MICROFLORISTIC EVIDENCE ON THE BOUNDARY BETWEEN THE CARBONIFEROUS AND THE PERMIAN SYSTEMS IN PFALZ (W. GERMANY)

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ABSTRACT

The *Sporae dispersae* recovered out of the coals from the Upper Carboniferous (Stephanian C)-Lower Rotliegend succession in Pfalz (W. Germany), assigned to 17 spore genera, have been described. It includes an account of four new species of *Sporae dispersae*.

It has been discovered that *Lycospora* disappears at the end of Stephanian C and *Triquitrites* continues to remain absent in *Kuseler Schichten* even. The succeeding microflora in *Kuseler Schichten* (Lower Rotliegend) continues as a much depleted Stephanian C microflora till finally dying out in Upper *Kuseler Schichten*. It has been concluded that microfloristically *Kuseler Schichten* can form a part of the Carboniferous and the boundary between the Permian and the Carboniferous can preferably lie between *Kuseler Schichten* and the succeeding *Lebacher Schichten*.

INTRODUCTION

WHEN one of the authors (Bhardwaj) concluded his study of the *Sporae dispersae* of the Saar Coals (1955), the question as to how do the dispersed spores of the uppermost subdivision of Upper Carboniferous in the Saar, i.e. Stephanian C, compare with the *Sporae dispersae* of the overlying division, i.e. Lower Rotliegend, naturally occurred to him. It is in fulfilment of the same question that the present study has been undertaken.

The floristic relation of the upper part of Upper Carboniferous and Lower Rotliegend has never been precisely defined. The difficulty has always arisen while fixing a floristic boundary between the Upper Carboniferous and Rotliegend. As this boundary is also the dividing line between the Carboniferous and the Permian Systems, its importance has been further enhanced. Magafloristically a gradual transition from the uppermost part of the Upper Carboniferous into Lower Rotliegend has been noted in all the regions where continuously bedded strata from Carboniferous to Rotliegend have been investigated. Thus in the U.S.A., a gradual transition has been responsible for the creation of Dunkard Division which is partly made up of the Upper Carboniferous and partly of the Lower Rotliegend equivalents of Europe. In the French-interior basins too it has proved difficult to separate the Stephanian from the Autunian (Rotliegend).

In the Saar, the youngest coal seam is the *Grenzkohlen* seam, and shortly above this lies the supposed boundary of Upper Carboniferous - Rotliegend, characterized by chalky bands. To the east of the Saar, a continuation of the Saar coal-basin lies in Pfalz (W. Germany). In this region the sedimentation began late in the Upper Carboniferous and continued to give rise to the younger strata of the Lower and Upper Rotliegend. The Upper Carboniferous and the Lower Rotliegend layers of Pfalz contain a few thin coal seams which provided the material for our study.

The availability of suitable material, carefully collected by Dr. K. Josten (then a doctorate student of Mainz University, Pfalz) in 1953, made it possible for us to study the *Sporae dispersae* of the Upper Carboniferous - Lower Rotliegend succession of Pfalz and thereby to contribute towards the understanding of the floristics on the basis of the distribution of dispersed spores. We are thankful to Dr. Josten for the material.

MATERIAL AND METHODS

The material was collected either from mines which are working their seams or from outcrops in the field. In the latter case the seams were thin, so-called " *Kohlenschmitzen* ", which have not been named and due to their thinness are not being worked. The details of the localities and their stratigraphical position as communicated by the collector (Dr. K. Josten) are given in Table 1. As is evident from Table 1, the sampling of the thicker seams, especially those collected from the mines, was detailed, taking 2-4 samples vertically along the height in each seam. The outcrop samples from the thin seams are single.

TABLE 1

Sample No.	Stratigraphical position	Location: In topographical sheet	Location: Spot	Maceration Nos.
1	Upper Ottweiler Schichten	Godelhausen	Roof seam, Mine Kleeb	1
2	do	do	Main Seam Top, Mine Kleeb	2
3	do	do	Main Seam Bottom, Mine Kleeb	3
4	do	Steinbach	Roof Seam, Mine Maria	4
5	do	do	Main Seam Middle, Mine Maria	5
6	do	do	Main Seam Bottom, Mine Maria	6
7	do	Labach	Main Seam Top, Mine Labach	7
8	do	do	Main Seam Bottom, Mine Labach	8
9	Middle Kuseler Schichten	Kirn	Main Seam Top, Mine Medicus	9
10	do	do	Main Seam below the top, Mine Medicus	10
11	do	do	Main Seam Middle, Mine Medicus	11
12	do	do	Main Seam Bottom, Mine Medicus	12
13	Upper Kuseler Schichten	Lauterecken	Near Hohenhollen	13
14	do	do	Near Cronenberg	14
15	do	do	Near Heinzenhausen	15
16	Middle Kuseler Schichten	Kusel	Near Rammelsbach	16
17	Upper Kuseler Schichten	Lauterecken	Near Odenbach	17
18	do	do	Near Adenbach	18
19	do	do	Near Adenbach	19
20	do	Wolfstein	Nd. Staufenbach	20

The maceration of the material was done by Zetsche & Kälin's method, as described by Bhardwaj (1957), during 1953 at *Amt für Bodenforschung* Krefeld, W. Germany, by Mr. Jost to whom our thanks are due. The slides were mounted in Canada balsam.

THE COAL-BEARING PALAEOZOIC SUCCESSION IN PFALZ

The coal-bearing Palaeozoic strata in Pfalz rest unconformably on a Devonian base. Unlike the Saar basin, the sedimentation in this part began very late during Upper Carboniferous. The oldest coal-bearing horizon thus was deposited during Stephanian C. Overlying these, the sedimentation continued into Lower Rotliegend in a conformable succession (TABLE 2). The Lower Rotliegend was followed by Upper Rotliegend, the latter resting unconformably over the former. The Upper Rotliegend is again separated from the overlying Triassic *Buntsandstein* by an unconformity.

