Mineral Matter and Petrography of Microenvironments in the Springfield Coal (V) in Southwestern Indiana

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Introduction

The Springfield coal member (V) of the Petersburg formation along with the stratigraphically equivalent Harrisburg coal (No. 5) of Illinois and the number 9 seam in Kentucky represent the most widespread mineable coal in the Illinois basin (Figure 1). As with other eastern coals, the heating value is very high averaging around 12800 BTU/lb., but the detrimental sulfur content is very high averaging about 3.3% (6). A relationship between sulfur content and depositional environment is well known (4). Low sulfur coals are often associated with contemporaneous sandstone channels and coal with a fluvial gray shale or sandstone roof rock is likely to have a lower sulfur content than coal in the same seam which is overlain by marine or brackish black shale.

Relationships of other mineral constituents and the petrographic constituents of the coal itself with depositional microenvironments are less well known. Depositional microenvironments in the Springfield coal range from nonmarine fluvial to brackish and marine backswamp (1). This study is an attempt to examine coals from these different microenvironments for mineral content and petrographic characteristics to determine if any useful diagnostic relationships exist.

Geologic Setting and Sampling

The Illinois basin is an intracratonic depression encompassing most of central and southern Illinois, southwestern Indiana, and western Kentucky (Figure 1). The basin underwent slow subsidence throughout Pennsylvanian time and was characterized by a broad delta platform resulting from sediment brought in by a large river system from the northeast. As this delta complex advanced across the basin, its fluctuating shoreline often produced a cyclic pattern of alternating marine and nonmarine sediments (7). The delta provided a vast lowland area upon which swamp vegetation accumulated to form peat and ultimately coal.

The Springfield coal ranges from 3 to 13 feet in thickness and extended over almost the entire Illinois basin (Figure 1). The Springfield coal is at the top of the Petersburg formation which is the middle formation of the Carbondale group (Figure 2). The Petersburg formation consists mainly of shales and sandstones which underly the Springfield coal. In places the Springfield coal is partially or completely cut out by sandstone channels. These fresh water deltaic distributary channels apparently represented quite a different microenvironment from the backswamp regions flanking them. Palynological evidence suggests that the flow may have varied somewhat with distance from such channels. The sulfur value of coal deposited near a channel is often considerably lower than that of the rest of the seam (4).

FIGURE 1. *Extent of Springfield Coal (V) and Its Equivalents in the Illinois Basin.*

A total of six sets of samples were collected at two locations in Pike County, Indiana and one in Wabash County, Illinois (Figures 3 and 4). These locations were chosen with reference to their proximity to the major sandstone channels known to cut through the Springfield coal in these areas. Samples 1 (ABC) and 2 (ABC) were collected from Old Ben Coal Company's West Field Pit in Pike County and Samples 3 (ABC) and 4 (ABC) were collected from Old Ben's Alford Pit. Samples 3 and 4 were adjacent to a sandstone channel and samples 1 and 2 were about 4.5 miles from the nearest channels. Samples 5 (ABC) and 6 (ABC) were collected from Amax Coal Company's Wabash mine in Wabash County, Illinois. Sample 5 was adjacent to a sandstone channel and sample 6 was 3.5 miles away from the channel.

At each location three channel samples representing approximately the top, middle, and bottom third of the seam were collected. The only exception was at location 2 where an 8 inch fusain interval was sampled separately as 2F. All part-

