UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Preliminary Report on Coal Resources of the Otter Creek EMRIA Site, Powder River County, Montana

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

Illustrations

Tables

Abstract

The Knoblock coal bed in the Otter Creek EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) site--an area of about 1,177 acres (476 hectares)--contains estimated identified coal resources of about 126 million short tons (114 million metric tons). The area around and including the Otter Creek EMRIA site--an area of about 2,975 acres (1,204 hectares)--contains estimated identified coal resources of about 318 million short tons (289 million metric tons). All estimated coal resources in the Knoblock bed are categorized as measured and indicated resources, and all but about 62 million tons (56 million metric tons) are at depths of less than 200 feet (60 metres). The average thickness of the Knoblock is about 61 feet (18.6 metres) and the overall relationship of quantity of overburden to tons of coal in the area with 200 feet (60 metres) or less of overburden is about 2 cubic yards (1.5 cubic metres) of overburden per ton of coal.

The coal is subbituminous C in rank, has an average sulfur content of less than 0.2 percent, and has an average ash content of about 5.5 percent. The major and minor element composition of coal, coal-ash, and rock samples from the area is similar to the average composition of other coals of the Northern Great Plains and to the average rock composition of the Earth's crust. Only the selenium content of the Knoblock coal is more than an order of magnitude higher than that in the continental crust.

Introduction

This report was prepared as a contribution to a study of the reclamation potential of an area in the northern part of the Powder River Basin, about six miles southeast of the town of Ashland, Powder River County, Mont. The area was selected for investigation by the EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) program of the Bureau of Land Management. The Bureau of Reclamation was the principal investigator and had the assistance of the U.S. Geological Survey in parts of the program of study.

The area selected for intensive study--the EMRIA site proper--is about 1,177 acres (476 hectares). A logical contiguous area surrounding and including the EMRIA site proper--an area of about 2,975 acres (1,204 hectares)--was also geologically mapped and studied. The coal resources of the major, thick, strippable coal bed in the area were estimated using information derived from geologic mapping and core-drilling. Samples of the coal and of the rock sequence that would be disturbed during recovery of the coal by mining were analyzed to determine the major and minor element composition.

Geologic Setting

The Otter Creek EMRIA site (figure 1) and surrounding area are largely underlain by sandstone, siltstone, shale, and coal that compose several hundred feet of the lower part of the Tongue River Member of the Fort Union Formation of Paleocene age. The valleys of Home, Otter, and Threemile Creeks contain alluvium made up of sand, silt, clay, and gravel.

The coal beds in the Tongue River Member, particularly the 60-foot-plus-thick (18 metre) Knoblock bed, have burned over large areas and baked and fused the overlying rocks. The baked material, called "clinker," is more than 100 feet (30 metres) thick in parts of the Otter Creek EMRIA site.

The drill program was specifically designed to yield samples of the rocks above the Knoblock coal bed, the Knoblock coal bed itself, and the rocks within 20 to 30 feet (6 to 9 metres) below the base of the Knoblock bed. In addition, several of the drill holes were deepened about 150 feet (46 metres) to allow coring of the rock sequence between the Knoblock bed and the Flowers-Goodale coal bed, the Flowers-Goodale coal, and as much as 35 feet (11 metres) of the rock sequence beneath the Flowers-Goodale bed. Other coal beds are present in the Tongue River but are generally thin, lenticular, and nonpersistent.

The strata of the Tongue River Member are nearly flat-lying except around the edges of the areas where the coal beds have burned. Near the clinker areas, the otherwise flat or gently-dipping strata have slumped and collapsed.

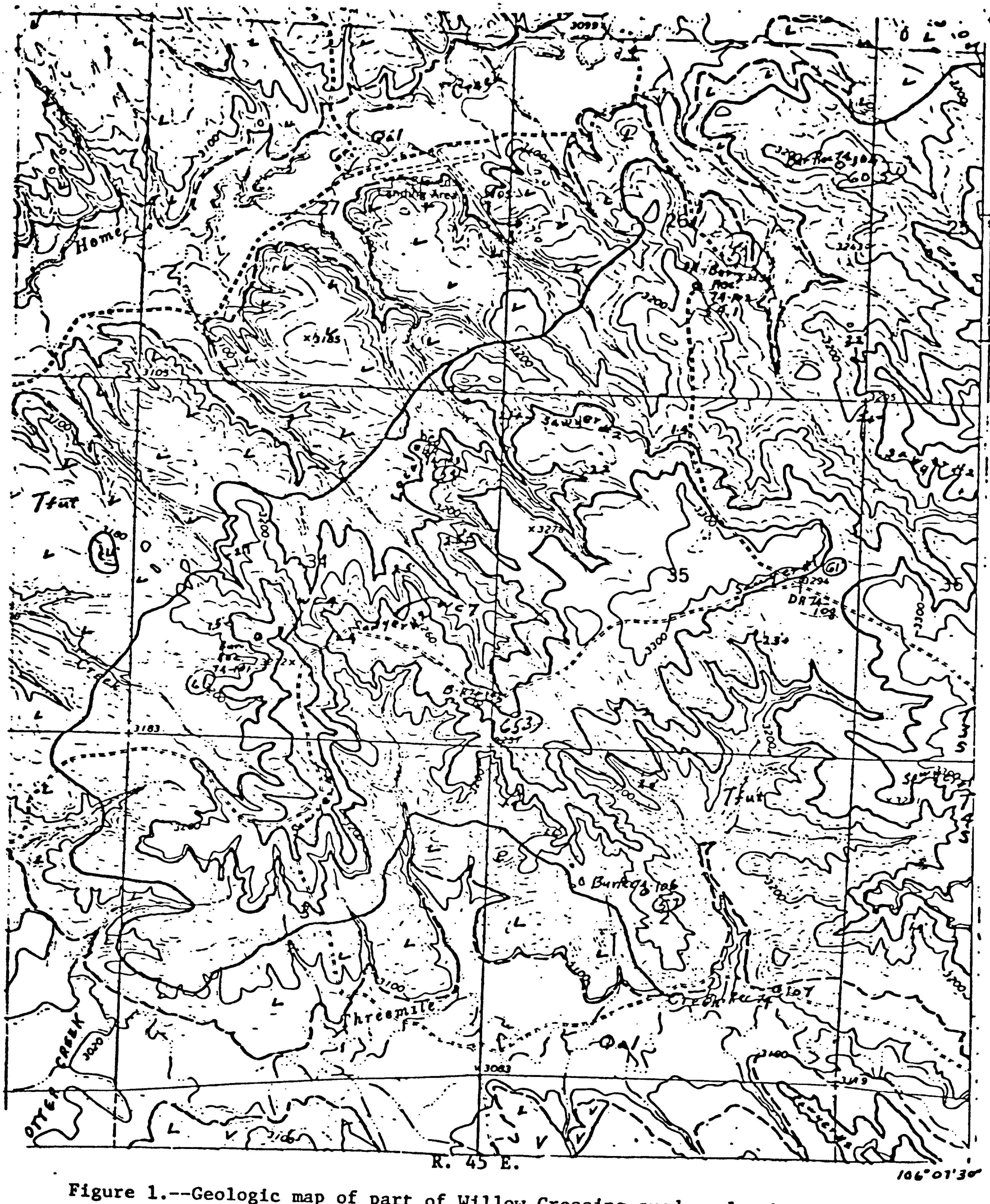


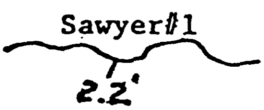
Figure 1.--Geologic map of part of Willow Crossing quadrangle showing EMRIA site (secs. 26, 34, T. 3 S., sec. 2, T. 4 S., R. 45 E.) and location of Bureau of Reclamation drill holes.

Explanation for Figure 1

Qal ALLUVIUM (HOLOCENE)--Unconsolidated silt and sand on streams and larger tributaries

Tfut FORT UNION FORMATION (PALEOCENE)

Tongue River Member--Light-gray and very light yellowish gray slabby very fine grained sandstone and siltstone, medium-gray mudstone and claystone, brown and black carbonaceous shale, and coal



Outcrop of coal bed--Drawn on base of coal. Number shows thickness of coal, in feet

Clinker above burned Knoblock coal

BurRec 74-101 (61')

Bureau of Reclamation drill hole--Circled figure shows thickness of Knoblock coal bed, in feet. Lithologic logs of drill holes are shown on Plate 1

Acknowledgments

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Coal

Origin

Coal has been defined as "a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade), are characteristics of the varieties of coal" (Schopf, 1956). Inherent in the definition is the specification that coal originated as a mixture of plant remains and inorganic mineral matter that accumulated in a manner similar to that in which modern-day peat deposits are formed. The peat then underwent a long, extremely complex process called "coalification," during which diverse physical and chemical changes occurred as the peat changed to coal, and the coal assumed the characteristics by which members of the series are differentiated from each other. The factors that affect the composition of coals have been summarized by Francis (1961, p. 2) as follows:

1) The mode of accumulation and burial of the plant debris forming the deposits.
2) The age of the deposits and their geographical distribution.
3) The structure of the coal-forming plant, particularly details of structure that affect chemical composition or resistance to decay.
4) The chemical composition of the coal-forming debris and its resistance to decay.
5) The nature and intensity of the plant-decaying agencies.
6) The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

For extended discussions of these factors, the reader is referred to such standard works as Moore (1940), Lowry (1945), Tomkeieff (1954), Francis (1961), and Lowry (1963).

Classification

Coals can be classified in many ways (Tomkeieff, 1954, p. 9; Moore, 1940, p. 113; Francis, 1961, p. 361), but the classification by rank--that is, by degree of metamorphism in the progressive series that begins with peat and ends with graphocite (Schopf, 1966)--is the most commonly used system. Classification by type of plant materials is commonly used as a descriptive adjunct to rank classification when sufficient megascopic and microscopic information is available, and classification by type and quantity of impurities (grade) is frequently used when utilization of the coal is being considered. Other categorizations are possible and are commonly employed in discussion of coal resources: such factors as the weight (specific gravity) of the coal, the thickness and areal extent of the individual coal beds, and the thickness of overburden are generally considered.

Rank of coal

The designation of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent upon the temperature and pressure to which the coal has been subjected and the duration of time of subjection. Because coal is largely derived from plant material, it is mostly composed of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the major coal constituents: the higher rank coals have more carbon and less hydrogen and oxygen than the lower ranks.

Two standarized forms of coal analyses--the proximate analysis and the ultimate analysis--are generally made, though sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (U.S. Bureau of Mines, 1965, p. 121-122):

> "The proximate analysis of coal involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cakelike residue that burns at higher temperatures after volatile matter has been drived off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion, the determination of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference."

Most coals are burned to produce heat energy, so the heating value of the coal is an important property. The heating value (calorific value) is commonly expressed in British thermal units (Btu) per pound: 1 Btu is the amount of heat required to raise the temperature of 1 lb of water 1°F (1 Btu equals 0.252 kilogram-calories). Additional tests are sometimes made, particularly to determine caking, coking, and other properties, such as tar yield, that affect classification or utilization.

Figure 2 compares in histogram form the heating value, and the moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used, but the one most commonly employed in the United States is the "Standard specifications for classification of coals by rank," adopted by the ASTM (American Society for Testing and Materials, 1974; table 1).

