RESOURCE SERIES 7

EVALUATION OF COKING COALS
IN COLORADO

By

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Department of Natural Resources
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PREFACE

This paper represents the final report for a two-year cooperative project entitled "Evaluation of Coking-Coal Deposits in Colorado." Funding for the first year of this study was furnished by the U.S. Bureau of Mines; and for the second year, by the U.S. Department of Energy. During the first project year, David C. Jones and D. Keith Murray conducted research which resulted in the publication of Colorado Geological Survey Open-File Report 78-1, "First Annual Report--Evaluation of Coking-Coal Deposits in Colorado." This publication served as the foundation for the second year of the study.

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TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

ABSTRACT

Certain coals from the State of Colorado have long served as a major component for the manufacture of coke in the western United States. However, decision-makers in both private industry and in all levels of government have been hampered by the lack of a comprehensive and detailed statewide coking-coal resource evaluation. To alleviate this problem, a two-year project was initiated to evaluate the resources of coking coal in Colorado.

A detailed examination of published coking-coal classification and evaluation systems revealed several applicable methods by which the State's coal resources could be evaluated. Classification systems utilizing either coal petrography or the Ruhr dilatometer were found to be relatively flawless in denoting the suitability of a coal deposit for use as coke oven feedstock. However, the lack of a large data base eliminated the use of these systems in evaluating Colorado coal resources.

Based on a precedent set by workers in the U.S. Bureau of Mines and Department of Energy, a classification system was established to evaluate coking-coal resources in Colorado. The classification system uses coal ash and sulfur content and ASTM rank designations to categorize coal resources as being either premium (0-1.0% S, 0-8.0% ash), marginal (1.1-1.8% S, 8.0-12.0% ash), or latent (1.9-3.0% S, 12.1-15.0% ash) grade coking coal. Using this classification system, in conjunction with general technologic and geologic considerations for coke oven feedstocks, the Uinta, San Juan River, and Raton Mesa coal regions, Colorado, were selected as areas containing potential coking-coal reserves.

Identified original in-place coking-coal reserve estimates then were made utilizing the proposed coking-coal classification system, coal resource evaluation maps, and published coal reserve estimates. In Colorado, the Raton Mesa region contains 2.05 billion short tons, the San Juan River region 1.78 billion short tons, and the Uinta region 0.45 billion short tons of identified coking-coal reserves. The total identified original in-place coking-coal reserves for the State of Colorado are estimated at 4.3 billion short tons.

INTRODUCTION

PURPOSE

A significant portion of Colorado's coal production has been used for the manufacture of coke since the Nineteenth Century. Indeed, Jones and Murray (1978) reported that "Colorado has been the leading producer of coking coal in the West for many years." Averitt (1966) states that two of the four coal fields in the West which produce the largest quantity and best quality coke are located in Colorado. However, a comprehensive and detailed evaluation of Colorado's coking-coal resources has been lacking.

Consequently, accurate and intelligent decisions could not be made in the public sector concerning the location, production, and utilization of coking coal in Colorado. To alleviate this problem, the Colorado Geological Survey, in cooperation with the U.S. Bureau of Mines, initiated a two-year study to evaluate Colorado's coking-coal resources. This publication represents a summation of the two-year cooperative project, entitled "Evaluation of Coking-Coal Resources in Colorado."

In order that this publication can be applied to a broad range of problems encountered by the general public, private industry, and governmental agenices, two primary objectives were considered. To fulfill the first, general information concerning the use of coal by the appropriate industries has been included so that decisions can be made by those parties unfamiliar with the production and utilization of coking coals. The second objective has been addressed by including specific information for use by decision-makers interested in more detailed studies of Colorado's coking coals.

PREVIOUS WORK AND INVESTIGATIONS

Although a comprehensive and detailed evaluation of the coking-coal resources of Colorado has been lacking, past authors have dealt with the subject to varying degrees. West (1874, 1875) and Weeks (1884) published statewide coking coal data prior to 1900. However, Arthur Lakes presented a more detailed study on the thriving coke industry in Colorado during the 1800's (Lakes, 1899a). His article is based both on his own research and on work by R. C. Hills (1893). According to Lakes (1899a), "abundant coking coal is mined principally for locomotive purposes, the slack being made into coke and sold to the metallurgical establishments." In his description of the Raton field, Lake lists 222 beehive coke ovens at Sopris, 250 at El Moro, 80 at Starkville, 100 at Grey Creek, and 100 at Victor. Lakes also mentions production of coke from coal mined at the Porter and San Juan mines in the "La Plata Field." Full coal production fro the two mines was coked and sold locally to supply the smelting works of the district. Although Lakes waited until a subsequent article (Lakes, 1899b) to describe the coal resources of the "Grand River Field" (now called the Uinta region), he does describe the coal of the Yampa field as being semicoking rather than true coking coal.

In 1937, George and others published a major statewide report on Colorado's coal resources. Although numerous reports dealing with coking coal in local areas were published prior to 1937, the publication by George and others represents the first detailed description of Colorado's coal resources. This report tabulates all coal analyses performed by the U.S. Bureau of Mines before 1936 and gives a brief description of the production and market of each mine sampled. However, the publication does not contain a section dealing specifically with coking coal in Colorado. Nevertheless, reference is made to coking coal in a general description of the various coal fields and also in discussions of the markets for individual mines.

Perry (1943) later presented detailed locations of known coking-coal deposits in Colorado. His article, dealing with energy sources in the Rocky Mountain area, is based upon work by the U.S. Bureau of Mines. Table 1 represents a summation of Perry's work concerning Colorado coking coals.

Statistical data pertaining to Colorado's coking coals have been published in several nationwide studies. For example, Brown and others (1954) and Ortuglio and others (1975) present data on the coking properties of Colorado coals. A general description of Colorado's coal resources, including data on the State's coking coals, can be found in Hornbaker and others (1976) and in the Keystone Coal Industry Manual [1976, 1977, 1978, 1979 (in press)]. In their discussion of coking coal in the western United States, Grosvenor and Scott (1976) also refer to Colorado coals.

However, the most important publications in recent years dealing specifically with Colorado coking coals are those of Averitt (1966) and Jones and Murray (1978). Paul Averitt describes the coking-coal deposits of the western United States and incorporates descriptions of Colorado coal regions into his work. He considers the coal resources of the San Juan region to be historically interesting but indicates that the important coking-coal deposits in Colorado are located in the Uinta (Somerset, Crested Butte, and Carbondale fields) and Raton Mesa regions. In describing these regions, Averitt gives a brief account of the past work, geology, major producing beds, and importance of each coal field or district.

Table 1. Location of coking coal in Colorado according to Parry (1943).

	County	Mining field	Area having coking coal[1]	Coking properties[2]
1)	Las Animas	Trinidad	From state line to about 5 miles south of Walsenburg	Very good to poor; coked in byproduct ovens
2)	La Plata and Montezuma	Durango	Durango west of Montezuma	Good to poor; coked in beehives
3)	Montrose	Norwood		Good
4)	Gunnison	Crested Butte	Near Crested Butte	Fair to poor
5)	Gunnison and Delta	Paonia	From Bowie to Hawk's Nest and south 8 miles	Good to poor
6)	Mesa	Grand Junction	From Palisade 15 miles northwest	Poor
7)	Pitkin	Glenwood	From Marble 16 miles north	Very good to poor

[1] Extent is approximate, as analysis and available information do not cover entire field.

[2] This estimate is based on correlation with analysis, on laboratory tests, and on historical data from Bureau of Mines Technical Papers 345, 484, 529, 569, and 574, and from McGraw-Hill Coal Buyers' Manual.

Table 2. Data on Western Steel Producers (after Jones and Murray, 1978).

State	Steel Corporation	No. & Type of Coke Ovens	Daily Coal Consumption Capacity (short tons)	Daily Coke Production Capacity (short tons)	Percent of Coal Used in Blending, and Source		
					High-Vol.	Med.-Vol.	Low Vol.
California	Kaiser Steel Corporation	315 Koppers-Becker	6,400	3,900	New Mexico	Colorado	--
Colorado	C.F.& I. Steel Corporation	146 Koppers-Becker 60 Koppers-Becker	3,650	2,370	80 Colorado	none	20 Arkansas
Utah	United States Steel Corporation	252 Koppers-Becker	--	--	37.5	25	--

(References: Coal Age, 1973; Keystone, 1977; Sheridan, 1976; and U.S. Bureau of Mines, 1965).

As a summary of the first year of research on this grant project, Jones and Murray (1978) published Colorado Geological Survey Open-File Report 78-1, entitled "First Annual Report--Evaluation of Coking-Coal Deposits in Colorado." Because their publication forms the foundation upon which the present work has been built, the contents of their report will be briefly reiterated here. In addition, certain data obtained during the second year of research have led to modifications of some sections of the first year's report.

Although a small portion of the coking coal produced in the West is shipped east to be used in coal blends for coking, the primary consumers of the coal are the three major steel mills located at Pueblo, Colorado, Provo, Utah, and Fontana, California. Table 2 is a summation of statistical data on these mills. As indicated on Table 2, the coal used for the manufacture of coke for the steel mills is supplied primarily from Colorado, New Mexico, and Utah. According to 1976 production figures (Sheridan, 1976), Colorado mines supply approximately 41 percent of the premium and marginal grade coking coals. Utah produces the balance of the premium grade coking coal, and New Mexico the balance of the marginal grade. (For definitions of the terms "premium" and "marginal" grades, see page 17).

Historically, coking coal was mined in Colorado to supply either the railroads with boiler fuel or the mining districts with smelting fuel. Where coking coal was produced as railroad boiler fuel, the slack was coked and sold to the metallurgical industries. As larger users of coking coal, including steel mills, began operations in the West, company-owned coal mines were opened. Today, CF&I Steel Corporation and United States Steel Corporation own captive coal mines (mines owned and their production utilized by one company) in Colorado. Table 3 is a tabulation showing the historical locations of coke ovens in Colorado and their present operating status.

Jones and Murray also discuss several other aspects of their research, including literature search and bibliography, coal classification systems, Colorado bituminous coal regions, and the mines sampled during the first project year. Also included in their report are several tables listing statistics on bituminous coal mines in Colorado. The results of the literature search and bibliography are incorporated in Fender and others (1978).

Dawson and Murray list the 1978 producing coking-coal mines in Colorado and present a brief discussion of the production from these mines (Dawson and Murray, 1978). Table 4 summarizes the findings reported in their publication. Their report also includes detailed data sheets on each active or proposed coal mine in the State, including coking-coal mines.

Table 3. Coke ovens in Colorado (after Jones and Murray, 1978).

County	Geographic Location (town or area)	(Sec.,Twp.,Rge.)	Type of Coke Oven	Present Status
1) Dolores	Rico	25-40N-11W	Beehive	Abandoned
2) Garfield	Cardiff	27-6S-89W	Beehive	Abandoned
3) Garfield	Jerome Park[1]	15-8S-89W	Beehive	Abandoned
4) La Plata	Durango	19-35S-9W	Beehive	Abandoned
5) La Plata	Porter	25-35S-10W	Beehive	Abandoned
6) Las Animas	Cokedale	25-33S-65W	Beehive	Abandoned
7) Las Animas(?)	Cuatro	--	Beehive	Abandoned
8) Las Animas	El Moro	29-32S-63W	Beehive	Abandoned
9) Las Animas	Segundo	36-33S-66W	Beehive	Abandoned
10) Las Animas	Sopris	33-33S-64W	Beehive	Abandoned
11) Las Animas	Tercio	21-34S-68W	Beehive	Abandoned
12) Pitkin	Redstone	20-10S-88W	Beehive	Abandoned
13) Pueblo, Co.	Pueblo	6-21S-64W	Slot	Active[2]

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[1] No reference has been found which refers to this former coking operation; consequently, it has been listed soley by its approximate location.

[2] This coke plant is owned by C.F.&I. Steel Corp., Pueblo, Colorado, and has been the only active plant in the State for approximately 20 years.

Table 4. Currently producing coking-coal mines in Colorado (from Dawson and Murray, 1978).

Mine Name	County	Production (short tons)		Overburden Thickness (feet)
		1976	1977	
Bear	Gunnison	109,226	226,221	1200
Hawk's Nest East (#2)	Gunnison	26,787	190,350	1600
Hawk's Nest West (#3)	Gunnison	155,732	12,363	1600-2000
Somerset	Gunnison	950,156	914,552	200-2000
Allen	Las Animas	618,867	582,257	400-1100
Maxwell (New)	Las Animas	0	31,815	400-1400
Coal Basin	Pitkin	108,874	123,182	100-3000
Bear Creek	Pitkin	115,547	58,352	100-3000
Dutch Creek #1	Pitkin	132,408	232,481	100-2500
Dutch Creek #2	Pitkin	268,902	208,142	100-3000
L.S. Wood	Pitkin	263,109	298,405	100-3000
Thompson Creek #1 (New)	Pitkin	530	7,455	400-1300
Thompson Creek #2 (New)	Pitkin	150	8,413	400-1300
	Total	2,749,988	2,893,988	

USE AND MANUFACTURE OF COKE

COKE USES

The American Society for Testing and Materials (1975) defines coke as "a carbonaceous solid produced from coal, petroleum or other materials by thermal decomposition with passage through a plastic state". The unique physical properties of coke make it a very desirable fuel for metallurgical and chemical processing. As a high-quality fuel, it is nearly 100 percent fixed carbon, with only minor amounts of ash and sulfur, and practically no volatile matter content (Sheridan, 1976).

The predominant and most important use of coke is as a fuel for the manufacture of iron (Lowry, 1963). Basically, there are three essential ingredients within the "charge" used in blast furnaces at steel plants: iron ore, limestone, and coke. Coke serves three purposes in the charge (Lowry, 1963; Holway, 1975). First, it provides the heat which results in melting iron ore. Second, the carbon from the coke forms carbon monoxide, which reduces the iron-bearing material to metallic iron. And third, coke allows the air blast and reducing gases to move uniformally up through the furnace by providing a strong, porous physical structure that supports the charge.

Although the utilization of coke in the blast furnaces of steel plants is its most important use, coke is also required in various iron foundries, nonferous smelters, and chemical plants (Sheridan, 1976). Within the metallurigical industry, Lowry (1963) states that "coal is used in sintering, pelletizing, zinc retort-smelting, blast furnace smelting, and other metallurgical processes." Coke breeze is often used as a fuel for steam generation in boiler houses and for smelting plants (McGannon, 1971). Rose and Glenn (1956) discuss the various processes in which coke is used in the chemical industry. In most of these processes, coke is used to furnish carbon for conversion of oxide to chlorides or to carbides and for the reduction of nonmetals.

The basic differences between foundry, metallurgical, and chemical coke are illustrated on Figure 2. On this figure, the physical characteristics of the three types of coke are graphed with the petrographic characteristics of the coals used to make the coke.

COKE MANUFACTURING

Regardless of its use, coke in Colorado has been manufactured by two different methods. The early production of coke in the State was accomplished by the use of beehive coke ovens. Eventually, CF&I Steel Corporation installed a byproduct recovery or slot-oven process at their steel plant in Pueblo. Because of economic and environmental considerations, the use of beehive ovens has been discontinued in Colorado, leaving the slot-oven process in Pueblo as the only coke manufacturing operation in the state for the past 20 years (Table 3).

A close examination of beehive coke oven ruins in Colorado's coking-coal regions reveals the principle of the carbonizing process. These ovens are dome-shaped with two openings: a door and a hole in the roof called the trunnel head (Figure 1). The oven is charged through the trunnel head from a lorry car above. The coal charge is then levelled in the oven and the door bricked up to within 1 1/2 inches of the top. Heat retained in the oven from the previous coking cycle causes the coal to begin liberating volatile matter or gases. As the temperature of the gases rises, the ignition or "kindling" point is reached and the gases begin to burn with a slight explosion. The flames supply heat to continue the process and are regulated by adjusting the size of the door opening.

Coking time is primarily a function of the depth of the coal charge. During the process, the coal becomes plastic and then solidifies into a porous mass similar to scoria. At the end of the coking time, the brick door is torn down, and the coke is watered out to arrest the burning process. The coke is then drawn out of the oven, either by hand or machine, and is screened. Resulting products include coke and the finer coke breeze (McGannon, 1971).

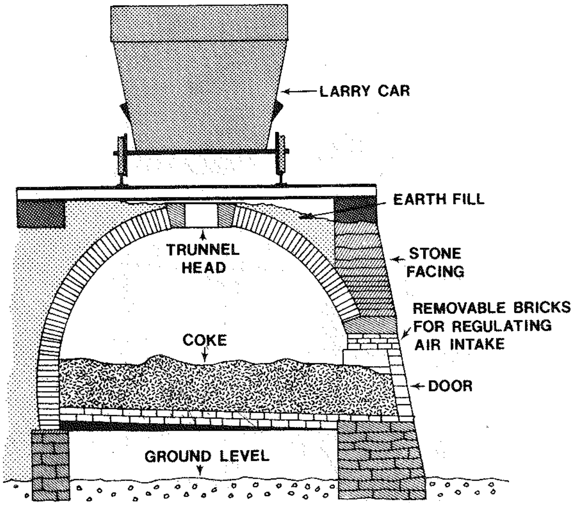
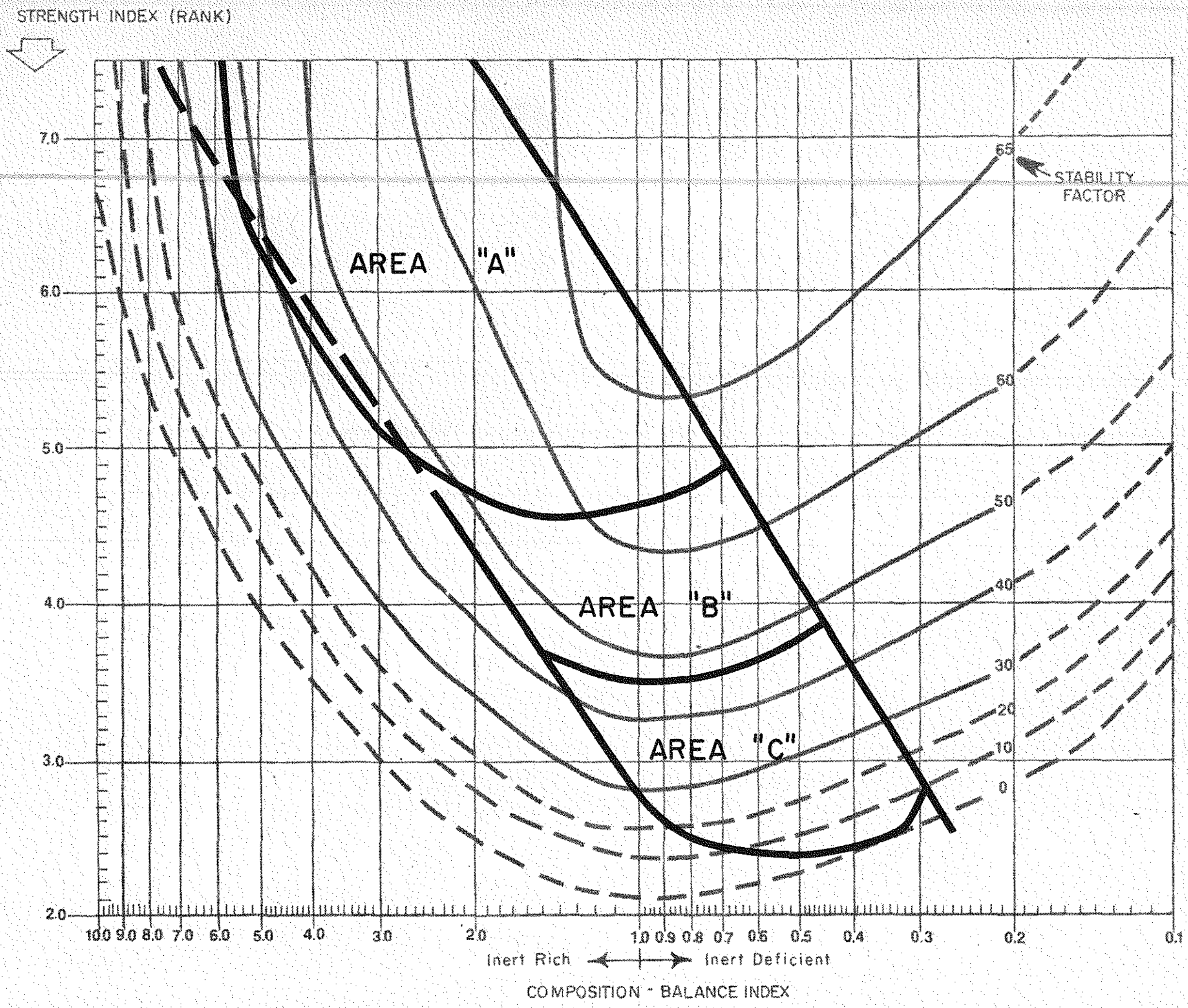


Figure 1. Schematic diagram of a beehive coke oven (after McGannon, 1971).



Contrasting Properties of Coke in Each Area

Area A	Coke meets Foundry Coke Specifications High Coke Yield (75%) Low Porosity Coke Destructive Coke Oven Pressures Highly Expanding Coke Large Blocky, high density, low reactivity coke
Area B	Coke meets Blast Furnace Specifications
Area C	Coke meets Chemical Coke Specifications Low Coke Yield (65%) Very High Porosity Coke Coke is highly contracting Small coke size, light density, highly reactive

Figure 2. Contrasting foundry, blast furnace, and chemical coal properties (modified from Berry, 1978).

Coke ovens in Colorado can be found in batteries that were constructed in three general arrangements. The simplest, called the bank system, is exemplified by ovens near Cokedale, in Las Animas County, in which the ovens are built into the hillside in a single row. With the single-block system, a single row of ovens is built with a retaining wall on both the front and back. Most commonly, the ovens was built in the double-block system, in which a double row of ovens were built back to back or staggered with a retaining wall at the front of each row. Figures 3, 4, and 5 illustrate some of the ruins of coke ovens found in Colorado.

In contrast to the beehive coke oven process, in which most of the work is done by hand, the by-product or slot oven process is a highly mechanized and modern procedure. Figure 6 is a schematic illustration of a slot oven. A typical oven is 30 ft long, 12 to 22 ft high, and 18 in. wide. Coal is charged from the top and mechanically levelled. Heat for the process is then supplied by burning gas in the oven walls. As volatile matter is liberated from the heated coal, it is recovered and processed. A portion of the processed gas is recycled and burned to heat later coal charges.

After the coal charge has coked, which generally takes about 18 hours, the doors of the oven are removed. The coke is then pushed out of the oven with a large ram and cooled in a quenching car. Table 5 depicts the production of coke and the by-products recovered through the use of a typical slot oven process. Although a beehive oven typically produces 1,332 lbs of coke per ton of coal, no by-products are recovered in the process. In contrast, a slot oven produces 1,520 lbs of coke per ton of coal and recovers commercially valuable by-products (Rose and Glenn, 1956). More detailed information concerning the coking process and the various products produced can be found in Rose and Glenn (1956), Strassburger (1969), and McGannon (1971).

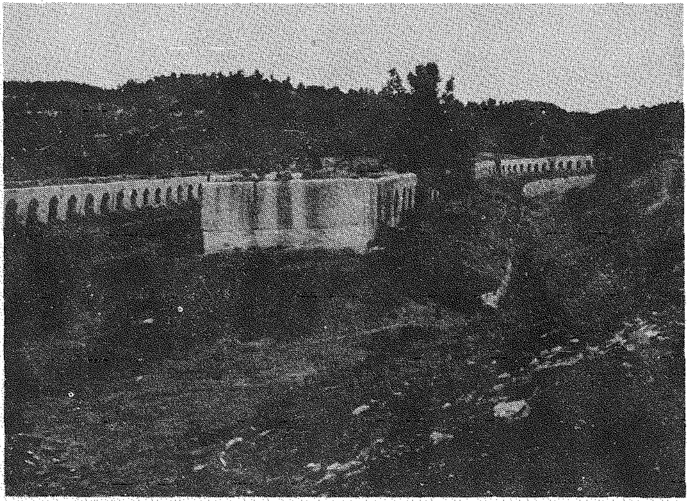


Figure 3. Beehive coke oven batteries located in the Raton Mesa coal region, near Cokedale, Las Animas County, Colorado.

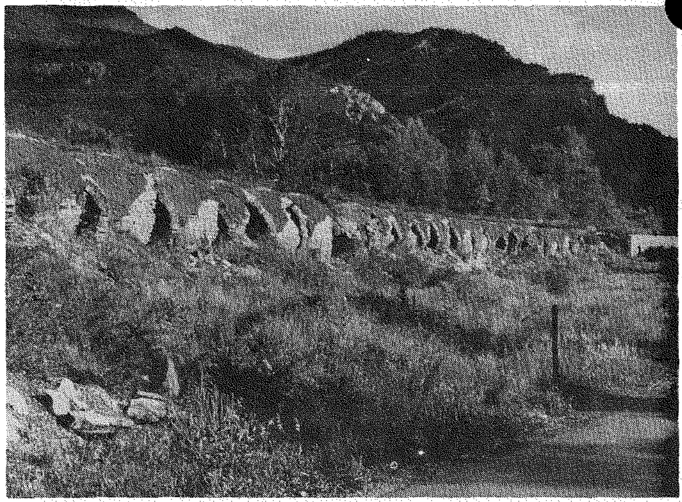


Figure 4. Beehive coke oven batteries located in the Carbondale coal field, near Redstone, Pitkin County, Colorado.

Figure 5. Ruins of a beehive coke oven located in the Raton Mesa coal region, near Ludlow, Las Animas County, Colorado.

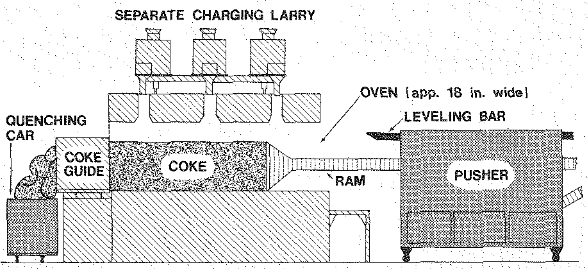


Figure 6. Schematic diagram of a slot or by-product coke oven (after McGannon, 1971).

COKING COAL EVALUATION PARAMETERS

To properly evaluate the coal resources of a region as to their potential use in the coking-coal industry, parameters must be established to distinguish coking-coal resources from non-coking-coal resources. Coke properties are, however, influenced not only by the coals used in the manufacturing process but also by several other factors. Therefore, the parameters used and the application of those parameters vary from company to company, even within the same facet of the coking-coal industry. For example, at the onset of this project, investigators with the Colorado Geological Survey wrote to several steel manufacturing companies in the United States to determine their coke oven feedstock parameters. Tables 6 and 7 summarize the response to our survey and illustrate the variability of parameters used to evaluate coking coals. Even though several companies surveyed use similar parameters in their coal evaluations, the acceptable ranges of values for these parameters differ from company to company.

The two primary factors that influence coke properties are the coal used in the coke oven feedstock and the technical process used in the manufacture of the coke. This fact has been demonstrated by many workers, including Gomez and others (1967), who stated that "both carbonization conditions in the coke oven and the properties of the coal charged enter into complex interrelationships to influence the resultant coke." Figure 7 clarifies the importance of these two factors and illustrates some of the individual elements to be considered within the two categories. A detailed discussion of the various aspects of technical processes used in the manufacture of coke is beyond the scope of this paper. However, a brief discussion concerning some of the technical practices used in the industry can illustrate why the parameters used to evaluate coking coals vary to such a degree.

One practice that can influence the selection of coals needed by a coke manufacturer is that of

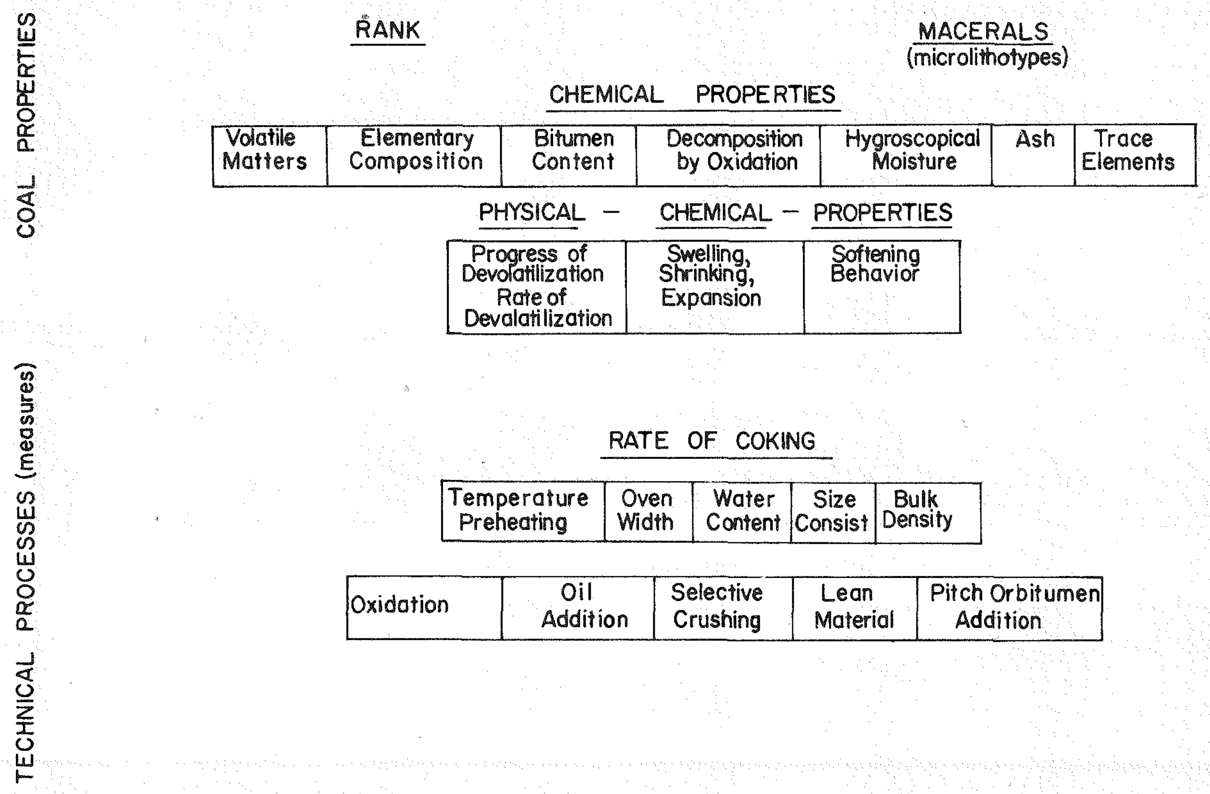


Figure 7. Possible coal properties and technical processes that can influence the coking capacity of coal blends (after Stach and others, 1975).

adding materials other than coal into the oven feedstock. Some coke producers blend low percentages of machine carbon, anthracite, coke breeze, or char into the coal before initiating the coking process (Boley and others, 1972). Various petroleum products are also added by some manufacturers. These blending additives are used either for economic considerations or for their effects on desired coke properties.

Conditions within the coke oven itself also can effect coke properties. For example, the size and strength of coke are strongly influenced by oven width, flue temperature, and bulk density. In turn, a change in any one of these parameters brings about a change in coal expansion, coking time, and the coking rate (Gomez and others, 1967). After a study of the change in physical properties of 112 cokes as a function of eight different variables, including coke oven variables, Gomez and others (1967, p. 34), concluded that "A given property of the coke reflects the sum of multivariable interactions occurring in the carbonization reaction."

Another technical innovation in the coking-coal industry in relatively recent years is the practice of blending several different coals to establish reliable coke oven charges. Traditionally, when beehive coke ovens were used to manufacture coke, one coal was considered adequate to produce a good coke. However, with increased reliance on by-product coke ovens, and with depletion of readily obtainable premium coking coals, the industry has turned increasingly to the use of blends of several different coals. Today, only one coke producer in the United States uses a single coal as oven feedstock (Jones and Murray, 1978).

Smith and Reynolds (1955) state that the blending of coals affords a means of (1) controlling coke oven expansion pressure, (2) physically and chemically improving the quality and uniformity of coke, and (3) effectively using and conserving the premium grades of coking coals. In a beehive coke oven, expansion pressure is of little concern because the coal charge is unconfined (Fig. 2). In a modern by-product oven,

Table 5. Yields of selected chemicals from high-temperature coal carbonization (after Rose and Glen, 1956).

Principal products from carbonization in a slot-type oven	Average yield/ton
Coke and breeze	1,520
Tar	78
Light oil	20
Ammonium sulfate	20
From coal tar and light oil	Pounds/ton
Benzene	11.80
Toluene	2.72
Xylenes	1.33
Naphthalene	6.48
Phenanthrene	2.26
Anthracene	0.64
Pyridine	0.16
Quinoline	0.13
Phenol	0.95
From coal gas	
Carbon monoxide	43.2
Hydrogen	30.4
Methane	132.0
Hydrogen sulfide	6.7
Hydrogen cyanide	1.7
Ethylene	19.6
Propylene	3.4
From liquor	
Ammonium sulfate	20.0

Table 6. Coke-over feedstock parameters used by various coke manufacturers in the United States (modified from Jones and Murray, 1978).

Coke Manufacturer	Feedstock Parameters		
Kaiser Steel Corporation	H_2O	6-7%	
	Ash	7-7.5% (DB)	
	Volatile Matter	32-34% (DB)	
	Sulfur	0.75-0.85% (DB)	
	Fluidity	500-1,500 ddpm	
	FSI	6-7	
	Pulverization	70+% - 1/8 inch	
	Bulk Density	46-48 lbs/cu ft	
Bethlehem Steel	25-30% low-volatile coal (vit. reflectance 1.40-1.65%)		
	70-75% high-volatile coal		
	18 inch oven tests at 2100° F (wall temp.)		
	Pulverization	80% - 1/8 inch	
	Bulk Denstity	50 lbs/cu ft	
	FSI	8	
	Weathered coal	max. 2%	
CF&I Steel Corp.	H_2O	8.5%	
	Ash	8.0%	
	Volatile Matter	33.0%	
	Sulfur	0.65%	
	Phosphorous	0.33%	
	FSI	6.5	
	Fluidity	300-1000 ddmp	
	Pilot scale oven tests		
Consolidation Coal	H_2O	6.0%	
	Ash	4-7%	
	Sulfur	0.4-1.0%	
	Volatile Matter	28-32%	
	Bulk Density	46-50 lbs/cu ft	
	FSI	6-9	
	Fluidity	1000-5000 ddpm max.	
	Size Consist	100% - 1/4 inch	
	Max. coking Press.	1.5 psi	
	Contraction	7-12%	
Dominion Foundries and Steel, Ltd.	Ash	7%	
	Sulfur	1%	
	Volatile matter	16-35%	
	FSI	6	
	Fluidity	50 or greater (low-volatile) 15,000 or less (high-volatile)	
	Vitrinite Reflect.	1.20 (blends)	
Jim Walter Resources, Inc.		Furnace Coke	Foundry Coke
	H_2O	6.10%	5.50%
	Volatile Matter	30.50%	25.00%
	Ash	7.80%	4.80%
	Fixed Carbon	61.70%	70.20%
	Sulfur	1.05%	0.70%
	FSI	7.5%	8.5%
	Pulverization	80% - 1/8 inch	
	Fluidity	10 ddpm or more (low-volatile); 20,000 ddpm or less (high-volatile)	
Jones and Laughlin Steel Corp.	Petrographically established stability indices		
	Contraction	7% at 55 lbs/cu ft bulk density (blends)	
	Coking pressure	2%	
	30-lb test oven		
United States Steel Corp.		Good	Acceptable
	Ash, %	6.0	8.0
	Sulfur %	0.7	1.0
	Potassium and Sodium Oxides, % of ash	1.0	3.0
	Ash-Fusion Temp., °F	2500	2300
	Phosphorus, %	0.01	0.03
	(see Table 7 for additional parameters used by U.S. Steel Corp.)		

however, charge expansion pressures of more than 1.5 to 2 percent can cause substantial damage to the oven.

In the United States, the general practice is to use a high-volatile coal as a base coal and to blend lower percentages of medium- or low-volatile coals with it. This practice is followed because high-volatile coals are usually more readily available than are low- or medium-volatile coals. However, high-volatile coals produce low coke yields and comparatively weak cokes. The addition of lower volatile coals raises the resultant coke strength and also increases the coke yield. If too much low- or medium-volatile coal is added, however, excessive expansion pressures result, and oven damage can occur. Blending also makes possible the use of coals normally considered excessively high in sulfur or ash. Blending combinations are, therefore, virtually unlimited and any coal may be used in a blend so long as coke with acceptable properties is produced (Sheridan, 1976).

The technical process used to manufacture the coke is not the only factor influencing the selection of coals to be coked. The use for which a coke is manufactured determines the coke properties required and, therefore, influences the coals needed as feedstock. Economic considerations related to coal availability, environmental restrictions, mining conditions, or transportation costs also can influence the selection of one coal over another. The variability of the different parameters to be considered in the selection of coal for coking is illustrated in the following list of general coking coal requirements (Strassburger, 1969):

1. Uniformity
2. Ash and sulfur contents
3. Coking properties
   a. Coking strength
   b. Expansion-contraction and pressure characteristics
4. Availability, mine price, and transportation costs
5. Coke, gas, and coal chemicals yields, including water of decomposition
6. Ash composition and fusibility
7. Moisture content
8. Storage and handling characteristics
   a. Oxidation - weathering behavior
   b. Size segregation
   c. Dustiness and windage loss
   d. Freezing in transit
9. Pulverization and breakage properties
   a. Grindability and friability
   b. Hardness and abrasiveness

Table 7. The United States Steel Corporation ranking of coking-coals for blending (from Gray and others, 1978).

