

3. HIGH TEMPERATURE EFFECT OF SOME BISACCATE GYMNOSPERM POLLEN GRAINS

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Abstract

The qualitative and quantitative secondary alterations of the pollen grains of *Pinus silvestris*, *Pinus mugo* and *Picea glauca* were investigated. The pollen grains were heated at 200°C during different lengths of time. Peculiar attention was paid to the nomenclature of the light microscopical morphology of the bisaccate pollen grains. The high temperature effect damages the sacci. After a long length of time heating the pollen grains lost the bladders, and these secondary altered forms are similar to early sulcate fossil taxa, such as *Bennettitaceaeacuminella*, etc. The alterations in the size are evaluated by the corpus and the saccus.

Key words: Palynology, recent, bisaccate *Gymnospermatophyta*, high temperature effect.

Introduction

It was emphasized previously that after our first observations on the secondary alterations of the *Brevaxonate Amentiflorae* pollen grains (KEDVES and KINCSEK, 1989) in consequence of the high temperature effect, several research programs started with different basic concepts. The LM and the TEM method was used. These two methods have very different aspects. The LM method is important in the investigations of the fossil spores and pollen grains, in particular at those extracted from the metamorphic layers. The secondary alterations of the saccate gymnosperm pollen grains are included in the systematic study of all kinds of spore and pollen types. In this way the aims of this research are as follows.

- i. To establish the qualitative morphological alterations in particular which has taxonomic importance.
- ii. To investigate the secondary alterations of the size of the corpus and the saccus.
- iii. Interpretation of the experimental data with the fossil types from different geological ages.

Material and Methods

The investigated species are the following:

Pinus silvestris L.

Collected: DR. K. MARGÓCZI, 18. 5. 1988., in the Botanical Garden of the J. A. University. Experiment numbers: 246—350, 905, 907, 910, 759, 913, 916.

Pinus mugo TURRA

Collected: DR. K. MARGÓCZI, 18. 5. 1988., in the Botanical Garden of the J. A. University. Experiment numbers: 366—370, 445, 908, 911, 760, 914, 917.

Picea glauca (MOENCH.) VOSS.

Collected: DR. K. MARGÓCZI, 18. 5. 1988., in the Botanical Garden of the J. A. University. Experiment numbers: 351—355, 906, 909, 912, 758, 915, 918.

Temperature: 200°C.

Length of time: 1^h Experiment No: 346, 366, 351

2^h Experiment No: 347, 367, 352

3^h Experiment No: 348, 368, 353

4^h Experiment No: 349, 369, 354

5^h Experiment No: 350, 370, 355

10^h Experiment No: 905, 445, 906

25^h Experiment No: 907, 908, 909

50^h Experiment No: 910, 911, 912

100^h Experiment No: 759, 760, 758

200^h Experiment No: 913, 914, 915

300^h Experiment No: 916, 917, 918

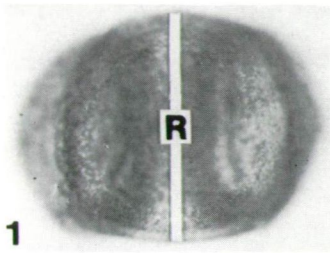
The pollen grains were mounted in glycerin-jelly hydrated at 39.6%, and investigated with the light-microscope method.

As regards the light microscopical morphology of the bisaccate gymnosperm pollen grains there are several concepts, in particular the points of symmetries and the measurements of the different parts of the pollen grain. There are a lot of publications in this subject, some selected establishments are summarized as follows.

AYTUG (1959) used the data of the quantitative measurements to establish the hybride character of *Abies Equi Trojani* ASCHERS et SINTEN. Basic establishments were published later (AYTUG, 1960). By the repeated measurements of the same slide in different intervals (one, two and four months) the expansion of the corpus was observed. Worth of mentioning is the fact that the dimension of the saccus has not altered. Later (AYTUG, 1962) measured the parameters of four species of the genus *Cedrus* LINK. BARTH (1962) used also the data of the measurements of the corpus, saccus and the total diameter, in two positions of the pollen grain. FREUDENTHAL (1964) in his paper emphasized as follows., p. 213: "JANSONIUS (1962) was the first to give a good method of describing of bisaccate pollen grains." KRUTZSCH (1971) reviewed several previous publications in this respect, in connection with the monograph of the Middle and Upper Tertiary fossil gymnosperm pollen grains. SIVAK (1975) dealt also in detail with this problem, and pointed out the following, p. 352: "KRUTZSCH (1971) a fait une synthèse partielle des termes utilisés; nous regrettons qu'il n'existe pas de vocabulaire commun, voici celui que nous proposons (fig. 1):" The proposal of SIVAK (1975) was slightly modified, and it is presented in Plate 3. 1., with the original French terms. ACCORSI et al. (1978) investigated from this point of view the species of the genus *Pinus* from Italy. As regards the general morphology of these pollen grains we cite from the publication of LIEUX (1980), p. 20, 21: "Type 2" "Pollen description: disaccate, heteropolar, monosulcate. Sulcus represented by a thinned area on distal side of grain; sulcus area more or less psilate in all species examined." POCKNALL (1981) investigated in detail the New Zealand pollen grains of the species of *Dacrydium* SOLANDER, *Podocarpus* L'HÉRITIER and *Dacrycarpus* ENDLICHER. Basic morphological establishments were published. But it is necessary to emphasize that the term saccus "reticulum" was used inside the alveoli. RIABKOVA (1982) dealt in detail with the LM and TEM structure of the gymnosperm pollen grains. Further important data are in the paper of HANSEN and ENGSTROM (1985) and BRADY (1988).

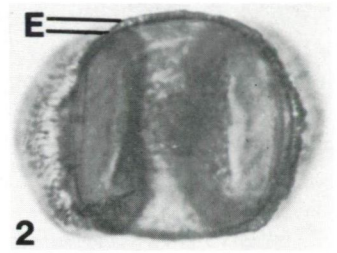
Plate 3. 2. summarizes the basic, general morphological establishments about the bisaccate gymnosperm pollen grains. For the saccus alveolar structure the paper of M. VAN CAMPO (1973) was used. In general the above mentioned and discussed works were followed with attention. The 16 (extremal) landmarks are from the publication of BRADY (1988), p. 487:

VUE PROXIMALE



épaisseur
de la calotte

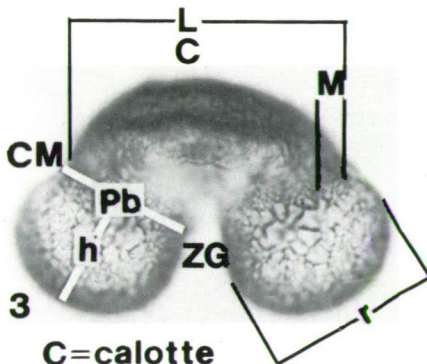
R= largeur
du corps



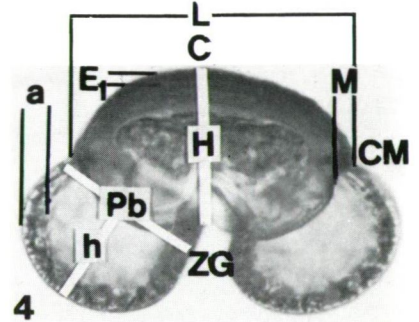
VUE DE PROFIL

L=longueur du corps
H=hauteur du corps

M=épaisseur de la crête
marginale



C=calotte
ZG=zone germinale
CM=crête marginale
Pb=plancher du ballonnet

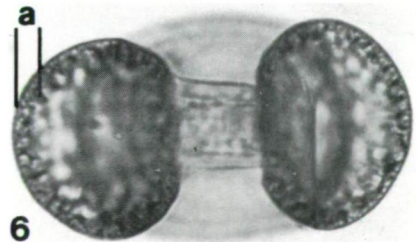
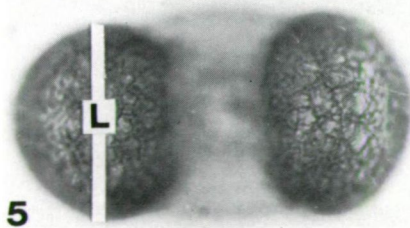


E₁=épaisseur de la calotte
h=hauteur du ballonnet
r=largeur du ballonnet
a=hauteur des alvéoles

VUE DISTALE

L=longueur du ballonnet

hauteur des alvéoles



◀ Plate 3.1.