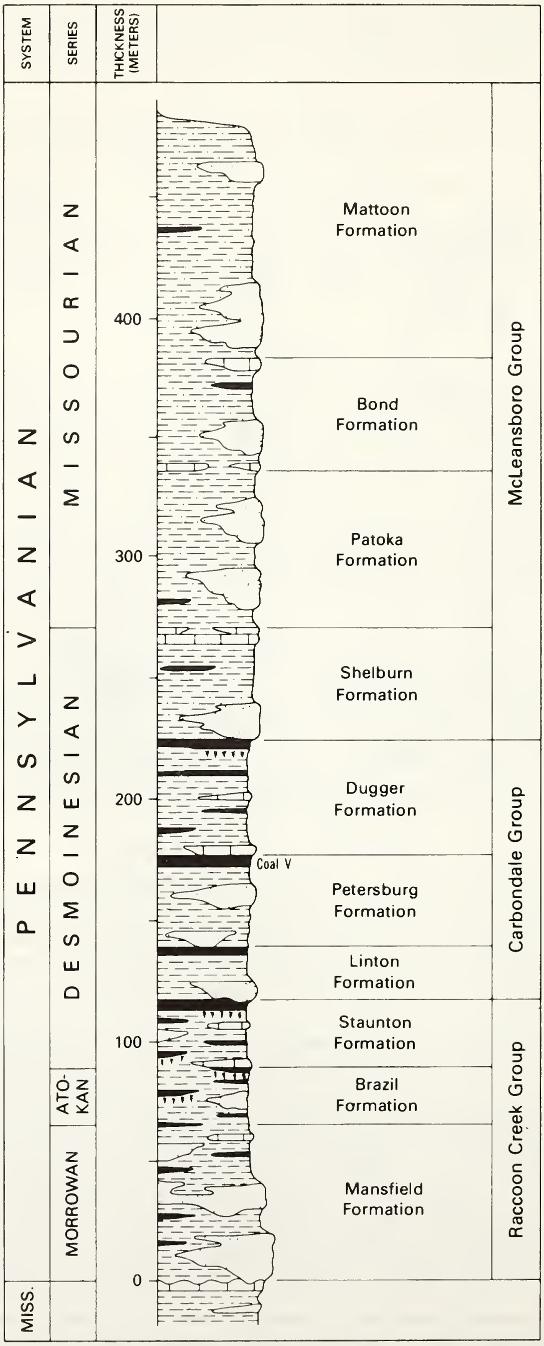

FIGURE 2. *Stratigraphic column of Pennsylvanian Rocks in Indiana (4).*

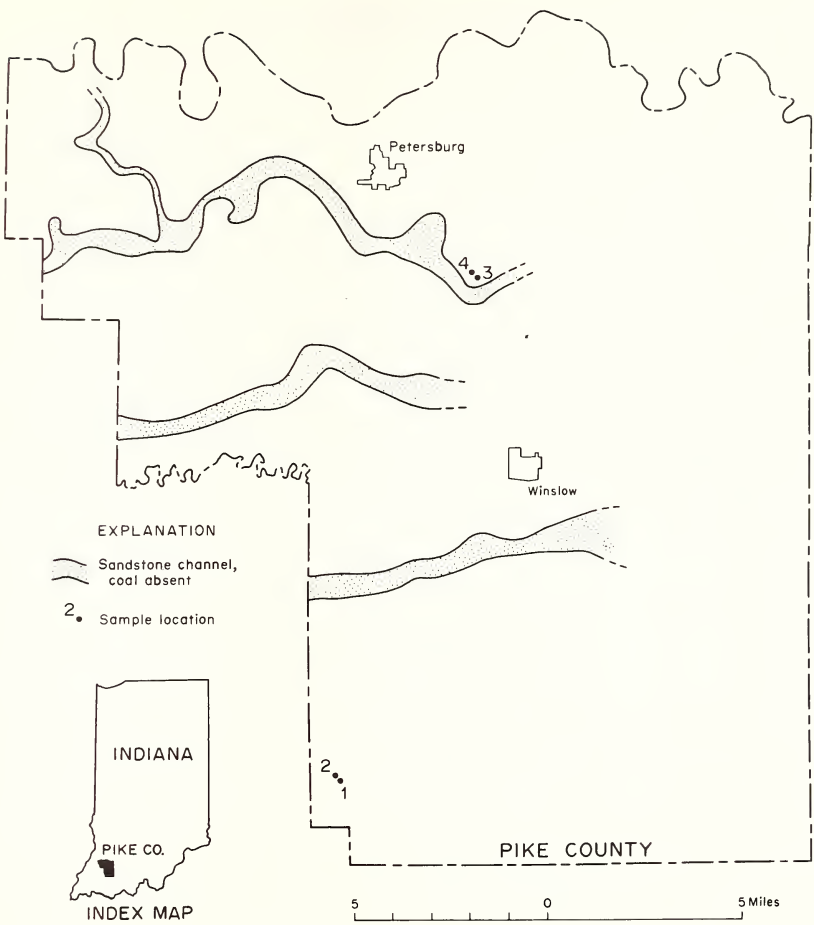

FIGURE 3. *Location of Samples and Sandstone Channels in the Springfield (V) Coal in Pike County, Indiana.*

ings and concretions more than 3/8 inches thick were excluded from the samples but were sampled separately.

