). The *Betula* curve, on the other hand, turns to the right in all profiles, and in the Brörup Hotel bog at one time attains as much at 96 %. In the same diagram we find *Picea* later with 60 %, while in the remaining diagrams it is rather on the decline. *Pinus* shows unaltered or increasing frequency. This evidence of the pollen flora must be taken in conjunction with the species whose macroscopic remains were found in Zones *l* and *m*, that is to say, on the whole, the same species which made up the lower temperate flora. A noticeable feature in the vegetation of the IV stage was that heath-element from the Middle Bed period, which must undoubtedly have continued to exist here and there, despite the evident complete alteration in climatic conditions which had now taken place. It is natural to regard this community, represented in the washing lists by *Betula nana, Empetrum nigrum, Arctostaphylus uva ursi*, as relicts from the Middle Bed period. There are, as we know, instances in the present day of a similar sub-arctic flora in the bogs of temperate lowlands, as in the regions south of the Baltic[1]). The same remarks apply to *Myriophyllum alterniflorum*.

Both paleontological and stratigraphical conditions in the 4 deposits of the Herning type show that the climatic and floristic line of development followed to the sub-arctic period of the Middle Bed then gave place to a new rise in temperature and the return of the forest growths. How far the thermophile forest trees had been driven south must be left to the decision of future investigations in Central Europe, but when the climate again improved, they were soon able to advance and regain their old positions. The climatological inference from the paleontological material representing the IV stage of the interglacial period must be that the climate then prevailing gave almost as mild summers as in the time of the *f* zone in the II stage. Glaciologically, it must be concluded that the inland ice, which was supposed to have spread out from the Scandinavian highlands in the time of the Middle Bed attaining its maximal extent during the first part of that stage, again withdrew to a minimal extent in the IV stage. Our demonstration of the Herning type among the Danish interglacial fresh-water deposits thus shows that a very considerable climatic oscillation took place during the last northern interglacial period. That it can only have been an oscillation, and not a glacial period itself corresponding to the glaciation of so distally situated regions as those reached by the last northern ice sheet is evident from what is stated on p. 364—365.

## Stage V. The Upper Sub-arctic Flora.

Zone *n*. The *m* zone of the diagrams affords evidence of the fact that the forest vegetation known from the latter part of the IV stage of the interglacial period was again altered in the direction of such conditions as now prevail in countries north of Denmark. From this we may conclude that the mild climate, which favoured the upper temperate flora in its most luxuriant development, was now superseded by colder climatic conditions. This conclusion is supported also by the scanty flora found in the clay and sand beds immediately above the upper strata with a temperate flora, at Herning (Strata E and F, p. 46 f.), Nörbölling (Stratum E, p. 74 f.) and in the Brörup Hotel bog (Stratum D, p. 86 f.) as we here again encounter *Betula nana*

[1]) For *Betula nana* in temperate interglacial floras see C. A. Weber, Neues Jahrb. f. Mineralogi etc. 1891, II., p. 62 f. — M. Beyle, Mitteilungen a. d. Mineralog-Geologischen Staatsinstitut. Heft. VI. Hamburg 1924, p. 17. Cf. also p. 119 in this work.

together with other dwarf bushes, in addition to *Betula pubescens*, and among aquatic plants, especially *Batrachium aquatile (coll.)*, *Potamogeton filiformis* and *Myriophyllum alterniflorum*. That is to say, a flora of the same character as that found in the Middle Bed. This V stage is one of transition to the last glacial period, but only inconsiderable strata or remains of strata are preserved from this stage, as the solifluction occasioned by the periglacial climate during the last glacial period has affected and to a great extent destroyed the upper sediments in the basins (cf. p. 59 and p. 81 f.).

The considerations set forth in the foregoing warrant the view that the climatic oscillations i Jutland during the last interglacial period took place in correspondance with 1) the advance and retreat of the glaciation of Scandinavia, and 2) the displacement of the see shore.