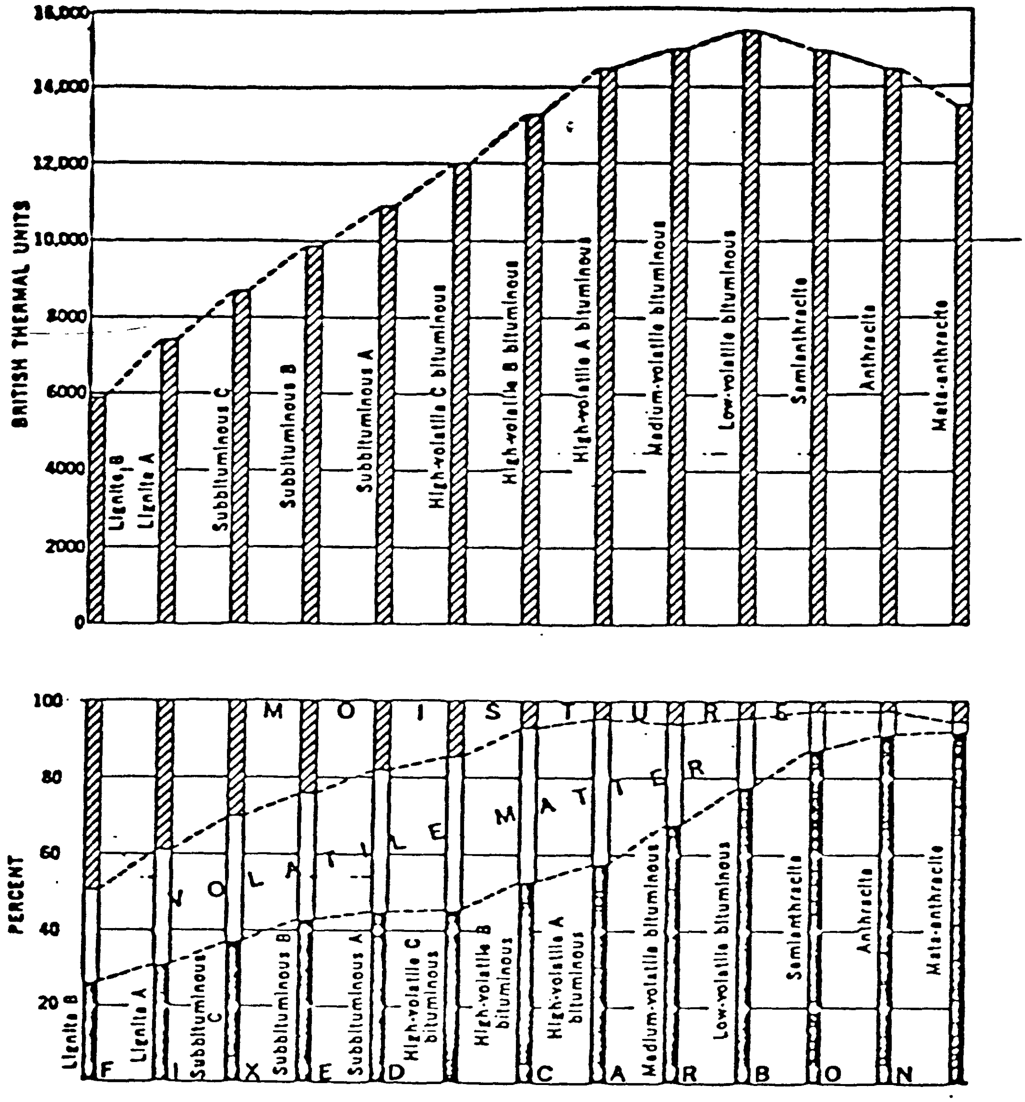

Figure 2.--Comparison on moist, mineral-matter-free basis of heat values, and proximate analyses of coal of different ranks.

Table 1.--Classification of coals by rank[1]

[American Society for Testing and Materials Standard D388-66 (Reapproved 1972); 1 Btu equals 0.252 kilogram-calories]

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis): Equal or Greater Than	Fixed Carbon Limits: Less Than	Volatile Matter Limits, percent (Dry, Mineral-Matter-Free Basis): Greater Than	Volatile Matter Limits: Equal or Less Than	Calorific Value Limits, Btu per pound (Moist,[2] Mineral-Matter-Free Basis): Equal or Greater Than	Calorific Value Limits: Less Than	Agglomerating Character
I. Anthracite	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	nonagglomerating
	3. Semianthracite[3]	86	92	8	14	...	...	nonagglomerating
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	Commonly agglomerating[5]
	3. High volatile A bituminous coal	...	69	31	...	14 000[4]	...	Commonly agglomerating[5]
	4. High volatile B bituminous coal	...	...	...	...	13 000[4]	14 000	Commonly agglomerating[5]
	5. High volatile C bituminous coal	...	...	...	...	11 500	13 000	Commonly agglomerating[5]
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	...	...	...	...	10 500	11 500	nonagglomerating
	2. Subbituminous B coal	...	...	...	...	9 500	10 500	nonagglomerating
	3. Subbituminous C coal	...	...	...	...	8 300	9 500	nonagglomerating
IV. Lignitic	1. Lignite A	...	...	...	...	6 300	8 300	nonagglomerating
	2. Lignite B					...	6 300	nonagglomerating

[1]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2]Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3]If agglomerating, classify in low-volatile group of the bituminous class.

[4]Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[5]It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile C bituminous group.

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter, and the heating value supplemented by determination of agglomerating (caking) characteristics. "Coals which in the volatile matter determination produce either an agglomerate button that will support a 500-g weight without pulverizing, or a button showing swelling or cell structure, shall be considered agglomerating from the standpoint of classification" (ASTM, 1974, p. 56).

As pointed out by the ASTM (1974, p. 55), a standard rank determination cannot be made unless the samples were obtained in accordance with standardized sampling procedures (Snyder, 1950; Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank".

The proximate, ultimate, Btu, and forms-of-sulfur analyses of samples of the Otter Creek coals are presented in table 2. The analyses indicate that the Otter Creek coals have an apparent rank of subbituminous C. Twenty-four samples of the Knoblock have an average of 8,110 Btu (2,044 kilogram-calories) as received.

Table 2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 101, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Mont.

[All analyses except Btu are in percent. One Btu equals 0.252 kilogram-calories. Original moisture content may be slightly more than shown because samp were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and as free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.]

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite sample of depth interval 198.4 to 215.2 ft														
D169041	A	30.9	27.0	34.7	7.4	6.6	45.4	0.8	39.7	0.1	7790	0.02	0.04	0.07
	B	--	39.0	50.3	10.7	4.6	65.7	1.1	17.7	.2	11270	.02	.06	.10
	C	--	43.7	56.3	--	5.1	73.6	1.3	19.8	.2	12620	.03	.07	.11
Knoblock bed, composite sample of depth interval 215.2 to 230.0 ft														
D169042	A	30.3	28.7	35.4	5.6	6.7	47.7	0.7	39.2	0.1	8220	0.02	0.04	0.09
	B	--	41.2	50.8	8.0	4.8	68.5	1.0	17.5	.2	11790	.02	.06	.12
	C	--	44.8	55.2	--	5.2	74.5	1.1	19.0	.2	12820	.03	.07	.13
Knoblock bed, composite sample of depth interval 230.0 to 245.0 ft														
D169043	A	28.2	29.3	36.0	6.5	6.5	48.6	0.7	37.6	0.1	8370	0.02	0.04	0.04
	B	--	40.8	50.1	9.1	4.7	67.6	1.0	17.5	.1	11660	.02	.06	.05
	C	--	44.9	55.1	--	5.2	74.4	1.1	19.2	.1	12830	.03	.07	.05
Knoblock bed, composite sample of depth interval 245.0 to 259.4 ft														
D169044	A	29.3	26.8	36.5	7.4	6.4	46.9	0.7	38.4	0.2	8050	0.01	0.11	0.02
	B	--	37.9	51.6	10.5	4.4	66.3	1.1	17.5	.2	11390	.02	.18	.04
	C	--	42.4	57.6	--	4.9	74.1	1.2	19.5	.3	12720	.03	.21	.04
Flowers-Goodale bed, composite sample of depth interval 376.9 to 385.4 ft														
D169481	A	26.4	28.7	39.1	5.8	6.2	51.2	0.9	35.5	0.4	8710	0.01	0.07	0.29
	B	--	39.0	53.1	7.9	4.4	69.5	1.2	16.5	.5	11830	.01	.09	.39
	C	--	42.4	57.6	--	4.8	75.4	1.3	18.0	.5	12840	.01	.10	.40

Table 2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 102, Tongue Rive Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Mont.--Continued

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite sample of depth interval 127.7 to 136.4 ft														
D169477	A	29.1	29.8	35.6	5.5	6.6	48.6	0.7	38.4	0.2	8220	0.01	0.01	0.15
	B	--	42.0	50.2	7.8	4.8	68.5	1.0	17.7	.2	11590	.01	.01	.21
	C	--	45.5	54.5	--	5.2	74.2	1.1	19.2	.3	12560	.01	.01	.23
Knoblock bed, composite sample of depth interval 136.4 to 151.3 ft														
D169478	A	30.9	29.4	34.5	5.2	6.8	47.3	0.7	39.9	0.1	8120	0.02	0.04	0.08
	B	--	42.6	49.9	7.5	4.8	68.4	1.0	18.1	.2	11750	.03	.06	.12
	C	--	46.1	53.9	--	5.2	73.9	1.0	19.7	.2	12700	.03	.07	.12
Knoblock bed, composite sample of depth interval 151.3 to 166.3 ft														
D169479	A	30.1	29.0	35.1	5.8	6.7	47.9	0.7	38.8	0.1	8240	0.01	0.01	0.10
	B	--	41.5	50.3	8.2	4.8	68.6	1.0	17.2	.2	11800	.01	.01	.15
	C	--	45.3	54.7	--	5.2	74.7	1.0	18.9	.2	12850	.01	.01	.16
Knoblock bed, composite sample of depth interval 166.3 to 181.3 ft														
D169480	A	29.7	27.9	35.3	7.1	6.5	47.1	0.7	38.4	0.2	8090	0.00	0.06	0.14
	B	--	39.6	50.4	10.0	4.6	66.9	1.0	17.2	.3	11500	.00	.08	.20
	C	--	44.1	55.9	--	5.1	74.4	1.1	19.1	.3	12790	.00	.09	.23
Flowers-Goodale bed, composite sample of depth interval 289.2 to 299.2 ft														
D169725	A	28.8	27.8	36.4	7.0	6.5	48.1	0.8	37.2	0.4	8220	0.01	0.07	0.37
	B	--	39.0	51.1	9.9	4.6	67.5	1.1	16.3	.6	11550	.01	.10	.51
	C	--	43.3	56.7	--	5.1	75.0	1.2	18.0	.7	12830	.01	.11	.57

Table 2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 103, Tongue Ri Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Mont.--Continued

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite sample of depth interval 128.5 to 141.8 ft														
D169719	A	31.4	28.3	34.7	5.6	6.8	46.4	0.8	40.2	0.2	7880	0.01	0.05	0.11
	B	--	41.3	50.6	8.1	4.8	67.6	1.1	18.2	.2	11500	.01	.08	.16
	C	--	44.9	55.1	--	5.3	73.7	1.2	19.5	.3	12520	.01	.09	:17
Knoblock bed, composite sample of depth interval 141.8 to 156.7 ft														
D169720	A	33.5	28.1	34.3	4.1	6.9	46.0	0.6	42.2	0.2	7910	0.03	0.07	0.07
	B	--	42.3	51.5	6.2	4.8	69.3	1.0	18.5	.2	11900	.04	.10	.10
	C	--	45.1	54.9	--	5.1	73.8	1.0	19.8	.3	12680	.05	.11	.11
Knoblock bed, composite sample of depth interval 156.7 to 171.2 ft														
D169721	A	26.6	31.0	37.2	5.2	6.5	50.6	0.7	36.8	0.2	8710	0.01	0.03	0.13
	B	--	42.2	50.7	7.1	4.9	68.9	.9	18.0	.2	11860	.01	.05	.18
	C	--	45.4	54.6	--	5.2	74.2	1.0	19.3	.3	12770	.01	.05	.20
Knoblock bed, composite sample of depth interval 171.2 to 186.7 ft														
D169722	A	26.8	29.0	38.3	5.9	6.4	50.2	0.7	36.6	0.2	8570	0.01	0.04	0.14
	B	--	39.7	52.3	8.0	4.6	68.6	1.0	17.5	.3	11700	.01	.06	.20
	C	--	43.1	56.9	--	5.0	74.6	1.1	19.0	.3	12720	.01	.06	.21

Table 2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 104, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Mont.--Continued

