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Preliminary survey of the palynological content of the Lower Devonian in the Oesling, Luxembourg

by

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Résumé: Quarante échantillons palynologiques de l'Oesling ont été prélevés dans le Dévonien inférieur. Une méthode de traitement des échantillons en laboratoire a été adaptée pour remédier au problème de l'altération thermique intense de la matière organique. La plupart des échantillons contiennent de la matière organique déterminable: miospores, acritarches et phytodébris. Les miospores permettent une datation de plusieurs des échantillons. L'origine continentale de la matière organique implique une origine continentale ou côtière des couches. Le degré de l'altération thermique varie avec l'âge des échantillons. Elle a davantage affecté le Praguien et l'Emsien inférieur que l'Emsien supérieur. Ceci peut être dû à un phénomène thermique précoce affectant les couches antérieures au dépôt de l'Emsien supérieur.

Summary: Forty palynological samples from the Northern part of the Grand Duchy of Luxembourg were taken from the Lower Devonian. The laboratory process for the preparation of the samples has been adapted to overcome the problem of the intense thermal alteration. Most of the samples contained determinable organic matter, Miospores, Acritarchs and Phytodebris. The Miospores allowed a dating of many samples. The continental origin of the organic matter implies that the layers are either continental or nearshore marine. The degree of thermal alteration varies with the age of the samples and is much more pronounced in the Pragian and Early Emsian than in the Late Emsian. This suggests that an early thermal phenomenon affected the Pragian and Lower Emsian rocks, before the Upper Emsian deposits.

1. Introduction and scope of the study

This paper discusses a preliminary study designed to determine the extent to which palynology offers potential to further knowledge of the Devonian in the Oesling region by ascertaining whether the beds sampled contained identifiable palynomorphs and if so, whether those might be useful for dating and paleogeographic purposes.

The rock facies involved are poorly differentiated and macrofossils are usually scarce. Moreover, macrofossils have been shown to be of limited biostratigraphic use in the subject strata.

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The Devonian in the Oesling region has been the subject of various geological studies, and notably the major compilations published by Gosselet (1885), Asselberghs (1946) and Lucius (1950). The latter also drew up the detailed geological map of Luxembourg.

The stratigraphic scale used by Lucius is not always easy to correlate with those used in the Belgian Ardennes and in the Eifel region.

Since the 1970's, German universities have regularly performed field surveys in the Oesling region whose findings are only available in students' project reports. In this context, Lunkenheimer (1989) tried to match Lucius' stratigraphic scale with the one established by the German geologists, and especially that of Mittmeyer (1974).

Table 1 summarizes the data for the Ardenne, the Oesling and the Eifel. The "Siegenian"/Emsian limit and the subdivisions in the Emsian are problematic and are shown as broken lines. The problems, which stem from the difficulty of reproducing limits established solely on lithological criteria and from the lack of fossils, have led some authors to group several units together. Konrad und Wachsmut (1973) propose an alternating sequence of schists, greywackes and quartzites covering the "Upper Siegenian" and the Lower Emsian.

Palynology, and more specifically the study of fossil spores, has provided significant results in the Lower Devonian of the Belgian Ardenne (Steemans 1989), which belong to the same massif.

2. Stratigraphic position of the samples (Fig. 1)

Forty samples were taken, covering the major lithostratigraphic formations of the Oesling region as defined by Lucius (1950). The samples were ascribed to the various levels mainly on the basis of the detailed geological map. The cross-sections were chosen to cover the main tectonic units of the Oesling. The name "Siegenian" has to be considered as a lithostratigraphic term. In chronostratigraphy it has been replaced by the term: Pragian.

2.1. "Middle Siegenian" (Sg2)

Outcrops of the "Middle Siegenian" are to be found in the western part of the Oesling region, in two anticline cores near Bastogne-Oberwampach and Martelange.

In the Martelange area, where samples were taken (N° 25, and possibly N° 19, from near the limit with the "Upper Siegenian"), the "Middle Siegenian" consists mainly of quartz phyllites ("quartzophyllades"), with coarse-grained schist and frequent layers of quartzite. Certain levels are rich in fossils and often seem "decayed" owing to the dissolution of the carbonate fraction.

According to Asselberghs (1946), the abundance of marine fauna and the lithology of these rocks are indicative of deposition in a shallow, alternately troubled and calm sea.

2.2. "Upper Siegenian" (Sg3)

Outcrops of the "Upper Siegenian" are far more frequent and occur in East-West strips on either side of the Wiltz synclinorium. The "Upper Siegenian" consists mainly of coarse-grained blue-black schists that are sandy in places. In the Martelange-Perlé area, the bottom of the Sg3 is slate (Sg3a on the detailed geological map).

Table 1. Comparison between the stratigraphic subdivisions in use in the Oesling and surrounding areas. The broken lines indicates an uncertain position of a limit.

