Trace Elements of the Springfield (V) Coal and Characteristics of Associated Rocks

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Introduction

The Springfield (V) coal member is an important commercial coal in Indiana and the Illinois basin where the Illinois Harrisburg (5) coal and the Kentucky #9 are stratigraphically equivalent to the Springfield. This coal accounts for some 30% of the coal reserves in the Illinois basin (Malhotra, 1977). In Indiana the Springfield coal (V) member accounts for 35% of the annual coal production (Ault et al, 1979). It is a high volatile bituminous coal with an average heat value of 11,500 BTU's per pound, an average ash content of 12%, and an average sulfur value of 3.3%.

The Springfield coal extends from Vermillion County to Warrick County and ranges from 3 to 13 ft. in thickness. Coal V is at the top of the Petersburg formation which is the middle formation of the Carbondale group (Figure 1). The Petersburg

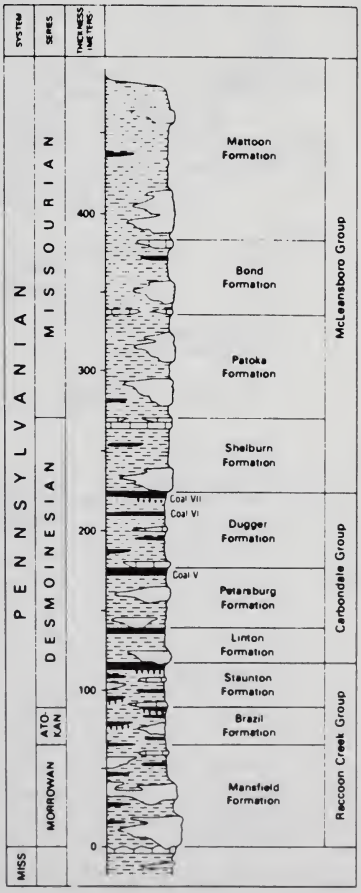

FIGURE 1. Stratigraphic section of Pennsylvania rocks in southwestern Indiana

formation consists mainly of shales and sandstones and in places the Springfield coal (V) member is partially or completely cut out by sandstone channels. These fresh water deltaic distributory channels apparently represented quite a different microenvironment from the backswamp region flanking them. The sulfur value of coal deposited near a channel is often considerably lower than that of the rest of the seam (Eggert, 1983).

Samples were collected from areas near a sandstone channel in Pike County, Indiana, and Wabash County, Illinois, and in backswamp areas distant from the channels (Figures 2 and 3). Samples were collected from the Old Ben Coal Company mines in Pike County, Indiana, and from the Underground Amax mine in Wabash County, Illinois. The coal seam was divided into thirds and channel samples of each third were collected.

Coal Petrography and Mineraology of Associated Rocks

Vitrinite is the most abundant maceral comprising about 90% of the samples which is indicative of a forest swamp environment (Murray and Mathews, 1981). In-

