PALYNOLOGICAL STUDIES OF MERLABACH COALS IN CONJUNCTION WITH PETROGRAPHIC STRUCTURE

G. K. B. NAVALE

Birbal Sahni Institute of Palaeobotany, Lucknow

ABSTRACT

Palynological studies of Merlabach coals from Veine 6 etage 686 have been made along with petrographic structure. The detailed qualitative and quantitative studies of microspore and petrographic components of coals indicate three main zones of microlithotypes and microspore assemblages. Even minor zones are indicated in the main zones. Recognition of these zones suggest sequential coalification of the heterogeneous coal seam. Also the study has shown a distinct relationship between some microspores and petrographic components.

INTRODUCTION

THE general knowledge concerning the petrography and palynology of French coals is now available (ALPERN, 1955-60). The results are successfully employed in correlating coal seams and for stratigraphic zonation. However, no attempt has been made so far for palynological study in conjunction with petrographic structure. A good knowledge of the interrelation between the dispersed spores and pollen grains and petrographic components, and their interrelation may provide some useful information in understanding the heterogeneity of coals (NAVALE, 1963).

Coal seams compose of layers which are capable of identification by their palyno-petrographic characters (SCHOPF, 1948-52). These layers exhibit changes which are not well understood and therefore hinder proper understanding of the formation of coals and their correlation. The facies of coal could be known by recognizing petrographic and microspore assemblage zones (KREMP, 1952; SMITH, 1957, 1962 & NAVALE, 1962). Spores and pollen grains provide an index by which litho- or microlithotypes could be recognized (KREMP & FEDERIKSEN, 1960). The microflora retain certain morphological features during all stages of metamorphism and thereby each litho- or microlithotypes reflect a particular source of material and metamorphism. A proper understanding of the vegetational source, sedimentary environment and deposition help in resolving the complex nature of the coal constitution.

The present study is mainly pursued to know the interrelationship between microfloristic and petrographic components of Merlabach coals and their bearing on coal formation and constitution. Hence this investigation deals with palynological studies of coals in conjunction with petrographic structure from Merlabach seam 6 which lies in Saar-lorraine coal basin situated in the east of France. This basin forms a large sinking zone which extends N.E.-S.W. from Lorraine to West Germany.

The position of Merlabach is in the centre of south east of the Saar-Lorraine basin. The terrain of this basin is composed of sedimentary rocks of continental origin. The deposit is purely limnic without any trace of marine invasion. The different lithological and palaeontological evidences of Saar-Lorraine coal basin distinguishes two grand association of coal deposits. The first is more ancient known as Saarebruck coals having 30000 thick deposit and the other grand deposit is Ottweiler coals. The later can be differentiated from Saarebruck coals in their nature of colour, ash content and associated rock types.

Merlabach coals lie in Saarebruck coal deposit. Coal seams in this deposit are very numerous, variable in thickness, more or less regular and are intercalated in schists and conglomerates. The stratigraphical position of the deposit is Westphalian. Merlabach veine (seam) 6 from which the present study has been made lies in Westphalian D. This seam runs in between schists and conglomerates. It lies immediately above Merlabach seam 7. The inclination between the two seams is 0·38 m. to 7 m. and its continuity in the basin is 3400 m.

MATERIAL AND METHODS

The general object of the present studies has already been mentioned. It is necessary to adopt suitable methods for studying petrographic as well as sporological constitution of the coals. The methods for palyno-petrographic studies include (i) selection of suitable apparatus and chemicals (ii) preparation of coals for petrographic studies and (iii) preparation of coals for palynological studies.

(I) *Apparatus and Chemicals* — Apparatus for embedding (Ph. 2), oven, cutting and polishing machines (Ph. 1), Centrifuges and counters (Phs. 3 & 4), microscopes (Ph. 4 & 5), bakelite solution, palatal, carborandum powder of different grades, alumina of different suspensions, concentrated nitric acid, potash, mounting medium and other accessories.

(II) *Preparation of Coal Samples for Petrographic Studies — Sampling* is the first stage of preparation. It is done depending on the nature and the type of the investigation to be taken up. For general petrographic studies of coal seams, about 150 grams of material has to be collected from total thickness of the bed and a homogeneous mixture of material has to be made, and after which a median mixture of 5 grams of coal < 5 mm. has to be taken up for further preparation. For lateral correlation of coal seams, samples have to be collected at suitable intervals (artificial unit) from each seam. After homogeneous mixture of these samples a median mixture of the material selected from different levels from each seam has to be petrographically analysed and compared.

For the present investigation complete core samples from Merlabach (Veine 6) were taken. The method of sampling was done by selecting a suitable spot and cutting a channel. The channel was cut on either side leaving 15 in. to 20 in. wide gap of the bed. On a strip of paper all noticeable partings were taken. Samples as nearly as 15″ square block were removed. Each block was marked with their face (top, bottom) positions. Samples were kept in a box in a regular order so that complete core was laid out as it appeared on the face of the coal bed. They were recorded on paper also to assure proper assembling in the laboratory. Samples were covered with plaster to retain moisture and prevent disrupting effect.

Embedding — After transport of coal samples to laboratory and deplastering, proceeded with embedding the coal material. It is necessary to embed the coals (butiminous) as they are fragile (Ph. 2) for 3 hours for proper enrobage of fragile coal particles. Later they were kept in hot oven for another 3 hours for hardening the material. Coal samples were then treated with palatal mixture. This was done by keeping the coal blocks in suitable metallic disks and covering with palatal mixture completely. The materials were kept in oven until they were hardened before taking up for polishing.

Polishing was done with Carborundum powder on a metallic and glass plates The coarse grinding was done on the metallic plate mounted on a rotating lap, while finer grinding was done on glass plate alone. The quality of silicon carbide grain used in three stages were 80 μ on metallic disque and 18 μ and 5 μ on glass plates. Grinding made the blocks uniform and rendered smooth surface free from scratches. The block was observed from time to time under low power binocular microscope making the ground surface dry which was quickly achieved by blast air. Thus a uniform, smooth and fine block was achieved completely free from scratches enabling for finer polishing. Finer polishing was done with polishing alumina diluted with 10 parts of distilled water. It was applied to a wet revolving wheel covered with polishing cloth (Ph. 1). Two grades of alumina (3 hours and 24 hours) were used. The first finer polishing was done with alumina (3 hours). After a period of alumina alone, a small flow of water was applied and polishing continued. Similarly finer polishing was continued with the other grade of alumina (24 hours) with intermittent water. Finally blocks were polished in pure water until it was free from all polishing material. The polished block was mounted and fixed horizontally by the help of plastacene. The surface was smeared with glycerine.

Examination and Analysis of petrographic components were made by metallographic microscope in reflected light. Microlithotypes in each centimeter of the coal samples were analysed by integrated counter (Ph. 4) specially devised by CERCHAR (ALPERN, 1959).

(III) *Preparation of Coal Samples for Palynological Studies — Sampling*: For general studies of dispersed spores in coals, representative coal samples have to be collected and prepared a homogeneous mixture. A median mixture of these samples has to be considered for studies. For lateral correlation of coal seams, samples have to be collected at vertical intervals (artificial limits) from each seam and a separate homogeneous mixture of these samples has to be prepared for studies. For complete analysis of palynological data samples have to be collected from full profile.

In the present study, petrographic investigation has been followed by palynological studies. Therefore 39 cms. thick coal seam studied petrographically centimeter by centimeter has been split up into 39 samples by cutting centimeter by centimeter. This was done to compare the petrographic components of each centimeter studied with that of palynological constitution. The samples thus obtained were cleared from extraneous material such as palatal, bakelite, etc. After cleaning all the samples, they were ground to obtain a homogeneous mixture. Samples were sieved in 1 mm.-0·1 mm. sieve. Material between 0·1 m. and 1 mm. were taken for further preparation. Suitable methods were adopted to obtain a representative coal sample from each centimeter. In most of the cases one centimeter of coal was just sufficient for 2 grms. of material for maceration. Sometimes less also. In case of more material of coal samples, they were split and resplit into different portions and a representative unit was taken from all split portions. Likewise a mean mixture of all samples were prepared. Each sample was collected in suitable containers and numbered before taking for maceration.

Maceration — It is a chemical process to release the organic constituents loose from each other. This process renders all spores and cuticles and other woody fragments free from colloidal ground mass. 2 grms. of coal material was treated with a mixture of 28 cc. of Nitric acid and 4 grms. of pottasium chlorate. The ratio was proportionately adjusted in case of material less than 2 grms. Before adding 28 cc. of nitric acid, a homogeneous mixture of 2 grms. of coal material and 4 grms. of pottasium chlorate was made and taken in a clear air dry flask. After covering the samples with nitric acid, the time of attack was recorded. The duration of the maceration depends upon the type of the material. In the present investigation, time required for maceration of samples was 5 days. Necessary precautions were taken to render complete action by shaking once a day and adding acid when found necessary. After the required action of acid treatment, the chemical process was stopped by adding water. The macerates were then treated with 10 per cent KOH solution removing the excess of water. This treatment renders spores and other organic matter free from matrix enabling recouperation.

Recouperation begins with sieving the macerate through a Nylon (0·2 mm. sieve) cloth. The material below the sieve was taken for recovering spores, and the material over and above was examined for megaspores. For microspores, residue 0·2 mm. was taken and washed with centrifuge having speed 2,900 t/m. (Ph. 3). This action helps in eliminating all heavy particles and allowing a fine sediment to settle. Further the fine residue was washed in a smaller hand centrifuge to eliminate all extraneous material. Later the macerates were treated with hydrofluoric acid (50 per cent) for some time to remove mineral matter. The residue from hydrofluoric acid was washed and rewashed by centrifuging until the material was free from acid and other organic matter. Further centrifuging was done in alcohol. Finally macerates were preserved in glycerine. The small storage tubes of all the macerates were carefully labelled.