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite sample of depth interval 128.9 to 143.9 ft														
D170249	A	29.0	29.1	37.9	4.0	6.7	49.8	0.7	38.6	0.2	8420	0.01	0.07	0.11
	B	--	41.0	53.4	5.6	4.8	70.1	1.0	18.2	.3	11850	.01	.10	.16
	C	--	43.4	56.6	--	5.1	74.3	1.1	19.2	.3	12550	.01	.11	.17
Knoblock bed, composite sample of depth interval 143.9 to 158.9 ft														
D170250	A	29.3	29.4	36.8	4.5	6.6	49.3	0.7	38.7	0.2	8400	0.01	0.08	0.10
	B	--	41.6	52.0	6.4	4.7	69.8	1.0	17.8	.3	11880	.01	.11	.14
	C	--	44.5	55.5	--	5.0	74.5	1.0	19.2	.3	12690	.01	.12	.15
Knoblock bed, composite sample of depth interval 158.9 to 173.9 ft														
D170251	A	28.2	29.8	35.7	6.3	6.4	48.7	0.7	37.7	0.2	8350	0.01	0.07	0.11
	B	--	41.4	49.8	8.8	4.6	67.8	1.0	17.5	.3	11620	.01	.09	.16
	C	--	45.4	54.6	--	5.0	74.3	1.0	19.4	.3	12750	.01	.10	.17
Knoblock bed, composite sample of depth interval 173.9 to 188.9 ft														
D170252	A	29.1	28.5	37.0	5.4	6.5	48.9	0.7	38.3	0.2	8280	0.02	0.05	0.13
	B	--	40.3	52.1	7.6	4.6	69.0	.9	17.6	.3	11680	.02	.07	.18
	C	--	43.6	56.4	--	5.0	74.7	1.0	19.0	.3	12640	.02	.07	.19

Table 2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 105, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Mont.--Continued

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite sample of depth interval 200.8 to 210.8 ft														
D170197	A	35.1	26.4	31.3	7.2	6.9	43.3	0.7	41.7	0.2	7270	0.01	0.07	0.09
	B	--	40.6	48.3	11.1	4.6	66.6	1.2	16.2	.3	11190	.01	.11	.13
	C	--	45.6	54.4	--	5.1	74.9	1.3	18.4	.3	12580	.01	.13	.15
Knoblock bed, composite sample of depth interval 210.8 to 225.8 ft														
D170198	A	32.3	27.6	34.0	6.1	6.8	45.9	0.7	40.4	0.1	7860	0.07	0.06	0.01
	B	--	40.8	50.2	9.0	4.7	67.9	1.1	17.1	.2	11620	.10	.09	.01
	C	--	44.9	55.1	--	5.1	74.6	1.2	18.9	.2	12770	.11	.10	.01
Knoblock bed, composite sample of depth interval 225.8 to 240.8 ft														
D170199	A	32.6	27.8	33.5	6.1	6.9	46.2	0.7	39.9	0.2	7840	0.01	0.02	0.12
	B	--	41.2	49.8	9.0	4.8	68.6	1.0	16.4	.2	11640	.01	.04	.18
	C	--	45.3	54.7	--	5.3	75.4	1.1	18.0	.2	12790	.01	.04	.19
Knoblock bed, composite sample of depth interval 240.8 to 255.8 ft														
D170200	A	32.8	26.7	34.7	5.8	6.7	46.2	0.6	40.5	0.2	7830	0.01	0.09	0.08
	B	--	39.7	51.7	8.6	4.6	68.7	.9	16.9	.3	11660	.01	.14	.12
	C	--	43.5	56.5	--	5.0	75.3	1.0	18.4	.3	12770	.01	.15	.13
Knoblock bed, composite sample of depth interval 255.8 to 265.8 ft														
D170201	A	33.6	27.0	34.9	4.5	6.8	46.3	0.6	41.5	0.3	7920	0.01	0.05	0.26
	B	--	40.7	52.5	6.8	4.6	69.6	1.0	17.5	.5	11920	.01	.07	.39
	C	--	43.6	56.4	--	4.9	74.7	1.0	18.9	.5	12790	.01	.07	.42
Flowers-Goodale bed, composite sample of depth interval 385.2 to 394.0 ft														
D170202	A	27.5	26.2	34.4	11.9	6.0	45.8	0.7	35.0	0.6	7790	0.01	0.15	0.43
	B	--	36.1	47.5	16.4	4.1	63.1	1.0	14.6	.8	10740	.01	.21	.59
	C	--	43.2	56.8	--	4.9	75.6	1.2	17.3	1.0	12850	.01	.25	.71

Table 2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 106, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Mont.--Continued

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Orga[illegible]
		Knoblock bed, composite core bench sample, depth 169.5 to 184.5 ft												
K-52805	A	30.9	29.0	34.9	5.2	6.5	47.8	0.8	39.5	0.2	8110	0.01	0.06	[illegible]
	B	--	42.0	50.4	7.6	4.4	69.2	1.2	17.3	.3	11750	.01	.08	[illegible]
	C	--	45.5	54.5	--	4.8	74.9	1.2	18.8	.3	12710	.01	.08	[illegible]
		Knoblock bed, composite core bench sample, depth 184.5 to 199.5 ft												
K-52806	A	29.7	28.6	37.2	4.5	6.7	49.1	0.7	38.8	0.2	8400	0.02	0.08	[illegible]
	B	--	40.7	52.9	6.4	4.8	69.9	1.0	17.6	.3	11950	.02	.11	[illegible]
	C	--	43.5	56.5	--	5.2	74.7	1.1	18.7	.3	12770	.02	.12	[illegible]
		Knoblock bed, composite core bench sample, depth 199.5 to 214.5 ft												
K-52807	A	28.9	30.7	35.6	4.8	6.7	47.7	0.7	40.0	0.1	8190	0.01	0.07	[illegible]
	B	--	43.2	50.0	6.8	4.9	67.0	1.0	20.1	.2	11510	.01	.10	[illegible]
	C	--	46.4	53.6	--	5.3	71.9	1.1	21.5	.2	12350	.01	.10	[illegible]
		Knoblock bed, composite core bench sample, depth 214.5 to 228.1 ft												
K-52808	A	26.8	31.3	36.8	5.1	6.6	48.9	0.7	38.4	0.3	8410	0.01	0.13	[illegible]
	B	--	42.8	50.3	6.9	4.9	66.9	1.0	19.9	.4	11490	.01	.18	[illegible]
	C	--	46.0	54.0	--	5.3	71.8	1.0	21.5	.4	12350	.01	.20	[illegible]

Table 2.--Proximate, ultimate, Btu, and forms-of-sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 107, Tongue Ri
Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Mont.--Continued

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Org
Knoblock bed, composite core bench sample, depth 54.2 to 64.2 ft														
K-52809	A	26.0	32.5	34.7	6.8	6.5	48.3	0.8	37.4	0.2	8310	0.01	0.11	
	B	--	43.9	47.0	9.1	4.9	65.2	1.1	19.4	.3	11220	.01	.15	
	C	--	48.3	51.7	--	5.4	71.8	1.2	21.2	.4	12350	.01	.16	
Knoblock bed, composite core bench sample, depth 64.2 to 79.2 ft														
K-52810	A	31.5	29.1	34.8	4.6	6.8	47.0	0.7	40.7	0.2	8120	0.01	0.11	
	B	--	42.5	50.8	6.7	4.8	68.6	1.1	18.5	.3	11850	.01	.16	
	C	--	45.6	54.4	--	5.2	73.5	1.1	19.9	.3	12710	.01	.17	
Knoblock bed, composite core bench sample, depth 79.2 to 94.2 ft														
K-52811	A	29.1	31.2	35.3	4.4	6.7	49.3	0.7	38.7	0.02	8480	0.01	0.07	
	B	--	44.0	49.8	6.2	4.9	69.5	1.0	18.1	.03	11970	.01	.10	
	C	--	47.0	53.0	--	5.2	74.2	1.1	19.2	.03	12770	.01	.11	
Knoblock bed, composite core bench sample, depth 94.2 to 109.2 ft														
K-52812	A	28.7	30.6	35.4	5.3	6.6	49.0	0.7	38.2	0.02	8420	0.00	0.08	
	B	--	42.8	49.8	7.4	4.7	68.7	1.0	18.0	.02	11810	.00	.11	
	C	--	46.3	53.7	--	5.1	74.2	1.1	19.3	.03	12760	.00	.12	
Knoblock bed, composite core bench sample, depth 109.2 to 120.3 ft														
K-52813	A	30.4	29.3	35.9	4.4	6.7	48.9	0.7	39.0	0.3	8390	0.01	0.12	
	B	--	42.1	51.5	6.4	4.8	70.2	1.0	17.2	.4	12050	.01	.18	
	C	--	44.9	55.1	--	5.1	74.9	1.1	18.5	.4	12870	.01	.19	

Type of coal

Classification of coals by type--that is, according to the types of plant materials present--takes many forms, such as the "rational analysis" of Francis (1961) or the semicommercial "type" classification commonly used in the coal fields of the eastern United States (U.S. Bureau of Mines, 1965, p. 123). However, most of the type classifications are based on the same or similar gross distinctions in plant material used by Tomkeieff (1954, table II and p. 9), who divided the coals into three series; humic coals, humic-sapropelic coals, and sapropelic coals, based upon the nature of the original plant materials. The humic coals are largely composed of the remains of the woody parts of plants, and the sapropelic coals are largely composed of the more resistant waxy, fatty and resinous parts of plants, such as cell walls, spore-coatings, pollen, and resin particles, and coals composed mainly of algal material. Most coals fall into the humic series, with some coals being mixtures of humic and sapropelic elements and, therefore, falling into the humic-sapropelic series. The sapropelic series is quantitatively insignificant and when found is commonly regarded as an organic curiosity.

In common with most coals of the United States, the Otter Creek coals fall largely in the humic series.

Table 3.--Estimated identified coal resources in the Knoblock bed in the area around and including the Otter Creek EMRIA site

[In thousands of short tons, one short ton equals 0.9078 metric tons]

	Measured resources	Indicated resources	Totals
EMRIA site------------------- (sec. 2, T. 4 S., R. 45 E., and secs. 26 and 34, T. 3 S., R. 45 E.)	88,652	37,210	125,862
Area surrounding EMRIA site[1]-	------	192,422	192,422
Total identified resources---	88,652	229,632	318,284

[1]Area bounded by Home Creek, Three Mile Creek, and 106° 7 1/2' W. long.

Grade of coal

Classification of coal by grade, or quality, is based largely on the content of ash, sulfur, and other constituents that adversely affect utilization. Most detailed coal resource evaluations of the past do not categorize known coal resources by grade, but coals of the United States have been classified by sulfur content in a gross way (DeCarlo and others, 1966).

The range and average of the ash and sulfur contents of 642 coal samples from all parts of the United States were determined by Fieldner, Rice, and Moran (1942). Ash and sulfur contents of these U.S. coals as received were as follows:

Number of samples	Ash, percent		Sulfur, percent	
	Range	Average	Range	Average
642	2.5 - 32.6	8.9	0.2 - 7.7	1.9

The coal in the Otter Creek area is slightly below average in ash content and considerably below average in sulfur content. The average ash content as received of Knoblock coal in five drill holes is 5.5 percent and that of Flowers-Goodale coal in three drill holes is 8.2 percent. Average sulfur content in the Knoblock is 0.15 percent; in the Flowers-Goodale--0.46 percent.

Estimation and Classification of Coal Resources

Preparation of a coal resource estimate involves certain procedures and definitions that have been established in an attempt to standardize, insofar as possible, coal resource appraisals in the United States. As used in this report, the term "coal resource" designates the estimated quantity of coal in the ground.

Tabulation of estimated coal resources

Table 3 summarizes the estimated coal resources in the Knoblock coal bed in the Otter Creek EMRIA site and the surrounding area. In accordance with conventions adopted by the U.S. Geological Survey and the U.S. Bureau of Mines, the resources in the Otter Creek EMRIA site are classed as "identified-subeconomic resources"; that is, specific bodies of coal whose location, quality, and quantity are known from geologic evidence supported by engineering measurements with respect to the demonstrated category, and that are presently classed as subeconomic because the estimated tonnage of coal is in beds that are not presently classed as reserves, but may become so as a result of changes in economic and legal conditions.

No estimates are presented for the Flowers-Goodale bed in the area, because the focus of the present study is on coal resources that are potentially recoverable by surface-mining methods.