Laboratory Procedures

In addition to hand specimens which were crushed to minus 20 mesh and made into polished pellets for petrographic analysis, each channel sample was ground using a very small crusher which automatically separated 20% of the total volume. After splitting the ground sample, the remaining sample was pulverized to a fine powder using a laboratory Raymond mill. About 1.75 grams of each powdered sample were ashed at a temperature of less than 150°C using a Trapeloh TA-504 low-temperature asher. The residue from the ashing process was x-rayed to determine the minerals present.

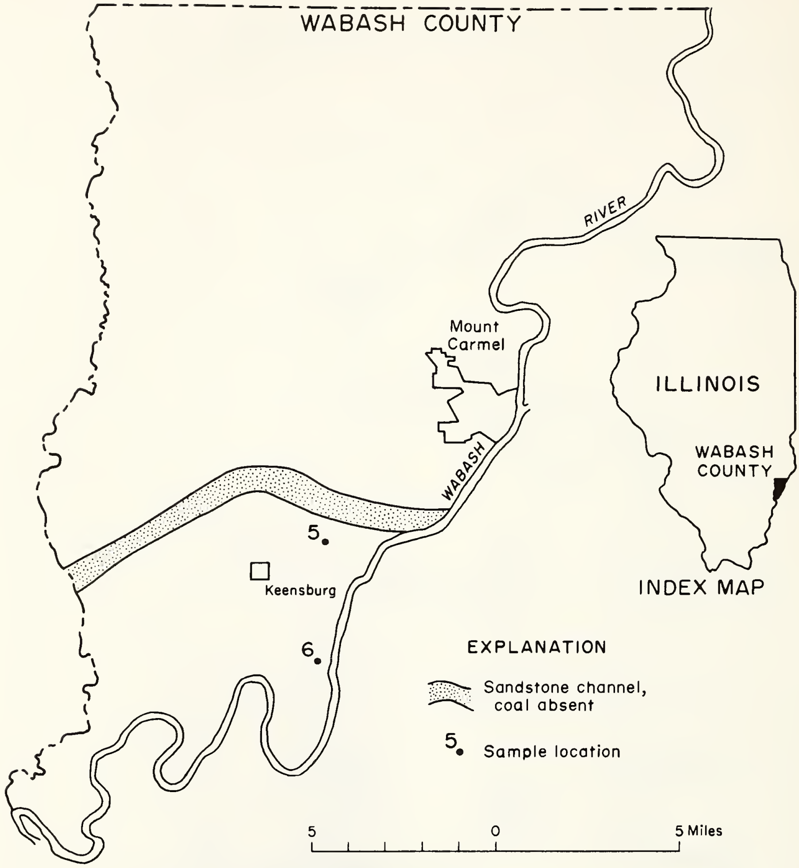

FIGURE 4. *Location of Samples and Sandstone Channel in the Springfield (V) Coal in Wabash County, Illinois.*

The petrographic analyses were carried out according to the combined maceral microlithotype analysis procedure outlined in the International Handbook of Coal Petrography. A minimum of 1200 points were counted on each pellet. From the data the percentages of macerals and minerals, microlithotypes and carbominerites, and the components of individual microlithotypes were determined.

Results and Discussion

The results of the low temperature ashing are shown in Figure 5. With the exception of sample 6 the highest ash percentage is in the top third of the seam followed by the bottom, with the lowest percentage in the middle. The minerals present in the ash were identified by x-ray diffraction and are shown in Table 1. The clay minerals kaolinite, and illite, quartz, and pyrite were present in every sample. In most samples the illite showed a mixed layer component smectite. The highest concentration of the clay minerals were found in the top third or bottom third of the

