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SPORE STRATIGRAPHY AT THE DEVONIAN-CARBONIFEROUS BOUNDARY IN THE NORTHERN "RHEINISCHES SCHIEFERGEBIRGE", GERMANY

Kenneth HIGGS & Maurice STREEL

(11 figures, 1 table, 4 plates)

INTRODUCTION

The most complete and continuous miospore succession at the Devonian/Carboniferous boundary in Western Europe occurs in the extremely thick marine clastic sequences of Southern Ireland. Here a miospore zonation scheme comprising eight biozones has been described for the late Devonian-early Carboniferous (uppermost Famennian or Strunian to Upper Tournaisian) interval. The lack of diagnostic goniatite and conodont control in the southern Irish sections limits their value as possible Devonian-Carboniferous boundary stratotypes. Therefore the present study was undertaken in an attempt to apply the Irish spore zonation scheme to the considerably thinner but well dated marine sequences in the classic area of the Northern Rhenish Slate Mountains in Germany.

The present authors have been studying the Northern Rhenish Slate Mountains sequence since 1979 as part of the I.U.G.S. Working Group project on the Devonian-Carboniferous boundary. Preliminary results were published in the field guidebook edited by PAPROTH & STREEL (1982). Palynological studies of the Devonian-Carboniferous beds in this area were first made by STREEL (1966, 1969) and were then expanded by PAPROTH & STREEL (1970). Several of the sections studied by PAPROTH & STREEL (1970) have been re-sampled together with the investigation of several new sections, trenches and boreholes.

The miospore zonation of CLAYTON *et al.* (1978) for the late Devonian and Carboniferous of Britain and Ireland has recently been modified by HIGGS *et al.* (in press) (See fig. 1) and this new zonation scheme has been used in the present study. The zonation scheme has been successively applied to many areas in Ireland and Britain and its independence of sedimentary facies has been demonstrated (CLAYTON & HIGGS, 1979).

CHRONO-STRATIGRAPHY		MIOSPORE ZONATION		
		CLAYTON *et al* 1978		HIGGS *et al* (in press)
CARBONIFEROUS	Upper Tournai	CM Biozone		CM Biozone
		PC "		PC "
	Middle Tournai	NV Biozone	VI Subzone	BP "
				HD "
	Lower Tournai			VI "
DEVONIAN	Uppermost Famenne or Strunian		LN "	LN "
		PL Biozone	LE "	LE "
			LL "	LL "

Fig. 1. Comparison of miospore zonations

LOCATION OF SECTIONS AND SAMPLING

The location of the sections studied is shown on Figure 2 and details of each section is described separately in the text. Geologically all the sections with the exception of Stockum are located on the northern flank of the Remscheid-Altena anticline. The Stockum sections are located on the Ebbe anticline to the South.

A first version of this paper was delivered on the 15th September 1983 at the Symposium "Devonian-Lower Carboniferous (Mississippian) boundary" held in Madrid during the 10th International Congress of Carboniferous Stratigraphy and Geology.

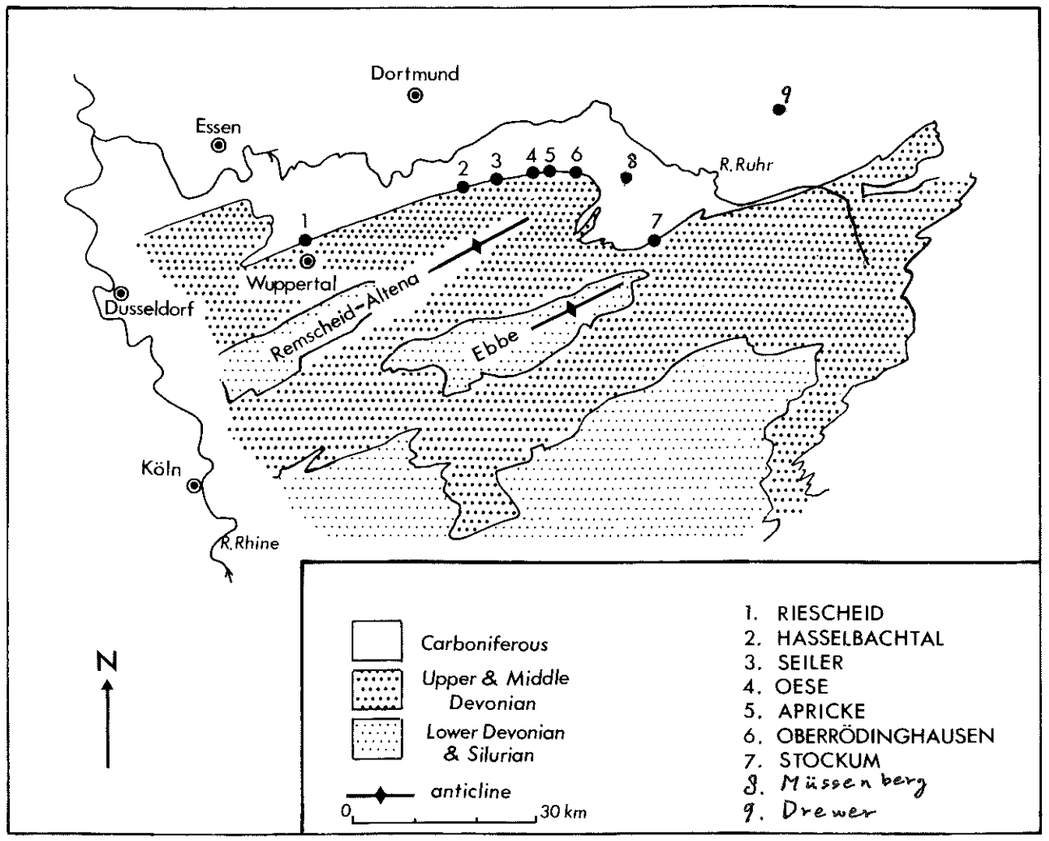

Fig. 2. Location of the sections studied

In the course of this study some sixty samples have been processed and thirty seven productive samples have been obtained. Figures 3 to 8 show the stratigraphical levels of these productive samples, together with some of the productive levels of PAPROTH & STREEL (1970). Ninety six miospore taxa have been identified and their occurrence within each sample is shown on Table 1. The majority of these taxa are well described in the literature so no systematic treatment is given. However, several new spore types and two new species have been recognized and these are formally described in the systematic part of the paper. A selection of the most stratigraphically useful miospores referred to in the succeeding chapter are shown on the range chart (Fig. 9). A representative selection of the miospore taxa is illustrated in Plates 1-4.

The figured specimens are housed in the Micropaleontological collections of the Geological Survey of Ireland in Dublin, Ireland.

STRATIGRAPHICAL PALYNOLOGY

1.- RIESCHEID

The section is located in a disused railway cutting in the hillside north of the river Wupper near the town of Wuppertal (Sheet 4709 Wuppertal-Barmen r83640 n 84600). Geologically it is situated on the northern flank of the Remscheid-Altena anticline.

