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ÅRSBOK 54 (1960) N:o 6

THE INTERGLACIAL OOZE AT  
PORSI IN LAPLAND

BY

G. LUNDQVIST

STOCKHOLM 1960

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## ABSTRACT

At Porsi in Swedish Lapland (fig. 1) a deposit of ooze below 9 m moraine (till) was found. This ooze is investigated from different points of view and C 14-dated at > 40 000 B. P. In this connection all the Swedish interglacial or possibly interstadial occurrences (fig. 4) are discussed. These are distributed in a special way that is best seen from the little map fig. 4: in the southern part there is a zone with spruce wood in the the layers; farther to the north we find *Picea* pollen and finally in the northernmost and western zone *Picea* pollen is seldom or never found. There the plant remains indicate an alpine type of vegetation or a mountain heath. To this zone the Porsi occurrence belongs. The distribution and the age of the different occurrences are discussed. It is remarkable that very large interglacial wood fragments are found in finiglacial sediments (f. i. Fryksta and Rättvik, p. 16).

## The Interglacial Ooze at Porsí in Lapland

### Introduction

During the course of extensive building activity in connection with the large dam at Porsí, about 45 km SE of Jokkmokk in Lapland an organic layer was found between two till beds. The rapid tempo of this work did not allow a thorough study of the easily visible layer to be made because caterpillar shovels remove about 5000 m<sup>3</sup> of soil a day. By good fortune an agronomist attached to the Survey Department (BPU) of the Vattenfallsstyrelsen (The Swedish State Power Board) I. Hector, passed the place of work and observed immediately the organic layer between the moraine beds. He collected a core from the entire thickness of the layer and smaller samples of all the individual layers and sent them to the chief of BPU, mining engineer A. Nordström, who passed them on to me. I am much obliged to both of them, but specially to Hector, for supplying the material to me for examination and permitting publication of the results.

The first glance in the microscope showed the organic material to be an ooze very rich in mineral grains. It contains pollen, diatoms, sticks, mosses etc. and because of this variety I found it necessary to use the expert knowledge of many specialists for the determinations including H. Flodkvist (the common pollen analysis), G. Erdtman and J. Radwan Praglowski (herb pollen determinations); H. Sjörs (Sphagna and sticks), R. W. Kolbe † and U. Miller (diatoms), H. Persson (mosses) and G. Östlund (C 14-determination). The manuscript has been critically studied by Jan Lundqvist and some corrections to the English of the manuscript have been made by P. Padgett.

To all the above I wish to express my deep gratitude.

### Description of the Locality

The ooze layer was found in the large "Moräntag" (moraine pit — till pit) about 3 km SE of the junction of the rivers Stora and Lilla Lule älv (fig. 1). On the common topographic map the locality is situated near the southern part of the largest tarn about 1 km east of Norrvik. But it must be pointed out that the whole area is now so changed by the dam building that it is very difficult to locate oneself exactly by means of the map. Before the great excavations were made (fig. 2) the locality must have been a flat moraine hill. Of the latter about 100 m has been removed.

The stratification is best seen in fig. 3. This shows the uppermost layer to be a sandy — fine sandy moraine, 2,8 m thick. Below it there is about 3 m of stratified and folded sediments of silt, very fine sand and fine sand. Hector has described them as varved. Possibly this layer in reality is a Kalix till (Kalix-pinmo). Below it there is a sandy moraine 1,3 m thick.



Fig. 1. The occurrence of the ooze at Porsifvan is situated near the junction of the Rivers Lilla Luleälv (L. Lule älv on the map) and Stora Luleälv (on the map with the name Porsifvan). — From the map sheet 29 Harads. With permission of Generalstabens Litografiska Anstalts Förlag.

The next layer downwards is a varved sediment of the type just described but it is not folded. The lower part is rust stratified. About 8,7 m below the surface there is found 50 cm of a series of "sparse, dark layers with organic material between more thick strata of fine-grained sediments". And then follows the most important layer: 30 cm of "a dense dark layer with organic material between thin strata of fine-grained sediments. Smell of mud". The quotations are taken from the description by Hector.

This organic layer rests on a rusty sand layer which in turn rests on rusty varved fine sand, about 30 cm thick.

The rest of the visible stratification down to 13 m below the surface is a



I. Hector 1959.

Fig. 2. The moraine section at Porsi. The pit wall is collapsed. The thick black line marks the ooze layer. The section of the latter was 70 m.

sandy — fine sandy moraine. At the top this layer is rusty. Such was the stratification at the first examination.

By the time of my visits (17. and 18. 9. 59) to the locality much material had been removed. Yet it was still possible to identify the stratigraphy described by Hector. This was especially the case for the sample core that was sent to me. Most remarkable was that the minerogenous laminae both above and below the organogenous layer were undisturbed, at least in the exposed parts of the pit. But they show slender ripples on the surfaces of the strata as there was a slight current stratification. Yet the shape of every laminae appears to be undisturbed and it is possibly built like a varve, consequently denoting a period of about a year.

The organogenous layer at first glance appears quite homogeneous. On further scrutiny it proves to be compressed. The lower part is almost peat-like on account of a richness in mosses, especially Sphagna.

The sample core appears in the wet state to be homogeneous, but when dried it is lighter in color and some features become evident. In the organic mass, which is rich in mineral grains, glands and lenses of sand or fine sand are more clearly visible. The layer hence seems to resemble clearly a current deposit.<sup>1</sup>

<sup>1</sup> H. Munthe (1946 p. 12) has described an occurrence from 5 km NNW of Porsi with some cm thick strata of clay-mixed sand rich in vegetation remains about 11 m below the surface. The sediment was described as a fluvialite sediment. From the collection of Sveriges geologiska undersökning I have taken out the sample collected by H. Munthe 14.8.1900. It is without doubt a river sediment. Munthe (1946, p. 13) writes about it: "The strata in question cannot be interglacial, because they are deposited in the Ancylus lake." The proof should be the diatoms; but according to my opinion it is not satisfactory. But I shall have some chance to get new samples from this occurrence and then there is a certain possibility to give new contributions to the solution of the problem.

†2—600735. SGU. Ser. C 575. Lundqvist

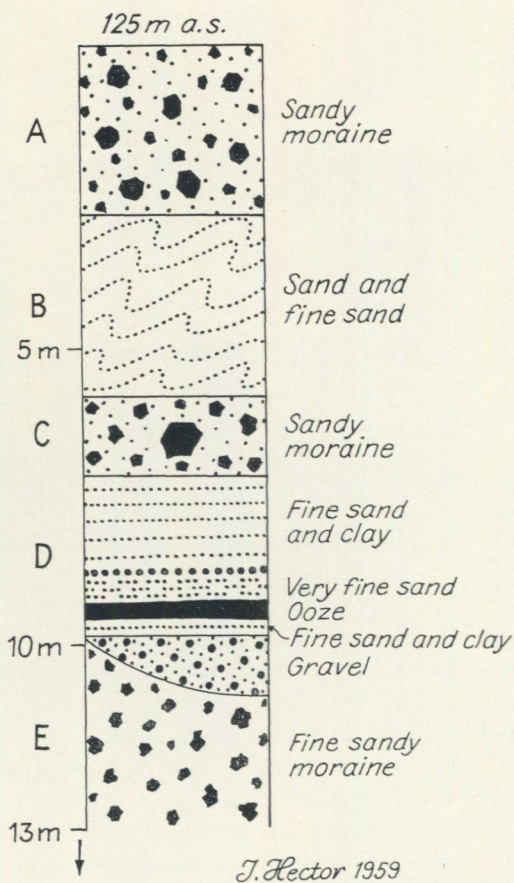


Fig. 3. The stratification in August 1959 according to I. Hector. The thickness and appearance of the different layers varies within the section.