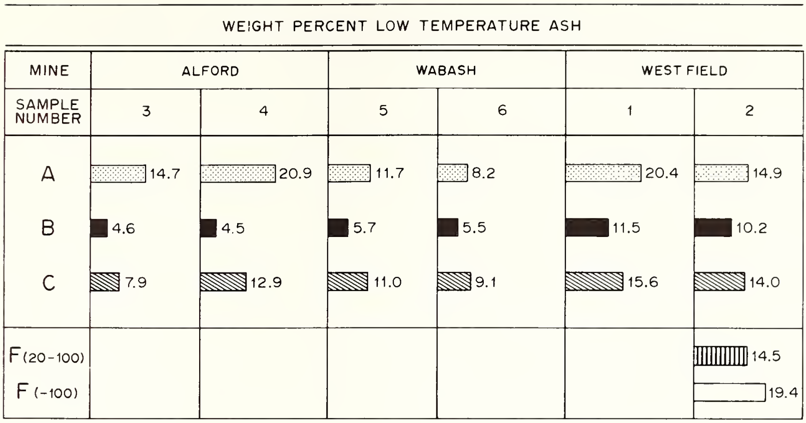

Figure 5. *Percentage of Mineral Matter Residue from Low Temperature Ashing.*

Table 1. *Minerals present in low-temperature ash samples as determined by x-ray diffraction.*

Sample Number	1A	1B	1C	2A	2B	2C	2F -20	2F -100	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	6C
Qtz.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fspar.	X			X			X		X	X	X	X	X				X	X	X	X
Kao.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ill.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chlor.									X	X		X					X	X		
Pyr.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Calc.	X	X	X	X	X	X	X	X					Y	Y	X	X	X	X	X	X
Dolo.	X															X				
Sid.	X						X	X	X			X			X	X	X			
Ank.									X			X								
Anhyd.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Szom.	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X

Qtz.—quartz; Fspar.—feldspar; Kao.—kaolinite; Ill.—illite (and mixed layereds); Chlor.—chlorite (and mixed layereds); Pyr.—pyrite; Calc.—calcite; Dolo.—dolomite; Sid.—sidzerite; Ank.—ankerite; Anhyd.—anhydrite, Szom.—szomolnokite.

X indicates the mineral is present

Y indicates the mineral is present, but in considerably smaller amounts than elsewhere.

