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Preliminary report on rank of deep coals in part of the southern Piceance Creek basin, Colorado

by

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Introduction

A large amount of the coal in the Piceance Creek Basin is beneath overburden so thick that the coal is not now considered minable. The possible future use of this coal depends on many factors including the properties of the coal itself. This paper deals with just one of those properties; the rank[1] of the coal.

The area of this report (fig. 1) is in western Colorado in Garfield, Mesa, Pitkin, Delta, and Gunnison Counties. It is part of a geologic structural basin known as the Piceance Creek basin. The coal is within the Mesaverde Formation of Late Cretaceous age. It occurs throughout the area considered and crops out along the edges of the basin where it has been mined at New Castle, Carbondale district, Coal Basin, Somerset, Paonia, Grand Mesa district; and Cameo. The coal occurs in a few zones of large horizontal extent; each zone contains several discontinuous beds. Geophysical logs of

1/ This is a general use of the term "rank"; its determination is by measurement of the reflectance of vitrinite. It is neither "rank" nor "apparent rank" as defined by ASTM standards D 388-77. That there is an acceptance by the ASTM of the correlation of rank with vitrinite reflectance is shown by the following quote from Note 15, ASTM standards D 2796-77: "Vitrinite, the predominant maceral in most coals, is produced by the gradual alteration of plant cell substance, the structure of which may either be well discernible or more or less obscured by the effects of degradation. In extreme cases tissue may be reduced to a featureless substance, so that the material is quite homogeneous in appearance. The optical properties of vitrinite change progressively with increase in coal rank, the change being measured best by the progressive increase in reflectance as determined by a microscope photometer with oil immersion objective. The change of reflectance of vitrinite correlates well with the change of its other properties, such as volatile matter and carbon content, calorific value, porosity, hardness, and plasticity during carbonization."

wells in the area show at least one thick (2.5-14 meters) bed at each well site. In each coal mining district, different names have been applied to the beds and zones. The present terminology of the strata and of the coal zones and beds is summarized by Collins (1976) and by Murray, Fender, and Jones (1977). Briefly, for the area of this report, the coal zone above the Rollins Sandstone Member of the Mesaverde Formation (correlative to the Trout Creek Sandstone Member of the Iles Formation to the north) is called the Cameo zone in the west (Erdmann, 1934) and the Fairfield zone (Collins, 1976) or the Wheeler zone (Fender, 1977) in the east. In this paper the coal-rank figures and references to depth apply to the lowest thick coal of the Cameo-Fairfield zone; it probably is not a single continuous seam.

Acknowledgments: Most of the samples used in rank determinations were obtained from American Stratigraphic Company of Denver, Colo. Other samples were collected from gas wells of Norris Oil Company and Union Oil of California. The generous help of John Gordon, Edward Carr, and Robert Glaze in making these samples available is greatly appreciated. I also wish to thank and acknowledge the help of Neely Bostick and Claudia Waddell, my guides to vitrinite-reflectance measurement; and to Bion Kent, David Gaskill, Philip Eager, Joseph Hatch, Edwin Landis, and John Dyni for sharing their knowledge of the coal geology in the area.

Coal-Rank Determination

Ideally, the rank of the coal from a bed or zone of interest would be determined from large, unweathered samples carefully taken by methods conforming to ASTM standards. This is possible for coal from fresh exposures such as at working mines. Adequate samples can also be obtained by core drilling, but no such samples are available of the deep coals of the area. The rank can be determined by measuring the reflectance of the vitrinite component of coal in cuttings samples obtained from wells drilled for oil or gas. The questions arises, however, of whether the cuttings samples are representative of the coal bed and whether a determination of rank using a vitrinite-reflectance method corresponds with a determination by standard ASTM methods.

Cuttings of coal known to come from a given coal bed adequately represent that bed when used for vitrinite-reflectance work because the vitrinite throughout the bed has only slight variation in reflectance. Errors are possible if the sample of cuttings includes pieces of coal that have come from higher beds than the one being sampled or if the treatment of the cuttings has in some way altered the reflectance of the vitrinite. The samples of cuttings used in this study are of two kinds: A few are relatively large samples taken from the screen at the well. In these samples, pieces slumped from the higher beds are a minor part of the sample; moreover, they were washed and dried carefully at room temperatures, which preserves the characteristics of the coal. However, most of the samples used are from collections of cuttings from which only a very few pieces of coal were available and a single slumped piece from a higher bed would notably change the result. The treatment of these samples is only partly known, but it can be assumed that most were washed with high velocities of water which carried away much of the coal with the mud and that the remainder were then dried at elevated temperatures. Tests have been run indicating that such short-term high temperatures usually do not affect the vitrinite reflectance (Neely Bostick, oral communication, 1978).

