Danmarks Geologiske Undersøgelse.
IV. Række. Bd. 3. Nr. 2.

Measurement as a Means of Identifying Fossil Pollen.

By

B. Brorson Christensen.

With 1 Plate.

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KØBENHAVN

Contents.

Introduction.

In most places where pollen analysis is pursued more and more species have in recent years been included in pollen counting, and simultaneously the requirements as to the reliability and precision of identification — and the methods of identification — have of course become increasingly stringent.

As is only natural with pollen analysis as a young science, there are unfortunately no tables or keys even approximately comprising or distinguishing between all the species encountered in ordinary pollen counting, and probably many years will elapse before tables of this kind are available, if ever they will be.

In many cases when in the course of analysis unknown pollen grains are found, it may accordingly be a laborious task to classify them as to species, or even to families; no wonder that one has often been reluctant to spend so much effort on solitary pollen grains and has conserved one's energies for really large quantities of an unknown pollen type that constantly recurs or suddenly appears in an individual peat sample[1]). And yet, considerable endeavours have been made, perhaps particularly in the bog laboratories of Danmarks Geologiske Undersøgelse and the National Museum, to determine unknown pollen found only in very small quantities[2]).

Under these circumstances it has become very perceptible that whereas several of the features or characteristics used in identification (configuration of furrows and pores, the sculpture of the exine, etc.) have been made the subjects of excellent and, in some cases, thorough investigations, there is one means, measurement, whose usefulness and reliability have been taken up for discussion only in very special cases and in sharply delimited spheres, as far as I am aware.

Measuring of pollen is widely used and in certain cases has been

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[1]) See e. g. Knut Fægri, 1935 and 1945.

[2]) Such as *Saussurea*, *Vitis* and several others.

employed as the decisive argument in determining fossil pollen[1]). Nevertheless, it has nearly always been necessary to make reservations owing to the well-known disposition of pollen grains, live or dead, to alter in size and form under very different influences.

Consequently, it would be very desirable if these changes of size and shape could be "mapped" as it were, if one could discover the laws according to which the said changes take place so that it would no longer be necessary to the same extent to abstain from comparisons between the dimensions of pollen grains in samples of different origins or preparation.

The present short paper is only an imperfect attempt to ascertain if these laws do exist. It makes no claim to have provided the final answers to the questions, especially as it chiefly explains the working methods daily employed at the two bog laboratories named above. Furthermore, in the course of the work several new question marks have made their appearance every time one was apparently disposed of. Nevertheless, preliminary as this paper is, it is published now because some of the results are so universal in their application that presumably they may count upon some interest from other pollen-analysts too.

Chapter I.

Description of the Methods employed.

The pollen measurements on which this work is based were, all except one (Fig. 1 B), made by the author and with the same instrument: a Leitz microscope, Leitz eyepiece micrometer "6×St", and a Winkel-Zeiss 70 diameter objective, n. a. 0,90. This combination was chosen for the purpose of making the unit of measurement suitably small without having to undertake the increased labour and the inconveniences it would have entailed if such a large number of measurements were to be made with an immersion lens.

As the measurements were carried out, each degree of the scale represented 1,20 μ.

The importance of having a small unit in proportion to the object measured—in casu pollen—will be obvious, at any rate when as in the present instance one wishes to distinguish very small variations. Nevertheless, the lower the value of the units—especially where

[1]) See e. g. Knut Fægri, 1935 and 1945 and F. Firbas 1937.

smallness is obtained by means of an eyepiece micrometer with a very finely divided scale—the more will individual peculiarities of interpretation in the person doing the work be likely to affect the result. This source of error is rather imponderable but probably not of great importance if the measurements to be compared are made by the

