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Comparative spore morphology of the living Lycopodiaceae, I. European spores

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Abstract: The spores of nine European Lycopodiaceae species from the genera Lycopodium, Huperzia, Lepidotis and Diphasium are compared. Five morphotypes are distinguished on the basis of spore wall ornamentation.

INTRODUCTION

The spores of recent Lycopodiaceae have been studied by many authors, as listed ERDTMAN and SORSA (1971, p.111., and p.188.). GREGUSS (1941) figured the spores of six Central European Lycopodiaceae species, KNOX (1950), on the basis of spore ornamentation, established five morphotypes: three foveolate (selago, phlegmaria, verticillatum), one reticulate (clavatum) and one echinate (densum). KRUTZSCH (1963) has studied spores of living Lycopodiaceae genera, namely, Phyllo-glossum, Urostachys, Lycopodium and created four morphological groups: foveolate, reticulate, hamulate and echinate morphogroups, with altogether twelwe morphotypes. Spore descriptions of some modern Lycopodiaceae can be found in the works of ERDTMAN, BERGLUND and PRAGLOWSKI (1961), ERDTMAN and SORSA (1971). The pollen and spore key prepared by NILSSON and PRAGLOWSKI (ERDTMAN, PRAGLOWSKI, NILSSON 1963) was also useful information for us.

TUTIN et al. (1964) in Flora Europaea I., subdivided the family Lycopodiaceae into four genera and placed there ten species which occur also in Europe.
These are as follows: 1. Genus: Huperzia Bernh.: Huperzia selago, 2. Genus: Lepidotis Beauv.: L. cernua, L. inundata, 3. Genus: Lycopodium L.: L. annotinum, L. clavatum, L. dubium, 4. Genus: Diphasium C. Presl: D. complanatum, D. tristachyum, D. issleri, D. alpinum.

In this paper the following problems were investigated:

1. Is it possible to separate the four genera on the basis of spore morphology?
2. Which qualitative and quantitative characteristics can be used to identify the species?
3. What is the geographical distribution of the species investigated?
4. In what morphological groups and morphological types can the spores of the European Lycopodiaceae be arranged?
5. Is there any morphological similarity between the fossil dispersed spores and the recent spores of the Lycopodiaceae species studied by the authors?

MATERIAL AND METHOD

Spore samples were collected from selected herbarium specimens which are deposited in Herbarium of Hungarian Natural History Museum.

The following specimens were taken from the herbarium (BP):

Registration No.	Species	Locality
43482	Lycopodium annotinum L.	Bohemia australis, montis sokol (Antigel), prope vicum Kvilda, 1150 m. s. m.
43382	Lycopodium clavatum L.	Felkaer Thal (now this place is Czechoslovakia)
43436	Diphasium alpinum (L.) Rothm.	W Greenland: Godthab, SW of Lille Malene
43360	Diphasium complanatum (L.) Rothm.	Pálháza, montes Sátorhegység (Hungary)
45133	Diphasium issleri (Rouy) Holub	Bad Wildungen, Hessen, Deutschland
45273	Diphasium tristachyum (Pursh) Rothm.	Groenl.
43397	Lepidotis cernua (L.) Beauv.	Sierra Maestra, Mt. Gran Piedra, Cuba
45132	Lepidotis inundata (L.) C. Börner	Senice (Czechoslovakia)
45131	Huperzia selago (L.) Bernh. ex Schrank & Mart	Alpe Serbán, supra pagum Terebesfejérpatak (now it is Roumania)

Samples were taken using Erdtman's method for recent spores and pollen grains. The slides were preserved in glycerine-yelly. Observations and microphotographs were made using an NfpK-light microscope.

RESULTS

We have examined spores of nine of the ten European species of the genera Lycopodiaceae (we did not have any material of the species Lycopodium dubium Zoega) and mapped the areas of distribution of the species (Hultén 1958, Jalas et al. 1972 and Meusel et al. 1965). Following Krutzsch's method for grouping the spores, we have placed them into five morphotypes of three morphogroups.

Morphogroup I: Reticulate sculpture

annotinum - morphotype: distal surface of spores reticulate, muri winding; lack of ornamentation on proximal surface clearly seen.

Lycopodium annotinum L. 1753
Plate I., Figs 1-3.

Description: spores trilete, laesurae distinct, reaching the equator. Amb rounded triangular. Distal face with a perfect reticulum. Lumina of reticulum 7 µ to 10 µ in basal diameter, irregularly pentagonal and hexagonal in outline. Muri membraneous, 0.7 µ wide, 2.5-3 µ high. Proximal face smooth or faintly scabrate. Exine 3-4 µ thick. Spore size: 41-46 µ.

clavatum - morphotype: spores reticulate both proximally and distally, but reticulum on distal face well developed, on proximal face less so.

Lycopodium clavatum L. 1753
Plate I., Figs 4-9.

Description: spores trilete, length of laesurae 13-15 µ, 2/3 of spore radius. Amb subcircular to circular. Reticulate both distally and proximally. Muri conspicuously winding, lumina of reticulum irregularly polygonal, 3-7 u in diameter. Height of muri 4-5 µ, ca. 0.5 µ wide. Exine 3 µ thick. Spore size: 37-40 µ.

Diphasium alpinum (L.) Rothm. 1944
Plate II., Figs 1-3.

