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A POLLEN DIAGRAM FROM THE SUB-ALPINE REGION OF CENTRAL SOUTH NORWAY

BY

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With 1 diagram.

INTRODUCTION

After having completed the investigations on the Late-Pleistocene development of the coastal districts of West Norway, I intended to take up for similar studies the Hardangervidda plateau in Sentral Norway, a part of mountain massif forming the "back-bone" of the Scandinavian peninsula. For military reasons, however, access to the greatest part of Hardangervidda has been forbidden for some years, and the realization of my plans consequently had to be postponed.

In order to gain some experience with regard to sub-alpine material I collected a series of peat samples from a small bog near the Haugastøl railway station, 988 m alt. The railway here runs through Ustedalen, the topmost part of Hallingdal, along the extreme northern edge of the Hardangervidda plateau.

The bog is situated on the small peninsula between the railway station and the northernmost cove of the lake, Sløtfjorden (982 m alt.), in what looks like a kettle-hole in the level ground-moraine. The peninsula is covered with a *Betula nana* scrub. On the lower parts of the hillsides round the lake there is a belt of mountain birch forest — presumably *B. tortuosa* hybrids. The flora is the usual one of our sub-alpine hill-sides on relatively favorable soil; a short description of it has been given by Dahl (1908, p. 23).

TECHNICAL NOTES

Pollen analysis has been carried out in the usual manner; as the sediments were fairly rich in pollen, no chemical treatment was necessary (but most samples had to be sieved after boiling with KOH). This had the great advantage that it was possible to carry out *Betula*

analyses, making use of the statistical material provided by Eneroth (cp. Fægri 1940, p. 24, Aario 1941, p. 615). As the *Betula* percentages were rather low, a very great number of AP¹ had to be counted before a minimum of 100 *Betula* pollen grains was reached. This had the additional effect that it was possible to follow those small, but important variations of the curves of *Alnus* and other demanding species, which otherwise most probably would have disappeared within the statistical errors. Because of the great extra work involved in measuring the pollen grains, *Betula* analysis has not been carried out in all spectra.

As the bog is very small, the pollen diagram is much influenced by the vegetation of the immediate surroundings. In a number of samples evidence of "macroscopic sedimentation" was found, i. e. lumps of pollen grains showing that whole anthers or even flowers had fallen into the pond or bog. In many cases such macroscopic sedimentation completely destroys the pollen diagram, causing a great maximum of the curve in question and corresponding minima of other curves. It is frequently advantageous to correct this by calculation (cp. Fægri 1944 b, p. 456), assuming a rather even course of the affected curve. Such re-calculations must not, however, be carried out indiscriminately, or we run the risk of calculating all individuality out of the curves. Re-calculation must be carried out on the following conditions only: 1. There must be clear evidence of macroscopic sedimentation (exception: *Sphagnum* spores which practically always occur singly). 2. The course of the other curves must become less irregular after re-calculation than before. 3. The re-calculation must be clearly indicated in the diagram. I have tried to do this by using thinner lines² for "pollen lines" to (i. e. the lines connecting the signatures of the same pollen type from spectrum to spectrum) and signatures of re-calculated values. Signatures in full black (*Pinus*, QM) cannot be changed in this way, we may use a smaller signature than usual, which I have not done in this case, however. The original values must be indicated in addition to the re-calculated ones on the same spectrum line, e. g. by means of full-size signatures which are

¹ AP: Arboreal pollen, NAP: Non-arboreal pollen, QM: Quercetum mixtum = *Ulmus*, *Tilia* and *Quercus* + *Corylus*, which in this diagram has been included in the QM for practical reasons.

² The signature lines of the *Betula* diagram of course do not fall under this rule!

not connected by pollen lines. To save room and prevent confusion only the re-calculated value is indicated in the diagram if the difference between it and the original value is less than 5 % (resp. 5 ‰).

The diagram as presented here is essentially a composite dot signature diagram, but I have found it practical to adopt for special purposes both signature lines (*Betula* diagram), histogram ("d" values, cp. below), and area signatures ("total" diagram). As the individual constituents of the "total" diagram are already represented in the 100 % sum by their resp. totals, ΣAP and ΣNAP , their curves must be dotted like other curves representing categories not included in the 100 % sum, e. g. *NAP* and *Sphagnum* in the *AP* diagram.

THE DIAGRAM

The pollen diagram as presented here is a rather complicated affair, and it is necessary to deal with each partial diagram separately.

The sequence of strata is quite normal; below 2.20 (m below the surface) the profile is made up of typical sediments, chiefly a bright gyttja (nekron-mud, Godwin 1938) which on microscopical examination proved to consist almost exclusively of the remains of some unicellular alga, occurring singly or a few packed together. I am not certain whether the alga belonged to *Protococcaceae* or *Chroococcaceae* — other possibilities are less probable. There is an abrupt contact between the gyttja and the underlying gravel, i. e. the ground moraine.

In its upper part the gyttja becomes darker from increasing admixtures of colloidal humus, and at 2.20 it is completely changed into dy (gel-mud Godwin l. c.). At the same time the alga remains have disappeared, and coarser constituents have taken their place. Below 1.50 these are chiefly leaves and stems of *Drepanocladus fluitans* or in some cases *Carex* rootlets (2.10); above 1.50 *Sphagnum* remains dominate. It is difficult to decide whether this part of the deposit ought to be characterized as a *Sphagnum* dy or a peat. At present the bog was an oligotrophic Caricetum with the exception of the central part (where the samples were taken) which was a very wet *Sphagnetum Lindbergii* with very few phanerogams. The upper part of the series was extremely wet and contained little dry substance; in the lowlands such peat would have been formed very rapidly.

The general impression of the series is: 1. a hydrosere reaching the telmato-terrestrial stage, 2. a gradual oligotrophication. No retro-grade or cyclic development can be traced.

The first diagram proper is the classical AP diagram with an appendix showing in detail the variations of some of the constituents. These appendices have the same base-line as the main diagram, their percentages must be read in the opposite direction. The classical diagram can be divided into 7 zones which I have given a preliminary lettering A—G.

Zone G is characterized by *Betula* values above 20 %, culminating in sample 2.20: 36.1 %. This high value is not due to macroscopic sedimentation of *Betula* pollen, cp. the *Alnus*, NAP and *Sphagnum* curves, all of which should have exhibited a minimum if macroscopic sedimentation had taken place. The *Alnus* values of zone G are low, < 2 % and the QM values very low, 0.2—0.7 %. It is noteworthy that the NAP values of the two bottom samples are very low.

Zone F forms a transition between G and E. *Betula* has fallen to ca. 10 %, *Alnus* and QM have not yet risen.