All of the estimated identified coal resources shown in table 3 fall into a category called Reserve Base, which is defined as that portion of the identified coal resource from which reserves are calculated. Reserves in the strict sense used here are defined as "that portion of the identified coal resource that can be economically and legally mined at the time of determination--also referred to as Recoverable Reserve. The reserve is derived by applying a recoverability factor to that component of the identified coal resource designated as the Reserve Base."

Recoverability

The recoverability factor is "the percentage of total tons of coal producible from a given area in relation to the total tonnage estimated to be in place in the ground."

Recoverability determinations can be made (1) by using mine maps, (2) by using production versus reserve base estimates, or (3) by using an average recoverability factor based on past experience. All coal remaining in the ground after mining is completed is considered as lost in mining and includes coal that is (1) left to support mine roofs, (2) too thin to mine, (3) left unmined beneath rivers, lakes, highways, and legal reservations, (4) left unmined around oil, gas, water, and disposal wells, (5) left unmined as barrier pillars adjacent to mine or property boundaries, and (6) left unmined because of environmental, safety, quality, or hydrologic considerations. Coal losses incurred during cleaning and preparation are not considered when determining recoverability. Recoverability determined in existing mined areas can be projected to similar unmined areas, assuming other conditions are equal, to calculate recoverable reserves from reserve base. In the United States, recoverability in underground mining ranges from 10 to 80 percent, depending on variables such as the thickness of coal bed, security of roof and floor rock, operator, and mining methods, and probably averages about 50 percent. Recoverability for strip mining is locally as great as 90 percent, but studies indicate that nationally it also averages about 50 percent owing to barriers left to protect mine boundaries, to restrictions on highwalls, and to restrictions about mining near lakes, streams, railroads, highways, and farmed areas.

Resources categorized by degree of geologic assurance

Two categories according to degree of geologic assurance were used in the present study.

Measured - Tonnage of coal for which estimates of the quality and quantity have been computed, within a margin of error of less than 20 percent, from sample analyses and measurements from closely spaced and geologically well-known sample sites.

Indicated - Tonnage of coal for which estimates of the quality and quantity have been computed partly from sample analyses and measurements and partly from reasonable geologic projections.

The measured resources estimated for the Otter Creek ERMIA site and adjoining area are within 1/4 mile (0.4 kilometres) of points of information; the indicated resources are contained in bodies whose inner limits are 1/4 mile (0.4 kilometres) from points of information and whose outer limits are within 3/4 mile (1.2 kilometres) of points of information.

Characteristics used in resource evaluation

The coal characteristics that are commonly used in classifying coal resources are the rank, grade, and weight of the coal, the thickness and areal extent of the coal beds, and the thickness of the overburden. The rank and grade of the coal sampled as part of this study have been discussed previously.

Weight

The weight of coal ranges considerably with differences in rank and ash content. In areas such as the Otter Creek area, where specific gravities of the coals have not been determined, an average specific gravity value based on many determinations in other areas is used to express the weight of the coal for resource calculations. The average weight of subbituminous coal is taken as 1,770 short tons per acre-foot (1,607 metric tons)--a specific gravity of 1.30.

Thickness of beds

Because of the important relation of coal-bed thickness to utilization potential, most coal resource estimates parepared by the U.S. Geological Survey are tabulated according to three thickness categories. For subbituminous coal the categories are thin--2.5 to 5 feet (0.75 to 1.5 metres); intermediate--5 to 10 feet (1.5 to 3 metres); and thick--more than 10 feet (3 metres). In the EMRIA site and surrounding area, all of the estimated resources in the Knoblock bed are in the thick category.

Thickness of overburden

Coal resources are commonly divided into categories based on the thickness of overburden, in feet, as follows: 0-1,000 (0 to 300 metres), 1,000-2,000 (300 to 600 metres), and 2,000-3,000 (600 to 900 metres). For estimates of total resources and undiscovered resources--for example, an estimate for a complete coal basinal area--a depth of 6,000 feet (1,800 metres) may be used. However, most of the coal in the Knoblock bed in the Otter Creek EMRIA site and surrounding area is overlain by 200 feet (60 metres) or less of overburden and can be recovered by surface mining methods. Table 4 shows detailed and aggregate volume of overburden in the EMRIA site. Comparison of tables 3 and 4 indicates that the ratio of cubic yards of overburden to total estimated coal resources with less than 200 feet (60 metres) of overburden in the Otter Creek EMRIA site is about 2 cubic yards (1.5 cubic metres) of overburden per ton of coal.

Table 4.--Quantity of overburden above the Knoblock bed in the Otter Creek EMRIA site

[Overburden thickness 200 ft (60 m) or less, one acre equals 0.4047 hectares; one ft equals 0.3048 metres; one cubic yard equals 0.7646 cubic metres]

Contour interval (ft)	Acreage between 20-ft contours		Average footage above Knoblock coal		Square feet in acre		Cubic feet in cubic yard		Cubic yard overburden
Sec. 2, T. 4 S., R. 45 E.									
3,260 - 3,240	17.8	X	190	X	43,560	÷	27	=	5,456,000
3,240 - 3,220	43.6	X	170	X	43,560	÷	27	=	11,958,000
3,220 - 3,200	40.9	X	150	X	43,560	÷	27	=	9,898,000
3,200 - 3,180	55.1	X	130	X	43,560	÷	27	=	11,556,000
3,180 - 3,160	59.2	X	110	X	43,560	÷	27	=	10,506,000
3,160 - 3,140	44.9	X	90	X	43,560	÷	27	=	6,519,000
3,140 - 3,120	41.9	X	70	X	43,560	÷	27	=	4,732,000
3,120 - 3,100	36.9	X	50	X	43,560	÷	27	=	2,977,000
3,100 - 3,080	55.4	X	30	X	43,560	÷	27	=	2,681,000
3,080 - 3,060	21.5	X	10	X	43,560	÷	27	=	347,000
Totals	417.2								66,630,000
Sec. 34, T. 3 S., R. 45 E.									
3,260 - 3,240	69.8	X	190	X	43,560	÷	27	=	21,396,000
3,240 - 3,220	60.9	X	170	X	43,560	÷	27	=	16,703,000
3,220 - 3,200	66.3	X	150	X	43,560	÷	27	=	16,045,000
3,200 - 3,180	82.8	X	130	X	43,560	÷	27	=	17,366,000
3,180 - 3,160	66.2	X	110	X	43,560	÷	27	=	11,748,000
3,160 - 3,140	36.8	X	90	X	43,560	÷	27	=	5,343,000
3,140 - 3,120	10.8	X	70	X	43,560	÷	27	=	871,000
3,120 - 3,100	2.1	X	50	X	43,560	÷	27	=	169,000
Totals	395.7								89,641,000
Sec. 26, T. 3 S., R. 45 E.									
3,260 - 3,240	5.2	X	190	X	43,560	÷	27	=	1,594,000
3,240 - 3,220	38.3	X	170	X	43,560	÷	27	=	10,504,000
3,220 - 3,200	55.2	X	150	X	43,560	÷	27	=	13,358,000
3,200 - 3,180	82.1	X	130	X	43,560	÷	27	=	17,219,000
3,180 - 3,160	71.8	X	110	X	43,560	÷	27	=	12,742,000
3,160 - 3,140	63.3	X	90	X	43,560	÷	27	=	9,191,000
3,140 - 3,120	39.6	X	70	X	43,560	÷	27	=	4,472,000
3,120 - 3,100	8.5	X	50	X	43,560	÷	27	=	686,000
Totals	364.0								69,765,000
All totals	1,176.9--in which overburden in 200 ft or less								226,036,000

Summary of resources

The Knoblock coal bed in the area around and including the Otter Creek EMRIA site--an area of about 2,975 acres (4.6 square miles and 1,204 hectares)--contains estimated identified coal resources of about 318 million tons (289 million metric tons). The Otter Creek EMRIA site itself--an area of about 1,177 acres (1.7 square miles and 476 hectares)--contains estimated identified coal resources of about 126 million tons (114 million metric tons). All estimated coal resources in the Knoblock bed are categorized as measured and indicated resources, and all but about 62 million tons (56 million metric tons) are at depths of less than 200 feet (60 metres). The overall ratio of cubic yards of overburden to tons of coal in the area with 200 feet (60 metres) or less of overburden is about 2 cubic yards (1.5 cubic metres) of overburden per ton of coal.

Chemical Composition

Twenty-eight core samples of the Knoblock and Flowers-Goodale coal beds and 39 core samples of the rock sequence above and below the Knoblock were analyzed for the following constituents (following the procedure shown on figure 3):

1. Proximate analysis for percent moisture, volatile matter, fixed carbon, and ash; ultimate analysis for percent hydrogen, carbon, nitrogen, oxygen, and sulfur; and forms-of-sulfur analysis for percent sulfate-sulfur, pyritic sulfur, and organic sulfur.
2. Major composition of the ash of coal--percent ash, SiO_2, Al_2O_3, Na_2O, K_2O, CaO, MgO, Fe_2O_3, P_2O_5, Cl, MnO, TiO_2, and SO_3.
3. Trace element composition of coal
   a. Individual quantitative determinations--ppm As, Cd, Cu, F, Hg, Li, Pb, Sb, Se, Th, U, and Zn.
   b. Semiquantitative spectrographic analysis--ppm of 20-30 elements detected by this method.

Results of the analytical determinations are listed in tables 5, 6, 7, and 8.

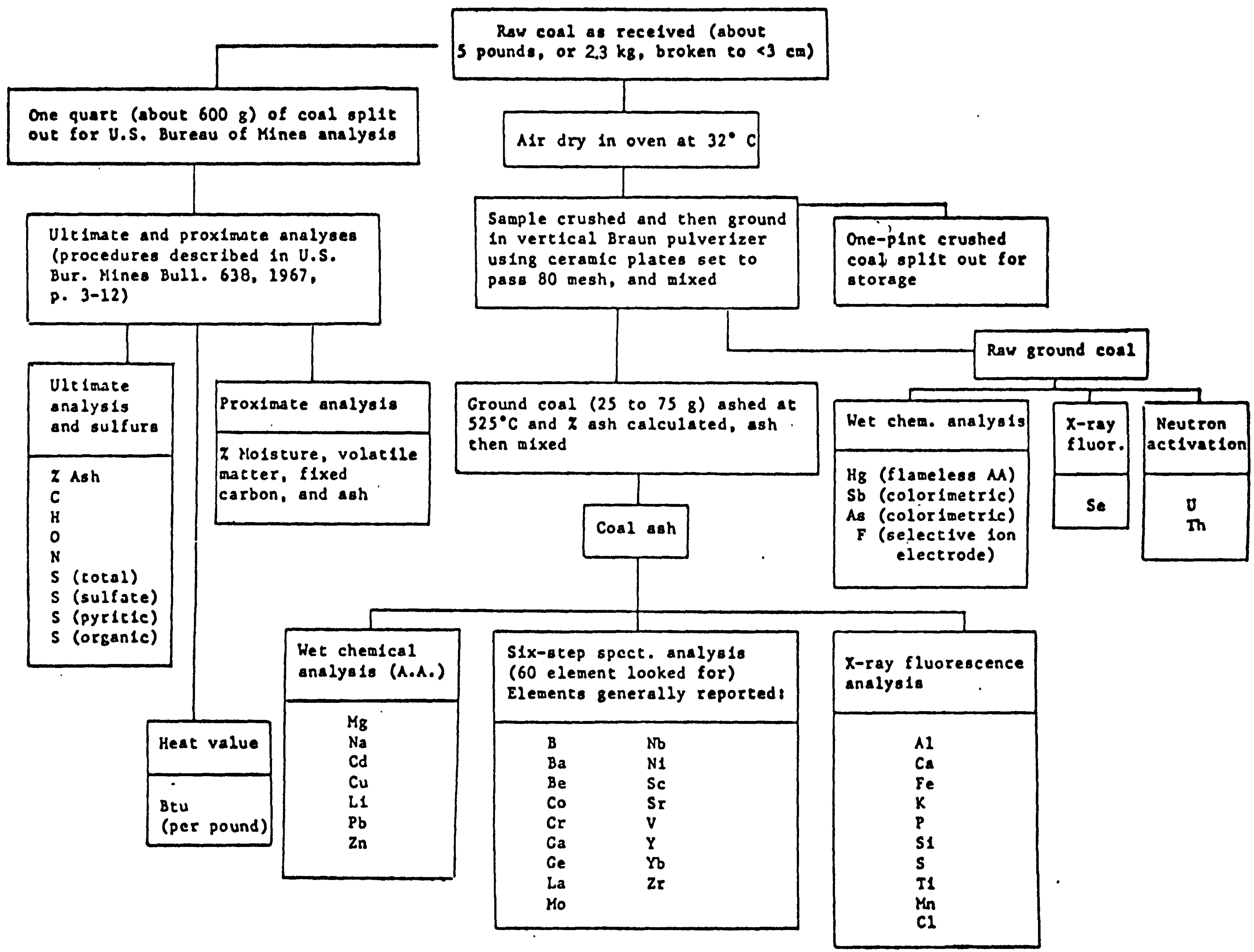

Figure 3.--Sequence of sample preparation and chemical analysis.