The strata comprised of Stephanian C and Lower Rotliegend consist mostly of conglomerates, sandstones, sandy and clayey shales and chalkbands together with a few thin coal seams (TABLE 2). Although the deposits of coal seams end as early as Lower *Lebacher Schichten*, the occurrence of plant-fossil remains is reported almost up to the close of the Lower Rotliegend sedimentation in the basin.

The investigation was restricted to the study of coal seams only. Out of the 5 coal seams reported in the succession (TABLE 2), samples collected from only 3 out of these, i.e. one each from the Upper *Ottweiler Schichten*, Middle *Kuseler Schichten* and Upper *Kuseler Schichten*, proved useful. The thin coal seams occurring in the Lower *Kuseler Schichten* and Lower *Lebacher Schichten* were not collected by Dr. Josten, but a number of hand samples of coaly shale from these horizons, sent by Professor Falke of Mainz University, were examined by one of us (BHARDWAJ) and were found barren of microfossils.

DESCRIPTION OF *SPORAE DISPERSAE*

The sequence of description of the *Sporae dispersae* pertains to the system of classification by Potonié & Kremp (1955-56). For explanation of the descriptive terminology employed here see Potonié & Kremp (1955, p. 9).

Super-division — *Sporites* H. Pot.

Division — *Triletes* (R.) Pot. & Kr.

Subdivision — *Azonotriletes* Luber.

Series — *Laevigati* (B. & K.) Pot. & Kr.

***Leiotriletes* (Naum.) Pot. & Kr.**

Leiotriletes levis (Kos.) Pot. & Kr.

Pl. 1, Figs. 1, 2

For holotype and description see Kosanke (1950, p. 21).

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

Punctatisporites minutus Kos.

Pl. 1, Figs. 3-6

For holotype and description see Kosanke (1950, p. 15).

TABLE 2 — COAL-BEARING GEOLOGICAL SUCCESSION IN PFALZ (ADOPTED FROM FALKE, 1953)

STANDARD PROFILE OF UPPER CARBONIFEROUS — LOWER ROTLIEGEND SUCCESSION IN PFALZ						
GEOLOGICAL FORMATION	GEOLOGICAL DIVISION	STATIGRAPHIC SUBDIVISIONS	PROFILE OF STRATA (NOT TO SCALE)	COMPOSITION OF STRATA	PLANT MEGAFOSSIL ZONE	OLD STRATIGRAPHIC DESIGNATIONS
LOWER PERMIAN	UPPER ROTLIEGEND		BOUNDARY	ZONE		
		UPPER THOLEYER SCHICHTEN		ALTERNATING PED & GREEN SHALY CLAYS CONGLOMERATE & SANDST.		OLSBRÜCKER SCHICHTEN
		MIDDLE THOLEYER SCHICHTEN		CONGLOMERATE & SANDSTONE & SHALY CLAY / GREY SHALE & SANDST.		SCHWEISWEILER SCHICHTEN
	LOWER ROTLIEGEND	LOWER THOLEYER SCHICHTEN		RED SHALY CLAY CONGLOMERATE SANDSTONE RED SANDY SHALE		
		UPPER LEBACHER SCHICHTEN		FINE-GRAINED SANDST. SANDY SHALE SHALY CLAYS		LEBACHER SCHICHTEN
		MIDDLE LEBACHER SCHICHTEN		CHALKY BAND SHALY CLAY AND SANDY CLAY SANDST. & CHALKY BAND		HOOFER SCHICHTEN
		LOWER LEBACHER SCHICHTEN		SHALY CLAY & SANDY SHALE (SAND STONE) SANDY SHALE COAL SEAM SHALY CLAY SANDY SHALE SANDSTONE ARKOSE CONGLOMERATE – SANDST.		ALSENZER SCHICHTEN
		UPPER KUSELER SCHICHTEN		SANDY SHALE CHALK BAND SANDY SHALE & SHALY CLAY CHALK – COAL SEAM SANDY SHALE & SANDSTONE CONGLOMERATE		ODENBACHER SCHICHTEN
		MIDDLE KUSELER SCHICHTEN		CHALK BAND COAL & SHALE RED & GRAY SANDSTONE CONGLOMERATE & SANDY SHALE SANDSTONE CONGLOMERATE & SANDY SHALE & SANDSTONE		WAHNWEGER SCHICHTEN
		LOWER KUSELER SCHICHTEN		SHALE SANDY COAL CHALK BAND CONGLOMERATE		ALTENGLANER SCHICHTEN REMIGIUSBERGER SCHICHTEN
UPPER CARBONIFEROUS	STEPHANIAN C (WESTPHALIAN E)	UPPER OTTWEILER SCHICHTEN		STR. CHALK SANDY SHALE COAL SEAM SHALE SANDSTONES SHALE CONGLOMERATE		BREITENBACHER SCHICHTEN POTZBERG SCHICHTEN

Calamospora S.W. & B.

Calamospora cf. *microrugosa* (Ibr.) S. W. & B.

Pl. 1, Figs. 7-10

For holotype, diagnosis and description refer to Potonié & Kremp (1955, p. 49) and Bhardwaj (1957).

Remarks — *C. microrugosa* is a mid-westphalian type.

Calamospora breviradiata Kos.

Pl. 1, Fig. 11

For holotype and description see Kosanke (1950, p. 41).

Calamospora saariana Bhard.

Pl. 1, Figs. 12, 13

For holotype, diagnosis and description see Bhardwaj (1957).

Calamospora sp.

Pl. 1, Fig. 14

Description — Size 50 μ, Y-mark distinct, rays ½ the length of the spore radius, straight, *labra* thin, inter-ray area darkened but the darkening clearly delimited, unlike the undefined nature seen in *C. microrugosa*, *C. breviradiata* and *C. saariana*. The darkening is also not uniform in the 3 areas but is more in one than in the other two, appearing as if it is formed by the shifting of an inner globular body.