The uppermost Devonian sediments are represented here by greenish silty shales (Hangenberg Schiefer equivalent). Carbonate lens within the shales have yielded conodont faunas of the *costatus* Zone (LANE & ZIEGLER *in* PAPROTH & STREEL, 1982). The greenish silty shales are succeeded by a thin black shale and an allodapic limestone with conodonts of the upper *Siphonodella crenulata* zone (LANE & ZIEGLER, *op. cit.*).

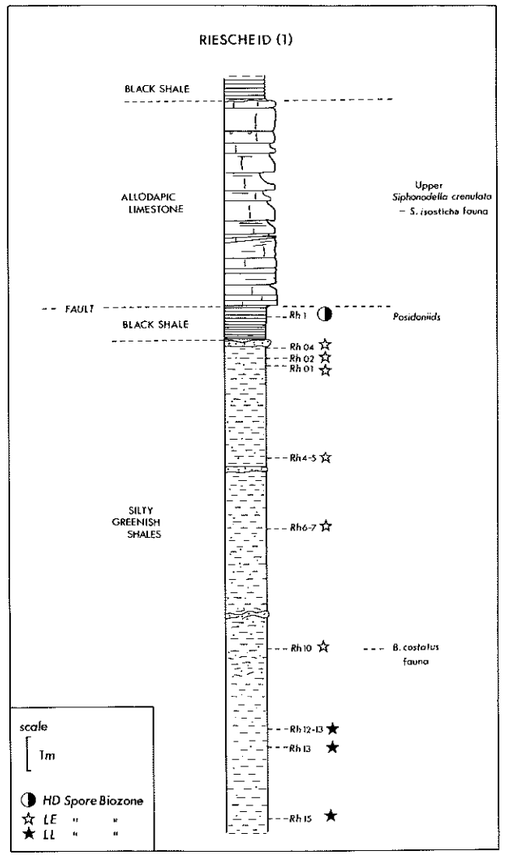

Fig. 3. Stratigraphic position of spore assemblages in the section of Riescheid.

The upper 15 metres of shales below the allodapic limestone have yielded well preserved spore assemblages. Their stratigraphic positions and composition are shown on Figure 3 and Table 1, respectively.

LL Biozone

Between levels 12.5 m and 15 m. three LL Biozonal assemblages were recorded.

These assemblages are rich and diverse in composition with *Retispora lepidophyta* and species of the *Diducites* complex being particularly abundant. The assemblages also contain several large sized taxa such as *Auroraspora torquata, Retispora cassicula, Hystricosporites multifurcatus,* together with numerous small acritarchs.

LE Biozone

Between levels 1 m and 10 m six LE Biozone assemblages were recorded. These assemblages differ in composition from the LL Biozone assemblages in the absence of the large-sized taxa mentionel above and the presence of the zonal species *Hymenozonotriletes explanatus.* A notable feature of these assemblages is the presence of a large and diverse population of *Vallatisporites* specimens (see Plate 4). The majority of these falling into the *Vallatisporites pusillites* concept of DOLBY & NEVES (1970). Most of the specimens possess rather bulbous based spines, 2-10 μ in length (sometimes fused). Occasional verrucate forms belonging to *Vallatisporites verrucosus* are also present.

The lowest LE assemblage (Rh 10) occurs at a level more or less equivalent with the *costatus* conodont fauna.

HD Biozone

The uppermost metre of the shale succession is composed of black shale. Approximately 25 cms below the top of the black shale a HD Biozone assemblage was recorded. The assemblage is rather poor in composition with species such as *Retusotriletes incohatus* and *Verrucosisporites nitidus* being the most commonly occurring elements. A single occurrence of *Kraeuselisporites hibernicus* allows an assignment to the HD Biozone.

The absence of the LN and VI spore biozones indicates that there is either strong condensation or a non sequence in the lower part of the black shale. The presence of an *isostichia* - upper *crenulata* conodont fauna in the allodapic limestone above the black shale also indicates there is a non-sequence as several of the lower Hangenberg Kalk faunas are missing.

In conclusion the palynological and faunal evidences indicate that the critical levels at the Devonian-Carboniferous boundary ie. the upper part of the Hangenberg Schiefer and the Hangenberg Kalk are missing at Riescheid.

2.- HASSELBACHTAL

The Hasselbachtal section is located on the northern margin of the Rhenish Massif, geologically it is on the northern flank of the Remscheid-Altena anticline. The

locality is north of the town of Hagen-Hohenlimburg (sheet 4611 Hohenlimburg, R 07000, H 94220) and is a stream section in the valley of the Hasselbach (Hasselbrook) which is a eastern tributary of the Lenne River.

The succession begins stratigraphically with nodular limestone beds and subordinate shales of the Wocklum Kalk. These strata contain the transition between the middle and upper *costatus* conodont faunas and also the boundary between the *hemispherica-dichotoma* and *h. latior*-interregnum ostracod Zones (GROOS-UFFENORDE & UFFENORDE, 1974). The Wocklum Kalk is succeeded by approximately 5 m of the Hangenberg Schiefer. Levels close to the top of the shales (36-46 cms below the top) contain a goniatite fauna with *Acutimitoceras* cf. *prorsum prorsum*. The succeeding argillaceous limestones and thin shales constitute the Hangenberg Kalk. The lowest two beds of the Hangenberg Kalk (bed 84 and 83) contain conodont faunas of the *Siphonodella sulcata* Zone (GROOS-UFFENORDE & UFFENORDE, 1974). Limestones from the upper part of the Hangenberg Kalk contain a *S. sandbergi* Zone fauna.

Spore assemblages have been obtained from the top of the Wocklum Kalk, the upper part of the Hangenberg Schiefer and the base of the overlying Hangenberg Kalk. Detailed sampling of the top 25 cms of the Hangenberg Schiefer has allowed fine resolution of the LN/VI biozonal boundary. The stratigraphic positions of the productive samples are shown on Figure 4.

LE Biozone

Sample Hb 1 from 50 cms below the top of the Wocklum Kalk yielded a small and rather poorly preserved LE biozonal assemblage.

LN Biozone

LN Biozone assemblages have been obtained from the upper part of the Hangenberg Schiefer. The oldest LN assemblage come from 120 cms below Limestone bed 83 and the youngest LN assemblage is from 18.5 cms below bed 83.

The assemblages are composed of abundant and well preserved spores. In the highest LN assemblages *Retispora lepidophyta* is less abundant (less than 4 %) and taxa such as *Cyrtospora cristifer, Corystisporites* sp. and *Spelaeotriletes obtusus* appear. Also *Retusotriletes incohatus* becomes a very abundant element in the assemblages (more than 40 %).

