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Geological Survey of Denmark . Yearbook 1980

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Contents

Indhold

Pollen morphological definitions and types

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Preface

The present article is a translation of Johs. Iversen and J. Troels-Smith: *Pollenmorphologische Definitionen und Typen,* whcih originally appeared both in a Danish and a German version. The Plates I-XVI are reproduced without changes; hence it was necessary to retain the Danish sign "÷" to indicate a minus, although this has a different meaning in English. The English text was read critically by Dr. M. Tooley, University of Durham, and by Dr. J. Troels-Smith and Mr. B. Brorson Christensen, The Danish National Museum, and was revised with reference to the Danish version, *Pollenmorfologiske definitioner og typer,* by Olivia C. Collin, The Geological Survey of Denmark.

Foreword

When research on pollen analysis began a generation ago, the structure of the pollen exine had already been explained in principle in the classic works of v. Mohl, Fritzche and Fischer. The rise of pollen analysis brought no new interest in questions of pollen morphology. Quite naturally, the first task of the new research became that of gaining an overall view of the most important episodes of post-glacial forest development. It was therefore at first sufficient to count the pollen of the most important genera of trees, which are – with certain exceptions – easily identifiable.

Today, the situation is different. The first aim of pollen statistical research has been achieved; the main features of forest development in northern

Europe have been traced. In order to progress, we must now take into account the pollen of other plants. This does not merely apply to vegetation study of epochs which had very little forest: even the problems of forest development themselves can be thoroughly illuminated only by an examination of pollen flora as a whole. Frequently, the pollen curves of herbaceous plants show evidence of important ecological connections, and thus become the key to a causal understanding of characteristic phases in forest development.

Naturally, any further progress in this field presupposes absolutely accurate pollen determinations. It can hardly be disputed that earlier standards in this respect were in general too low. The fact that *Salix* and *Artemisia* pollen were at one time confused with one another shows that research was content with a rather superficial examination of the form of the pollen grain in such cases. For reliable classification of pollen grains whose form is not especially characteristic, an accurate observation of the structural composition of the pollen exine is a *sine qua non.* Experience has shown that this creates considerable difficulties for the beginner, and that no one attains the necessary sharpness of eye without taking time to study the various pollen structures very thoroughly.

The beginner's best tactic is to work out precise descriptions of pollen grains. This forces one to observe accurately, and the eye becomes practised in grasping, quickly, all the essential traits. Even for the more advanced observer, descriptions of fossil pollen grains are a prerequisite for subsequent classification or for the documentation of classifications. Reports on finds of important or abstruse fossil pollen types are worthless without descriptions, drawings or photographs.

In our laboratories at the Danish Geological Survey and at the Danish National Museum, we have been working for a number of years on diagnoses of recent and fossil pollen types, both Quaternary and pre-Quaternary. Our terminology has evolved during the work, and was initially intended for use only in our laboratories. There are two reasons for the publication of these terms here: in the first place, the present work can be viewed as an introduction to an on-going series of communications on important pollen finds in post-glacial, late-glacial and Tertiary deposits, documented by diagnoses and photomicrographs; in the second place, it is the basis of the chapters on morphology and of the keys to classification in a book now in the press by Knut Faegri and Johs. Iversen[1].

In Section A, the pollen morphological definitions are discussed. This section is especially elaborate since we regarded it as important to cite all the possibilities that are included in a given concept, in order to make clear where to place divisions in practice. Section B on pollen morphological measurements is also very detailed. This is not because we consider that size characteristics in general have great significance: on the contrary, these data are the last to which one should resort. But if one is to take measurements (and in certain cases this is necessary in order to distinguish between closely-related forms), then one must know exactly what one is measuring and how; otherwise one is groping in the dark[2]. This pollen typology makes no claim to represent a natural classification: it is entirely artificial, and its aim is the practical one of of making classification easier[3]. Clarity and simplicity were for us the essentials.

In our choice of terminology we have, in order to avoid misunderstanding, as far as possible avoided terms used by other authors in a sense different from ours. We may also refer readers to the works of Wodehouse, Potonié and Erdtman, which we have used extensively. Over the years, we have discussed the whole extent of the present work with our friend and colleague, Professor Dr. Knut Faegri, Bergen, and we owe many improvements to him. Conservator B. Brorson Christensen has been so kind as to prepare illustrations for all the concepts and types, thereby making them more readily accessible to others. Lektor A. Kragelund has advised us on matters of Latin terminology.

Johs. Iversen J. Troels-Smith

Section A. Pollen morphological definitions

The following conventions are used in the abbreviations:

1. No hyphen is used when an entity is being considered; for example, in pollen morphological types: C_3P_3=Tricolporate.
2. A comma denotes that the abbreviation following the comma gives a more specific definition; for example, a part of a pore: P,op = operculum of a pore.
3. Parentheses are used when additional information is given elucidating the subject; for example, P(op) = pore with an operculum.
4. Hyphens precede an indication of dimensions; for example, P-M = the diameter of a pore. It can also be used for the indication of distance; for example, (P,1-P,1)-M, see page 15.

1. Orientation of the pollen grain

pol,ax = *axis poli* = polar axis: axis of symmetry in radio-symmetrical pollen grains. If more than one axis of symmetry occurs, only that which runs through the centre of the pollen tetrad during the formation of the pollen grain is designated a polar axis. In such cases, the polar axis can be recognised only in pollen grains which occur in tetrads.

Po = *polus* = pole: point of intersection of the polar axis with the surface of the pollen grain.

aeq = *aequator* = equator: line of intersection between the surface of a pollen grain and a plane which passes through the centre of the polar axis and is perpendicular to it.

2. Colpi (Plate I)

C = *colpus:* an area which forms or surrounds the normal point of emergence of the pollen tube, and whose arbitrary length-breadth ratio is grater than 2. In relation to the surrounding exine, the colpus is designated in one of three ways:

C(ex = 0): by the absence of the exine
(for example, in consequence of the loss of an operculum);

C(mb): by thinning of the exine;

C(mb, ekt = 0): ektexine elements missing;

C(mb, ekt): ektexine elements present;

C(op): by the delimitation of a section of normal exine by a furrow or seam.

C,1 = *limes colpi* = edge of colpus: demarcation line of the colpus; *i.e.,* either the furrow or seam mentioned above – or, with a thinned or absent exine, the external limit of the lighter area thus caused.

C,ap = *apex colpi* = apex of the colpus.

C,mb = *membrana colpi* = membrane of the colpus: the thinned exine of a colpus.

C,op = *operculum colpi* = the thicker part of a colpus situated within a furrow or seam. The structure of the operculum is similar in nature to that of the remaining exine of the pollen grain.

C,med = *medianum colpi* the median of the colpus: a line which divides a colpus into two approximately symmetrical halves. A distinction is made between:

C,med,+ = *medianum colpi longitudinalis:*
the longitudinal median of the colpus;

C,med,÷ = *medianum colpi transversalis:*
the transverse median of the colpus.

C,cent = *centrum colpi* = the intersecting point of the medians.

mg = *margo:* an area which surrounds a colpus like a belt and which is distinguished from the remaining exine of the pollen grain by deviations in the ektexine.

mg,l = *limes marginis* = edge of margo: external limit of the margo.

mg,ap = *apex marginis* = apex of the margo.

cost C = *costae colpi* = ridges of thickened endexine along a colpus.

tr C = *colpus transversalis* = transversal colpus: a colpus which intersects another colpus at a near right angle, and which is connected to the endexine.

cost tr = *costae transversales:* ridges of thickened endexine along the transversal colpus.

cost aeq = *costae aequatoriales:* two parallel encircling ridges of thickened endexine which occur on either side of the equator, such that the intervening space gives the impression of an equatorial colpus.

pseudo C = *pseudocolpus* : differs from a colpus in that it does not normally function as the point of emergence of the pollen tube. *Cf.*, pseudospore.

3. Pores (Plate I)

P = *porus* = pore: area which serves as normal point of emergence of the pollen tube and whose arbitrary length-breadth ratio is less than 2. The relation of the pore to the surrounding exine is designated in one of three ways:

P(ex = 0) = *diaporus* = open pore: when the exine is missing (for example, if the operculum has been lost);

P(mb): by thinning of the exine;

P(mb,ekt = 0): ektexine elements missing;

P(mb,ekt): ektexine elements present;

P(op): by the delimitation of a piece of normal exine by a furrow or seam.

P,1 = *limes pori* = edge of pore: line demarcating the pore, *i.e.,* either the furrow or seam, or – with a thinned or missing exine – the outer limit of the lighter area thus caused.

P,mb = *membrana pori* = pore membrane: the thinned exine of a pore.

P,op = *operculum pori* = operculum of the pore: the thickened part of a pore, situated in a furrow or a seam. The structure of the operculum is similar in nature to that of the remaining exine of the pollen grain.

P,vest = *vestibulum pori* = a small, more or less well-defined, space created when the exine at the edge of the pore appears split in optical cross-section (foc. 5).

anl = *anulus:* an area which surrounds the pore like a ring, and which is distinguished from the rest of the exine of the pollen grain by differences in the ektexine; *e.g,* by a greater or lesser thickness of the ektexine.

If an anulus has concentric zones with different structure, these zones can be identified from the inside outwards: anl(1), anl(2) . . .

anl,l = *limes anuli* = edge of the anulus: external demarcation line of the anulus.

If an anulus has concentric zones with different structure, the demarcation lines of such zones may be designated from the inside outwards: anl,l(1); anl,l(2) . . .

cost P = *costae pori:* the ring-shaped thickening of the endexine around a pore.

P,cent = *centrum pori:* centre of the pore.

pseudo P = *pseudoporus* = pseudo pore: deviates from a true pore in that it is not the normal point of emergence of the pollen tube.

lac = *lacuna:* a term which includes both pseudopores and pseudocolpi.

4. Intercolpia, interporia, and polar area

These concepts are only applicable to bi-polar pollen grains.

inter C = *intercolpium:* an area delimited by the edges of the colpi (or by the edges of the margo, if clearly defined margo-edges are present), and by the connecting lines of the apices of adjacent colpi.

inter C,med = *medianum intercolpii:* a line which divides an intercolpium into two approximately symmetrical halves.

inter C, cent = *centrum intercolpii:* point of intersection of the medians of an intercolpium.

inter P = *interporium:* area delimited by the edges og the pores (or by the edges of the anuli, if clearly defined anulus-edges are present) and by the lines which are tangential to the edges of two adjacent pores (or their anuli).

inter P,med = *medianum interporii:* a line which divides an interporium into two approximately symmetrical halves.

inter P,cent = *centrum interporii:* the point of intersection of the medians of an interporium.

polar = *area polaris* = polar area: an area which surrounds a pole and which is limited by the intercolpia or interporia.

5. Structure of the Exine (Plate II)

ex = *exina* = exine: the highly resistant external skin of the pollen grain, which may be composed of one or two layers.

matrix: the homogeneous fundamental substance of the exine.

gran = *granula:* sharply delimited granules, rods and similar structural elements which are embedded in or deposited upon the homogeneous basic substance.

end = *endexina* = endexine: the inner homogeneous layer of a double-layered exine.

ekt = *ektexina* = ektexine: the outer layer of a double-layered exine, consisting of granules which may or may not form a continuous surface.

tec = *tectum:* the external skin-like part of the ektexine which more or less entirely covers the endexine.

tec(perf) = *tectum perforatum:* tectum with holes.

col = *columellae:* ektexine elements (granules) which support the tectum like pillars.

col(simpl) = *collumellae simplices:* simple columellae.

col(dig) = *columellae digitatae:* distally branching columellae.

con(conj) = *columellae conjunctae:* columellae united distally in groups. The granules of intectate pollen grains may also be termed columellae if they occur in composite structures (*e.g.,* in a reticulum).

cav = *cavea:* hollow space in the exine created by the detachment of the ektexine from the endexine.

6. Sculpture of the exine (Plates III, IV and V)

Elementa punctualia: dot-shaped sculptural elements: the greatest diameter is less than twice as large as the smallest[4].

ver = *verrucae* = warts: the greatest diameter equals or exceeds the height[4]: the sculptural elements are neither pointed nor constricted.

gem = *gemmae* = grains: like verrucae, but proximally constricted.

bac = *bacula* = rod: the greatest diameter is less than the height[4]: the sculptural elements are neither pointed nor club-shaped.

cla = *clavae* = clubs: like bacula, but club-shaped.

ech = *echini* = spines: sharply-pointed sculptural elements. The greatest diameter can be larger or smaller than the height[4].

Elementa elongata: elongated sculptural elements: the greatest diameter is more than twice as large as the smallest. These sculptural elements can sometimes be created by the close juxtaposition of dot-shaped elements.

val = *valla* = ridges, crests, keels *etc.,* in various shapes: elongated, serpentine curves or with irregular outlines.

ret = *reticulum* = network: formed by the regular merging of elongated sculptural elements.

mur = *muri:* the walls of a reticulum.

pl,lum = *plateae luminosae:* the surface of the exine between sculptural elements.

lum = *lumina* (sing.: *lumen*): the meshes of a reticulum defined by the muri.

Section B. Pollen morphological measurements

The following abbreviations have been used in giving the various dimensions:

M = *mensura* = measurement: any measurement in general. M does not of itself denote any orientation with respect to the pollen grain. It is used in the following indications of size:

1. Dimensions of the pollen grain
2. Dimensions of the polar area
3. Interporial and intercolpial measurements
4. Dimensions of the pores and the colpi
5. Dimensions (thickness) of the exine

Lg = *longitudo* = length: a measurement parallel to the polar axis in bi-polar pollen grains; with this proviso, used as M.

Lt = *longitudo transversa* = breadth: a measurement perpendicular to the polar axis in bi-polar pollen grains; with this proviso, used as M.

D = *diameter:* a measurement parallel to the surface of the exine, but applicable only to structures and sculptures.

H = *altitudo* = height: a measurement perpendicular to the surface of the exine; applicable only to structures and sculptures

For more specific descriptions of these measurements, the following abbreviations have been used: + and ÷ denote respectively the largest and smallest measurement, where several are possible.

(÷) indicates that the measurement given is perpendicular to a corresponding + measurement.

foc 0–3 denotes that the measurement has been taken by observation of the surface of the pollen grain. For definitions of the various angles of view (foc 0–5), see p. 18.

foc 5 denotes that the measurement has been taken by observation of the pollen grain in optical cross-section.

Measuring pollen grains:

Practical guidelines for taking measurements:

1. All measurements are taken to the outer boundary (*limes exterior*) of the pollen grain (Plate X). The outer boundary is defined as the more or less rotation-ellipsoidal basic surface which bears the sculptural elements; however, in cases where the distal surfaces of the sculptural elements (seen in profile) constitute more than 50% of the outer demarcation line described, then this is taken as the outher boundary line of the pollen grain, and the corresponding more or less rotation-ellipsoidal surface is taken to be the outer boundary (Plate X).
2. When defective pollen grains are measured, this must be explicitly stated; *e.g.*, in the following manner:
   x = *exina fissa* = split exine.
   () = *exina crispa* = crumpled exine.
   (x) = *exina fissa et crispa* = exine both split and crumpled.

1. All pollen types (Plate VI):

M,+: the distance between two parallel planes which are tangential to the pollen grain and which are so arranged that the greatest possible distance is achieved between the planes.

M,(÷): the distance between two parallel planes which are tangential to the pollen grain and which are perpendicular to the two planes indicated by M,+.

If two or more different measurements can thus be obtained, then:

M,(÷),+ indicates the greatest measurement

M,(÷),÷ indicates the smallest measurement

In certain cases – for example, when the pollen grain is firmly embedded – one is obliged to take measurements from an arbitrary position. This can be indicated as follows:

M,+(fix) = M,+ when the pollen grain is fixed in an arbitrary position.

M,(÷)(fix) = M,(÷) when the pollen grain is fixed in an arbitrary position.

2. Bi-polar pollen grains (Plate VI):

Lg = *longitudo* = length: the length of the polar axis from pole to pole. For colpi, pores, intercolpia and interporia, *etc.,* Lg denotes a measurement parallel to the polar axis.

Lt = *longitudo transversa* = the breadth at the equator: the distance between two parallel planes which are tangential to the pollen grain at its equator and which are parallel to a plane of symmetry passing through the polar axis; or else, a measurement at right angles to such a measurement, similarly in the equatorial plane.

If two or more measurements can be obtained thus, then:

Lt,+ denotes the largest measurement

Lt,÷ denotes the smallest measurement

For colpi, pores, intercolpia, interporia, *etc.,* Lt denotes a transverse measurement in the equatorial plane.

In cases where the greatest length and breadth of bi-polar pollen grains are not identical with the length of the polar axis or the breadth at the equator respectively, they can be indicated thus:

Lg,max = *maximum longitudinis* = maximum length: the distance between two parallel planes which are perpendicular to the polar axis and which are tangential to the pollen grain.

Lt,max = *maximum longitudinis transversae* = maximum breadth: the distance between two planes which are parallel to the plane of symmetry passing through the polar axis and tangential to the pollen grain; or else, a measurement at right angles to such a measurement and, similarly, perpendicular to the polar axis.

In cases where two or more different measurements can thus be obtained, then:

Lt,max,+ denotes the greatest

Lt,max,÷ denotes the smallest

Colpi measurements (Plate VII):

C-M,+ = length of colpus: length of longitudinal median of colpus

C-M,÷ = breadth of colpus: length of tranverse median of colpus

C-Lg = length of colpus in bi-polar pollen grains

C-Lt = breadth of colpus in bi-polar pollen grains

mg-M = breadth of margo: distance between edge of colpus and edge of margo

(C,ap-C,ap)-M: distance between apices of two adjacent colpi

(mg,ap-mg,ap)-M: distance between apices of two adjacent margines.

Pore Measurements (Plate VII):

P-M = Diameter of the pore. For pores that are not circular, the largest and smallest diameters can be denoted, respectively, thus:

P-M,+

P-M,÷

and for bi-polar pollen grains:
P-Lg
P-Lt
anl-M = breadth of the anulus: the distance between the edge of the pore and the edge of the anulus.
(P,l-P,l)-M: the distance between the edges of two adjacent pores.
(anl,l-anl,l)-M: the distance between the edges of the anuli of two adjacent pores.

Intercolpium, interporium, and polar area measurements (Plate VIII)
inter C-M: the length of a median of an intercolpium
inter C-M,+: the length of the greatest median
inter C-M,÷: the length of the smallest median
inter C-Lg: the length of a median perpendicular to the equator (in bi-polar pollen grains)
inter C-Lt: the length of a median congruent with the equator (in bi-polar pollen grains)
inter P-M: the length of a median of the interporium
inter P-M,+: the length of the greatest median
inter P-M,÷: the length of the smallest median
inter P-Lg: the length of a median perpendicular to the equator (in bi-polar pollen grains)
inter P-Lt: the length of a median congruent with the equator (in bi-polar pollen grains)
polar-M = *mensura areae polaris* = measurement of the polar area: the longest diagonal or the longest side of a polar area.

Measurement of the exine[5] (Plate IX):
The thickness of the exine, the endexine, the ektexine and the tectum is measured in optical cross-section (foc 5). If, for the same pollen grain, several measurements can be obtained, then M,+ and M,÷ denote the greatest and smallest measurements respectively.
ex-M: the thickness of the exine.
ex-M,+: the maximum thickness of the exine.
ex-M,÷: the minimum thickness of the exine.
end-M: the thickness of the endexine.
end-M,+: the maximum thickness of the endexine.
end-M,÷: the minimum thickness of the endexine.
ekt-M: the thickness of the ektexine.
ekt-M,+: the maximum thickness of the ektexine.
ekt-M,÷: the minimum thickness of the ektexine.

tec-M: the thickness of the tectum.

tec-M,+: the maximum thickness of the tectum.

tec-M,÷: the minimum thickness of the tectum.

If desired, measurements can also be given for specific points on the pollen grain; for example, at the pole: ex(pol)-M.

Sculpture[6] and columella measurements (Plate IX):
Example of sculpture measurement: clava.

cla-D,+,(foc 0–3)
cla-D,÷,(foc 0–3)
cla-D,+,(foc 5)
cla-D,÷,(foc 5)
cla-H,(foc 5)

In the example given above, columella can be substituted for clava.

Lumina measurements:

lum-D,+
lum-D,÷

Section C. Pollen morphological size proportions

1. Absolute dimensions

a. The size of a pollen grain is denoted by the greatest measurement of the grain (M,+; Lg,max or Lt,max,+). According to Erdtman (1945), the following size categories can be distinguished:

p(<10μm)	= *pollina perminuta*	= very small pollen grains
p(10–25μm)	= *pollina minuta*	= small pollen grains
p(25–50μm)	= *pollina media*	= medium pollen grains
p(50–100μm)	= *pollina magna*	= large pollen grains
p(>100μm)	= *pollina permagna*	= very large pollen grains

b. Exine, sculpture and lumina measurements are denoted by the greatest measurements within each catagory (*c.f.*, pollen morphological measurements, p. 15): The following size-catagories can be distinguished:

M,+(<1μm) = *micro-* (*e.g.*, lum-M(<1μm) = micro-reticulate)
M,+(1–4μm) = *meso-*
M,+(>4μm) = *macro-*

c. Columella measurements are given according to the diameter of the thickest collumellae: the largest diameter of the unbranched part of the columella is measured. The following size-categories can be distinguished:

col-D,+(<0.5µm)
col-D,+(0.5–1.0µm)
col-D,+(1–4µm)
col-D,+(>4µm)

col(*incertae*) signifies that no clear columellae can be distinguished.

2. Relative Size

a. Pollen shape index. The pollen shape for bi-polar pollen grains can be expressed by the relation of length to greatest breadth (Lg/Lt,+ or – possibly – Lg/Lt,max,+). The following categories of shape can be distinguished (Erdtman 1943):

perprol	= *pollina perprolata:*	Lg/Lt,+ >2.00
prol	= *pollina prolata:*	Lg/Lt,+ 2.00–1.33
subsph	= *pollina subsphaeroidea*[7]:	Lg/Lt,+ 1.33–0.75
obl	= *pollina oblata:*	Lg/Lt,+ 0.75–0.50
perobl	= *pollina peroblata:*	Lg/Lt,+ <0.50

b. Polar area index (polar-I). The relative size of the polar area can be expressed by the relation of the measurements of the polar area (polar-M) to the greatest breadth of the pollen grain (Lt,+ or Lt,max,+): The following classes can be distinguished:

polar-I(0):	polar area absent
polar-I(<0.25):	polar area small
polar- I(0.25–0.50):	polar area medium
polar-I(0.50–0.75):	polar area large
polar-I(>0.75):	polar area very large

c. Exine index (ex-I). The relative thickness of the exine can be denoted by the relation between the greatest thickness of the exine (ex-M,+) and the greatest breadth of the pollen grain (M(÷),+; Lt,+ or – possibly – Lt,max,+).

ex-I(<0.05):	exine-index small
ex-I(0.05–0.10):	exine-index medium
ex-I(0.10–0.25):	exine-index large
ex-I(>0.25):	exine-index very large

Section D. Pollen morphological description

One great difficulty in the observation and description of a pollen is caused by the fact that the image which one sees under a microscope differs according to the depth of focus. A description can only be achieved in one of two ways: either the pollen grain is described exactly as one sees it under the microscope, or one describes it according to the interpretation of what has been seen. The first procedure, which is analytical, is cumbersome because the image in every focus has to be described separately. The second procedure, which is synthetic, produces a simple and organic description – but there is the risk that complex structures may be misunderstood and the resulting descriptions, misleading. In practice, both methods are used in combination. For the analytical description of a pollen grain, the following scheme may be applied:

A. Indicate the orientation of the pollen grain; *i.e.,* which part is facing upwards toward the observer (for example, a pole, a colpus or an intercolpium).

B. Indicate which part of the pollen grain is being described (for example, a wart or a pore).

C. Indicate the level of focus in relation to the upper or lower boundary of the pollen grain (*cf.,* pollen measurements, p. 12, and Plate X). This can be denoted in the following way:

   foc 0: focusing above the outer boundary of the pollen grain (*cf.*, foc 1). Foc 0 can be further divided from the top downward into a, b, c, *etc.*; *e.g.*, foc 0,a.

   foc 1: focusing on the outer boundary of the pollen grain. Small distances above and below the boundary can be indicated by ÷ (above) and + (below).

   foc 2: focusing between foc 1 and foc 3. Foc 2 can be further divided from the top downward into a, b, c, *etc.*

   foc 3: focusing on the inner boundary of the exine of the pollen grain; small distances above and below can be indicated by ÷ or +.

   foc 4: focusing between foc 3 and foc 5. Foc 4 can be further divided into a, b, c, *etc.*

   foc 5: focusing on the centre of the pollen grain; at this focus, the exine is seen sharply in profile. Small distances above and below can be indicated by ÷ or +.

   foc ÷ 4 to ÷ 0: focus positions below the centre of the pollen grain, corresponding to those above but preceded by a ÷.