We have no data concerning the flora of Western Jutland, during the maximum of the last glaciation, when it was free from ice and solifluction must be supposed to have been at its height there. Interglacial lakes, larger and deeper than the lake at Herning, must be found before we can expect to meet with remains of the glacial flora which presumably flourished at the time of the maximal extent of the ice sheet. Such a flora would hardly have been a rich one. The plant life of the lakes in arctic regions at the present day is extremely poor[1]) and in those tracts where solifluction took place, the conditions of growth for land vegetation would have been particularly unfavourable. On the other hand, we may presume that favourable exposed, gravelly or sandy hillsides offering no opportunity for solifluction, would have afforded the best localities for land vegetation. Xeromorphous dwarf-bush-heaths and formations of the fell-field type may have found suitable sites in localities of this sort.

## The Penultimate Interglacial Period.

## The Jutland Area.

The Danish interglacial deposits from the penultimate interglacial period, situated at Harreskov, Rind, Starup, Tirslund and Vejen, can be divided on the basis of the pollen analyses into zones corresponding to those known from the II stage of the last interglacial period, though we have not found the complete series of zones from here in the few known formations. Pollen diagrams are available only for Harreskov

1) Eug. Warming: Über Grönlands Vegetation. Eng. Botan. Jahrb. Bd. X. 1888.

and Starup. The general view of the development of the penultimate interglacial period may be given in the table p. 369.

Zone *c* is known only from Starup. In both diagrams, *Ulmus* is very conspicuous in Zone *e*, with 29—38 %. In Zone *f*, which constitutes by far the greater part of the Starup pollen diagram, the various species of deciduous trees do not culminate in the same order in both diagrams; the order of sequence is, for Harreskov: *Alnus* and *Ulmus* (secondary maximum) — *Corylus* — *Quercus* and *Tilia*; for Starup: *Quercus* — *Alnus* and *Tilia* — *Ulmus* (slight secondary maximum) — *Corylus* (only 9 %). The *Tilia* pollen is comparatively abundant at Rind, Harreskov and Starup.

*Carpinus* pollen amounts to only 1—2 % in Zone *i* at Vejen, where it must doubtless be regarded as brought from far away by the wind, and to 1 % at Starup, in the uppermost part of Zone *f*. It remains an open question whether *Carpinus betulus* was altogether lacking in Jutland during the penultimate interglacial period[1]), but at the root of the Cimbrian Peninsula, viz. Ütersen-Glinde, *Carpinus betulus* has been found dating from this period, see p. 372. *Picea* has a slight first maximum in Zones *c* and *d*, where it shows 5—7 %. Throughout the greater part of the *f* zone, only 0—2 % of this species of pollen was found; the rational lower limit for the upper *Picea* zone lies at the upper margin of Zone *f*. In the Starup interglacial, *Picea* pollen only amounts to 11 %, whereas in the *h* zone of the Harreskov diagram, the maximum lies at 14 %. Zone *i* is represented both at Harreskov and Vejen, as also Tirslund. In the pollen diagram from the first-named locality, *Picea* has its absolute maximum here. As regards *Alnus*, we find a considerable frequency in some spectra from Vejen, otherwise, the pollen of the deciduous species, with exception of *Betula*, is here doubtless represented only by casual importations of pollen by the wind from far away. A couple of pollen spectra from Vejen may perhaps be ascribed to Zone *k*. From the analogy between the floristic development in the corresponding sections of the two interglacial periods on Danish ground we must suppose a similar alteration in the climate of the penultimate interglacial to that of the first stages in the last interglacial period, and this will appear the more likely if it can be shown that the great land subsidence known from this interglacial period in south-western Holstein was synchronous with the mixed oak forest zone.

[1]) It may be remembered that in the deposits from the last interglacial period *Carpinus* pollen may be very rare in some areas, viz. at Rodebæk.