	Coal Classification								
	High Volatile A Rating			Medium Volatile* Rating			Low Volatile Rating		
Property	Good	Medium	Poor	Good	Medium	Poor	Good	Medium	Poor
1) Volatile matter, percent	31.0-33.0	33.0-36.0	+36.0	21.0-24.0	24.0-27.0	27.0-31.0	18.0-21.0	15.0-18.0	15.0
2) Vitrinoid reflectance, %**	0.92-1.09	0.85-0.95	0.68-0.85	1.40-1.50	1.20-1.40	1.10-1.20	1.51-1.70	1.70-1.85	1.85
3) Fluidity, ddpm***	+20,000	5,000-20,000	5,000	500-8,000	300-20,000	300- 20,000	100-300	30-1,000	30- 1,000
4) Free-swelling index	9	6-8	6	9	7-8	7	9	7-8	7
5) Hardgrove grindability index	48-75		32-70	80-135		60-90	90-120		85-105
6) Composition-balance index**	0.40-0.80	0.80-1.40	1.40	1.0-1.50	1.50-2.00	2.0	2.0-3.50	3.50-5.0	5.00
7) Rank index**	3.4-4.3	3.0-3.4	2.2-3.0	6.0-6.5	4.3-5.5	4.3	6.8	6.0-7.5	7.5

---

* Those properties such as volatile-matter content, reflectance in oil, and rank index have little bearing in the ranking of medium-volatile coals because the rank required for a medium-volatile coal is dependent upon the rank and amount of the other coals used in the blend.

** Determined petrographically

*** Dial divisions per minute

COAL CLASSIFICATION SYSTEMS

Many classification systems have been devised for determining the desirability of any specific coal for its use in coke oven blends. Although these systems are influenced by the foregoing considerations, they have been applied in varying degrees to the evaluation of coking-coal resources in different areas. The following is a brief review of the various coal classification systems and their applicability in evaluating Colorado's coal resources.

Coal classification systems are generally established using the compositional, plasticity, or petrographic properties of the coal utilized in the coke manufacturing process. Testing procedures used to establish compositional and plasticity properties of coal have been standardized in the United States by the American Society for Testing and Materials. In their annually updated publication, the Society outlines procedures for coal sampling, testing, and reporting (ASTM, 1978). Petrographic standardization has been established through the work of the International Committee of Coal Petrography and published in the International Handbook of Coal Petrography and its supplements (1963, 1971, 1975).

However, standardization of coal sampling, testing, and reporting procedures does not preclude discrepancies and problems in the use of laboratory results for the construction of coal classification systems. The problems that are inherent in coal testing and reporting procedures are discussed in Lowry (1963), Allen (1964), Rees (1968), Givens (1969), and Givens and Yarzab (1975). These problems can lead to discrepancies within any coal classification system based upon the reported laboratory analysis. Therefore, although there are exceptions, few coal classification systems define coal properties rigidly enough to adequately predict what the properties of the resultant coke oven charge will be. Discrepancies may lead to such problems as excessive oven pressures, decreased coke strength, or decreased coke stability.

To insure that problems associated with coal classification systems will not lead to economic losses, coke manufacturers generally test new coal blends in pilot scale coke ovens before implementing coke production with the blend. A typical pilot size coke oven is illustrated in Jackman and others (1955), Jackman (1963), and Strassburger (1969). These small ovens hold coal charges of approximately 35 to 1000 pounds. Pilot scale oven tests are run to measure oven expansion pressures, to experiment with the effects of time and temperature on resultant cokes, and to obtain coke for quality tests (Strassburger, 1969).

GENERAL COAL CLASSIFICATION SYSTEMS

The classification of coal by rank following the standards established by the American Society for Testing and Materials is the most widely utilized classification method used to evaluate American coal resources. Coal rank is determined using those compositional and plasticity parameters designated in the annual book of ASTM standards (ASTM, 1978). The classification method is illustrated on Table 8. Using this table, coals are classified according to their calorific value (moist, mineral-matter-free Btu per pound) until coals of 69 percent or greater dry, mineral-matter-free fixed carbon are attained. Coals containing 69 percent or greater fixed carbon are classified according to their fixed carbon contents, regardless of their Btu values. The agglomerating character of the coals is used to differentiate between some closely related groups.

The rank of a coal as established according to Table 8 can be used to gain some insight into the application of any coal resource to the manufacture of coke. As indicated by the table, only coals of bituminous rank are agglomerating and hence are considered to be potentially coking coals. As discussed previously, coals of other ranks are sometimes added to a coke oven charge to enhance certain resultant coke properties. However, only a relatively minor percentage of coals exclusive of bituminous rank are used in the coking-coal industry. Coke manufacturers in the United States use coals of bituminous rank as the major component in their blends. In addition, no coke manufacturers in this country use coals of high-volatile C bituminous rank as a major component in their blends (Strassburger, 1969). A coking-coal evaluation program in America, therefore, need only consider those coals between high-volatile B and low-volatile bituminous in rank.

Although the ASTM classification of coals by rank is the primary classification system used in this country, various other international and national coal classification systems exist. In some cases, the rank names used in these classifications may be the same as those used in the ASTM system. However, different compositional and plasticity parameters form the basis for the various classification schemes. Jones and Murray (1978) have discussed the discrepancies that occur in attempting to form a correspondence between European and ASTM classification systems. Because most European classification systems use ultimate carbon instead of fixed carbon as a significant parameter, the rank name of one coal may vary depending on which system used (Fig. 8). All coal ranks reported in this report are determined using ASTM procedures.

An International Classification of Hard Coals by Type has been devised through the efforts of the Coal Committee of the Economic Commission for Europe, Geneva, Switzerland (Table 9). Lowry (1963), Strassburger (1969), and Montgomery (1974) give detailed discussions of the use of the International system. The term "type" in the International Classification corresponds to rank designations in the ASTM system. Using various compositional and plasticity parameters depicted on Table 9, a three-digit number is generated to characterize the "type" of each coal. Figure 9 illustrates the correlation between the International Classification class number and ASTM designated group names. The International Classification has not found wide acceptance in the United States, however, because neither the Audibert-Arnu dilatometer test nor the Gray-King assay method are commonly performed by American coal laboratories.

COKING-COAL CLASSIFICATION SYSTEMS

Compositional Classifications

Strassburger (1969) reported a coking-coal classification based upon the ASTM classification of coals by rank and coal "variety" or "type" (Table 10). According to Strassburger, coal type (not associated with the International Classification) may be determined simply by a megascopic examination of coal samples. However, Schopf (1960) reports that a microscopic examination is the only method of differentiating between nonbanded coal types. As depicted by Table 10, bright (common banded) coals are the common layered-appearing coals composed of various coalified plant remains. Splint coal is a variety of banded coal with uneven, blocky fracture and granular texture (Thrush, 1968). Cannel coal is a nonbanded coal composed predominantly of spore coats. A coal derived from the remains of colonial algae is termed boghead coal. All commercially produced coals in the coking-coal regions of Colorado are common banded coals.

During those times in which the Beehive coke oven was the major producer of coke, determining the coking potential of a coal was much simpler than it is today. Formerly, there was no need to evaluate the ways in which different coals would interact in coal blends. Oven feedstocks consisted of only one coal. Personnel from the U.S. Bureau of Mines devised a method to determine the coking potential of a coal through the use of commonly performed laboratory chemical analysis. A coking index was computed by the following method (Perry, 1943; Jones and Murray, 1978):

Table 8. Coal rank classification method following the standards of the American Society for Testing and Materials (after ASTM, 1978).

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,[b] 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. Anthracitic	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	
	3. Semianthracite[c]	86	92	8	14	...	...	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[e]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	
	3. High volatile *A* bituminous coal	...	69	31	...	14 000[d]	...	
	4. High volatile *B* bituminous coal	...	...	...	...	13 000[d]	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	

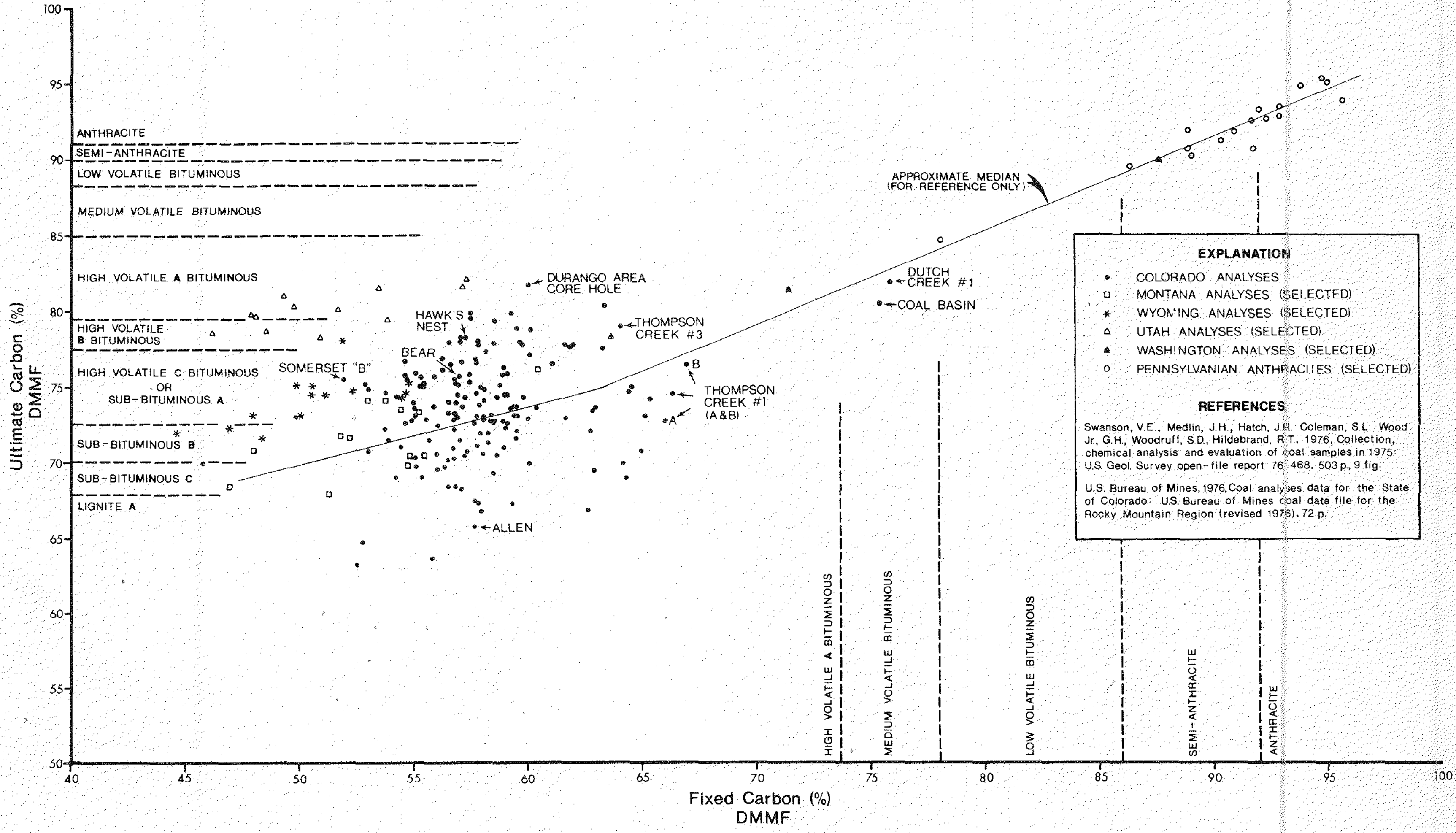
[a] This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less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

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

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

[d] 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.

[e] 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.



Swanson, V.E., Medlin, J.H., Hatch, J.R. Coleman, S.L. Wood Jr., G.H., Woodruff, S.D., Hildebrand, R.T., 1976, Collection, chemical analysis and evaluation of coal samples in 1975: U.S. Geol. Survey open-file report 76-468, 503 p., 9 fig.

U.S. Bureau of Mines, 1976, Coal analyses data for the State of Colorado: U.S. Bureau of Mines coal data file for the Rocky Mountain Region (revised 1976), 72 p.

Figure 8. Fixed carbon vs. ultimate carbon for selected Western coal analyses (from Jones and Murray, 1978).

$$\text{Coking index} = \frac{a+b+c+d}{5}$$

Where: $a = 22/O_2$

$b = (2)\ H_2/O_2$

$c = \frac{FC}{(1.3)\ VM}$

$d = \frac{Btu}{13{,}600}$

and: 1) The O_2 content should be under 11% to possibly be of coking quality.

2) The H_2/O_2 ratio should be greater than 0.5 to possibly be of coking quality.

3) The FC/VM ratio should be greater than 1.5 to possibly be of coking quality.

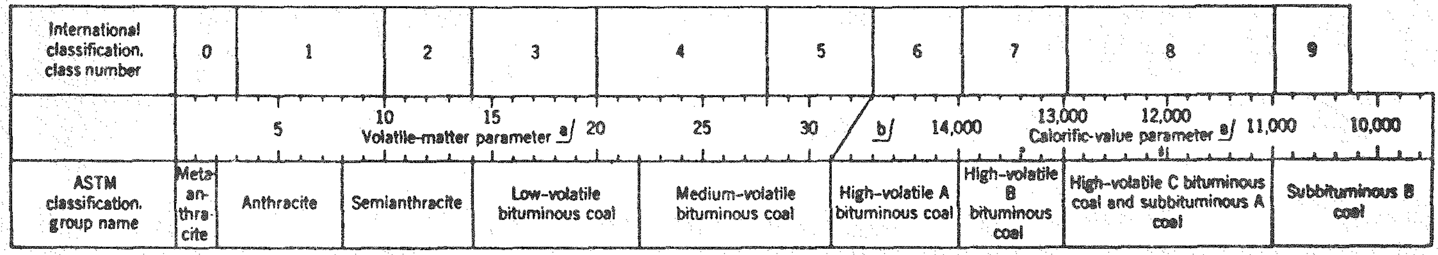
4) A coking index of greater than 1.10 indicates a "fairly good coking coal;" an index of between 1.00 and 1.10 indicates that coke may be produced under special conditions.

Using this procedure, Jones and Murray (1978) computed coking indices for bituminous rank coals from several regions in Colorado. However, as reported in their publication, such coking indices are of little value to the modern coke producer using coal blends as oven feedstock.

Leonard (1965, 1978) has developed a method of predicting ASTM coke stability indices for coal blends by the utilization of Hardgrove grindability index (HGI), bulk density, pulverization, and volatile matter. Using a set of graphs based on Leonard's work (Fig. 10), the properties of coke obtained from binary coal blends can be established. Depicted on Figure 10 is an example in which coal of 50 HGI and a moisture- and ash-free VM (volatile matter) content of 40 percent is blended with a coal of 110 HGI and 15 percent VM. After respective coal values are connected with straight lines, the path represented by the the dashed lines represents 35%/65% coal blend with 71 HGI and 32 percent VM. Transferring this value to the expanded VM scale (scale I) and using a pulverization level of 82-88 percent, an ASTM coke stability index of 60 is predicted. Leondard's prediction method is well suited for use in the industry for evaluating the potential of two coal resources. However, it is of only limited value for a statewide evaluation program because (1) very few HGI values are published for Colorado coals, and (2) the evaluation method does not define the limits of what is considered to be a good coking coal.

Between 1960 and 1965, three scientists at Steinkohlenbergbaurverein, Germany, developed a method for predicting coke stability indices by the use of the Ruhr dilatometer. Details outlining the prediction method have been published in English by Walters and others (1971) and discussed by Ignasiak (1974). Walters and his associates found excellent agreement between predicted and resulting coke stability indices determined using American coals. However, they point out several disadvantages in the use of the prediction method by American coke producers. First, the predicted coke strength index is expressed in Micum 40 tumbler value rather than ASTM stability index. The experimental procedures also follow German standard methods, and all parameters are expressed in the metric system. This method, therefore, has not found wide acceptance in the United States.

A statistical method has recently been applied to the correlation of coal compositional parameters, coal plasticity parameters, and ASTM coke indices (Wu and Frederic, 1971). Their research established linear correlations using 63 parameters representing chemical analysis, three plastometer and dilatometer tests, four miscellaneous plasticity tests, and three ASTM coke



a/ Parameters in international system are on ash-free basis; in ASTM system, they are on mineral-matter-free basis.

b/ No upper limit of calorific value for class 6 and high-volatile A bituminous coals.

Figure 9. The correlation between the International Hard Coal class number and ASTM designated group names (from Montgomery, 1978).

indices. Although the work does not result in a coking-coal classification system, it is significant in illustrating the reliability of a classification system based on any of the various parameters and indices used in research work. For example, maximum Gieseler fluidity was found to have no significant linear correlation with any compositional parameter or ASTM coke indice, although Gieseler solidification temperature does have a significant correlation. A classification system based on Giesler solidification temperature would probably be more reliable than one based on Gieseler maximum fluidity.

Recently, a classification system has been established for coking-coal resource evaluation based on the sulfur and ash content of the coal. Strassburger (1969) referred to the importance of sulfur and ash control in selecting coals for the manufacture of blast furnace coke. Sulfur and ash content are of primary importance, according to Strassburger, because they determine the effective carbon available for smelting in the furnace, the furnace flux requirements, and the sulfur elimination required. A high sulfur content leads to increased blast furnace slagging, decreased metal production, and, consequently, decreased profits. Most of the sulfur content of coal feedstocks is retained throughout the coke and metal manufacturing process and, therefore, has a detrimental effect on the finished metal product.

A classification system has been established using sulfur and ash contents as guidelines. Sheridan (1967) reported that, in accordance with previous Bureau of Mines investigations, the specifications for metallurgical-grade coals are that they must be strongly coking and contain no more than 1.25% sulfur and 8.0% ash, mined or after cleaning. In 1976, he revised those percentages,

Table 9. The International Classification of Hard Coals by Type (from Montgomery, 1974).

GROUPS (determined by caking properties)			CODE NUMBERS										SUBGROUPS (determined by coking properties)		
GROUP NUMBER	ALTERNATIVE GROUP PARAMETERS		The first figure of the code number indicates the class of the coal, determined by volatile-matter content up to 33% V. M. and by calorific parameter above 33% V. M. The second figure indicates the group of coal, determined by caking properties. The third figure indicates the subgroup, determined by coking properties.										SUBGROUP NUMBER	ALTERNATIVE SUBGROUP PARAMETERS	
	Free-swelling index (crucible-swelling number)	Roga index												Dilatometer	Gray-King
3	> 4	> 45	▨	▨	▨	▨	435	535	635	▨	▨	▨	5	> 140	> G_8
			▨	▨	▨	334	434	534	634	▨	▨	▨	4	> 50-140	G_5-G_8
			▨	▨	▨	333	433	533	633	733	▨	▨	3	> 0-50	G_1-G_4
			▨	▨	▨	332 a 332 b	432	532	632	732	832	▨	2	≤ 0	E-G
2	2½-4	> 20-45	▨	▨	▨	323	423	523	623	723	823	▨	3	> 0-50	G_1-G_4
			▨	▨	▨	322	422	522	622	722	822	▨	2	≤ 0	E-G
			▨	▨	▨	321	421	521	621	721	821	▨	1	Contraction only	B-D
1	1-2	> 5-20	▨	▨	212	312	412	512	612	712	812	▨	2	≤ 0	E-G
			▨	▨	211	311	411	511	611	711	811	▨	1	Contraction only	B-D
0	0-½	0-5	▨	100 A B	200	300	400	500	600	700	800	900	0	Nonsoftening	A
CLASS NUMBER →			0	1	2	3	4	5	6	7	8	9	As an indication, the following classes have an approximate volatile-matter content of: Class 6 33-41% volatile matter 7 33-44% " " 8 35-50% " " 9 42-50% " "		
CLASS PARAMETERS	Volatile matter (dry, ash-free) →		0-3	> 3-10 >3-6.5 >6.5-10	> 10-14	> 14-20	> 20-28	> 28-33	> 33	> 33	> 33	> 33			
	Calorific parameter [a] →		—	—	—	—	—	—	> 13,950	> 12,960-13,950	> 10,980-12,960	> 10,260-10,980			
CLASSES (Determined by volatile matter up to 33% V. M. and by calorific parameter above 33% V. M.)															

Note: (i) Where the ash content of coal is too high to allow classification according to the present systems, it must be reduced by laboratory float-and-sink method (or any other appropriate means). The specific gravity selected for flotation should allow a maximum yield of coal with 5 to 10 percent of ash.
(ii) 332a . . . >14-16% V. M.
332b . . . >16-20% V. M.

[a] Gross calorific value on moist, ash-free basis (30 C., 96% relative humidity) B. t. u./lb.

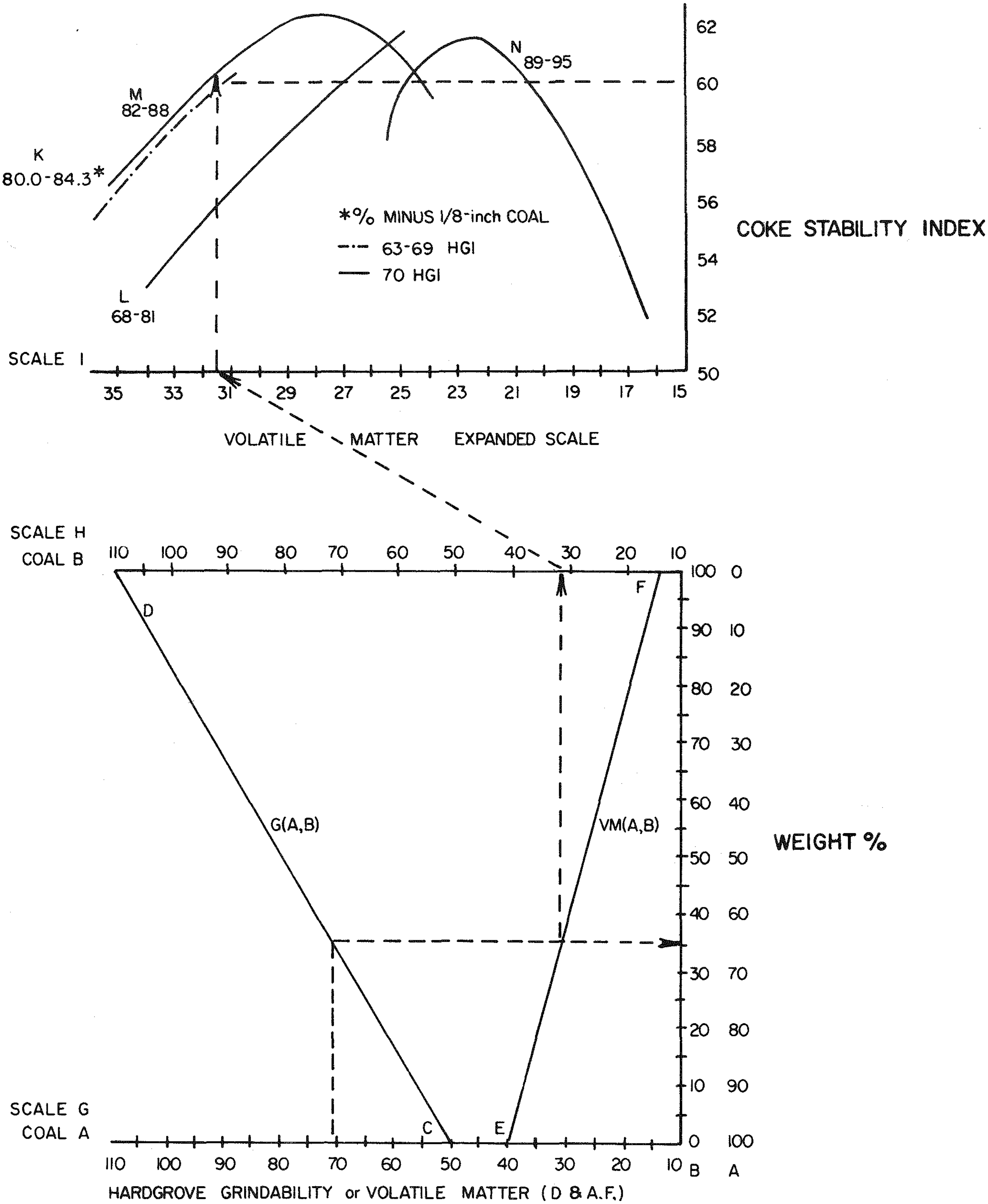


Figure 10. Leonard's coke stability index prediction method (see text for explanation) (after Leonard, 1978).

stating that "premium-grade coking coal," as generally accepted, should contain no more than 8.0% ash and 1.0% sulfur. "Marginal grade" coking coals were those with higher percentages of ash and sulfur (Sheridan, 1976). Mutschler (1975) used contents of less than 8.1% ash and 1.3% sulfur as criteria for "premium-grade" bituminous coals with potential for coke manufacuture. Using guidelines suggested by William S. Sanner, Sr., and subsequently published by him (Sanner and Benson, 1979), Jones and Murray (1978) used coal ash and sulfur contents as one criterion in their coking-coal classification system.

In the classification system proposed by Jones and Murray, the desirability of any coal for coke manufacture is defined using various criteria. The criteria include coal rank, coal ash and sulfur content, coal carbonizing pressure, volatile matter content, fluidity, grindability, and individual coke producer's preferences (Table 11). These parameters are used to establish a three-part blending classification. The first part of this classification is a number used to designate the coal rank. A capital letter follows the number to denote a high, moderate, or low sulfur and ash content in the coal (corresponding to the "latent", "marginal", or "premium" grade coking coal classification of Sanner). Finally, a lower-case letter is used to indicate a "desirability factor" based on carbonization pressure, fluidity, grindability, volatile matter content, or coke producer's preferences. For example, a coal designated 1Aa would be a low-volatile bituminous coal with a sulfur content of less than 1.0% and an ash content below 8.0%. In addition, the coal would have a volatile matter content of between 18.0 and 22.0% and a Gieseler maximum fluidity of greater than 300 ddpm.

Although there are good attributes to the classification system proposed by Jones and Murray (1978), several detrimental factors preclude the use of the system for a statewide resource evaluation. Coal rank does play a large part in the selection of coking coals. The scarcity and properties of low- and medium-volatile bituminous coals make them substantially more expensive and, therefore, more desirable than high-volatile bituminous coals. Low sulfur and ash content will, as previously discussed, cause a coal to be more desirable. However, further subdivision of coals in these groups by a "desirability factor" rapidly leads to discrepancies. As previously discussed, in the selection of coking coals, coke producers are influenced by many outside factors besides just the inherent coal properties. Within rank divisions, there is no basis for delineating one coal as being more desirable than another on the basis on volatile matter content. Coke manufacturers may, on the basis of all other factors influencing their decision, choose a coal with a low "desirability factor" within a rank division. Additional problems with the classification system are encountered when attempting to use maximum Geiseler fluidity as a classification parameter. Research by the U.S. Bureau of Mines indicates that Gieseler maximum fluidity does not have a significant correlation with coke strength indices or compositional parameters, including volatile matter content (Wu and Frederic, 1971). Figure 11 illustrates this point. In this figure, maximum Gieseler fluidities have been plotted against corresponding mean vitrinite reflectances, which do have a significant correlation to volatile matter content (Stach and others, 1975). Similar problems arise in attempting to correlate maximum Geiseler fluidity with carbonization pressure, Hardgrove grindability, or free-swelling indices (FSI). A test for maximum Geiseler fluidity is usually performed on a potential coking coal to measure its fluid temperature range. If the fluid ranges of the constituent coals in a blend do not overlap, a strong coke does not result when the blend is coked (Gray and others, 1978).

Petrographical Classifications

Currently, the most widely utilized and reliable evaluation method for establishing the blending potential of a coal for coking without actual carbonizing tests is through the use of coal petrography. Coal petrography has been defined as the earth science related to petrography which deals with the study, classification, and origin of coal (Berry and others, 1967; Moses, 1976). Coal microscopy is the main field of coal petrography (Stach and others, 1975). In recent years, coal microscopy has lead to the development of a system to predict coke stability indices for any coal blend.

Within the scope of this report, the primary application of coal petrography is in its use in determining coke stability indices for Colorado coals. However, in the coking-coal industry, coal petrography has been utilized for a score of other uses. For example, Benedict and Berry (1964a, 1964b), Berry and others (1967), and Benedict and Thompson (1976) have described several applied industrial uses of coal petrography. These uses include the following:

1. Determination of coal carbonization product yields
2. Prediction of free-swelling indices and Btu values
3. Determination of coal oxidation tendencies
4. Categorization of coal for certain combustion uses
5. Guiding coal preparation practices
6. Aiding in solving combustion and boiler problems
7. Prediction of coke oven pressures

Stach and others (1975) reported additional industrial applications, including those involved with coal mining, coal preparation, carbonization, briqueting, and combustion. Recent work has also

Table 10. Classification of coals by coal "variety" or "type", and their respective carbonizing properties (after Strassburger, 1969).

BITUMINOUS COAL TYPE OR VARIETY			
BRIGHT (COMMON BANDED) COAL	SPLINT COAL	CANNEL COAL	BOGHEAD COAL
CARBONIZED COMMERCIALLY ALONE AND IN BLENDS BY HIGH- AND LOW-TEMPERATURE PROCESSES. FUSE TO FORM COKE AND YIELD COMMERCIAL QUANTITIES OF TAR, LIGHT OIL, AND GAS. SEMISPLINT, SPLINT-TYPE AND CANNELOID COALS ARE USED SUCCESSFULLY IN BLENDS. USE OF ILLINOIS HIGH VOL. B COALS IN BLENDS IS GROWING. HIGH VOL. C NOT USED FOR COKING AT PRESENT TIME.	NOT CARBONIZED COMMERCIALLY. BECAUSE LUMPS RETAIN SHAPE AND STRENGTH ON HEATING, THIS COKE IS USED IN SOME SCOTTISH BLAST-FURNACES IN PLACE OF COKE; SOURCE OF SCOTTISH BLAST-FURNACE TAR.	NOT CARBONIZED COMMERCIALLY. FORMERLY DISTILLED TO OBTAIN "COAL OIL" FOR ILLUMINATION. CHAR USED AS FUEL IN PROCESS OR WASTED.	NOT COMERCIALLY CARBONIZED. FORMERLY PROCESSED LIKE CANNEL COAL TO OBTAIN "COAL OIL."

Table 11. The bituminous coking-coal classification for blending used by Jones and Murray, (1978).

	- 1 - Low-Volatile(1) (14.1-22.0% V.M.)	- 2 - Medium-Volatile(2) (22.1-31.0% V.M.)	- 3 - High-Volatile A(3) (31.1-39.0% V.M.)	- 4 - High-Volatile B (39.1-42.0% V.M.)	- 5 - High-Volatile C (42.1-47.0% V.M.)
- A - Low 0.0-8.0% Ash 0.0-1.0% Sulfur	a=18.0-22.0% V.M. +300 ddpm b=15.0-17.9% V.M. 100-300 ddpm c=14.1-14.9% V.M. 0-100 ddpm	a=22.1-24.0% V.M. 1000-5000 ddpm b=24.1-27.0% V.M. 5000-15000 ddpm c=27.1-31.0% V.M. +15000 ddpm	a=31.1-33.0% V.M. +20000 ddpm b=33.1-36.0% V.M. 5000-20000 ddpm c=36.1-39.0% V.M. less than 5000 ddpm	a= b= c= 39.1-42.0% V.M.	a= b= c= d= 42.1-47.0% V.M.
- B - Moderate 8.1-12.0% Ash 1.1-1.8% Sulfur	a=18.0-22.0% V.M. +300 ddpm b=15.0-17.9% V.M. 100-300 ddpm c=14.1-14.9% V.M. 0-100 ddpm	a=22.1-24.0% V.M. 1000-5000 ddpm b=24.1-27.0% V.M. 5000-15000 ddpm c=27.1-31.0% V.M. +15000 ddpm	a=31.1-33.0% V.M. +20000 ddpm b=33.1-36.0% V.M. 5000-20000 ddpm c=36.1-39.0% V.M. less than 5000 ddpm	a= b= c= 39.1-42.0% V.M.	a= b= c= d= 42.1-47.0% V.M.
- C - High 12.1-15.0% Ash 1.9-3.0% Sulfur	a=18.0-22.0% V.M. +300 ddpm b=15.0-17.9% V.M. 100-300 ddpm c=14.1-14.9% V.M. 0-100 ddpm	a=22.1-24.0% V.M. 1000-5000 ddpm b=24.1-27.0% V.M. 5000-15000 ddpm c=27.1-31.0% V.M. +15000 ddpm	a=31.1-33.0% V.M. +20000 ddpm b=33.1-36.0% V.M. 5000-20000 ddpm c=36.1-39.0% V.M. less than 5000 ddpm	a= b= c= 39.1-42.0% V.M.	a= b= c= d= 42.1-47.0% V.M.

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(1) The low-volatile coal desirability factor (a, b, or c) is based on the carbonization pressure in lbs./sq.in. (psi) generated under actual test conditions, but fluidity is used for a better comparison.

(2) The medium-volatile coal desirability factor is based on individual coke producers' preferences.

(3) The high-volatile A coal desirabiltiy factor is based on the fluidity (dial divisions/min.) and grindability characteristics. The high-volatile B & C coals are rated only on possible coke producers' preferences.

indicated that coal petrography can be utilized as a tool in the study of coal conversion processes (Montgomery, 1974; Given and others, 1975; Davis and others, 1976; Mason, 1976; and Jansen, 1978). Furthermore, within the geological sciences, coal petrography has been used as an aid in coal bed correlations, petroleum maturation, tectonic problems, paleogeography, stratigraphy, paleoecology, origin of coals, methane generation in coals, and in coal exploration (Berry and others, 1967; Stach, 1968; Bostick, 1971; Dutcher and others, 1974; Stach and others, 1975; Strauss and others, 1976; and Jansen, 1978).

The first publication dealing with the use of coal petrography to calculate coking-coal charges was published by Russian scientists (Ammosov and others, 1957). Relying heavily on this publication and on a reflected light petrographic classification system for coals developed at The Pennsylvania State University by William Spackman's group (Berry and others, 1967), petrographers at the U.S. Steel Corporation laboratory were able to establish a significant correlation between petrographic data and coke strength data (Schapiro and others, 1961; Schapiro and Gray, 1964). Since that time, other workers have modified the U.S. Steel method to accommodate the particular coals and coking processes with which they work. A more complete and detailed account of the history of the adoption of applied coal petrography to the problem of coking charges can be found in Harrison (1962), Berry and others (1967), or Stach and others (1975).

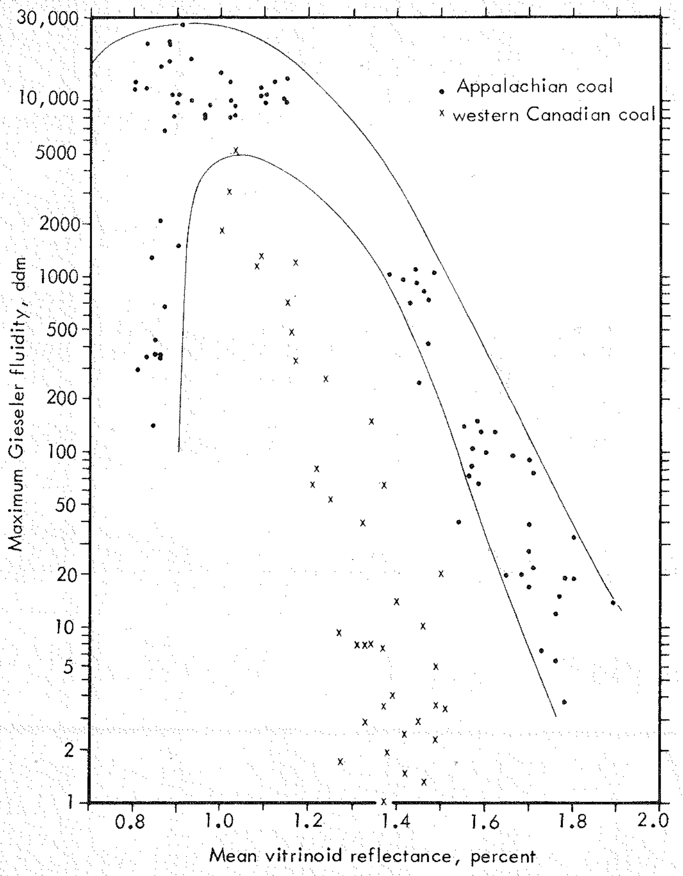


Figure 11. Mean vitrinite reflectance vs. maximum Gieseler fluidity (from Paulencu and others, 1974).

The reflected-light classification system for coal that forms the basis for determining coke stability indices is fully described in Harrison (1962), Harrison and others (1964), Berry and others (1967), Stach (1968), Stach and others (1975), and Moses (1976). The classification system is based on the concept that coal is a heterogeneous substance composed of various constituents called macerals. Macerals in coal are analogous to minerals in rocks and can be defined as genetically-related groups of carbonaceous entities which differ from other groups to various degrees in chemical and physical properties (Stach, 1968; Stach and others, 1975; Moses, 1976). Macerals conventionally have been classified into three groups: vitrinite, liptinite (or exinite), and inertinite (Stach and others, 1975). The major macerals and maceral groups are summarized on Table 12.

Although other coke oven charge prediction methods utilizing coal petrography exist (Stach and others, 1975), the primary method used today is based on the work of Schapiro, Gray and Eusner (1961). This prediction method has been fully described in various publications (Harrison, 1961; Schapiro and others, 1961; Harrison and others, 1964; Berry and others, 1967; Stach and others, 1975; and Berry, 1978). The following brief description of the method is adopted from Schapiro and others (1961) and Moses (1976).