Description: spores trilete, laesurae distinct, length 3/4 of spore radius, with lips. Reticulate both distally and proximally. On proximal face contact area unornamented, remaining part reticulate. Lumina of distal reticulum rounded polygonal, 7-11 µ in diameter. Muri 1.5-2 µ wide, and 6-7 µ high. Exine 4-5 µ thick. Spore size: 42-47 µ (excluded muri).

Diphasium complanatum (L.) Rothm. 1944
Plate II., Figs 4-6.

Description: spores trilete, laesurae straight, almost reaching the equator, with membraneous lips, 1.5 µ wide, 2 u high. Laesura arms about 15 µ. Amb subcircular. Reticulate both distally and proximally. Distal face with a more or less perfect reticulum. Lumina of reticulum irregularly hexagonal in outline. Muri faintly winding. Height of muri 3 µ wide 0.5 µ. Proximal face with tangentially arranged muri of reticulum running to osilate contact area. Exine 3 u thick. Spore size: 35-37 µ.

Diphasium issleri (Rouy) J. Holub 1960
Plate III., Figs 1-3.

Description: spores trilete, laesurae straight, long, reaching almost the equator, with lips. Amb subcircular. Reticulate both distally and proximally. Distal face with perfect reticulum. Lumina of reticulum 6-8 µ in diameter, regularly hexagonal, muri straight, 1 µ thin, and 3 µ high. Proximal face with a smooth contact area, but around the equator the surface reticulate. Exine 3.5-4 µ thick. Spore size: 40-42 µ.

Diphasium tristachyum (Pursh) Rothm. 1944
Plate III., Figs 4-6.

Description: spores trilete, laesurae straight, reaching the equator. Amb circular. Proximal face reticulate, but with a smooth contact area. Distal face also reticulate, lumina of reticulum regularly hexagonal. Muri straight, 1.5 µ wide, 6-7 µ high. Exine 3-3.5 µ thick. Spore size: 42-45 µ.

Morphogroup II: Hamulate sculpture

cernua - morphotype: proximal surface unsculptured, distal surface hamulate; exine in interapical region thicker than in apical region.

Lepidotis cernua (L.) Beauv. 1804
Plate IV., Figs 1-4.

Description: trilete, tricrassate spores. Laesurae straight, simple, length 3/4 of spore radius. Amb rounded triangular, with strongly convex sides. Proximal face smooth, distal face hamulate: ornamented by more or less developed anastomosing rugulae up to 2-3 µ across. Exine 1.5 µ thick apically, and 5 µ wide interapically. Spore size: 32-38 µ.

inundata - morphotype: proximal surface ornamented with granulae or verrucae; laesurae often surrounded by a margo. Distal surface hamulate.

Lepidotis inundata (L.) C. Börner 1912
Plate IV., Figs 5-9.

Description: spores trilete, laesurae reaching or almost reaching the equator, often surrounded by a disting margo, which 2-4 µ wide, 1-2 µ high. Proximal surface sculptured by granulae or verrucae. Distal surface hamulate, consisting of irregularly winding, densely spaced low rugulae. Exine 4-5 µ thick at apices, 5-7 µ thick at sides (slightly tricrassate). Amb rounded triangular. Spore size: 62-66 µ.

Morphogroup III: Foveolate sculpture

selago - morphotype: amb hexagonal, foveolate both proximally and distally.

Huperzia selago (L.) Bernh. ex Schrank & Mart 1829
Plate IV., Figs 10-12.

Description: trilete spores, laesurae straight, reaching the equator; length 17-20 µ. Amb hexagonal (sides facing laesura arms slightly convex, remaining sides concave). Proximal face sparsely, distal face closely pitted (foveolate). Pits 0.7-1.5 µ wide, 2-3 µ apart. Exine 2-3 µ thick. Spore size: 40-46 µ.

CONCLUSIONS

The issues brought up in the introduction can be answered as follows:
1. Of the four Lycopodiacea genera, Huperzia spores are foveolate, those of Lepidotis hamulate and well differentiated from the other two genera. Spores of the genera Lycopodium and Diphasium are reticulate and cannot be well distinguished. Perhaps a distinction of these two genera is not valid.
2. For the characterization of the species the qualitative features of the ornamentation of the proximal and distal faces and the structure of muri were given. For the quantitative features of the ratios of exine thickness (spore size and diameter of lumina of reticulum) spore size are suitable (Table I.).
3. The spores of the Lycopodiaceae investigated by the authors are worldwide distributed. Most of them also occur in temperate, subtropic and tropic areas outside Europe. According to Ito (1978) "the fern flora of a certain region is composed of two groups of species. One of them has monolete (m) spores and the other has trilete (t) ones. The ratio of the number of the former species to the latter (ratio m:t) can be calculated and value is obtained in the region. The ratios increase as the latitude increases." The spores of Lycopodiaceae are trilete and the spores with monolete aperture occur only in small number independently of geographical latitude in maximum 1-2 % in a specimen.
4. The spores examined were placed in three morphological groups and five morphotypes. Lycopodium clavatum and some Diphasium species belong to the morphotypes clavatum. The muri are conspicuously winding on the reticulum of L. clavatum, in the case of the other species they are faintly winding or straight.
5. For a comparison of the recent spores with the fossils the descriptions of the dispersed lycopodiaceous spores from the Tertiary by Krutzsch (1963), from the Lower Cretaceous by Juhász (1975) and the illustrations in the latter paper are available (Plate V.). It can be established that the morphotypes and the types of ornamentation have only slightly changed during the evolution of the lycopodiaceous flora.