Section E. Pollen types
(Plates XI, XII, XIII, and XIV)

A. Pollen grains in combination		
B. Pollen grains combined in groups of more than four	1. Poly	= Polyadeae
BB. Pollen grains combined in groups of four	2. Tetr	= Tetradeae
BBB. Pollen grains combined in groups of two	3. Dy	= Dyadeae
AA. Pollen grains single		
B. One aperture, or none		
C. Pollen grains with air sacs	4. Ves	= Vesiculatae
CC. Pollen grains without air sacs		
D. Colpus absent		
E. Pore rudimentary or absent	5. Inap	= Inaperturatae
EE. One clearly-defined pore	6. P_1	= Monoporatae
DD. One colpus	7. C_1	= Monocolpatae
BB. Two or more clearly-defined apertures		
C. Without lacunae (pseudocolpi or pseudo pores)		
D. Colpi present, no free pores		
E. Colpi fused into rings, spirals, etc	8. C syn	= Syncolpatae
EE. Colpi not fused, but discrete		
F. Two colpi	9. C_2	= Dicolpatae
FF. More than two colpi		
G. Colpi without distinct pores or transversal colpi		
H. All colpi are meridional		
I. Three colpi	10. C_3	= Tricolpatae
II. More than three colpi	11. C stp	= Stephanocolpatae
HH. Not all colpi are meridional	12. C peri	= Pericolpatae
GG. Colpi with pores or transverse colpi (sometimes one or two pores or transversal colpi may be absent)		
H. All colpi are meridional		
I. Three colpi	13. C_3P_3	= Tricolporatae
II. More than three colpi	14. CP stp	= Stephanocolporatae
HH. Not all colpi are meridional	15. CP peri	= Pericolporatae
DD. Free pores present, colpi absent		
E. Pores predominantly equatorial		
F. Two to three pores		
G. Two pores	16. P_2	= Diporatae
GG. Three pores	17. P_3	= Triporatae
FF. More than three pores	18. P stp	= Stephanoporatae
EE. Pores not equatorial	19. P peri	= Periporatae
CC. Lacunae (pseudocolpi or pseudopores) present		
D. With pseudopores	20. Fen	= Fenestratae
DD. With pseudocolpi		
E. Some colpi with, others (pseudocolpi) without pores (free pores absent)	21. C het	= Heterocolpatae
EE. With free pores	22. P extra	= Extraporatae

Section F. Pollen-sculpture types

(Plates III, IV, and V)

Abbreviations derive from the first three letters of each term.
(for example, psi = psilatus)

A. True sculptural elements absent
- B. Indentations absent or less than $<1\mu m$ ..... psilatus
- BB. With holes or pits $\geqq 1\mu m$ ..... foveolatus[8]
- BBB. With scattered, elongated hollows ..... fossulatus[9]

AA. Sculptural elements present, all dot-shaped
- B. All dimensions are $<1\mu m$ ..... scabratus
- BB. At least one of the dimensions is $\geqq 1\mu m$
  - C. Sculptural elements not pointed
    - D. Greatest diameter $>$ the height of the element
      - E. Without proximal constriction ..... verrucatus
      - EE. With proximal constriction ..... gemmatus
    - DD. Greatest diameter $<$ the height of the element
      - E. Without distal thickening ..... baculatus
      - EE. With distal thickening ..... clavatus
  - CC. Sculptural elements pointed ..... echinatus

AAA. Sculptural elements present, all or some elongated
- B. Elements irregularly distributed, or without a predominant pattern ..... rugulatus
- BB. Elements predominantly parallel ..... striatus
- BBB. Elements arranged in a network ..... reticulatus

According to the distribution of the dot-shaped sculptural elements, two types can be distinguished:
inord = inordinatus: sculptural elements more or less randomly distributed.
ord = ordinatus: sculptural elements arranged in a pattern.

Section G. Types of pollen structure

A. Tectum absent ..... intec = intectatus
AA. Tectum present ..... tec = tectatus

For tectate pollen grains, the following structural types can be distinguished according to the distribution of the granulae below the tectum, by analogy with the sculptural types given above:

intra-bac ≷ intra-baculatus
intra-rug = intra-rugulatus
intra-str = intra-striatus
intra-ret = intra-reticulatus

Within the intra-baculatus type, two sub-types can be distinguished (*c.f.*, above):

inord = inordinatus
ord = ordinatus

Section H. Form, demarcation and structure of the apertures

(Plate XV)

Colpi

α = form

A. No irregularities at the equator
  B. Edges of the colpus turned neither outwards nor inwards .... α 1
    C. Colpus developed as a seam or very small fissure .... α 1a
    CC. Edges of colpus separated .... α 1b
  BB. Edges of the colpus turned outwards or inwards .... α 2
    C. Edges turned inwards .... α 2a
    CC. Edges turned outwards .... α 2b
AA. With irregularities at the equator in the form of constriction, fraying, or a bridge-shaped interruption.
  B. Constriction or fraying but no bridge-shaped interruption .... α 3
    C. With regular constriction at the equator, but no fraying.
      D. Constriction not pronounced. The edges of the colpus form acute angles at the equator.
        E. Length of the constricted section < the breadth of the colpus.
          F. Constriction not S-shaped .... α 3a
          FF. Constriction is S-shaped .... α 3b
        EE. Length of the constricted section > the breadth of the colpus .... α 3c
      DD. Constriction pronounced. The edges of the colpus form obtuse angles or curves at the equator.
        E. Length of the constricted section < the breadth of the colpus
          F. Constriction not S-shaped .... α 3d
          FF. Constriction is S-shaped .... α 3e
        EE. Length of the constricted section > the breadth of the colpus .... α 3f
    CC. Colpus frayed at the equator. Constriction, if any, irregular.
      D. Colpus irregularly constricted .... α 3g
      DD. Colpus not constricted .... α 3h
  BB. Colpus completely interrupted at the equator by a bridge .... α 4

β = demarcation

A. Margo absent
  B. Demarcation of the colpus diffuse, at least at the apices .... β 1 (diffusus)
    C. Diffuse demarcation in all directions .... β 1a
    CC. Diffuse demarcation only at the colpus apices .... β 1b
  BB. Demarcation of the colpus distinct and rectilinear .... β 2 (distinctus)
    C. The apices of the colpus are pointed or sharp .... β 2a
    CC. The apices of the colpus are blunt or rounded .... β 2b
AA. Margo present .... β 3 (marginatus)
  B. Outer demarcation of the margo is diffuse .... β 3a
  BB. Outer demarcation of the margo is distinct .... β 3b

γ = structure

A. Operculum absent
  B. Colpus membrane absent or naked .... γ 1 (nudatus)
  BB. Colpus membrane present and equipped with ektexine elements (granulae) .... γ 2 (granulatus)
AA. Operculum present .... γ 3 (operculatus)

Pores

α = form

1 - 4 seen in optical cross-section

A. Vestibilum absent
- B. Pore neither depressed nor raised .... α 1
- BB. Pore depressed .... α 2
- BBB. Pore raised .... α 3

AA. Vestibulum present .... α 4

a - d seen from above and in combination with a colpus

A. Pores not constricted into a figure-eight form
- B. Pores elongated in the direction of the polar axis - or of the colpus .... α a
- BB. Pores with length and breadth approximately equal .... α b
- BBB. Pores elongated at right angels to the polar axis or the colpus .... α c

AA. Pores constricted into a figure-eight form .... α d

β = demarcation

Anulus absent
- B. Demarcation of the pore diffuse in all or, possibly, two opposite directions .... β 1 (diffusus)
  - C. Demarcation diffuse on all sides .... β 1a
  - CC. Demarcation diffuse only on two opposite sides .... β 1b
- BB. Demarcation of the pore distinct and regular .... β 2 (distinctus)

AA. Anulus present .... β 3 (anulatus)
- B. Outer demarcation of the anulus diffuse .... β 3a
- BB. Outer demarcation of the anulus distinct .... β 3b

γ = structure

Operculum absent
- B. Pore membrane naked or missing .... γ 1 (nudatus)
- BB. Pore membrane present and equipped with ektexine elements (granulae) .... γ 2 (granulatus)

AA. Operculum present .... γ 3 (operculatus)

Section I. Groupings according to the number of apertures

In pollen grains with more than three apertures, the following groups can be distinguished according to the number of appertures:

4; 5–6; 7–12; 13–24; 25–48; >48.

Footnotes.

1. Faegri, Knut and Iversen, Johs.: Textbook of Modern Pollen Analysis, Ejner Munkcgaard, Copenhagen, 1950.
2. One of the authors (Troels-Smith) has taken measurements for a number of years with a view to illuminating variations in size within the same species, and also changes in size when various methods of chemical treatment have been applied. This material, which is to be published shortly, shows a quite extraordinary variation according to the method of treatment (*c.f.*, Brorson Christensen 1946). On the other hand, relative proportions in size between species show unexpectedly little change; *i.e.*, the relationship between, for example, *Corylus* and another pollen type remains relatively constant.
3. Such a typology is especially necessary where identifications are made with the aid of a punch-card system (see Plate XVI).
4. In sculptural and structural elements, a measurement parallel to the surface of the exine is termed "diameter"; a measurement perpendicular to the surface is termed "height".
5. All exine measurements apply to the exine *exclusive* of colpi, pores, lacunae, anuli, margines, and costae; *n.b.,* the outer boundary of the pollen grain – *c.f.*, p. 13.
6. That is, measurements of sculptural elements, abbreviated for the sake of convenience throughout.
7. The group of *subsphaeroidea* includes the classes of subprolate + spheroidal + suboblate in Erdtman 1943.
8. The dividing line between *foveolatus* and *reticulatus* has been established as follows: the diameter of the lumina is ≧ the breadth of the surrounding muri (*reticulatus*); the diameter of the fovea is < the smallest distance to the adjacent fovea (*foveolatus*).
9. The *fossulatus* types presupposes that the fossulae do not anastomose in such a way that sculptural elements (verrucae or valla) are formed.

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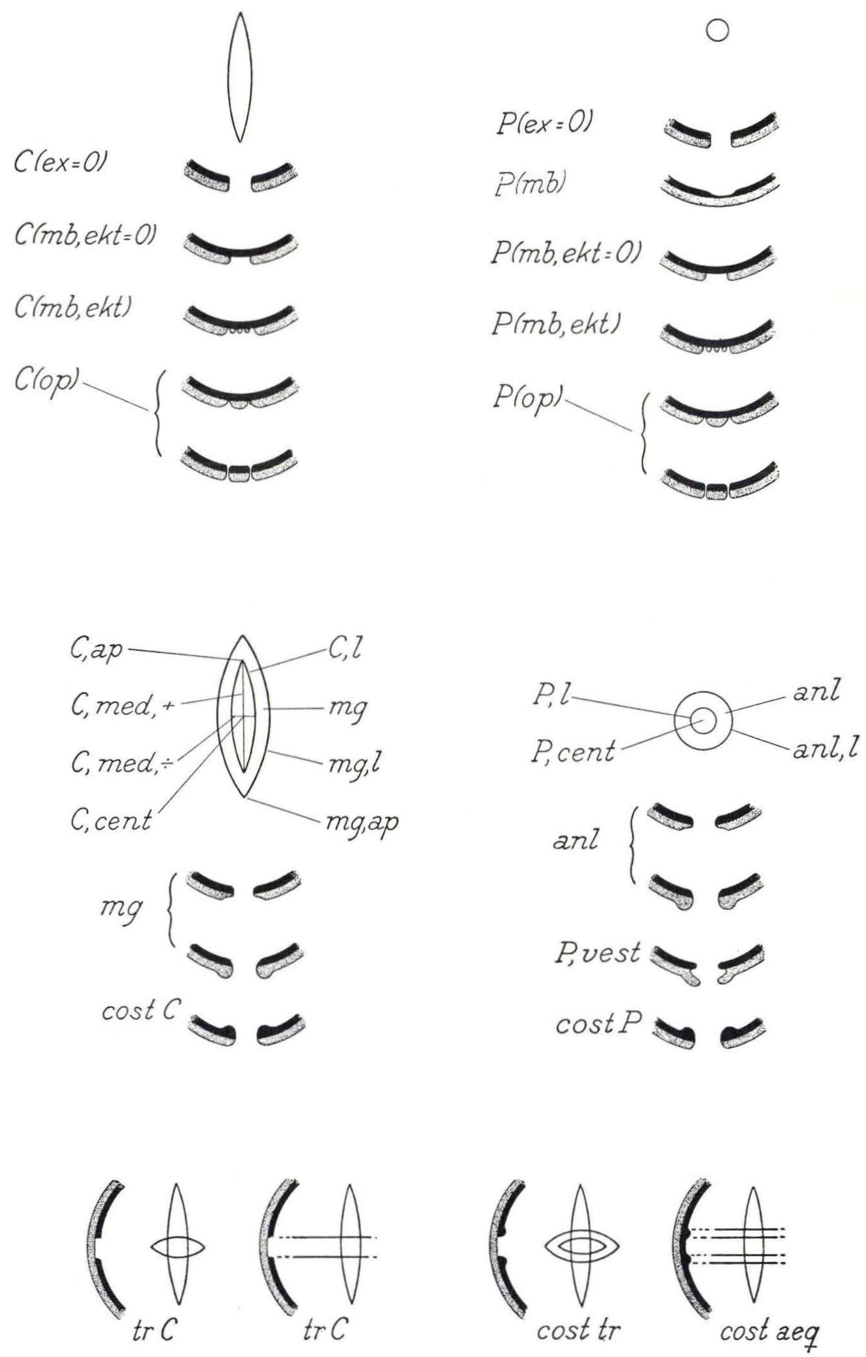
Index

Abbreviations

aeq = aequator. aequatorialis
anl = annulus, annulatus
ap = apex
ax = axis
bac = bacula, baculatus
C = colpus
C_1 = Monocolpatae
C_2 = Dicolpatae
C_3 = Tricolpatae
C_3P_3 = Tricolporatae
$C\alpha$; $C\beta$; $C\gamma$ = cf. p. 21
C het = Heterocolpatae
C peri = Pericolpatae
C P peri = Pericolporatae
C P stp = Stephanocolporatae
C stp = Stephanocolpatae
C syn = Syncolpatae
cav = cavea, cavatus
cent = centrum
cla = clavae, clavatus
col = columellae
conj = conjunctae
cost = costae
D = diameter
dig = digitatae
Dy = Dyadeae
ech = echini, echinatus
ekt = ektexina
end = endexina
ex = exina
l = limes
lac = lacuna
Lg = longitudo
Lt = longitudo transversa
lum = lumen, lumina, luminosae
M = mensura
med = medianum
max = maximum
mb = membrana
mg = margo, margines
mur = muri
obl = oblata
op = operculum
p = pollina
P = porus
P_1 = Monoporatae
P_2 = Diporatae
P_3 = Triporatae
$P\alpha$; $P\beta$; $P\gamma$ = cf. p. 22
P extra = Extraporatae
P peri = Periporatae
P stp = Stephanoporatae
perobl = peroblata
perprol = perprolata
pl = plateae
pol = polus
polar = area polaris
Poly = Polyadeae
prol = prolata
psi = psilatus

Fen	= Fenestratae
fix	= fixus
foc	= focus
fos	= fossula, fossulatus
fov	= foveolatus
gem	= gemmae, gemmatus
gran	= granula
H	= altitudo
I	= index
Inap	= Inaperturatae
inord	= inordinatus
intec	= intectatus
inter C	= intercolpium
inter P	= interporium
intra e	= intra-baculatus e
ret	= reticulatus
rug	= rugulatus
sca	= scabratus
simpl	= simplices
subsph	= subsphaeroidea
str	= striatus
tec	= tectum, tectatus
tec(perf)	= tectum perforatum
Tetr	= Tetradeae
tr	= transversalis
val	= valla
ver	= verrucae, verrucatus
Ves	= Vesiculatae
vest	= vestibulum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C(mb,ekt=0)
C(mb,ekt)
C(op)
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P(mb,ekt)
P(op)
C,ap
C,l
C, med, +
mg
C, med, ÷
mg,l
C, cent
mg,ap
P,l
anl
P,cent
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cost P
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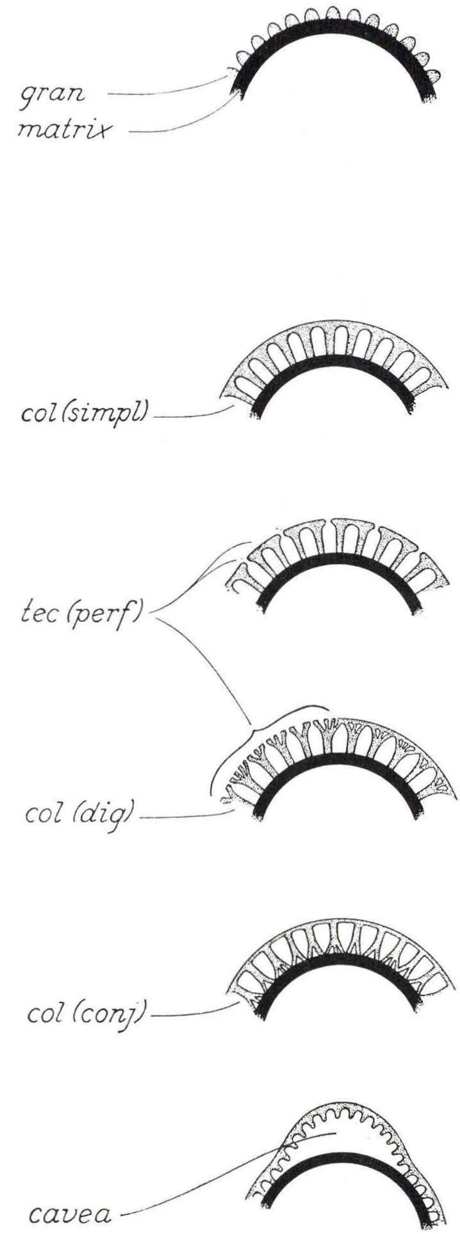
tr C
cost tr
cost aeq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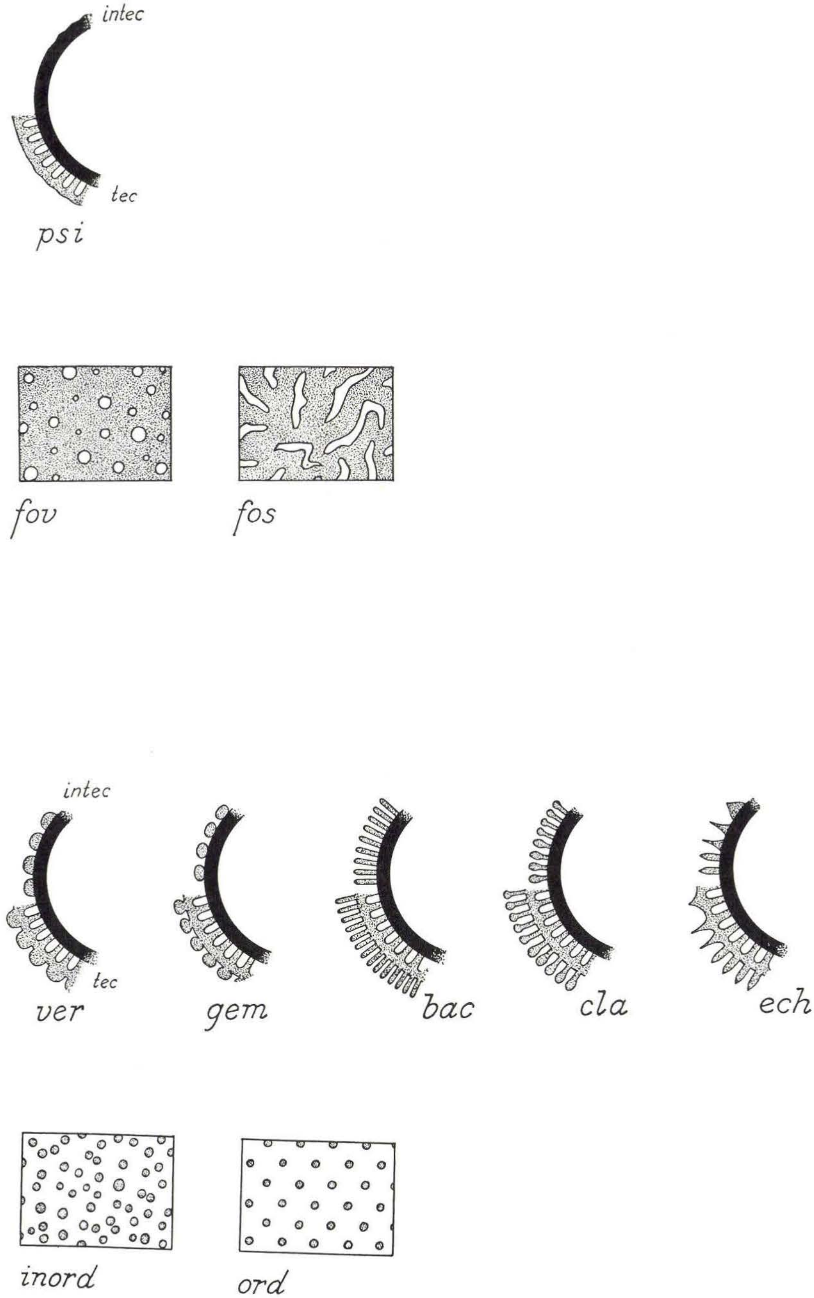
tec (perf)
col (dig)
col (conj)
cavea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cla
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inord
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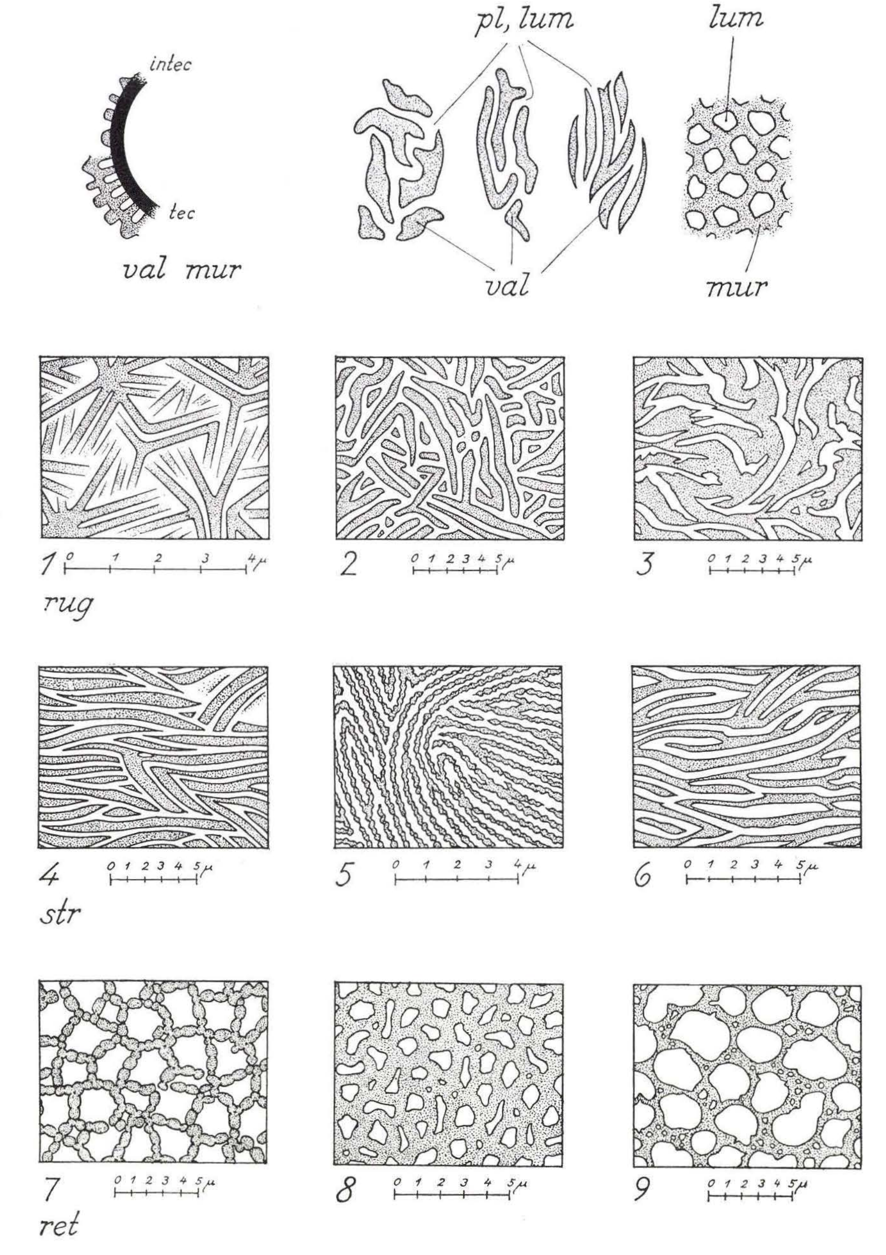
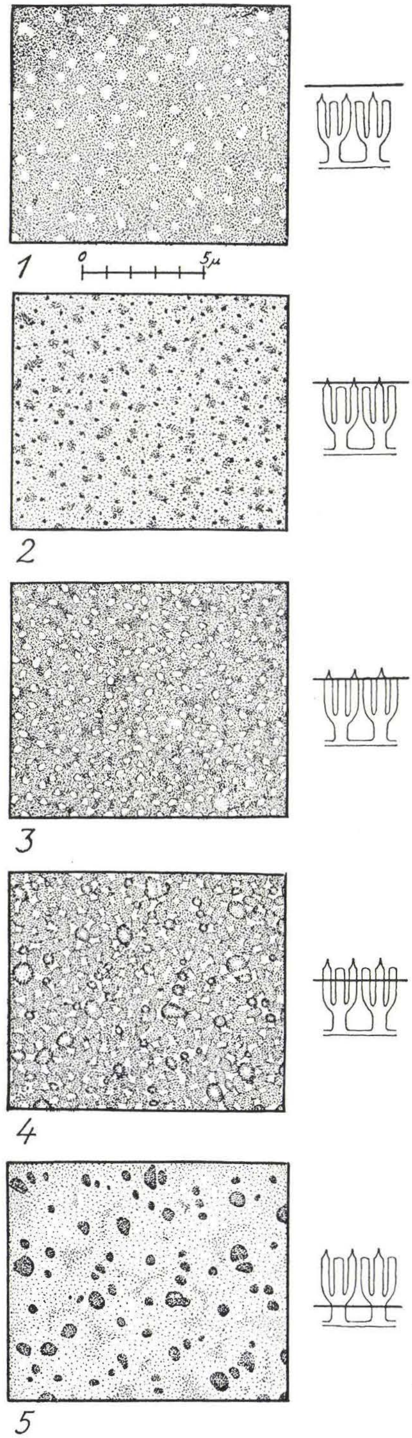
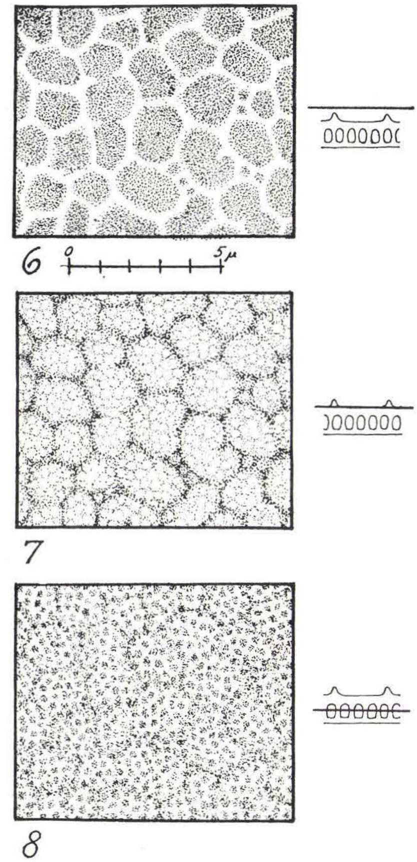


1. *Sedum rosea* (L) Scop. 2. *Nymphoides peltata* (S. G. Gmel.) O. K. 3. *Prunus insititia* L. 4. *Menyanthes trifoliata* L. 5. *Acer pseudoplatanus* L. 6. *Saxifraga oppositifolia* L. 7. *Iris pseudacorus* L. 8. *Lysimachia thyrsiflora* L. 9. *Thesium ebracteatum* Hayne.