Comparison — *C. pallida* (Loose) S.W. & B. has smaller rays and lacks the inter-ray darkening. *C. pedata* Kos. is bigger and lacks the inter-ray darkening. No other species of *Calamospora* described by Kosanke (1950) or Bhardwaj (1957) is comparable.

Cyclogranisporites Pot. & Kr.

Cyclogranisporites micrograms Bhard.

Pl. 1, Figs. 15, 16

For holotype, diagnosis and description see Bhardwaj (1957).

Series — *Apiculati* (B. & K.) Pot. & Kr.

Lophotriletes (Naum.) Pot. & Kr.

Lophotriletes commissuralis (Kos.) Pot. & Kr.

Pl. 1, Fig. 18

For holotype, diagnosis and description, see Potonié & Kremp (1955, p. 73).

Verrucosisporites (Ibr.) Pot. & Kr.

Verrucosisporites cf. *donarii* Pot. & Kr.

Pl. 1, Fig. 19

For holotype, diagnosis and description see Pot. & Kr. (1955, p. 67).

Remarks — Although the specimen figured here agrees very closely with the holotype of *V. donarii*, the disparity in the age of the two specimens must not be lost sight of.

Division — *Zonales* (B. & K.) Pot. & Kr.
Subdivision — *Zonotriletes* Waltz.
Series — *Cingulati* Pot. & Klaus.

Crassispora Bhard.

Crassispora pfalzensis sp. nov.

Pl. 1, Fig. 17

Holotype — Pl. 1, Fig. 17.

Diagnosis — Size 56-66 μ, holotype (compensated) 58×66 μ, roundly triangular Y-mark not visible, coni unequal in size, subequatorial dense zone (*crassitudo*) 12-14 μ broad, exine sculpture with unequal, small coni.

Comparison — Larger in size as well as having thicker and wider *crassitudo* than *C. ovalis* Bhard. Smaller in size than *C. kosankei* (Pot. & Kr.) Bhard.

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

Lycospora micrograrulata Bhard.

Pl. 1, Figs. 20-23

For holotype, diagnosis and description see Bhardwaj (1957).

Lycospora triangulata Bhard.

Pl. 1, Figs. 24-26

For holotype, diagnosis and description see Bhardwaj (1957).

Lycospora perforata sp. nov.

Pl. 1, Fig. 27

Holotype — Pl. 1, Fig. 27.

Diagnosis — Size 24-30 μ, equilaterally triangular, angles rounded, *crassitudo* and flange ⅓ the length of the spore radius, *crassitudo* well demarcated and uniformly 2-3 μ wide; flange perforated Y-rays prominent and granular; exine granular.

Comparison — *L. micrograndulata* is bigger in size; ovoloid triangular, i.e. with one side longer than the other two sides, *crassitudo* not as broad and prominent, *L. punctata* Kos. is considerably bigger.

Densosporites (Berry) Pot. & Kr.

Densosporites sp.

Pl. 1, Fig. 28

Description — Size 34 μ, roundly triangular, Y-rays hardly noticeable; *cingulum* as a thick, submarginal zone, (crassitudinous) up to 10 μ broad, margin and surface of the *cingulum* rough and uneven, dense, *cingulum* sharply demarcated from the hyaline, inner, triangular area. Exine of the inner area finely verrucose.

Comparison — The paratype of *D. sinuosus* Kos. (KOSANKE, 1950, PL. 6, FIG. 2) compares very well with the specimen figured here. Among the species of *Densosporites* described by Potonié & Kremp (1956) only the forms described as *D. sphaerotriangularis* Kos. show some organizational similarity to the specimen illustrated here, but the former are distinctly bigger in size. Among the Saar coals such form has never been observed by Bhardwaj (1957).

Remarks — The specimen figured here is the only one found in all the macerations undertaken for the present investigation. The chances of the presence of the specimen due to contamination in the laboratory appear to be remote because it does not agree with any of the species of *Densosporites* described by Potonié & Kremp or by Bhardwaj, who were the only people dealing with the coals of the Ruhr basin and the Saar basin, respectively, at that time in the Laboratory of *Amt für Bodenforschung*, Krefeld.

Division — *Monoletes* Ibr.

Subdivision — *Azonomonoletes* Luber.

Laevigatosporites Ibr.

Laevigatosporites medius Kos.

Pl. 2, Figs. 29-32

For holotype and description see Kosanke (1950, p. 29).

Laevigatosporites vulgaris Ibr.

Pl. 2, Figs. 33-35

For holotype, diagnosis and description see Potonié & Kremp (1956, p. 139).

Laevigatosporites desmoinesensis (Wils. & Coe) S.W. & B.

Pl. 2, Figs. 36, 37

For description see Potonié & Kremp (1956, p. 139).

Laevigatosporites minimus (Wils. & Coe) S. W. & B.

Pl. 2, Figs. 38, 39

For description see Potonié & Kremp (1956, p. 138).

Latosporites Pot. & Kr.

Latosporites saarensis Bhard.

Pl. 2, Fig. 40

For holotype, diagnosis and description see Bhardwaj (1957).

Latosporites minutus Bhard.

Pl. 2, Fig. 41

For holotype, diagnosis and description see Bhardwaj (1957).

Latosporites sp. A.

Pl. 2, Fig. 42

Description — Size 23-27 × 20-24 μ in lateral view, monolete mark $\frac{2}{3}$ the long axis, exine laevigate.

Latosporites sp. B.

Pl. 2, Fig. 43

Description — Size 50 × 46 μ in polar view, monolete mark $\frac{2}{3}$ the long axis, exine laevigate.

Punctatosporites Ibr.

Punctatosporites cf. *minutus* Ibr.

Pl. 2, Figs. 44, 45

For holotype and description see Potonié & Kremp (1956, p. 143).

