Technical Report

Institute for Mining and Minerals Research
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PETROGRAPHIC CHARACTERIZATION OF
KENTUCKY COALS:

QUARTERLY PROGRESS REPORT

March 1982 to May 1982

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INTRODUCTION

The project "Petrographic characterization of Kentucky coals" consists of three specific areas of coal petrology: spectral fluorescence of liptinite macerals, properties of semi-inert macerals, and size/form/microlithotype association of pyrite/marcasite. Additional research on the Mannington and Dunbar coals in western Kentucky and the Alma coal zone in eastern Kentucky will apply techniques developed in the first three areas. Suites of coals from other states will also be studied to expand the variability in the sample set.

SPECTRAL FLUORESCENCE OF WESTERN KENTUCKY COALS

This project involves the determination of coal rank through the use of spectral fluorescence measurements on sporinite.

A suite of Allegheny Formation coals from Pennsylvania was added to the study to test both the nature of fluorescence of higher rank coals (as measured on our system) as well as the nature of similar rank coals from a different environment of deposition. All coal samples have now been studied. The data manipulation is now complete and the revisions of the final report (in the form of a master's thesis) are underway. The discussion of the results should be available in the next quarter.

SEMI-INERT MACERALS IN KENTUCKY COALS

Pseudovitrinite reflectance values for 42 of the 57 originally selected coals from eastern Kentucky's Big Sandy Coal District have been determined. Table 1 shows details of the studied samples, including a comparative listing of vitrinite and pseudovitrinite reflectances. Reflectance on the 15 remaining "Big Sandy" coals will be completed this quarter, and work will proceed to coals in one or more of the remaining five coal districts of eastern Kentucky.

Studies of pseudovitrinite in western Kentucky coals follow similar procedures used for preliminary investigations of eastern Kentucky coals: percentage of pseudovitrinite in maceral composition make-up of individual coals is determined, and comparison of pseudovitrinite reflectance with vitrinite reflectance is made. Completion of these parameters is expected this quarter and specific data will be presented in form similar to Table 1.

Examinations of physical/chemical properties of pseudovitrinite will be initiated this quarter when Vicker's microhardness analyses are begun in earnest.

PYRITE IN WESTERN KENTUCKY COALS

The characterization of western Kentucky coals continued with petrographic work to determine pyrite (and marcasite) size, morphology, and microlithotype association.

As reported from the previous quarter, pyrite analysis has been completed on the first set of samples from coal preparation plants in western Kentucky. Data reduction has been completed on these samples, however statistical analysis will not be employed until all samples are finished.

During this quarter, a second set of samples from coal preparation plants was studied. Pyrite analysis was performed on each sample, with samples representing divisions such as run-of-mine feed, total clean coal, total refuse, and for some plants different size fractions.

From one plant, pyrite was studied in samples representing specific stages of fine coal beneficiation such as froth flotation (both clean and refuse) and high gradient magnetic separation.

At this time pyrite analysis and data reduction is still in progress. The results from different methods of data manipulation will be presented in future reports.

VARIATIONS IN PETROGRAPHY AND PYRITE IN WESTERN KENTUCKY COALS

Field and laboratory studies of two Tradewater formation coals, the Dunbar and Mannington (No. 4, Mining City), are being initiated. Both coals, as well as several others in the Tradewater formation, are known to undergo significant variations in sulfur and ash content. In particular, low ash (less than 3%) and low sulfur (less than 1%) coals are found in various locations in the eastern portion of the Western Kentucky Coal Field. Using established field and laboratory petrographic techniques, as well as the procedures refined under this grant for the study of pyrite/marcasite assemblages and the study of fluorescing macerals, we hope to establish the nature of the variation in the coals from both a stratigraphic viewpoint and also in regard to the interaction of the petrographic variables. With few exceptions neither coal is extensively mined at present but both are probably present at depth throughout much of the Western Kentucky Coal Field. Knowledge of the nature of the variation in accessible sites could help predict the nature of the coals where not currently mined. The following discussion of the Tradewater Formation serves to establish the framework for future study.

