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Coal resources of the Alton, Utah, EMRIA site

By

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Abstract

The estimated original identified coal resources of the Alton, Utah, EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) site--an area of about 3.6 square miles (9.3 square kilometres)--total almost 49 million tons (45 megatonnes). A larger area that surrounds and includes the Alton EMRIA site proper contains estimated original identified coal resources of almost 309 million tons (281 megatonnes). Of these estimated resources in the EMRIA site proper, almost 27 million tons (25 megatonnes) are in beds more than 10 feet thick (3 metres); these beds are overlain by less than 200 feet (60 metres) of overburden. In the larger area around and including the EMRIA site, about 88.5 million tons (81 megatonnes) are in beds more than ten feet (3 metres) thick with less than 200 feet (60 metres) of overburden. All the estimated resources are in the Smirl zone in the upper part of the Dakota Formation of Cretaceous age.

The coal has an apparent rank of subbituminous B, an average heating value of about 9,560 Btu, an average sulfur content of about 1.0 percent, and an average ash content of 7.2 percent. When compared with the average abundance of elements in the crust of the Earth as a whole, only selenium and boron were present in the Alton area coal samples in amounts an order of magnitude greater than the average crustal abundance. Beryllium, fluorine, nickel, zinc, and zirconium are all present in the Alton area samples in amounts that are about an order of magnitude less than the average crustal abundance.

Introduction

This report was prepared as a contribution to a study of the reclamation potential of an area in Kane County in southwestern Utah, about 20 miles (32 kilometres) north-northeast of the town of Kanab. 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 3.6 square miles (9.3 square kilometres). A logical contiguous area surrounding and including the EMRIA site proper--an area of about 26.9 square miles (69.7 square kilometres)--was also geologically mapped and studied. The coal resources of the major, strippable coal zone in the area were estimated using information derived from geologic mapping and core-drilling. Samples of the coal were analyzed to determine the major and minor element composition.

Geologic Setting

The geologic map of the area around and including the Alton EMRIA site (pl. 1) shows the outcrop of the upper (Smirl) coal zone and location of the drill holes. Lithologic logs of the drill holes are also shown.

The coal of the Alton area is in the Dakota Formation of Cretaceous age. Two important coal zones, the upper, or Smirl, and the lower, or Bald Knoll, contain all of the coal of potential economic importance. The Smirl zone at the top of the Dakota contains thicker coal beds than does the Bald Knoll and was the primary target of the drilling and trenching program conducted as part of the present investigation (pl. 1). Two of the drill holes were extended below the Smirl zone to obtain information and samples about the rocks and coal beds between the Smirl zone and the base of the Dakota Formation.

The Dakota Formation unconformably overlies the Winsor Member of the Carmel Formation of Jurassic age and conformably underlies the Tropic Shale of Cretaceous age. The Tropic is composed of marine shale with a few very thin interbeds of very fine grained sandstone and bentonitic clay.

Surficial deposits of several different types, all of Quaternary age, unconformably overlie and mask the older rock units. As shown on plate 1, the surficial deposits range widely in thickness; only detailed examination of potential surface-mining areas will yield definitive data on the distribution of the different rock materials overlying the coal beds in the area.

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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 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 plants, particularly details of structure that affect chemical composition of 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 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 standardized 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 driven 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 (in the metric system, heating value is expressed in kilogram-calories per kilogram). Additional tests are sometimes made, particularly to determine caking, coking, and other properties, such as tar yield, that affect classification or utilization.

Figure 1 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).