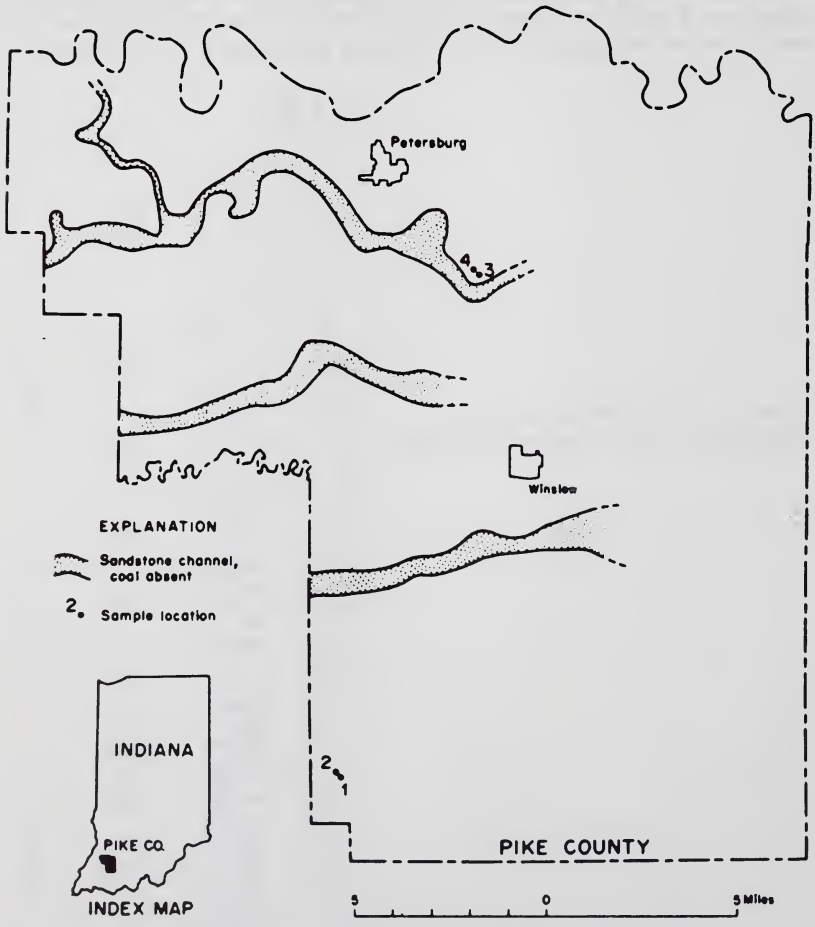

FIGURE 2. Sample locations in Pike County, Indiana

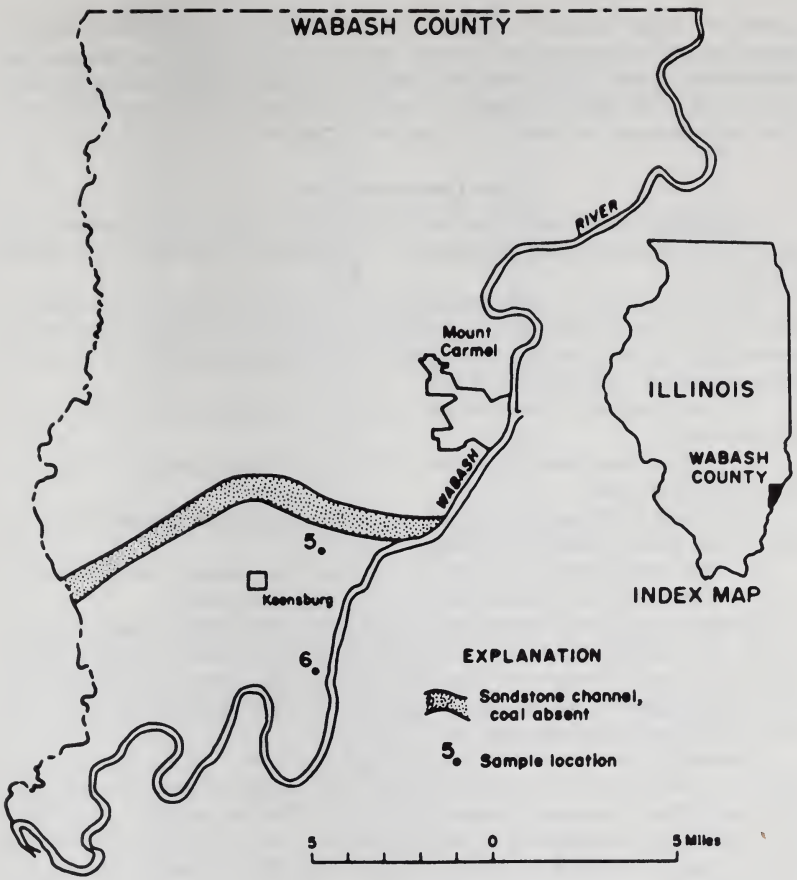

FIGURE 3. Sample locations in Wabash County, Illinois

tertinite and exinite comprise the remainder of the maceral content and are present in about equal proportions. The coal swamp is populated primarily by the tree ferns and lycopoda (Ault et al, 1977), the woody parts of which are the parent material for vitrinite. Inertinite is a product of the same types of materials that produce vitrinite except that intertinite was subjected to oxidation during the peat formation. Exinite is comprised of more resistant material, such as spore exines and leaf cuticles.

The mineral matter in coal V is comprised largely of quartz, kaolinite, illite, and pyrite along with anhydrite, feldspar, calcite, and siderite. The highest percentage of mineral matter was in the top and bottom thirds of the coal seam (Murray and Mathews 1981). The highest concentration of pyrite was where the coal was overlain by black shale and the least amount was found when the coal was overlain by gray shale.

The mineralogy of the associated rocks reflects their lithology. In the underclay the major minerals are kaolinite, illite, a mixed layer smectite-illite, and quartz. The black fissile shale contains quartz, kaolinite, illite and chlorite with minor amounts of feldspar, pyrite, siderite, and calcite at locations 1 and 2. At location 3 a light gray shaly sandstone is comprised largely of quartz along with kaolinite, illite, and

chlorite with minor amounts of feldspar, calcite, and pyrite. At locations 4 and 5 a blocky gray shale above the coal contains kaolinite, illite, chlorite, and quartz along with feldspar, calcite, and siderite. The dominant minerals in each rock type are illite and kaolinite in the underclay, illite in the black, fissile shale, quartz in the shaly sandstone, and illite and kaolinite in the gray blocky shale.

Trace Elements in Coal V

Goldschmidt (1935) was one of the first to recognize that coal incorporated certain trace elements including germanium in concentrations well above their crustal average.

Many trace element studies have been performed on coals including studies by Zubovic et al (1960), Yudovich et al (1972), Rich et al (1974), Gluskoter et al (1977), Abernethy et al (1969), and Kuhn et al (1980). The following generalizations have been made concerning trace elements in coal.