Zone E is very interesting. There is a statistically significant rise of the *Betula* curve and a corresponding fall of the curve of *Pinus*, but the changes in the appendix curves are much more important. *Alnus* rises to a maximum of 6 % in sample 1.70 and QM follows with 1.9 % in the same sample.

Both curves fall again, however, and zone D is a repetition of zone F. Zone C is again a repetition of zone E with another *Alnus* and *Betula* maximum. As in E QM follows *Alnus* with a maximum of 1.3 %. Then comes zone B, the character of which is very like that of zone F and D. The NAP values are somewhat higher in zone B than in the older samples (the maxima in zone D, 1.10 and 1.60, are due to macroscopic sedimentation of *Cyperaceae* pollen).

At 0.35 another very interesting change takes place: The NAP curve definitely rises to values about 50 % and is followed by the *Sphagnum* curve, which rises from values below 10 % (82 % and 238 % in 0.90 and 0.80 due to macroscopic sedimentation) to almost 30 %. The *Alnus* values are with one exception much lower than in the preceding zones. The most important characteristic of zone A is, however, the appearance of *Picea*, which rises from 0 to 3 %. In the older zones some few *Picea* pollen grains were found singly or 2—3 together.

The *Betula* diagram follows next. It has been constructed on the same principles as in my previous publications (cp. Fægri 1940, p. 24 seqq.); one new feature has, however, been introduced. The variation curve of the artificial mixtures of types set up to match the empirical curve is not absolutely congruent with the latter. To obtain an indication of the "goodness of fit" I have calculated a value $\Sigma\delta^2$ = the sum of the squares of all differences between the observed and the calculated values. As the number of classes of the calculated curve varies between 5 (one component only) and 8 ("*nana*" and "*tortuosa*" present at the same time), $\Sigma\delta^2$ is better replaced by $d = \frac{\Sigma\delta^2}{n}$ where n is the number of classes.

If d is less than 2, the curves are practically identical; d between 2 and 5 indicates a fairly good correspondence of the curves, but if d is more than 5, even the closest obtainable correspondence between the observed and any calculated curve is rather bad. In most of these cases the maximum of the observed curve is too high and the curve itself too narrow ("leptokurtic" curves) to fit in with the calculated one. Curves of the opposite type ("pachykurtic") are more easily compensated for by the adding of another *Betula* type.

The limit $d = 5$ corresponds to the d found by a 10 % interchange (e. g. between a 50—50 % and a 40—60 % mixture) of *B. nana* and *B. verrucosa* or *B. verrucosa* and *B. pubescens*. In both cases $d = 5.5$. In the case of *B. pubescens*—*B. tortuosa* d is only 1.7. A 10 % interchange between *B. nana* and *B. pubescens* gives $d = 11.2$, *B. verrucosa*—*B. tortuosa*: 7.6. Of interest in connexion with the changes that take place in the *Betula* diagram of zone A (cp. below) are the d values of 5 and 10 % interchange *B. nana*—*B. tortuosa*: 2.7, resp. 10.8.

The value of d is indicated by the heavy part of the spectrum line in the *Betula* diagram. Unit of d is the 5 % interval, the two levels of goodness are therefore indicated by the 10 % and the (dotted) 25 % lines.

I have used this d test instead of the usual χ^2 , the distribution of which is known, because the latter is of little use in *Betula* analysis. This is shown by table 1, the calculation of which is based upon the following assumption: A mixture of two of Eneroth's *Betula* types is considered the hypothetical, "calculated" curve, a somewhat different mixture is considered the empirical, "observed" curve. χ^2 is then cal-

culated in the normal manner³ and the probability taken out of a table (e. g. Bonnier and Tedin 1940, tab. IV; the better, graphic table by Patau, 1943 a, has not been accessible owing to war circumstances).

The table indicates that if an observed mixture of *Betula* pollen grains is calculated to consist of e. g. 50 % *B. nana* and 50 % *B. verrucosa* (phytogeographically a rather improbable mixture), we may be fairly certain that it is not really composed of 20 % of one component and 80 % of the other. But there is a possibility that the real mixture is as unequal as 30—70 %. In the case of the mixture *B. pubescens*—*B. tortuosa* the numbers are even less favorable. If the observations indicate pure *B. nana* or *B. verrucosa*, the case is a little better, and we may be fairly certain that there is not as much as 20 % of the other component present. If the original curves are further apart, the statistical significance is better, cp. *B. nana*—*B. pubescens* in tab. 1.

In these calculations the errors of the Eneroth *Betula* curves have not been considered. I possess no data on them, but as the curves are based upon a very great material, these errors are probably less important.

The χ^2 test thus indicates an extreme uncertainty of the *Betula* analysis, even more extreme than indicated by experience. It is obvious that a single-spectrum maximum or minimum of the *Betula* curve is of very little significance, and it is equally clear that the really significant part of the *Betula* diagram is the general trend of the curves: Even if the individual *B. tortuosa* values are highly uncertain, the *B. tortuosa* curve above 0.70 is of great importance, etc.

It is also obvious that the χ^2 test is of no help in deciding between variation curves that are so similar to each other as those of the different *Betula* mixtures. As an example may be quoted the extremely unsatisfactory analysis 1.30 giving $P \sim 0.50$.

It must, however, be borne in mind that χ^2 is no measure of the reliability of the *Betula* diagnosis, it simply expresses the degree of conformity between the observed curve and the nearest of the calculated ones. The χ^2 test shows that this conformity may be purely accidental and that the real composition of the *Betula* flora of the

³ It must be noted that for χ^2 analysis the actual frequencies should be used instead of the percentages, but as the total number of *Betula* pollen grains is usually not far from 100, this theoretical consideration is of no practical importance. My thanks are due to Dr. Ottestad of the Agricultural College, Ås, for assistance with regard to this part of the paper.

Table 1.

Mixture	"Observed"	"Calculated"	P
B. nana + B. verrucosa	50+50	40+60 30+70 20+80	~ 0.70 ~ 0.15 ~ 0.01
B. nana + B. pubescens	50+50	40+60 30+70 20+80	~ 0.55 ~ 0.015 < 0.001
B. nana + B. tortuosa	50+50	40+60 30+70 20+80	~ 0.60 ~ 0.02 < 0.001
B. pubescens + B. tortuosa	50+50	40+60 30+70 20+80 10+90 0+100	~ 0.95 ~ 0.70 ~ 0.40 ~ 0.15 ~ 0.02
B. nana + B. verrucosa	100+0	90+10 80+20 70+30	~ 0.40 ~ 0.04 < 0.001

All numbers except the P values are percentages. Concerning the meaning of P, cp. foot-note to tab. 5, p. 115.

sample in question may be represented by another calculated curve, lying at a distance of some 10 or 20 % from the former and giving a much higher d.

