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Gary B. Glass, State Geologist

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ABSTRACT

The petrography of Ferris and Hanna Formation coals of Paleocene and Eocene age from the Hanna Coal Field, Wyoming is characterized. The Hanna Coal Field is located in south-central Wyoming and coincides with the Hanna and Carbon Basins.

The maceral analysis (white light and fluorescent) indicates that the Hanna Basin samples have a high vitrinite content (84.2 percent average), a moderate to low liptinite content, and a low inertinite content. Pseudovitrinite comprises 26.6 percent of the total vitrinite content on the average. The maceral composition of Ferris Formation samples is similar to those of the Hanna Formation except for a slightly higher inertinite content. Between 17 percent and 139 percent more liptinite macerals are visible using fluorescence compared to white light petrographic methods. The maceral composition of Carbon Basin samples is only estimated because the samples were not channel samples of the entire coal beds. Estimates of the Carbon Basin maceral composition indicate slightly higher liptinite contents than Hanna Basin samples.

Mean maximum vitrinite reflectance values are between 0.46 and 0.57 percent. Both calorific value (Btu content) and mean maximum reflectance indicate a rank ranging between subbituminous A and high volatile C bituminous. However, in this study no correlation exists between reflectance values and the Btu content of individual samples. Reflectance values vary irregularly in a narrow range compared to the range in Btu content. The rank of Hanna and Ferris Formation coals is more accurately described by calorific value.

ACKNOWLEDGMENTS

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INTRODUCTION

The Hanna Coal Field, located in south-central Wyoming, coincides with the Hanna and Carbon Basins (Figure 1). The two adjacent basins, which are separated by the Saddleback Hills anticline, are asymmetric subdivisions of an east-west-trending structural trough that formed in the Precambrian crystalline basement during the Laramide orogeny. The geologic history of this area has been described by Bowen (1918), Dobbin et al. (1929), Knight (1961), Love (1970), Gill et al. (1971), Fox (1972), Blackstone (1975), Brooks (1977), Ryan (1977), and Glass and Roberts (1980).

The Hanna Coal Field is limited to those areas of the two basins that are underlain by the Cretaceous Mesaverde Group and younger coal-bearing rocks. Although coal occurs in the Mesaverde Group and the Medicine Bow Formation (Upper Cretaceous), most of the commercially-valuable coal is found in the Paleocene (upper) portion of the Ferris Formation and the Paleocene and Eocene Hanna Formation. Whereas most coals in the Hanna Basin are associated with flood-plain deposits, at least the upper coals in the Carbon Basin appear more closely associated with braided-stream deposits (Glass, 1980).

The occurrence, quality, and quantity of coal in the Hanna Field has been described by Glass (1975; 1978) and Glass and Roberts (1979; 1980; and 1984). The Ferris Formation contains at least 28 coal beds greater than five feet thick; the Hanna Formation contains at least 32 coals greater than five feet thick. On an average, Hanna Formation coals are thicker than Ferris Formation coals. The rank of the coals in the Hanna Coal Field as defined by calorific value* (ASTM, 1983, p. 240-244) varies from subbituminous B to high volatile C bituminous (Dobbin et al. 1929; Berryhill et al., 1950; and Glass and Roberts, 1979; 1984). Glass and Roberts (1980) state that coal rank based on calorific value increases eastward across the Hanna Field probably due to differences in heat flow (Figure 2).

Petrographic characterization of the composition and rank of coal also provides information on the origin, history of coalification, and potential for utilization. Coal is composed of a number of organic components called macerals, each having a distinct set of chemical and physical properties. Macerals can be divided into three main groups: vitrinite, derived from the woody tissues of plants; inertinites, derived from plant material altered by oxidation or biochemical processes, and liptinites (primary and secondary) derived from waxy and resinous components of plants. The mean maximum reflectance of vitrinite provides an accurate measurement of rank because: (1) the reflectance of vitrinite increases in a uniform manner throughout the coalification series, and (2) vitrinite is usually the most abundant maceral in coal.

Only limited work describes the petrography of coals in the western United States. Crelling and Dutcher (1980a) evaluated the occurrences and properties of fluorescent macerals in Colorado coking coals. Dutcher et al. (1982) described the effects of increasing rank on petrographic properties of coal in the Spanish Peaks region, Colorado. By using quantitative fluorescence, Crelling et al. (1982) and Crelling (1983) identified four distinct types of resinite in various Rocky Mountain coals. Although numerous chemical analyses of coals from the Hanna Coal Field have been published (Glass, 1975; 1978; and Glass and Roberts, 1979; 1984), no previously published data describes the petrography of the coals.

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* Calorific value reported as British Thermal Units (Btu) per pound on a moist, mineral-matter-free (Mmmf) basis.