Pinus mugo TURRA

Fresh pollen grains coloured with Toluidin blue, from different aspects. The morphological terms follows the paper of SIVAK (1975). 1000 x.

- “a Proximal pole Proximal-most point on pollen grain; bisector of arc of corpus between proximal radices.
- b Distal pole Bisector of arc of corpus between distal radices, or if distal groove present, then point at base of groove.
- c Right proximal radix Proximal-most point of attachment of right saccus to corpus.
- d Left proximal radix Proximal-most point of attachment of left saccus to corpus.
- e Right terminus Right-most point on pollen grain; point furthest to right of line between proximal and distal poles.
- f Left terminus Left-most point on pollen grain; point furthest to left of line between proximal and distal poles.
- g Left centrum Bisector of line between proximal and distal radices of left saccus.
- h Left vertex Bisector of arc between proximal and distal radices of left saccus.
- i Left distal flexus Distal-most point on line perpendicular to, and bisecting, line between centrum and vertex of left saccus.
- j Left proximal flexus Proximal-most, point on line perpendicular to, and bisecting, line between centrum and vertex of left saccus.
- k Right distal radix Distal-most point of attachment of right saccus to corpus.
- l Left distal radix Distal-most point of attachment of left saccus to corpus.
- m Right centrum Bisector of line between proximal and distal radices of right saccus.
- n Right vertex Bisector of arc between proximal and distal radices of right saccus.
- o Right distal flexus Distal-most point on line perpendicular to, and bisecting, line between centrum and vertex of right saccus.
- p Right proximal flexus Proximal-most point on line perpendicular to, and bisecting, line between centrum and vertex of right saccus.”

The enumerated publications in the following are also important from the point of view of the bisaccate gymnosperm pollen grains: VAN CAMPO-DUPLAN (1946, 1947 a, b), M. VAN CAMPO (1973), M. VAN CAMPO and SIVAK (1972), MARTENS and WATERKEYN (1961), VASIL (1978), and KURMANN (1989).

To get quantitative data for the degradation of the sacci, three groups were established (Text-fig. 3. 1.):

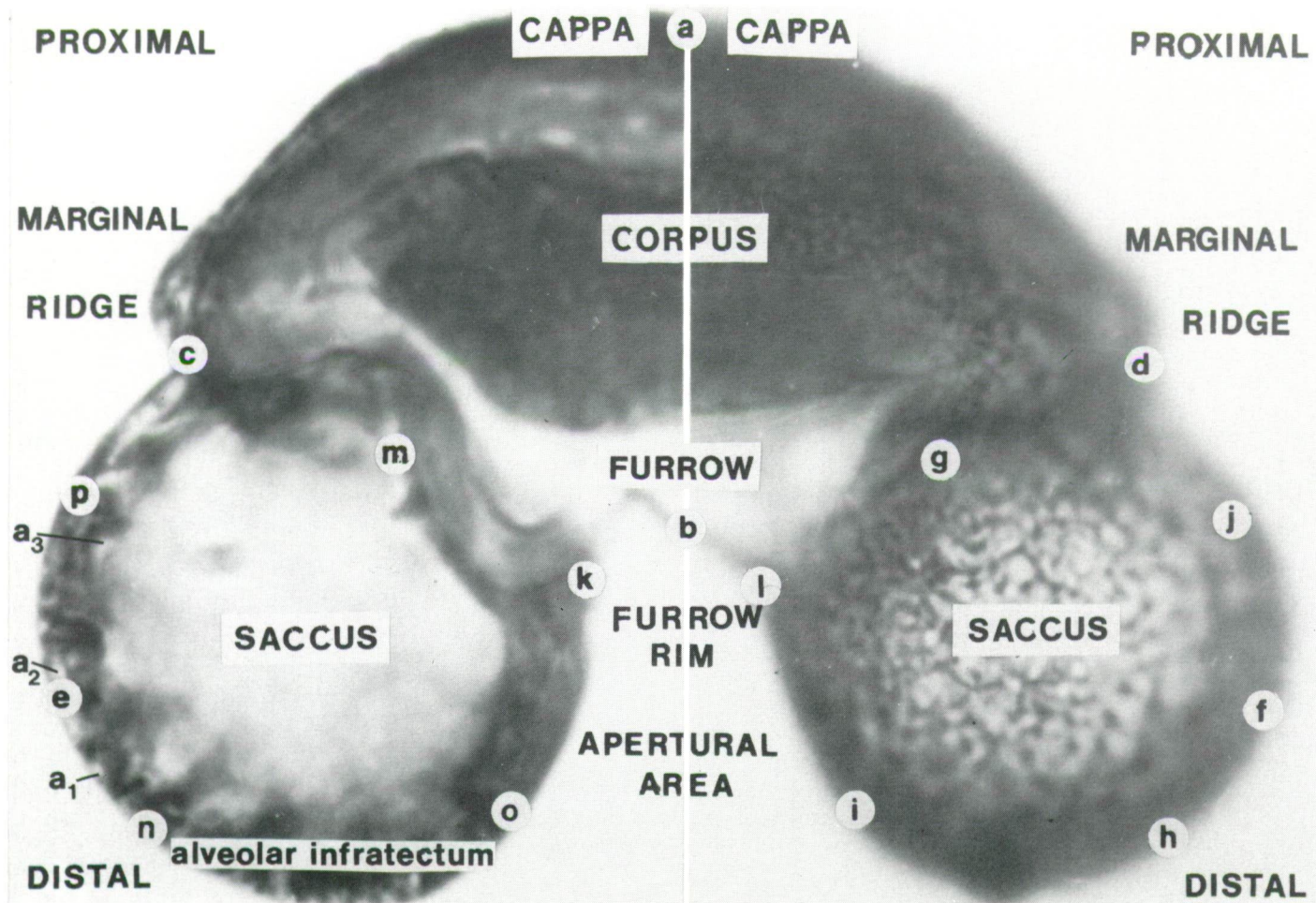
- i. The intact form with two sacci (bladders).
- ii. The partially degraded pollen grains, in general with one saccus.
- iii. The corpus, without saccus.

For the quantitative investigations of the bisaccate forms, the following parameters were measured (Plate 3. 2.). Corpus: c—d (corpus breadth), and a—b (corpus height). Saccus: p—o (saccus width) and g—h (saccus height). The alterations in consequence of the high temperature of the pollen grains are illustrated in Plate 3. 3. —3. 6.

Plate 3.2. ▶

Pinus mugo TURRA

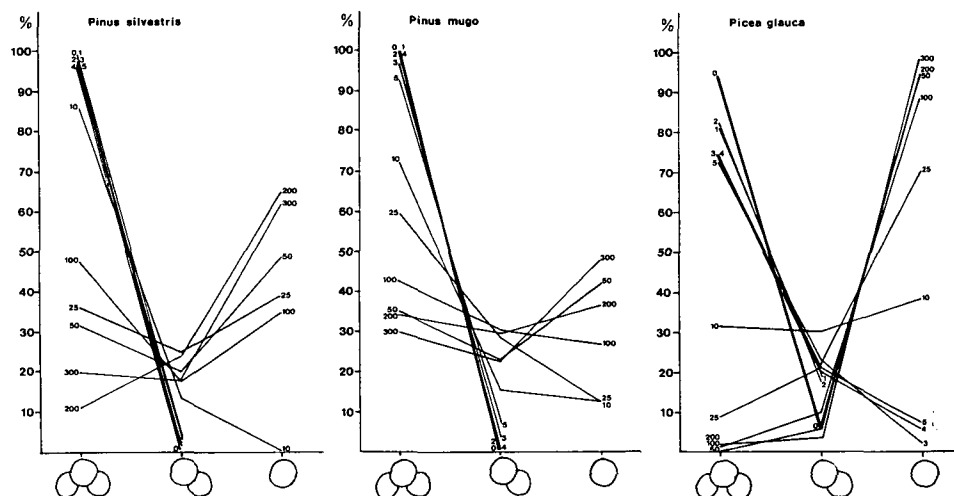
Fresh pollen grain coloured with Toluidin blue. The surface and the optical sections are illustrated, with the most important terms in English, and points of symmetries. Particularly the following publications were used: M. VAN CAMPO (1973), POCKNALL (1981), HANSEN and ENGSTRÖM (1985) and BRADY (1988).



Results

Pinus silvestris L.