Whereas the *Betula* analyses of my previous publications have been carried out in oligotrophic sediments only, those of the upper part of the Haugastøl bog come from telmatic peat (?). Aario has (1941) shown that *Betula* analyses from peat are less reliable than those from sediments, but in this case just zone A has provided the best *Betula* diagram.

The two lowermost samples of zone G are very dubious, d is high, and I am inclined to suppose that the pollen grains have shrunk (lime effect? cp. Fægri 1940, p. 26). This would explain both the "nana" pollen and the lack of *B. pubescens*. In the rest of zone G and zones F—B the "verrucosa" and the "pubescens" types are almost the only ones present. They are equally frequent; where their curves move away from each other and from the 50 % line, d is so high that the results seem rather unreliable.

At 1.10 and 1.00 the big pollen of "*tortuosa*" type appears for the first time, but it disappears again in 0.90 (zone C). As the quantities are very small and one of the spectra is not too good, the significance of this occurrence is rather dubious. From 0.70 on the occurrence of the big "*tortuosa*" pollen is established beyond doubt. It is equally important as the two other types. At 0.15 the small "*nana*" type appears again, and this time there can hardly be any doubt that it really represents *B. nana*, which grows plentifully round the bog at present. It is noteworthy that the other types exhibit a *pro rata* decrease with the great increase of "*nana*" in the topmost sample. This fact indicates that the great rise of "*nana*" is caused by local overrepresentation from the surrounding scrub. In the topmost sample fossilized pollen grains only were measured, those with preserved intine and cell contents were discarded (but counted for calculation of the total *Betula* percentage!).

The NAP diagram is very monotonous, with exclusive dominance of *Cyperaceae*, pollen which certainly to a great extent comes from the bog itself and its immediate surroundings. This is also indicated by the lower *Cyperaceae* values below 2.20, in the purely limnic sediments. The only other feature of interest is the crossing of the *Gramineae* and *Ericales* curves at the zone transition E—D. Below that level the *Gramineae* values are the higher, above it those of *Ericales* dominate (one exception). I can offer no reasonable explanation for this change of dominance; if it is more than a local phenomenon, it certainly indicates profound changes in the ecology of the region.

Ericales consists chiefly of *Empetrum*. Of the 1093 *Ericales* tetrads met with, 136 were indeterminable, 858 belonged to *Empetrum*, 87 to *Calluna*, and 12 were vaccinioid. Of the 858 *Empetrum* tetrads 378 from 10 samples were measured (in the same 10 samples 48 had collapsed and could not be measured). The variation curves of the *Empetrum* pollen from those 10 samples, belonging to all parts of the diagram, were essentially identical. The main class in all of them was that of 13 index units (35.2 μ), cp. table 2. There can be no doubt that the material consisted of *E. hermaphroditum* with no appreciable admixture of *E. nigrum*. This was corroborated by the morphology of the pollen grains, which had the lax habit of the *E. hermaphroditum* grains. The morphology of the *E. nigrum* grains has been discussed by Overbeck (1934), who does not, however,

emphasize the characteristic, subtetrahedric shape of a great percentage of the *Empetrum* grains. It is less distinct in *E. hermaphroditum*, the pollen grains of which are in many cases rather difficult to distinguish from some vaccinioid grains of the same size. The shorter, narrower, and deeper furrows of the *Empetrum* grains are the best diagnostic characters, but I must admit that some of my diagnoses are rather uncertain.

Table 2.

The size of Empetrum tetrads.

Size in μ Scale units Nr. of sample	24.5	27.2	29.9	32.6	35.3	38.1	40.8
	9	10	11	12	13	14	15
0.00	-	1	7	17	31	7	1
0.03	-	-	3	9	20	7	2
0.10	-	1	7	13	35	9	-
0.30	-	-	1	13	19	8	-
0.70	1	1	1	15	33	16	2
0.80	-	-	1	8	15	8	2
1.00	-	-	1	6	9	4	-
1.10	-	-	3	7	12	4	-
1.90	-	1	2	3	6	3	-
2.10	-	-	-	2	1	-	-
Total	1	4	26	93	181	66	7
Frequency %	0.3	1.1	6.9	24.6	47.9	17.5	1.9

Mean: 12.8 units = 34.7 μ .

Few, if any, *E. nigrum* types were observed in those samples where measurements were not carried out.

It must be noted that the mean size of the tetrads in tab. 2 is considerably lower than that found by Erdtman (1938, p. 131) and Arwidsson (1943, p. 127). This is principally due to the fact that the samples measured by the said authors had been subject to acetolysis. This method of preparation tends to slightly exaggerate the size of pollen grains, most probably because the walls swell a little. In the case of pollen tetrads this difference is rather great, as will be seen from table 3. As the *Empetrum hermaphroditum* material was rather small, I have included measurements of the pollen grains of a

Table 3.

Material	Treatment	Mean size, unit: 2.7 μ	P for the difference against	
			KOH treatment	acetolysis
<i>Empetrum hermaphroditum</i>	KOH acetolysis	12.6	-	< 0.001
		14.6	< 0.001	-
<i>Vaccinium microcarpum</i>	KOH acetolysis H ₂ SO ₄	11.3	-	< 0.001
		13.6	< 0.001	-
		12.3	< 0.001	< 0.001
<i>Eriophorum vaginatum</i>	KOH acetolysis H ₂ SO ₄	13.89	-	> 0.2
		14.08	> 0.2	-
		14.19	0.05 > P > 0.01	> 0.2

KOH treatment: Boiled with 10% KOH for 2–3 hours.

Acetolysis: cp. Erdtman 1934, 1936.

H₂SO₄: Suspended in cold H₂SO₄ conc. for 24 hours.

Concerning P, cp. foot-note to tab. 5.

specimen of *Vaccinium microcarpum*, treated in the same 3 ways. It will be seen that there is a considerable difference between the results of the different treatments. By comparison with tab. 2 it is also seen that there is almost complete identity between the fossil material⁴ and the result of KOH treatment of *Empetrum hermaphroditum*: the difference is without any statistical significance ($v^2 < 1$). This is in good accordance with previous experiences with *Betula* pollen: Material that has been boiled sufficiently long (cp. Overbeck l. c. p. 570) with 10% KOH has the same size as fossilized material after KOH boiling for a few seconds. The effect of acetolysis varies a great deal with the nature of the pollen grain and is especially marked in thick-walled tetrad pollen. I have also included in tab. 3 the results of the same 3 treatments in a thin-walled, single-grain

⁴ Which has also been treated with KOH. Erdtman (1944) maintains that different treatments may result in different spectra from the same sample, e. g. a "KOH spectrum", an "acetolysis spectrum", etc., and that it is not a priori certain that any of these is more correct than the others. Here is not the place to enter upon this remarkable statement (cp. Erdtman and Erdtman 1933, Erdtman 1934). When it comes to size analysis it must be noted that whereas the KOH method gives comparable results in fossil and recent material, the acetolysis does not always do so, even if it is not preceded by chlorination.

pollen, viz. that of *Eriophorum vaginatum*. In this case there is practically no difference.