Table 5.--Major and minor oxide and trace element composition of the laboratory ash of 28 samples of coal from the Otter Creek area, Powder River County, Mont.

[Values are in either percent or parts per million. The coals were ashed at 525°C. L after a value means less than the value shown, N means not detected, and B means not determined. S after the element title means that the values were determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data is approximately one bracket at 68-percent or two brackets at 95-percent confidence. Locations of drill holes are shown on fig. 1 and sample intervals are shown on plate 1]

Sample	Field No.	Thickness (ft)	Ash %	Al_2O_3%	CaO%	Fe_2O_3%	MgO%	Na_2O%	K_2O%	SO_3%	SiO_2%	Cl%
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)												
D169028	74-101-1	1.6	13.4	17.	11.	3.2	5.0	3.3	1.0	9.3	45.	0.10L
D169029	74-101-2	5.	12.9	18.	11.	3.6	3.2	3.5	1.3	4.4	45.	.10L
D169030	74-101-3	5.	6.1	16.	21.	3.6	3.9	7.5	.47	7.8	24.	.10L
D169031	74-101-4	5.	7.0	17.	17.	3.6	3.5	6.5	1.0	5.6	34.	.10L
D169032	74-101-5	5.	6.9	16.	17.	3.5	3.8	6.8	.78	6.8	33.	.10L
D169033	74-101-6	5.	8.5	18.	16.	3.4	3.1	5.6	.70	10.	33.	.10L
D169034	74-101-7	4.8	7.6	19.	15.	5.3	3.0	5.7	.26	18.	30.	.10L
D169035	74-101-8	5.	5.3	10.	21.	4.3	4.2	8.0	.49	9.1	25.	.10L
D169036	74-101-9	5.	12.4	7.3	8.4	1.5	1.8	3.2	.10	3.2	69.	.10L
D169037	74-101-10	5.	7.8	14.	13.	2.6	2.6	5.4	.092	7.5	47.	.10L
D169038	74-101-11	5.	6.5	12.	17.	3.0	3.4	6.8	.035	11.	39.	.10L
D169039	74-101-12	5.	6.9	13.	15.	3.0	3.0	6.3	.11	16.	39.	.10L
D169040	74-101-13	4.4	12.0	17.	7.8	2.8	2.2	3.7	1.5	12.	52.	.10L
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)												
D169437	74-102-1	4.	9.20	20.	14.	3.2	5.1	1.4	0.68	7.5	40.	0.10L
D169438	74-102-2	4.7	6.94	16.	18.	4.5	6.4	2.1	1.1	6.8	30.	.10L
D169439	74-102-3	5.	9.46	16.	17.	3.9	4.9	1.6	1.4	5.0	34.	.10L
D169440	74-102-4	4.9	7.64	17.	18.	3.6	5.2	2.3	1.2	5.0	33.	.10L
D169441	74-102-5	5.	8.44	21.	17.	2.6	4.2	1.7	.78	4.4	34.	.10L
D169442	74-102-6	5.	8.68	21.	17.	2.3	4.1	1.7	.61	5.1	34.	.10L
D169443	74-102-7	5.	6.06	17.	22.	3.2	5.2	2.9	.70	6.1	27.	.10L
D169444	74-102-8	5.	7.90	15.	18.	2.3	4.0	1.9	.32	6.1	38.	.10L
D169445	74-102-9	5.	10.7	17.	16.	2.7	3.4	1.6	.84	5.4	42.	.10L
D169446	74-102-10	5.	8.96	12.	22.	3.1	3.4	1.7	.45	7.3	35.	.10L
D169447	74-102-11	5.	11.2	14.	11.	2.0	2.7	1.5	.37	6.7	53.	.10L
Flowers-Goodale bed, BurRec DH 74-101												
D169475	74-101-14	4.5	8.44	24.	15.	3.5	2.5	4.5	0.15	11.	37.	0.10L
D169476	74-101-15	5.2	6.78	22.	16.	4.4	2.6	5.6	.32	18.	30.	.10L
Flowers-Goodale bed, BurRec DH 74-102												
D169723	74-102-12	5.	11.0	24.	9.6	4.4	1.9	3.7	1.1	14.	43.	0.10L
D169724	74-102-13	5.	6.30	17.	19.	4.4	3.1	6.4	.33	16.	26.	.10L

Table 5.—Major and minor oxide and trace element composition of the laboratory ash of 28 samples of coal from the Otter Creek area, Powder River County, Mont.—Continued

Sample	MnO %	P_2O_5 %	TiO_2 %	Cd PPM	Cu PPM	Li PPM	Pb PPM	Zn PPM	B PPM-S	Ba PPM-S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)										
D169028	0.052	0.10L	0.54	1.L	70.	72.	70.	160.	300	3000
D169029	.056	.10L	.51	1.L	60.	104.	90.	160.	300	3000
D169030	.046	.10L	.38	1.L	53.	68.	50.	94.	1000	3000
D169031	.033	.10L	.52	1.L	62.	60.	55.	156.	1000	3000
D169032	.031	.10L	.54	1.L	68.	70.	60.	142.	700	3000
D169033	.034	.10L	.92	1.L	114.	114.	70.	176.	700	5000
D169034	.020L	.10L	1.0	1.L	92.	135.	70.	138.	1000	3000
D169035	.029	.10L	.40	1.L	64.	45.	85.	214.	1000	7000
D169036	.020L	.10L	.86	1.L	48.	52.	40.	96.	500	1000
D169037	.020L	.10L	.91	1.L	72.	100.	60.	76.	1000	2000
D169038	.020	.10L	.53	1.L	56.	74.	40.	72.	1000	3000
D169039	.021	.10L	.84	1.L	102.	66.	50.	80.	1000	1500
D169040	.020L	.10L	.71	1.L	96.	53.	40.	100.	700	1500
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)										
D169437	0.020L	0.10L	0.71	1.L	56.	114.	70.	97.	1000	3000
D169438	.046	.10L	.43	1.L	56.	36.	55.	119.	1000	7000
D169439	.052	.10L	.49	1.L	46.	36.	55.	122.	500	15000
D169440	.033	.10L	.50	1.L	56.	42.	460.	1180.	700	7000
D169441	.020L	.10L	.92	1.L	66.	118.	70.	79.	700	1500
D169442	.020L	.10L	1.1	1.L	106.	116.	50.	67.	700	2000
D169443	.020L	.10L	.55	1.L	66.	106.	50.	98.	1000	10000
D169444	.020L	.10L	.85	1.L	94.	84.	50.	74.	700	5000
D169445	.021	.10L	.75	1.L	70.	90.	65.	122.	700	5000
D169446	.060	.10L	.58	1.L	72.	36.	40.	82.	1000	3000
D169447	.020L	.10L	1.2	1.L	102.	60.	40.	57.	700	2000
Flowers-Goodale bed, BurRec DH 74-101										
D169475	0.040	0.10L	0.65	1.L	94.	74.	60.	60.	1000	7000
D169476	.041	.10L	.71	1.L	104.	62.	40.	69.	1500	7000
Flowers-Goodale bed, BurRec DH 74-102										
D169723	0.030	0.10L	0.64	1.L	92.	78.	45.	129.	700	3000
D169724	.034	.10L	.55	1.L	92.	46.	55.	67.	1500	7000

Table 5.--Major and minor oxide and trace element composition of the laboratory ash of 28 samples of coal from the Otter Creek area, Powder River County, Mont.--Continued

Sample	Be PPM-S	Co PPM-S	Cr PPM-S	Ga PPM-S	Ge PPM-S	La PPM-S	Mo PPM-S	Nb PPM-S	Ni PPM-S	Sc PPM-S	Sr PPM-S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E)											
D169028	20	15	30	20	70	70	7	30	20	15	1500
D169029	N	7 L	30	30	N	N	7	20	15	10	2000
D169030	3	7 L	30	20	N	70	7	20 L	20	15	5000
D169031	N	7 L	30	30	N	70	7	20 L	20	10	3000
D169032	N	7 L	30	20	N	N	70	20 L	15	10	3000
D169033	N	7 L	50	30	N	N	7	20 L	10	10	5000
D169034	N	7 L	30	30	N	N	7	20 L	10	10	5000
D169035	N	7 L	30	15	N	N	10	20 L	15	10 L	5000
D169036	N	N	20	15	N	N	10	20	10 L	N	1500
D169037	N	N	30	30	N	N	7 L	20	10 L	10	3000
D169038	N	N	20	15	N	70	10	20 L	10	10	5000
D169039	N	N	20	20	N	70	7 L	20 L	10	10 L	3000
D169040	15	10	70	30	N	70	7	20	15	15	2000
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E)											
D169437	3	N	30	30	N	70	7	20	10	10	3000
D169438	3	7 L	30	15	N	70	7	N	15	10	5000
D169439	N	7 L	30	20	N	70	7	N	15	10	5000
D169440	N	7 L	50	50	N	70	70	20 L	15	15	7000
D169441	N	7 L	30	30	N	70	7 L	20 L	15	15	5000
D169442	N	7 L	30	30	N	70	7 L	20 L	10	15	3000
D169443	N	7 L	30	30	N	70	7	20 L	15	10	7000
D169444	N	N	30	30	N	70	N	20 L	10	15	5000
D169445	N	N	30	30	N	N	7 L	20 L	10 L	10	3000
D169446	N	7 L	30	20	N	N	7	N	10 L	10	7000
D169447	N	N	30	30	N	N	N	20	10	10	3000
Flowers-Goodale bed, BurRec DH 74-101											
D169475	10	7 L	30	30	N	70	10	20 L	15	20	5000
D169476	20	10	50	50	N	70	15	20	15	30	5000
Flowers-Goodale bed, BurRec DH 74-102											
D169723	10	10	30	50	N	N	15	20 L	20	20	3000
D169724	10	10	20	30	N	70	7	20 L	10	15	7000

Table 5.--Major and minor oxide and trace element composition of the laboratory ash of 28 samples of coal from the Otter Creek area, Powder River County, Mont.--Continued

Sample	V PPM-S	Y PPM-S	Yb PPM-S	Zr PPM-S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)				
D169028	70	50	5	200
D169029	70	20	3	150
D169030	70	30	3	150
D169031	70	20	3	150
D169032	70	20	2	150
D169033	70	20 L	2 L	200
D169034	70	20 L	2 L	150
D169035	50	20	2	100
D169036	20	20	2	300
D169037	70	20	2	200
D169038	50	20	2	150
D169039	50	20 L	2	150
D169040	150	30	3	150
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)				
D169437	50	20	2	200
D169438	50	30	2	150
D169439	70	20	2	150
D169440	70	20	2	150
D169441	100	20	2	200
D169442	70	20	2	200
D169443	70	20	2	150
D169444	70	20	2	200
D169445	70	20	2	200
D169446	70	20	2	200
D169447	70	20	2	300
Flowers-Goodale bed, BurRec DH 74-101				
D169475	70	50	5	200
D169476	100	50	5	200
Flowers-Goodale bed, BurRec DH 74-102				
D169723	100	30	3	200
D169724	50	30	3	150

Table 6.--Content of seven trace elements in 28 coal samples from the Otter Creek area, Powder River County, Mont.

