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Paleoecology of the Springfield Coal Member (Desmoinesian, Illinois Basin) near the Leslie Cemetery paleochannel, southwestern Indiana

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Abstract

The Springfield Coal Member (Carbondale Group, Petersburg Formation of Indiana) is split locally in Warrick and Gibson Counties, Indiana, by clastic rocks of the Folsomville Member (Carbondale Group, Petersburg Formation) that represent the Leslie Cemetery paleochannel, part of a large, interconnected paleochannel system in the Springfield coal bed. This study incorporated analysis of miospore and megaspore assemblages, coal petrography, plant compression fossils and conodonts from the coal and clastic split to document changes in the swamp and its vegetation in response to the activity of the Leslie Cemetery paleochannel. Palynological and petrographic data indicate that environmental conditions and vegetation in the lower bench of coal near the Leslie Cemetery paleochannel were similar to those found in profiles through the coal bed at sites near the larger, more extensive Galatia paleochannel. Miospore floras of the high-vitrinite, lower bench of coal were dominated by tree-fern miospores, with those of lycopsids ranking second in abundance; megaspore assemblages were dominated by lycopsid megaspores. Near the contact between the lower bench of coal and clastic split, medullosan prepollen increases in abundance and fusain bands are more common, which may indicate the occurrence of fire, either within or outside the swamp. Vegetation in the Folsomville Member and upper bench of coal differ markedly from that of the lower bench of coal. Plant megafossils from the Folsomville Member indicate dominance by pteridosperms and/or lycopsids and Folsomville Member miospore assemblages are dominated by lycopsid miospores most typically found in mudstones, including *Lycospora torquifer* and higher than normal abun-

dances of *Granasporites medius*. In the transition from clastic rocks of the Folsomville Member to the upper bench of coal, miospores of 'ecotonal' lycopsids (*Paralycopodites*) reach their peak abundance, pteridosperms dominate megafossil assemblages and inertinite levels are relatively high. At higher levels of the upper bench of coal, vitrinite levels are higher and miospore assemblages are dominated by lycopsid miospores typical of coal swamps (*Lycospora granulata*, *L. pusilla*). The presence of conodonts in coalballs in the upper bench of coal and spirorbid worms in the split indicate that the paleoswamp may have received some marine or brackish water influence. Higher than normal salinity levels may explain the vegetational changes observed in the upper bench of coal near the Leslie Cemetery paleochannel.

1. Introduction

The presence of channel systems within peat-forming mires inherently affects the biotic component of swamps as well as the physical characteristics of the peat itself. Vegetation proximate to channels typically differs in composition from that of more distal areas as a consequence of clastic influx into the peat (Morley, 1981; Eble, 1990; Calder, 1993). The preservation of peat as coal allows study of temporal and spatial changes associated with such channels, particularly changes in peat thickness, the composition of plant communities and petrographic and chemical changes in the peat. Such changes have been noted in numerous coal beds, including the Desmoinesian Springfield Coal Member (Carbondale Group, Petersburg Formation of Indiana) in the Illinois Basin, which contains an interconnected channel complex that can be traced in the subsurface over several hundred kilometers. The Springfield coal bed provides an excellent opportunity for a detailed study of the effect of paleochannels on various aspects of the adjacent coal.

Previous research has noted striking changes in coal petrography, clay and sulfur content, and paleobotanical composition of Middle Pennsylvanian coal beds near paleochannel systems of the Illinois Basin (Ward, 1977; Harvey and Dillon, 1985; Phillips et al., 1985; DiMichele and Phillips, 1988). Typically, coal adjacent to paleochannels is thicker (Ward, 1977; Guion, 1987), has a lower sulfur content (<2.5%) and has higher than average ratios of vitrinite to inertinite (V/I) (Harvey and Dillon, 1985). Clay mineral suites from coal near paleochannels are more similar to those of extrabasinal clastic strata than are those from elsewhere in the coal (Ward, 1977).

The relative abundance of major plant groups, represented by both megafossils

Fig. 1. Map showing extent of the Springfield Coal Member (Petersburg Formation) in southwestern Indiana and part of western Kentucky and location of sample sites in relation to channels in the coal. Sites marked with an asterisk were studied palynologically and petrographically. Sites marked with dots were studied petrographically only. Sites marked with a circle were studied palynologically only; of these, only miospores were studied from site OBC, and only megaspores were studied from site W7.

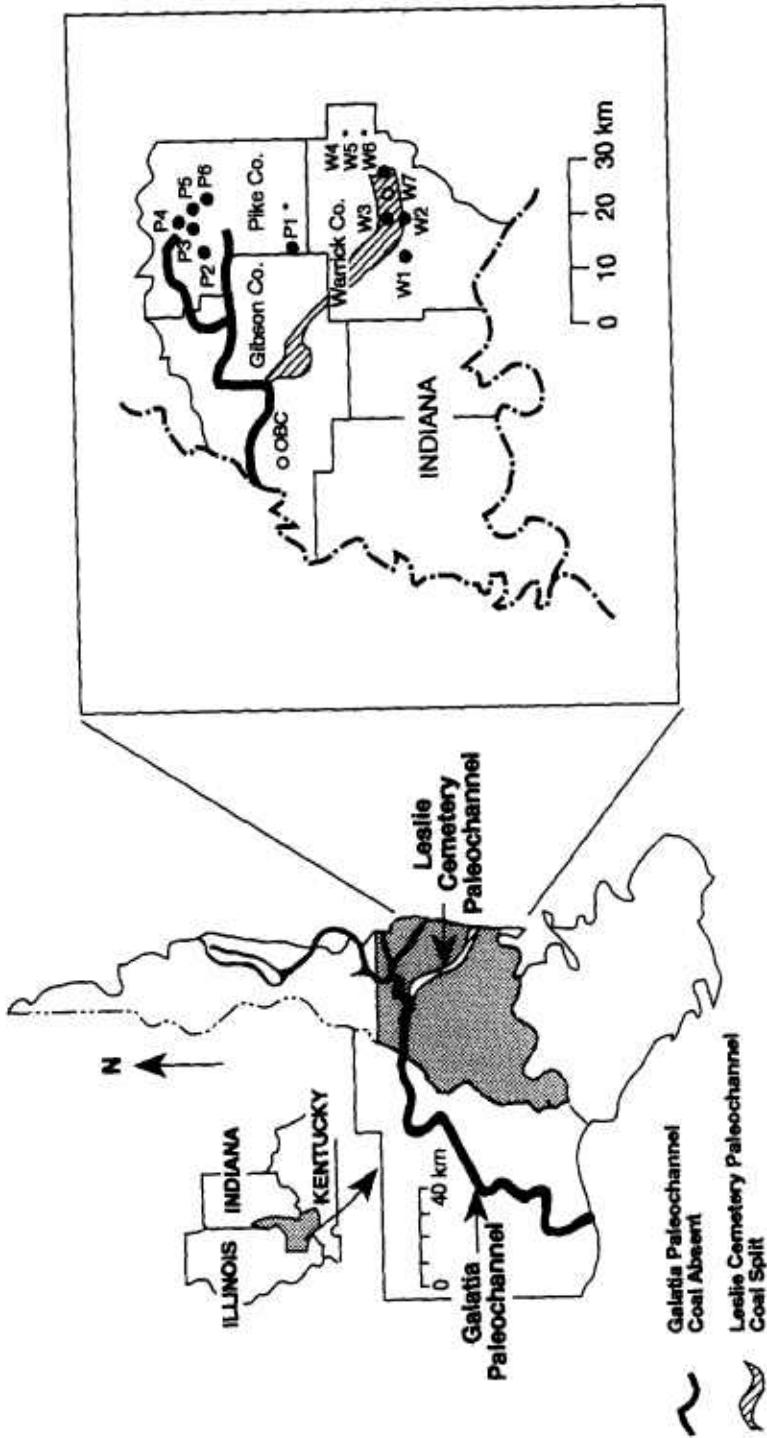


Fig. 1.

and microfossils, also changes in proximity to paleochannels. In Middle Pennsylvanian coal beds, such as the Springfield and Herrin Coal Members (Petersburg and Dugger Formations, Indiana, respectively) of the Illinois Basin, studies of coal-ball floras show that the greatest abundances of the arborescent lycopsids *Lepidophloios* and *Lepidodendron hickii* occur near paleochannels (DiMichele et al., 1985; DiMichele and Phillips, 1988). Similarly, plants more characteristic of clastic swamps and flood basins than mires, such as *Sigillaria* and medullosan pteridosperms (Eggert et al., 1983), tend to be more abundant near paleochannels. The palynological record reveals similar patterns. *Lycospora*, the microspore of two arborescent lycopsid genera (*Lepidophloios* and *Lepidodendron*) is typically more abundant near paleochannels than elsewhere in the coal (Phillips et al., 1985) and changes in tree-fern species composition, particularly the decrease in abundance of *Thymospora pseudothiessenii*, near paleochannels have been noted (Mahaffy, 1988; Willard, 1993).

In the Springfield coal bed, two parts of an interconnected paleochannel system have been mapped, the Galatia paleochannel in Indiana and southern Illinois (Hopkins, 1968; Eggert and Adams, 1984) and the Leslie Cemetery paleochannel in southwestern Indiana (Eggert, 1982) (Fig. 1). The Leslie Cemetery paleochannel shifted across the Springfield peat swamp and interrupted peat accumulation, which resumed after the channel was abandoned. As a result, the coal near the paleochannel typically is split into two benches by a thick clastic wedge. This geometry makes it possible to study changes in the peat vertically and to assess changes in various coal characteristics that are associated with activity of the contemporaneous channel system (Eggert et al., 1983).

This study of the Springfield coal bed was designed to document changes in the parent mire vegetation and the derived coal in relation to the activity of the Leslie Cemetery paleochannel. Using palynological and petrographic data, we studied the history of the peat and vegetation prior to, during and after the deposition of overbank materials that temporarily caused cessation of peat accumulation. We also studied the vegetation that colonized the muds of the split using plant compression fossils. Conodonts from the upper bench of coal provide information on the source of water supplying the peat that formed the upper bench. Petrographic and palynological patterns from sites in the Springfield coal bed near the Leslie Cemetery paleochannel were also compared to those from the Galatia paleochannel 45–50 km to the north (Fig. 1).

2. Depositional setting and coal characteristics

The presence of paleochannels in the Springfield coal bed of the Illinois Basin has been documented extensively, revealing an interconnected channel complex that extends over about 4800 km² in the eastern part of the Illinois Basin (Fig. 1) (Hopkins, 1968; Wanless et al., 1969, 1970; Eggert and Adams, 1984). Linear sand bodies representing the Galatia paleochannel have been mapped by Trescott (1964) and Wanless et al. (1969, 1970). The Galatia paleochannel is the major

paleochannel in the Springfield coal bed and it has been mapped for more than 120 km in southeastern Illinois (Hopkins, 1968).

The Leslie Cemetery paleochannel represents another part of the paleochannel system in southwestern Indiana (Burger and Weir, 1970; Eggert, 1982; Eggert and Adams, 1984). The clastic rocks of the channel were mapped by Eggert (1982) and Eggert and Adams (1984) in Warrick and Gibson Counties, Indiana, as the Folsomville Member of the Petersburg Formation. They showed that these channel deposits merge with those of the larger Galatia paleochannel near Princeton, Indiana. Rocks of the Folsomville Member reach up to about 15 m in thickness and separate the Springfield coal bed into two benches (Fig. 2). In areas with split coal, the lower bench of the Springfield coal bed ranges from about 0.6 to 1.2 m thick, and the upper bench, which ranges from a few centimeters to about 0.7 m in thickness, thins over the convex, lens-shaped Folsomville deposits (Eggert, 1984). Although the upper bench of the Springfield coal bed occasionally is only a few centimeters thick, it is continuous over the Folsomville Member, indicating that the swamp re-established itself over channel deposits once the Leslie Cemetery paleochannel was abandoned. This sequence is illustrated well in the Eby Pit (Lynnville Mine, Peabody Coal Company), where the coal is, in turn, overlain by black, organic-rich, pyritiferous shales of marine or marginal marine origin, equivalent to the Turner Mine Shale Member, Carbondale Formation of Illinois (Fig. 2).

Detrital sediments of the Folsomville Member generally coarsen toward the axis of the channel. Distally from the axis, the split consists of an organic mudstone and gray shale with abundant plant compression fossils. Toward the channel axis, the mudstones and shales grade laterally into a zone of interbedded thin sandstone and mudstone, and paleocurrent indicators suggest flow at right angles to the main channel trend. Sediments coarsen toward the channel axis, with sandstones more common than mudstones (Fig. 2). Sedimentological observation of eight sections in the Folsomville Member (Fig. 3) indicate that the sandstones do not occur within one single channel but, rather, within a channel complex with several smaller sand-filled channels cut by a large channel. These clastic deposits exhibit cut-and-fill relationships suggesting channel migration; two exposures of cross beds in this cut-and-fill facies indicate that the flow direction was to the west. Because of the nature of the open-pit high wall, detailed observation of these channels was not possible, but paleocurrent observations were consistently unimodal, with no bimodal paleocurrent directions, indicative of tidal influence, observed. The upper part of the clastic interval became finer grained and more organic-rich before passing into the coal of the upper bench. Pockets of coalballs were associated with these coaly shales at several intervals along the high wall.