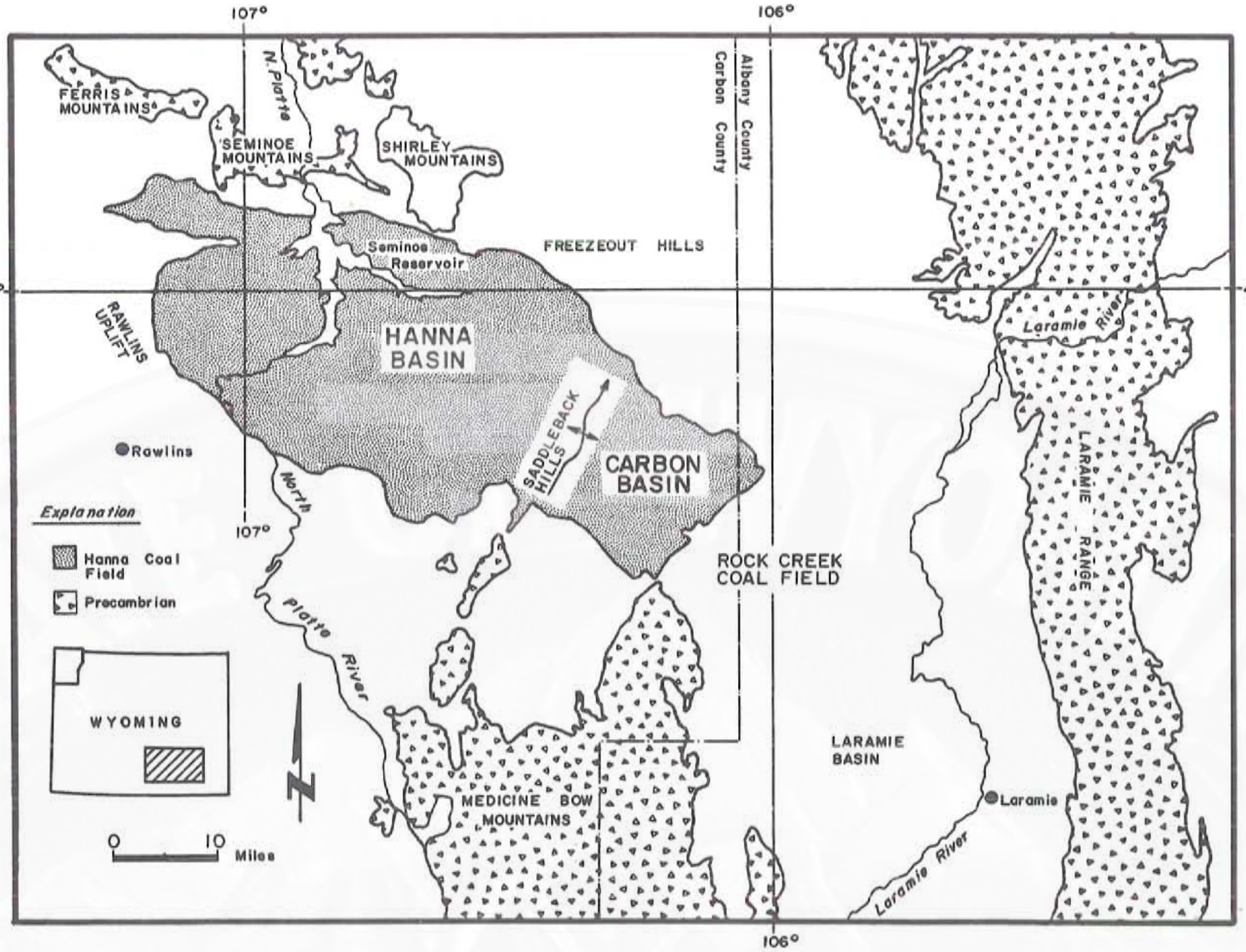

Figure 1. Location and regional setting of the Hanna Coal Field, Wyoming (modified from Brooks, 1977).

OBJECTIVES

The purpose of this study was to petrographically characterize selected coals from the Hanna and Ferris Formations in the Hanna Coal Field by completing two specific objectives: (1) describe the maceral content and occurrence by using both white light and fluorescence techniques; and (2) measure the vitrinite reflectance (mean maximum) to determine the rank of Hanna Field coals and define any apparent rank variations.

PROCEDURES

Coal samples were collected by the Geological Survey of Wyoming. Samples from the Hanna Basin were collected from outcrops, strip mines, and underground mines. Two types of samples were collected: (1) channel samples, where a single sample represented the entire thickness of the coal bed; and (2) benched channel samples, where a sample only represented a portion of the entire thickness of the coal bed. Carbon Basin samples consisted of drill cores from

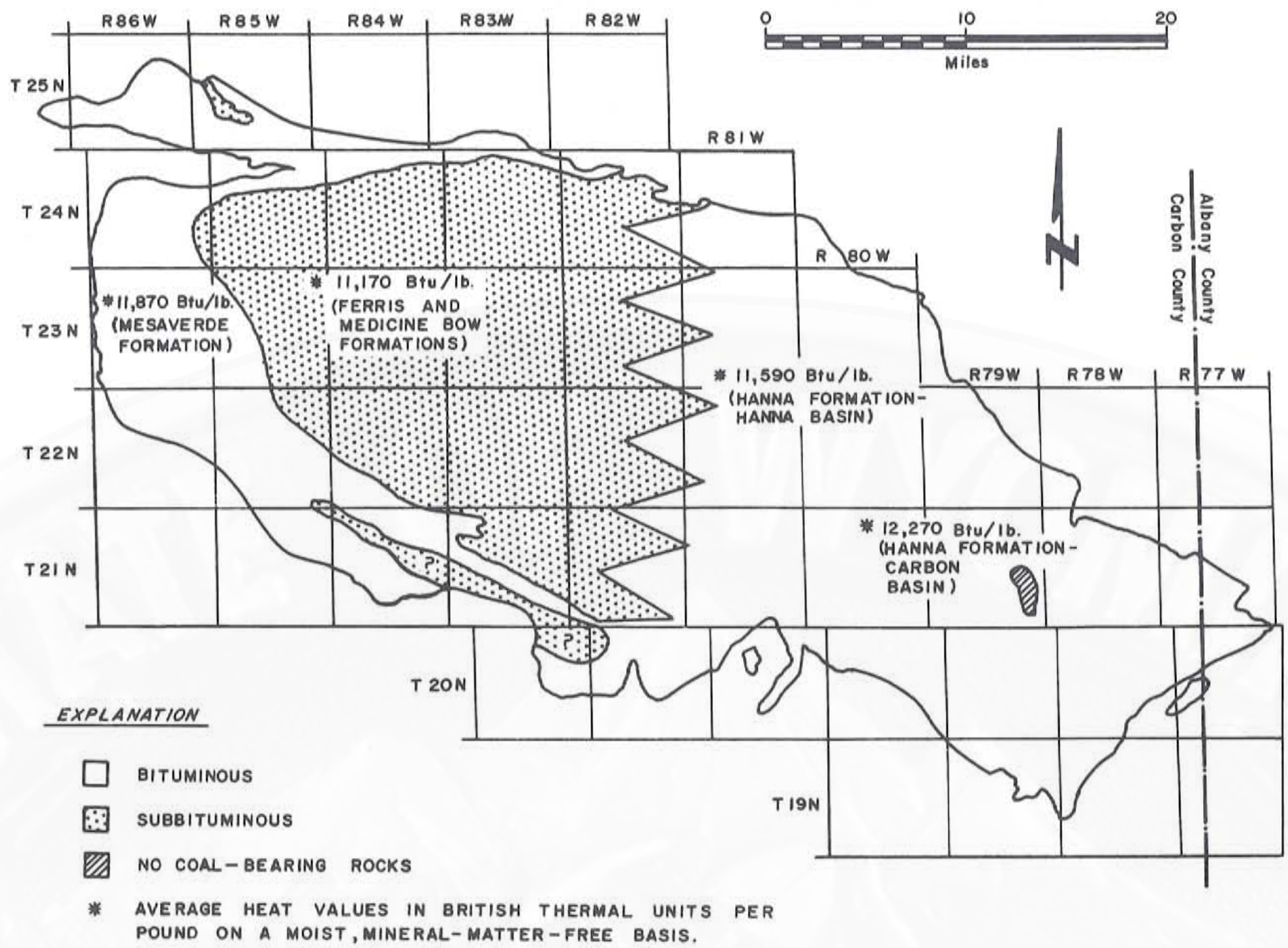

Figure 2. Variation in apparent coal rank (based on calorific value) across the Hanna Coal Field, Wyoming (modified from Glass and Roberts, 1980).

the Hanna Formation only; however, these samples were not representative of entire coal beds because only parts of the coal cores were petrographically examined. The stratigraphic positions of the coals used in this study are based on nomenclature from Glass (1975; 1978) and Glass and Roberts (1979; 1984). Sample identifications and locations are listed in stratigraphic order in Tables 1 and 2.

Sample preparation procedures are those described by Crelling and Dutcher (1980b). Coal samples were crushed and split according to American Society for Testing and Materials (ASTM) Standard D 2013-72 (ASTM, 1983, p. 295-309). Three crushed particle pellets were made from each sample and polished to a final stage of 0.05 microns. Vitrinite reflectance and maceral analyses were completed using a Leitz MPV-II microscope equipped with a 50x oil immersion objective and 10x occulars for 500x magnification. Immersion oil with refractive index 1.5180 was used.

REFLECTANCE ANALYSIS

The rank of each of the coals examined in this study was determined by measuring the mean maximum reflectance of vitrinite in oil at 546 nanometers (nm). Microscope specifications include: polarizer set at 45 degrees,

Table 1. Sample identifications and locations, Hanna Basin.