Mounting of Microspores was done with glycerine jelly. While mounting, a uniform representative residue was taken on a glass rod with a piece of glycerine jelly. It was transferred over a clean microslide slightly warmed by heater to dissolve the jelly and to get mixed up with the material. After proper mixing the material with jelly two microslides were prepared to have sufficient statistical data.

Examination and Analysis of spores were made under high power of the microscope. For statistical studies 500 microspores were counted as it was found sufficient for the present investigation. Before spore analysis a proper identification of sporae dispersae was done on the basis of their morphological characters. Counting with the help of point counters (Ph. 5) was done under high power.

STUDY AND ANALYSIS OF PETROGRAPHIC COMPONENTS

The petrographic aspect of the coal seam has been studied by examining the microscopic constituents of coals. The principles and the terminology applied for petrographic studies have been outlined in my earlier paper (1963). The following description comprises, the study and distribution pattern of microlithotypes recognized in the coals of Merlabach seam 6. The term microlithotype was introduced by Seyler (1954) to designate in the microscopy of humic coals for the typical associations of macerals, the minimum width of which has been fixed provisionally at 50 microns. The microlithotype bear suffix "ite".

Vitrite Potonie 1924 (Plate 2, ph. 6)

The vitrite microlithotype consists principally of Collinite and Telinite macerals. It contains atleast 95 per cent Vitrite. The megascopic appearance of the coal shows bright vitrain bands. The appearance in polished surfaces does not vary much. Some vitrite exhibits cell structure (Telinite). This microlithotype forms a major component in the petrographic constitution of the coal seam investigated. The distribution percentage of the microlithotype ranges from ± 17 to ± 78 per cent (FIG. 1) in the total thickness of the bed (39 cm.). The average frequency is usually more than 40 per cent. But characteristically the microlithotype suddenly decreases in its frequency and almost disappears in the region between 10 and 14 cms. of the coal bed (FIG. 1). However it regains its original position even to a maximum percentage after the zone of minimum presence.

Clarite Potonie 1924 (Plate 2, Phs. 7-8 & 12-14)

The clarite microlithotype constitutes mainly (at least 95 per cent) Vitrite and Exinite as maceral components. The proportions of these two macerals vary widely but each maceral is greater in proportion than Inertinite. The megascopic appearance of coal shows clarain bands. The microspores and cuticles are well associated with clarite. Clarite can be differentiated into three types (1) Microspore clarite (2) Cuticle clarite (3) Megaspore clarite.

Microspore Clarite (Plate 2, Phs. 7, 8 13 & 14) — Microspores are abundantly associated with clarite. The frequency distribution of microspores ranges from ± 0 to ± 40 per cent. The spore exines are of diversed type because of rich variety of spores. Dominant and distinct spore exines such as exines of *Torispora* (Plate 2, Ph. 8) and *Densosporites* (Pl. 2, Ph. 10 & 11) could be recognized.

Cuticle Clarite (Pl. 2, Ph. 12) — Cuticles are also equally well associated with clarite. It shows a wide range of variation in frequency. The distribution percentage ranges from ± nil to ± 65 per cent. Conspicuously, high distribution frequency is recognized in the basal portion of the coal pillar along with vitrite bands. Cuticles differ in appearances depending on the structures. Individual cuticles are thinner than megaspore exines but has much lateral extensions. The cuticles lie between contiguous bands of vitrite and clarite.

Megaspore Clarite — Megaspore exines are not abundant. They are seen only in few centimeters of the pillar. When present its distribution ranges up to ± 7 per cent. The exines show different patterns. Megaspore exines are thicker than cuticle exines. In general clarite microlithotype forms an important component in the petrographic constitution having a percentage range from ± 10 per cent to 75 per cent (FIG. 1). The average frequency of the microlithotype is about 28 per cent. However, clarite characteristically decreases in the region between 10 to 14 cm. But this microlithotype also regains its original position like vitrite after the minimum zone.

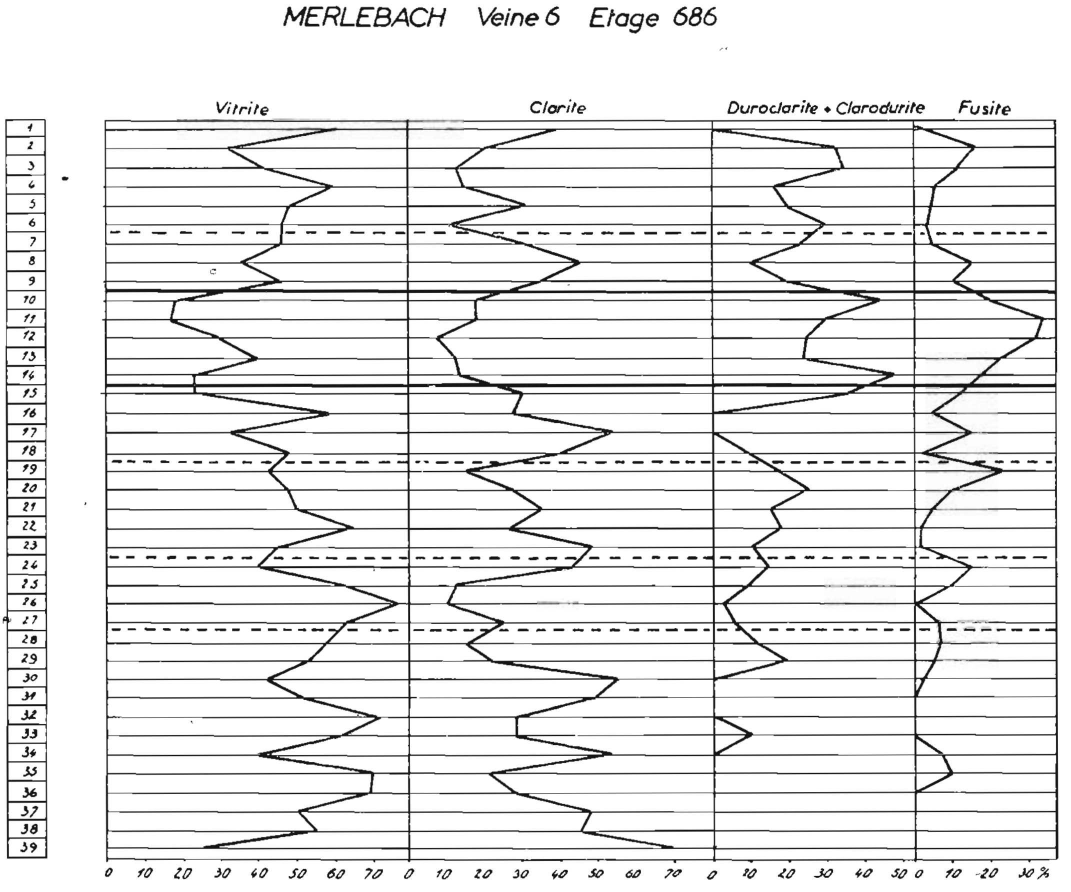
Duroclarite Potonie 1924 (Pl. 2. Fig. 11)

The maceral composition of this microlithotype is inbetween those of clarite and Durite but closer to clarite than Durite. The maceral composition being Vitrinite > 5 per cent, Exinite > 5 per cent, and Inertinite > 5 per cent. The proportion of Vitrinite always exceeds Inertinite. It is difficult to recognize this microlithotype megascopically. However, the microscopic observation of the microlithotype shows three types namely (1) Microspore duroclarite (2) Cuticle duroclarite (3) Megaspore duroclarite.

Microspore duroclarite is associated with microspores. The distribution frequency ranges from 0 to 40 per cent. Spore exines may be of different types depending on the nature of spores. Spore exines of *Torispora* and *Densosporites* could be recognized.

Cuticle duroclarites are not many and found only in few samples. The range of frequency of the type when present varies from 0 to ± 12 per cent. Megaspore clarite are extremely rare and are found only in two or three cms. in the total thickness. When present in the coal constitution it's frequency range is from 0 to ± 1 per cent.

Duroclarite microlithotype though not abundant yet is observed in most of the



TEXT-FIG. 1 — Frequency variations of principal microlithotypes

samples having a distribution frequency from 0 to ± 45 per cent (FIG. 1). Maximum presence of this microlithotype has been recognized between 10 and 14 cms. of the coal seam. The average frequency is about 10 per cent. But there is a gradual decrease from 14 cms. onwards.

Clarodurite Cady 1942 (Pl. 2, Figs. 9, 10, 11)

The constitution of this microlithotype is inbetween those of clarite and durite but closer to Durite than Clarite. The maceral composition of Vitrinite > 5 per cent, Exinite > 5 per cent, and Inertinite > 5 per cent. The proportion of Inertinite is more than Vitrinite. It is difficult to recognise this microlithotype megascopically but under microscope it could be recognized only in 3 cms. of the coal pillar. It is rather extremely rare and does not show any types unlike Clarite and Duroclarite. When present its distribution ranges ± 0 to ± 8 per cent having maximum of only 8 per cent recorded at 12th cm. of the coal bed (FIG. 1). It is of interest to note its association with high Duroclarite and Fusite content.

(*Fusite* Potonie 1924, Pl. 2, Fig. 9)

The principal maceral components of this type are Fusinite, Semifusinite and Sclerotinite. They form 95 per cent of the total composition. The megascopic examination of the coal shows grey black bands having friable fibrous structure. The range of frequency of the component is from nil to 35 per cent (Fig. 1). The average frequency is just about 8 per cent. But conspicuously it increases in the region between 10 and 14 cm. of the coal pillar. It is associated with Duroclarite.