(Plate 3.3., figs. 1—51, text-fig. 3.1., 3.2., and 3.3)



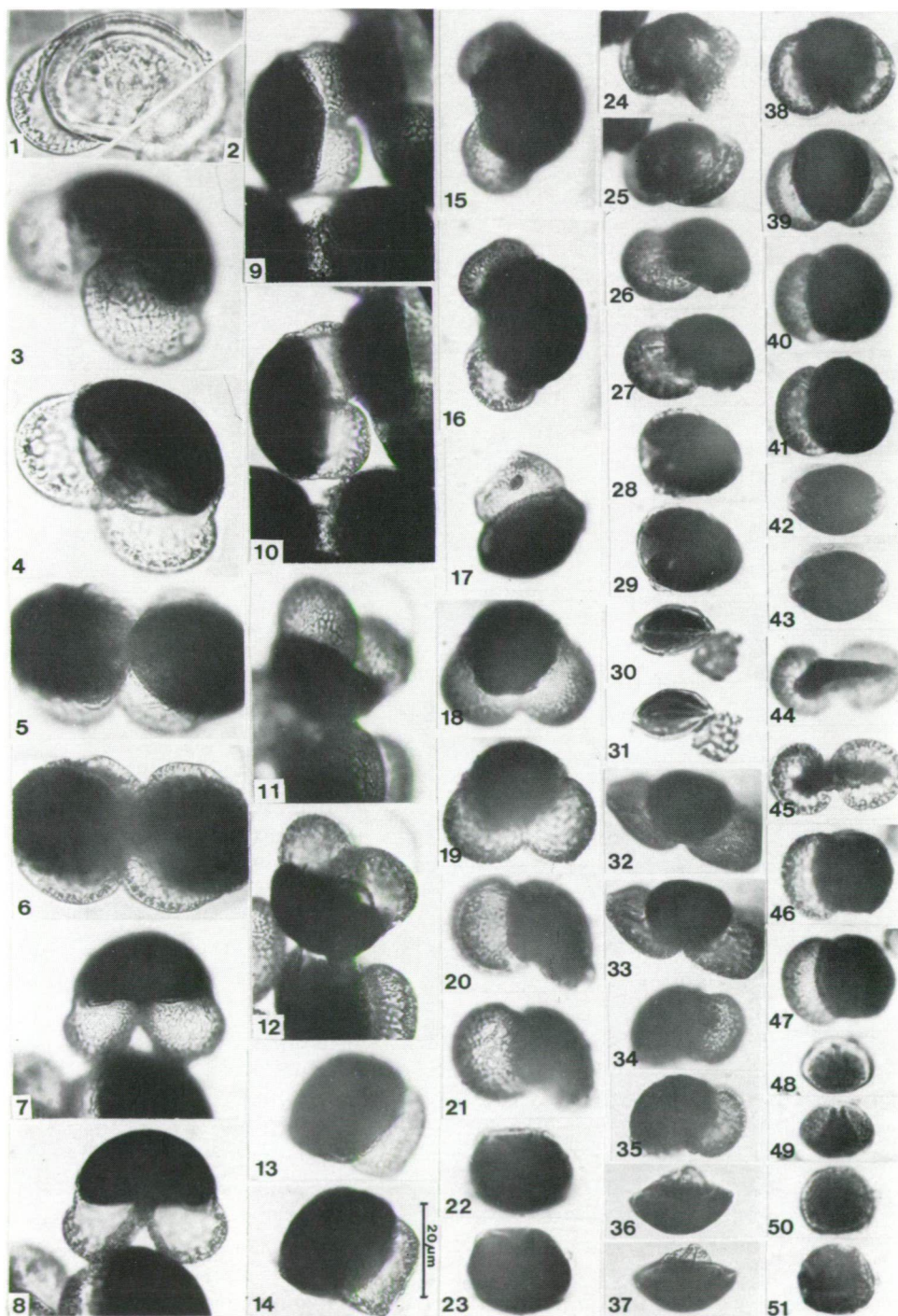
Text-fig. 3.1.

Variation statistical graphs of the saccus degradation of the species investigated, in consequence of high temperature (200 °C). The numbers at the graphs indicate the length of times of heating.

The microphotographs in Plate 3.3 well illustrate the alterations, which appeared in consequence of the high temperature. The pollen grains without saccus can be similar to extremely altered algal cysts (Plate 3.3., fig. 22, 23), or fossil monosulcate form genera, such as *Bennettitaceaeacuminella* MALYAVKINA 1953 (Plate 3.3., fig. 30, 31), or *Gynkgaletes* LYUBER 1955 (Plate 3.5., fig. 42, 43) (cf. POTONIÉ, 1958).

In connection with the saccus degradation the results of the non-experimental and those heated during 1—5 hours are essentially the same. The bisaccate forms are predominant, with very few monosaccate pollen grains. The small differences between the above mentioned experiments are well-regulated. The first important change appears after the heating during 10 hours. Remarkable (more than 10 per cent) is the quantity of the monosaccate forms, and the pollen grains without saccus appear. The graphs representing the degradation process from 25—300 hours show another group, which is characteristically different from the above discussed ones. In general, the quantities of the disaccate forms diminish, and the per cents of the non-saccate pollen grains increase. But it is interesting that these alterations are irregular. The most important “anomaly” can be established at the pollen grains heated during 100 hours.

The alterations in the dimension of the corpus can be summarized as follows (Text-fig. 3.2.).



- 1—51. *Pinus silvestris* L., Recent.
- 1, 2. Pollen grains without staining or heating.
- 3, 4. Experiment No 346, length of time 1 hr.
- 5, 6. Experiment No 347, length of time 2 hrs.
- 7, 8. Experiment No 348, length of time 3 hrs.
- 9, 10. Experiment No 349, length of time 4 hrs.
- 11, 12. Experiment No 350, length of time 5 hrs.
- 13, 14. Experiment No 350, length of time 5 hrs.
- 15, 16. Experiment No 905, length of time 10 hrs.
17. Experiment No 905, length of time 10 hrs.
- 18, 19. Experiment No 907, length of time 25 hrs.
- 20, 21. Experiment No 907, length of time 25 hrs.
- 22, 23. Experiment No 907, length of time 25 hrs.
- 24, 25. Experiment No 910, length of time 50 hrs.
- 26, 27. Experiment No 910, length of time 50 hrs.
- 28, 29. Experiment No 910, length of time 50 hrs.
- 30, 31. Experiment No 910, length of time 50 hrs.
- 32, 33. Experiment No 759, length of time 100 hrs.
- 34, 35. Experiment No 759, length of time 100 hrs.
- 36, 37. Experiment No 759, length of time 100 hrs.
- 38, 39. Experiment No 913, length of time 200 hrs.
- 40, 41. Experiment No 913, length of time 200 hrs.
- 42, 43. Experiment No 913, length of time 200 hrs.
- 44, 45. Experiment No 916, length of time 300 hrs.
- 46, 47. Experiment No 916, length of time 300 hrs.
- 48, 49. Experiment No 916, length of time 300 hrs.
- 50, 51. Experiment No 916, length of time 300 hrs.

Corpus breath

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	40.0	47.5	55.0	15.0 μm
1 ^h	35.0	40.0	50.0	15.0 μm
2 ^h	27.5	37.5	42.5	15.0 μm
3 ^h	32.5	37.5	42.5	10.0 μm
4 ^h	30.0	37.5	45.0	15.0 μm
5 ^h	27.5	35.0	42.5	15.0 μm
10 ^h	27.5	35.0	52.5	25.0 μm
25 ^h	22.5	30.0	37.5	15.0 μm
50 ^h	22.5	27.5	32.5	10.0 μm
100 ^h	22.5	25.0	30.0	7.5 μm
200 ^h	20.0	25.0	30.0	10.5 μm
300 ^h	17.5	22.5	27.5	10.0 μm

Regarding these data, the following can be emphasized.

Similarly to the saccus degradation, two groups of graphs can be distinguished based on the length of times in hours at 200 °C: 1—5 and 25—300. The length of time of heating during 10 hours is also peculiar, particularly the value of the distance of the smallest and largest specimens.

The so-called dislocation of the graphs is nearly at the heating during 25 hours. (The largest pollen grain of the experimental sample is identical or near identical with the smallest specimen of the fresh — non-experimental — material).