Remarks — *P. minutus* is a species of the middle Westphalian age as recorded from the central European basins as well as the Donetz basin (U.S.S.R.).

Striatosporites Bhard.

Striatosporites pfalzensis sp. nov.

Pl. 2, Fig. 46

Holotype — Pl. 2, Fig. 46.

Diagnosis — Size 80-110 × 80-85 μ in polar view, monolete mark more than $\frac{2}{3}$ the long axis.

Description — Broad canals perceptible, finer canals more numerous than in *S. major*. The size of *S. pfalzensis* is distinctly smaller than *S. major*.

Striatosporites major Bhard.

Pl. 2, Fig. 47

For holotype, diagnosis and description see Bhardwaj (1954).

Super-division — *Pollenites* R. Pot.

Division — *Saccites* Erdtm.

Subdivision — *Monosaccites* Chitaley.

Series — *Triradites* (Pant) Bhard.

Guthörlisporites Bhard.

Guthörlisporites sp.

Pl. 2, Fig. 48

Description — Size ± 65 μ, roughly triangular; central body subcircular, ± 30 μ in diameter, brownish, Y-mark evident, rays ± reaching the margin of the central body; bladder thin, finely intrasculptured, *limbus* absent.

Comparison — The genotype of *Guthörlisporites*, i.e. *G. magnificus* Bhard., is bigger in its overall size as well as the body size.

Series — *Aradiati* Bhard.

Florinites S.W. & B.

Florinites pfalzensis sp. nov.

Pl. 2, Figs. 49, 50

Holotype — Pl. 2, Fig. 49.

Diagnosis — Size 70-85 μ, subcircular, central body well defined, subcircular, 25-30 μ in size, thin-walled, brownish in colour. Bladder uniformly expanded all round the body.

Comparison — Bigger than the known range of overall size in *F. ovalis* Bhard. Organizationally very similar to a specimen referred by Bhardwaj (1957, Pl. 31, Fig. 3) to *F. ovalis*. *F. antiquus* is considerably older and its central body is not so distinct.

Florinites sp.

Pl. 2, Fig. 51

Description — Size 70-85 × 50-65 μ in polar view, body thin-walled, 56 × 45 μ. No Y-mark or monolete mark apparent.

Subdivision — *Disaccites* Cookson.

Illinites Kos.

Illinites sp.

Pl. 2, Fig. 52

Description — Size 76 × 44 μ, body oval, dense, smooth, having two, laterally-uniting, arcuate, dense regions where the two bladders are attached to the body on each side. In between the zones of the bladder attachment, a slit apparent. Bladders uniform, intrareticulate.

Comparison — *I. unicus*, the genotype has a more distinct Y-mark.

Pityosporites (Sew.) Pot. & Kr.

Pityosporites schaubergeri Pot. & Kl.

Pl. 2, Figs. 53, 54

For holotype, diagnosis and description see Potonié & Klaus (1954).

Series — *Sulcati* Bhard.

Alisporites Daugh.

Alisporites saarensis Bhard.

Pl. 2, Fig. 55

For holotype, diagnosis and description, see Bhardwaj (1957).

MICROFLORISTIC COMPOSITION OF THE COAL SEAMS

From the details in Table 3, it is apparent that the coal seams from mines Kleeb, Maria and Labach of Upper *Ottweiler Schichten* are the richest in the number of types, having 27 species distributed in 16 spore genera. The next in order come the seams from mine Medicus of the Middle *Kuseler Schichten* and the poorest of all are the seams from the Upper *Kuseler Schichten*, having been represented by only 6 spore species. It is apparent that Upper *Ottweiler Schichten* which is the oldest in the succession is richest and Upper *Kuseler Schichten*, the youngest of the strata investigated, is the poorest in its spore and pollen contents. It can thus be surmised that the flora had a tendency to become poorer from the oldest to the youngest strata in the succession.

Within Upper *Ottweiler Schichten*, the compositions of the seams from different mines do not agree with each other. Here the

TABLE 3 — MICROFLORISTIC COMPOSITION OF THE COAL SEAMS

(In the table below the percentages of the spores and pollen contained in each seam has been given.)

Sr. No.	*Sporae dispersae*	Samples 1-3 %	Samples 4-6 %	Samples 7-8 %	Samples 9-12 %	Sample 13 %	Sample 14 %	Sample 15 %	Sample 16 %	Sample 17 %	Sample 18 %	Sample 19 %	Sample 20 %
1	*Leiotriletes levis*	—	—	0·4	1·5	—	—		—		—		—
2	*Punctatisp. minutus*	—	—	—	—	25·0	—		4·0		—		73·0
3	*Calamosp.* cf. *microrugosa*	—	—	—	17·7	—	33·3		2·0		31·5		1·4
4	*C. breviradiata*	—	0·3	—	—	—	—		—		—		—
5	*C. saariana*	2·4	2·4	1·2	1·5	—	—		—		—		—
6	*C.* sp.	0·8	0·3	0·8	5·9	—	—		—		—		—
7	*Cyclogranisp. microgranus*	—	—	2·0	—	—	—		—		—		—
8	*Crassisp. pfalzensis*	—	—	0·4	—	—	—		—		—		—
9	*Lophotriletes commissuralis*	0·4	—	—	—	—	—		—		—		—
10	*Verrucosisp.* cf. *donarii*	0·4	—	0·4	—	—	—		—		—		—
11	*Lycospora microgranulata*	27·0	51·3	42·8	—	—	—		—		—		—
12	*Lycosp. triangulata*	11·0	5·0	13·6	—	—	—	NO SPORES	—	NO SPORES	—	NO SPORES	—
13	*Lycosp. perforata*	—	—	1·6	—	—	—		—		—		—
14	*Densosporites* sp.	0·4	—	—	—	—	—		—		—		—
15	*Laevigatosp. medius*	11·7	24·0	17·6	7·3	—	—		—		—		—
16	*L. vulgaris*	8·6	3·3	12·0	—	—	—		—		—		—
17	*L. desmoinesensis*	6·5	1·6	1·2	—	—	—		—		—		—
18	*L. minimus*	9·5	2·3	2·0	1·5	—	—		—		—		—
19	*Latosporites saarensis*	3·0	1·3	0·4	—	—	—		—		—		—
20	*L. minutus*	6·0	4·0	0·4	2·9	75·0	3·3		—		—		8·6
21	*L.* sp. A.	3·0	1·6	0·4	—	—	—		—		—		—
22	*L.* sp. B.	3·0	2·3	0·4	59·0	—	58·6		92·0		59·0		—
23	*Punctatosp.* cf. *minutus*	5·2	—	—	—	—	—		—		—		—
24	*Striatosp. pfalzensis*	0·4	0·3	—	—	—	—		—		—		—
25	*Striatosp. major*	—	—	0·4	—	—	—		—		—		—
26	*Guthörlisp.* sp.	—	—	0·8	—	—	—		—		—		—
27	*Florinites pfalzensis*	—	0·3	1·2	2·9	—	—		2·0		9·5		—
28	*Florinites* sp.	—	—	—	—	—	0·6		—		—		—
29	*Illinites* sp.	—	0·3	—	—	—	—		—		—		—
30	*Pityosporites schaubergeri*	—	—	—	—	—	—		—		—		17·0
31	*Alisporites saarensis*	—	0·3	—	—	—	—		—		—		—
	Total No. of spores counted	230	300	250	68	4	150		50		200		70