COMMENTS ON THE COMPOSITION AND DISTRIBUTION OF PETROGRAPHIC COMPONENTS

The detailed petrographic examination of the coal shows that the coal bed is principally constituted by *Vitrite*, *Clarite*, *Duroclarite* and *Fusite* components. Some important facts are that Vitrite dominates in the composition closely followed by Clarite as a secondary component. But both the microlithotypes characteristically decrease in the distribution with a minimum frequency in the zone between 10th to 14th cms. However at the same zone the Fusite is conspicuous and dominant with high percentage associated with Duroclarite and Clarodurite. The statistical analyses and composition of the different components of the coal bed indicate 3 main petrographic zones. Also these three main zones suggest minor subdivisions (FIG. 2).

10th cm. and dominate in the frequency up to 14 cm. Together they form about ± 62 per cent including Clarodurite. However, this main zone has a small range and soon Vitrite and Clarite reappear (FIG. 2).

The third main zone Vitrite and Clarite follows immediately after Duroclarite and Fusite zone indicating a cycle of the components. Again this main zone shows 4 minor sub-zones. From 15 to 18 cm. of the coal seam Vitrite and Clarite are equal in distribution indicating the first minor sub-zone. It is followed by another minor sub-zone from 19 to 23 cm. by having Vitrite more than Clarite. Further Vitrite reaches maximum frequency showing another minor sub-zone. Finally yet another minor sub-zone is indicated from 28 to 39 cm. with Vitrite more than Clarite (FIG. 2).

Thus two minor sub-zones in the main

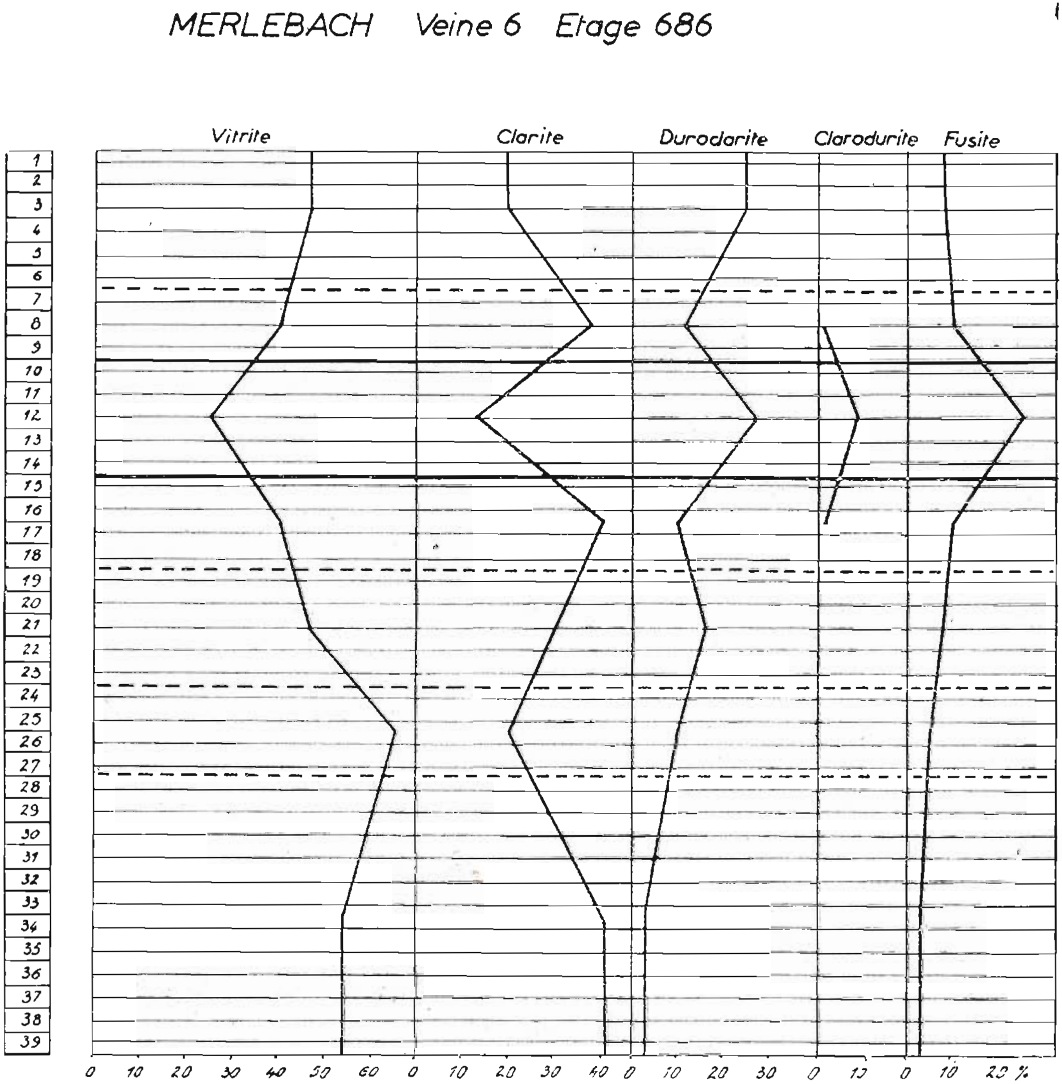
Main Zones	**Minor Zones**
I. Vitrite + Clarite dominant, with Duroclarite (1-9 samples)	1. Vitrite = Clarite + Duroclarite (1-6 samples) 2. Vitrite = Clarite (6-9 samples)
II. Duroclarite + Clarodurite + Fusite dominant, with Vitrite (10-14 samples)	
III. Vitrite + Clarite dominant, with Duroclarite (15-39 samples)	1. Vitrite = Clarite (15-18 samples) 2. Vitrite > Clarite (19-23 samples) 3. Vitrite maximum (24-27 samples) 4. Vitrite > Clarite (28-39 samples)

The first main zone Vitrite and Clarite extends up to 9 cm. of the Coal bed. They together form about 74 per cent of the total constitution of microlithotypes. Further, this main zone indicates two minor sub-zones. From 1 to 6 cms. Vitrite is the main component associated with more or less equally distributed Clarite and Duroclarite, forming the first minor sub-zone (FIG. 2). But in the 7th, 8th and 9th cm., the frequency distribution indicates an increase in the percentage of Clarite while Vitrite and Duroclarite decrease showing the second minor sub-zone (FIG. 2).

The second main zone Duroclarite, Clarodurite and Fusite suddenly appear at the

Vitrite and Clarite zone just above the Duroclarite and Fusite main zone, and four minor sub-zones of Vitrite and Clarite main zone which reappeared again below the Duroclarite and Fusite main zone could be recognized.

Petrographic studies of Merlabach Veine 6 coal bed reveals that it is mainly constituted by three main zones of Petrographic components. They are (1) Vitrite and Clarite (2) Duroclarite, Clarodurite and Fusite, and (3) the reappearance of Vitrite and Clarite microlithotypes. The distinct different compositions suggest the possible process of different diagenesis stage. It is apparent that the source of material to form coal was



TEXT-FIG. 2 — Petrographic zonation

not uniform but differed suddenly (between 10 and 14 cm. of the bed) effecting a change in diagenesis and thereby resulting in different microlithotypes. This aspect shown by petrographic studies were examined by palynological investigations in order to understand the bearing of microflora on the changes observed.

STUDY AND ANALYSIS OF MICROSPORE ASSEMBLAGE

Merlabach (Lorraine) coals are rich in microspore forms. There are different types of triletes, monoletes and monosaccate microspores. The following description deals with a systematic morphographic and statistical studies of microspores recognized in the coal seam investigated.

SUPER DIVISION — **Sporites** H. Pot. 1893
DIVISION — **Triletes** (Reinch) Pot. & Kr. 1954
SUB-DIVISION — **Azonotriletes** Luber 1935
SERIES — **Laevigati** (B. & K.) Pot. & Kr. 1956

Leiotriletes **(Naumova) Pot. & Kr. 1954**

Triangular, concave to convex forms, exine thick intrapunctate to infragranulate. This genus is represented by two species in the coal seam. However they are rarely found.

Leiotriletes gulaferus Pot. & Kr. 1954 (Pl. 3, Fig. 15).

Spore triangular, convex form, 30-70 μ, a longfold in one of the branches of the Y rays forming axis.

Leiotriletes adnatoides Pot. & Kr. 1955 (Pl. 3, Ph. 15).

Spore triangular, concave form, 30-40 μ, Y-rays = 3/4 R.

Punctatisporites **(Ibr.) Pot & Kr. 1955**

Spores ± round, punctate ornamentation, exine thick. A rarely distributed genus with one species in the coal seam.

Punctatisporites punctatus Ibr. 1933 (Pl. 3, Ph. 17).

Spores ± round, Y rays > 2/3 R, exine infrapunctate sometimes folded.

Calamospora **S.W. & B. 1944**

Spores ± round, exine thick, area contiguous marked, Y rays > 2/2 R. This genus is represented by *C. perrugosus* which is rarely distributed in the coals.

Calamospora perrugosus Loose 1934 (Pl. 3, Ph. 18).

Spores round, 130-160 μ, Y rays > 1/3 R, exine fine and very thick and sometimes infrapunctate.

SERIES — **Granulati** Dayb. & Jac. 1957

Granulatisporites **(Ibr.) Pot. & Kr. 1955**

Spores triangular, triradiate, exine granular, granules round and regular. Represented in the coal seam by *G. piroformis* and *G. parvus* with very limited distribution.

Granulatisporites piroformis Loose 1934 (Alp. 1959. Ph. 52).