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EXPLANATION OF PLATES

Plate I.

1-3. Lycopodium annotinum L., 1 = proximal face, 2 = optical view, 3 = distal face
4-9. Lycopodium clavatum L. 4,5 = proximal face, 6,7 = distal face, 8,9 = lateral view

Plate II.

1-3. Diphasium alpinum Rothm. 1 = proximal face, 2 = optical view, 3 = distal face
4-6. Diphasium complanatum (L.) Rothm. 4 = proximal face, 5 = optical view, 6 = distal face

Plate III.

1-3. Diphasium issleri (Rouy) J.Holub, 1 = proximal face, 2 = optical view, 3 = distal face
4-6. Diphasium tristachyum (Pursh) Rothm. 4 = proximal face, 5 = optical view, 6 = distal face

Plate IV.

1-4. Lepidotis cernua (L.) 1,3 = proximal face, 2,4 = distal face
5-9. Lepidotis inundata (L.) C.Börner, 5,9 = proximal face with granulate ornamentation, 7 = optical view, 6,8 = distal face. X 600

Plate V.

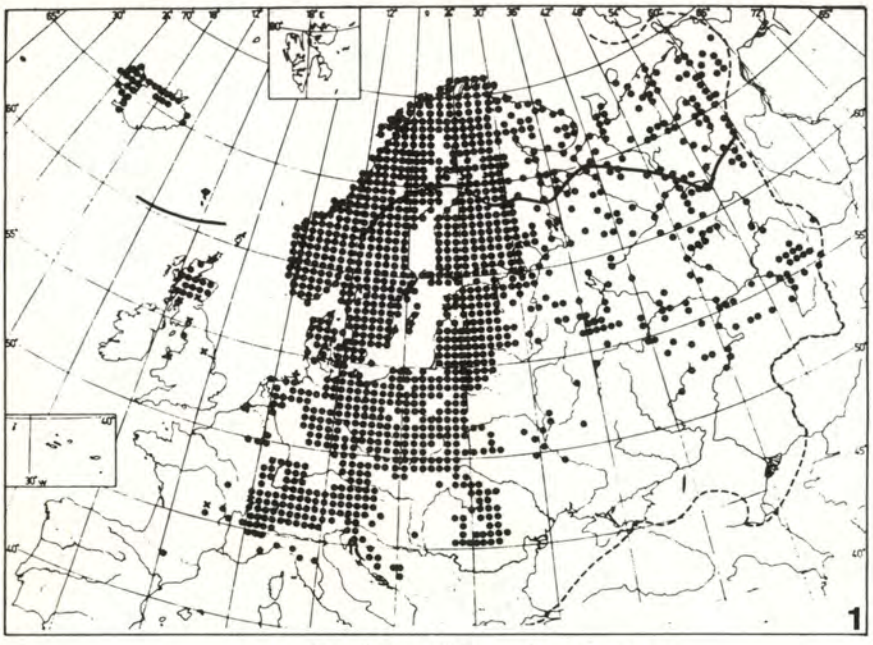
Fossil dispersed lycopodiaceous spores from Hungarian Albian rocks (100 million years old).

1,2. Retitriletes austroclavatidites (Cookson) D.K.M.S. 1963, (annotinum morphotype)
3. Retitriletes clavatoides (Couper) D.K.M.S. 1963, (annotinum morphotype)
5. Vadaszisporites urkuticus (Deák) Deák et Combaz 1967
6. Vadaszisporites sacali Deák et Combaz 1967, (clavatum morphotypes)
7,8. Camarozonosporites insignis Norris 1967, (inundata morphotype)
9. Camarozonosporites hammeni Van Amerom 1965, (cernua morphotype)