The problem of correlating vitrinite reflectance with rank determined by standard ASTM methods is minor except in high-volatile bituminous coals. The problem is caused by slight disagreement in published works as to which values of percent vitrinite reflectance are to be placed at boundaries between rank

Table 1.--The rank of coal and values of vitrinite reflectance used in figure 1

[References: McCartney, J. T., and Teichmuller, M. (1972, p. 68); Stach, E., and others (1975, p. 42).]

Correlation of vitrinite reflectance in oil (Ro^{random}, in percent) to rank of coals used in figure 1.

Ro^{random}	Rank
	High-volatile B bituminous
0.78	
	High-volatile A bituminous
1.12	
	Medium-volatile bituminous
1.51	
	Low-volatile bituminous
1.92	
	Semianthracite
2.50	

ASTM classification of coals by rank[a]
from American Society for Testing and Materials (1977, p. 217)

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.

designations. Much of this disagreement comes from variations in the maceral and mineral composition of the coals, which influence the volatile and thermal analyses on which ASTM rank classes are based. The values used on figure 1 and shown in table 1 are from McCartney and Teichmuller (1972) and from Stach and others (1975). Dow (1977), for example, gives different values. More information on the methods and use of vitrinite reflectance is given by Murchison (1964), Teichmuller and Teichmuller (1966), Davis (1978), and Dow (1978), among others.