The last diagram, the "total", is the same as Iversen (1941) has introduced under the name of "Formationsdiagram". This name is not good, as the phytosociological term "formation" is rather obscure. "Phytocoenose diagram" is better, but I prefer the simpler and absolutely neutral term "total diagram". Generally total diagrams ought only to be prepared from limnic deposits where local effects are very small and can easily be detected. In this case the diagram is greatly disturbed by local over-representation and other irregularities.

The total diagram is a summary of the AP and NAP diagrams and does not convey any new facts, but it serves to emphasize some important points, especially with regard to the question of the density of the forest cover. This has obviously been much thinner during zone A than during all the preceding zones, and it is also evident that this is caused by the disappearance of *Pinus*, the curve of which falls from 60—70 % in zones G—B to 30—40 % in zone A. The *Betula* curve of zone A is a little higher than that of zones B and D.

In the total diagram *Betula nana* has been transferred from the AP to the NAP — where it naturally belongs. This ought to be done in the AP diagram too, but practical considerations, especially the question of comparability with other diagrams where *Betula* analysis has not been or cannot be carried out, speak in favour of including the species in the ordinary *Betula* curve.

One diagram that is frequently seen in the publications of other pollen analysts, viz. the diagram of NAP types expressed in per cent of AP has not been included here. This diagram does not show anything that is not shown quite as well or better in the diagrams represented here, and the finer variations in the NAP diagram (e. g. the relation between *Gramineae* and *Ericales* in this case) are lost in the greater fluctuations caused by the variation of Σ NAP as a whole. I have maintained before and repeat it here: The NAP-in-per-cent-AP diagram is of use primarily where most of the NAP is derived from the local vegetation of the sample plot itself. The NAP variations of these diagrams are totally dependent upon macroscopic sedimentation, and the NAP curves are consequently so irregular that it is of no use to calculate a complete NAP diagram. In such cases the variations of the individual NAP constituents may be analysed by means of curves expressing their quantities in per cent of AP (e. g.

the Andals-torvmyrane diagram Fægri 1944 a, pl. 8). In sediments the complete NAP diagram can always be used, in peat we may have to resort to curves of the other type. At any rate a Σ NAP curve should be included in *all* pollen diagrams.

Another feature lacking in my diagram is the absolute pollen frequency (APF). I am at a loss to understand the great importance ascribed by some colleagues to the APF. Generally it does not tell anything that is not told much better by other curves, especially the NAP curves. Whereas the relative values depend only upon the pollen production and sedimentation of a more or less wide area round the sample plot (apart from possible destruction during the fossilization etc.), the APF also depends upon the rate of growth of the peat or sediment in question. This introduces another "unknown" in our equations, which are sufficiently difficult to solve beforehand. Aario (1943, p. 6) maintains that in sub-arctic Finland the NAP curve in many cases is of little value as a diagnostic of the density of the forest cover. The APF does not seem to be much better (cp. Aario 1944, p. 340).

Mannerfelt (1940, p. 36) has also pointed out that the distribution of NAP pollen is of less value in the study of deforestation and forest limits in the mountains than in the lowlands. This is quite natural: The pollen grains of the lowland forests are carried by turbulence far up into the higher strata of the atmosphere, and distribute themselves more or less evenly both on the mountains and on the surrounding lowlands, where they were generated. The smaller and the more isolated the mountain is, the stronger is this effect. For some years I have collected the recent pollen rain at a number of stations across the Central Norwegian mountains. So far, I have not had any opportunity to work out the results, but a preliminary reconnaissance has shown that there is a marked decrease in the quantity of AP in the central part of the massif. However, the quantity of NAP also decreases with increasing altitude, and it is not always easy to predict the proportion of NAP in relation to AP at the different stations. Nevertheless I am of opinion that a careful NAP analysis is the most effective means of diagnosticising the density of the forest cover. This presumes that the pollen analyst is able to "think botanically", to translate his diagrams in vegetational terms, not to use pollen grains like index fossils (Erdtman 1944, p. 411). Pollen analysis is one of the most marvellous instruments of research ever presented to the

quaternary geologist, but it must not be forgotten that it is essentially a branch of botany. Any schematic, non-vegetational, index fossil interpretation of a pollen diagram is likely to lead to confusion as soon as difficulties present themselves.

A simple, but necessarily rather inexact expression of the APF is the number of pollen grains per square unit of preparation. That value can be obtained almost without any extra labour during ordinary analysis. In cases like the Haugastøl bog, where the samples cannot be analysed in their original state, we have to make special preparations for the calculation of the APF. I do not think the work pays.

Discussion.

What does this complicated diagram tell about the development of vegetation and climate? In all zones below A the *Pinus* curve is so high and the NAP curve so low that the bog must have been surrounded by pine forest. This is also corroborated by the find of stomatar cells of *Pinus*. Their occurrence is summarized in table 4.

Table 4.

Zone	Number of samples ⁵	Average frequency of stomata, ‰
A	7	5.3
B	4	16.0
C	2	34.5
D	4	27.8
E	6	12.2
F	2	4.5
G	6	9.7

⁵ Samples forming the border between two zones have been counted twice. The calculation of this and some of the following tables has been carried out with a preliminary value for the sample 1.00. The final values are, however, so similar that no material changes result.

At present the conifer forest goes to Geilo, 20 km due E, 750 m alt. There is a considerable quantity of conifers in the birch forest at the western end of Ustedalsvatn, some 5 km further W, 770 m alt., which is probably the present limit of conifer forest in the area. According to Dahl (1908, p. 23) isolated specimens of conifers are found further W, the highest — *Picea* — at Karistølen, only 3 km E

of Haugastøl. As there is no fall of the *Pinus* curve, nor of the number of stomata in the topmost samples, the conifer forest limit cannot have changed materially in recent times, and the conclusion is that at the beginning of zone A the pine forest disappeared from the surroundings of Haugastøl and withdrew to the Geilo region. It is remarkable that some few stomatar cells nevertheless occur in the samples of zone A.⁶ They may either be secondary, coming from other bogs that are subject to erosion, or they may come from needles blown — most probably on and with the snow, cp. Heintze 1914, Du Rietz 1931 — from the occurrences within the present pine area. As the drainage area of our bog is very small and does not include any other bogs, I prefer the latter explanation.