Corpus height

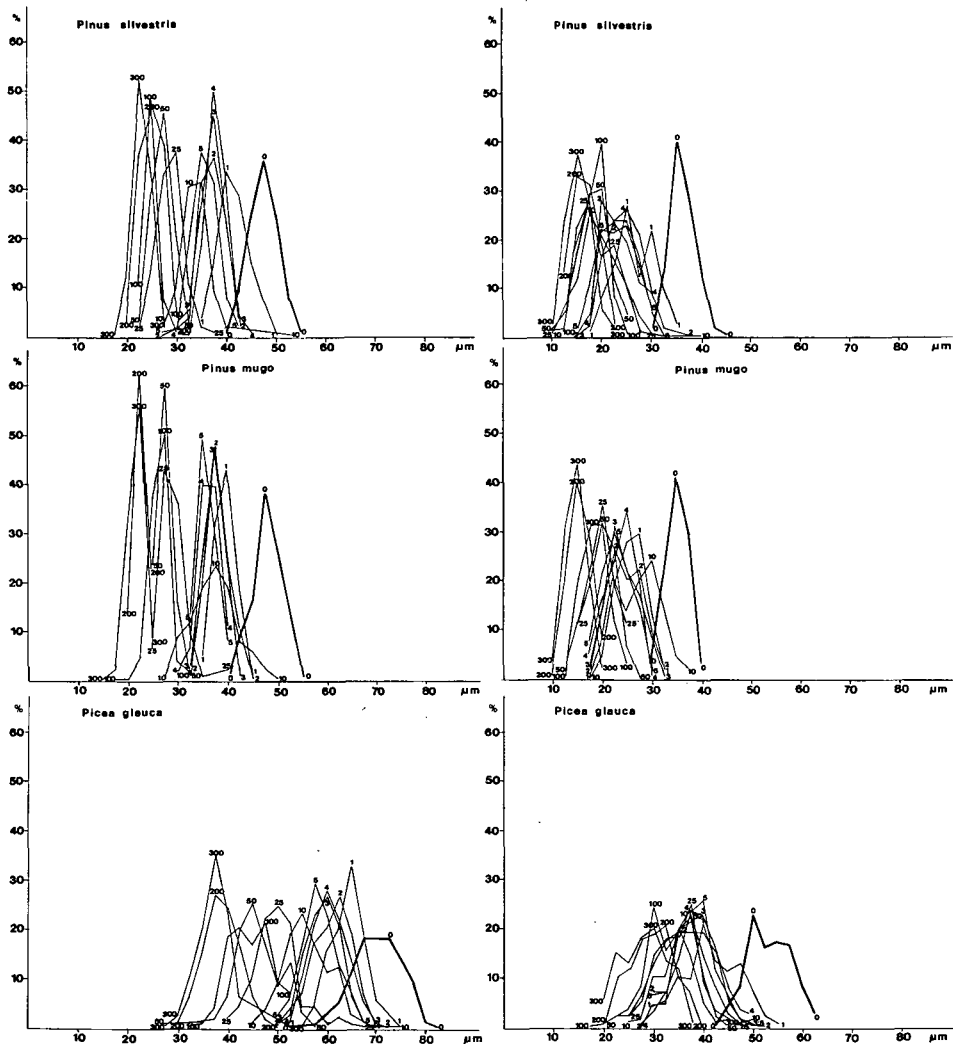
Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	30.0	35.0	45.0	15.0 μm
1 ^h	17.5	25.0	35.0	17.5 μm
2 ^h	15.0	22.5	37.5	22.5 μm
3 ^h	15.0	20.0	32.5	17.5 μm
4 ^h	17.5	25.0	30.0	12.5 μm
5 ^h	15.0	25.0	30.0	15.0 μm
10 ^h	10.0	17.5	37.5	27.5 μm
25 ^h	10.0	17.5	30.0	20.0 μm
50 ^h	10.0	20.0	25.0	15.0 μm
100 ^h	12.5	20.0	25.0	12.5 μm
200 ^h	12.5	15.0	22.5	10.0 μm
300 ^h	10.0	15.0	22.5	12.5 μm

The two groups of the graphs of the experimental material can also be established. But these two groups separate not so well as previously, at the corpus length. There are differences, as follows. The graph of the heating during one hour have two maxima. At the maxima of the graphs, there are some “anomalies” in contrast to the previous. So, the lengths of times of one hour 2 and 4 hours represent one group. The maxima of the further experiments (3, 5, 10, 25, 100, 200, 300) are in another group. There is not so characteristic difference of the experimental data of the pollen grains heated during 200 and 300 hours. As regards the distances in μm between the smallest and the largest specimens, this is in general 12.5—17.5 μm . Extreme values were observed at 2, 10 and 25 hours, in particular at 10 hours.

The dislocation of the non-experimental, and the experimental graph is exactly at 25 hours of heating.

Saccus width

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	22.5	32.5	40.0	17.5 μm
1 ^h	17.5	27.5	35.0	17.5 μm
2 ^h	17.5	25.0	30.0	12.5 μm
3 ^h	17.5	22.5	27.5	10.0 μm
4 ^h	20.0	22.5	30.0	10.0 μm
5 ^h	17.5	25.0	32.5	15.0 μm
10 ^h	17.5	22.5	32.5	15.0 μm
25 ^h	15.0	20.0	30.0	15.0 μm
50 ^h	15.0	20.0	25.0	10.0 μm
100 ^h	15.0	20.0	25.0	10.0 μm
200 ^h	12.5	17.5	22.5	10.0 μm
300 ^h	12.5	17.5	20.0	7.5 μm

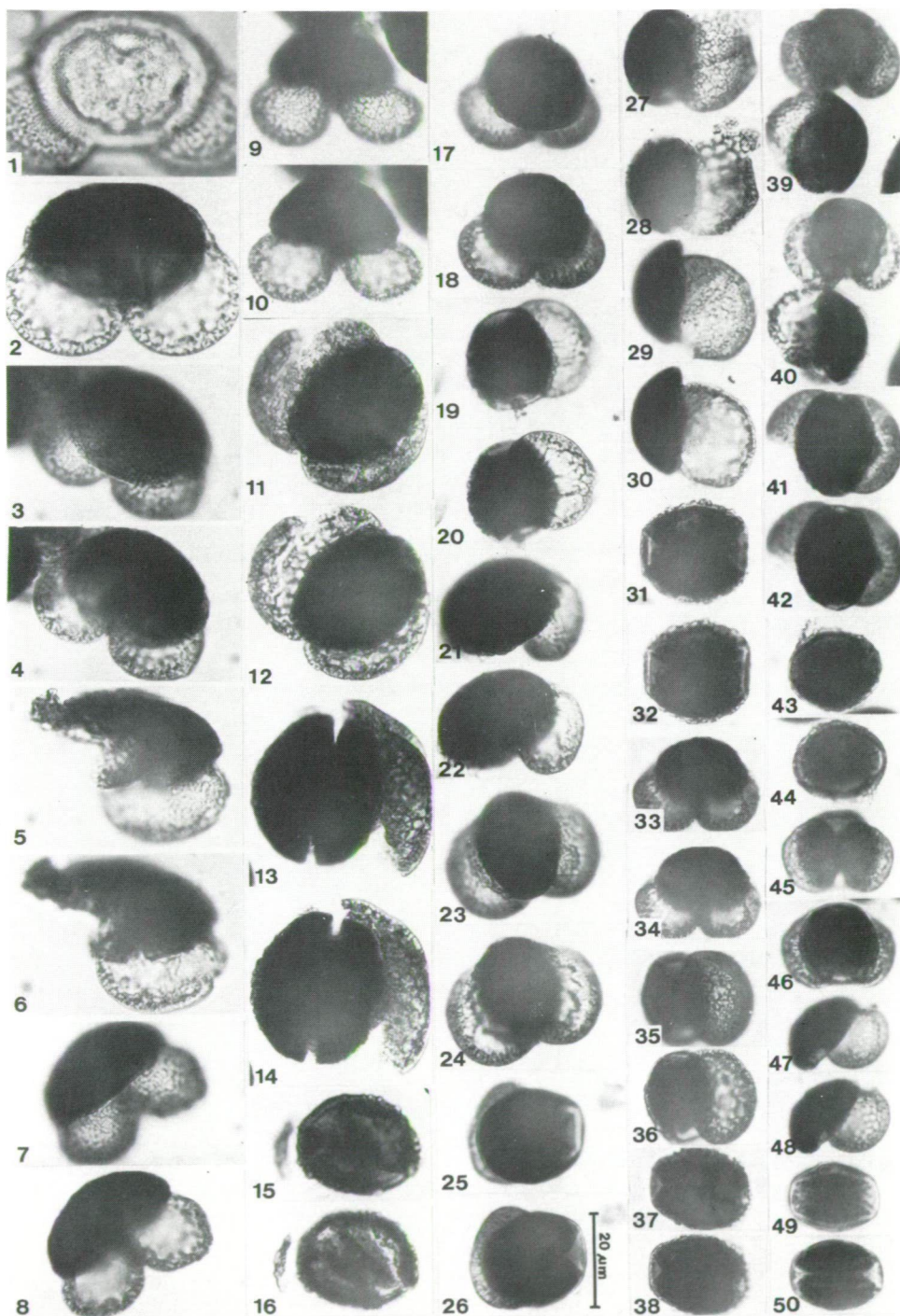


Text-fig. 3.2.