Table 12. Summary of the macerals of hard coals (modified from Stach and others, 1975).

Group Macerals	Macerals
Vitrinite	Telinite Collinite Vitrodetrinite
Liptinite (or Exinite)	Sporinite Cutinite Resinite Alginite Liptodetrinite
Inertinite	Micrinite Macrinite Semifusinite Fusinite Sclerotinite Inertodetrinite

The petrographic prediction method was established by considering two primary principles. In the first principle, coal macerals are considered as being either reactive or inert with respect to their performance in a coke oven. Reactive macerals are those which become plastic and undergo significant physical changes when heated in the absence of oxygen. To obtain the highest coke strength from a coal blend, an optimum ratio of reactive to inert macerals must be obtained. This principle has conventionally been depicted by the use of an analogy. The analogy compares the optimum ratio of inert to reactive macerals needed to form the strongest coke with the optimum ratio of cement and gravel needed to form the greatest strength concrete. Vitrinite, liptinite, and one-third of the semifusinite are considered reactive macerals; while micrinite, macrinite, sclerotinite, fusinite, two-thirds of the semifusinite, and mineral matter are considered inert.

The chief concern of the second principle is consideration for the change in the optimum reactive-to-inert ratio with changes in coal rank. Because coal rank can be determined using vitrinite reflectance, a petrographic point-count method is employed both to delimit the volumetric percentage of each maceral in the coal and to define rank variations in the coal. Rank variations are denoted as V-steps or V types, which are groups of values for different vitrinite reflectances.

Two parameters, therefore, are produced for each coal and utilized to predict the strength of a coke obtained by carbonizing the coal. These two parameters, called the balance index and the strength index, are plotted against each other (Fig. 12). The balance index is resolved by considering the ratio of reactives to inerts that actually exists in the coal under consideration with what the optimum ratio should be for a coal of that rank. This is illustrated on Figure 13. Figure 14 is a summation of the method used to delineate the strength index. Using the figure, each individual reactive type (rank variation indices determined by vitrinite reflectance) is compared with the volume percent of inerts in the coal to determine the strength index.

After cross-plotting the strength index and balance index on Figure 12, the predicted ASTM coke strength index can be delineated using the empirically determined isostability lines labled "stability factor". The predicted stability index will normally be within ± 1.5 of the actual stability index of the resultant coke, provided that the following parameters are met (Stach and others, 1975):

1. Size consist: 80% below 3 mm
2. Moisture content: below 2%
3. Bulk density: 88 kg/m3
4. Ash yield: 12%

To determine the coke stability index resulting from a blend of coals, two methods can be employed. A rapid approximation may be obtained by averaging just the balance and strength indices of the blend coals in the desired proportions. A more precise prediction may be obtained by taking all reactive macerals in the coals to be blended and averaging them by reactive type.

As previously stated, this prediction method has been modified by different workers to accommodate their particular coals and coking processes. One new prediction method has been established by coal petrographers at the Homer Research Laboratories of the Bethlehem Steel Corporation. These workers believe that the anomalous coking behavior of certain coals may be caused by a partially non-reactive response in coke ovens by a fraction of the vitrinite macerals. This fraction of vitrinite, called psuedovitrinite, can be distinguished from reactive vitrinite by differences in various physical properties. The percentage of psuedovitrinite that is included with the inert macerals is determined by comparing the reflectance of the psuedovitrinite with that of the vitrinite macerals. Detailed discussions concerning the identification, origin, and use of psuedovitrinite in coke charge predictions may be found in Thompson and others (1966), Benedict, Thompson, Shigo, and Aikman (1968), Benedict, Thompson, and Wenger (1968), Thompson and Benedict (1974, 1975, 1978), and Moses (1976).

Modifications to the original method which could have greater ramifications in the use of petrographic prediction methods with respect to Colorado Cretaceous coals have been presented by Canadian coal petrographers (Cameron and Botham, 1966; Cameron, 1974). They found anomalous coke oven reactions in attempting to use the original method with their Western Cretaceous coals. Because the original method is based primarily on coking charges of Appalachian Carboniferous coals, Canadian workers felt justified in modifying the method to suit their Cretaceous coals. However, the Canadian method has not found wide acceptance among coal petrographers working with American Cretaceous coals.

Published and publicly available coke charge predictions for Colorado coals are notably scarce. Jansen (1978) gives a brief description of the petrographic prediction method and presents data on three Colorado coal samples. The results of Jansen's investigation are catalogued on Table 13. Currently, Jansen's investigation is the only formal publication addressing the use of petrographic prediction methods with respect to Colorado coals.

However, Colorado Geological Survey personnel have been able to establish coke charge strength indices for several coal samples from Colorado's coking coal regions. Our work is based on petrographic analyses of Colorado coals performed by workers at The Pennsyvlania State University and presented publicly in their PSU/DOE Coal Bank Data Printout. Our predictions were computed using the U.S. Steel Corporation method as outlined by Stach and others (1975), and an adoption of the method outlined in Moses (1976). Using this method, the reactive macerals were prorated on the basis of the quantity of each V-step present (Stach and others, 1975, p. 362). An abbreviated version of the petrographic analysis and resulting CGS predictions are listed on Table 14, and the analytical data on Table 15. Additional data concerning these coals may be obtained from The Pennsylvania State University Coal Research Section.

The Colorado Geological Survey is also engaged in a cooperative program with Drs. Russell R. Dutcher and John C. Crelling, of Southern Illinois University at Carbondale, to petrographically characterize Colorado coking coals. The Colorado Geological Survey ships representative crushed coal from full-seam channel samples to Southern Illinois University for petrographic analysis. The coal samples are obtained from the storage facilities of the Branch of Coal Resources of the U.S. Geological Survey in Denver. The results of this cooperative program will be published at a later date when all the data have been received.

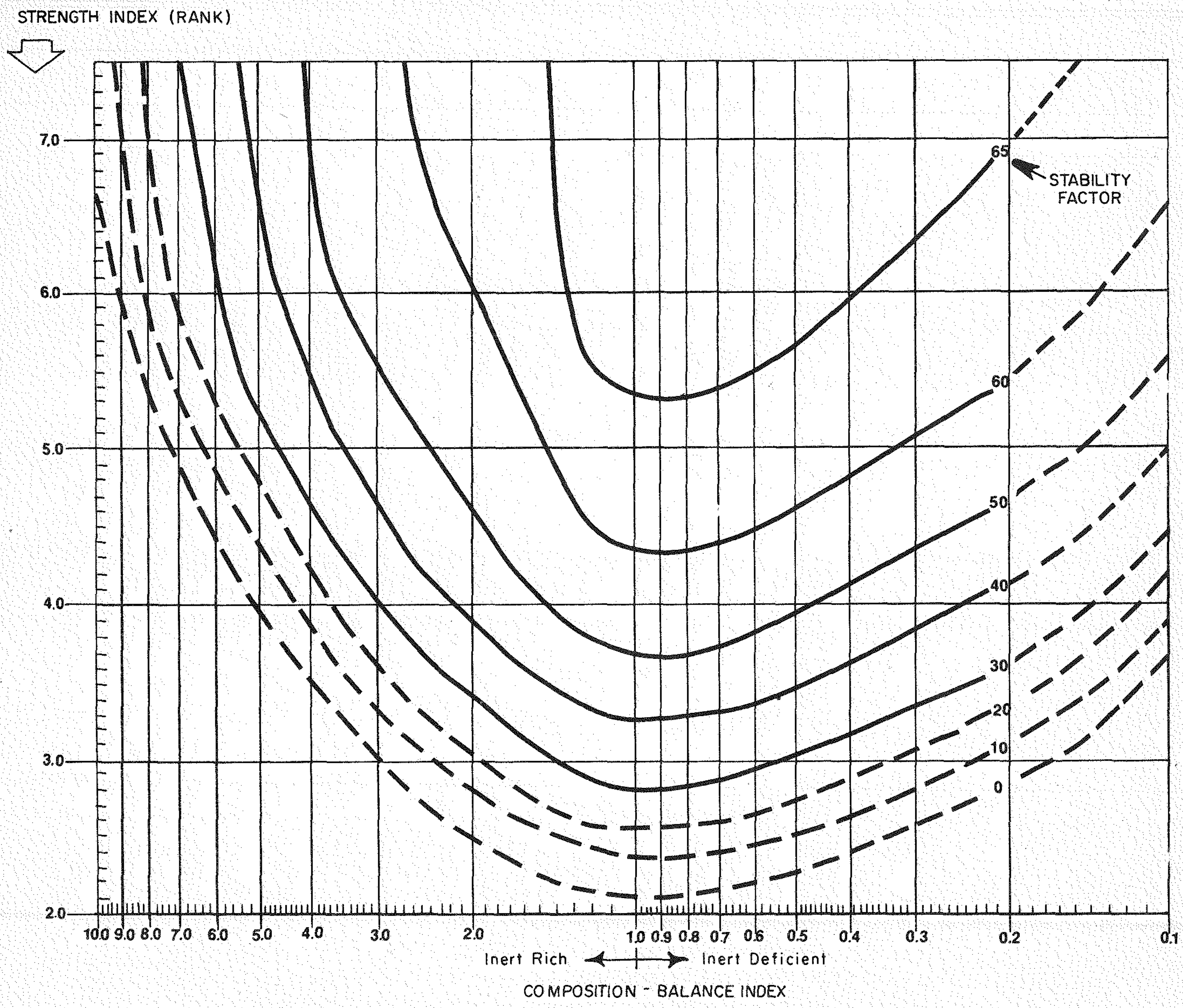


Figure 12. Correlation curves relating coal petrographic composition to ASTM stability indices (after Schapiro and others, 1961; Schapiro and Gray, 1964).

Table 13. Petrographic data for Colorado coals (adopted from Jansen, 1978). [All data are volume percentages except R_o, mean maximum reflectance]

Coal Sample Location	vitrinite	exinite	resinite	semifusinite	fusinite	micrinite	mineral matter	percent R_o
Marr Strip Mine North Park Region	85.3	6.2	2.4	0.7	0.7	1.8	2.8	0.53
Deep Creek Routt County	68.8	8.7	1.9	5.4	3.3	5.4	6.5	0.60
Denton Strip Mine Routt County	73.6	6.0	2.6	4.2	3.5	4.7	5.4	0.63

Table 14. Petrographic data and stability index predictions (petrographic data adopted from the Pennsylvania State University/DOE Coal Bank Printout, 1978).

Coal Sample Location	Point Number	vitrinite vol. %	inertinite vol. %	liptinite vol. %	semifusinite vol. %	mineral matter vol. %	vitrinite types percent	stability index
Dutch Creek Mine Sec. 17, T10S, R89W	1	88.5	7.1	0.1	0.5	3.8	V12-1.0;V13-16.8;V14-72.3;V15-9.9	>65
	2	88.1	5.5	0.0	1.9	4.5	V13-11.2;V14-57.9;V15-30.0;V16-0.9	>65
	3	88.3	3.5	0.0	2.3	5.9	V13-61.1;V14-38.9	>65
Crested Butte #2 Mine Sec. 3, T14S, R86W	4	79.6	7.8	6.0	3.5	3.1	V6-14.0;V7-64.0;V8-22.0	4
Somerset Mine Sec. 8, T14S, R90,91W	5	83.0	7.1	3.2	2.4	4.4	V5-0.8;V6-51.8;V7-47.3	20
Hawks Nest Mine Sec. 11, T13S, R90W	6	89.4	3.1	1.2	4.3	2.0	V5-3.6;V6-69.4;V7-26.5;V8-0.4	19
Old Victory Mine (now Coal Gulch Mine) Sec. 15,16,20,22, T35N, R10W	7	70.1	20.6	2.8	3.7	2.8	V6-6.7;V7-30.0;V8-60.0; V9-3.3	32

Table 15. Analytical data for Colorado coals (from the Pennsylvania State University/DOE Coal Data Bank Printout, 1978).

Coal Sample Location	Point Number	Moisture AR	Ash AR	VM AR	FC AR	Sulfur AR	BTU AR	FSI	Comments
Dutch Creek Mine Sec. 17, T10S, R89W	1	1.41	6.63	24.49	67.47	0.55	14,484	-	Prep. Plant Sample
	2	0.70	7.96	22.70	68.64	0.49	14,521	-	Working Section
	3	0.95	9.85	23.85	65.35	1.34	13,977	9.0	Working Section
Crested Butte #2 Mine Sec. 3, T14S, R86W	4	2.69	5.31	38.21	53.79	0.47	13,326	-	Grab, Mine Dump
Somerset Mine Sec. 8, T14S, R90,91W	5	3.87	7.35	39.50	49.28	0.65	12,739	-	Working Section
Hawks Nest Mine Sec. 11, T13S, R90W	6	4.33	3.29	38.11	54.27	0.57	13,251	3.5	Working Section
Old Victory Mine (now Coal Gulch Mine) Sec. 15,16,20,22, T35N, R10W	7	2.10	4.64	38.65	54.61	1.02	13,774	-	Grab, Crushed Coal

To aid in rapid assessment of the blending possibilities of Colorado coals, all of the previously mentioned stability indices are plotted on Figure 15. Figure 16 is included in order that an evaluation of the blending possibilities may be made. Empirically determined variations in coke properties are functions of changes in the petrographic content of the coal blends used to make the coke. Figure 17 illustrates some of the variations of coke properties superimposed on the stability index graph.

Although additional petrographic analyses exist for Colorado coal samples, they cannot be applied to the determination of petrographic stability indices. These petrographic data were obtained for use in solving detailed geological problems and are not applicable to the prediction of stability indices. For example, Toenges and his associates (1949, 1952) presented detailed petrographic analyses for coal core samples obtained from the Somerset coal field in Gunnison County. However, the petrographic method used in this study was the thin section transmitted light method, which cannot be correlated with the reflected light method used to determine stability indices (Harrison, 1962; Berry and others, 1967).

More recently, Dutcher and his associates have employed coal petrography in studies of contact metamorphism and coal property variations (Dutcher and others, 1966; Crelling and Dutcher, 1968; Podwipocki and Dutcher, 1971). In his studies of

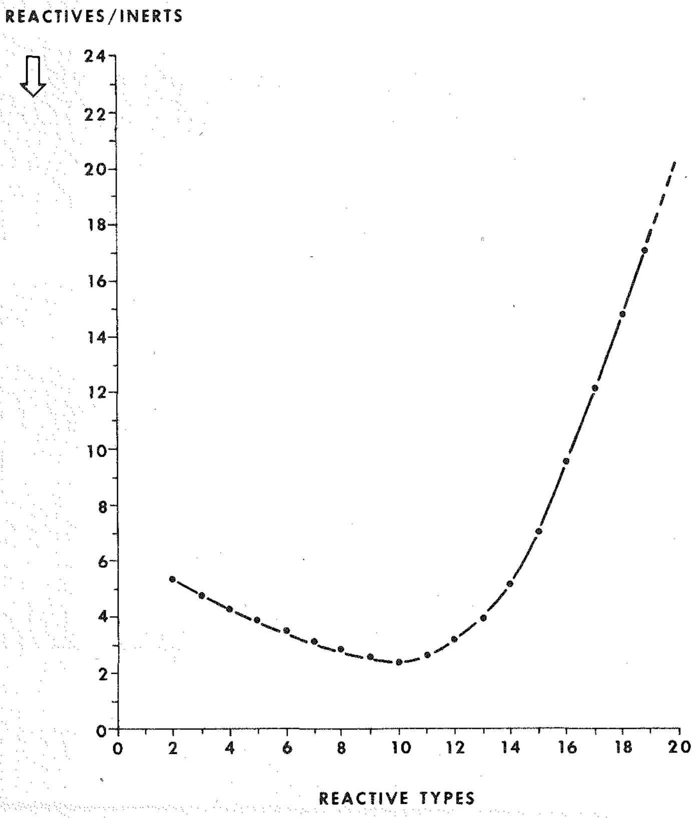


Figure 13. Optimum inerts chart used to obtain the optimum ratio of reactive to inert components for reactive maceral types (after Schapiro and others, 1961; Schaprio and Gray, 1964).

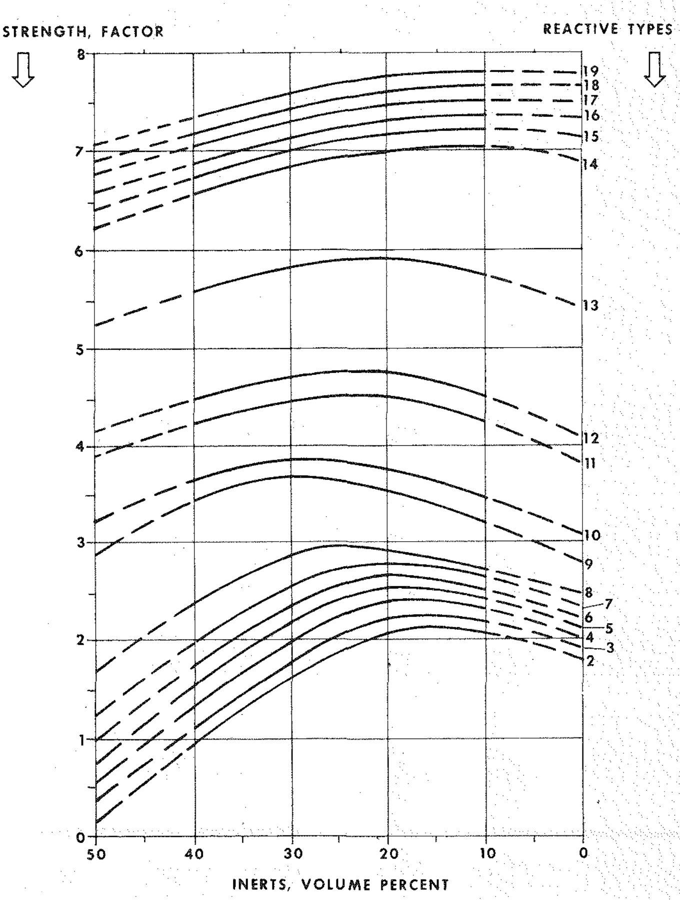


Figure 14. Volume inerts strength chart (after Schapiro and others, 1961; Schapirio and Gray, 1964).

Cretaceous coals in the Uinta region of Colorado, Collins (1970, 1975, 1976, 1977) also utilized coal petrography to a limited extent. Although the petrographic data presented in these studies are instrumental in solving geological problems, insufficient data are furnished to establish coke stability indices for the coals studied.

The petrographic stability indices presented herein are included to form a basis for coal exploration and evaluation programs. Any commercial utilization of the coals used as examples should be preceded by independent testing and evaluation. The Colorado Geological Survey cannot take responsibility for the improper use of data included in this report.

Colorado Geological Survey Classification

The classification system used in our research to evaluate Colorado coking coals is depicted on Table 16. The system utilizes ash and sulfur content, as proposed by William S. Sanner, Sr., in conjunction with ASTM coal rank designations. Listed below are factors that influenced the decision to use this very general classification system:

1) Further subdivision of the coal groups can rapidly lead to discrepancies, as indicated in the discussion concerning Jones and Murray's (1978) coal classification system.

2) Although other classification systems, such as coal petrographic methods or the Ruhr dilatometer method, can yield more reliable results, they cannot be applied to an evaluation of Colorado's coal resources because of the limited nature of the data pertaining to these systems. In contrast, a broad historical data base exists and can can be utilized for the proposed classification system.

Table 16. Coking-coal classification system used to evaluate coal resources in Colorado.

COKING-COAL GRADE	ASTM COAL RANK (BITUMINOUS) LOW-VOLATILE	 MEDIUM-VOLATILE	 HIGH-VOLATILE A	 HIGH-VOLATILE B	SULFUR =	ASH =	COKING-COAL "DESIRABILITY"
PREMIUM	PREMIUM GRADE LOW-VOLATILE BITUMINOUS COKING COAL	PREMIUM GRADE MEDIUM-VOLATILE BITUMINOUS COKING COAL	PREMIUM GRADE HIGH-VOLATILE A BITUMINOUS COKING COAL	PREMIUM GRADE HIGH-VOLATILE B BITUMINOUS COKING COAL	0-1.0%	0-8.0%	GREATEST
MARGINAL	MARGINAL GRADE LOW-VOLATILE BITUMINOUS COKING COAL	MARGINAL GRADE MEDIUM-VOLATILE BITUMINOUS COKING COAL	MARGINAL GRADE HIGH-VOLATILE A BITUMINOUS COKING COAL	MARGINAL GRADE HIGH-VOLATILE B BITUMINOUS COKING COAL	1.1-1.8%	8.0-12.0%	↕
LATENT	LATENT GRADE LOW-VOLATILE BITUMINOUS COKING COAL	LATENT GRADE MEDIUM-VOLATILE BITUMINOUS COKING COAL	LATENT GRADE HIGH-VOLATILE A BITUMINOUS COKING COAL	LATENT GRADE HIGH-VOLATILE B BITUMINOUS COKING COAL	1.9-3.0%	12.1-15.0%	LEAST
COKING-COAL "DESIRABILITY"	GREATEST ←			→ LEAST			

3) The classification system is specific enough to fulfill the objectives of this coal resource evaluation.

Coking-coal grades, as used in this classification system, are determined using as-received sulfur and ash contents on a dry basis. Coal sulfur and ash contents can sometimes be reduced significantly through various washing or cleaning processes. Therefore, it may be possible to shift some latent or marginal grade coals into the premium or marginal grade groups through the use of coal washing techniques (Sanner and Benson, 1979). Deurbrouck (1970) conducted washability studies with Colorado coals and concluded that all of the coals studied can be readily washed to desirable ash levels. However, to avoid confusion, in the present report all coking-coal grades are determined using analyses of uncleaned or unwashed coals.

This classification system, in conjunction with several additional general constraints, was used by the authors to evalute coking-coal resources in Colorado. The additional constraints include considerations of the general requirements of coke oven feedstocks, currently producing

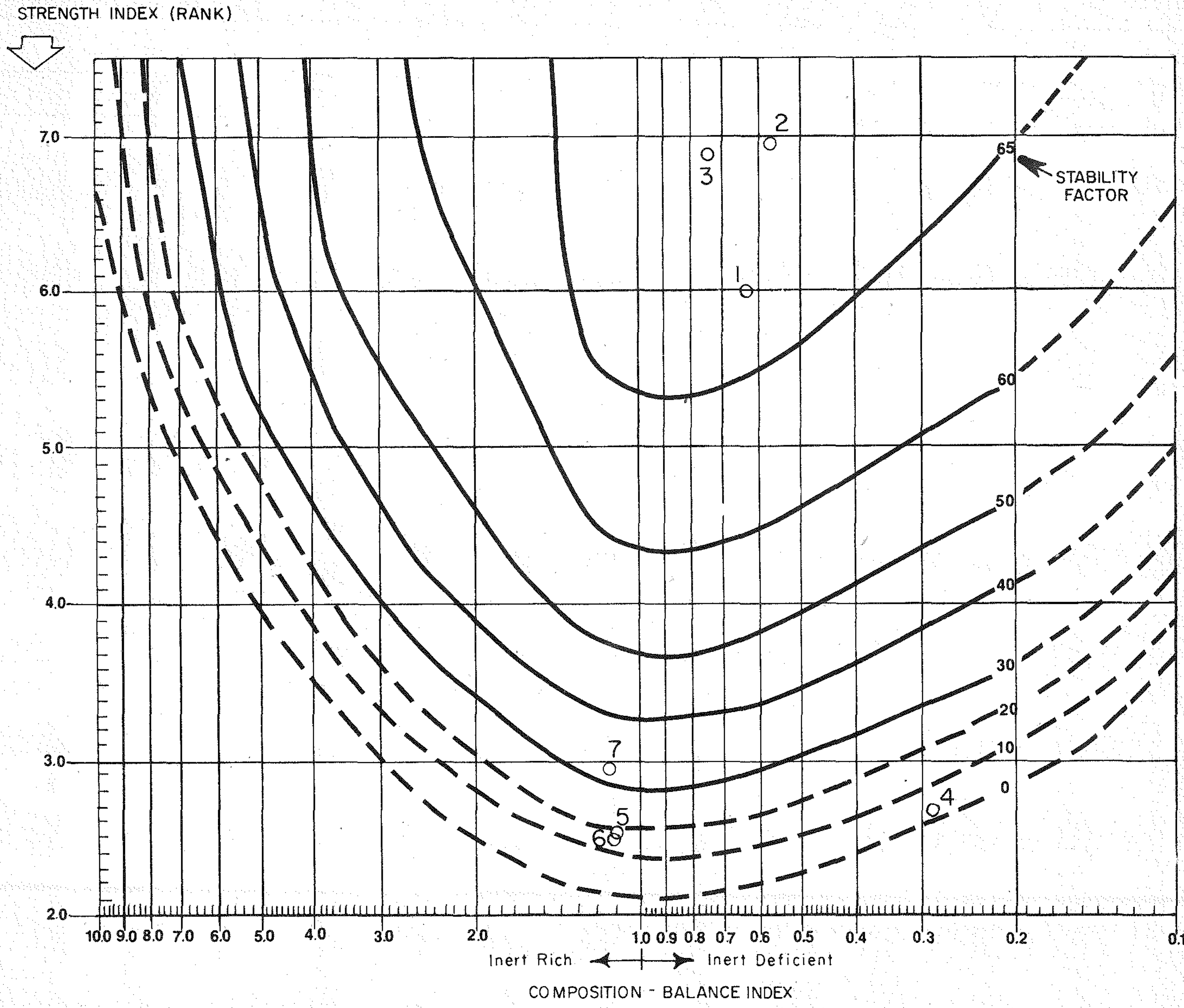


Figure 15. Strength index vs. composition-balance index for Colorado coals. Point numbers correspond to the point numbers listed in Table 13.

coking-coal areas, and areas of former coking coal production. Utilizing these additional parameters, three of the eight coal regions of Colorado were selected for detailed evaluations. Additional areas (for example, the Green River region) contain coals ranging in rank from subbituminous B to anthracite for which there are historic references to coking quality coals. However, these areas were deleted from detailed coking-coal evaluation after research indicated that the mines that produced the coking coals were located in areas affected by intrusive dikes and sills. Coal rank generally increases rapidly as an igneous dike or sill is approached in a mine because of the effects of heat from the intrusive igneous body. Such a mine may produce coal varying in rank from subbituminous to anthracite. Because coal uniformity is a major general requirement of coke oven feedstock, coal from a mine affected by dikes or sills generally cannot be used in modern coke ovens. Hence the deletion of the Green River region as a potential coking-coal resource area.

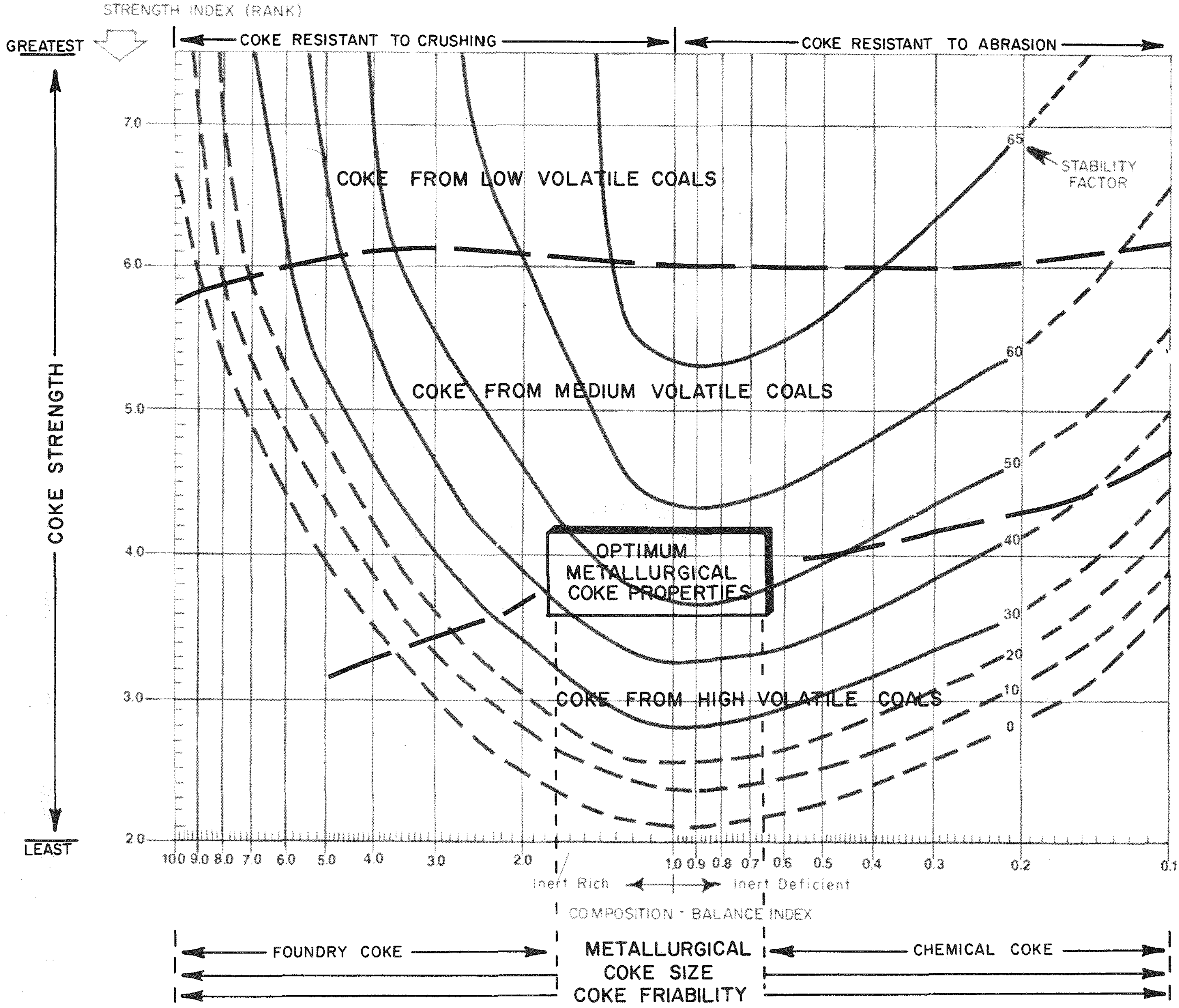


Figure 16. Optimum petrographic composition for metallurgical, foundry, and chemical coke oven feedstocks (after Schapiro and others, 1961; Schapiro and Gray, 1964; Moses, 1976).

Detailed evaluations were conducted to determine the potential for coking coal resources in the following coal regions and involved counties (Fig. 18):

1. Raton Mesa Coal region
    - Las Animas County
    - Huerfano County
2. San Juan River Coal region
    - Archuleta County
    - La Plata County
    - Montezuma County
    - Dolores County
    - San Miguel County
    - Montrose County
    - Delta County
    - Mesa County
3. Uinta Coal region
    - Mesa County
    - Delta County
    - Gunnison County
    - Garfield County
    - Rio Blanco County
    - Pitkin County

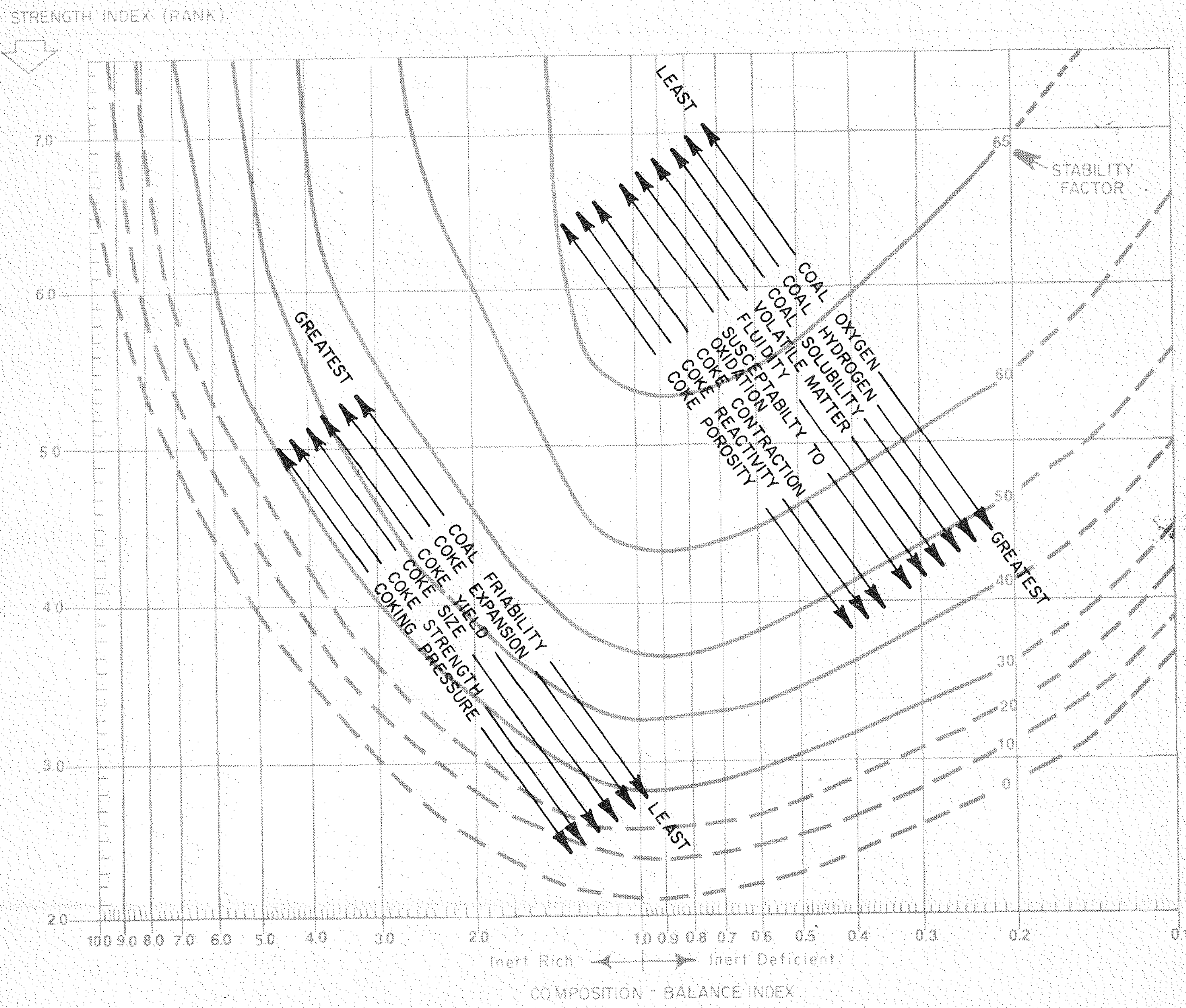


Figure 17. Coke property variations as a function of coal petrographic variations (after Schapiro and others, 1961; Schapiro and Gray, 1964; Berry, 1978).

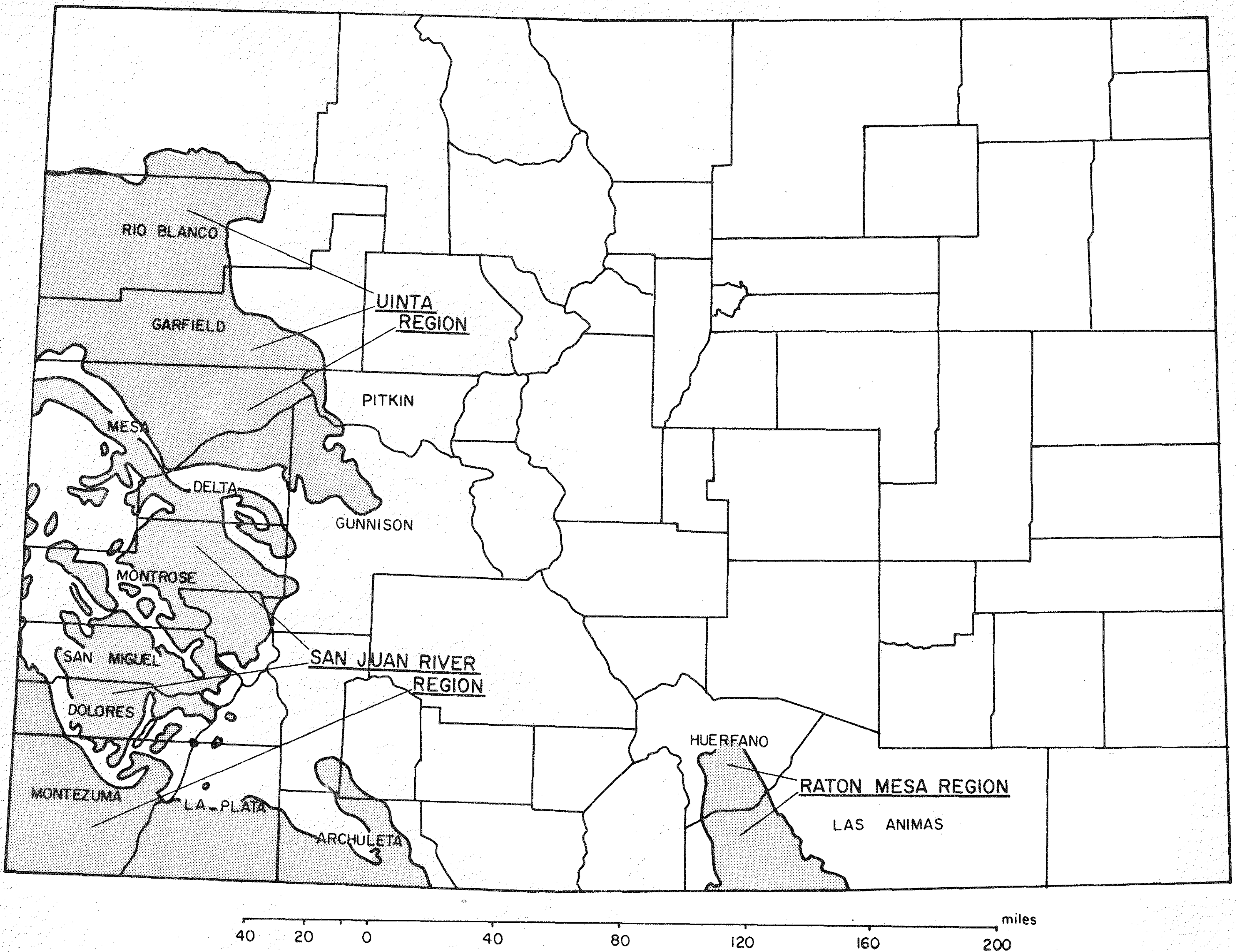


Figure 18. Index map of coal regions and counties in Colorado, for which detailed coking-coal evaluations were conducted.