The Springfield coal bed is typically more than 1.3 m thick in southwestern Indiana and Kentucky but locally may increase to more than 4 m thick near the paleochannel deposits (Smith and Stall, 1975; Eggert et al., 1983; Eggert and Wier, 1986). In the area of this study, the thickness of the upper and lower benches of the coal decreases west of sites W4–W6 and the thickness of the Folsomville Member increases. The Springfield coal bed is usually a bright banded coal with

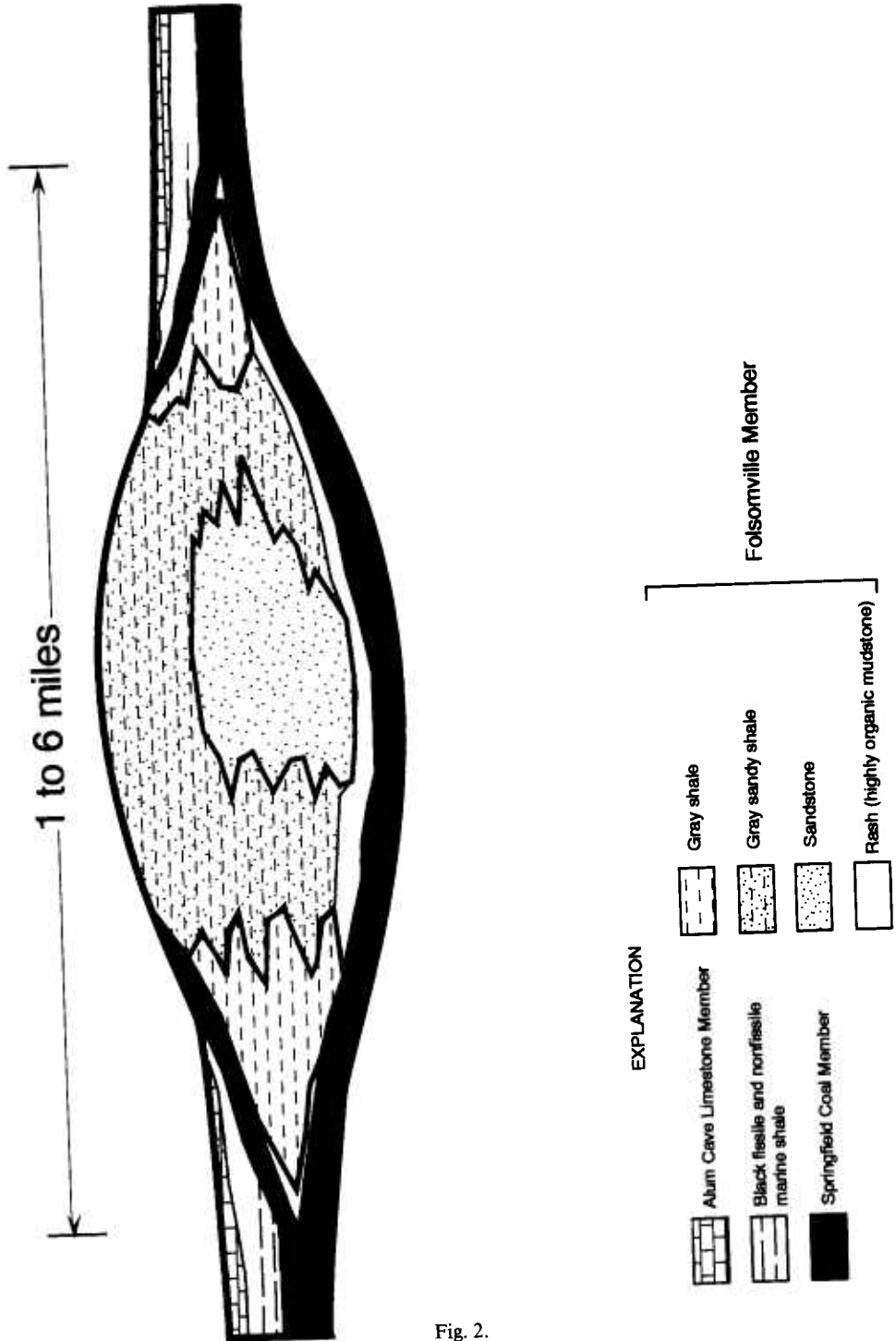


Fig. 2.

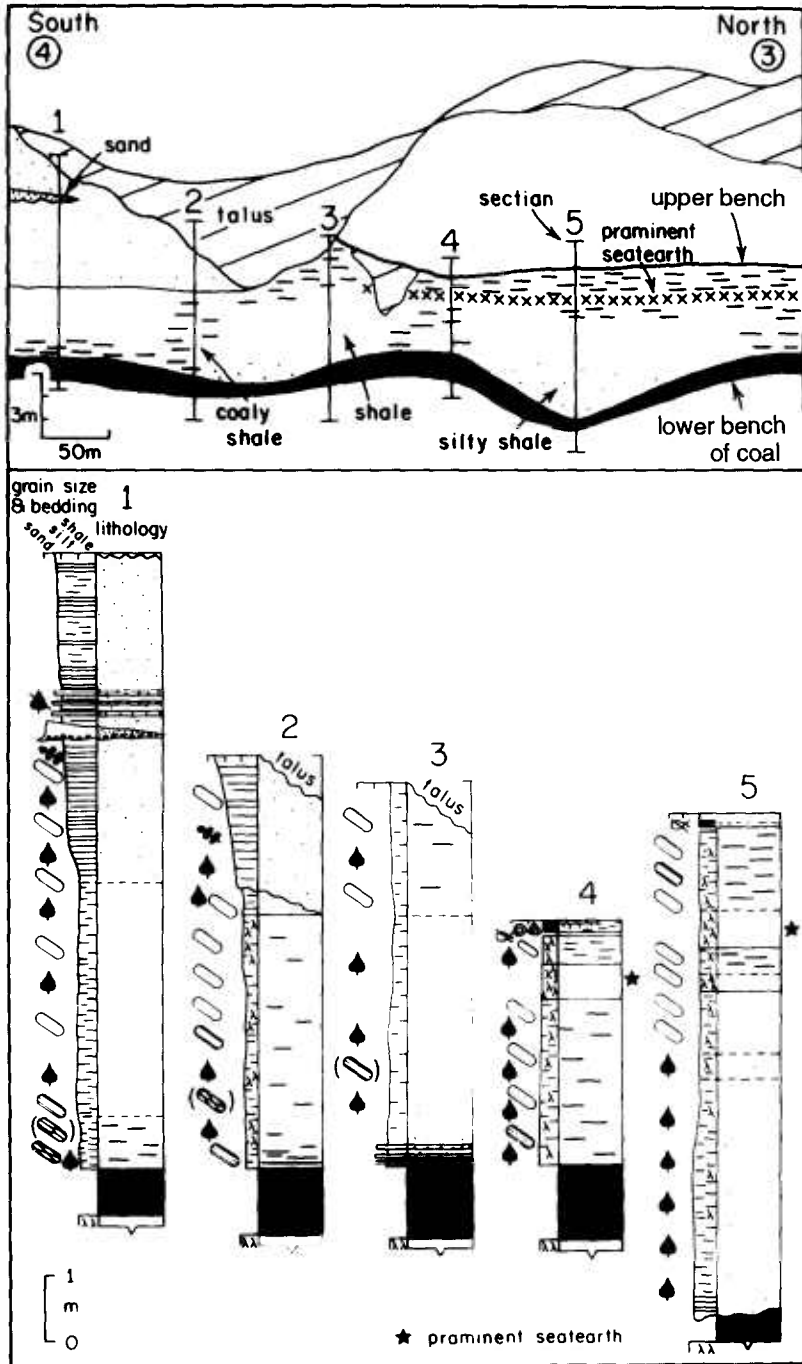
a high overall vitrinite content (>80%; Hower et al., 1990); the highest proportions of vitrinite are found in the lower half of the coal with, coal of a duller appearance in the upper half (Ault et al., 1979). However, the dull appearance of the coal results from the finer texture of the maceral assemblages in the upper half and vitrinite does not comprise less than 65% of the maceral assemblages (Hower et al., 1990).

For this study, petrographic data were derived from five profiles in the Eby Pit (W2–W6; Fig. 1). Of these, two were analyzed palynologically. In addition, several profiles collected near the Galatia paleochannel to the north were analyzed petrographically and geochemically. Petrographic seam descriptions were made in accordance with procedures modified from those outlined in Stach et al. (1982). Of the five sites sampled for coal petrography and geochemistry at the Eby Pit (Fig. 4), only samples from W3 and W5 include both the upper and lower benches of coal. Samples from sites W4 and W6 are from the upper bench and samples from site W2 are from apparently unsplit coal (Fig. 3). The lower bench of coal was present but not accessible at sites W4 and W6. Coal from all five profiles has a high vitrinite content (commonly >90%) with increases in inertinite content (up to 29%) above and below the clastic split (Table 1).

The lower bench of coal was analyzed petrographically at site W5 (samples 8344–8352) at the eastern sites; these samples also have a high vitrinite content, with the exception of the second and third samples below the mudstones of the Folsomville Member, which average about 20% inertinite (Table 1). Comparison of the petrography of samples from the upper bench of coal at sites W4–W6 shows that a relatively high inertinite lithotype occurs in the middle of the upper bench at two sites (W5 and W6). This is particularly striking in sample 8331 (site W5), which has 28.6% fusinite and semifusinite (Table 1). At site W4, the only high inertinite content is found near the base of the upper bench, where there is 10% fusinite and semifusinite (Table 1). Ash and sulfur content from the upper bench of coal at W3 are higher (30.7% and 5.5%, respectively) than in samples from the lower bench of coal (8.8–14.6% and 1.4–4.4%, respectively) (Table 1). The pattern of higher ash and sulfur content in the upper bench was also recorded by Eggert (1984), who showed the upper bench to have 13.6% ash and 4.9% sulfur, compared to lower bench values of 5.2–10.1% ash and 0.8–2.8% sulfur.

Sites W2 and W3 are located about 7.5 km west of sites W4–W6. Site W3 consists of the upper and lower benches of coal and site W2 consists of samples from the full thickness of unsplit coal. Both sites have relatively high inertinite contents but samples from site W3 have a slightly lower vitrinite content (83–90%) than samples from site W2 (92–93% vitrinite), located about 0.3 km to the south. Detectable calcite was not present in samples from either site (note the low CaO

Fig. 2. Diagrammatic cross section of Folsomville Member and upper and lower benches of the Springfield Coal Member (Petersburg Formation, southwestern Indiana) (modified from Eggert, 1984).



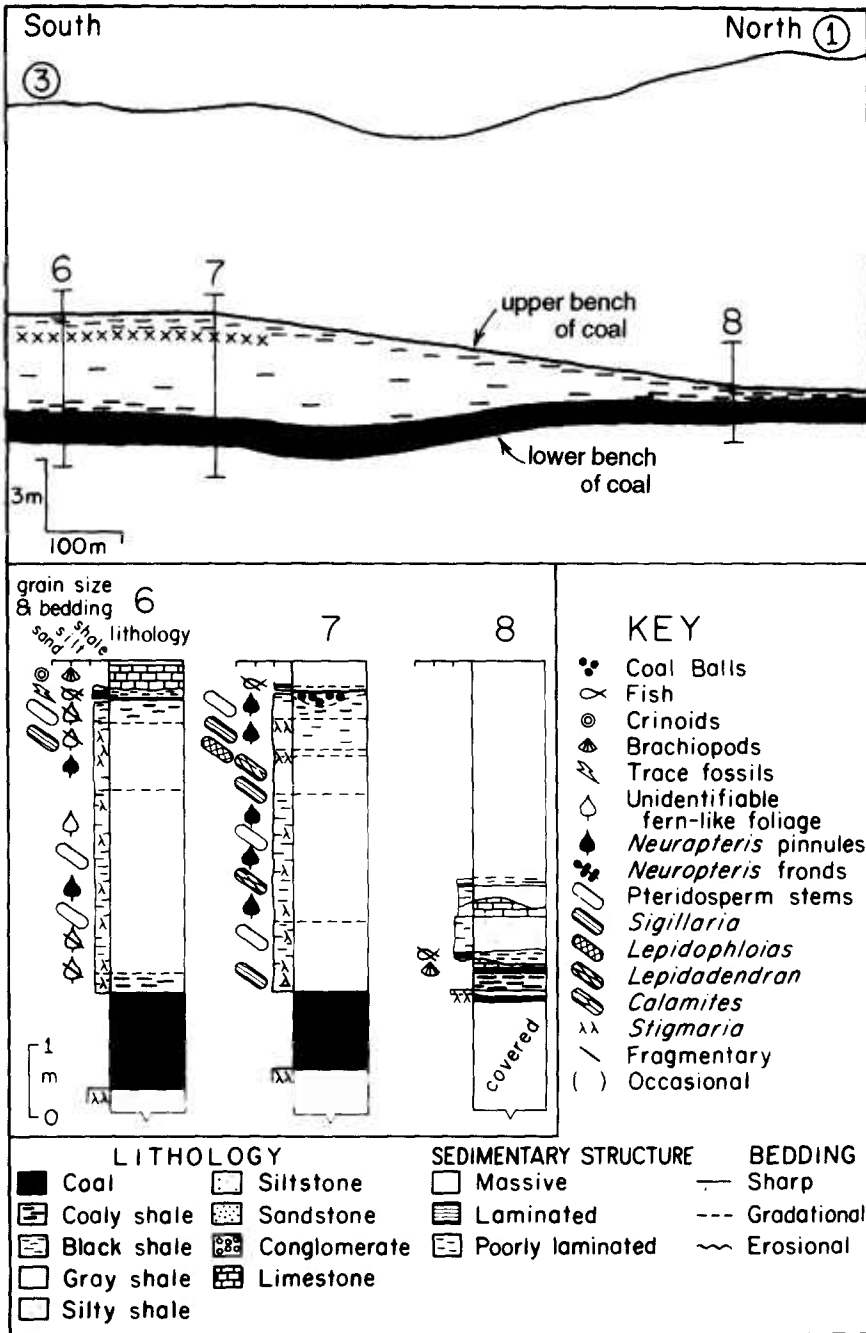


Fig. 3. Lithologic logs of eight sections through the Springfield Coal Member and Folsomville Member (Petersburg Formation) at site W7 in the Eby Pit, Lynnville Mine, Warrick County, Indiana.

