MIOSPORE ASSEMBLAGE PATTERN IN THE MICROLITHOTYPES OF JURA COALS

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ABSTRACT

This paper deals with palynological studies of Jura Coals in conjunction with petrographic structure. The morphographic and statistical analyses of maceral and miospores indicate distinct petrographic and miospore assemblage pattern. The presence of zonations in the coal bed recognizable by palyno-petrographic patterns not only suggest sequential formation of Jura Coals but also show an intimate relation between certain microlithotypes and miospores such as Durite and *Densosporites* and probably Vitrite and Clarite with monolete miospores.

INTRODUCTION

In my previous paper (NAVALE, 1963), I have discussed some principles and utility of palyno-petrographic approach of coal and its importance to resolve the heterogeneous complex components of coal. The present investigation comprises a detailed systematic study of petrographic and miospore constitution of Jura coals. Petrographic determination in conjunction with sporological studies of the present coals has helped to interpret the origin and history of Durite and Clarite microlithotypes, and *Densosporites* and monolete miospores. Recognition of coal facies shown by the presence of microlithotype and miospore zonations indicate sequential coal formation of Jura coals from Lons basin.

Lons basin is formed by a complex Permo-Carboniferous strata. A part of the substratum is crystalline and the other part is overlain by Triassic and Jurassic sediments. The whole stratigraphical sequence has been determined on the evidence of successive tectonic activities. The Carboniferous part of the basin is of stephanian age or more precisely stephanian inferior. By analogy with Ronchamp and Blanzy the general orientation of the basin is N.W.-S.W. The roof of the basin in the north (St. Lothain) is 605 m. in depth, in the centre (Domblans, Lavigny) the depth is more than 1000 m. and in the south the depth is 475 m. The basin forms a shallow syncline in the central part and is covered by Permian formations. Thickness of coal in the basin is 730 m. in north, 300 to 600 m. in centre, and 350 m. in south. The coal basin is limited by plateau of Jura. The coal strata is highly folded and faulted due to tectonic movements and consequently coal seams are not well distributed. The total carbon content of coal is about 3 per cent. The locations of the coal bed indicated by boring are as follows: Lons I-11 m. 85, Montmorot 12 m. 56, Lons II-13 m. 76, Perrigny I-9 m. 22, Perrigny II-6 m. 63.

MATERIAL AND METHODS

The bore core coal from Lons II collected by Prof. Dr. Alpern was entrusted to me for sporological studies in conjunction with petrographic structure. Nine coal seams were recovered from the bore core. The present study is from seam (couche) 1. The method of preparation of coal samples for petrographic and miospore studies has been done in the same way as was done for Merlabach coals described in my earlier paper (NAVALE, 1964) except in the mode of sampling for miospore examination. Here (in Jura coals), samples taken for petrographic analysis have been split up into many different petrographic units (microlithotypes) for miospore studies and not by centimeter by centimeter. However some units have been examined for miospore composition in each centimeter to establish a standard unit.

STUDY AND ANALYSIS OF PETROGRAPHIC COMPONENTS

Microlithotypes of the Lons II Couche 1 of the Jura coals have been considered by examining the petrographic constituents of coals. The definition of the term microlithotype and other petrographic components have already been discussed in my earlier paper (NAVALE, 1963). The following description deals with a study and distribution pattern of different microlithotypes recognized in the coals under investigation.

Vitrite R. Potonié 1924

This microlithotype consists principally of Collinite and Telinite macerals. Collinite is usually without botanical structure whereas Telinite shows clearly defined cell structure (Wood, peridermis etc.). It contains at least 95% of Vitrinite (*see* LEXIQUE, 1957). Bands of Vitrinite having width more than 50 microns are recorded as Vitrite. Vitrite forms one of the important components of the petrographic constitution of the Jura coals. The frequency distribution of this microlithotype varies from 10 to 60 per cent except in three samples wherein the percentage is less than 10 per cent (FIG. 1). The average frequency is usually more than 25 %. There is an increase in the frequency distribution of this microlithotype in the last five samples.

Clarite R. Potonié 1924

This microlithotype consists principally of Vitrinite and Exinite macerals (Vitrinite is a group name comprising of Collinite and Telinite macerals whereas Exinite comprises Sporinite, Alginite, Resinite macerals). Clarite contains at least 95% Vitrinite and Exinite. The proportions of these two macerals vary widely but each is greater than the proportion of Inertinite. Bands of Vitrinite and Exinite having a width more than 50 microns are recorded as Clarite. Clarite can be recognized as miospore Clarite and cuticular Clarite. Miospore Clarite can be differentiated as Tenui-clarite (PL. 2, PHS. 16-18) and Crassi-clarite (PL. 1, PHS. 1-3). The Tenui-clarite is composed of thin-walled spores or tenuispores whereas Crassi-clarite consists of densospores (*Densosporites*) or Crassispores (PL. 1. PHS. 1-3). But contrary to Durite, compact Micrinite is not found in Crassi-clarite. It is for the first time that Clarite has been recognized both as Crassi and Tenui-clarite. So far it was believed that Clarites are in general Tenui-clarites. Cuticular clarite is constituted with different cuticles. Clarite is well associated with cuticles which are thin with lateral extensions. Clarite is recognized in most of the present coal samples except in five samples wherein it is totally absent. The frequency distribution of this microlithotype ranges from 0 per cent to 58 per cent (FIG. 1). Average frequency is about 18 per cent. It is of interest to note that Clarite also increases in the frequency similar to Vitrite in the last five samples (FIG. 1).

Duroclarite Nomenclature subcommittee 1957

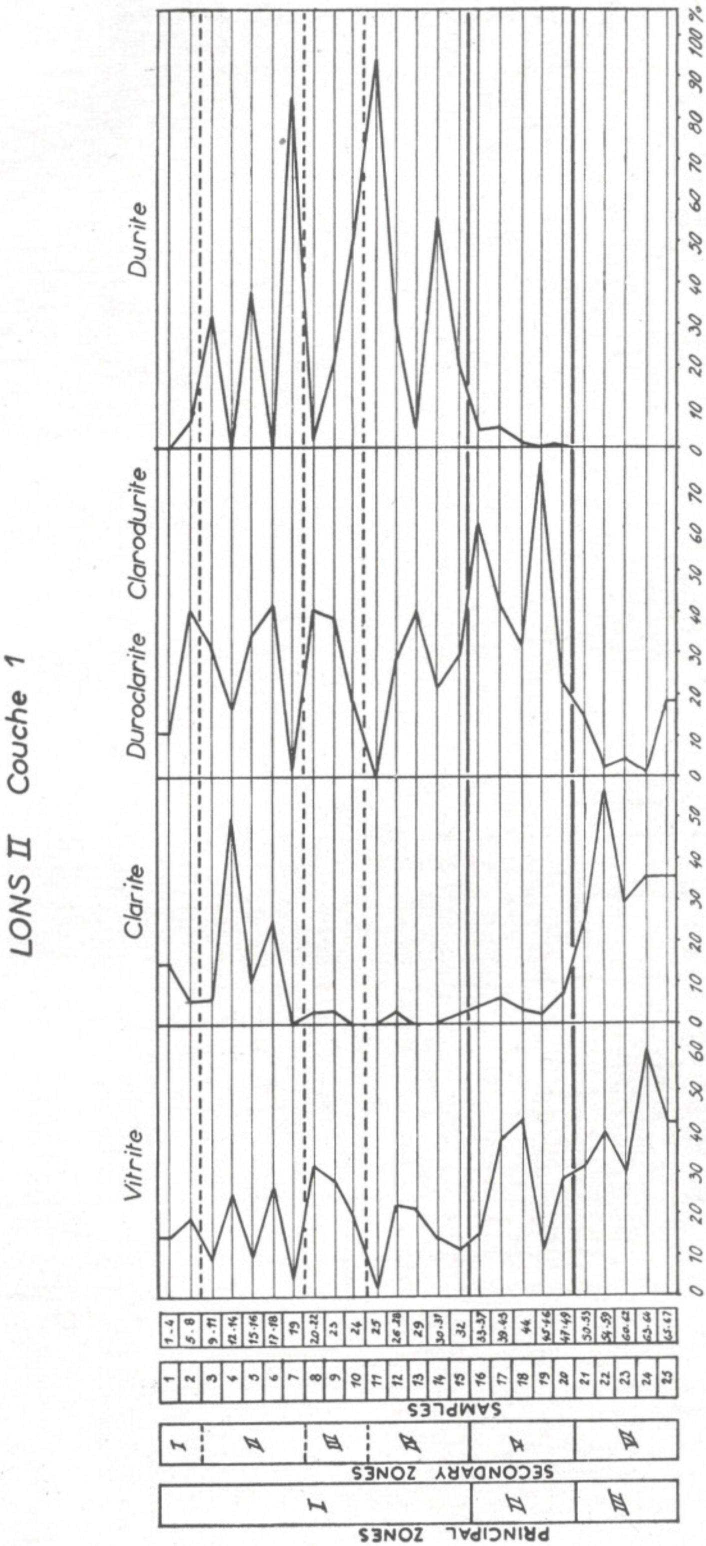
This microlithotype constitutes the microlithotypes with maceral composition between those of Clarite and Durite but closer to Clarite than Durite. Bands of these maceral composition having more than 50 microns wide are recorded as Duroclarite. Vitrinite exceeds Inertinite in maceral composition proportions. Duroclarite is found in all samples except in the last five samples of the coal bed. It is rather irregularly distributed. The percentage distribution ranges from 2% to 76% (FIG. 1) with an average frequency of about 15%. This microlithotype can be differentiated as miospore Duroclarite and cuticular Duroclarite. However, Duroclarite is mostly constituted by miospores (PL. 2; PHS. 13-15). Some spore exines such as exines of *Torispora* and *Densosporites* may be recognized. It is characteristically absent in the basal layers of the coal seam.