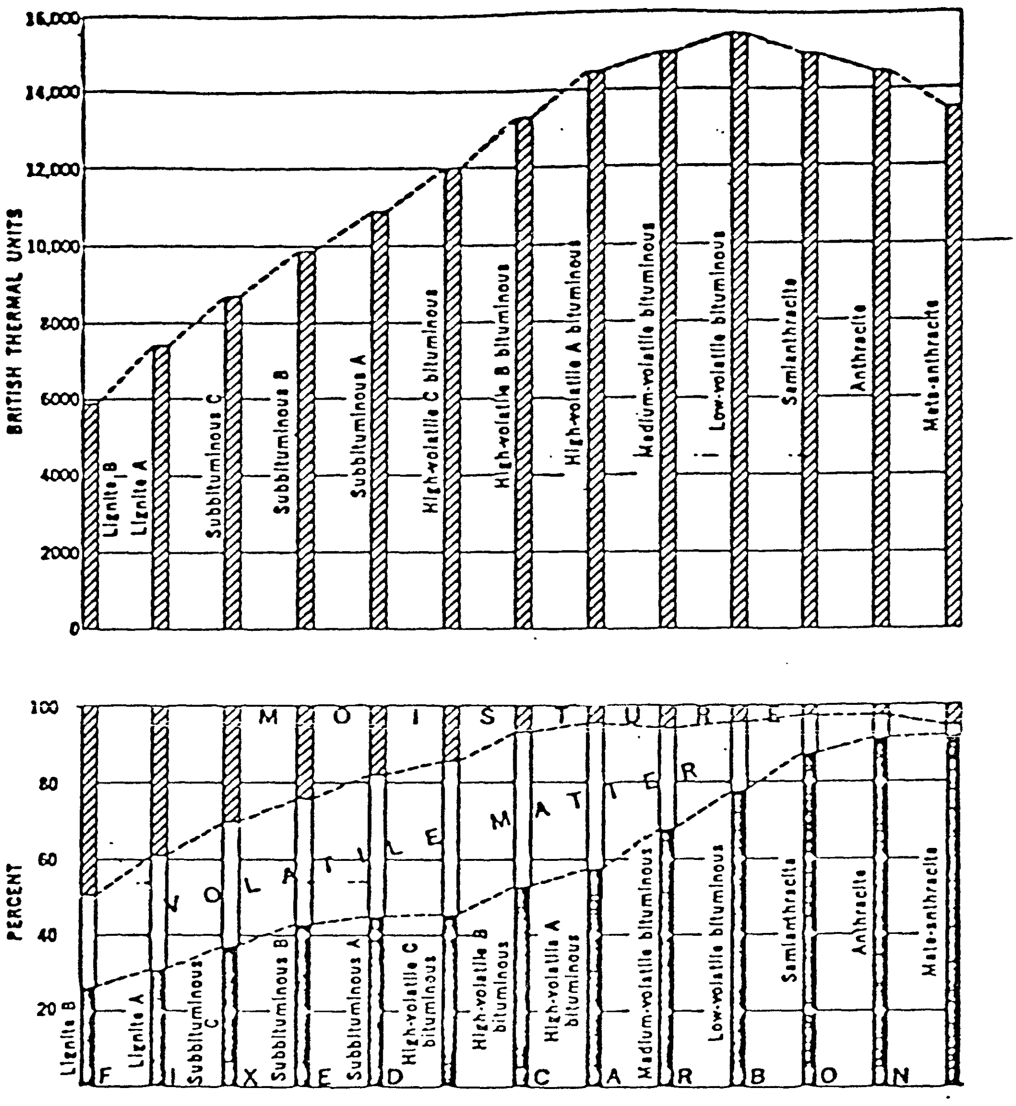

Figure 1.--Comparison on moist, mineral-matter-free basis of heat values, and proximate analyses of coal of different ranks.

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

[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."

All samples listed in table 2, except D169563, show an apparent rank of subbituminous B. The sample came from weathered coal in test trench 102, and therefore the analysis may not be representative.

Because of the lack of definitive information about the distribution of coals of various groups in the Alton coal field, the coal in the area of this study is considered to be all subbituminous B in rank.

Table 2.--Proximate, ultimate, Btu, and forms of sulfur analyses of samples of the Smirl and Bald Knoll coal zones in the Dakota Formation (Cretaceous age), Alton coal field, Kane County, Utah. (All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash 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
Smirl zone, face channel sample, Test Trench 102, 10 ft thick with a 0.6 ft thick mudstone parting included, SW 1/4, sec. 13, T. 40 S., R. 5 W.														
D169563	A	29.9	30.3	29.2	10.6	5.8	39.3	0.9	42.1	1.3	6260	0.64	0.07	0.58
	B	--	43.2	41.7	15.1	3.5	56.0	1.3	22.3	1.8	8930	.91	.10	.83
	C	--	50.9	49.1	--	4.1	66.0	1.5	26.2	2.2	10520	1.07	.12	.98
Smirl zone, composite core bench sample, Drill Hole 101, depth 200.0 to 214.3 ft, SW 1/4, sec. 8, T. 40 S., R. 4 1/2 W.														
D169559	A	19.9	34.1	37.7	8.3	6.0	55.0	1.0	28.3	1.4	9540	0.01	0.54	0.83
	B	--	42.5	47.2	10.3	4.7	68.7	1.3	13.3	1.7	11900	.01	.68	1.03
	C	--	47.4	52.6	--	5.3	76.6	1.4	14.8	1.9	13270	.01	.76	1.16
Smirl zone, composite core bench sample, Drill Hole 103, depth 191.0 to 204.0 ft, SW 1/4, sec. 8, T. 40 S., R. 4 1/2 W.														
D169560	A	21.3	31.4	38.9	8.4	6.0	54.1	1.0	29.3	1.2	9370	0.02	0.57	0.65
	B	--	39.9	49.4	10.7	4.6	68.8	1.3	13.0	1.6	11910	.02	.72	.83
	C	--	44.6	55.4	--	5.2	77.0	1.4	14.6	1.8	13330	.02	.81	.93
Smirl zone, composite core grab sample, Drill Hole 104, depth 80.6 to 97.9 ft, SW 1/4, sec. 18, T. 40 S., R. 4 1/2 W.														
D169763	A	21.9	32.6	40.7	4.8	6.3	56.2	1.1	31.0	0.6	9780	0.02	0.14	0.46
	B	--	41.8	52.1	6.1	5.0	71.9	1.4	14.8	.8	12520	.02	.18	.59
	C	--	44.5	55.5	--	5.3	76.6	1.5	15.8	.8	13330	.02	.19	.63
Bald Knoll zone, composite core grab sample, Drill Hole 104, depth 264.6 to 268.7 ft, 0.6 ft mudstone not included, SW 1/4, sec. 18, T. 40 S., R 4 1/2 W.														
D169764	A	16.2	28.2	34.7	20.9	5.3	46.6	0.9	25.3	1.0	8120	0.01	0.45	0.51
	B	--	33.6	41.5	24.9	4.2	55.6	1.0	13.1	1.2	9700	.01	.54	.61
	C	--	44.8	55.2	--	5.6	74.1	1.4	17.4	1.5	12920	.01	.72	.81
Smirl zone, composite core grab sample, Drill Hole 105, depth 169.2 to 186.6 ft, NW 1/4, SW 1/4, sec. 13, T. 40 S., R. 5 W.														
D169765	A	20.6	31.8	40.2	7.4	6.1	54.5	1.1	30.0	0.9	9530	0.01	0.18	0.73
	B	--	40.0	50.7	9.3	4.8	68.6	1.4	14.8	1.1	11990	.01	.22	.91
	C	--	44.1	55.9	--	5.3	75.6	1.5	16.3	1.3	13210	.01	.25	1.01