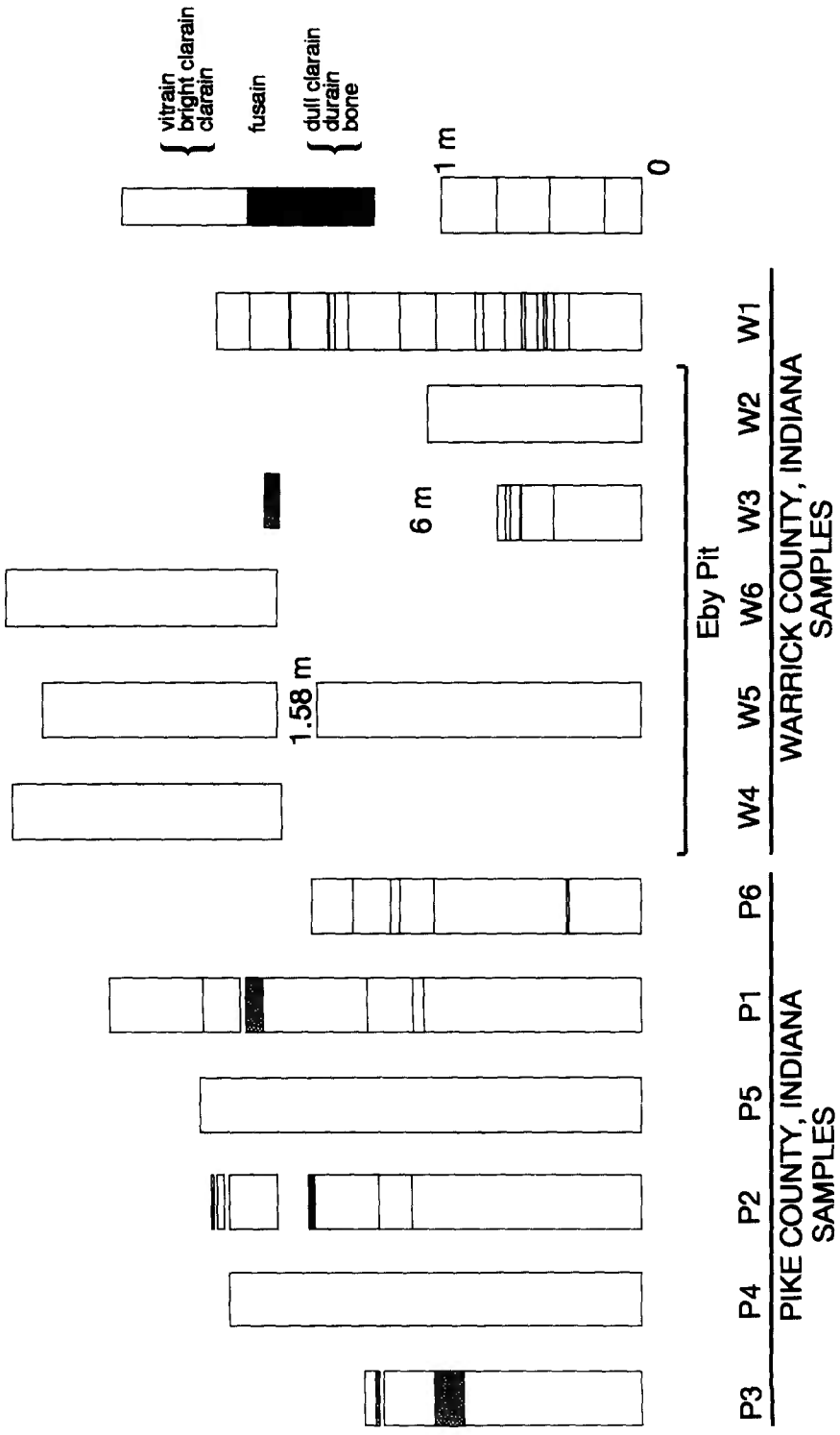


Fig. 4. Thickness of sections studied petrographically and distribution of different lithotypes within each section.

Table 1
Comparison of maceral, ash, and sulfur content for incremental samples, Springfield Coal Member

Channel	Site	KCER #	Bench	Thickness	Vit	Int	Mic	Lip	R_{\max}	Dry Ash	Dry TSulf		
Galatia	P1	8127	1/4 (T)	39.62	90.3	5.8	0.8	3.1	0.508	11.23	2.86		
		8128	2/4	48.77	81.9	14.0	0.5	3.6	0.421	6.53	3.06		
		8129	3/4	30.48	81.2	5.9	6.9	6.0	0.431	8.70	4.88		
		8130	4/4	36.58	90.5	6.7	0.9	1.9	0.428	13.10	4.20		
Galatia	P2	8284	1/5 (T)	59.99	91.6	5.4	0.1	2.9	0.434	15.19	3.68		
		8285	2/5	30.00	81.1	16.5	0.2	2.2	0.455	17.02	3.10		
		8286	3/5	46.99	82.1	14.3	0.2	3.4	0.484	11.88	4.63		
		8287	4/5	56.01	91.3	5.5	0.2	3.0	0.473	9.22	4.26		
Galatia	P3	8288	5/5	52.50	90.1	6.1	0.4	3.4	0.471	11.54	6.60		
		8131	1/5 (T)	45.72	89.2	4.8	1.0	5.0	0.518	20.33	1.59		
		8132	2/5	45.72	77.3	9.2	5.9	7.6	0.521	7.55	2.29		
		8133	3/5	18.90	90.0	5.9	0.2	3.9	0.463	5.58	1.51		
Galatia	P4	8134	4/5	48.77	90.3	4.9	2.4	2.4	0.474	5.09	1.27		
		8135	5/5	39.62	93.1	2.5	0.9	3.5	0.462	6.42	2.42		
		8302	1/4 (T)	24.89	79.4	15.0	0.3	5.3	0.576	24.37	2.61		
		8303	2/4	20.07	90.2	7.3	0.2	2.3	0.572	6.36	1.70		
Galatia	P5	8304	3/4	38.10	92.0	5.5	0.1	2.4	0.569	6.94	2.81		
		8305	4/4	44.45	80.1	13.2	0.4	6.3	0.613	7.28	2.31		
		8364	1/11 (T)	26.67									
		8365	2/11	19.99									
Galatia	P5	8366	3/11	16.00	84.5	8.4	0.0	6.5					
		8367	4/11	19.99	79.1	13.1	0.4	7.4					
		8368	5/11	19.00	80.3	9.9	0.8	9.2					
		8369	6/11	24.00	88.8	6.6	0.3	4.3					
		8370	7/11	27.99	91.6	4.0	0.0	4.4					
		8372	8/11	24.00	92.2	4.1	0.0	3.7					
		8372	9/11	40.01	92.6	3.3	0.0	4.1					
		8373	10/11	19.99	90.9	5.4	0.0	3.7					
		8374	11/11										
		Leslie Cemetery	W1	8307	1/6 (T)	33.78	92.7	3.9	1.0	2.4	0.400	12.54	4.03
				8308	2/6	17.02	87.6	7.6	1.4	3.4	0.417	11.02	4.79
8309	3/6			71.12	88.2	7.6	1.0	3.2	0.426	7.86	3.35		
8310	4/6			47.50	92.5	4.7	0.8	2.0	0.393	14.08	6.57		
8311	5/6			17.53	90.6	7.3	0.1	2.0	0.388	13.32	5.32		
8312	6/6			14.48	88.5	8.0	0.7	2.7	0.396	15.75	6.33		
Leslie Cemetery	W2	8124	1/3 (T)	33.53	94.2	1.5	0.5	3.8	6.03	1.60			
		8125	2/3	36.58	92.6	3.1	1.0	3.3	0.573	6.25	1.09		
		8126	3/3	36.58	91.8	4.9	1.1	2.2	0.655	15.69	4.54		
Leslie Cemetery	W3	8120	Top bench	10.67	82.7	3.0	5.4	8.9	0.441	30.66	5.50		
		8121	1/3 (T)	22.86	90.3	4.7	0.8	4.2	0.588	9.13	3.96		
		8122	2/3	22.86	84.9	5.5	4.4	5.2	0.645	8.81	1.36		
		8123	3/3	22.86	85.2	4.0	4.7	6.1	0.646	14.64	4.43		
Leslie Cemetery	W4	8321	1/9 (T)	10.01	95.1	2.0	0.0	2.9					
		8322	2/9	27.00	92.8	4.6	0.1	2.5					
		8323	3/9	27.00	81.9	17.3	0.0	0.8					
		8324	4/9	11.99	92.3	7.0	0.0	0.7					
		8325	5/9	10.01	93.7	5.8	0.0	0.5					
		8326	6/9	5.00	86.7	10.0	0.0	3.3					
		8327	7/9	2.54									
		8328	8/9	11.00									
		8329	9/9	19.99									

Table 1 (cont.)

Channel	Site	KCER #	Bench	Thickness	Vit	Int	Mic	Lip	R_{\max}	Dry Ash	Dry TSulf
Leslie Cemetery	W5	8330	1/23 (T)	30.00	95.2	1.8	1.9	1.1			
		8331	2/23	19.99	70.5	28.6	0.0	0.9			
		8332	3/23	13.00	93.6	5.4	0.0	1.0			
		8333	4/23	19.99							
		8334	5/23	22.00							
		8335	6/23	24.00	93.6	5.5	0.0	0.9			
		8336	7/23	23.01							
		8337	8/23	19.99							
		8338	9/23	10.01							
		8339	10/23	16.00							
		8340	11/23	19.99							
		8341	12/23	24.99							
		8342	13/23	15.01							
		8343	14/23	5.00							
		8344	15/23	11.00		89.0	5.3	0.2	5.5		
		8345	16/23	8.00		74.4	21.4	0.2	3.9		
		8346	17/23	8.00		78.3	18.7	0.0	3.4		
		8347	18/23	15.01		84.8	7.2	0.7	6.3		
		8348	19/23	16.00		93.5	4.2	0.1	2.2		
		8349	20/23	16.99		93.1	2.5	0.0	4.4		
8350	21/23	21.01		90.6	4.9	0.7	3.8				
8351	22/23	19.99		92.1	4.2	0.1	3.6				
8352	23/23	37.01		90.4	7.0	0.0	2.6				
Leslie Cemetery	W6	8353	1/11 (T)	23.01	89.0	5.2	0.0	5.8			
		8354	2/11	32.99	84.2	15.1	0.0	0.8			
		8355	3/11	23.01	89.2	6.5	0.1	4.2			
		8356	4/11	30.00							
		8357	5/11	19.99							
		8358	6/11	51.99	92.7	5.2	0.0	2.4			
		8359	7/11	50.98	84.8	11.3	0.0	3.2			
		8360	8/11	57.00	92.6	3.1	0.0	4.3			
		8361	9/11	32.00	93.1	4.3	0.0	2.6			
		8362	10/11	15.01	88.7	5.9	0.3	5.1			
		8363	11/11	82.8	9.0	0.6	8.0				

KCER# = sample numbers assigned at the Kentucky Center for Applied Energy Research.

Bench numbers followed by (T) indicate the top sample of the set.

Thicknesses are given in centimeters, and maceral, ash and sulfur contents are given in percentages.

Vit = Vitrinite, Int = Inertinite, Mic = Micrinite, Lip = Liptinite, R_{\max} = vitrinite reflectance.

Samples lacking data in one or more categories were not analyzed for those categories.

in Table 2), which, together with the absence of marcasite, is unusual compared to samples of the Springfield coal bed in Kentucky (Hower et al., 1990). These low CaO values may be indicative of lesser marine influence than for overlying sediments at the Indiana sites.

3. Biological assemblages in the Eby Pit

Samples from the Springfield coal bed and the Folsomville Member were collected for palynological, paleobotanical and conodont analysis from sites around

Table 2
Comparison of major oxide elements (% ash basis) for incremental samples, Springfield Coal Member

Channel	Site	KCER#	Bench	SO ₃	MgO	Na ₂ O	Fe ₂ O ₃	TiO ₂	SiO ₂	CaO	K ₂ O	P ₂ O ₅	Al ₂ O ₃
Galatia	P1	8127	1/4(T)	8.56	0.96	0.37	11.15	0.84	48.06	7.43	2.62	0.13	19.09
		8128	2/4	3.71	0.55	0.19	21.35	0.81	40.91	5.58	1.61	0.08	23.92
		8129	3/4	3.82	0.52	0.07	48.89	0.74	25.53	4.00	1.61	0.04	14.40
Galatia	P2	8130	4/4	13.50	0.65	0.00	25.44	0.70	31.79	10.99	1.80	0.07	13.68
		8284	1/5(T)	2.51	0.81	0.65	11.49	0.91	54.43	2.49	3.01	0.11	23.58
		8285	2/5	3.10	0.71	0.47	7.23	0.91	52.69	3.36	2.89	0.12	28.01
		8286	3/5	6.58	0.49	0.44	27.77	0.74	37.20	5.32	1.89	0.09	19.32
Galatia	P3	8287	4/5	15.29	0.56	0.44	19.54	0.76	31.21	11.72	1.82	0.09	17.63
		8288	5/5	0.86	0.54	0.48	46.90	0.70	34.00	1.10	1.57	0.12	13.21
		8131	1/5(T)	0.08	1.10	0.00	7.34	1.08	55.38	0.86	3.63	0.43	28.56
		8132	2/5	0.05	0.71	0.00	27.80	0.82	41.39	1.09	1.79	0.36	25.76
		8133	3/5	0.11	0.73	0.00	22.47	1.22	43.10	1.17	2.13	0.09	27.55
Galatia	P4	8134	4/5	0.29	0.84	0.00	10.95	1.49	51.97	1.15	2.71	0.09	28.76
		8135	5/5	0.05	0.77	0.00	26.70	1.21	44.61	1.02	2.31	0.07	21.68
		8302	1/4(T)	12.77	0.59	0.26	8.66	0.52	34.39	17.87	1.38	1.57	20.17
		8303	2/4	0.45	0.24	0.25	17.60	1.01	48.12	1.24	1.37	0.30	27.81
Leslie Cemetery	W1	8304	3/4	4.49	0.19	0.29	33.75	0.83	34.12	4.91	1.40	0.18	18.02
		8305	4/4	2.79	0.53	0.28	20.84	1.03	44.89	3.68	1.96	0.12	22.02
		8307	1/6(T)	6.18	0.90	0.74	13.86	0.87	50.72	5.40	2.77	0.09	18.18
		8308	2/6	7.97	0.59	0.52	27.30	0.74	39.70	6.08	1.48	0.06	14.48
		8309	3/6	12.94	0.46	0.71	12.61	0.62	36.78	15.14	1.46	0.21	17.70
Leslie Cemetery	W2	8310	4/6	7.03	0.48	0.52	43.35	0.63	28.57	4.93	1.36	0.09	12.39
		8311	5/6	15.98	0.80	0.52	29.76	0.51	28.17	11.42	1.19	0.29	10.56
		8312	6/6	15.77	0.67	0.45	29.34	0.54	26.93	12.58	1.51	0.60	10.87
		8124	1/3(T)	0.03	0.94	0.11	19.25	1.02	47.92	1.10	2.30	0.40	26.62
Leslie Cemetery	W3	8125	2/3	0.08	1.26	0.00	8.86	1.34	57.77	1.39	2.95	0.38	25.37
		8126	3/3	0.14	0.78	0.00	39.77	0.83	37.32	1.09	2.16	0.27	16.12
		8120	Top	0.67	1.38	0.00	21.41	0.87	44.93	0.99	3.57	0.14	25.91
		8121	1/3(T)	0.52	0.72	0.01	45.10	0.79	33.12	1.57	1.74	0.32	15.85
Leslie Cemetery	W3	8122	2/3	0.28	1.15	0.00	9.00	1.23	58.08	2.39	2.97	1.04	23.98
		8123	3/3	0.19	0.81	0.00	42.39	0.85	35.88	1.17	2.13	0.32	15.64

KCER# = sample numbers assigned at the Kentucky Center for Applied Energy Research.