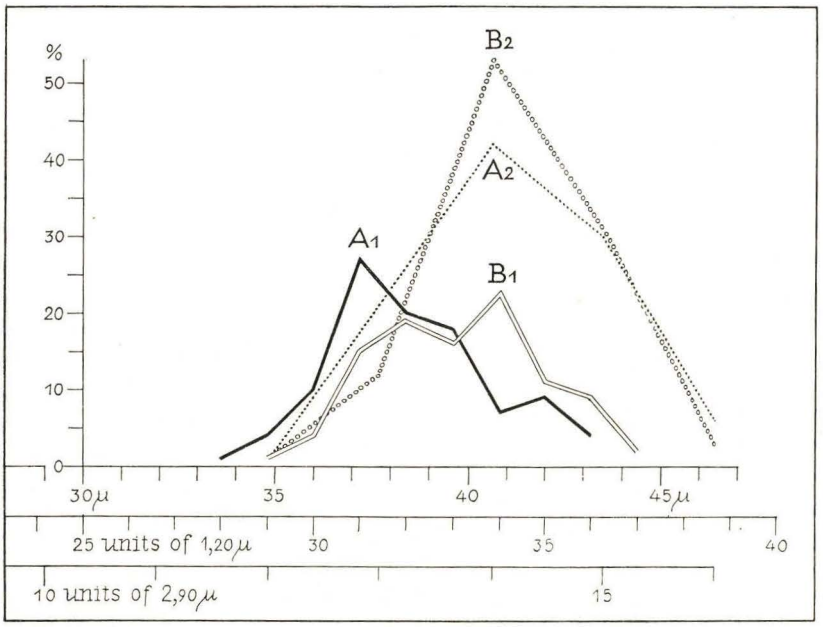

Fig. 1. The curves show the results of four measurements of the same sample of pollen (acetolysed, recent material of *Tilia sp.*). The measurements A1 and A2 were carried out by one person "A", measurements B1 and B2 by another, "B". In all cases 100 pollen grains were measured. For A1 and B1 the unit was 1,20 μ, for A2 and B2 it was 2,90 μ. It is easy to see that the four measurements agree in pairs: A1 with B1 and A2 with B2. The agreement is apparently conditioned by equality in the size of the measuring unit (scale degrees), as two "coarse" and two "fine" results are coupled, regardless of the fact that they were made by different persons. The mean values are distributed as follows:

A1:	38,5 μ =	32,1 units	of 1,20 μ
B1:	39,7 μ =	33,1 ,,	of 1,20 μ
A2:	41,2 μ =	14,1 ,,	of 2,90 μ
B2:	41,2 μ =	14,1 ,,	of 2,90 μ.

There can scarcely be any doubt that the last named measurements are simply unreliable, despite their handsome mutual conformity and notwithstanding the fact that a calculation of their mean error gives an apparently favourable result.

same person, with the same instrument and within a short time interval. The above diagram (Fig. 1) will make this clear, perhaps better than many words and just as well as a lot of mathematics.

The number of pollen grains in each measurement was with few exceptions at least 100, in many cases much more, right up to 250–350 in cases where there was any likelihood of doubt as to whether two components were identical or not.

On the subject of the measurements it may be added that as far as possible they were carried out a short time (a few days; for live pollen immediately) after the preparation of the samples and slides in order to avoid possible changes of size as a consequence of long storage. It must however be said that no such changes of size after storage have yet been observed[1]), although the measuring of several slides has been repeated after the expiration of about a year.

The methods of preparation that were employed, and whose influence on the size of the pollen it was the purpose to investigate, were for the greater part and in all essentials in accordance with those employed in the daily routine at the National Museum bog laboratory in Copenhagen. Tabularized according to the nature and condition of the pollen the methods were as follows:

A. Recent samples.

Dried pollen samples. No artificial drying processes of any kind were employed. The samples were simply dried in the sun or in a warm room over a minimum period of fourteen days (though a few, mostly herbarium material, considerably longer, up to many years, which by the way seems not to have had any effect on the reaction of the grains). The methods of preparation included in the investigations were:

1. No treatment. This "non-treatment" was performed as described by R. P. WODEHOUSE[2]). A small portion of the material was placed on a slide and moistened with a drop of alcohol. When this had almost evaporated a drop of melted glycerol-jelly (coloured with methylene blue) was added. The pollen material was mixed in this with a needle and the cover glass laid on. Staining with methylene blue was usually omitted, however.

[1]) This of course does not apply to pollen that was alive when the first measurement was made.

[2]) R. P. WODEHOUSE, 1935, p. 106.

2. Boiling in potassium hydroxyde solution. In a porcelain dish the material was covered with a 10 per cent. solution, followed by heating (direct, no water-bath) to boiling point, continued for about 60 seconds. The potassiumhydroxyde was then removed in the normal manner by repeated rinsing with water followed by centrifuging.

3. Acetolysis in the somewhat modified form[1]) used at the bog laboratories at Danmarks Geologiske Undersøgelse and the National Museum:

In a centrifuge tube the material was covered with cold, concentrated acetic acid[2]), which was removed a moment later by centrifuging; 10 c.c. acetic anhydride and 1 c.c. concentrated sulphuric acid were then added, and the tube was placed in a boiling water-bath, where it remained for exactly 60 seconds (in some special cases rather shorter or longer). (All short periods of this nature were checked by stop-watch). After acetolysis the material was rinsed and washed with water.

4. Acetolysis after boiling in potassium hydroxyde solution proceeded of course as method "2" followed by "3".

Boiling in melted potassiumhydroxyde without the addition of water was employed in one case; it lasted only a few seconds and was followed by a thorough and several times repeated washing with water.