| Stages | Character of Flora | | | Zones | Climatic conditions<br>Changes of level | | |
|---|---|---|---|---|---|---|---|
| III | Sandy Mud | | *Betula pubescens*, *Pinus silvestris* | *k* | Climate more continental, gradually cooler | Changes of Level but little known in Denmark | In Holstein: Subsidence? Rise of Land? |
| II | Mud (and Peat) with Temperate Flora — Forest mainly of | Conifers | *Pinus silvestris* dominant, *Picea excelsa's* second maximum (Harreskov), *Betula pubescens* frequent | *i* | | | |
| | | | *Pinus silvestris* dominant, *Picea excelsa's* first maximum, mixed oak forest species disappear | *h* | | | |
| | | Deciduous trees | [No *Carpinus*-Zone discovered in Jutland] | *[g]* | Atlantic climate, temperature optimum | | |
| | | | Mixed oak forest. *Quercus sp.*, *Corylus avellana*, *Alnus glutinosa*, *Tilia sp.*, culminate. *Pinus silvestris* and *Betula pubescens* minimal | *f* | | | |
| | | | *Ulmus*-maximum; *Pinus* and *Betula* on the decline | *e* | Cooler in the first time, gradually milder climate of continental type | | |
| | | Conifers | *Pinus silvestris* dominant, mixed oak forest species immigrating | *d* | | | |
| | | | *Betula pubescens* dominant, *Pinus silvestris*, traces of *Picea excelsa* | *c* | | Rise of Land[1]) | Vognsböl deposits, Esbjerg *Yoldia* clay |
| I | | | [Sub-arctic and arctic flora not discovered] | *[a, b]* | Melting away of the inland ice | | |

Development of the penultimate interglacial Period.

[1]) Cf Axel Jessen: Changes of level. Summary of the Geology of Denmark. Published by Victor Madsen. D. G. U. V. R. No. 4. Köbenhavn 1928, p. 159.

## The North-west German Area.

In the North-west German area there is greater possibility of arriving at an exhaustive description of the climatic and floristic development in the penultimate interglacial period than in Jutland, thanks to the considerable number of deposits, both marine and limnian, from the period in question. At the present stage of research however, only suggestions can be given, where a thorough modern investigation of the deposits in question, might be expected to furnish more definite results. The outline of floristic and climatic history during the interglacial period here given is based especially on the extant analyses of floras from Ütersen Glinde[1]), Hummelsbüttel[2]), Lauenburg, Honerdingen[3]), Ober Ohe, Westerweyhe and Nedden-Averbergen[4]).

The most complete view of the floristic development in the penultimate interglacial period in North-west Germany is that given in C. A. WEBER's account of the Honerdingen profile; this may be briefly expressed as follows:

| | |
|---|---|
| Sandy peat over mud | *Pinus silvestris* and *Betula alba* almost exclusively prevailing.<br>*Picea excelsa* shows great decline in frequency. |
| Calcareous mud ..... | *Abies pectinata* culminates and disappears.<br>Rich mixed forest of *Picea excelsa* and deciduous trees: *Quercus cf. sessiliflora*, *Carpinus betulus*, *Alnus glutinosa*, *Ilex aquifolium*, the three *Tilia* species, *Juglans sp.* with many others, and *Taxus baccata*[5].)<br>*Pinus silvestris*, *Betula sp.* |
| Sand ............... | *Betula nana.* |

We find then, here a line of development following much the same laws as those which marked the course of events in the penultimate interglacial period in Jutland as well as in the two first stages

[1]) H. SCHROEDER und J. STOLLER: Diluviale marine u. Süsswasser-Schichten bei Ütersen-Schulau. Jahrb. K. Pr. G. Landesanstalt für 1906. Bd. XXVI, p. 503 f., 520.

[2]) W. WOLFF: Das Diluvium der Gegend von Hamburg. Ibidem für 1915, p. 266.

[3]) C. A. WEBER: Über die fossile Flora von Honerdingen und das nordwestdeutsche Diluvium. Abh. Naturw. Ver. Bremen 1896, Bd. XIII.
The same: Die Geschichte der Pflanzenwelt des norddeutschen Tieflandes seit der Tertiärzeit. Resultats scientifiqe du Congrès internat. de Botanique. Wienne 1905. Jena 1906, p. 102.

[4]) On the litterature of Lauenburg, Ober Ohe, Westerweyhe and Nedden-Averbergen see Chapter IV, p. 296 f.