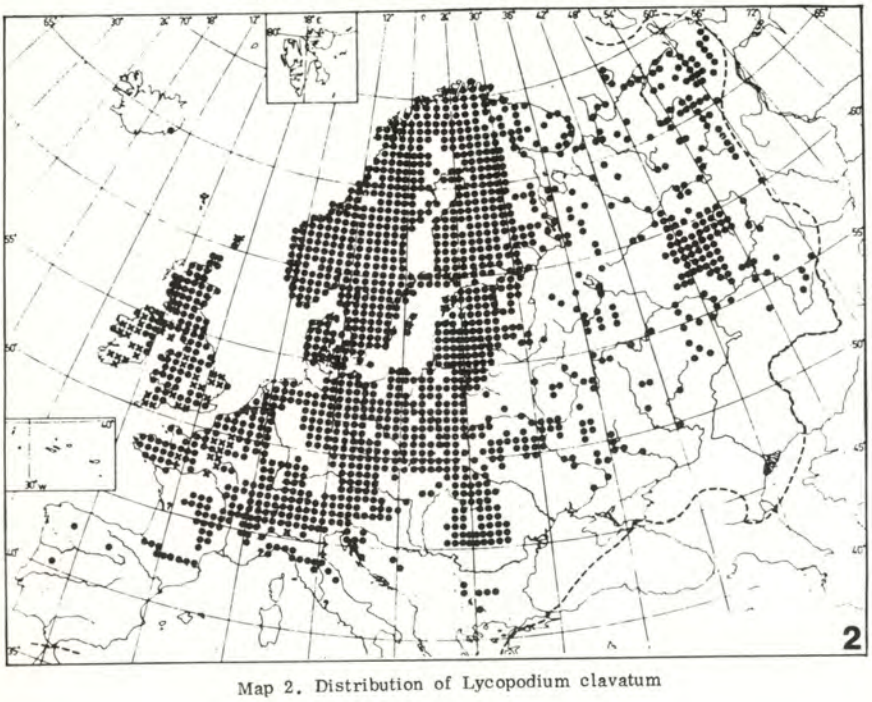
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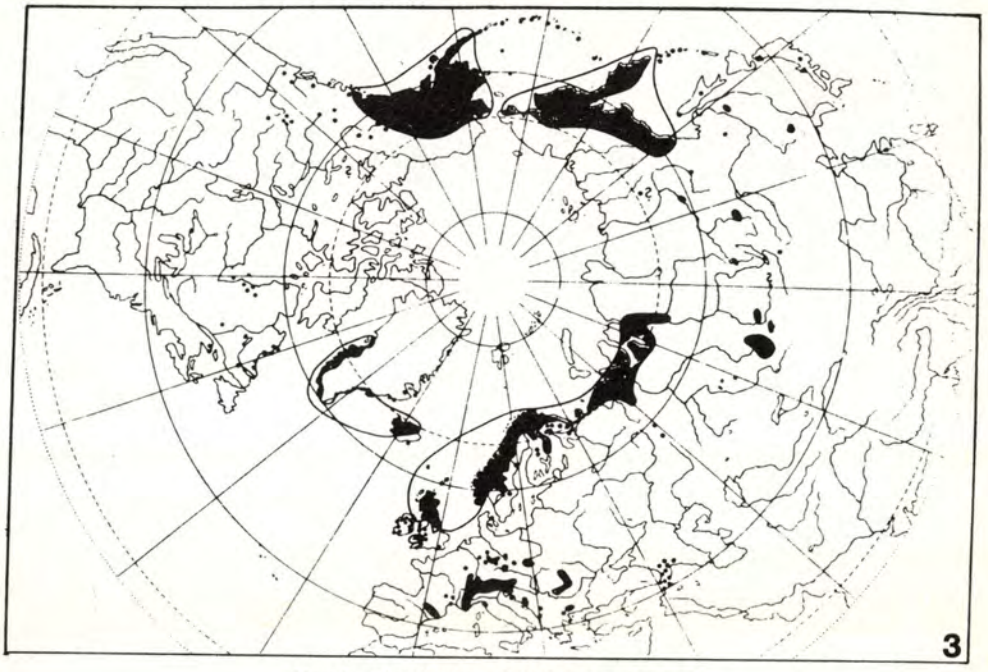
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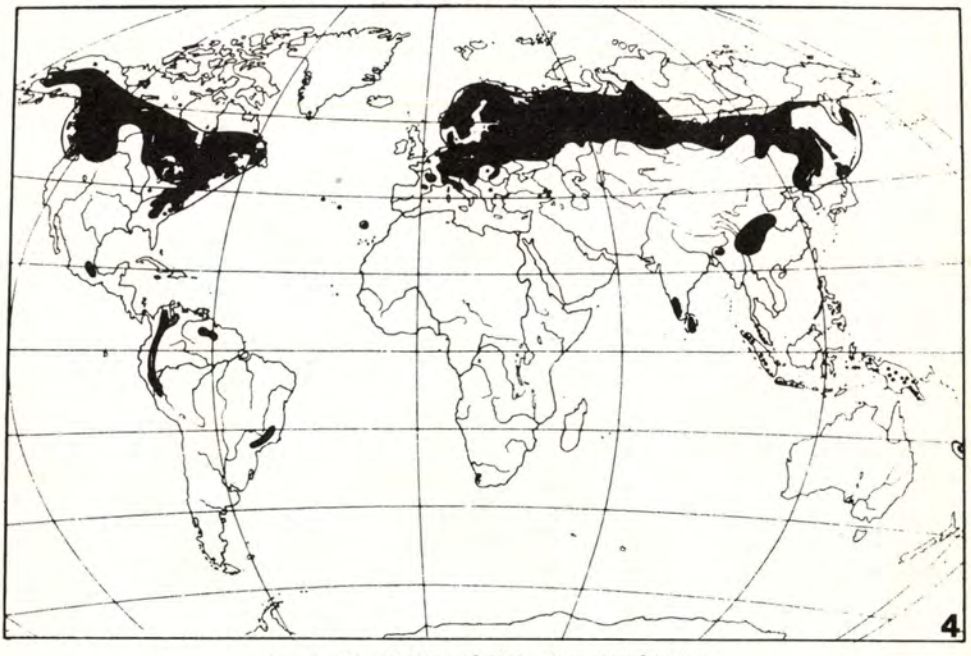
Map 1. Distribution of Lycopodium annotinum