Variation-statistical graphs of the alterations of the corpus breadth and height in consequence of high temperature. The numbers at the graphs indicate the length of times of heating at 200 °C.

The graphs of the widths of the saccus after experiment are in one group only, in contrast to the corpus. The non-experimental graph is slightly separated from the others. There is an approximately gradual alteration, which is not completely regular. Pairs worth of mentioning can be established in the maxima of the graphs of experiments 50 and 100 hours, respectively 200 and 300 hours.

The dislocation of the non-experimental and experimental graph is exactly at 200 hours of heating.



◀ Plate 3.4.

- 1—50. *Pinus mugo* TURRA, Recent.
1. Pollen grains without staining or heating.
 2. Experiment No 366, length of time 1 hr.
 - 3, 4. Experiment No 367, length of time 2 hrs.
 - 5, 6. Experiment No 368, length of time 3 hrs.
 - 7, 8. Experiment No 369, length of time 4 hrs.
 - 9, 10. Experiment No 370, length of time 5 hrs.
 - 11, 12. Experiment No 445, length of time 10 hrs.
 - 13, 14. Experiment No 445, length of time 10 hrs.
 - 15, 16. Experiment No 445, length of time 10 hrs.
 - 17, 18. Experiment No 908, length of time 25 hrs.
 - 19, 20. Experiment No 908, length of time 25 hrs.
 - 21, 22. Experiment No 908, length of time 25 hrs.
 - 23, 24. Experiment No 911, length of time 50 hrs.
 - 25, 26. Experiment No 911, length of time 50 hrs.
 - 27, 28. Experiment No 911, length of time 50 hrs.
 - 29, 30. Experiment No 911, length of time 50 hrs.
 - 31, 32. Experiment No 911, length of time 50 hrs.
 - 33, 34. Experiment No 760, length of time 100 hrs.
 - 35, 36. Experiment No 760, length of time 100 hrs.
 - 37, 38. Experiment No 760, length of time 100 hrs.
 - 39, 40. Experiment No 914, length of time 200 hrs.
 - 41, 42. Experiment No 914, length of time 200 hrs.
 - 43, 44. Experiment No 914, length of time 200 hrs.
 - 45, 46. Experiment No 917, length of time 300 hrs.
 - 47, 48. Experiment No 917, length of time 300 hrs.
 - 49, 50. Experiment No 917, length of time 300 hrs.

The distance between the maximum and minimum values vary from 17.5 μm until 7.5 μm . A not completely regular decreasing may be established at these values. Extremely sudden values have not been observed.

Saccus height

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	15.0	22.5	30.0	15.0 μm
1 ^h	10.0	15.0	27.5	17.5 μm
2 ^h	10.0	12.5	20.0	10.0 μm
3 ^h	7.5	12.5	17.5	10.0 μm
4 ^h	10.0	12.5	17.5	7.5 μm
5 ^h	7.5	12.5	27.5	20.0 μm
10 ^h	10.0	15.0	22.5	12.5 μm
25 ^h	7.5	12.5	20.0	12.5 μm
50 ^h	7.5	12.5	20.0	12.5 μm
100 ^h	7.5	10.0	17.5	10.0 μm
200 ^h	7.5	10.0	15.0	7.5 μm
300 ^h	7.5	10.0	15.0	7.5 μm

All experimental variation-statistical graphs represent one group. This separates quite well from the non-experimental one. Taking into consideration the fine details, the following can be pointed out. The maxima of the experiments of one hour and 10 hours are at the same value. The maxima of 25, 5, 2, 3, 50 and 4 hours represent another group. Finally the maxima of the heated pollen grains during 100, 300 and 200 hours, represent another group. The irregular decreasing in the height of the saccus is extremely expressive.

Similarly to the saccus width, the dislocation of the non-experimental, and experimental graphs is exactly at heating during 200 hours.

The distances between the maximum and minimum values vary from 20.0—7.5 μm . As extreme value, the 20.0 μm can be pointed out at 5 hours of heating.

Pinus mugo TURRA

(Plate 3.2., and 3.4., figs. 1—50, text-fig. 3.1., 3.2., and 3.3)

The morphological alterations in consequence of the high temperature are well shown in the microphotographs of Plate 3.4. As regards the furrows, pictures 13 and 14 can be pointed out. The early non-saccate type of gymnosperm pollen which appeared secondarily is illustrated in Plate 3.4., fig. 49, 50.

The saccus degradation process (Text-fig. 3.1.) is similar to the previous species, *Pinus silvestris* L. The non-experimental and the heated pollen grains during one hour 2, 3, 4 and 5 hours are very similar. Most of the pollen grains are bisaccate very few pollen grains with one saccus in consequence of the degradation. At this species also as first important change at heating during 10 hours can be established. Important is the appearance of the saccus lost forms. The increase of the quantity of the non-saccate forms is near regular, except the experiment of 50 hours.

The results of the measurements are the following (Text-fig. 3.2.).

Corpus breath

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	40.0	47.5	55.0	15.0 μm
1 ^h	35.0	40.0	45.0	10.0 μm
2 ^h	32.5	37.5	45.0	12.5 μm
3 ^h	32.5	37.5	42.5	10.0 μm
4 ^h	30.0	35.0	40.0	10.0 μm
5 ^h	32.5	35.0	40.0	7.5 μm
10 ^h	27.5	37.5	50.0	22.5 μm
25 ^h	25.0	27.5	40.0	15.0 μm
50 ^h	25.0	27.5	32.5	7.5 μm
100 ^h	17.5	27.5	32.5	15.0 μm
200 ^h	20.0	22.5	25.0	5.0 μm
300 ^h	15.0	22.5	25.0	10.0 μm

Three groups of graphs of the experimental material can be established. There is a remarkable difference between the graph of the non-experimental and those heated during one hour. The alterations until five hours of heating are more or less regular. The graph of the experiment during 10 hours is inside this group, but its character is completely different. The maximum is low, but its value is at the experiment of 3 hours. The heated pollen grains during 25, 50 and 100 hours have maxima at the same value, but the alteration is irregular. The variation-statistical graphs of experiments of 200 and 300 hours are near the same.

The dislocation of the non-experimental, and the experimental graph is exactly at 25 hours of heating.

The distances in μm between the maximum and minimum values vary from 22.5 μm until 5.0 μm . Extreme is at heating during 10 hours (22.5 μm) and at 200 hours (5.0 μm).