SIU No.[1]	WGS No.[2]	Bed Name	Formation	Thickness sampled (in feet)	Sample site	Location
1066	74-11	Bed No. 82	Hanna	7.9	Strip Mine	sec. 36, T.23N., R.81W.
1019	74-25	Bed No. 80	Hanna	18.1	Strip Mine	sec. 28, T.23N., R.81W.
1020	74-26	Hanna No. 2	Hanna	35.4	Strip Mine	sec. 4, T.22N., R.81W.
1067	77-12	Hanna No. 5	Hanna	8.7	Outcrop	sec. 7, T.22N., R.81W.
1021	74-27	Brooks Seam	Hanna	7.5	Strip Mine	sec. 9, T.22N., R.82W.
1022	74-28	Bed No. 65	Ferris	6.7	Underground Mine	sec. 8, T.22N., R.82W.
1059	75-15	Bed No. 65	Ferris	9.7	Outcrop	sec. 33, T.23N., R.83W.
1063	77-7	Bed No. 61	Ferris	7.1	Outcrop	sec. 17, T.23N., R.83W.
1060	76-3	Bed No. 51	Ferris	8.2	Outcrop	sec. 6, T.22N., R.83W.
1023	74-29	Bed No. 50	Ferris	9.4	Underground Mine	sec. 18, T.22N., R.82W.
1070	79-1	Bed No. 31 (lower bench)	Ferris	8.0	Outcrop	sec. 23, T.22N., R.83W.
1027	74-33	Bed No. 25 (lower bench)	Ferris	7.2	Outcrop	sec. 12, T.22N., R.84W.
1069	77-14	Bed No. 25	Ferris	9.7	Outcrop	sec. 16, T.22N., R.83W.

[1] Southern Illinois University sample number.

[2] Geological Survey of Wyoming sample number.

(compiled from Glass, 1975; Glass and Roberts, 1984).

S-547 interference filter set in front of the photometer, 0.5 mm fixed spot measuring diaphragm, and a Berek prism set in the vertical illuminator. The microscope was calibrated using Shott Glass standards of known reflectance.

Two different reflectance methods were used depending on sample type. Reflectance measurements of Carbon Basin samples were completed according to ASTM standard D 2798-79 (ASTM, 1983, p. 380-383). Additional reflectance measurements of pseudovitrinite were taken on Hanna Basin coals to provide a combined reflectance value based on the "normal" vitrinite and pseudovitrinite content in each sample. To ensure that equivalent results were obtained from the two reflectance methods, several Hanna Basin samples were measured using both procedures. Both reflectance methods provided results that agreed within the ASTM limit of $\pm$0.02 percent. A combined reflectance for Carbon Basin samples could not be obtained because the pseudovitrinite content could not be determined.

Tables 3 and 4 list results of the reflectance analysis for each basin. The mean difference in reflectance between "normal" vitrinite and pseudovitrinite ranges from 0.03 percent to 0.07 percent. This apparent difference in reflectance was further evaluated by a two-sample t-test. Results of the t-test indicate that at the 99 percent confidence level, "normal" vitrinite and pseudovitrinite are from different reflectance populations.

Based on vitrinite reflectance limits of Davis (1978), the ranks of the examined Hanna and Ferris Formation coals range between subbituminous A and the high volatile C/B bituminous boundary. In contrast to Glass and Roberts (1980), who state that calorific value, and

Table 2. Sample identifications and locations, Hanna Formation, Carbon Basin.

SIU No.[1]	WGS No.[2]	Core Number	Bed Name	Sample Interval (feet from surface)	Location
1088	77-1	C4	Carbon No. 6 (Upper Rider)	64.0- 65.95	NE1/4, sec. 12, T.21N., R.80W.
1072	76-4	C1	Carbon No. 6 (Upper Rider)	159.0-160.2	SE1/4, sec. 34, T.22N., R.80W.
1084	76-16	C3	Upper Carbon No. 7 (lower bench)	270.3-272.0	SE1/4, sec. 35, T.22N., R.80W.
1077	76-9	C1	Upper Carbon No. 7 (lower bench)	275.9-277.8	SE1/4, sec. 34, T.22N., R.80W.
1089	77-2	C4	Bed No. 111	314.4-317.6	NE1/4, sec. 12, T.21N., R.80W.
1079	76-11	C1	Bed No. 111	488.7-493.0	SE1/4, sec. 34, T.22N., R.80W.
1080	76-12	C2	Upper Bed No. 109	100.9-106.7	SE1/4, sec. 24, T.21N., R.80W.
1087	76-19	C3	Upper Bed No. 109	566.8-570.6	SE1/4, sec. 35, T.22N., R.80W.

[1] Southern Illinois University sample numbers.

[2] Geological Survey of Wyoming sample numbers.
(compiled from Glass, 1978).

therefore rank of the Tertiary coals, increases eastward across the Hanna Coal Field, reflectance values (of the same coals measured for Btu content) do not show any distinctive trend throughout the Hanna and Carbon Basins. The reflectance of Hanna Formation coals apparrently does not significantly increase eastward into the Carbon Basin. The older and previously more deeply-buried Ferris Formation coals have reflectance values similar to Hanna Formation coals.

Overall, vitrinite reflectance data and calorific value indicate a similar rank. However, reflectance values do not increase with increasing calorific value; no correlation can be made between these two parameters (Figure 3). Although the calorific value of Ferris and Hanna Formation coals varies by almost 2,000 Btu, reflectance results do not accurately detect this variation in rank. McCartney and Teichmuller (1972) described a similar relationship between reflectance values and volatile matter in low ranks coals (less than 0.70 percent mean reflectance). They suggest that calorific value is a more sensitive measurement of rank at this level of coalification. According to Teichmuller and Wolf (1977), reflectance values in low rank coals show considerable scatter due to the biological imprint that is still in the vitrinite. For this reason, ASTM uses calorific value (Btu/pound, Mmmf) to define rank in this range of coalification.

Table 3. Results of reflectance analysis, Hanna Basin samples.

	MEAN MAXIMUM REFLECTANCE		
SIU No.[1]	"Normal" vitrinite	Pseudo-vitrinite	Combined
1066	0.46	0.51	0.47
1019	0.45	0.50	0.46
1020	0.49	0.53	0.50
1067	0.54	0.58	0.56
1021	0.50	0.55	0.51
1022	0.52	0.55	0.53
1059	0.51	0.55	0.52
1063	0.48	0.54	0.49
1060	0.56	0.60	0.57
1023	0.49	0.53	0.50
1070	0.49	0.53	0.50
1027	0.53	0.57	0.54
1069	0.53	0.60	0.54

[1] Southern Illinois University sample numbers.

The sensitivity and accuracy of the calorific value to define coalification in coals of the Hanna Field is confirmed by coal bed moisture data from Glass (1975; and 1978), and Glass and Roberts (1984). As Btu content increases, there is a corresponding decrease in the moisture content showing an essentially linear relation (Figure 4). This relationship between bed moisture and calorific value has been previously described by Damberger (1971) and Ode and Gibson (1960).

MACERAL ANALYSIS

The white-light maceral analysis was completed following ASTM Standard D 2799-72 (ASTM, 1983, p. 384-385), except for two modifications. First, the macerals pseudovitrinite, semi-macrinite, and macrinite were counted in addition to vitrinite, semifusinite, fusinite, micrinite, exinite, and resinite. Descriptions of the macerals counted in this study are given in *Stach's textbook of coal petrology* (Stach and others, 1975), in the *International handbook of coal petrology* (International Committee for Coal Petrology, 1963), and in Crelling and Dutcher (1980b). Second, only five hundred points were counted on each of two pellets instead of 1,000 points.