### Pollen analyses

From the core 8 samples were collected at 5 cm vertical intervals for pollen analyses. Moreover, one sample was taken from a lump that was sent to me first; it is numbered with X. All these pollen analyses were routine analyses performed by H. Flodkvist. The results are as follows:

The pollen frequency is quite large except in samples 6 and 7, where the NAP-pollen is richer than in the others. All these pollen spectra are similar to each other with regard to the AP-pollen — the single *Pinus* pollen in nr 2 do not challenge the validity of this statement. *Betula* is predominantly *B. nana*. *Salix* is quite regular in most of the samples. The samples 4 and 5 are rich in *Sphagnum* spores, which is not unusual because macroscopical *Sphagnum* are quite common in them.

Further, the high frequency of Composité-pollen in sample 8 is very remarkable. A special increase of Graminés and Cyperacés in nr 5—8, that is, in the older sediments, is noteworthy.

A more scrupulous specification of the NAP pollen was not done for these

	X	1	2	3	4	5	6	7	8
<i>Pinus</i> .....	—	—	1	—	—	—	—	—	— %
<i>Betula</i> .....	96	99	98	95	98	99	(2 ex)	(11 ex)	100 %
<i>Salix</i> .....	4	1	1	5	2	1	(3 ex)	(2 ex)	— %
NAP .....	11	10	9	17	13	62	120	112	32 %
<i>Ericacæ</i> .....	4	3	2	3	1	1	—	—	8 %
<i>Cyperacæ</i> .....	1	6	2	2	6	22	111	97	3 %
<i>Graminacæ</i> .....	3	1	5	10	7	22	9	8	— %
<i>Lycopodium</i> .....	8	4	3	—	—	1	—	1	9 %
<i>Sphagnum</i> .....	—	2	—	1	86	61	—	—	— %
Other NAP .....	4	—	1	3	—	3	—	7	19 %
<i>Artemisia</i> .....	—	1	—	—	—	—	—	—	— %
<i>Epilobium</i> .....	—	—	—	—	—	—	—	—	3 %
<i>Compositæ</i> .....	—	—	—	—	—	—	—	—	16 %

analyses. Surely these pollen types must be very important in such a milieu indicated by the pollen spectra, probably a heath of some kind with dwarf birch. Therefore special analyses were made by prof. G. Erdtman and dr J. Radwan Pragłowski, at the Palynological Laboratory of Stockholm. They studied the NAP pollen and spores. Most of the work was done by Pragłowski but more critical species were checked by Erdtman.

To the table on page 10 Erdtman has given the following comments which are here somewhat re-written.

1) Anthemidés are i. a. *Achillea*, *Artemis*, *Artemisia*, *Chrysanthemum* incl. *Tanacetum*, *Cotula*, *Matricaria* and *Tripleurospermum*.

The Anthemidé pollen type belongs at least to three types: partly *Artemisia* (easy to identify; we have only seen few pollen grains), partly of *Achillea* type and partly an as yet unidentified type (probably not a specially noteworthy species). The last type, *Achillea* indicates a local mass occurrence.

2) This Graminé pollen is 38—40 $\mu$  in diameter.

3) "A couple of pollen grains; one of them is very swollen; it is surely not defilement".

4) This one is quite similar to *Silene nutans*, but probably it is another Caryophyllacé species. In spite of much effort it has not yet been identified with certainty. It is not *Melandrium*, *Lychnis*, *Stellaria*, *Sagina* etc.

5) In the sample nr 2 a large multitude of spores of a moss or a cysta occurs. According to Skuja "it is not of the nature of an alga" and to Nannfeldt probably not of a fungus nature. Erdtman has not seen moss spores of this type, but he will not exclude the possibility that spores of this type really occur.

It should be of great interest to know where such an experienced pollen expert as Erdtman would place a pollen spectrum of the above type. His answer was: "Possibly on Röst! But it is a random guess". The reason for his opinion is the richness of Anthemidé pollen.

A comparison between the routine analyses and the special one is of some interest. Both have shown that the main bulk of *Betula* pollen is *B. nana*. Flodkvist has noted composité pollen in nr 8, where Erdtman found abundant anthemidé pollen. It is remarkable that the palynologist has not noted *Sphagnum*

The result of the special analyses are the following.

Name	Sample 8	Sample 5	Sample 2
Cf <i>Achillea ptarmica</i> .....	—	—	+
Anthemidé-pollen <sup>1</sup> .....	+	—	—
<i>Artemisia</i> sp. ....	—	—	+
<i>Betula nana</i> .....	+	—	+
<i>Betula</i> sp. ....	+	+	+
<i>Chamaenerium angustifolium</i> .....	+	—	—
cf <i>Corylus</i> .....	+	—	—
Cyperacæ .....	—	—	+
cf <i>Eriophorum</i> <sup>2</sup> .....	—	+	—
Graminé-pollen .....	—	—	+
Graminé cf <i>Dactylus</i> .....	—	+	—
<i>Pinus</i> <sup>3</sup> .....	+	—	—
<i>Silene acaulis</i> .....	+	—	—
<i>Silene</i> sp. <sup>4</sup> .....	—	—	+
<i>Vaccinium vitis-idea</i> .....	—	+	—
<i>Vaccinium</i> sp. ....	+	—	+
<i>Lycopodium alpinum</i> .....	+	—	—
<i>Lycopodium</i> (other) .....	+	—	—
Moss-spores <sup>5</sup> .....	—	+ (14 $\mu$ )	?
<i>Sphagnum</i> -spores .....	—	—	+

spores in nr 5, but Flodkvist has very much of it and macroscopical *Sphagnum* is found.

In nr 8 the one observed *Epilobium* and the other *Chamaenerion*. It is certainly the same pollen (in this connection) and therefore the find to me appears to be of a certain interest. *Chamaenerion* is at the present day a weed everywhere in the country. It is particularly common along the railways but it is also found at nearly every old lap dwelling. According to the pollen examinations it occurred in these districts also in Interglacial time.

### Pollen Finds in Recent Lakes

In the preceding chapter the "guess" of Erdtman was mentioned: that the pollen spectrum possibly should illustrate the vegetation type of the Isle of Röst in the distant Lofoten chain of N. Norway. But it is certainly of interest to look for the pollen spectra in our relatively adjacent high mountains. In my old collection of lake samples (Lundqvist 1939) there is a good deal of material that is useful in this connection. I chose among them 6 samples, 3 from unconsolidated surface sediments and 3 from sediments underlying them. These lakes are Singijaure in Tjäktjavagge west of Kebnekaise, an extremely alpine milieu, Apporjaure south of Abisko, alpine but not so pronounced as the preceding, and finally Vassijaure in a subalpine milieu.