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, 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 Alton coals fall largely in the humic series.

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 ash and sulfur content of the four cored samples from the Smirl coal zone in the Alton field, as determined by the Bureau of Mines analyses, were: ash range 4.8 to 8.4 percent, average 7.2 percent; sulfur range 0.6 to 1.4 percent, average 1.0 percent. The sample from the lower or Bald Knoll coal zone in DH-104 showed 20.9 percent ash and 1.0 percent sulfur.

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 that is in the ground in such a form that economic extraction is currently or potentially feasible.

Tabulation of estimated coal resources

Tables 3 and 4 summarize the estimated coal resources of the Alton EMRIA site, about 3.6 square miles (9.3 square kilometres), and of a larger area, about 26.9 square miles (69.7 square kilometres), that is composed of the EMRIA site proper and adjoining areas. Table 5 lists the estimated resources of the area in a more detailed form. In accordance with conventions adopted by the U.S. Geological Survey and the U.S. Bureau of Mines, the resources in the Alton 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.

Table 3.--Summary of estimated identified coal resources of the Smirl zone in the Alton EMRIA site

[In thousands of tons]

	Overburden thickness (feet)			
	0-200	200-1,000	More than 1,000	Total
Coal beds 5 to 10 feet thick				
Demonstrated[1] resources	520	--	--	520
Inferred resources	---	--	--	---
Total	520			520
Coal beds more than 10 feet thick				
Demonstrated[1] resources	26,727	21,385	--	48,112
Inferred resources	------	------	--	------
Total	26,727	21,385		48,112
Total identified resources	27,247	21,385	--	48,632

[1]A collective term for the sum of coal in both measured and indicated resources.

Table 4.--Summary of estimated identified coal resources of the Smirl zone in the area around and including the Alton EMRIA site

[In thousands of tons]

	Overburden thickness (feet)			
	0-200	200-1,000	More than 1,000	Total
Coal beds 5 to 10 feet thick				
Demonstrated[1] resources	4,804	--	--	4,804
Inferred resources	-----	--	--	-----
Total	4,804	--	--	4,804
Coal beds more than 10 feet thick				
Demonstrated[1] resources	85,953	85,128	-----	171,081
Inferred resources	2,577	127,595	2,684	132,856
Total	88,530	212,723	2,684	303,937
Total identified resources	93,334	212,723	2,684	308,741

[1]A collective term for the sum of coal in both measured and indicated resources.

Table 5.--Estimated coal resources of the Smirl zone in the area around and including the Alton EMRIA site

[In thousands of tons]