1—5. Stellaria longipes GOLDIE.



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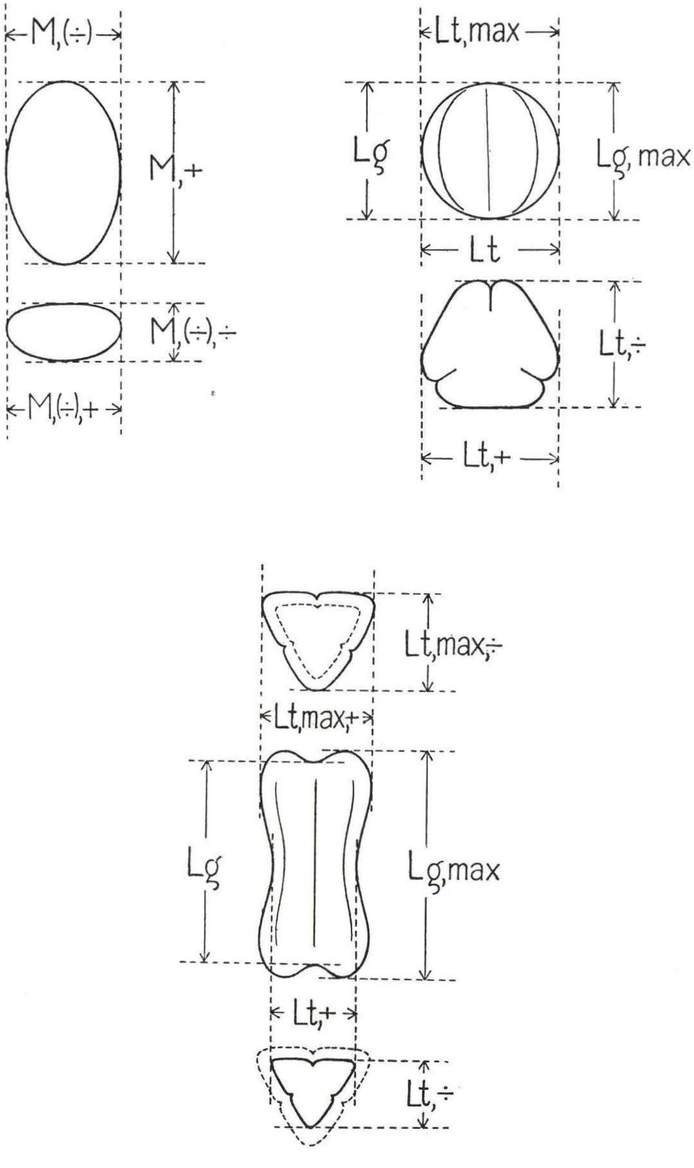
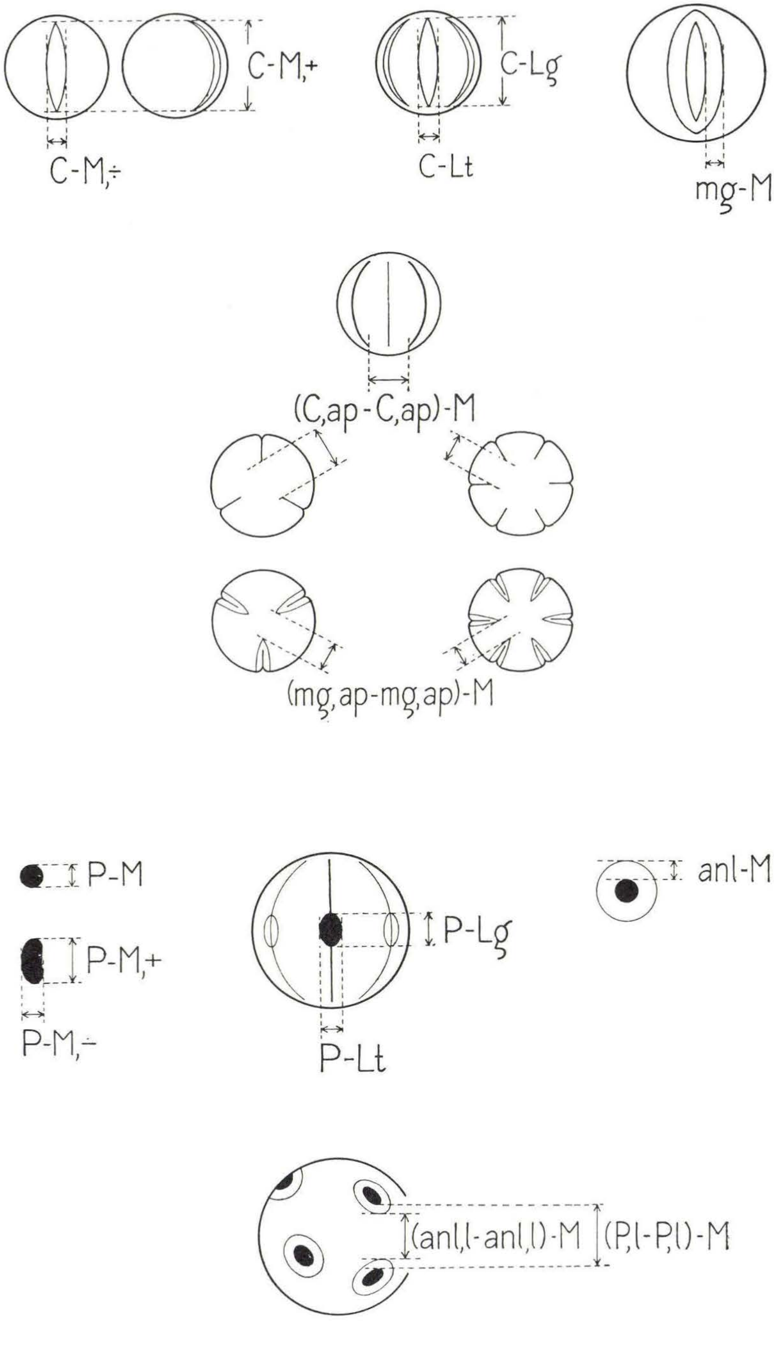

M,(÷)
M,+
M,(÷),÷
M,(÷),+
Lt,max
Lg
Lg,max
Lt
Lt,÷
Lt,+
Lt,max,÷
Lt,max,+
Lg
Lg,max
Lt,+
Lt,÷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C-Lg
C-Lt
mg-M
(C,ap-C,ap)-M
(mg,ap-mg,ap)-M
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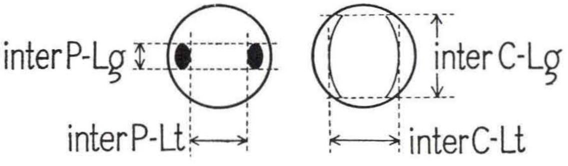
P-M,÷
P-Lg
P-Lt
anl-M
(anl,l-anl,l)-M
(P,l-P,l)-M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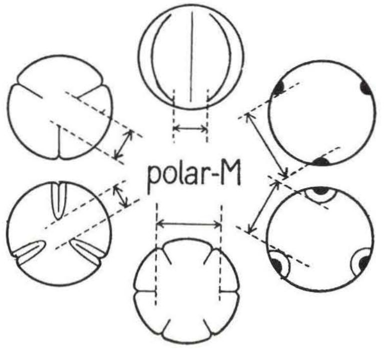
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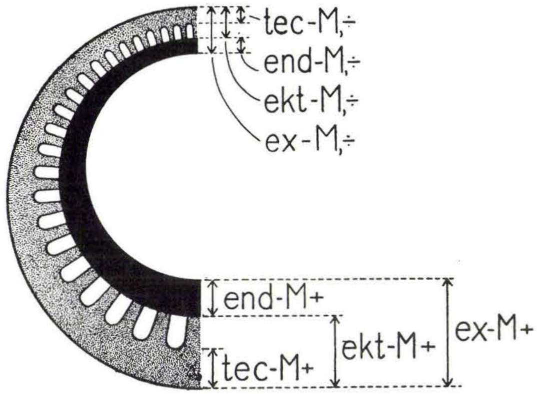
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end-M,÷
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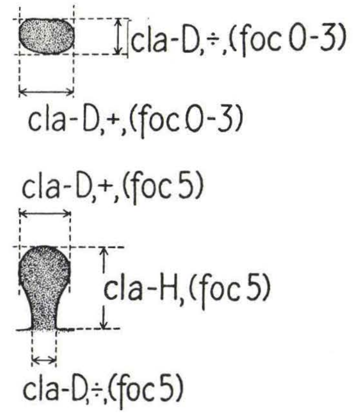
ex-M+
tec-M+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cla-H,(foc 5)
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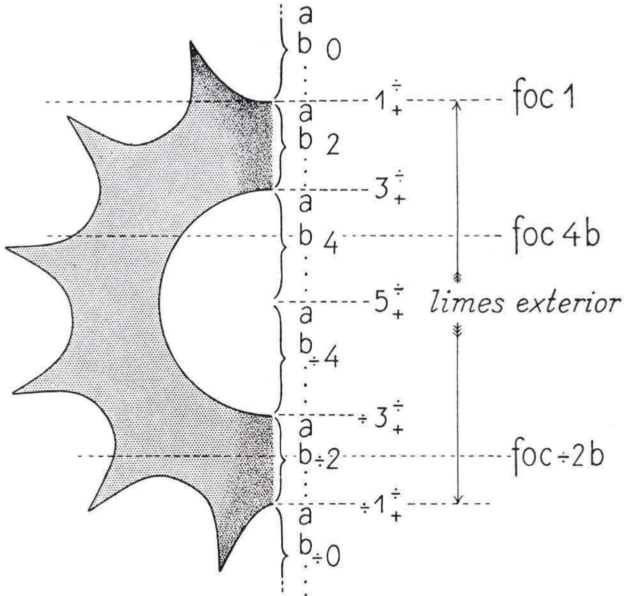
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b 0
1 ÷ +
foc 1
a
b 2
3 ÷ +
a
b 4
foc 4b
5 ÷ +
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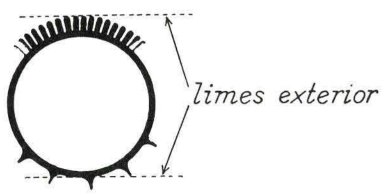
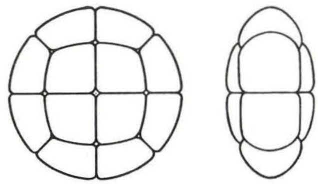
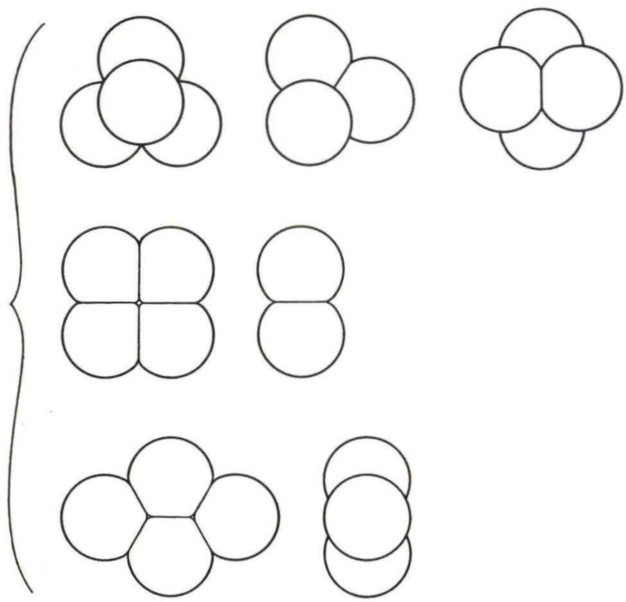
÷1 ÷ +
a
b ÷0


limes exterior

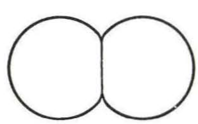
1 *Poly*
Polyadeae



2 *Tetr*
Tetradeae



3 *Dy*
Dyadeae



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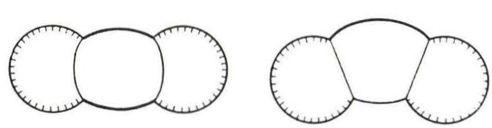
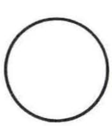
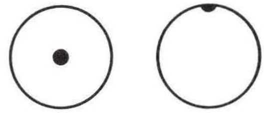
Vesiculatae



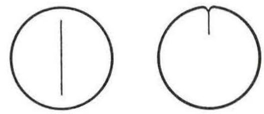
5 *Inap*
Inaperturatae



6 P_1
Monoporatae



7 C_1
Monocolpatae



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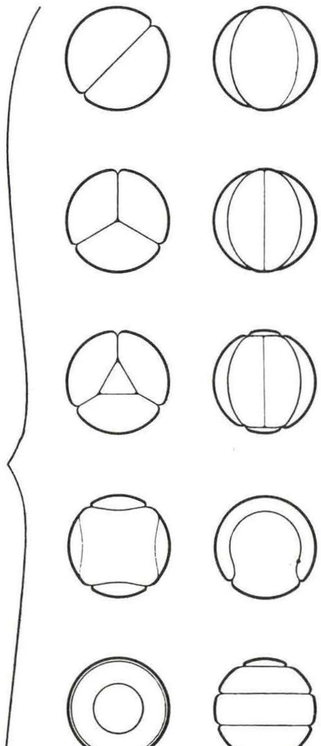
Syncolpatae



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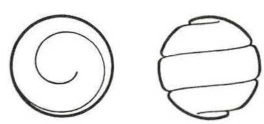
Dicolpatae



10 C_3
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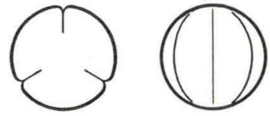
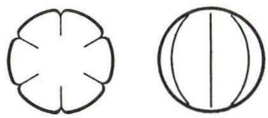
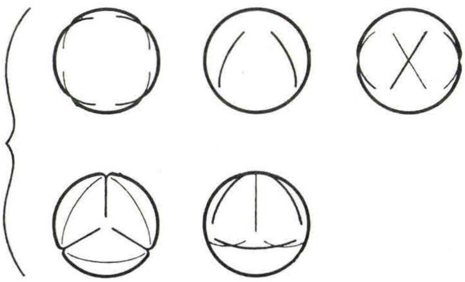


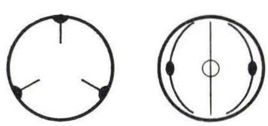
11 *Cstp*
Stephanocolpatae



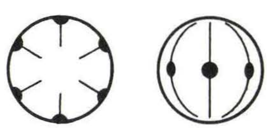
12 *Cperi*
Pericolpatae



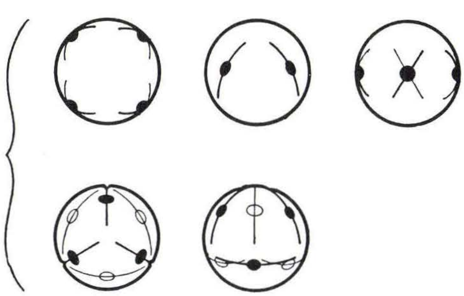
13 C_3P_3
Tricolporatae



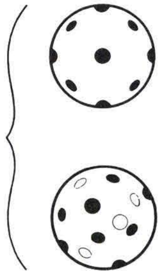
14 *CPstp*
Stephanocolporatae



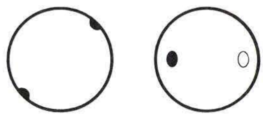
15 *CPperi*
Pericolporatae



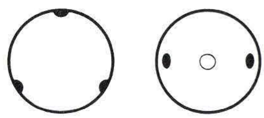
19 *P peri*
Periporatae



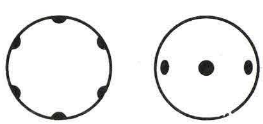
16 P_2
Diporatae



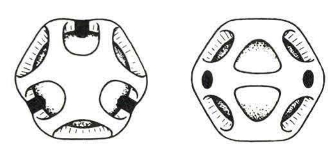
17 P_3
Triporatae



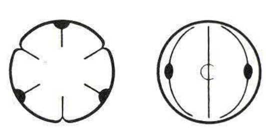
18 *P stp*
Stephanoporatae



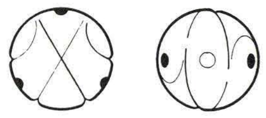
20 *Fen*
Fenestratae

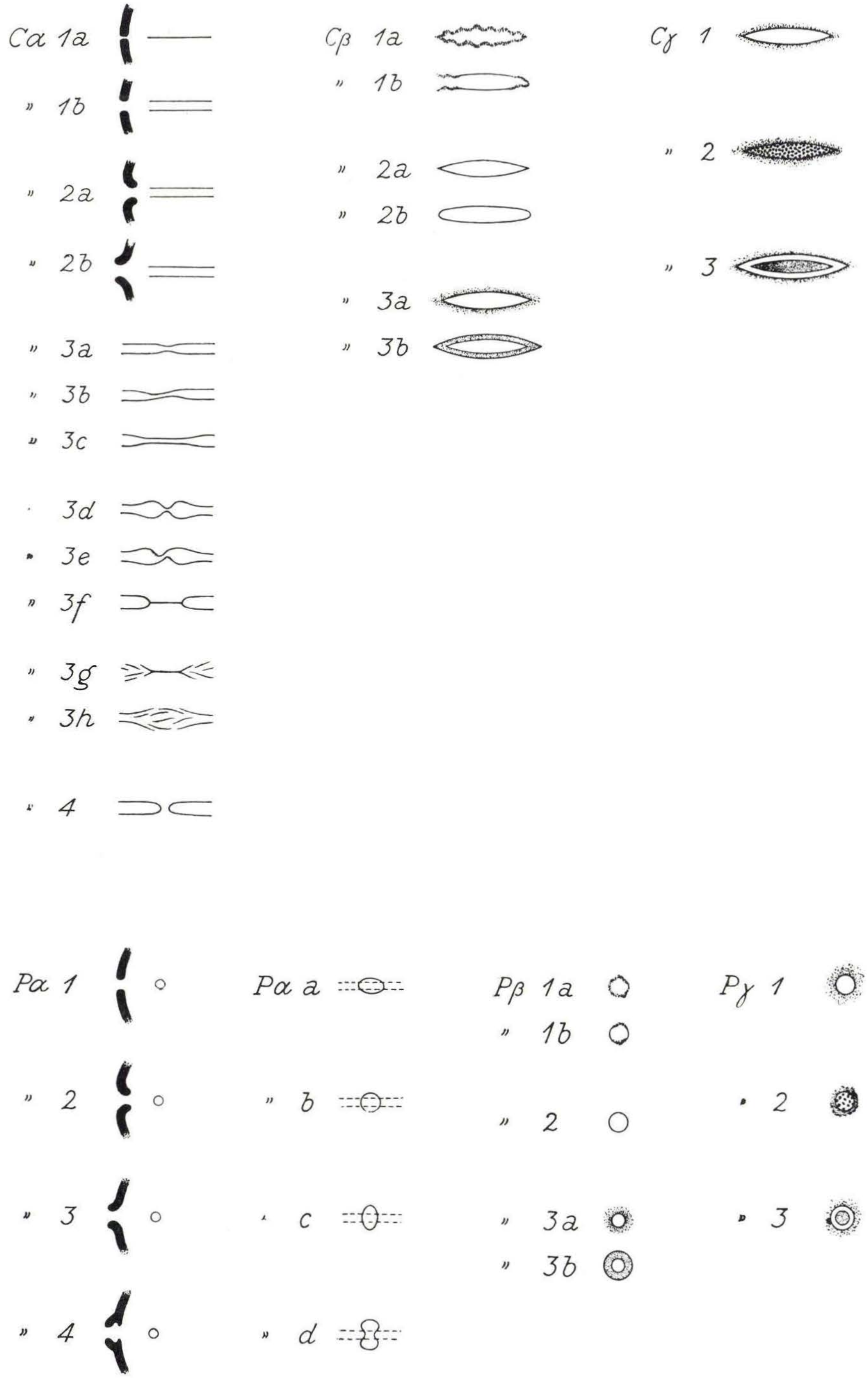


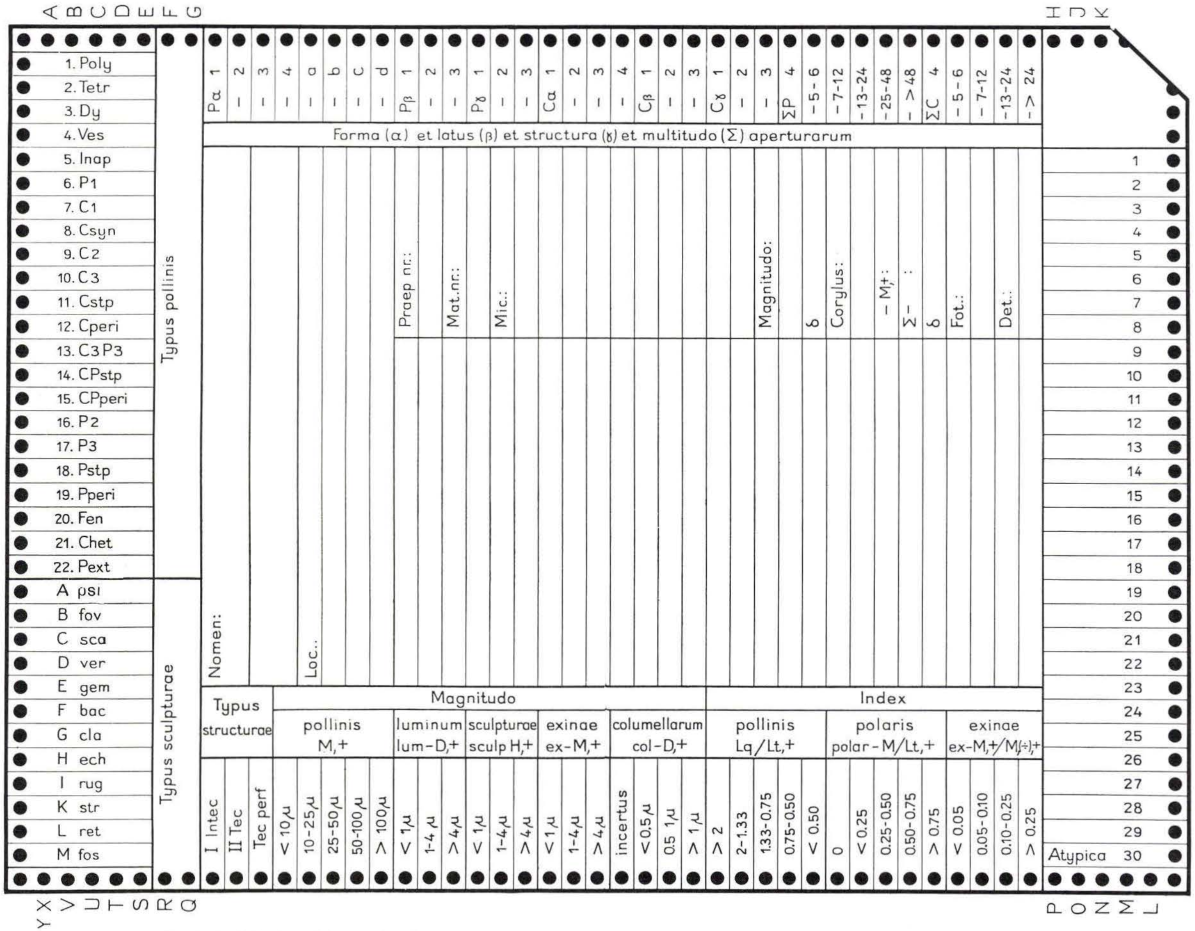
21 *Chet*
Heterocolpatae



22 *P extra*
Extraporatae




Cα 1a
" 1b
" 2a
" 2b
" 3a
" 3b
" 3c
3d
3e
" 3f
" 3g
" 3h
4
Cβ 1a
" 1b
" 2a
" 2b
" 3a
" 3b
Cγ 1
" 2
" 3
Pα 1
" 2
" 3
" 4
Pα a
" b
c
" d
Pβ 1a
" 1b
" 2
" 3a
" 3b
Pγ 1
2
3



Punch Card for description and registration of unidentified fossil pollen grains, and for use in the construction of a "Key" to recent pollen flora. See Clark 1938, Faegri and Iversen, 1950.