Durite R. Potonié 1924

This microlithotype consists principally of groups of macerals Inertinite (Micrinite, Fusinite, Semifusinite, Sclerotinite) and Exinite (particularly Sporinite). Bands of Inertinite and Exinite having a width more than 50 microns are recorded as Durite. It contains at least 95% of Inertinite and Exinite. The proportion of these two groups vary widely but each is greater than the proportion of Vitrinite. Two types of Durites, Crassi-durite and Tenui-Durite are recognized depending on the nature of the spores. Durite with Tenuispores or thin-walled spores is termed as Tenui-durite (PL. 1, PHS. 4-6) and Durite with crassispores or densospores or thick-walled spores (*Densosporites*) are termed as Crassi-durite (PL. 1. PHS. 7-9). Thick-walled miospores are dumb-bell shaped (PL. 2, PHS. 11-12) and can be identified here as *Densosporites*. Micrinite is extensively associated with Crassi-durite. This microlithotype is very characteristic in the petrographic composition. It is found only up to 32 cm. of the coal pillar taken in 15 samples. The frequency distribution of durite ranges up to 94 per cent. Conspicuously it disappears in the later samples or after 32nd cm. of the coal pillar (FIG. 1).

Fusite R. Potonié 1924

This microlithotype consists principally of the macerals Fusinite, Semifusinite and Sclerotinite. It contains at least 95 per cent of these macerals. Bands of Fusinite,



TEXT-FIG. 1 — Variation of frequences of microlithotypes.

Semifusinite and Sclerotinite having a width more than 50 microns are recorded as Fusite. Although this microlithotype is widely distributed in Jura coals yet it is not an abundant component. The range of distribution being from 1 per cent to 35 per cent (FIG. 1). It is least distributed in the last five samples.

COMMENTS ON THE COMPOSITION AND DISTRIBUTION OF THE PETROGRAPHIC COMPONENTS

The petrographic studies and the distribution pattern of the microlithotypes reveal that the coal is principally constituted by Durite, Duroclarite, Vitrite and Clarite microlithotypes. The general pattern of the distribution is that Vitrite and Clarite is distributed in most of the samples, conspicuously having a large percentage in the last five samples. The Duroclarite on the contrary is least in the last five samples but having a higher percentage among samples between 15 and 20 cm. Durite is a very characteristic component in the first fifteen samples only. The statistical analysis and the composition of different components clearly indicate three main petrographic zones (FIG. 1).

(i) Durite Zone	1-32 cm. of the coal pillar
(ii) Duroclarite Zone	33-50 cm. of the coal pillar
(iii) Vitrite and Clarite Zone	51-67 cm. of the coal pillar

Durite zone extends up to 32 cm. of the coal bed taken in 15 samples. The percentage of Durite ranges up to 94%. Though Durite is characteristic of this zone, it is rather irregularly distributed. This broad zone may be differentiated into 4 minor zones on the basis of the frequency distribution pattern of the Durite microlithotype. To begin with, Durite is minimum from 1-8 cm., forming a minor zone (4%). In the second minor zone from 9-19 cm., Durite is maximum with 32%. Again Durite decreases in the third minor zone from 20-24 cm. having a frequency of 13%. Finally in the last minor zone from 25-32 cm., Durite increases in the percentage ranging up to 60%.

Duroclarite zone is dominant immediately succeeding the Durite zone extending from 33 to 50 cm. taken in five samples (i.e. from 16 to 20). The average frequency of Duroclarite microlithotype is about 60 per cent. Some Vitrite is associated in this zone.

Vitrite and Clarite Zone following up Duroclarite zone extends from 51 to 67 cm. taken in five samples (i.e. from 21 to 25). The average frequency of this zone is about 70% (both Vitrite and Clarite having 35% each). Neither Durite nor Duroclarite microlithotypes are present.

Thus the petrographic studies clearly indicate that the heterogeneous coal bed of Lons II Jura is mainly composed of Durite, Duroclarite, Vitrite and Clarite microlithotypes. It may be presumed that these changes in composition are due to some environmental changes in coal forming swamps of this coal formation. The results are examined from botanical (palynological) studies of the coals.

STUDY AND ANALYSIS OF MIOSPORE ASSEMBLAGES

The coal pillar of Lons II Couche 1 of Jura has been suitably splitted (taking into consideration the petrographic composition) for palynological investigations. The method of maceration and statistical analysis have already been described (NAVALE, 1964). Following is the systematic description of the rich variety of trilete, monolete and monosaccate miospores recognized in the coals.

DIVISION	**Trilete** (Reinsch) Pot. & Kr. 1954
SUB-DIVISION	**Azonotriletes** Luber 1935
SERIES	**Laevigati** (B. & K.) Pot. & Kr. 1954

Leiotriletes (Naumova) Pot. & Kr. 1954

Miospores triangular, concave or convex to sometime round, exine thick, intrapunctate or infragranulate Y = 1/2 R.

Leiotriletes sphaerotriangulus (Loose) Pot. & Kr. 1955 (PL. 5, PH. 69)

Size 40-60 μ, exine intrapunctate, Y-mark reaching equator.

Leiotriletes convexus (Kosanke) Pot. & Kr. 1955 (PL. 5, PH. 70)

Size 44-67 μ, exine intrapunctate to infragranulate, Y = 3/4 radius.

Leiotriletes adnatoides Pot. & Kr. 1955

Size 30-40 μ, exine intrapunctate, Y = R.

Calamospora S.W. & B. 1944

Miospores ± round, spore wall translucent, unsculptured, structureless, exine thick.

Calamospora mutabilis (Loose) S. W. & B. 1944 (PL. 5, PH. 65)

Size 65-130 μ, Y = 1/2 R.

Calamospora hartungiana Schopf 1944 (PL. 3, PH. 24)

Size 80-100 μ, Y = 1/3 R, exine finely granular.

Punctatisporites (Ibr.) Pot. & Kr. 1954

Miospores ± round, exine smooth, punctate, reticulate, Y = 1/2 R.

Punctatisporites punctatus Ibr. 1933 (PL. 5, PH. 67)

Size 50-80 μ, Y = 2/3 R, exine infrapunctate, thick.

SERIES **Granulati** Dyb. & Jac. 1957

Granulatisporites (Ibr.) Pot. & Kr. 1955

Miospores triangular, triradiate, exine granular, granules round and regular.

Granulatisporites parvus Ibr. 1933 (Pl. 4, PH. 62)

Size 30-50 μ, apex round, granules 0·5 μ.

Cyclogranisporites Pot. & Kr. 1954

Miospores round, exine granular, grain visible.

Cyclogranisporites aurens (Loose) Pot. & Kr. 1955 (PL. 4, PH. 63)

Size 50-80 μ, 70-100 grains of 1 μ, Y = 1/2 R faintly visible.

SERIES **Apiculati** (B. & K.) Pot. & Kr. 1955

Lophotriletes (Naumova) Pot. & Kr. 1954

Miospores triangular, convex to concave, sometimes round, exine ornamentated allover the surface by cones which are high and large.

Lophotriletes gibbosus (Ibr.) Pot. & Kr. 1954 (PL. 4, PH. 58)

Size 40-50 μ, ± 40 coni, Y = 2/3 R, exine coni negative reticulum, homogeneous.

Lophotriletes insignitus (Ibr.) Pot. & Kr. 1955 (PL. 4, PH. 57)

Size 45-85 μ, ± 30 terminal coni, Y = 2/3 R.

Acanthotriletes (Naumova) Pot. & Kr. 1954

Miospores triangular, spines longer (twice) than broad.

Acanthotriletes microsaetosus ?

Size 26-39 μ, Y = 2/3 R, spines 2 to 3 μ.

Raistrickia (S.W. & B.) Pot. & Kr. 1954

Miospores ± round, bacula cylindrical.

Raistrickia saetosa (Loose) S. W. & B. 1944 (Pl. 3, PH. 28)

Size 60-90 μ, Y = 2/3 R, bacula 14 μ.

Raistrickia superba (Ibr.) S. W. & B. 1944 (PL. 3, PH. 27)

Size 40-60 μ, Y = R, bacula 4-8, 2-5 μ.

SERIES **Muronati** Pot. & Kr. 1954

Microreticulatisporites (Knox.) Pot. & Kr. 1954

Miospores round or triangular, fine to imperfect reticulam ornamentation.

Microreticulatisporites nobilis (Wisher) Knox 1950 (PL. 4, PHS. 59-60)

Size 30-45 μ, Y = R, contour equatorial, ± 50 arcs.

Foveolatisporites Bhard. 1955

Miospores oval, or elongated, exine with foveola.

Foveolatisporites fenestratus (Kos. & Brok.) Bhard. 1955

Size 60-100 μ, foveola round or oval, muri coarser, Y-mark not visible or illformed.

Dictyotriletes (Naumova) Pot. & Kr. 1954

Miospores ± round, exine reticulate, trilete mark fine.

Dictyotriletes comptatus Alp. 1959 (PL. 3, PHS. 19-23)

Size 60-100 μ, Y-mark reaching equator, exine thick, reticulate.

Reticulatisporites (Ibr.) Pot. & Kr. 1954

Miospores round, exine with network.

Reticulatisporites muricatus Kos. 1950

Size 82-97 μ, mesh 10-12 μ, Y = 1/3 R.

DIVISION **Zonates** (B. & K.) Pot. & Kr. 1954

SUB-DIVISION **Auritotriletes** Pot. & Kr. 1954

SERIES **Ariculati** (Schopf) Pot. & Kr. 1954

Triquitrites (Wils. & Coe) Pot. & Kr. 1954

Miospores triangular, with angular thickenings (valvae) or with angular projections (auriculae).