Spores triangular, ± concave, 25-40 μ, granules 1 μ, ± 65 granules, visible on the equatorial contour.

G. parvus (Ibr.) Pot. & Kr. 1955 (Pl. 3, Ph. 19).

Spores triangular to rectilinear, 30-50 μ, apex round, granules 0·5 μ.

Cyclogranisporites **Pot & Kr. 1954**

Spores round, exine granulate having wide range of variation. This genus is represented by *C. pergranulus* and *C. aureus* having a minimum distribution in all samples (4 to 15 per cent).

Cyclogranisporites pergranulus Alp. 1958 (Pl. 3, Ph. 21).

Spores round, 64 × 72 μ, exine granulate, grains broader than high, Y-mark rarely visible.

C. aureus (Loose) Pot. & Kr. 1955 (Pl. 3, Ph. 20).

50-80 μ, ± 65 grains on equator, Y rays = 1/2 R visible.

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

Apiculatisporites **(Ibr.) Pot. & Kr. 1955**

Spores round, cones variable, always higher than broad. A rare form represented by one species i.e. *A. setulosus*.

Apiculatisporites setulosus (Kos.) Pot. & Kr. 1956 (Alp. 1959. Phs. 70-73).

60-80 μ, Y rays = 1/2 R, ± 40 to 50 cones, spaced on equator.

Acanthotriletes **(Naum.) Pot. & Kr. 1954**

Spores triangular, spines longer than broad. A very seldom spore in the coals, represented by one species *A. microsaetosus*.

Acanthotriletes microsaetosus (Loose) Pot. & Kr. 1955 (Pl. 3, Phs. 23 & 24).

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

Raistrickia **(S.W. & B.) Pot. & Kr. 1955**

Spores ± round, bacula or setae ornamentation Represented rarely by *R. aculeata* species only.

Raistrickia aculeata Kos 1960 (Pl. 3, Ph. 25).

62-75 μ, Y rays faint, bacula 7 to 10 μ long and 3 μ broad.

Lophotriletes **(Naum.) Pot. & Kr. 1955**

Spores triangular, convex to concave to sometimes round, exine ornamentation with cones longer than broad.

L. mosaicus and *L. microsaetosus* are two species rarely distributed in the coal seam.

L. mosaicus Pot. & Kr. 1954 (Alp. 1959, Phs. 66-68 — Pl. 3, Ph. 22).

30-40 μ, concave, 8-10 cones, cones 2 μ, reticulam negative, irregular. Y rays = 1/2 R.

Lophotriletes microsaetosus (Loose) Pot. & Kr. 1954 (Alp. 1959. Phs. 62-64).

Spores triangular, concave, 25-40 μ, ± 35 cones, cones with irregular negative reticulam.

***Verrucosisporites* (Ibr.) (Pot. & Kr.) Bhard. & Venk. 1961**

Spores ± round, ornamentation verrucate. Represented by a single rare species *V. microverrucosus.*

Verrucosisporites microverrucosus (Ibr.) Pot. & Kr. 1954 (Alp. 1959. Ph. 88).

45-75 μ, Y R, verrucae 3-7 μ.

SERIES — **Muronati** Pot. & Kr. 1954

***Cristatisporites* Pot. & Kr. 1954**

Spores triangular or round, exine ornamentation-spines or cones, Y-mark faint. It is rather difficult to differentiate this genus from *Densosporites*. *Critatisporites* is very rare and represented by a single species, *C. connexus.*

Cristatisporites connexus Pot. & Kr. 1954 (Pl. 3, Ph. 32).

Spores ± round, 45-70 μ, ± 30 cones, Y-mark not visible.

***Microreticulatisporites* (Knox) Bhard. 1955**

Spores round or triangular, ornamentation with reticulum. This genus is rarely found in the seam and represented by a single species in the present coals.

Microreticulatisporites nobilis (Wischer) Knox 1950 (Alp. 1959. Ph. 98).

Spores triangular, convex, 30-45 μ, Y rays net = R, contour equatorial, ± 50 arcs, exine thick.

***Foveolatisporites* Bhard. 1955**

Spores oval or elongated, exine having all over the surface small foveolae giving an aspect of an infrareticulum. Only one species is rarely distributed in the present coals.

Foveolatisporites fenestratus (Kos. & Brok.) Bhard. 1955 (Pl. 3, Ph. 26).

Spores round or oval, 60-100 μ, punctations 3 μ, Y-mark not visible or ill-formed.

DIVISION — **Zonales** (B. & K.) R. Pot. 1954

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

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

***Triquitrites* (Wilson & Coe) Pot. & Kr. 1954**

Spores triangular, with angular thickenings or auriculae, exine thick and ornamented.

T. sculptilis Balme 1952 (Alp. 1959. Ph. 147).

23-45 μ, Y = R, ornamentation all over the surface of the spore giving an appearance of a reticulum. This species is common among the rarely distributed forms of this genus.

T. concavus Alp. 1958 (Alp. 1959. Ph. 144).

Spores concave, 35-50 μ, tendency to form 3 branches in the centre.

T. palvinatus Kos. 1950 (Pl. 3, Phs. 27 & 28).

Spore triangular, 41-53 μ, Y = R, apex thick.

***Ahrensisporites* Pot. & Kr. 1954**

Spores triangular, exine projections at the triangular apices are connected by Kyrtome. This genus is rarely found and represented by a single species in the coal seam.

Ahrensisporites angulatus (Kos.) Pot. & Kr. 1954 (Alp. 1959, Ph. 160).

66-75 μ, Y mark hidden in the arcuate thickenings, exine about 2-3 μ thick, infrapunctate.

SUB-DIVISION — **Zonotriletes** Waltz 1935

SERIES — **Cingulati** Pot. & Kr. 1954

***Lycospora* (S.W. & B.) Pot. & Kr. 1954**

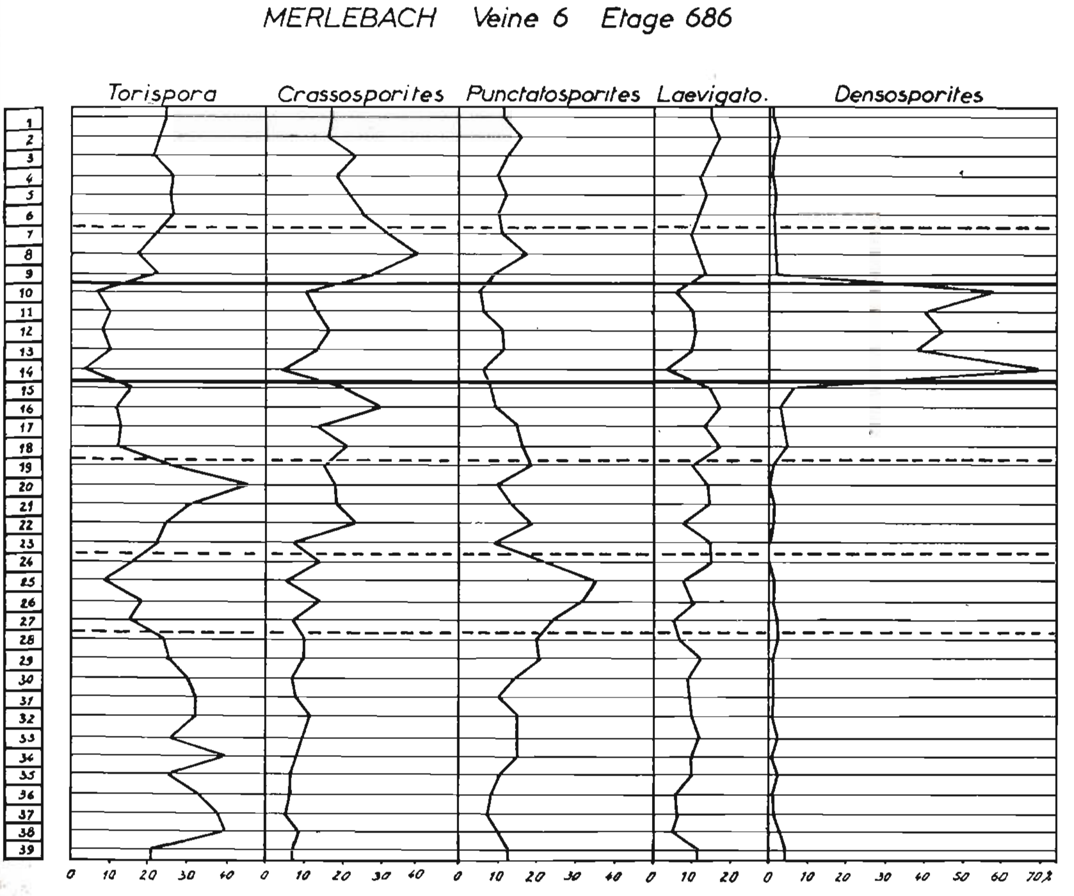
Spores small, characteristic cingulum surrounds the spore body, trilete rays reach up to cingulum, exine ± punctate or granulate. It is very rare in the present coals and represented by one species only.

Lycospora punctata (Kos.) Pot. & Kr. 1954 (Pl. 3, Ph. 29, 30 & 31).

30-42 μ, cingulum 2-3 μ, exine thick and punctate, cingulum 1/3 to 1/4 R.

***Densosporites* (Berry) Pot. & Kr. 1954**

Spores ± round or triangular, convex, cingulum large and thick, trilete rays distinct



TEXT-FIG. 3 — Frequency variations of principal microspores

or indistinct, reach up to equator, exine thick. This spore forms a characteristic and dominant type only in few samples that is from 10 to 14 cm. of the coal bed. The distribution percentage of the form ranges from nil to 70 per cent. The maximum presence of the spore is found only in five samples (10-14 cm.) having 40-70 per cent (FIG. 3), whereas in the rest of samples it is sparcely distributed (nil to 5 per cent). The common species are *D. faunus, D. glandulosus* and *D.* sps. (Alp.).