Thickness of overburden (feet)	Location	5 to 10 feet thick Demonstrated	5 to 10 feet thick Inferred	5 to 10 feet thick Total	More than 10 feet thick Demonstrated	More than 10 feet thick Inferred	More than 10 feet thick Total	Totals Demonstrated	Totals Inferred	Totals Total
0 - 200		--	--	--	--	--	--	--	--	--
200 - 1000	T. 39 S., R. 4 1/2 W.	--	--	--	--	19,035	19,035	--	19,035	19,035
>1000		--	--	--	--	655	655	--	655	655
Total		--	--	--	--	19,690	19,690	--	19,690	19,690
0 - 200		--	--	--	--	--	--	--	--	--
200 - 1000	T. 39 S., R. 5 W.	--	--	--	--	5,300	5,300	--	5,300	5,300
>1000		--	--	--	--	2,029	2,029	--	2,029	2,029
Total		--	--	--	--	7,329	7,329	--	7,329	7,329
0 - 200		3,790	--	3,790	37,176	--	37,176	40,966	--	40,966
200 - 1000	T. 40 S., R 4 1/2 W.	--	--	--	43,031	44,297	87,328	43,031	44,297	87,328
>1000	(including EMRIA site)	--	--	--	--	--	--	--	--	--
Total		3,790	--	3,790	80,207	44,297	124,504	83,997	44,297	128,294
0 - 200		179	--	179	20,325	--	20,325	20,504	--	20,504
200 - 1000	T. 40 S., R. 4 1/2	--	--	--	18,130	--	18,130	18,130	--	18,130
>1000	(EMRIA site only)	--	--	--	--	--	--	--	--	--
Total		179	--	179	38,455	--	38,455	38,634	--	38,634
0 - 200		1,014	--	1,014	48,777	2,577	51,354	49,791	2,577	52,368
200 - 1000	T. 40 S., R. 5 W.	--	--	--	42,097	58,963	101,060	42,097	58,963	101,060
>1000	(including EMRIA site)	--	--	--	--	--	--	--	--	--
Total		1,014	--	1,014	90,874	61,540	152,414	91,888	61,540	153,428
0 - 200		341	--	341	6,402	--	6,402	6,743	--	6,743
200 - 1000	T. 40 S., R. 5 W.	--	--	--	3,255	--	3,255	3,255	--	3,255
>1000	(EMRIA site only)	--	--	--	--	--	--	--	--	--
Total		341	--	341	9,657	--	9,657	9,998	--	9,998
0 - 200		4,804	--	4,804	85,953	2,577	88,530	90,757	2,577	93,334
200 - 1000	Entire area including	--	--	--	85,128	127,595	212,723	85,128	127,595	212,723
>1000	EMRIA site	--	--	--	--	2,684	2,684	--	2,684	2,684
Total		4,804	--	4,804	171,081	132,856	303,937	175,885	132,856	308,741
0 - 200		520	--	520	26,727	--	26,727	27,247	--	27,247
200 - 1000	Total EMRIA site only	--	--	--	21,385	--	21,385	21,385	--	21,385
>1000		--	--	--	--	--	--	--	--	--
Total		520	--	520	48,112	--	48,112	48,632	--	48,632

The estimated identified coal resources shown in tables 3, 4, and 5 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. (See the following discussion.) 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 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 method, but nationally it is about 50 percent. Recoverability for strip mining is locally as great as 90 percent, but studies indicate that nationally it 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.

Demonstrated - Composed of both measured resources, which have been estimated from closely spaced and geologically well-known measurements and sample sites to within a margin of error of less than 20 percent, and indicated resources, which have been estimated partly from sample analyses and measurements and partly from reasonable geologic projections.

Inferred - Coal in unexplored extensions of demonstrated resources for which estimates of the quality and size are based on geologic evidence and projection.

Resources estimated for the Alton EMRIA site and listed in the tables as demonstrated resources are in bodies of coal whose outer limits are within 3/4 mile (1.2 kilometres) of points of information. Inferred resources are in bodies of coal whose inner boundaries are bodies of demonstrated resources and whose outer boundaries are as much as 3 miles (4.8 kilometres) from points of observation.

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 the coal varies considerably, related to differences in rank and ash content. In areas such as the Alton field, where true 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 tons per acre-foot--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 prepared 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 (0.7 to 1.5 metres); intermediate-- 5 to 10 feet (1.5 to 3 metres); and thick--more than 10 feet (3 metres). About 2 percent of the estimated resources of the study area are in the intermediate category, and about 98 percent are in the thick category. In the EMRIA site proper, about 1 percent of the estimated resources are in the intermediate category, and about 99 percent are in the thick category.

Coal-bed thicknesses used in calculating resource estimates were derived from both isopach maps and weighted average thicknesses. Bed-thickness maps were prepared where the distribution of data allowed, but, in some areas, particularly in areas of isolated and widely spaced outcrop data, weighted average thicknesses of coal beds in the area were derived. The total area of coal of all classes in each bed may be determined in several ways: (1) Where the continuity of the bed is well established by maps of the outcrops, mine working, drill holes, and so forth, as in the Pittsburgh bed of the eastern United States, the entire area of known occurrence may be taken, even though points of observation are widely spaced. (2) Persistent beds that have been traced around a basin or spur may be considered to underlie the area enclosed by the outcrop. (3) A length of outcrop within the thickness limits listed above is considered to establish the presence of coal of all classes in appropriately spaced belts roughly parallel to and inside the outcrop. (4) An isolated drill hole may be considered to determine an area of coal of each class extending for an appropriate radius around the hole.