GEOLOGICAL CONSIDERATIONS

All coal deposits have been influenced by various geological processes that can directly govern the feasibility of using a particular coal as coke oven feedstock. These geological processes are initiated with the deposition of the original plant material, continue with the coalification and diagenesis of that material, and end with geological considerations for mining the coal. This section of the report will present a brief, general discussion concerning the geological factors that may have influenced Colorado coking coals.

GEOLOGIC AGE

Coal resources in the western United States were deposited during the Cretaceous and Tertiary Periods (95 to 50 million years before the present). During the Cretaceous Period, coal swamps developed along the western margin of a shallow, epicontinental seaway (Fig. 19). In contrast to those in the Cretaceous, Tertiary coal swamps generally developed within intermontane basins. Depositional conditions tended to remain relatively stable for long periods of time within these intermontane basins, resulting in coal beds of as much as 250 ft in thickness (Obernyer, 1978). Normal coal bed thicknesses in the marine-influenced Cretaceous sequence are approximately 10 ft, although somewhat thicker beds occur locally. In Colorado, most of the resources of coking coal were deposited during the Cretaceous Period. The only exception to this are coals in the *Raton Formation*, which were deposited during Late Cretaceous and Paleocene times. The following discussion, therefore, deals primarily with coal resources deposited during the Cretaceous Period.

COAL GENESIS

Weimer (1977) has discussed the principal factors that influence the formation of commercial coal deposits in the western United States. The constraints are listed below:

1. Peat accumulation in predominantly clear, fresh-water environments. Muddy water accumulation sites can result in high ash contents in the coal.
2. The accumulation of land-derived plant material.
3. A balance must exist between the depositional interface and the groundwater table as the plant remains are deposited. If the organic matter is exposed to the atmosphere during its deposition, it will become oxidized, and little or no peat will accumulate. A A lake or bay will develop if the groundwater table is too high. Therefore, water must continually cover the organic debris but not become deep enough for open circulation if peat is to accumulate.
4. A favorable climate must exist for high rates of plant growth. Research indicates that a sub-tropical to tropical climate existed during Cretaceous time in Colorado.
5. The foregoing considerations must be persistent over long periods of time and over broad areas for thick commercial coals to develop.

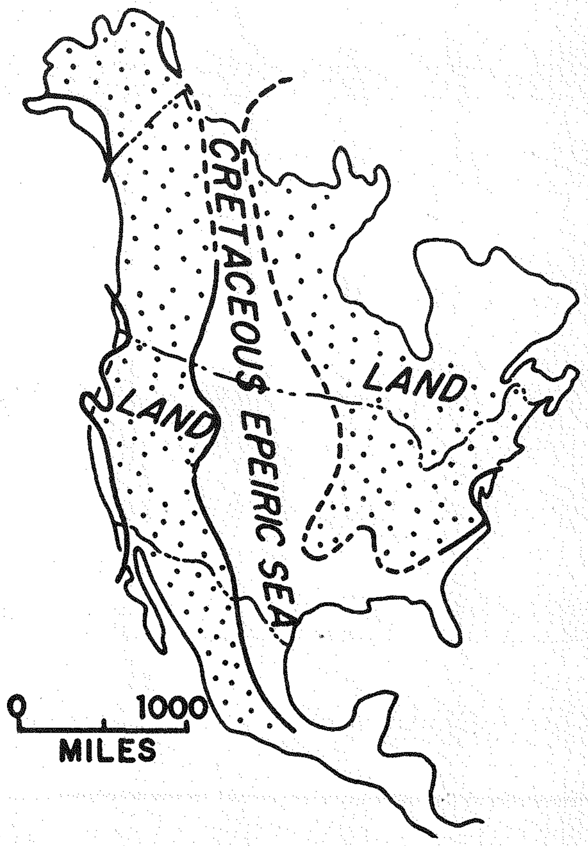
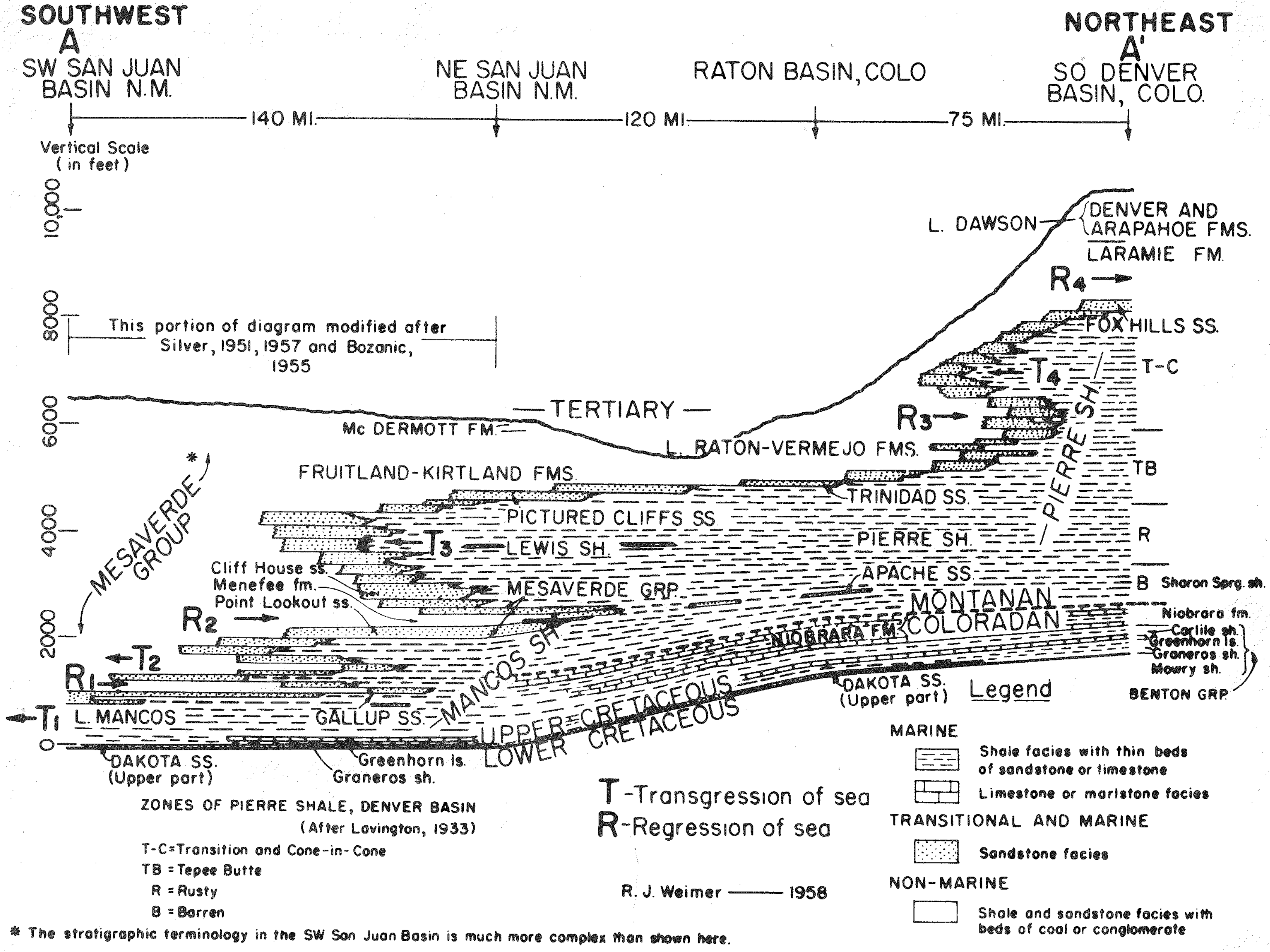


Figure 19. Map of the depositional basin for Cretaceous marine beds in North America (after Weimer, 1977).



ZONES OF PIERRE SHALE, DENVER BASIN (After Lavington, 1933)

T-C = Transition and Cone-in-Cone
TB = Tepee Butte
R = Rusty
B = Barren

* The stratigraphic terminology in the SW San Juan Basin is much more complex than shown here.

Figure 20. Restored stratigraphic section across the western portion of the Cretaceous depositional basin, showing transgressive-regressive and coal-bearing facies (after Weimer,1977).

Weimer concludes that these basic parameters may be modified by tectonic influences on sedimentation rates. This influence is illustrated by the transgressive and regressive cycles depicted in Figure 20. When the rate of subsidence in a depositional basin exceeds the rate of sedimentation, a marine transgression occurs and the shoreline is inundated by the sea. If the rate of sedimentation exceeds the subsidence rate, a progradation (i.e., a regression) of the shoreline into the depositional basin occurs.

DEPOSITIONAL ENVIRONMENTS

A large number of depositional models have been developed for sedimentary systems similar to those found in the Cretaceous of the western United States. Using these depositional models in conjunction with the foregoing basic constraints, areas of potential commercial-quality coking coal may be isolated for more detailed evaluation.

Recent research has determined that many coal deposits are heavily influenced by their original depositional setting. Cretaceous coals in Colorado are usually depicted as being associated with five primary depositional settings. These settings are transitional with each other and are interacting systems. Depositional models depicting some or all of these environmental settings, as listed below, can be found in Collins (1976, 1977), Caruccio and others (1977), Weimer (1977), Donaldson (1978), Horne and others (1978), and Siemers (1978). The primary depositional settings are as follows:

1. Alluvial Plain
2. Upper Delta Plain
3. Lower Delta Plain
4. Barrier Island
5. Interdeltaic Embayment

Coal may be deposited in several major environments of deposition in these primary settings. Weimer (1977) has discussed the environments of deposition most commonly associated with Western Cretaceous and Tertiary coal deposits. The major _in situ_ depositional environments of alluvial and delta systems, as listed by Weimer, include (1) channel margin environments (back levee and flood basin swamps), (2) channel fill swamps, and (3) coastal swamps or marshes. He further states that channel margin peat swamps form the most important commercial coals in the West.

Basic considerations for the foregoing coal depositional parameters can aid in the evaluation of potential coking-coal resources, both on a regional and local basis. Variations in coking-coal properties that may be attributed to these depositional considerations include the ash, sulfur, and trace element content of the coal, as well as the thickness, geometry, and geographic distribution of the coal deposits. Depositional conditions also influence roof and floor lithologies and stabilities in coal mines (Horne and others, 1978).

SULFUR OCCURRENCE

Research emphasizing an understanding of the sulfur content of coal has increased recently, both because of environmental problems associated with sulfur, and because of the detrimental effects of sulfur in various coal utilization processes. This work has established that sulfur occurs in coal in four forms: (1) elemental sulfur, (2) sulfate sulfur, (3) organic sulfur, and (4) pyritic sulfur. The presence of elemental sulfur in coal is controversial and, if it does occur, is rare (Rees, 1966, p. 33). Sulfate sulfur is a secondary weathering product and is relatively minor in importance unless the coal has been heavily weathered. Organic sulfur is indigenous in the original plant material from which the coal was derived; it cannot be easily removed from coal, as demonstrated by Deurbrouck (1970). Therefore, it is usually the pyritic sulfur content of a coal that determines the commercial feasibility of mining.

Pyritic sulfur occurs in coal as euhedral grains, as coarse-grained masses that replaced original plant material, as coarse-grained platy masses in joints, and as framboidal pyrite (Caruccio and others, 1977; Horne, Ferm, and others, 1978; Horne, Howell, and others, 1978). Research has shown that the coarse grained masses of pyrite may be removed from the coal commercially by mechanical washing processes. However, the fine grained disseminated pyrite (i.e., framboidal pyrite) cannot be removed from coal commercially at the present time (Walker and Harnter, 1966). Furthermore, it is the framboidal pyrite that has the greatest detrimental effect on the environment (Caruccio and others, 1977).

Discussions dealing with the possible origins of framboidal pyrite may be found in Love and Amstutz (1966), Hemingway (1968), Rickard (1970), and Caruccio and others (1977). Although more than one origin of framboids is probable (Richard, 1970), their occurrence in coal is usually attributed to sulfur reduction by bacterial action (Cohen and others, 1971). Many workers have shown that sulfur-reducing bacteria have usually been associated with marine and/or brackish water depositional environments during the formation of ancient coal swamps (Williams and Keith, 1963; Love and Amstutz, 1966; Guber, 1972; Caruccio and others, 1977; Horne, Ferm, and others, 1978; Horne, Howell, and others, 1978). Coal deposits with low framboidal pyrite contents would be expected to have been deposited in alluvial plain and upper delta plain depositional settings, away from the influence of marine or brackish waters.

Although the foregoing discussion illustrates the feasibility of using depositional models to determine areas of potential coking-coal deposits, this particular sulfur occurrence model has only limited application in the Rocky Mountain region. The sulfur distribution data presented in Walker and Hartner (1966) reveal that the largest percentage of total sulfur in Colorado coals occurs as organic sulfur. The relative deficiency of pyritic sulfur in Cretaceous coals in Colorado may be attributed to a restricted influence by marine and brackish waters during peat depositon. For example, low tidal ranges may have restricted brackish water swamps to limited coastal areas. However, other factors may explain the deficiency, and little data are available on the distribution of framboidal pyrite in Colorado coals. Additional research will be necessary to determine the reason for anomalously low pyritic sulfur contents in Western coals.

COALIFICATION

After the deposition of the original plant material in a swamp, the coalification process becomes a major factor in the evaluation of coking-coal resources. Coalification is the development from peat through the various stages of lignite, subbituminous, and bituminous rank coals, to anthracite and meta-anthracite (Stach and others, 1975). Traditionally, the coalification process has been attributed to the effects of time, heat, and pressure on the original plant material. Research has demonstrated that pressure has a physical effect upon the plant material. It is the effects of heat and time that cause the chemical changes that result in the progressive rank changes of the material (Teichmuller and Teichmuller, 1966, 1968; Stach and others, 1975).

Geothermal energy normally is considered to be the source of heat that causes progressive changes in coal rank. Because the geothermal gradient typically increases with depth, coal rank also generally increases with depth of burial. The relationship between coal rank and burial depth is shown on Plate 2, Map 2 of this report. The map depicts an increase in coal rank to medium-volatile bituminous as the deeper parts of the San Juan basin are approached. Val L. Freeman, of the U.S. Geological Survey (Freeman, 1979), also has found this general relationship in the Uinta region, Colorado, where coals of semianthracite rank are found in the deeper parts of the basin.

There are, however, important exceptions to this general relationship between coal burial depth, coal rank, and the geothermal gradient. Heat from igneous activity or abnormalities in the "normal" geothermal gradient may also cause local increases in coal rank. These local rank increases may either be detrimental or beneficial to the utilization of the affected coal as coke oven feedstock.

In certain areas in Colorado, igneous dikes and sills have detrimentally affected the quality of the coal. Major sills and dikes found in the coking-coal regions in Colorado are depicted o[illegible] each map on Plates 1, 2, and 3. The dikes a[illegible] sills shown on the maps either have completely destroyed the coal bed they intrude, or they have altered the properties of the coal bed within close proximity to the igneous body. Dutcher and others (1966), Crelling and Dutcher (1968), and Podwysocki and Dutcher (1971) have given detailed evaluations of the effects of dikes and sills on coal deposits in Colorado. Their investigations indicate that the properties of intruded coal deposits are increasingly affected as the igneous body is approached. Because coal uniformity is of major importance to coke producers, coal found in close proximity to igneous dikes and sills generally cannot be used as coke oven feedstock. Figures 21 and 22 illustrate the typical effects of igneous dikes on coal beds in Colorado.

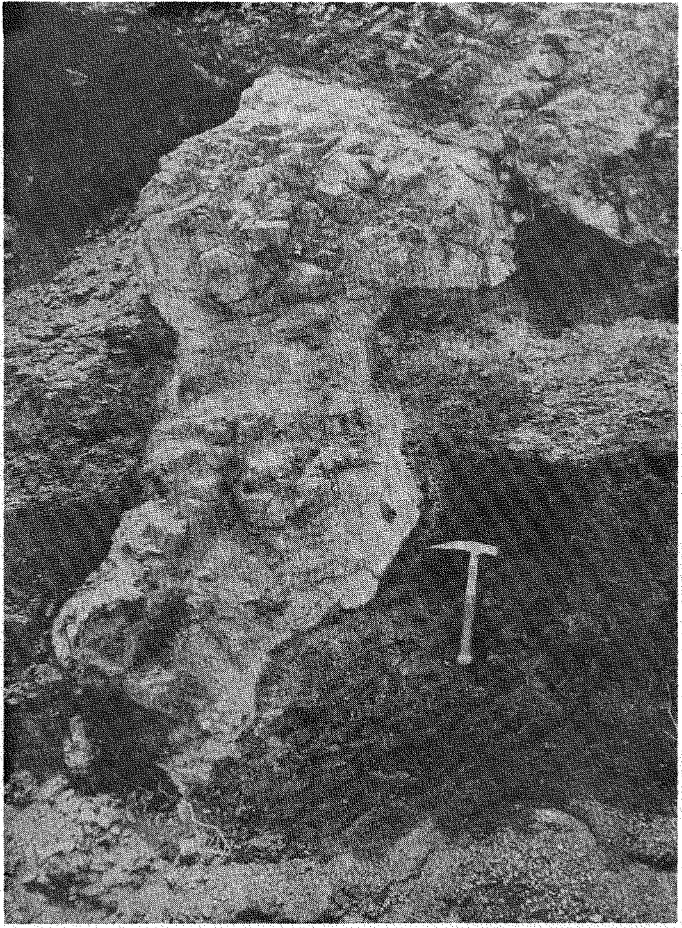


Figure 21. Intrusive igneous dike located in a railroad cut through the Raton Formation near Trinidad, Colorado. A thin layer of natural coke appears as jointed prisms at the tip of the rock hammer.

However, beneficial effects may be gained as a result of the intrusion of large igneous bodies into coal-bearing regions. In those regions in which large igneous bodies have intruded coal-bearing strata, extensive areas may have been heated, and higher average coal rank may have resulted. The metallurgical quality medium-volatile bituminous coal mined in Pitkin County represents a local area in which a large intrusive igneous body is thought to have beneficially upgraded the rank of the coal (Collins, 1975, 1976, 1977).

Igneous bodies associated with the coking-coal regions of Colorado are depicted on each map on Plates 1, 2, and 3. Close inspection of these maps shows that the Crested Butte coal field in the Uinta region (Plate 3) has been particularly influenced by igneous intrusions. In this field, coal rank varies considerably because of igneous intrusions; therefore, an evaluation of the coal in this area is difficult (Plate 3, Map 2). Additional discussions concerning the effects of large igneous bodies on Colorado coal deposits may be found in Dapples (1939), Johnson (1952, 1976), and Johnson and others (1963).

Abnormally high heat flow can also locally and beneficially raise coal rank. Abnormalities in the geothermal gradient are usually associated with some type of igneous activity. For example, a deeply buried large igneous intrusion may contribute additional heat energy to the regional heatflow gradient, causing a local geothermal anomaly. If this abnormal heat flow continues for a significant period of time, coal rank may be locally increased. The Coal Basin area in Pitkin County is a good example of a local abnormally high heat-flow causing increased coal rank.

Geothermal gradient anomalies are depicted on Map A, Plates 1, 2, and 3. Although these heat-flow isotherms are very general, they do illustrate the importance of geothermal considerations in evaluating coking-coal resources. Areas of increased coal rank may correspond to high heat-flow anomolies. For example, locally high coal rank tends to correspond to the high heat-flow area in the Raton Mesa region (Plate 1, Maps A and B). This model must, however, be used with some caution for several reasons. Although heat is an important consideration in the coalification process, time is another important factor that cannot easily be dealt with in this model. Also, other high heat flow areas, now dormant, may have existed in the coking-coal regions. However, detailed geothermal research, conducted in conjunction with detailed gravity and magnetic surveys, can be an important aid in the local evaluation of coal resources.

ADDITIONAL GEOLOGICAL CONSIDERATIONS

Additional general geological considerations are applicable to an evaluation of coking-coal resources. For example, Johnson (1952, 1953) has discussed the impact of circulating groundwater on Western coking coal. Structural problems caused by faulting, jointing, or folding may also be important geological considerations in coal resource evaluations.

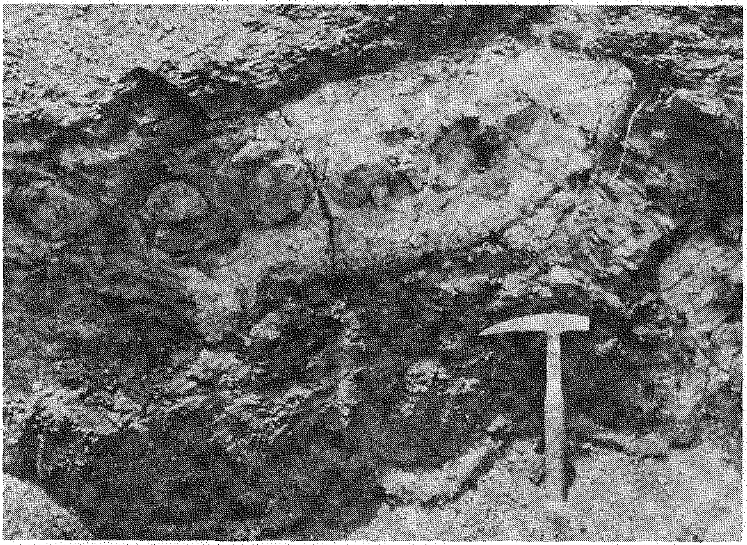


Figure 22. Intrusive igneous dike in the Raton Formation near Trinidad, Colorado. Note the layer of natural coke above the rock hammer.

REGIONAL EVALUATIONS

As previously stated, three coal regions in Colorado contain coking-coal deposits of potential economic value (Fig. 18). These three regions, the Raton Mesa, San Juan River, and Uinta, were selected for detailed evaluation and reserve estimates. The basis for the selection was consideration of past and present coking coal production, and general geological and technological considerations of coke oven feedstocks. Our investigations indicate total identified original in-place coking-coal reserves in the three regions of approximately 4.3 billion short tons.

The coking-coal reserve estimates contained in this publication were derived through the use of several sources of data. Original tonnage figures were first taken from various U.S. Geological Survey publications, as noted in the descriptions of each region that follow. Reserve estimates were then obtained by modifying these tonnage figures in accordance with the currently accepted coal resource classification system of the U.S. Bureau of Mines and U.S. Geological Survey (U.S. Geological Survey, 1976). Under this classification system, bituminous coal reserves include those beds 28 in. or more in thickness that occur within 1000 ft of the surface. The estimates include measured, indicated, and inferred reserves. Using the coking-coal classification systems illustrated on Table 16, and the maps depicted on Plates 1, 2, and 3, these reserve estimates were then classified according to coal rank and coking-coal grade. In areas deficient in sample control, the reserve estimates were not given a coking-coal classification.

THE RATON MESA COAL REGION

The Raton Mesa coal region of Colorado encompasses an area of 1100 sq mi as defined by the lower contact of the coal-bearing Vermejo Formation within Las Animas and Huerfano Counties (Fig. 18; Plate 1). This region consists of an asymmetric, north-south trending syncline bounded by the Sangre de Cristo mountains on the west, the Apishipa arch on the north, and the Las Animas arch on the east (Fig. 23). Cretaceous-age sedimentary rocks have been intruded by Tertiary igneous bodies in the center of the basin, and by associated dikes and sills throughout the entire basin (Plate 1).

Coal-bearing formations, coal zones, and coal-bed stratigraphy in the Raton Mesa region are summarized on Figures 24 and 25 (after Boreck and Murray, 1979). Coal occurs in the Vermejo Formation of Upper Cretacous age and in the Raton Formation of Upper Cretaceous and Paleocene ages. In the Raton Mesa region, correlation of single coal beds over long distances is difficult because of their discontinuous nature. This difficulty in correlation has led to many discrepancies and much confusion in older descriptions of the region's coal resources. Correlations of coal "zones", therefore, is more applicable in this region than a correlation of individual beds. This principle is generally true for coal bed correlations in most of the coal regions in Colorado. Figure 24 illustrates two typical coal "zones" in the Vermejo Formation.

Previous geological work and coal resource evaluations for the Colorado portion of the Raton Mesa region have been summarized by Johnson (1961). Brief summations of the geology and coal resources of the region may also be found in Landis (1959), Johnson and others (1966), Hornbaker and others (1975), Amuedo and Bryson (1977), and Murray (1979). Averitt (1966) has briefly described the importance of the region's coking-coal resources.

Traditionally, the Raton Mesa region has been divided by many workers into two coal fields based upon general coal quality variations (Landis, 1959;

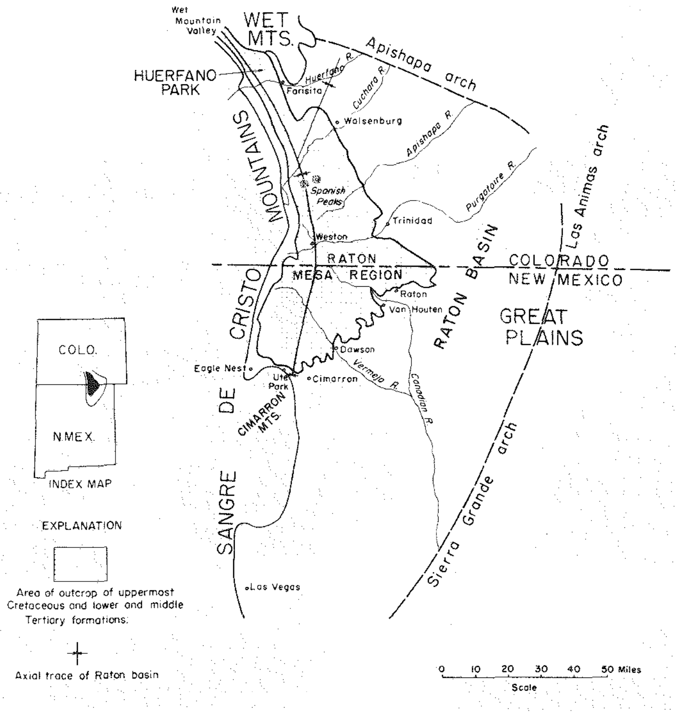


Figure 23. Structural map of the Raton Basin of New Mexico and Colorado (after Johnson and others, 1966).

Hornbaker and others, 1975; Amuedo and Bryson, 1977; Murray, 1979). The coal resources of the Trinidad coal field are usually of coking-quality, in contrast to the generally non-coking coal resources in the Walsenburg coal field to the north. The Huerfano-Las Animas County line generally serves as a convenient boundary between the two fields. However, research has indicated that coal production from some of the mines in the southern part of the Walsenburg field was used in the manufacture of coke (Boreck and Murray, 1979). A close examination of the coal quality parameters presented in Appendix Table 1 and Plate 1 demonstrates that a general and continuous increase in coal rank can be traced from the Walsenburg field southward to the Trinidad field. Caution should be exercised in using the county line as a convenient boundary between coking and non-coking resources.

Generally excellent coal quality and ready access to most of the area has made the Trinidad coal field one of the most important coking-coal areas in the West. Coal produced from both the Vermejo and Raton Formations serves as an excellent high-volatile bituminous blending coal for the production of coke. CF&I Steel Corporation has used coal from this field as the major source of blending coal for their coke ovens in Pueblo, Colorado. In the New Mexico portion of the Raton Mesa region, Kaiser Steel Corporation produces high-volatile bituminous blending coal for shipment to their mill in Fontana, California for the manufacture of coke.

A close examination of representative coal analysis (Plate 1, Maps B & C) indicates that the coal resources in the Raton Mesa region are predominantly marginal grade high-volatile A and B

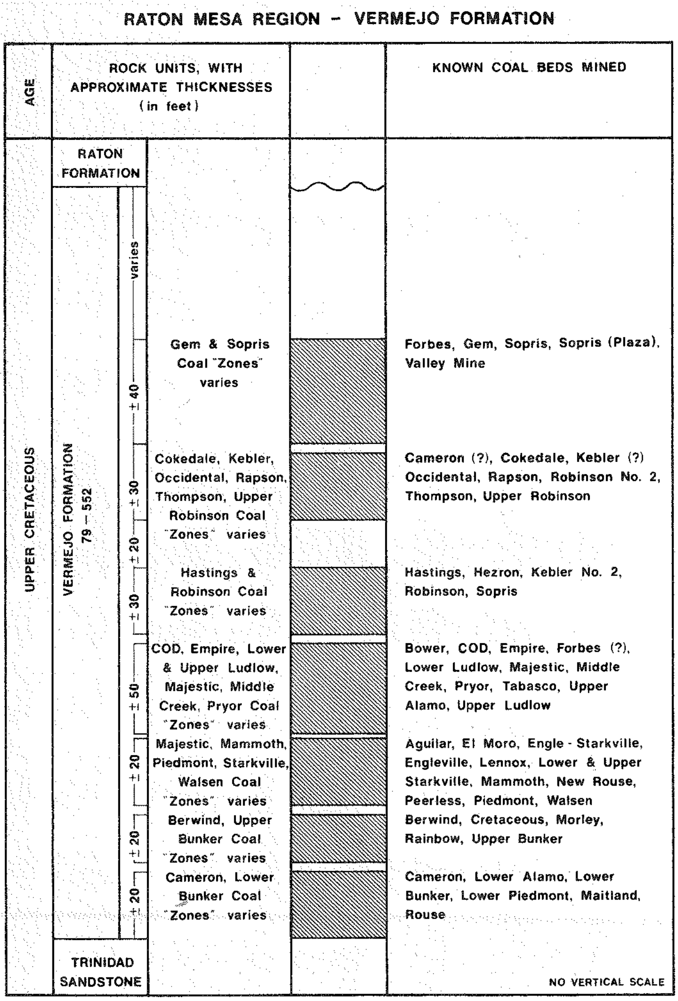


Figure 24. The stratigraphy of the coal-bearing Vermejo Formation in the Raton Mesa coal region, Colorado (from Boreck and Murray, 1979).

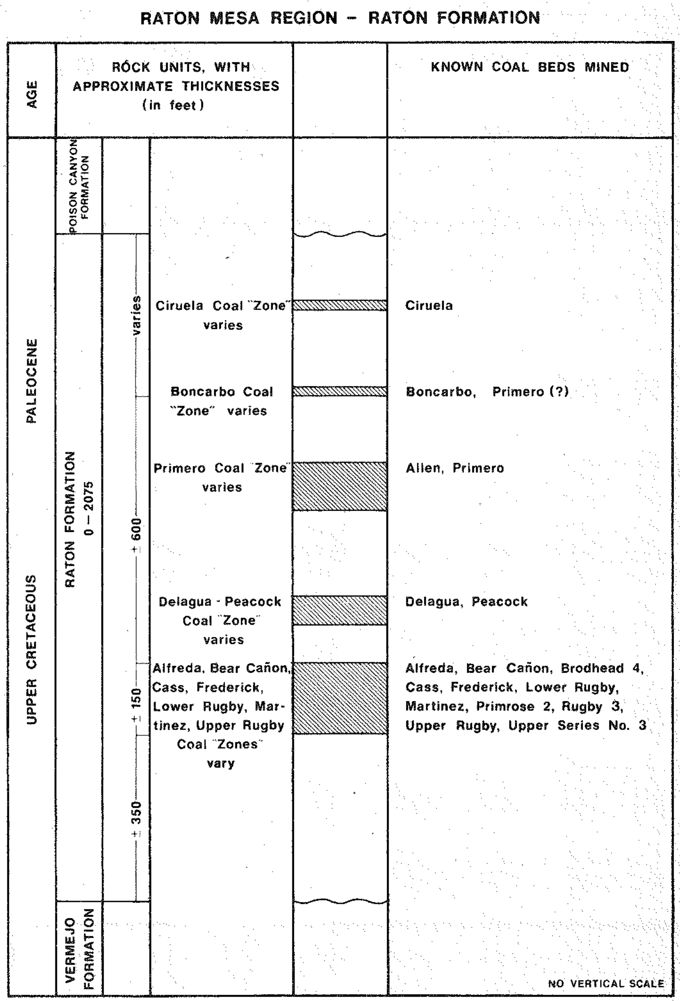


Figure 25. The stratigraphy of the coal-bearing Raton Formation in the Raton Mesa coal region, Colorado (from Boreck and Murray, 1979).

bituminous coking coals. Although the sulfur content of the coal is within the bounds imposed by a premium grade designation, the ash content consistently conforms to the limits imposed by a marginal grade designation (see Table 16). However, as previously stated, coal preparation processes (washing) can significantly lower the ash content and upgrade the coal to a premium grade coking coal.

Changes in the "desirability" of the coal resources for use as coke-oven feedstock can be attributed to variations in coal rank. Those resources occurring south of Township 28 South are high-volatile A bituminous in rank, with minor exceptions. Coals found north of Township 29 South are predominantly high-volatile B bituminous, with isolated areas of high-volatile C bituminous. Coal analysis data for deposits contained within the steeply dipping strata along the western margin of the basin are limited. However, this meager data base does indicate that high-volatile B and C bituminous coals occur in the northern portions of this area. No data could be found for coal deposits located in the deeply buried and unmined portions of the region.

Coal reserve estimates for the Colorado portion of the Raton Mesa region have been summarized by Johnson (1961). However, the method used to determine reserve estimates has been changed since 1961 (see U.S. Geological Survey, 1976). Using modifications imposed by this change, Johnson's reserve estimates, and the coking-coal classification presented on Table 16, reserve estimates were determined for the coking-coal resources in the region. The measured, indicated, and inferred coking-coal reserves for the Raton Mesa region are listed on Table 17.

Coal production during 1977 and 1978 from the Colorado portion of the Raton Mesa region is listed on Table 18. In those cases in which coal analysis data are available (Appendix Table 1), the coking-coal classification is also noted. Preliminary data indicate that CF&I Steel Corporation produced 582,003 short tons, or 88.7 percent of the total, during 1978. No data are available concerning the market for the rest of the region's production.

THE SAN JUAN RIVER COAL REGION

The San Juan River coal region, as defined in this report, encompasses that area in southwestern and west-central Colorado underlain by the coal-bearing Dakota Formation (Fig. 18; Plate 2). Large areas in the region, in west-central Colorado, are typified by relatively simple structure and by near-horizontal bedding in the Dakota Formation. However, the southern part of the region is dominated structurally by the San Juan basin, a large synclinal depression that extends well into New Mexico (Fassett, 1977). The coal-bearing formations located along the northern margin of the basin in Colorado dip as much as 40 degrees to the south, into the depression.

In the San Juan River region, coal deposits occur in three formations of Upper Cretaceous age. As previously defined, the entire region is underlain by the coal-bearing Dakota Formation. Significant areas in the southern portion of the region also are underlain by coal deposits in the Menefee Formation of the Mesaverde Group, and in the Fruitland Formation. The stratigraphy of the coal-bearing formations, coal beds, and coal zones is summarized on Figures 27, 28, 29, and 30 (after Boreck and Murray, 1979). General stratigraphic relationships for Cretaceous and Tertiary rocks in the San Juan basin, Colorado and New Mexico, are illustrated on Figure 31.

General discussions of the geology and coal resources in the Colorado portion of the San Juan River region are contained in Cullins and Bowers (1965), Shomaker and others (1971), Shomaker and Holt (1973), Amuedo and Ivey (1975), Hornbaker and others (1976), Johnson and others (1976), and Murray (1979). Coal reserve estimates for the region have been published in Wood and others (1948), Zapp (1949), Barnes (1953), Barnes and others (1954), Landis (1959), Wanek (1959), and Landis and Cones (1972). Shomaker and others (1971) and Speltz (1976) have specifically addressed the strippable coal resources of the region.

Figure 26. Photograph of the two lower coal "zones" mined in the Jewell Strip mine, sec. 21, T30S, R65W, Las Animas County, Colorado. Three coal "zones" in the Vermejo Formation have been mined at this location.

In the northern portions of the region, geological information concerning the Dakota Formation is notably meager. The Nucla-Naturita field is the only coal field in the region that contains coal deposits exclusively in the Dakota Formation. However, large areas of southwestern Colorado are underlain by minable coal deposits in the Dakota Formation (Landis, 1959, 1972; Speltz, 1976; Hornbaker and others, 1975; Murray, 1979). Boyer and Lee (1925) conducted detailed studies of the Dakota Formation in southwestern Colorado and eastern Utah. Additional work pertaining to the Nucla-Naturita field area has been published by Williams (1954), Speltz (1976), and Haines (1978). Studies of the stratigraphy and depositional environments of the Dakota Formation have been more extensive in the New Mexico portions of the San Juan basin (Beaumont and others, 1976; Molenaar, 1977; Fassett, 1977; Owen and Siemers, 1977; and Peterson and Kirk, 1977).