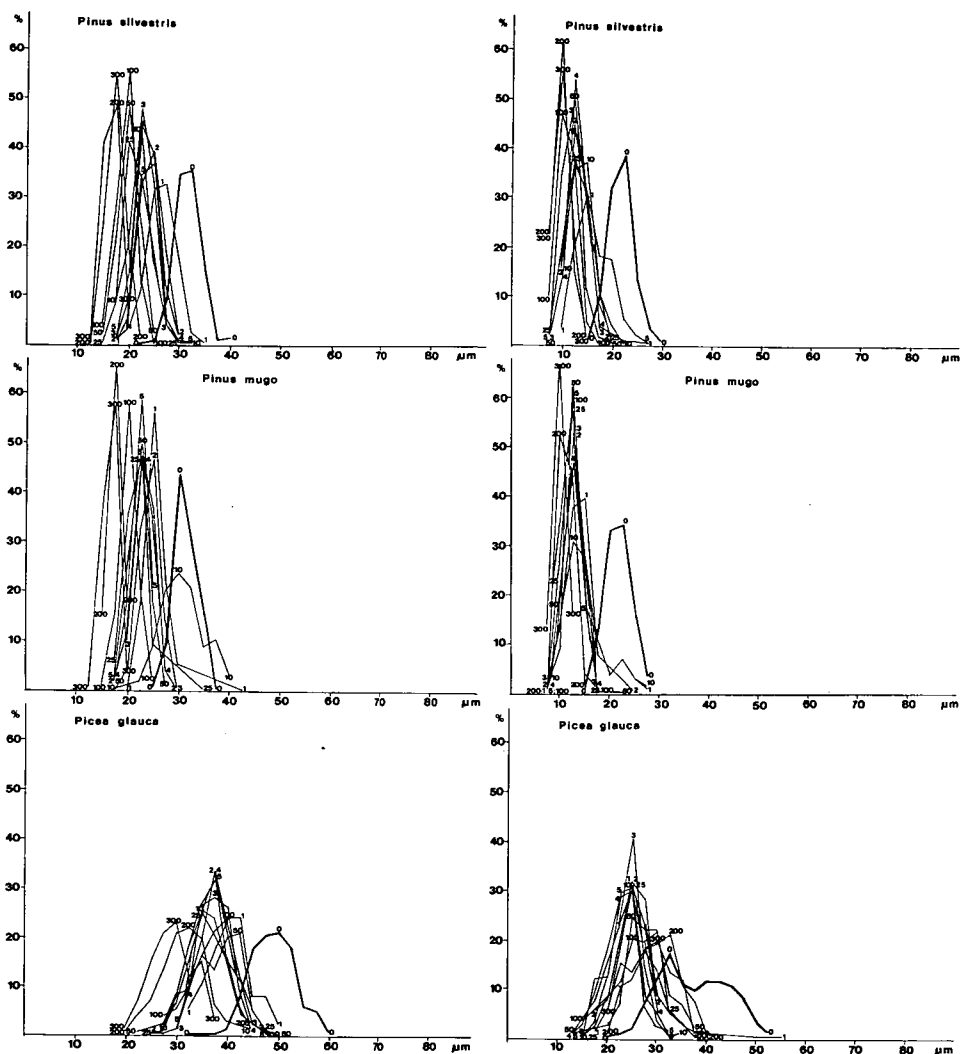
Corpus height

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	30.0	35.0	40.0	10.0 μm
1 ^h	17.5	27.5	32.5	15.0 μm
2 ^h	17.5	22.5	32.5	15.0 μm
3 ^h	17.5	22.5	32.5	15.0 μm
4 ^h	17.5	25.0	30.0	12.5 μm
5 ^h	17.5	22.5	30.0	12.5 μm
10 ^h	17.5	30.0	37.5	20.0 μm
25 ^h	15.0	20.0	25.0	10.0 μm
50 ^h	12.5	20.0	27.5	15.0 μm
100 ^h	12.5	17.5	25.0	12.5 μm
200 ^h	10.0	15.0	20.0	10.0 μm
300 ^h	10.0	15.0	20.0	10.0 μm

The variation-statistical graphs are separated not so characteristically as at the corpus breath. The experiments of heating during 1—5 hours represent more or less one units, but the alterations are not regular. In this respect the heated pollen grains during 10 hours are also irregular. The values of heating at 25, 50 and 100 hours are very similar. The experiments during 200 and 300 hours are practically identical.

The dislocation of the non-experimental and experimental graphs is interesting. It is at about 20 hours. But the largest size of the experiments during 4 and 5 hours (30 μm) is the same at the smallest specimen of the non-experimental pollen grain.

The distances in μm between the maximum and minimum values vary from 20.0 μm until 10.0 μm . There is one extreme value, at 10 hours of heating.



Text-fig. 3.3.

Variation-statistical graphs of the alterations of the saccus width and height in consequence of high temperature. The numbers at the graphs indicate the length of times of heating at 200 °C.

Saccus width

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	25.0	30.0	37.5	12.5 μm
1 ^h	20.0	25.0	42.5	22.5 μm

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
2 ^h	17.5	25.0	30.0	12.5 μm
3 ^h	20.0	22.5	30.0	10.0 μm
4 ^h	17.5	22.5	27.5	10.0 μm
5 ^h	17.5	22.5	25.0	7.5 μm
10 ^h	17.5	30.0	40.0	22.5 μm
25 ^h	17.5	22.5	35.0	17.5 μm
50 ^h	17.5	22.5	27.5	10.0 μm
100 ^h	15.0	20.0	25.0	10.0 μm
200 ^h	15.0	17.5	20.0	5.0 μm
300 ^h	12.5	17.5	20.0	7.5 μm

The variation-statistical graphs are nearly in one group. A particular exception is the experiment during 10 hours. Its maximum is at the value of the non-experimental. The maximum of experiments of 1–25 hours (except the above mentioned experiment during 10 hours) are nearly in one group. The maximum of the experiment during 100 hours is a little "isolated", but the variation-statistical graphs of the saccus width of the pollen grains heated during 200 and 300 hours are approximately identical.

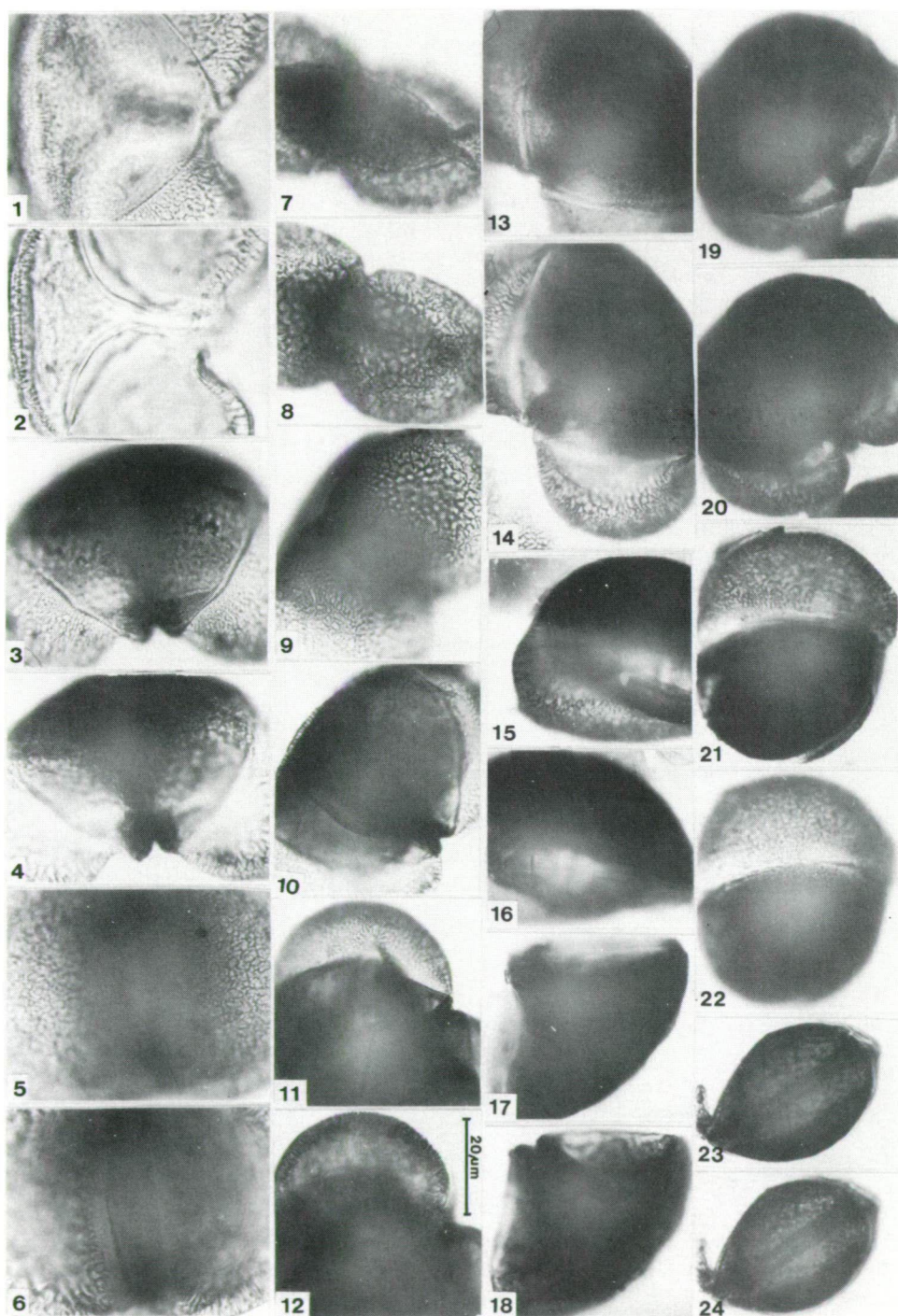
The dislocation of the non-experimental, and the experimental graphs are exactly at 25 hours of heating.