In Apporjaure there was no pollen with the exception of two *Betula* pollen and some graminés. In the other lakes the result was (analyses by H. Flodkvist):

	Vassijaure		Singijaure	
	Surface %	5 cm below %	Surface %	5 cm below %
<i>Picea</i> .....	—	—	3	6
<i>Pinus</i> .....	15	6	76	56
<i>Betula</i> .....	78	88	21	35
<i>Alnus</i> .....	7	6	—	—
<i>Quercetum mixtum</i> .....	—	—	—	—
<i>Salix</i> .....	—	—	—	2
<i>Corylus</i> .....	2	3	—	—
<i>Hippophaë</i> .....	—	—	—	1
NAP .....	52	54	67	39
Ericacæ .....	10	6	7	8
Graminacæ .....	10	10	12	12
Cyperacæ .....	7	20	14	7
Remaining NAP .....	15	7	17	8
<i>Selaginella</i> .....	1	—	—	—
<i>Lycopodium</i> .....	3	3	—	5
<i>Sphagnum</i> .....	—	—	—	2

Both of the lakes mentioned show surprising features in respect to their pollen content.

*Picea* is lacking in Vassijaure but occurs regularly in Singijaure. The *Pinus* percentage is essentially more abundant in the lastmentioned lake, that is far away in the high mountains. Because these pollen spectra mathematically influence each other it is not peculiar, that there is considerably less *Betula* in Singijaure. At the latter place it must be *B. nana* that dominates (in the *Betula*) and determines the frequency. *Alnus*, surely *A. incana*, is found in Vassijaure. Probably it is transported by the west winds from Norway. Possibly *Corylus* is misidentified because the *Corylus* localities on the windward side are very rare and distant. But the same cannot be said of *Hippophaë*, in spite of the very surprising find. *Hippophaë*, however, is found, be it ever so seldom, on the Norwegian coast. Thus long transportation is not absurd.

Broadly speaking these pollen spectra are not surprising. The regular content of *Picea* and *Pinus* in Singijaure, contrary to Vassijaure, is a direct expression of the long distance of transport. This can reach important dimensions (G. Lundqvist 1953) in a short time. Therefore the total absence of *Picea* in Vassijaure is surprising.

In connection with the long distance of transport of pollen an observation of Darwin from his voyage round the world may be recalled. He reported from the South Atlantic: "In some dust which was collected on a vessel three hundred miles from the land, I was much surprised to find particles of stone above the thousandth of an inch square, mixed with finer matter. After this fact one need not be surprised at the diffusion of the far lighter and smaller sporules of cryptogamic plants". The mentioned mineral grains correspond to very fine sand in the Swedish terminology or finmo in Swedish. These samples give a good idea of the importance of the long distance of transport.

With the support of these analyses many more ought to have been done. The following results are, however, obtained regarding the ecological milieu in Inter-glacial time. The Porsi district was a mountain heath (of one development type or other). It contained a luxuriant *Betula nana* vegetation and the herb element was very abundant. The distance to the pine forest, *Pinus*, was obviously quite considerable.

### Diatom analyses

At first examination under the microscope this ooze proved to be very rich in diatoms. A thorough scrutiny of two samples, nr 5 and 2 from Hector's sample core, was done. They are the same numbers that were used in the preceding. Nr 5 was chosen because it is rich in mosses and nr 2 because it is more representative for the stratification as a whole. The examination of the diatoms was done by Dr R. W. Kolbe † and his results are as follows:

Sample nr 5	Sample nr 2
<i>Dominating species</i>	<i>Dominating species</i>
<i>Pinnularia divergens</i> var. <i>elliptica</i> Grun.	<i>Cyclotella Kützingiana</i> Thw. var. <i>radiosa</i> Fr.
— » — <i>stomatophora</i> Grun.	<i>Melosira distans</i> var. <i>alpigena</i> Grun.
— » — <i>streptoraphe</i> var. <i>styliformis</i> (Gr.) Cl.	<i>Tabellaria fenestrata</i> Ktz.
	— » — <i>flocculosa</i> Ktz.
	Chryomonad (?) — cysts.

### The remaining species.

	Nr 5	Nr 2
<i>Achnantes linearis</i> W. Sm. . . . .	—	+
<i>Anomoeoneis exilis</i> (Ktz.) Cl. . . . .	—	+
» <i>serians</i> var. <i>brachysira</i> (Br.) Cl. . . . .	+	+
<i>Cyclotella Kützingiana</i> var. <i>planetophora</i> Fr. . . . .	—	+
<i>Cymbella Cesatii</i> (Rabh.) Gr. . . . .	+	+
» <i>cistula</i> (typ. (Hempr.) Gr. . . . .	—	+
» var. <i>maculata</i> (Ktz.) V. H. . . . .	—	+
» <i>cuspidata</i> Ktz. . . . .	+	+
» <i>Ehrenbergii</i> (Ktz.) (not typical) . . . . .	—	+
» <i>gracilis</i> (Rabh.) Cl. . . . .	+	+
» <i>hebridica</i> (Greg.) Cl. . . . .	+	+
» <i>naviculiformis</i> Auersw. . . . .	+	+
» <i>turgida</i> (Greg.) Gr. . . . .	—	+
» <i>ventricosa</i> Ktz. . . . .	—	+
<i>Diploneis funnica</i> Cl. . . . .	—	+
» <i>oculata</i> (Breb.) Cl. . . . .	—	+
<i>Eunotia bigibba</i> Ktz. . . . .	—	+
» <i>exigua</i> (Breb.) Gr. . . . .	+	—
» <i>faba</i> (Ehr.) . . . . .	—	+
» <i>fallax</i> var. <i>gracillima</i> Krss. . . . .	+	+
» <i>lunaris</i> (E.) Gr. . . . .	+	—
» <i>Meisteri</i> Hust. . . . .	—	+
» <i>monodon</i> Ehr. . . . .	1 ex.	1 ex.
» <i>paludosa</i> Grun. . . . .	+	—
» <i>parallela</i> Ehr. . . . .	—	+
» <i>pectinalis</i> var. <i>minor</i> Ehr. . . . .	—	+
» <i>polylyphis</i> Gr. . . . .	+	+
» <i>praerupta</i> Ehr. . . . .	+	+
» <i>robusta</i> var. <i>tetraodon</i> (Ehr.) . . . . .	—	+
» <i>suecica</i> A. Cl. . . . .	+	—
» <i>veneris</i> (Ktz.) O. M. . . . .	—	+