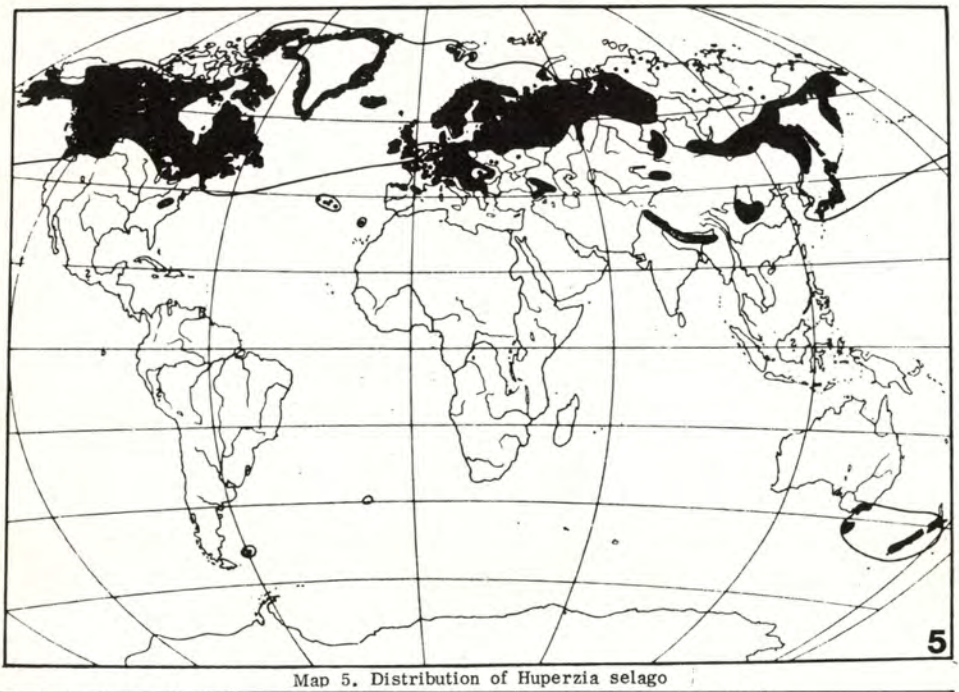
Map 2. Distribution of Lycopodium clavatum



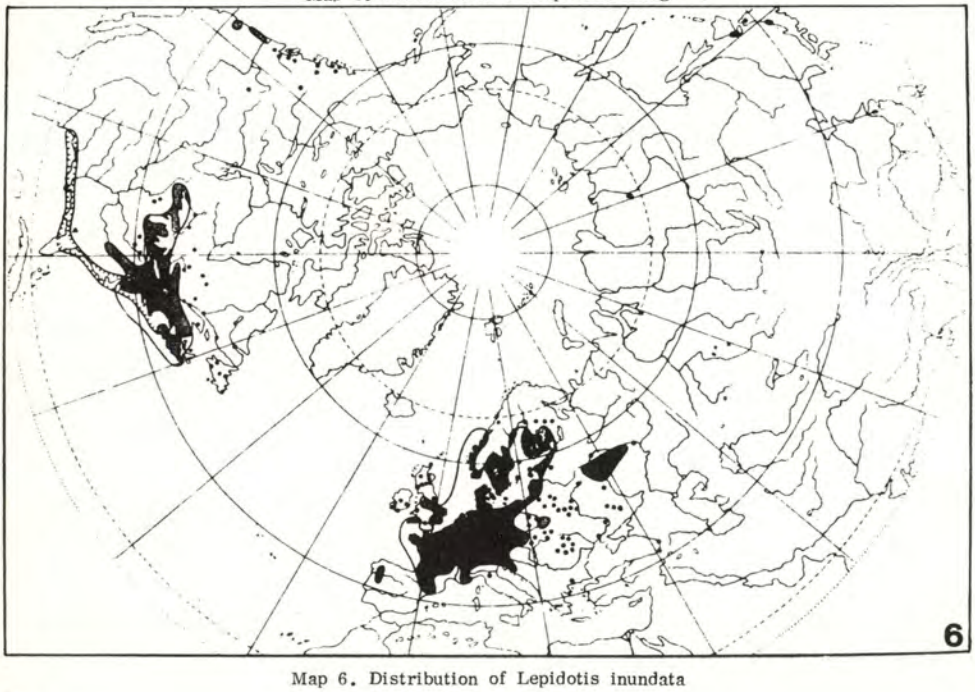
Map 3. Distribution of Diphasium alpinum



Map 4. Distribution of Diphasium complanatum



Map 5. Distribution of Huperzia selago



Map 6. Distribution of Lepidotis inundata

Table 1. Data of the examined spores

Species name	amb	proximal face	distal face	spore size	exine thickness spore size	lumina of reticulum spore size
Lycopodium annotinum L.1753	rounded triangular	smooth	reticulate	41-46 µm	0.1-0.12	0.4-0.43
Lycopodium clavatum L.1753	subcircular to circular	reticulate	reticulate	37-40 µm	0.09-0.1	0.42-0.46
Diphasium alpinum (L.) Rothm. 1944	subcircular	reticulate	reticulate	42-47 µm	0.08-0.1	0.44-0.46
Diphasium complanatum (L.) Rothm. 1944	subcircular	reticulate	reticulate	35-37 µm	0.10-0.11	0.14-0.16
Diphasium issleri (Rouy) J. Holub 1960	subcircular	reticulate	reticulate	40-42 µm	0.75-0.8	0.16-0.18
Diphasium tristachyum (Pursh) Rothm. 1944	circular	reticulate	reticulate	42-45 µm	0.20-0.22	0.13-0.15
Lepidotis cernua (L.) Beauv. 1804	rounded triangular	smooth	hamulate	32-38 µm	0.13-0.18	-
Lepidotis inundata (L.) C. Börner 1912	rounded triangular	scabrate-granulate	hamulate	62-66 µm	0.12-0.04	-
Huperzia selago (L.) Bernh. ex Schrank & Mart 1829	hexagonal	smooth	foveolate	40-46 µm	0.08-0.09	-



Map 7. Distribution of Diphasium tristachyum

Plate I.