The Dunbar and Mannington coals (Tradewater Formation, Pennsylvanian) are coals which characteristically have a variable sulfur and ash content. The Tradewater coals often have lower sulfur and ash contents than the middle and upper Pennsylvanian coals. These coals are also more discontinuous and thinner than later coals. The factors responsible for these variations may be partially due to differences in topography among other things but these factors have not been fully delineated as a result of inadequate study. This report will consist of a short summary of the Tradewater Formation including

the structure of the area, the stratigraphy, the paleobotany, and the paleontology, which will provide a background for further study of the coals and the depositional environments of the lower Tradewater rocks.

The Illinois Basin was a subsiding basin during most of the Paleozoic. The basin is considered to have been open to the south during most of this time because the strata generally thicken to the south and contain finer and fewer clastic sediments in the south in what appears to have been a deeper water environment (Buschbach and Atherton, 1979). This opening was later closed by faults and uplift along its southern border (Krausse and Treworgy, 1979), resulting in its present day spoon shaped structure (Buschbach and Atherton, 1979). There are two main depressional features in the Illinois Basin (Figure 1). These are the Fairfield Basin in southeastern Illinois and the Moorman Syncline in western Kentucky (Krausse, and Treworgy, 1979). The Moorman Syncline is bounded by the Shawneetown-Rough Creek Fault System to the north and the Pennyrile Fault System to the south.

The Rough Creek Fault System, which extends from central Kentucky through western Kentucky to the border of the state, is approximately five to eight kilometers wide (Rice and others, 1979). It is an east-west trending fault system composed primarily of high angle faults which have normal, reverse, and strike-slip displacement (Krausse and Treworgy, 1979). There is up to 1200 meters of vertical displacement of these faults and the dips are from 25 degrees to nearly vertical (Smith and Palmer, 1974). Along the fault zone there is no consistent direction of throw which is in contrast to the Shawnee Fault Zone where the Pennsylvanian strata are consistently downthrown to the north (Krausse and Treworgy, 1979). There are also many scissor faults and small grabens. Heyl (1972) concluded that the fault zone resulted from

FIGURE 1. STRUCTURAL FEATURES OF THE SOUTHERN ILLINOIS BASIN
(from Krausse and Treworgy, 1979).

strike-slip movement over a fracture zone in the Precambrian basement. Smith and Palmer (1974) on the other hand concluded that the fault zone formed as a result of major compressional forces from the south (Krausse and Treworgy, 1979). The major displacement on the faults is considered to have occurred in the latest Pennsylvanian to Permian with a general downward displacement to the north.

The Moorman Syncline in Kentucky is an east-west trending half graben (Whaley and others, 1979) which is bounded by the Rough Creek Fault Zone to the north, the Pennyryle Fault System to the south, and the Fluorspar Area Fault Complex to the west (Krausse and Treworgy, 1979). The Pennyryle Fault System is a group of east-west trending block faults. The Fluorspar District consists of northeast-southwest trending horsts and grabens. The Moorman Syncline is asymmetrical in structure and dips slightly to the south (five degrees) and more steeply to the north (up to forty degrees), (Krausse and Treworgy, 1979). The syncline plunges to the west from the Cincinnati Arch and it plunges and widens from the Eagle Valley to the east into the deepest part of the basin (Krausse and Treworgy, 1979). In this part of the basin the Pennsylvanian sediments may attain thicknesses over 1000 meters. The Moorman Syncline is cut at the center by the Central Faults which are northeast-northwest trending normal faults (Krausse and Treworgy, 1979).