	Nr 5	Nr 2
<i>Fragilaria capucina</i> Desm. var. . . . .	—	+
» <i>intermedia</i> Gr. . . . .	—	+
» <i>pinnata</i> Ehr. . . . .	—	+
» <i>virescens</i> var. <i>elliptica</i> Hust. . . . .	—	+
<i>Frustulia rhomboides</i> (Ehr.) D:V . . . . .	—	+
» » var. <i>amphipleuroides</i> Gr. . . . .	—	+
» » var. <i>saxonica</i> (Rab.) D. T. . . . .	—	+
<i>Gomphonema acuminatum</i> var. <i>Breissonii</i> (Ktz.) Cl. . . . .	+	—
» » var. <i>coronatum</i> (Ehr.) W. Sm. . . . .	—	+
» » var. <i>turris</i> (Ehr.) Cl. . . . .	—	+
» <i>constrictum</i> Ehr. . . . .	—	+
» <i>gracile</i> Ehr. . . . .	—	+
» <i>intricatum</i> Ktz. . . . .	—	+
» <i>parvulum</i> Ktz. . . . .	—	+
<i>Hantzschia amphioxys</i> (E.) Gr. . . . .	+	+
» <i>elongata</i> (Hant.) Gr. . . . .	—	+
<i>Melosira italica</i> (E.) Ktz. . . . .	—	+
<i>Meridion circulare</i> Ag. . . . .	+	—
<i>Navicula cocconeiformis</i> Greg. . . . .	—	+
» <i>cryptocephala</i> var. <i>exilis</i> (Ktz.) Gr. . . . .	—	+
» <i>pseudoscutiformis</i> Hust. . . . .	—	+
» <i>pupula</i> Ktz. . . . .	—	+
» <i>radiosa</i> Ktz. . . . .	—	+
<i>Neidium affine</i> (E.) Cl. . . . .	—	+
» <i>bisulcatum</i> (Lagst.) Cl. . . . .	—	+
» <i>dilatatum</i> (E.) Cl. . . . .	—	+
» <i>Hitchcockii</i> (E.) Cl. . . . .	—	+
» <i>productum</i> (W. Sm.) Cl. . . . .	—	+
<i>Pinnularia borealis</i> E. . . . .	+	+
» <i>Braunii</i> (Gr.) Cl. . . . .	—	+
» <i>divergens</i> W. Sm. . . . .	—	+
» » var. <i>elliptica</i> W. Sm. . . . .	+	—
» <i>divergentissima</i> (Grun.) Cl. . . . .	+	—
» <i>gibba</i> var. <i>parva</i> (E.) Gr. . . . .	+	+
» <i>interrupta</i> W. Sm. . . . .	—	+
» <i>lata</i> (Breb.) W. Sm. . . . .	—	1 ex.
» <i>major</i> Ktz. . . . .	—	+
» <i>mesolepta</i> (E.) W. Sm. . . . .	—	+
» <i>nodosa</i> Ehr. . . . .	—	1 ex.
» <i>stomatophora</i> Gr. . . . .	+	+
» <i>subcapitata</i> Greg. . . . .	+	+
» <i>viridis</i> var. . . . .	—	+
<i>Stauroneis anceps</i> Ehr. . . . .	—	+
» <i>legumen</i> Ehr. . . . .	—	+
» <i>phoenicenteron</i> Ehr. . . . .	+	+
<i>Stephanodiscus astraea</i> var. <i>minutula</i> (Ktz.) Gr. . . . .	—	+
<i>Surirella linearis</i> var. <i>constricta</i> (E.) Gr. . . . .	—	+
» » var. <i>helvetica</i> (Br.) Meist. . . . .	—	+
<i>Surirella robusta</i> var. <i>splendida</i> (E.) V. H. . . . .	—	+
<i>Tetracyclus emarginatus</i> (E.) W. Sm. . . . .	—	+
» <i>lacustris</i> Rifs. . . . .	—	+
» » var. <i>capitata</i> Hust. . . . .	—	+

The table shows a very great difference between the two samples, that is, between the older and the younger part of the stratification.

In the older one (nr 5) the *Pinnularia* species dominate quantitatively. Specially prominent is *P. stomatophora*, *P. streptoraphe* var. *styliformis* and *P. divergens* var. *elliptica*. In this part of the stratification there are mostly typical bottom forms, characteristic for shallow, not dystrophic water. Apart from these the flora is very poor.

The younger part of the ooze is very rich in species and they are almost

entirely epiphytic, that is, the diatoms grow on the higher vegetation, twigs, stones etc. Nor in this sediment is any dystrophical feature to be found worth mentioning.

### Macroscopical Finds

These are of two kinds: small branches, pegs, stems etc. and mosses or parts of them. During the whole work of sorting attention was directed to finds of fruits and seeds. None were however found which is very remarkable as such fossils are mostly to be found in deposits of this type.

The branches etc. were examined by H. Sjörs, but the result was very poor, in spite of the material being quite abundant. The cause of this is that the branches are to a greater or lesser extent compressed and are therefore difficult to determine.

Only two species were definable: *Betula nana* and *Empetrum*. About these Sjörs says that their structures — as was hinted above — are more or less crushed. But it is remarkable that within the crushed material it was possible to find small and very delicate tissue remainders.

The mosses are very abundant, especially in the lower part of the ooze layer. Actually there is a stratum about one centimetre thick that is best described as almost oozy moss peat. This stratum as well as outwash material from other parts of the stratification was examined by H. Persson. He has given the following report concerning his work. Three moss species are found. Two of them are very common: *Drepanocladus purpurascens* and *Sphagnum* cfr *squarrosum* (the determination is nearly 100 % sure). The third one, *Polytrichum* cfr *affine*, was sparsely found in the outwash material.

*Drepanocladus* is the only moss that gives some information of value about the climatic conditions. *Drepanocladus purpurascens* (Schimp.) Loeske is from a systematic point of view a very disputed species (Dr Persson's discussion about the taxonomical value of this moss species and the interpretations of different moss specialists is interesting but not relevant to our discussion.)

The distribution of the *Dr. purpurascens* is of subalpine-alpine type and is especially found on the high mountain range, where it is very common in moss vegetation. However, its occurrence in the Porsi material indicates that the climate was quite cold there. Regarding the nourishment conditions it is almost mesotrof, that is it represents a medium type.

In his moss flora of Torne Lappmark Mårtensson does not denote it as a separate species but as *Dr. exannulatus* s.str. Regarding its distribution type Mårtensson writes (p. 256): "occur almost everywhere in wet places . . . The most usual habitats are not too rich fens, percolation streaks and the flood zone of lakes and streams".

*Sphagnum squarrosum* Pers. belongs to a well characterized group of only two species within the genus; besides *Sph. squarrosum* there is *Sph. teres* Ångstr. They are closely related and similar to each other. Both have a very extensive distribution from the lowland right up to the lower part of the alpine region of the high mountains (*Sph. teres* also in the middle part). Therefore these two

species do not say anything about the climatic conditions. Regarding the nourishment conditions *Sph. squarrosum* is one of the less demanding species within the genus. Possibly it is obligotrof — mesotrof but *Sph. teres* is meso — eutrof.