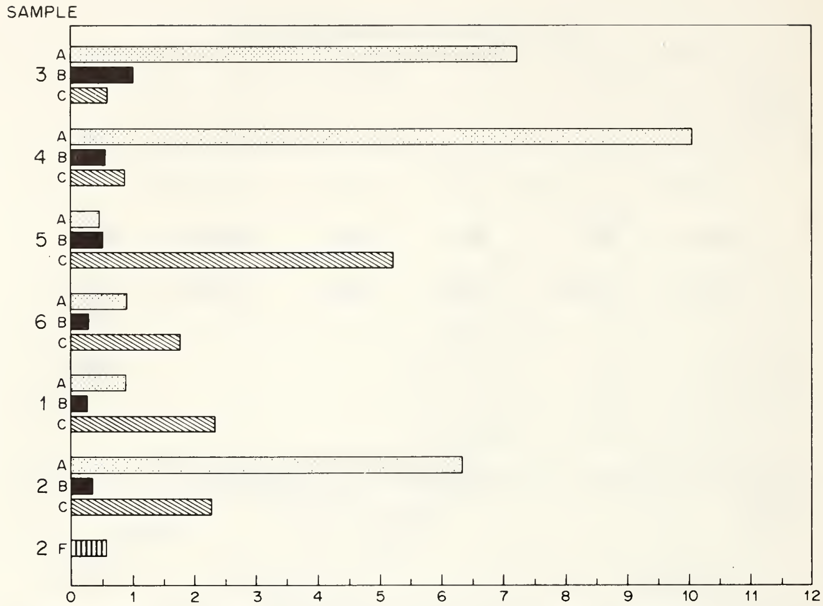

FIGURE 6. *Volume Percent Clay.*

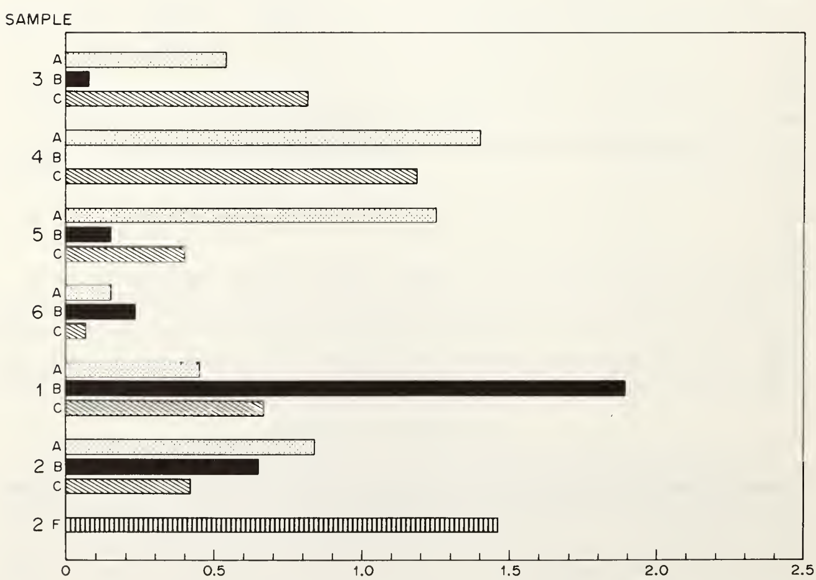

FIGURE 7. *Volume Percent Pyrite.*

seam as shown on Figure 6. Also the amount of clay minerals present decreased farther from the sandstone channel. Quartz was more abundant in the top and bottom third of the seam but was more evenly distributed throughout the seam at locations closest to the sandstone channels.

Pyrite was more concentrated in the top and bottom third of the seams (Figure 7) and the highest concentration of pyrite were found at locations 1 and 2 where the coal was overlain by black shale. The least amount of pyrite was found under gray shale at location 3 and 6. The vertical distribution of pyrite appears to depend on the distance of the sample location from a sandstone channel. Near the channel the pyrite is concentrated in the top and bottom of the seam whereas away from the channel the highest concentrations are in the middle of the seam. Also the form of the pyrite changes with distance from the channel. Away from the channel, there is a change in dominance from tiny euhedral to larger euhedral to framboidal forms. Euhedral pyite grains are shown in Figure 8 and framboidal pyrite in Figure 9. It has been suggested that pyrite takes on a framboidal shape as a result of the activity of sulfate reducing bacteria (5). These cannot tolerate the low pH of fresh water peats (2) and as a result more sulfate reducing bacteria and therefore more framboidal pyrite are found in the backswamp microenvironment.

Calcite abundance is highest in the backswamp areas and lowest near the channel. Its presence appears to be related to the higher pH brackish and marine swamp areas.