Acetolysis after boiling in melted potassium hydroxyde was employed once.

Pollen samples which had been stored in concentrated acetic acid for a long time (up to several years) were examined either:

5. Without further treatment, merely after washing out the acetic acid, or after

6. Acetolysis. This process was exactly the same as described under "3", except that of course the brief extraction with acetic acid was omitted.

Live pollen:

7. Was stirred in water and measured at once—or it was treated by

[1]) Regarding the "orthodox" form of acetolysis see G. Erdtman 1934 and 1936.

[2]) Acetic acid was employed here with dry material because it was desired to employ the methods as uniformly as possible, and also because in this manner it is easier to get the pollen out of the anthers and flowers, with the consequence that the slides are richer in pollen.

=2. Boiling with potassium hydroxyde solution, or by
=3. Acetolysis.

B. Fossil pollen samples:

The investigations were preliminarily confined to postglacial material: lake marl, gyttja, peat, and a single sample which presumably consisted of fossil honey (or mead?—the sample came from a birch-bark pail in a Bronze Age oak coffin[1])). For reasons which will be given below the measurements comprised *Corylus* alone (the honey sample forms the sole exception). The methods of preparation which came into consideration were the following:

=1. No treatment except possibly pulverisation or other comminution of the sample.

=2. Boiling with potassium hydroxyde solution.

=3. Acetolysis.

=4. Acetolysis after boiling with potassium hydroxyde solution.

Boiling with melted potassium hydroxyde was tried with one sample as described above.

Acetolysis after boiling with melted potassium hydroxyde (see above) was tried with the same sample.

8. Treatment with hydrofluoric acid was applied to a sample of gyttja containing neither clay nor calcium[2]), the method being as follows: In a copper crucible the sample was thoroughly mixed with hydrofluoric acid (40%), whereafter crucible and contents were slowly heated for half an hour up to somewhat lower than boiling point. The hydrofluoric acid was then removed by centrifuging, after which the gyttja in the tube was covered with hydrochloric acid (10%) and placed in a boiling water-bath for about three minutes. This was followed by repeated washing with water.

9. Acetolysis after treatment with hydrofluoric acid proceeded as "8" followed by "3".

It should perhaps be observed that each of the samples after thorough mixing and comminution was subjected to as many of

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[1]) See Th. Thomsen 1929, p. 184.

[2]) This was almost necessary, as the sample had also to be measured without hydrofluoric acid treatment for the sake of comparison. It is obvious that this work would be almost insuperable with a clay gyttja, in which the quantity of pollen is very small as compared with the volume of the material.

these processes—followed by measurement—as was practicable or permitted by the quantity of material, but always with the processes "no treatment" and the simplified acetolysis, which the writer considers to be the most stable, as the primary ones, so as to provide a basis for comparison partly with the remaining investigations of the same sample and partly with others.

In almost every case the recent samples came from single individuals.

Glycerol-jelly was employed in preparing the slides except for "7".

Chapter II.

Reactions of Pollen Grains to various Kinds of Treatment.

1. Changes of Shape.

Among the obstacles to fully reliable identifications of fossil pollen, one of the most important is the disposition of the grains to alter in shape; it extensively increases the demands on the powers of observation and concentration on the part of the worker and has possibly in many cases been the cause of errors. These changes of shape may be of various kinds: For example, in gyttja which has been allowed to dry before preparation, the pollen grains may be considerably shrunken, crumpled and torn; another and truer kind of alteration in shape is the expansion and contraction for which the exine of some grains is so to say adapted.

As to the former type of alteration, ordinary size statistics of course will be less reliable when based upon pollen samples containing many crumpled or "collapsed" individuals which cannot be measured. In many species of pollen the wall of the largest specimens is relatively thinner than that of the smaller ones, for which reason they collapse more readily and thereby disturb the result of measurements.

The latter type of alteration is associated with certain pollen types, especially those with furrows or fissures such as *Quercus*, *Fraxinus*, *Salix*, *Artemisia* and many others. The normal changes common to these types (described in detail by R. P. WODEHOUSE) are in live pollen governed by the greater or smaller volume of the plasma (depending on the degree of moisture in the pollen). Nevertheless, these changes continue after the plasma has disappeared.—All who occupy themselves with pollen counting will know how in one sample

a large number of individuals of, e. g. *Quercus robur*. may be almost spherical, whereas in another the majority are long and slender. Sometimes this difference is so striking that it is hard to believe that the pollen grains are of the same species.