The Quaternary bryoflora of Denmark. I. Species list.

Bent Vad Odgaard

Odgaard, B.V: The Quaternary bryoflora of Denmark. I. Species list. *Danm. geol. Unders., Årbog 1980:* 45–74, København, 15. december 1981.

Abstract. A list is presented of all bryophytes reported in literature from Quaternary deposits in Denmark, excluding Greenland and the Faroe Islands. 159 species have been reported. The arrangement is systematic and chronostratigraphic.

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The Danish geological, archaeological and botanical literature contains a welth of reports of fossil Quaternary mosses. A compilation of this material is useful in helping to understand recent bryogeography, and furthermore it is of value to the palaeobotanist, since the bryoflora of a specific geological period may often give information about the palaeoenvironment. A list has therefore been made of all the reports of Quaternary bryophytes from Denmark, the intention being that this is the first part of a general treatment of the Danish Quaternary bryoflora. Part II will mainly contain conclusions on the palaeoenvironment drawn from the bryophytes recovered.

Material

The basis of the list are literature reports of macroscopic bryophyte remains from Quaternary deposits in Denmark, excluding Greenland and the Faroe Islands.

The ambiguous reports of "*Amblystegium*" and "*Hypnum*" as used in lithological descriptions have been excluded as well as reports of "*Sphagnum* sp." unless this was the only *Sphagnum* report from the geological period concerned.

Several mosses are reported by Vaupell (1851) but of these only taxonomically unproblematic taxa are included in the list. Of the reports in Steenstrup (1841), only those revised by Hesselbo (in K. Jessen 1920: 84, 87, footnotes) are included.

The majority of the identifications were made early in the 20'th century by the bryologists A. Hesselbo and C. Jensen. In the few cases where the material is still unpublished, the identifications were made by the present author, who, however, has not checked the identifications of the published material.

The list

The list is divided into two parts.

In part 1, all the taxa reported are listed alphabetically with author names followed by letters and numbers for the geological periods (cf. Table 1 and part 2) from which deposits containing the taxon are known. 2 species of hepatics, 14 Sphagna and 143 mosses have been reported. The nomenclature follows Grolle (1976) for Hepaticopsida, Nyholm (1954–69) for Sphagnopsida and A. G. Andersen et al. (1976) for Bryopsida. For mosses not in the latter, the nomenclature is according to Nyholm (1954–69). Two mosses, however, are found in neither of these works:

Cinclidium latifolium Lindb.

Drepanocladus brevifolius (Lindb.) Warnst.

Part 2 is arranged according to the age of the deposits following the division of the Danish Quaternary in Table 1. Since many deposits were dated by pollenanalysis alone, it has been necessary to correlate the pollen assemblage zones of the Flandrian with the chronozones in this period, although the boundaries may not be strictly synchronous. The division of the Eemian Stage into substages has been made here for convenience. These substages correspond to the protocratic, the mesocratic and the oligo-telocratic stages respectively of S. T. Andersen (1975).

Authority is not cited in part 2 but literature references are given (Arab figures) as well as the localities. The taxonomic synonyms used in the references are only cited in the list (in brackets) when they are unusual or likely to cause confusion. The common synonyms can be found in A. G. Andersen et al. (1976) and Nyholm (1954–69).

In case a taxon has been reported more than once from the same deposit and same chronostratigraphic unit, it is only mentioned once in the list. If, however, these reports are from different chronostratigraphic units, the taxon is listed under all periods concerned, even if these are of different rank, e.g. Allerød and Late Weichselian. In order to avoid too many chronostratigraphic subdivisions, a taxon from a deposit which may belong to one or the other chronostratigraphic unit of the same rank has been put into the unit of the nearest higher rank, e.g. a moss from a layer deposited in either Bølling or Older Dryas has been listed as Late Weichselian.

Stage	Substage	Chronozone	C-14 Years BP	Pollen assemblage zone
	Gc. Late	Gc1. Subatlantic		IX
			2.500	
		Gb2. Subboreal		VIII
G. Flandrian	Gb. Middle		5.000	
		Gb1. Atlantic		VI + VII
			8.000	
		Ga2. Boreal		V
	Ga. Early		9.000	
		Ga1. Preboreal		IV
			10.000	
		Fc4. Younger Dryas		LW 3
			11.000	
		Fc3. Allerød		LW 2
	Fc. Late		11.800	
		Fc2. Older Dryas		LW 1c
			12.000	
		Fc1. Bølling		LW 1a+b
			13.000	
F. Weichselian	Fb. Middle	Fb1. Hengelo	37.000	
			50.000	
		Fa4. Brørup		EW2e-5
	Fa. Early	Fa3. Upper Herning		EW2d
		Fa2. Rodebæk		EW2c
		Fa1. Lower Herning		EW1-2b
			(115.000)	
	Ec. Late			E7 E6 E5
E. Eemian.	Eb. Middle			E4 E3
	Ea. Early			E2 E1
			(130.000)	
D. Saalian				
C. Holsteinian				
B. Elsterian				
?				
A. Harreskovian				
?				

Table 1. The division of the Danish Quaternary used in the list. References: S. T. Andersen (1965, 1975, 1980), Houmark-Nielsen and Kolstrup (in press), Mangerud et al. (1974).

It has not been possible to include in the list the considerations which have led to the dating, if any, of the deposits.

Abbrevations
R: Fossils possibly or probably rebedded from deposits belonging to older chronostratigraphic units.
T: Identification considered tentative by the identifier.
U: Age of deposit considered somewhat uncertain.

1. Systematic part

Hepaticopsida.
Marchantia polymorfa L. (Ec, Fc, Fc4)
Trichocolea tomentella (Ehrh.) Dum. (Ec)

Sphagnopsida.
Sphagnum sp. (A, Fa3, Fc4)
S. cuspidatum Hoffm. (Ga, Ga1, Gb2, Gc)
S. fallax (Klinggr.) Klinggr. (Gb2, Gc)
S. fallax (Klinggr.) Klinggr. var. *angustifolium* (C. Jens.) (Ea, Gb2)
S. fimbriatum Wils. (Ga)
S. imbricatum Russ. (Ec, Gc)
S. magellanicum Brid. (Gc)
S. magellanicum Brid. or *S. palustre* L. (X)
S. molle Sull. (Gc)
S. nemoreum Scop. (Fc)
S. palustre L. (Ea, Eb, Ec, Fa, Fa1, Ga, Ga1, Ga2, Gb1, Gb2, Gc)
S. papillosum Lindb. (Ea, Ec, Fa, Gc, X)
S. rubellum Wils. (Fb, Gc, X)
S. subnitens Russ. et Warnst. (Ga)
S. subsecundum Nees (Gc)
S. tenellum (Brid.) Brid. (Gb2, Gc)
S. teres (Schimp.) Ångstr. (Ea, F, Fb, Fc, Ga, Ga1)

Bryopsida.
Abietinella abietina (Hedw.) Fleisch. (D, Fb)
Amblystegiella confervoides (Brid.) Loeske (X)
Amblystegium varium (Hedw.) Lindb. or *A. juratzkanum* Schimp. (X)
Anisothecium schreberianum (Hedw.) Dix. (Fa)
Anomodon viticulosus (Hedw.) Hook. et Tayl. (Ec)

Antitrichia curtipendula (Hedw.) Brid. (Ea, Ec, Ga2)
Aulacomnium palustre (Hedw.) Schwaegr. (D, E, Ec, F, Fa3, Fb, Fc, Fc1, Fc3, Fc4, G, Ga, Ga1, Ga2, Gb1, Gb2, Gc).
A. turgidum (Wahlenb.) Schwaegr. (Fb, Fc)
Brachythecium sp. (Ga2)
B. albicans (Hedw.) B.S.G. (D, Fb)
B. plumosum (Hedw.) B.S.G. (Fb)
B. populeum (Hedw.) B.S.G. (Ea)
B. reflexum (Stark.) B.S.G. (Fc)
B. rutabulum (Hedw.) B.S.G. (Ec)
B. salebrosum (Web. et Mohr) B.S.G. (X)
B. velutinum (Hedw.) B.S.G. (Ec)
Bryoerythrophyllum recurvirostre (Hedw.) Chen (Fb, Fc)
Bryum sp. (Fa, Fa1, Fb, Fc, Fc3, Fc4, G)
B. cyclophyllum (Schwaegr.) B.S.G. (Fb)
B. neodamense Itzigs. (Fb)
B. pallescens Schwaegr. (Fb)
B. pseudotriquetrum (Hedw.) Gaertn., Meyer et Scherb. (D, F, Fa1, Fb, Fc, Fc2, Fc3, Fc4, Ga)
Calliergon cordifolium (Hedw.) Kindb. (Ec, F, Fb, Fc, Fc3, G, Ga)
C. giganteum (Schimp.) Kindb. (D, E, Ea, Ec, F, Fb,Fc,Fc2,Fc4,G, Ga,Gc,X)
C. richardsonii (Mitt.) Kindb. (D, E, Fa3, X)
C. sarmentosum (Wahlenb.) Kindb. (D)
C. stramineum (Brid.) Kindb. (D, E, Ec, Fa1, Fa3, Fa4, Fb, Fc, Fc1, Ga, Ga1, Gb2, Gc)
C. trifarium (Web. et Mohr) Kindb. (Fa3, G, Ga, Ga1, Ga2, Gb1)
Calliergonella cuspidata (Hedw.) Loesk. (E, Ea, Eb, Ec, Fa, Ga, Gb1, Gc)
Camptothecium lutescens (Hedw.) B.S.G. (Ec, G, X)
Campylium calcareum Crundw. et Nyh. or *C. sommerfeltii* (Myr.) Bryhn (Fc)
C. chrysophyllum (Brid.) J. Lange (Fb, X)
C. polygamum (B.S.G.) C. Jens. (D, F, Fa, Fb, Fc, Fc3, X)
C. protensum (Brid.) Kindb. (Fb, Fc4,)
C. stellatum (Hedw.) C. Jens. (D, E, F, Fa, Fa1, Fb, Fc, Gb1)
Catoscopium nigritum (Hedw.) Brid. (X)
Ceratodon purpureus (Hedw.) Brid. (D, F, Fa, Fb, Fc, Fc3, Fc4)
Cinclidium arcticum (B.S.G.) Schimp. (Fb)
C. latifolium Lindb. (Fb)
C. stygium Sw. (G)
Cirriphyllum cirrosum (Schwaegr.) Grout (Fb)
Climacium dendroides (Hedw.) Web. et Mohr (E, Fa, Fa1, Fb, Fc, Fc3, Fc4, Ga, Gc)

Conostomum tetragonum (Hedw.) Lindb. (Fb)
Cratoneuron commutatum (Hedw.) Roth var. *falcatum* (Brid.) Moenk. (Fc)
C. decipiens (De Not.) Loesk. (Fb, Ga2)
C. filicinum (Hedw.) Spruc. (Fa, Fa1, Fb, Fc)
Cyrtomnium hymenophylloides (Hüb.) Kop. (Fb)
Dichodontium pellucidum (Hedw.) Schimp. (Fa, Fa1)
Dicranum sp. (Fb, Fc)
D. bonjeanii De Not. (Ec)
D. fuscescens Turn. var. *congestum* (Brid.) Husn. (D, Fb)
C. scoparium Hedw. (D, Ec, Ga, Gb2)
Didymodon tophaceus (Brid.) Lisa (Fc)
Distichium capillaceum (Hedw.) B.S.G. (D, Fb, Fc, Fc4, X)
Ditrichum flexicaule (Schwaegr.) Hamp. (D, Fa, Fb, Fc, Fc4, X)
Drepanocladus aduncus (Hedw.) Warnst. or *D. polycarpus* (Voit) Warnst. (D, E, Ea, Eb, Ec, F, Fa, Fa3, Fb, Fc, Fc4, G, X)
D. brevifolius (Lindb.) Warnst. (Fb, X)
D. exannulatus (B.S.G.) Warnst. (D, E, Ea, Eb, Ec, F, Fa, Fa1, Fa2, Fa3, Fa4, Fb, Fb1, Fc, Fc3, Fc4, Ga, X)
D. fluitans (Hedw.) Warnst. (E, Ea, Ec, Fb, Fc, Fc4, Ga, Gc, X)
D. intermedius (Lindb.) Warnst. (E, Eb, Ec, Fa1, Fb, Fc, Ga1, Ga2, Gb1, Gc, X)
D. lycopodioides (Brid.) Warnst. (Eb, X)
D. polycarpus (Voit) Warnst. var. *capillifolius* (Warnst.) (Fb, Fc4)
D. revolvens (Sw.) Warnst. (D, Ec, F, Fb, Fc, Fc4, G, X)
D. sendtneri (Schimp.) Warnst. (F, Fb, Fc, X)
D. uncinatus (Hedw.) Warnst. (D, Ea, Fa, Fa1, Fa3, Fb, Fc3, Fc4)
Encalypta sp. (X)
E. alpina Sm. (Fb)
E. rhabdocarpa Schwaegr. (Fa, Fb, Fc4, X)
E. streptocarpa Hedw. (Fc4)
Eurhynchium striatum (Hedw.) Schimp. (Ec)
Fissidens adianthoides Hedw. (Fb)
Fontinalis sp. (Fc, Ga)
F. antipyretica Hedw. (Fc, Ga)
F. hypnoides Hartm. (Fc)
Helodium blandowii (Web. et Mohr) Warnst. (D, Eb, Fb, Fc1, Fc4, Ga, X)
Homalothecium sericeum (Hedw.) B.S.G. (E, Ec)
Hygrohypnum molle (Hedw.) Loesk. or *H. dilatatum* (Wils.) Loesk. (Fb)
Hylocomium splendens (Hedw.) B.S.G. (D, E, Ec, Fa, Fb, Fc, Fc3, Fc4, Gb2)
Hypnum cupressiforme Hedw. (Ec, Ga, Gb, Gb2, Gc)
H. imponens Hedw. (Gb2)

H. revolutum (Mitt.) Lindb. (Fb)
Isothecium myosuroides Brid. (D, Ec)
I. myurum Brid. (E, Ec)
Leptobryum pyriforme (Hedw.) Wils. (Fb, Fc)
Leptodictyum riparium (Hedw.) Warnst. (Fb, Fc, X)
Lescuraea radicosa (Mitt.) Moenk. (D, Ec, Fa3, Fc4)
Leskea polycarpa Hedw. (Fc)
Leucobryum glaucum (Hedw.) Aongstr. (Gc)
Meesea longiseta Hedw. (Ea, Ec, Fc, G, Ga)
M. trifaria Crum, Steere et Anders. (D, Fa, Fb, Fc, G, Ga2, X)
M. uliginosa Hedw. (Fb, Fc)
Mniobryum wahlenbergii (Web. et Mohr) Jenn. (Fa, Fb, Fc)
Mnium sp. (s.l.) (Fc, X)
M. marginatum (With.) P. Beauv. (Fb)
M. stellare Hedw. (E)
Neckera complanata (Hedw.) Hueb. (E, Ec, Ga, X)
N. crispa Hedw. (E, Ec)
Oncophorus sp. (Incl. *Cynodontium* and *Cnestrum*?) (Fc)
O. virens (Hedw.) Brid. (Fb)
Orthothecium chryseum (Schwaegr.) B.S.G. (Fb)
Oxyrrhynchium praelongum (Hedw.) Warnst. (E, Ec)
O. swartzii (Turn.) Warnst. (Ec)
Paludella squarrosa (Hedw.) Brid. (Ea, Fa, Fc4, Ga, X)
Philonotis fontana (Hedw.) Brid. (D, Fa, Fa1, Fa3, Fb, Fc, Ga)
P. tomentella Mol. (D, Fc4)
Plagiomnium affine (Funck) Kop. (D, Ec, F, Fa, Fa1, Fb, Fc, Fc3, Fc4)
P. cuspidatum (Hedw.) Kop. (Ec)
P. ellipticum (Brid.) Kop. (Ga1)
P. medium (B.S.G.) Kop. (Fb, G, X)
P. undulatum (Hedw.) Kop. (Ec)
Pleurozium schreberi (Brid.) Mitt. (Ec, Fc3, Gb2)
Pogonatum urnigerum (Hedw.) P. Beauv. (Fc4, Ga)
Pohlia cruda (Hedw.) Lindb. (Fc4)
P. drummondii (C. Muell.) Andr. (Fb)
P. nutans (Hedw.) Lindb. (Ec, Fa, Fb, Fc, Fc3, Gb2, Gc)
P. obtusifolia (Brid.) L. Koch (Fb)
Polytrichum or *Pogonatum* sp. (Ec, Fa1, Fa3, Fb, Fc, G)
Polytrichum sect. *juniperina* (Fb)
P. affine Funck (D, Ec, Fa, Fa1, Fb, Fc, Fc4, Ga, Gb2, Gc)
P. alpinum Hedw. (Fb, Fc4)
P. commune Hedw. (Eb, Ec, Fb, Ga, Gc)

P. formosum Hedw. (Ec)
P. juniperinum Hedw. (D, Ec, Fa, Fa1, Fc, Fc1, Fc3, Fc4)
P. piliferum Hedw. (Fb)
Pseudobryum cinclidioides (Hueb.) Kop. (Fa, Ga2)
Racomitrium sp. (Fa, Fb)
R. fasciculare (Hedw.) Brid. (Fa1)
R. canescens (Hedw.) Brid. or *R. ericoides* (Hedw.) Brid. (Fa, Fa1, Fc)
R. ericoides (Hedw.) Brid. (Fb)
R. lanuginosum (Hedw.) Brid. (Fb)
Rhizomnium pseudopunctatum (Bruch et Schimp.) Kop. (Ec)
R. punctatum (Hedw.) Kop. (Ec)
Rhythidiadelphus squarrosus (Hedw.) Warnst. (A, E, Ec, Gb2)
R. triquetrus (Hedw.) Warnst. (Eb, Ec)
Rhythidium rugosum (Hedw.) Kindb. (F, Fb)
Schistidium apocarpum (Hedw.) B.S.G. (Fb)
Scleropodium purum (Hedw.) Limpr. (E, Ec, Gb2)
Scorpidium scorpioides (Hedw.) Limpr. (D, E, Ea, Eb, Ec, F, Fa2, Fa3, Fb, Fb1, Fc, Fc3, Fc4, G, Ga, Gb1, Gc, X)
S. turgescens (Th. Jens.) Loesk. (Fb, Fc)
Thamnobryum alopecurum (Hedw.) Nieuwl. (Ec)
Thuidium sp. or *Abietinella* (D, X)
Thuidium sp. or *Abietinella* or *Helodium* (Fc)
T. delicatulum (Hedw.) Mitt. (D)
T. delicatulum (Hedw.) Mitt. or *T. recognitum* (Hedw.) Lindb. (Fb)
T. tamariscinum (Hedw.) B.S.G. (E, Ec)
Timmia bavarica Hessl. (Fb)
T. norvegica Zett. (Fb)
Tomenthypnum nitens (Hedw.) Loesk. (D, E, Ec, Fb, Fc, Fc1, Fc3, Fc4, G, Ga, X)
Tortella fragilis (Hook. et Wils.) Limpr. (Fc)
T. tortuosa (Hedw.) Limpr. (Fb, Fc, Fc4)
Tortula norvegica (Web.f.) Wahlenb. (Fb)
T. ruralis (Hedw.) Gaertn., Meyer et Scherb. (D, Fa, Fb, Fc, Fc3)

2. Chronostratigraphic part

A. Harreskovian.

Sphagnopsida.
Sphagnum sp. 29: Harreskov.

Bryopsida.
Rhythidiadelphus squarrosus. 29: Starup.

B. Elsterian.

No bryophytes reported.

C. Holsteinian.

No bryophytes reported.

D. Saalian.

The bryophyte-containing deposits from the Saalian are all from the late part, lying immediately below Eemian deposits.

Bryopsida.
Abietinella abietina. 29: Herning.
Aulacomnium palustre. 29: Herning.
Brachythecium albicans. 29: Herning.
Bryum pseudotriquetrum. 29: Herning.
Calliergon giganteum. 29: Herning.
C. richardsonii. 29: Dalager Nygård.
C. sarmentosum. 29: Herning.
C. stramineum. 29: Dalager Nygård. Herning.
Campylium polygamum. 29: Herning.
C. stellatum. 29: Herning.
Ceratodon purpureus. 10: Ejstrup,T.
Dicranum fuscescens var. *congestum.* 29: Herning.
D. scoparium. 29: Herning.
Distichium capillaceum. 29: Herning. Dalager Nygård.
Ditrichum flexicaule. 29: Herning.
Drepanocladus aduncus or *D. polycarpus.* 29 (as *Hypnum aduncum*): Herning.

D. exannulatus. 29: Herning. Dalager Nygård.
D. revolvens. 29: Herning.
D. uncinatus. 29: Herning.
Helodium blandowii. 29: Dalager Nygård.
Hylocomium splendens. 29: Herning.
Isothecium myusuroides. 29: Dalager Nygård.
Lescuraea radicosa. 29 (as *L. Breidleri*): Herning.
Meesea trifaria. 29: Herning.
Philonotis fontana. 29: Dalager Nygård.
P. tomentella. 29: Herning.
Plagiomnium affine. 29 (as *Mnium cuspidatum*): Herning. Dalager Nygård.
Polytrichum affine. 29: Herning.
P. juniperinum. 29: Herning.
Scorpidium scorpioides. 29: Herning.
Thuidium sp. or *Abietinella.* 29: Herning.
T. delicatulum. 29: Dalager Nygård.
Tomenthypnum nitens. 29: Herning.
Tortula ruralis. 29: Herning.

E. Eemian.

Bryopsida.
Aulacomnium palustre. 29: Tuesbøl. Over Gestrup. Nørbølling.
Calliergon giganteum. 29: Hørup. Rodebæk I.
C. richardsonii. 38: Vejnæs Nakke.
C. stramineum. 29: Hørup. Rodebæk I.
Calliergonella cuspidata. 10: Ejstrup.
Campylium stellatum. 29: Hørup.
Climacium dendroides. 29: Herning.
Drepanocladus aduncus or *D. polycarpus.* 29 (as *Hypnum aduncum*): Egtved. 38 (as *Amblystegium Kneiffii*): Vejnæs Nakke.
D. exannulatus. 29: Over Gestrup. Hørup. Nørbølling. Brørup Hotel Mose, U.
D. fluitans. 29: Solsø.
D. intermedius. 29: Hørup.
Homalothecium sericeum. 29: Herning. 37: Egtved. Brørup Mergelgrav.
Hylocomium splendens. 29: Herning.
Isothecium myurum. 29: Herning.
Mnium stellare. 29: Herning.
Neckera complanata. 37: Egtved.