Because fluorescence microscopy allows identification of a greater variety of liptinite macerals with increased accuracy, the white-light analysis was supplemented with fluorescence. The following microscope accessories were used for fluorescent maceral analysis: 100-watt mercury lamp, BG-23 heat filter, BG-12 excitation filter (350-450 nm wavelength), TK-400 dichroic mirror, and K-510 barrier filter. To complete the fluorescent maceral analysis, each field was first viewed in white light to ensure a maceral was being counted, then the maceral was counted in fluorescence. The following macerals were counted: sporinite, cutinite, resinite, exudatinite, fluorinite, and liptodetrinite; a nonfluorescent maceral category was also counted. The fluorescent maceral analysis was compared and combined with the white-light analysis. A combination of the white-light and fluorescent analysis is the most accurate method of obtaining the actual maceral composition.

The maceral composition of Hanna and Ferris Formation samples from the Hanna Basin are listed in Table 5. Because samples from the Carbon Basin were not representative of entire coal beds,

Table 4. Results of reflectance analysis, Carbon Basin samples.

	Mean maximum reflectance
SIU No.[1]	Total vitrinite
1088	0.52
1072	0.54
1084	0.53
1077	0.54
1089	0.50
1079	0.51
1080	0.53
1087	0.55

[1] Southern Illinois University sample numbers.

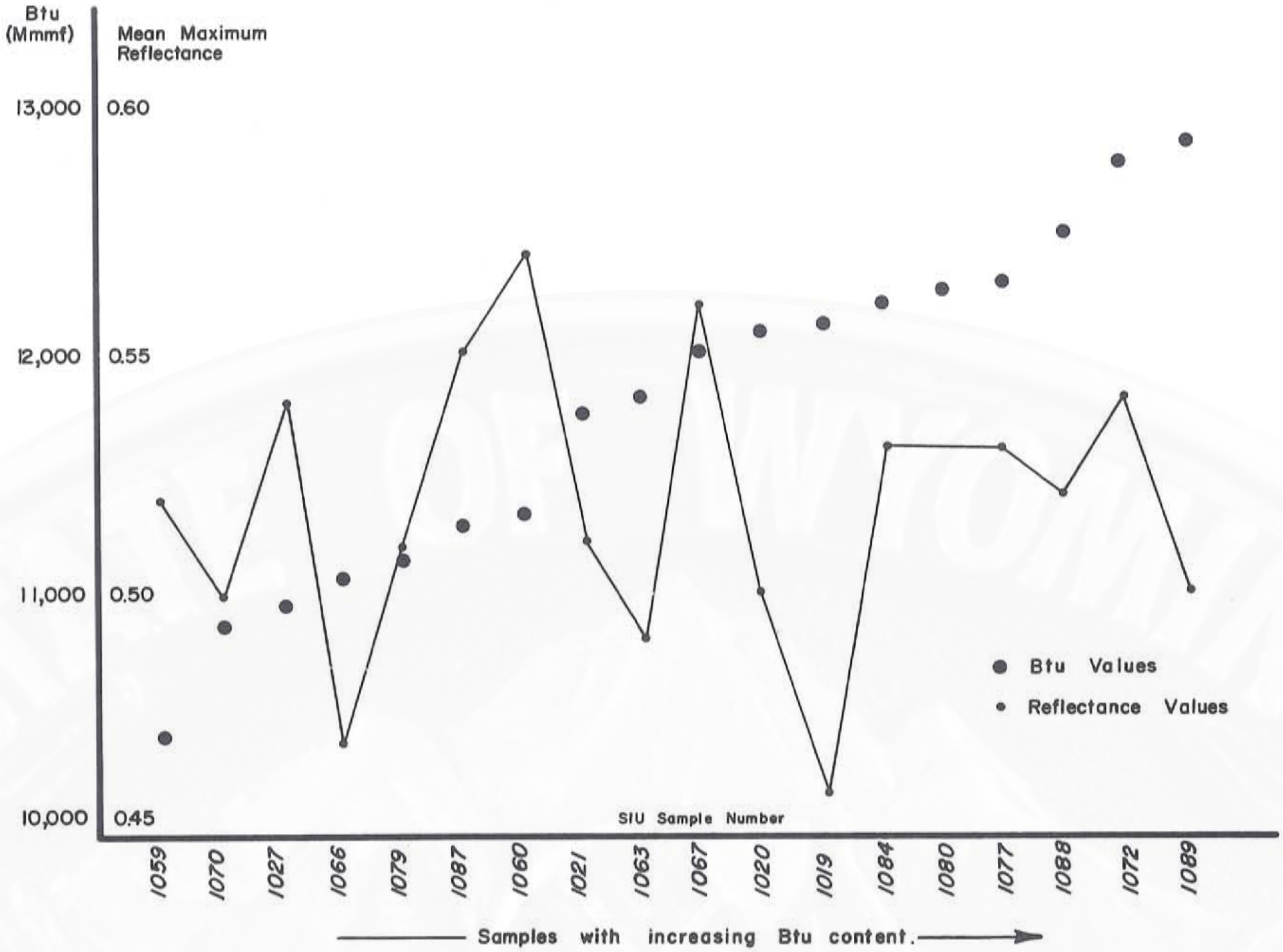

Figure 3. Comparison of calorific values and mean maximum reflectance values of individual samples. (Calorific values are given as British Thermal Units (Btu) per pound on a moist, mineral-matter-free (Mmmf) basis).

their maceral composition was only estimated. Hanna and Ferris Formation coals have a high vitrinite content, a moderate-to-low liptinite content and a low inertinite content. The variation in the three main maceral groups is shown in Figure 5.

Pseudovitrinite was distinguished from "normal" vitrinite primarily by its higher reflectance and the lack of other macerals and mineral matter incorporated in it (Plate 1: A and B). A milky appearance suggesting destroyed cellular structure (Thompson and Benedict, 1974) was commonly observed in pseudovitrinite. Slitted structures, en echelon fractures, brecciated edges, remnant cell structure, and wedge-shaped fractures were also used to identify pseudovitrinite (Plate 1: B). The petrographic characteristics and content of pseudovitrinite in the Hanna Basin samples are similar to the Appalachian coking coals described by Benedict et al. (1968).

The high pseudovitrinite content of the Hanna Basin samples probably corresponds to the vitrain-rich coals described by Glass (1975 and 1981). Pseudovitrinite mainly occurs in the vitrain lithotype (Kravits 1980, and Padgett 1980). The absence of other macerals and mineral matter in pseudovitrinite suggests the source material

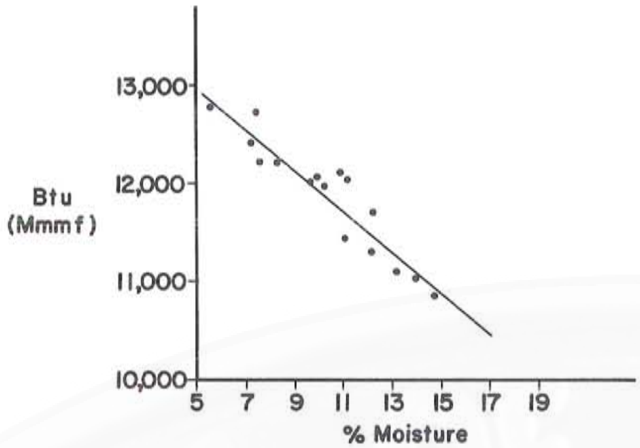

Figure 4. Relationship between calorific values and moisture contents of coal samples from the Hanna and Ferris Formations, Hanna Coal Field, Wyoming. Calorific values are given as British Thermal Units (Btu) per pound on a moist, mineral-matter-free (Mmmf) basis).

was solid enough during peat deposition to prevent incorporation of other components. Pseudovitrinite probably originated from a different source material than "normal" vitrinite.