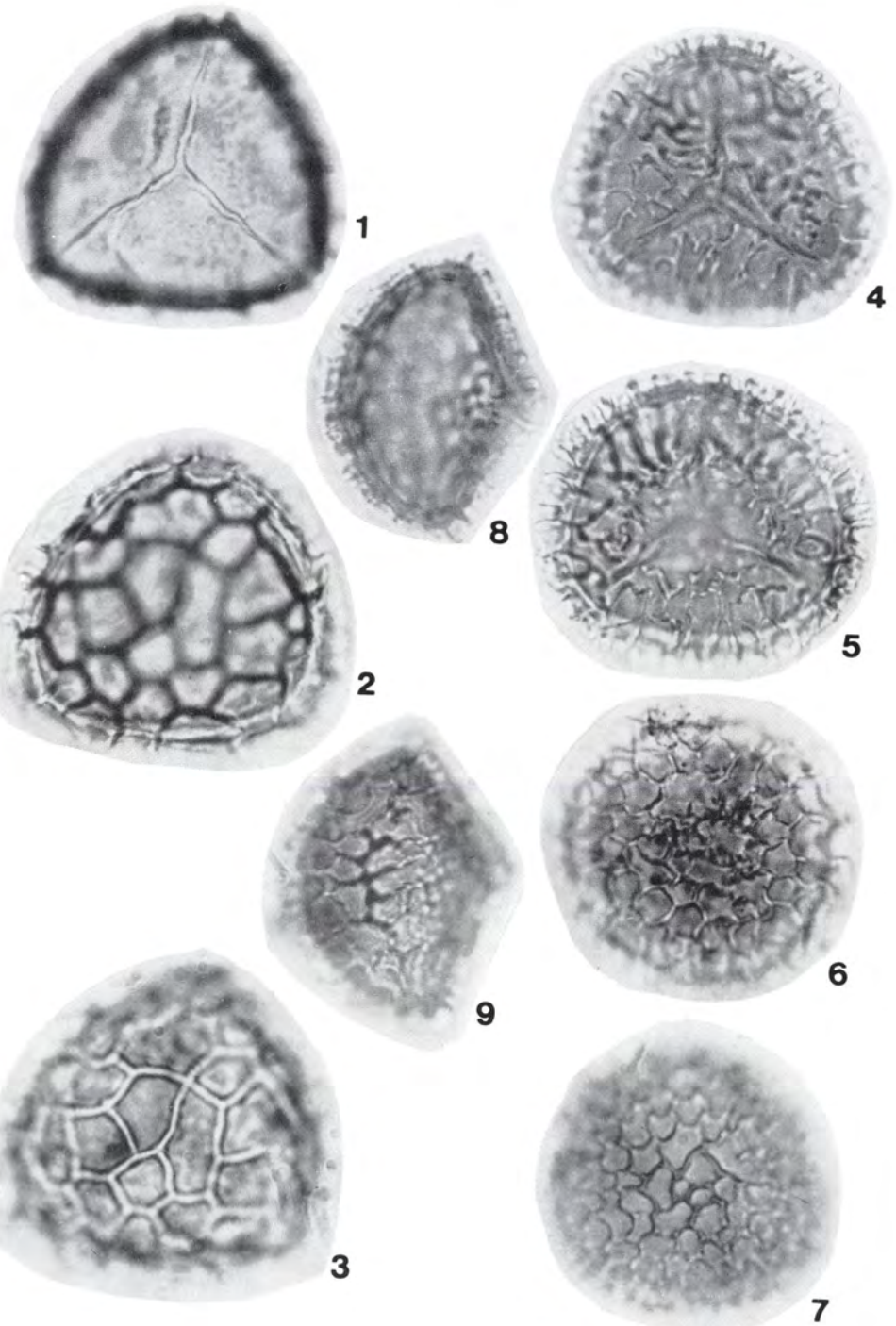


Plate II.

