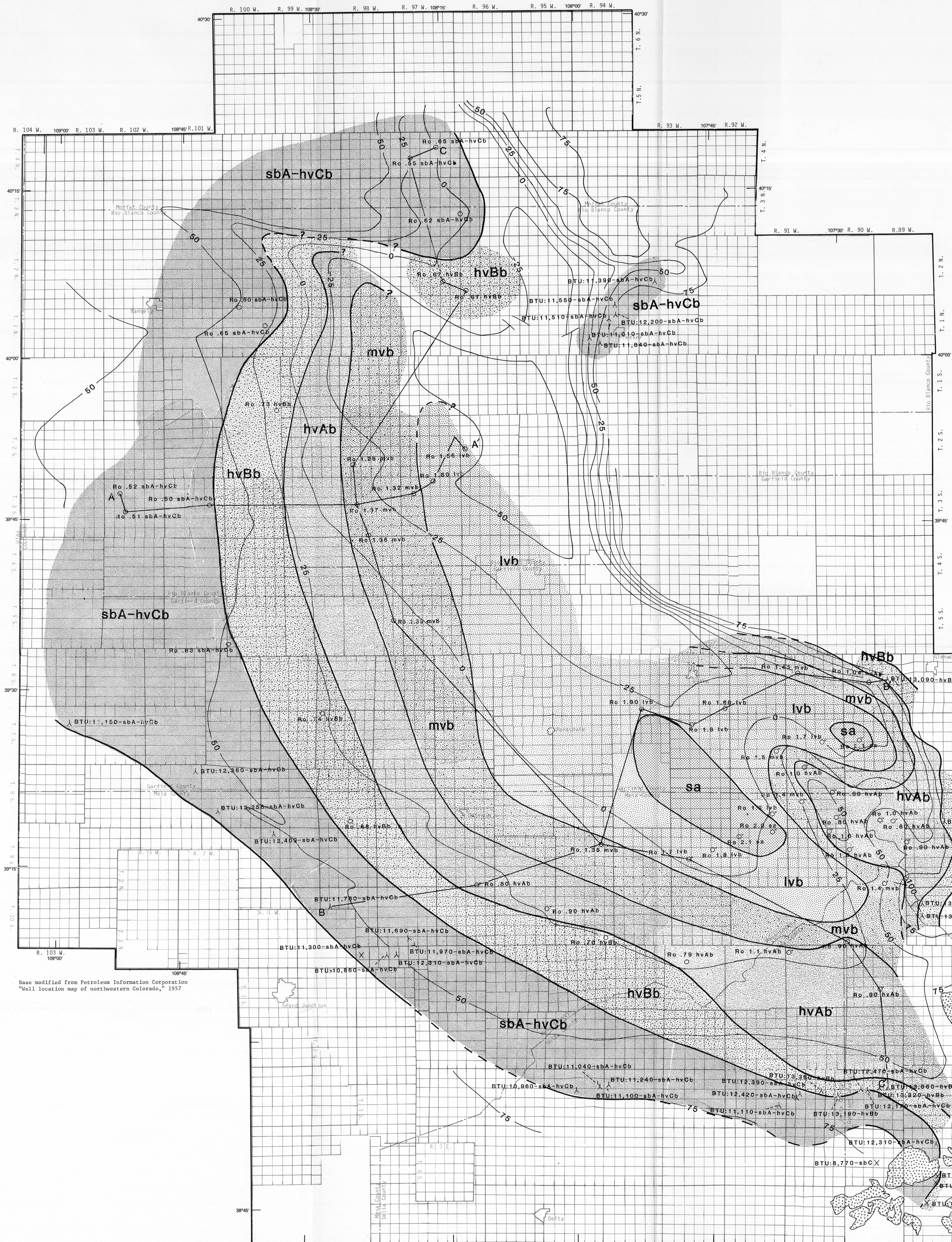
PREPARED IN COOPERATION WITH THE U. S. DEPARTMENT OF ENERGY

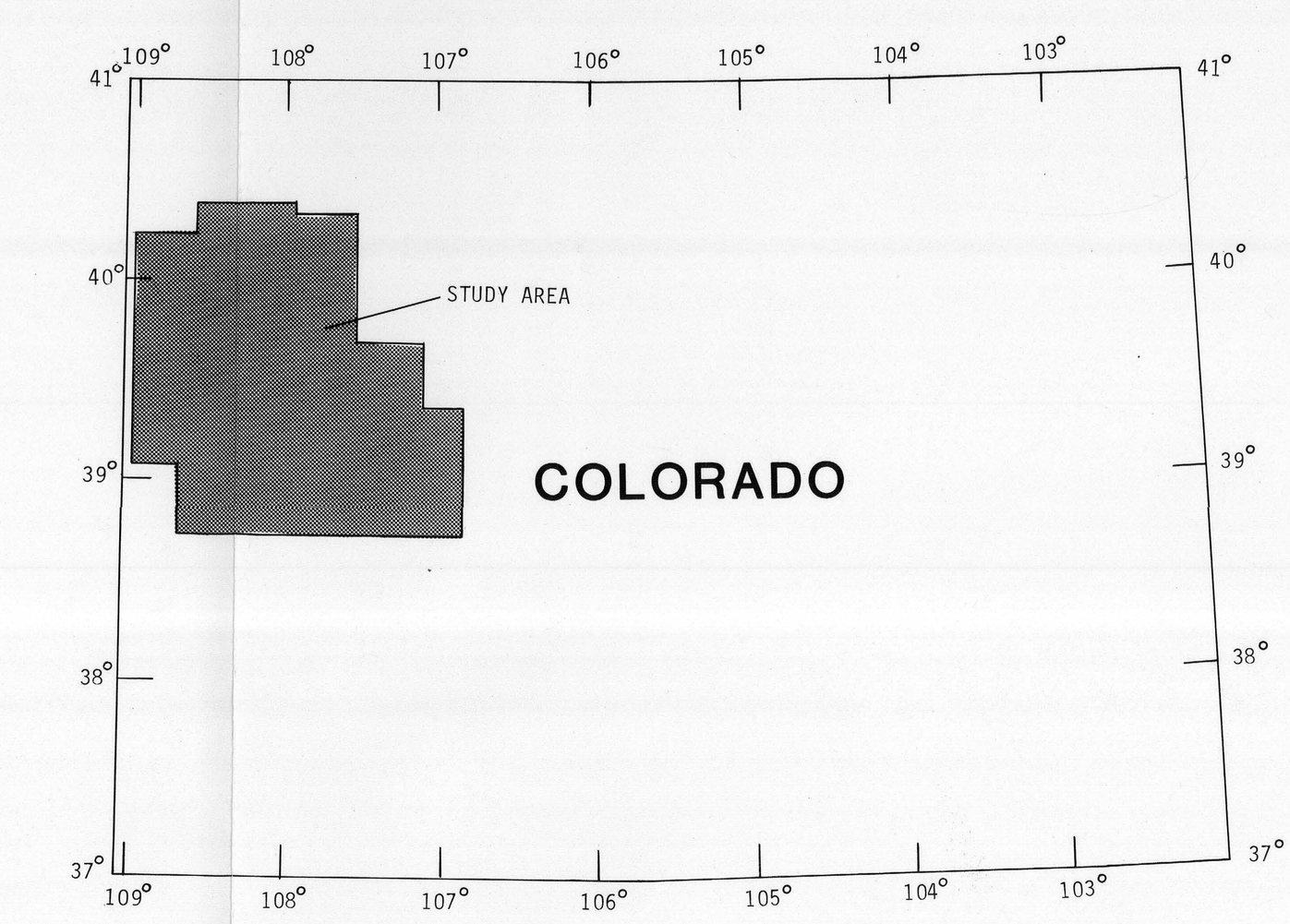


Base modified from Petroleum Information Corporation "Well location map of northwestern Colorado," 1957

Extent of intrusive rocks simplified from Tweto and others (1976, 1978)

PRELIMINARY THERMAL-MATURITY MAP OF THE CAMEO AND FAIRFIELD OR EQUIVALENT COAL ZONE IN THE PICEANCE CREEK BASIN, COLORADO