Semifusinite is the most abundant inertinite maceral in the Hanna Basin samples. Sclerotinite, which is counted as semifusinite, is single- or multi-celled fungal remains (Plates 1: C and D); it is rare in these samples. Its reflectance ranges between vitrinite and semifusinite. Micrinite, occurs as fine granular particles (1-2 microns) either concentrated in a zone or band in vitrinite (Plate 1: E) or as finely dispersed particles in the vitrinitic matrix. Sometimes micrinite is associated with resinous impregnations in vitrinite (Plate 1: F). Macrinite and semi-macrinite (ovoid bodies lacking internal structure) were rarely observed in these samples. Inertinite particles were occasionally observed having a morphology similar to liptinite macerals; these probably originated from some type of oxidation of liptinitic materials as described by Kosanke and Harrison (1957), Taylor and Cook (1962), Spackman and Thompson (1964), and Bell and Murchison (1966).

The liptinite macerals identified in white light were counted as either exinite (sporinite or cutinite) or resinite. Morphological variation of liptinite macerals are difficult to identify in white light. Fluorescent light was used to accurately identify the type, morphology, and quantity of liptinite macerals in the Hanna Basin coals.

Using fluorescence, sporinite and cutinite exhibit the same general morphology as in white light. Sporinite fluoresces a moderate intensity yellow to yellow-orange. Miosporinite was the dominant type of sporinite observed (Plate 2: A and B); megaspores and sporangium were rarely observed. Cutinite (both tenuicutinite and crassicutinite) occurs as linear or folded strands displaying a crenulated appearance, and fluoresces a moderate to strong intensity yellow-orange to orange (Plate 2: C and D).

Several different types of resinite macerals occur in the Hanna Basin samples. Based on morphology, occurrence, and fluorescent properties, resinite was classified into one of the following three types: primary globular, primary cell-filling, and secondary.

Primary globular resinite usually occurs as either individual globules or bands of globules within the vitrinite matrix (Plate 2: E and F). Globular resinite is the most abundant of the three resinite types. In white light, globular resinite is gray, light to dark brown, black, or translucent. Globular resinite fluoresces the following colors: (1) green, ranging from dark to very light green; (2) yellow; and (3) orange-brown; nonfluorescing globular resinite was also occasionally observed. Globular resinites display the following textures: zoned, vesiculated, granular, and with internal cracks (Plate 3: A and B).

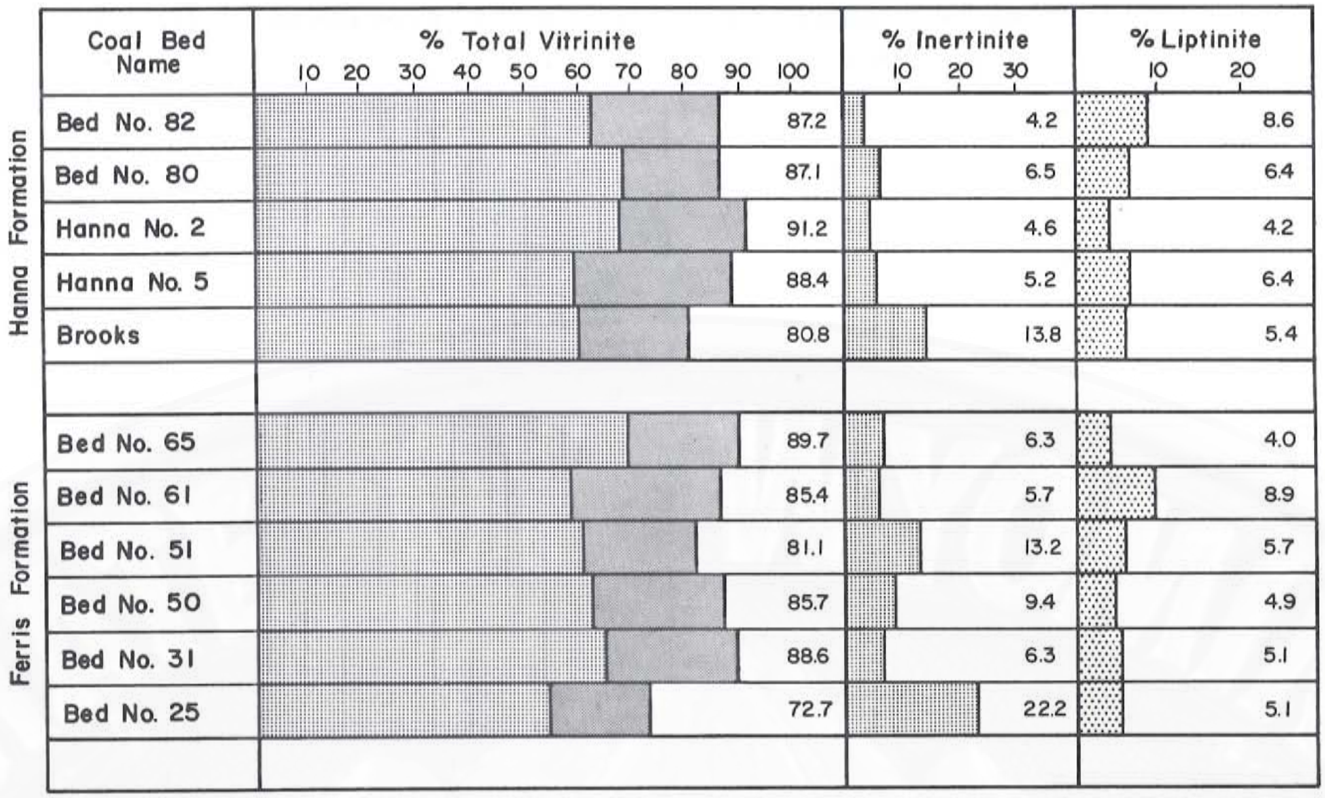

Figure 5. Maceral composition of coal samples from the Hanna and Ferris Formations, Hanna Basin, Wyoming. (Pseudovitrinite content is the shaded portion of the "Total Vitrinite" bar graph [right side of bar]).

Cell-filling resinite, also a primary resinite, fills cellular cavities in telinite (vitrinite with cellular structure) or occurs as a concentrated impregnation of resin in vitrinite (Plate 3: C and D). Some cell-filling resinite appears as a transition between resinite and vitrinite. In white light, cell-filling resinite has a lower reflectance than the surrounding vitrinite, ranging from slightly less than vitrinite to that of other liptinites. Although cell-filling resinite has the same qualitative fluorescent properties as globular resinite, yellow and orange-brown cell-filling resinite is most commonly observed. Cell-filling resinites have been described in detail by Murchison and Jones (1964) and by the International Committee for Coal Petrology (1963).

Secondary resinite fills voids and cracks in vitrinite and inertinite macerals (Plate 3: E and F). Jones and Murchison (1963) and Murchison and Jones (1964) state that secondary resinite forms from the mobilization of primary resinite due to a subtle increase in temperature and pressure during coalification. In white light, secondary resinites are difficult to recognize. Secondary and primary resinites display similar qualitative fluorescent properties. Occasionally, secondary resinite fills cracks extending from globular resinite, demonstrating the mobilization of the primary resinite.