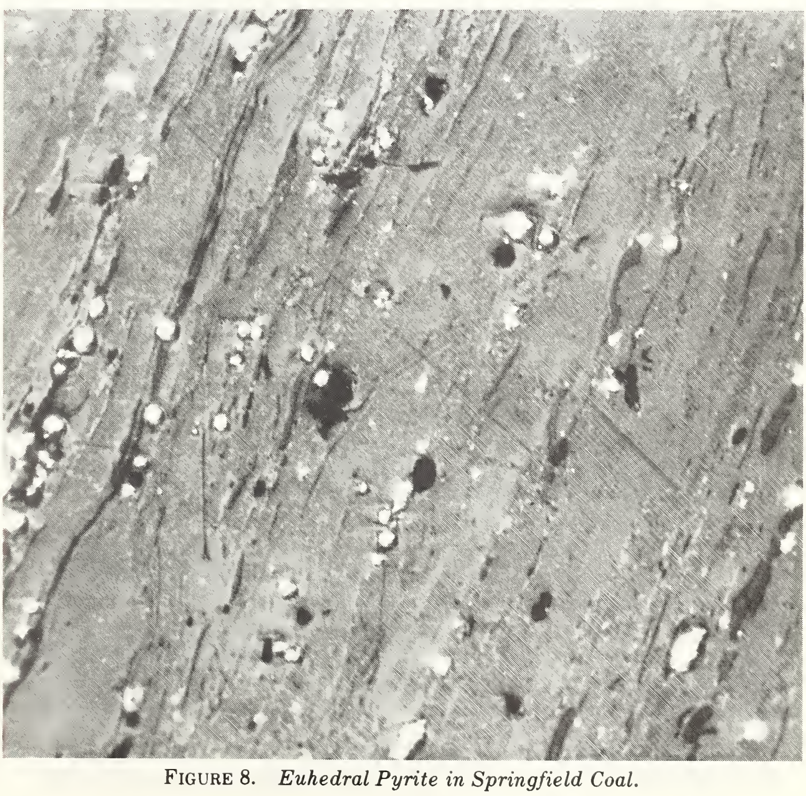

FIGURE 8. *Euhedral Pyrite in Springfield Coal.*

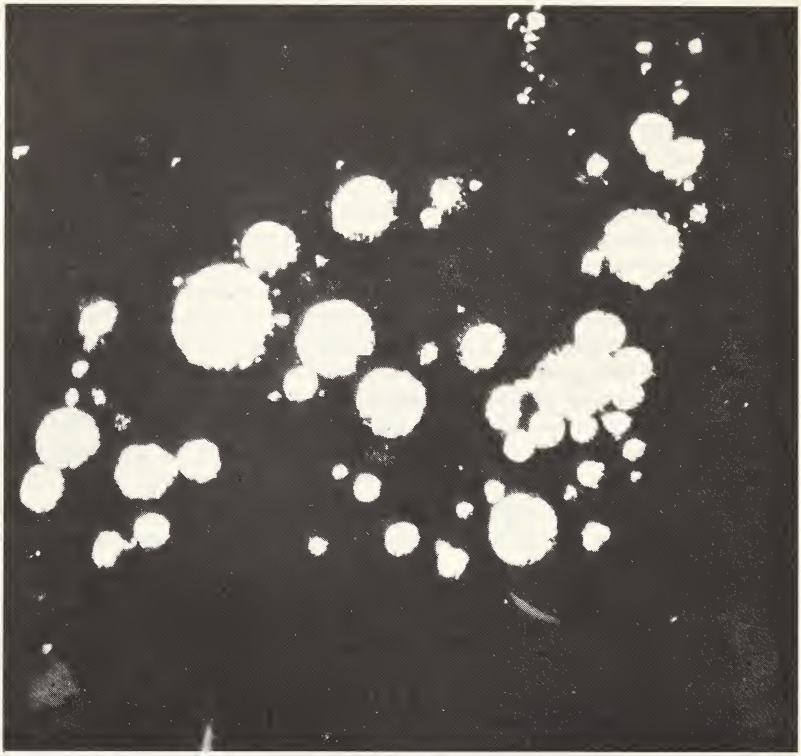

FIGURE 9. *Framboidal Pyrite in Springfield Coal.*

The distribution of the maceral groups helped to formulate a picture of how conditions in the coal swamp varied through time and with distance from the delta distributaries which meandered through the swamp. Vitrinite is by far the most abundant maceral comprising about 90% of most of the samples (Figure 10) which is indicative of a forest swamp environment. The swamp was populated primarily by tree ferns and lycopoda (1), the woody parts of which served as the raw material for the vitrinite. Inertinite abundance peaks in the middle of the seam (Figure 11). Inertinite is a product of the same types of materials which produce vitrinite except that inertinite was subjected to a certain amount of oxidation during the peat formation. The increase in inertinite percentage in the middle of the seam may indicate that there was shallowing and an increased subaerial exposure because of a drop in water level or a build up of peat and organic debris above the water surface. Exinites in general reached their greatest abundance in the top third of the seam. Exinites are composed of such resistant materials as spore exines and leaf cuticles. This would indicate more decay of the woody material and relatively a higher percentage of exinite. As the swamp matured then there would be more frequent subaerial exposure and decay which appears to be the case.

In addition to the vertical variations there was some horizontal changes in relative abundance of the macerals. The exinite content was highest closest to the

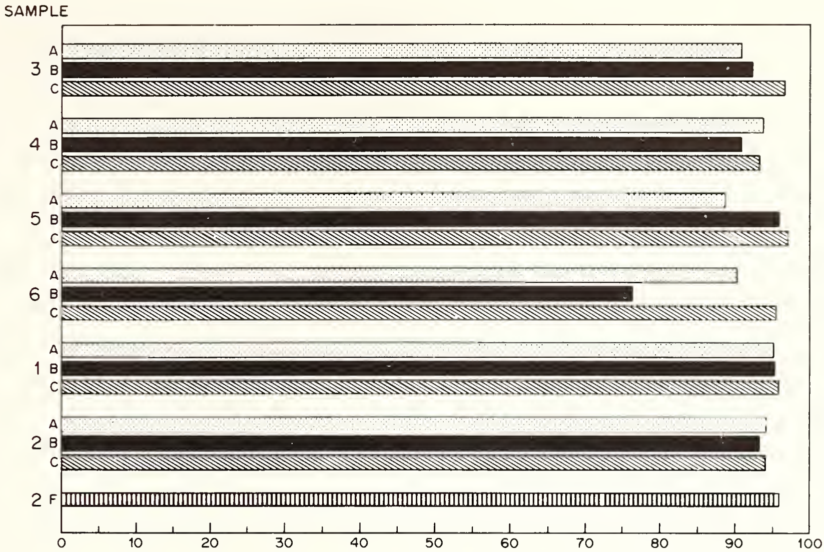

FIGURE 10. *Volume Percent Vitrinite.*

fresh water channels indicating that the more oxygenated water entering the swamp stimulated aerobic bacterial decay of the woody substances leaving a higher percentage more exinite behind. The intertinite content increases with distance from the channel indicating more aerial exposure of the woody material.