[5]) *Fagus silvatica* is also noted, from an earlier source not confirmed, cf. p. 345.

of the last interglacial period. It will easily be seen that if our pollen diagram from Westerweyhe is to be placed in this evolutionary series it must be in the upper conifer period, and the sedimentation in this basin seems to have been subjected to conditions similar to those which marked the profile at Honerdingen. It will also be seen that the two pollen spectra from the calcareous mud at Nedden-Averbergen must have their synchronous levels in the zone with deciduous trees at Honerdingen. The forests at Ober Ohe were apparently strongly marked by *Pinus silvestris* during the formation of the kieselgur, though numerous deciduous trees contributed (see p. 297), but the three zones noted from there in the pollen diagram, viz. the *Abies*, the *Carpinus* and the mixed oak forest-*Corylus* zone, nevertheless suggest as most likely that the lower part of the kieselgur stratum at Ober Ohe is synchronous with the upper part of the calcareous mud at Honerdingen. J. STOLLER[1]) also mentions from the kieselgur stratum at Bispingen in Luhetal a rich mixed flora which suggests that the kieselgur stratum here is from the same section of the interglacial period as that at Ober Ohe.

Turning then to the Hamburg District, we find, according to W. WOLFF[2]) and E. KOCH[3]), the following profile:

Sand with stones

Peat

"Bänderton" — Moraine clay

Peat

Marine deposits with *Ostrea* etc.

Peat

"Lauenburger Ton" and fine sand

Moraine clay.

The upper peat bed belongs to the last interglacial period (Schulau, Winterhude, Kuhgrund etc.), the lower peat beds and the marine deposits to the penultimate interglacial period (Ütersen-Glinde, Hummelsbüttel, Prisdorf, Lauenburg and elsewhere.

SCHROEDER and STOLLER have dealt with the flora in the peat above the marine deposits at Ütersen-Glinde. According to these writers, it belongs to the northern temperate zone, and more especially to the cold temperate part; most of the species however, are also typical constituents of the bog communities, and are therefore not particularly

[1]) J. STOLLER: Sonderdruck aus Festschrift vereinigte deutsche Kieselgurwerke. Hannover 1925, p. 18.

[2]) W. WOLFF: Das Diluvium der Gegend von Hamburg.

[3]) E. KOCH: Die prädiluviale Ablagerungsfläche unter Hamburg und Umgebung. Mitt. a. d. Mineralog.-Geologischen Stadtsinstitut. H. VI. Hamburg 1924.

suitable as a basis for climatological inferences. Among the ligneous plants were found especially *Betula alba* (including *B. pendula), Alnus glutinosa, Pinus silvestris, P. montana, Picea excelsa*, two nuts of *Carpinus betulus* at the bottom of the peat bed, *Frangula alnus*, together with *Calluna vulgaris, Empetrum nigrum, Erica tetralix* and *Myrica gale*. Both these last-named species, as also *Pinus montana*, require very moist air and abundant precipitation. Several marsh growths were also found, as for instance *Cladium mariscus*, and among aquatic plants e. g. a fruit of *Ceratophyllum demersum var. apiculatum*. None of the species peculiarly characteristic of the mixed oak forest is mentioned. This applies also to the little flora noted by W. Wolff (l. c.) after M. Beyle from the peat bed above the marine deposits at Hummelsbüttel. Here were found inter alia *Betula alba, Alnus glutinosa, Cladium mariscus, Najas marina ?* and *Potentilla erecta*.

These upper peat strata from the penultimate interglacial period in the Hamburg district seem, both as regards their stratigraphical position and their flora, to be naturally referable to the time of the upper conifer zone at Honerdingen, and similarly, we may find a parallel between the lower peat bed of the Hamburg profile (Lauenburg, Prisdorf[1]) and the lower conifer zone at Honerdingen. If these stratigraphical associations are in accordance with the facts, — assuming that the deposits belong to one and the same interglacial period, thorough pollen statistical investigations must decide the point — it follows that the deciduous forest period in North-west Germany during the penultimate interglacial period, with its wealth of species, must have been synchronous with the transgreesion of the North Sea in the Elbe Valley and western Holstein, just as the mixed oak forest (zone *f*) in the last interglacial period was synchronous with the trangression of the Eem Sea. There will then be a profound similarity between the two northern interglacial periods in regard to development of the flora and climate (cf. p. 269), though we do not know of any climatic oscillation from the penultimate interglacial period corresponding to that which, as we learn from the profiles of the Herning type, must have occurred in the last interglacial period. As regards the parallel between the Harreskov-Starup profiles and the Honerdingen profile, the generally uniform development here is at once conspicuous, but points of difference are not lacking, and before we can arrive at any complete appreciation of the floristic differences between the two areas, renewed investigations must extend our knowledge, firstly as regards especially macroscopic plant material in the Jutland interglacial deposits in question, and also as to the develop-

[1]) The occurrence at Prisdorf consists of an isolated flake (Scholle); Wolff, l. c. p. 268.

ment of the pollen flora in the contemporary formations of Northwest Germany.