N. crispa. 37: Egtved.
Oxyrrhynchium praelongum. 29: Herning.
Rhythidiadelphus squarrosus. 29: Herning.
Scleropodium purum. 10: Brørup Station.
Scorpidium scorpioides. 29: Hørup. Brørup Hotel Mose,U. 37: Egtved. 38: Vejnæs Nakke.
Thuidium tamariscimum. 37: Egtved.
Tomenthypnum nitens. 29: Hørup.

Ea. Early Eemian.

Sphagnopsida.
Sphagnum fallax var. *angustifolium.* 29: Astrup.
S. palustre. 29: Astrup.
S. papillosum. 10: Tuesbøl Mark,U.
S. teres. 29: Astrup.

Bryopsida.
Antitrichia curtipendula. 10: Ejstrup.
Brachythecium populeum. 10: Ejstrup.
Calliergon giganteum. 10: Brørup Station. Skovlyst.
Calliergonella cuspidata. 10: Brørup Station.
Drepanocladus aduncus or *D. polycarpus.* 10 (as *Amblystegium Kneiffii*): Brørup Station,T.
D. exannulatus. 29: Astrup,U.
D. fluitans. 10: Brørup Station.
D. uncinatus. 29: Føvling.
Meesea longiseta. 10: Brørup Station.
Paludella squarrosa. 29: Føvling.
Scorpidium scorpioides. 10: Brørup Station. 29: Føvling.

Eb. Middle Eemian.

Sphagnopsida.
Sphagnum palustre. 29: Over Gestrup. Nørbølling,U. Tuesbøl Mark.

Bryopsida.
Calliergonella cuspidata. 10: Brørup Station. Tuesbøl Mark.
Drepanocladus aduncus or *D. polycarpus.* 10 (as *Amblystegium Kneiffii*): Skovlyst at Brørup.

D. exannulatus. 29: Duedam I,U. Føvling.
D. intermedius. 29: Duedam I,U. Føvling.
D. lycopodioides. 29: Føvling.
Helodium blandowii. 10: Brørup Station.
Polytrichum commune. 10: Brørup Station.
Rhythidiadelphus triquetrus. 10: Tuesbøl Mark.
Scorpidium scorpioides. 29: Føvling.

Ec. Late Eemian.

Hepaticopsida.
Marchantia polymorpha. 10: Ejstrup.
Trichocolea tomentella. 29: Rodebæk III.

Sphagnopsida.
Sphagnum imbricatum 29: Nørbølling.
S. palustre. 29: Nørbølling. 37: Egtved.
S. papillosum. 29: Over Gestrup. 10: Høllund.

Bryopsida.
Anomodon viticulosus. 10: Ejstrup.
Antitrichia curtipendula. 10: Ejstrup.
Aulacomnium palustre. 37: Egtved.
Brachythecium rutabulum. 10: Ejstrup.
B. velutinum. 10: Ejstrup. Tuesbøl Mark.
Calliergon cordifolium. 10: Ejstrup.
C. giganteum. 37: Egtved.
C. stramineum. 29: Over Gestrup,U. 37: Egtved.
Calliergonella cuspidata. 10: Ejstrup. 37: Egtved.
Camptothecium lutescens. 10: Ejstrup.
Dicranum bonjeanii 10: Ejstrup.
D. scoparium. 10: Ejstrup.
Drepanocladus aduncus or *D. polycarpus*. 29 (as *Hypnum aduncum*): Kollund.
D. exannulatus. 10: Høllund. 29: Nørbølling. 37: Egtved.
D. fluitans. 10: Høllund.
D. intermedius. 29: Føvling.
D. revolvens. 37: Egtved.
Eurhynchium striatum. 10: Ejstrup.
Homalothecium sericeum. 10: Ejstrup.

Hylocomium splendens. 10: Ejstrup. Bramminge. Lervad Mark.
Hypnum cupressiforme. 10: Ejstrup. Tuesbøl Mark.
Isothecium myosuroides. 10: Ejstrup.
I. myurum. 10: Ejstrup.
Lescuraea radicosa. 29: (as *L. Breidleri*, contamination ?): Herning.
Meesea longiseta. 29: Føvling.
Neckera complanata. 10: Tuesbøl Mark. Ejstrup.
N. crispa. 10: Tuesbøl Mark. Ejstrup. Bramminge.
Oxyrrhynchium praelongum. 10: Tuesbøl Mark. Ejstrup.
O. swartzii. 10: Ejstrup.
Plagiomnium affine. 10 (as *Astrophyllum cuspidatum*): Ejstrup.
P. cuspidatum. 10 (as *Astrophyllum silvaticum*): Ejstrup.
P. undulatum. 10: Ejstrup.
Pleurozium schreberi. 10 (as *Hylocomium parietinum* and *Dicranum* parietinum): Ejstrup. 29: Over Gestrup,U. 37: Egtved.
Pohlia nutans. 10: Tuesbøl Mark, T.
Polytrichum or *Pogonatum* sp. 10: Tuesbøl Mark. 37: Egtved.
Polytrichum affine. 10: Tuesbøl Mark. Høllund.
P. commune. 10: Brørup Station. Bramminge.
P. formosum. 10: Ejstrup.
P. juniperinum. 10: Tuesbøl Mark.
Rhizomnium pseudopunctatum. 10: Ejstrup.
R. punctatum. 10: Ejstrup.
Rhythidiadelphus squarrosus. 10: Ejstrup.
R. triquetrus. 10: Ejstrup.
Scleropodium purum. 10: Ejstrup.
Scorpidium scorpioides. 29: Føvling.
Thamnobryum alopecurum. 10: Ejstrup.
Thuidium tamariscinum. 10: Ejstrup. 37: Egtved.
Tomenthypnum nitens. 37: Egtved.

F. Weichselian.

Sphagnopsida.
Sphagnum teres. 19: Lønstrup.

Bryopsida.
Aulacomnium palustre. 17: Gjærum Gård. Kovstrup. Engebæks Gård. Volbro. 18: Møgelmose.
Bryum pseudotriquetrum. 17: Engebæks Gård. Volbro. 18: Møgelmose.

Calliergon cordifolium. 17: Tolstrup Hede. Gulbækskjær.
C. giganteum. 17: Volbro. 18: Møgelmose.
Campylium polygamum. 29: Herning.
C. stellatum 17: Volbro. 17 and 18: Møgelmose. 19: Lønstrup.
Ceratodon purpureus. 17: Engebæks Gård.
Drepanocladus aduncus or *D. polycarpus.* 17 (as *Amblystegium Kneiffii*): Gjærum Gård.
D. exannulatus. 17: Gjærum Gård. Kovstrup. Volbro. Albæk Kirke. 18: Møgelmose. 19: Lønstrup. 29: Herning.
D. revolvens. 29: Herning.
D. sendtneri. 17: Engebæks Gård.
Plagiomnium affine. 29 (as *Mnium cuspidatum*): Herning.
Rhythidium rugosum. 18: Møgelmose.
Scorpidium scorpioides. 17: Gjærum Gård. Engebæks Gård. Volbro. 18: Møgelmose. 29: Herning.

Fa. Early Weichselian.

Sphagnopsida.
Sphagnum palustre. 29: Nørbølling,U.
S. papillosum. 29: Herning.

Bryopsida.
Anisothecium schreberianum. 29: Herning.
Bryum sp. 29: Herning.
Calliergonella cuspidata. 29: Herning.
Campylium polygamum. 29: Herning.
C. stellatum. 29: Herning. Rodebæk I.
Ceratodon purpureus. 29: Herning.
Climacium dendroides. 29: Herning.
Cratoneuron filicinum. 29: Herning.
Dichodontium pellucidum. 29: Herning.
Ditrichum flexicaule. 29: Brørup.
Drepanocladus aduncus or *D. polycarpus.* 29 (as *Hypnum aduncum*): Herning.
D. exannulatus. 29: Nørbølling, U. Rodebæk I.
D. uncinatus. 29: Herning.
Encalypta rhabdocarpa. 29: Herning.
Hylocomium splendens. 29: Herning.
Meesea trifaria. 29: Herning.

Mniobryum wahlenbergii. 29: Herning.
Paludella squarrosa. 29: Herning.
Philonotis fontana. 29: Herning.
Plagiomnium affine. 29 (as *Mnium cuspidatum*): Herning.
Pohlia nutans. 29: Herning.
Polytrichum affine. 29: Herborg, R. Rodebæk I.
P. juniperinum. 29: Herning.
Pseudobryum cinclidioides. 29: Herning.
Racomitrium sp. 29: Herning.
R. canescens or *R. ericoides.* 29: Herning. Rodebæk I.
Tortula ruralis. 29: Herning.

Fa1. Lower Herning.

Sphagnopsida.
Sphagnum palustre. 29: Herning.

Bryopsida.
Bryum sp. 29: Herning.
B. pseudotriquetrum. 29: Herning.
Calliergon stramineum. 29: Herning.
Campylium stellatum. 29: Herning.
Climacium dendroides. 29: Herning.
Cratoneuron filicinum. 29: Herning.
Dichodontium pellucidum. 29: Herning.
Drepanocladus exannulatus. 29: Herning.
D. intermedius. 29: Herning.
D. uncinatus. 29: Herning.
Philonotis fontana. 29: Herning.
Plagiomnium affine. 29 (as *Mnium cuspidatum*): Herning.
Polytrichum or *Pogonatum* sp. 29: Herning.
Polytrichum affine. 29: Herning.
P. juniperinum. 29: Herning.
Racomitrium canescens or *R. ericoides.* 29: Herning.
R. fasciculare. 29: Herning.

Fa2. Rodebæk.

Bryopsida.
Drepanocladus exannulatus. 29: Herning.
Scorpidium scorpioides. 29: Herning.

Fa3. Upper Herning.

Sphagnopsida.
Sphagnum sp. 29: Herning,R.

Bryopsida.
Aulacomnium palustre. 29: Herning,R.
Calliergon richardsonii. 29: Herning,R.
C. stramineum. 29: Herning,R.
C. trifarium. 29: Herning,R.
Drepanocladus aduncus or *D. polycarpus.* 29 (as *Hypnum aduncum*): Herning,R.
D. exannulatus. 29: Herning,R.
D. uncinatus. 29: Herning,R.
Lescuraea radicosa. 29 (as *L. Breidleri*): Herning,R.
Philonotis fontana. 29: Herning,R.
Polytrichum or *Pogonatum* sp. 29: Herning,R.
Scorpidium scorpioides. 29: Herning,R.

Fa4. Brørup.

Bryopsida.
Calliergon stramineum. 29: Herning.
Drepanocladus exannulatus. 29: Herning. Brørup Hotel Mose.

Fb. Middle Weichselian.

Sphagnopsida.
S. rubellum. 17: Toftegård,R,U.
S. teres. 17: Lønstrup,R,U.

Bryopsida.

Abietinella abietina. B. Odgaard, unpubl.: Hirtshals.

Aulacomnium palustre. 17: Ørsø,R,U. 20: Skærumhede,R. B. Odgaard, unpubl.: Hirtshals.

A. turgidum. 17: Ørsø,R,U. 20: Skærumhede,R. B. Odgaard, unpubl.: Hirtshals.

Brachythecium albicans. 20: Skærumhede,R.

B. plumosum. 20: Skærumhede,R.

Bryoerythrophyllum recurvirostre. 20: Skærumhede,R,U.

Bryum sp. 20: Skærumhede,R.

B. cyclophyllum. 20: Skærumhede,R.

B. neodamense. 20: Skærumhede,R.

B. pallescens. 20: Skærumhede,R,T.

B. pseudotriquetrum. 17: Tolstrup Hede,R,U. 20 (as *B. ventricosum* and *B. crispulum*): Skærumhede,R.

Calliergon cordifolium. 20: Skærumhede,R,U.

C. giganteum. 17: Ryd,R,U. 20: Skærumhede,R.

C. stramineum. 10 and 17: Lønstrup,R,U. 17: Øster Flade,R,U. 20: Skærumhede,R.

Campylium chrysophyllum. 17: Toftegård,R,U. 20: Skærumhede,R.

C. polygamum. 17: Ørsø,R,U. 20: Skærumhede,R.

C. protensum. 20: Skærumhede,R.

C. stellatum. 20: Skærumhede,R.

Ceratodon purpureus. 17: Ryd,R,U. Ørsø,R,U. 17 and 19: Lønstrup,R,U. 20: Skærumhede,R.

Cinclidium arcticum. 20: Skærumhede,R.

C. latifolium. 20: Skærumhede,R,U.

Cirriphyllum cirrosum. 20: Skærumhede,R.

Climacium dendroides. 20: Skærumhede,R,U.

Conostomum tetragonum. B. Odgaard, unpubl.: Hirtshals.

Cratoneuron decipiens. 20: Skærumhede,R.

C. filicinum. 20: Skærumhede,R.

Cyrtomnium hymenophylloides. 20: Skærumhede,R.

Dicranum sp. B. Odgaard, unpubl.: Hirtshals.

D. fuscescens var. *congestum*. 20: Skærumhede,R.

Distichium capillaceum. 20: Skærumhede,R. B. Odgaard, unpubl.: Hirtshals,T.

Ditrichum flexicaule. 20: Skærumhede,R. B. Odgaard, unpubl.: Hirtshals.

Drepanocladus aduncus or *D. polycarpus*. 17 and 19 (as *Amblystegium Kneiffii*): Lønstrup,R,U. 20 (as *A. Kneiffii*): Skærumhede,R.

D. brevifolius. 20 (as *Amblystegium latifolium*): Skærumhede,R.

D. exannulatus. 17: Øster Flade,R,U. Gulbækskjær,R.T,U. Lønstrup,R,U. Ørsø,R,U. 20 (as *Amblystegium exannulatum* and *A. Rotae*): Skærumhede,R.

D. fluitans. 17: Teklaborg,R,U. Ryd,R,U. Gulbækskjær,R,U. Lengsholm,R,U. Ørsø,R,U. Toftegård,R,U. 17 and 19: Lønstrup,R,U. 20: Skærumhede,R.

D. intermedius. 10 and 17: Lønstrup,R,U. 17: Ryd,R,U. Ørsø,R,U. Skjelgård,R,T,U. 20: Skærumhede,R.

D. polycarpus var. *capillifolius*. 20: Skærumhede,R.

D. revolvens. 20 (as *Amblystegium revolvens* and *A. Cossoni*): Skærumhede,R.

D. sendtneri. 17 (as *Amblystegium sendtneri* and *A. Wilsonii*): Øster Flade,R,U. Krattet,R,T,U. Ørsø,R,T,U. 20 (as *A. sendtneri* and *A. Wilsonii*): Skærumhede,R.

D. uncinatus. 20 (as *Amblystegium aduncum*): Skærumhede,R.

Encalypta alpina. 20: Skærumhede,R.

E. rhabdocarpa. 20: Skærumhede,R,T.

Fissidens adianthoides. 20: Skærumhede,R.

Helodium blandowii. 20 (as *Thyidium lanatum*): Skærumhede,R.

Hygrohypnum molle or *H. dilatatum*. 20: Skærumhede,R.

Hylocomium splendens. B. Odgaard, unpubl.: Hirtshals.

Hypnum revolutum. 20: Skærumhede,R.

Leptobryum pyriforme. 20: Skærumhede,R.

Leptodictyum riparium. 17: Tolstrup Hede,R,U. Ryd,R,U.

Meesea trifaria. 20: Skærumhede,R.

M. uliginosa. 20: Skærumhede,R.

Mniobryum wahlenbergii. 20 (as *Pohlia albicans*): Skærumhede,R.

Mnium marginatum. 20: Skærumhede,R.

Oncophorus virens. 20: Skærumhede,R.

Orthothecium chryseum. 20: Skærumhede,R.

Philonotis fontana. 20: Skærumhede,R.

Plagiomnium affine. 20 (as *Astrophyllum cuspidatum*): Skærumhede,R.

P. medium. 20 (as *Astrophyllum curvatulum*): Skærumhede,R.

Pohlia drummondii. 20: Skærumhede,R.

P. nutans. 20: Skærumhede,R,U.

P. obtusifolia. 20 (as *P. cuculata*): Skærumhede,R.

Polytrichum or *Pogonatum* sp. 20: Skærumhede,R.

Polytrichum sect. *juniperina*. B. Odgaard, unpubl.: Hirtshals.

P. affine. 20: Skærumhede,R.

P. alpinum. B. Odgaard. unpubl.: Hirtshals.

P. commune. 20: Skærumhede,R.

P. piliferum. 20: Skærumhede,R,U.
Racomitrium sp. B. Odgaard, unpubl.: Hirtshals.
R. ericoides. 20: Skærumhede,R.
R. lanuginosum. 20: Skærumhede,R.
Rhythidium rugosum. 20: Skærumhede,R.
Schistidium apocarpum. 20: Skærumhede,R.
Scorpidium scorpioides. 10, 17 and 19: Lønstrup,R,U. 17: Øster Flade,R,U. Ryd,R,U. Gulbækskjær,R,U. Ørsø,R,U. Skjelgård,R,U. Toftegård,R,U. 20: Skærumhede,R. B.Odgaard, unpubl.: Hirtshals.
S. turgescens. 20: Skærumhede,R.
Thuidium delicatulum or *T. recognitum*. 20: Skærumhede,R.
Timmia bavarica. 20: Skærumhede,R.
T. norvegica. 20: Skærumhede,R.
Tomenthypnum nitens. 20: Skærumhede,R. B. Odgaard, unpubl.: Hirtshals.
Tortella tortuosa. 20: Skærumhede,R.
Tortula norvegica. 20: Skærumhede,R.
T. ruralis. 17: Øster Flade, R,T,U. 20: Skærumhede,R.

Fb1. Hengelo.

Bryopsida.
Drepanocladus exannulatus. 12: Sejerø,T.
Scorpidium scorpioides. 12: Sejerø.

Fc. Late Weichselian.

Hepaticopsida.
Marchantia polymorfa. 21: Nørre Lyngby.

Sphagnopsida.
Sphagnum nemoreum. 10: Silkeborg,U.
S. teres. 10: Bovbjerg,U.

Bryopsida.
Aulacomnium palustre. 9 and 21: Nørre Lyngby. 29: Herning.
A. turgidum. 9, 17 and 21: Nørre Lyngby,T.
Brachythecium reflexum. 21: Nørre Lyngby.
Bryoerythrophyllum recurvirostre. 10: Grevinge,U.
Bryum sp. 9: Martørv Bakker. 9 and 17: Nørre Lyngby.
B. pseudotriquetrum. 10: Grevinge,U. 21: Nørre Lyngby. 32: Petersminde at Stenstrup. 41: Alkærsig,U.

Calliergon cordifolium. 9: Martørv Bakker. 10: Silkeborg,U.
C. giganteum. 9: Kvistgård. Martørv Bakker. 10: Silkeborg,U. Bovbjerg,U. 21: Nørre Lyngby. 42: Vintappermosen.
C. stramineum. 29: Herning.
Campylium calcareum or *C. sommerfeltii.* 10: Grevinge,U.
C. polygamum. 9 and 21: Nørre Lyngby,T. 9 and 32: Juelsbjerg at Stenstrup. 23: Femsølyng.
C. stellatum. 9: Allerød. 23: Nivå. 41: Alkærsig,U. 42: Vintappermosen.
Ceratodon purpureus. 9: Ejby. 9 and 17: Nørre Lyngby. 9 and 32: Juelsbjerg at Stenstrup.
Climacium dendroides. 9 and 21: Nørre Lyngby. 23: Nivå.
Cratoneuron commutatum var. *falcatum.* 9: Martørv Bakker.
C. filicinum. 9 and 17: Nørre Lyngby.
Dicranum sp. 32: Petersminde at Stenstrup,T.
Didymodon tophaceus. 34 (as *Barbula brevifolia*): Møens Klint,U.
Distichium capillaceum. 10: Grevinge,U. 32: Petersminde at Stenstrup. Juelsbjerg at Stenstrup.
Ditrichum flexicaule. 10: Grevinge,U. 23: Nivå.
Drepanocladus aduncus or *D. polycarpus.* 21 (as *Amblystegium Kneiffii*): Nørre Lyngby.
D. exannulatus. 9: Allerød. Kvistgård. Ejby. Vestergård. Martørv Bakker. 9, 17 and 21: Nørre Lyngby. 29: Herning. 43: Søborg Sø,U. 10: Silkeborg,U. B. Odgaard, unpubl.: Solsø.
D. fluitans. 9: Allerød. Vestergård.
D. intermedius. 9: Frigård. Petersminde at Stenstrup. 34: Møens Klint,U. 42: Vintappermosen.
D. revolvens. 21 (as *Amblystegium Cossoni*): Nørre Lyngby. 23: Nivå. Københavns Frihavn,U. 41 (as *Amblystegium Cossoni*): Alkærsig,U.
D. sendtneri. 9: Kvistgård. 42: Vintappermosen.
Fontinalis sp. 9: Ålsgårde,U.
F. antipyretica. 9: Kvistgård,T. 9 and 42: Vintappermosen.
F. hypnoides. 43: St. Havelse.
Hylocomium splendens. 9: Martørv Bakker. 21: Nørre Lyngby. 23: Nivå.
Leptobryum pyriforme. 21: Nørre Lyngby.
Leptodictyum riparium. 9: Nørre Lyngby.
Leskea polycarpa. 43: Søborg Sø,U.
Meesea longiseta. 9, 17 and 21: Nørre Lyngby.
M. trifaria. 42: Vintappermosen.
M. uliginosa. 9: Nørre Lyngby.
Mniobryum wahlenbergii. 9: Martørv Bakker. 21: Nørre Lyngby.
Mnium sp. 23: Nivå.

Oncophorus sp. 21 (incl. *Cynodontium* and *Cnestrum* ?): Nørre Lyngby.
Philonotis fontana. 9: Martørv Bakker. 21: Nørre Lyngby. 41: Alkærsig,U.
Plagiomnium affine. 9 (as *Astrophyllum cuspidatum*): Martørv Bakker. 21 (as *Mnium affine* var. *integrifolium*): Nørre Lyngby.
Pohlia nutans. 9: Martørv Bakker.
Polytrichum or *Pogonatum* sp. 29: Solsø.
Polytrichum affine. 9 and 17: Nørre Lyngby. 9 and 32: Juelsbjerg at Stenstrup. 29: Herning.
P. juniperinum. 9: Martørv Bakker. 9 and 21: Nørre Lyngby.
Racomitrium canescens or *R. ericoides.* 29: Herning.
Scorpidium scorpioides. 9: Vestergård. Martørv Bakker. 32: Petersminde at Stenstrup. Egebjerg at Stenstrup. 39: Kjellerup at Ringe. 46: Femsølyng. 23: Nivå. Københavns Frihavn.
S. turgescens. 9: Kvistgård. 32: Petersminde at Stenstrup. Juelsbjerg at Stenstrup. Langhøj at Stenstrup. 34: Møens Klint,U. 41: Alkærsig,U.
Thuidium sp. or *Abietinella* or *Helodium.* 9: Martørv Bakker.
Tomenthypnum nitens. 21: Nørre Lyngby. 23: Nivå. 43: Lynge.
Tortella fragilis. 10: Grevinge,U.
T. tortuosa. 23: Nivå. 29: Herning. 32: Petersminde at Stenstrup.
Tortula ruralis. 9 and 21: Nørre Lyngby. 23: Nivå.

Fc1. Bølling.

Bryopsida.
Aulacomnium palustre. 9, 17 and 21: Nørre Lyngby,U.
Calliergon stramineum. 21: Nørre Lyngby,U.
Helodium blandowii. 21: Nørre Lyngby,U.
Polytrichum juniperinum. 21: Nørre Lyngby,U.
Tomenthypnum nitens. 21: Nørre Lyngby,U.

Fc2. Older Dryas.

Bryopsida.
Bryum pseudotriquetrum. 9: Allerød,U. 23: Nivå,U.
Calliergon giganteum. 9: Allerød,U.

Fc3. Allerød.

Bryopsida.
Aulacomnium palustre. 9: Allerød. 21: Nørre Lyngby. 23: Femsølyng. Nivå,U. 24: Faurbo Knold.
Bryum sp. 9: Allerød.
B. pseudotriquetrum. 9: Allerød.
Calliergon cordifolium. 9: Allerød. 24: Faurbo Knold.
Campylium polygamum. 21: Nørre Lyngby. 23: Femsølyng.
Ceratodon purpureus. 9: Allerød.
Climacium dendroides. 9: Allerød.
Drepanocladus exannulatus. 23: Femsølyng.
D. uncinatus. 9: Allerød.
Hylocomium splendens. 9: Allerød.
Plagiomnium affine. 9 (as *Astrophyllum cuspidatum*): Allerød.
Pleurozium schreberi. 9: Allerød.
Pohlia nutans. 9: Allerød. 23: Femsølyng.
Polytrichum juniperinum. 23: Femsølyng.
Scorpidium scorpioides. 30: West Jutland.
Tomenthypnum nitens. 21: Nørre Lyngby.
Tortula ruralis. 23: Femsølyng.