[Analyses on air-dried (32°C) coal. All values are in parts per million. L after a value means less than the value shown, B means not determined. Locations of drill holes are shown on fig. 1 and sample intervals are shown on Plate 1]

Sample	Field No.	Thickness (ft)	As PPM	F PPM	Hg PPM	Sb PPM	Se PPM	Th PPM	U PPM
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)									
D169028	74-101-1	1.6	3.	70.	0.12	2.3	0.3	3.1	1.2
D169029	74-101-2	5.	1.	80.	.02	.2	.2	4.0	1.3
D169030	74-101-3	5.	1.	40.	.01	.1	.2	2.0L	.3
D169031	74-101-4	5.	2.	50.	.03	.2	.2	2.3	.3
D169032	74-101-5	5.	1.	45.	.01	.2	.2	1.9	.4
D169033	74-101-6	5.	1.	45.	.02	.3	.1	2.2	.7
D169034	74-101-7	4.8	12.	35.	.01	.5	.3	2.3	.7
D169035	74-101-8	5.	1.	35.	.01	.1	.4	2.0L	.1L
D169036	74-101-9	5.	1.L	30.	.02	.2	.4	3.6	.8
D169037	74-101-10	5.	1.L	30.	.01	.3	.3	2.9	1.1
D169038	74-101-11	5.	1.L	25.	.01	.1	.2	1.9	.4
D169039	74-101-12	5.	1.L	25.	.04	.2	.3	2.0L	.6
D169040	74-101-13	4.4	2.	85.	.06	.7	.5	2.6	1.2
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)									
D169437	74-102-1	4.	1.	55.	0.05	0.5	0.5	7.3	1.8
D169438	74-102-2	4.7	1.	50.	.05	.2	.2	2.3	.2
D169439	74-102-3	5.	1.	65.	.04	.3	.6	2.6	.4
D169440	74-102-4	4.4	1.	60.	.06	.3	.6	3.3	.1L
D169441	74-102-5	5.	1.	50.	.05	.5	.4	2.4	.7
D169442	74-102-6	5.	1.	70.	.32	.5	.9	3.8	1.0
D169443	74-102-7	5.	1.	45.	.06	.4	.4	2.1	.3
D169444	74-102-8	5.	1.	30.	.05	.2	.6	2.9	.8
D169445	74-102-9	5.	1.	50.	.05	.3	.5	5.3	.9
D169446	74-102-10	5.	1.	45.	.05	.2	.6	2.3	.6
D169447	74-102-11	5.	1.	50.	.08	.4	1.0	2.0L	1.0
Flowers-Goodale bed, BurRec DH 74-101									
D169475	74-101-14	4.5	2.	25.	0.06	0.8	0.6	2.0L	1.5
D169476	74-101-15	5.2	2.	30.	.05	1.0	.7	3.1	1.0
Flowers-Goodale bed, BurRec DH 74-102									
D169723	74-102-12	5.	4.	45.	0.11	1.4	0.4	4.0	2.6
D169724	74-102-13	5.	1.	40.	.04	.4	.2	1.9	.6

Table 7.--Major, minor, and trace-element composition of 28 coal samples from the Otter Creek area, Powder River County, Mont., reported on whole-coal basis

[Values are in either percent or parts per million. Al, Ca, Fe, Mg, Na, K, Si, Cl, Mn, P, Ti, Cd, Cu, Li, Pb, and Zn values were calculated from analyses of ash. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal. The remaining analyses were calculated from spectrographic determinations (-S) on ash. L after a value means less than the value shown, N means not detected, and B means not determined. Locations of drill holes are shown on fig. 1 and sample intervals are shown on plate 1]

Sample	Field No.	Thickness (ft)	Al %	Ca %	Fe %	Mg %	Na %	K %	Si %	Cl %	Mn PPM	P PPM
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)												
D169028	74-101-1	1.6	1.2	1.0	0.30	0.40	0.32	0.11	2.8	0.01L	54.	58.L
D169029	74-101-2	5.	1.2	1.1	.32	.25	.34	.14	2.7	.01L	56.	56.L
D169030	74-101-3	5.	.53	.90	.15	.14	.34	.024	.69	.01L	22.	27.L
D169031	74-101-4	5.	.62	.84	.17	.15	.34	.058	1.1	.01L	18.	31.L
D169032	74-101-5	5.	.60	.85	.17	.16	.35	.045	1.1	.01L	16.	30.L
D169033	74-101-6	5.	.79	.99	.20	.16	.35	.049	1.3	.01L	22.	37.L
D169034	74-101-7	4.8	.75	.83	.28	.14	.32	.017	1.1	.01L	12.L	33.L
D169035	74-101-8	5.	.29	.80	.16	.13	.31	.022	.63	.01L	12.	23.L
D169036	74-101-9	5.	.48	.75	.13	.13	.30	.011	4.0	.01L	19.L	54.L
D169037	74-101-10	5.	.57	.74	.14	.12	.31	.016	1.7	.01L	12.L	34.L
D169038	74-101-11	5.	.42	.79	.14	.13	.33	.002	1.2	.01L	10.	28.L
D169039	74-101-12	5.	.46	.74	.14	.13	.32	.006	1.3	.01L	11.	30.L
D169040	74-101-13	4.4	1.1	.66	.23	.16	.33	.15	2.9	.01L	19.L	52.L
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)												
D169437	74-102-1	4.	1.0	0.91	0.20	0.28	0.093	0.052	1.7	0.01L	14.L	40.L
D169438	74-102-2	4.7	.59	.91	.22	.27	.11	.065	.98	.01L	25.	30.L
D169439	74-102-3	5.	.78	1.2	.26	.28	.11	.11	1.5	.01L	38.	41.L
D169440	74-102-4	4.4	.68	.99	.19	.24	.13	.076	1.2	.01L	19.	33.L
D169441	74-102-5	5.	.92	1.0	.15	.21	.11	.055	1.3	.01L	13.L	37.L
D169442	74-102-6	5.	.98	1.1	.14	.21	.11	.044	1.4	.01L	13.L	38.L
D169443	74-102-7	5.	.55	.96	.13	.19	.13	.036	.76	.01L	9.L	26.L
D169444	74-102-8	5.	.64	1.0	.13	.19	.11	.021	1.4	.01L	12.L	34.L
D169445	74-102-9	5.	.97	1.2	.20	.22	.13	.075	2.1	.01L	17.	47.L
D169446	74-102-10	5.	.55	1.4	.19	.18	.11	.033	1.5	.01L	41.	39.L
D169447	74-102-11	5.	.81	.91	.15	.18	.12	.034	2.8	.01L	17.L	49.L
Flowers-Goodale bed, BurRec DH 74-101												
D169475	74-101-14	4.5	1.1	0.90	0.20	0.13	0.28	0.011	1.5	0.01L	26.	37.L
D169476	74-101-15	5.2	.78	.76	.21	.10	.28	.018	1.0	.01L	22.	30.L
Flowers-Goodale bed, BurRec DH 74-102												
D169723	74-102-12	5.	1.4	0.75	0.34	0.13	0.30	0.099	2.2	0.01L	26.	48.L
D169724	74-102-13	5.	.58	.83	.19	.12	.30	.018	.78	.01L	31.	27.L

Table 7.--Major, minor, and trace-element composition of 28 coal samples from the Otter Creek area, Powder River County, Mont., reported on whole-coal basis--Continued

Sample	Ti %	As PPM	Cd PPM	Cu PPM	F PPM	Hg PPM	Li PPM	Pb PPM	Sb PPM	Se PPM
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)										
D169028	0.043	3.	0.1L	9.4	70.	0.12	9.6	9.4	2.3	0.3
D169029	.040	1.	.1L	7.7	80.	.02	13.4	11.6	.2	.2
D169030	.014	1.	.1L	3.2	40.	.01	4.1	3.1	.1	.2
D169031	.022	2.	.1L	4.3	50.	.03	4.2	3.9	.2	.2
D169032	.022	1.	.1L	4.7	45.	.01	4.8	5.5	.2	.2
D169033	.047	1.	.1L	9.7	45.	.02	9.7	5.9	.3	.1
D169034	.047	12.	.1L	7.0	35.	.01	10.3	5.3	.5	.3
D169035	.013	1.	.1L	3.4	35.	.01	2.4	4.5	.1	.4
D169036	.064	1.L	.1L	6.0	30.	.02	6.4	5.0	.2	.4
D169037	.042	1.L	.1L	5.6	30.	.01	7.6	4.7	.3	.3
D169038	.021	1.L	.1L	3.6	25.	.01	4.8	2.6	.1	.2
D169039	.035	1.L	.1L	7.0	25.	.04	4.1	3.5	.2	.3
D169040	.051	2.	.1L	11.8	85.	.06	6.4	4.6	.7	.5
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)										
D169437	0.039	1.	0.1L	5.3	55.	0.05	10.5	6.4	0.5	0.5
D169438	.018	1.	.1L	3.9	50.	.05	2.5	3.8	.2	.2
D169439	.028	1.	.1L	4.5	65.	.04	3.4	5.2	.3	.6
D169440	.023	1.	.1L	4.3	60.	.06	3.2	35.1	.3	.6
D169441	.046	1.	.1L	5.6	50.	.05	10.0	5.9	.5	.4
D169442	.059	1.	.1L	9.4	70.	.32	10.1	4.3	.5	.9
D169443	.020	1.	.1L	4.1	45.	.06	6.4	3.0	.4	.4
D169444	.040	1.	.1L	7.4	30.	.05	6.6	3.9	.2	.6
D169445	.048	1.	.1L	7.5	50.	.05	9.6	7.0	.3	.5
D169446	.031	1.	.1L	6.5	45.	.05	3.2	3.6	.2	.6
D169447	.080	1.	.1L	11.4	50.	.08	6.7	4.5	.4	1.0
Flowers-Goodale bed, BurRec DH 74-101										
D169475	0.033	2.	0.1L	7.9	25.	0.06	6.2	5.1	0.8	0.6
D169476	.029	2.	.1L	7.1	30.	.05	4.2	2.7	1.0	.7
Flowers-Goodale bed, BurRec DH 74-102										
D169723	0.042	4.	0.1L	10.1	45.	0.11	8.6	4.9	1.4	0.4
D169724	.021	1.	.1L	5.8	40.	.04	2.9	3.5	.4	.2

Table 7.—Major, minor, and trace-element composition of 28 coal samples from the Otter Creek area, Powder River County, Mont., reported on whole-coal basis—Continued

Sample	Th PPM	U PPM	Zn PPM	B PPM-S	Ba PPM-S	Be PPM-S	Co PPM-S	Cr PPM-S	Ga PPM-S	Ge PPM-S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)										
D169028	3.1	1.2	21.4	50	500	3	2	5	3	10
D169029	4.0	1.3	20.6	50	500	N	.7L	5	5	N
D169030	2.0L	.3	5.7	70	200	.2	.7L	2	1	N
D169031	2.3	.3	10.9	70	200	N	.7L	2	2	N
D169032	1.9	.4	9.8	50	200	N	.7L	2	1.5	N
D169033	2.2	.7	15.0	70	500	N	.7L	5	2	N
D169034	2.3	.7	10.5	70	200	N	.7L	2	2	N
D169035	2.0L	.1L	11.3	50	300	N	.7L	1.5	.7	N
D169036	3.6	.8	11.9	70	150	N	N	2	1.5	N
D169037	2.9	1.1	5.9	70	150	N	N	2	2	N
D169038	1.9	.4	4.7	70	200	N	N	1.5	1	N
D169039	2.0L	.6	5.5	70	100	N	N	1.5	1.5	N
D169040	2.6	1.2	12.0	100	200	2	1	10	3	N
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)										
D169437	7.3	1.8	8.9	100	300	0.3	N	3	3	N
D169438	2.3	.2	8.3	70	500	.2	.7L	2	1	N
D169439	2.6	.4	11.5	50	1500	N	.7L	3	2	N
D169440	3.3	.1L	90.2	50	500	N	.7L	3	5	N
D169441	2.4	.7	6.7	70	150	N	.7L	2	2	N
D169442	3.8	1.0	5.8	70	150	N	.7L	2	3	N
D169443	2.1	.3	5.9	70	700	N	.7L	2	2	N
D169444	2.9	.8	5.8	50	500	N	N	2	2	N
D169445	5.3	.9	13.1	70	500	N	N	3	3	N
D169446	2.3	.6	7.3	100	300	N	.7L	3	2	N
D169447	2.0L	1.6	6.4	70	200	N	N	3	3	N
Flowers-Goodale bed, BurRec DH 74-101										
D169475	2.0L	1.5	5.1	100	700	1	0.7L	2	2	N
D169476	3.1	1.0	4.7	100	500	1.5	.7	3	3	N
Flowers-Goodale bed, BurRec DH 74-102										
D169723	4.0	2.6	14.2	70	300	1	1	3	5	N
D169724	1.9	.6	4.2	100	500	.7	.7	1.5	2	N