Bench numbers followed by (T) indicate the top sample of the set.

Samples from sites P5 and W4–W6 were not analyzed geochemically and are not included in the table.

the Leslie Cemetery paleochannel in Warrick County, Indiana. Additional coal samples were collected for palynological analysis from sites near the Galatia paleochannel in Pike and Gibson Counties, Indiana (Fig. 1). Coal samples for miospore and petrographic analysis were collected as incremental samples from the entire thickness of the coal, with the thickness of each sample interval determined by natural breaks in the coal. Miospores (spores and pollen < 200 μm : Guennel, 1952) were analyzed from two profiles collected in the Eby Pit, one through both the lower and upper benches of coal and the mudstones of the split (site W5) and the other through the upper bench of coal only (site W6). Miospores were also quantified from a profile from site P1 in Pike County, Indiana, and a core (OBC) from Gibson County, Indiana. Megaspores were analyzed from a different profile collected in the lower bench of coal (W7, Fig. 1). Petrographic data were derived from two of the same profiles analyzed for miospores from the Eby Pit (W5, W6) and from a profile at site P1, as well as several other sites in the area (Fig. 1). Samples for miospore analysis were processed and analyzed using standard preparation techniques outlined in Kosanke (1950) and Traverse (1988). The megaspore sampling and processing procedure was that used by Scott and King (1981), where a 1 cm increment of coal was collected every 10 cm plus additional 1 cm samples where there were major macroscopic changes in the coal. Miospore slides are stored in slide collections at the Paleobotanical Research Center at the University of Illinois at Urbana-Champaign under accession numbers 21,816–21,838, 21,871–21,876 and 21,961–21,965.

The distribution of plant compression fossils in relation to facies within the Folsomville Member was documented during sedimentological study of eight sections along 2 km of high wall. These range from a section distal to the channel axis, where the two benches of coal were split by only 98 cm of fine-grained coaly mudstone, to a more central section where the split was more than 15 m thick and contained a variety of facies including gray shales and sandstones (Fig. 3).

Plant compression fossils also were collected from ten sites (Table 3) from the Folsomville Member between the lower and upper benches of the Springfield coal bed over a period of 7 yr (1980–1987). Specimens were collected in situ directly from the face of the mine highwall, with two exceptions (USNM 38370 and 38372) that were collected from stripping-spoil piles. Collections are essentially 'random' in that all identifiable specimens were kept, as were numerous marginally identifiable specimens for which microscopic examination was needed for identification; collectors did not extensively cull specimens on the outcrop. Most of the collections were from gray to buff, blocky claystones and siltstones, and three (USNM 38366, 38367, 38368) included both dark, friable, organic-rich claystones and gray to buff siltstones, which were separated in the laboratory based on field notes and distinctive lithological characteristics. This segregation raised the number of distinct 'samples' to 13 from the 10 collecting sites. These samples reside in collections of the U.S. National Museum. Conodonts were isolated from coal-balls collected from the upper bench of coal and are deposited in the Indiana Geological Survey–Indiana University repository under repository numbers 17,876–17,922.

Table 3
Collection localities for plant compression fossils from the Folsomville Member

USNM locality	Site	Lithology and position
38367A	1	Organic claystone, lower part of top bench
38367B	1	Gray mudstone below 38367A
38365	2	Gray mudstone from center of split
38366	3	Gray mudstone from center of split, heavily rooted
38369A	4	Buff claystone from center of split
38369B	4	Organic mudstone from center of split
38371	5	Gray mudstone from center of split
38368A	6	Organic claystone at top of 38368B, 38373
38368B	6	Top of sideritic gray mudstone
38373	7	Sideritic gray mudstone forming roof of lower bench
38866	8	Gray claystone, siltstone and sandstone forming roof of lower bench, heavily rooted
38370	9	Gray mudstone and sandstone from spoils
38372	10	Gray mudstone from spoils

The stratigraphic order is from top to bottom.

4. Eby Pit miospore assemblages

Site W5, at the eastern edge of the Leslie Cemetery paleochannel system (Fig. 1), was the main area for palynological and petrographic study. On a whole-bed basis, lycopsid miospores dominate the assemblage from site W5, comprising 51% of the coal palynoflora. Tree-fern miospores rank second in abundance, averaging 35%, and sphenopsid and small-fern miospores are common, comprising 9.5% and 3.5% of the assemblages, respectively (Fig. 5, Table 4). Cordaite pollen and miospores of unknown affinity are rare, comprising only 0.2% and 0.8% of the assemblages, respectively.

The most common lycopsid miospore genus in the coal bed as a whole is *Lycospora* (averaging 43.7% of the miospore assemblage), followed by *Granasporites* (2.0%) and *Crassispora* (2.0%) (see Table 5 for miospore–source plant correlations). The most common tree-fern species are *Laevigatosporites minimus* (9.3%), *L. globosus* (9.3%), *Punctatosporites minutus* (7.9%) and *Thymospora pseudothiessenii* (6.3%). Sphenopsids are represented both by *Calamospora* (4.3%) and *Vestispora* (4.4%).

Within the clastic split, lycopsid miospores are more strongly dominant than within the coal, averaging 58.8% of the assemblages (Table 4). Tree-fern miospores rank second in abundance (25.5%), followed by miospores of small ferns (8.9%), sphenopsids (5.1%), spores of unknown affinity (0.9%) and cordaite pollen (0.8%). The most common lycopsid genus is *Lycospora* (averaging 46.6% of the assemblages), followed by *Granasporites* (9.8%) and *Crassispora* (1.8%). *Granasporites* is almost five times as abundant in the split as in the coal (Table 6). Common tree-fern species are *Laevigatosporites globosus* (9.8%), *Punctatosporites minutus* (7.9%), *Laevigatosporites minimus* (2.9%) and *Thymospora*

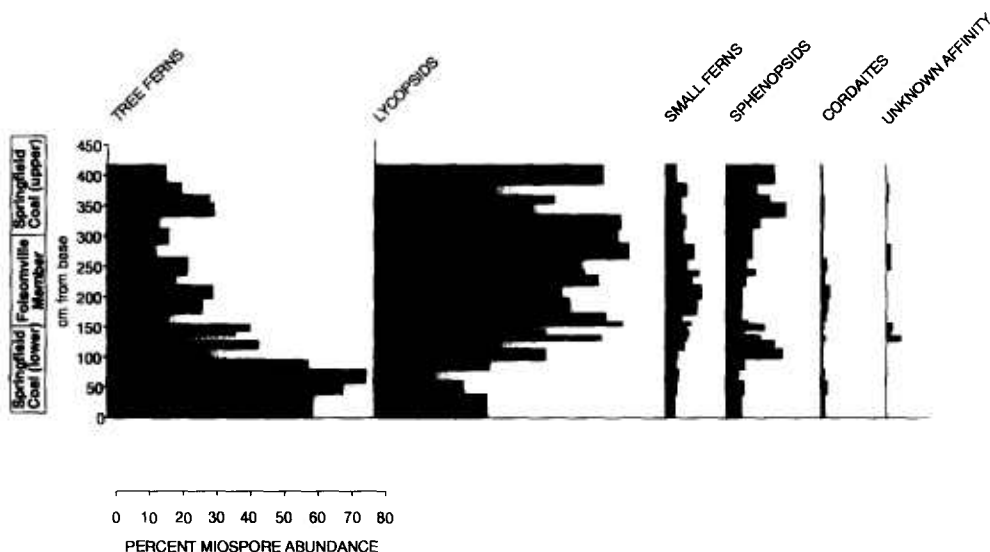


Fig. 5. Percent abundance of miospores of major plant groups in both benches of the Springfield Coal Member and Folsomville Member (Petersburg Formation), site W5, Warrick County, Indiana.

Table 4

Average percentage abundance of miospores of major plant groups in profiles of the Springfield Coal collected near the Leslie Cemetery paleochannel and the Galatia paleochannel

Miospore	Leslie Cemetery paleochannel			Galatia paleochannel (Willard, 1990)	'Normal' coal distal to paleochannels (Willard, 1990)
	Site W5		Spur Mine		
	Coal (both benches)	Split	Unsplit Coal (Mahaffy, 1988)		
Ferns	38.5	34.4	52.5	60.1	59.9
Lycopsids	51.0	58.8	32.5	33.7	32.9
Sphenopsids	9.5	5.1	10.2	2.7	4.8
Cordaites	0.2	0.8	-	2.5	1.4
Unknown affinity	0.8	0.9	-	1.0	1.0

Values given for coal near the Galatia paleochannel and 'normal' coal distal to the paleochannels represent average abundances from several mines located throughout the Illinois Basin.

Dashes indicate that no abundance values were given for these categories

pseudothiessenii (1.3%). Both *Laevigatosporites minimus* and *Thymospora pseudothiessenii* are much less abundant in the split than they are in the coal. Sphenopsids are represented by species of *Calamospora* (3.5%) and *Vestispora* (1.4%).

4.1. Vertical patterns of miospore abundance

Miospore assemblages from the lower bench of coal are unique among the sample suite in the dominance of tree-fern miospores and subdominance of lycopsid miospores (Fig. 5). Three tree-fern species attain their peak abundance in the

Table 5

Source-plant and miospore correlations for most abundant miospore taxa in Springfield Coal Member and Folsomville Member near the Leslie Cemetery paleochannel, southwestern Indiana

Major plant group	Miospore taxon	Source plant taxon
Lycopsids	<i>Lycospora granulata</i>	<i>Lepidophloos hallii</i>
	<i>Lycospora pusilla</i>	<i>Lepidodendron hickii</i>
	<i>Lycospora torquifer</i>	<i>Lepidostrobus praelongus</i> .
		<i>Lepidostrobus variabilis</i>
	<i>Lycospora orbicula</i>	<i>Paralycopodites</i>
	<i>Granasporites medius</i>	<i>Diaphorodendron</i>
Tree ferns	<i>Crassispora kosankei</i>	<i>Sigillaria</i>
	<i>Thymospora pseudothiessenii</i>	<i>Scolecopteris vallumii</i>
	<i>Laevigatosporites minimus</i>	<i>Scolecopteris gnoma</i> ,
		<i>Scolecopteris minor</i>
	<i>Laevigatosporites globosus</i>	<i>Scolecopteris mamayi</i>
	<i>Punctatosporites minutus</i>	<i>Scolecopteris altissima</i>
	<i>Cyclogranisporites spp.</i>	<i>Scolecopteris latifolia</i>

(Lesnikowska, 1989; Willard, 1989a,b).

Table 6

Average abundance of major miospore species from profiles in the Springfield Coal: in Eby Pit of the Peabody Coal Company's Lynnville Mine, in mines near the Galatia paleochannel and in mines distal to both paleochannel systems

Species	Leslie Cemetery paleochannel				Galatia paleochannel (Willard, 1990)	'Normal' coal distal to paleochannel (Willard, 1990)
	Site W5		Spur Mine			
	Coal Lower bench	Split Coal Upper bench	Coal Upper bench	Unsplit Coal (Mahaffy, 1988)		
Tree Fern Miospores						
<i>Thymospora pseudothiessenii</i>	13.2	1.3	0.1	17.3	18.2	26.9
<i>Laevigatosporites globosus</i>	13.3	9.8	5.8	8.1	9.8	15.4
<i>Laevigatosporites minimus</i>	19.7	2.9	0.2	-	9.5	2.2
<i>Punctatosporites minutus</i>	4.8	7.9	10.5	-	12.9	5.2
Lycopsid Miospores						
<i>Lycospora spp.</i>	26.8	46.6	53.8	27.9	23.1	12.3
<i>Crassispora kosankei</i>	3.0	1.8	1.1	1.6	2.7	3.1
<i>Granasporites medius</i>	2.4	9.8	1.7	-	4.7	6.7
<i>Anacanthotriletes spinosus</i>	1.0	0.3	1.3	-	4.1	11.3

Dashes indicate that no values were given for those taxa.

lower bench of coal: *Laevigatosporites globosus*, *L. minimus* and *Thymospora pseudothiessenii* (Fig. 6). In the clastic split, lycopsid miospores are dominant and tree-fern miospores are subdominant (Fig. 5). *Laevigatosporites minimus* becomes absent midway through the split and *Thymospora pseudothiessenii* is rare; both species remain rare in the upper bench of coal. Among the lycopsid miospores, *Lycospora orbicula* is rare in the lower samples but increases in abundance upward and *Granaspores medius* is abundant in the split (Fig. 6). In the