Fc4. Younger Dryas.

Hepaticopsida.
Marchantia polymorfa. 21: Nørre Lyngby,U.

Sphagnopsida
Sphagnum sp. 30: West Jutland.

Bryopsida.
Aulacomnium palustre. 9: Allerød. 21: Nørre Lyngby,U. 24: Faurbo Knold.
Bryum sp. 9: Skinderbygård.
B. pseudotriquetrum. 32: Egebjerg at Stenstrup.
Calliergon giganteum. 21: Nørre Lyngby,U. 32: Egebjerg at Stenstrup.
Campylium protensum 9: Allerød.
Ceratodon purpureus. 24: Faurbo Knold.
Climacium dendroides. 21: Nørre Lyngby,U.
Distichium capillaceum. 24: Faurbo Knold.
Ditrichum flexicaule. 9: Allerød,T.

Drepanocladus aduncus or *D. polycarpus*. 21 (as *Amblystegium Kneiffii*): Nørre Lyngby,U.
D. exannulatus. 21: Nørre Lyngby,U. 23: Nivå.
D. fluitans. 32: Egebjerg at Stenstrup.
D. polycarpus var. *capillifolius*. 23: Nivå.
D. revolvens. 23: Nivå. 24: Faurbo Knold.
D. uncinatus. 21 (as *Amblystegium aduncum*): Nørre Lyngby,U. 29: Herning.
Encalypta rhabdocarpa. 9: Allerød,T.
E. streptocarpa. 32: Egebjerg at Stenstrup.
Helodium blandowii. 21: Nørre Lyngby,U.
Hylocomium splendens. 21: Nørre Lyngby,U.
Lescuraea radicosa. 24 (as *L. Breidleri*): Faurbo Knold.
Paludella squarrosa. 23: Nivå.
Philonotis tomentella. 24: Faurbo Knold.
Plagiomnium affine. 21: Nørre Lyngby,U.
Pogonatum urnigerum. 9: Allerød.
Pohlia cruda. 9: Allerød.
Polytrichum affine. 9: Skinderbygård. 25: Sejerslev,U.
P. alpinum. 21: Nørre Lyngby,U. 23: Nivå.
P. juniperinum. 21: Nørre Lyngby,U. 24: Faurbo Knold.
Scorpidium scorpioides. 23: Nivå.
Tomenthypnum nitens. 21: Nørre Lyngby,U.
Tortella tortuosa. 9: Allerød.

G. Flandrian.

Bryopsida.
Aulacomnium palustre. 46: Rungstedmose.
Bryum sp. 39: Kjellerup at Ringe.
Calliergon cordifolium. 39: Kjellerup at Ringe.
C. giganteum. 39: Kjellerup at Ringe. 45 (in 23): Vidnesdam.
C. trifarium. 39: Kjellerup at Ringe. 46: Gunnerød Mose. Øverød Mose.
Camptothecium lutescens. 45 (in 23): Vidnesdam.
Cinclidium stygium. 46: Rungstedmose.
Drepanocladus aduncus or *D. polycarpus*. 39 (as *Amblystegium Knieffii*): Kjellerup at Ringe.
D. revolvens. 13: Fjerritslev.
Meesea longiseta. 45 (in 23): Vidnesdam.
M. trifaria. 45 (in 23): Vidnesdam.

Plagiomnium medium. 39: Kjellerup at Ringe.
Polytrichum sp. 46: Rungstedmose. Rudersdalmose.
Scorpidium scorpioides. 39: Kjellerup at Ringe.
Tomenthypnum nitens. 39: Kjellerup at Ringe. 46: Bog between Blovserød and Donse.

Ga. Early Flandrian.

Sphagnopsida.
Sphagnum cuspidatum. 23: Maglemose.
S. fimbriatum. 9: Esbjerg,T.
S. palustre. 23: Maglemose.
S. subnitens. 23: Maglemose,T.
S. teres. 23: Maglemose.

Bryopsida.
Aulacomnium palustre. 9: Skinderbygård. Esbjerg,U.
Bryum pseudotriquetrum. 9: Lundbæk.
Calliergon cordifolium. 9: Esbjerg,U.
C. giganteum. 9: Skinderbygård. Lundbæk.
C. stramineum. 9: Esbjerg,U. 23: Maglemose. Københavns Frihavn. 45 (in 23): Lillemose.
C. trifarium. 45 (in 23): Lillemose.
Calliergonella cuspidata. 9: Lundbæk.
Climacium dendroides. 9: Esbjerg,U. 31: Snarup.
Dicranum scoparium. 31: Snarup,T.
Drepanocladus exannulatus. 9: Lundbæk.
D. fluitans. 23: Maglemose.
Fontinalis sp. 9: Skinderbygård. Lundbæk.
F. antipyretica. 9: Skinderbygård.
Helodium blandowii. 9: Esbjerg,U.
Hypnum cupressiforme. 23: Kongedybet,U. 31: Snarup,U.
Meesea longiseta. 45 (in 23): Lillemose.
Neckera complanata. 23: Kongedybet,U.
Paludella squarrosa. 9: Esbjerg,U.
Philonotis fontana. 9: Lundbæk.
Pogonatum urnigerum. 9: Lundbæk.
Polytrichum affine. 23: Lille Gribsø,U.
P. commune. 9: Esbjerg,U.
Scorpidium scorpioides. 9: Lundbæk.
Tomenthypnum nitens. 9: Esbjerg,U. 29: Lørup.

Ga1. Preboreal.

Sphagnopsida.
Sphagnum cuspidatum. 27: Hjortespring Mose.
S. palustre. 23: Femsølyng.
S. teres. 23: Maglemose.

Bryopsida.
Aulacomnium palustre. 23: Nivå. 39: Ringe,U.
Calliergon stramineum. 23: Københavns Frihavn,U.
C. trifarium. 23: Femsølyng.
Drepanocladus intermedius. 23: Femsølyng.
Plagiomnium ellipticum. 23: Maglemose,T.

Ga2. Boreal.

Sphagnopsida.
Sphagnum palustre. 23: Femsølyng.

Bryopsida.
Antitrichia curtipendula. 23: Kongedybet,U.
Aulacomnium palustre. 23: Nivå.
Brachythecium sp. 23: Kongedybet,U.
Calliergon trifarium. 23: Femsølyng.
Cratoneuron decipiens. 39: Kjellerup,U.
Drepanocladus intermedius. 23: Femsølyng.
Meesea trifaria. 23: Femsølyng.
Pseudobryum cinclidioides. 23: Kongedybet,U.

Gb. Middle Flandrian.

Bryopsida.
Hypnum cupressiforme. 31: Snarup.

Gb1. Atlantic.

Sphagnopsida.
Sphagnum palustre. 23: Femsølyng.

Bryopsida.
Aulacomnium palustre. 26: Fyn. 30: West Jutland.
Calliergon trifarium. 23: Femsølyng.
Calliergonella cuspidata. 30: West Jutland.
Campylium stellatum. Aaby, unpubl.: Holmegårds Mose.
Drepanocladus intermedius. 23: Femsølyng.
Scorpidium scorpioides. Aaby, unpubl.: Holmegårds Mose.

Gb2. Subboreal.

Sphagnopsida.
Sphagnum cuspidatum. 3: Draved Mose. 28: Vebbestrup.
S. fallax. 23: Maglemose,U.
S. fallax var. *angustifolium.* 23: Maglemose,U.
S. palustre. 23: Maglemose,U.
S. tenellum. 3: Draved Mose.

Bryopsida.
Aulacomnium palustre. 23: Vandmosen,U.
Calliergon stramineum. 23: Maglemose.
Dicranum scoparium. 15: Arnum.
Hylocomium splendens. 14 and 15: Jels. 15. Skrydstrup. 23: Sækkedammen,U.
Hypnum cupressiforme. 14 and 15: Jels. 15: Arnum. Skrydstrup.
H. imponens. 15: Arnum,T.
Pleurozium schreberi. 14 and 15: Jels.
Pohlia nutans. 23: Maglemose,U.
Polytrichum affine. 23: Maglemose,U. Vandmosen,U.
Rhythidiadelphus squarrosus. 14 and 15: Jels.
Scleropodium purum. 14 and 15: Jels. 15: Arnum. Skrydstrup.

Gc. Late Flandrian (Subatlantic).

Sphagnopsida.
Sphagnum cuspidatum. 1, 2 and 3: Draved Mose. 30: West Jutland. 35: Lille Vildmose. 36: Bornholm.
S. fallax. 23: Sækkedammen,U. Lille Gribsø. Vandmosen. 31: Snarup,U.
S. imbricatum. 1, 2 and 3: Draved Mose.
S. magellanicum. 1, 2 and 3: Draved Mose.

S. molle. 2 and 3: Draved Mose.
S. palustre. 23: Sækkedam,U. Femsølyng. Lille Gribsø. 31: Snarup,U.
S. papillosum. 1 and 3: Draved Mose. 30: West Jutland. 31: Snarup,U.
S. rubellum. 1, 2 and 3: Draved Mose,T. 23: Sækkedammen,U. 31: Snarup,U.
S. subsecundum. 23: Sækkedammen,U.
S. tenellum. 1, 2 and 3: Draved Mose.

Bryopsida.
Aulacomnium palustre. 23: Sækkedammen,U. Maglemose,U. Lille Gribsø. 30: West Jutland. 35: Lille Vildmose.
Calliergon giganteum. 23: Sækkedammen,U.
C. stramineum. 23: Sækkedammen,U.
Calliergonella cuspidata. 31: Snarup,U.
Climacium dendroides. 23: Sækkedammen,U.
Drepanocladus fluitans. 35: Lille Vildmose,T.
D. intermedius. 23: Sækkedammen,U.
Hypnum cupressiforme. 1: Draved Mose,T.
Leucobryum glaucum. 1: Draved Mose.
Pohlia nutans. 23: Sækkedammen,U.
Polytrichum affine. 1: Draved Mose,T.
P. commune. 35: Lille Vildmose.
Scorpidium scorpioides. 35: Lille Vildmose.

X. Age uncertain.

Sphagnopsida.
Sphagnum magellanicum or *S. palustre.* 16: Anholt.
S. papillosum. 10: Lyngs Odde near Fredericia.
S. rubellum. 16: Anholt,T.

Bryopsida.
Amblystegiella confervoides. 10: Kolding,T.
Amblystegium varium or *A. juratzkanum.* 10 (as *A. radicale*): Kolding.
Brachythecium salebrosum. 10: Kolding.
Calliergon giganteum. 10 and 44: Københavns Frihavn. 16: Anholt.
C. richardsonii. 10: Valby. Københavns Frihavn.
Camptothecium lutescens. 10: Hulkjær Vandmølle.
Campylium chrysophyllum. 10: Københavns Frihavn.
C. polygamum. 10: Kolding.

Catoscopium nigritum. 29: Ringdal.
Distichium capillaceum. 10: Kolding. Valby. Københavns Frihavn.
Ditrichum flexicaule. 10: Kolding. Valby. Københavns Frihavn.
Drepanocaldus aduncus or *D. polycarpus*. 10 (as *Amblystegium Kneiffii*): Københavns Frihavn.
D. brevifolius. 10: Valby. Københavns Frihavn.
D. exannulatus. 10: Kolding. Valby. Ordrup. Førslevgård. Københavns Frihavn. 16: Anholt. 29: Ringdal.
D. fluitans. 10: Kolding. Ordrup. Valby. 10 and 44: Københavns Frihavn.
D. intermedius. 10: Ordrup. Valby.
D. lycopodioides. 10: Valby. Københavns Frihavn.
D. revolvens. 10 (as *Amblystegium revolvens* and *A. Cossoni*): Valby. Ordrup. Københavns Frihavn.
D. sendtneri. 10: Valby. Ordrup. Københavns Frihavn.
Encalypta sp. 10: Valby.
E. rhabdocarpa. 10: Kolding.
Helodium blandowii. 10: Kolding.
Leptodictyum riparium. 10: Førslevgård.
Meesea trifaria. 10: Valby.
Mnium sp. (s.l.). 16: Anholt.
Neckera complanata. 10: Hulkjær Vandmølle.
Paludella squarrosa. 16: Anholt.
Plagiomnium medium. 10: Kolding.
Scorpidium scorpioides. 10: Ordrup. Valby. 10 and 44: Københavns Frihavn. 29: Ringdal.
Thuidium sp. or *Abietinella*. 29: Ringdal.
Tomenthypnum nitens. 10: Valby. Københavns Frihavn.

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Identification of naturally fractured reservoirs by optimal control methods*

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The dynamic behavior of naturally fractured petroleum reservoirs is described by a mathematical model based on the assumption that the reservoir rock can be represented by an array of identical, rectangular parallelopipeds where the blocks correspond to the matrix and the spacing between, to the fractures. Material balance conditions imposed on the oil and/or gas phases result, in general, in a coupled set of nonlinear partial differential equations. By solving this system of equations one gets reservoir pressure history. Physical properties of the reservoir such as porosity and permeability and those characterizing the deviation of the behavior of a medium with »double porosity« from that of a homogeneous porous medium are represented by parameters appearing in the model. This paper deals with the problem of determination of the parameters described above in real life naturally fractured reservoirs.

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In this paper the problem of estimation of naturally fractured petroleum reservoir properties on the basis of data obtained during a production test is described. More specifically, the paper deals with interference tests performed in hard formations where presence of fractures is of great importance: they act as channels between matrix and a borehole. On the other hand, their contribution to the overall porosity and their volume are negligible as compared to the matrix porosity and the total volume of the reservoir.

In an interference test one deals with a system composed of two (or more) wells: an active well (producing or injecting fluids) and an observation well. The active well is shut in after some time and the resulting pressure change is registered at the observation well. The pressure response can help determine formation continuity, degree of fracturing, and areal average transmissibility and storage between a well pair.

The problem of estimation of reservoir parameters using production data is inherently undetermined because the number of parameters usually exceeds the available data. The undeterminacy can be reduced by a classification of porous rock property distributions, each possible distribution being referred

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to one of a final number of categories. The success of this approach (also known as parametrization) requires that the number of potential categories is small.

A typical example of parametrization is the zonation technique: the estimated property distributions are assumed to be uniform within each of several regions of the reservoir (zones). Thus, they change abruptly at the boundaries of the zones causing a considerable modelling error.

An alternative approach to dimensionality reduction is that based on Bayesian estimation where an a priori statistical information concerning the unknowns is incorporated in the estimation algorithm.

Recently, several papers have been published reflecting increasing interest in methods used to detect fractures from logs (e.g., Aguilera 1976). Warren & Root (1963) pointed out that for good models of naturally fractured reservoirs the most important aspect of the model design strategy is that "all available measurements and observations are utilized, furthermore the model must be consistent with the physical inferences obtained from the performance of actual reservoirs of this particular type".

The parallel problem of estimation of properties in a homogeneous petroleum reservoir has been treated previously by Gavalas et. al. (Gavalas 1976).

Some remarks on the origin of naturally fractured reservoirs

The genesis of naturally fractured reservoirs, in which salt domes are part of a trapping system, can be conveniently explained via the fluid mechanical hypothesis for the formation of salt domes. The first to demonstrate the applicability of this hypothesis to the formation of salt domes was Nettleton (1936). He assumed that the density difference between the salt and the surrounding sediments acts as an upward driving force of buoyancy. Moreover, the salt and the overlying sediments behave like highly viscous fluids. Since the salt is covered by denser sedimentary strata, the system becomes inherently unstable and any initial perturbation (caused, for example, by some tectonic movement) will start the flow of the salt from an underlying bed to a rounded salt pillow. The next steps in this dynamic process are, broadly speaking, as follows (see Braunstein et. al. 1968):

a. the flow continues into the centre of the pillow, doming the overlying strata,

b. simultaneously with the process described in a, the area from which salt has flowed subsides,

c. the strata overlying the flowing salt are exposed to tension which causes a development of fractures.

The problem of estimation of parameters concerned with the fractured reservoir rock will be taken up in the subsequent sections.

Mathematical model of a single-phase homogeneously fractured reservoir

A petroleum reservoir can be viewed as a gigantic chemical reactor and, consequently, it is modelled according to the same principles as chemical reactions in a spatial domain. More specifically, the following classification can be used as a frame for all models (Arnold 1980):

i) global description (no diffusion, spatially homogeneous or "well stirred" case) versus local description (with diffusion, spatially inhomogeneous case),

ii) deterministic description (macroscopic, in terms of concentrations) versus stochastic description (operating with the number of particles and including internal fluctuations).

By a combination of i) and ii) one gets four essential mathematical models. In this paper we shall be concerned only with the local-deterministic type. The reader interested in more details about various reaction models may consult Prigogine et. al. (1977).

The problem of modelling a behaviour of naturally fractured reservoirs has been treated in many papers. The classical work dealing with this subject is that of Warren and Root (1963). In their model the fractured reservoir is represented by a system of identical, rectangular parallelopipeds separated by a regular network of fractures (see Fig. 1). Moreover, the formation fluid is assumed to flow through these (high conductivity) fractures. The crucial assumption i the Warren-Root model is that each fracture is parallel to one of the principal axis of permeability. A somewhat different model was suggested by Odeh (1965). He makes no assumptions about the size of the matrix blocks, their uniformity or geometric pattern. The only extension of the Odeh's model as compared with the conventional nonfractured reservoir is an introduction of the parameter β describing the degree of fracturing meant as fractures' bulk volume per unit reservoir volume. Finally, Kazemi (1969) described a naturally fractured reservoir using a multilayered system com-

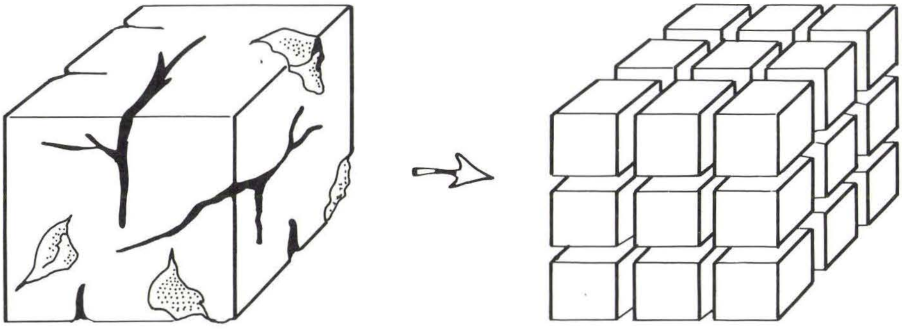

Fig. 1. Mathematical idealization of the naturally fractured reservoir.

posed of a thin, highly conductive layer representing the fracture which is adjacent to a thicker layer endowed with low conductivity and high storage capacity representing the matrix (see Fig. 2). The results given by Kazemi are consistent with those of Warren- Root and Odeh. For more details and comparative analysis of different models the reader may consult the survey paper of Crawford et. al. (Crawford 1976).

The basic differential equation governing the radial, single phase flow of oil in a naturally fractured reservoir is based on the following assumptions:

a. the reservoir rock corresponding to the primary porosity is contained within an array of blocks which act like sources feeding the fractures with oil,

b. all fluid flow is due to fractures (there is no fluid traffic in the primary blocks),

c. the reservoir is assumed to be homogeneously fractured, i.e., the fractures' flow capacity and the degree of fracturing in the reservoir are uniform,

d. the usual assumptions ensuring fully radial flow are fulfilled (see Dake 1978).

It should be noted that the Warren-Root model formally belongs to the zonation type of parametrization and, consequently, it has all the shortcomings of that approach: the constraint of uniformity of rock properties within each zone is very inflexible and does not usually correspond to geological knowledge about the reservoir. In real life petroleum reservoirs the estimated

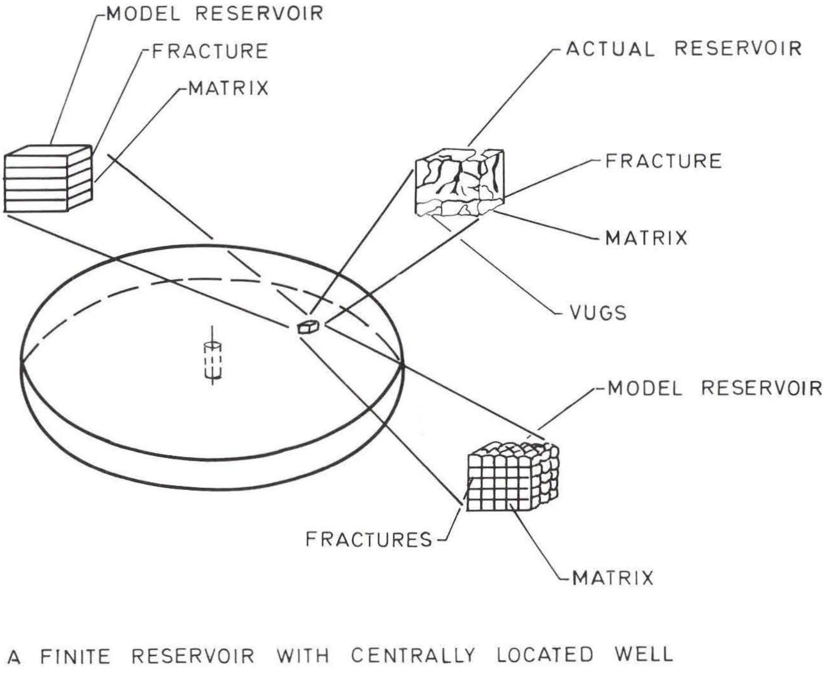

Fig. 2. Mathematical models of naturally factured reservoir [after Kazemi (1969)]

parameters cannot be described with sufficient accuracy by a piecewise constancy. Since they can be regarded as the result of several random conditions during sedimentation, a model given by a random process with a certain probability distribution seems to be much more appropriate.

Looking more closely at the Warren-Root model one can easily discover that it implies heterogeneity only on a microscopic scale. If the dimensions of the blocks are small in comparison with the dimensions of the reservoir, it may be considered as homogeneous. Thus, the "zones" in the model should be viewed as a tool in the process of averaging the unknowns rather than reflecting the existing physical spacing. In fact, it has been shown that the behaviour of a homogeneously heterogeneous system can be approximated by that of a homogeneous system with a (global) permeability equal to a geometric mean of the individual (local) permeabilities (see Matheron 1966).

In order to derive the differential equation for the fluid flow in a homogeneously heterogeneous system two pressures are defined at each point following Warren & Root (1963).

$$p_1 = \int_V p\, g_1(V)dV \;/\; \int_V g_1(V)dV, \tag{1}$$

$$p_2 = \int_V p\, g_2(V)dV \;/\; \int_V g_2(V)dV, \tag{2}$$

where V denotes an elementary volume and

$$g_1(V) = \begin{cases} 1, & \text{in the primary porosity,} \\ 0, & \text{outside of primary porosity,} \end{cases}$$

$$g_2(V) = \begin{cases} 1, & \text{in the secondary porosity,} \\ 0, & \text{outside of secondary porosity,} \end{cases}$$

and two porosities

$$\int_V g_1(V)dV = \varphi_1, \tag{3}$$

$$\int_V g_2(V)dV = \varphi_2, \tag{4}$$

We are now in a position to derive the partial differential equation for radial flow in naturally fractured reservoirs.

From the principle of mass conservation (Fig. 3)

Mass flow rate IN − Mass flow rate OUT = Rate of change of mass in the volume element

$$q\varrho_2|_{r+dr} - q\varrho_2|_r = 2\pi\, rhdr \left(\varphi_1 \frac{\partial p_1}{\partial t} + \varphi_2 \frac{\partial p_2}{\partial t}\right) \tag{5}$$

where $2\pi rhdr$ is the total volume of the infinitesimal element of thickness dr and

q=flow rate, positive for production and negative for injection,
ϱ_i=density of oil (i=1 refers to the matrix, i=2 to the fractures).