Table 7.--Major, minor, and trace-element composition of 28 coal samples from the Otter Creek area, Powder River County, Mont., reported on whole-coal basis--Continued

Sample	La PPM-S	Mo PPM-S	Nb PPM-S	Ni-PPM-S	Sc-PPM-S	Sr-PPM-S	V PPM-S	Y PPM-S	Yb PPM-S	Zr PPM-S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)										
D169028	10	1	5	3	2	200	10	7	0.7	30
D169029	N	1	3	2	1.5	200	10	3	.5	20
D169030	5	.5	2 L	1	1	300	5	2	.2	10
D169031	5	.5	2 L	1	.7	200	5	1.5	.2	10
D169032	N	5	2 L	1	.7	200	5	1.5	.1	10
D169033	N	.7	2 L	1	1	500	7	1.5L	.1L	15
D169034	N	.5	2 L	1	.7	300	5	1.5L	.1L	10
D169035	N	.5	2 L	1	.7L	300	3	1	.1	5
D169036	N	1	2	1L	N	200	2	2	.2	30
D169037	N	.5L	1.5	1L	.7	200	5	1.5	.2	15
D169038	5	.7	2 L	1	.7	300	3	1.5	.1	10
D169039	5	.5L	2 L	1	.7L	200	3	1.5L	.1	10
D169040	10	.7	2	2	2	200	20	3	.5	20
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26; T. 3 S., R. 45 E.)										
D169437	7	0.7	2	1	1	300	5	2	0.2	20
D169438	5	.5	N	1	.7	300	3	2	.1	10
D169439	7	.7	N	1	1	500	7	2	.2	15
D169440	5	5	2 L	1	1	500	5	1.5	.2	10
D169441	7	.5L	2 L	1	1.5	500	7	1.5	.2	15
D169442	7	.5L	2 L	1	1.5	200	7	1.5	.2	15
D169443	5	.5	2 L	1	.7	500	5	1	.1	10
D169444	5	N	2 L	1	1	500	7	1.5	.2	15
D169445	N	.5L	2 L	1L	1	300	7	2	.2	20
D169446	N	.7	N	1L	1	700	7	2	.2	15
D169447	N	N	2	1	1	300	7	2	.2	30
Flowers-Goodale bed, BurRec DH 74-101										
D169475	7	0.7	2 L	1	1.5	500	7	5	0.5	15
D169476	5	1	1.5	1	2	300	7	3	.3	15
Flowers-Goodale bed, BurRec DH 74-102										
D169723	N	1.5	2 L	2	2	300	10	3	0.3	20
D169724	5	.5	2 L	1	1	500	3	2	.2	10

Table 8 compares analyses of 24 samples of the Knoblock coal bed in the Otter Creek area to 67 samples of subbituminous coals from 7 mines and 12 drill holes in the Powder River Basin of Wyoming and Montana (Swanson and others, 1974). The lower heat value (Btu), greater moisture and oxygen content, and smaller fixed carbon content of the Knoblock coal as compared to the average of subbituminous coals in the Powder River Basin are a direct reflection of the lower rank (lesser degree of metamorphism) of the Knoblock coal. No other significant differences are shown by the comparison in table 8.

Table 9 shows the range of and average elemental content, on the whole-coal basis, of those constituents commonly regarded as being of importance from the standpoint of coal utilization. Some of the elements, such as mercury and arsenic, are of interest because of the environmental problems that might occur if they are present in inordinate amounts; others, such as thorium and uranium, are of interest because they could be recovered from coal ash if they are present in sufficently large quantities. On the basis of the 5.5 percent average ash content of the Knoblock coal, trace elements such as thorium and uranium will be enriched in the ash approximately 18 times their whole-coal values.

Table 8.--Comparison of composition of Knoblock with composition of the subbituminous coals of the Northern Great Plains

	Knoblock coal (24 samples)	NGP subbituminous coals (67 samples[1])
Btu	8,110	9,000
	in percent	
Moisture (as received)	30	20
Fixed carbon (as received)	35	38
Oxygen (as received)	39	30
SiO_2 (in ash)	38	25
Na_2O (in ash)	4	.5
CaO (in ash)	16	15
MgO (in ash)	4	4
	in parts per million	
As (whole coal)	2	2
B (whole coal)	70	50
Ba (whole coal)	300	200
Hg (whole coal)	.05	.08
Pb (whole coal)	6.4	6
Se (whole coal)	.4	.8 (51 samples)
U (whole coal)	.8	.7
Zn (whole coal)	13	7

[1]Swanson, V. E., and others, 1974.

Table 9.--Elements that can affect potential utilization of coals--content in 24 samples from Otter Creek area in parts per million

Element	Concentration in Knoblock bed: Range	Concentration in Knoblock bed: Average	Average, continental crust (Taylor, 1964)
As	1 - 12	2	1.8
Cd	<.1 - .1	.1	.2
Cu	3.2 - 12	6.4	55
F	25 - 85	48	625
Hg	.01 - .32	0.05	.08
Li	2.5 - 13	6.7	20
Pb	2.6 - 35	6.4	12.5
Sb	.1 - .7	.4	.2
Se	.1 - 1.0	.4	.05
Th	<2.0 - 7.3	3.0	9.6
U	<.1 - 1.6	.8	2.7
Zn	4.7 - 90	13	70

Analyses of overburden rocks

Thirty-nine samples, believed to be representative of the lithology (plate 1) overlying and underlying the Knoblock coal bed, have been analyzed in detail (table 10). The sequence for analysis of rock samples is similar to that shown on figure 3, except for the Bureau of Mines analyses and the addition of analyses for percent total sulfur and percents total carbon, mineral carbon, and organic carbon. Their composition was found to be similar to that of limy sandstones, siltstones, and claystones occurring in other parts of the United States.

The analyses show that three-quarters of the rock is composed of silica and alumina, and the remainder is composed mostly of oxides of calcium, magnesium, potassium, iron, and sodium.

The analyses of trace elements, some of which are potentially toxic, show that none of these elements are present in abnormally higher amounts than are present in similar rocks in the United States. A few samples with high values have little significance when averaged with analyses of other samples from the same core.

Table 10.--Major and minor oxide and trace element composition of 39 composited core samples of rocks above and below the Knoblock coal bed from the Otter Creek area, Powder River County, Mont.

[See fig. 4 for lithology of samples. Values are in either percent or parts per million. L after a value means less than the value shown, N means not detected, and B means not determined. S after the element title means that the value listed was determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data is approximately one bracket at 68-percent, or two brackets at 95-percent confidence. Locations of drill holes are shown on fig. 1 and sample intervals are shown on Plate 1]

Sample	Field No.	Depth from surface (ft)	ASH %	Al_2O_3 %	CaO %	Fe_2O_3 %	MgO %	Na_2O %	K_2O %	SO_3 %	SiO_2 %	Cl %
D169726	74-101-A	0.5 - 5.6	97.7	13.	8.0	4.3	3.6	1.0	2.5	.20	60.	.10L
D169727	74-101-B	5.6 - 14.4	98.3	12.	8.7	2.8	3.1	1.0	2.2	.13	59.	.10L
D169728	74-101-C	14.4 - 30.9	95.4	18.	6.6	4.4	3.7	.72	2.4	.90	58.	.10L
D169729	74-101-D	30.9 - 41.9	96.2	18.	4.1	4.1	2.8	.57	2.8	1.0	59.	.10L
D169730	74-101-E	41.9 - 74.0	92.0	19.	2.6	3.8	2.1	.90	2.7	.90	63.	.10L
D169731	74-101-F	74.0 - 116.2	98.6	14.	2.2	2.0	1.6	1.3	2.3	.11	72.	.10L
D169732	74-101-G	119.9 - 135.2	98.7	14.	6.7	3.5	3.8	.99	2.7	.10L	59.	.10L
D169733	74-101-H	135.2 - 164.6	99.9	10.	8.2	2.1	4.0	.84	1.8	.10L	62.	.10L
D169734	74-101-I	164.6 - 168	99.4	11.	9.6	5.0	4.2	.89	2.0	.10L	64.	.10L
D169735	74-101-J	168 - 198.4	99.0	18.	7.0	4.2	4.1	.54	3.2	.10L	62.	.10L
D169751	74-101-K	259.4 - 260.2	95.8	20.	.36	3.1	1.6	.34	3.8	.18	66.	.10L
D169752	74-101-L	260.2 - 284.5	97.0	14.	4.4	3.9	3.5	.65	2.4	.10L	70.	.10L
D169753	74-101-M	286.7 - 298.7	97.4	15.	13.	4.3	4.8	.53	2.8	.10	49.	.10L
D169754	74-101-N	299.7 - 302.0	96.3	17.	9.9	3.1	4.4	.49	3.0	.10L	55.	.10L
D169755	74-101-O	302.0 - 312.2	95.7	17.	7.3	4.5	3.8	.65	3.1	.25	60.	.10L
D169756	74-101-P	313.2 - 358.2	97.3	12.	7.8	2.7	3.8	.80	2.1	.10L	68.	.10L
D169757	74-101-Q	361.9 372.8	99.1	13.	7.4	2.8	3.6	1.8	2.1	.10L	67.	.10L
D169758	74-101-R	385.4 - 401.5	99.0	11.	5.0	2.0	2.9	1.9	2.0	.16	71.	.10L
D169759	74-101-S	401.5 - 407.5	96.3	14.	10.	5.1	5.2	.80	2.8	.10L	50.	.10L
D169736	74-102-A	0 - 3.5	99.7	8.8	13.	2.9	5.9	.62	1.6	.10L	56.	.10L
D169737	74-102-B	3.5 - 16	96.9	17.	7.1	4.6	3.7	.72	3.1	.10L	65.	.10L
D169738	74-102-C	16 - 17.2	98.4	13.	7.1	1.8	3.4	.84	2.2	.10L	74.	.10L
D169739	74-102-D	17.2 - 23.7	94.9	19.	5.0	8.9	3.6	.58	3.6	.10L	60.	.10L
D169740	74-102-E	23.7 - 88.7	100.0	11.	8.0	2.2	3.8	.88	2.1	.10L	70.	.10L
D169741	74-102-F	88.7 - 110.7	97.1	16.	8.4	3.4	3.9	.80	2.7	.10L	65.	.10L
D169742	74-102-G	110.7 - 126.1	97.3	15.	5.0	3.7	4.0	.69	2.8	.10L	63.	.10L
D169743	74-102-H	185.2 - 192.4	98.2	18.	4.1	3.7	3.7	.40	3.2	.15	50.	.10L
D169744	74-102-I	192.4 - 198.7	97.8	13.	8.0	3.3	2.5	.58	2.2	.10L	59.	.10L
D169745	74-102-J	201.1 - 204.2	97.7	17.	5.2	2.7	3.9	.61	2.8	.47	60.	.10L
D169746	74-102-K	204.2 - 212.9	98.2	11.	7.7	1.9	4.0	.67	2.0	.13	63.	.10L
D169747	74-102-L	212.9 - 234.7	95.7	18.	8.3	4.4	4.0	.57	3.3	.90	52.	.10L
D169748	74-102-M	234.7 - 289.2	97.5	12.	9.3	3.1	4.5	.76	2.2	.10L	57.	.10L
D169749	74-102-N	299.7 - 329.7	98.1	12.	8.2	2.5	4.5	.80	2.1	.10L	61.	.10L
D169750	74-102-O	329.3 - 334.2	95.4	17.	8.5	7.2	4.3	.69	2.8	.10L	55.	.10L