International Scale	Belgique (Asselberghs 1941)		Luxembourg (Lucius 1950)		Deutschland (Mittmeyer 1974)			
					Stufe	Unterstufe	Westeifel	Mosel
Emsian	Emsien supérieur	Schiste de Wiltz Quartzite de Berlé	Oberes Emsien	Schiefer von Wiltz Quarzit von Berlé	Ober-Ems	Lahnstein	Wiltz-Schichten Berlé-Quarzit	Hohenrhein-Schichten Emsquarzit
	Emsien inférieur	Schistes bigarrés de Clervaux	Mittleres Emsien	Clerf-Schichten	Unter-Ems	Vallendar	Klerf-Schichten Gladbach-Schichten	Nellenköpfchen-Schichten Rittersturz-Schichten
		Quartzophyllade de Schuttbourg	Unteres Emsien	Quartzophylladen von Schüttburg		Singhofen	Biederburg-Schichten Reudelsterz-Schichten	
				Schiefer von Stolzemburg		Ulmen	Eckfeld-Schichten	Hunsrück-schiefer
Pragian	Siegenien supérieur	Phyllades de Neufchâteau et de Martelange	Oberes Siegenien	Grobschiefer	Siegen	Herdorf	Obersiegen	
	Siegenien moyen	Quartzophyllades de Longlier	Mittleres Siegenien	sandige Schiefer und Sandsteine		Rauhflaser	Mittelsiegen	
	Siegenien inférieur	Phyllades, quartzo-phyllades, quartzites d'Alle et d'Anlier	Unteres Siegenien	Phylladen und Quarzophylladen		Tonschiefer	Untersiegen	
Lochkovian	Gedinnien							

The "Upper Siegenian" was deposited in shallow seas and fossils are scarce.

A first series of samples were taken near Martelange: from the transition from Sg2 to Sg3a (N° 19), from the slate (N^{os} 17, 18 and 24) and from the coarse-grained schist (N^{os} 20 to 23).

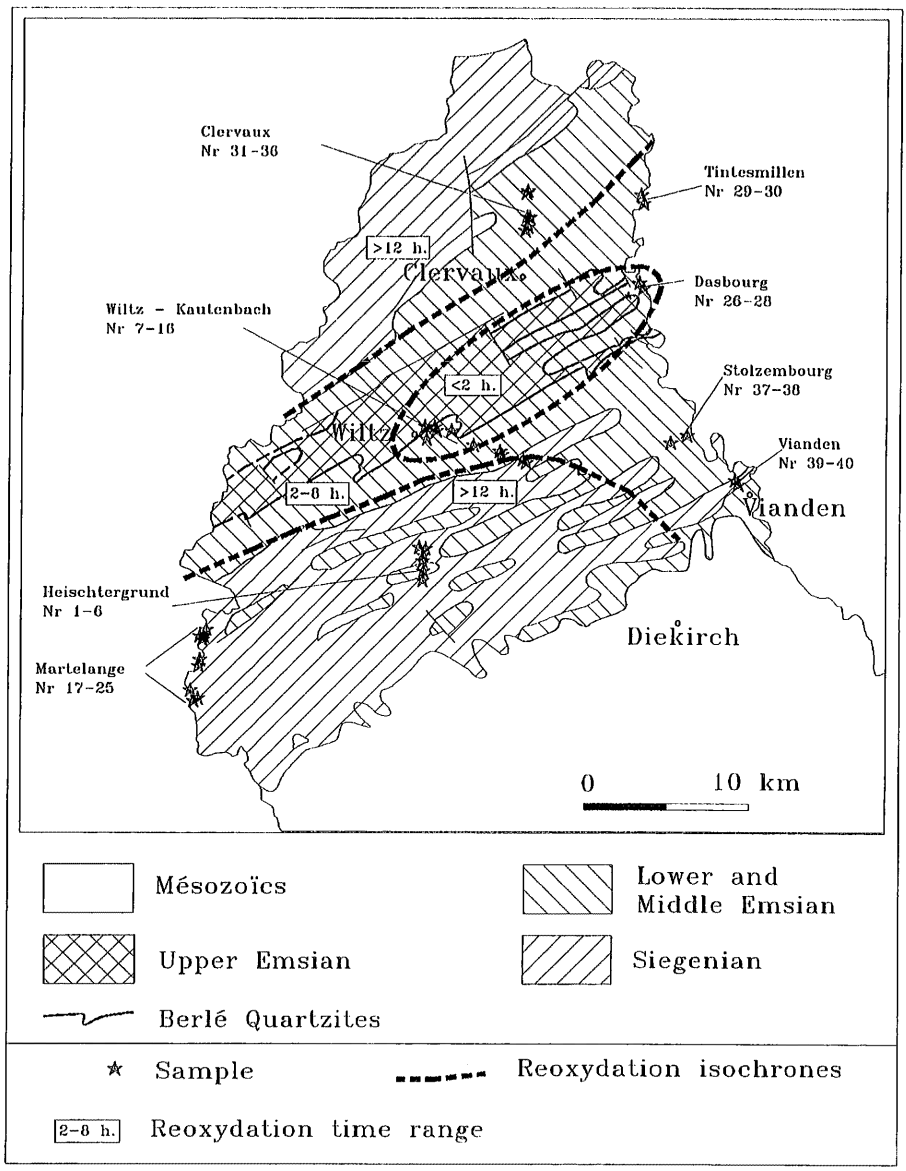


Fig. 1. Simplified geological map of the Oesling locating the main lithostratigraphical units of the lower Devonian, the major faults, the sampling points and the reoxydation time ranges of the samples.

It should be noted that, on the basis of the fauna described by Lucius (1950) in the Martelange area, Mittmeyer (in Lunkenheimer 1989) placed these rocks higher up in the stratigraphic scale.