The distance in μm between the maximum and minimum values vary from 22.5 μm until 5.0 μm . Extreme values are at heating during one and 10 hours (22.5 μm) respectively at the experiment of 200 hours (5.0 μm).

Saccus height

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	15.0	22.5	27.5	12.5 μm
1 ^h	7.5	15.0	27.5	20.0 μm
2 ^h	7.5	12.5	17.5	10.0 μm
3 ^h	7.5	12.5	17.5	10.0 μm
4 ^h	7.5	12.5	17.5	10.0 μm
5 ^h	7.5	12.5	15.0	7.5 μm
10 ^h	7.5	12.5	27.5	20.0 μm
25 ^h	10.0	12.5	17.5	7.5 μm
50 ^h	10.0	12.5	22.5	12.5 μm
100 ^h	7.5	12.5	17.5	10.0 μm
200 ^h	7.5	10.0	15.0	7.5 μm
300 ^h	7.5	10.0	12.5	5.0 μm

The variation-statistical graphs of the experimental pollen grains are in a relatively narrow group. Experiments during one hour 2, 3 and 5 hours have regularly altered graphs. Materials heated for 4, 10, 25, 100 and 50 hours are irregular. The isolation of the variation-statistical graph of the experiment during 10



hours is inside the above mentioned group. Worth of mentioning is that the maximum size of the non-experimental and heated during one hour and 10 hours are at the same value. The maxima of experiments during 200 and 300 hours are at the same value, but the per cents are quite different in contrast to the previous.

The dislocation of the non-experimental, and experimental material is interesting. Really it is at heating during 200 hours, but this value appears also at the experiment during 5 hours.

The distances in μm between the maximum and minimum values vary between 20.0 μm and 5.0 μm . As extreme value the experiment during one hour and 10 hours may be pointed out.

Picea glauca (MOENCH.) VOSS.

(Plate 3.5., figs. 1—24, plate 3.6., figs. 1—27, text-fig. 3.1., 3.2., and 3.3)

The morphological alterations, which appeared in consequence of the high temperature, are illustrated in two plates (Plate 3.5., and 3.6.). The apertural area is very characteristic, e.g.: Plate 3.5., fig. 3,4, plate 3.6., fig. 1,2, 11, 12, 22, 23. The degradation processes of the sacchi are illustrated. The non-saccate forms may be triangular (Plate 3.6., fig. 11, 12), or nearly isodiametric (Plate 3.6., fig. 7,8). The "secondary monosulcate" form is not so characteristic as at the species of *Pinus*.

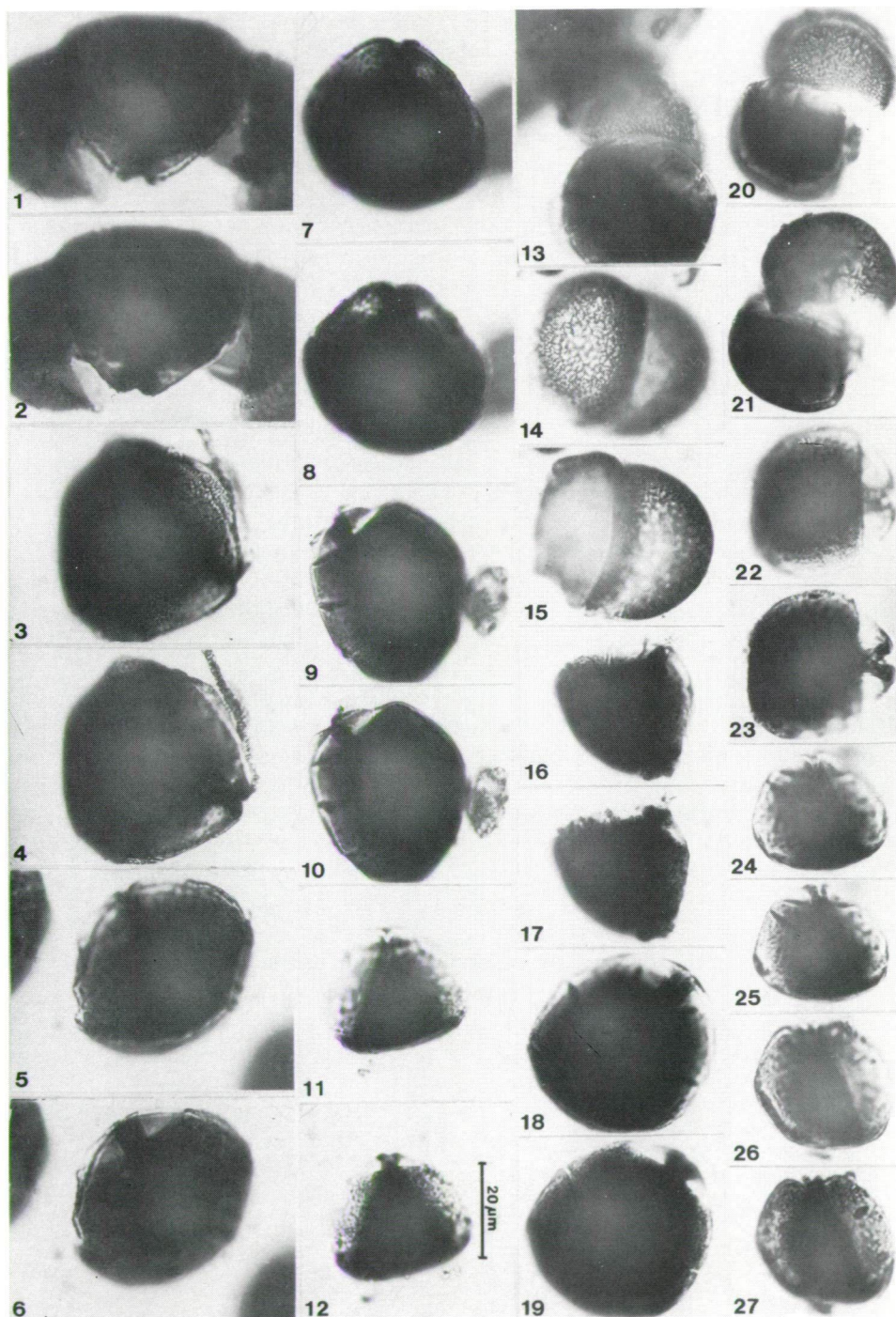
The quantitative data about the saccus degradation may be summarized in the following (Text-fig. 3.1.).

After one hour of heating, a remarkable decrease can be established at the bisaccate forms. But the heating during two hours does not resulted in important alterations in contrast to the experiment of one hour. The graphs of experiments during 3,4, and 5 hours represent another group. Important alterations are in contrast to the previous, namely the non-saccate forms appeared. The increasing of the per cents of the pollen grains without saccus is regular. Particularly peculiar is the variation-statistical graph of the experiment of 10 hours. Heating during 25, 100, 50, 200 and 300 hours resulted gradually saccus lost pollen grains. This alteration is nearly regular.

The results of the measurements can be summarized as follows.

◀ Plate 3.5.

- 1—24. *Picea glauca* (MOENCH.) VOSS., Recent.
- 1, 2. Pollen grains without staining or heating.
- 3, 4. Experiment No 351, length of time 1 hr.
- 5, 6. Experiment No 351, length of time 1 hr.
- 7, 8. Experiment No 352, length of time 2 hrs.
- 9, 10. Experiment No 352, length of time 2 hrs.
- 11, 12. Experiment No 353, length of time 3 hrs.
- 13, 14. Experiment No 354, length of time 4 hrs.
- 15, 16. Experiment No 354, length of time 4 hrs.
- 17, 18. Experiment No 354, length of time 4 hrs.
- 19, 20. Experiment No 355, length of time 5 hrs.
- 21, 22. Experiment No 355, length of time 5 hrs.
- 23, 24. Experiment No 355, length of time 5 hrs.