Fluorinite appears as black "pods" resembling lenses of clay. It fluoresces a moderate to strong yellow-green, usually occurring in layer-like agglomerations associated with cutinite (Plate 4: A and B). Fluorinite is considered to have originated from fats and oils of plants (Teichmuller, 1974a).

Table 5. Combined maceral composition of coal samples from the Hanna and Ferris Formations of the Hanna Basin.

	VITRINITE MACERALS		INERTINITE MACERALS					LIPTINITE MACERALS					
SIU Number[1]	"Normal" vitrinite	Pseudo-vitrinite	Fusinite	Semi-fusinite	Macrinite	Semi-macrinite	Micrinite	Sporinite	Cutinite	Resinite	Fluorinite	Exudatinite	Liptodetrinite
1066	62.8	24.4	0.9	2.9	-	-	0.4	1.7	0.5	3.1	0.2	0.2	2.9
1019	69.1	18.0	0.8	3.7	0.1	0.9	1.0	2.6	0.7	0.9	0.2	0.3	1.7
1020	68.4	22.8	0.4	2.3	0.1	0.5	1.3	1.7	0.2	0.8	-	0.2	1.3
1067	58.8	29.6	0.7	3.7	-	-	0.8	2.4	0.1	0.9	0.3	0.4	2.3
1021	59.2	21.6	3.3	9.3	-	-	1.2	1.9	0.3	1.3	0.2	0.3	1.6
1022	57.5	27.4	0.8	6.3	-	0.4	0.9	2.0	0.6	1.4	0.8	0.3	1.6
1059	69.2	20.5	1.2	4.7	-	0.1	0.3	1.2	0.2	1.4	0.2	0.3	0.7
1063	57.0	28.4	0.6	2.8	0.1	1.0	1.2	1.9	0.5	2.4	0.2	0.1	3.8
1060	60.2	20.9	2.3	9.3	0.1	0.1	1.4	1.9	0.3	0.7	0.1	0.2	2.6
1023	61.2	24.5	1.3	6.0	0.2	0.3	1.6	1.4	0.3	1.0	0.1	0.2	1.9
1070	63.2	25.4	0.9	3.4	-	0.7	1.3	1.5	0.4	1.3	0.1	0.3	1.5
1027	56.1	18.7	3.4	14.2	0.6	1.1	1.0	1.4	0.4	1.4	-	0.5	1.2
1069	54.2	16.4	4.7	14.0	1.2	0.3	3.9	0.5	-	2.9	-	0.2	1.7

[1] Southern Illinois University sample numbers.

Exudatinite fluoresces a weak to moderate intensity reddish-orange to reddish-brown. It is usually found in the cell lumens of inertinites and filling fractures in vitrinite (Plate 4: C and D). Most occurrences of exudatinite are similar to secondary resinite. Occasionally, exudatinite is observed around the edges of corpocollinite, and as a "film" associated with framboidal pyrite. Exudatinite appears as a non-solid substance, which occasionally develops a smear film under fluorescence and always displays an absence of polishing scratches. It is a secondary maceral, an exudate that has originated from other macerals as described by Teichmuller (1974a and 1974c).

Liptodetrinite consists of unidentifiable fragments of liptinite macerals. These fragments cannot be assigned to a primary liptinite maceral because of their indistinct morphology or minute size. Most liptodetrinite probably originates from physically or biologically degraded cutinite, sporinite, and resinite. Bituminite and algal matter, both of which were rarely observed, were also included in the liptodetrinite category.

A small proportion of vitrinite displays a weak orange-brown fluorescence. Only "normal" vitrinite appears to fluoresce; pseudovitrinite does not emit any visible fluorescence. The fluorescence of vitrinite is probably due to cellulose, resin, or other fluorescing substances incorporated into the vitrinite (Teichmuller and Durand, 1983). Fluorescing vitrinite was not counted because of its weak fluorescent intensity, and the resultant difficulty in achieving consistent results.

Clay pods or micropartings found within coal particles sometimes appear to be impregnated with an oily substance when viewed in fluorescence. These partings fluoresce a low intensity greenish-yellow or orange-brown. Observations by Spackman et al. (1976) suggest that the fluorescence displayed by some clay partings may be due to adsorption of bitumen generated by liptinitic macerals.

The maceral composition of Ferris Formation samples is similar to Hanna Formation coals except for a slightly higher inertinite content. Petrographic estimation of the maceral content of the Carbon Basin samples suggests a slightly higher liptinite content than Hanna Basin samples. Carbon Basin samples also contain a higher proportion of vitrodetrinite (detrital vitrinite), liptodetrinite, and mineral matter.

Table 6. Comparison of percent liptinite macerals counted in white light versus fluorescent (blue) light.

SIU No.[1]	Liptinite content (percent counted): White light	Fluorescence	Percent increase
1066	5.7	8.6	51
1019	5.3	6.4	21
1020	3.6	4.2	17
1067	3.0	6.4	114
1021	2.8	5.6	100
1022	2.8	6.7	139
1059	3.1	4.0	29
1063	5.7	8.9	56
1060	4.1	5.8	41
1023	4.1	4.9	20
1070	2.4	5.4	113
1027	3.9	4.9	26
1069	4.2	5.3	26

Southern Illinois University sample numbers.

In the Hanna Basin samples, the increase in liptinite macerals counted in fluorescence compared to white light ranges between 17 and 139 percent. This increase in the liptinite content is mainly due to an increase in liptodetrinite, fluorinite, exudatinite, and cell-filling and secondary resinite counted in fluorescence. Comparison of the liptinite content counted in white light and fluorescent (blue) light is shown in Table 6.

EFFECTS OF WEATHERING

Because most of the coal samples are from outcrops or strip mines, petrographic analysis was completed to determine the effects of weathering. The following petrographic characteristics were observed in some of the coal samples in order of their occurrence: (1) abundant fracturing (cracks and blind fractures) in particles, (2) a dark brown tint on coal particles, (3) high relief around weathered macerals or particles, (4) a mottled, granular, or "chewed-up" appearance, and (5) a dark tint or reaction rim around particle borders (Plate 4: E and F). These weathering characteristics are similar to those described by Crelling et al. (1979) and Gray et al. (1976). The percentage of weathered macerals in the Hanna Basin coal samples are listed in Table 7. Carbon Basin core samples show no evidence of weathered macerals. It is believed that storage of the Hanna Basin samples did not contribute to weathering because all samples were stored in dry, inert, sealed containers.

Babcock (1981) demonstrated that Btu content is only affected for coals having greater than five percent weathered macerals. Based on this knowledge, the Btu content of only three samples from the Hanna Basin was affected by weathering (Table 7). Weathering, therefore, did not influence the varia-

Table 7. Percent of weathered macerals based on petrographic analysis, Hanna Basin.

SIU No.[1]	Percent weathered macerals	Btu content[2]
1066	1.2	11,063
1019	1.1	12,096
1020	0.5	12,059
1067	0.8	11,993
1021	3.5	11,712
1022	-	11,973
1059	11.8	10,428
1063	0.8	11,798
1060	2.2	11,318
1023	0.8	11,419
1070	2.2	10,886
1027	6.5	10,946
1069	84.7	7,157

[1] Southern Illinois University sample numbers.

[2] Btu content (Mmmf) from Glass (1975); Glass and Roberts (1984)

tion in Btu content across the Hanna Basin as described by Glass and Roberts (1980).