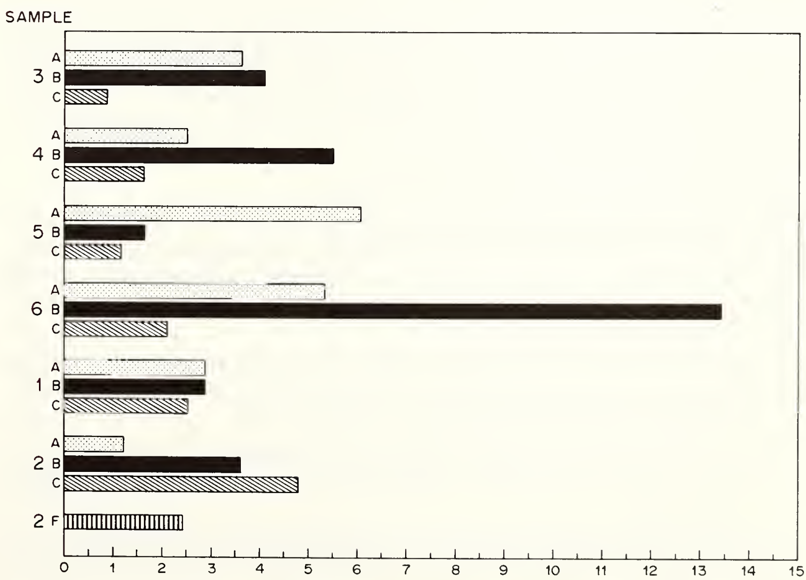

FIGURE 11. *Volume Percent Inertinite.*

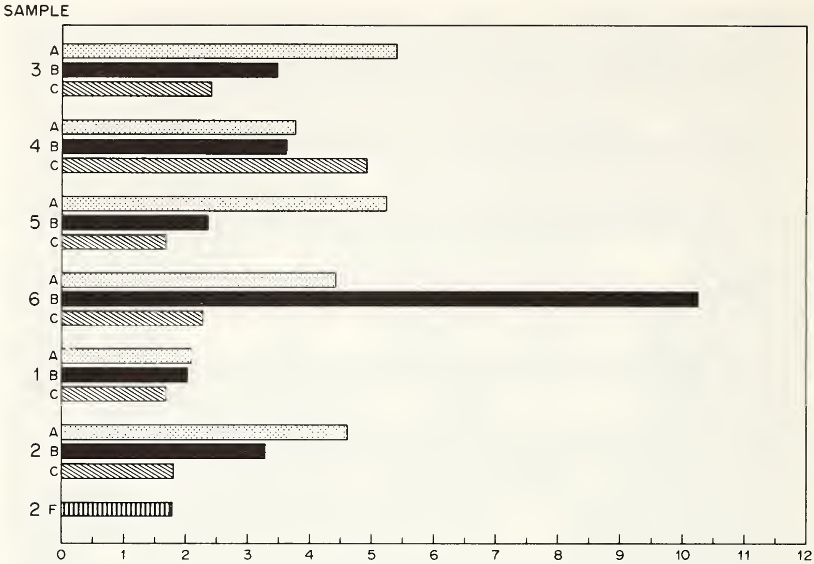

FIGURE 12. *Volume Percent Exinite.*

Conclusions

A detailed microscopic study of macerals and a determination of the mineral matter in coal can provide a better understanding of the microenvironments of deposition in a coal swamp. The relative abundance of the macerals can indicate the water conditions and the amount of subaerial exposure in the swamp as it progressed through time. The detrital mineral matter is highest near the distributary channels and the form of the pyrite changes relative to the distance from the channels with the framboidal pyrite more abundant in the backswamp brackish microenvironments.

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