Petrographic and Trace Element Characteristics of the Hymera (VI) Coal in Indiana

HAYDN H. MURRAY, RICHARD P. HEBERTON AND ROLAND S. MERKL
Department of Geology, Indiana University
Bloomington, Indiana 47405

Introduction

The Hymera (VI) coal is one of the more important commercially mined coals in southwestern Indiana. This coal is traceable from Vigo County south through Sullivan, Greene and Knox Counties where it thins and to the south is believed to correlate with the Lower Millersburg coal in Pike, Gibson, and Warrick Counties (Wier, 1973). The Hymera coal member is part of the Carbondale group of Desmoinesian age and is in the Dugger formation (Figure 1).

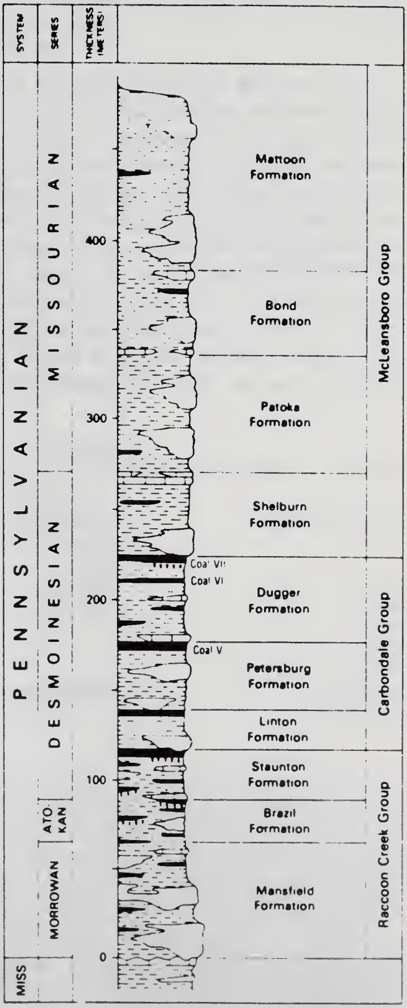

FIGURE 1. Stratigraphic section of Pennsylvanian rocks in southwestern Indiana

The Hymera coal was originally referred to as coal VI (Ashley, 1899) and is a bright-banded bituminous coal ranging from about 1 to 11 feet (15 cm to 330 cm) in thickness. The coal contains numerous thin shale and pyrite partings and is normally overlain by gray, silty shale, or fine-grained sandstone. A thin underclay usually occurs below the coal.

The stratigraphic correlation of the Hymera coal member with coals in Illinois has been uncertain. The lateral inconsistency displayed by the cyclic deposits in the Pennsylvanian in the Illinois basin is the root of this correlation problem. For many years it was believed that the Hymera correlated with the Herrin coal in Illinois but Shaver (1970) suggested that it correlates with the Jamestown coal which is above the Herrin.

In order to provide more information on the Hymera coal that might be helpful in this correlation problem, a study of the petrography and trace elements was undertaken. These results are reported in this paper from coal samples collected from locations in Sullivan, Knox, Pike, and Warrick counties in southwestern Indiana (Figure 2).

Petrography

The maceral composition of the Hymera coal member was determined from polished sections. Macerals are the fundamental building units of coal and are analogous to minerals in rocks. However, a mineral is characterized by its definite chemical composition and structural arrangement whereas a coal maceral varies widely in chemical and physical characteristics. Maceral composition directly influences the ultimate utilization of the coal. Also it, in combination with mineral and trace element analyses, permits better paleoenvironmental and sedimentological interpretations.

Maceral groups occur in humic coals in characteristic associations called microlithotypes. In this study the classification established by the International Committee for Coal Petrology was used (Int. Handbook of Coal Petrography, 1971). Details of the method used are given in a masters thesis at Indiana University by Merkl (1985). Table 1 shows the ICCP petrographic nomenclature used in this study.