The Pennsylvanian rocks of western Kentucky have been subdivided into four formations. The Caseyville Formation occurs at the base, followed by the Tradewater Formation (which includes the Dunbar and Mannington Coals), the Carbondale Formation, and the Sturgis Formation. The Caseyville Formation contains pebbly, the fine-grained, well-sorted orthoquartzitic sandstone, though in some areas it is dominantly siltstone and shale making it indistinguishable from the overlying Tradewater Formation above (Whaley and

others, 1979). These sandstones are thought to originate from the Canadian Shield or upland areas in northern Appalachians (Peppers and Popp, 1979). These sediments are thought by some authors (Potter and Desborough, 1965; Simon and Hopkins, 1966; Wanless, 1975) to be indicative of a deltaic to fluvial environment as is indicated by the occurrence of large scale cross-bedding ripple marks, flute marks, mudstone-pebble conglomerates, and the geometry of the sandstone bodies (Peppers and Popp, 1979). According to Bristol and Howard (1971), these sandstones were deposited in dendritic channels which cut into previously deposited Mississippian sediments. An alternative view to the above discussion would be that these sands were continually reworked to produce orthoquartzitic sands (Horne and Ferm, 1979). There is one marine limestone, the Sellers Limestone Member which occurs in one small area in Hardin County, Illinois, along the Ohio River. There are several coals in the formation but they are rarely greater than a meter in thickness and are very discontinuous (Peppers and Popp, 1979).

The Tradewater Formation (Abbott and Spoon Formations of Illinois) differs from the Caseyville by containing more and thicker coals (Peppers and Popp, 1979). The sandstones in this formation are less massively bedded, more argillaceous, micaceous, and carbonaceous, and are interbedded with more dark shales and siltstones (Peppers and Popp, 1979). Correlation between coals in this part of the section is difficult due to the discontinuous nature of the coals and the abrupt changes in facies of the other units. The sandstones often abruptly change from channel to sheet facies (Peppers and Popp, 1979). The sandstones are also thicker in the eastern and southern part of the basin which may indicate an eastern or northeastern source (Peppers and Popp, 1979), but may also only indicate different rates of subsidence within the basin. There are two limestones in the Tradewater Formations which are somewhat

regionally persistent. These are the Curlew Limestone (above the Mannington coal) and the Lead Creek or Dunbar Limestone. The Lead Creek Limestone however only occurs in the eastern portion of the coalfield (Rice and others, 1979). The Lead Creek Limestone consists of a least two beds of massive to shaley, fossiliferous limestone. The upper bed is often cherty. The microfauna of this limestone has been studied in some detail by Thomson and others (1959), Thomson and Shaver (1964), and Shaver and Smith (1974). The Dunbar coal and its equivalent, the Mariah Hill Coal of Indiana lies beneath the Lead Creek and has a thickness up to 1.5 meters (Pepper and Popp, 1979). The Curlew Limestone is a light-to-dark-gray, fine-grained, one-to five-foot thick, fossiliferous limestone. Articulate brachiopods are abundant but crinoids and corals can also be found. Many of the limestones and coals in this formation have not been recognized and named as a result of inadequate study and also as a result of the discontinuous nature of these units (Whaley and others, 1979). In general the sediments of the Tradewater Formation were deposited under fluvial to deltaic environments.

A study of descriptions of Tradewater strata in 23 boreholes in western Kentucky was undertaken in order to gain a preliminary understanding of the depositional environments. In general it appears that most of the Tradewater units were deposited on an extensive, gently sloping surface. Greater subsidence along the southern rim of the coal field resulted in thicker coals and more limestones. The sandstones had a source from the north and northeast. In general the strata appears to be more marine to the west.

In general there are five major types of swamp plants which occur in North America and Europe. There are three types of lower vascular plants which are the Lycophytina (lycopods), the Filicophytina (ferns), and the Spenophytina (sphenopsids). Two types of gymnosperms also occurred in these

swamps. They are the Cordaitales (cordiates), and the Pteridospermales (seed ferns). Of these types of swamp inhabitants, the lycopods dominated in the early to middle Pennsylvanian. Cordaitales were dominant in extreme coastal environments (Phillips, 1979).