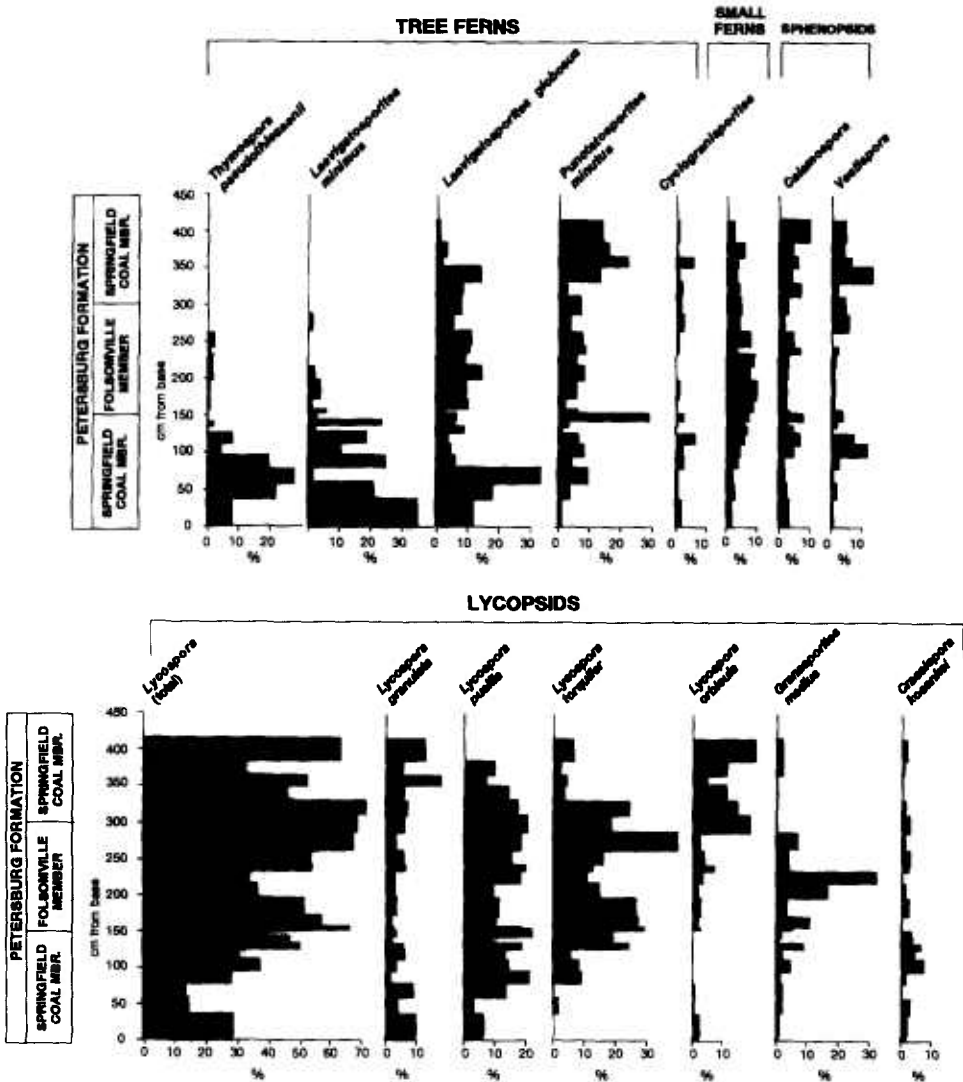


Fig. 6. Percentage abundance of miospore taxa in both benches of the Springfield Coal Member and shale split of the Folsomville Member (Petersburg Formation), site W5, Warrick County, Indiana.

upper bench of coal, lycosid miospores reach their peak abundance and tree-fern miospores are subdominant (Fig. 5). *Lycospora* is the most abundant genus in the upper bench and the most abundant species is *Lycospora orbicula*. The tree-fern miospores *Punctatosporites minutus* and *Laevigatosporites globosus* are common throughout the upper bench (Fig. 6).

5. Eby Pit megaspore assemblages

Megaspores were quantified from the lower bench of coal at site W7 (Fig. 1) and, as a whole, the megaspore assemblages were dominated by two forms: *Lagenicula rugosa*, produced by *Paralycopodites*, and *Valvisporites auritus*, produced by *Chaloneria* (Table 7). These and other common megaspore species have been illustrated by Scott and Hemsley (1994). In general, *Lagenicula rugosa* dominates assemblages in the bottom 1 m of the coal and *Valvisporites auritus* dominates the upper 30 cm of coal in the lower bench of coal (Fig. 7). A few specimens of *Cystosporites giganteus*, *Cystosporites diabolicus* (formerly *C. varius*), *Triangulatisporites triangulatus*, *Tuberculatisporites mammilarius* and *Laevigatosporites glabratus* were recovered. There appeared to be no clear relationship between coal lithotype and megaspore assemblage. Three additional observations were made. *Monoletes* (also known as *Schopfipollenites*) was occasionally recovered in high abundances, especially from the uppermost part of the lower bench of coal. Because of its relatively large size (100–500 μm : Schopf et al., 1944), *Monoletes* is often not encountered in miospore assemblages (DiMichele and Phillips, 1994). Plant cuticle is often abundant in the macerated samples; most of the cuticle was produced by pteridosperms, and these are particularly abundant near the top of the upper bench of coal. In addition, several fusain bands were observed in this section. One fusain band, at 58 cm above the base of the profile, is 1 cm thick. Fusain also was particularly abundant in macer-

Table 7

Source plant and megaspore correlations for most abundant megaspore taxa in the lower bench of the Springfield Coal Member near the Leslie Cemetery paleochannel, southwestern Indiana

Major plant group	Megaspore taxon	Source plant taxon
Lycosids	<i>Cystosporites diabolicus</i>	<i>Diaphorodendron</i>
	<i>Cystosporites giganteus</i>	<i>Lepidophloios</i> , <i>Lepidodendron</i>
	<i>Lagenicula rugosa</i>	<i>Paralycopodites</i>
	<i>Laevigatosporites glabratus</i>	<i>Sigillaria</i>
	<i>Triangulatisporites triangularis</i>	<i>Paurodendron</i>
	<i>Tuberculatisporites mammilarius</i>	<i>Sigillaria</i>
	<i>Valvisporites auritus</i>	<i>Chaloneria</i>
Pteridosperms	<i>Monoletes</i>	<i>Medullosa</i>

(Bateman et al., 1992; Schopf et al., 1944.)

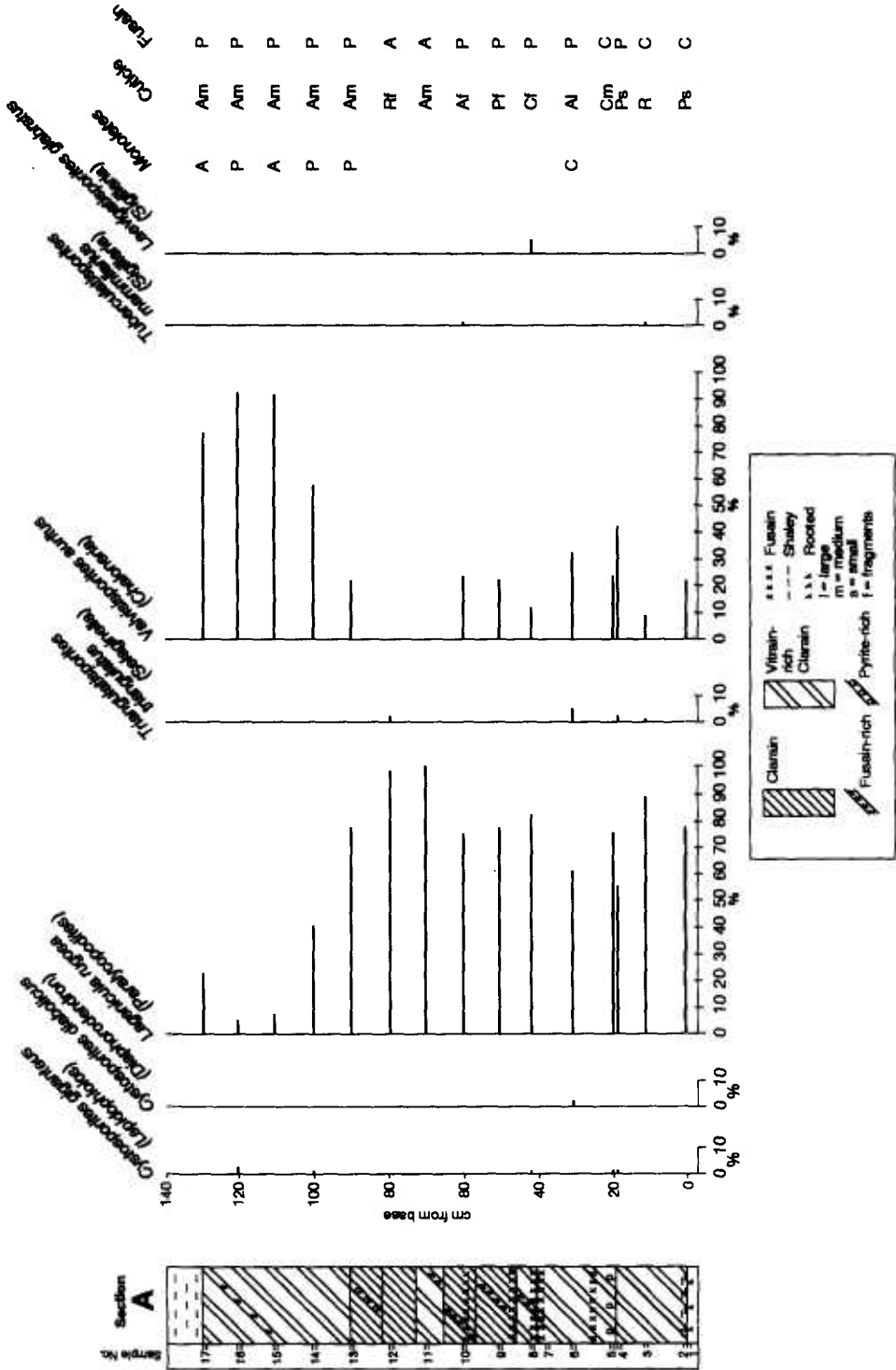


Fig. 7.

ates from the succeeding samples (11 and 12: Fig. 7) and a change in megaspore assemblages follows this lithologic change.

6. Eby Pit plant compression fossil assemblages

6.1. Plant compression fossil distribution in the Folsomville Member

The distribution of plant compression fossils in the clastic split was studied in eight sections, ranging from the thinnest part of the split distal to the channel axis to the thicker sediments near the channel axis. Where the split was at its thinnest, few plant compression fossils could be identified in the coaly shale (section 8, Fig. 3). However, where the split was 4 m thick (sections 6 and 7, Fig. 3), numerous layers with plant compressions occurred. Above the lower bench of coal, dark shales with pteridosperm pinnules occurred, together with fusain layers. Going upward, the shales became medium gray in color and lycopod axes were common. A prominent seat earth with stigmarian rootlets underlay coaly shales with pockets of coalballs near the top of the section. This seat earth ultimately graded laterally into the thin upper bench of coal. The topmost coaly shales contained abundant pteridosperm pinnules and rachises and, in some sections, layers with trunks of *Sigillaria* or *Lepidophloios* were observed. In sections where the split was thicker than 9 m (Section 1, Fig. 3), pteridosperm foliage, including *Neuropteris scheuchzeri*, *N. ovata* and *Sphenopteris*, was abundant in the gray/dark gray shales. Sandstones occurred in distinctive channels and contained large logs; because of the position of the largest channel deposits in the high wall, detailed paleobotanical and sedimentological observations could not be made but fallen blocks of laminated siltstones contained fragments of *Pecopteris*, *Alethopteris* and *Neuropteris*.

6.2. Taphonomy

For the most part, the gray to buff siltstones of the Folsomville Member contained an apparently parautochthonous (sensu Behrensmeier and Hook, 1992) to allochthonous flora, composed of fragmentary plant remains scattered throughout the rock matrix. No evidence of entire fronds or trees, such as those reported by Wnuk and Pfefferkorn (1987) was encountered. Roots of the pinnularia type, from pteridosperms or calamites, occurred in 7 of the 10 collections and stigmarian axes from lepidodendrids occurred in 1 gray shale collection. In several instances well preserved remains of pteridosperm pinnules, such as *Neuropteris scheuchzeri*, were penetrated by roots. Accumulations of large axes up to 10 cm in diameter, probably rachis segments of pteridosperms, were common in the coarser siltstones and smaller pteridosperm and fern rachises were found in all but one collection. Plant-bearing gray siltstones and claystones were generally massive, lacking clear bedding, with irregular fracture. Bedding planes generally corresponded to the positions of horizontally disposed plant fossils. Spirorbid

worms, which are found in a variety of water conditions ranging from fresh to marine (Howell, 1962; Mamay, 1966; Pearse et al., 1987), were found attached to plant fossils in 2 collections (USNM 38372 and 38866: Table 3). The presence of these worms in gray mudstones from the roof of the lower bench of coal (USNM 38366: Table 3) indicates that water influencing the Leslie Cemetery paleochannel early in its development was not necessarily fresh but may have been brackish or marine.

The complexity of the gray to buff mudstone deposits suggests deposition in splays from an intermittently active channel. Such splays apparently actively aggraded for some time and were colonized by plants. The taphonomic character of the deposits suggests wet soils in which the vegetated surfaces were rapidly buried and rerooted. These may be similar to the *Nipa* dominated environments described by Gastaldo and Huc (1992) in the Mahakam delta of Kalimantan. Some plant remains appear to have been buried rapidly in high-energy systems that destroyed all but the most resistant pteridosperm axes. In most cases, however, burial of litter during vertical sediment aggradation seems to account for most of the plant-rich deposits.

Organic claystones occurred at several levels within the Folsomville Member between the upper and lower benches. The main collection (USNM 38367: Table 3) was made from the base of the upper bench of coal in a coaly organic shale that contained coalballs and graded up into the bright-banded Springfield coal bed. The few specimens of organic shale from USNM 38368 (Table 3) came from a thin layer in the middle of the split; this collection capped a dark, organic, and siderite-rich silty mudstone (USNM 38373: Table 3) of variable thickness that formed the roof of the lower bench of the Springfield coal bed. A third collection of organic shales (USNM 38369: Table 3) also was made between the two benches. Plant material in the organic shales was generally composed of axes, fragmentary pteridosperm foliage and abundant, finely comminuted, dispersed, organic detritus. The deposits appear to have been in situ accumulations in clastic swamps and suggest periods of standing water contributing to the preservation of plant matter in organic muck (see Gastaldo et al., 1989, for a taphonomic analog from the Mobile delta). Such environments evidently recurred periodically prior to the onset of the formation of the mire that formed the upper bench and indicate the spatiotemporal complexity of the split deposit.