Triquitrites triturgidus (Loose) Pot. & Kr. 1956 (PL. 4, PH. 52)

Size 45-60 μ, Y = 2/3 R.

Triquitrites pulvinatus Kos. 1950 (PL. 4, PH. 50)

Size 41-53, Y = R.

Triquitrites inusitatus Kos. 1950 (PL. 4, PH. 51)

Size 60-73 μ, angular projections or auriculae divided into many auricules, 8 μ long, finely granular.

Triquitrites concavus Alp. 1959 (PL. 4, PH. 49)

Size 35-50 μ, globuloid, tendency to form 3 branches.

Ahrensisporites Pot. & Kr. 1954

Miospores triangular, concave, exine forming kyrtome.

Ahrensisporites angulatus ? Kos. 1950 (PL. 4, PH. 54)

Size 66-75 μ, apex thick and large having proximal auriculae.

SUB-DIVISION **Zonotriletes** Waltz 1935
SERIES **Cingulati** Pot. & Kr. 1954

Lycospora S.W. & B. 1944

Miospores small, $\pm$ round, characteristic cingulum surrounding the spore body equatorially, Y-mark reach girdle like cingulum, exine $\pm$ punctate or granulate.

Lycospora pusilla (Ibr.) S. W. & B. 1944 (Pl. 4, PH. 56)

Size 30-40 μ, cingulum 2-3 μ, exine punctate.

Lycospora granulata Kos. 1950 (PL. 4, PH. 55)

Size 30-45 μ, exine granular.

Angulisporites Bhard. 1954

Miospores triangular, convex, exine granular cingulum large, Y = R.

Angulisporites splendidus Bhard. 1954 (PL. 5, PH. 66)

Size 75-95 μ, cingulum more clear than central body = 1/3 R, Y-mark reach equator.

Anulatisporites Loose 1934

Miospores triangular, convex, cingulum large, massive, Y $\pm$ net, exine of the central body infrapunctate.

Anulatisporites anulatus Loose 1934 (PL. 3, PH. 31 & PL. 4, PH. 41)

Size 35-60 μ, round, Y-mark very feeble, cingulum thick, exine infragranulate.

Densosporites (Berry) Pot. & Kr. 1954

Miospores $\pm$ round, triangular, cingulum large and thick, smooth to apiculate and rugose ornamentation, Y-mark faint. This genus with many species form a characteristic and dominant type with *Torispora* in the first 32 cm. of the coal bed (taken in 1-15 samples). It is rather irregularly distributed though a characteristic type. The frequency distribution ranges up to 80 % (FIG. 2). This spore, however significantly disappears from the miospore association in the remaining portions of the coal pillar (i.e. from 33-67 cm. or 16-25 samples). The distribution pattern of this miospore is inversely proportional to that of *Torispora*. Following are the common species.

Densosporites sphaerotriangularis Kos. 1950 (PL. 4, PHS. 40 & 42)

Size 46-55 μ, Y-mark more or less clear, cingulum divided into internal and external cingulum, Central body $\pm$ infrareticulate.

Densosporites lobatus Kos. 1950 (PL. 3, PH. 30; PL. 4, PH. 36)

Size 35-60 μ, Y-mark faintly visible, cingulum partly clear and partly lobed, central body granular, length of the cingulum = R.

Densosporites duriti Pot. & Kr. 1954 (PL. 3, PH. 34)

Size 50-70 μ, large cingulum corroded, clear and dark zone of cingulum distinct, central zone infragranulate.

Densosporites (*cristatisp*) *indignabundus* Loose (PL. 4, PHS. 44 & 45)

Size 50-80 μ, 40 dents visible on the equator, Y-mark not visible.

Densosporites major Alp. 1959 (PL. 4, PH. 37)

100-160 μ, Y-mark scarcely visible, cingulum large, frequently deformed, central part clear, infrareticulate.

Polymorphisporites Alp. 1959

Miospores triangular, $\pm$ round to concave or convex, Y-mark clear in cingulum, exine $\pm$ reticulate, cingulum thick, regular or irregular.

Polymorphisporites reticuloides Alp. 1959 (PL. 6, PH. 89)

Size 50 μ, Y-mark in centre of the spore, cingulum with 3 branches, exine reticulate.

Polymorphisporites laevigatus Alp. 1959 (PL. 6, PHS. 90 & 91)

Size 40 to 80 μ, Y-mark asymmetric, cingulum $\pm$ regular, large, exine thick spotted.

SERIES **Zonati** Pot. & Kr. 1954

Cirratriradites

Miospores triangular, convex, Y-mark reach equator, enclosed by a large and clear zone, one or many foveolae.

Cirratriradites saturni (Ibr.) S. W. & B. 1944 (PL. 5, PHS. 75 & 78)

70-100 μ, $\pm$ round, Y = R.

Cirratriradites flabelliformis Wilson & Koe. 1940 (PL. 5, PH. 76)

70-100 μ, Y-mark clear, 3 polar foveolac

Reinschospora (S.W. & B.) Pot. & Kr. 1954

Miospores triangular with equatorial fibrous fringe, fibres of the fringe separated, ± rectilinear, punctate or granulate.

Reinschospora magnifica (Kos.) 1950 (PL. 6, PH. 86)

Size 60-78 μ, exine thick or finely granulose, fibres 10 μ long and 25 μ broad.

Reinschospora gulaferus Alp. 1959 (PL. 6, PHS. 84 & 85)

Size 58-75 μ.

DIVISION **Monoletes** Ibr. 1933
SUB-DIVISION **Azonomonoletes** Luber 1935

Laevigatosporites Ibr. 1933

Miospores oval or bean shaped, monolete mark ± rectilinear, exine smooth or infrapunctate. This miospore is uniformly distributed throughout the coal pillar. The percentage distribution of the genus ranges 5 % to 30 % (FIG. 2). The common species are *L. desmoinesensis*, *L. medius* and *L. minimus*.

Laevigatosporites desmoinesensis (WILS. & COE) S. W. & B. 1944

Size 45-70 μ.

Laevigatosporites medius Wils. & Coe 1940

Size 35-45 μ.

Laevigatosporites minimus

Size 20-35 μ.

Punctatosporites Ibr. 1933

Miospores oval, exine finely granular. This genus is uniformly distributed up to 50 cm. of the coal pillar or in first 20 samples. However it significantly dominates in the miospore association without *Densosporites* and *Torispora* in the basal layers of the coal pillar i.e. from 51 cm. to 67 cm. taken in from 21-25 samples. The frequency distribution in the first 50 cm. (1-25 samples) ranges from 10 per cent to 30 per cent (FIG. 2) and that in the region between 51 and 67 cm. of the pillar (21-25 samples) the frequency distribution ranges from 35 to 80 per cent (FIG 2). The common species is *P. granifer*.

Punctatosporites granifer Pot. &. Kr. 1954 (PL. 6, PH. 94)

Size 25-35 μ, oval or round, 50 grains allover surface of the spore.

Torispora Balme 1952

Miospores oval to oblong, pear shaped, exine thick, dark brown, monolete mark variable. This miospore is well represented in the coal seam up to 50 cm. taken in 20 samples. *Densosporites* is conspicuously not found along with *Torispora* from 32 cm. i.e. from 16th sample. But *Torispora* also disappears from the miospore association in the remaining portion of the coal bed (from 51 cm.-67 cm. taken in from 21-25 samples). The frequency distribution ranges up to 53 % (FIG. 2) but less than 2 % in the region between 51-67 cm. of the pillar (FIG. 2) taken in from 21-25 samples. The common species are *T. securis* and *T. laevigatus*.

Torispora securis Balme 1952 (PL. 6, PHS. 97, 100 & 101)

Size 26-44 μ, thick part = 1/3 to 1/2 of L, exine finely punctate.

Torispora laevigatus Bhard. 1954 (PL. 6, PHS. 96 & 98)

Size 26-28 μ, thickening ± parallel to monolete slit, exine thick and smooth.

Crassosporites Alp. 1958

Miospores of intermediate forms of *Punctatosporites* in punctation and *Torispora* in thickness; differentiate from *Torispora* by shape (oval) and from *Punctatosporites* and *Speciosporites* by exine thickening.

Crassosporites punctatus Alp. 1958 (PL. 6, PH. 95)

Size 30-38 μ, exine punctate or granulate, monolete slit curved or rectilinear.

Crassosporites triletoides Alp. 1958.

Size 20-25 μ, exine granular or intrareticulate, pseudo cingulum and pseudo trilete present, monolete slit on the border.

SUB-DIVISION **Zonomonoletes** Luber 1933

Speciosporites Alp. 1958

Miospores round to oval, cingulum narrow, thick and regular, exine granulate, finely verrucose or microreticulate.