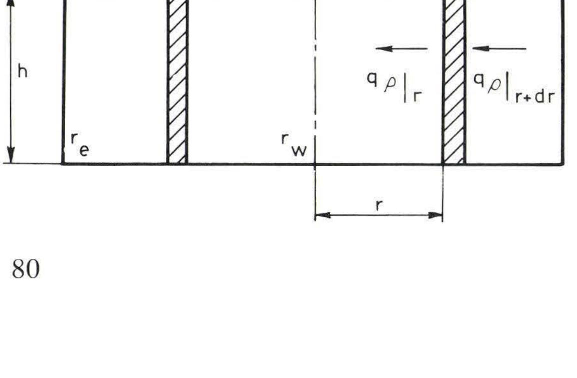

Fig. 3. Radial model of a single phase fluid flow

After some straightforward, but tedious calculations the following equations can be obtained (see Kazemi 1969).

$$\frac{\partial^2 p_{2D}}{\partial r_D^2} + \frac{1}{r_D}\frac{\partial p_{2D}}{\partial r_D} - (1\text{-}\omega)\frac{\partial p_{1D}}{\partial t_D} = \omega\frac{\partial p_{2D}}{\partial t_D}$$

$$0< r_D<\infty, \qquad t_D> 0 \tag{6}$$

$$(1\text{-}\ \omega)\frac{\partial p_{1D}}{\partial t_D} = \lambda(p_{2D}-p_{1D}),$$

$$0< r_D<\infty, \qquad t_D> 0 \tag{7}$$

where the second equation (7) describes the rate of feed to the fractures by the matrix blocks and

r_D = dimensionless radius: r/r_w,

t_D = dimensionless time:
$2.637 \times 10^{-4}(k_2t)/((c_1\varphi_1+\varphi_2c_2)\mu r_w^2)$,

k_2 = effective permeability (md),

$p_D(r_D,t_D)$= dimensionless pressure: $(p_i-p)/(\frac{141.2\ q\mu\ B}{kh})$,

μ = viscosity(cp),

λ = interporosity flow parameter:

$$\frac{\alpha k_1 r_w^2}{k_2},$$

ω = ratio of storage capacity of fractures to the total storage capacity:

$$\frac{\varphi_2c_2}{\varphi_1c_1+\varphi_2c_2}$$

The boundary conditions corresponding to the interference test are as follows

a) $p_{1D} = p_{2D} = 0,\ t_D=0,\ 0< r_D< \infty$ (8)

b) $$\lim_{r_D\to 0} r_D\frac{\partial p_{2D}}{\partial r_D} = -1, \qquad t_D>0$$

c) $$\lim_{r_D \to \infty} p_{2D} = 0 \quad , t_D > 0 \qquad (10)$$

In the next section the identification problem will be formulated. We have assumed that the solution of eqs. (6) and (7) subject to the boundary conditions (8), (9) and (10) is available either in an analytical or in a numerical form.

Formulation of the identification problem

The usual procedure used in the identification of naturally fracture reservoir properties via pressure tests is, broadly speaking, as follows:

a) define a mathematical model describing fluid flow in the reservoir rock,

b) derive the solution of the equation introduced in (a). Variable production tests can be treated by convoluting the constant rate solutions. Problems with two or more wells with different production schedules can be solved by superposition.

c) match the theoretically predicted pressure response (obtained via the mathematical model) with measured field data and identify the parameters appearing in the model. If the unknown parameters can be described by an a priori probability distribution, it should be incorporated into the model. This is equivalent to the requirement that the parameters follow some preconceived pattern.

Among the most important sources of information about the estimated parameters the following can be mentioned:

a) well logs run inside the drilled wells,
b) analysis of rock and fluid samples,
c) production tests and history,
d) seismic data.

Since changes in lithology may have similar influence on recording as the presence of fractures, the interpretation of available information should be

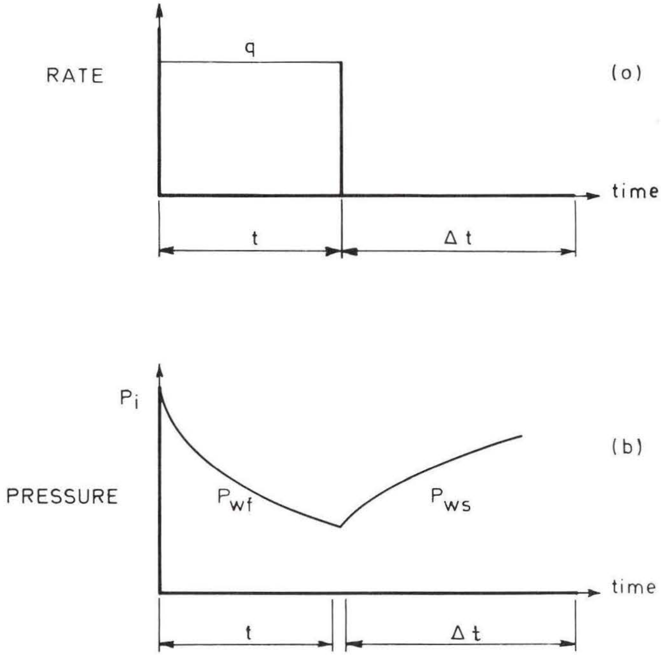

Fig. 4. Typical build-up test; (a) rate, (b) Wellbore pressure response.

done with care. In many cases the prior statistical information, concerning the unknowns, is limited to the knowledge of the size of their fluctuations.

The property estimation problem is defined as follows. Firstly, a conventional buildup test is matched to the Warren-Root model and the parameters,

$$\omega \triangleq \varphi_2 c_2/(\varphi_1 c_1+\varphi_2 c_2) \qquad (11)$$

$$\lambda \triangleq (\alpha k_1/k_2) r_w^2$$

are determined. It should be noted that the second of the above parameters can be used to calculate fracture permeability k_2 (all other parameters assumed known from laboratory experiments and core studies).

Secondly, the average diffusivity between the producing and the observation wells

$$D_{av} \triangleq k/\varphi\mu c = (k_1+k_2)/((\varphi_1 c_{1tot}+\varphi_2 c_{2tot})\mu) \qquad (13)$$

where

$$c_{1tot} = c_o + c_w S_{wm}/(1-S_{wm}) + c_1/(1-S_{wm}) \qquad (14)$$

$$c_{2tot} = c_o + c_2, \qquad (15)$$

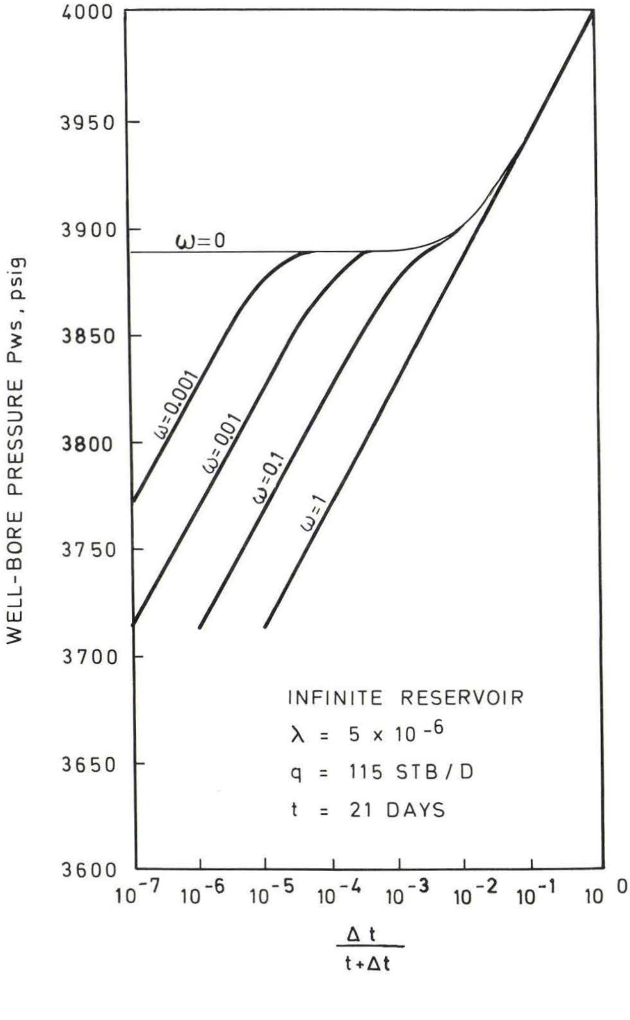

Fig. 5. Build-up curves obtained via Warren-Root model. (after Warren, 1963).

is estimated via an interference test. By combining the above equations one can estimate φ_2 and c_2. Especially, the parameter φ_2 (fracture porosity) is extremely important in reservoir engineering calculations. In som cases (when there is no porosity in the matrix blocks) it is not accessible for direct measurements and an interference test is the only way to estimate its range.

In a buildup test a well is flowed at a constant rate q for a total time t and then closed in. The rate schedule and the corresponding pressure response for a simple buildup test are shown in Fig. 4.

The parameter ω can be obtained from the following relationship

$$\omega = \text{antilog}\,(-\delta p/m) \qquad (16)$$

where

δp=vertical separation of the two straight lines(psi) of the buildup plot,

m= slope of the abovementioned lines (see Fig. 5).

Recently, a method of estimation of the parameter λ via the coordinates of the inflection point on a buildup plot was presented (see Uldrich, 1979).

In the next section the main lines of the solution of the identification problem will be described.

Strategy of the solution

The interference test data are matched to the solution of the system of equations (6) and (7) subject to the boundary conditions (8), (9) and (10) by minimizing the following functional with respect to the parameters ω and λ:

$$J_p = \sum_{i=1}^{M} (w_i) \{ p_{wint}(\omega,\lambda, (\Delta t_i)_D) - (p_{wint})_{ob} (\Delta t_i)_D\}^2 \qquad (17)$$

where

M=total number of measurements,

$p_{wint}(\Delta t_i)_D$= wellbore pressure at the observation well computed at $(\Delta t_i)_D$ from the theoretical model,

$(p_{wint})_{ob}(\Delta t_i)_D$= measured wellbore pressure at the observation well,

w_i= weighting coefficients depending on statistics of different observation errors.

The minimization of J_p corresponds to the incorporation the information contained in the pressure measurements into the estimation procedure. In order to include also the prior geological information about the identified parameters we have to redefine the objective function (17)

$$J = J_p + J_g \qquad (18)$$

The term J_g is defined in the following way

$$J_g = \gamma^T P_o^{-1} \gamma \qquad (19)$$

where

$\gamma = \{ (\omega - \hat{\omega}) (\lambda - \hat{\lambda}) \}$,

$P_o = E\{\gamma\gamma^T\}$ is the prior covariance associated with the parameter γ,

and $\hat{\omega}$, $\hat{\lambda}$ denote the prior mean values of the respective parameters.

In order to estimate the parameters ω and λ, we have to find a particular vector

$$\tau = (\omega^o, \lambda^o),$$

so that the composite functional J (defined by eq. 18) is minimum.

The above considerations can be generalized to cover a multiwell case. The simplest example is that with N wells spaced equidistantly along a straight line.

Let $\pi^T = (\omega^T, \lambda^T)$ be the 2N composite vector of parameteres, $e_1 > e_2 > \ldots > e_{2N}$ the characteristic values of P_o (P_o is a symmetric and positive definite matrix, consequently, all of its eigenvalues are real and positive), and $z(1), z(2), \ldots z(2N)$ the corresponding characteristic vectors. Defining the matrices

$$Z = (z(1), z(2), \ldots, z(2N))$$

$\Lambda = \mathrm{diag}(e_1, e_2, \ldots, e_{2N})$,

we can write the prior covariance matrix in the following form

$$P_o = Z \Lambda Z^T \qquad (20)$$

Assuming that $\pi - \hat{\pi}$ is a stationary random vector, it can be decomposed along the complete, orthonormal set of vectors $z(1), z(2), \ldots, z(2N)$

$$\pi - \hat{\pi} = Zu = \sum_{j=i}^{2N} u_j z(j) \qquad (21)$$

or (as a result of orthogonality of Z)

$$u = Z^T(\pi - \hat{\pi})$$

where $\hat{\pi} = E\{\pi\}$ and u is a Gaussian random vector with the following properties

$$E\{u\} = O$$

$$E\{uu^T\} = Z^T P_o Z = \Lambda \tag{22}$$

The above results can be used to rewrite the Bayesian penalty term in the eq.19. Using the fact that $Z^T P_o Z$ is diagonal (with entries $1/e_J$), and that $\gamma = \pi - \hat{\pi} = Zu$, we get

$$J_g = (\pi - \hat{\pi})^T P_o^{-1} (\pi - \hat{\pi}) = (Zu)^T P_o^{-1} (Zu) = u^T Z^T P_o^{-1} Z u = u^T \Lambda^{-1} u$$

Thus,

$$J_g = \sum_{j=1}^{2N} \frac{u_j^2}{e_j^2} \tag{23}$$

and the estimation problem has been reduced to the class of nonlinear least squares problems. It can be solved by, for example, the Newton-Raphson or the Gauss-Newton method (see Mc Keown 1979).

In many real life cases the reservoir properties are spatially correlated. Sometimes the best evidence of such correlation can be obtained by seismic facies analysis (see Payton, ed. 1977). Seismic facies analysis involves the description and geologic interpretation of seismic reflection parameters such as amplitude, frequency and interval velocity. Frequency can be related to lateral changes in interval velocity and, consequently, to variations in porosity.

In the case of spatial correlation of the estimated parameters the characteristic values decline with increasing j (see eq. 23) and those u_j which correspond to very small e_j will be effectively suppressed in the minimization. Thus, the modified functional J_g can be rewritten as follows

$$J_g = \sum_{j=1}^{K} \frac{u_j^2}{e_j} \tag{24}$$

The number of parameters to be estimated is now K ($u_1, \ldots u_K$) instead of 2N. This is an important contribution of seismic stratigraphy to the alleviation of the »curse of dimensionality". Unfortunately, practical applicability of this approach depends heavily on the quality of seismic data.

Concluding remarks

In this paper we have described a methodology for parameter identification in naturally fractured reservoirs. The estimation problem has been posed as a minimization of a composite functional including the prior geological information about the unknowns. Its solution will usually require the knowledge of the derivatives of the abovementioned functional with respect to the estimated parameters. An efficient calculation method using the adjoint equation approach of the optimal control theory has been given by Chavent (1975).

It should be noted that in practical applications of the described methodology some serious obstacles can be encountered. They are mainly due to a poor quality of production tests. Consequently, there will be no sufficient basis for the prior statistical information about the estimated parameters. Also, in some cases, certain combination of the parameters result in the pressure response which is identical for homogeneous and uniformly fractured cases (see Odeh 1965).

The approach to parameter identification described in this paper stresses a multidisciplinary character of a reservoir developement study: geological, geophysical and engineering knowledge must be combined in order to produce reliable estimates.

Notation

(only the parameters not defined explicitly in the paper)

φ_1 = matrix porosity, fraction
φ_2 = fracture porosity, fraction
c_o = oil compressibility, psi^{-1}
c_w = water compressibility, psi^{-1}
c_1 = matrix compressibility, psi^{-1}
c_2 = fracture compressibility, psi^{-1}
h = reservoir thickness, ft
S_{wm} = connate water saturation in the matrix, fraction
r_w = wellbore radius, ft, r_e = reservoir radius, ft
k_1 = matrix permeability, md
k_2 = fracture permeability, md
p_i = initial reservoir pressure, psi
α = shape factor depending on geometry of the matrix blocks, $1/ft^2$
B = formation volume factor, fraction

Subscripts

1 = primary porosity, 2 = secondary porosity
D = dimensionless, f=flowing (pressure), s = shut-in (pressure)
int = interference (refers to properties measured during an interference test)
w = wellbore.

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Mass: Fortran program for calculating mass-absorption coefficients

Åge Nielsen and Tom Svane Petersen

Nielsen, Å. and Petersen, T. S. 1981: Mass: fortran program for calculating mass-absorbtion coefficients *Danm. geol. Unders., Årbog 1980:* 91–103. København, 15. december 1981.

A FORTRAN program is presented for calculating the mass-absorption coefficients at different wavelengths commonly used in x-ray analysis of trace elements from the major element analysis of rock material.

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Determinations of mass-absorption coefficients in the x-ray analysis of trace elements are an important and time consuming part of the arithmetic calculation. In the course of time different methods have been used (Steele 1973, Reynolds 1963, Leroux 1962). The program MASS calculates the mass-absorption coefficients from a given major element analysis at the x-ray wavelengths normally used in trace element determinations and lists the chemical analysis and the mass-absorption coefficients. The program is coded in FORTRAN IV, and is operational on the IBM 370/165 computer (NEUCC Data Centre, Copenhagen), on the UNIVAC 1110 (RECKU Data Centre, Copenhagen) and on PDP 11/05 (Geological Survey of Greenland).

Description of method

The method is based on atomic coefficients and not on oxide coefficients. First, the cation percentages are calculated from the formula:

$$AMET_j = (AWT_j/CWT_j)WT_j$$

where AWT_j is the cation weight of element j
CWT_j is the molecular weight of oxide j
WT_j is the weight percentage of the oxide j (input)

Based on the above the total amount of $^1/_2O_2$, oxygen is calculated as

$$SUM1_i = \sum_{j=1}^{n} (WT_j\text{-}AMET_j)$$

N is equal to the number of cations. Then the mass-absorption coefficients are calculated for a specific line as follows:

$$SUM2_i = \sum_{j=1}^{n} (AMET_j \times MASK_j) \times 0.01 + SUM1_i \times MASK_{1/2O_2} \times 0.01$$

where $MASK_j$ is the mass-absorption coefficient for major element j on trace element i and $MASK_{1/2O_2}$ is the mass-absorption coefficient for oxygen on element i.

The mass-absorption coefficients for cations at a specific line are from tables given by Heinrich (1966) and are stored in the program. This procedure is repeated for all the measured x-ray lines and the values are written out together with the major element analysis. The structure of the program is shown in the flowchart of Fig. 1.

Description of data cards and parameter cards

Card No.	Column No.	Description of input
1	1–3	Number of analyses
	4–6	Number of analyses written out on each page (if not stated 14 are written out).
	7	A number to specify data format (see later).
2	1–80	Text to be written out as heading on each page.
3–N	1–60	Weight percentages of oxides, each filling 4 columns, starting with tens, followed by units, tenths and hundredths. Decimal points are not punched but there must be two decimal places.
	61–65	The sum of oxides.
	68–74	Sample number.

If column 7 on card 1 is greater than 0 the format of cards 3–N is:

3–N(4)	1–72	The oxides must have decimal points and should be separated by commas. On this card the first 11 oxides are punched.

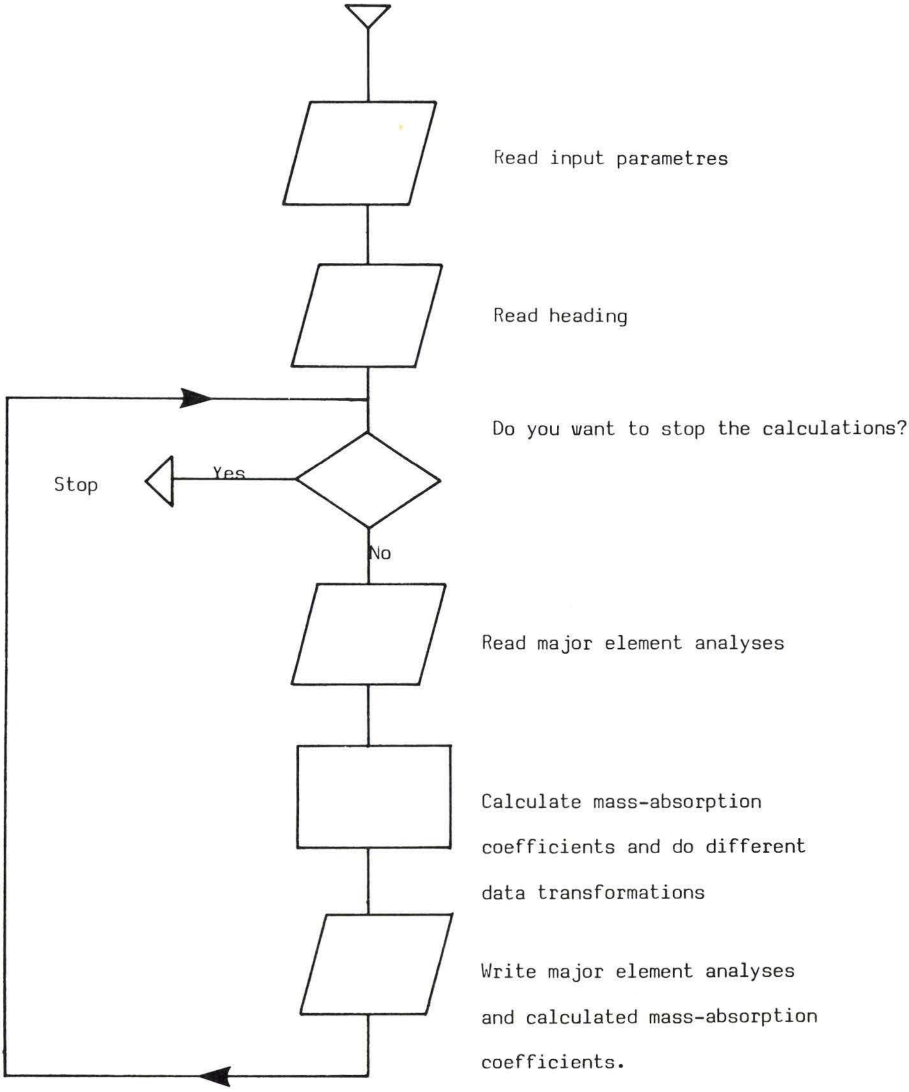

Fig. 1. General Structure.

(5)	1–72	The oxides from numbers 11 to 15, and the total as number 16, punched with decimals and separated by commas.
(6)	1–7	Sample number.

The order of oxides is specified as follows:

1:SiO_2 2:Al_2O_3 3:Fe_2O_3 4:FeO 5:MgO 6:CaO 7:Na_2O 8:K_2O 9:MnO 10:TiO_2 11:P_2O_5 12:ZrO 13:Cr_2O_3 14:CO_2 15:H_2O 16:Total.

Abbreviations used in program

Abbreviation	for	Abbreviation	for
PB LB	Lead $L_{\beta}1$	BA LB	Barium $L_{\beta}1$
TH LA	Thorium $L_{\alpha}1$	Y KA	Yttrium K_{α}
ZR KA	Zirconium K_{α}	NB KA	Niobium K_{α}
NI KA	Nickel K_{α}	SR KA	Strontium K_{α}
RB KA	Rubidium K_{α}	S KA	Sulfur K_{α}
CL KA	Chlorine K_{α}	SN KA	Tin K_{α}
TI KA	Titanium K_{α}	BA LA1	Barium $L_{\alpha}1$
CE LB1	Cerium $L_{\beta}1$	ND LA1	Neodynium $L_{\alpha}1$
CU KA	Copper K_{α}	ZN KA	Zinc K_{α}
CO KA	Cobalt K_{α}	CR KA	Chromium K_{α}
GA KA	Gallium K_{α}	V KA	Vanadium K_{α}
LA KA	Lanthanum K_{α}	SC KA	Scandium K_{α}

If trace element analysis is made at wavelengths at which massabsorption coefficients are not calculated, the necessary atomic coefficients are easily put into the program and the mass-absorption coefficients can be calculated.

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Dansk sammendrag

Der præsenteres et FORTRAN program, der beregner masseabsorptions koefficienter ved forskellige bølgelængder, som ofte bruges i røntgen-fluoroscence analyse af sporelementer, udfra hovedelementanalysen af bjergarten.

Resultaterne præsenteres i en form, som er direkte anvendelig for videre behandling af andre programmer, der foretager geokemiske beregninger og plot.