CONCLUSIONS

The mean maximum vitrinite reflectance of Hanna and Ferris Formation samples was between 0.46 percent and 0.57 percent, indicating the coals range from subbituminous A to high volatile C bituminous in rank. The older, previously more-deeply buried Ferris Formation coals have similar reflectance values as the Hanna Formation coal samples. Reflectance values do not show any distinctive spacial variation across the Hanna Basin in contrast to the eastward increase in Btu content. Consequently, the Btu content is apparently a more sensitive measurement of coalification or rank than vitrinite reflectance in the sampled Hanna and Ferris Formation coals.

White-light and fluorescent maceral analysis indicates that Hanna Basin coals have a high vitrinite content, a moderate-to-low liptinite content, and a low inertinite content. The increase in liptinite macerals counted in fluorescence compared to white light in the Hanna Basin samples ranges between 17 percent and 139 percent, and demonstrates the need for fluorescent maceral analysis to adequately describe the maceral composition of these Tertiary coals.

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PLATE 1

A Pseudovitrinite (PV) occurring in a microlithotype (vitrite) surrounded by "normal" vitrinite (NV). SIU Sample Number 1084, 500X.

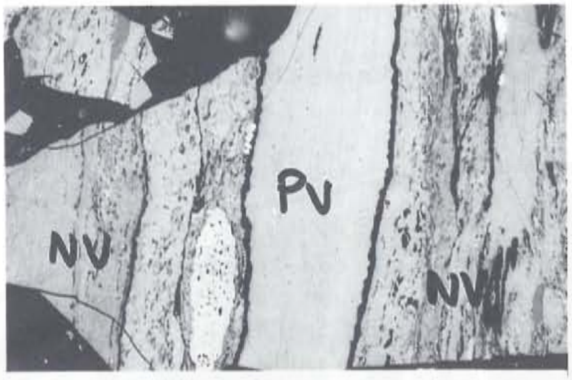
B Variation in reflectance and morphology between pseudo-vitrinite (PV, lower particle) and "normal" vitrinite (NV). Note characteristic fractures and the absence of other macerals or mineral matter in pseudovitrinite. SIU Sample Number 1023, 500X.

C Multi-celled sclerotia in vitrinite groundmass. SIU Sample Number 1060, 500X.

D Single-celled sclerotia concentrated in a specific layer. SIU Sample Number 1087, 500X.

E Micrinite (M) "band" across vitrinite particle SIU Sample Number 1021, 500X.

F Micrinite occurring as ovoid bodies associated with resinous impregnations in vitrinite (arrow). Resinous impregnations also display internal reflections. SIU Sample Number 1087, 500X.



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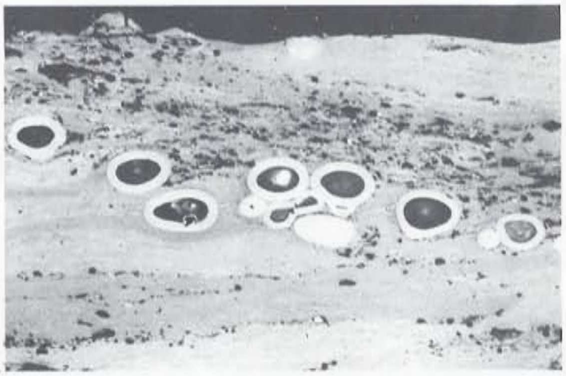

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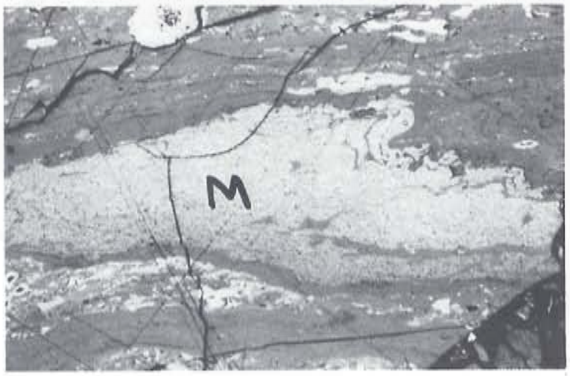

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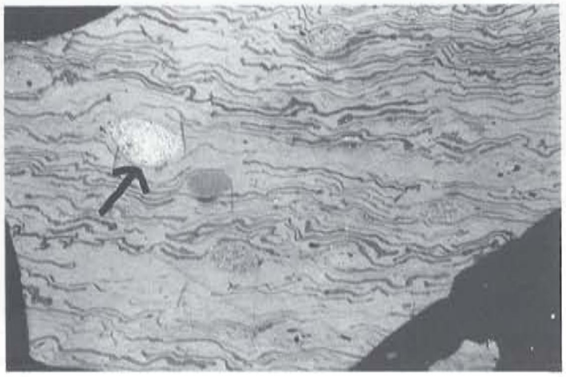

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PLATE 2

A Sporinite, incorporated in vitrinite; fluoresces bright yellow. SIU Sample Number 1063, 500X.

B Sporinite in white light, same field as A. SIU Sample Number 1063, 500X.

C Cutinite, crassicutinite (thick-walled), and tenuicutinite (thin-walled) displaying crenulated appearance; fluoresces yellow-orange. SIU Sample Number 1088, 500X.

D Crassicutinite and tenuicutinite in white light. Same field as C. SIU Sample Number 1088, 500X.

E Globular resinite, irregular and ovoid bodies; fluoresces green and yellow-green. SIU Sample Number 1066, 500X.

F Globular resinite in white light. Same field as E. SIU Sample Number 1066, 500X.


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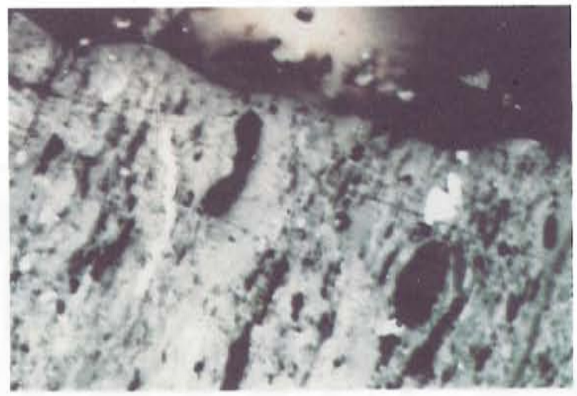
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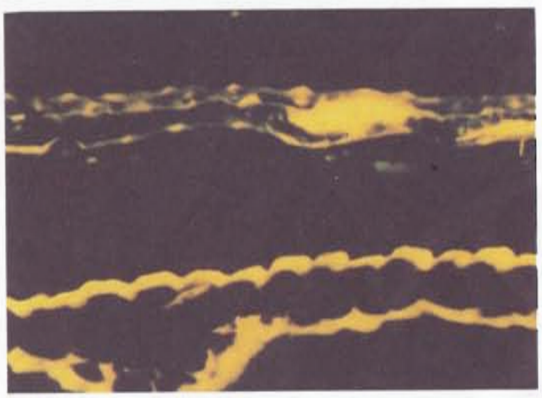
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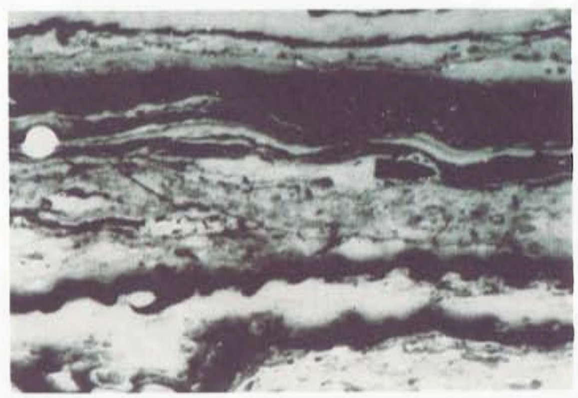
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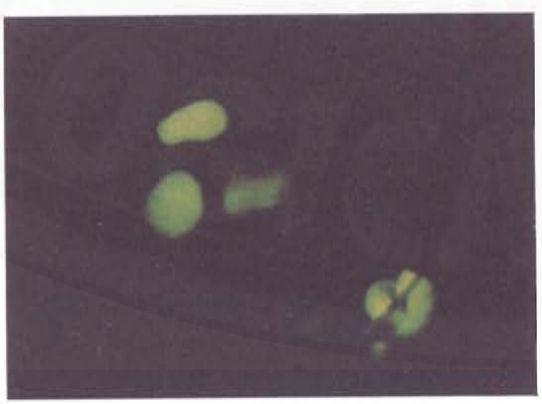
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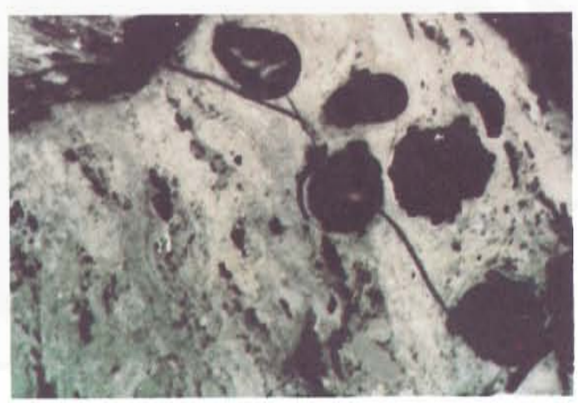
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PLATE 3