We have not succeeded in finding any decisive floristic difference between the fresh-water deposits from the two interglacial periods. *Dulichium spathaceum* however, does not appear to have been met with as yet in those deposits which can be referred with certainty to the penultimate interglacial period, but *D. vespiforme* is mentioned from "Interglacial I" (Seelze, Tegelen a. o.) as well as from the last interglacial period[1]). *Brasenia purpurea* seems not to be common in deposits from the penultimate interglacial period. This species has not been found, for instance, in deposits of calcareous and diatomaceous mud but seems generally to have preferred lake basins of like constitution to those favoured by *Trapa natans*. From such, it is known at Lütjenbornholt[2]) in Holstein, and from the plant-bearing strata at Langenfelde and Schmalenbeck near Hamburg[3]), deposits which should possibly be referred to the penultimate interglacial period. *Hydrocharis morsus ranae*, in all probability identical with *Aldrovanda vesiculosa* (cf. p. 351), is mentioned from Schmalenbeck by M. BEYLE[4]), and this thermophile species is then presumably also to be referred to the penultimate interglacial period. *Hydrocotyle natans* and *Najas minor* are hitherto known only from "Interglazial I" or older strata[5]), and *Pinus montana* in NW-Germany seems also to date from the penultimate interglacial period or even older parts of the quaternary time just as *Picea omorikoides*.[6])

The parallelism between the two interglacial periods in point of development as here shown can however be extended so as to embrace also the floristic and climatic development of the post-glacial period in northern Europe, with such modifications as appear in the comparisons freqently made in the foregoing. The two interglacial periods show, as regards the sections concerned, an almost complete cycle from arctic via mild temperate to sub-arctic climate, which, stage by stage, as far as the development has progressed, finds its corre-

1) J. STOLLBR: Über altdiluvial Leineschotter bei Isernhagen und das altdiluviale Torflager bei Seelze in der Umgebung von Hannover. 11 Jahresber. d. Niedersächsischen geolog. Vereins zu Hannover. 1919, p. 66.

2) C. GAGEL: Centralblatt für Mineralogie etc. 1910, p. 77 and 97 f.

3) M. BEYLE: Über einige Ablagerungen fossiler Pflanzen . . . Jahrb. d. Hamburgischen wissenschaftlichen Anstalten XXX. Hamburg 1913, p. 83 f. and XXXVI. 1919, p. 44. — W. WOLFF. Jahrb. Königl. Preuss. Geolog. Landesanst. f. 1915, XXXVI, II. p. 283.

4) M. BEYLE: Über einige Ablagerungen . . . Jahrb. XXXVI. Hamburg. 1919, p. 44.

5) J. STOLLER: Über altdiluviale Leineschotter . . . l. c. p. 69.

6) G. MÜLLER und C. A. WEBER: Über eine frühdiluviale und vorglaziale Flora bei Lüneburg. Abhandl. K. P. G. Landesanstalt. N. F. Heft. 40. Berlin. 1904.

sponding analogues in the post-glacial period — save for the sub-boreal section of the latter — the climatic optimum of the post-glacial period being a stage long past. Turning to other regions of Europe, especially Central Europe, and Russia, we find several instances of successions in the post-glacial forest development demonstrated by pollen analysis [1]) which in certain respects differ greatly from the contemporary northern types; interglacial deposits in these regions on the other hand have hitherto been very little dealt with by pollen analysis. As far as I am aware, there is only a pollen diagram, by J. FIRBAS [2]), from the interglacial peat beds at Schladming, near Enns, showing this development: *Pinus* zone — *Picea* zone — *Picea* and *Abies* zone, and the pollen analyses of the same autor [3]) from interglacial deposits in the Inn valley in the Alps showing successions as: *Picea* zone — *Pinus (montana* vel *silvestris)* zone or *Fagus* zone — *Picea* and *Pinus*