Thickness of overburden

Coal resources are commonly divided into categories based on the thickness of overburden, in feet, as follows: 0-1,000, 1,000-2,000, and 2,000-3,000. However, because the present study is aimed at areas where the coal resources can be recovered by surface mining methods, resources were also estimated for depths of 200 feet (60 metres) or less, a parameter that probably reflects present capabilities of earth-moving equipment used in surface mining.

Summary of Resources

Total estimated identified original coal resources in the Alton EMRIA site and adjoining area are 308,741 thousand tons (280.954 megatonnes). Coal beds from 5 to 10 feet (1.5 to 3 metres) thick make up 4,804 thousand tons (4.372 megatonnes) of the estimated resources, and beds more than 10 feet (3 metres) thick make up 303,937 thousand tons (276.583 megatonnes).

Coal beds in the study area are commonly burned along the outcrop and may be burned back as much as 100 feet (30 metres) from the outcrop face. In areas under shallow overburden, the coal may have burned over much of the area. Resource estimates for this report were calculated for all areas behind the outcrop and include some areas where, owing to burning, coal is actually no longer present.

The estimated identified original coal resources having 200 feet (60 metres) or less of overburden in the Smirl zone in the Alton EMRIA site and adjoining area total 93,334 thousand short tons (84.934 megatonnes) of which 90,757 thousand tons (82.589 megatonnes) are classed as demonstrated (measured plus indicated) and 2,577 thousand tons (2.345 megatonnes) are classed as inferred resources. Beds more than 10 feet (3 metres) thick make up 88,530 thousand tons (80.562 megatonnes) of the estimated resources having 200 feet (60 metres) or less of overburden.

In the EMRIA site proper, the estimated identified original coal resources having 200 feet (60 metres) or less of overburden total 27,247 thousand tons (24.795 megatonnes). All of the coal resources within the EMRIA site are classed as demonstrated (measured plus indicated) resources. Coal beds from 5 to 10 feet thick (1.5 to 3 metres) make up 520 thousand tons (0.473 megatonnes), and beds more than 10 feet (3 metres) thick make up 26,727 thousand tons (24.322 megatonnes).

The estimated resources presented in this report are original resources; that is, resources in the ground before the beginning of mining operations.

Composition

Eight core samples from the Alton area were analyzed for trace elements, following the procedure shown on figure 2, as an aid in solution of problems of coal utilization. The U.S. Geological Survey analytical laboratories routinely provide the following analytical determinations on all samples:

1. 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.
2. 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.
   c. Individual quantitative determinations of abnormal amounts indicated by semiquantitative analysis or on spot-check basis--ppm Ag, Au, Be, Vi, Ge, Mo, Ni, Te, Tl, and V.