Speciosporites laevigatus Alp. 1958

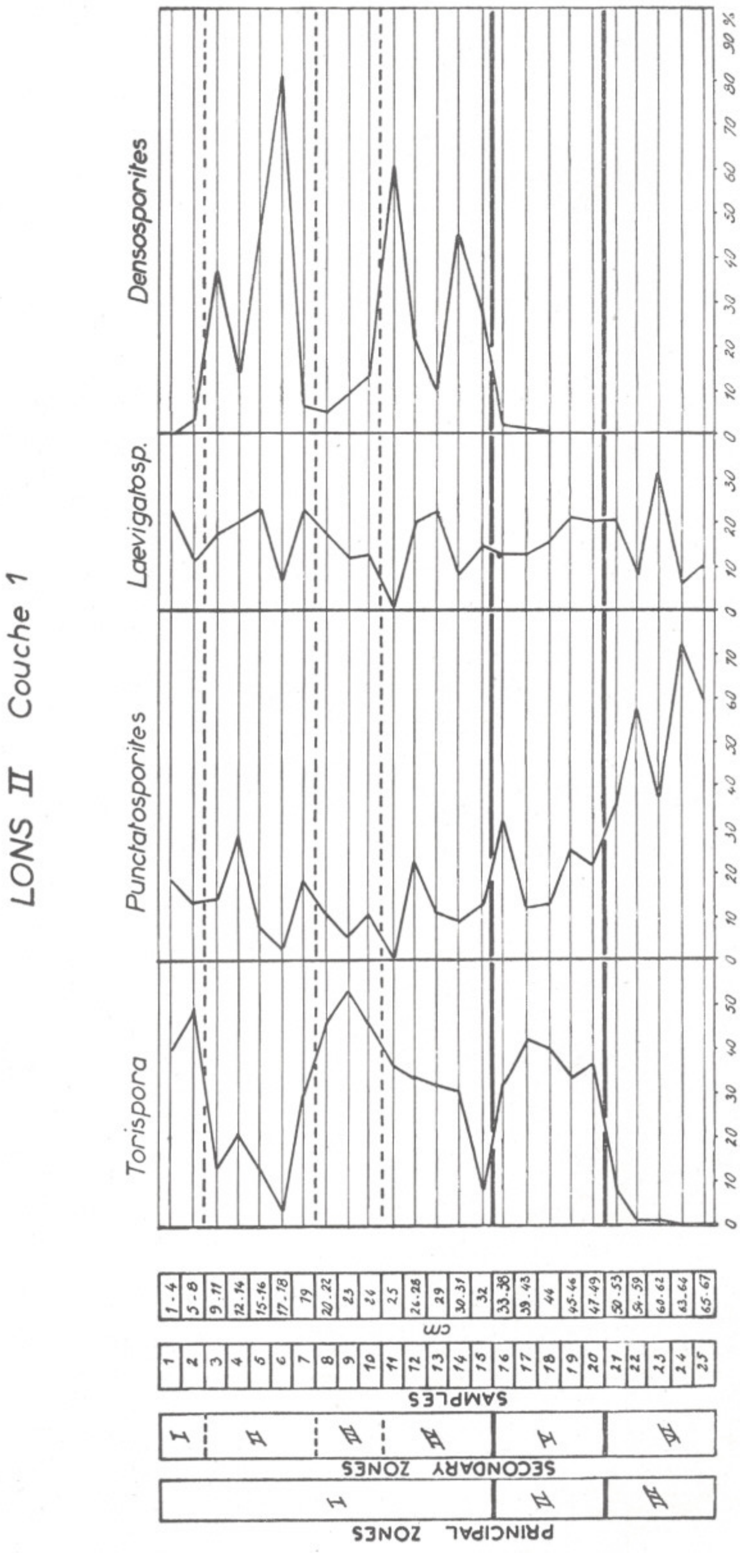
Size 35 μ, cingulum 2 μ large, exine smooth or without structure.

Speciosporites minor Alp. 1958

Size 28 to 35 μ, cingulum 2 μ, exine finely granular.

Speciosporites plicatus Alp. 1958 (PL. 6, PH. 93)

Size 25-59 μ, monolete slit curved, cingulum narrow, exine punctate.



TEXT-FIG. 2 — Variation of frequences of principal miospores.

Speciosporites bilateralis Alp. 1958 (PL. 6, PH. 92)

Size 50-58 μ, cingulum = 1/8 L, ornamentation $\pm$ 60 protuberances.

SUPRA-DIVISION **Pollenites** Potonié 1931
DIVISION **Saccites** Erdtman 1947
SUB-DIVISION **Polysaccites** Cookson 1947

Alatisporites Ibr. 1933

Pollen trilete, exoexine separated by intexine, air sacs generally three.

Alatisporites varius Kos. 1950 (PL. 5, PHS. 72-74)

Size 128 μ, triangular to round, 3 sacs 90 μ long, sacs punctate.

Alatisporites verrucosus Alp. 1959

Size 60-70 μ, Y = R of central body, sac exine granular, central body with verrucae, verrucae 4-5 μ, diameter.

SUB-DIVISION **Monosaccites** Chitaley 1951
SERIES **Saccizonati** Bhard. 1957

Endosporites Wil. & Coe 1940

Trilete miospores, shape triangular to oval, central body circular or oval, Y = R of central body, air sac separated by central body on the distal face.

Endosporites ornatus Wil. & Coe 1940 (PL. 3, PH. 32)

Size 90-120 μ, round or oval, Y = R. Crown = R.

Endosporites zonalis ? (Loose) Knox 1950 (PL. 5, PH. 77)

Size 90-100 μ, $(\text{Crown})^2$ = R of C.B.

SERIES **Aradiati** Bhardwaj 1955

Florinites S.W. & B. 1944

Monosaccate pollen, central body free on distal side, usually not evident tetrad mark on the proximal side. This genus is widely distributed with uniform minimum frequency ranging from 5 % to 20 % throughout the coal seam. The common species are:

Florinites antiquus Schopf 1944 (PL. 6, PHS. 81 & 83)

Size 65-95 μ, Central body (C.B.) clear, crown = R of C.B., Y-mark faintly visible, sac with infrareticulate network.

Florinites junior Pot. & Kr. (PL. 6, PH. 82)

Size 70-90 μ, C.B. clear, $\pm$ oval, Y (trilete) not visible. Crown = R of C.B. (4/3).

Florinites pumicosus Ibr.

Size 80-100 μ, C.B. faintly visible, Crown = R of C.B. Y-mark not visible.

Florinites triletus Kos. 1950

Size 49-69 μ, Y clear, Crown = R of C.B.

Latensina Luber 1938

The position of this genus in the sub-division of monosaccites is uncertain.

Latensina triletus Alp. 1959

Size 55-80 μ, Y clear, central part finely granular surrounded by fibrous concentric black lines.

SUB-DIVISION **Disaccites** Cookson 1947

Alisporites Daugherty 1941

Sacs two, symetrical, no trilete in the C.B. germinal slit on the distal side.

Pityosporites Seward 1914

Sacs two, open on the distal side, trilete absent or rare, sacs infrareticulate.

Pityosporites schanbergeri Pot. & Kl.

Size 25-70 μ, C.B. oval, finely reticulate.

DIVISION **Napites** Erdtman 1947

Amancisporites Alp. 1959

Pollen oval, round or quadrangular, neither sac nor germinal mark visible, exine fine, clear and traversed by few 1 μ large band along parallel and transverse axis of the pollen.

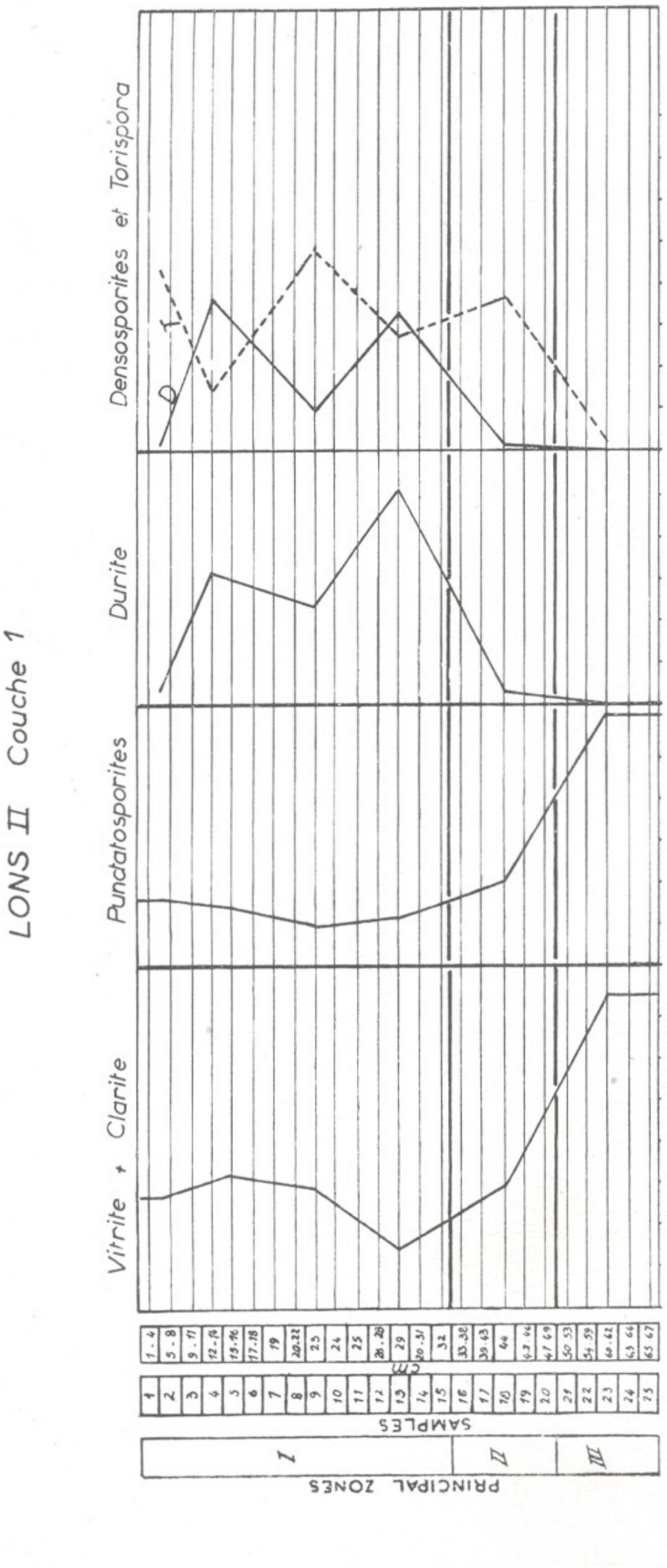
Amancisporites striatus Alp. 1959

Size 50-70 μ, exine traversed by fine bands (0·5 to 1 μ large).