Of *Sph. squarrosum* Mårtensson says that it "occurs in subalpine mires and especially in the wet birch forest. It grows in the low-alpine belt under willow scrub beside streams, springs and in other wet places". Of *Sph. teres* he writes (p. 9): "in the rich fens . . . also frequent in the wet birch forest, . . . at higher altitudes in various wet flushed habitats, such as the upper parts of the flood zone of streams in percolation streak and latish snow-areas".

The third species is a *Polytrichum* which belongs to a little group of two species: *P. affine* Funck (more commonly known as *P. strictum* Banks) and *P. juniperinum* Hedw. They are like the above mentioned *Sphagnum*-species, very similar to each other and there are scarcely any sure microscopical characters that distinguish them. Therefore Persson is not quite certain that the determination of the small leaves is quite correct. The short leaves indicate that it is *P. affine*. Though many bryologists do not divide them, they are easily distinguished by their habitat and grow on quite a different substratum. *P. affine* is typical for mires and bogs: It often grows together with peat mosses such as *Sph. fuscum* but not with *Sph. squarrosum* or *teres*. *P. affine* is pronouncedly intolerant of lime and it is to be characterized as oligotrof. Concerning the distribution Persson says that it is a cosmopolite that is, it is found at different heights and is quite as common in the lowland. *P. affine* is common on the mires over the whole of the country. And Mårtensson (p. 38) writes: . . . "Subalpine belt and lower parts of the low-alpine belt, very common; with decreasing frequency to the middle alpine belt". In the following he states about the conditions of growth: "With increasing altitude it becomes more or less a heath moss and grows on less peaty soil . . . This species is completely absent where the substratum is definitely calcareous".

Thus no definite statement can be made regarding the milieu but one might cautiously say that *Drepanocladus* indicates quite well an alpine-subalpine milieu rich in mires. The other mosses do not contradict this conclusion.

### Interglacial Deposits in Sweden

Earlier, the opinion about the age of submorainic occurrences was quite different from now, but here we shall not consider such historical points of view. Most of the occurrences discussed below are controlled by C 14-datings (cfr. G. Lundqvist 1957 and fig. 4). They are here mentioned from south to north.

1. *Fryksta*. The locality of this occurrence is the large delta at Fryksta at Kil in Värmland. Wood of spruce was found here and described by L. von Post (1918). The delta is of finiglacial age and therefore von Post spoke about the finiglacial spruce at Fryksta. He made short work of the possibility that the spruce was of interglacial age. A C 14-dating of the spruce wood gave > 30000 B. P. (Jan Lundqvist 1958). In 1958 a long spruce log was found in the same

delta and — as far as could be determined — in the same bed as the earlier find. This log too is very old giving an age of  $> 34000$  B. P. (Östlund 1959).

Thus the result is that the delta is finiglacial but the spruce interglacial.

2. *Öje*. This find was a long spruce log and other wood in undisturbed, partly varved, sediments under moraine (till). In the sediments there were found the common pollen types (AP) and spores. But of the greatest interest among the spores is, according to G. Erdtman, the presence of *Osmunda claytoniana*. This species has not been previously found in deposits from the last interglacial but only from the last but one. The age is  $> 40000$  B. P. (G. Lundqvist 1955, 1957).

In connection with the *Öje* occurrence it is worth recalling another find in the county of Kopparberg. It is wood of spruce and aspen from about 28,4 m in a glacifluvial delta near Rättvik, near Lake Siljan. The find was made and described before the C 14-method was available in Sweden (G. Lundqvist, 1951, s. 17), and therefore a sure dating could not be made. Yet I thought that the spruce was interglacial. If this opinion is right then this spruce occurrence must be of the same type as the above mentioned one at Fryksta; i. e. interglacial spruce wood in a finiglacial delta.

3. *Bollnäs* is the second interglacial occurrence in Sweden and it has been carefully described by Halden (1912 [Eriksson], 1915 and 1948 [in Sandegren 1948]).

This occurrence was found during a well digging in 1909 in the vicinity of Bollnäs. The combination of macroscopical *Picea* and *Picea* pollen and brackish water diatoms at a high level is interesting. This combination of *Picea* and brackish water diatoms is never found on this level in postglacial time. From this fact alone Halden could, with great certainty, maintain that it must be an interglacial deposit. It was later confirmed to be so by C 14-dating  $> 30000$  B. P. (G. Lundqvist 1957).

4. *Ryggesbo*. This locality is situated about 30 km west of Bollnäs in Middle Sweden, but the occurrence has not yet been described and dated. The reason is that the material is insufficient for a C 14-dating. But it is not necessary to make such a dating because of the local circumstances: The plant-containing stratum is situated about 27 m below the surface under moraine. This is located 2—3 m above and directly at a lake, Mörtsjön. Thus the stratum is situated more than 20 m below the water surface.

Some preliminary data, partly by Flodkvist, about the fossils are as follows. The amount of *Picea*-pollen varies between 7—15 %. In some samples pollen from mixed oak forest occurs with quite a high frequency (2—6 %), which is rare in Swedish interglacial deposits.

G. Erdtman states regarding the pollen flora inter alia that *Betula* is not *B. nana*, but probably this species is to be found there. *Alnus* is represented both by *A. glutinosa* and *A. incana*. Furthermore *Lycopodium* cf. *annotinum* and *Selaginella selaginoides* occur.

Two finds of mosses, determined by Persson, are *Drepanocladus exannulatus* and *Calliergon sarmentosum*. The first one has a very wide distribution. *Calliergon* is now found mostly north of the district with Ryggesbo.