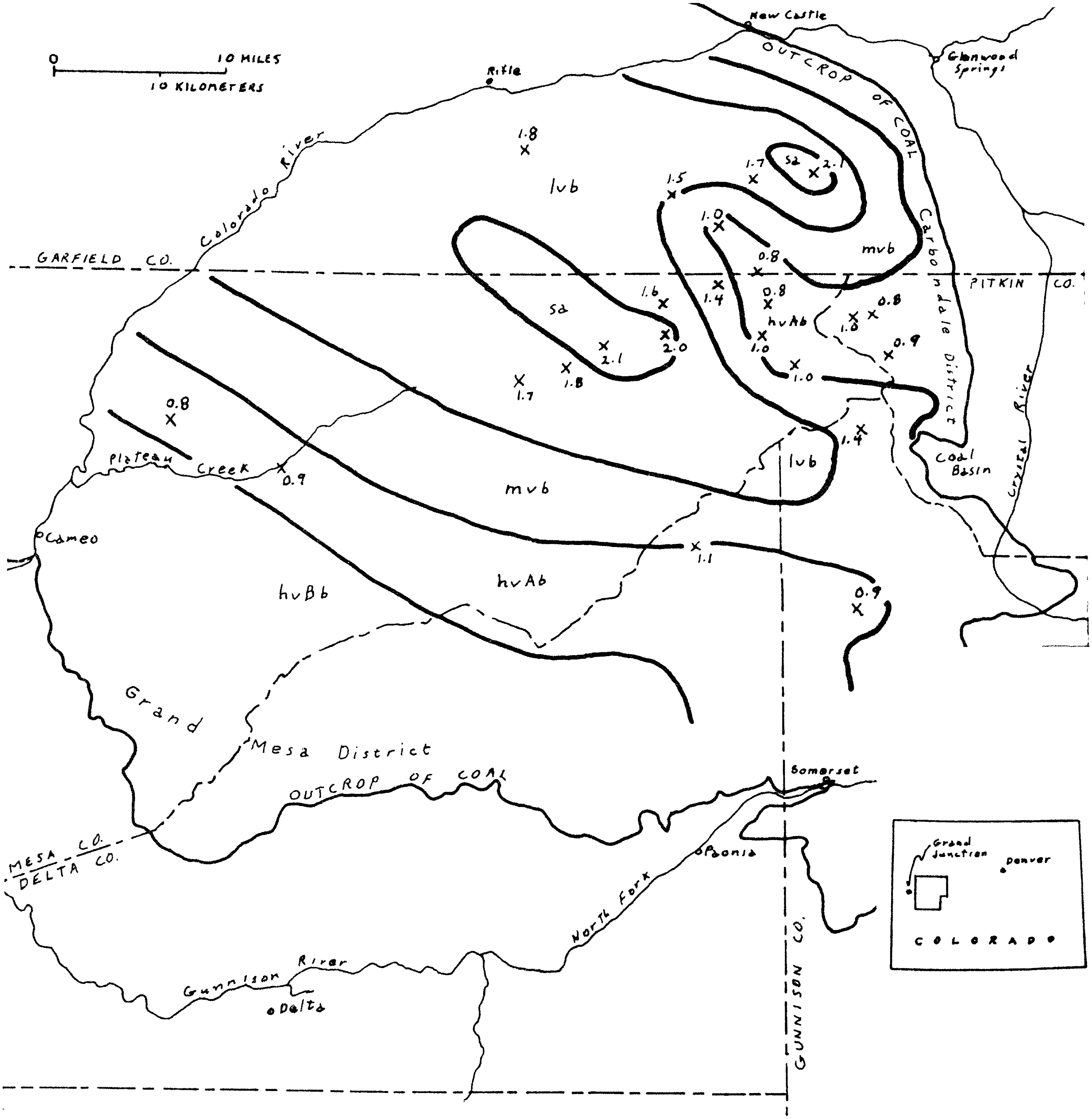

Figure 1.--Part of the southern Piceance Creek basin, Colo. showing vitrinite reflectance and rank of lowest thick coal bed in Cameo-Fairfield coal zone in the Mesaverde Formation. Localities of samples shown by X; numbers at localities show percent mean random vitrinite reflectance (Ro_{random}) of coal. Semianthracite, sa; low-volatile bituminous, lvb; medium-volatile bituminous, mvb; high-volatile A bituminous, hvAb; high-volatile B bituminous, hvBb.

Coal-rank results

The results of rank determination by vitrinite reflectance is shown on figure 1. The vitrinite-reflectance percentages shown at each sample locality are for the basal coal of the Cameo-Fairfield zone. Either the sample was from this basal bed or from a higher bed and the result extrapolated to the basal bed.[2]

As can be seen in figure 1, the rank of this deep coal bed ranges from high-volatile B bituminous to semianthracite. For comparison, the rank of the coal of the same zone where it crops out ranges from high-volatile C bituminous (possibly some subbituminous) to anthracite. The anthracite occurs locally south of Coal Basin adjacent to a laccolith. The high-volatile C bituminous occurs at the outcrop along the southwest and northeast sides of the basin (Murray and others, 1977).

The distribution of coal rank can be geologically explained in general terms. Primarily, the rank reached by a coal during maturation depends on he maximum temperature reached and on the length of time the coal was at that temperature. The temperature reached is dependent on depth of burial, regional heat flow and consequent temperature gradients (depending on rock conductivity), and local heat flow due to intrusions. Because the geologic and thermal history of the southern part of the Piceance Creek Basin is complex, the rank of the coal cannot be directly correlated with either present depth or estimated past burial depth. However, a possible burial effect is seen on figure 1. The gradual increase in rank from the southwest

2/ The extrapolation was made using a preliminary plot of vitrinite reflectance versus depth of burial in the Piceance Creek Basin. This is not very accurate; however, none of the samples were from more than 400 feet above the basal bed and extrapolations were no more than 0.05 percent reflectance.

edge of the basin northeastward to south of Rifle probably corresponds more closely with past depth of burial than with other factors. Both areas of semianthracite seen on figure 1 are located where past burial depth was great and where the coal is still very deeply buried (2,300 to 3,700 meters). In the Divide Creek anticline area between the two areas of semi-anthracite, the coal was once nearly as deeply buried but present depth is as shallow as 1,000 meters. Erosion along the anticline probably started in late Eocene time, so the duration that the coal was at or near maximum depth of burial and hence near maximum temperature is much less than in the semianthracite areas.

The data of coal rank on figure 1 must be considered preliminary for several reasons. The sample distribution is nonuniform. More samples are needed in parts of the basin and, hopefully, will be obtained in the next few years as wells are drilled. Even in the part of the area (fig. 1) having the most samples errors are possible because those samples consisted of a very few pieces of coal and the effect of rough sample treatment is not known. Near the outcrops of the coal, the increase of rank basinward from the outcrop is poorly known, although especially important because this coal may be utilized sooner than the deep coal.

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