VI Biozone

VI Biozone assemblages have been obtained from five levels below bed 83, and from a level in the lower part of bed 83 itself.

The composition of these VI assemblages is very similar to those obtained from the basal VI Biozone in Ireland. They are dominated by simple laevigate taxa such as *Retusotriletes incohatus* (50-70 %) and *Punctatisporites irrasus,* and are characterized by the absence of *Retispora lepidophyta* and many of its associated taxa. Also there are no new forms appearing at this interval.

The LN/VI biozonal boundary lies 14 cms below the level with *Siphonodella sulcata* (bed 84). The section at Hasselbachtal gives the most complete miospore succession at the Devonian-Carboniferous boundary yet investigated in the Rhenish Slate Mountains.

3.- SEILER

The temporary trenches studied are located in the wooded hills north of Iserlohn, in an area called Seilerberge and Iserlohner Stadtwald. Geologically the sequences are located on the northern flank of the Remscheid-Altena anticline.

The uppermost Devonian is represented here by particularly sandy and silty sediments. The strata close to the Devonian-Carboniferous boundary are characterized by a argillaceous and silty beds with intercalated nodular limestones.

In trench 1 (1979) a limestone bed close to the top of the Hangenberg Schiefer possesses a lower *Protognathodus* conodont fauna. The base of the Hangenberg Kalk contains an upper *Protognathodus* fauna and approximately 1 metre higher is a level with *Siphonodella sulcata.* In trench 2 (1969) ZIEGLER (unpublished data, see PAPROTH & STREEL, 1982, p. 58) claims to have found *S. sulcata* with the upper *Protognathodus* fauna.

Well preserved spore assemblages have been obtained from levels within the upper part of the Hangenberg Schiefer in the 1969 trench 2 and 1979 trench 1 (see Fig. 5).

Trench 1 (1979)

Three LN biozonal assemblages were obtained from 40 cms to 6.5 metres below the Hangenberg Kalk. The composition of these assemblages indicates a position in the upper part of the biozone. An unusual feature of the LN microflora is the presence of *Vallatisporites vallatus* and the absence of *V. pusillites* and *V. verrucosus.*

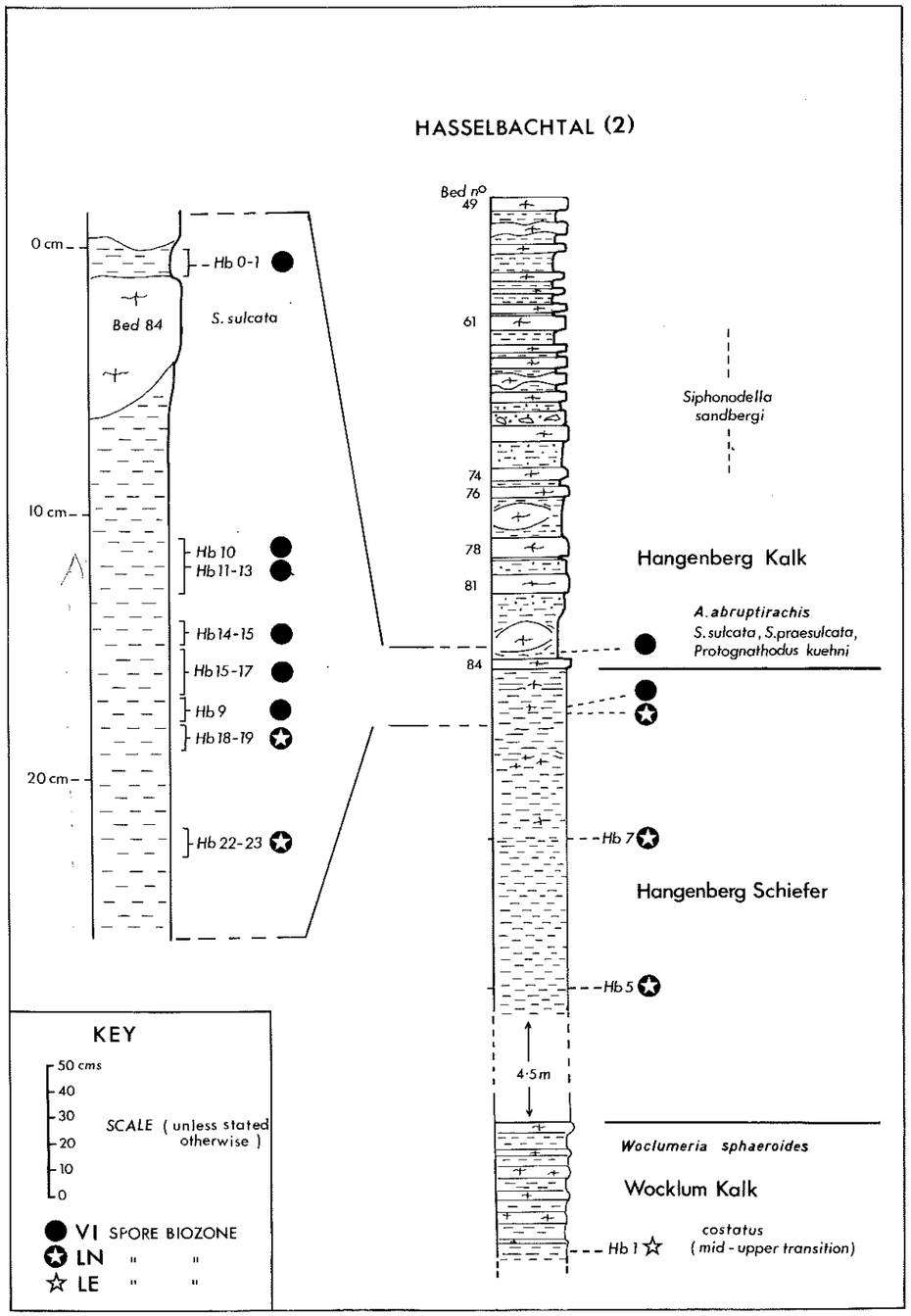

Fig. 4. Stratigraphic position of spore assemblages in the section of Hasselbachtal