Table 10.--Major and minor oxide and trace element composition of 39 composited core samples of rocks above and below the Knoblock coal bed from the Otter Creek area, Powder River County, Mont.--Continued

Sample	MnO %	P_2O_5 %	TiO_2 %	Cd PPM	Cu PPM	Li PPM	Pb PPM	Zn PPM	B PPM-S	Ba PPM-S
D169726	0.083	0.10L	0.51	1.L	26.	30.	25.L	64.	70	700
D169727	.048	.10L	.43	1.L	18.	26.	25.L	50.	50	500
D169728	.084	.10L	.57	1.L	36.	46.	25.L	94.	70	700
D169729	.058	.10L	.57	1.L	32.	46.	25.L	100.	70	1000
D169730	.050	.10L	.64	1.L	36.	42.	25.	114.	50	700
D169731	.027	.10L	.39	1.L	14.	20.	25.L	62.	50 L	1500
D169732	.048	.10L	.50	1.L	26.	30.	25.	60.	50	300
D169733	.029	.10L	.43	1.L	10.L	18.	25.L	40.	70	200
D169734	.060	.10L	.34	1.L	16.	42.	25.L	51.	50	300
D169735	.074	.10L	.47	1.L	28.	40.	25.L	82.	70	500
D169751	.024	.18	.69	1.L	38.	42.	25.L	94.	70	700
D169752	.048	.10L	.48	1.L	19.	28.	25.L	56.	50	500
D169753	.064	.10L	.49	1.L	26.	32.	25.	82.	70	500
D169754	.064	.10L	.55	1.L	30.	32.	25.L	88.	70	700
D169755	.068	.10L	.56	1.L	29.	32.	25.L	88.	70	500
D169756	.034	.10L	.45	1.L	14.	22.	25.L	50.	50	500
D169757	.041	.10L	.46	1.L	19.	28.	25.L	58.	50	500
D169758	.020L	.10L	.38	1.L	10.L	22.	25.L	44.	50	300
D169759	.090	.10L	.48	1.L	30.	32.	25.L	78.	70	500
D169736	.045	.10L	.27	1.L	10.L	16.	25.L	38.	50 L	300
D169737	.071	.10L	.47	1.L	24.	34.	25.L	76.	70	500
D169738	.024	.10L	.41	1.L	18.	24.	25.L	62.	50	300
D169739	.13	.10L	.47	1.L	26.	44.	25.L	80.	70	700
D169740	.029	.10L	.40	1.L	10.L	22.	25.L	48.	50	300
D169741	.068	.10L	.46	1.L	24.	30.	25.L	70.	70	500
D169742	.054	.10L	.52	1.L	30.	30.	25.L	70.	70	500
D169743	.046	.10L	.57	1.L	24.	32.	25.L	80.	70	500
D169744	.054	.10L	.46	1.L	26.	20.	25.L	60.	50	300
D169745	.020L	.10L	.52	1.L	28.	30.	25.L	140.	50	500
D169746	.022	.10L	.37	1.L	10.L	20.	25.L	48.	50	300
D169747	.083	.10L	.52	1.L	30.	36.	25.L	86.	70	500
D169748	.048	.10L	.44	1.L	20.	24.	25.L	50.	50	500
D169749	.040	.10L	.45	1.L	24.	24.	25.L	58.	50	500
D169750	.16	.10L	.51	1.L	26.	32.	25.L	82.	50	700

Table 10.—Major and minor oxide and trace element composition of 39 composited core samples of rocks above and below the Knoblock coal bed from the Otter Creek area, Powder River County, Mont.—Continued

Sample	Be PPM-S	Co PPM-S	Cr PPM-S	Ga PPM-S	Ge PPM-S	La PPM-S	Mo PPM-S	Nb PPM-S	Ni PPM-S	Sc PPM-S	Sr PPM-S
D169726	N	10	50	15	N	70	N	20 L	15	10	200
D169727	N	7 L	30	15	N	70	N	20 L	10	10 L	200
D169728	N	15	50	20	N	70	N	20 L	30	10	150
D169729	N	15	70	20	N	70	7 L	20 L	30	15	300
D169730	N	15	70	20	N	70	7 L	20 L	30	15	200
D169731	N	10	70	15	N	70	N	20 L	20	10 L	200
D169732	N	7 L	30	15	N	70 L	N	N	15	10 L	70
D169733	N	N	20	10	N	70 L	N	N	10	N	70
D169734	N	10	30	10	N	N	N	N	15	N	100
D169735	N	10	50	15	N	N	N	N	15	10	70
D169751	2 L	7 L	70	20	N	70	N	20 L	10	15	70
D169752	N	7 L	30	10	N	N	N	20 L	15	10	50
D169753	N	7 L	50	15	N	N	N	N	15	10	150
D169754	N	10	70	20	N	70 L	N	N	15	10	150
D169755	N	7 L	50	15	N	70 L	N	N	10	10 L	100
D169756	N	7 L	50	10	N	N	N	N	10 L	N	100
D169757	N	7 L	30	10	N	N	N	N	10	N	100
D169758	N	N	20	10	N	N	N	N	10 L	N	30
D169759	N	7 L	50	15	N	N	N	N	10	10 L	150
D169736	N	N	20	10	N	N	N	N	10 L	N	150
D169737	N	7 L	50	20	N	N	N	N	15	10	100
D169738	N	7 L	20	10	N	70 L	N	N	10 L	N	70
D169739	2 L	10	50	20	N	70 L	N	20 L	20	15	100
D169740	N	N	20	10	N	N	N	N	10 L	N	70
D169741	N	10	30	15	N	N	N	N	15	10	100
D169742	N	10	50	15	N	N	N	20 L	15	10	70
D169743	N	7 L	50	15	N	N	N	20 L	15	10	70
D169744	N	7 L	30	15	N	N	N	N	10	N	70
D169745	N	15	70	20	N	N	7	N	30	10 L	100
D169746	N	7 L	30	10	N	N	N	N	10	N	70
D169747	N	10	70	15	N	N	N	N	15	10	150
D169748	N	7 L	50	15	N	N	N	N	10	10 L	150
D169749	N	7 L	30	10	N	N	N	N	10	10 L	100
D169750	N	7 L	50	15	N	N	N	N	15	10	150

Table 10.—Major and minor oxide and trace element composition of 39 composited core samples of rocks above and below the Knoblock coal bed from the Otter Creek area, Powder River County, Mont.—Continued

Sample	V PPM-S	Y PPM-S	Yb PPM-S	Zr PPM-S	As PPM	F PPM	Hg PPM	Sb PPM	Se PPM	Th PPM
D169726	70	30	3	150	5.	710.	0.02	1.1	0.1	9.2
D169727	70	20	2	150	4.	570.	.24	1.0	.1L	7.5
D169728	100	30	3	150	8.	935.	.03	1.6	.2	12.0
D169729	150	20	3	150	12.	785.	.05	1.6	.3	12.2
D169730	150	30	3	200	12.	710.	.07	1.4	.2	9.9
D169731	70	20 L	2	150	10.	495.	.02	.5	.1L	6.7
D169732	70	20	2	150	5.	815.	.02	1.6	.1L	9.5
D169733	50	20 L	2	100	5.	480.	.03	1.0	.1L	8.0
D169734	70	20	3	150	5.	540.	.03	1.4	.1L	8.3
D169735	70	30	3	150	12.	825.	.05	2.3	.1L	11.5
D169751	70	20	3	150	8.	1010.	.12	1.2	.9	14.1
D169752	50	20 L	2	150	5.	584.	.06	1.0	.4	7.7
D169753	70	20	2	100	12.	736.	.09	1.6	.1L	9.2
D169754	70	20	2	100	12.	770.	.07	1.7	.1L	10.7
D169755	70	20	2	100	20.	855.	.08	1.9	.1	12.4
D169756	50	20 L	2	200	4.	560.	.04	1.0	.1L	7.9
D169757	50	20 L	2	200	5.	530.	.05	1.0	.1L	7.6
D169758	30	20 L	2 L	150	8.	450.	.05	1.0	.1L	7.6
D169759	50	20 L	2 L	100	5.	825.	.05	1.3	.1L	10.1
D169736	30	20 L	2 L	100	4.	495.	.02	.9	.1L	6.0
D169737	70	30	3	150	8.	830.	.03	1.6	.1L	10.3
D169738	30	20	3	150	5.	525.	.02	1.3	.1L	9.4
D169739	100	30	3	100	25.	935.	.05	1.8	.1	10.3
D169740	30	20 L	2 L	150	8.	500.	.02	1.0	.1L	9.1
D169741	70	30	3	150	8.	695.	.05	1.7	.1L	11.8
D169742	70	20	3	150	5.	720.	.07	1.4	.2	10.8
D169743	70	20	3	100	20.	880.	.08	1.7	.2	10.7
D169744	50	20	2	100	5.	585.	.05	1.1	.1	9.1
D169745	70	30	3	150	20.	760.	.17	2.2	.3	10.8
D169746	50	20	3	150	10.	435.	.08	.9	.1L	7.8
D169747	70	20	3	70	30.	920.	.13	3.0	.3	8.6
D169748	70	20 L	2	100	5.	535.	.05	1.1	.1L	9.2
D169749	30	20 L	2	150	5.	520.	.05	1.2	.1L	9.2
D169750	70	20	3	100	8.	772.	.07	1.2	.1L	11.7

Table 10.--Major and minor oxide and trace element composition of 39 composited core samples of rocks above and below the Knoblock coal bed from the Otter Creek area, Powder River County, Mont.--Continued

Sample	U PPM	TOTAL C%	ORGNC C%	CRBNT C%	TOTAL S%
D169726	4.4	2.37	.10L	2.37	0.11
D169727	3.2	2.52	.10L	2.52	.03
D169728	3.8	1.85	.20	1.65	.33
D169729	4.1	2.68	1.40	1.28	.47
D169730	4.5	>2.85	2.00	.85	.37
D169731	2.1	.90	.20	.70	.02
D169732	3.5	2.56	.10	2.46	.02
D169733	2.9	2.72	.10L	2.72	.01L
D169734	3.4	3.08	.10L	3.08	.01
D169735	3.6	2.78	.30	2.48	.04
D169751	4.6	.54	.40	.11	.02
D169752	3.3	2.15	.20	1.95	.05
D169753	3.4	4.21	.10L	4.14	.11
D169754	3.2	3.34	.10L	3.32	.06
D169755	3.6	3.20	.70	2.50	.12
D169756	2.9	2.70	.10L	2.67	.02
D169757	3.1	2.66	.10L	2.59	.01L
D169758	2.4	1.76	.10L	1.76	.09
D169759	3.4	3.75	.10L	3.75	.03
D169736	2.4	4.53	.10L	4.53	.01L
D169737	3.5	2.40	.10L	2.35	.01L
D169738	3.1	2.19	.10	2.07	.01L
D169739	3.7	2.79	.50	2.29	.05
D169740	3.3	2.64	.10L	2.60	.01
D169741	3.3	2.95	.30	2.65	.03
D169742	3.8	2.38	.30	2.08	.03
D169743	3.6	2.68	.90	1.78	.06
D169744	3.0	3.16	.20	2.96	.03
D169745	7.4	2.94	1.00	1.94	.41
D169746	2.8	2.95	.30	2.65	.14
D169747	4.0	4.69	2.00	2.64	.42
D169748	3.1	3.33	.10L	3.33	.02
D169749	3.5	3.00	.10L	2.99	.03
D169750	3.1	3.46	.10	3.33	.04

The average concentration of trace elements in the Knoblock bed of the Otter Creek area is shown in table 10 to be generally less than the average concentration of these elements in the continental crust. Only selenium (average concentration in the Knoblock bed 0.4 ppm, compared to 0.05 ppm average crustal abundance) is higher, and even this amount is relatively low.

Conclusion

The tentative conclusion, based on inspection of analyses in this report, is that little variation in composition of coal and overburden occurs from one drill hole to another. If this conclusion is valid, then it can be assumed that composition of reclaimed overburden rock is a constant factor among other parameters used in soil studies.

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