TABLE 1. Macerals and Microlithotypes (ICCP, 1971)

Microlithotype Group	Group Maceral	Maceral
Vitrite	Vitrinite	Telinite
		Collinite
Liptite	Liptinite	Resinite
Inertite	Inertinite	Semi Fusinite
Clarite		Fusinite
Durite		Macrinite
Vitrinertite		Micrinite
Trimacerite	Mineral Matter	Pyrite
Carboninerite		Minerals

The macerals of coal rarely occur in association with only the same type but rather they are usually associated with macerals of the same or the other two maceral groups. Depending on their abundance, they are organized into three groups: monomaceral, bimaceral, and trimaceral microlithotypes, based on the percentage of a maceral in a microlithotype (Stach et al, 1982).

Vitrite is usually derived from stems, branches, and liquified tree roots where trees were protected from oxidation by high water level. The association vitrite and clarite, particularly exinite poor clarite, suggests a strongly decomposed forest litter

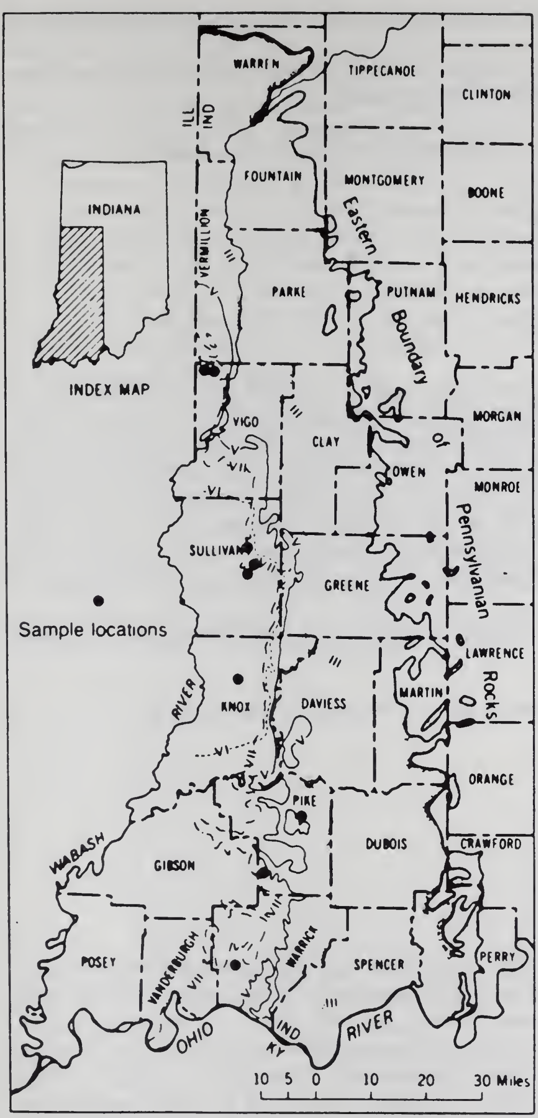

Figure 2. Map of southwestern Indiana showing sample locations

of wood and bark which was degraded to humic detritus. Exinite rich clarites are derived from reed peat and reed lignites intermingled with subaquatic deposits. Clarites often display microlayers and suggest formation under wet conditions normally associated with vitrinitic carbargillites and syngenetic pyrite. Durites are derived from a subaquatic ooze of oxidized peat characterized by a low spore content and low water table. Vitrinertites are characteristic of frequent swamp dessication.

Trimacerites, transitional microlithotypes between clarites and durites, have different histories of formation, depending on their composition which can vary between clarite and durite. Maceral group composition, type, and condition of preservation of macerals, mineral matter, and texture all contribute to a genetic explanation of a microlithotype.

The Hymera coal member is characterized by the maceral group content as shown in Table 2. This is based upon 30 bench samples.