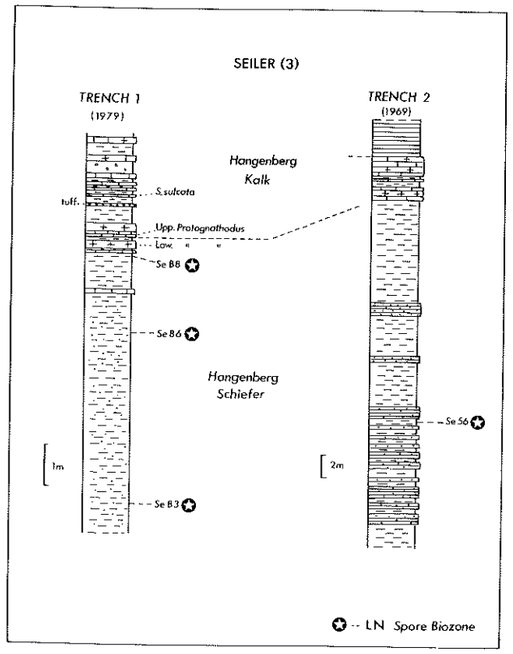

Fig. 5. Stratigraphic position of spore assemblages in the trenches of Seiler

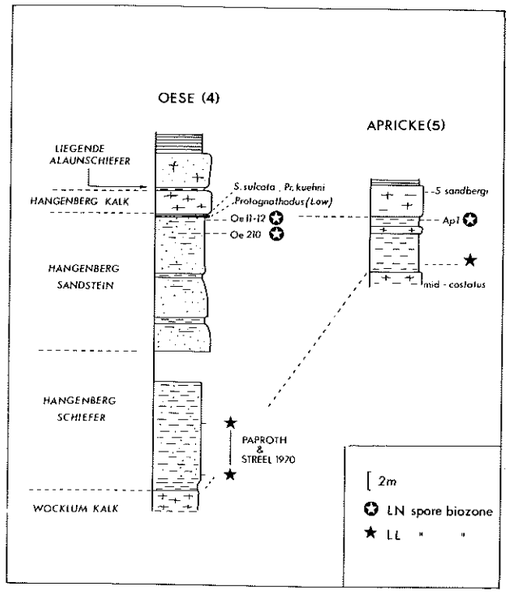

Fig. 6. Stratigraphic position of spore assemblages in the section of Oese and Apricke

Trench 2 (1969)

A typical LN biozonal assemblage was obtained from 18 metres below the Hangenberg Kalk.

4.- OESE

The Oese section is located in a series of roadside and quarry exposures on the B 7 road between Menden and Hemer (Sheet 4512 Menden).

Geologically the section is located on the northern flank of the Remscheid-Altena anticline. The top of the Wocklum Kalk contains an upper *costatus* conodont fauna. The limestones are succeeded by the Hangenberg Schiefer with *Cymaclymenia euryomphala* at the base. There is a thick sandstone development - the Hangenberg Sandstein - above the shales in this area. The top sandstone bed (bed A) has yielded a lower *Protognathodus* conodont fauna. The overlying Hangenberg Kalk contains a *Siphonodella sulcata - Protognathodus kuehni* conodont fauna at their base and goniatites of the *Gattendorfia subinvoluta* Zone.

The stratigraphical position of the palynological samples is shown on Figure 6.

LL Biozone

Spore assemblages obtained by PAPROTH & STREEL (1970) from the lower part of the Hangenberg Schiefer are assigned to the LL Biozone. Their composition is very similar to those obtained from the Hangenberg Schiefer at Oberrödinghausen.

LN Biozone

Two LN assemblages were recorded from the uppermost part of the Hangenberg Sandstein. The highest of these occurs 11-12 cms below the base of bed A. Both assemblages are rather restricted in composition and poorly preserved, but contain diagnostic LN elements.

5.- APRICKE

The section is in a brook valley north east of the village of Apricke about 3 km east of Hemer Sheet 4612 Iserlohn, r 17690, h. 96250.

The section is located geologically on the northern flank of the Remscheid-Altena anticline. The top of the Wocklum Kalk contains a middle *costatus* conodont fauna. This is succeeded by 5 metres of Hangenberg Schiefer with *Cymaclymenia euryomphala* at the base. The Hangenberg Kalk as far only yielded conodonts of the *Siphonodella duplicata* and *S. sandbergi* Zones.

The stratigraphical position of the productive sample is shown on Figure 6.

LL Biozone

LL L Biozone assemblages have been reported by PAPROTH & STREEL (1970) from lower levels of the Hangenberg Schiefer. Their composition is similar to those from the lower part of the shales at Oberrödinghausen.

LN Biozone

A LN miospore assemblage was obtained from a level close to the top of the Hangenberg Schiefer. The assemblage is well preserved and diverse in composition, and is probably from a level high in the Biozone.

6.- OBERRÖDINGHAUSEN

The section is located on the left bank of the Hönne brook, in a railway cutting of the Menden-Balve line about 450 m south of the Oberrödinghausen Station. Sheet 4613 Menden r. 19400 h. 96100. Geologically the section is located on the northern flank of the Remscheid-Altena anticline. The section is the present type section of the Devonian-Carboniferous boundary as defined and accepted at the Heerlen Congress 1935. The base of the Carboniferous being defined by the first appearance of the goniatite *Gattendorfia subinvoluta* which occurs in the lower part of the Hangenberg Kalk.

Spore assemblages have been obtained from most of the Hangenberg Schiefer (by PAPROTH & STREEL, 1970) and the base of the Liegende Alaunschiefer, immediately above the Hangenberg Kalk. Spore assemblage has also been recovered from the Hangenberg Schiefer in a borehole core drilled about 200 m to the type section (see Fig. 7).

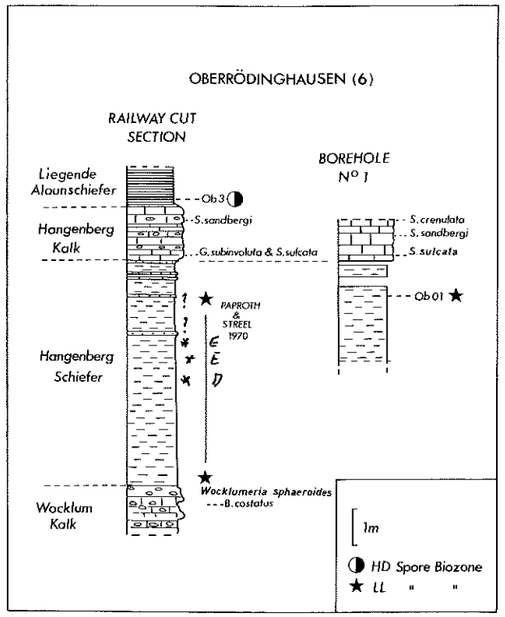

Fig. 7. Stratigraphic position of spore assemblages in the section and borehole of Oberrödinghausen

LL Biozone

All the assemblages recorded by PAPROTH & STREEL 1970 from the type section and by the authors from the Oberrödinghausen Core nº 1 are assigned to the LL Biozone. However, they are slightly different in composition to the Irish LL assemblages in that they contain species such as *Vallatisporites verrucosus* and *Lophozonotriletes triangulatus*. Also the typical *Diducites* complex of spores is absent.

In both the type section and in the borehole the uppermost metre of the Hangenberg Schiefer did not yield any spores.

HD Biozone

A fairly diverse miospore assemblage was obtained from the base of the Liegende Alaunschiefer which succeeds the Hangenberg Kalk. The presence of *Kraeuselisporites hibernicus* in the assemblage indicates a position in the HD Biozone. The assemblage is associated with the lower *Siphonodella crenulata* conodont Zone.