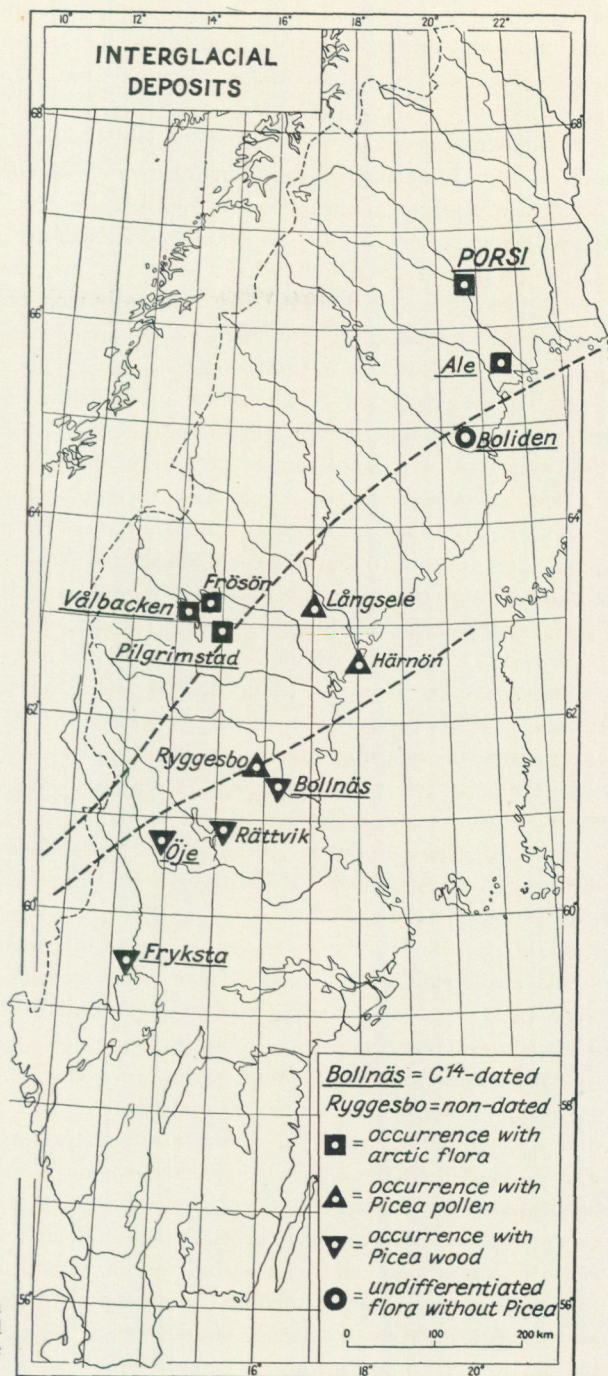


Fig. 4. Interglacial deposits with organic matter in Sweden. All the C<sup>14</sup>-dated layers are more than 24 000 years B. P.

According to U. Miller diatoms are quite abundant. Only fresh-water types are found and among them the planktonic dominate: *Cyclotella comta* and *C. Kützingiana* with varieties. *Melosira distans* and *Tabellaria flocculosa* are frequent too.

A further account of the occurrence will be given in the description to the map of the Quaternary deposits in the county of Gävleborg.

5. *Härnön*. This is the oldest known certain interglacial occurrence of this type. It was found as early as 1889 by H. Munthe and was immediately the subject of much discussion which need not now be recapitulated. (Munthe 1890, 1904, 1909, 1910, 1946). An unusually rich collection of different fossils was found including very much *Picea* pollen (*Picea excelsa*). Moreover there was a rich diatom flora but only of fresh-water types. Both marine and brackish water types were lacking. The combination of low height above the sea, a little over 5 m, with macroscopical spruce and only fresh-water diatoms definitely indicates that the deposit must be interglacial. A C 14-dating has not been carried out because the material was preserved in formaline.

6. *Långsele*. This occurrence was found in 1945 when building the power-generating station at Hjälta near Långsele in Ångermanland. The deposit was a sandy compact ooze. It has been comprehensively investigated (Sandegren 1948) and a rich collection of fossils (plants of different types and insects) described. Of special interest is a pollen diagram from the 2 m thick deposit. It belongs to the common diagram type from Norrland. There is *Picea*-pollen especially in the upper part of the bed (to about 10 %). C 14-dating has not been made, because the interglacial age appears to be quite clear.

7. *Boliden*. The occurrence was found in a well-digging in the vicinity of the well known mine Boliden. There are no special features characterizing it (Grip 1949, Jan Lundqvist 1955). Thus *Picea*-pollen is not found and no fossil indicating a climatic type abnormal for the district was observed. C 14-dating with the early Libby method gave > 24000 B. P.

8. *Pilgrimstad*. In the large gravel pit at Pilgrimstad SE of Östersund sediments and fossils were found. The most interesting of these were bones and parts of a tusk from a mammoth. The dominating pollen type was *Betula*, while *Pinus* pollen was very insignificant in the analysis (Kulling 1945). On the other hand of *Lycopodium* spores were very abundant: 310 to every 400 of pollen and spores. The number of pollen was in these samples very small and those observed indicate a vegetation characteristic of a mountain heath. Two C 14-datings have been performed, one on a sample collected by P. Thorslund, giving > 35000 B. P. (G. Lundqvist 1957), the other, taken by Kulling, giving > 39000 B. P. (Östlund 1957). The difference between the two samples is quite insignificant and falls within the limits of analytical error.

9. *Vålbacken*. This locality is a great clay pit SE of Storsjön at Östersund and the stratification is a thick clay layer between two moraine beds. The lower till has westerly material and the upper one material, according to Thorslund (1939), from the SE but according to Frödin (1954) from the NNE. The upper part of the clay is folded. In the lowermost clay — which is unfolded —

the plant fossils (*Salix polaris*, *S. herbacea* and other) were found (Thorslund 1939). Thus the vegetation type was alpine. C 14-datings gave > 37000 B. P.

10. *Frösön*. On this isle west of Östersund there are found sediments (clay or gravel) under moraine in diggings and drillings. The clay is very poor in pollen, but there *Picea* pollen is found (Asklund 1936). The milieu is very similar to a mountain heath. C 14-dating has not been performed.

11. *Ale*. This occurrence was found at a well digging at Ale, west of Luleå and has been recently described by Fromm (1960). The milieu is best characterized as subarctic fresh-water.

12. *Porsi*. This occurrence is described above and I will only recall here the lack of *Picea*-pollen and the fact that the flora is most similar to that of a mountain heath. C 14-datings gave > 40000 B. P.

All the data collected here indicate that the ooze was deposited in a small shallow lake on a mountain heath in interglacial time.

A retrospective survey shows clearly that C 14-datings enable the above occurrences to be classed without any hesitation as interglacial unless they do not belong to some unknown interstadials. The lowest age was given by Boliden (> 24000 B. P.) but this was the maximum limit with the old Libby method.

If the deposits derive from the last interglacial time this must have been quite long; it is commonly estimated as having lasted about 50,000 years. This is much longer than all the time which has elapsed since our country became ice-free. Therefore large deposits must have accumulated during this time, but we only know it very incompletely. Nor do we know where these deposits are to be placed in the whole of the development. Thus it is quite impossible to compare the different occurrences with each other. The pollen diagram of Sandegren (1948) is for the Swedish interglacial deposits unusually long and differentiated (fig. 5). But even here a considerable part must be lacking. Fromm (1960) has called attention to the work of Znamenskaia (1959), where there is a pollen diagram representing what must be the greatest part of the interglacial development analogous to our postglacial. A comparison between this diagram and that from Långsele is of interest for judging the relation of our occurrences to each other.

In fact we do not know which parts of the interglacial stratification are represented in our described deposits. But the map fig. 4 shows a certain regularity (cf. p. 23).