The disappearance of the pine forest from Haugastøl at the beginning of zone A is an established fact. Is this disappearance climatically conditioned, or is it due to extermination by man? We know that the climate deteriorated at the beginning of the sub-atlantic period, but it is nevertheless very difficult to answer the question, and this diagram alone can hardly settle the point definitely. The appearance of cultivation indicators just on the A—B zone transition speaks for the latter alternative.

The NAP diagram does not react in any way, and the rather unexpected reaction of the total diagram — rise of the *Sphagnum* curve while that of NAP remains constant — is difficult to interpret climatologically. Also most of the curves of the AP diagram are useless in this connexion; the *Alnus* values are a little lower than in

⁶ The comparatively high average, 5.3‰, is primarily due to the value 12 from sample 0.35, which forms the transition to zone B. If that sample is not included, the average is 4.2. Because of the great dispersion of the numbers, even that value does not give more than medium statistical assurance that it is lower than the average of zones B—F: $0.05 > P > 0.01$. This unevenness of the occurrence is due to many causes. The stomata are easily over-looked, and they are not typical micro-fossils, being remains of a small macro-object, viz. the pine needles. The occurrence of pine needles in deposits is subject to some errors, which are of less importance in the case of pollen grains, i. a. the sorting out in relation to the coarseness of the deposit. In very fine-grained sediments, e. g. those of zone G, pine needles — and stomata — are rarer than in the coarser deposits of the upper strata. In extreme cases this sorting out may even influence the composition of the pollen flora; most likely the abnormally low *Pinus* values in the lower part of the Løningsvatn diagram from Bømlo (Fægri 1944 a, pl. 10) may be explained in this way.

the preceding zones, but the difference is rather slight. The *Picea* curve is important, its rise during zone A cannot be conditioned by cultivation, it must be due to another influence, which may simply be the gradual wandering westwards of the species. In this locality the *Picea* curve cannot at any rate be interpreted as an evidence of climatic deterioration.

The only positive evidence for climatic deterioration is given by the *Betula* diagram. The appearance of *B. nana* may be due to cultivation, but it is very difficult to interpret the rise of *B. tortuosa* in the last part of zone B in the same manner.

I therefore consider the topmost part of our diagram as a vague evidence of climatic deterioration, but I am not quite certain if cultivation has not played a very great part, especially in the last rise of *B. nana* and possibly also in the disappearance of *Pinus*. About 3 km further W there was — until 40 years ago, before the days of the Bergen—Oslo railway — a lonely farm, Nygård,⁷ and there is a number of “seters” (summer outfarms), all of which have needed great quantities of fuel. This fuel consumption may have been sufficient to account for the disappearance of the pine and the appearance of *Betula nana* — instead of the more useful arboreal birches. The question why the pine forest disappeared from Haugastøl cannot be settled definitely by this diagram alone. On the other hand I must take express reservations against its being interpreted in the opposite direction: It gives absolutely no evidence that climatic deterioration did *not* take place.

Let us now turn to another extreme: zone E. Its most important characteristic is the great *Alnus* maximum. *Alnus* is pollen-analytically for many reasons a rather unsatisfactory genus, primarily because it includes two species, the climatic demands of which are different, but the pollen grains of which are very similar. Erdtman (1936) has discussed the morphology of the pollen grains of *A. incana* and *A. glutinosa* and concludes that the difference is great enough to be of diagnostic value. However, in actual analytical work it is hardly possible to undertake the complicated measurements advocated by Erdtman for the separation of the species. The *Alnus* pollen grains found in this Haugastøl bog were rather different from those of the

⁷ Where Dahl (1908, p.26) i. a. found *Plantago lanceolata* and *Rumex domesticus* among the weeds.

lowland areas where I have made my previous experiences. Whereas there is no difference between the exine of *Betula* and *Alnus* pollen grains in the lowlands, in the Haugastøl bog that of the *Alnus* grains is much thinner and takes a much lighter colour than that of *Betula*. The "bright arches" of the *Alnus* grains are less distinct than in lowland material and although the state of preservation of the other pollen types was generally excellent, the *Alnus* grains had often collapsed. These thin-walled *Alnus* pollen grains, the pores of which are — in those cases when they can be observed — more circular, no doubt represent *A. incana*, whereas the ordinary thick-walled grains, the pores of which are more lanceolate with their longest axis in meridional direction, represent *A. glutinosa*. As intermediate forms are far from scarce, a quantitative analysis of the *Alnus* population is hardly practicable; in the Haugastøl bog the *A. glutinosa* type was rare, and the *Alnus* curve may be considered to represent *A. incana*.

Zone E is thus characterized by an *Alnus incana* maximum in the pollen diagram from a pine covered area; what does this mean? At present *Alnus* goes a little higher in the mountains than *Pinus*, occurring also in the birch belt. On the other hand these occurrences are rather insignificant, they may be compared with the sporadic occurrence of conifers high above the conifer limit, and we are justified in stating that the thermic demands of *Alnus incana* and *Pinus* in our mountains are practically coincidental (cp. VE 1940, pp. 106, 156).

Alnus is generally considered to indicate humid conditions, which is certainly true with regard to *A. glutinosa*; but everybody who has become acquainted with the *A. incana* vegetation of our steep mountain sides, knows that this species thrives excellently under mesohygrobic conditions: in sub-arctic, sub-alpine, and montane areas *A. incana* is far from being a bog species (cp. Ve l. c.). As *Pinus* is rather euryhygrobic, the interchange *Pinus*—*Alnus* cannot without reservations be interpreted as a result of changing hygrobic conditions. It can be added that although *A. incana* is favoured by cultivation (Ve l. c., p. 105), this cannot, of course, explain the very old *Alnus* maxima of zones E and C. But this fact may be the explanation of the comparatively high *Alnus* values of sample 0.15 (cp. the cultivation pollen!).

There is also a *Betula* maximum in zone E, indicating that the monotony of the pine forest was broken by an increased admixture

of foliiferous trees. The *Betula* diagram does not show any decisive reaction in zone E; below 0.70 it does not tell much at all, only that the *Betula* population consisted of a more or less equal mixture of *B. verrucosa* and *B. pubescens* types. It is impossible to state anything definitely about the thermic demands of such a *Betula* population in comparison with those of *Pinus*. The NAP diagram gives no information about the character of zone E. Any interpretation of the character of this zone, based upon the curves discussed so far, must remain more or less conjectural.