TABLE 2. Mean maceral group content of the Hymera coal member

Vitrinite	86.2%
Exinite	5.5%
Semifusinite	0.8%
Fusinite	0.9%
Macrinite/Micrinite	1.0%
Pyrite	1.7%
Other minerals	3.9%

The vitrinite occurs predominantly as the structureless variety collinite. Stopes (1935) defined collinite as a reprecipitated gel contributed from decay of plants. Stach (1982) concluded that the lack of plant structure in coal is because the original cellular structure is masked as a result of the cells being filled with colloidal humic gel precipitated from solutions. Exinite macerals consist of waxes, resins, fats, and oils of vegetable origin (Stach et al, 1982). Exinites, usually sporinites, commonly occur in durites and trimacerites as thin discontinuous elongated stringers. The inertinite group with the macerals semifusinite, fusinite, macrinite, and micrinite occurs in smaller amounts as isolated particles.

Microlithotype analyses were also made for each bench sample and the results are shown as Table 3.

TABLE 3. Mean microlithotype content of the Hymera coal member

Vitrite	53.3%
Liptite	0.1%
Inertite	1.1%
Clarite	26.5%
Durite	0.1%
Vitrinertite	1.3%
Trimacerite	10.4%
Carbominerite	7.3%

The Hymera coal member has a high vitrite and clarite microlithotype content. Broad vitrite bands are usually derived from stems, branches, or liquified tree roots and are abundant in a forest swamp (Stach et al, 1982). Clarite was exinite poor which forms from forest peat detritus consisting of decomposed wood and bark which degraded to humic detritus (Stach et al, 1982). Teichmueller (1952) pointed out that a clarite with dominant vitrinitic composition is characteristic of coal in which branches and trees formed the more vitrinitic layers whereas finer material such as leaves, twigs, and rootlets with minor amounts of spores and protobituminens contribute more to the formation of clarite. The low content of semifusinite and fusinite indicates a constant water level in which anaerobic conditions prevailed with little exposure to oxidation or fungal activity.

Trace Elements

Interest in the abundance of trace elements in coal began early in this century and the first comprehensive study was by V. M. Goldschmidt (1935), who was the first geochemist to call attention to the relationship between certain elements and the inorganic or organic portions of the coal. Zubovic et al (1964) reported that high concentration of trace elements at the base of a coal seam represented those taken up from the original subsoil by the first plants. The main portion of the coal seam received trace elements syngenetically with the accumulation of organic matter from sources outside the swamp. He also reported that the enrichment of trace elements in the top of the coal seam is probably caused by leaching from overlying strata and then they are absorbed or precipitated in the top layers of the coal seam.

Zubovic et al (1960) studied the geochemical factors that controlled the affinity of certain elements that formed complexes with organic matter and those that are associated with the inorganic fraction of coal. Trace elements are incorporated in coals in four major ways: 1) organic-metal complexes (chelates); 2) adsorption or absorption by both the inorganic minerals and the organic matter; 3) presence within minerals deposited syngenetically with peat accumulation; and 4) reduction and subsequent precipitation usually in sulfides.

Some 40 samples of the Hymera coal member were analyzed using an ICP (Inductively Coupled Plasma Spectrometer). The sampling and analytical procedures are explained in detail in a masters thesis by Heberton (1983). The raw data was analyzed statistically and is shown in Table 4. The trace element results are given in parts per million (ppm) while the major and minor elements are given in weight percent of their oxide. The geometric means of the major and minor elements were recalculated to ppm concentration of the element in order to facilitate comparisons.