microflora of the seam in Labach mine is qualitatively the richest followed by that of the seams in Maria and Kleeb mines.

Between the two samples of Middle *Kuseler Schichten* similar nonagreement is noticeable. The sample from mine Medicus/Kirn is richer in quality and quantity than the sample from Kusel/Rammelsbach. Likewise the samples of Upper *Kuseler Schichten* from Lauterecken area differ among themselves.

From the above comparisons we conclude that the tendency for the microflora to be progressively poorer in quality as well as quantity, as one proceeds from the older to the younger divisions, is manifest equally strongly within the divisions as well. On this basis we have arranged the histograms of the seams in Table 4, within the 3 geological subdivisions in a sequence commensurate with the tendency of the microflora to become poorer in younger horizons. The richest coal seam from Labach mine is placed at the base. Samples 13, 15, 17 and 19 have not been considered here for lack of any or adequate spores. The rearrangement of samples 14, 16 and 18 is on floristic grounds only and till this can be substantiated by field studies, it must be considered tentative.

COMPARISON BETWEEN THE MICROFLORA OF THE VARIOUS GEOLOGICAL SUBDIVISIONS

Upper *Ottweiler Schichten*—Gothan, Guthörl & Heintz (*see* BHARDWAJ, 1955, TABLE 2) have renamed Upper *Ottweiler Schichten* as *Breitenbacher Schichten*. In the conception of these authors, this *Schichten* contained only the *Grenzkohlen* seam in the Saar geological profile. But the latest findings of Bhardwaj (1955) suggest that microfloristically *Illinger* seams show closer relationship to *Grenzkohlen* seam than to the *Schwalbacher* seam. The *Illinger* as well as *Grenzkohlen* seams of the Saar contain a microflora which, in main, has a rich representation of *Lycospora* but is completely devoid of *Triquitrites*. The microflora from the coal seam of Upper *Ottweiler* (i.e. *Breitenbacher*) *Schichten* of Pfalz shows full agreement in these features, i.e. the abundance of *Lycospora* and the absence of *Triquitrites*, just as has been noted in the *Illinger* and *Grenzkohlen* seams of the Saar; all the same, the former are not as rich qualitatively as the latter. Such spore genera as *Valvisisporites, Cyclobaculisporites, Raistrickia, Angulisporites, Wilsonia,* and *Potonieisporites*, which are present in the *Illinger* and *Grenzkohlen* seams of the Saar, have not been found in the coal seams of Pfalz. Even among those spore genera which are represented in both regions while a large number of species are the same, a significant number are not known from one region or the other. In spite of these differences, which the similarities outweigh, it can be concluded that the microfloras of these horizons agree in general.

Middle *Kuseler Schichten* — The microflora of Middle *Kuseler Schichten* is devoid of *Lycospora* unlike the microflora of *Breitenbacher Schichten*. *Triquitrites* continues to be absent and a large number of other genera present in the older horizon such as *Verrucosisporites, Crassispora, Striatosporites, Illinites* and *Alisporites* are also not present any longer. *Calamospora* cf. *microrugosa* makes new appearance.