COMMENTS ON DISTRIBUTION AND COMPOSITION

Among the rich variety of miospores recognised in the coal seam only *Densosporites*, *Torispora*, *Punctatosporites*, *Laevigatosporites* and *Florinites* are principal types in the distribution and statistical studies. The other miospores are either secondary or accessory forms.

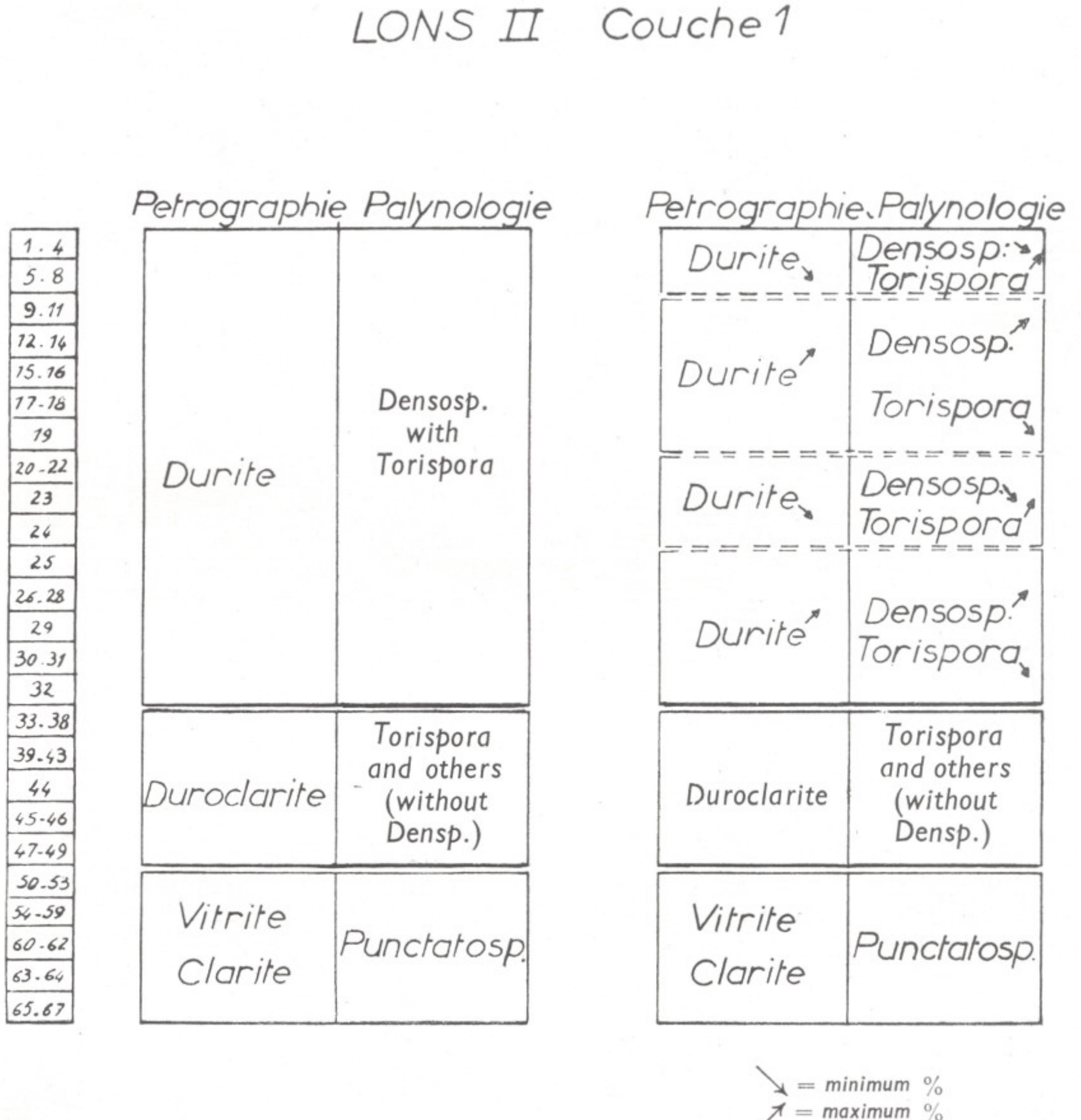
The pattern of the frequency distribution of principal miospores reveal certain significant features (FIG. 2). *Densosporites* is dominant in the micspore association with *Torispora* in the first 32 cm. (taken in 15 samples) of the coal pillar. But immediately after 32 cm. (i.e. after 15 samples), *Densosporites* totally looses its hold and completely disappears from the miospore assemblage in the remaining portions of the coal bed (i.e. from 33-67 cm. or from 16-25 samples).



TEXT-FIG. 3 — Comparison of petrographic and palynological frequences.

However, *Torispora* which existed fairly well from the beginning dominates in the dispersed spores without *Densosporites* from 33 cm. to 50 cms. of the coal seam (or from 16-20 samples). Conspicuously enough, even *Torispora* becomes almost extinct after 50 cm. (or 20 samples) and replaced by *Punctatosporites* which dominates in the miospore association in the remaining portion of the coal pillar i.e. from 51-67 cm. or from 21-25 samples. The three main zones shown by statistical and distribution pattern studies are —

I. *Densosporites* zone — 1-32 cm. of the coal bed (1-15 samples) (With *Torispora*)
II. *Torispora* Zone — 33-50 cm. of the coal bed (16-20 samples) (Without *Densosporites*)
III. *Punctatosporites* Zone — 51-67 cm. of the coal bed (21-25 samples) (without *Torispora* and *Densosporites*)



TEXT-FIG. 4 — Synthesis and comparison of zonations

Densosporites Zone (I) is characterised by the presence of miospore *Densosporites* in association with *Torispora*. Though irregularly distributed, *Densosporites* dominates in the miospore association having a percentage distribution ranging up to 80% in this zone. However in the succeeding portions after 32 cm., it totally disappears from the miospore assemblage. This broad zone can be differentiated into 4 minor zones on the basis of an inversely related distribution pattern of *Densosporites* and *Torispora* (FIG. 2). In the first minor zone (1-8 cm.), *Densosporites* is minimum (2%) with *Torispora* maximum (44%). In the second minor zone (9-19 cm.) *Densosporites* is maximum (36%) with *Torispora* minimum (15%). In the third minor zone (20-24 cm.) *Densosporites* is minimum (10%) with *Torispora* maximum (49%) and in the last minor zone *Densosporites* is maximum (63%) with *Torispora* minimum (20%).

Torispora Zone (II) is characterised by the presence of *Torispora without Densosporites* (FIG. 2). Although *Torispora* is represented in the earlier zone, but it gains prominance in this zone because of absence of *Densosporites*. The average frequency of *Torispora* in this zone reaches above 36 per cent. This miospore also becomes extinct in the next zone.

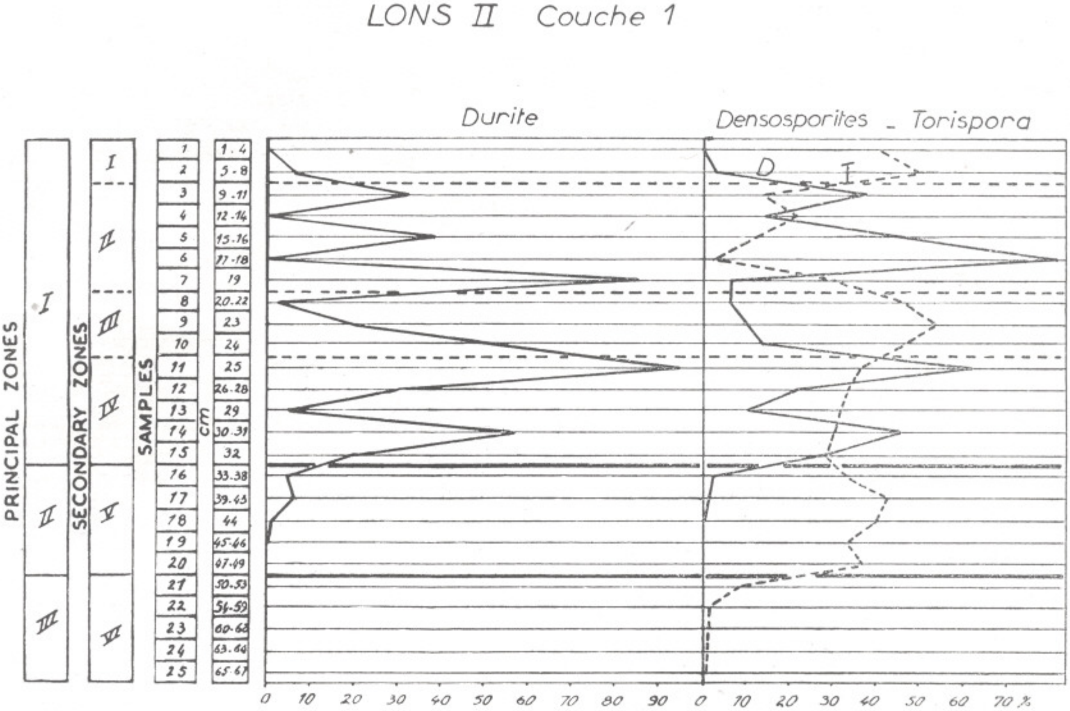
Punctatosporites Zone (III) is characterized by the dominance of *Punctatosporites* miospore without *Densosporites* and *Torispora* (FIG. 2). The average frequency of *Punctatosporites* is about 60%. This miospore remains in an uniform minimum distribution in the first two zones but suddenly becomes prominent in this zone in the absence of both *Densosporites* and *Torispora* miospores.