6.3. Flora

Eighteen whole-plant taxa have been identified in the flora (Table 8), plus a number of dispersed organs. In some instances (e.g., *Lepidocarpon* from *Lepidophloios*), the parent plant of the dispersed organ is known; for other organs, such as seeds, the parental source is unknown or highly speculative. All organ-taxa are listed and are grouped with the relevant whole plant where appropriate (Table 8). Representatives of the major taxa are illustrated in Figs. 8–10; some taxa were represented by specimens that were 'non-photogenic' and, therefore, have not been illustrated. Three elements of the flora occurred in a majority of the 13 samples: *Neuropteris scheuchzeri*, *N. ovata* and *Diaphorodendron scleroti-*

Table 8
Distribution of plant megafossil taxa from the Folsomville Member by site number

	1	2	3	4	5	6	7	8	9	10	11	12	13
Lycopsiids													
<i>Diaphorodendron</i> sp.			X	X		X			X		X	X	
<i>Synchysidendron</i> sp.											X		
<i>Sigillaria</i> sp.			X			X							
<i>Lepidodendron aculeatum</i>						X	X						
<i>Lepidophloios</i> sp.	X												
<i>Lepidocarpon</i> sp.	X												X
Pteridosperms													
<i>Neuropteris scheuchzeri</i>	X		X	X			X		X	X	X	X	X
<i>Neuropteris ovata</i>	X		X	X		X	X		X		X	X	X
<i>Neuropteris rarinervis</i>	X			X			X						
<i>Neuropteris cf. flexulosa</i>				X									
<i>Reticulopteris muensteri</i>	X							X					X
<i>Mariopteris</i> sp.							X						
Sphenopsids													
<i>Asterophyllites equisetiformis</i>					X								
<i>Paleostachya</i> sp.					X								
<i>Annularia stellata</i>							X				X		
<i>Sphenophyllum emarginatum</i>		X		X	X						X		
Tree ferns													
<i>Lobatopteris cf. vestita</i>				X	X		X				X		X
<i>Pecopteris polymorpha</i>											X		
<i>Pecopteris</i> sp.					X		X		X			X	
Cordaites													
<i>Artisia</i> sp.											X		
Miscellanea													
Axes of pteridosperms and ferns	X		X		X		X		X	X	X	X	X
Ovules	X									X			X
Pinnularia		X	X			X		X		X	X	X	
<i>Stigmaria</i>									X				
Species Richness	6	1	4	7	4	4	8	1	3	2	9	4	4
Lithology (Organic; Gray, Buff)	O	G	G	G	B	O	G	O	G	G	G	G	G
Dominants*	PT	NA	LE	PT	SP	PT	PT	NA	PT	PT	LE	LE	PT
	LE		PT			LE					PT	PT	FE

Sites in stratigraphic order, see Table 2.

* LE=lepidodendrids; PT=pteridosperms; SP=sphenopsids; FE=ferns; NA=not applicable due to small sample size.

cum. The pecopterid *Lobatopteris cf. vestita* occurred in five of the samples. Identifications of species and whole-plant assemblages, where appropriate, were based on standard paleobotanical literature: neuropterids: Crookall (1959) and Laveine (1967); calamites: Barthel (1980); pecopterids and sphenophylls: Corsin (1951), Boureau and Doubinger (1975), Gillespie et al. (1978), Storch (1980), Laveine (1989). The lepidodendrids were determined by comparing the leaf cushions of better known petrifications with compression specimens (e.g., Bateman et al., 1992), hence the recognition of *Diaphorodendron* and possibly *Syn-*

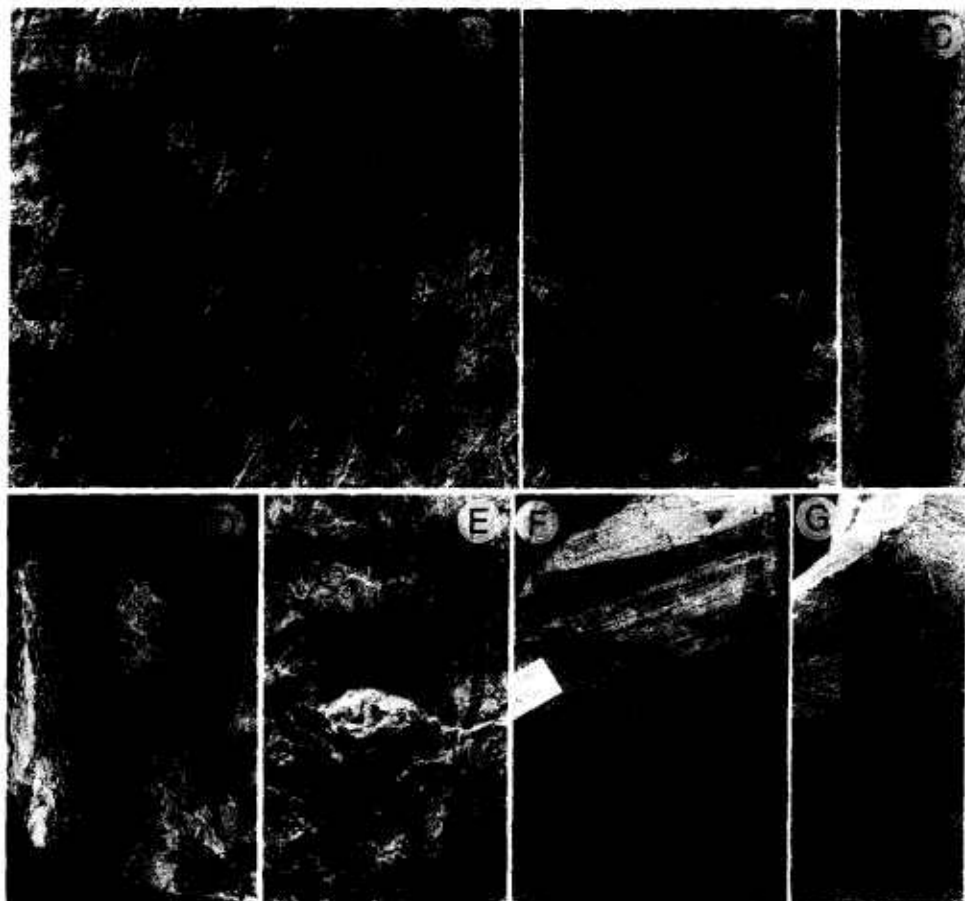


Fig. 8. Compression–impression remains of lycopsids from shales of the Folsomville Member. (A) *Diaphorodendron* stem illustrating small leaf cushions, lacking infrafoliar parichnos, $\times 2$. USNM 458531. (B) Stem of *Diaphorodendron* or *Synchysidendron*, $\times 2.6$. USNM 458532. (C) Small terminal twig of *Diaphorodendron*, $\times 2$. USNM 458533. (D) Anisotomously branched stem of *Diaphorodendron*, S 1. USNM 458534. (E) Leaf cushions of *Lepidodendron aculeatum* with infrafoliar parichnos and barred keels, $\times 0.7$. USNM 458535. (F) Lycopsid cone, probably *Achlamydocapron varius*, broken and compressed showing transverse section, $\times 0.7$. USNM 458536. (G) Lycopsid sporangium and attached distal lamina from *Lepidodendron*, $\times 0.7$. USNM 458537.

chysidendron; the name *Lepidodendron* is restricted to the sense of its usage in DiMichele (1983).

The flora from the gray shales is the most diverse; a maximum of nine species were present in Site 8, which is a siltstone over 6 m thick with plant fossils throughout. Six species occurred in the largest organic shale collection (Site 1), including *Lepidophloios* and *Reticulopteris münsteri*, which are common in coal ball deposits from coals in the late Westphalian D; *Lepidophloios*, in particular, is considered an indicator of standing water conditions (DiMichele and Phillips,

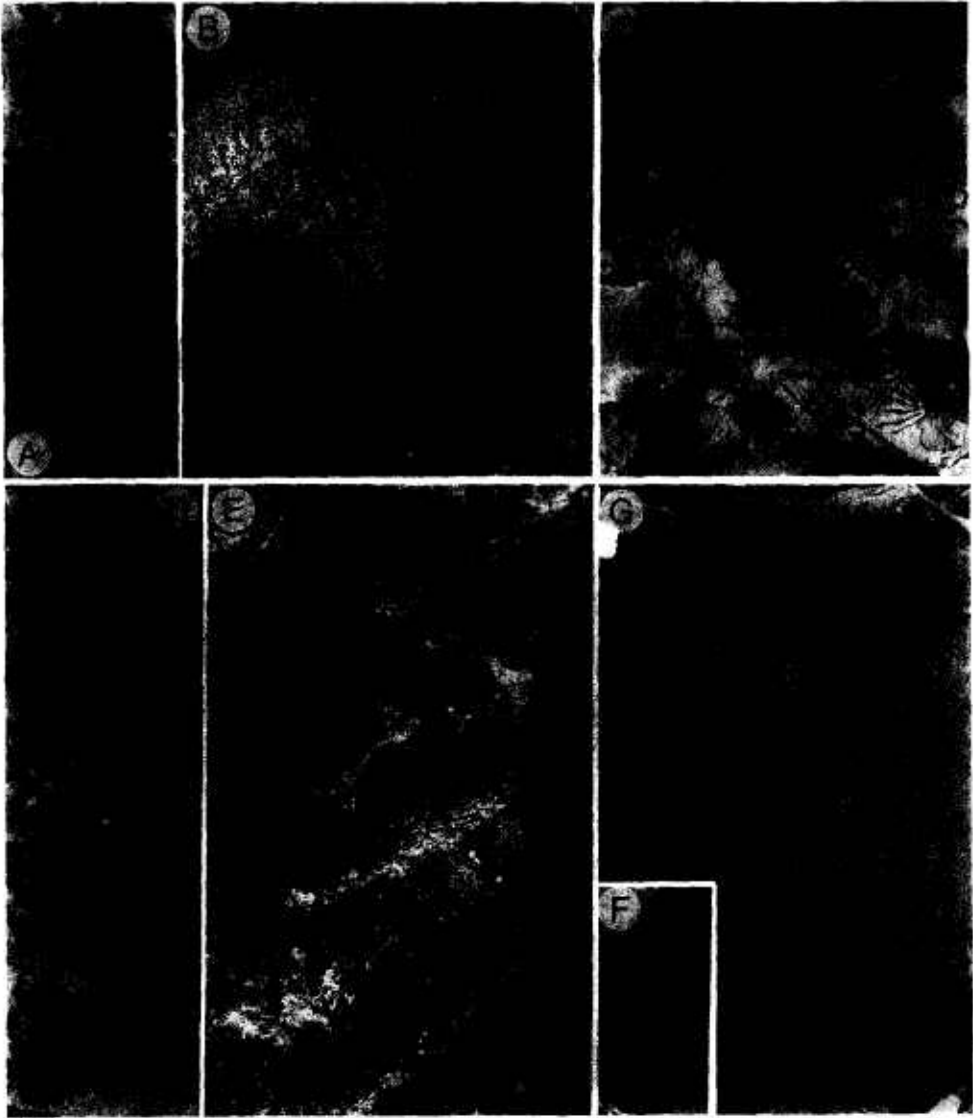


Fig. 9. Compression–impression remains of marattialean tree ferns and sphenopsids from shales of the Folsomville Member. (A) *Lobatopteris* cf. *vestita*, $\times 0.7$. USNM 458538. (B) *Lobatopteris* cf. *vestita*, $\times 2$. USNM 458537. (C) *Sphenophyllum emarginatum*, in center of specimen; *Asterophyllites equisetiformis* forma *typica*, calamitean foliage, at top and bottom of specimen, $\times 0.7$. USNM 458539. (D) *Pecopteris* (*Polymorphopteris*) *polymorpha*, $\times 0.7$. USNM 458540. (E) *P. polymorpha*, detail, $\times 2$. USNM 458540. (F) *Pecopteris* sp., $\times 0.7$. USNM 458541. (G) *Annularia stellata*, $\times 0.7$. USNM 458542.

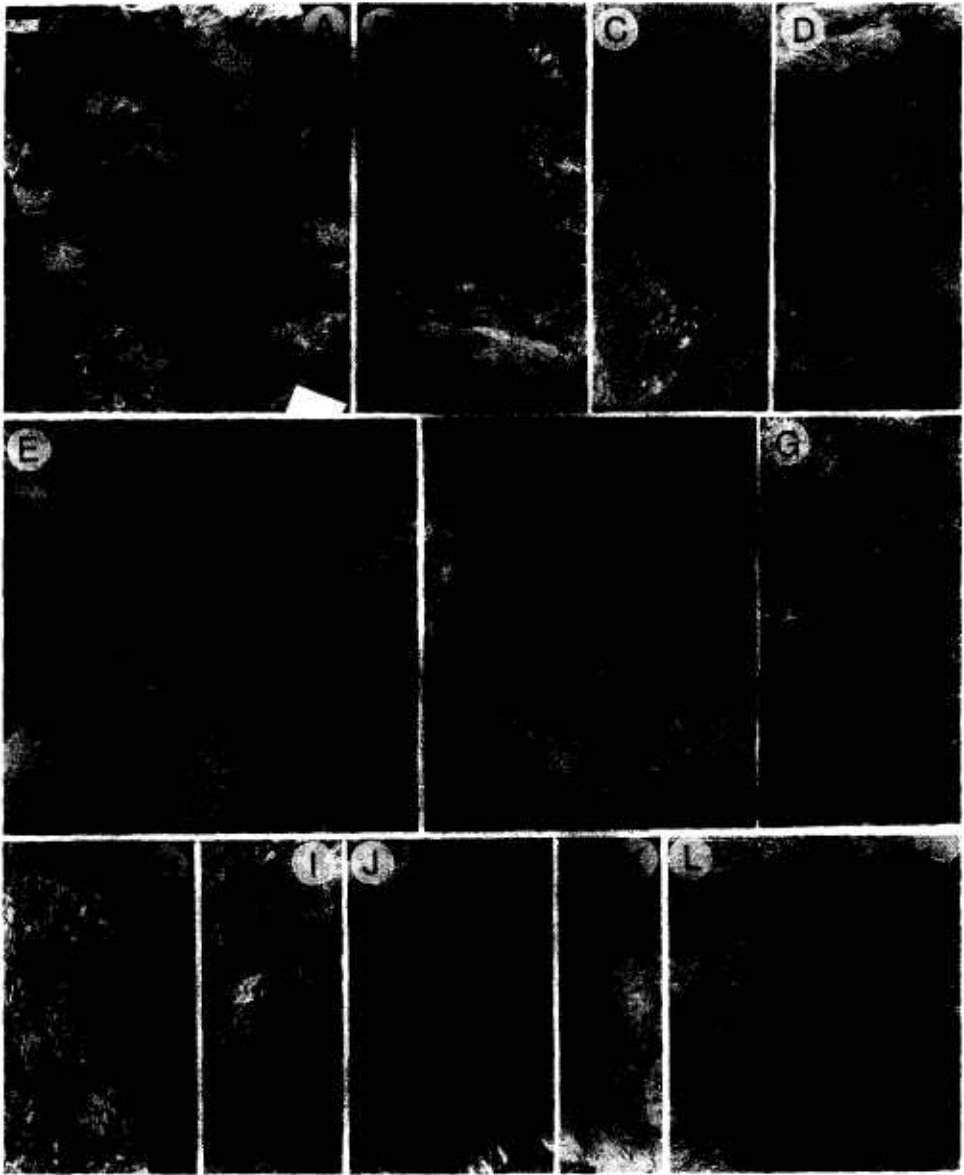


Fig. 10. Compression–impression remains of seed plants from shales of the Folsomville Member. (A) *Neuropteris ovata*, $\times 0.7$. USNM 458543. (B) *Neuropteris* cf. *ovata*, $\times 0.7$. USNM 458544. (C) Fimbriate cyclopteris pinnule of *Neuropteris ovata*, $\times 0.7$. USNM 458545. (D) *Neuropteris rarinervis*, $\times 0.7$. USNM 458546. (E) *Neuropteris scheuchzeri*, $\times 0.7$. USNM 458538. (F) cf. *Mariopteris* sp., $\times 0.7$. USNM 458547. (G) *Reticulopteris münsteri*, $\times 2$. USNM 458548. (H) *Holcospermum* sp., $\times 0.7$. USNM 458549. (I) *Carpolithus* sp., $\times 0.7$. USNM 458550. (J) cf. *Samaropsis* sp., $\times 2$. USNM 458551. (K) *Artisia*, pith case of cordaite stem, $\times 0.7$. USNM 458552. (L) Pteridosperm axis with attached *Spirorbis*, $\times 2$. USNM 458553.