◀ Plate 3.6.

- 1—27. *Picea glauca* (MOENCH.) VOSS., Recent.
 1, 2. Experiment No 906, length of time 10 hrs.
 3, 4. Experiment No 906, length of time 10 hrs.
 5, 6. Experiment No 906, length of time 10 hrs.
 7, 8. Experiment No 909, length of time 25 hrs.
 9, 10. Experiment No 909, length of time 25 hrs.
 11, 12. Experiment No 909, length of time 25 hrs.
 13. Experiment No 912, length of time 50 hrs.
 14, 15. Experiment No 912, length of time 50 hrs.
 16, 17. Experiment No 912, length of time 50 hrs.
 18, 19. Experiment No 758, length of time 100 hrs.
 20, 21. Experiment No 758, length of time 100 hrs.
 22, 23. Experiment No 915, length of time 200 hrs.
 24, 25. Experiment No 918, length of time 300 hrs.
 26, 27. Experiment No 918, length of time 300 hrs.

Corpus breath

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	52.5	62.5/72.5	82.5	30.0 μm
1 ^h	52.5	65.0	75.0	22.5 μm
2 ^h	50.0	62.5	72.5	22.5 μm
3 ^h	50.0	60.0	70.0	20.0 μm
4 ^h	52.5	60.0	70.0	17.5 μm
5 ^h	50.0	57.5	67.5	17.5 μm
10 ^h	45.0	55.0	75.0	30.0 μm
25 ^h	40.0	50.0	67.5	27.5 μm
50 ^h	27.5	45.0	57.5	30.0 μm
100 ^h	32.5	47.5	52.5	20.0 μm
200 ^h	30.0	37.5	50.0	20.0 μm
300 ^h	30.0	37.5	52.5	22.5 μm

The variation-statistical graphs of the heated pollen grains well represent the decrease in size of the corpus. The alterations are regular until 25 hours of heating. The graph of the experiment during 100 hours is irregular, with two maxima. The highest points of the experiments during 200 and 300 hours are at the same value. But the two graphs are quite different.

The dislocation of the non-experimental, and experimental graphs is at heating during 100 hours. This value appears newly at the experiment during 300 hours.

The distances between the maximum and minimum values vary from 30.0—17.5 μm .

Corpus height

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	42.5	50.0	62.5	20.0 μm
1 ^h	30.0	40.0	55.0	25.0 μm
2 ^h	30.0	35.0/40.0	52.5	22.5 μm
3 ^h	27.5	40.0	50.0	22.5 μm
4 ^h	27.5	37.5	50.0	22.5 μm
5 ^h	30.0	40.0	50.0	20.0 μm
10 ^h	25.0	37.5	50.0	25.0 μm
25 ^h	25.0	37.5	47.5	22.5 μm
50 ^h	20.0	37.5	45.0	25.0 μm
100 ^h	17.5	30.0	45.0	27.5 μm
200 ^h	20.0	32.5	40.0	20.0 μm
300 ^h	20.0	30.0	37.5	17.5 μm

The variation-statistical graphs of the experimental pollen grains represent two groups. These are not characteristically separated. The sizes of the pollen grains heated during one hour, 2, 3, 4, 5, 10, 25 and 50 hours are similar to each other. In this case, the variation-statistical graphs of the pollen grains heated during 100, 200 and 300 hours are also similar.

The dislocation of the non-experimental, and the experimental graphs is between heating during 100 and 200 hours.

The distances between the maximum and minimum values vary from 27.5 μm , until 17.5 μm , mostly 20.0 μm and 22.5 μm . As extreme value the heating during 100 hours may be pointed out (27.5 μm).

Saccus width

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	32.5	50.0	60.0	27.5 μm
1 ^h	32.5	40.0/42.5	50.0	17.5 μm
2 ^h	25.0	37.5	47.5	22.5 μm
3 ^h	30.0	37.5	45.0	15.0 μm
4 ^h	32.5	37.5	45.0	12.5 μm
5 ^h	30.0	37.5	47.5	17.5 μm
10 ^h	27.5	35.0	45.0	17.5 μm
25 ^h	25.0	35.0	47.5	22.5 μm
50 ^h	22.5	42.5	50.0	27.5 μm
100 ^h	27.5	40.0	47.5	20.0 μm
200 ^h	20.0	32.5	45.0	25.0 μm
300 ^h	20.0	30.0	37.5	17.5 μm

The variation-statistical graphs are very interesting. Heating during one hour, 50 and 100 hours represents the first group. The maximum values of the experiments

during 2, 4 and 5 hours are practically the same, but the graph of 3 hours is also in this region. The maxima of the variation-statistical graph of heating during 10 and 25 hours are opposite to those of the one and 100 hours. Heating during 200 and 300 hours resulted in similar, but not identical, graphs.

The dislocation of the non-experimental, and the experimental graphs has not happened after 300 hours of heating.

The distances between maximum and minimum values vary from 27.5 μm until 12.5 μm . This latter mentioned, extreme value is at 4 hours of heating.

Saccus height

Length of time of heating	Smallest	Sizes dominant in quantity	Largest	Distance between smallest and largest specimens
0 ^h	20.0	32.5	52.5	32.5 μm
1 ^h	17.5	25.0	55.0	37.5 μm
2 ^h	17.5	25.0	30.0	12.5 μm
3 ^h	15.0	25.0	32.5	17.5 μm
4 ^h	12.5	25.0	30.0	17.5 μm
5 ^h	12.5	25.0	32.5	20.0 μm
10 ^h	15.0	25.0	35.0	20.0 μm
25 ^h	15.0	25.0	32.5	17.5 μm
50 ^h	12.5	25.0	37.5	25.0 μm
100 ^h	15.0	30.0	37.5	22.5 μm
200 ^h	20.0	32.5	40.0	20.0 μm
300 ^h	20.0	30.0	37.5	17.5 μm

The variation-statistical graphs are in every respect irregular. The experiments of one hour 2, 3, 5, 10 and 25 hours are in the same group. The graph of heating during 3 hours is different.

The maximum of the graph of 200 hours is at the same value, as the non-experimental. The maximum of heating during 300 hours is also not so far from the above mentioned ones.

Similarly to the saccus width, the dislocation of the non-experimental, and the experimental graphs has not happened.

The distance between the maximum and minimum values vary from 37.5 μm until 12.5 μm .

Discussion and Conclusions

The degradation process of the saccus is interesting and irregular, as it was described previously. There are some peculiar lengths of time of heating, as it was described previously. Probably as an important fact, the appearance of the saccus lost forms can be pointed out. These as extremely altered secondary forms are very important in the determination of the fossil forms, particularly in the more or less metamorphic layers. This problem was discussed in our several earlier papers, new data can be summarized as follows.

- i. The extremely altered bisaccate pollen grains may be similar to altered algal cysts.
- ii. These above mentioned forms may also be similar to the thermal altered forms of the genus *Equisetum*.
- iii. It is interesting that the so-called monosulcate forms similar to the early Mesozoic gymnosperms (cf. *Bennettitaceaeacuminella* MALYAVKINA 1953, *Gynkgaletes* LYUBER 1955) appear, probably indicating the ancestors of the earliest — Paleozoic — stage of evolution. Worth of mentioning is that these forms are mostly characteristic to the pollen grains of the genus *Pinus*, but occurred sporadically among the altered pollen grains of *Picea glauca* too.
- iv. In general the apertural area developed more characteristically after several heating. It may be presumed that some altered forms can be determined as extremely early angiosperm pollen grain, in the fossil palynological associations.
- v. The appearance of the triangular forms firstly at the pollen grains of *Picea glauca* indicates also angiosperm-like forms.

Concerning the quantitative data the following can be pointed out:

- i. There are also irregularities in the dimensional alterations of the corpus and the saccus.
- ii. The variation-statistical graphs may be arranged into groups, these also can be regular or irregular.
- iii. The dislocation point (length of time of heating) of the variation-statistical graphs are as follows.

	Corpus		Saccus	
	breath	height	width	height
<i>Pinus</i>				
<i> silvestris</i>	25 ^h	25 ^h	200 ^h	200 ^h
<i>Pinus mugo</i>	25 ^h	about 20 ^h	100 ^h	200 ^h
<i>Picea glauca</i>	100—(300) ^h	100—200 ^h	0 ^h	0 ^h

The results of the saccus at *Picea glauca* are unusual and interesting.

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