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

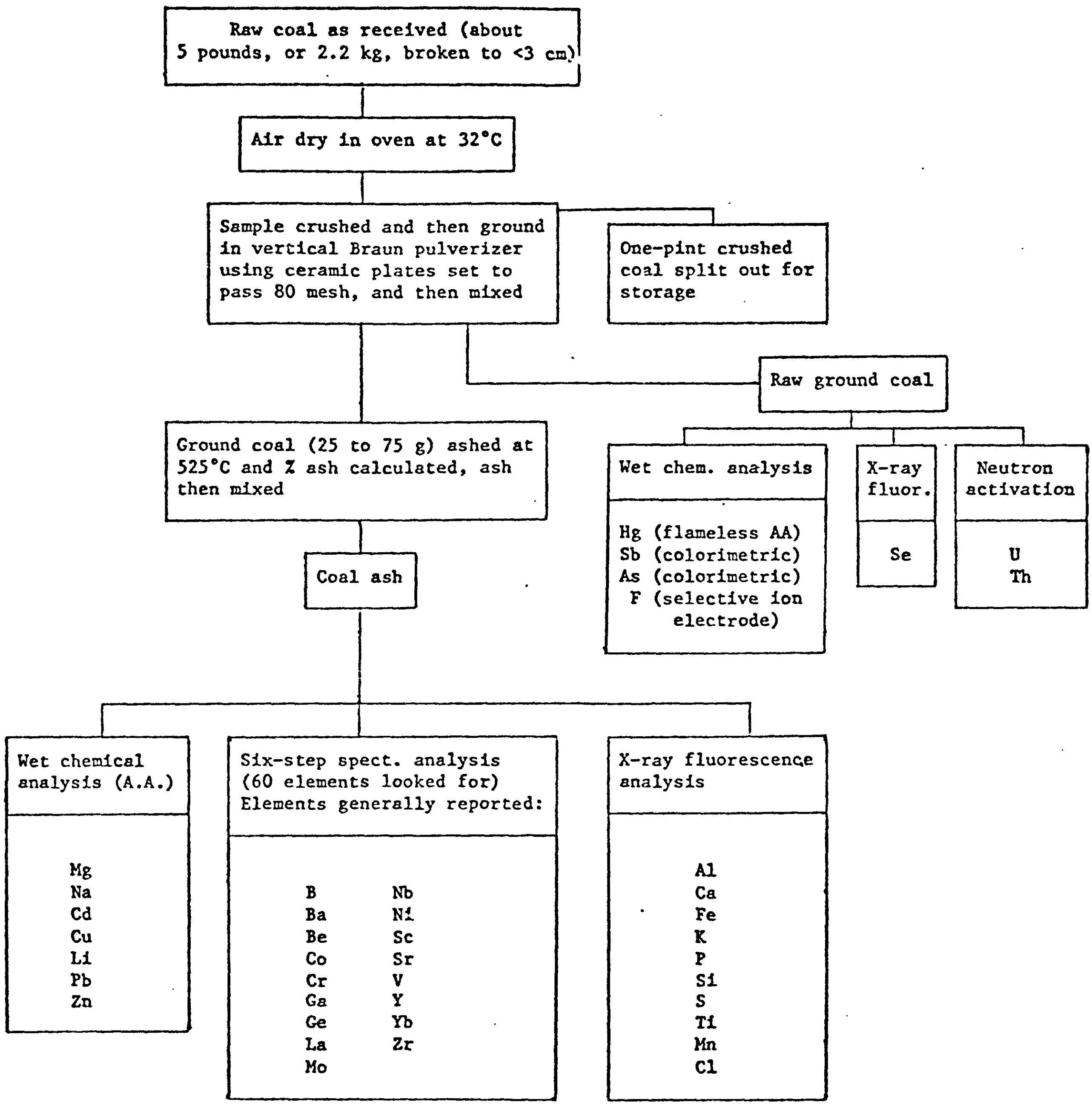

Figure 2.--Sequence of sample preparation and analysis.

Table 6.--Major and minor oxide and trace-element composition of the laboratory ash of eight samples from the Alton area, Utah

[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 listed 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. See figure 3 for sample location]

SAMPLE	Ash %	SiO_2 %	Al_2O_3 %	CaO %	MgO %	Na_2O %	K_2O %	Fe_2O_3 %	MnO %	TiO_2 %
D169559	9.60	35.	24.	9.3	2.6	1.6	0.12	8.2	0.020L	1.1
D169560	10.7	38.	17.	8.2	1.4	2.8	.06	12.	.020L	1.1
D169561	8.60	29.	21.	10.	2.0	5.0	.12	5.0	.020L	.75
D169562	9.20	21.	16.	14.	1.7	2.5	.32	14.	.020L	.60
D169563	13.8	46.	19.	5.9	1.3	2.4	.74	9.3	.020L	.79
D169763	6.20	34.	21.	14.	4.0	1.0	.11	4.0	.020L	1.1
D169764	25.3	54.	35.	2.3	.68	1.1	.28	4.6	.020L	1.3
D169765	11.7	39.	28.	6.5	1.5	2.4	.32	4.1	.020L	.75

SAMPLE	Cl %	P_2O_5 %	SO_3 %	Cd PPM	Cu PPM	Li PPM	Pb PPM	Zn PPM	B PPM-S	Ba PPM-S
D169559	0.10L	0.10L	19.	1.L	74.	314.	25.	27.	1500	500
D169560	.10L	.10L	18.	1.L	82.	326.	40.	20.	1000	1500
D169561	.10L	.10L	27.	1.L	68.	220.	25.L	50.	1000	500
D169562	.10L	.10L	29.	1.L	60.	98.	30.	39.	500	700
D169563	.10L	.10L	15.	1.L	60.	170.	25.	48.	1000	500
D169763	.10L	.10L	18.	1.L	106.	158.	40.	32.	2000	1500
D169764	.10L	.10L	3.4	1.L	62.	122.	65.	98.	300	200
D169765	.10L	.10L	1.2	1.L	54.	210.	50.	45.	1000	700

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
D169559	5	L	50	50	30	N	10	20	15	15
D169560	N	L	30	30	N	70	15	20	20	15
D169561	5	10	30	30	N	70	10	20	15	15
D169562	N	L	20	30	N	70	7	L	20	10
D169563	N	L	30	30	N	70	10	L	15	15
D169763	3	15	50	30	N	100	15	20	30	15
D169764	15	15	20	50	50	200	30	20	15	15
D169765	5	15	30	50	20	70	7	20	20	10

SAMPLE	Sr PPM-S	V PPM-S	Y PPM-S	Yb PPM-S	Zr PPM-S
D169559	2000	150	20	3	200
D169560	2000	100	20	5	200
D169561	2000	100	30	5	150
D169562	2000	70	30	3	100
D169563	1000	150	30	3	200
D169763	2000	100	50	3	200
D169764	500	150	100	15	200
D169765	1000	100	30	3	150

Table 7.—Content of seven trace elements in eight samples from the Alton area, Utah

[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]