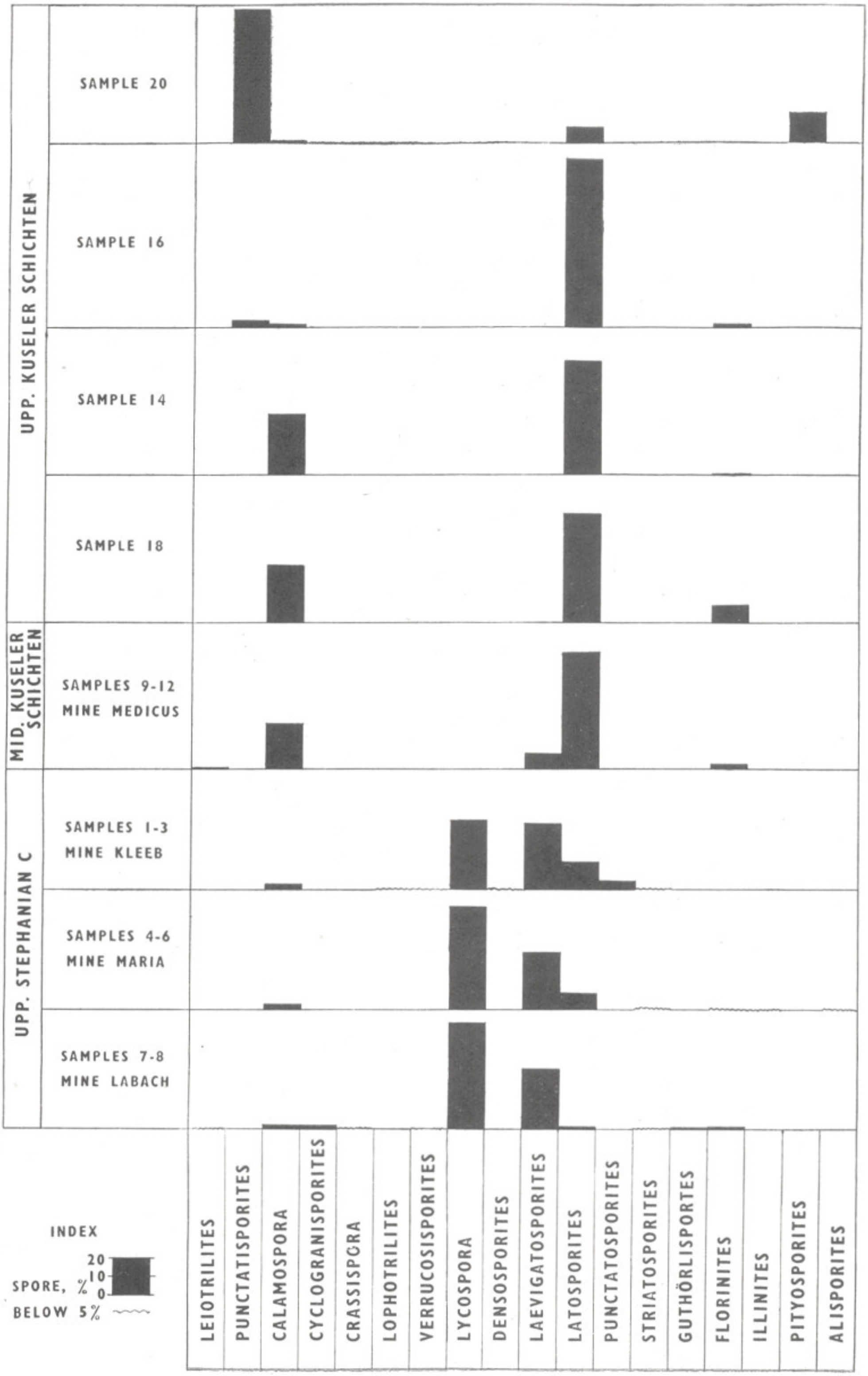
Upper *Kuseler Schichten* — The microflora of Upper *Kuseler Schichten* is all the more poor as compared to Middle *Kuseler Schichten* by the absence of such genera as *Leiotriletes* and *Laevigatosporites*. On the other hand, two genera, *Punctatisporites* and *Pityosporites*, are the new additions to the flora. The latter genus is present only in one sample and so does not seem to be normal for the horizon. It appears that *Pityosporites* heralds the beginning of the next horizon.

Lebacher and *Tholeyer Schichten* — The microflora of these subdivisions is not known. But from the analysis of the Saar-Pfalz flora by Weiss (1869-1872) as well as by Doubinger (1956) it is apparent that during the time these subdivisions were deposited the megaflora once again became rich by the addition of a large number of new, chiefly coniferous forms as compared to the scanty flora of *Kuseler Schichten*. Sample 20 might be the beginning of *Lebacher Schichten*.

DISCUSSION

The chief purpose of this study has been to ascertain the microfloristic relationship of the Upper Carboniferous strata in Pfalz to the overlying Lower Rotliegend strata. From the comparisons made above it has become apparent that the Upper *Ottweiler* coal seams of Pfalz are in microfloristic continuation of the Stephanian C (*Illinger* seams and *Grenzkohlen* seam) of the Saar basin. As the microfloral composition of the Upper Carboniferous seams in Pfalz is distinctly