In the cutting along the N15 road south of Heischtergronn, which is well-known for the numerous sedimentary structures to be observed (Macar & Antun 1950, Bintz et al. 1973 and Maquil et al. 1984), five samples (N^{os} 1 to 5) come from the area mapped by Lucius as Sg3, and a sixth (N° 6) from the stratigraphic top of the outcrops, mapped as E1a.

Lunkenheimer (1989) also studied this section and described two lithostratigraphic units: the " Siltstein-Tonschiefer-Wechselfolge " whose macrofauna is from the "Upper Siegenian", and the "Obere Tonschiefer Abfolge" whose fauna is similar to that of the "Lower Emsian". Lunkenheimer's map shows the limit between these two units a little further to the north than Lucius' Sg3/E1a limit, and according to this interpretation, only samples 1 and 2 would be "Siegenian".

The problem of establishing a correspondence between the lithological divisions (coarse-grained schists / Stolzembourg Schists) and the biostratigraphic divisions ("Upper Siegenian" / Emsian, the traditional criterion being the disappearance of *Acrospirifer primaevus*, a fossil rarely observed in Luxembourg) is encountered throughout the Oesling region.

A series of samples was taken in the Woltz valley, north of Clervaux (N^{os} 34, 36 and N° 33 near the Sg3/E1 limit).

The Sg3 was further sampled (N^{os} 39 and 40) in the easternmost outcrops of Luxembourg, close to the German border, north of Vianden, near the dam on the river Our.

2.3. Lower Emsian (E1a and E1b)

Outcrops of the Lower Emsian are common in the Oesling region, from east to west on either side of the Wiltz synclinorium. Lucius divided the Lower Emsian into E1a, Stolzembourg Schists, and E1b, Schuttbourg "Quartzophyllades".

The Stolzembourg Schists consist of dark grey or blue-grey schist with interbedded quartzite layers. Although in general terms the schist is predominant, Asselberghs noted an increase in the proportion of quartzite layers from west to east, indicating a transition from neritic facies to shallower facies, supported by sedimentary features such as ripple marks.

Samples were taken from the E1a in the cutting along the N15 road south of Heischtergronn mentioned above (N^{os} 6 and possibly 3-5).

Further samples were taken from outcrops along the RN 25 road in Merkholz (N^{os} 13 and 14), from the Woltz valley north of Clervaux (N^{os} 31, 32 and possibly 33) and in Stolzembourg (N^{os} 37 and 38).

The Schuttbourg "Quartzophyllades" also consist of alternating dark-coloured schist and quartzite, but the latter is present in a far greater proportion and is usually micaceous.

Samples of the E1b were taken in the Merkholz quarries (N° 11) and in the Our valley, near Tintesmillen (N^{os} 29 and 30).

2.4. Middle Emsian (E2)

The Middle Emsian comprises the Clervaux Schists, which are generally red or variegated and consist mainly of schist, with quartzite layers.

It is relatively easy to establish a correlation between this formation and the "Klerf-Schichten" of the Vallendar substage in the Westeifel area. The absence of fossils makes it impossible to locate these layers precisely on the stratigraphic scale. The generally accepted bottom limit is based on the gradual increase of red coloration, whereas at the top, a clear boundary distinguishes this formation from the Berlé Quartzites, whose fauna is Upper Emsian.

These rocks were deposited in a littoral environment, and where this formation extends into the Eifel region, even brackish water fauna has been observed (Asselberghs 1946).

One sample was taken from a quarry in the Tutschemillen locality near Wiltz (N° 10). The outcrops show ripple marks and mud cracks, evidence of shallow sea deposits, at times emerged.

The top of the formation was sampled in Erpeldange, in a quarry located in the Himmelbaach valley (N° 8).

Another sample (N° 12) was taken from an outcrop of variegated schist in the Himmelbaach valley between Wiltz and Merkholz, and two further samples (N^{os} 27 and 28) were taken from an outcrop of red schist and quartzite on the bank of the river Our near Dasburg.

2.5. Upper Emsian (q and E3)

The Upper Emsian comprises, at the bottom, a series of white quartzite beds, usually containing fossils, known as the Berlé Quartzites.

A sample of schist interbedded in the quartzite was taken from a quarry in the Himmelbaach valley (N° 9), and another from near Dasburg (N° 26).

For the most part, the Upper Emsian consists of the Wiltz Schists (E3), which consists of dark blue to grey-black schist. The bedding planes are emphasised by rows of elongated siliceous nodules.

Sample N° 7 was taken from Wiltz Schists in Erpeldange.

3. Sampling and laboratory processing

Forty palynological samples from the Northern part of Luxembourg were taken from the Lower Devonian, more precisely from layers ranging from the lithostratigraphic subdivisions "Sg2" to "E3". The data on their stratigraphic and geographic origin is summarized in Table 2. All the samples were taken from thin blue shales affected by a strong schistosity.

The thermal alteration is particularly intense, requiring particular laboratory processing. Initially, classic palynological techniques were used (Streel 1965) to extract the organic matter from the shales. To clarify the palynomorphs, the attack residue was reoxydized, using a mixture of HNO_3 63% and $KClO_3$, for times ranging from less than 2 hours for the youngest samples to more than 16 hours for the oldest samples. The different approximate reoxydation times are given in Fig. 1. The best results were obtained using HNO_3 63% for long reoxydation times and fuming HNO_3 99% for shorter times.