There is one curve left, however, that may to a certain degree help us, viz. the QM (incl. *Corylus*) curve. It is parallel with the *Alnus* curve, and an analysis of covariance of QM and *Alnus* gives the results that are summarized in tab. 5 (cp. Bonnier and Tedin 1940, p. 139).

Table 5.

Cause of variance	Degrees of freedom	Sum of squares	Mean square
Regression of QM upon <i>Alnus</i>	1	115	115
Rest	27	312	11.6
Total	28	427	

$$v^2 = 10.0 \quad 0.01 > P > 0.001.$$

$$v = t = 3.15 \quad P \sim 0.005 \text{ (cp. Pättau 1943 b)*}.$$

There is consequently a strong correlation between *Alnus* and QM (incl. *Corylus*). The thermal demands of the constituents of the QM curve are — for once — undisputable: they represent the demanding element of the flora, they are indicators of more favourable conditions. The correlation between QM and *Alnus* consequently proves that *Alnus* also is a relatively demanding species and that also the *Alnus* maxima of zones E and C really indicate more favourable climatic conditions. The same is, of course, indicated by the QM maxima of the same zones.

* P is a measure of probability that the observed distribution is due to chance only. In the present case there is 0.5 % probability that the observed regression is due to chance only, 99.5 % that it is due to some other factor, i. e. that it is real.

Table 6.
Analysis of variance of the Alnus and the QM curves.

Cause of variance	Degr. of freedom	<i>Alnus</i>			
		Sum of squares	Mean square	v^2	P
Between all zones	6	3024	-	-	-
Between zones:					
A and B—G	1	783	783	14.0	~ 0.001
G and B—F	1	412	412	7.3	~ 0.01
C+E and B+D+F ..	1	1685	1685	30.0	< 0.001
C and E	1	53	53	< 1	-
B, D, and F	2	93	46.5	< 1	-
C+E and D	1	672	672	12.0	~ 0.001
A and B+D+F	1	136	136	2.4	$0.2 > P > 0.05$
Within zones	24	1346	56.1	-	-
Total	30	4370	-	-	-

Cause of variance	Degr. of freedom	QM (incl. <i>Corylus</i>)			
		Sum of squares	Mean square	v^2	P
Between all zones	6	179	-	-	-
Between zones:					
A and B—G	1	4	4	< 1	-
G and B—F	1	70	70	5.8	$0.05 > P > 0.01$
C+E and B+D+F ..	1	72	72	6.0	$0.05 > P > 0.01$
C and E	1	16	16	1.3	> 0.2
B, D, and F	2	17	9	< 1	-
C+E and D	1	28	28	2.3	$0.2 > P > 0.05$
A and B+D+F	1	8.5	8.5	< 1	-
Within zones	24	289	12.04	-	-
Total	30	468	-	-	-

This great importance being ascribed to the said maxima, the question naturally arises: are they statistically significant. An analysis of variance of the *Alnus* and the QM curves gives the results that are summarized in table 6; The quantity of *Alnus* in zone A is decidedly lower than the average of the preceding zones, but the difference between the *Alnus* percentage of zone A and the less favourable zones B, D, and F, may be due to chance. The difference in this

respect between zone G and zones B—F is fairly significant. The difference between zones C and E — the favoured ones — and B, D, and F is statistically very good, and so is that between E and C on one side and the intermediary zone D on the other. The corresponding numbers for QM are much less significant. Best are the differences between G and the other zones (except A) and between C + E and B, D, and F. Now it must be remembered that the numbers themselves are subject to some statistical uncertainty. In the case of the very small percentages of the QM curve these statistical errors are relatively very great and disturbing, even when as much as 1000 or more pollen grains have been counted per spectrum. Another factor that may tend to disturb the curves, is the accidental occurrence of long-distance transported grains. This factor is especially of importance during zone A (cp. below), but when the percentages are sufficiently low, it disturbs also during the other zones.

The *Betula* and *Pinus* maxima and minima are so obvious that it is unnecessary to use statistical analysis to prove their reality.

The result of this discussion of the character of zone E — and of the almost identical zone C — is that the zones represent a vegetation demanding a more favourable climate than the vegetation of zones B, D, and F. It is especially noteworthy that the intermediary period D represents a less favourable climate than that of periods E and C. This result raises another group of problems, 4 of which shall be dealt with here.

First: If we take zone A to represent a climatic deterioration as compared with zone B, the total climatic deterioration from the optimum during zone C becomes a rather considerable one.

Secondly: The diagram shows a double climatic optimum. During the last years I have repeatedly attracted the attention to the fact that, whereas the climatic optimum in less oceanic regions is considered to fall in the atlantic period, it is unquestionably situated in the sub-boreal period in the hyper-oceanic regions of West Norway. The detection of a double optimum is therefore of very great interest, even if this is not the first time it has been demonstrated. As long ago as 1939 Florin was able to give some statements on the occurrence of a double climatic optimum and a climatic deterioration between the atlantic and sub-boreal periods in eastern Middle Sweden. In a recent publication he has verified this statement pollen-analytically (1944,

p. 567); the sub-boreal optimum is a little lower than the atlantic one, but this may be due to cultivation.

In a lecture many years ago I predicted upon purely theoretical grounds that there ought to be a short period of unfavourable climate between the atlantic and sub-boreal periods. My prediction was a consequence of a strict application of the Ice Age theory of Simpson (1929). The salient points of the theory are the following: If solar radiation is too strong, precipitation is ample, but the general temperature level is too high to permit the existence of glaciers in lower latitudes. If solar radiation is too low, temperature conditions are favourable for glaciation, but the general atmospheric circulation is too weak, precipitation is insufficient to maintain glaciers. The greatest "glaciation potential" is connected with a medium quantity of solar radiation, the "glacigenous interval". If the climate of the atlantic period belonged to the first type and that of the sub-boreal period to the second, solar radiation must have passed the glacigenous interval at the zone transition. No Glacial Age resulted because the transition was too rapid: the formation of large glaciers is a slow process.

This is certainly too strict an application of a theory, the correctness of which has been disputed and which was, at any rate, not intended for the explanation of these phenomena, but it may serve as a warning against the tendency of many quaternary geologists to let the climate pass from one type to another without considering all the consequences.