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Listing of programme:

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C***********************************************************************
C******                        VERSION 1                           *****
C      *  PROGRAM FOR CALCULATION OF MASSABSORPTION COEFFICIENTS         *
C      *  AFTER HEINREICH (1966)                                        *
C      *                                                                *
C      *  INPUT:                                                        *
C      *  NUMBER OF ANALYSES                                            *
C      *  MAJOR ELEMENT OXIDES IN FOLLOWING ORDER                       *
C      *  SIO2,AL2O3,FE2O3,FEO,MGO,CAO,NA2O,K2O,MNO,TIO2,P2O5,CR2O3,ZRO, *
C      *  CO2,H2O.                                                      *
C      *                                                                *
C      *  LINES CALCULATED:                                             *
C      *  TI KA,BA LA1,BA LB1,CE LB1,ND LA1,NB KA,ZR KA,SR KA,RB KA,Y KA *
C      *  TH KA,PB LB1,CU KA,ZN KA,CO KA,NI KA,GA KA,V KA,LA KA,SC KA   *
C      *  SN LA1,CL KA,S KA                                             *
C      *                                                                *
C      *                                                                *
C      *  NAME OF PARAMETERS:                                           *
C      *  N NUMBER OF ANALYSES                                          *
C      *  NBA NUMBER OF ANALYSES PER PAGE                               *
C      *  WT WEIGHT PERCENT MAJOR ELEMENTS                              *
C      *  TEX1 AND TEX2 ARRAY FOR TEXT(ROCK NUMBER)                     *
C      *                                                                *
C      *  PROGRAMMER:                                                   *
C      *  TOM SVANE PETERSEN, GEOLOGICAL SURVEY OF DENMARK, COPENHAGEN  *
C      *                                                                *
C      *  SUBROUTINES REQUIERED:                                        *
C      *  DATE                                                          *
C      *  TIME                                                          *
C      *                                                                *
C      *  METHOD:                                                       *
C      *  FEIKO KALSBEEK, GEOLOGICAL SURVEY OF GREENLAND, COPENHAGEN    *
C      *                                                                *
C      *                                                                *
C******                                                            ******
C***********************************************************************
      REAL SRKA(16),TIKA(16),BALA1(16),CELB1(16),NDLA1(16)
      REAL CUKA(16),ZNKA(16),CRKA(16),GAKA(16),VKA(16),LALA1(16)
      REAL SCKA(16),SNLA1(16),CLKA(16),SKA(16),COKA(16)
      REAL CWT(15),AWT(15),SUM1(15),SUM2(15),SUM3(15)
      REAL SUM4(15),SUM5(15),SUM6(15),SUM7(15),SUM8(15),SUM9(15)
      REAL SUM10(15),SUM11(15),SUM12(15),SUM13(15),SUM14(15)
      REAL SUM15(15),SUM16(15),SUM17(15),SUM18(15),SUM19(15)
      REAL SUM20(15),SUM21(15),SUM22(15),SUM23(15),SUM24(15)
      REAL SUM25(15),SUM26(15)
      REAL NBKA(16),THLA(16),NIKA(16),BALB(16),PBLB(16)
      REAL YKA(16),ZRKA(16)
      DIMENSION OX1(16),OX2(16),BPT(30)
      DIMENSION FONM(3),FOOX(3),FRMT(34)
      REAL AMET(20,20),WT(20,20),RBMA(16)
      INTEGER TEX1(15),TEX2(15),TEX3(16),ELN1(24),ELN2(24),TEX4(20)
      DATA ELN1/´RB´,´PB´,´ Y´,´ZR´,´NB´,´TH´,´NI´,
     * ´SR´,´BA´,´TI´,´BA´,´CE´,´ND´,´CU´,´ZN´,
     * ´CO´,´CR´,´GA´,´ V´,´LA´,´SC´,´SN´,´CL´,´ S´/
      DATA ELN2/´KA´,´LB1´,´KA´,´KA´,´KA´,´LA1´,´KA´,
     * ´KA´,´LB1´,´KA´,´LA1´,´LB1´,´LA1´,´KA´,´KA´,
     * ´KA´,´KA´,´KA´,´KA´,´LA1´,´KA´,´LA1´,´KA´,´KA´/
      DATA CWT/60.09,101.96,159.70,71.85,40.32,56.08,61.98,94.20,70.94,
     1 79.9,141.95,123.22,152.02,44.01,18./
      DATA FONM,FOOX,BLNK,PRSNT,FILL,ENDF/4H(6X,,4HA2,3,2HX,,4H(4X,
60:>
```

```
      1 ,4H2A3,,3H1X,,2H6X,4HF6.2,4H,1X,,1H)/
        DATA OX1/2HSI,2HAL,2HFE,2HFE, 2HMG,2HCA,2HNA,2HK2,2HMN,2HTI,2HP2,
      1 2HZR,2HCR,2HCO,2HH2,2HSU/
        DATA OX2/2HO2,3H2O3,3H2O3,1HO,1HO,1HO,2H2O,1HO,1HO,2HO2,2HO5,
      1 2H2O,3H2O3,1H2,1HO,1HM/
        DATA TEX3/´SI´,´AL´,´  ´,´FE´,´MG´,´CA´,´NA´,´K´,
      *  ´MN´,´TI´,´ P´,´  ´,´  ´,´  ´,´ H´,´ O´/
C
C       MASSABSORPTION  FOR THE PARTICULAR WAVELENGTHS.
C
        DATA TIKA /304.3,247.0,185.6,185.6,197.9,772.2,151.9,685.0
      * ,165.1,110.6,370.0,0.,0.,0.,0.,65.7/
        DATA AWT/28.09,53.96,111.70,55.85,24.31,40.08,45.98,78.20,
      * 54.94,47.90,61.94,0.,0.,0.,2.02/
        DATA RBMA/15.0,12.0,78.0,78.0,9.5,39.3,7.3,34.5,70.5,
      * 50.5,18.2,0.,0.,0.,0.,3.1/
        DATA BALA1/312.6,253.9,190.6,190.6,203.3,793.2,156.1,703.7,
      * 169.5,113.6,380.2,0.,0.,0.,0.,67.6/
        DATA CELB1/198.7,161.0,121.9,121.9,128.8,506.5,98.9,448.6,
      *  108.4,664.4,241.6,0.,0.,0.,0.,42.6/
        DATA NDLA1/201.9,163.7,123.9,123.9,130.9,514.8,100.5,456.0,
      *  110.2,654.9,245.6,0.,0.,0.,0.,43.3/
        DATA CUKA/61.4,49.6,311.1,311.1,39.5,158.6,30.3,139.8,
      * 281.6,202.6,74.7,0.,0.,0.,0.,12.9/
        DATA ZNKA/50.4,40.7,256.3,256.3,32.4,130.5,24.8,115.0,
      * 232.0,166.8,61.3,0.,0.,0.,0.,10.5/
        DATA COKA/92.8,75.0,57.6,57.6,59.8,238.6,45.9,210.7
      * ,422.5,304.4,112.9,0.,0.,0.,0.,19.6/
        DATA CRKA/183.8,149.0,113.0,113.0,119.1,469.2,91.4,415.4
      * ,100.5,597.0,223.6,0.,0.,0.,0.,39.4/
        DATA GAKA/41.7,33.6,212.8,212.8,26.7,108.1,20.5,95.2
      * ,192.6,138.3,50.7,0.,0.,0.,0.,8.7/
        DATA VKA/235.2,190.8,144.0,144.0,152.7,598.6,117.2,503.4
      * ,128.1,85.8,286.0,0.,0.,0.,0.,50.6/
        DATA LALA1/279.5,226.9,170.7,170.7,181.6,710.0,139.4,629.6
      * ,151.8,101.7,339.9,0.,0.,0.,0.,60.3/
        DATA SCKA/399.5,324.7,242.7,242.7,260.3,1011.1,199.8,897.7
      * ,215.9,144.6,485.9,0.,0.,0.,0.,86.7/
        DATA SNLA1/642.9,523.4,387.9,387.9,420.3,168.4,322.7,142.3
      * ,345.0,231.1,781.9,0.,0.,0.,0.,140.8/
        DATA CLKA/1367.8,1116.6,816.4,816.4,899.2,354.4,690.2,299.5
      * ,726.1,486.4,1663.6,0.,0.,0.,0.,303.7/
        DATA SKA/1949.3,1593.4,1157.5,1157.5,1284.8,502.4,986.2,424.6
      * ,1029.5,689.6,2370.7,0.,0.,0.,0.,435.5/
        DATA PBLB/17.6,14.1,91.2,91.2,11.2,46.1,8.6,40.4,
      * 72.5,59.1,21.4,0.,0.,0.,0.,3.6/
        DATA YKA/11.0,8.9,57.7,57.7,7.0,29.0,5.4,25.5,
      * 52.2,37.3,13.4,0.,0.,0.,0.,2.2/
        DATA ZRKA/9.5,7.6,49.9,49.9,6.0,25.1,4.6,22.0,
      * 45.2,32.3,11.6,0.,0.,0.,0.,1.9/
        DATA NBKA/8.2,6.6,43.2,43.2,5.2,21.7,4.0,19.0,
      *  39.6,27.9,10.0,0.,0.,0.,0.,1.7/
        DATA THLA/16.3,13.1,84.8,84.8,10.4,42.8,8.0,37.6,
      * 76.7,54.9,19.9,0.,0.,0.,0.,3.3/
        DATA NIKA/75.2,60.7,379.6,376.6,48.4,193.7,37.2,
      * 171.0,343.6,247.3,91.4,0.,0.,0.,0.,15.8/
        DATA SRKA/12.8,10.3,66.8,66.8,8.1,33.7,6.3,33.7,
      * 60.5,43.3,15.6,0.,0.,0.,0.,2.6/
        DATA BALB/251.9,204.4,154.1,154.1,163.6,640.7,
      * 125.6,567.9,137.0,91.8,307.4,0.,0.,0.,0.,54.2/
```

```
C
C       INPUT NUMBER OF ANALYSES
C
        WRITE(6,230)
230     FORMAT(/' **TYPE NUMBER OF ANALYSIS,NUMBER OF ANALYSIS '
     *   'ON EACH PAGE AND CODE FOR FORMAT')
        READ(5,101)N,NBA,IFOR
101     FORMAT(2I3,I1)
        WRITE(6,221)
221     FORMAT( ' **TYPE HEADING OF THE PROBLEM')
        READ(5,106)(TEX4(IA),IA=1,20)
106     FORMAT(20A4)
231     FORMAT(/' **TYPE ANALYSES IN SPECIFIED FORMAT(SEE MANUAL)')
        WRITE(6,231)
        IB=0
        IF(NBA.EQ.0)NBA=14
800     CONTINUE
        IF(N-NBA) 30,30,31
30      NN=N
        IB=1
        GO TO 32
31      CONTINUE
        N=N-NBA
        NN=NBA
32      CONTINUE
        DO 1 IA=1,NN
        SUM1(IA)=0.
        SUM4(IA)=0.
        SUM5(IA)=0.
        SUM6(IA)=0.
        SUM7(IA)=0.
        SUM8(IA)=0.
        SUM9(IA)=0.
        SUM10(IA)=0.
        SUM11(IA)=0.
        SUM2(IA)=0.
        SUM3(IA)=0.
        SUM12(IA)=0.
        SUM13(IA)=0.
        SUM14(IA)=0.
        SUM15(IA)=0.
        SUM16(IA)=0.
        SUM17(IA)=0.
        SUM18(IA)=0.
        SUM19(IA)=0.
        SUM20(IA)=0.
        SUM21(IA)=0.
        SUM22(IA)=0.
        SUM23(IA)=0.
        SUM24(IA)=0.
        SUM25(IA)=0.
        SUM26(IA)=0.
        SUM19(IA)=0.
1       CONTINUE
        I=0
70      CONTINUE
        I=I+1
        IF(IFOR)75,75,76
75      READ(5,100)(WT(I,J),J=1,16),TEX1(I),TEX2(I)
100     FORMAT(15F4.2,F5.2,2X,A3,A4)
180:>
```

```
      GO TO 77
76    CONTINUE
      READ(5,105)(WT(I,J),J=1,16),TEX1(I),TEX2(I)
105   FORMAT()
77    CONTINUE
      DO 15 II=1,15
      AMET(II,I)=(AWT(II)/CWT(II))*WT(I,II)
C
C     CALCULATE ATOMIC PERCENTAGE  FOR MAJOR ELEMENTS
C
      AHB=WT(I,II)-AMET(II,I)
      SUM1(I)=AMET(II,I)+SUM1(I)
15    SUM2(I)=AHB+SUM2(I)
      DO 16 IL=1,15
      AMAS2=AMET(IL,I)*PBLB(IL)*0.01
      AMAS3=AMET(IL,I)*YKA(IL)*0.01
      AMAS4=AMET(IL,I)*ZRKA(IL)*0.01
      AMAS5=AMET(IL,I)*NBKA(IL)*0.01
      AMAS6=AMET(IL,I)*THLA(IL)*0.01
      AMAS7=AMET(IL,I)*NIKA(IL)*0.01
      AMAS8=AMET(IL,I)*SRKA(IL)*0.01
      AMAS9=AMET(IL,I)*BALB(IL)*0.01
      AMAS12=AMET(IL,I)*TIKA(IL)*0.01
      AMAS13=AMET(IL,I)*BALA1(IL)*0.01
      AMAS14=AMET(IL,I)*CELB1(IL)*0.01
      AMAS15=AMET(IL,I)*NDLA1(IL)*0.01
      AMAS16=AMET(IL,I)*CUKA(IL)*0.01
      AMAS17=AMET(IL,I)*ZNKA(IL)*0.01
      AMAS18=AMET(IL,I)*COKA(IL)*0.01
      AMAS19=AMET(IL,I)*CRKA(IL)*0.01
      AMAS20=AMET(IL,I)*GAKA(IL)*0.01
      AMAS21=AMET(IL,I)*VKA(IL)*0.01
      AMAS22=AMET(IL,I)*LALA1(IL)*0.01
      AMAS23=AMET(IL,I)*SCKA(IL)*0.01
      AMAS24=AMET(IL,I)*SNLA1(IL)*0.01
      AMAS25=AMET(IL,I)*CLKA(IL)*0.01
      AMAS26=AMET(IL,I)*SKA(IL)*0.01
      SUM4(I)=SUM4(I)+AMAS2
      SUM5(I)=SUM5(I)+AMAS3
      SUM6(I)=SUM6(I)+AMAS4
      SUM7(I)=SUM7(I)+AMAS5
      SUM8(I)=SUM8(I)+AMAS6
      SUM9(I)=SUM9(I)+AMAS7
      SUM10(I)=SUM10(I)+AMAS8
      SUM11(I)=SUM11(I)+AMAS9
      SUM12(I)=SUM12(I)+AMAS12
      SUM13(I)=SUM13(I)+AMAS13
      SUM14(I)=SUM14(I)+AMAS14
      SUM15(I)=SUM15(I)+AMAS15
      SUM16(I)=SUM16(I)+AMAS16
      SUM17(I)=SUM17(I)+AMAS17
      SUM18(I)=SUM18(I)+AMAS18
      SUM19(I)=SUM19(I)+AMAS19
      SUM21(I)=SUM21(I)+AMAS21
      SUM22(I)=SUM22(I)+AMAS22
      SUM23(I)=SUM23(I)+AMAS23
      SUM24(I)=SUM24(I)+AMAS24
      SUM25(I)=SUM25(I)+AMAS25
      SUM26(I)=SUM26(I)+AMAS26
      SUM20(I)=SUM20(I)+AMAS20
```

```
      AMAS=AMET(IL,I)*RBMA(IL)*0.01
16    SUM3(I)=SUM3(I)+AMAS
      SUM3(I)=SUM3(I)+SUM2(I)*RBMA(16)*0.01
      SUM4(I)=SUM4(I)+SUM2(I)*PBLB(16)*0.01
      SUM5(I)=SUM5(I)+SUM2(I)*YKA(16)*0.01
      SUM6(I)=SUM6(I)+SUM2(I)*ZRKA(16)*0.01
      SUM7(I)=SUM7(I)+SUM2(I)*NBKA(16)*0.01
      SUM8(I)=SUM8(I)+SUM2(I)*THLA(16)*0.01
      SUM9(I)=SUM9(I)+SUM2(I)*NIKA(16)*0.01
      SUM10(I)=SUM10(I)+SUM2(I)*SRKA(16)*0.01
      SUM11(I)=SUM11(I)+SUM2(I)*BALB(16)*0.01
      SUM12(I)=SUM12(I)+SUM2(I)*TIKA(16)*0.01
      SUM13(I)=SUM13(I)+SUM2(I)*BALA1(16)*0.01
      SUM14(I)=SUM14(I)+SUM2(I)*CELB1(16)*0.01
      SUM15(I)=SUM15(I)+SUM2(I)*NDLA1(16)*0.01
      SUM16(I)=SUM16(I)+SUM2(I)*CUKA(16)*0.01
      SUM17(I)=SUM17(I)+SUM2(I)*ZNKA(16)*0.01
      SUM18(I)=SUM18(I)+SUM2(I)*COKA(16)*0.01
      SUM19(I)=SUM19(I)+SUM2(I)*CRKA(16)*0.01
      SUM20(I)=SUM20(I)+SUM2(I)*GAKA(16)*0.01
      SUM21(I)=SUM21(I)+SUM2(I)*VKA(16)*0.01
      SUM22(I)=SUM22(I)+SUM2(I)*LALA1(16)*0.01
      SUM23(I)=SUM23(I)+SUM2(I)*SCKA(16)*0.01
      SUM24(I)=SUM24(I)+SUM2(I)*SNLA1(16)*0.01
      SUM25(I)=SUM25(I)+SUM2(I)*CLKA(16)*0.01
      SUM26(I)=SUM26(I)+SUM2(I)*SKA(16)*0.01
      IF(I-NN)70,71,71
71    CON TINUE
C
C*****************************************************************
C     WRITE PROCEDURE
C*****
      WRITE(6,205)
205   FORMAT(1H1,'        MASSABSORPTION CALCULATION')
      WRITE(6,206)
      WRITE(6,5000)
5000  FORMAT(/)
C
C     WRITE ROCK NAME
C
      WRITE(6,222)(TEX4(IK),IK=1,20)
222   FORMAT(/20A4/)
      WRITE(6,6000)(TEX1(ID),TEX2(ID),ID=1,NN)
6000  FORMAT(10H TROG. NO    16(A3,A4))
      WRITE(6,6001)
6001  FORMAT(/)
      DO 61 I=1,3
61    FRMT(I)=FOOX(I)
      DO 67 I=1,16
      M=0
      L=4
      DO 65 K=1,NN
C
C     CHECK IF WT PERCENT IS  ZERO
C
      IF(WT(K,I))63,62,63
C     NOT PRESENT
62    FRMT(L)=BLNK
      GO TO 64
C
```

```
C       OXIDE-I PRESENT
C
63      M=M+1
        BPT(M)=WT(K,I)
        FRMT(L)=PRSNT
64      FRMT(L+1)=FILL
65      L=L+2
C
C       CHECK IF ANY ANALYSES HAS OXIDE-I
C
        IF(M)67,67,66
66      FRMT(L)=ENDF
206     FORMAT(2(/))
C
C       WRITE OXIDES
C
        WRITE(6,FRMT)OX1(I),OX2(I),(BPT(K),K=1,M)
67      CONTINUE
C
C       WRITE MASSABSORPTION COEFFICIENTS
C
        WRITE(6,206)
        WRITE(6,220)
220     FORMAT( '    **MASSABSORPTION COEFFICIENT ')
        WRITE(6,207)ELN1(1),ELN2(1),(SUM3(JB),JB=1,NN)
        WRITE(6,207)ELN1(2),ELN2(2),(SUM4(JB),JB=1,NN)
        WRITE(6,207)ELN1(3),ELN2(3),(SUM5(JB),JB=1,NN)
        WRITE(6,207)ELN1(4),ELN2(4),(SUM6(JB),JB=1,NN)
        WRITE(6,207)ELN1(5),ELN2(5),(SUM7(JB),JB=1,NN)
        WRITE(6,207)ELN1(6),ELN2(6),(SUM8(JB),JB=1,NN)
        WRITE(6,207)ELN1(7),ELN2(7),(SUM9(JB),JB=1,NN)
        WRITE(6,207)ELN1(8),ELN2(8),(SUM10(JB),JB=1,NN)
        WRITE(6,207)ELN1(9),ELN2(9),(SUM11(JB),JB=1,NN)
        WRITE(6,207)ELN1(10),ELN2(10),(SUM12(JB),JB=1,NN)
        WRITE(6,207)ELN1(11),ELN2(11),(SUM13(JB),JB=1,NN)
        WRITE(6,207)ELN1(12),ELN2(12),(SUM14(JB),JB=1,NN)
        WRITE(6,207)ELN1(13),ELN2(13),(SUM15(JB),JB=1,NN)
        WRIT(6,207)ELN1(14),ELN2(14),(SUM16(JB),JB=1,NN)
        WRITE(6,207)ELN1(15),ELN2(15),(SUM17(JB),JB=1,NN)
        WRITE(6,207)ELN1(16),ELN2(16),(SUM18(JB),JB=1,NN)
        WRITE(6,207)ELN1(17),ELN2(17),(SUM19(JB),JB=1,NN)
        WRITE(6,207)ELN1(18),ELN2(18),(SUM20(JB),JB=1,NN)
        WRITE(6,207)ELN1(19),ELN2(19),(SUM21(JB),JB=1,NN)
        WRITE(6,207)ELN1(20),ELN2(20),(SUM22(JB),JB=1,NN)
        WRITE(6,207)ELN1(21),ELN2(21),(SUM23(JB),JB=1,NN)
        WRITE(6,207)ELN1(22),ELN2(22),(SUM24(JB),JB=1,NN)
        WRITE(6,207)ELN1(23),ELN2(23),(SUM25(JB),JB=1,NN)
        WRITE(6,207)ELN1(24),ELN2(24),(SUM26(JB),JB=1,NN)
207     FORMAT(T3,A3,A3,T11,14F7.2)
        IF(IB) 800,800,900
900     CONTINUE
        CALL DATE(NDATE)
        CALL TIME(NTIME)
        CALL DATE(NDATE)
        WRITE(6,1257)NDATE,NTIME
1257    FORMAT(2(/),2(' *'),'***** DATE ',A6,'**  TIME ',
     2 A6,' ** BY GEOEDB MASS VER 2 *****' )
        STOP
        END
EOF:359 SCAN:58
```

```
SUBROUTINE TIME(NTIME)
CALL ERTRAN(9,NDATE,NTIME)
RETURN
END
```

```
SUBROUTINE DATE(NDATE)
CALL ERTRAN(9,NDATE,NTIME)
RETURN
END
```

An example of execution of the programme:

```
§XQT GGU*GEOKEMI.MASS2

 **TYPE NUMBER OF ANALYSIS,ANALYSIS NUMBER ON EACH PAGE AND FORMAT
> 8 80
 **TYPE HEADING OF THE PROBLEM
> ANALYSES FROM TOSKANA, ITALY.

 **TYPE ANALYSIS IN SPECIFIED FORMAT(SEE MANUAL)
>
51211856 504 225 280 765 175 781 013 079 050           058 9907    31201
52972034 443 121 127 538 250 924 014 060 034           104 9946    31203
50301886 343 376 277 795 192 823 012 079 052           090 9955    31208
52852006 264 286 135 554 244 927 014 060 034           137 9946    31210
51111837 389 329 278 764 195 811 012 078 050           082 9936    31212
51461879 412 281 252 733 201 803 012 076 045           109 9949    31213
49041890 475 223 266 824 154 901 012 073 045           153 9920    31216
49681733 402 295 4311038 165 595 010 084 042           183 9946    31218
```

MASSABSORPTION CALCULATION

ANALYSES FROM TOSKANA, ITALY.

TROG. NO	31201	31203	31208	31210	31212	31213	31216	31218
SI 02	51.21	52.97	50.30	52.85	51.11	51.46	49.04	49.68
AL 203	18.56	20.34	18.86	20.06	18.37	18.79	18.90	17.33
FE 203	5.04	4.43	3.43	2.64	3.89	4.12	4.75	4.02
FE 0	2.25	1.21	3.76	2.86	3.29	2.81	2.23	2.95
MG 0	2.80	1.27	2.77	1.35	2.78	2.52	2.66	4.31
CA 0	7.65	5.38	7.95	5.54	7.64	7.33	8.24	10.38
NA 20	1.75	2.50	1.92	2.44	1.95	2.01	1.54	1.65
K2 0	7.81	9.24	8.23	9.27	8.11	8.03	9.01	5.95
MN 0	.13	.14	.12	.14	.12	.12	.12	.10
TI 02	.79	.60	.79	.60	.78	.76	.73	.84
P2 05	.50	.34	.52	.34	.50	.45	.45	.42
H2 0	.58	1.04	.90	1.37	.82	1.09	1.53	1.83
SU M	99.07	99.46	99.55	99.46	99.36	99.49	99.20	99.46

**MASSABSORPTION COEFFICIENT

RB KA	15.25	14.20	15.45	14.26	15.31	15.08	15.41	15.25
PB LB1	17.84	16.62	18.08	16.68	17.92	17.65	18.03	17.85
Y KA	11.21	10.44	11.36	10.48	11.26	11.09	11.33	11.21
ZR KA	9.68	9.01	9.80	9.04	9.72	9.57	9.78	9.68
NB KA	8.39	7.82	8.50	7.84	8.43	8.30	8.48	8.40
TH LA1	16.56	15.43	16.78	15.48	16.64	16.38	16.73	16.57
NI KA	75.62	70.60	76.57	70.81	75.94	74.81	76.41	75.63
SR KA	13.30	12.45	13.48	12.50	13.37	13.16	13.47	13.24
BA LB1	189.97	187.72	192.79	188.22	191.19	189.85	195.34	191.90
TI KA	229.40	226.71	232.80	227.31	230.88	229.27	235.87	231.72
BA LA1	235.72	232.96	239.21	233.57	237.24	235.58	242.37	238.10
CE LB1	152.67	150.21	154.90	150.60	153.61	152.47	156.71	154.39
ND LA1	155.08	152.59	157.34	152.99	156.02	154.88	159.19	156.81
CU KA	61.89	57.75	62.69	57.96	62.17	61.23	62.54	61.91
ZN KA	50.84	47.43	51.51	47.60	51.08	50.30	51.38	50.87
CO KA	71.72	70.57	72.74	70.76	72.13	71.59	73.59	72.44
CR KA	141.22	138.95	143.29	139.32	142.09	141.04	144.97	142.81
GA KA	42.11	39.28	42.66	39.42	42.31	41.67	42.56	42.13
V KA	175.65	173.22	178.19	173.68	176.73	175.49	180.40	177.88
LA LA1	210.77	208.28	213.89	208.83	212.12	210.64	216.72	212.90
SC KA	301.12	297.62	305.57	298.40	303.05	300.95	309.59	304.14
SN LA1	320.93	323.56	320.43	322.82	320.91	321.62	315.44	317.46
CL KA	684.13	689.89	683.04	688.31	684.08	685.65	672.42	676.79
S KA	975.83	984.17	974.27	981.90	975.75	978.03	959.12	965.39

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