All the samples contain organic matter except for N° 27 - "E2" shales from Dasburg in the Wiltz Synclinorium. The samples from pre-"E2" layers contain organic matter which is generally less well preserved than in samples from "E2" and "E3". The organic matter is frequently fragmented by pyrite and other physico-chemical alterations. For each sample, organic matter preservation was estimated on a scale of five levels ranging from very poorly preserved to very well preserved (Table 2).

Table 2. Preparation and content of the samples.

Number	Topo-Graphical Map	Lithostrati-Graphy	Tectonic Units	Spores Abundance	Acritarches Abundance	Phytodebris Abundance	Preservation States	Reoxydation Times
1	Esch/Sûre	Sg3	Wiltz Syncl.	fairly rich	very rare	very rich	very bad	>16h
2	Esch/Sûre	Sg3	Wiltz Syncl.	fairly rich	very rare	very rich	very bad	>16h
3	Esch/Sûre	Sg3	Wiltz Syncl.	fairly rich	_	very rich	very bad	>16h
4	Esch/Sûre	E1a	Wiltz Syncl.	fairly rich	very rare	very rich	very bad	>16h
5	Esch/Sûre	Sg3	Wiltz Syncl.	fairly rich	very rare	very rich	very bad	>16h
6	Esch/Sûre	E1a	Wiltz Syncl.	very rare	_	very rich	very bad	>16h
7	Wiltz	E3	Wiltz Syncl.	very rare	very rare	very rich	very bad	<2h
8	Wiltz	E2	Wiltz Syncl.	very rare	_	very rich	fair	<2h
9	Wiltz	E3q	Wiltz Syncl.	rare	_	very rich	good	<2h
10	Wiltz	E2	Wiltz Syncl.	rich	_	very rich	good	8-12h
11	Wiltz	E1b	Wiltz Syncl.	rare	very rare	little rich	good	<2h
12	Wiltz	E2	Wiltz Syncl.	rare	_	very rich	good	<2h
13	Wiltz	E1a	Wiltz Syncl.	very rare	_	rich	very bad	8-12h
14	Wiltz	E1a	Wiltz Syncl.	rare	very rare	very rich	bad	8-12h
15	Wiltz	Sg3	Wiltz Syncl.	very rare	_	very rich	very bad	>16h
16	Wiltz	Sg3	Wiltz Syncl.	very rare	_	very rich	very bad	>16h
17	Martelange	Sg3a	Givonne Anticl.	very rare	_	very rich	very bad	8-12h
18	Martelange	Sg3a	Givonne Anticl.	very rare	_	very rich	very bad	>16h
19	Martelange	Sg2 or Sg3a	Givonne Anticl.	very rare	_	very rich	very bad	>16h
20	Martelange	Sg3	Givonne Anticl.	rare	very rare	very rich	bad	>16h
21	Martelange	Sg3	Givonne Anticl.	rare	very rare	very rich	bad	>16h
22	Martelange	Sg3	Givonne Anticl.	very rare	_	very rich	very bad	>16h
23	Martelange	Sg3	Givonne Anticl.	very rare	_	very rich	very bad	>16h
24	Martelange	Sg3a	Givonne Anticl.	very rare	_	very rich	very bad	>16h
25	Martelange	Sg2	Givonne Anticl.	rare	very rare	little rich	bad	>16h
26	Dasburg	E3q	Wiltz Syncl.	very rich	_	very rich	very good	<2h
27	Dasburg	E2	Wiltz Syncl.	_	_	_	_	<2h
28	Dasburg	E2	Wiltz Syncl.	very rare	_	very rich	good	<2h
29	Heinerscheid	E1b	Wiltz Syncl.	_	_	poor	fair	8-12h
30	Heinerscheid	E1b	Wiltz Syncl.	very rare	_	poor	fair	8-12h
31	Clervaux	E1a	Bastogne Anticl.	little rich	very rare	very rich	bad	>16h
32	Clervaux	E1a	Bastogne Anticl.	rare	very rare	very rich	bad	>16h
33	Clervaux	Sg3 or E1a	Bastogne Anticl.	little rich	very rare	very rich	bad	>16h
34	Clervaux	Sg3	Bastogne Anticl.	rare	_	very rich	bad	>16h
35	Clervaux	Sg3	Bastogne Anticl.	rare	_	very rich	bad	>12h
36	Clervaux	Sg3	Bastogne Anticl.	rare	_	very rich	bad	>16h
37	Vianden	E1a	Givonne Anticl.	rare	very rare	very rich	bad	8-12h
38	Vianden	E1a	Givonne Anticl.	rare	_	very rich	bad	8-12h
39	Vianden	Sg3	Givonne Anticl.	fairly rich	very rare	very rich	bad	>16h
40	Vianden	Sg3	Givonne Anticl.	fairly rich	very rare	very rich	bad	>16h

4. Findings

4.1. Miospores

This first study only considers stratigraphically significant miospores. 28 species were identified. Many other ubiquist species were not taken into account because of their lack of stratigraphic significance. This is the case for most species of *Apiculiretusispora* and *Retusotriletes.*

The following species were identified:

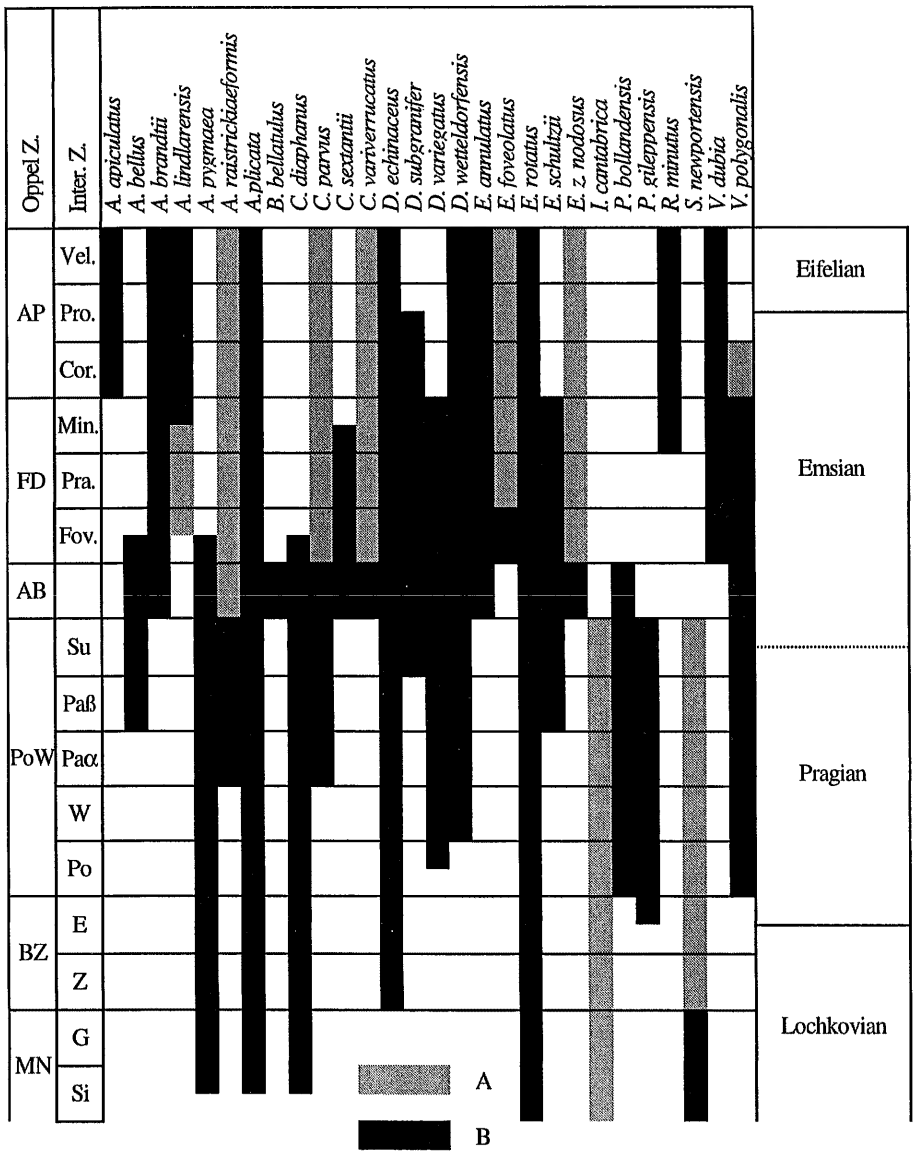
Acinosporites apiculatus (Streel) Streel, 1967
Acinosporites bellus (Arkhangelskaya) Steemans, 1989
Acinosporites lindlarensis Riegel, 1968
Apiculiretusispora brandtii Streel, 1964
Apiculiretusispora plicata (Allen) Streel, 1967
Apiculiretusispora pygmaea McGregor, 1973
Anapiculiretusispora raistrickiaeformis Streel et al., 1981
Brochotriletes bellatulus Steemans, 1989
Cirratriradites diaphanus Steemans, 1989
Camarozonotriletes parvus Owens, 1971
Camarozonotriletes sextantii McGregor & Camfield, 1976
Dibolisporites echinaceus (Eisenack) Richardson 1965 emend. McGregor 1973
Dibolisporites variegatus McGregor, 1973
Dibolisporites wetteldorfensis Lanninger, 1968
Dictyotriletes subgranifer McGregor, 1973
Emphanisporites annulatus McGregor, 1961
Emphanisporites foveolatus Schultz, 1968
Emphanisporites rotatus McGregor, 1961
Emphanisporites schultzii McGregor, 1973
Emphanisporites zavallatus Richardson et al., 1982 var. *nodosus* Steemans, 1989
Iberoespora cantabrica Cramer & Diez, 1975
Perotrilites bollandensis Steemans, 1989
Perotrilites gillepensis Steemans 1989
Rhabdosporites minutus Tiwari & Schaarschmidt, 1975
Streelispora newportensis Richardson & Lister, 1969
Verruciretusispora dubia (Eisenack) Richardson & Rasul, 1978
Verrucosisporites polygonalis Lanninger, 1968

All these species are typical of the Lower Devonian and more precisely of layers ranging from the Pragian to the Emsian. Only two species, *S. newportensis* and *I. cantabrica*, are characteristic of the Lochkovian. These are probably reworked.

Table 3 gives the stratigraphic extensions of the species on which the biostratigraphical results below are based. The data is based on works published by Riegel (1973), Schultz (1968), Lanninger (1968), McGregor (1973), Turnau (1986), Steemans (1989), Richardson & McGregor (1986). The biostratigraphical and chronostratigraphical scales used are published by Steemans 1989, Streel et al. 1987 and in-press.