When I prepared the lecture referred to above, I had very few observations to support my view. The most important were perhaps the — not quite convincing — observations of Grønlie (1927 and previous publ.) indicating a less demanding mollusc fauna some time during the Tapes period. Iversen (1941) later explained the curious Danish pollen diagrams that apparently pointed in the same direction and proved them to reflect, not a climatic deterioration, but the settling of the land. My own diagrams from West Norway gave no definite indications, and I had long ago abandoned my view when Mr. Sten Florin in a recent letter re-informed me about his finds in Sweden. And now the same observation can be made at Haugastøl. One single diagram, of course, is not sufficient material to support revolutionary theories, but I do not see any other way of interpreting my diagram. I have always wondered at the apparently complete recovery of the Danish forests after the "settling phase". Perhaps there is in that

country a coincidence between the settling and the climatic deterioration?

The third point to be stressed is the great part played by *Alnus* as an indicator of a more favourable climate. This is in good accordance with the finds from other parts of the Norwegian mountains, viz. the pollen diagrams from Sylene and Sikilsdalen, published by Nordhagen (1933, p. 206, 211, cp. 1943, p. 29, the great *Alnus* maximum at the bottom of the Sylene diagram must be due to local overrepresentation) and from Fongen (Mannerfelt 1940, p. 34). Many instances of *Alnus* maxima as indicators of climatic optima are known from North Sweden (Sandegren 1924, Malmström 1934, Fromm 1938, et al.), and I suppose that the great expansion of *Alnus* in North Finland during the atlantic period (Aario 1943, p. 89) may be less due to hygric than to thermic causes, even if we must not forget that *Alnus* is certainly more hygrobic in continental regions than in relatively oceanic ones.

The fourth point is a more controversial one. *Pinus*, different *Betula* types, and *Alnus incana* undoubtedly occurred in the immediate vicinity during the climatic optima of the Haugastøl bog. But what about the QM constituents, *Ulmus*, *Tilia*, *Quercus*,⁹ and in this case also *Corylus*?

The problem must be discussed separately for zone A and for the older zones. There can be no doubt that the comparatively high QM values of zone A are due to long-distance transport, which naturally plays a more important part the thinner the forest cover of the region is. As a matter of fact, the comparatively high QM values of zone A are in themselves an indicator of the lack of forest, as pointed out by Aario previously (1940, p. 85).

The case of the older zones is more difficult. The Eidestjønn diagram (Fægri 1944 a, pl. 7, cp. Lassetjern 1944 b, pl. III) shows the importance of long-distance transport even in a forested area,¹⁰

⁹ The supposed similarity between *Quercus* and *Viola* pollen has caused some investigators to consider *Quercus* in the sub-alpine diagrams dubious or to drop it altogether. The smoother and more thin-walled *Viola* grains are, however, rather easily distinguished from those of *Quercus*.

¹⁰ I therefore emphatically disagree with Erdtman's (1944) repetition of v. Post's old statement about the significance of the scattered occurrences of pollen grains of *Fagus* and *Carpinus* outside the present areas of occurrence of the two genera. A continuous curve is necessary before any conclusions can be drawn with regard to the local occurrence of wind-pollinated mega- and macro-phanerophytes.

and I do not think the comparatively small quantities of QM pollen in zones B, D, and F represent any local occurrence of the species in question: The pollen comes from the last outposts of the species further down the valley. The higher values of zones C and E indicate that these outposts have advanced further up the valley and closer to our bog, but not even the greatest maxima (4—6 ‰!) can be interpreted as evidence that any QM constituent ever grew in the neighbourhood of Haugastøl. The nearest occurrences were probably not far away, perhaps in the same places where the pine forest ends to-day, but the QM constituents hardly ever came into what is now regio sub-alpina in this part of Norway.

The bed-rock of the Hallingdal region is rather unfavourable, and the vegetation is very monotonous, *Picea* and *Pinus* being — besides *Betula* — almost the only trees in the forests. The best part of the soil — where demanding species might have existed — has been settled long ago, and our “noble deciduous trees” are therefore very scarce. According to Dahl (1908) the only occurrence of *Corylus* in the valley is at Hesla, some 60 km further E, 250 m alt. It is noteworthy that the name is derived from *hesli*, meaning a place where *Corylus* grows (Rygh and Falk 1909, p. 109). The only other place-name indicating the occurrence of any of these species is Lindelien in the lowest part of the valley, in a place where *Tilia* (“lind”) still grows (Rygh and Falk l. c., p. 71). According to information from Mr. Johs. Lid, curator of the Oslo herbarium, none of these species are known to occur in other places in Hallingdal to-day.

Nordhagen (1943, p. 27) has interpreted the Sikilsdalen pollen diagram in a different manner and supposes that the “noble deciduous trees” occurred sporadically on the warm S-exposed hill-sides during the post-glacial climatic optimum. I agree with him with regard to *Corylus*, which possesses an almost continuous curve, reaching 4 ‰, but I find it less probable that any of the QM constituents proper should have occurred within the Sikilsdalen basin, even in the lowest part of regio sub-alpina and in the most favourable places. The pollen diagram (l. c.) is very primitive and based upon few pollen grains per spectrum ($\pm 150?$), and the *Ulmus* and *Tilia* percentages are so small and scattered that they do not average more than a few per mille. Under those circumstances long-distance transport is a more likely explanation.

Fraxinus pollen is very scarce in the lowlands. It was not observed in any of the samples from Haugastøl.

The *Salix* curve is unexpectedly low; the maximum at 1.60 is due to macroscopic sedimentation. As there is very little *Salix* even in the topmost sample, it is not possible to draw any conclusion with regard to the former occurrence of willow copses, which are at present fairly plentiful on some of the neighbouring hill-sides. Even in the mountains *Salix* obviously belongs to the species that are under-represented in the pollen diagrams.

The quantity of herb pollen, especially that of entomophilous herbs, is also very small, and as an indicator of deforestation the herb pollen does not play the same part as it does in arctic Finland and the Alps according to Aario (1944, p. 338). Some few grains are met with in each sample. Composites (types H and T, cp. Zander 1935) were the most frequent, among the others may be noted *Cariophyllaceae*, *Umbelliferae*, *Ranunculus*, *Valeriana*, and *Geranium*, all of them families and genera that occur in the sub-alpine forest of the region at present. Of greater interest are two pollen grains of *Succisa pratensis* from zone E (samples 1.60 and 1.80). *Succisa* is essentially a lowland plant (Nordhagen 1943, p. 59, cp. Norman 1895, p. 337) even if there are records of its occurrence up to the *Betula* limit (Dahl 1915, p. 138, Selland 1920, p. 225) and above that (Dahl 1907, p. 49, Smith 1920, p. 225, Lange 1938, p. 145). Some of these records may refer to anthropochoric dispersal, the species being an apophyte (cp. Linkola 1921, p. 439). It is not recorded by Dahl (1908) from the Haugastøl region nor from the rest of the valley. According to information from Mr. Lid the nearest present occurrences of *Succisa* in Hallingdal are — as far as we know — in Krødsherad, more than 100 km further SE.