A Resinite displaying a vesiculated texture; fluoresces green. Vesiculated texture due to early devolatilization. SIU Sample Number 1066, 500X.

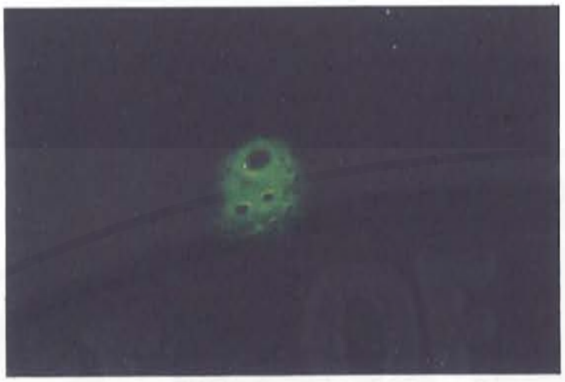
B Zoned resinite, outer rim fluoresces with lower intensity yellow-brown due to oxidation before deposition. SIU Sample Number 1079, 500X.

C Cell-filling resinite; fluoresces yellow. SIU Sample Number 1063, 500X.

D Cell-filling resinite in white light. Same field as C. SIU Sample Number 1063, 500X.

E Secondary resinite filling fracture in pseudovitrinite; fluoresces yellow. Note difference in fluorescence between secondary resinite and mounting medium. SIU Sample Number 1079, 500X.

F Secondary resinite in white light, note difficulty in identification of resinite filling fracture. Same field as E. SIU Sample Number 1079, 500X.



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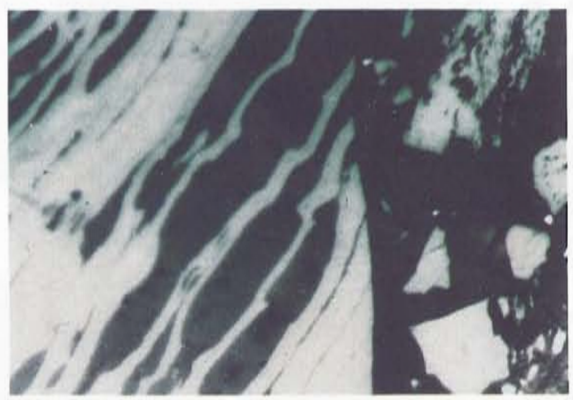

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PLATE 4

A Fluorinite "lenses: occurring between strands of cutinite; fluoresces yellow-green. SIU Sample Number 1072, 500X.

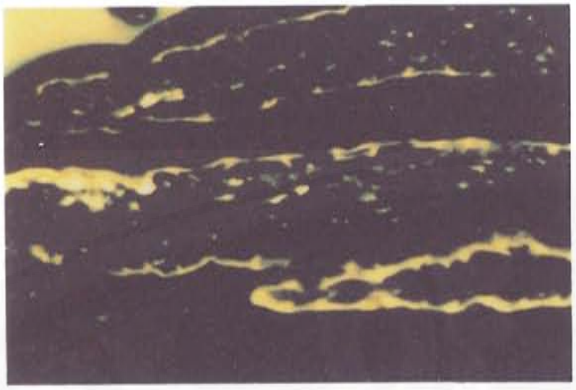
B Fluorinite lenses (arrow) in white light, appearing as clay pods. Same field as A. SIU Sample Number 1072, 500X.

C Exudatinite in cell lumens of inertinite, fluoresces reddish-brown. Note fluorescent halo (H) in mounting medium to left of inertinite particle. Mounting medium acts as a solvent resulting in exudatinite (bitumen) mixing with epoxy. SIU Sample Number 1027, 500X.

D Exudatinite in cell lumens of inertinite; difficult to identify in white light. Same field as C. SIU Sample Number 1027, 500X.

E Weathered coal particle displaying dark tint and mottled appearance. SIU Sample Number 1059, 500X.

F Weathered coal particle displaying dark tint and abundant fracturing. SIU Sample Number 1069, 500X.



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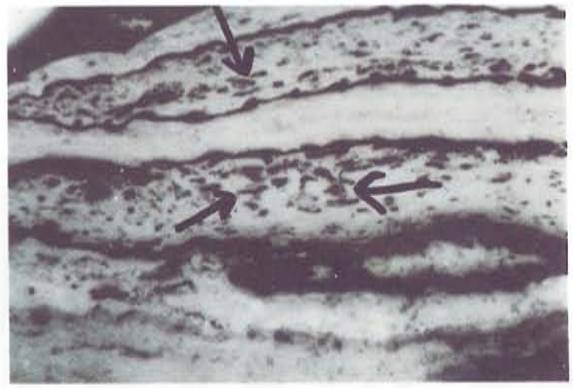

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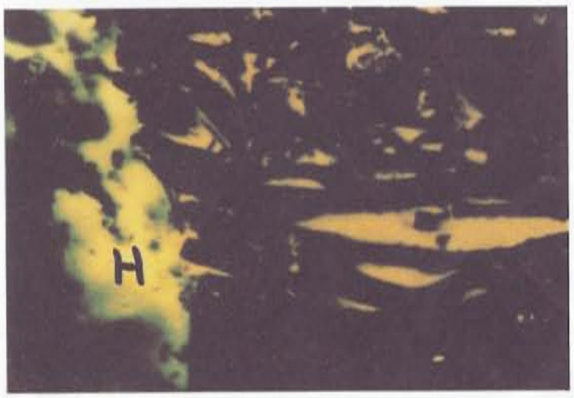

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STATE OF WYOMING

1933

GEOLOGICAL SURVEY