This being so, it must alas be said that measuring the length and width of a fossil pollen—as one is tempted to do in many cases when trying to identify it—is of little value if the pollen is of this type, one that comprises innumerable plant families. Mention may be made of *Rosaceae*, *Amygdalaceae*, *Pomaceae* and many others.

If we could discover a method of preparation which brought all pollen grains (in fossil as well as recent samples) to the same degree of distension, it would be extremely useful, not only for measuring. In the course of the preparatory work on this paper the writer essayed a procedure which partly—but only partly—gave the desired result. The method cannot be recommended for use in pollen analysis, as it is very destructive to fossil pollen; recent pollen seems to stand it better. The experiment is mentioned here because the results showed so clearly what great faculties pollen grains have of changing shape, and how cautious one ought to be about drawing conclusions from relative measurements such as the size and shape of pores, the width of furrows in proportion to the intermediate lunae, etc., all features which have been employed for identification.

In this experiment two pollen samples, a recent one of *Filipendula*

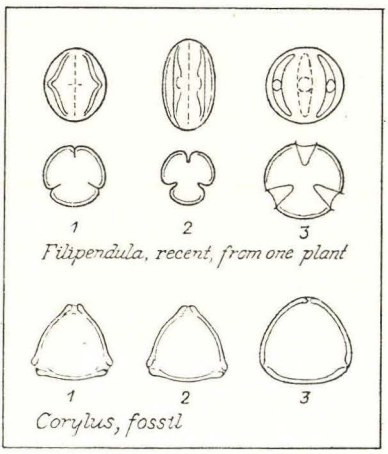

Fig. 2. Shows the typical shape of pollen grains after: 1, acetolysis, 2, acetolysis after boiling in potassium hydroxyde solution, and 3, acetolysis after boiling in melted potassium hydroxyde.

hexapetala and a fossil gyttja sample were each divided into three portions. Of these portions one of each kind was merely acetolysed (see page 9 "3"), one was boiled with potassium hydroxyde solution and then acetolysed, and one was boiled for a few seconds in melted potassiumhydroxyde prior to acetolysing. It was found that in this third process a large number of the pollen grains assumed the size (?) and shape of living, fully expanded pollen of the same kind. (See fig. 2).

2. Dimensional Changes.

In the following the writer will endeavour to give an account of the results of the measurements which form the principal basis of this investigation. First, however, some general remarks:

That which changes size when a pollen grain swells or shrinks is, of course, the volume. In the present case, however, the diameter was measured, and as volume and diameter are by no means proportionate in the same manner for all bodies, the resnlts are capable of comparison only when the bodies are of the same form: spherical pollen of all kinds can be compared mutually. Apart from these, one must in most cases be content to compare pollen of the same species or type, *Corylus* with *Corylus*, and so on. A conversion from diameter to volume for non-spherical pollen is a problem that will deter all but the fewest.

Pollen of other types than spherical were measured in the following manner:

"Trilobate" pollen such as *Filipendula* and *Forsythia* from pole to pole. Here the methods of preparation influenced both size and shape, which undeniably complicated matters still more (see fig. 2).

"Triangular" pollen. In the case of *Corylus* a "median" was measured. Only specimens with a pole extending straight up were measured. The same applies to *Tilia*.

Alnus was measured along one side on specimens with four pores; a "median" was measured on those with five.

While being measured the grains were embedded in glycerol jelly, as indicated above.

"Untreated" pollen samples. (See Pl. I). A glance at the results of measuring these samples will show that the fact of their not having undergone any treatment by no means made them homogeneous as regards the relative dimensions of the grains.

It turned out that the grains so to say had an answer ready for each condition or form of preservation. E. g. fossil grains were clearly rather smaller than dried, recent ones, as will be seen merely by comparing the measurements of the different *Corylus* samples. It may be interposed here that WODEHOUSE's average value for *Corylus avellana* is 26,5 μ[1]).

Protracted soaking in acetic acid was liable to cause shrinkage; on the other hand, pollen preserved in this manner can hardly be included among the untreated samples.

Live, moist pollen grains were of course large and swollen; but as this unquestionably is the most unstable of all conditions and moreover the one farthest removed from fossil pollen as appearing from the methods of preparation now available, no great importance was attached to these measurements.

For the rest, the "initial stages": dried samples, fossil samples, etc. proved not to be equally sensitive to the processes described below.

Boiling in potassium hydroxyde solution showed as its principal result a diminution of recent pollen, an approach—not only in respect of size—to the condition of the fossil grains[2]). That there actually was an approach seems to be confirmed not only by the fact that when subsequently acetolyzed the recent pollen behaved almost like fossil material (see below and Plate I), but also more indirectly by the complete absence of measurable reactions of fossil grains to boiling with potassium hydroxyde solution.