Studies on plant compression fossils and pollen in the Atokan-Desmoinesian Stages have indicated some possible influencing factors under which the early Pennsylvanian coals in western Kentucky were deposited. Changes in the surrounding environments in these swamps resulted in changes in the plants themselves which can be seen in the fossils and pollen found in these coals today.

According to Peppers (1979), in Morrowan time (Caseyville Formation), coals swamps formed in topographic lows within the Illinois Basin. The Plants which grew in these lows consisted primarily of arborescent lycopods (Lycospora bearing Lepidodendrids). These plants are though to have grown in uncirculating, brackish, shallow waters. The coals deposited in these swamps as a result of the deposition in topographic lows are generally discontinuous and cannot be easily or accurately correlated. The topography of the land surface was leveled in the middle and late Pennsylvanian so that the coals became more continuous. In the late Atokan, the first major limestones were deposited in the basin. At this time also, an increase in the diversity of the coal swamp plants occurred. There was an increase in the number of Sigillarian lycopods which were later followed by herbaceous lycopods, Cordaites, Psaronius, Medullosa, and Calamites (Phillips, 1979). The number of spore species also indicates that the floras were rapidly evolving or migrating at this time. During this period it is thought that the climate was slightly dryer than it was before and that this change in environment resulted in the evolution and migration of plants more suited to a wetter environment.

Those plants which may have lived at the margins of the swamp in dryer areas may have migrated into lowland swamps that had periodic wet and dry conditions. Later in the early Desmoinesian, the Lycospora-bearing Lepidodendrids dominated again as a result of wetter conditions.

The paleontology of the Pennsylvanian System in western Kentucky has not been well documented. Studies on microfauna (fusilinids and ostracods) have been done by Thomason, Shaver, and Riggs (1959), Thomson and Shaver (1964), and Shaver and Smith (1974). Most of the limestones in which these faunas occur are discontinuous in the area which makes biostratigraphic correlation difficult.

In the early Atokan of western Kentucky, the oldest fusilinids occur in the Tradewater Formation. In the Lead Creek Limestone, the fusilinid genus Profusulinella, and Millerella occur. In the late Atokan, the Curlew Limestone Member contains the fusilinid species Fusulinella iowensis among other species. This fauna is also present in the Seville Limestone Member of the Spoon Formation in Indiana (Douglass, 1979).

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Table 1

Sample No.	Coal Seam	Location		% Pseudovit.	Vitrinite	Pseudovitrinite
		County	7 1/2-Minute Quadrangle			
1	Upper Elkhorn #3	Floyd	Prestonsburg	8.3	0.631	0.711
2	Upper Elkhorn #2	Floyd	Harold	17.8	0.754	0.870
3	Upper Elkhorn #3	Floyd	Lancer	24.2	0.605	0.788
4	Upper Elkhorn #3	Floyd	Lancer	21.9	0.721	0.801
5	Upper Elkhorn #3	Floyd	Lancer	16.5	0.607	0.784
6	Upper Elkhorn #2	Floyd	Martin	11.6	0.683	0.768
7	Pond Creek Rider	Pike	Lick Creek	9.3	0.741	0.822
8	Pond Creek	Pike	Lick Creek	13.7	0.878	1.018
9	Upper Elkhorn #3	Floyd	Martin	10.7	0.714	0.800
10	Upper Elkhorn #3	Floyd	Martin	8.9	0.775	0.843
11	Upper Elkhorn #1	Floyd	Martin	10.9	0.756	0.860
12	Pond Creek	Pike	Belfry	19.7	0.997	0.977
13	Upper Elkhorn #2	Pike	Dorton	17.0	0.940	1.039
14	Upper Elkhorn #2	Pike	Dorton	13.8	0.906	0.996
15	Lower Elkhorn	Pike	Dorton	15.5	1.008	1.050
16	Upper Elkhorn 1 or 2	Pike	Millard	15.7	0.913	0.962
17	Upper Elkhorn #3 (2nd rider)	Pike	Millard	12.3	0.678	0.743
18	Upper Elkhorn #3	Pike	Millard	10.3	0.800	0.919
19	Upper Elkhorn #2	Pike	Dorton	12.4	0.992	N.A.
20	Upper Elkhorn #1	Pike	Dorton	11.8	0.923	N.A.
21	Upper Elkhorn #3 (rider)	Pike	Dorton	13.3	1.007	1.025
22	Upper Elkhorn #2	Floyd	McDowell	13.6	0.653	0.781
23	Pond Creek	Pike	Williamson	9.3	0.869	0.977
24	Pond Creek	Pike	Matewan	13.2	1.018	1.024
25	Upper Elkhorn #3	Floyd	McDowell	19.9	0.843	0.986
26	Upper Elkhorn #1	Floyd	McDowell	11.2	0.830	0.972
27	Upper Elkhorn #1	Floyd	Wayland	18.6	0.856	0.933
28	Upper Elkhorn #1	Pike	Broad Bottom	22.5	0.866	0.867
29	Lower Elkhorn	Pike	Pikeville	13.3	0.800	0.844
30	Lower Elkhorn	Pike	Millard	32.1	0.932	1.019