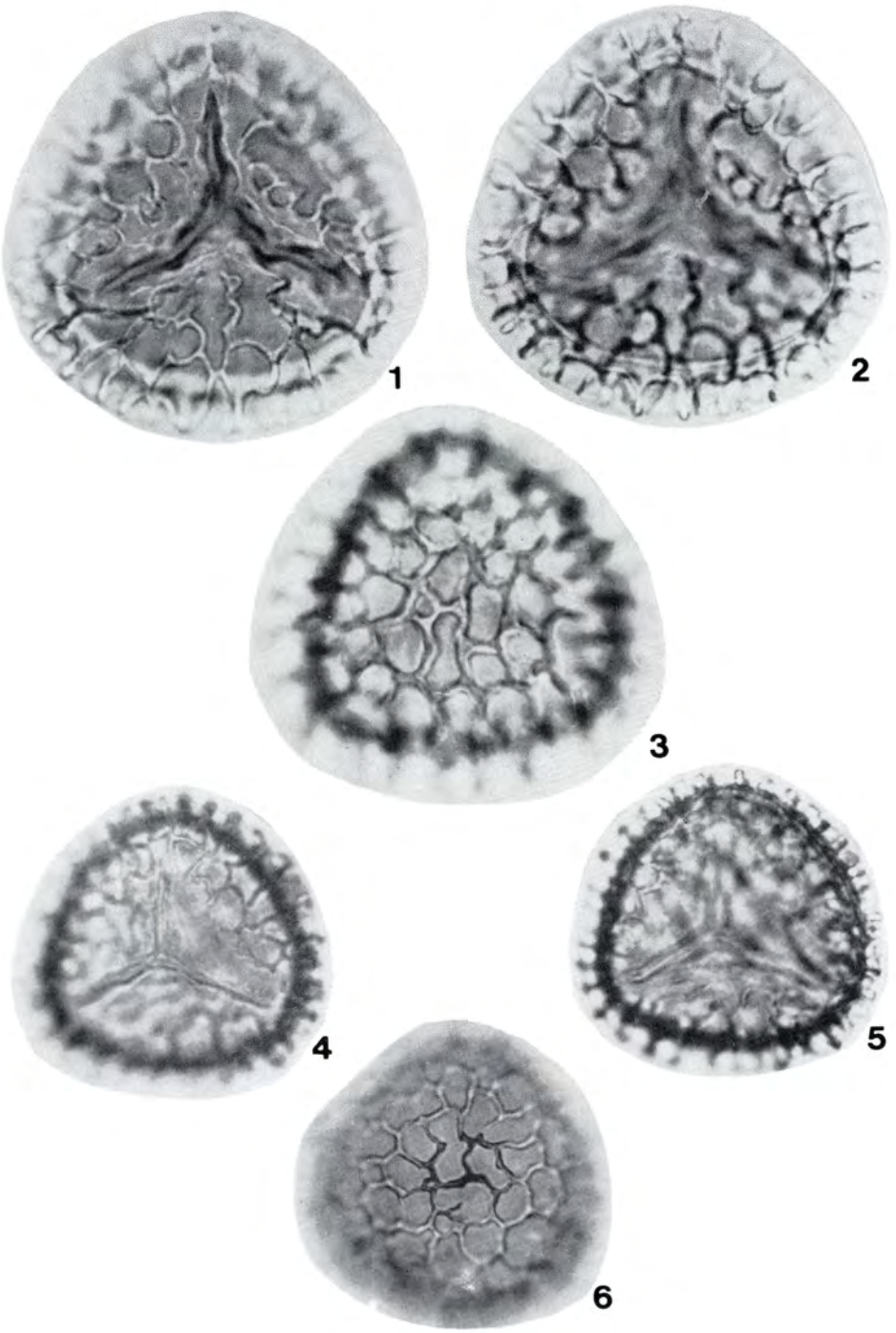


Plate III.