Acetolysis. This process, which on account of its many excellent properties is becoming more and more popular (though in a somewhat modified form in Denmark, see page 9), is known to exercise drastic effects on the size of the pollen grains. It was therefore followed with special attention.

First the question was examined of whether the shorter or longer duration of acetolysis (by which is meant the duration of the actual period in the water-bath) had any other influence than the usual staining of the pollen. This test was made with several recent samples (of *Corylus*, *Alnus*, *Thalictrum*, *Helianthus* and others) and one fossil (*Corylus* in "Algae gyttja II", see Plate I), and it gave the

[1]) WODEHOUSE 1935, p. 369.

[2]) A more protracted treatment with potassium hydroxyde (which, by the way, would have to take place in a water-bath) would in all probability show this reaction more clearly.

somewhat paradoxical result that the longer acetolysation lasted, the smaller the grains became! True, they became much larger than for instance untreated material; but the actual increase in size took place so suddenly and completely when the acetic anhydride—sulphuric acid mixture was poured over them that it was terminated before the sample even came into the water-bath. Heating in the bath caused merely a kind of stiffening or "fixing" of the pollen grains (also as regards their shape), during which they slowly became slightly smaller, and finally, when the reactions in the fluid had

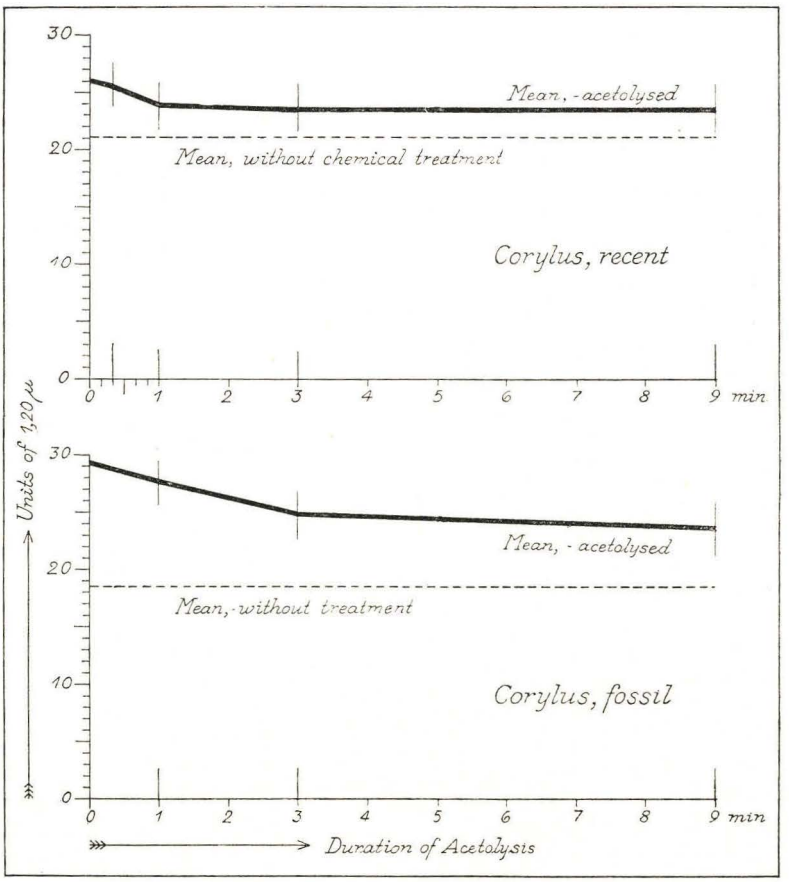

Fig. 3. Diminution of pollen grains when heated in the mixture of acetic anhydride and sulphuric acid. For the recent sample the shrinkage was slight, but the curve is sufficiently reliable as the mean errors on the various measurements are quite small; 200 pollen grains or more were measured in each case.

come to an end or quietened down, stopped at a constant size which seemed to have a certain relation to the size of dried, untreated pollen, but which in most cases was not inconsiderably in excess of the latter's dimensions.

As might have been expected, these fluctuations were most marked in the fossil sample (see fig. 3).

In the subsequent investigations on the effects of acetolysis the "boiling time" was exactly 60 seconds.

The results of these subsequent investigations showed—as far as comparisons are admissible—a fairly uniform size increase in almost every case, though it was distinctly greater for the fossil samples than for the recent ones. As regards the latter it was as if something deadened their sensitivity to acetolysis. The author does not pretend to have an explanation of what caused this effect; but attention is involuntarily drawn to the oleaginous or resinous substances that are associated with the exine, and which to some extent may have an inhibitive effect. The results for *Dactylis* and *Thalictrum* were quite outside the general picture and thus provided a reminder of the imperfections of these investigations. They registered no growth at all after acetolysis (in fact one shrank slightly); but whether this was due to a different chemical composition of the exine or to its slight thickness is a question that remains unanswered for the present[1]).