Coal deposits in the Dakota Formation are generally thin, lenticular, and high in ash content. Map D, Plate 2, illustrates the high ash content of the formation in the northern part of the region. Although analytical data for the coal deposits in this area are limited, the data base shown on this map indicates that the coal resources are predominantly marginal grade high-volatile B and C bituminous coking coals, at best. Although selective mining practices and coal washing could lower the sulfur and ash contents, Dakota Formation coal resources are probably better suited for electrical generation than for the production of coke. In local areas in the southern portion of the region, Dakota Formation coals attain the rank

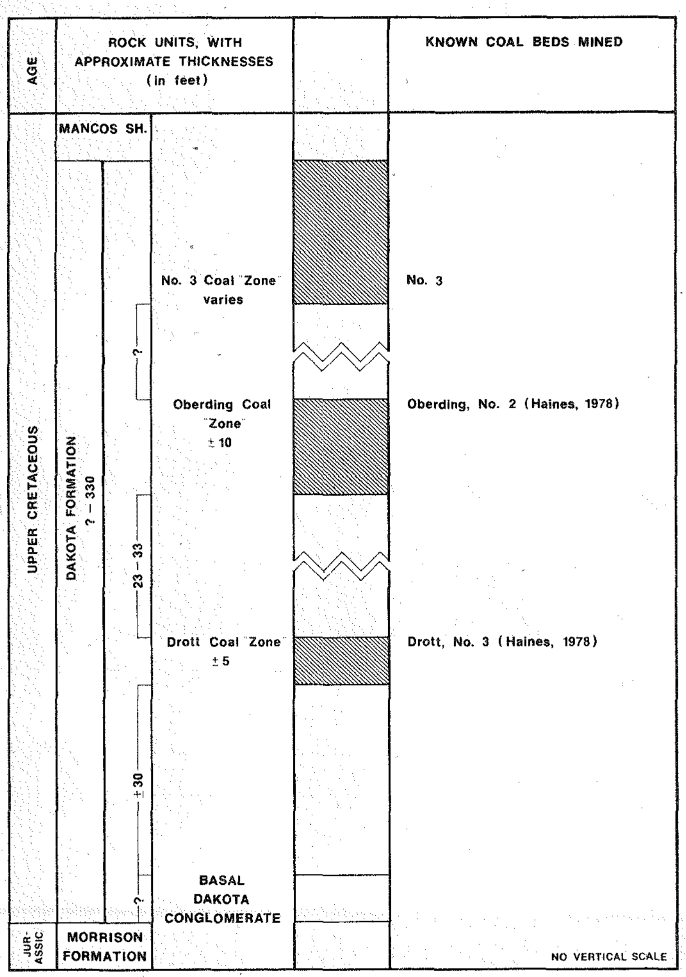


Figure 27. The stratigraphy of the Dakota Formation in the Nucla-Naturita field, San Juan River region, Colorado (from Boreck and Murray, 1979).

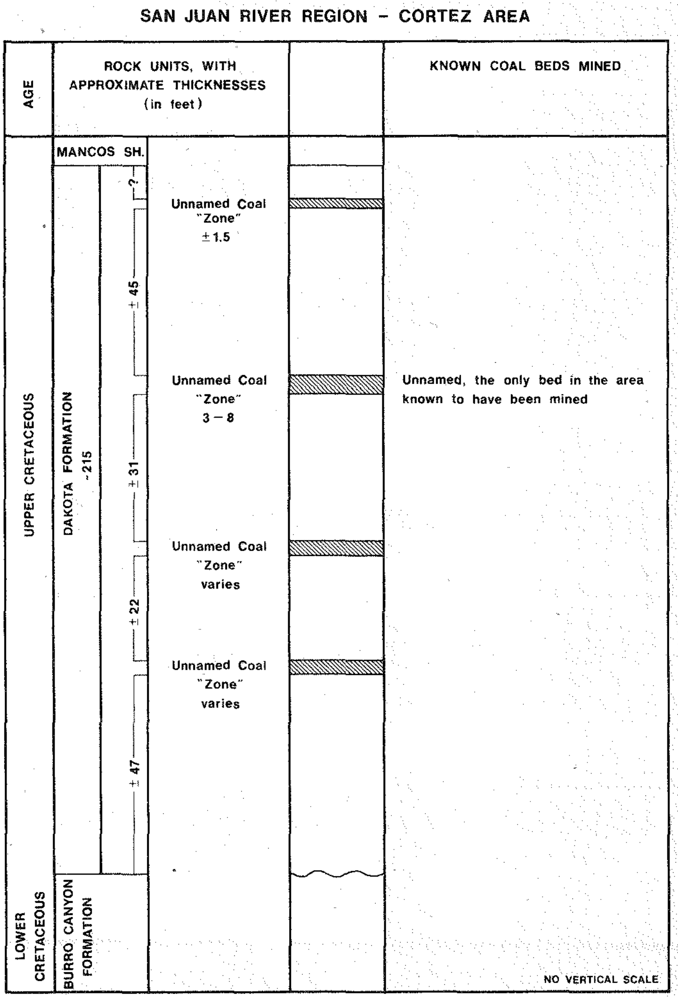


Figure 28. The stratigraphy of the Dakota Formation in the Cortez area, San Juan River region, Colorado (from Boreck and Murray, 1979).

of high-volatile A bituminous. However, the ash and sulfur content of these coals still indicate that they are not suited for the production of coke (Maps B and C, Plate 2).

In Colorado, coal deposits in the Menefee Formation range from premium grade high-volatile C bituminous to marginal grade high-volatile A bituminous coking coal (Maps B and C, Plate 2). The rank of Menefee coals generally increases to the northeast. Along the western margins of the basin, the coal is premium grade high-volatile C bituminous coking coal. In Ranges 12 and 13 West, the coal becomes high-volatile B bituminous in rank, but the grade decreases to marginal in local areas. East of Range 12 West, the coal is high-volatile A bituminous in rank, but the coking-coal grade may decrease to latent in local areas because of variations in both ash and sulfur contents.

Traditionally, coal deposits in the Fruitland Formation have been considered non-coking in the San Juan River region. However, recent research indicates that coal from this formation can serve as coke-oven feedstock. In Colorado, the coal resources in this formation are predominantly marginal to latent grade high-volatile A bituminous coking coal. It is usually the ash content that precludes a premium grade designation for the coal deposits in the Fruitland Formation (Maps B and C, Plate 2).

Coal reserve estimates and coking-coal grades are tabulated on Table 19 for the San Juan River region. These estimates are based upon

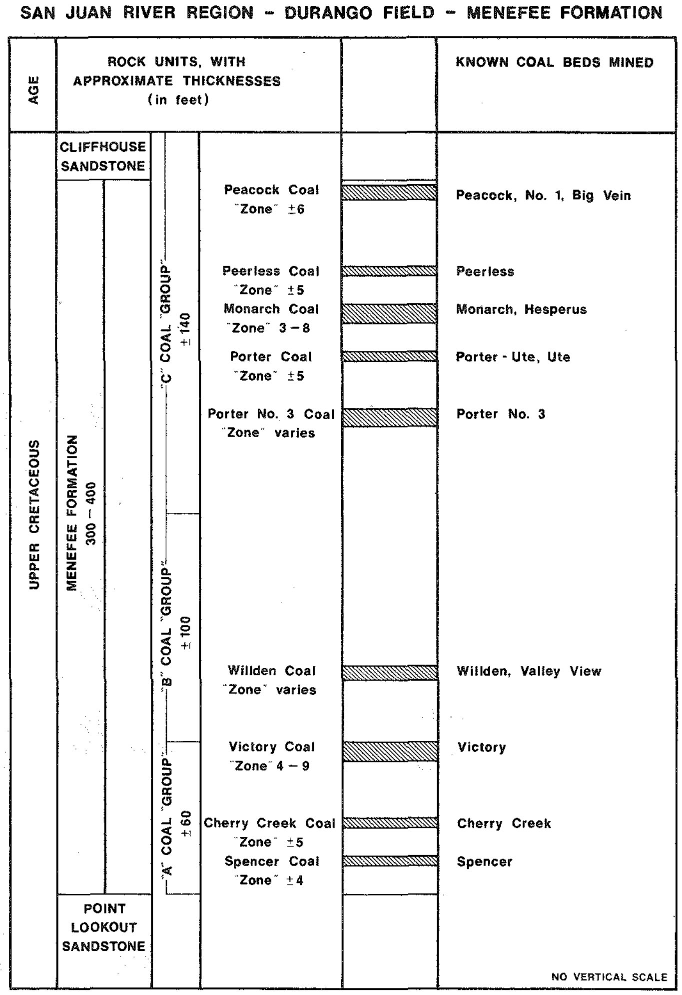


Figure 29. The stratigraphy of the Menefee Formation in the Durango field, San Juan River region, Colorado (from Boreck and Murray, 1979).

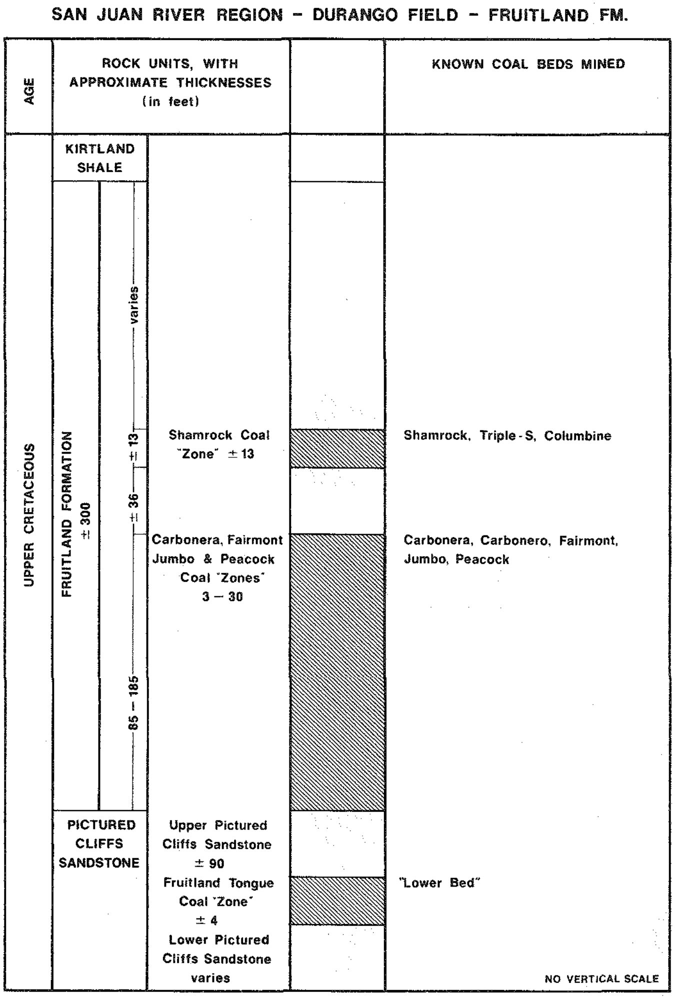


Figure 30. The stratigraphy of the Fruitland Formation in the Durango field, San Juan River region, Colorado (from Boreck and Murray, 1979).

Table 17. Coking-coal reserve estimates for the Raton Mesa region.

Coking-Coal Classification	Short tons x 1,000	% of total
Marginal grade high-volatile A bituminous	1,834,677	87.5
Marginal grade high-volatile B bituminous	216,876	10.3
Non-coking (high-volatile C bituminous)	44,038	2.1
Total	2,095,591	99.9[1]
Total mined through 1977[2]	250,124	
Total depletion through 1977[2]	500,211	

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[1] Does not equal 100% due to independent rounding.

[2] From Boreck and Murray (1979).

Table 18. Licensed coal mines, coking-coal classification, and 1977 and 1978 coal production in the Raton Mesa region.

Mine	County	Production (in short tons)[1] 1977	Production (in short tons)[1] 1978	Coking-Coal[2] Classification
Allen	Las Animas	582,257	495,120	MhvAb
Cissey Lee Strip	Las Animas	-	3,592	?
Delagua Strip	Las Animas	6,700	29,900	MhvAb
Healy Strip	Las Animas	95,952	18,258	MhvAb
Jewell Strip	Las Animas	25,591	6,050	MhvAb
Maxwell	Las Animas	31,815	86,883	MhvAb
Viking	Huerfano	-	16,342	?
Total		742,315	656,145	

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[1] 1977 production data from Colorado Division of Mines, 1978b; 1978 production data are preliminary (Colorado Division of Mines, 1978a).

[2] MhvAb = Marginal grade high-volatile A bituminous

Table 19. Identified original in-place coking-coal reserves in the Durango, Nucla-Naturita, and Pagosa Springs fields, the San Juan River region.

Coking-Coal Classification	Short tons x 1,000,000	% of total
Premium to marginal grade high-volatile A bituminous	87.23	4.90
Premium to marginal grade high-volatile A to B bituminous	585.99	32.92
Premium to marginal grade high-volatile B bituminous	14.50	0.81
Marginal grade high-volatile A bituminous	155.37	8.73
Marginal to latent grade high-volatile A bituminous	365.26	20.52
Marginal to latent grade high-volatile B bituminous	7.73	0.43
Latent grade high-volatile A bituminous	171.71	9.65
Unclassified high-volatile bituminous	392.08	22.03
Total	1,779.87	99.99[1]

---

[1] Does not equal 100% due to independent rounding.

considerations of the coal parameters depicted on Plate 2, as well as on coal reserve estimates by Wood and others (1948), Zapp (1949), Barnes (1953), Barnes and others (1959), Landis (1959), Wanek (1959), and Landis and Cone (1972).

Coal production from the San Juan River region totalled 345,087 short tons during 1977 and 1978, as illustrated on Table 20. The largest coal-producing mine in the region during that two-year period, the Nucla Strip, produced 196,796 short tons of coal. This production, representing 57 percent of the total, was utilized for electric power generation.

Although the coal resources of the San Juan River region can be utilized for the production of coke, current large-scale development of this resource is severely hampered by transportation considerations (Dawson and Murray, 1978). At the present time, no railroad serves southwestern Colorado. As a consequence, coal production for major markets outside of the region must be trucked approximately 150 miles to the nearest railhead for shipment. Such shipping practice adds at least $7.00 per ton to the price of the coal. This economic deterrent will continue to hamper large-scale coal development in the region until the area is connected by rail.

THE UINTA COAL REGION

The Colorado portion of the Uinta coal region is the eastern extension of an important coal-bearing region that encompasses large areas of eastern Utah and western Colorado. In this study, the boundary of the region in Colorado is marked by the contact of the coal-bearing Mesaverde Group with the underlying Mancos Shale, and by t[illegible] Colorado-Utah State line to the west (Plate 3; Fi[illegible] 18). The Piceance Creek basin is the most prominent structural feature in the region, and consists of the southeast lobe of the Laramide-age Uinta structural basin of eastern Utah. The Douglas Creek arch separates the two basins and forms the western boundary of the Piceance Creek basin. The remainder of the basin's periphery is formed by several other uplifts, including the Axial Basin uplift to the north, Book Cliffs and Grand Mesa on the south and southwest, the Elk and West Elk Mountains and the Gunnison uplift on the southeast, and the Grand Hogback monocline on the east. In local areas around the periphery of the basin,

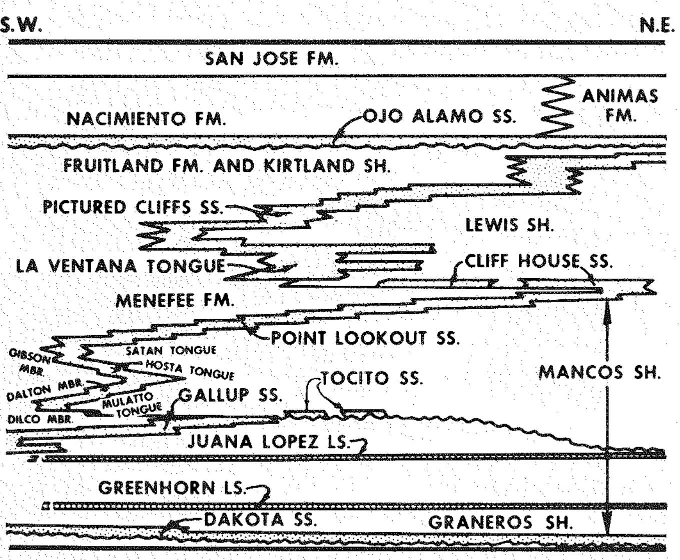

Figure 31. Diagrammatic stratigraphic cross section of the Cretaceous and Tertiary rocks of the San Juan basin, northwest New Mexico (from Fassett, 1977).

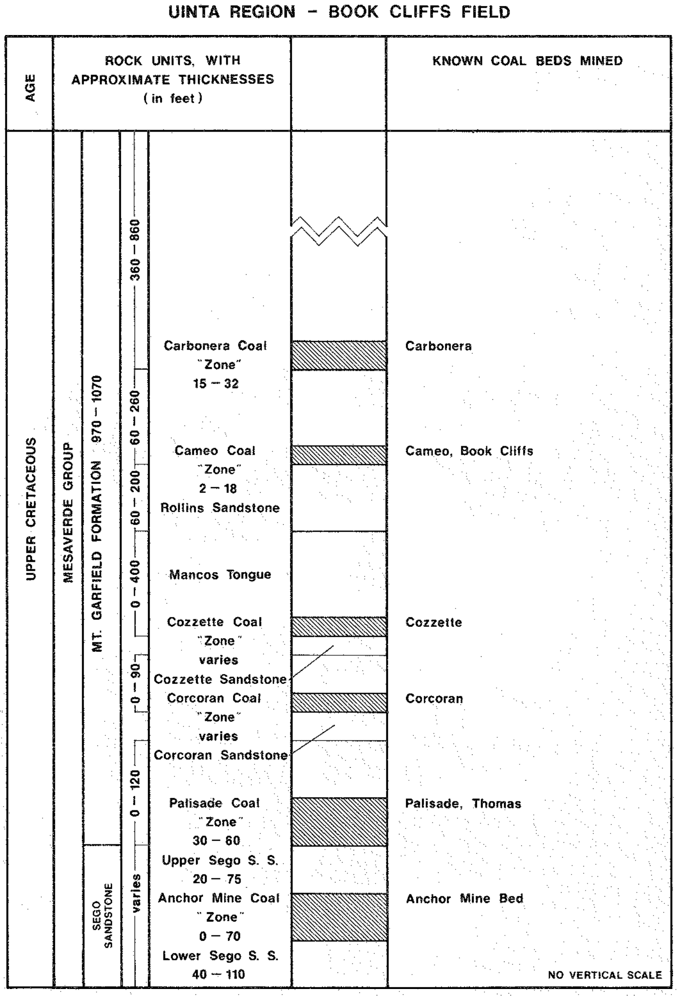

Figure 32. Coal-bearing formation, coal zone, and coal bed stratigraphy of the Book Cliffs field, Colorado (from Boreck and Murray, 1979).

folding, faulting, and Tertiary igneous intrusions have modified the coal-bearing strata, resulting in complex structural areas (Hornbaker and others, [illegible]76; Murray and others, 1977; and Murray, 1979).

Correlation of the Cretaceous coal-bearing formations (or members) in the region is still subject to discrepancies and controversy. Previous geological investigations and the stratigraphy of the region have been discussed by Fisher and others (1960) and by Collins (1976). Boreck and Murray (1979) have summarized the stratigraphy of the coal-bearing formations, coal "zones," and coal beds in the Book Cliffs field (Fig. 32), Somerset field (Fig. 33), Grand Hogback and Carbondale fields (Fig. 34), and Danforth Hills field (Fig. 35). In the Uinta region, coal deposits occur in the Iles and Williams Fork Formations of the Mesaverde Group, or in their lithogenetic equivalents.

The Uinta coal region is divided into eight coal fields (see Landis, 1959). General discussions of these eight coal fields, and of the coal resources they contain, may be found in Landis (1959), Collins (1976), Hornbaker and others (1977), Murray and others (1977), and Murray (1979). Important coking-coal resources are located in four of the eight coal fields in the region. The Somerset (Delta and Gunnison Counties), Crested Butte (Gunnison County), Carbondale (Pitkin and Garfield Counties), and Grand Hogback (Garfield County) coal fields contain significant coking-coal resources.

UINTA REGION - SOMERSET FIELD

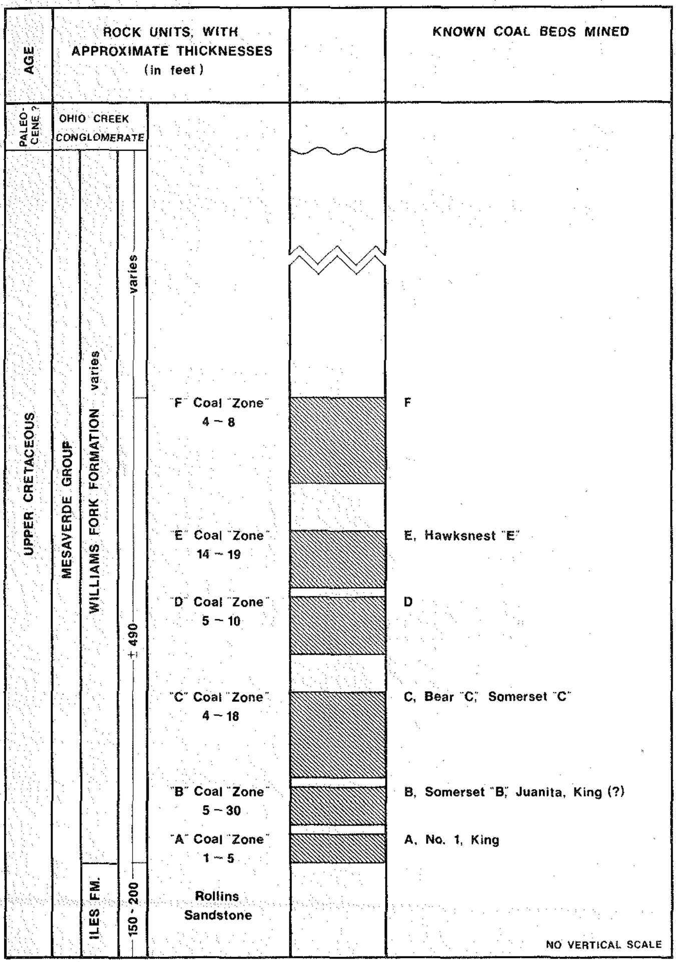

Figure 33. Coal-bearing formation, coal zone, and coal bed stratigraphy of the Somerset field, Colorado (from Boreck and Murray, 1979).

UINTA REGION - GRAND HOGBACK & CARBONDALE FIELDS

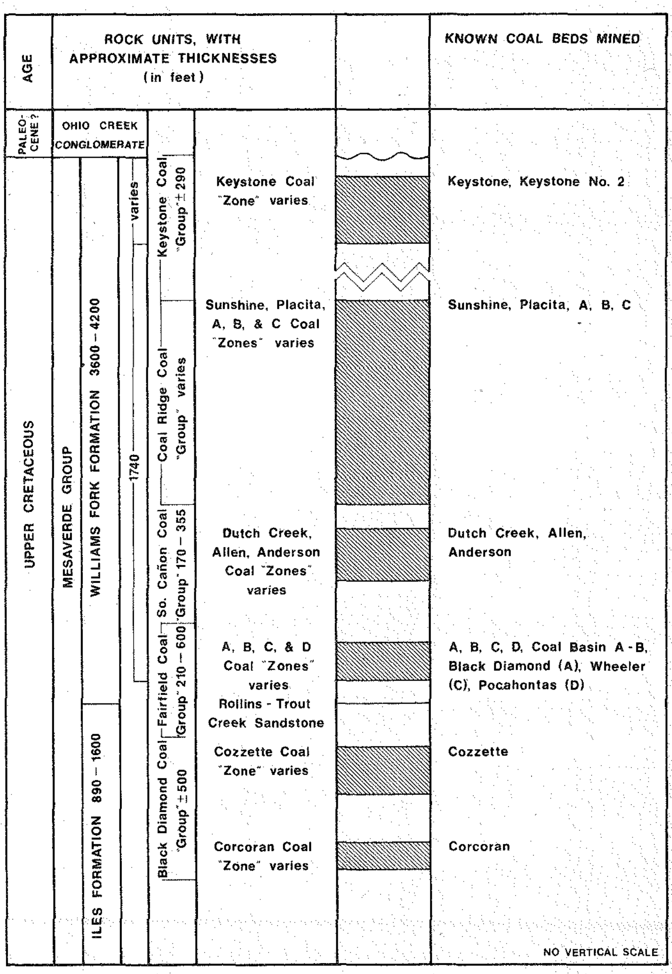

Figure 34. Coal-bearing formation, coal zone, and coal bed stratigraphy of the Grand Hogback and Carbondale fields, Colorado (from Boreck and Murray, 1979).

In the Grand Hogback field, coal rank varies in a progressive manner, from high-volatile C bituminous to high-volatile A bituminous. North of Township 5 South, the coal is predominantly non-coking high-volatile C bituminous. Its rank increases southward until marginal to premium grade high-volatile A and B bituminous coking coals are attained in Township 5 South. Continuing southward, the coals again become non-coking high-volatile C bituminous in rank near Rifle Gap (Plate 3, Maps C and B).

The most "desirable" coking coal produced today in the West comes from the Coal Basin area in Pitkin County, Colorado, in the southern portion of the Carbondale field. The coal rank in this area locally has been upgraded by one or more buried Tertiary intrusions. The coal here varies from high-volatile A bituminous to medium-volatile bituminous. Five mines, owned by Mid-Continen Coal and Coke Company, produced 908,000 tons o coal for use as coke-oven feedstock from the Coal Basin area during 1978 (Table 21). This coking coal varies from premium grade high-volatile A bituminous to premium grade medium-volatile bituminous (Plate 3, Maps B and C). North of the Coal Basin area, the coal is predominantly premium to marginal grade high-volatile A and B bituminous coking coal. The limited coal analyses available indicate that the coal resources between the Coal Basin area and Crested Butte field are premium grade high-volatile A bituminous coking coals. Beehive coke oven ruins located north of the Coal Basin area are depicted on Figure 37.

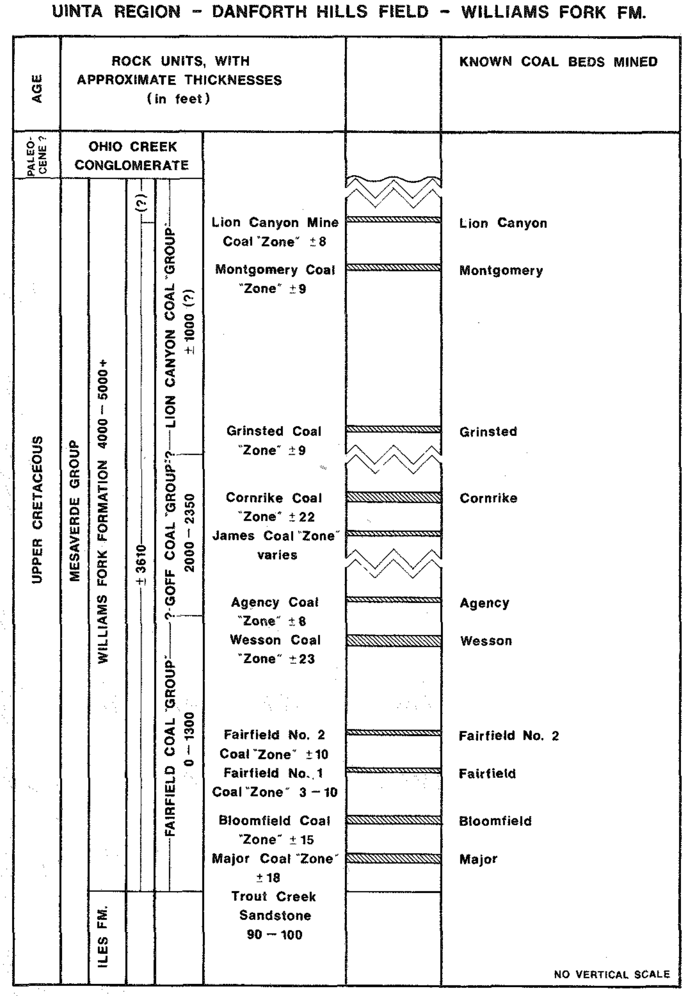

Figure 35. Coal zone and coal bed stratigraphy of the Williams Fork Formation, Danforth Hills field, Colorado (from Boreck and Murray, 1979).

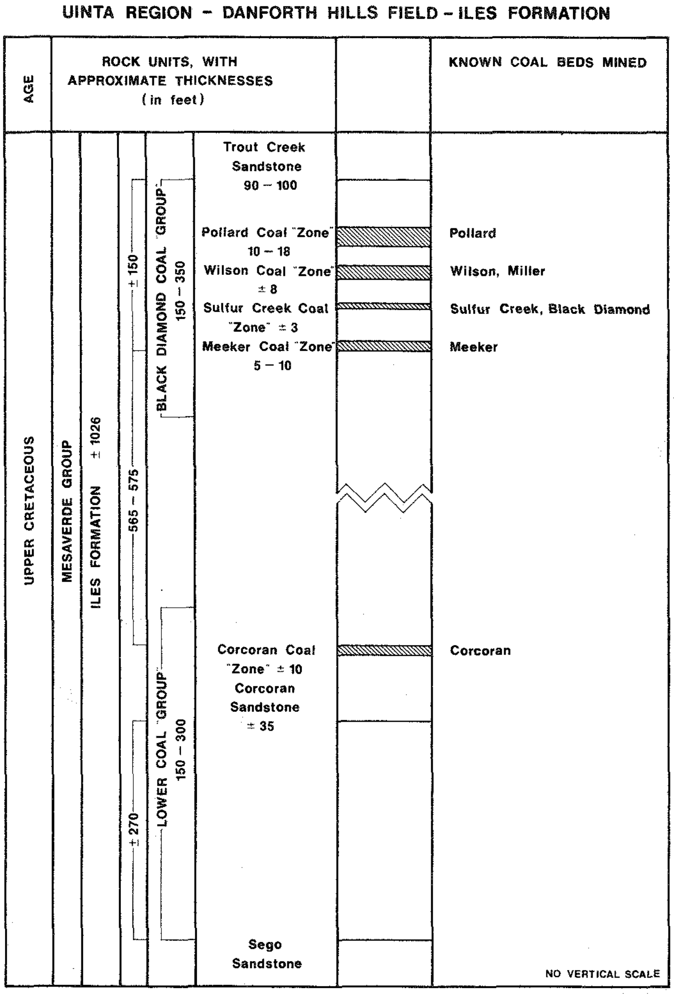

Figure 36. Coal zone and coal bed stratigrahy of the Iles Formation, Danforth Hills field, Colorado (from Boreck and Murray, 1979).

Table 20. Licensed coal mines, coking-coal classification, and 1977 and 1978 coal production in the San Juan River region.

Mine	County	Production (in short tons)[1] 1977	1978	Coking-Coal[2] Classification
Martinez Strip	Archuleta	4,070	38,676	MhvAb
Blue Flame	La Plata	-	-	PhvBb
Coal Gulch	La Plata	1,250	13,851	PhvAb
Hay Gulch	La Plata	-	-	?
King	La Plata	22,570	66,046	PhvAb
Peacock	La Plata	1,828	-	?
Nucla Strip	Montrose	94,402	102,394	MhvBb
Total		124,120	220,967	

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1) 1977 production data from Colorado Division of Mines, 1978b; 1978 production data are preliminary (Colorado Division of Mines, 1978a).

2) MhvAb = Marginal grade high-volatile A bituminous
PhvBb = Premium grade high-volatile B bituminous
PhvAb = Premium grade high-volatile A bituminous

Table 21. Licensed coal mines, coking-coal classification, and 1977 and 1978 coal production in the Uinta region.

Mine	County	Production (in short tons)[1] 1977	1978	Coking-Coal[2] Classification
Eastside	Garfield	257	253	PhvBb
Nu-Gap No. 3	Garfield	397	281	?
Sunlight	Garfield	1,792	487	MhvBb
Bear Creek	Pitkin	58,352	44,171	Pmvb
Coal Basin	Pitkin	123,182	132,396	Mmvb
Dutch Creek No. 1	Pitkin	232,481	161,208	Mmvb
Dutch Creek No. 2	Pitkin	208,142	225,464	Pmvb
L. S. Wood	Pitkin	298,405	318,212	Pmvb
Thompson Creek No. 1	Pitkin	7,455	15,733	MhvAb
Thompson Creek No. 3	Pitkin	8,413	-	PhvAb
Blue Ribbon	Delta	16,640	15,294	PhvBb
King	Delta	2,996	-	PhvAb
Bear	Gunnison	226,221	226,705	PhvBb
Hawk's Nest East	Gunnison	190,350	330,997	PhvBb
Hawk's Nest West	Gunnison	12,362	-	PhvBb
Somerset	Gunnison	914,552	650,210	PhvAb
Total		2,301,997	2,094,618	

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1) 1977 production data from Colorado Division of Mines, 1978b; 1978 production data are preliminary (Colorado Division of Mines, 1978a).

2) Pmvb = Premium grade medium-volatile bituminous
Mmvb = Marginal grade medium-volatile bituminous
PhvAb = Premium grade high-volatile A bituminous
MhvAb = Marginal grade high-volatile A bituminous
PhvBb = Premium grade high-volatile B bituminous
MhvBb = Marginal grade high-volatile B bituminous

The Crested Butte field, located at the southeastern tip of the Uinta region, in Gunnison County, has been heavily influenced by Tertiary intrusions, folding, and faulting. Consequently, coal rank in the field varies from high-volatile C bituminous to anthracite over small areas. However, the field does contain important coking-coal resources, although the only current coal production there is sold as steam coal. The coking-coal resources occurring in local areas of this field are premium grade high-volatile A and B bituminous (Plate 3, Maps B and C).

Figure 37. David Jones examining beehive coke oven ruins located in the Carbondale coal field, Sec. 15, T8S, R89W, Garfield County, Colorado.

Important premium to marginal high-volatile A and B coking-coal resources are located in the Somerset coal field, Delta and Gunnison Counties. The largest producing underground coal mine in Colorado is the United States Steel Corporation Somerset mine, which produces coke-oven feedstock for their ovens near Provo, Utah. The Somerset mine produced 650,201 short tons of premium grade high-volatile A bituminous coal in 1978 (Table 21).

The identified original coking-coal reserves in the Uinta region are listed on Table 22. These estimates are derived from data displayed on Maps B and C, Plate 1, and from original identified coal reserve estimates made by Landis and Cone (1972). The total identified reserves, 446,720,000 short tons, do not reflect estimates for coal occurring at depths greater than 1,000 ft. Many of the mines in the Uinta region are drift mines that quickly attain overburden cover of between 1,000 and 3,000 ft. Therefore, this reserve estimate reflects only a small part of the amount of coking-coal available for mining in the region.

The production of coking-grade bituminous coal during 1977 and 1978 and the producing mines are tabulated on Table 21. During those two years, 4,396,615 short tons of coal that could be used as coke-oven feedstock was produced from the region.

Table 22. Identified original in-place coking-coal reserves in the Grand Hogback, Carbondale, Crested Butte, and Somerset coal fields, the Uinta region.

Coking-Coal Classification	Short Tons x 10^6	% of Total
Premium grade high-volatile A to medium-volatile bituminous	21.23	4.75
Premium grade high-volatile A bituminous	128.05	28.66
Premium grade high-volatile B bituminous	78.86	17.65
Premium grade high-volatile A to B bituminous	129.37	28.96
Premium to marginal grade high-volatile B bituminous	54.04	12.10
Marginal grade high-volatile B bituminous	35.17	7.87
Total	446.72	99.99*

*Note: Total does not equal 100% due to independent rounding

CONCLUSIONS

The future production of coal for use in the manufacture of coke in the United States is affected by numerous complex and interrelated factors. For example, the demand for coke has declined in recent years due to the increased usage of higher iron content agglomerates, modifications of blast furnace practices, and the increased use of supplemental injection fuels. Development and utilization of formcoke technology could also have a large impact on the future of the coke industry in the United States (Mutsher, 1975). However, major supplies of coke for the manufacture of steel will be obtained from conventional coking processes through at least the year 1985 (Sheridan, 1976). With approximately 4.3 billion short tons of coking quality coal reserves, Colorado will remain the major source of coking coal in the West so long as coke is manufactured by conventional processes.

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APPENDIX

EXPLANATION OF APPENDIX TABLES

The following tables categorize representative coal analysis data for samples collected from coal mines and drill cores in the Raton Mesa, San Juan River, and Uinta coal regions of Colorado. Using these tables, the coal resource evaluation maps depicted on Plates 1, 2, and 3 were constructed. Any attempt to categorize coal analysis data quickly leads to inherent problems which should limit the use of the data in a coal resource evaluation program. For example, in the following tables, 38 references, dating from 1912 to the present, were used as sources of coal analysis data. During that period of time, sample collection, sample preservation, sample shipping, and laboratory analytical methods all have changed. The most significant result of these changes is that only very general comparisons can be made between analytical results reported from different references.

Another problem in categorizing coal analysis data is imposed by the authors' bias in the selection of representative samples from the literature. In many cases, several samples were collected from different locations in one mine. Since there is only limited space for presentation of the data in the tables, the authors selected and averaged those samples that appeared to be most representative of the total coal bed in the mine (for example, the least weathered samples, or a channel sample instead of a grab sample). Also, if more than one mine is located in a section, the map scale dictated averaging the analytical results for those mines so that they could be presented on the coal evaluation maps. This averaging is indicated in the appendix tables, when more than one mine is listed under one map number. Because of this averaging and the bias imposed by the authors' selection process, the coal analysis data should not be considered as "absolute" values, but rather as "representative" values for general evaluation work only. Detailed coal evaluation work on a local basis in these coal regions should be preceded by an examination of the literature sources listed in the tables to aquire "absolute" analytical data.