Petrographic studies of the coal bed reveal that Durite, Duroclarite, Vitrite and Clarite are principal microlithotypes, and these mark out three distinct zones constituting initially with Durite up to 32 cm., followed by Duroclarite from 33 to 50 cm. and finally by Vitrite and Clarite from 51 to 61 cms. of the coal pillar. The very similar three zonations indicated by petrographic components are well shown by miospore assemblage pattern (FIG. 3). *Densosporites* is significant with *Torispora* in miospore association in the first 32 cm., later by *Torispora* without *Densosporites* from 33-50 cm., and *Punctatosporites* in the remaining portion of the coal pillar (i.e. from 51-67 cm. of the coal bed). The comparative three zonations of the coal seam exhibited by microlithotypes and miospores (FIG.4) are:

Zones	Microlithotypes	Thickness of the coal bed.	Miospores
I.	Durite	1-32 cm.	*Densosporites* (with *Torispora*)
II.	Duroclarite	33-50 cm.	*Torispora* (without *Densosporites*)
III.	Clarite and Vitrite	51-67 cm.	*Punctatosporites* (without *Torispora* and *Densosporites*)

The synthesis of the palyno-petrographic studies (FIG. 4) indicate an inter-relationship between certain microlithotypes and miospores. Conspicuous relationship is shown by Durite and *Densosporites*. The frequency distribution of the two types is exactly similar (FIG. 5). High or low frequency of *Densosporites* correspond well with high or low content of Durite. It is significant to note dominance of *Densosporites* in association with high Durite content and complete disappearance of it in the absence of Durite (FIG. 5).

An association of *Torispora* and *Densosporites* in an inversely related frequency has been observed in Durite zone (FIG. 5). But both *Torispora* and *Densosporites* dis-



TEXT-FIG. 5 — Relation in Durite and *Densosporites & Torispora*.

appear with high Vitrite and Clarite contents (FIG. 3). *Punctatosporites* dominate in the region of high Vitrite and Clarite microlithotype indicating probable relation of monolete spores with microlithotype. The frequency pattern of monoletes particularly *Punctatosporites* shows maximum distribution in the region with maximum Clarite and Vitrite microlithotypes (FIG. 3). However, a particular kind of Clarite has been recognised associated with *Densosporites*, a thick-walled spore for the first time though usually Clarites are constituted by thin-walled spores (STACH, 1954; KREMP, 1952; SMITH, 1957).

CONCLUSIONS

Jura coals from Lons II Couche 1 are heterogeneous having different miospore assemblage patterns in the microlithotypes. The coal components, their mode of association and distribution suggest three main facies which are not only marked out by three main petrographic zones but also by three main miospore assemblage zones (FIG. 4). It is evident therefore, there were some environmental changes during this coal formation.

Palyno-petrographic components of the present coal seam apart from recognizing distinct miospore assemblages in various microlithotypes also reveal a relation of some petrographic components and miospores. Most striking relation is seen between Durite and *Densosporites*. The interrelationship of these two components help in classifying durites of the Jura coals, into Crassi-durite and Tenui-durite. The Crassi-durite is constituted by thick-walled miospores with massive Micrinite whereas Tenui-durite is constituted by thin-walled miospores. It is only with Crassi-durite, *Densosporites* (thick-walled) is associated. The Tenui-durite is constituted by thin-walled spores (STACH, 1954). The frequency pattern of Durite and *Densosporites* indicates large distribution of *Densosporites* in high Durite content. The decrease or absence of Crassi-durite simultaneously shows decrease or absence of *Densosporites*. Conspicuously *Densosporites* and *Torispora* are associated among the miospore assemblage in the Durite zone of the coal seam having relation inversely proportional frequency between each other.

Clarites of Jura may also be classified into Crassi-clarite and Tenui-clarite on the basis of miospore relation with the microlithotype. So far, it is regarded Clarites are Tenui-clarites (STACH, 1952) but the present coals exhibit Crassi-clarite also associated with thick-walled spore (*Densosporites*). It is however significant to observe that no Micrinite is associated with Crassi-clarite contrary to Crassi-durite which is always associated with Micrinite. Stach (1954), Kremp (1952) and Smith (1957) have generalised from their studies that Micrinite is always associated with *Densosporites*. But the present study as opposed to the above fact has shown no association of Micrinite with *Densosporites* of Crassi-clarite.

Monolete spores of Jura coals show a clear relation with Vitrite and Clarite microlithotypes. It has been observed that *Punctatosporites* is dominantly distributed with high Vitrite and Clarite content. *Laevigatosporites* is a transitory form in the microfloral assemblage.

The present studies indicate the probable origin of *Densosporites* and Durite, and likewise monoletes and Vitrite and Clarite components on the basis of their inter-relationship.

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EXPLANATION OF PLATES

Plate 1

1. Clarite with *Densosporites*.

2 & 3. Clarite with *Densosporites* (higher magnification).

4. Tenui-durite.

5 & 6. Tenui-durite in high magnification.

7. Crassi-durite.

8 & 9. Crassi-durite in high magnification.

Plate 2

10. Crassi-durite.

11 & 12. Crassi-durite in high magnification.

13. Duro-clarite with miospores.

14 & 15. Duro-clarite in high magnification.

16 & 17. Clarite with cuticles and miospores.

18. Clarite with miospores in high magnification (*Punctatisporites* ?)

Plate 3

19. *Dictyotriletes comptatus*, 104 μ.
20. *Dictyotriletes comptatus*, 82 μ.
21. *Dictyotriletes comptatus*, 90 μ.
22. *Dictyotriletes comptatus*, 84 μ.
23. *Dictyotriletes comptatus*, 96 × 86 μ.
24. *Calamospora hartungiana*, 73 × 80 μ.
25. Undetermined, 83 × 56 μ.
26. *Raistrickia* sp., 80 × 73 μ.
27. *Raistrickia superba*, 96 μ.
28. *Raistrickia saetosa*, 90 × 72 μ.
29. Undetermined, 64 × 67 μ.
30. *Densosporites lobatus*, 104 × 72 μ.
31. *Anulatisporites anulatus*, 61 × 56 μ.
32. *Endosporites ornatus*, 99 μ.
33. *Densosporites* sps., 80 × 54 μ.
34. *Densosporites duriti*, 68 × 66 μ.
35. *Densosporites faunus*, 54 × 72 μ.

Plate 4

36. *Densosporites lobatus*, 53 × 48 μ.
37. *Densosporites major*, 96 × 104 μ.
38. *Densosporites lobatus* , 74 × 87 μ.
39. *Densosporites* sp., 78 × 66 μ.
40. *Densosporites sphaerotriangularis*, 56 × 52 μ.
41. *Anulatisporites anulatus*, 56 × 52 μ.
42. *Densosporites sphaerotriangularis*, 68 × 56 μ.
43. *Densosporites duriti*, 55 × 48 μ.
44. *Densosporites indignabundus*, 48 × 60 μ.
45. *Densosporites indignabundus*, 48 × 60 μ.
46. *Densosporites solaris*, 60 × 56 μ.
47. *Densosporites* sp., 55 × 48 μ.
48. Undetermined, 54 × 44 μ.
49. *Triquitrites concavus*, 39 × 48 μ.
50. *Triquitrites puluinatus*, 39 × 26 μ.
51. *Triquitrites insitatus*, 40 × 44 μ.
52. *Triquitrites triturgidus*, 41 × 48 μ.
53. *Polymorphisporites gulaferus*, 40 × 38 μ.
54. *Ahrensisporites* sp., 40 × 42 μ.
55. *Lycospora granulata*, 32 μ.
56. *Lycospora pusilla*, 24 μ.
57. *Lophotriletes insignitus*, 41 μ.
58. *Lophotriletes gibbosus*, 38 × 36 μ.
59. *Microreticulatisporites nobilis*, 40 × 32 μ.
60. *Microreticulatisporites nobilis*, 56 × 48 μ.

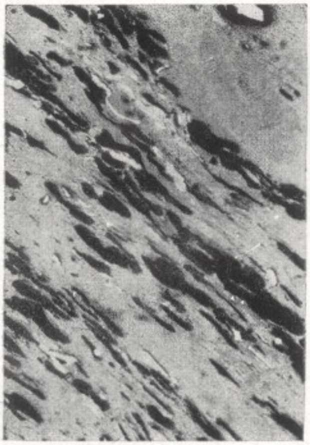
61. *Punctatisporites* sp., 50 × 40 μ.
62. *Granulatisporites parvus*, 48 × 52 μ.
63. *Cyclogranulatisporites aurers*, 68 × 52 μ.

PLATE 5

64. Undetermined.
65. *Calamospora mutabilis*, 78 × 61 μ.
66. *Angulisporites splendidus*, 75 × 95 μ.
67. *Punctatisporites punctatus*, 78 × 74 μ.
68. *Calamospora*.
69. *Leiotriletus sphaerotriangularis*, 56 × 52 μ.
70. *Leiotriletus convexus*, 65 × 53 μ.
71. *Calamospora mutabiles*, 56 × 60 μ.
72. *Alatisporites varius*, 132 × 107 μ.
73. *Alatisporites varius*, 112 × 123 μ.
74. *Alatisporites varius*, 116 × 96 μ.
75. *Cirratriraditus saturni*, 127 × 161 μ.
76. *Cirratriraditus flabelliformis*.
77. *Endosporites ? zonalis ?* 104 × 88 μ.
78. *Cirratriraditus saturni*, 104 × 88 μ.
79. *Cirratriradites* sp., 74 × 99 μ.
80. *Cirratriradites* sp.