Acetolysis after boiling with potassium hydroxyde solution showed how the potassium hydroxyde had brought the recent pollen samples into a state which in its characters approached that of the fossil samples. The increase of size was almost just as great for the former as for the latter; thus the insensitivity to acetolysis had disappeared[2]). On the other hand, the homogeneity of the material suffered to some extent; these measurements revealed greater ranges of variation than when untreated material was acetolysed[3]).

In good harmony with this "fossilisation" of the recent pollen,

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[1]) It has been suggested by various authors that the dimensions of the size changes in pollen depend on the relative thickness of the exine, and in fact it is very probable that this is so.

[2]) As the result of a saponification of the aforesaid oleaginous or resinous substances?

[3]) Possibly because the saponification of the resinous substances was not quite completed.

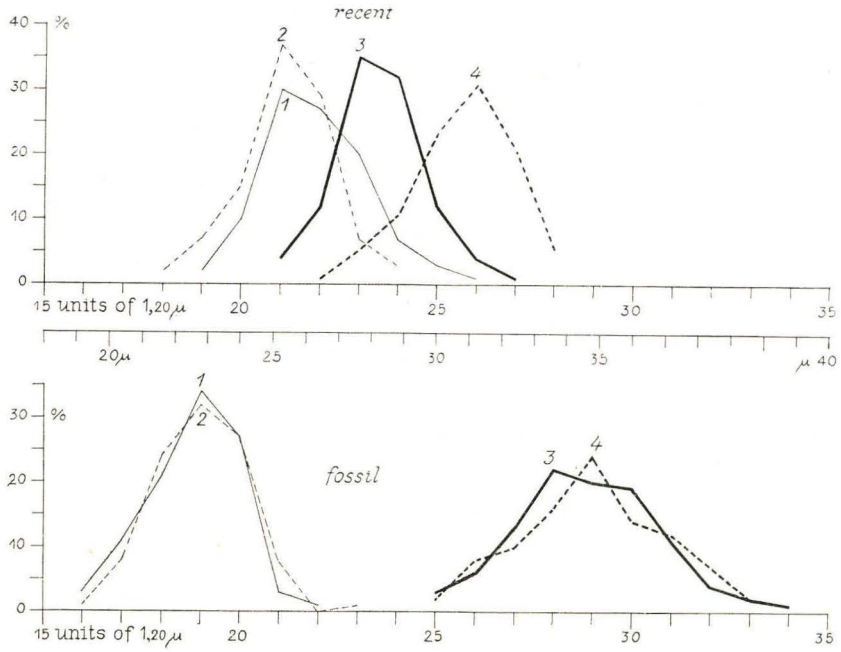

Fig. 4. The curves show typical size variations in recent and fossil material in response to the more important of the processes described in this paper:

Top: recent *Corylus* (1 individual, Frederiksberg, see Pl. I).

1 — untreated

2 — treated with potassium hydroxyde solution

3 — acetolysed

4 — acetolysed after treating with potassium hydroxyde solution.

Bottom: fossil *Corylus* ("alga gyttja I", see Plate I).

1 — untreated

2 — treated with potassium hydroxyde solution

3 — acetolysed

4 — acetolysed after treating with potassium hydroxyde solution.

the effects of acetolysis on the size of the fossil material were practically the same whether it was boiled in potassium hydroxyde solution or not.

Hydrofluoric acid treatment. For reasons previously stated the somewhat superficial investigation of the effects of this treatment was carried out on a sample of gyttja which contained no clay (or calcium). As was to be expected, the result was that the size of the pollen grains had diminished a little, but not so much as might perhaps have been assumed after the experience of others. It may turn out that the pollen grains in clayey gyttja are smaller than in

other gyttjas and peats, so that treatment with hydrofluoric acid may perhaps be only partly to blame for the familiar small size of pollen in analyses of this kind.

Acetolysis after hydrofluoric acid treatment naturally caused the pollen to swell again, but not to the same size as the pollen from the same sample acetolysed on the ordinary basis. The increase in size was also relatively smaller, which means that the hydrofluoric acid treatment endowed the pollen grains with a certain insensitivity to acetolysis, almost the same as was described above in respect of the recent samples.

Chapter III.

A possible Method of making Measurement more reliable as a Means of Identification.