As shown in Table 4 the relative abundances of nearly all elements are depleted in the Hymera coal member on a whole coal basis. Only germanium and lead show enrichment. Figure 3 compares the geometric means of some trace elements in the

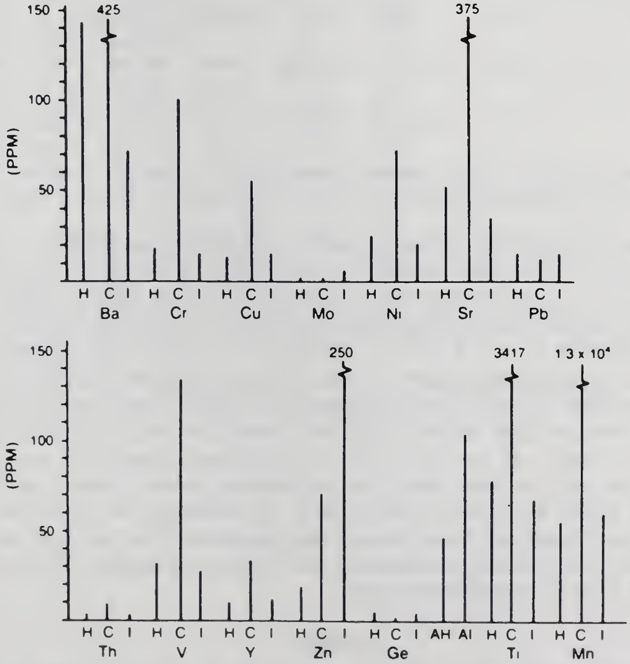

FIGURE 3. Comparative trace element concentrations between the Hymera Coal (H), the average crustal abundance (C), and the Illinois basin coals (I)

Hymera with other Illinois basin coal samples and the average crustal abundance (Clarke value). The geometric means of the other Illinois basin samples closely approximate those of the Hymra coal. The means are generally within 33 percent of each other. Three exceptions are barium, zinc, and molybdenum. Barium is twice as concentrated in the Hymera as in the other Illinois basin coals while molybdenum is five times and zinc four times as concentrated in the Illinois coals over the Hymera coal.

TABLE 4. Chemical and trace element composition of Hymera coal member.

PPM	Arithmetic Mean	Geometric Mean	Standard Deviation	Range	Clarke (Taylor, 1964)	Calc. ppm
(Air-Dry Whole Coal Basis)						
Barium	169.41	143.2	72.9	44-582	425	—
Chromium	21.1	18.9	8.2	7-39	100	—
Copper	20.9	13.4	16.7	6-129	55	—
Molybdenum	1.75	1.75	1.0	0-7	1.5	—
Nickel	27.9	19.9	18.05	4-87	75	—
Lead	32.35	17.6	31.27	4-171	12.5	—
Strontium	132.3	52.77	166.4	12-846	375	—
Thorium	3.1	2.49	1.6	1-12	9.6	—
Vanadium	43.65	31.5	30.8	13-150	135	—
Yttrium	10.65	9.6	4.0	5-22	33	—
Zinc	27.85	19.55	17.9	5-149	70	—
Germanium	8.91	5.81	7.0	1.5-65.5	1.5	—
(Weight % of Oxide)						
Aluminum	2.93	2.62	1.09	1.08-4.92	8.23	1.39×10^{4}
Iron	3.90	1.99	3.29	0.45-19.2	5.63	1.39×10^{4}
Magnesium	0.15	0.11	0.099	0.038-0.576	2.33	6.63×10^{2}
Calcium	0.36	0.21	0.27	0.052-2.76	4.15	1.50×10^{3}
Sodium	0.08	0.06	0.046	.021-.205	2.36	4.45×10^{2}
Potassium	0.2	0.16	0.117	.040-.519	2.09	1.33×10^{3}
Manganese	0.014	0.006	0.015	.001-.034	0.095	4.45×10^{1}
Titanium	0.145	0.128	0.061	.052-.251	0.57	7.67×10^{2}
Phosphorus	0.039	0.026	0.031	.007-.149	0.105	1.13×10^{2}
Low-Temp. Ash	20.97%	17.2	—	8.67-55.3	—	—