1985). Overall, this is a typical late Westphalian D flora (Gillespie and Pfefferkorn, 1979; Wagner, 1984), although it is remarkably non-diverse, containing only the most common taxa known from this time interval. This low diversity may result in part from inadequate sampling. It is more likely, however, that the relatively narrow range of physical conditions represented by the clastic split deposits, all of which indicate wet to standing water substrates, contributed to the low diversity.

7. Eby Pit conodont faunule

Preservation of conodonts in calcareous coalballs from the upper part of the upper bench of coal is variable but generally good, suggesting that the conodonts were deposited contemporaneously with peat deposition. The most abundant conodont recovered from the samples is *Idiognathodus claviformis* (Table 9). *Neognathodus roundyi*, *Hindeodus minutus* and *Idioproniodus conjunctus* are

Table 9
Distribution of conodonts in coalballs from the Springfield Coal Member

Taxon	1	2	3	4	5
Sample weight (kg)	1	1	0.42	0.8	0.36
<i>Idiognathodus</i> Pa	16	323	72	125	20
<i>Neognathodus roundyi</i> Pa	9	56	6	11	2
<i>N. bothrops</i> Pa					
<i>Idiognathodus/Neognathodus</i> Pb	4	53	3	9	4
<i>Idiognathodus/Neognathodus</i> M	0	5	2	1	0
<i>Idiognathodus/Neognathodus</i> Sa	0	4	0	0	0
<i>Idiognathodus/Neognathodus</i> Sb/Sc	42	42	34	0	5
<i>Hindeodus minutus</i> Pa	0	3	3	5	2
<i>Hindeodus minutus</i> Pb	0	0	4	5	2
<i>Hindeodus minutus</i> M	0	2	2	2	1
<i>Hindeodus minutus</i> Sa	0	1	0	2	0
<i>Hindeodus minutus</i> Sb	0	2	1	1	0
<i>Hindeodus minutus</i> Sc	0	1	0	1	0
<i>Idioproniodus conjunctus</i> Pa?	2	8	1	3	1
<i>Idioproniodus conjunctus</i> Pb?	1	6	0	0	0
<i>Idioproniodus conjunctus</i> M1	0	3	1	0	0
<i>Idioproniodus conjunctus</i> M2	0	6	0	1	0
<i>Idioproniodus conjunctus</i> Sa	0	9	2	2	0
<i>Idioproniodus conjunctus</i> Sb1	0	2	2	2	1
<i>Idioproniodus conjunctus</i> Sb2	1	0	1	0	0
<i>Idioproniodus conjunctus</i> Sb3	0	1	0	1	0
<i>Idioproniodus conjunctus</i> Sc1	0	5	1	1	0
<i>Idioproniodus conjunctus</i> Sc2	0	8	0	0	0
<i>Idioproniodus conjunctus</i> Sc3	0	3	1	0	0
<i>Adetognathus</i> M	0	0	0	0	1
<i>Adetognathus</i> Sa	0	1	0	0	0
<i>Ligonodina</i> -like element	0	2	1	0	1
Total	75	546	137	172	40

common. *Adetognathus* sp., *Neognathodus medadultrimus*, *Aethotaxis* and a *Ligonodina*-like Sc element are rare (Rexroad, 1993). The presence of *Neognathodus roundyi*, *Idiognathodus claviformis* and longer-ranging species is consistent with a middle Desmoinesian age for the Springfield coal bed.

With the exception of sample 1, the proportions of species and the quality of preservation are similar among the samples. Having the fewest conodonts per kilogram, sample 1 was unusual for the excellent preservation of very delicate features. Also, the proportion of *Neognathodus* Pa elements to those of *Idiognathodus* was strikingly high in sample 1 and the overall proportion of *Neognathodus* in these samples is much higher than expected, considering its rarity in the overlying Alum Cave Limestone Member of the Dugger Formation. Sample 1 also contained the highest proportion of ramiform elements of *Neognathodus* and *Idiognathodus*, which, in conjunction with the excellent preservation, suggests that at least some of the conodonts may have been carried into the coalball area within conodont carcasses (Rexroad, 1993).

8. Paleocology

8.1. Overall vegetational and petrographic patterns

Comparison of miospore and petrographic data from coal near the Leslie Cemetery and Galatia paleochannels indicates that environmental conditions near the two channels were similar during the initial stages of peat accumulation. Deposition of clastics associated with the Leslie Cemetery paleochannel, however, strongly affected the vegetation, both during deposition of clastics and after resumption of peat accumulation. Miospore assemblages from sites near the Leslie Cemetery paleochannel are unique among samples from the Springfield coal bed in the dominance of lycopsid miospores and in vertical patterns of miospore abundance, whether collected from split or unsplit coal (Table 6) (Mahaffy, 1988; Willard, 1990, 1993). In all profiles collected near the Leslie Cemetery paleochannel, *Thymospora pseudothiessenii* is abundant (as much as 60%) in the lower one-third of the seam but is nearly absent in the upper parts of the seam. *Lycospora* dominates the assemblage in the upper two-thirds of the seam and tree-fern and small-fern miospores are common (see Fig. 5 and Mahaffy, 1988). The presence of similar patterns in profiles from at least three different mines around the Leslie Cemetery paleochannel suggests that such assemblages are representative for the area.

8.2. Early phases of the Springfield peat swamp

The palynological and petrographic characteristics of the Springfield coal bed, as a whole, near the Leslie Cemetery paleochannel differ distinctly from samples collected near the Galatia paleochannel and from the 'normal' coal distal to the channels (Table 6). In the lower bench of coal near the Leslie Cemetery paleochannel, however, the composition and abundance of tree-fern miospore species

resemble those of the whole seam near the Galatia paleochannel. Four species (*Punctatosporites minutus*, *Thymospora pseudothiessenii*, *Laevigatosporites globosus* and *L. minimus*) are consistently abundant throughout these sections and species of *Cyclogranisporites* also are present in low abundances. The miospore taxa indicate the presence of at least five species of tree-fern fructifications: *Scolecoperis altissima* (*Punctatosporites minutus*), *S. latifolia* (*Cyclogranisporites*), *S. vallumii* (*Thymospora pseudothiessenii*), *S. mamayi* (*Laevigatosporites globosus*), and *S. gnoma* or *S. minor* (*Laevigatosporites minimus*) (Lesnikowska, 1989). Except for *S. vallumii*, all these species have been documented from coal ball megafossil assemblages from sites near the Leslie Cemetery paleochannel; the absence of *S. vallumii* may be due to the fact that most coalballs studied were from the upper bench of the coal (Lesnikowska, 1989).

The most abundant lycopsid miospore in both the lower bench of coal near the Leslie Cemetery paleochannel and in samples collected near the Galatia paleochannel is *Lycospora* (produced by *Lepidodendron* and *Lepidophloios*), but *Crassispora kosankei* (produced by *Sigillaria*) reaches its highest abundance (7.3%) in the lower bench and *Granasporites medius* (produced by *Diaphorodendron*) also is common. Comparison of abundance of plant taxa in the megafossil and miospore records indicates that *Sigillaria* (source plant of *Crassispora*) is poorly represented in the miospore record (Willard, 1993); the relatively high abundance of *Crassispora* in the lower bench of coal indicates that *Sigillaria* was probably a prominent component of the flora in the early coal swamp.

Megaspore data from the lower bench of coal provides additional information on vegetational changes during its accumulation. Lycopsid megaspores dominate assemblages from the lower bench of coal, with *Lagenicula rugosa* (produced by *Paralycopodites*) most abundant in the lower 1 m of coal and *Valvisisporites auritus* (produced by *Chaloneria*) dominant in the upper 40 cm. The miospores produced by these lycopsids were rare in the assemblages studied (from sites W5 and W6), and the differences between the miospore and megaspore records probably reflect local differences in vegetation. The assemblages dominated by *L. rugosa* are similar to phase 1 assemblages described by Bartram (1987), which represent plant communities growing on waterlogged substrates after the cessation of clastic influx. The upper assemblages near the coal–clastic split contact are similar to phase 2 assemblages (Bartram, 1987). Coals with these megaspore assemblages typically contain more semifusinite and Bartram (1987) suggests that the change from phase 1 to phase 2 assemblages results from edaphic changes, such as would have occurred during the change from a peat-accumulating to a clastic-dominated environment.

Petrographically, the lower bench of coal near the Leslie Cemetery paleochannel and the whole seam near the Galatia paleochannel are characterized by high vitrinite content, with values typically about 93%, and an inertinite content around 5% (Table 1). A higher inertinite content (19–21%), including an increase in fusain, near the top of the lower bench corresponds to decreases in the abundance of the tree-fern miospore *Thymospora pseudothiessenii* (produced by *Scolecoperis vallumii*, Lesnikowska, 1989) and *Vestispora*, a sphenopsid miospore (Fig.

6) and increases in the abundance of *Monoletes* (produced by medullosan pteridosperms) and species of *Lycospora*, primarily those produced by clastic swamp lycopsids (i.e., *Lycospora torquifer* — see Willard, 1989a). These changes near the contact between the lower bench of coal and the clastic split may be indicative of instabilities in the system, such as repeated fires or subsidence prior to channel development, and subsequent influx of clastics. The latter situation may be represented in the Fire Clay coal bed in the Breathitt Formation of eastern Kentucky, where the coal bed thickness directly north of a post-depositional channel is about 33% greater than elsewhere in the coal bed, suggesting that factors influencing channel emplacement may also have influenced coal thickness prior to channel establishment (Andrews et al., 1994). The occurrence of fusain in the upper layers of the lower bench of coal may also indicate the occurrence of fire (Scott and Jones, 1994) but, in general, it is not possible to identify whether this was within or outside the mire. The presence of important fusain horizons and the associated vegetational change, however, may indicate fire within the mire itself (Scott and Jones, 1994).

8.3. Clastic split in coal

The mudstones of the split in the coal provide detailed information on the composition of both miospore and megafossil assemblages, as well as an opportunity to study preservational biases in the two records. The miospore record provides a regionally averaged insight into the composition of the vegetation. Assemblages within the clastic split are dominated strongly by lycopsid miospores (Fig. 5), particularly species most commonly found in shales. Different species of *Lycospora* have been isolated from *Lepidostrobus* cones preserved as compressions and coalball petrifications, suggesting natural species differences in clastic versus peat swamps (Table 5; Willard, 1989a,b). Species of *Lycospora* produced by *Lepidostrobus* species found only as compressions include *Lycospora punctata*, *L. torquifer* and *L. trigonoreticulata* (Willard, 1989a). These species are most abundant in the split. Ratios of compression/petrification species of *Lycospora* range from 0.6–1.5 (compared to 0–0.4 in the lower bench of coal). *Lycospora orbicula*, produced by *Paralycopodites* (Felix, 1954; Willard, 1988), an 'ecotonal' lycopsid preserved both in compression and petrification floras (Phillips and DiMichele, 1992), also increases in abundance upward through the split. *Granasporites medius*, produced by *Diaphorodendron*, comprises up to 32% of assemblages. Similar differences in the species composition of *Lycospora* have been noted between coal and shale assemblages (Marshall and Smith, 1964).

Tree-fern miospore assemblages in the split differ from those in the lower bench. The upward decrease in abundance of *Laevigatosporites minimus* and *Thymospora pseudothiessenii* suggest that the source plants (*Scolecoperis gnoma* and/or *S. minor*, and *S. vallumii*, respectively) were primarily peat swamp taxa and were poorly adapted to or unable to compete in substrates dominated by clastic deposition. Indeed, the low abundance of *Thymospora pseudothiessenii* near paleochannels has been noted elsewhere (Mahaffy, 1988; Willard, 1993) and Mahaffy

(1988) suggested that the source plant may have been relatively intolerant to environmental perturbations. Another hypothesis, suggested by the presence of spirorbid worms on plants from the split, is that these species may have been unable to survive the influence of brackish or marine water. The other two tree-fern species that were abundant in the lower bench of coal (*Laevigatosporites globosus*, produced by *Scolecopteris mamayi*, and *Punctatosporites minutus*, produced by *S. altissima*) continue to be abundant throughout the split and the upper bench of coal (Fig. 6). The higher miospore diversity in the split (24–31 species compared to 18–23 species in the lower bench of coal) is typical of clastic palynofloras. This higher diversity may reflect the relatively greater nutrient availability in the clastic sediments and, perhaps, the greater landscape habitat heterogeneity.

The dominance of lycopsids in the miospore assemblages is reflected inconsistently by the megafossil assemblages, which are usually dominated by pteridosperms and/or lycopsids. The difference between the two records results primarily from the poor representation of pteridosperms in the miospore record, which includes only palynomorphs $< 200 \mu\text{m}$ (Guennel, 1952). Many of the pteridosperm prepollen grains are $> 200 \mu\text{m}$ and, therefore, are not included in miospore studies; thus, the compression record provides a more accurate and localized view of the dominant taxa. Miospore assemblages also tend to average across small-scale habitat differences on the landscape, whereas the largely autochthonous to parautochthonous compression assemblages reflect local habitat variability.