The age of the samples was determined not only on the basis of the association of species observed, but also considering the absence of other species which would be expected in younger biozones. The extinction of species is also used to date the samples, though this criterion is somewhat imprecise. The criteria used for dating were selected because the samples come from different outcrops, and were not sufficiently close to each other. Therefore, it was not possible to attribute all the samples to specific biozones.

Table 3. Biostratigraphic range of the identified species. A: uncertain stratigraphic range. B: approximate stratigraphic position.



The miospore associations of each samples are given in Table 4. In fifteen samples, mainly from "Sg3a" and "E1b" layers, the miospores are too scarce or too poorly preserved to enable dating. Only three samples were precisely dated. The 22 other samples are attributed to a range of two or more biozones.

Table 4. Determined miospores in the samples.

SAMPLES	LITHOSTRATIGRAPHY	*A. apiculatus*	*A. bellus*	*A. brandtii*	*A. lindlarensis*	*A. plicata*	*A. pygmaea*	*A. raistrickiaeformis*	*B. bellatulus*	*C. diaphanus*	*C. pravus*	*C. sextantii*	*C. variverrucatus*	*D. echinaceus*	*D. subgranifer*	*D. variegatus*	*D. wetteldorfensis*	*E. annulatus*	*E. foveolatus*	*E. rotatus*	*E. schultzii*	*E. zavallatus var. nodosus*	*I. guzmanii*
25	Sg2					X	X			X							X			X			
19	Sg2/Sg3a										X												
17	Sg3a																						
18	Sg3a																						
24	Sg3a																						
1	Sg3					X	X				X						X			X			
2	Sg3										X						X						
3	Sg3					X					X						X			X			
5	Sg3						X				X						X			X			
15	Sg3																						
16	Sg3																						
20	Sg3					X	X				X						X						
21	Sg3					X	X				X						X			X			
22	Sg3																						
23	Sg3																						
34	Sg3						X				X						X						
35	Sg3					X	X				X						X			X	X		
36	Sg3					X	X			X	X						X			X			
39	Sg3						X			X	X			X			X			X			
40	Sg3						X			X	X						X			X			X
4	E1a		X			X	X				X						X			X			
6	E1a																						
13	E1a																						
14	E1a		X					X			X			X		X				X			
31	E1a						X				X			X			X			X	X	X	
32	E1a						X				X						X						
33	E1a						X				X						X						
37	E1a					X					X						X						
38	E1a					X			X		X			X			X						
11	E1b				X	X									X		X	X		X			
29	E1b																						
30	E1b																						
8	E2					X																	
10	E2				X					X										X		X	
12	E2	X						X					X							X			
27	E2																						
28	E2	X																					
9	E3q	X												X				X	X	X			
26	E3q	X		X	X							X		X	X		X			X			
7	E3																						

Table 4 (continued)

SAMPLES	LITHOSTRATIGRAPHY	*P. bollandensis*	*P. gileppensis*	*R.minutus*	*S. newportensis*	*V. dubia*	*V. polygonalis*	*C. cristatus*	*Laevitubulus sp.*	*L. crassus*	*L. frondifera*	*L. tenuis*	*Porcatitubulus sp.*	*P. annulatus*	*P. spiralis*	*Acanthodiacrodium sp.*	*Cymbosphaeridium sp.*	*Peteinosphaeridium sp.*	*Prototaxites sp.*	*Stelliferidium sp.*	*S. striatulum*	*V. trispinosum*
25	Sg2				X				X				X									
19	Sg2/Sg3a																					
17	Sg3a																					
18	Sg3a																					
24	Sg3a																					
1	Sg3	X								X		X										
2	Sg3							X		X		X	X									
3	Sg3						X	X		X		X	X						X			
5	Sg3							X		X		X	X									
15	Sg3																					
16	Sg3																					
20	Sg3									X		X		X								
21	Sg3						X			X		X		X								
22	Sg3																					
23	Sg3																					
34	Sg3								X				X									
35	Sg3								X				X									
36	Sg3								X				X									
39	Sg3	X							X				X							X		
40	Sg3	X							X				X				?			X		
4	E1a	X	X							X	X	X										
6	E1a								X													
13	E1a								X													
14	E1a							X		X		X							X			
31	E1a						X		X				X							X		
32	E1a				X				X				X									
33	E1a						X		X				X							X		
37	E1a								X				X			X						
38	E1a								X				X									
11	E1b			X			X			X		X	X					X			?	?
29	E1b																					
30	E1b																					
8	E2								X													
10	E2					X				X		X										
12	E2			X		X	X		X													
27	E2																					
28	E2																					
9	E3q			X						X		X		X	X							
26	E3q			X			X	X		X		X		X	X							
7	E3																					

Table 5 gives the position of the samples on the biostratigraphical scale.

Sample 25 was collected from the oldest layers, i.e. "Sg2" in lithostratigraphic terms. The presence of *D. wetteldorfensis* indicates that this sample is not older than the W Interval Biozone. Among the other species observed, *C. diaphanus*, disappearing in the earliest FD Biozone, is the species with the oldest extinction point. Therefore, sample N° 25 was attributed to a zone ranging from the W Biozone to the earliest FD biozone. But in view of the absence of *C. parvus*, which is the index species of the Pa Interval Biozone overlying the W biozone and is abundant in all the "Sg3" samples, one can deduce that it comes from the W Biozone.