The authors have attempted to present the analytical data as completely as possible in the limited space available. The following list of guidelines is included to fully explain the tables:

1) The map numbers correspond to the numbers on each Map A on Plates 1, 2, and 3, and to Map D on Plate 2.

2) The most recent mine name is the only mine name listed in the tables. Additional mine names may be located by referring to the published sources listed, or to Boreck and Murray (1979).

3) The formations, beds, and depths listed are those reported in the literature sources denoted in the tables. The authors have not attempted to correlate any of the strata listed on the tables. Therefore, the names for the strata listed are those reported in the most recent sources.

4) In those cases in which more than one set of data was completed for one mine over a period of years, the most recent set is listed in the tables.

5) As-received values may be computed for each set of data by the addition of moisture back into the dry-basis values listed.

6) Moist-mineral-matter-free (MMMF) Btu listed are those reported in the sources. When the MMMF Btu were not reported in the literature, the value listed in the tables was computed according to ASTM (1975) standards.

7) All dry-mineral-matter-free (DMMF) fixed carbon values are computed according to the Parr formula, as established by ASTM standards (1975, p. 214).

8) When available, free-swelling indices (FSI) are listed in the table. If carbonizing information, such as Gieseler fluidity or dilatometer tests, are available in one or more of the sources listed, a C appears in the FSI column.

9) The letters in the source column correspond to the appendix references listed at the end of the table. A letter in parentheses indicates that additional data can be found in that source which has not been listed in the tables.

Appendix Table 1. Coal analyses data for representative mines and coal cores in the Raton Mesa coal region, Colroado.

Map No.	Mine or Well Name Location (Sec-T-R)	Formation Bed(s) or Depth	Dry Basis VM %	 FC %	 Ash %	As Received Moist. %	 S. %	 Btu	Btu MMMF	FC DMMF %	App. Rank	FSI Carb. Info.	Source
					HUERFANO COUNTY								
1	Alamo No. 1 35-27S-68W	Vermejo Mammoth	40.1	50.2	9.7	6.2	0.6	11,930	13,240	56.4	HvB		D,Q
2	Black Beauty 36-27S-67W	Vermejo U. Robinson	38.6	49.4	12.0	5.2	0.6	11,810	13,490	57.1	HvB		JJ,U
	Maitland No. 1	Vermejo L. Robinson	37.6	48.4	14.0	6.3	0.6	11,240	13,110	57.4	HvB		JJ,U,(Q)
	Maitland No. 2	Vermejo Dirty Robinson	38.6	49.1	12.3	5.9	0.6	11,730	13,420	57.2	HvB		JJ,U,(Q)
	Average		38.3	49.1	10.7	5.8	0.6	11,590	13,340	55.8	HvB		
3	Black Hawk 25,26-29S-66W	Raton Blackhawk	41.3	50.8	7.9	3.5	0.6	13,010	14,190	55.7	HvA		D,JJ,U
4	Blue Blaze 19-29S-65W	Vermejo Lower Robinson	37.6	50.7	11.7	3.5	0.6	12,530	14,290	58.2	HvA		JJ,U
5	Brennan 14-27S-67W	Vermejo Robinson	41.5	50.4	8.1	7.3	0.7	12,050	13,130	55.7	HvB		Q
6	Butte Valley 25,36-27S-68W	Vermejo Vermillo	38.1	50.5	11.4	7.4	0.8	11,380	12,870	58.1	HvC		JJ,U
7	Caddell No. 2 5-28S-66W	Vermejo L. Robinson	38.7	46.9	14.4	4.7	0.6	11,630	13,660	55.8	HvB		JJ,U
8	Calumet No. 2 15-27S-67W	Vermejo Cameron, Lennox	39.2	49.8	11.0	6.1	0.8	11,730	13,220	56.9	HvB		U,(Q)
9	Cameron 20-28S-66W	Vermejo Walsen, Cameron	38.8	48.3	12.9	4.2	0.6	12,090	13,980	56.4	HvB		Q
10	Fern 22-29S-69W	Vermejo C.O.D.	37.0	48.3	14.7	6.1	1.9	11,390	13,440	58.1	HvB		D,Q
11	Gordon 23-27S-67W	Vermejo Various	39.9	47.9	12.3	6.1	0.8	11,550	13,210	55.6	HvB		JJ,U,(Q)
12	Kebler No. 2 17-27S-67W	Vermejo Walsen (Kebler)	38.7	50.1	11.2	6.0	0.5	11,690	13,200	57.4	HvB	C	JJ,U,KK,(AA, Q)
13	Klickus 22,23,27-29S-69W	Vermejo UC	40.1	48.2	11.7	5.1	0.7	12,070	13,740	55.5	HvB		JJ,U
14	Leader No. 3 31-29S-65W	Raton U. Rugby	36.1	57.5	6.4	3.7	0.5	13,170	14,130	61.9	HvA		D,JJ,U
	Leader	Raton U. Rubgy	40.1	50.8	9.1	3.8	0.8	12,810	14,190	56.5	HvA		JJ
	Leader No. 2	Raton L. Rugby	40.7	50.9	8.4	3.7	0.7	12,870	14,120	56.2	HvA		JJ,U
	Rugby No. 6	Vermejo U. Rugby	40.1	48.1	11.8	3.2	0.8	12,500	14,280	55.3	HvA		JJ,U
	Average		39.3	51.8	8.9	3.6	0.7	12,840	14,180	57.5	HvA		
15	Loma Park Strip 6-28S-66W	Vermejo Walsen	36.5	47.5	16.0	5.4	1.1	10,740	12,850	57.9	HvC		JJ,(K)
16	Major No. 2 8,9-27S-67W	Vermejo Cameron, Walsen	39.6	48.7	11.8	7.5	0.8	11,410	12,940	56.3	HvC		JJ,U,(Q,W)
17	Morning Glory 25,26-27S-67W	Vermejo Cameron	38.5	50.7	10.8	5.1	0.6	11,920	13,410	57.6	HvB		JJ,U,(FF)
18	Mutual 18-28S-66W	Vermejo Walsen	37.9	46.5	15.6	4.8	0.5	11,480	13,700	56.2	HvB		Q
19	Oakdale 10-29S-69W	Vermejo Mammoth	41.8	48.5	9.7	7.8	0.5	11,540	12,780	54.6	HvB		D,O,Q,W
20	Pryor (Old) 13,24-29S-66W	Vermejo L. Robinson, Walsen	37.2	49.9	12.9	3.0	0.7	12,380	14,330	58.1	HvA		JJ,U,(Q,W)

	Ravenwood Strip 21-28S-66W	Vermejo Cameron, M. & U. Robinson	38.5	51.3	10.2	3.6	0.6	12,470	13,960	57.8	HvB		JJ,U[illegible]N)
22	Robinson No. 1 NW 17-28S-66W	Vermejo Robinson	39.1	49.7	11.2	3.9	0.6	12,340	13,990	56.7	HvB		Q,W
23	Robinson No. 2 8-28S-66W	Vermejo Walsen	38.4	50.6	11.0	4.8	0.6	12,250	13,830	57.7	HvB		Q
24	Robinson No. 4 16-28S-66W	Vermejo Walsen, Cameron	37.1	48.4	14.5	4.7	0.5	11,720	13,790	57.6	HvB		JJ,U
25	Rouse 1-29S-66W	Vermejo Cameron	37.1	49.9	13.0	2.7	0.8	12,480	14,480	58.1	HvA		JJ
26	Rouse No. 1 30-29S-65W	Vermejo Walsen & UC	37.2	58.0	4.8	3.2	0.4	13,460	14,170	61.3	HvA		D,JJ,U

LAS ANIMAS COUNTY

27	Aguilar Imperial 2-31S-65W	Vermejo Empire	32.2	56.1	11.7	3.4	0.7	12,770	14,570	64.4	HvA		D,JJ,U
28	Allen 27-33S-68W	Raton Allen	40.8	51.7	7.5	2.1	0.5	13,850	15,060	56.3	HvA	8.0-8.5, C	S,A,C,X,(JJ,U)
29	Anchor No. 2 32-32S-65W	Raton Primero	31.5	53.0	15.5	3.6	0.6	11,950	14,270	63.9	HvA		JJ
	Anchor	Raton Primero	31.7	47.6	20.7	3.1	0.6	11,360	14,530	61.6	HvA		JJ,(FF)
	Boncarbo	Raton Primero	33.2	52.6	14.2	2.9	0.6	12,340	14,520	62.3	HvA		D,JJ,U
	Average		32.1	51.1	16.8	3.2	0.6	11,880	14,440	62.6	HvA		
30	Baldy 24-32S-64W	Vermejo UC	30.8	48.9	20.3	1.9	0.5	11,770	15,020	62.8	HvA		JJ,(FF)
31	Bear Canon No. 3 11-32S-65W	Raton Bear Canon	39.8	48.7	11.5	1.9	0.8	13,160	15,020	56.2	HvA		D,Q
32	Bear Canon No. 6 2,11-32S-65W	Raton Bear Canon No. 6 (Cass?)	35.0	54.8	10.2	1.9	0.6	13,250	14,880	61.7	HvA		JJ,U
33	Berwind Canon 25,36-31S-65W	Vermejo Tobasco	29.1	52.9	18.0	1.6	0.6	12,180	15,090	65.9	HvA		JJ
34	Berwind No. 4 36-31S-65W	Vermejo U. Hastings	32.8	52.0	15.2	2.5	0.6	12,150	14,480	62.3	HvA		JJ
35	Bisulco 16-30S-65W	Vermejo Walsen	33.4	54.6	12.0	2.9	0.7	12,640	14,490	63.0	HvA		JJ,U
	Jewell-Creston	Vermejo Walsen	35.7	53.4	10.9	2.2	0.7	13,000	14,720	60.7	HvA		JJ,U
	Average		34.6	54.0	11.4	2.6	0.7	12,820	14,610	61.7	HvA		
36	Bowman 9-33S-65W	Raton UC	35.4	55.4	9.2	1.8	0.6	13,630	15,120	61.6	HvA		JJ,U
37	Burro Canyon No. 3 1-33S-66W	Raton Primero	32.8	53.3	13.9	2.1	0.5	12,650	14,850	62.8	HvA		D,JJ,U
38	Cissy Lee Strip 23-32S-64W	? ?	(No Analysis)										R
	Baldy No. 2	Vermejo UC	31.7	50.6	17.7	2.0	0.6	12,120	14,930	62.7	HvA		JJ
	Average		31.7	50.6	17.7	2.0	0.6	12,120	14,930	62.7	HvA		
39	Cokedale 25-33S-65W	Vermejo Cokedale	26.4	55.9	17.7	2.3	0.5	12,340	15,200	69.2	Mv		Q,W,(N)
40	Daisy No. 2 32-30S-65W	Raton UC	36.1	50.3	13.6	2.7	0.6	12,340	14,410	59.1	HvA		U
41	Delagua No. 3 1/2 15,16-31S-65W	Raton Delagua	37.2	51.0	11.8	2.9	0.5	12,550	14,340	58.7	HvA		U
42	Delagua Strip No. 1 15-31S-65W	Raton Delagua	37.6	51.4	11.0	2.3	0.6	12,850	14,560	58.4	HvA		R, S

Appendix Table 1. Coal analyses data for representative mines and coal cores in the Raton Mesa coal region, Colorado(CONT.).

Map No.	Mine or Well Name Location (Sec-T-R)	Formation Bed(s) or Depth	Dry Basis VM %	Dry Basis FC %	Dry Basis Ash %	As Received Moist. %	As Received S. %	As Received Btu	Btu MMMF	FC DMMF %	App. Rank	FSI Carb. Info.	Source
		LAS ANIMAS COUNTY (CONT.)											
43	Dix 5,6-33S-65W	Raton Cass (Primero)	32.9	53.9	13.2	2.0	0.5	12,760	14,840	62.2	HvA		D,JJ,U
44	Empire 28-30S-65W	Vermejo Empire	33.9	52.7	13.4	2.6	0.7	12,650	14,760	61.8	HvA		Q
45	Engleville No. 2 29-33S-63W	Vermejo Engle	30.9	55.9	13.2	2.7	0.6	12,670	14,720	65.3	HvA		JJ,U
46	Forbes No. 9 15,16-32S-64W	Vermejo Walsen	31.3	57.9	10.8	2.2	0.6	13,520	15,270	65.7	HvA		D,O,Q
47	Francisco 34-33S-64W	Vermejo Piedmont	29.7	60.5	9.8	1.6	0.7	13,890	15,540	67.8	HvA		Q,W
48	Frederick 32-33S-65W	Raton Frederick	30.3	53.3	16.4	1.8	0.6	12,520	15,200	64.9	HvA	C	D,JJ,M,U,KK,X
49	Gem 33,34-30S-65W	Raton Gem	35.5	53.8	10.7	2.1	0.7	13,040	14,730	61.0	HvA		JJ,U
50	Gray Creek No. 4 & 6 26,34-33S-63W	Vermejo Walsen ?	33.7	51.6	14.7	2.2	0.8	12,590	14,940	61.6	HvA	6.0-6.5, C	JJ,U
51	Green Canon No. 1 16,21-30S-65W	Vermejo Walsen	37.2	52.6	10.2	3.2	0.5	12,760	14,300	59.3	HvA		D,U
52	Hastings 25-32S-64W	Vermejo Hastings	33.3	53.2	13.5	2.7	0.8	12,630	14,730	62.5	HvA		O,Q,(N)
53	Healy Strip 8-31S-65W	Raton ?	(No Analysis)										R
54	Kenneth 5-30S-65W	Vermejo Robinson,Rapson	36.1	51.3	12.6	2.2	0.6	12,650	14,600	59.5	HvA		D,JJ,U
55	Jewell Strip 21-30S-65W	Vermejo Middle	38.7	49.3	12.0	2.2	0.6	12,610	14,460	56.7	HvA	4.0-6.0	R,S
	Jewell Strip	Vermejo Dirty Robinson	38.8	48.4	16.8	2.2	0.6	11,740	14,290	59.2	HvA	2.5-3.5	R,S
	Average		38.8	48.9	14.3	2.2	0.6	12,180	14,380	57.9	HvA	2.5-6.0	
56	Las Animas No. 4 20-30S-65W	Vermejo Brodhead #4	36.0	57.8	6.2	2.4	0.4	13,550	14,520	62.0	HvA		Q,W
57	Las Vega (Tercio) 21-34S-68W	Vermejo No. 3 & 2	33.8	52.6	13.6	2.2	0.7	12,960	15,160	61.9	HvA		D,Q,W
58	Ludlow No. 1, 2 & 3 32-31S-64W	Vermejo Hastings,Berwind	32.7	52.4	14.9	1.7	0.7	12,630	15,020	62.6	HvA		U
59	Martinez No. 1 11-33S-65W	Raton UC	31.4	54.9	13.7	2.0	0.5	12,800	14,980	64.5	HvA		JJ,U
60	Maxwell 29-33S-67W	Vermejo Apache	34.6	54.8	10.6	2.1	0.4	13,440	15,150	62.0	HvA	8.5	R, S
61	Montoya 27-33S-63W	Vermejo Engle-Starkville	30.5	50.3	19.2	1.8	0.6	11,940	15,030	63.7	HvA		JJ
62	Morley 31-34S-63W	Vermejo Morley, Starkville	31.4	53.8	14.8	1.8	0.7	12,750	15,140	64.1	HvA		JJ,U,(N)
63	New Primrose 5-30S-65W	Raton Primrose #2	39.8	50.4	9.8	3.0	0.6	12,700	14,170	58.2	HvA		JJ,U
64	Peacock 20,29-32S-64W	Raton UC	34.9	50.7	14.4	2.1	0.6	12,520	14,790	60.1	HvA		JJ,U
65	Prairie Canon 10-32S-65W	Raton Bear Canon	36.2	53.7	10.1	3.2	0.6	13,130	14,700	61.2	HvA		Q
66	Primero 26-33S-66W	Raton Primero	31.8	58.0	10.2	2.4	0.6	13,510	15,150	65.3	HvA		D,O,Q,W,Z

[illegible]7	Prosperity No. 2 22-30S-65W	Vermejo UC	37.4	50.3	12.3	2.7	0.7	12,700	14,610	58.2	HvA	JJ,U
68	R & G 25-33S-64W	Vermejo No. 4	29.5	49.6	20.9	1.8	0.6	11,800	15,190	64.2	HvA	FF,JJ
69	Rapson No. 1 4-30S-65W	Vermejo Cameron	37.2	52.2	10.6	2.8	0.7	12,780	14,410	59.2	HvA	JJ,U
70	Rapson No. 2 4,9-30S-65W	Vermejo Cameron	35.9	51.5	12.6	2.3	0.6	12,610	14,570	59.7	HvA	JJ,U
71	Red Robin (Turner) 18-35S-63W	Raton Savage or Turner	37.0	48.0	15.0	2.3	0.6	12,530	14,900	57.5	HvA	Q,W
72	Sopris No. 1 33,34-33S-64W	Vermejo L. Cameron	31.4	57.5	11.1	1.9	0.7	13,510	15,340	65.5	HvA	N,Q,U
73	Suffield 13-32S-64W	Vermejo Walsen	33.5	52.1	14.4	3.0	0.7	12,490	14,740	70.0	HvA	Q,W
74	Thor 11-32S-64W	Vermejo Hastings	34.4	48.6	17.0	2.0	0.7	12,340	15,080	59.7	HvA	JJ,(Q)
75	Toller 35,36-31S-65W	Vermejo Berwind	33.6	54.4	12.0	5.9	0.7	12,700	14,490	62.9	HvA	O,Q,W
76	USGS Hole #1 4-33S-67W	2000'	(Results unpublished)									H
77	USGS Hole #2 27-33S-66W	1100'	(Results unpublished)									H
78	USGS Hole #3 2-33S-65W	900'	(Results unpublished)									H
79	USGS Hole #4 36-33S-64W	250'	(Results unpublished)									H
	Starkville No. 4	Vermejo U. Starkville	30.2	51.4	18.4	1.9	0.7	12,210	15,210	65.5	HvA	JJ,(FF,Q)
	Starkville No. 7	Vermejo L. Starkville	29.6	51.5	18.9	1.7	0.7	12,190	15,280	64.9	HvA	JJ
	Average		29.9	51.5	18.6	1.8	0.7	12,200	15,250	65.8	HvA	

Appendix Table 2. Coal analyses data for representative mines and coal mines and coal cores in the San Juan River coal region, Colorado and northern New Mexico.

Map No.	Mine or Well Name Location (Sec-T-R)	Formation; Bed(s) or Depth	Dry Basis			As Received			Btu MMMF	FC DMMF %	App. Rank	FSI Carb. Info.	Source
			VM %	FC %	Ash %	Moist. %	S. %	Btu					
	ARCHULETA COUNTY												
80	Bellino 32-33N-2W	Fruitland UC	38.5	47.3	14.2	3.4	0.9	12,380	14,570	56.0	HvA		JJ,U
81	Columbine 20-35N-5W	Fruitland UC	39.4	47.1	13.5	4.5	0.6	12,110	14,090	55.4	HvA	4.0	JJ,U
82	Kleckner 36-36N-1W	Fruitland UC	38.4	50.6	11.0	9.5	1.1	--	--	57.6	-		Q,W
83	Martinez Strip 29,30-33½N-4W	Fruitland A	29.1	57.1	13.8	4.9	0.8	11,740	13,700	67.4	HvB	1.0	R,S
	Martinez Strip	Fruitland B	30.9	57.4	10.7	1.3	0.9	13,640	15,440	65.2	HvA	8.5	R,S
	Martinez Strip	Fruitland C	27.8	51.2	19.3	1.7	0.9	12,070	15,220	64.9	HvA	7.0-8.5	R,S
	Average		29.3	55.2	14.5	2.6	0.9	12,480	14,790	65.7	HvA	1.0-8.5	
84	O.K. 29-33N-2W	Fruitland UC	39.3	54.3	6.4	2.8	1.1	13,730	14,770	58.5	HvA	C	AA, D
85	Yellow Jacket 9-34N-5W	Fruitland UC	34.3	50.6	15.1	2.8	0.6	12,630	15,030	60.6	HvA		JJ, U
	LA PLATA COUNTY												
86	(No Name) 13-35N-6W	Fruitland UC	38.6	50.9	10.5	3.6	0.6	12,650	14,220	57.5	HvA		CC
87	Black Diamond 22-35N-10W	Menefee UC	38.6	54.2	7.2	2.3	1.3	13,710	14,870	59.0	HvA		JJ,U
	Castle	Menefee UC	38.4	54.8	6.8	2.1	0.9	13,830	14,940	59.4	HvA	6.5	JJ,U
	Morning Star	Menefee UC	38.6	55.3	6.1	2.2	1.3	13,860	14,860	59.5	HvA	5.5-7.0	JJ,U
	O.K. No. 1	Menefee UC	38.2	56.7	5.1	3.7	0.9	13,610	14,400	60.2	HvA		JJ,U
	Sunshine	Menefee UC	39.9	55.7	4.4	2.5	1.0	14,170	14,890	58.7	HvA		JJ,U
	Victory No. 2	Menefee UC	37.9	55.9	6.2	3.4	0.7	13,710	14,680	60.1	HvA	6.0	JJ,U
	Victory No. 3	Menefee UC	39.5	54.6	5.7	2.7	1.1	13,970	14,890	58.4	HvA	6.5-7.0	JJ,U,(DD)
	Average		38.8	55.3	5.9	2.7	1.0	13,840	14,790	59.2	HvA	5.5-7.0	
88	Blue Flame 31-35N-11W	Menefee Pueblo	39.3	55.1	5.6	3.8	0.8	13,080	13,910	58.9	HvB	1.0	R,S,(JJ)
89	Blue Jay 16-35N-6W	Fruitland UC	38.6	47.7	13.7	3.1	1.3	12,360	14,470	56.3	HvA		JJ,U

[illegible]0	Burnwell No. 1 29-35N-11W	Menefee UC	40.4	54.4	5.2	5.0	1.1	13,250	14,020	57.9	HvA	4.5	JJ,U
	Fort Lewis	Menefee UC	42.1	48.7	9.2	3.6	0.8	12,980	14,380	54.3	HvA		JJ,U
	Hay Gulch No. 1	Menefee UC	39.0	53.9	7.1	4.7	1.6	12,920	13,990	58.9	HvB		JJ,U
	Hay Gulch No. 2	Menefee UC	38.6	52.8	8.6	7.3	1.1	11,970	13,120	58.7	HvB	1.5	JJ,U
	Peacock	Menefee UC	40.5	52.4	7.1	5.9	2.1	12,450	13,470	56.7	HvB	1.5-5.0	JJ,U
	Rasmussen	Menefee UC	40.6	52.3	7.1	4.0	2.3	13,090	14,200	57.2	HvA	4.5-5.5	JJ,U,(Q)
	Average		40.2	52.4	7.4	5.1	1.5	12,730	13,860	57.3	HvB	1.5-5.5	
91	Burnwell No. 2 29,32-35N-11W	Menefee UC	39.7	54.0	6.3	3.9	0.6	13,320	14,280	58.2	HvA	4.5-5.5	JJ,U,(DD)
92	Carbon Junction 32-34½N-9W	Fruitland Carbonero	28.4	43.1	28.5	2.5	0.7	10,380	14,870	62.6	HvA		D,JJ
93	Cinder Butte 14-32N-12W	Fruitland B	35.5	45.4	19.1	11.6	0.6	8,300	10,160	58.3	subB		P,Q
94	Coal Gulch 15,16,20,22-35N-10W	Menefee A-1,A-2,B-4	39.5	55.8	4.7	2.1	1.0	13,770	14,520	58.9	HvA		R,Y
95	D.H. 31X-5 5-32N-7W	Fruitland 2656'-2669'	21.6	56.9	21.5	0.8	0.7	12,140	15,800	74.2	Mv		L
96	D.H. 32-10, No. 15-1 15-32N-10W	Fruitland 2825'-2890'	24.2	55.9	19.9	2.3	0.7	12,070	15,320	71.4	Mv		L
97	D.H. 34-10, No. 3X 36-34N-10W	Fruitland 2406'-2438'	21.0	52.2	26.8	0.9	0.8	11,230	15,800	73.7	Mv		L
98	Gold King Consol. 28-35N-9W	Menefee UC	33.7	61.4	4.9	2.7	0.7	--	--	65.1	-		Q
99	Gold Prince 31-34½N-9W	Menefee UC	33.8	56.7	9.5	1.4	0.6	--	--	63.3	-		Q
100	Hay Gulch Strip 36-35N-12W		(No Analysis)										R
101	Henderson 36-33N-12W	Fruitland UC	38.9	51.8	9.3	5.4	0.9	12,660	14,010	57.9	HvA		DD,Q
102	Hesperus No. 2 14-35N-11W	Menefee UC	39.4	51.0	9.6	6.4	0.5	12,300	13,640	57.2	HvB		JJ,U,(0,Q)
103	King 32-35N-11W	Menefee Pueblo	40.3	52.4	7.3	4.6	1.2	12,990	14,050	54.9	HvA	2.0-5.5	JJ,R,U
	Coal King No. 1	Menefee UC	40.3	53.4	6.3	4.2	1.0	13,270	14,220	57.3	HvA	4.5-5.0	JJ,U
	Coal King No. 2	Menefee UC	40.4	53.0	6.6	3.9	0.9	13,260	14,260	57.3	HvA	5.0	JJ,U
	Average		39.7	52.9	6.8	3.6	1.0	13,360	14,420	57.4	HvA	2.0-6.5	
104	La Plata (New) 11-35N-11W	Menefee UC	40.7	50.4	8.9	5.6	0.6	12,440	13,700	56.0	HvB	3.0	D,JJ,U
105	La Plata (Old) 27-35N-9W	Fruitland UC	33.7	49.0	17.3	3.1	1.4	11,900	14,540	60.6	HvA		DD,0
106	Mormon 17-33N-11W	Fruitland UC	38.6	47.2	14.2	4.7	0.9	11,950	14,040	56.1	HvA		P,Q
107	Murphy 26-35N-10W	Menefee UC	35.2	57.2	7.6	2.4	0.7	13,580	14,820	62.4	HvA		Q
108	Palmer 15-35N-6W	Fruitland B	35.8	52.4	11.8	3.3	0.9	12,510	14,300	60.3	HvA		CC,F,Q
109	Peerless 21-35N-10W	Menefee UC	39.0	55.7	5.3	3.0	0.7	13,790	14,620	59.3	HvA	5.0-6.5	JJ,U
110	Perin Peak No. 1 14-35N-10W	Menefee Peacock	41.2	52.8	6.0	5.3	2.1	13,220	14,150	57.0	HvA		0,Q,U
111	Porter No. 1 & 2 35-35N-10W	Menefee Peacock	35.0	55.5	9.5	3.0	0.9	--	--	62.1	-		Q,U
112	Pruitt 23-32N-12W	Fruitland Carbonero	36.1	50.3	13.6	7.1	0.6	--	--	59.5	-		Q,W

Appendix Table 2. Coal analyses data for representative mines and coal mines and coal cores in the San Juan River coal region, Colorado and northern New Mexico (CONT.).

Map No.	Mine or Well Name Location (Sec-T-R)	Formation; Bed(s) or Depth	Dry Basis VM %	Dry Basis FC %	Dry Basis Ash %	As Received Moist. %	As Received S. %	As Received Btu	Btu MMMF	FC DMMF %	App. Rank	FSI Carb. Info.	Source
	LA PLATA COUNTY (CONT.)												
113	San Juan 25-35N-10W	Menefee Peacock?	35.9	57.0	7.1	3.0	0.7	13,710	14,840	61.9	HvA		Q,U
114	Schutz 14-35N-7W	Menefee UC	33.2	42.8	24.0	2.5	1.7	10,890	14,640	58.1	HvA		CC,Q,(L)
115	Shamrock No. 2 13-35N-9W	Menefee UC	38.4	50.0	11.6	4.6	0.8	12,290	13,990	57.5	HvB		JJ,U,(CC)
	Fireglow	Menefee UC	32.9	59.3	7.7	1.7	0.7	13,830	15,110	64.9	HvA		AA,D
	Average		35.7	54.6	9.7	3.1	0.7	13,060	14,550	61.1	HvA		
116	Soda Spring 1-32N-12W	Fruitland UC	37.7	46.6	15.7	4.2	0.7	11,700	14,000	56.4	HvA		D,P,Q,(DD)
117	Supreme 28-35N-11W	Menefee UC	40.6	50.0	9.4	3.8	3.0	12,750	14,210	56.3	HvA		JJ,U
	Wright No. 1 & 2	Menefee Peacock	40.5	50.1	9.4	3.5	3.7	12,830	14,330	56.5	HvA	5.5, C	D,FF,JJ
	Average		40.5	50.1	9.4	3.7	3.4	12,790	14,270	56.5	HvA	5.5	
118	Triple "S" 13-35N-6W	Menefee UC	40.7	47.5	11.8	3.6	0.9	12,560	14,350	54.8	HvA		JJ,U
119	Victory No. 1 21,22-35N-10W	Menefee UC	39.2	54.7	6.1	2.6	1.2	13,870	14,860	58.9	HvA	6.0-7.0	JJ,U
	MONTEZUMA COUNTY												
120	Burnham 35-36N-13W	Menefee UC	42.4	51.4	6.2	8.1	0.6	12,360	13,190	55.5	HvB		Q
	Fielding-Spencer	Menefee Spencer	40.6	50.0	9.4	5.5	0.8	12,550	13,910	60.0	HvB		DD,Q
	Average		42.5	50.7	7.8	6.8	0.8	12,460	13,550	55.8	HvB		
121	Cortez 23-36N-16W	Dakota UC	35.1	49.5	15.4	8.1	0.6	10,440	12,340	59.8	HvC		CC,F,O,Q
122	Haller (old) 29-37N-13W	Dakota UC	31.8	54.6	13.6	1.5	1.0	--	--	64.3	-		W
123	Haller Prospect 30-37N-13W	Dakota UC	30.2	52.1	17.7	7.7	1.0	11,480	13,970	65.5	HvB		F,O,W
124	Hamilton Prospect 3-35N-18W	Dakota UC	22.8	63.6	13.6	7.7	0.5	10,860	12,570	75.1	HvC		F,O
125	Jackson 33-35N-16W	Menefee Spencer	47.4	46.1	6.5	12.8	0.5	11,360	12,110	50.5	HvC		O,Q
126	Mancos No. 2 36-36N-13W	Menefee UC	41.9	50.8	7.3	7.5	0.6	12,280	13,260	55.5	HvB		JJ,U,(DD,Q,W)
127	Montezuma No. 2 29-36N-15W	Dakota UC	33.0	55.0	12.0	5.5	0.6	12,390	14,130	63.5	HvA	1.0-1.5	JJ,U,(F)
	Montezuma	Dakota UC	34.3	60.5	5.2	4.7	0.6	13,500	14,290	64.4	HvA		CC,JJ,U(F)
	Average		33.7	57.8	8.6	5.1	0.6	12,950	14,210	64.1	HvA	1.0-1.5	
128	Mowry 35-36N-16W	Dakota UC	36.3	44.5	19.2	4.8	7.6	11,070	14,050	58.0	HvA		CC,F,O,Q
129	Prospect 21-36N-12W	Dakota UC	23.8	42.4	33.8	2.6	0.5	--	--	66.9	-		F,O

[illegible]30	Spencer 2-35N-13W	Menefee Spencer	41.2	54.0	4.8	7.0	0.6	12,940	13,620	57.4	HvB	DD,[illegible]
131	Spencer (Old) 3-35N-13W	Menefee Peacock	40.9	53.0	6.1	5.4	1.0	12,910	13,800	57.1	HvB	DD,Q
132	Test Hole No. 8 18-36N-14W	Dakota 74.3'-83.4'	19.8	32.1	48.1	3.5	0.5	6,810	13,810	67.2	HvB	CC,DD
133	Todd 25-35N-16W	Menefee Spencer	42.9	50.2	6.9	12.1	0.6	11,390	12,200	55.2	HvC	DD,(Q,P)
134	Todd (Old) 28-35N-14W	Menefee UC	39.7	52.2	8.2	20.9	0.4	--	--	60.3	-	W
135	Willden No. 2 7-35N-12W	Menefee UC	40.0	50.9	9.1	4.8	1.0	12,590	13,920	56.8	HvB	JJ,U,(P,Q)

NEW MEXICO (SAN JUAN COUNTY)

136	Barret No. 1 20-31N-9W	Fruitland 3230'-3255'	34.1	49.9	16.0	1.3	0.7	12,830	15,500	60.4	HvA	EE,L
137	Bill Thomas 22-32N-13W	Fruitland Carbonero	41.5	46.8	11.7	5.9	0.6	12,050	13,690	53.9	HvB	K
138	Case No. 9 8-31N-11W	Fruitland 2710'-2740'	41.0	47.9	11.1	1.7	0.7	13,350	15,180	54.5	HvA	EE,L
139	Castelone 12-31N-1W	Menefee UC	39.7	52.7	7.6	14.4	0.4	9,940	10,700	58.8	subB	K
140	Federal No. 1-31A 31-30N-13W	Fruitland 1070'-1080'	41.2	45.5	13.3	5.7	0.6	11,840	13,710	56.5	HvB	EE,L
141	Freeman No. 1-11 11-31N-13W	Fruitland 1776'-1782'	38.8	44.7	16.5	2.3	1.3	12,040	14,640	54.6	HvA	EE,L
142	Jones 21-32N-13W	Fruitland Carbonero	41.0	46.2	12.8	6.9	1.3	11,630	13,380	54.1	HvB	K
143	Kutz 10-31N-1W	Menefee UC	37.4	51.8	10.8	3.3	0.9	12,950	14,620	58.8	HvA	CC,K
144	Ludwig No. 20 29-30N-9W	Fruitland 2340'-2360'	33.9	40.9	25.2	2.3	0.7	10,800	14,760	56.4	HvA	E,L
	Ludwig No. 20	Fruitland 2505'-2515'	42.9	45.6	11.5	2.6	0.6	13,080	14,900	52.1	HvA	EE,L
	Average		38.4	43.1	18.4	2.5	0.7	11,890	14,830	53.9	HvA	
145	Lunt No. 62 18-30N-13W	Fruitland 1425'-1440'	41.6	45.9	12.5	2.8	0.6	12,390	14,270	53.1	HvA	EE,L
146	Marcelius 28-30N-15W	Fruitland UC	45.7	45.2	9.1	8.8	0.6	11,660	12,820	50.6	HvC	K
147	Milder (Banns-Bigg?) 8-31N-1W	Menefee UC	36.9	56.1	7.0	1.7	0.7	13,730	14,860	60.9	HvA	CC,(K)
148	Mitchell No. 1-5 5-31N-12W	Fruitland 2215'-3000'	40.4	48.5	11.1	2.4	0.5	13,000	14,750	55.1	HvA	EE,L
149	Moore No. 6 5-30N-8W	Fruitland 2800'-3028'	33.2	42.1	24.7	1.7	1.8	11,250	15,340	57.9	HvA	EE,L
150	New Mexico 22-32N-12W	Fruitland A	37.9	48.0	14.1	6.6	0.7	11,490	13,400	57.0	HvB	K
151	Old Sims 7-31N-1E	Menefee UC	40.0	54.3	5.7	7.2	0.7	12,160	12,910	58.2	HvC	CC,(K)
152	Prospect 16-30N-15W	Fruitland UC	41.2	44.8	14.0	9.6	2.4	10,530	12,270	53.9	HvC	K
153	Rosa Unit No. 41 5-31N-5W	Fruitland 3124'-3136'	23.8	50.9	25.3	1.6	0.7	11,550	15,830	70.1	HvA	EE,L
154	Ruby Jones No. 1 7-30N-11W	Fruitland 2020'-2030'	37.7	44.8	17.5	1.4	0.6	12,010	14,790	55.3	HvA	EE,L
155	S.J.U. 30-6 No. 37 10-30N-6W	Fruitland 3100'-3105'	24.5	50.1	25.4	1.5	0.7	11,310	15,530	69.2	HvA	EE,L
156	S.J.U. 32-50,No. 2-27 27-32N-6W	Fruitland 2811'-2830'	20.8	51.2	28.0	1.1	0.6	11,020	15,760	73.6	Mv	EE,L
157	Shiprock School 21-30N-16W	Menefee UC	44.4	51.0	4.6	10.1	0.9	12,010	12,600	54.4	HvC	K,(DD)

Appendix Table 2. Coal analyses data for representative mines and coal mines and coal cores in the San Juan River coal region, Colorado and northern New Mexico (CONT.).