Densosporites faunus Ibr. 1944 (Alp. 1959. Ph. 209).

50-70 μ, cingulum large corroded, central zone infragranulate. Y-rays long and fine.

D. glandulosus Kos. 1950 (Pl. 3, Ph. 33).

Round to oval, 25-38 μ, exine granulate. Verrucae all over the surface, 4 μ long, 1-2 μ thick, Y-rays faintly visible.

***Polymorphisporites* Alp. 1958**

Spore trilete, concave to convex or round, large cingulum, exine thick, Y-rays fine all along cingulum, sometimes absent, ± reticulate. This spore is rarely distributed by one species.

Polymorphisporites cf. *reticuloides* Alp. 1958 (Pl. 4, Ph. 34).

Spore triangular to round, 58 μ, Y rays dissametric, cingulum ± regular, exine thick, reticuloid.

SERIES — **Zonati** Pot. & Kr. 1954

***Cirratriradites* Wilson-Coe 1940**

Spores triangular, convex, surrounded by a large and clear zone, trilete rays reach equator over the flange, one or many polar foveolae. Two species are represented with very limited frequency distribution.

Cirratriradites rarus Ibr. 1933 (Pl. 4, Ph. 35).
Spore subtriangular, 60-100 μ, Y rays visible, without foveolae.
C. flabelliformis Wil.-Coe 1940 (Pl. 4, Phs. 36 & 37).
70-100 μ, Y rays net, 3 polar foveolae.

DIVISION — **Monoletes** Ibrahim 1933
SUB-DIVISION — **Azonomonoletes** Luber 1935

Laevigatosporites Ibr. 1933

Spores oval or bean-shaped, monolete mark ± rectilinear, exine thick or infra-punctate. This genus is uniformly distributed in all samples. The distribution percentage varies from 4 per cent to 17 per cent (FIG. 3). The average frequency being 10 per cent *Laevigatosporites* represented by 3 species is more or less a transitory spore in the distribution of sporae dispersae of this coal seam.

Laevigatosporites desmoinesensis (Wil-Coe) S.W. & B. 1944 (Pl. 4, Ph. 38).
20-35 μ.
L. medius Kos. 1850 (Pl. 4, Ph. 39).
35-45 μ.

Punctatosporites Ibr. 1933

Spores oval, monolete mark rectilinear, exine finely granular. This spore is also uniformly distributed having the distribution range from 5 per cent to 35 per cent (FIG. 3). The average frequency being 10 to 12 per cent (FIG. 3), except in the region between 24th to 27th cm. wherein it is dominant by having 35 per cent of the total number spores. This genus is also a transitory form. *P. granifer* Pot. & Kr. 1954 (Pl. 4, Ph. 40 & 41) is most eommonly represented.

Torispora Balme 1952

Spores oblong, pear shaped; exine thick brown or dark brown colour, asymmetrical, monolete mark very variable. This genus forms a dominant type in the microspore association except in few samples. The frequency distribution of this spore ranges from 6 per cent to 45 per cent (FIG. 3) in the total composition. The average frequency of the spore is about 25 per cent in most of the samples. But this spore conspicuously disappears (more or less) in the samples from 10 to 14 cm. (FIG. 3). However, it regains its normal position after the zone of minimum presence. Most common species found is *T. securis*.

Torispora securis Balme 1952 (Pl. 4, Phs. 42 & 43).
26-44 μ, thick, exine finely punctate.

Crassosporites Alp. 1958

Spores intermediate of *Torispora*, *Punctatosporites* and *Speciosporites*. However this genus can be differentiated from *Torispora* by its shape which is always oval, and from *Punctatosporites* and *Speciosporites* by exine thickenings. This spore closely associates with *Torispora* forming a second major type in the microspore association. The range of distribution of the genus is from 4 per cent to 39 per cent (FIG. 3). The average frequency being 18 per cent. The distribution pattern of the spore (FIG. 3) suggests that it forms a major type before and after the zone of minimum *Torispora*. It is often difficult to delimit well some forms of *Torispora* with *Crassosporites* and *Speciosporites*. *Crassosporites punctatus* is the common species represented in this coals.

C. punctatus Alp. 1958 (Pl. 4, Ph. 44).
Spore oval, 30 to 38 μ, exine punctate, monolete mark curved.

SUB-DIVISION — **Zonomonoletes** Luber 1935

Speciosporites Pot. & Kr. 1954

Spores oval with thick and regular cingulum, exine granulate, finely verrucose or microreticulate.

Speciosporites minor Alp. 1958 (Pl. 4, Phs. 45 & 46).
Spores round, 28-35 μ, cingulum 2 μ, exine granular to finely infrareticulate.

SUPER-DIVISION — **Pollenites** R. Pot. 1931
DIVISION — **Saccites** Erdtman 1947
SUB-DIVISION — **Monosaccites** Chitaley 1951
SERIES — **Saccizonati** Bhard. 1957

Endosporites Wil. & Coe. 1940

Spores round or oval to triangular, central body contains an air sac separated on the distal side, Y = R of C.B. Represented rarely by two species in the coal seam.

Endosporites zonalis Wil. & Coe. 1940 (Pl. 4, Ph. 48).

90-100 μ (Crown)[2] < R of C.B.

E. ornatus Wil. & Coe. 1940 (Pl. 4, Ph. 47)

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

Florinites S.W. & B. 1944

Monosaccate pollen grain, central body free on distal side, no evidence of tetrad mark on proximal side. This genus although present in most of the samples having a distribution range from nil to 18 per cent, yet has a little value in microspore association. The following three species are represented in the coal seam.

Florinites pumicosus Ibr. 1933 (Pl. 4, Ph. 49).

80-100 μ, C.B. clear, Y rays not visible, Crown < R of C.B.

F. mediapudens Loose 1932 (Pl. 4, Ph. 50)

50-65 μ, C.B. clear, Crown < R of C.B. Y rays not visible.

F. antiquus S.W. & B. 1944 (Alp. 1959, Ph. 406).

65-90 μ, C.B. clear, Crown = R. C.B., Y rays visible, sac with secondary infrareticulation.

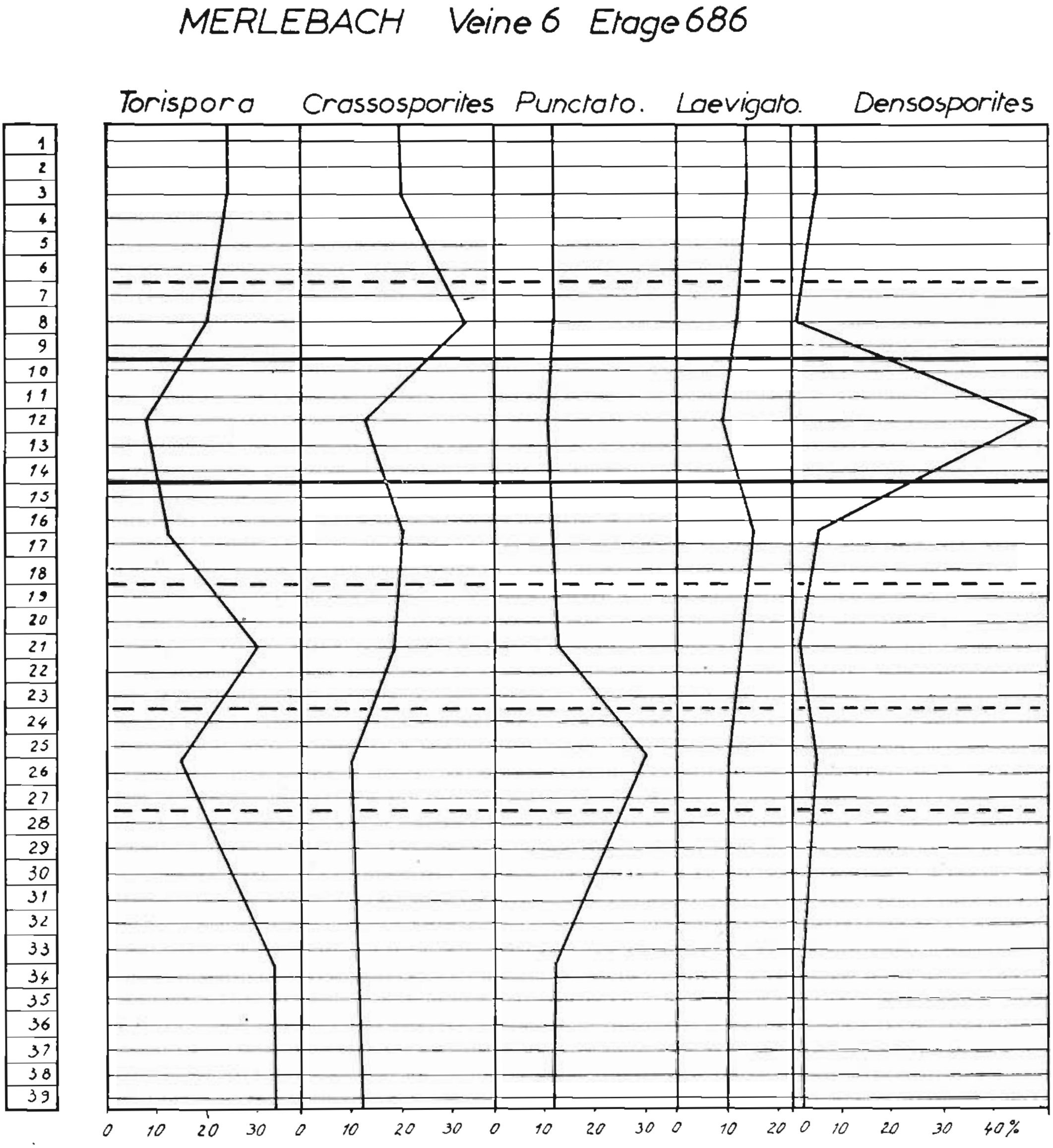
Among the above forms, the principal types are *Torispora*, *Crassosporites*, *Punctatosporites*, *Laevigatosporites*, *Densosporites*, *Cyclogranisporites* and *Florinites*. The remaining other forms are megererly represented and form secondary or accessory spores in the microspore composition in the coals. The rare forms are found in few samples having mostly less than 1 per cent in the total composition of spores.