Several authors have pointed out that the complete development of the interglacial physical conditions must be represented in the following manner: arctic, subarctic, boreal, warm optimum, boreal, subarctic and arctic, whereupon the last (latest) glaciation occurred. Other and newer terms are cryocratic (glacial time), protocratic, mesocratic (warm optimum), telocratic and a new cryocratic period (e. g. Erdtman 1959). And this development — whatever the different parts are called — appears to be quite plausible. And it is also plausible that there are zones developed in the country. Therefore let us study the map fig. 4

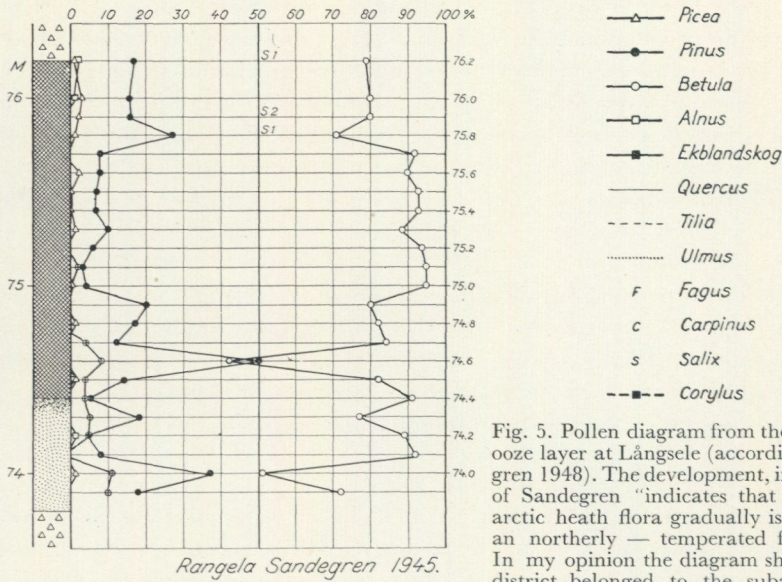


Fig. 5. Pollen diagram from the interglacial ooze layer at Långsele (according to Sandegren 1948). The development, in the opinion of Sandegren "indicates that an alpine—arctic heath flora gradually is replaced by an northerly — tempered forest flora". In my opinion the diagram shows that the district belonged to the subalpine birch forest.

against this background and with the pollen diagrams of Sandegren and Znamenskaia as a support.

It is then possible to see a zonal distribution even in these small fragments of deposits. In the south there are occurrences with macroscopical spruce (wood, cones, etc.). North of this follows a zone without wood etc. but with *Picea* pollen. North of the latter there is one with a pollen flora, which to me seems to indicate a mountain heath flora.

The latter interpretation will not be changed if investigations in the future show *Picea*-pollen to occur also within this zone, because it can be spread over long distances by the wind. (I wish to refer to e. g. Singijaure p. 11.) Most important for our discussion is the type of vegetation and this is well indicated by the plant remains.

This hint of a zonation of the vegetation may be a coincidence, but to me it does not appear to be so.

The problem is now which part of the Interglacial these short parts of the stratification represent. No indication of a warm time has yet been found in Sweden. I think that Rygesbo is the "warmest". Therefore it must be the beginning or the end of the development. To me it seems most probable that it is the first, i. e. the oldest part of the stratification, because the upper layer must have been more easily swept away by the advancing ice. The Porsi deposit is contrary to this interpretation because the stratigraphical shape appears to show a continuous development from the deposit itself to the moraine, i. e. to the land ice.

The hypothesis that the remains of these interglacial deposits derive from the

older part of the indicated period is less probable also in regard to Bollnäs. It was pointed out that irrespective of the spruce the brackish water diatoms are the characteristic element. In this respect Bollnäs differs from all the other deposits. This is in contrast to Härnö, which as pointed out above has the combination low height above the sea and freshwater diatoms as evidence of its interglacial age. Thus we have two deposits, one of which belongs to brackish water comparatively high above the sea (95—96 m). The other to freshwater and situated only a few metres above sea. These contradict each other.

Halden (Eriksson 1912) has discussed the differences between Bollnäs and Härnö and he comes to the following conclusion (in translation): "The decidedly more northern impression of the Härnö ooze could be explained by the higher geographical latitude or by the fact that forms from quite another part of the interglacial period have been preserved here. Completing the analogy with the postglacial time one can think that the Härnö ooze has been deposited much later than at least the older parts of the Bollnäs ooze or at a time when the first signs of a coming glaciation had been still more noticeable than in the youngest parts of the Bollnäs ooze".

The geographical latitude is probably quite without significance and in any case it cannot explain the different diatom floras. It may not be denied that Halden conceives the possibility that the brackish water diatoms are secondary. But from which deposit?

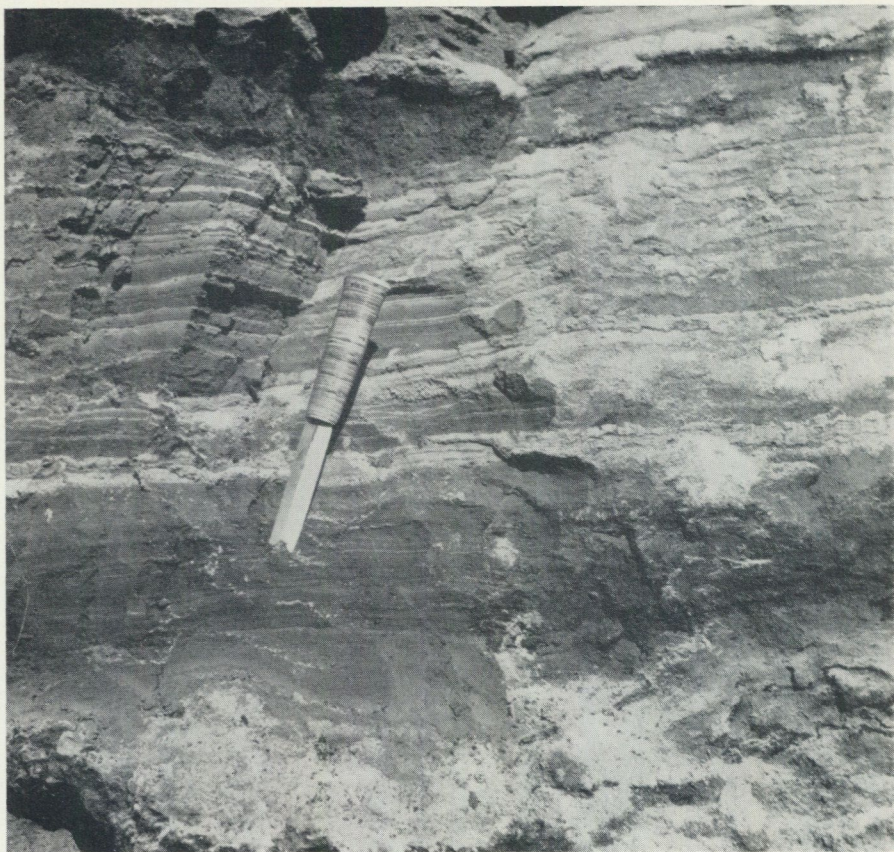
It is most probable that both deposits are of quite different ages. According to the opinion of Halden Härnö is much younger. Thus we get a certain parallelism with the postglacial development.

Continued speculation with the little material we have is as yet, really quite useless, but it is tempting to try. It must, however first be pointed out that Bollnäs, owing to its brackish water element cannot be correlated with the other occurrences, so it is best to ignore this deposit. All the other deposits are from freshwater or mires.

Fromm (1960) has briefly spoken about the interglacial shore displacements which "may have differed considerably from post-Glacial conditions". As a matter of fact we do not know anything about the interglacial level conditions but Fromm writes: "There may have existed other relations between crustal movements in Scandinavia and the world-wide eustatic changes of level during the period now concerned, causing a progress of the shore displacement, different from that in late-Glacial and post-Glacial time. It must, however, be admitted, that the known facts are too fragmentary to permit a coherent reconstruction of the interglacial development in central and northern Sweden". Upon that point we are quite agreed.