The palynological results from the Oberrödinghausen section indicate a non-sequence near the top of the Hangenberg Schiefer with LE, LN and low VI Biozones missing.

7.- STOCKUM

The trenches are located in a forested area about 1 km from the village of Stockum (Sheet 4713 Plettenberg, r. 30190, h. 84600). The Böschung trench occurs at the side of a small road (Stockum Böschung) and the Stockum trenches 1 and 2 of ALBERTI *et al.*, 1974 occur about 100 m east of the Böschung. A parallele new trench to trench 2, opened in 1982, is used here (Fig. 8). Geologically the sections are located on the northern flank of the Ebbe anticline, the next structure south of the Remscheid-Altena anticline.

The Hangenberg Schiefer in this area is rather sandy in the upper part with its top characterized by a lenticular goniatite bearing limestone (the Stockum Limestone). This limestone level has yielded a goniatite fauna containing *Acutimitoceras prorsum prorsum* and a conodont fauna with *Protognathodus kuehni*.

A calcareous sandstone some 50 cms below this level contains a conodont fauna with *Siphonodella praesulcata* and *Protognathodus kockeli*. The limestones and shales above the Stockum limestone have not yet been fully investigated and the Hangenberg Kalk faunas are still not known.

The composition of the productive samples is shown on table 1. The stratigraphic position of samples from trenches 1 and 2 is shown on Figure 8, and the position of the samples from Stockum Böschung is noted in the text.

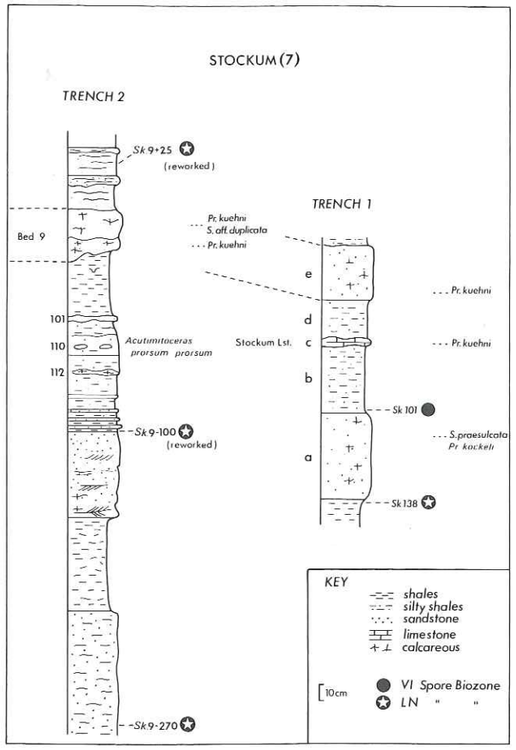

Fig. 8. Stratigraphic position of spore assemblages in the trenches of Stockum.

Trench 1

A LN biozonal assemblage (SK 138) has been obtained from directly below the 50 cm calcareous sandstone (bed a) which underlies the Stockum Limestone. The assemblage contains taxa such as *Cyrtospora cristifer,* and *Corystisporites* sp. and rare specimens of *Retispora lepidophyta* and *Vallatisporites pusillites* which indicates a position near the top of the biozone. Sample SK 101 taken from directly above the calcareous sandstone contains a VI biozonal assemblage. The LN/VI biozonal boundary occurs below the Stockum Limestone level and close to the upper *praesulcata* Zone fauna in the top of bed "a".

Trench 2

LN Biozone assemblages were obtained from a mudstone level 170 cms below the top of the prominent sandstone bed equivalent to bed a of trench 1. The composition of the assemblage is similar to that obtained from sample SK 138 in trench 1. Two higher LN biozonal assemblages come from a 1.4 metre interval above the sandstone horizon. The composition of these two assemblages indicates reworking has taken place. The presence of taxa such as *Retispora cassicula, Endosporites admirandus,* and *Ancyrospora* spp. is anomalous, as they are normally characteristic elements of the older LL Biozone. Therefore the evidence suggests that LL Biozone spores have been reworked into VI biozonal assemblages.

Böschung section

LN miospore assemblage was obtained from two levels respectively 320 cms and 340 cms below the top of the prominent sandstone bed equivalent to bed a of trench 1. The composition of the assemblage is shown on table 1.

In conclusion, the evidence from trench 1 shows that the LN/VI biozonal boundary is associated with the upper *praesulcata* Zone, with the upper *Protognathodus* fauna (*sulcata* Zone) occurring just above the lowest VI subzonal level. Evidence from trench 2 cannot be relied upon due to the reworking problem of the spore microfloras.

BIOSTRATIGRAPHY

The following section discusses the stratigraphical relationships between the spore biozones and the other fossil groups which have been recorded in the sections.

CONODONTS

Conodont faunas have been reported from all the sections investigated, so it is possible to make some correlations between the spore and the conodont zonations. Figures 10 and 11 illustrate these correlations.

i) The low *crenulata* Zone correlates approximately with the HD Biozone in Oberrödinghausen.

ii) The *sulcata* Zone occurs in the basal VI biozonal assemblages in Hasselbachtal.

iii) The upper *praesulcata* Subzone, with *Protognathodus kockeli,* occurs between LN Biozone and VI Biozone in Stockum, and on top of the LN Biozone in Oese and Seiler.

iv) The transition between middle and upper *costatus* faunas is firmly correlated with LE Biozone in Hasselbachtal. This faunal level is more or less equivalent to the boundary between the lower and middle *praesulcata* (ZIEGLER & SANDBERG, 1983), depending on how many and which *Palmatolepis* species are disappearing at that level. It is uncertain therefore whether the LL biozonal assemblages occurring on the Wocklum Kalk in the area Oberrödinghausen-Apricke-Oese correspond to the lower or the middle *praesulcata* Zone (Fig. 10).