It was stated in the Introduction that this paper makes no pretence of having solved, or even occupied itself with all the problems embraced by the subject. Consequently, the question of how measurement can assist in determining fossil pollen can only be outlined very broadly. For the same reasons, the following should not be regarded as much more than hypotheses, for use in further studies of the same subjects.

Judging from the measurements described (see especially Pl. I), the changes in the dimensions of pollen grains seem to be subject to certain rules. True, these rules are extremely varied, and the reasons why this or that happens are mostly uncertain; there are many more factors than those dealt with here, and there are unpleasantly many unknown quantities in the mathematical problem one would wish to solve, a problem which might be formulated thus: "A fossil pollen grain has the diameter a. How large would this diameter be if the grain were recent, acetolysed?"—(or were in another recent state, no matter which; the material for comparison may be chosen at will).

In order to reduce the number of unknown quantities one might make chemical analyses, either of the pollen for the purpose of determining differences in the material structure of the exine of pollen grains from various groups of plants[1]), or of pollenbearing

[1]) It seems certain that there are such differences. It is common knowledge that the various kinds of pollen display very different degrees of resistance to destruction in the fossil state.

deposits in order to ascertain the hydrogen-ion concentration and other properties essential to preservation; but it is rather doubtful if this would lead to the desired result.

However, there is another possibility. On measuring seven different recent pollen samples of *Corylus avellana*, each of one individual but from widely different localities (see Pl. I), and, be it noted, in the same initial state, i. e. desiccated, the mean values for the ordinary acetolyzed material (and for the untreated) showed surprisingly slight variation. (Also within each separate measurement *Corylus* showed only a small range of variation). Accordingly it would be a very attractive idea if it were feasible—after having established the size of recent acetolysed pollen of *Corylus avellana* by making many more measurements as exactly as possible—to employ this species as a kind of barometer for the dimensional status in fossil samples subjected to pollen analysis. On measuring for instance 100 *Corylus* pollen grains[1]) in each sample (provided that *Corylus* is contained in it, otherwise any common species, which would then have to assume the role of a recent basis for comparison), we shall arrive at a mean value which, placed in relation to the mean value for recent Corylus, will be capable of giving useful indications if applied with circumspection.

Of course, this method is of limited advantage as long as we do not know to what extent the changes of size lack uniformity in pollen of different plant groups, and also because it would be incorrect to compare ordinary measurements—i. e. diameters—of pollen grains of different shapes; but this does not prevent employment of the method.

If for example we have determined the family or genus of a certain fossil pollen type (or a single pollen grain) which we may call "x", and wish to take our classification still further, we may measure recent material from the genera or species likely to be involved[2]), in the untreated state and treated as far as possible in the same man-

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[1]) The chances in Northern Europe of encountering pollen of other *Corylus* species than *C. avellana* in a pollen count are slight; and even if it should happen, the numbers would be so small that they would have no statistical bearing on the measurements.

[2]) In most cases it will doubtless be advisable to measure the pollen of several recent individuals of each species; in doing so it is better not to get the material mixed, even when it is from the same species, as in that case one has no means of ascertaining whether the result of the measuring is dominated by a single plant which for some reason may have yielded most pollen.

ner as "x". By this means we acquire a certain knowledge of both size and changes in size as well as possible changes of shape in the particular pollen; from the results here presented however (Pl. I and elsewhere) it will be seen that we cannot directly arrive at a reliable result by comparing the size of "x" with the aforesaid measurements if the "general dimensional status" of the pollen in the sample containing "x" is unknown. It is then that *Corylus* measurements (or measurements of another suitable pollen type) in the fossil sample containing "x" will be useful as just stated, in that they express the "general dimensional status" and thus improve the chances of estimating the size of "x" in recent condition.

It is obvious that a complicated manner of proceeding as the above described could never be used except for determining fossil pollen believed to be of vital importance. In a few cases it has been employed in the bog laboratory of the National Museum, but as yet it is too early to say more than that the measurements, which have to be made under high magnification in order to be accurate enough, entail no small increase of the already laborious work involved by counting pollen samples. On the other hand, we cannot expect to achieve much in the endeavour to include more species in pollen analysis without spending time and labour whether the chief burden of the work may happen to lie in this domain or somewhere else.

Should the foregoing suggestion prove to be unfruitful, there may still be a possibility that the small investigations here described may perform a mission in other ways. If they can help at all to show how manifold are the changes in pollen sizes and shapes and thereby be a means of preventing incorrect conclusions, the work will not have been in vain.

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Statsgeolog J. IVERSEN, Ph. D., I want to thank for much encouragement and many instructive talks.