Since all the "Sg3" samples contain *C. parvus*, it is at least possible to attribute these levels to the Pa Biozone. Sample 3 is not older than the Paß subbiozone because it contains large *Acinosporites* not observed below this biozone (Steemans 1989). *P. bollandensis*, observed in samples 39 and 40, is only known in the biozones Su and AB (Steemans 1989). No Sg3 samples are younger than the earliest FD Biozone because of the presence of *C. diaphanus* in sample 36, and *A. pygmaea* in samples 1, 2, 3, 20, 21, 33, 34 and 35.

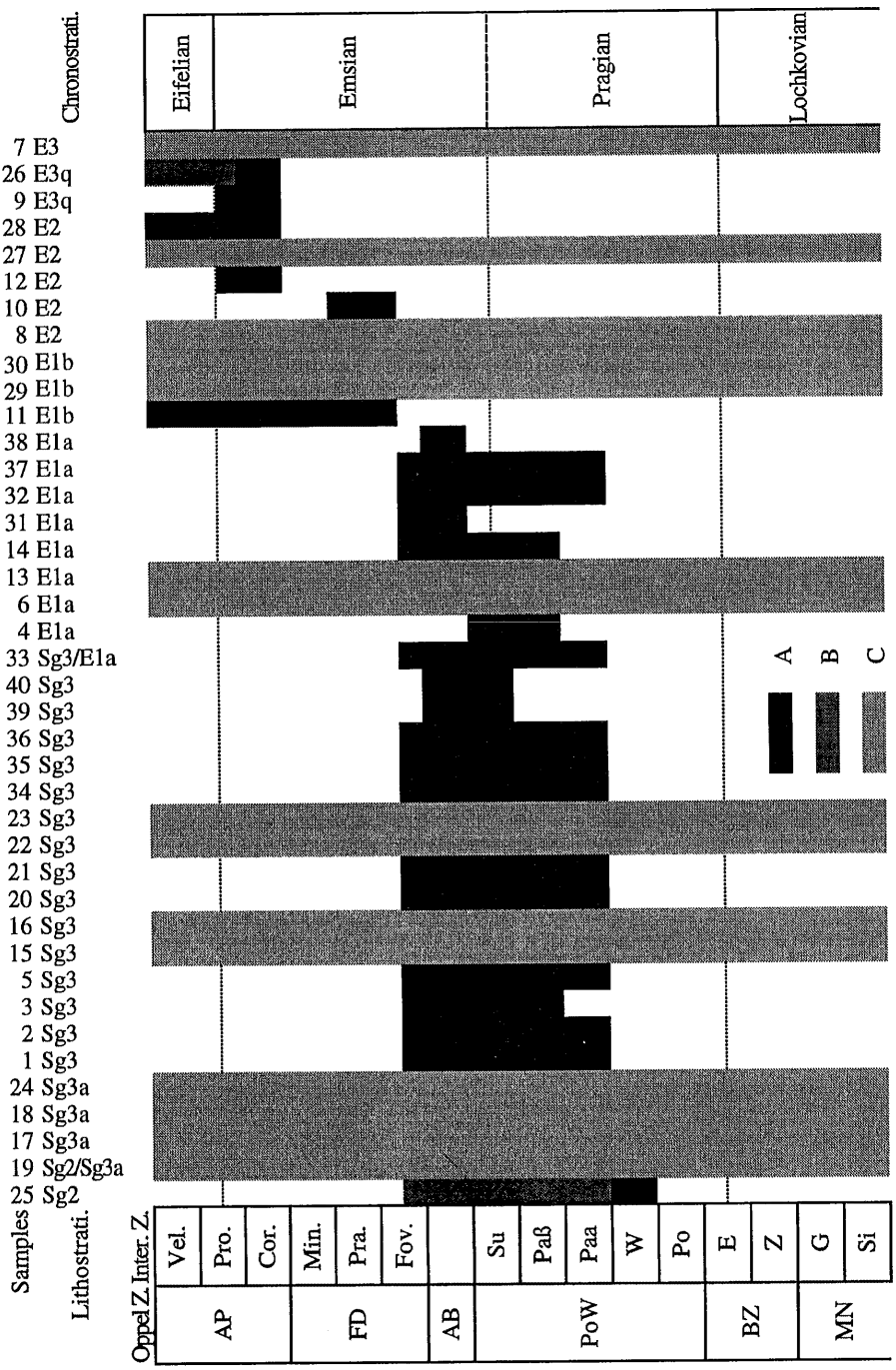
The biostratigraphical results for the samples taken from "E1a" layers are as follows. The presence of *C. parvus* and *A. pygmaea* indicates that samples 31 and 32 belong to biostratigraphic levels ranging from the Pa to the earliest FD Biozones. *A. bellus* has a stratigraphic extension ranging from the Paß to the earliest FD Biozones. Samples 4 and 14 therefore come from the latter. As *P. gillepensis* is not observed above the Su Biozone, sample 4 can only belong to either the Paß or the Su Biozone, but the stratigraphic extension of this species is not well known. *Emphanisporites zavallatus* var. *nodosus* appears in the AB Biozone and *A. pygmaea* disappears in the earliest FD Biozone, so sample 31 comes from this time frame. Sample 38 belongs to the AB Biozone because *B. bellatulus*, observed in that sample, is only known in that biozone.