| Post-glacial Period (SERNANDER) | Last Interglacial Period in Poland (SZAFER) | Last Interglacial Period [4]) in NW Europe, Stages I and II (KNUD JESSEN & V. MILTHERS) |
|---|---|---|
| Present time | Pre-subarctic Phase | Gradually cooler Climate { moister, Zone *i*; continental, Zone *h* |
| Sub-atlantic Period | 2. Sub-atlantic Phase | Oceanic Climate, Temperature Optimum, Zones *f* and *g* |
| Sub-boreal Period | Meridional-pontic Phase (climatic optimum) | |
| | Hiatus | |
| Atlantic Period | 1. Sub-atlantic Phase | |
| Boreal Period | Boreal Phase | Warmer, continental Climate, Zones *c* - *e* |
| Sub-arctic Period | Sub-arctic Phase | Sub-arctic Climate, Zone *b* |
| Arctic Period | | Arctic Climate, Zone *a* |

1) PETER STARK: Der gegenwärtige Stand der pollenanalytischen Forschung. Zeitschr. f. Botanik, 17. Jahrg. 1925. Jena. — W. S. DOCTUROWSKY: Über die Stratigraphie der Russischen Torfmoore. Geolog. Fören. Förhandl. Stockholm. 1925, p. 81 f.

2) F. FIRBAS: Zur Waldentwicklung im Interglacial von Schlading an der Enns. Beihefte zum Bot. Centralbl. Bd. XLI. 1925. Abt. II. Dresden.

3) F. FIRBAS: Beiträge zur Kenntnis der Schieferkohlen des Inntals und der interglazialen Waldgeschichte des Ostalpen. Zeitschrift für Gletscherkunde. Bd. XV. 1927. — After I had received the proof of this sheet I became aquainted with P. GALENIEKS: The Interglacial Flora of Kraslava (Acta Hort. Bot. Univ. Latviensis. Riga. 1926, p. 179 f.) in which is given a pollen diagram from a 56 cm thick interglacial peat bed.

4) Cf. p. 336.

zone. Very interesting are also the results arrived at by W. SZAFER[1]) from the investigation of richly fossiliferous fresh-water deposits at Grodno, in Poland, supposed to date from the last interglacial period. He found here a richly varied floristic and climatic development, and compares it with SERNANDER's table for the post-glacial period as shown on the foregoing page.

This interglacial development at Grodno followed in the main the same line as we have shown in the case of Stages I and II of the last interglacial periods in NW Europe. A point of difference is noticeable especially in the oscillation towards the continental, which SZAFER's meridional-pontic phase denotes in the otherwise oceanic, warmest part of the interglacial period, nothing corresponding to this being discernible in our material. It must be supposed that pollen-analytical investigation of eastern and central European interglacial profiles would afford a basis for more certain parallels between these and the interglacial deposits of NW Europe, especially if it were possible to arrive at a more convincing age determination of the formations in question; possibly the standpoints we have adopted ourselves in regard to division of the diluvial in Jutland and NW Germany may here prove useful. At the same time, a task of far-reaching importance will be the further investigation as to whether there exists, in these regions floristic similarity between the interglacial and post-glacial historical sequence, such as we find in NW Europe.

## The Diluvium of North-western Europe, and the Paleolithic Chronology.

In the foregoing sections it has been shown that 1) there is in NW Europe a series of interglacial fresh-water deposits, e. g. Harreskov, Rind, Starup, Honerdingen, Ober Ohe, Neu-Ohe, Wiechel, Westerweyhe, Luhetal, which, by a glaciation extending over these deposits, became separated from a younger group of interglacial deposits covered by flow-earth or outwashed sand and clay, as found in great numbers in the region, outside the limit of last glaciation, from Herning in the north to Römstedt

1) W. SZAFER: Über den Charakter der Flora und des Klimas der letzten Interglazialzeit bei Grodno in Polen. Bull. international de l'academie Polonaise Série B. Sci. nat. 1925. Cracovie 1926, p. 277 - 314. — Cfr. HEINRICH WALTER: Einführung in die allgemeine Pflanzengeographie Deutschlands. Jena 1927, p. 209.

in the south, and 2) the floristic-climatic development during the earlier stages of the last interglacial period reveal, stage by stage, conditions corresponding to those which mark the penultimate interglacial period as well as the post-glacial — a very considerable climatic oscillation characterizing the later stages of the last interglacial period.