To Afdelingsgeolog, mag. scient. J. TROELS-SMITH it is my pleasant duty to express my gratitude for his untiring interest in this work, for a great many helpful discussions and for permission to carry out the chemical preparations in the bog laboratory of the National Museum, Copenhagen.

Assistent, mag. scient. ALFRED ANDERSEN has given me valuable help in procuring several pollen samples from foreign countries.

Frederiksberg, December the 5th, 1945.

B. BRORSON CHRISTENSEN.

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Measurement
as a Means of identifying Fossil Pollen.

Plate I.

Plate I. *Showing reactions in size to different chemical treatment. — Dimensions are in μ.*

With one exception each of the recent samples was taken from a single plant.

For further explanations see chapters I and II.2.

		Recent samples, desiccated Fossil samples, — see below						Recent samples preserved in acetic acid			Pollen samples alive when preparation started						
		without treatment	boiled in KOH-solution	acetolysed	acetolysed after boiling in KOH-solution	"3" in proportion to "1"	"4" in proportion to "2"	without treatment	acetolysed	"6" in proportion to "5"	live and moist	boiled in KOH-solution	acetolysed	"7" in proportion to "7"	treated with hydrofluoric acid	acetolysed after treatment with hydrofluoric acid	"9" in proportion to "8"
		1	2	3	4			5	6		7	=2	=3		8	9	
recent	*Silene vulgaris*, Aamosen, Sjælland	—	40.5	—	49.1	—	*1.21*	41.7	47.2	*1.16*	—	—	—	—			
	Ulmus sp., København	29.4	28.6	33.4	36.0	*1.14*	*1.26*	—	—	—	—	—	—	—			
	Thalictrum flavum, Aamosen, Sjælland	22.9	21.3	22.1	25.0	*0.96*	*1.14*	—	—	—	—	—	—	—			
	Dactylis glomerata, „ „	35.8	—	35.8	—	*1.00*	—	30.6	35.6	*1.24*	—	—	—	—			
	Helianthus sp., Charlottenlund, Sjælland	28.7	—	30.2	—	*1.05*	—	26.7	31.1	*1.16*	—	—	—	—			
	Forsythia sp., „ „	28.1	25.7	31.7	33.4	*1.13*	*1.30*	25.0	29.3	*1.17*	40.6	25.8	31.0	*0.76*			
	Filipendula hexapetala, Møen	18.1	18.1	19.9	23.9	*1.10*	*1.32*	—	—	—	—	—	—	—			
	Alnus sp., København	22.2	21.7	24.8	—	*1.12*	—	—	—	—	—	—	—	—			
	Corylus avellana, København	26.7	25.9	29.2	32.2	*1.09*	*1.24*	25.2	28.9	*1.15*	35.2	26.6	29.2	*0.83*			
	„ „ Frederiksberg, Sjælland	26.3	25.4	28.2	30.7	*1.07*	*1.21*	—	—	—	32.9	25.2	28.6	*0.87*			
	„ „ Farum, Sjælland, a	25.1	—	27.3	—	*1.10*	—	—	—	—	—	—	—	—			
	„ „ „ „ , b	24.6	—	27.7	—	*1.12*	—	—	—	—	—	—	—	—			
	„ „ Northern Jylland	—	—	28.1	—	—	—	—	—	—	—	—	—	—			
	„ „ Cluj, Rumania	—	—	28.4	—	—	—	—	—	—	—	—	—	—			
	„ „ Kasan, Russia	—	—	27.4	—	—	—	—	—	—	—	—	—	—			
	Corylus americana, Frederiksberg, Sjælland	25.3	—	28.6	—	*1.13*	—	—	—	—	—	—	—	—			
	Tilia sp.,—from several trees, Næstved, Sjælland	33.9	(32.5)	38.5	43.2	*1.14*	(*1.32*)	—	—	—	—	—	—	—			
fossil	*Corylus avellana*, alga gyttja I, moist	22.6	22.8	34.6	35.0	*1.54*	*1.53*										
	„ „ „ „ I, desiccated	—	22.8	—	34.6	—	*1.52*								—	—	—
	„ „ „ „ II, moist	22.1	22.9	33.3	—	*1.50*	—								—	—	—
	„ „ „ „ III, „	22.4	—	33.7	—	*1.50*	—								21.0	27.8	*1.33*
	„ „ detritus gyttja, „	23.7	—	—	(36.1)	—	—								—	—	—
	„ „ lake marl, „	—	23.0	—	33.0	—	*1.44*								—	—	—
	„ „ sphagnum-peat, desiccated	—	25.5	—	34.9	—	*1.34*								—	—	—
	Tilia sp., fossil honey(?) „	—	29.7	—	42.5	—	*1.43*								—	—	—