Germanium, chromium, nickel, vanadium, and yttrium are enriched in the top and bottom of the coal seam compared to that present in the middle of the seam. The reasons for this concentration are probably those given by Zubovic (1964) as discussed earlier in this section. Calculation of the ratio of the mafic and felsic trace elements abundance in coals 5 and 6 of Illinois and the Hymera coal member of Indiana resulted in confirming Shaver's et al (1970) belief that the Jamestown coal of Illinois is equivalent to the Hymera coal member of Indiana. Potter and Siever (1956) pointed out that the trace element character of sediments being washed into the Illinois basin changed with time during the Pennsylvanian. Utilizing this concept and calculating the mafic to felsic ratios gave the following values: Illinois coal 5 (3.9); Illinois coal 6 (6.9) and Hymera coal VI (8.3). This indicates that the Hymera was deposited after Illinois coal 6 and because the Jamestown is the first coal deposited after coal 6 it most probably correlates with the Hymera coal member. The exact procedure used is given by Heberton (1983).

Summary

The Hymera coal member was deposited in forest peat swamps under brackish water influence as indicated by the presence of syngenetic pyrite and the abundance of vitrite and clarite. The trace elements show a depletion in most trace elements compared to their "Clarke" values except for germanium and lead. No trace element was present in quantities that were high enough to consider commercial recovery. A calculation of the mafic to felsic ratio using trace elements indicate that the correlation of the Hymera coal member with the Jamestown coal of Illinois is probably correct.

Literature Cited

1. Ashley, G. H. 1899. The Coal Deposits of Indiana. Indiana University Department of Geology and Natural Resources Annual Report 23, 1573 pp.
2. Goldschmidt, V. M., 1935. Rare Elements in Coal Ashes. Ind. Eng. Chem., V. 27, p. 1100-1102.
3. Heberton, R. P., 1983. Trace and Minor Element Analyses of the Hymera Coal Member of Indiana (Coal VI). Masters Thesis, Indiana University, 107 pp.
4. International Committee for Coal Petrology 1963, 1971. International Handbook of Coal Petrography, 2nd ed. Centre National de la Recherche Scient. Figue, Paris.
5. Merkl, R. S., 1985. Petrographic and Depositional Characteristics of the Hymera and Danville Coal Members in Southwestern Indiana. Masters Thesis, Indiana University, 67 pp.
6. Potter, P. E., and Siever, R., 1956. Sources of Basal Pennsylvanian Sediments in the Eastern Interior Basin: Part 1. Cross-bedding. Journal of Geology, Vol. 64, p. 225-244.
7. Shaver, R. H., et al, 1970. Compendium of Rock Unit Stratigraphy in Indiana, Indiana Geological Survey Bull. 43, 229 pp.
8. Stach, E., 1965. Basic Principles of Coal Petrology: Macerals, Microlithotypes and Some Effects of Coalification. In Coal and Coal Bearing Strata, Inter-Univ. Geol. Congress 13, Murchison, J. and Westall, T. (eds.). Univ. of New Castle-Upon-Tyne, p. 19-29.
9. Stach, E. et al, 1982. Stach's Textbook of Coal Petrology, 3rd ed. Gebrueder Bormtrueqeu, Stuttgart.
10. Stopes, M. C., 1935. On the Petrology of Banded Bituminous Coals. Fuel 14 London, p. 4-13.
11. Teichmuller, M., 1952. Vergleichende Mikroskopische Unter Suchungen Versteinerter Torte der Ruhr Karbons und der daraus Enstandenen Steinkohlen. Compte Rendu 3, Congr. Stratig. Geol. Carboniferur, Heerlen, p. 607-613.
12. Wier, C. E., 1973. Coal Resources of Indiana. Indiana Geological Survey Bull. No. 42-I, 40 pp.
13. Zubovic, P. 1960. Minor Element Content of Coal From Illinois Beds 5 and 6, and Their Correlatives in Indiana and Western Kentucky. U.S. Geol. Survey Open File Report No. 79, p. 1.
14. Zubovic, P. T., 1964. Distribution of Minor Elements in Coal Beds of the Eastern Interior Region. U.S. Geol. Survey Bull. 1117-13, 41 pp.