TABLE 4—PERCENTAGE DISTRIBUTION OF SPORE GENERA IN DIFFERENT GEOLOGICAL SUBDIVISIONS

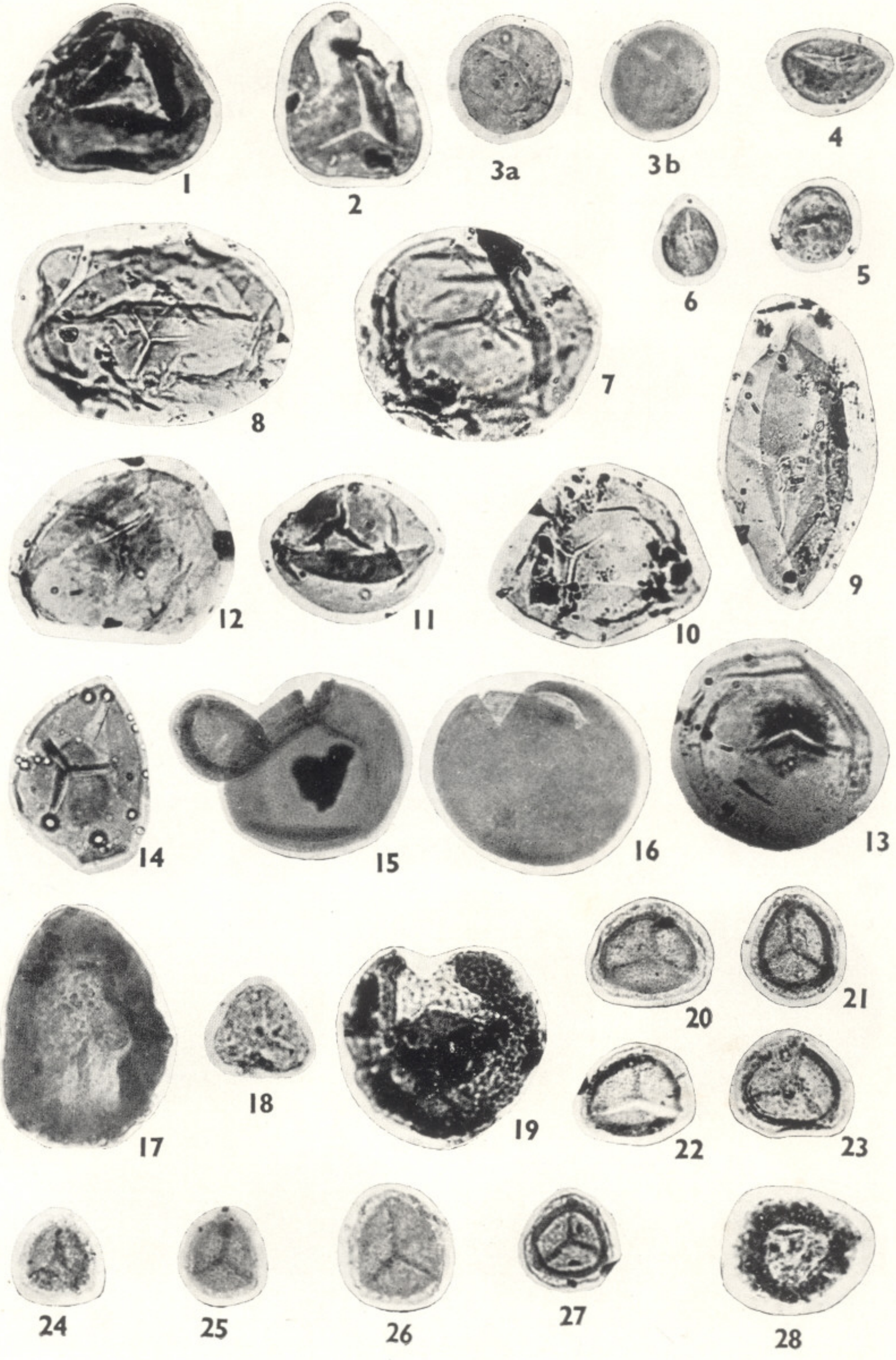


poorer than the Saar seams due to the absence of certain characteristic spore genera, it is presumbale that a minor floral change separated these two sections of Stephanian C.

Kuseler Schichten exhibits a major change in its microflora as compared to the underlying Upper *Ottweiler Schichten*. Not only that the microflora of *Kuseler Schichten* is much poorer in composition, it also lacks the important genus *Lycospora*. These differences suggest a significant change to justify a distinct separation of these two horizons. Now the question arises as to what ranking we should ascribe to this change, i.e. whether this change is of the nature to separate two systems, Carboniferous from Permian, or it can be considered a change within a system.

TABLE 5

System	Division	Subdivisions	Zones	Microfloristic Characteristics	
PERMIAN	LOWER ROTLIEGEND	THOLEYER SCHICHTEN		↑	
		LEBACHER SCHICHTEN		Predominantly coniferous *Sporae dispersae*	
CARBONIFEROUS	UPP. CARBONIFEROUS	KUSELER SCHICHTEN	UPPER	Predominantly non-coniferous *Sporae dispersae* Presence of — *Calamosp.* cf. *microrugosa*, *Latosporites* *Punctatisporites*, *Pityosporites*	Absence of *Lycospora* *Triquitrites*
			MIDDLE	Presence of — *Calamosp.* cf. *microrugosa*, *Latosporites*, *Laevigatosporites* and *Florinites pfalzensis*	
			LOWER		
		UPPER OTTWEILER SCHICHTEN (STEPHANIAN C – SAAR-PFALZ)	UPPER STEPHANIAN C — PFALZ	Presence of— *Lycospora*, *Florinites*, *Laevigatosporites*, *Striatosporites*, *Latosporites*, *Cyclogranisporites* etc., and absence of — *Calamosp.* cf. *microrugosa*	Presence of *Lycospora* Absence of *Triqultrites*
			LOWER STEPHANIAN C – SAAR	Presence of — *Calamosp.* cf. *microrugosa*, *Valvisisporites*, *Lycospora* *Wilsonia*, *Florinites* *Alisporites*, *Laevigatosporites* *Striatosporites*, *Raistrickia*. etc.,	
		STEPHANIAN A – B			Presence of — *Triquitrites* Absence of *Lycospora*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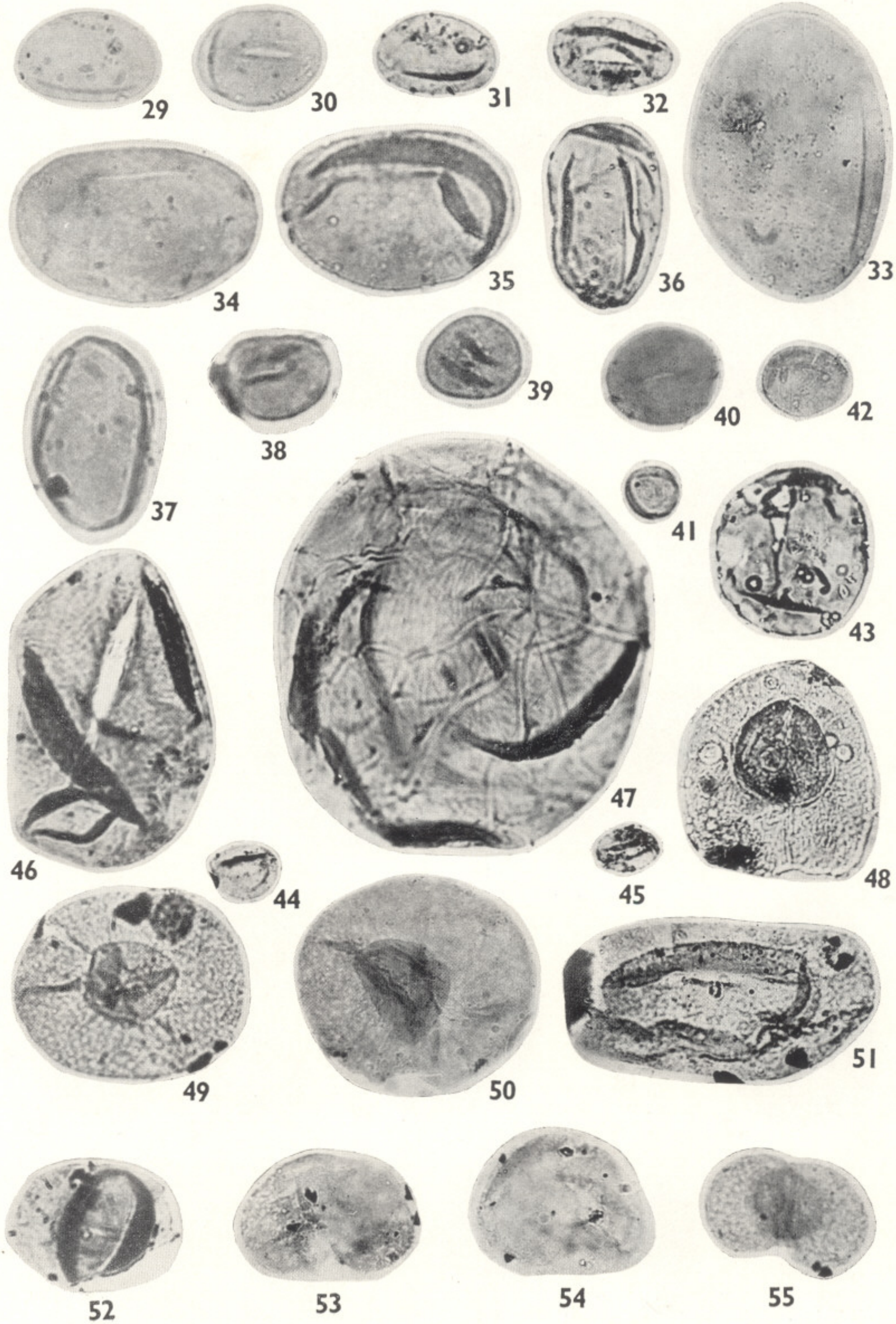
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The disappearance of *Lycospora* occurred twice in the Saar-Pfalz basin. It disappeared at the close of Westphalian separating it from the overlying Stephanian. Within Stephanian *Lycospora* reappeared during Stephanian C only to disappear once again by the close of that period. If we were to consider the two similar disappearances *at par*, *Kuseler Schichten* should become a part of Carboniferous. Even otherwise if we appreciate the significance of the microfloral continuity exhibited during the succession from Upper *Ottweiler Schichten* up to *Kuseler Schichten*, as if of a waning flora, we have to agree that the floral changes indicated are not of such magnitude as to put one part into the Carboniferous and the other in the Permian.