Map No.	Mine or Well Name Location (Sec-T-R)	Formation; Bed(s) or Depth	Dry Basis VM %	 FC %	 Ash %	As Received Moist. %	 S. %	 Btu	Btu MMMF	FC DMMF %	App. Rank	FSI Carb. Info.	Source
					NEW MEXICO (CONT.)								
158	Sullivan No. 1 22-30N-12W	Fruitland 1713'-1742'	39.7	48.3	14.0	2.2	0.6	12,370	14,540	57.1	HvA		EE,L
159	Turner No. 3 28-30N-9W	Fruitland 2385'-2390'	40.5	46.2	13.3	1.5	2.2	12,960	15,180	54.3	HvA		EE,L
160	Western Coal Co. 25-31N-15W	Fruitland UC	--	--	18.5	11.3	0.9	9,670	--	--	-		DD
161	Western Coal Co. 35-31N-15W	Fruitland UC	--	--	16.6	10.9	1.1	11,690	--	--	-		DD
162	Western Fuel Co. 20-31N-1E	Menefee UC	39.4	50.3	10.3	3.9	3.5	12,740	14,380	57.3	HvA		CC,K
163	Wickens No. 1 24-32N-10W	Fruitland 3370'-3400'	24.8	45.5	29.7	1.5	0.7	10,690	15,650	67.2	HvA		EE,L
					MESA COUNTY (NUCLA-NATURITA FIELD)								
164	Grand Junction (No. 1) 26-1S-1W	Dakota UC	28.7	38.6	32.7	5.4	1.0	8,820	13,290	60.2	HvB		V,(LL)
165	No. 2 C 5-2S-1E	Dakota UC	35.3	50.0	14.7	3.4	1.4	11,780	13,960	59.7	HvB		V,(LL)
166	Wells Gulch (No. 5) 18-4S-3E	Dakota UC	36.2	51.8	12.0	3.3	1.4	12,190	13,990	59.8	HvB		V,(LL)
					MONTROSE COUNTY (NUCLA-NATURITA FIELD)								
167	Bed 3 NW31-47N-15W	Dakota 3	31.6	44.8	23.6	3.2	0.7	10,610	14,110	60.1	HvA		T
168	Independence SW31-47N-15W	Dakota Oberding	33.8	56.5	9.7	5.9	0.7	12,330	13,690	63.4	HvB	1.0	D,JJ,U,(Q)
169	Liberty Bell 13-46N-16W	Dakota No. 1	32.6	56.5	10.9	3.1	0.8	12,660	14,320	64.3	HvA		D,JJ,U,(Q)
170	Nucla Strip 25,26-47N-16W	Dakota UC	33.1	58.1	8.8	5.2	0.8	12,630	13,890	64.6	HvB	1.0	R, S

Appendix Table 3. Coal analyses data for representative mines and coal cores in the Uinta coal region, Colorado.

Map No.	Mine or Well Name Location (Sec-T-R)	Formation; Bed(s) or Depth	Dry Basis			As Received			Btu MMMF	FC DMMF %	App. Rank	FSI Carb. Info.	Source
			VM %	FC %	Ash %	Moist. %	S. %	Btu					
			DELTA COUNTY										
171	Black Diamond SW 11-13S-95W	L. Mesaverde Basal	38.2	52.4	9.4	13.1	0.6	10,880	11,950	59.5	HvC		D,U,JJ,(Q,FF)
172	Blue Ribbon NE 2-13S-91W	Mesaverde No. 1	40.9	55.0	4.1	6.4	0.5	12,930	13,490	57.9	HvB	1.0-1.5	D,M,U,JJ
173	Delta W SW 27-13S-92W	Mesaverde Burdick	37.4	49.1	13.5	12.0	0.7	10,390	11,940	58.5	HvC		D,M,U,(FF)
174	D.H. #CE-77-2 11-13S-95W	Mesaverde	(Unpublished results)										J
175	D.H. #CE-77-3 15-13S-94W	Mesaverde	(Unpublished results)										J
176	D.H. #Fairlamb 75-2 18-13S-95W	Mesaverde	(Unpublished results)										J
177	D.H. #W-1,2 12-13S-94W	Mesaverde	(Unpublished results)										J
178	Emmons (Farmers) 17-13S-91W	Mesaverde C	41.8	53.9	4.3	8.8	0.6	12,380	12,930	57.0	HvC	1.0-1.5	D,U,JJ,(Q,FF,GG)
179	Green Valley No. 1 SE 12-13S-95W	Mesaverde Green Valley	39.8	53.7	6.5	14.5	0.6	11,010	11,730	59.2	HvC		D,U,JJ,(Q)
180	Green Valley No. 2 E 12-13S-95W	Mesaverde Green Valley	38.7	54.2	7.1	14.2	0.7	11,000	11,790	60.2	HvC		D,U,JJ
181	Independent No. 2 13-13S-95W	Mesaverde Green Valley	40.3	48.6	11.1	13.9	0.6	10,500	11,730	56.6	HvC		D,U,JJ,(Q)
182	King 15-13S-91W	Mesaverde Brookside No. 1	41.6	53.0	5.4	3.9	0.5	13,300	14,110	56.4	HvA	3.0-5.0	D,M,U,JJ,(I,N,Q)
183	Orchard Valley 24-13S-92W	L. Mesaverde B											R
184	Owens 23-13S-93W	Mesaverde Degraffenried	39.4	55.9	4.7	16.0	0.4	10,760	11,240	60.6	HvC		D,Q
185	Raven 19-13S-95W	Mesaverde Rollins	38.6	48.9	12.5	14.2	0.6	10,170	11,500	57.9	HvC		D,U,JJ,(Q,FF)
186	Red Canon No. 1 SW 12-13S-95W	Mesaverde Rollins	39.9	53.4	6.7	14.5	0.7	11,000	11,730	59.0	HvC		U,JJ,(Q,FF)
187	Red Mountain 18-13S-94W	Mesaverde Basal	38.5	51.2	10.3	13.3	1.2	10,760	11,920	59.1	HvC		D,U,JJ
188	States W 18-13S-94W	Mesaverde Rollins	39.0	49.0	12.0	12.8	1.4	10,500	11,860	57.6	HvC	1.5	U,JJ,(Q)
	Top		39.7	54.1	6.2	14.6	0.6	11,030	11,710	59.4	HvC		D,U,JJ,(FF)
	Average		39.4	51.5	9.1	13.7	1.0	10,770	11,790	58.5	HvC		
189	Tomahawk 10,15,16-13S-95W	Mesaverde Green Valley Rollins #4, Basal	38.4	52.3	9.3	13.9	0.9	10,790	11,820	59.6	HvC		D,M,U,JJ,(Q)
			GARFIELD COUNTY										
190	Atlas No. 3 28-5S-91W	Williams Fork Allen	41.8	53.7	4.5	5.1	0.6	12,960	13,610	56.7	HvB	1.5	D,JJ,U
191	Black Raven 16-5S-92W	Williams Fork Wheeler	44.6	51.1	4.3	7.3	0.4	12,290	12,860	53.9	HvC		D,JJ,U
192	Carbonera NW14-7S-104W	Mt. Garfield Carbonera	40.0	49.4	10.6	1.4	0.6	11,150	12,420	56.7	HvC		D,Q,W
193	Coryell NE3-6-91	U. Mesaverde Allen	39.8	55.0	5.2	3.8	0.5	13,250	14,010	58.5	HvA		F,Q,W,(M)

Appendix Table 3. Coal analyses data for representative mines and coal cores in the Uinta coal region, Colorado (CONT.).

Map No.	Mine or Well Name Location (Sec-T-R)	Formation; Bed(s) or Depth	Dry Basins			As Received			Btu MMMF	FC DMMF %	App. Rank	FSI Carb. Info.	Source
			VM %	FC %	Ash %	Moist. %	S. %	Btu					
			GARFIELD COUNTY (CONT.)										
194	Diamond 8-7S-89W	L. Mesaverde Diamond	40.0	53.3	6.7	1.4	1.2	11,230	12,020	58.4	HvC		JJ,U
195	Eastside 23-5S-92W	U. Williams Fork E	41.3	52.3	6.4	4.7	0.6	12,580	13,480	56.3	HvB	1.0	D,R,S
196	Harvey Gap No. 2 19-5S-91W, 24-5S-92W	Iles F	39.3	50.0	10.7	3.8	2.1	12,290	13,880	57.0	HvB	1.0-1.5	D,JJ,M,U
197	Harvey Gap No. 3 24-5S-92W	U. Williams Fork UC	39.5	51.9	8.6	4.1	0.8	12,690	13,940	57.4	HvB	1.0-1.5	D,JJ,M,U
198	I.H.I. No. 2 16-5S-92W	Williams Fork Wheeler	41.2	50.1	8.7	7.8	0.6	11,680	12,800	55.4	HvC	1.0-1.5	D,JJ,U
199	Keystone SW35-5-91	U. Mesaverde Keystone No. 2	37.6	56.1	6.4	4.0	0.4	13,020	13,960	60.4	HvB		D,F,Q,W
200	Marion-Kilroy 10-8S-89W	U. Mesaverde Allen,Anderson, Sunshine	39.7	55.2	5.1	4.0	0.5	13,250	14,000	58.6	HvA	2.5	D,JJ,U,(Q,W)
201	Mascot 28-7-89	U. Mancos Cozzette	37.6	50.8	11.6	8.8	1.4	11,000	12,430	58.9	HvC		F,Q,W
202	McClane Canyon SW20-7S-102W		(No Analysis)										D,R
203	McLearn 12-5S-93W	L. Williams Fork McLearn	39.1	54.8	6.0	6.8	0.9	12,390	13,200	59.0	HvB		D,Q,W
204	Midland SW34-7S-89W	L. Mesaverde A,C,D	39.2	54.3	6.5	7.3	0.9	12,180	13,050	58.9	HvB		D,F,Q,W
205	Munger Canyon 27-7S-102W		(No Analysis)										D,R
206	New Castle No. 1 1-6S-91W	L. Mesaverde Wheeler,E,Allen	41.4	50.4	8.2	4.4	0.6	12,490	13,650	55.5	HvB	2.0-3.0	D,JJ,M,U,(Q)
	New Castle-Vulcan	L. Mesaverde Wheeler,E	41.7	50.0	8.3	5.0	0.7	12,430	13,600	55.2	HvB	1.0	D,U,(M,O,Q)
	Average		41.5	50.2	8.3	4.7	0.6	12,460	13,630	55.3	HvB	1.0-3.0	
207	New Castle No. 4 3-6S-91W	U. Mesaverde Allen	41.7	50.0	8.3	5.0	0.7	12,430	13,600	58.2	HvB		JJ
208	New South Canon NW14-6S-90W	L. Mesaverde Wheeler, E & F	40.5	54.6	4.9	8.6	0.5	12,090	12,720	57.8	HvC		D,JJ,U
	South Canon No. 1	L. Mesaverde D,Wheeler,E,Allen	41.9	51.4	6.7	6.7	0.6	12,220	13,120	55.8	HvB		D,JJ,M,U,(F,O,Q,W)
	Average		41.9	52.1	6.0	7.2	0.6	12,190	12,990	56.1	HvC		
209	North Canon NW12-5S-93W	L. Williams Fork UC	41.5	53.7	4.8	9.4	0.5	11,760	12,340	57.6	HvC	1.5-2.0	JJ,U,(Q)
	Big Three	L. Williams Fork UC	39.3	49.3	11.4	6.2	1.7	11,580	13,130	56.7	HvB		D,JJ,U
	Average		40.4	51.5	8.1	7.8	1.1	11,670	12,740	57.0	HvC	1.5-2.0	
210	Nu-Gap No. 3 NE24-5S-92W	Williams Fork Sunnyridge	41.4	50.1	8.5	4.0	0.4	12,350	13,560	54.7	HvB	1.0	S,(D,R)
211	Pocahontas 27-7S-89W	L. Mesaverde A,C,D	41.0	57.0	2.0	6.1	0.5	13,170	13,460	58.5	HvB		D,Q,W
212	Rauman 7-5S-92W	Williams Fork UC	40.3	52.4	7.3	6.1	0.8	12,270	13,280	57.3	HvB		D,Q
213	Rex 24-6S-90W	M. Mesaverde Wheeler,Allen	39.1	55.5	5.4	11.9	0.7	11,290	11,920	60.0	HvC		D,JJ,U
214	Rio Blanco 3-4S-94W	U. Mesaverde UC	38.1	52.6	9.3	16.4	0.5	10,150	11,090	60.4	HvC		JJ,U

[illegible]5	Stove Canon SW12-8S-102W	Mt. Garfield Palisade	39.3	51.9	8.8	8.3	0.8	12,020	13,190	57.9	HvB	1.5	JJ,[illegible])
216	Sunlight NW34-7S-89W	L. Mesaverde A,C,D	40.9	52.8	6.3	4.0	1.5	12,610	13,520	55.8	HvB	1.0	S,(FF,JJ,Q,U,W)
217	Sunny Ridge 24-5S-92W	Williams Fork Sunny Ridge	41.6	49.7	8.7	5.1	0.4	12,280	13,500	55.1	HvB	1.5	JJ,M,U,(Q)
218	Zemlock 15,14-6S-90W	Mesaverde E	37.5	53.4	9.1	8.4	0.9	11,440	12,580	60.0	HvC		D,JJ,U

GUNNISON COUNTY

219	(No Name) SE28, NE33-13S-86W	Mesaverde	10.3	82.6	7.1	1.1	0.8	13,950	15,040	89.7	sa		Y
220	Alpine 7,17,18-15S-86W	Mesaverde L. Baldwin No. 2	40.9	53.4	5.7	11.9	0.7	11,550	12,220	57.9	HvC		D,JJ,U,(Q,W)
221	Baldwin 7,8-15S-86W	Mesaverde No. 2	41.2	52.6	6.2	11.2	0.7	11,540	12,280	56.3	HvC		D,JJ,U
222	Baldwin Star 17,18-15S-86W	Mesaverde No. 2	42.1	51.7	6.1	12.5	1.1	11,330	12,050	56.4	HvC		D,JJ,U,(FF)
223	Bear 9-13S-90W	Mesaverde Bear "C"	37.7	56.4	5.9	4.5	0.5	13,020	13,890	60.5	HvB	1.5	S,(D,FF,GG,JJ,M,U)
224	Buckley No. 2 14-14S-86W	Mesaverde No. 2	41.5	53.0	5.5	4.3	0.5	13,010	13,810	56.5	HvB		D,JJ,U
225	Bulkley 11-14S-86W	Mesaverde No. 3,4	37.2	57.5	5.3	9.4	0.4	12,200	12,880	61.5	HvC		D,Q,W
226	Crested Butte 3-14S-86W	L. Mesaverde No. 2	38.9	55.8	5.3	3.5	0.5	13,350	14,140	59.3	HvA	C	JJ,U(Y,D,N,Q,V)
227	D.H. #3-4 4-14S-90W	Mesaverde E (445')	43.2	52.1	4.7	7.3	0.4	12,330	12,950	55.2	HvC	C	GG
228	D.H. #4-10 10-14S-90W	Mesaverde E	42.9	52.2	4.9	8.4	0.5	12,250	12,890	55.5	HvC	C	GG
229	D.H. #5-33 33-13S-90W	Mesaverde E (395')	43.7	51.5	4.8	10.3	0.4	11,940	12,540	55.0	HvC	C	AA,GG,KK
	D.H. #1-33	Mesaverde E (408')	43.5	52.4	4.1	9.5	0.4	12,250	12,770	55.3	HvC	C	GG
	D.H. #2-33	Mesaverde E (354')	42.7	53.1	4.2	9.9	0.4	12,160	12,690	56.2	HvC	C	GG
	Average		43.3	52.3	4.4	9.9	0.4	12,120	12,670	55.6	HvC		
230	D.H. #6-16 16-13S-89W	L. Mesaverde Lower	39.4	53.0	7.6	2.8	0.5	13,320	14,490	57.8	HvA		II,KK
231	D.H. #8-9 9-13S-89W	L. Mesaverde Lower	39.2	52.7	8.1	2.3	0.6	13,350	14,630	57.9	HvA	C	BB,II
	D.H. #11-9	L. Mesaverde Lower	40.4	51.0	8.6	2.3	0.7	13,220	14,560	58.2	HvA		II
	Average		39.8	51.9	8.3	2.3	0.7	13,290	14,600	57.1	HvA		
232	D.H. #12-10 10-13S-89W	L. Mesaverde Lower	37.7	54.6	7.7	1.9	0.5	13,670	14,910	59.6	HvA		II
233	D.H. #13-11 11-13S-89W	L. Mesaverde Lower	39.0	54.9	6.1	1.8	0.6	13,940	14,930	58.9	HvA		II
234	D.H. #15-22 22-13S-89W	L. Mesaverde Lower	40.4	54.2	5.4	2.8	0.4	13,700	14,530	57.6	HvA		II
235	D.H. #17-23 23-13S-89W	L. Mesaverde Lower	39.0	54.0	7.0	2.7	0.8	13,480	14,570	58.6	HvA		II
	D.H. #21-23	L. Mesaverde Lower	41.1	54.0	4.9	2.8	0.6	13,930	14,710	57.2	HvA		II
	Average		40.0	54.0	4.9	2.8	0.7	13,700	14,470	57.2	HvA		
236	D.H. #18-21 21-13S-89W	L. Mesaverde Lower	40.3	52.5	7.2	2.7	0.7	13,380	14,500	57.1	HvA		II

Appendix Table 3. Coal analyses data for representative mines and coal cores in the Uinta coal region, Colorado (CONT.).

Map No.	Mine or Well Name Location (Sec-T-R)	Formation; Bed(s) or Depth	Dry Basis			As Received			Btu MMMF	FC DMMF %	App. Rank	FSI Carb. Info	Source
			VM %	FC %	Ash %	Moist. %	S. %	Btu					
	GUNNISON COUNTY (CONT.)												
237	D.H. #20-15 15-13S-89W	L. Mesaverde Lower	39.5	54.2	6.3	2.5	0.4	13,770	14,780	58.3	HvA		II
238	D.H. #23-4 14-13S-89W	L. Mesaverde Lower	38.5	46.8	14.7	2.2	1.2	12,610	14,990	55.9	HvA		II
239	D.H. #24-7 7-13S-89W	L. Mesaverde Lower	39.1	43.0	17.9	2.7	0.7	11,750	14,490	53.5	HvA		II
240	D.H. #25-14 14-13S-89W	L. Mesaverde Lower	38.5	55.4	6.1	2.1	0.6	13,750	14,720	59.5	HvA		II
241	D.H. #27-3 3-13S-89W	L. Mesaverde Lower	40.1	53.0	6.9	1.8	0.8	13,760	14,880	57.5	HvA		II
242	Edwards NE17-13S-90W	Mesaverde B & C	40.2	52.2	7.6	5.6	0.5	12,610	13,680	57.1	HvB	1.5-3.0	J,M,U,(FF)
243	Elk Mountain SW34-13S-86W	Mesaverde Lakeshore	9.8	84.7	5.5	2.8	0.7	14,230	15,140	90.3	sa		Q
244	Ferguson 12-13S-90W	Mesaverde UC	37.4	58.2	4.4	7.3	0.5	12,620	13,220	61.5	HvB		Q
245	Genter 20-11S-88W	U. Mesaverde UC	7.9	85.1	7.0	2.3	0.6	13,960	15,110	90.6	sa		D,Q
246	Hawk's Nest 11,12-13S-90W	Paonia Mesaverde E	41.0	54.1	4.9	5.3	0.5	13,100	13,800	57.4	HvB	1.5-4.0	JJ,I,U,(FF,Q,V,W)
247	Hawk's Nest East 11-13S-90W	Paonia Mesaverde E	39.8	56.7	3.4	4.3	0.6	13,070	13,500	59.1	HvB	3.5	Y,(U)
248	Hawk's Nest West[No. 3] 12-13S-90W	Mesaverde F	38.3	56.3	5.4	5.1	0.6	13,070	13,840	60.1	HvB	1.0-2.0, C	KK,S,(AA,GG)
249	Hinkle NE36-15S-87W	Mesaverde UC	40.1	51.5	8.4	18.5	1.1	10,150	10,960	59.0	subA		D,JJ
250	Mosely's Prospect[#70] 9-15S-89W	Mesaverde UC	14.2	80.5	5.3	3.3	0.7	13,990	14,830	85.7	sa		D,V,Q,W
251	Nu-Mine No. 1 9,16-15S-86W	L. Mesaverde Kubler	41.2	52.3	6.5	10.5	0.6	11,650	12,440	57.0	HvC		D,JJ,U,(FF)
252	Nu-Mine No. 2 5-15S-86W	Mesaverde No. 2, Kubler	39.3	53.6	7.1	8.9	0.4	11,880	12,790	58.6	HvC		JJ,U
253	Ohio Creek No. 1 15-15S-86W	L. Mesaverde Kubler	44.9	50.1	5.0	9.7	0.6	11,920	12,540	53.6	HvC		D,JJ,U,(Q)
254	Ohio Creek No. 2 16-15S-86W	L. Mesaverde Kubler	41.2	53.0	5.8	10.4	0.6	11,800	12,510	57.3	HvC		D,JJ,U
255	Oliver No. 2 SE10-13S-90W	Mesaverde E	40.3	52.3	7.4	6.0	0.5	12,500	13,540	57.1	HvB	1.5-2.0	D,JJ,U,(FF,M)
256	Oliver No. 3 SE10-13S-90W	Mesaverde D,E	41.2	54.4	4.4	6.5	0.5	12,910	13,520	57.5	HvB	1.5, C	D,JJ,U,(M)
	Oliver No. 1		40.5	52.8	6.7	5.4	0.6	12,810	13,760	57.2	HvB	C	AA,GG,JJ,KK,U,(Q)
	Average		40.8	53.6	5.6	6.0	0.6	12,860	13,640	57.3	HvB	1.5-2.0	
257	Peanut 28-13S-86W	Mesaverde UC	(Results not yet received)										D,R
	Horace	Mesaverde Cheyenne	2.2	84.5	8.9	6.2	0.7	13,750	15,150	94.2	an		D,JJ,(Q)
	Average		2.2	84.5	8.9	6.2	0.7	13,750	15,150	94.2	an		
258	Prospect No. 64B 27-14S-89W	Mesaverde	39.2	56.3	4.5	6.1	1.0	12,170	12,770	59.6	HvC		V
259	Prospect No. 66 34-14S-89W	Mesaverde	38.4	57.3	4.3	9.4	0.5	12,080	12,620	60.8	HvC		V

26	Richardson 32-14S-86W	Mesaverde Kubler	36.4	57.3	6.3	2.3	0.5	13,510	14,500	61.6	HvA		D,JJ,U,(
261	Ruby-Anthracite 16-14S-87W	Mesaverde	6.9	84.0	9.1	1.0	1.0	13,750	15,210	93.6	an	C	Y,(D,V,Q,W)
262	Smith (Hill) 17-13S-86W	Mesaverde No. 2 & 3	9.8	85.4	4.8	1.2	0.7	14,160	14,940	90.3	sa	C	Y
263	Somerset 7,8-13S-90W	Mesaverde Somerset B,C	39.0	53.5	7.5	3.2	0.6	13,130	14,270	58.4	HvA	1.5-4.0	D,S,(FF,JJ,N,O,Q,U,Y)

MESA COUNTY

264	Blue Flame SE2-11S-98W	M. Mesaverde Cameo	38.9	49.9	11.2	8.2	0.8	11,540	13,000	57.3	HvB	1.0-1.5	D,JJ,U
265	Book Cliff SW8-10S-99W	Mt. Garfield Cameo	38.7	50.2	11.1	11.4	0.8	11,100	12,430	58.1	HvC		D,Q,W
266	Cameo 27,28,33,34-10S-98W	Mt. Garfield Cameo	38.0	51.2	10.8	6.6	0.6	11,900	13,370	58.3	HvB	1.0-1.5	D,JJ,M,U,(FF,N,Q,W)
267	Coal Gulch SW18-8S-101W	L. Mt. Garfield Corcoran	39.2	47.9	12.9	9.4	1.9	11,240	12,910	56.6	HvC		D,JJ
268	Farmers Mutual 1 & 2 36-9S-100W	L. Mt. Garfield Cameo	38.8	53.2	8.0	7.6	0.7	12,200	13,270	58.7	HvB		D,JJ,U
269	Farmers Nearing 29,30-8S-101W	L. Mt. Garfield Cameo	41.1	57.5	7.4	9.2	1.3	12,100	13,070	56.8	HvB	1.5-2.5	D,JJ,U,(Q)
270	Garfield SE5,6-11S-98W	L. Mesaverde Palisade	38.5	50.3	11.2	10.6	0.8	11,130	12,490	58.1	HvC		JJ,U,(Q)
271	Gearhart NW6-11S-98W	L. Mesaverde Palisade	39.7	51.0	9.3	10.0	0.8	11,480	12,640	57.5	HvC	1.0-1.5	JJ,U,(Q)
272	Grasso Mutual SW36-9S-100W	L. Mt. Garfield Palisade	39.0	50.3	10.7	6.1	1.3	11,940	13,410	57.4	HvB	1.5	D,JJ,U,(Q)
273	Hidden Treasure SW5-9S-100W	L. Mt. Garfield Palisade	39.9	53.2	6.9	7.7	0.6	12,460	13,400	58.0	HvB	1.0-2.0	D,JJ,U,(FF)
274	Hunter SW5-9S-100W	U. Mt. Garfield Cameo	38.4	49.9	11.7	8.0	0.7	11,470	13,000	57.3	HvB	1.0-1.5	D,JJ,U,(Q,W)
275	Hy-Grade NW8-9S-100W	U. Mt. Garfield Palisade	39.5	51.9	8.6	8.5	0.6	12,040	13,000	57.6	HvB	1.0-1.5	JJ,U,(FF)
276	Kiel (Gross) 27-8S-101W	Mesaverde Cameo	39.2	54.5	6.3	9.4	1.0	12,260	13,090	59.2	HvB		Q
277	McGinley SE5-9S-100W	U. Mt. Garfield Cameo	38.7	51.5	9.8	8.5	0.6	11,740	13,020	57.8	HvB	1.0-2.0	D,JJ,M,U,(Q)
278	Midwest Red Arrow NW11-11S-98W	L. Mesaverde Palisade	39.8	52.8	7.4	7.3	1.7	12,330	13,360	58.0	HvB		D,JJ,M,U,(Q)
279	Monarch NW7-10S-99W	Mt. Garfield Palisade	38.7	45.3	16.0	9.1	0.8	10,750	12,770	55.5	HvC		D,JJ,(FF)
280	Nugent 29-8S-101W	Mesaverde Lower Mesa	39.1	55.3	5.6	9.7	1.3	12,260	13,000	59.7	HvB		Q,W
281	Palisade SE4-11S-98W	L. Mesaverde Palisade	40.0	50.7	9.3	7.8	0.9	12,000	13,240	56.9	HvB	C	JJ,KK,M,U,(FF,Q,V)
282	Peacock SE6-10S-99W	Mt. Garfield Cameo	40.3	52.4	7.3	9.5	0.7	12,050	12,990	57.5	HvC		D,Q
283	Riverside Farmers 3-11S-98W	L. Mesaverde Palisade	39.2	48.4	12.4	6.6	1.3	11,670	13,370	56.4	HvB		D,JJ,U,(FF,Q)
284	Roadside SE34-10S-98W	Mt. Garfield Cameo	37.5	50.0	12.5	5.5	0.6	11,650	13,370	58.1	HvB		S,(D,FF,JJ,Q,U,W)
285	Service SE10-1N-1E	Mt. Garfield Palisade	39.1	51.9	9.0	7.0	0.7	11,790	12,980	57.9	HvC		D,Q
286	Thomas SE35-9S-100W	L. Mt. Garfield Palisade	40.0	51.7	8.3	9.6	0.7	11,820	12,880	57.6	HvC		D,JJ,U
287	Williams NW7-10S-99W	Mt. Garfield Palisade	40.4	52.5	7.1	7.9	0.7	12,240	13,180	57.3	HvB		D,Q
288	Winger NWNE2-11S-98W	M. Mesaverde Cameo	39.1	49.7	11.2	7.2	0.8	11,730	13,230	57.0	HvB		D,JJ,U,(FF)

Appendix Table 3. Coal analyses data for representative mines and coal cores in the Uinta coal region, Colorado (CONT.).

Map No.	Mine or Well Name Location (Sec-T-R)	Formation; Bed(s) or Depth	Dry Basis			As-Received			Btu MMMF	FC DMMF %	App. Rank	FSI Carb. Info	Source
			VM %	FC %	Ash %	Moist. %	S. %	Btu %					
	MOFFAT COUNTY.												
289	Colowyo 2,3,4,9-3N-93W	Williams Fork X,Y,A-F	39.5	55.1	5.4	14.4	0.4	10,860	11,430	59.9	subA		R,S
290	James SW 15-3N-93W	Williams Fork Collum	45.4	50.2	4.4	11.4	0.5	11,360	11,870	53.5	HvC		D,F
	PITKIN COUNTY												
291	Aspen Gulch 15,27-8S-89W	L. Mesaverde A,B	38.1	53.6	8.3	3.3	0.5	13,030	14,270	59.0	HvA	3.0	D,JJ,U
292	Bear Creek SE21-10S-89W	L. Mesaverde B	25.3	70.1	4.6	4.0	0.5	14,680	15,430	74.0	Mv		JJ,M,U
293	Coal Basin SW5,6-10S-89W	L. Mesaverde B	23.1	67.2	9.7	4.2	0.7	13,600	15,150	75.4	Mv	9.0C	A,X,S,(D,JJ,M,Q,U,W)
294	Coryell 6-11S-88W	L. Mesaverde UC	31.2	63.7	5.1	2.3	0.6	14,350	15,190	67.6	HvA		Q
295	Dutch Creek No. 1 SE17-10S-89W	L. Mesaverde B	23.0	68.7	8.3	4.0	0.7	13,940	15,280	75.8	Mv	9.0	D,JJ,U,(M)
296	Dutch Creek No. 2 SW17-10S-89W	L. Mesaverde Dutch Creek	24.8	68.4	6.7	1.4	0.6	14,480	15,620	73.8	Mv	9.0 C	Y,(D,M,U)
297	L.S. Wood 8-10S-89W	L. Mesaverde B	22.6	69.6	7.8	3.0	0.8	14,520	15,840	76.4	Mv		D,S,(U)
298	Spring Gulch 22-8S-89W	U. & L. Mesaverde A, B, C, Allen, Anderson, Sunshine	34.9	57.7	7.4	3.2	0.6	13,610	14,770	62.9	HvA		D,Q,W,(U)
299	Thompson Creek No. 1 34,35-8S-89W	U. & L. Mesaverde A,B	30.5	57.6	12.0	3.6	1.0	13,090	14,990	66.5	HvA	7.0-9.0	JJ,M,U
300	Thompson Creek No. 2 NW35-8S-89W	L. Mesaverde A,B	29.5	58.2	12.3	3.1	1.1	13,220	15,210	67.4	HvA	8.0	JJ,M,U
301	Thompson Creek No. 3 34-8S-89W	U. Mesaverde Sunshine	33.7	58.4	7.9	3.0	0.7	13,750	15,020	64.1	HvA	7.0-8.0	JJ,M,U
	RIO BLANCO COUNTY												
302	Black Diamond NW15-1N-94W	U. Iles Sulfur Creek	41.8	49.2	9.0	10.8	0.5	11,220	12,290	55.3	HvC		D,F,O,Q,W
303	Blue Streak NW33-3N-93W	Williams Fork UC	41.7	51.2	7.1	12.6	0.7	11,140	11,950	56.6	HvC	C	JJ,U
304	Fairfield SW28-1N-94W	Iles Fairfield	43.3	49.7	7.0	11.0	0.9	11,370	12,200	54.7	HvC		Q,W
305	Foreman SW10-2N-93W	Williams Fork UC	38.3	55.3	6.4	13.5	0.9	10,930	11,630	60.1	HvC		Q
306	Meeker 22,28-1N-94W	U. Iles Old Pollard	41.1	52.2	6.7	12.7	0.4	11,390	12,160	57.3	HvC		D,O,Q
307	Montgomery NW29-1N-94W	Williams Fork Montgomery	44.1	48.9	7.0	12.4	0.7	10,790	11,560	53.9	HvC		D,F,O,Q
308	Pollard 15,21,22-1N-94W	U. Iles Old Pollard	37.6	56.4	6.0	12.1	0.5	11,580	12,290	61.3	HvC		L,Q
309	Rienau No. 1 SE29-2N-93W	Williams Fork Rienau	42.8	52.6	4.6	13.1	0.6	11,450	11,970	56.4	HvC		JJ,U
310	Sulfur Creek 3-1N-94W	U. Iles Sulfur Creek	37.6	54.8	7.6	11.9	0.5	11,340	12,230	60.8	HvC		D,Q,W

311	Wesson 30-2N-92W	Williams Fork Wesson	44.9	48.1	7.0	14.4	0.8	10,600	11,350	53.3	subA	D,F,O,Q
[illegible]2	White River NW11-2N-101W	U. Mesaverde UC	39.2	53.0	7.8	10.5	0.4	11,160	12,080	58.7	HvC	JJ,M,[illegible]
313	Wilson 29-3N-92W	Williams Fork UC	38.0	50.8	11.2	10.8	0.5	--	--	57.9	___	D,O,Q