COMMENTS ON THE COMPOSITION AND DISTRIBUTION OF MICROSPORES

The detailed statistical studies of microspore forms reveal that *Torispora*, *Crassosporites*, *Punctatosporites*, *Laevigatosporites*, *Densospories*, *Triquitrites* and *Florinites* are principal forms which appear in counting. However, among these *Torispora*, *Crassosporites*, *Punctatosporites*, *Laevigatosporites* and *Densosporites* are significant types in the microspore association and distribution (FIG. 3). The distribution pattern of the significant spore forms suggest three main zones of microspore association (FIG. 4). Also there is an indication of minor sub-zones within the main zones (FIG. 4).

Main Zones	Minor Zones
I. *Torispora* + *Crassosporites* (with *Punctatosporites* and *Laevigatosporites*) 1-9 samples	1. *Torispora* dominant 1-5 samples 2. *Crassosporites* dominant 6-9 samples
II. *Densosporites* 10-14 samples	
III. *Torispora* + *Crassosporites* (with *Punctatosporites* and *Laevigatosporites*) 16-39 samples	1. *Crassosporites* dominant 15-18 samples 2. *Torispora* dominant 19-23 samples 3. *Punctatosporites* dominant 4. *Torispora* dominant

Torispora and *Crassosporites* together form a major association in the first 9 cm. of the pillar (FIG. 4) forming a main zone. Also this broad main zone indicates two minor sub-zones. From 1-5 cm. of the pillar, *Torispora* predominating in the association suggest a minor sub-zone. Similarly 6-9 cm. of the seam another minor sub-zone is indicated by maximum distribution of *Crassosporites*. However, from 10 to 14 cm. of the bed, a sudden drastic change could be recognized in the spore complex. *Densosporites* microspore appears and dominates forming a second main zone. This zone being a small one, (10-14 cm. of the seam) does not indicate any minor sub-zones. However, *Densosporites* zone is very conspicuous in the microspore assemblage. The *Torispora* group with other monoletes reappear forming a third main zone from 15-39 cm. of the coal bed. It is of interest to note, four minor sub-zones are indicated by maximum distribution pattern of important spores. They are 15-18 cm. by *Crassosporites*, 19-23

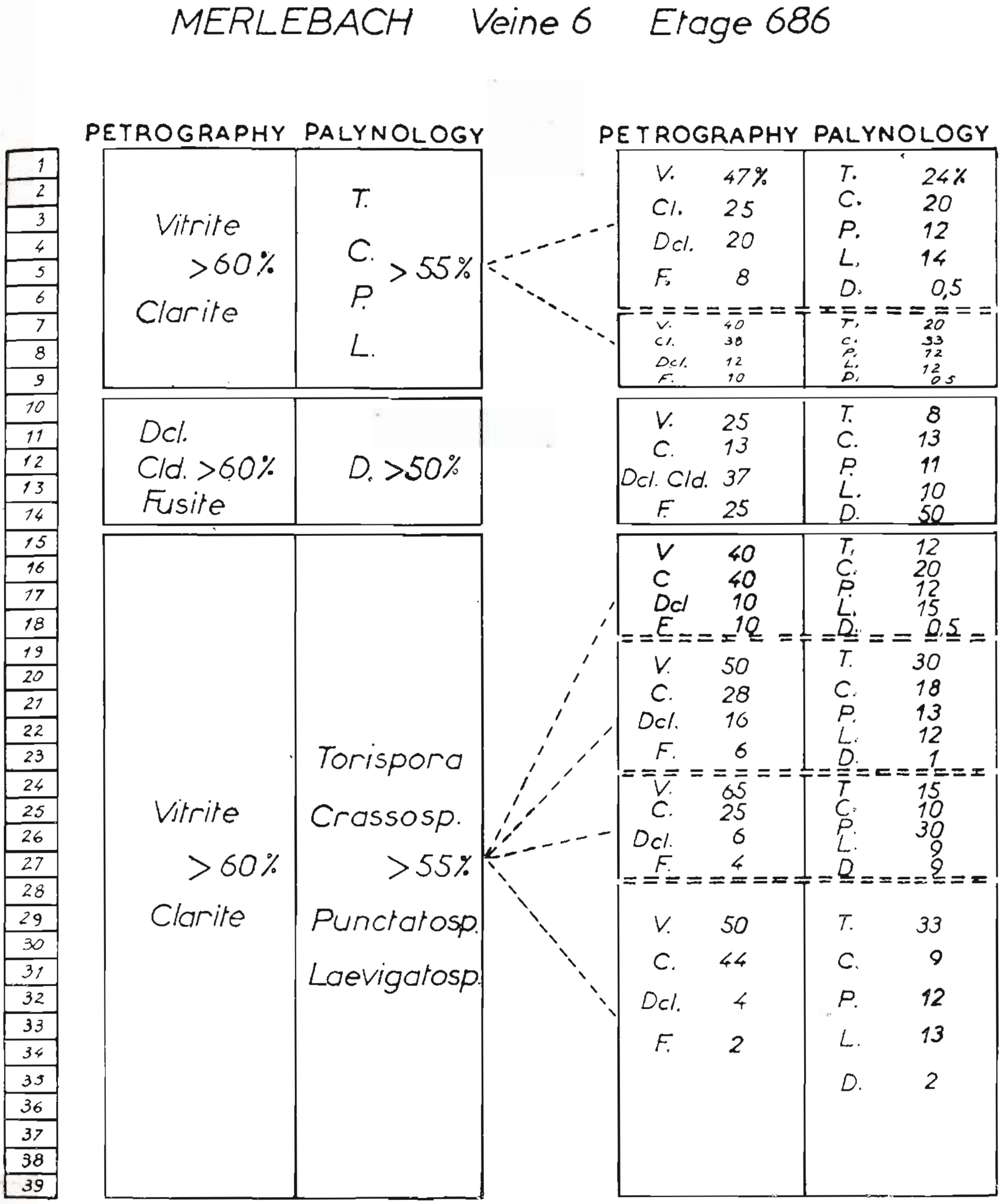


TEXT-FIG. 4 — Palynological zonation

cm. by *Torispora*, 24-27 cm. by *Punctatosporites* and 25-39 cm. again by *Torispora*.

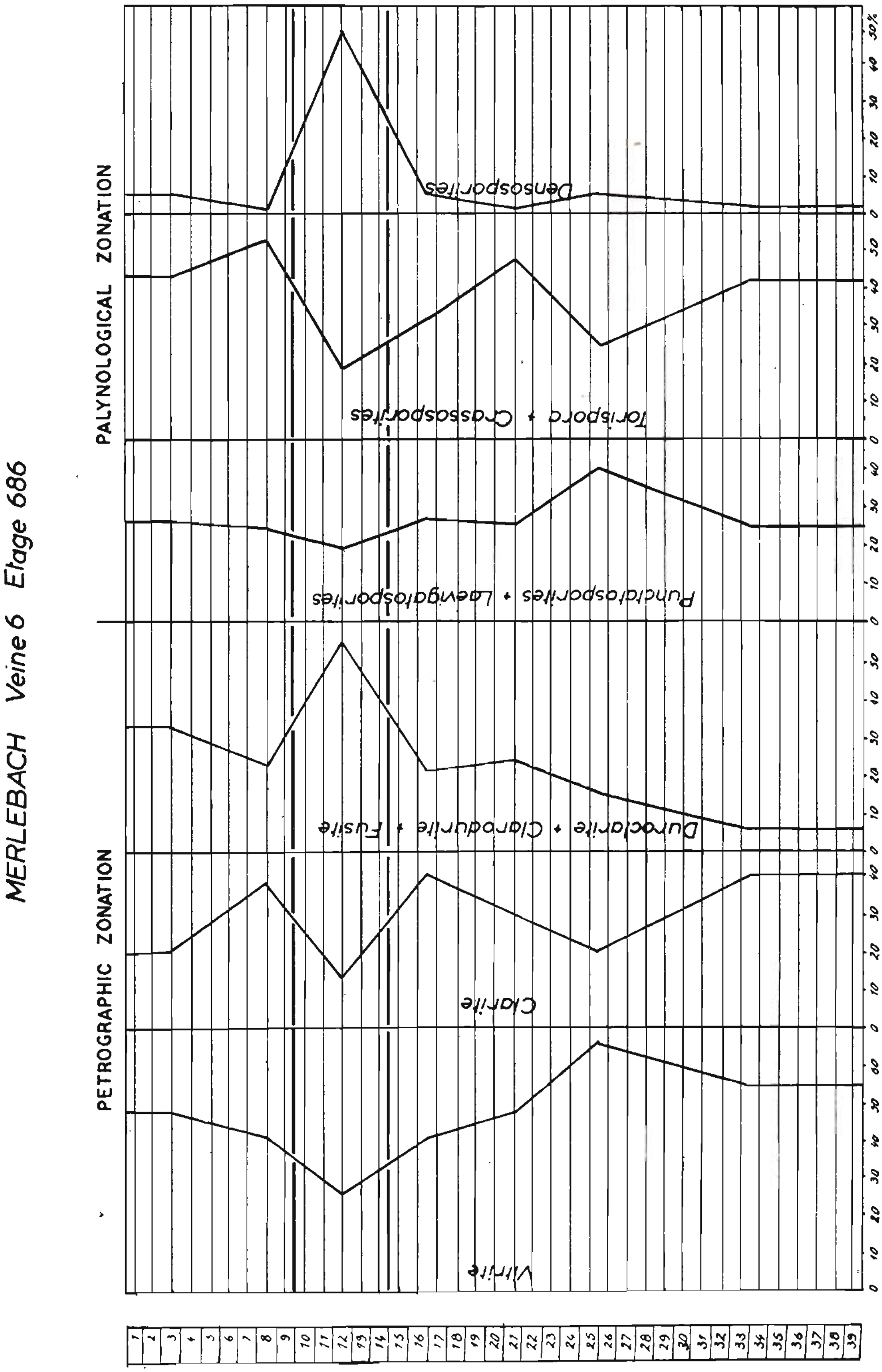
SYNTHESIS OF PALYNO-PETROGRAPHIC STUDIES