OSTRACODS

Ostracod transition between *hemisphaerica-dichotoma* Zone and *hemisphaerica/latior* Interregnum is also firmly correlated with LE Biozone in Hasselbachtal

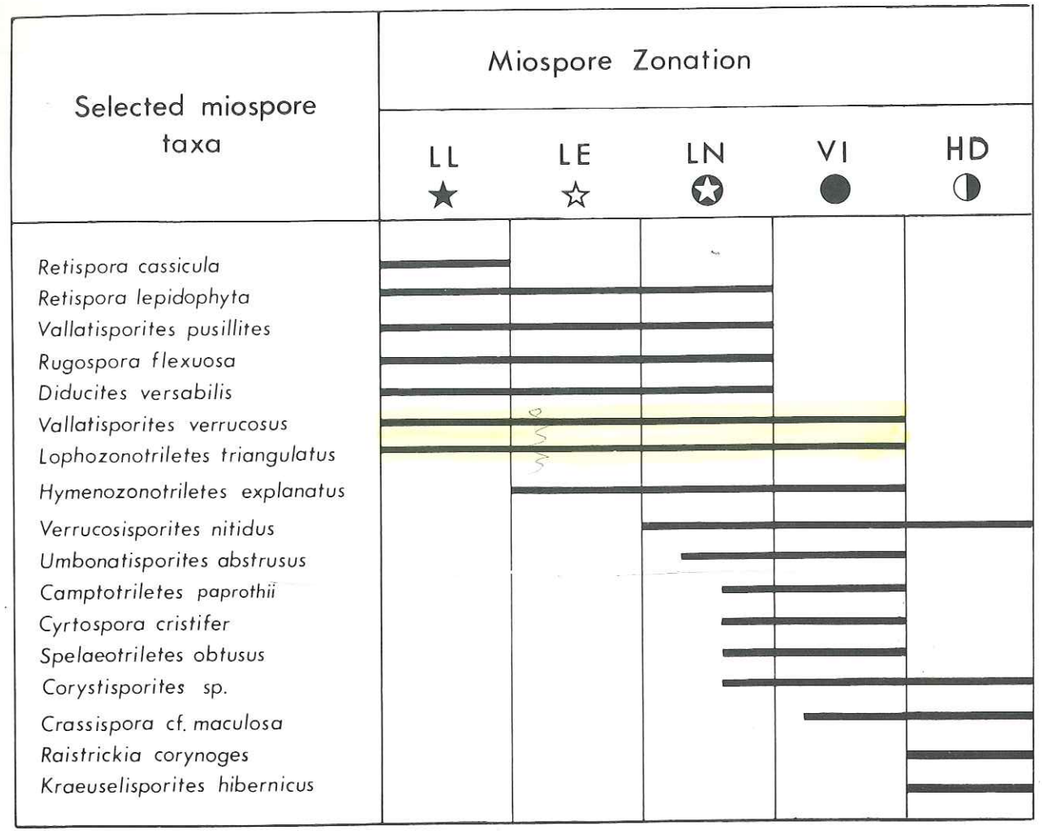

Fig. 9. Selection of the most stratigraphically useful miospores referred to in the present paper

(BLESS & GROOS-UFFENORDE, 1984). *Richterina latior* occurs in VI Biozone.

AMMONOIDS

Goniatite faunas have been recorded from most of the sections investigated. The upper part of the Wocklum Kalk contains the *Wocklumeria sphaeroides* Subzone fauna both at Hasselbachtal and at Oberrödinghausen. However, the spore evidence indicates the top of the Wocklum Kalk in these areas is of different age, in the Hasselbachtal area it corresponds to the LE Biozone whereas in the Oberrödinghausen-Apricke-Oese area it corresponds to the older LL Biozone. Alternatively, it may be argued that the LL biozonal assemblages have been reworked into younger sediments in this latter area. The sudden extinction of many ammonoid families at this stratigraphical level (PRICE & HOUSE, 1984) might well correspond to the mass transport on the slope of nearshore sediments (here carrying LL biozonal spores) which were triggered by earthquakes.

Towards the top of the Hangenberg Schiefer at Hasselbachtal the first *Acutimitoceras* fauna is associated with the uppermost LN Biozone whereas at Stockum the typical "Stockum fauna" with *Acutimitoceras prorsum prorsum* occurs in the lower part of the VI Biozone.

TRILOBITES

Trilobites faunas of the units 2 and 3 transition of BRAUCKMANN & HAHN (1984) *(Archegone abruptirhachis/A. drewerensis)* are associated with the VI Biozone at Stockum.

PALAEOENVIRONMENT

Figure 11 summarizes the stratigraphical and palaeoenvironmental conditions of the sections investigated. Three distinct areas can be recognized, from west to east they are :

i) **The Riescheid area.** In this area the Hangenberg Kalk equivalent is absent due to faulting and/or non sequence.

ii) **The Hasselbachtal and Seiler area** situated along the northern margin of the Remscheid-Altena

Table 1. Distribution of spores.

MIOSPORE TAXA \ SECTIONS & SAMPLES	Hasselbachtal										Stockum							Riescheid										Seiler				Oberrödinghausen		Apricke	Oese	
	Hb 83	Hb 10	Hb 11-13	Hb 9	Hb 14-15	Hb 15-17	Hb 18-19	Hb 22-23	Hb 7	Hb 5	Hb 1	Sk 9+25	Sk 0-10	Sk 20-30	Sk 101	Sk 138	Sk 9-100	Sk 9-270	Rh 1	Rh 04	Rh 02	Rh 01	Rh 4-5	Rh 6-7	Rh 10	Rh 12-13	Rh 13	Rh 15	Se B8	Se B6	Se B3	Se 56	Ob 3	Ob 01	Ap 1	Oe11-12 Oe 210
Ancyrospora furcula																											•								
Ancyrospora sp.																		•					•				•					•			
Aneurospora greggsi				•							•																								
Apiculiretusispora verrucosa							•	•				•					•			•	•		•	•	•	•	•	•	•	•			•	•	
Archaeozonotriletes minutus				•		•	•	•			•		•		•						•	•				•	•	•					•		
Aurorospora asperella								•											•														•		
A. hyalina var. tournensis							•																												
A. macra	•		•	•		•	•	•							•						•	•		•		•	•						•		
A. cf. panda															•																				
A. solisorta															•																			•	
A. torquata																											•								
Baculatisporites fusticulus																																•			
Camptotriletes paprothii	•	•	•	•	•	•	•	•	•							•	•												(•)	•			(•)		
Convolutispora ampla																														•					
C. caliginosa				•						•						•	•								•							•			
C. major																																	•		
C. oppressa				•			•	•	•	•		•	•	•	•	•	•	•		•	•	•	•	•					•	•	•	•		•		•
C. vermiformis		•		•	•	•	•		•	•						•	•		•								•		•		•		•		
Convolutispora sp.	•		•	•	•		•	•											•		•	•								•	•					
Corbulispora cancellata				•						•		•	•	•	•	•	•	•							•	•	•						•	•	•
Corystisporites sp. (in Higgs 1975)	•	•	•	•	•	•	•	•											•															(•)	
Crassispora catenata												•								•	•					•	•							•	
C. cf. maculosa	•																																		
Cristatisporites colliculus				•	•			•																											
C. menendezii									•													•													
Cyclogranisporites sp.												•										•							•	•					
Cyrtospora cristifer	•					•		•						•	•															(•)					
Densosporites spitsbergensis								•							•	•																			
Dictyotriletes submarginatus															•	•										•			•						
D. trivialis		•	•	•	•			•	•			•	•	•		•	•	•											•			•	•		
Diducites mucronatus								•	•	•	•		•	•															•						
D. plicabilis				•				•	•	•			•		•							•													
D. poljessicus							•	•	•	•			•													•	•	•							
D. versabilis								•	•	•			•			•	•									•	•	•						•	
Discernisporites crenulatus									•																					•					
D. micromanifestus			•		•			•																										•	
Emphanisporites hibernicus													•																						
E. rotatus																						•												•	
Endoculeospora gradzinskii																																			
Endosporites admirandus																																			
Grandispora cornuta																																			
G. echinata				•																															
G. cf. echinata (in Higgs 1975)																																			
Hymenozonotriletes explanatus				•																															
Hystricosporites multifurcatus																																			
Hystricosporites sp.																																			
Knoxisporites literatus	•	•		•											•																				
K. pristinus		•																																	
Kraeuselisporites hibernicus																																			
Leiotriletes trivialis																																			
Lophozonotriletes excicus																																			
L. triangulatus				•		•		•																											
Lophozonotriletes sp. A (Keegan 1977)																																			
Lophozonotriletes sp.		•																																	
Velamisporites perinatus																																			
Pulvinispora quasilabrata				•				•	•				•	•																					
P. scolecophora								•	•					•				•																	
Punctatisporites irrasus														•																					
P. minutus	•			•			•	•	•																										
P. planus					•		•		•			•						•																	
P. resolutus																														•					
Pustulatisporites gibberosus					•																														
Pustulatisporites sp. A (Higgs 1975)				•			•	•	•			•	•					•				•	•						•	•					
Raistrickia spathulata																																			
R. corynoges																																			
R. macrura	•	•	•		•		•							•				•																	
R. minor							•																												
R. variabilis		•		•			•	•							•																				
Raistrickia sp.																		•											•	•					
Retispora lepidophyta							•	•				•	•	•	•			•		•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
Retusotriletes avonensis															•															•			•		
R. communis	•		•					•					•	•	•							•											•		
R. crassus		•		•				•	•				•				•													•					
R. famenensis							•																												
R. incohatus	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•		•						•	•	•	•	•	•	•
R. minor							•																			•									
R. planus																																			
R. triangulatus												•	•																						
Rugospora flexuosa						•	•	•																											
R. granulatipunctata				•											•	•																			
Schopfites delicatus												•																							
Secarisporites sp.					•																														
Spelaeotriletes crustatus	•		•			•							•	•																					
S. obtusus																																			
Spinozonotriletes uncatus							•	•							•																				
Tumilispora ordinaria								•																											
Umbonatisporites abstrusus								•							•																				
Vallatisporites pusillites				•	•			•	•				•	•	•																			•	
V. vallatus								•									•																		
V. verrucosus				•				•																											
Velamisporites magnus																	•																		
Verrucosisporites nitidus				•				•									•																		
V. scurrus																																			
V. tuberculatus																																			
? Spelaeotriletes cumulus				•				•																											
Retispora cassicula															•																				