By Upper *Kuseler Schichten* time the microflora existing through Upper *Ottweiler* and Middle *Kuseler Schichten* reached its last limit, there having been left only two spore genera of the older flora. Towards the close of this period two new spore types, *Punctatisporites* and *Pityosporites*, appeared. The nature of the microflora which flourished during *Lebacher* and *Tholeyer Schichten* is not exactly known although the reported richness of these layers in fossil conifers (DOUBINGER, 1956) and the appearance of *Pityosporites* at the close of *Kuseler Schichten* (SAMPLE 28, TABLE 4) suggest a dominance of biwinged spore types just as in the rest of the Permian. It seems that the really Permian character of the flora began developing from *Lebacher Schichten* onwards. Thus so far as *Kuseler Schichten* is concerned, floristically it can preferably be considered a part of the Carboniferous and the boundary between Carboniferous and Permian can be assumed to lie between *Kuseler* and *Lebacher Schichten* (TABLE 5).

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EXPLANATION OF PLATES

All magnifications 500 ×. Slides preserved at Birbal Sahni Institute of Palaeobotany.

PLATE 1

1, 2. *Leiotriletes levis* (Kos.) Pot. & Kr.
3-6. *Punctatisporites minutus* Kos.
7-10. *Calamospora* cf. *microrugosa* (Ibr.) S.W. & B.
11. *Calamospora breviradiata* Kos.
12, 13. *Calamospora saariana* Bhard.
14. *Calamospora* sp.
15, 16. *Cyclogranisporites micrograms* Bhard.
17. *Crassispora pfalzensis* sp. nov.
18. *Lophotriletes commissuralis* (Kos.) Pot. & Kr.
19. *Verrucosisporites* cf. *donarii* Pot. & Kr.
20-23. *Lycospora micrograntdata* Bhard.
24-26. *Lycospora triangulata* Bhard.
27. *Lycospora perforata* sp. nov.
28. *Densosporites* sp.

PLATE 2

29-32. *Laevigatosporites medius* Kos.
33-35. *Laevigatosporites vulgaris* Ibr.
36, 37. *Laevigatosporites desmoinesensis* (Wils. & Coe.) S.W. & B.
38, 39. *Laevigatosporites minimus* (Wils. & Coe.) S.W. & B.
40. *Latosporites saarensis* Bhard.
41. *Latosporites minutus* Bhard.
42. *Latosporites* sp. A.
43. *Latosporites* sp. B.
44, 45. *Punctatosporites* cf. *minutus* Ibr.
46. *Striatosporites pfalzensis* sp. nov.
47. *Striatosporites major* Bhard.
48. *Guthörlisporites* sp.
49, 50. *Florinites pfalzensis* sp. nov.
51. *Florinites* sp.
52. *Illinites* sp.
53, 54. *Pityosporites schaubergeri* Pot. & Kl.
55. *Alisporites saarensis* Bhard.