It is also noteworthy that the species is not known from the northernmost provinces of Norway (Normann l. c., Dahl 1934, p. 400). According to Norman (l. c.) it is exclusively oceanic in the northern part of its area of distribution. Consequently its occurrence at Haugastøl during zone E gives valuable information both with regard to the thermic and hygric conditions of that zone.

In the sediments of zone G some few pollen grains of aquatic plants were observed. They all belonged to the *Sparganium* type; *Potamogeton* and the *Nymphaeaceae* were not observed. According to Samuelsson (1934, p. 44) the upper limits of the genera in the Swedish provinces of Dalarne-Jämtland are:

<i>Sparganium (hyperboreum)</i>	950 m
<i>Potamogeton (filiformis)</i>	1000 »
<i>Nuphar</i> spp.	750 »
<i>Nymphaea candida</i>	700 »

In Sikilsdalen in central Norway both *Sparganium (affine* and cfr. *hyperboreum)* and *Potamogeton (gramineus* and *alpinus)* grow at 1000 m alt. (Nordhagen 1943, p. 441), whereas *Nuphar luteum* does not occur above 900 m in East Norway (Samuelsson l. c., p. 131).

The Haugastøl region is situated so far away from all other areas in which pollen-analytical work has been carried out, and the Haugastøl diagram is so different from other, better known, diagram types that it is very difficult to date the zones. Nevertheless, the parallelization of the two optima of zones C and E with those of the Middle Swedish diagrams includes a dating, viz. to the sub-boreal, resp. the atlantic period. This dating can to a certain degree be controlled by means of the composition of the QM flora of the zones, cp. table 7. The *Quercus* dominance of zone A and the *Corylus* dominance of zone F are statistically significant ($P < 0.001$ in both cases). This *Corylus* dominance can be interpreted as the representation of the boreal *Corylus* maximum in the lowlands (zone VIII in the Jæren diagram, Fægi 1940).

Table 7.

The distribution of QM constituents, average numbers, per mille.

Zone:	A	B	C	D	E	F	G
<i>Ulmus</i>	0.3	0.3	4.5	1.3	2.2	0.5	0.3
<i>Tilia</i>	2.1	3.0	2.5	1.3	2.0	0.0	0.3
<i>Quercus</i>	4.4	0.7	5.0	2.3	1.8	2.0	0.8
QM-total	6.8	4.0	12.0	4.9	6.0	2.5	1.4
<i>Corylus</i>	1.0	0.5	1.0	3.3	3.3	4.5	1.8

In zone E *Corylus* and the individual QM constituents are equally frequent, whereas *Corylus* is lower than the others in zone C (it must be admitted, though, that the statistical significance of the QM dominance is very low: $P \sim 0.1$). This is in good accordance with the pollen-analytical character of the atlantic and the sub-boreal periods

as they are known, e. g. from West Norway. A more detailed discussion is hardly profitable at the present stage of our knowledge — especially as we know practically nothing about the vegetational development in East Norway — but the above points in the same direction as the parallelization with the Middle Swedish optima: Zones C and E represent the sub-boreal and atlantic periods, zone F the high boreal, and G most probably the early boreal. Zone A is the sub-atlantic, and B is most probably the late sub-boreal.

The dating of the other sub-alpine diagrams from Norway must perhaps be revised in view of these results. However, the important part is the *Alnus* curve. Unless it is calculated in per mille on the basis of a very great number of AP, the *Alnus* maxima are lost in the statistical errors, and unless the curve is drawn in a per mille scale, the maxima are lost graphically. It is therefore impossible to make any definite statements on the real significance of the post-glacial *Alnus* maxima of the sub-alpine diagrams mentioned above. This is deplorable, especially in the case of the Fongen diagram (Mannerfelt l. c.), as an exact dating would answer the important question whether the young, local moraines in our mountains may have been formed during the relatively unfavourable period D.

It is noteworthy that *Alnus* occurred during zones F and G, *A. glutinosa* did not assert itself in the diagrams from West Norway until the beginning of the atlantic period, but its occurrence during the boreal is proved by the diagrams from Randaberg (Fægri 1940, p. 90) and by some of the diagrams from Bømlo (Fægri 1944 a). *A. incana* most probably immigrated along another route, cp. the early occurrence of that species in Finland (e. g. Hyypä 1937), and came to the country as early as, or perhaps even earlier, than, *A. glutinosa*.

SUMMARY

1. Deposits from a small bog near Haugastøl were investigated pollen-analytically.

2. The decisive curves of *Alnus*, QM, etc. are so low that more than 1000 AP had to be counted per spectrum to give significant results.

3. *Betula* analysis was carried out, its statistical errors were discussed.

4. The methods of analysis of variance have been applied to the material (tabs. 3, 5, 6, etc.).

5. There are two climatic optima, one atlantic, and one sub-boreal, separated by a less favourable period.

6. The pine forest disappeared from the region after zone B (the sub-boreal period?).

7. *Betula tortuosa* and (later) *B. nana* spread during the last part of zone B and zone A (the sub-atlantic period?).

8. In the sub-alpine region the *Alnus (incana)* curve is the most important indicator of favourable climatic conditions.

9. *Empetrum hermaphroditum* dominated among the *Ericales* pollen through the entire series.

10. Whereas pollen grains that have been boiled for two hours with 10 % KOH are of the same size as fossil grains (after KOH treatment of the deposit), such recent grains as have been subject to acetolysis are in some cases bigger. Statistical diagnoses based upon acetolysed material is of less values.

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Knut Fægri: A Pollen Diagram from the Sub-Alpine Region of Central South Norway.

Haugastøl.

Signatures:

Arboreal pollen:

- AP – original value in re-calculated spectra
- Picea
- Alnus
- Quercetum mixtum incl. Corylus
- Alnus + Quercetum mixtum + Corylus
- B. verrucosa
- B. pubescens
- Pinus
- Betula
- Salix
- B. tortuosa
- B. nana

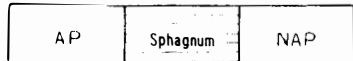
Non-arboreal pollen:

- Σ NAP – original value in re-calculated spectra
- Σ NAP in AP diagram
- Betula nana in total diagram
- Gramineae
- Ericaceae
- Cyperaceae

Other signatures:

- Sphagnum

Total diagram



- Moraine
- Alga mud
- Drepanocladus fluitans mud
- Sphagnum mud