The constitution of Merlabach Veine 6 coals is not uniform. The principal microlithotypes Vitrite and Clarite are distinctly separated by Duroclarite, Clarodurite and Fusite microlithotypes in the petrographic composition. This fact of heterogeneity is substantiated by microspore association. The principal *Torispora* and *Crassosporites* association is also well separated by *Densosporites* assemblage. Even minor sub-zones of the main zones shown by petrographic studies are indicated in the microspore assemblage pattern (FIGS. 5 & 6).



TEXT-FIG 5 — Comparison of petrographic and palynological zonations

The statistical data of petrographic and sporological components of the coal seam indicates some relationship of petrographic components with microspore forms. It can be seen from the distribution pattern of Vitrite and Clarite and microspore forms (FIG. 6) that *Torispora*, *Crassosporites* and *Punctatosporites* are main types associated with Vitrite and Clarite microlithotypes. Also suggests the presence of maximum *Punctatosporites* with maximum Vitrite component. It is probable that monolete spores associate with high content of Vitrite and Clarite component in this coal seam.



TEXT-FIG. 6 — Synthesis and comparison of zonations

TABLE 1

THICKNESS	FACIES MICROLITHOTYPE	DOMINANT MICROLITHOTYPE	MICROSPORE DOMINANT	SPORE ASSOCIATION	
1-6	V+Cl+Dcl	V	*Torispora*	T+C+P	and others
7-9	V+Cl+Dcl	V & Cl	*Crassosporites*	T+C+P	,,
10-14	Dcl+ClD+F	Dcl+F	*Densosporites*	D	,,
15-18	V+Cl+Dcl	V & Cl	*Crassosporites*	T+C+P	,,
19-23	V+Cl+Dcl	V	*Torispora*	T+C+P	,,
24-27	V+Cl+Dcl	V (macimum)	*Punctatosporites*	T+C+P	,,
28-39	V+Cl+Dcl	V	*Torispora*	T+C+P	,,

V, Vitrite; Cl, Clarite; Dcl, Duroclarite; ClD, Clarodurite; F, Fusite; T, *Torispora*; C, *Crassosporites*; P, *Punctatosporites*; D, *Densosporites*.

Considering *Densosporites*, this microspore suddenly appears and dominates in the microspore assemblage in the region between 10 and 14 cm. of the coal bed replacing *Torispora* and *Crassosporites*. Simultaneously the petrographic composition also changes in the region by having predominance of Duroclarite, Clarodurite and Fusite components replacing Vitrite and Clarite microlithotypes. These changes and the frequency pattern of the components suggest relationship between *Densosporites* and Durite.

CONCLUSIONS

The Merlabach Veine 6 coal seam is not uniform in constitution. The recognition of the various palyno-petrographic components, their association, and the detailed quantitative study of microlithotypes and microspore forms suggest that the coal bed is principally composed of three main facies. The present study has shown that the coal pillar is constituted not only by three main petrographic zones but also by three microfloral zones. Even the presence of minor layers of different set up in the main facies is indicated by the presence of minor subzones of petrographic and microspore zones.

The study has also shown distinct relationship of some petrographic components with microspore forms in this coal seam such as Vitrite and Clarite microlithotypes with monolete forms and durite with *Densosporites*.

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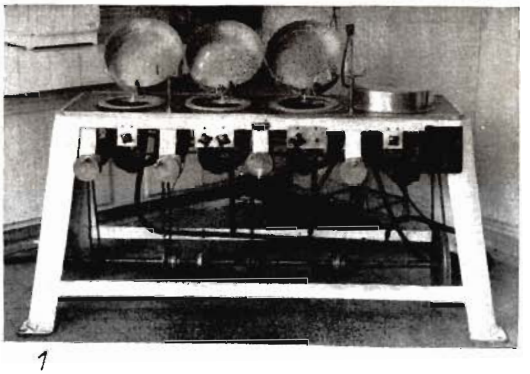

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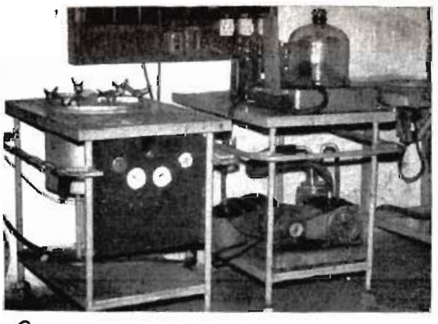

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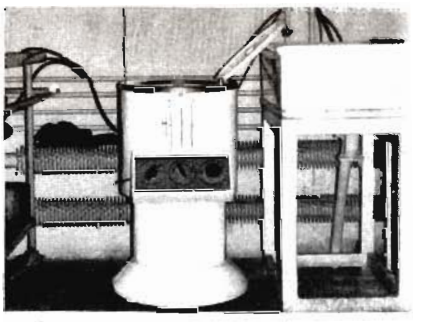

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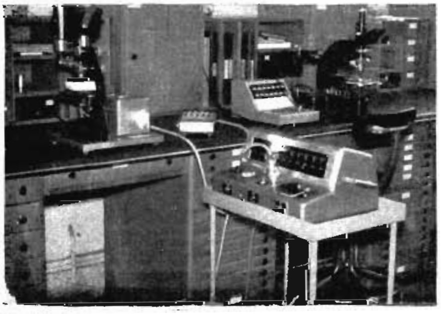

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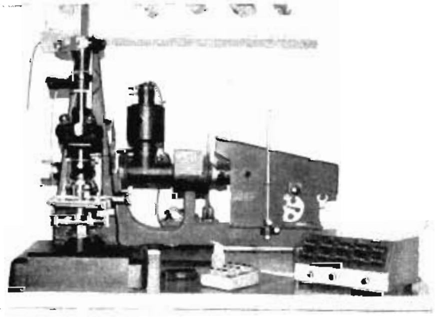

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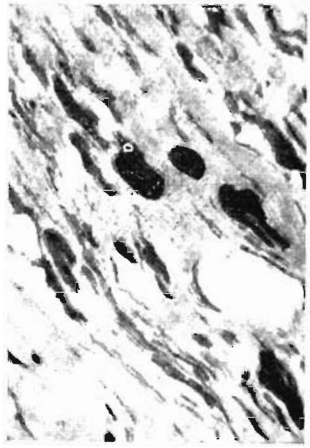

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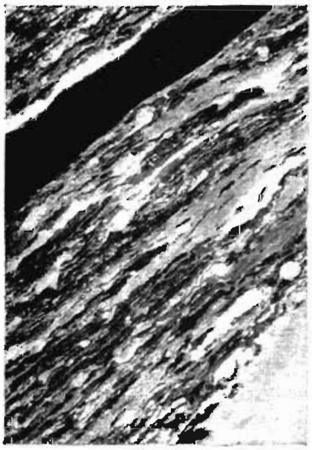