About the climate Fromm says: "The cold climate at Ale could be compatible with an interstadial stage during an earlier part of the last glaciation, older than the minimum<sup>1</sup> value of the radiocarbon dating. Such an oscillation must demand a rather long duration to permit an ice retreat into the central parts of

<sup>1</sup> The expression "minimum value of the radiocarbon dating" easily can cause some misunderstanding. But here Fromm has in mind the value 24 000 years mentioned on his p. 5.



G. Lundqvist 1959.

Fig. 6. Detail from the Porsi section. The knife stands in the organic layer; downwards the minerogenic matter increases. Fine layers of very fine sand are visible in the organic material.

the North European glaciation. The Göttsweiger interstadial might perhaps be considered as a possible dating". It appears to me plausible that the occurrences at Ale and Porsi both derive on the whole from the same part of the Interglacial, the protocratic, if we use the earlier mentioned terminology. If both of them should be interstadial it appears to me unlikely that they are from the Göttsweiger. An interstadial which includes the zone from North Germany to the Arctic Circle is not an interstadial in general opinion. The consequence would be that the last glaciation was in reality divided into two glaciations.

However, the age of the Göttsweiger Interstadial appears to be quite difficult to determine. de Vries (1958) writes on p. 15: "... this interstadial could well be correlated with the period between 33000 and 42000. According to Dr Brandtner (private discussion) the Göttsweiger interstadial was fairly cool and so it is not impossible that it is synchronous with the colder period further north". On the next page Brörup is mentioned as "more than 53000" and soon there-



G. Lundqvist 1959.

Fig. 7. Detail from the Porsi section. Below the organic layer (with the knife) the older moraine is visible with a sharp but undulating contact. Upwards the minerogenic layer is finely stratified up to the younger moraine.

after it seems as if de Vries wishes to correlate Göttsweig "with the Brörup interstadial instead of the colder period between 33000 and 42000...".

But the paper ends with a "Note added in proof". If I do not misunderstand de Vries he there states that a sample from Senftenberg in Austria, that is of importance for the problem, is contaminated by recent rootlets. Therefore the age of the sample must be greater than which he has found and "This also implies that the Göttsweig soil would have to be correlated with the Brörup interstadial, but more conclusive samples will be dated in the near future". First I wish to remark that absolute clean samples are a necessary condition for these datings. And then I do not think the radiocarbon method will reach longer than to 40000 years B. P., if any degree of certainty is required. Yet there are in the literature datings to almost 60000 B. P. Lastly it is remarkable (and possibly symptomatic?) that Andersen (et al. 1960) does not even mention the Göttsweig Interstadial.

Earlier I mentioned the vegetation zonation that is indicated on fig. 4. The crux in the whole reasoning is naturally, that we have no idea about the age relations between the occurrences within the zones. From the map the reader possibly thinks that my opinion is that the occurrences are synchronous but this is not my intention. Let us first assume that for each zone more or less complete deposits are developed. Then comes the question: which part of them must be preserved to illustrate the zonation that the map indicates? Above, it was pointed out as most probable that the lower parts of the stratification had the greatest chance of surviving the ice advance. Then we think of three occurrences with strata, one in each of the zones indicated on the map and approximately equally complete. Then the most proximal deposit must represent the shortest time, because the land ice has been situated there for the longest time. The nearer the outer limit of the ice, the more complete the stratification must be.

But how will this line of thought correspond to the reality? If it is right, the lowest, the subarctic layer ought to change into still "warmer" layers.

In reality the pictures 6 and 7 from Porsí show that the organogenous subarctic layer in the upper parts becomes richer in minerogenous material and more sterile. This is quite contrary to what we had expected. In, for example, the Långsele diagram the more subarctic part of the deposit is situated at the bottom. Upwards it grows more "warm", but the uppermost layer is decapitated. Bollnäs shows probably still younger material than Långsele, but there are only fragments of the layers.

In spite of the many sources of error in the reasoning given above I think that it is correct in principle. In some respect the diagram of Znamenskaia supports it.

Thus the conclusion is, that in fig. 4 the innermost zone is the youngest and the outermost the oldest part of the succession. Naturally it is remarkable that the youngest layer can be intact under the advance of the ice. But it is not absurd, because the layer freezes in front of the ice and thus it gets an increased power of resistance.

In this respect I wish to cite Antevs (1925, p. 55): ... "Thus, the ground was permanently frozen to some depth. The ground temperature consequently was considerably higher than in unglaciated high arctic regions." Possibly, under special circumstances such an ooze layer as we have found in Porsí has worked as a lubricant under the ice during its advance. Fromm is of the opinion, that the erosion capacity was quite insignificant at Ale. But it must be added, that the erosion of the ice obviously is very capricious. Valter Schytt has drawn my attention to the investigation of Goldthwait (1956), where especially the following (p. 136) is remarkable: "*Boulder Beneath North Ice Cap*. One boulder of about 22 kg. in weight was retrieved from the shaft (5.311 B in pocket) to the bottom of the glacier 30 m. from the front of the ice cliff and covered by 42.5 m. of ice. This boulder on its surface and sides had a continuous cover of lichens undamaged and apparently in living conditions... Five of these lichens were determined by Dr John W. Thomson, Department of Botany,

University of Wisconsin. These include the following, all previously reported from northwest Greenland:

- Alectoria pubescens* (L.) Howe
- Rhizocarpon chionophilum* T. Fr.
- Umbilicaria arctica* Nyl.
- Sporostatia cinerea* (Schaer.) Koerb.
- Lecidea auriculata* T. F."

The lichens nr 1 and nr 3 are of special interest. *Alectoria* is a fruticose lichen and *Umbilicaria* a foliaceous lichen. It is quite inconceivable that they have escaped a complete downcrushing under the advancing ice.

On p. 125 Goldthwait writes: "*Present Advance of North Ice Cap*. In the Red Rock Lake area, there is little direct positive evidence of recent changes in North Ice Cap. In the shaft at the head of the ice tunnel, which was dug down to the ground surface, boulders were found in place with lichens on them like those exposed on Survey Hill (9.37A). As explained elsewhere (3.43 and 9.37) this indicates that North Ice Cap has advanced over a marginal strip of land at least 30 m. wide, probably within the last few decades. In addition, excellent polygonal soil patterns on Survey Hill and Botanist Flat extend under the toe ice of the lower cliff. While these do not define the time of advance, they do demonstrate that the last change was advance of North Ice Cap and suggest that it has persisted long since the last minor advance of the main Greenland Ice Cap from the east".

The example just mentioned show that it is not peculiar that the apparently quite easily destroyed layer has resisted the overriding land ice. Against this background there appear to be good chances of finding many interglacial deposits in our country. In any case their number should be much larger than our present material shows. And without many more occurrences it is no good trying to discuss the climate and the changes of level during the Interglacial period. To non-Scandinavian occurrences the distance is too great.

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