In direct opposition to those writers who — as most recently J. BAYER[1]) — maintain that the last northern interglacial period is not to be regarded as such, but only as a Schwankung, or Interstadial period, we must assert that there is no difference in principle between the floristic and climatic development of the earlier stages of this period (the first warm period) and the penultimate interglacial; and also, that the interval of time seperating the maximal extent of the inland ice in the two last northern glaciations must rather be regarded as longer than the penultimate interglacial period. The definitive demonstration of the fact that the Eem subsidence belongs to the last northern interglacial period[2]) is in itself sufficient to render the view of this interglacial period as a Schwankung highly improbable.

The difference between a Schwankung or Interstadial period on the one hand and an Interglacial period on the other can be set forth, as far as regards the climatic development, in an ideal table such as that here given:

| Glacigenous or periglacial formations | |
|---|---|
| Interstadial climatic development | Interglacial climatic development |
| arctic<br>sub-arctic<br>boreal; summer temperature essentially lover than the climatic optimum of the post-glacial period<br>sub-arctic<br>arctic | arctic<br>sub-arctic<br>boreal<br>temperate climate with a summer temperature at least as high as during the post-glacial climatic optimum of the area in question<br>boreal<br>sub-arctic<br>arctic |
| Glacigenous formations. | |

1) J. BAYER: Der Mensch im Eiszeitalter. I. Leipzig. 1927. — Cf. also F. SCHAFFER: Lehrbuch der Geologie. II. Teil. Leipzig. 1927, p. 277 f.

2) V. NORDMANN: La position stratigraphique des dépôts d'Eem. D. G. U. II. R. No. 47. 1928.

Moreover, profiles of the Herning type show that sub-arctic and temperate climate can alternate repeatedly within one and the same interglacial period.

As an instance of an Interstadial deposit, undoubtedly in its primary position, the intramorainal mud bed, abt. 0.8 m thick, at Smidstrup,[1]) may be noted. Smidstrup lies 17 km NW of Vejle and 3 km NE of Rostrup (cf. Pl. I). The site is close behind an ice-front line, produced by an oscillation in the melting of the last ice sheet. In the lower horizon of the stratum were found, inter alia, *Betula nana* and *Arctostaphylus cf. alpina*; in the upper horizon, *Dryas octopetala, Salix herbacea* etc. Other items observed were *Betula pubescens, B. pubescens × nana, Juniperus communis, Rubus saxatilis, Geum urbanum* etc.; also excrements of elk and beaver. A pollen spectrum from the middle part of the mud bed was as follows: *Salix* 8 %, *Betula* 81 %, *Pinus* 11 %.

The decision as to whether a deposit should be regarded as an Interstadial formation can in reality only be arrived at with perfect justification where a thorough analysis of all the zones in the deposit show a climatic development such as that indicated in the left hand column of the table p. 376. An incomplete climatic cycle, such as for instance: sub-arctic — boreal or boreal — sub-arctic — arctic, might equally well be either the first part or the last part of a complete interglacial cycle. In a number of cases — especially post-glacial deposits — we know that sedimentation in the basin concerned only commenced at a late stage, and that the upper part of a strata sequence should be lacking in an interglacial deposit cannot be called surprising. It is thus, entirely contrary to the view of some geologists, by no means easy to determine whether a given diluvial, fossiliferous deposit is to be regarded as interstadial, and the mere occurrence of *Elephas primigenius* or the absence of *E. antiquus* should not be taken dogmatically as grounds for decision. The occurrence of mammoth remains together with such termophile animal and vegetable species as appear to have been found at Godenstedt at Zeven for instance, and elsewhere may indeed be taken as suggesting that there also existed a more thermophile form of *E. primigenius*, and the fact that *E. antiquus* has not been met with in the more northerly deposits from the last interglacial period shows that we are here outside the area of occurrence of this species; we do not however, know all the determining factors in the case.

After these preliminary observations, we will now proceed to further consideration of J. Bayer's division of the diluvial in Europe. He gives (l. c. p. 52 and 152—157) the following arrangement:

[1]) V. Milthers: Kortbladet Bække. D. G. U. I. R. Nr. 15. 1925, p. 122 f.