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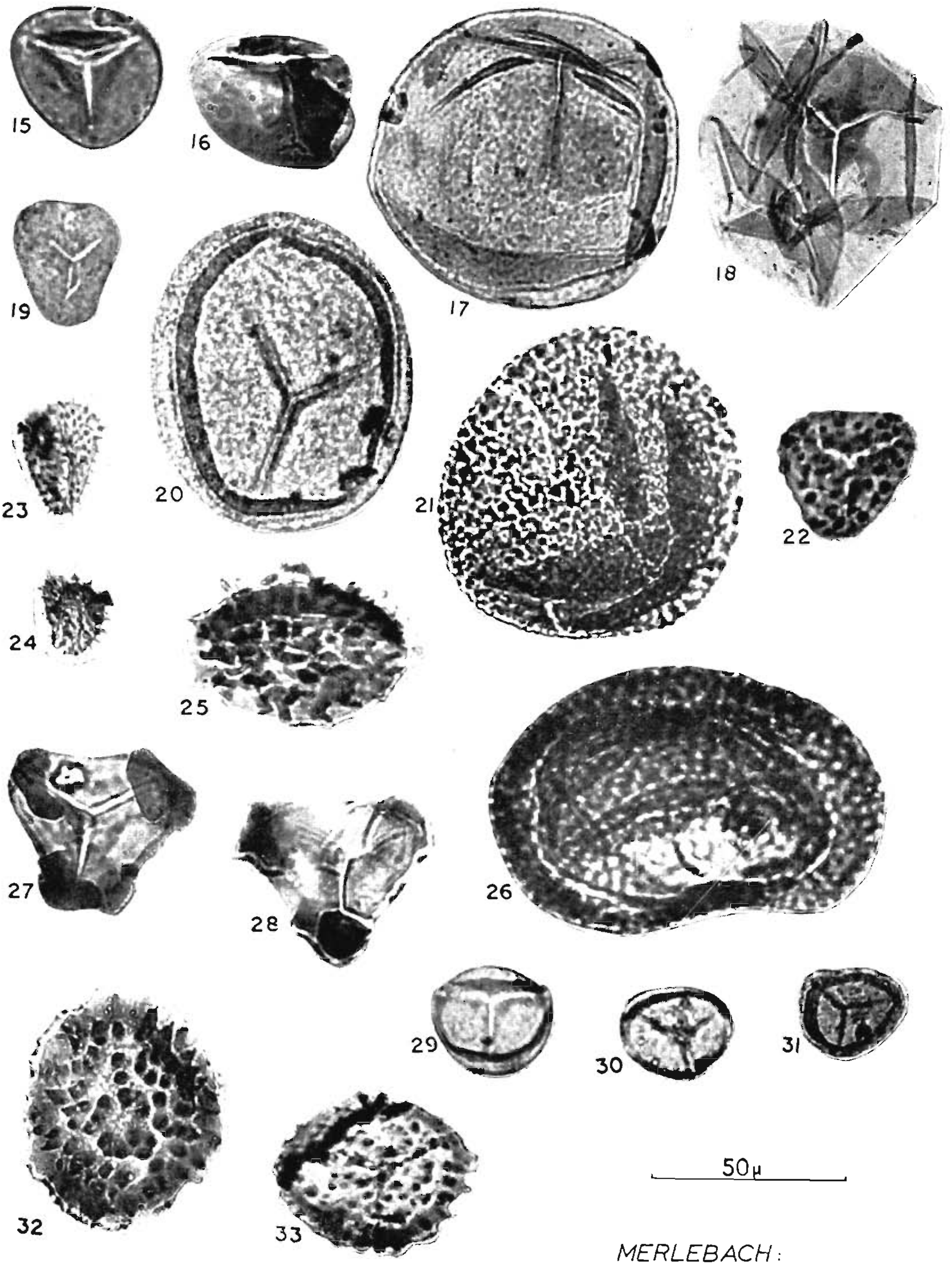
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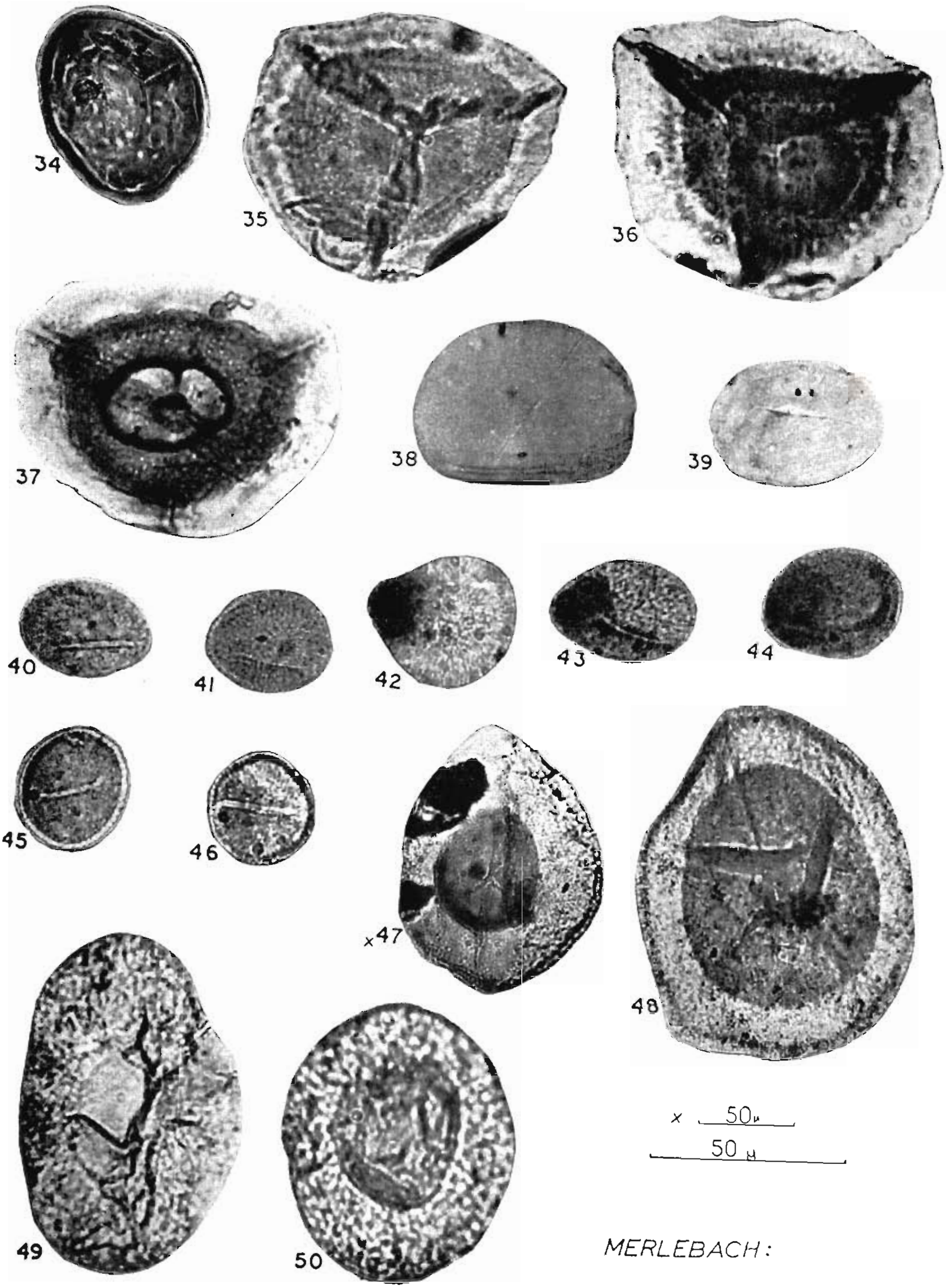
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EXPLANATION OF PLATES

Plate 1

1. Polishing Machine
2. Apparatus Impregnation
3. Centrifuge
4. Counters and Microscopes
5. Microscope with Photo-apparatus

Plate 2

6. Vitrite and Clarite with microspores

7, 8. Clarite with microspore (*Torispora*) — high magnification.

9. Clarodurite with microspores and megaspores

10, 11. Clarodrite with microspore (*Densosporites*) high magnification.

12. Clarite with cuticles.

13. Clarite with microspores

14. Clarite with microspores (*Torispora*) — high magnification.

Plate 3

15. *Leiotriletes adnatoides* (Pot. & Kr.) 36μ.
16. *Leiotriletes gulaferus* (Pot. & Kr.) 40 μ.
17. *Punctatisporites punctatus* (Ibr.) 78 μ.
18. *Calamospora perrugosus* (Loose) 73 × 60 μ.
19. *Granulatisporites parvus* (Ibr.) 32 × 26 μ.
20. *Cyclogranisporites aureus* (Loose) 82 × 64 μ.
21. *Cyclogranisporites pergranulus* (Alp.) 76 μ.
22. *Lophotriletes* cf. *mosaicus* (Pot. & Kr.) 36 × 34μ
23. *Acanthotriletes microsaetosus* (Loose) 20 × 29 μ.
24. *Acanthotriletes microsaetosus* (Loose) 22 × 20 μ.
25. *Raistrickia* cf. *aculeata* (Kos.) 41 × 60 μ.
26. *Foveolatisporites fenestratus* (Bhard.) 96 × 64 μ.
27. *Triquitrites pulvinatus* (Kos.) 48 × 38 μ.
28. *Triquitrites pulvinatus* (Kos.) 40 × 40 μ.
29. *Lycospora punctata* (Kos.) 32 × 26 μ.
30. *Lycospora punctata* (Kos.) 29 × 24 μ.
31. *Lycospora punctata* (Kos.) 25 × 22 μ.
32. *Densosporites* cf. *cristatolsporites connexus* (Pot. & Kr.) 52 × 65 μ.
33. *Densosporites* sp. (Pot. & Kr.) 52 × 42 μ.

Plate 4

34. *Polymorphisporites* cf. *reticuloides* (Alp.) 45 × 52 μ.
35. *Cirratriradites rarus* (Ibr.-S.W.B.) 76 × 65 μ.
36. *Cirratriradites* cf. *flaballiformis* (Wil. & Coe) 76 × 65 μ.
37. *Cirratriradites* cf. (Ibr.) S.W.B. 80 × 70 μ.
38. *Laevigatosporites desmoinesensis* (Wil. & Coe) 58 × 42 μ.
39. *Laevigatosporites medius* (Kos.) 45 × 32 μ.
40. *Punctatosporites granifer* (Pot. & Kr.) 32 × 24 μ.
41. *Punctatosporites granifer* (Pot. & Kr.) 32 × 26 μ.
42. *Torispora securis* (Balme) 36 × 32 μ.
43. *Torispora securis* (Balme) 36 × 25 μ.
44. *Crassosporites* (Alp.) 34 × 28 μ.
45. *Speciosporites minor* (Alp.) 29 × 32 μ.
46. *Speciosporites minor* (Alp.) 29 × 00 μ.
47. *Endosporites ornatus* (Wil. & Coe) 96 × 125 μ.
48. *Endosporites* cf. *zonalis* (Loose) 90 × 70 μ.
49. *Florinites pumicosus* (Ibr.) 84 × 56 μ.
50. *Florinites mediapudens* (Loose) 88 × 70 μ.