SAMPLE	As PPM	F PPM	Hg PPM	Sb PPM	Se PPM	Th PPM	U PPM
D169559	1.	20.	0.09	0.4	0.6	4.4	1.2
D169560	4.	30.	.31	.5	1.3	3.1	1.1
D169561	1.	50.	.09	.4	.3	2.6	1.6
D169562	5.	20.L	.32	.4	.8	2.0L	1.1
D169563	5.	95.	.17	.5	.6	4.7	2.7
D169763	1.	20.	.06	.4	.5	2.0L	.5
D169764	5.	135.	.19	5.2	1.5	16.8	9.5
D169765	2.	35.	.14	1.0	.7	8.8	2.0

Table 8.--Major, minor, and trace-element composition of eight samples from the Alton area, Utah, 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 on ash. L after a value means less than the value shown, N means not detected, and B means not determined]

SAMPLE	Si %	Al %	Ca %	Mg %	Na %	K %	Fe %	Mn PPM	Ti %	Cl %
D169559	1.6	1.2	0.64	0.15	0.11	0.010	0.55	15.L	0.065	0.010L
D169560	1.9	.97	.63	.089	.22	.006	.91	17.L	.069	.011L
D169561	1.2	.96	.64	.10	.32	.008	.30	13.L	.039	.009L
D169562	.90	.78	.93	.096	.17	.024	.87	14.L	.033	.009L
D169563	3.0	1.4	.58	.11	.25	.085	.90	21.L	.066	.014L
D169763	1.0	.70	.62	.15	.046	.006	.17	10.L	.042	.006L
D169764	6.4	4.6	.42	.10	.21	.060	.81	39.L	.20	.025L
D169765	2.1	1.7	.54	.11	.21	.032	.33	18.L	.052	.012L

SAMPLE	P PPM	As PPM	Cd PPM	Cu PPM	F PPM	Hg PPM	Li PPM	Pb PPM	Sb PPM	Se PPM
D169559	42.L	1.	0.1L	7.1	20.	0.09	30.1	2.4	0.4	0.6
D169560	47.L	4.	.1L	8.8	30.	.31	34.9	4.3	.5	1.3
D169561	38.L	1.	.1L	5.8	50.	.09	18.9	2.2L	.4	.3
D169562	40.L	5.	.1L	5.5	20.L	.32	9.0	2.8	.4	.8
D169563	60.L	5.	.1L	8.3	95.	.17	23.5	3.5	.5	.6
D169763	27.L	1.	.1L	6.6	20.	.06	9.8	2.5	.4	.5
D169764	110.L	5.	.3L	15.7	135.	.19	30.9	16.4	5.2	1.5
D169765	51.L	2.	.1L	6.3	35.	.14	24.6	5.9	1.0	.7

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
D169559	4.4	1.2	2.6	150	50	0.5	.5L	5	5	3
D169560	3.1	1.1	2.1	100	150	N	.5L	3	3	N
D169561	2.6	1.6	4.3	100	50	.5	1	2	2	N
D169562	2.0L	1.1	3.6	50	70	N	.5L	2	3	N
D169563	4.7	2.7	6.6	150	70	N	.5L	5	5	N
D169763	2.0L	.5	2.0	150	100	.2	1	3	2	N
D169764	16.8	9.5	24.8	70	50	3	3	5	15	15
D169765	8.8	2.0	5.3	100	70	.7	1.5	3	7	2

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
D169559	0.0N	1	2	2	1.5	200	15	2	0.3	20
D169560	7	1.5	2	2	1.5	200	10	2	.5	20
D169561	7	1	1.5	2	1.5	150	10	2	.5	15
D169562	7	.7	1 L	2	1	200	7	3	.3	10
D169563	10	1.5	1 L	2	2	150	20	5	.5	30
D169763	7	1	1.5	2	1	150	7	3	.2	15
D169764	50	7	5	3	3	150	30	20	3	50
D169765	7	.7	2	2	1	100	10	3	.3	15

Table 9 compares analyses of seven samples of the Smirl coal zone in the Alton area to 67 samples of subbituminous coals from various locations in the Powder River Basin of Wyoming and Montana (Swanson and others, 1974). The higher heat value (Btu) and slightly larger fixed carbon content of the Smirl coal as compared to the average of subbituminous coals in the Powder River Basin are a direct reflection of the higher rank (greater degree of metamorphism) of the Smirl coal.

Table 10 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 sufficiently large quantities. Based on the 7.2-percent average ash content of the Smirl coal, trace elements such as thorium and uranium will be enriched in the ash approximately 14 times their whole-coal values.