Table 1

Sample No.	Coal Seam	County	Location		% Pseudovit.	%R _{max}	
			7 1/2-Minute Quadrangle			Vitrinite	Pseudovitrinite
31	Alma	Pike	Majestic		1.2*	0.956	0.967
32	Upper Elkhorn #2	Floyd	McDowell		8.4	0.771	N.A.
33	Pond Creek	Martin	Naugatuck		9.4	0.808	0.881
34	Pond Creek	Martin	Naugatuck		8.6	0.824	N.A.
35	Upper Elkhorn #2	Pike	Pikeville		17.0	0.897	0.966
36	Pond Creek	Pike	Hurley		8.9	1.006	N.A.
37	Alma	Pike	Hurley		12.3	0.983	1.034
38	Upper Alma	Pike	Hurley		22.1	0.966	N.A.
39	Lower Cedar Grove	Pike	Hurley		10.4	0.991	N.A.
40	Lower Cedar Grove	Pike	Hurley		21.1	1.010	1.080
41	Upper Elkhorn #3 1/2	Pike	Hellier		11.6	0.969	1.013
42	Upper Elkhorn #3	Pike	Hellier		8.9	0.876	N.A.
43	Upper Elkhorn #3	Pike	Hellier		11.2	0.937	N.A.
44	Upper Elkhorn #3	Pike	Hellier		15.2	0.979	1.005
45	Lower Elkhorn	Pike	Hellier		15.5	1.099	1.132
46	Upper Elkhorn #2	Pike	Hellier		10.2	1.026	1.043
47	Upper Elkhorn #1	Pike	Broad Bottom		10.6	0.850	0.920
48	Upper Elkhorn #2	Pike	Broad Bottom		15.5	0.851	0.891
49	Upper Elkhorn #3	Floyd	Martin		14.1	0.759	0.779
50	Upper Elkhorn #3	Floyd	Martin		11.2	0.861	N.A.
51	Lower Elkhorn	Floyd	Martin		13.5	0.616	N.A.
52	Upper Elkhorn #3 (upper bench)	Floyd	McDowell		14.4	0.961	N.A.
53	Upper Elkhorn #3	Floyd	McDowell		15.8	0.915	N.A.
54	Upper Elkhorn #3	Floyd	Wayland		20.2	0.784	0.898
55	Upper Elkhorn #2	Floyd	Wayland		20.1	0.694	N.A.
56	Upper Elkhorn #1	Floyd	Wheelwright		9.0	0.936	N.A.
57	Pond Creek	Martin	Thomas		10.4	0.839	0.879

* High (17.4%) Semifusinite content will be used for Vicker's microhardness

n.a. - not available at present