The dominance of *Lycospora* in the miospore record is matched most closely by compression assemblages from organic shales, in which *Lepidophloios*, *Lepidodendron* and *Diaphorodendron* are common. The high percentages of *Granasporites medius* (32%) in miospore assemblages from the split are reflected by the several compression assemblages dominated or co-dominated by its source plant, *Diaphorodendron* (Table 5). These are largely gray shale floras, indicating wet, probably flooded, but oxygenated clastic swamps. *Granasporites*-rich miospore assemblages are unusual in the Springfield coal bed; typically, *G. medius* comprises $< 12\%$ of the assemblages, even when *Diaphorodendron* is abundant in coal-ball assemblages, reflecting the relatively low miospore output of the genus (Willard, 1993).

Small, herbaceous plants appear to be represented better in the miospore record than in the compression record. Ground cover plants are extremely rare in compression assemblages from the Eby Pit but their miospores are more abundant and exhibit a higher diversity in the split than in either bench of coal.

The floristics and taphonomy of plant remains in mudstones of the clastic split are consistent with a restricted range of physical settings; in this case, largely wet to flooded soils within a channel belt. In terms of taxonomic diversity, megafossil assemblages are all similar and represent a landscape of relatively low variability. Rapid rates of sediment aggradation occurred within this landscape, burying and preserving litter at the sites of plant growth. Miospore assemblages likewise show little variation vertically in the split, but they are significantly more diverse than their counterparts in the coal.

Microenvironmental differences are reflected in the megaf flora. In particular, the organic shales, representative of sites with the longest periods of standing, probably stagnant, water, are characterized by abundant lycopsids, particularly *Lepidophloios* and *Lepidodendron*, and by the pteridosperm *Reticulopteris müensteri*. Abundant calamites were found only in one deposit, a small collection of buff claystone dominated by *Asterophyllites equisetiformis*; pecopterids, although represented in over half of the samples, are also quantitatively rare. *Neuropteris scheuchzeri* and *N. ovata* occurred widely in all deposits but were most characteristic of gray mudstones, with taphonomic evidence suggesting wet, rapidly aggrading soils. *Diaphorodendron* was also most abundant in the gray mudstones, indicative of rapid aggradation, and, locally, stems were the most commonly encountered plant remains in these deposits. Noteworthy is the uncommon occurrence of ground cover. *Sphenophyllum emarginatum* is the only diagnostically low, shrubby or sprawling plant (Batenburg, 1982). Small fern and pteridosperm foliage (*Sphenopteris*, *Nemejcopteris*, etc.) is conspicuously absent, which is consistent with saturated to flooded substrates. This provides a puzzling contrast to miospore assemblages, which include relatively abundant miospores of small ferns in the split. Perhaps local hummocks or even extensive areas of well exposed substrate, where lush ground cover could develop, were not preserved within the split, even though they may have formed an extensive part of the landscape. Such 'phantom' areas also may have supported the tree ferns that are common in miospore assemblages but relatively uncommon in the compression flora.

A similar kind of assemblage was described by Wnuk and Pfefferkorn (1987) from the late Westphalian D from the western Northern Anthracite Field in north-central Pennsylvania, where they described a neuropterid and lepidodendrid-dominated flora (*N. scheuchzeri*, *N. ovata*, *Diaphorodendron* and *Synchisidendron*) from a dark mudstone. This deposit consisted of whole trees buried in place and demonstrated patchy clumping of lycopsids and pteridosperms, the latter in some places forming dense thickets on wet soils. Wnuk (1985) estimated that the lepidodendrids exceeded heights of 30 m and the pteridosperms formed a considerably lower canopy (Wnuk and Pfefferkorn, 1984). The Anthracite Field deposit appears to be an excellent analog for the clastic deposits of the Folsomville Member, given the marked similarity in dominance–diversity and depositional patterns. The comparison is consistent with the primary inferences from taphonomy and floristics. The clastic rocks separating the two benches of coal formed a changing complex of wet soils supporting mostly those trees and shrubs tolerant of saturated substrates. The rarity of ground cover and the minor abundance of marattialean ferns, which were of major importance in the peat substrate mires and which require exposed substrates to carry out their life histories, is consistent with occasional flooding and the regular introduction of clastics. The combination of palynology and megafossil analysis suggests areas of well exposed substrate within the larger wetland landscape. We note, however, that in some levels at the base of the clastic sequence fusain horizons are common. It is possible that the effects of fire were partly responsible for the termination of peat formation (linked to decrease in rainfall), along with increased erosion and deposition of

clastic sediments (see Scott and Jones, 1994). The effect of fires in peat-forming settings has been widely documented and may have had a strong influence on the Springfield peat swamp.

8.4. Late phases of the Springfield peat swamp

The miospore composition of the upper bench of coal near the Leslie Cemetery paleochannel is unique among samples from the Springfield coal bed. Lycosid miospores, particularly species of *Lycospora*, dominate assemblages in the upper bench of coal (Table 6). Petrification species of *Lycospora* (i.e., *L. granulata*, *L. pusilla*) are more abundant than compression species (i.e., *L. torquifer*), with ratios of compression to petrification species <0.3 in the upper bench. Also, *Lycospora orbicula*, produced by *Paralycopodites* (Felix, 1954; Willard, 1988), a lycosid characteristic of disturbed or 'ecotonal' environments (Phillips and DiMichele, 1992), is abundant in the upper bench (Fig. 6), comprising up to 31% of the assemblages. Comparison of its abundance in miospore assemblages and coal-ball megaflores from the Springfield coal bed suggests that *Paralycopodites* is represented equally in both records (Willard, 1993), so *Paralycopodites* was probably an important component of the flora in the peat that formed the upper bench of coal. Similarly, the abundance of miospores of *Lepidodendron hickii* (20%) and *Lepidophloios hallii* (18%), although only about half of their representation in coal-ball megaflores (Willard, 1993), suggests that these lycosids were also abundant. Unlike assemblages in the split, lycosid miospores *Crassispora kosankei* and *Granasporites medius* are both relatively rare, comprising $<2\%$ of the assemblages in the upper bench of coal. Megafossil data from the coaly shales beneath the thin coal of the upper bench shows an abundance of pteridosperm material. This is confirmed by data from associated coalballs, which contain abundant pteridosperm petioles and leaves (Phillips et al., 1985; Scott and Rex, 1985; Van Bergren et al., 1994; Collinson et al., 1994).

Only two tree-fern miospores (*Punctatosporites minutus* and *Laevigatosporites globosus*) are abundant in the upper bench of coal near the Leslie Cemetery paleochannel (Table 6) and the rarity of *Thymospora pseudothiessenii* and *Laevigatosporites minimus* suggests that their sources (*Scolecopteris vallumii* and *S. gnoma/minor*) were absent. Sphenopsids are common, particularly *Vestispora fenestrata*.

Overall, vitrinite contents of the upper bench of coal are slightly higher (95%) than either the lower bench or samples collected near the Galatia paleochannel. This slight increase may reflect the higher proportions of *Lepidodendron*, *Lepidophloios*, and *Paralycopodites* suggested by the miospore record. Periderm tissues (bark) from these plants may be a major source of the vitrinite group macerals.

Individual samples with higher inertinite content in the upper bench of coal correspond to the minimum abundance of *Lycospora* and higher than usual abundances of tree-fern and sphenopsid miospores. At site W5, *Punctatosporites minutus* (produced by *Scolecopteris altissima* (Lesnikowska, 1989)) reaches a peak

abundance for the upper bench of coal in the sample with the highest inertinite content (Fig. 6, Table 1). A similar pattern of higher tree-fern spore abundance and higher inertinite content has been noted in Upper Pennsylvanian coal beds of western Kentucky (Helfrich and Hower, 1989) and may indicate higher oxidation levels of the peat or the effect of wild fires (Scott and Jones, 1994).

Conodonts of the *Idiognathodus/Streptognathodus* plexus, which dominate conodont assemblages in coalballs from the upper bench, are found in nearly all marine environments except in the most restricted *Cavusgnathus* biofacies (Merrill and Von Bitter, 1984); *Cavusgnathus* (*Adetognathus* of many authors) is not represented in the coal-balls. *Hindeodus* similarly has a wide tolerance, although it seems to be more abundant in the higher energy *Aethotaxis* biofacies, which is not represented in this faunule, and is less abundant in association with *Idioprioniodus*. *Idioprioniodus* often is interpreted as preferring an organic-rich, quiet water environment with a low pH, as commonly represented in the geologic record by dark shales (e.g., Merrill, 1973; Merrill and Von Bitter, 1976, 1984). The ecological requirements of *Neognathodus* are less certain as it seems to have tolerated diverse environments but it is commonly associated with organic-rich deposits, including organic-rich shales, which suggests a vegetated, brackish water environment for some occurrences. On the basis of this evidence, we suggest that the majority of the conodonts found in the coalballs came from animals that lived in a nearby mud-trapping, salt water mire of nearly normal salinity not subject to major fluctuations in salinity.

The unusual composition of the peat swamp vegetation and presence of conodonts suggests a marine influence during accumulation of peat to form the upper bench of coal. Although no sedimentological indications of tidal influence were found in the Folsomville Member, the presence of spirorbid worms throughout the clastic split indicates that the channel may have been under tidal or marine influence during parts of its existence and the presence of conodonts in the upper bench of coal indicates that the influence of brackish to marine waters may have persisted or resumed after the distributary function of the channel was abandoned. In the Mahakam River delta of Indonesia, abandoned fluvial channels modified by tidal activity have been mapped in the 'interdistributary' area of the delta (Gastaldo and Huc, 1992). If this is the case for the Leslie Cemetery paleo-channel, then both the clastic split and upper bench of coal may have had significant influx of brackish/marine waters before that part of the channel was abandoned. Such influx could explain, in part, the differences seen in miospore assemblages from the upper and lower benches of coal.

9. Summary

Palynological and petrographic data indicate that environmental conditions near both the Leslie Cemetery and Galatia paleochannels were similar during early stages of peat accumulation. However, the conditions associated with deposition of muds of the split altered vegetation around the Leslie Cemetery paleo-

channel markedly and these differences continued even after peat accumulation resumed. Prior to deposition of the muds of the split, coal swamp miospore floras near the Leslie Cemetery paleochannel were dominated by tree-fern miospores with those of lycopsids ranking second in abundance, a similar situation to that near the Galatia paleochannel.

A general model of the development of the split at the Eby Pit is shown in Fig. 11. It should be noted that here the channel does not erode the lower bench of coal, but it has been shown to do so elsewhere (Eggert, 1984). The upper part of the lower bench of coal is inertinite-rich, which may be the result of frequent wild fires (Scott and Jones, 1994). A typical clastic-swamp flora is preserved in the mudstones of the Folsomville Member. Pteridosperms and, in some places, lycopsids are the dominant elements of the megafossil assemblages; lycopsid miospores, particularly those produced by *Lepidodendron*, *Lepidophloios* and *Diaphorodendron* dominate miospore assemblages. The flora and vegetation from these clastic environments overlap with those of contemporaneous mires (coals), particularly the 'ecotonal' settings in which pteridosperms were most abundant (Gastaldo, 1987; DiMichele and Phillips, 1988). The split deposits are floristically distinct from contemporaneous 'levee' deposits where soil saturation levels may have been lower and diversity considerably higher (Scott, 1977, 1978; Gastaldo, 1987). This leads to the conclusion that, although the physical character of the Leslie Cemetery paleochannel deposits differs markedly from the peat substrates of mires, the floras in this part of the Springfield peat swamp landscape were drawn from a complex of plants that most commonly colonized nutrient-rich, but wet, habitats, including clastic substrates and clastic-enriched parts of the peat swamps.

The resumption of peat accumulation to form the upper bench of coal above the Folsomville Member is tied to another vegetational change. Miospores of

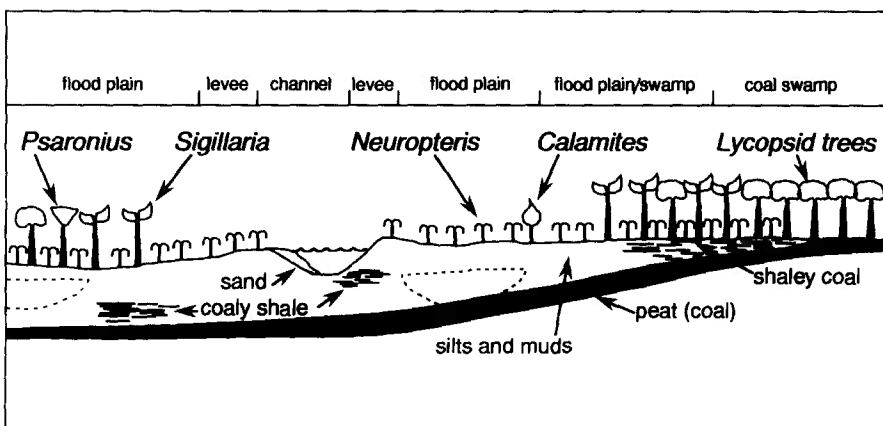


Fig. 11. Generalized model of development of clastic split (Folsomville Member) in Springfield Coal Member (Petersburg Formation), Eby Pit, Lynnville Mine, Warrick County, Indiana. Lycopsid trees as reconstructed here, include *Diaphorodendron*, *Lepidophloios*, *Lepidodendron* and *Paralycopodites*.

'ecotonal' lycopsids reach their peak abundance near the base of the upper bench, where inertinite levels are also high, possibly due to oxidation of the peat. Clastic megaflores from organic shales at the base of the upper bench and coalballs from the base of the upper bench (Phillips et al., 1985) contain a mixed lycopsid-pteridosperm flora characteristic of a transitional character from muds to peats. Tree-fern and lycopsid miospore composition in the upper bench of coal differs from the lower bench and from other sites in the Springfield coal bed. These differences and the presence of marine-brackish water conodonts in the upper bench indicate that the water for the upper bench and split may have been influenced by marine or tidal conditions shortly before abandonment. Sites near the Galatia paleochannel in Indiana apparently did not experience this influence. Near the Galatia paleochannel, clastics replace the Springfield coal bed completely (Eggert et al., 1983), with little splitting of the coal itself, and the paleochannel and adjacent coal are covered by nonmarine gray shales (Hopkins, 1968). In contrast, the coal near the Leslie Cemetery paleochannel is split extensively and coal in the entire region is covered by a black, marine shale roof (Eggert et al., 1983). It is likely that vegetational changes in the upper bench of coal result, at least in part, from the influx of brackish-marine waters into the peat.

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