Table 9.--Comparison of composition of Smirl zone coals with composition of subbituminous coals of the Northern Great Plains

	Smirl coal zone Kane County, Utah (7 samples)	Northern Great Plains subbituminous coals[1] (67 samples)
Moisture (as received)	[2]20.9%	20%
Fixed carbon (as received)	[2]39.4%	38%
Oxygen (as received)	[2]29.7%	30%
Btu (as received)	[2]9,560	9,000
SiO_2 (in ash)	35%	25%
Na_2O (in ash)	2.6%	0.5%
CaO (in ash)	9.9%	15%
MgO (in ash)	2.1%	4%
As (whole coal)	2.8 ppm	2 ppm
B (whole coal)	100 ppm	50 ppm
Ba (whole coal)	70 ppm	200 ppm
Hg (whole coal)	0.17 ppm	.08 ppm
Pb (whole coal)	3.3 ppm	6 ppm
U (whole coal)	1.5 ppm	.7 ppm
Zn (whole coal)	3.8 ppm	7 ppm

[1]Swanson and others, 1974.
[2]Four samples.

Table 10.--Elements that can affect potential utilization of coals--content in seven samples from the Smirl zone, Kane County, Utah

	Range (ppm)	Average (ppm)	Average continental crust (ppm) (Taylor, 1964)
As	1.0 → 5.0	2.8	1.8
Cd	<0.1	<.1	.2
Cu	5.5 → 8.8	6.9	55
F	<20 → 95	39	625
Hg	0.06 → 0.32	.17	.08
Li	9.0 → 34.9	22	20
Pb	<2.2 → 5.9	3.3	12.5
Sb	0.4 → 1.0	.51	.2
Se	0.3 → 1.3	.7	.05
Th	1.7 → 8.8	4.3	9.6
U	0.5 → 2.7	1.5	2.7
Zn	2.0 → 6.6	3.8	70
B	50 → 150	100	10
Be	.2 → .7	.3	2.8
Ni	2 → 2	2	70
Zr	10 → 30	15	165

In comparing the arithmetic mean of elements listed in table 10 with an average value of these elements in the continental crust (Taylor, 1964), only selenium (average value about 0.7 ppm compared to 0.05 ppm average crustal abundance) and boron (average value about 100 ppm compared to 10 ppm average crustal abundance) have higher values in the Smirl coal by more than an order of magnitude.

Beryllium, flourine, nickel, zinc, and zirconium are all present in the Smirl coal in amounts that are about an order of magnitude less than the average crustal abundance of these elements. The other trace elements are present in amounts that approximate (that is, same order of magnitude) their abundances in the continental crust.

References Cited

American Society for Testing and Materials, 1974, Standard specifications for classification of coals by rank [ASTM designation D388-66 (reapproved 1972)], in Gaseous fuels; coal and coke; Atmospheric analysis: Am. Soc. Testing Materials, pt. 26, p. 54-58.

DeCarlo, J. A., Sheridan, E. T., and Murphy, Z. E., 1966, Sulfur content of United States coals: U.S. Bur. Mines Inf. Circ. 8312, 44 p.

Fieldner, A. C., Rice, W. E., and Moran, H. E., 1942, Typical analyses of coals of the United States: U.S. Bur. Mines Bull. 446, 45 p.

Francis, Wilfried, 1961, Coal, its formation and composition: London, Edward Arnold (Publishers) Ltd., 806 p.

Goode, H. D., 1973a, Preliminary geologic map of the Bald Knoll quadrangle, Utah: U.S. Geol. Survey Misc. Field Studies Map MF-520.

______1973b, Preliminary geologic map of the Skutumpah Creek quadrangle, Utah: U.S. Geol. Survey Misc. Field Studies Map MF-521.

Lowry, H. H., ed., 1945, Chemistry of coal utilization, Volumes I and II: New York, John Wiley and Sons, Inc., 1868 p.

______1963, Chemistry of coal utilization, supplementary volume: New York, John Wiley and Sons, Inc., 1142 p.

Moore, E. S., 1940, Coal, its properties, analysis, classification, geology, extraction, uses and distribution: New York, John Wiley and Sons, Inc., 473 p.

Schopf, J. M., 1956, A definition of coal: Econ. Geology, v. 51, no. 6, p. 521-527.

______1960, Field description and sampling of coal beds: U.S. Geol. Survey Bull. 1111-B, 70 p.

Schopf, J. M., 1966, Definitions of peat and coal and of graphite that terminates the coal series (Graphocite): Jour. Geology, v. 74, no. 5, pt. 1, p. 584-592.

Snyder, N. H., 1950, Handbook on coal sampling: U.S. Bur. Mines Tech. Paper 133 (revised), 10 p.

Swanson, V. E., Huffman, Claude, Jr., and Hamilton, J. C., 1974, Composition and trace-element content of coal, Northern Great Plains area: Contribution to Mineral Resources Work Group, Northern Great Plains Resource Program.

Taylor, S. R., 1964, Abundance of chemical elements in the continental crust--a new table: Geochim. et Cosmochim. Acta, v. 28, no. 8, p. 1273-1285.

Tomkeieff, S. I., 1954, Coals and bitumens and related fossil carbonaceous substances: London, Pergamon Press Ltd., 122 p.

U.S. Bureau of Mines, 1965, Bituminous coal, _in_ Mineral facts and problems, 1965, p. 119-147.