PLATE 6

81. *Florinites antiquus*, 92 × 72 μ.
82. *Florinites junior*, 84 μ.
83. *Florinites antiquus*, 60 × 64 μ.
84. *Reinschospora gulaferus*, 57 × 64 μ.
85. *Reinschospora gulaferus*, 58 × 74 μ.
86. *Reinschospora magnifica*, 60 × 51 μ.
87. *Platysaccus*, 48 × 32 μ.
88. Undetermined, 36 × 44 μ.
89. *Polymorphisporites reticuloides*, 64 × 71 μ.
90. *Polymorphisporites laevigatus*, 56 × 58 μ.
91. *Polymorphisporites laevigatus*, 56 × 58 μ.
92. *Speciososporites bilateralis*, 57 × 42 μ.
93. *Speciosporites plicatus*, 36.
94. *Punctatosporites granifer*, 25 × 33 μ.
95. *Crassosporites punctatus*, 25 × 40 μ.
96. *Torispora laevigatus*, 66 μ.
97. *Torispora securis*, 45 × 30 μ.
98. *Torispora laevigatus*, 37 × 26 μ.
99. *Torispora securis*,
100. *Torispora securis*, 40 × 41 μ.
101. *Torispora securis*, 37 × 58 μ.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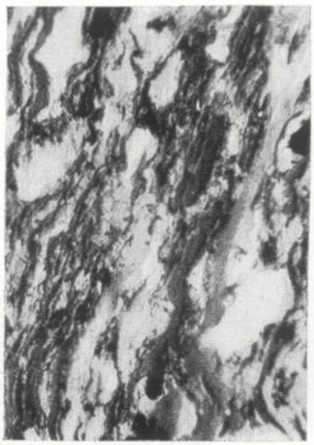