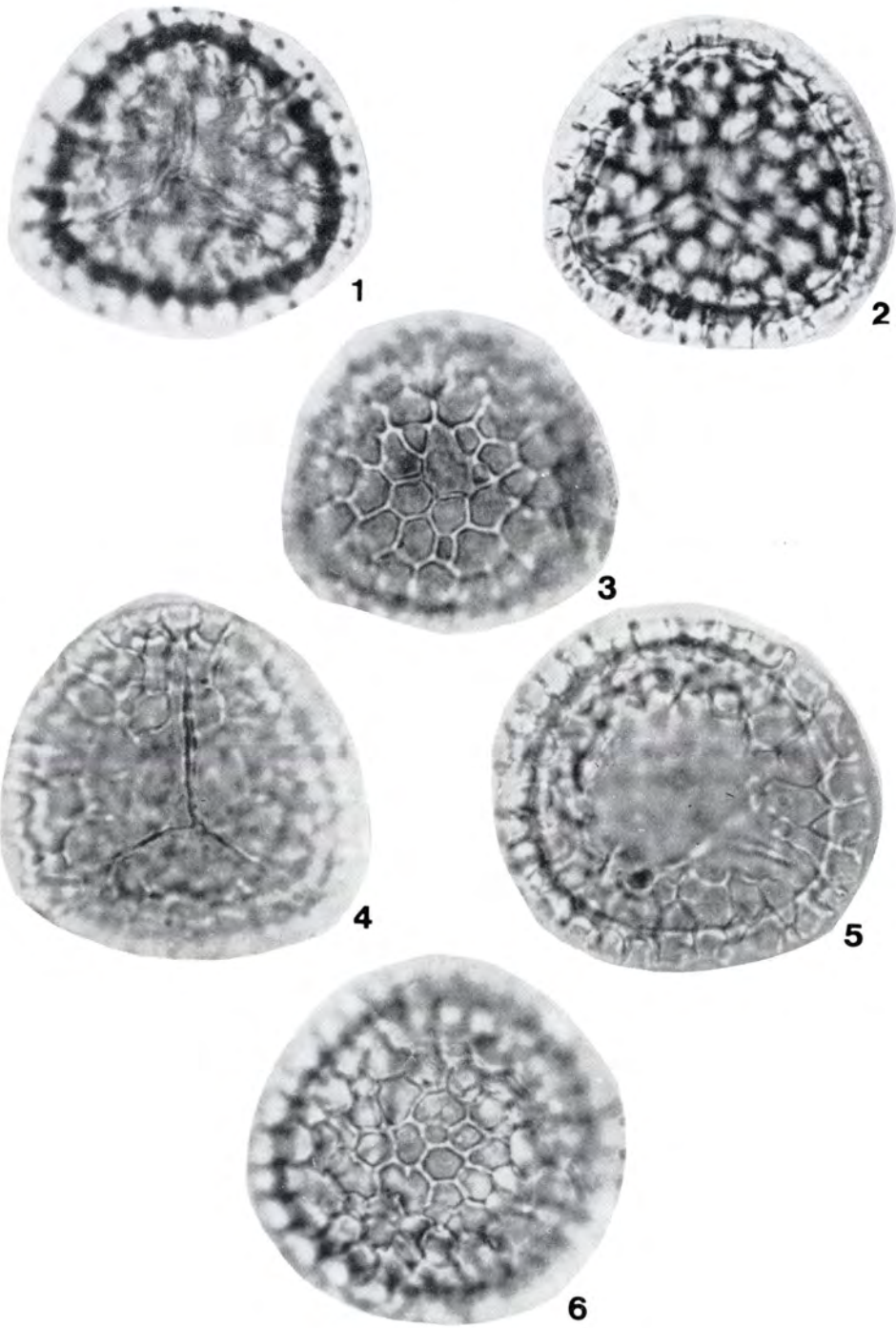


Plate IV.

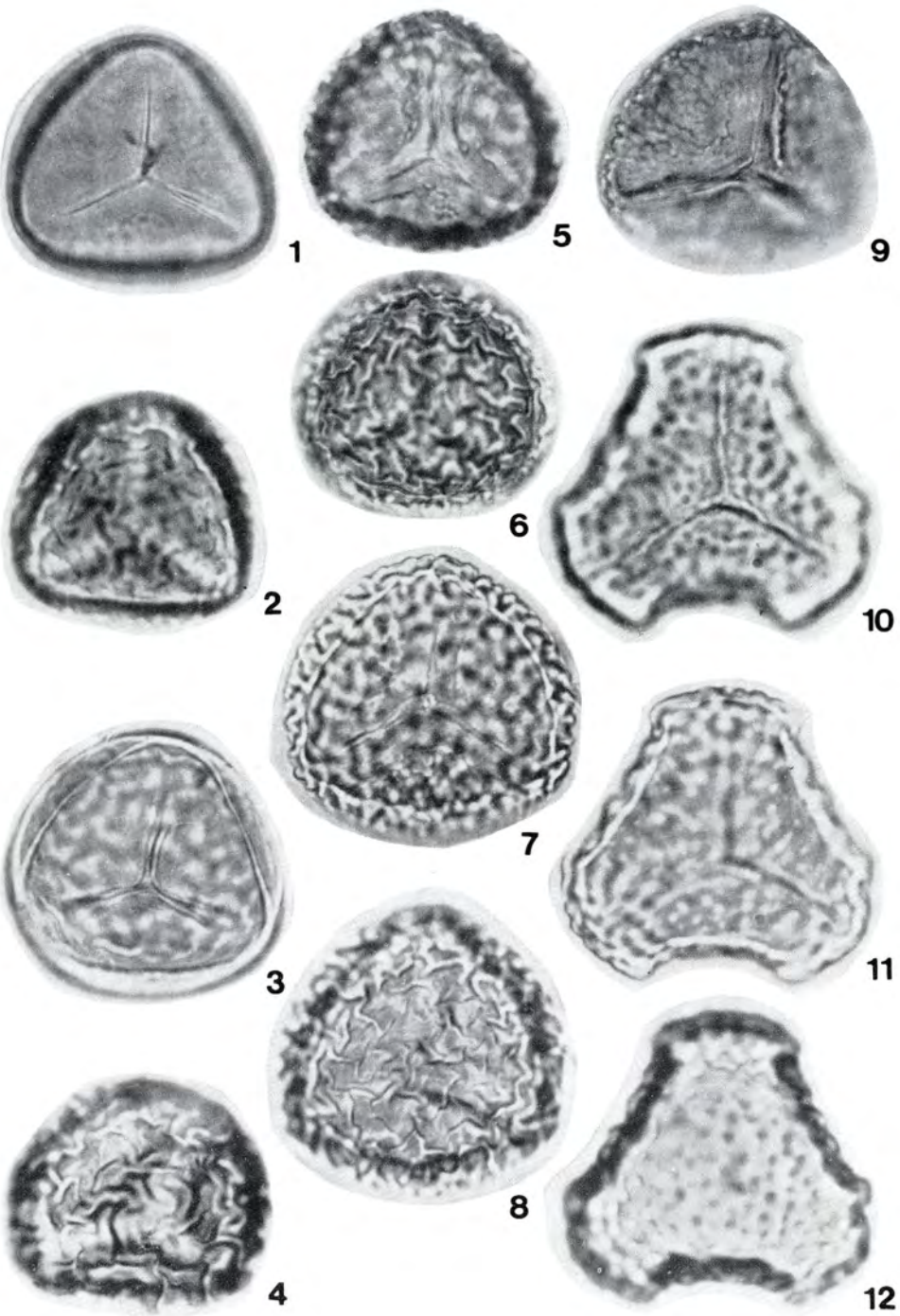


Plate V.