1. Trace elements are commonly enriched in the upper and lower most parts of coal seams.
2. Certain trace elements vary in concentration with the amount of inorganic mineral phases present.
3. Several trace elements including Ge, Zn, Ni, and Pb are enriched well above their normal crustal abundance ("Clarke" value).
4. The concentration and distribution of certain trace elements are often related to the provenance of the sediment and the paleodrainage patterns.

Zubovic et al (1960) believed that the concentration in coals of elements V, Ni, Cu, Nd, Co, which are commonly enriched in mafic rocks, show the composition of the sediment source. Because mafic minerals weather readily under near surface conditions, younger coals should be more enriched in these trace elements over sialic trace elements such as Be, B, Ga, Ge, Mo, Y, and La.

Samples of coal V were chemically analyzed for Al, Fe, Mg, Ca, Na, K, Ti, P, Ba, Cr, Cu, Ni, Pb, Sr, V, Y, Th, and Zn using an ICP spectrometer. Low temperature ashed samples were analyzed colorimetrically for Ge. The analyses show all elements are present in lower concentration than their crustal average except for Ti and Pb. Table 1 shows the statistics for elements in coal V and Table 2 shows enrichment factors compared to their "Clarke" value.

The fraction of the coal into which a particular element partitions is a function of the chemical affinity of the element for that fraction. Elements with strong affinity for silicate minerals are preferentially incorporated into clay minerals in the coals. Aluminum, potassium, and titanium are the most strongly associated with silicate minerals in these samples but the correlation analyses shows chromium, strontium, and yttrium are also associated with the silicates (Yates, 1984). Copper, barium, and vanadium correlate with the lithophite elements and with the percentage of clay in the samples but they also have strong affinities for other sites in coal.

The correlation between the chalcophile elements iron, zinc, lead, copper, and nickel with the pyrite percentage in these samples is low. Iron has a weak correlation with pyrite but the other chalcophile elements do not correlate with the amount of pyrite or with each other. Nickel and germanium correlate with each other and are enriched strongly in the upper and lower most parts of the seam. Both of these elements have strong organic affinities and are probably incorporated into organic material in these coals.

Summary

The Springfield coal (V) member was deposited in a large deltaic swamp and

TABLE 1. Statistics for Trace Elements in Coal V

	ARITHMETIC MEAN	GEOMETRIC MEAN	STANDARD DEV.	COEFF. OF VARIATION
Al	1.4717	1.2912	0.9612	0.6531
Fe	2.1224	1.5412	1.5553	0.7328
Mg	0.0840	0.0552	0.1045	1.2440
Ca	0.6820	0.3572	1.1042	1.6191
Na	0.0530	0.0407	0.0315	0.5943
K	0.0816	0.0548	0.0631	0.7733
Mn	0.0042	0.0031	0.0041	0.9762
Ti	0.0801	0.0745	0.0336	0.4195
P	0.0356	0.0282	0.0263	0.7388
Ba	312.0000	221.0000	303.3000	0.9721
Cr	12.7000	11.4299	6.8141	0.5365
Cu	15.8250	7.6370	31.2394	1.9741
Ni	28.1450	13.9048	61.6808	2.1915
Po	23.5000	16.7325	21.1106	0.8983
Sr	84.3750	40.0918	151.7470	1.7985
Th	3.8158	3.5931	1.3040	0.3417
V	22.8000	17.5220	20.1039	0.8918
Y	11.2750	9.5068	8.7981	0.7803
Zn	49.6500	25.4858	62.4340	1.2575
Ge	1.1173	0.2677	1.7207	1.5401

TABLE 2. Comparison of Trace Elements of Coals in the Illinois Basin with the "Clarke" Value

	ILLINOIS BASIN	EASTERN BASIN	CLARKE VALUE
Al	1.0760	0.7595	0.1569
Fe	0.7706	1.0275	0.2737
Mg	1.1040	0.9200	0.0237
Ca	0.5481	0.7813	0.0885
Na	0.8140	1.0175	0.0172
K	0.3812	0.2592	0.0310
Mn	0.5849	1.7222	0.0326
Ti	1.2417	0.8278	1.3070
P	4.4062	1.8800	0.2686
Ba	2.2100	1.1050	0.5200
Cr	0.6350	0.5715	0.1143
Cu	0.5455	0.4243	0.1389
Ni	0.6621	0.9270	0.1854
Po	0.5229	2.4250	1.3386
Sr	1.1455	0.3084	0.1069
Th	1.7966	0.7895	0.3743
V	0.5476	0.4611	0.1298
Y			0.2881
Zn	0.1019	1.0194	0.3641
Ge	0.0388	0.1673	0.1785

was derived largely from decomposed wood and bark as evidenced by the very high percentage of the maceral vitrinite. The associated sediments above the coal correlate with the sulfur content of the coal. Black fissile shale above the coal indicates a high sulfur value and a gray blocky shale indicates a low sulfur value in the coal. Only Ti and Pb are enriched in the coal relative to their "Clarke" value whereas the others are depleted.

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