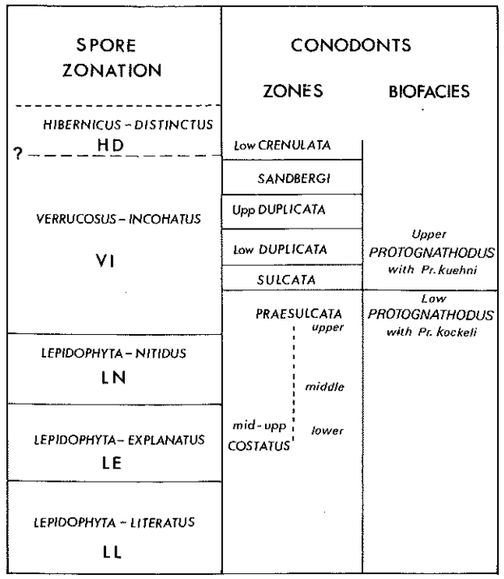

Fig. 10. Correlation between spore and conodont zonations at the Devonian-Carboniferous boundary

anticline where there are no notable gaps in the available sequences.

iii) **Oese, Apricke, Oberrödinghausen, Stockum area** corresponding to the top of the synsedimentary highs i.e. the Remscheid-Altena and Ebbe-anticlines with non-sequences and probable reworked processes. Sequences where the Hangenberg Kalk immediately overlies the Wocklum Kalk are well known in this latter area e.g. Müssenberg.

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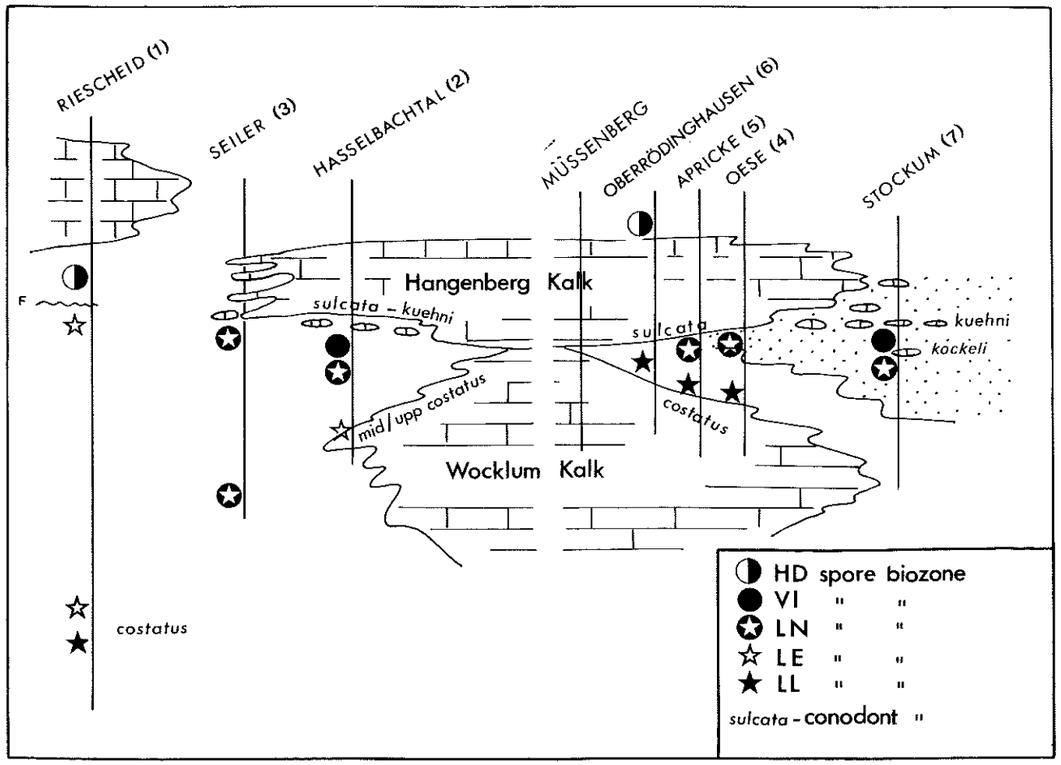

Fig. 11. Stratigraphical and palaeoenvironmental conditions of the sections investigated

SYSTEMATICS

Genus *CAMPTOTRILETES* (NAUMOVA) POTONIE & KREMP 1954

Camptotriletes paprothii sp. nov.