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COLORADO GEOLOGICAL SURVEY

RESOURCE SERIES 7

COAL RESOURCE EVALUATION MAPS OF THE RATON MESA COAL REGION, SOUTH-CENTRAL COLORADO

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DEPARTMENT OF NATURAL RESOURCES
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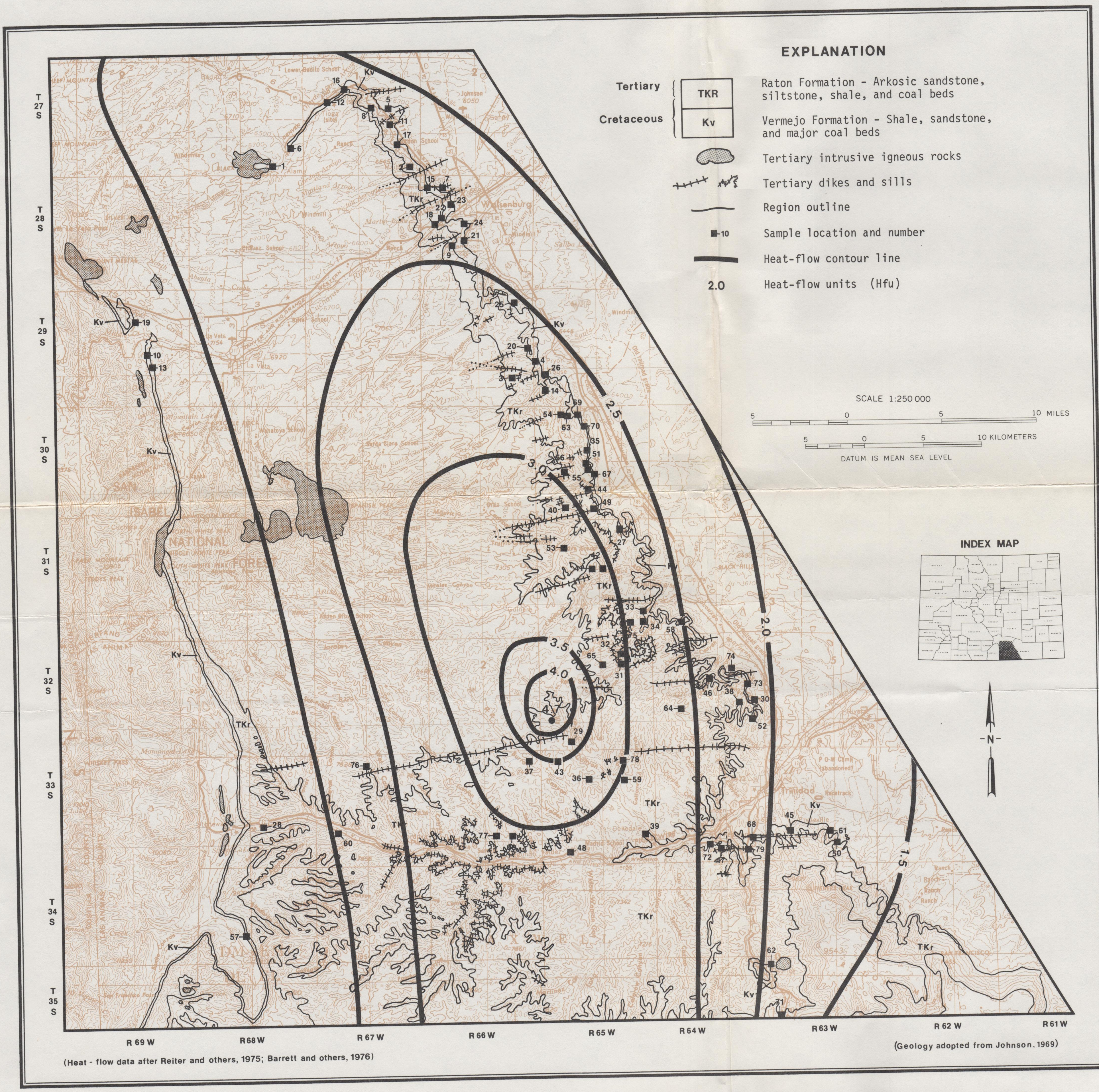
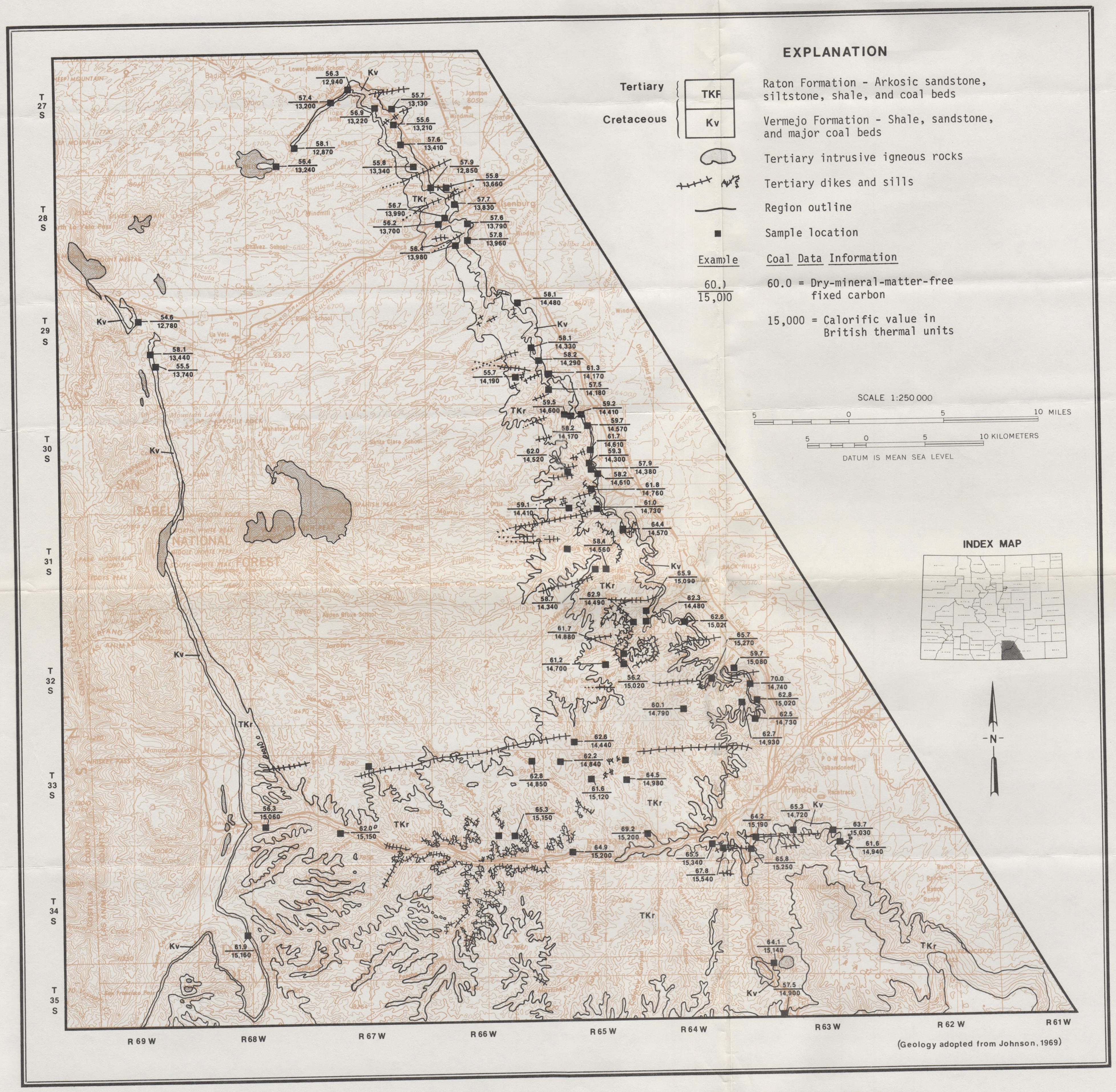
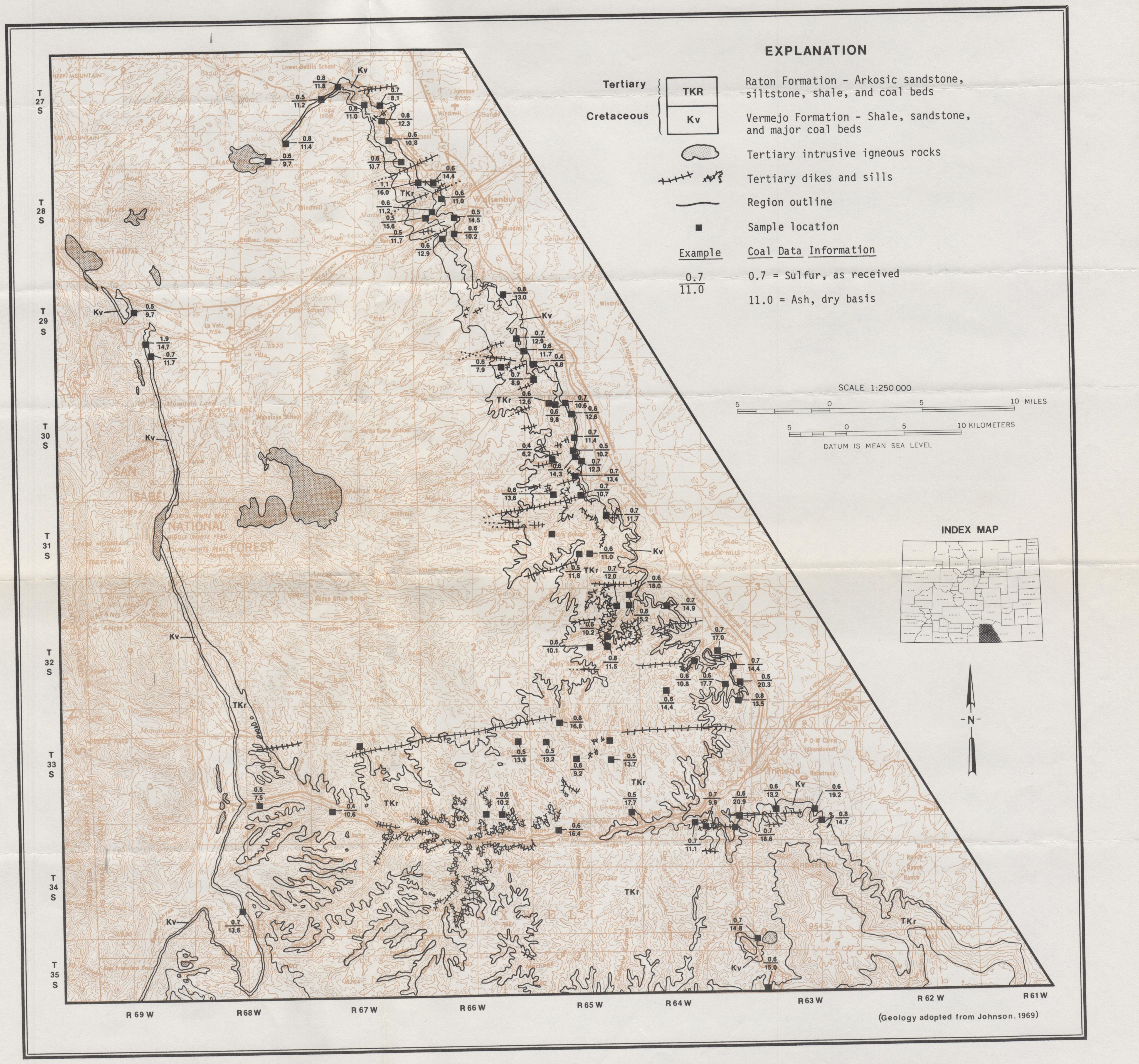


MAP A - COAL SAMPLE LOCATION AND HEAT FLOW MAP OF THE RATON MESA COAL REGION



MAP B - COAL RANK MAP OF THE RATON MESA COAL REGION



MAP C - COAL SULFUR AND ASH MAP OF THE RATON MESA COAL REGION

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RESOURCE SERIES 7

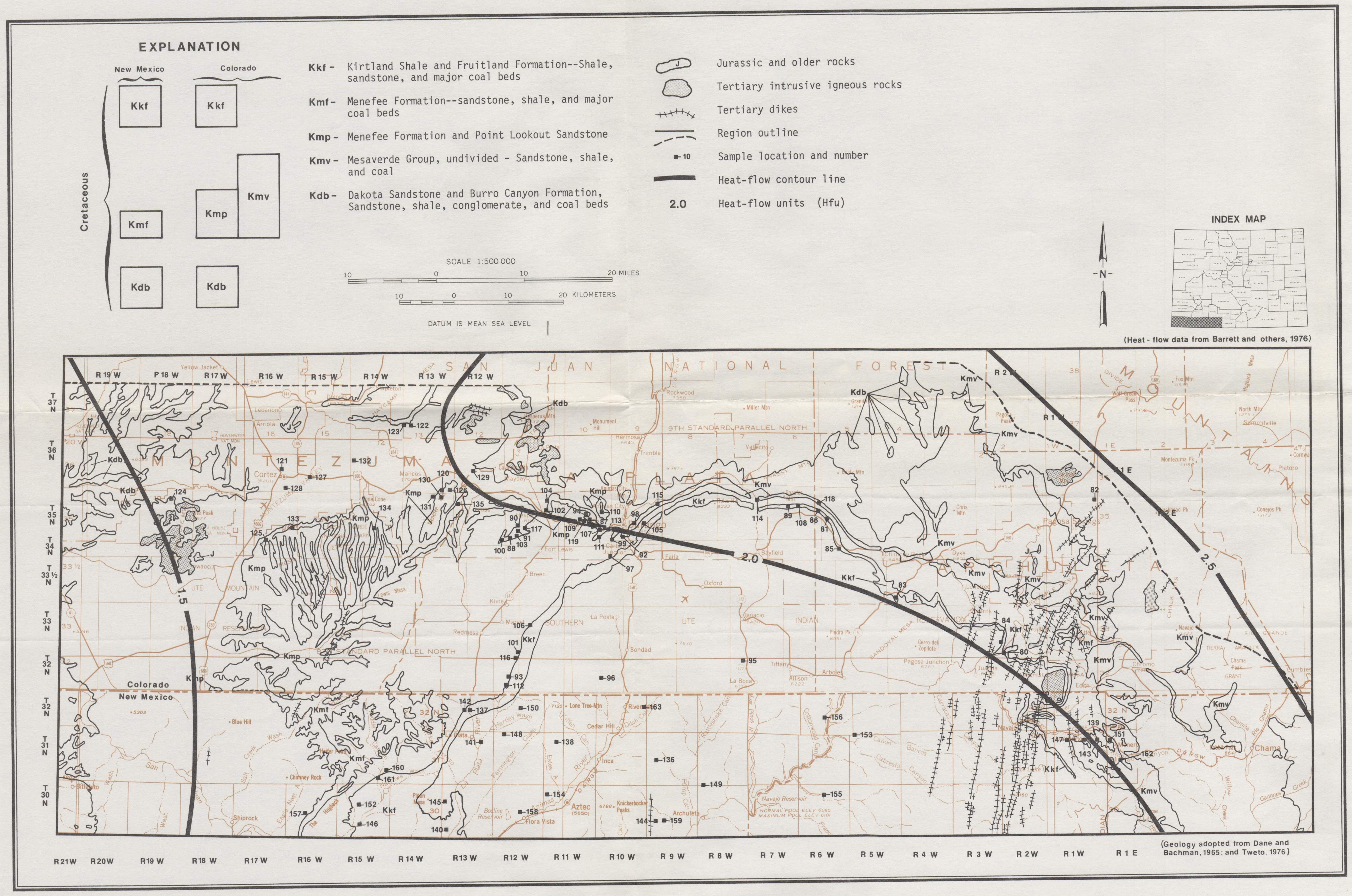
COAL RESOURCE EVALUATION MAPS OF THE SAN JUAN RIVER COAL REGION, SOUTHWESTERN COLORADO AND NORTHWESTERN NEW MEXICO

Compiled by

S. M. GOOLSBY, N. S. READE, and D. K. MURRAY

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
DENVER, COLORADO
1979

Drafted by
M. V. PERSICHETTI
S. J. SOUKUP



EXPLANATION

New Mexico — Colorado

Cretaceous

Kkf - Kirtland Shale and Fruitland Formation--Shale, sandstone, and major coal beds

Kmf - Menefee Formation--sandstone, shale, and major coal beds

Kmp - Menefee Formation and Point Lookout Sandstone

Kmv - Mesaverde Group, undivided - Sandstone, shale, and coal

Kdb - Dakota Sandstone and Burro Canyon Formation, Sandstone, shale, conglomerate, and coal beds

Jurassic and older rocks

Tertiary intrusive igneous rocks

Tertiary dikes

Region outline

■-10 Sample location and number

Heat-flow contour line

2.0 Heat-flow units (Hfu)

SCALE 1:500 000

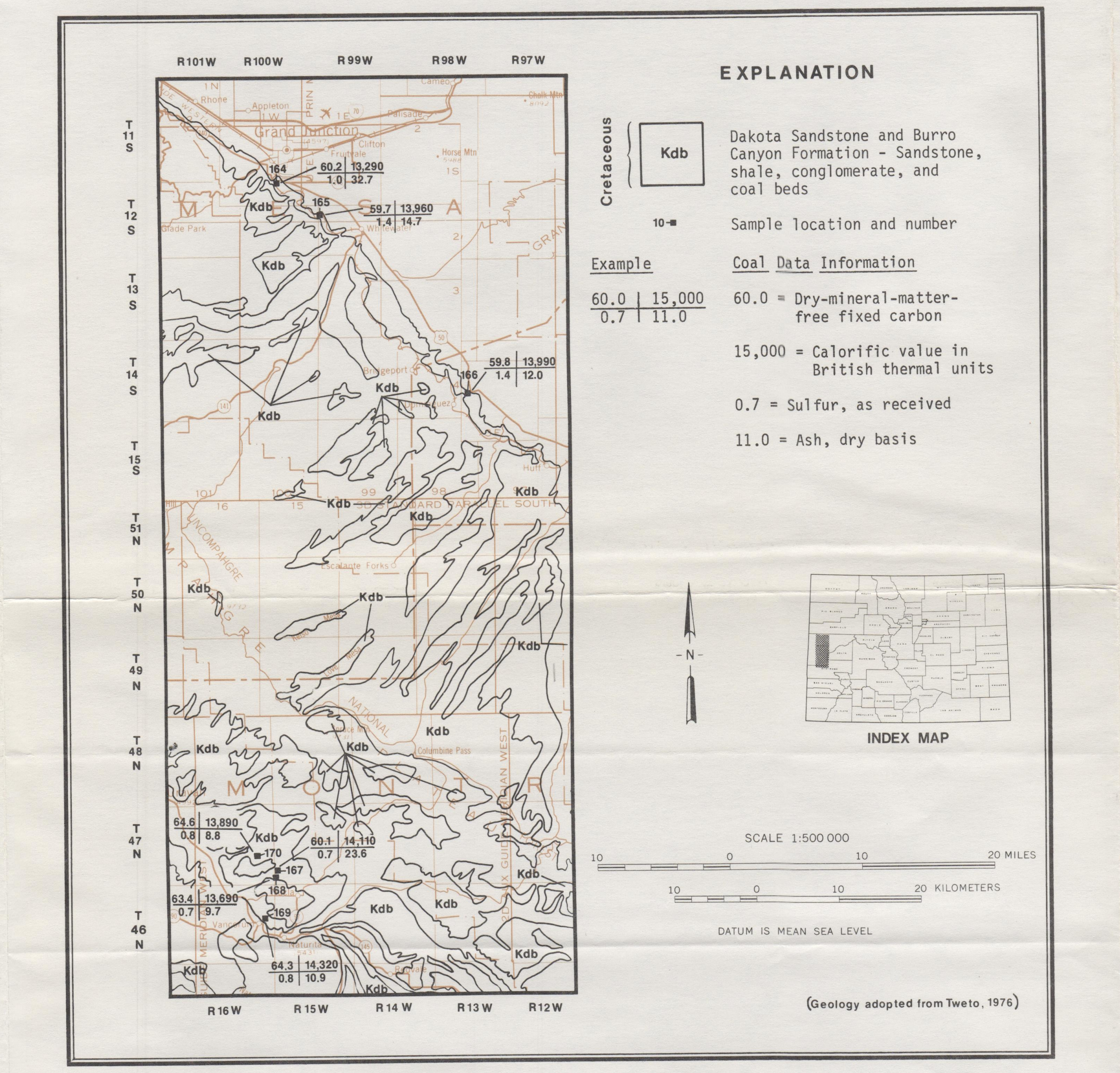
DATUM IS MEAN SEA LEVEL

INDEX MAP

(Heat - flow data from Barrett and others, 1976)

(Geology adopted from Dane and Bachman, 1965; and Tweto, 1976)

MAP A - COAL SAMPLE LOCATION AND HEAT FLOW MAP OF THE SAN JUAN RIVER COAL REGION



EXPLANATION

Cretaceous

Kdb - Dakota Sandstone and Burro Canyon Formation - Sandstone, shale, conglomerate, and coal beds

10-■ Sample location and number

Example	Coal Data Information
60.0 | 15,000 0.7 | 11.0	60.0 = Dry-mineral-matter-free fixed carbon 15,000 = Calorific value in British thermal units 0.7 = Sulfur, as received 11.0 = Ash, dry basis

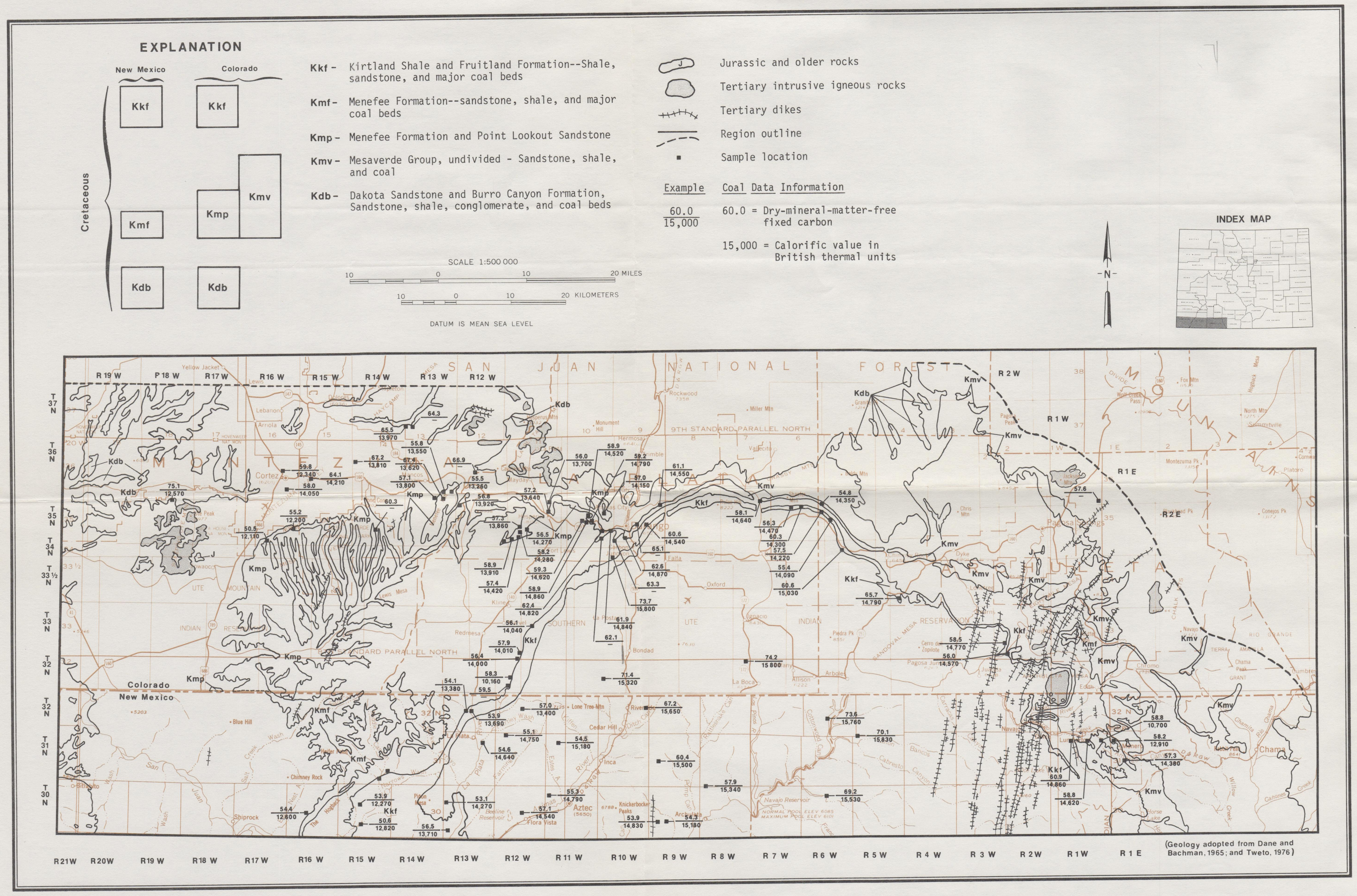
INDEX MAP

SCALE 1:500 000

DATUM IS MEAN SEA LEVEL

(Geology adopted from Tweto, 1976)

MAP D - COAL RESOURCE EVALUATION MAP OF THE NUCLA-NATURITA COAL AREA



EXPLANATION

New Mexico — Colorado

Cretaceous

Kkf - Kirtland Shale and Fruitland Formation--Shale, sandstone, and major coal beds

Kmf - Menefee Formation--sandstone, shale, and major coal beds

Kmp - Menefee Formation and Point Lookout Sandstone

Kmv - Mesaverde Group, undivided - Sandstone, shale, and coal

Kdb - Dakota Sandstone and Burro Canyon Formation, Sandstone, shale, conglomerate, and coal beds

Jurassic and older rocks

Tertiary intrusive igneous rocks

Tertiary dikes

Region outline

■ Sample location

Example	Coal Data Information
60.0 15,000	60.0 = Dry-mineral-matter-free fixed carbon 15,000 = Calorific value in British thermal units

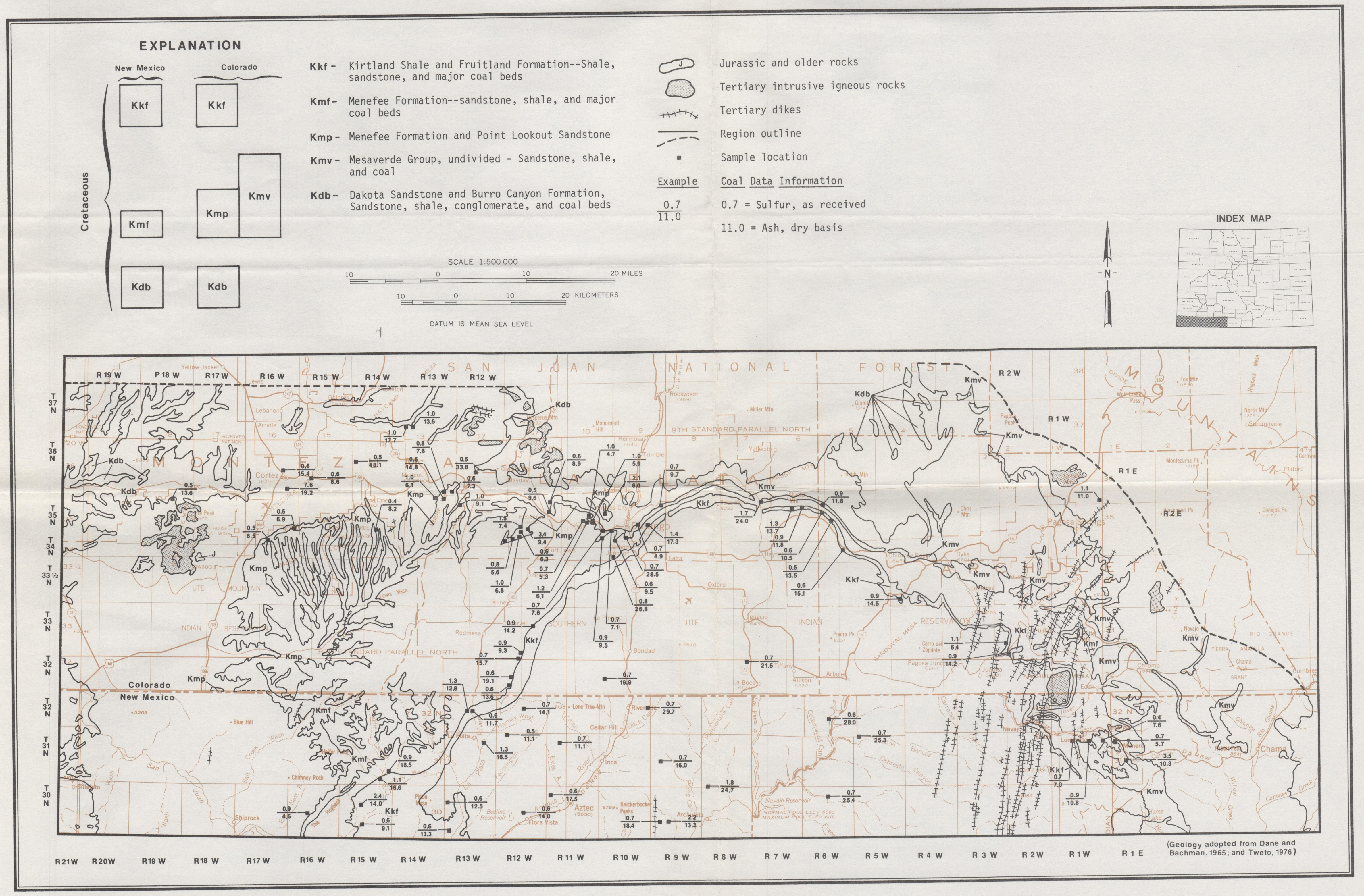
SCALE 1:500 000

DATUM IS MEAN SEA LEVEL

INDEX MAP

(Geology adopted from Dane and Bachman, 1965; and Tweto, 1976)

MAP B - COAL RANK MAP OF THE SAN JUAN RIVER COAL REGION



EXPLANATION

New Mexico — Colorado

Cretaceous

Kkf - Kirtland Shale and Fruitland Formation--Shale, sandstone, and major coal beds

Kmf - Menefee Formation--sandstone, shale, and major coal beds

Kmp - Menefee Formation and Point Lookout Sandstone

Kmv - Mesaverde Group, undivided - Sandstone, shale, and coal

Kdb - Dakota Sandstone and Burro Canyon Formation, Sandstone, shale, conglomerate, and coal beds

Jurassic and older rocks

Tertiary intrusive igneous rocks

Tertiary dikes

Region outline

■ Sample location

Example	Coal Data Information
0.7 11.0	0.7 = Sulfur, as received 11.0 = Ash, dry basis

SCALE 1:500 000

INDEX MAP

(Geology adopted from Dane and Bachman, 1965; and Tweto, 1976)

MAP C - COAL SULFUR AND ASH MAP OF THE SAN JUAN RIVER COAL REGION

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COLORADO GEOLOGICAL SURVEY

RESOURCE SERIES 7

COAL RESOURCE EVALUATION MAPS OF THE UINTA COAL REGION, NORTHWESTERN COLORADO

Compiled by

S. M. GOOLSBY, N. S. READE, and D. K. MURRAY

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
DENVER, COLORADO
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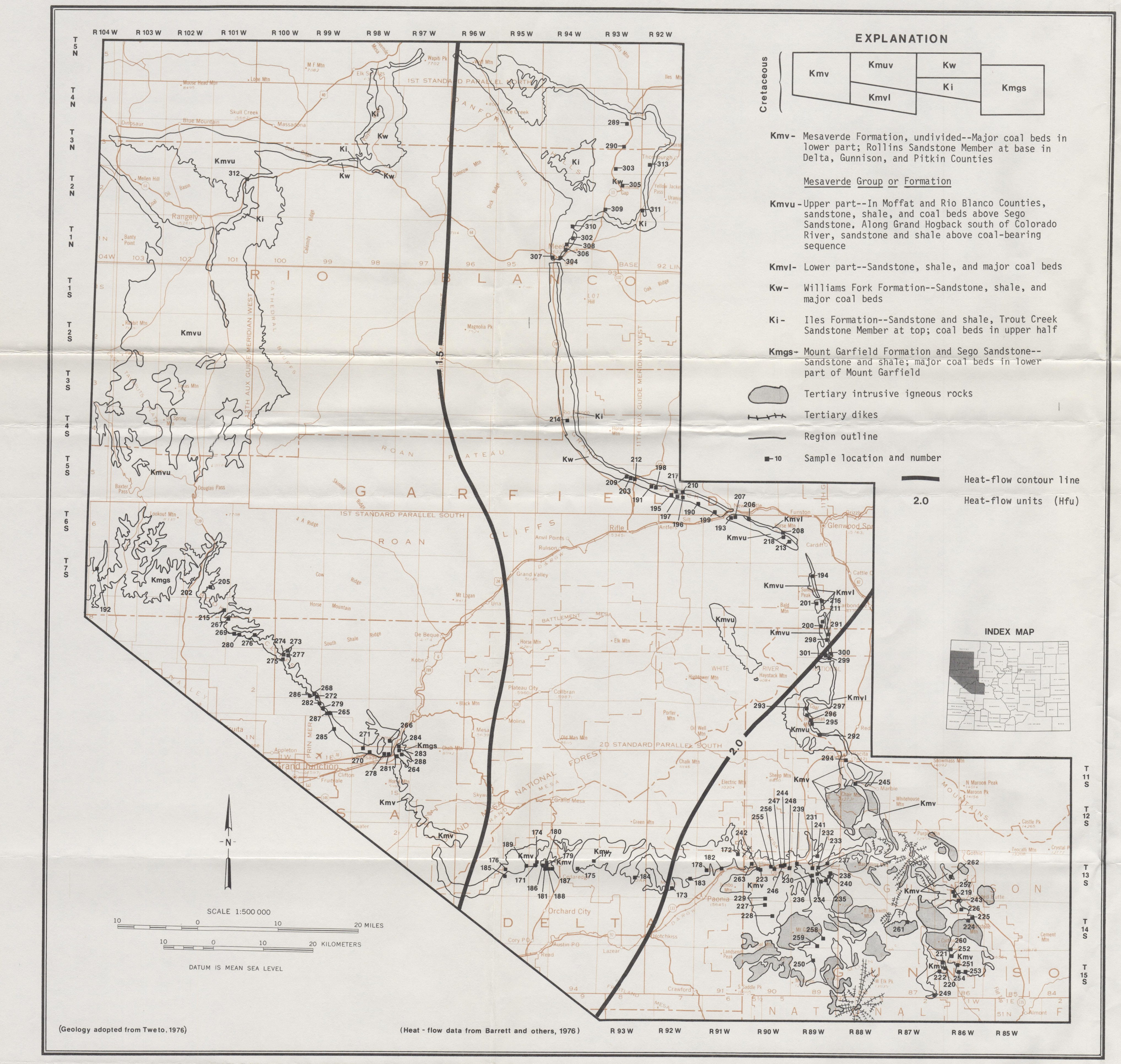
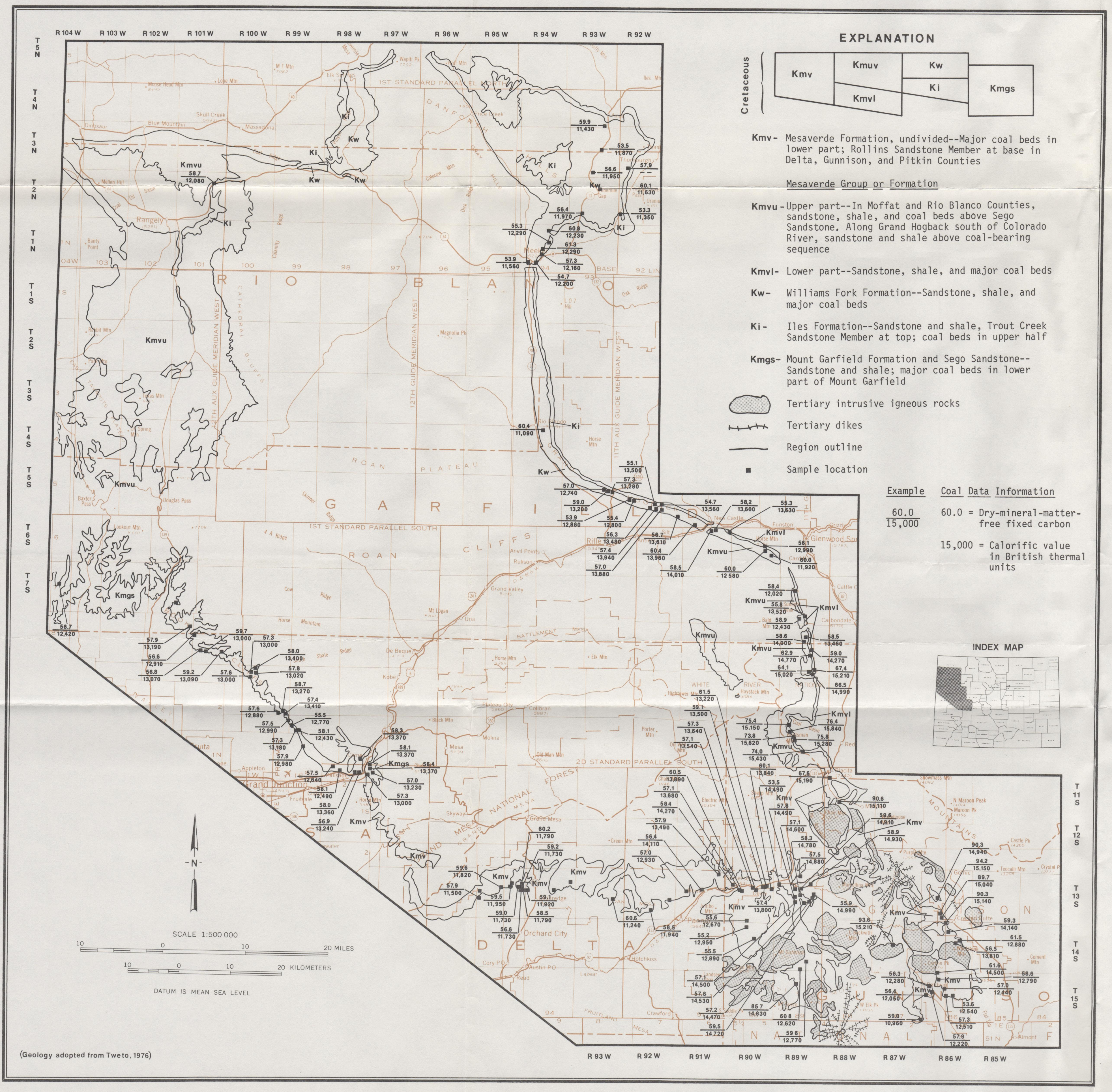
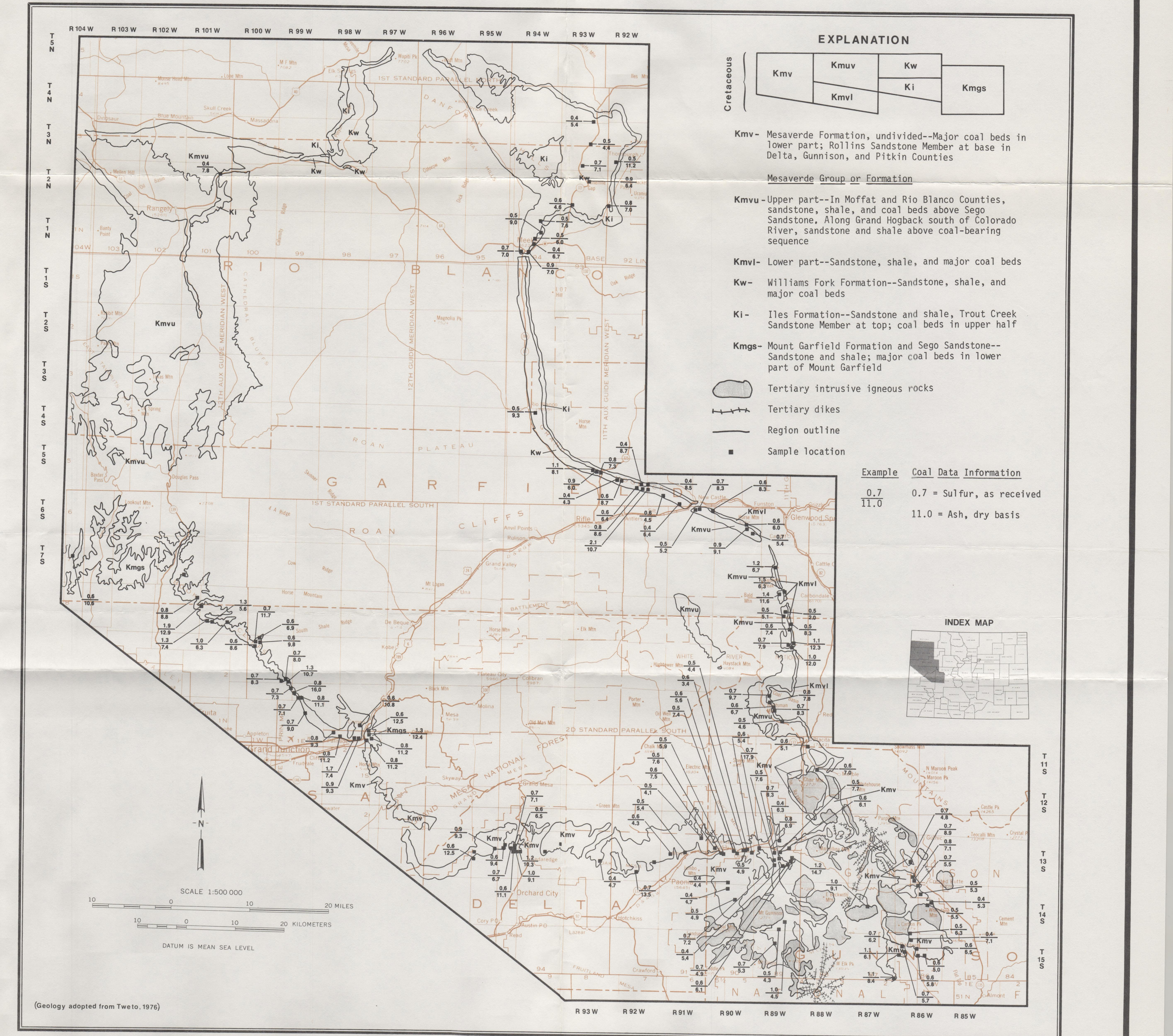


MAP A - COAL SAMPLE LOCATION AND HEAT FLOW MAP OF THE UINTA COAL REGION



MAP B - COAL RANK MAP OF THE UINTA COAL REGION



MAP C - COAL SULFUR AND ASH MAP OF THE UINTA COAL REGION