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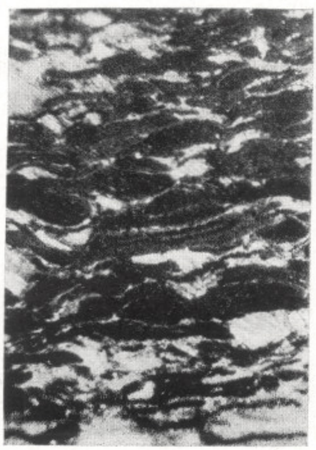
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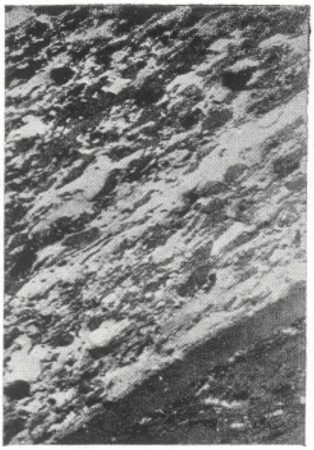
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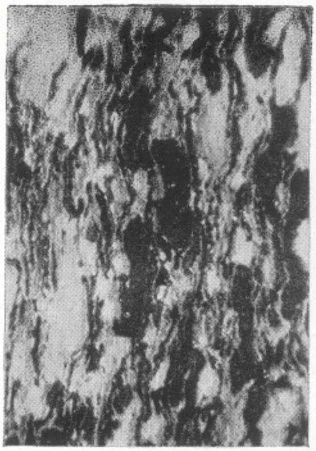
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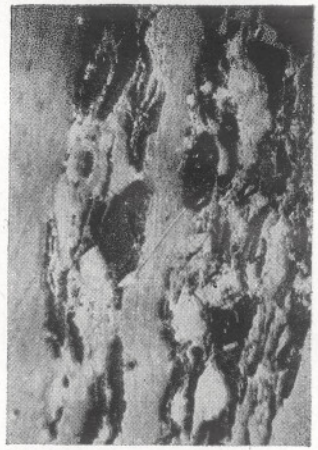
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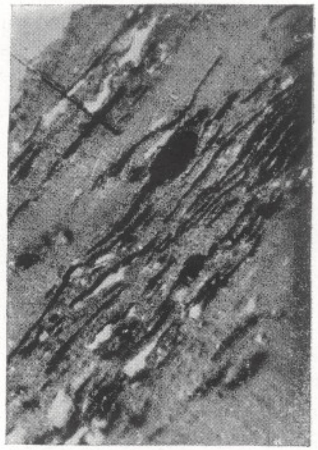
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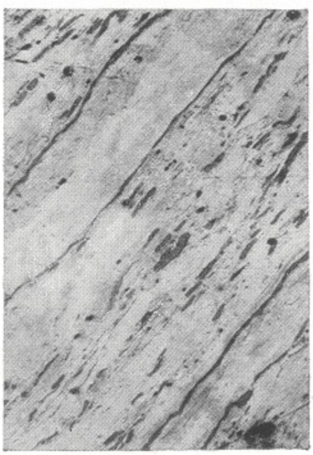
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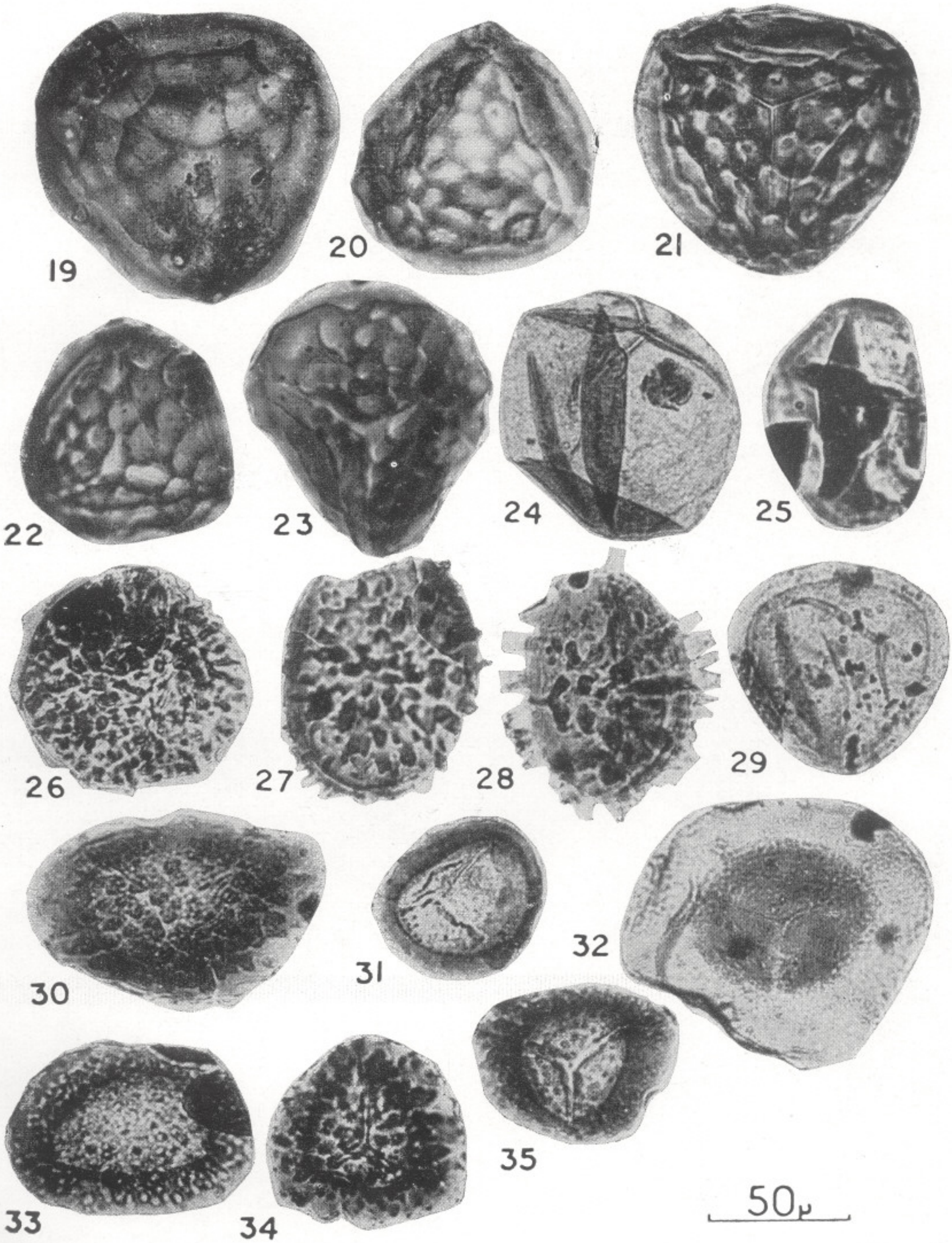
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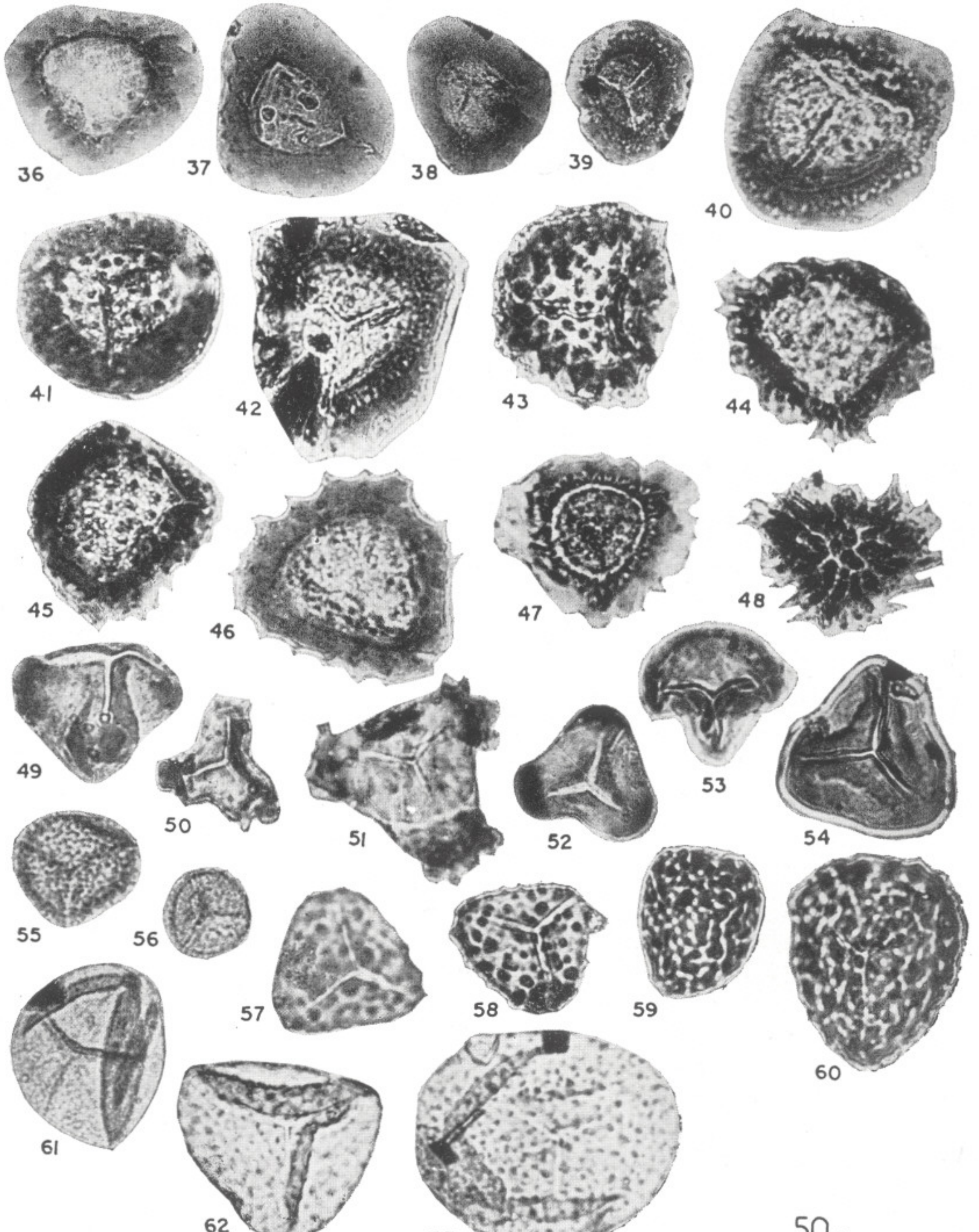
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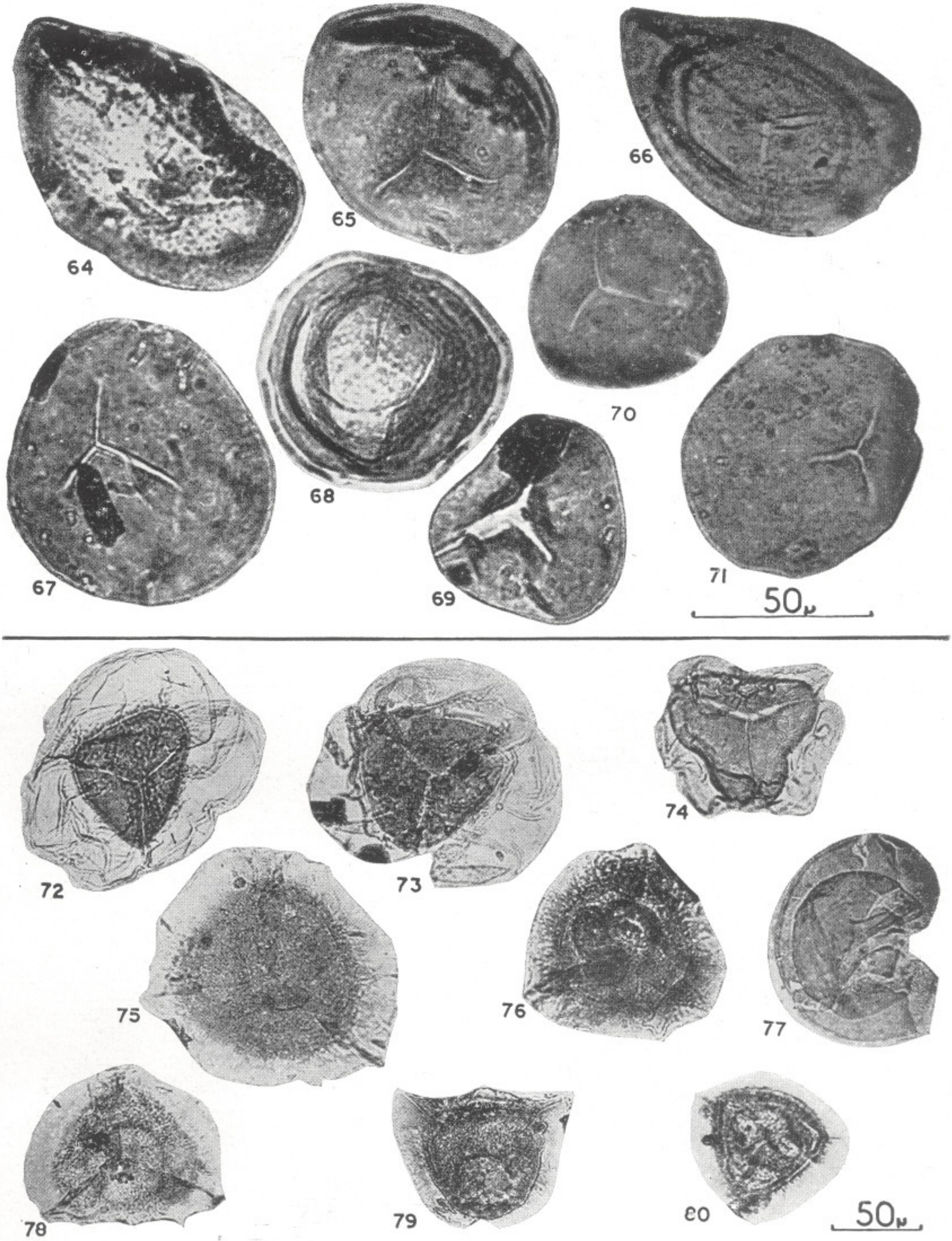
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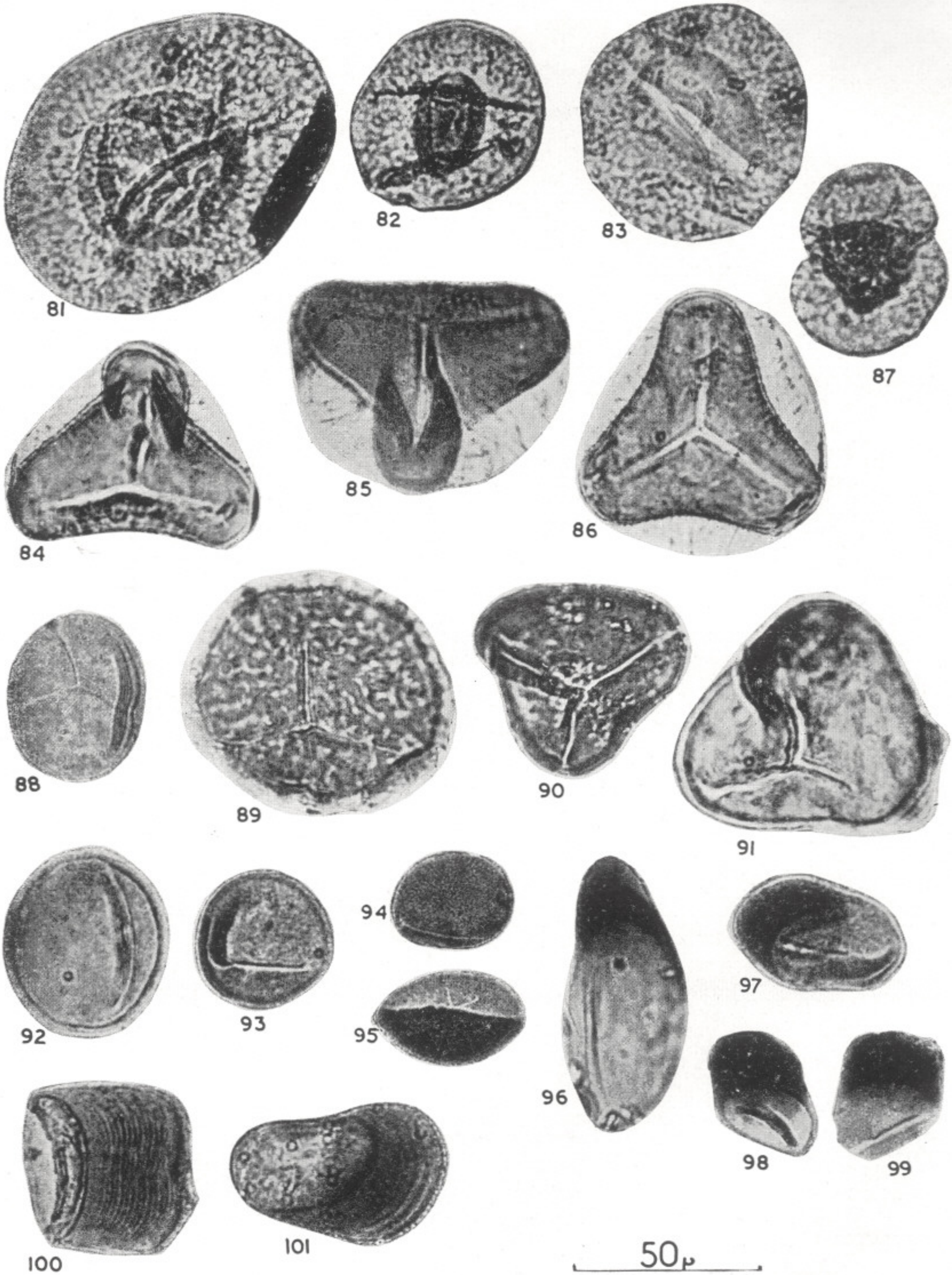
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