<table>
<tr><td rowspan="3">Jungquartäre Eiszeit</td><td>Solutré-Vorstosz</td></tr>
<tr><td>Aurignac-Schwankung</td></tr>
<tr><td>Moustier-Vorstosz</td></tr>
<tr><td colspan="2">Zwischeneiszeit (Pre-Chelléen, Chelléen, Acheulléen)</td></tr>
<tr><td colspan="2">Altquartäre Eiszeit</td></tr>
</table>

He finds in this the common denominator of all quaternary geological observations in the Alpine area and the North-German lowlands together with Denmark. Our investigations will however, make it abundantly evident that this is only possible by an application, of Procrustean methods, at any rate as regards the northern regions. Bayer's *Moustier-Vorstosz* was extensive enough *to transgress the highlands of the Lüneburger Heide* and there occasion, *inter alia*, profound disturbances in the interglacial kieselgur deposits. His *Aurignac-Schwankung* is *a fully developed interglacial period* with a climatic optimum which was indeed probably in excess of that of the post-glacial period in these regions, having, moreover a duration sufficient to permit the richly varied development exhibited in the profiles of the Brörup type and the Herning type; and finally, his *Solutré-Vorstosz reached far beyond the valley of the Baltic* and brought about extensive denudations in the whole of the periglacial belt which sheltered a purely arctic flora and fauna, as we learn from finds dating from the late-glacial time. Thus, with the necessary revision of his "Jungquartäre Eiszeit" involved by these actual conditions, Bayer's arrangement becomes naturally transformed in the direction of that northern type he so severely criticised with at least three glacial and two interglacial periods.

It is particularly interesting here to consider the traces of diluvial man mentioned by J. Stoller[1]) from the Lüneburger Heide. We have here finds of human skeletal remains in the kieselgur at Bispingen in Luhetal, part of a branch of fir worked by human hands from the grey kieselgur in the pit at Ober Ohe, splinters of animal bones,

1) J. Stoller: Spuren des diluvialen Menschen in der Lüneburger Heide. Jahrb. Kgl. Pr. Geolog. Landesanstalt. Bd. XXX. II. 1909, p. 433 ff. — H. Virchow: Menschliche Knocken aus einem Kieselgurlager. Zeitschr. f. Ethnologie. 1912, p. 540 f. — F. Wiegers: Diluviale Vorgeschichte des Menschen. I. Stuttgart. 1928, p. 63, 106, 170 f. Wiegers reckons the traces of culture in the interglacial beds at Westerweyhe, Ober Ohe and Luhetal to the older Moustérien, the "Weimar-Stufe", together with the culture layers at Rabutz and Ehringdorf-Taubach, and refers them to the last interglacial period.

regarded as waste products from some activity of man, in the lake marl at Westerweyhe, where bones of *Rhinoceros Mercki* have often been found, and finally, a partly charred branch of fir and a couple of splintered hollow bones of *Cervus* in the calcareous mud at Nedden-Averbergen. These deposits with traces of human activity or human skeletal remains must now, as a result of our investigations in the Lüneburger Heide, be regarded as dating from the penultimate interglacial period, and we have here proof of human occupation in the northernmost Germany as far back as this comparatively early part of the diluvial period. We have in this result also further confirmation of the correctness of PENCK-WIEGERS' fundamental scheme of paleolithic chronology[1]) as regards the assumption of human culture in the penultimate interglacial period. On the other hand, the demonstration of the presence of man in Northern Germany[2]) at this time can hardly be made to agree with the view of the Pre-Chelléen and Chelléen as belonging to the last interglacial period[3]) (Riss-Würm) in Western Europe, the main centre of paleolithic culture, these oldest paleolithic culturs may naturally be referred to the penultimate interglacial period.

1) Cf. the comparision given by J. BAYER, l. c. p. 19 f.
2) Cf. F. WIEGERS, l. c. p. 63.
3) M. BOULE: Les hommes fossiles. Paris. 1923, p. 48—49.

# Table of Errata.

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|---|---|---|---|---|---|---|
| Page | 90, | line 17 | from top, | water sheet, | read: | watershed. |
| — | 96, | — 5 | — — | laver, | — | layer. |
| — | 262, | — 12 | — bottom, | 13.0 m (41 ft.), | — | 13.8 m (44 ft.). |
| — | 334, | — 3 | — top, | Interglacial Period, | — | Interglacial Periods. |