Only one sample, N° 11 from "E1b" layers, contains miospores. The oldest biostratigraphical level to which this sample may be attributed is within the FD Biozone because of the presence of *A. lindlarensis*. The youngest biostratigraphical level is determined by *V. polygonalis* as it disappears at the FD/AP boundary Biozone. But this species is also found in samples 12 and 26, which are not older than the AP Biozone (see below). One must therefore deduce that *V. polygonalis* disappears in the early AP Biozone.

It was possible to date three samples from the "E2" layers. The oldest biostratigraphical level, attributed to sample 10, was within the FD Biozone because of the presence of *A. lindlarensis*. *C. diaphanus* disappears in the same biozone. Therefore sample 10 belongs to the FD Biozone. Sample 28 belongs at least to the AP Biozone since *A. apiculatus* was observed. This species is also present in sample 12 together with *V. polygonalis*. Therefore, sample 12 comes from the early AP Biozone.

Samples 9 and 26, from "E3q" layers owing to the presence of *A. apiculatus*, belong to the AP Biozone. Sample 26 also contains *V. polygonalis* and therefore belongs to the early AP Biozone. The youngest age limit of sample 9 is indicated by *E. foveolatus* which disappears in the Pro. Biozone.

Table 5. Biostratigraphical position of the samples. A: stratigraphic position of samples. B: uncertain stratigraphic position. C: unknown statigraphic position.



The Lochkovian/Pragian boundary is located in the E Interval Biozone, the Pragian/Emsian boundary in the Su Interval Biozone and the Emsian/Eifelian boundary in the Pro. Interval Biozone. On the basis of the biostratigraphic attributions, sample 25 is Pragian. All the samples from "Sg3" layers, together with samples 4, 14, 32 and 37 from "E1a" layers, are either late Pragian or early Emsian. Samples 31 and 38 from "E1a" layers are early Emsian. Samples 11 from "E1b" layers and 10 from the base of the "E2" layers are middle Emsian. Samples 12 from the upper part of the "E2" layers and 26 from the lower part of the "E3q" layers are late Emsian. Samples 28 from "E2" layers and 9 from "E3q" layers are either late Emsian or early Eifelian. These results are consistent with the lithostratigraphic succession.

4.2. Acritarchs

Very few acritarchs were observed in the slides (Table 2). Among them, *Polygonium* sp. and *?Veryachium trispinosum* are ubiquitous. On the contrary, *Cymbosphaeridium* sp. is reworked from Silurian or Lochkovian layers and *Acanthodiacrodium* sp., *Peteinosphaeridium* sp., *Stellisferidium* sp. and *S. striatulum* are reworked from Cambro-Ordovician layers. These reworking phenomena are frequently observed in the Lower Devonian of the Ardenno-Rhenan Basin as demonstrated in Belgium and Germany (Steemans 1989, Vanguestaine 1979).

4.3. Phytodebris

Among the abundant organic matter much phytodebris was recognized, but of no biostratigraphic interest. The species recognized are *Constrictubulus cristatus*, *Laevitubulus crassus*, *L. frondifera*, *L. tenuis*, *Porcatitubulus annulatus* and *P. spiralis.*

4.4. Paleogeography

All the organic matter found in the samples is of continental origin. Acritarchs are very rare, only 20 specimens in the 40 samples. In addition these were probably all reworked and have to be considered as continental sedimentary particles. Therefore, the depositional environment from which the samples were taken appears to be strongly influenced by continental influx. These layers are either continental or nearshore marine. In this last case, one must deduce that the sedimentary load and the influx of fresh water from the continent were so significant that the paleo-ecosystem was unsuited to the survival of marine palynomorphs.

4.5. The Thermal Alteration Index (TAI)

One way of estimating the TAI value very approximately is based on the reoxydation time needed to clear the organic wall of the palynomorphs. The more thermally altered, the longer the reoxydation time. The reoxydation times are shown in Table 2. All the "Sg2" and "Sg3" samples, but one, had reoxydation times longer than 16 hours. The "E1a" samples were reoxydized in times ranging from 8 to 12 hours (but in some instances longer than 16 hours). The "E1b" samples were reoxydized in times ranging from 8 to 12 hours (but in some instances shorter than 2H). The "E2" and "E3" samples were reoxydized in less than 2 hours.

The reoxydation isochrones (Fig. 1) are parallel with the boundary between the different formations as drawn on the geological map, perfectly centred on the Wiltz

synclinorium, where the youngest layers are to be found. On the basis of these findings, the thermal anomaly is not associated with a specific geographic area but only with the age of the sample. However, the degree of coalification differs considerably between samples from the "Sg3-E1" layers and those from the "E2-E3" layers. This cannot have been caused by burying alone. This finding, also observed in Belgium, north of La Roche (Steemans, unpublished), suggests that an early thermal phenomenon affected the "Sg3" and "E1" layers from these regions before the "E3" deposits. This hypothesis has to be confirmed by more accurate methods (PR %).

5. Conclusions

In spite of strong thermal alteration of the palynomorphs, it has been possible to obtain biostratigraphic results on 60 % of the samples. These results confirm the stratigraphic succession of the sampled formations. However, "E2" and "E3q" appear to be of the same age.

The Lochkovian/Pragian boundary is located in the "Sg3" layers. The Eifelian base is probably not reached by the "E3" layers studied here, although they are very close to it.

The palynofacies corresponds to a continental paleo-environment. A nearshore deposit can only be envisaged if we accept that the paleo-ecological conditions prevented the growth of a marine microflora and fauna.

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