Plate 1, figs 9–16

Holotype : Plate 1, fig. 13.

Type locality : Sample B 3 Seiler Trench 1 (1979), Hangenberg Schiefer.

Diagnosis : Trilete acamerate miospores. Amb surbcircular. Suturae simple, straight length 3/4 or more of the spore radius. Exine 1–2 µm in thickness, densely ornamented on both surfaces with small cristate ridges, rugulae and occasional discrete coni. The cristae and regulae are sinuous to irregular, closely spaced and in some cases interwoven to form an imperfect reticulum. Ridges 1.5 – 6 µm in length, 1 – 1.5 µm in height bearing pointed to rounded projections 1–2 µm in height. Occasional arcuate compressions present.

Size range : 30 – (40) – 55 µm, based on 20 speciments.

Name Derivation : After Dr. Eva PAPROTH (see Acknowledgements).

Comparison : The late Visean species *Camptotriletes cristatus* SULLIVAN & MARSHALL 1966, is very similar but differs in possessing mainly conate and sometimes spinose elements which are less densely distributed. *Crassispora catenata* HIGGS 1975 differs in possessing chains of granulate elements.

Genus *CONVOLUTISPORA* HOFFMEISTER STAPLIN & MALLOY 1955

Convolutispora sp.

Plate 2, fig. 9

Description : Trilete acamerate miospores. Amb subcircular to oval. Suturae often obscured by ornament, simple, length at least 1/2 of the spore radius. Exine densely ornamented with flexuous muroid folds. Folds 6–12 µm in height and up to 20 µm in length, characteristically sinuous, flexuous and convoluted. Folds branch and overlap but do not form a reticulum.

Size range : 80 – 98 µm, based on 9 specimens.

Genus *CYCLOGRANISPORITES* POTONIE & KREMP 1954

Cyclogranisporites sp.

Plate 1, fig. 22

Description : Acamerate trilete miospores. Amb subcircular. Suturae simple, straight, length 1/2 the spore radius. Exine ornamented with dense ornament of discrete grani and coni 0.5 – 1.5 µm in size. Exine bears large arcuate compression folds on both surfaces.

Size range : 67 – 74 µm based on 4 specimens.

Comparison : The specimens described are very similar to *Cyclogranisporites palaeophytus* NEVES & IOANNIDES 1974 however no darkenings of the contact areas were observed.

Genus *RAISTRICKIA* SCHOPF, WILSON & BENTALL emend POTONIE & KREMP 1954

Raistrickia sp.

Plate 2, fig. 7

Description : Trilete acamerate miospores. Amb subcircular. Suturae simple, straight, length approximately 3/4 of the spore radius. Exine densely ornamented with small stunted bacula, 1.5 – 3 µm in height. Elements mainly discrete, but in some cases their is basal fusion. Bacula possess straight sides and rounded, flattened and occasionally expanded tops. Ornament slightly reduced on the proximal surface.

Size range : 35–42 µm, based on 5 specimens.

Comparison : *Raistrickia pinguis* PLAYFORD 1971 is also very small in size but differs in possessing much coarser baculate ornament.

Genus *SECARISPORITES* NEVES 1961

Secarisporites sp.

Plate 2, fig. 16

Description : Trilete acamerate miospores. Suturae obscured by ornamentation, length at least 1/2 the spore radius and accompanied by narrow labra. Distal surface, equator and proximal equatorial areas ornamentated with large globose verrucae and rugulae, 5–15 µm in width, 10–20 µm in length. Ornament particularly prominent at equator where it imparts an irregular and undulate outline. Apical region of proximal surface laevigate. No inner body seen.

Size range : 70–75 µm, based on 3 specimens.

Comparison : The specimens described bear some resemblence to *Dictyotriletes tschernyschensis* JUSHKO 1960. However this species is predominately reticulate and also possesses broad labra. However, specimens figured by VAN VEEN (1981, pl. 2, figs. 7–8) as *D. tschernyschensis* are morphographically close to *Secarisporites* sp.

Genus *SPELAEOTRILETES* NEVES & OWENS 1966

Spelaeotriletes? cumulus sp. nov.

Plate 4, figs 17–19

Holotype : Plate 4, fig. 17.

Type Locality : Sample Hb. 22–23, Hangenberg Schiefer, Hasselbachtal.

Diagnosis : Trilete camerate miospores. Amb subcircular to subtriangular. Suturae often obscure, normally accompanied by flexuous folds 3–5 µm in height, which extend to the spore margin. Intexine distinct to barely perceptible, closely appressed to exoexine and comprising 3/4 or more of the spore diameter.

Outline of intexine conformable with amb, and possibly attached to the exoexine on both surfaces. Exine strongly infragranulate and ornamented distally with verrucae and subordinate grana. Verrucae subcircular in basal outline with rounded and flattened tops, 1.5 - 5 μm in diameter and up to 2.5 μm in height. Verrucae irregularly distributed, discrete and never crowded except at the distal apical pole where they are often clustered and fused to form a darkened mass. Large arcuate and irregular compression folds present on both surfaces.

Size range : 50 - (62) - 70 μm, based on 10 specimens.

Comments : This species is only tentatively assigned to the genus *Spelaeotriletes* due to the uncertainty concerning the nature of attachment of the exine layers.

Comparison : *Spelaeotriletes pretiosus* (PLAYFORD) NEVES & BELT differs in possessing a generally larger and more regular ornament of verrucae and mammillae together with a smaller intexine which is attached to the exoexine on the proximal surface only. The specimen figured as *? Schopfites* sp. by VAN VEEN (1981, pl. 3, fig. 7) from the Devonian-Carboniferous transition at Ballycrovane in Southern Ireland appears very similar to *Spelaeotriletes ? cumulus.*

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Dr. K. HIGGS

Geological Surbey of Ireland,
Beggars Bush, Haddington Road
DUBLIN 4 (Ireland)

Prof. M. STREEL

Paleontology, the University,
7 place du Vingt-Août,
B-4000 LIEGE (Belgium)

SPORE STRATIGRAPHY AT THE DEVONIAN-CARBONIFEROUS BOUNDARY IN THE NORTHERN "RHEINISCHES SCHIEFERGEBIRGE", GERMANY

ABSTRACT

Miospores have been studied from several sections (including trenches and boreholes) in the Devonian-Carboniferous transitional layers of the Northern Rhenish Slate Mountains. Correlations between the miospore and the conodont, ostracode, ammonoid and trilobite zonations are proposed.

Palaeoenvironmental conditions allow the subdivision of the region into three distinct areas.