By
Vito F. Nuccio and Ronald C. Johnson
1983



sbB — SUBBITUMINOUS B COAL

sbA-hvCb — SUBBITUMINOUS A COAL AND HIGH VOLATILE C BITUMINOUS COAL COMBINED--Coals not tested for agglomerating characteristics

hvBb — HIGH VOLATILE B BITUMINOUS COAL

hvAb — HIGH VOLATILE A BITUMINOUS COAL

mvb — MEDIUM VOLATILE BITUMINOUS COAL

lvb — LOW VOLATILE BITUMINOUS COAL

sa — SEMIANTHRACITE

MIDDLE TERTIARY INTRUSIVE ROCKS

CONTACT BETWEEN DIFFERENT COAL RANKS--Dashed and queried where uncertain

—50— STRUCTURE CONTOUR--Drawn on top of Rollins or Trout Creek; X100 ft

FAULT--Offsetting structure contour

Ro 2.1 sa — DRILL HOLE--Vitrinite reflectance (mean random, oil immersion) and associated rank of coal sample using ASTM classification. Superscript "v" indicates data from Freeman (1979)

BTU:13,310-hvBb — MINE--British thermal units (BTU) content and ASTM rank classification of coal sample

BTU:13,990-hvBb — PROSPECT--British thermal units (BTU) content and ASTM rank classification of coal sample

DISCUSSION

This map was prepared in cooperation with the U.S. Department of Energy's Western Gas Sands Project and was constructed to show the thermal maturity of the Upper Cretaceous Mesaverde Formation (or Group) in the Piceance Creek Basin. The ability of a source rock to generate oil and gas is directly related to its kerogen content and thermal maturity; hence, thermal maturity is commonly used as an exploration tool. This publication consists of two parts: a coal rank map for the basinwide Cameo and Fairfield or equivalent coal zone and three cross sections showing the variation in coal rank for the entire Mesaverde. Structure contours on the map show the top of the Rollins Sandstone Member of the Mesaverde Formation and its equivalent the Trout Creek Sandstone Member of the Iles Formation of the Mesaverde Group, which immediately underlie the Cameo and Fairfield zone. The structure contours show the fairly strong correlation between structure and coal rank in the basin, suggesting that maximum overburden was the key factor in determining the coal ranks. Even in the southern part of the basin where extensive plutonism occurred during the Oligocene, coal ranks still generally follow structure; indicating that the plutons had little affect on the coals. On the cross sections both the top of the Rollins and Trout Creek, and the top of the Mesaverde Formation/Group are shown. The usefulness of the cross sections is somewhat limited because they show the thermal maturity of the Mesaverde only near the three lines of section and cannot readily be used to determine the thermal maturity of the Mesaverde elsewhere. The coal-rank map of the Cameo and Fairfield zone gives some indication of thermal maturity throughout the map area, but chiefly shows the thermal maturity of sediments near the Cameo and Fairfield zone. A complete analysis of the entire Mesaverde in the basin would require more information than is presently available.

The Rollins and Trout Creek Sandstone Members are basinwide regressive marine sandstones that are near the top of the marine-nonmarine intertonguing part of the Mesaverde. Overlying the Trout Creek is about 2,000-4,600 ft of largely nonmarine Mesaverde (Granica and Johnson, 1980). The Rollins and Trout Creek were mapped as two units. The Rollins was mapped in the southern part of the basin and the Trout Creek was mapped in the northeast part of the basin and in the Sand Wash Basin to the north.

The Rollins Sandstone Member of the Mesaverde was first named and mapped by Lee (1912), who traced the prominent sandstone across the southern margin of the basin from Palisade to Crested Butte. The Trout Creek Sandstone Member of the Iles was originally named by Fennerman and Gale (1906), who mapped it in the southeastern part of the Sand Wash Basin, north of the Piceance Creek Basin. Later the Trout Creek was identified and mapped in the Meeker area in the northeast part of the Piceance Creek Basin by Hancock and Eby (1930). Warner (1964) traced the Rollins in the subsurface from the Book Cliffs north of Grand Junction to the Grand Hogback near Newcastle. He then traced the Rollins on an outcrop northward along the Grand Hogback to Meeker, where it was found to be correlative with the Trout Creek. Warner suggested that the name Trout Creek should be used along the Hogback as far south as Newcastle, and that Rollins should be used further to the south. Collins (1976), on the other hand, believes that the name Trout Creek has priority of nomenclature and should be used at least as far south as the south rim of Coal Basin and possibly throughout the entire Piceance Creek Basin. We will not resolve this conflict at this time.

The Cameo zone is defined as the first major coal zone above the Rollins Sandstone Member of the Upper Cretaceous Mesaverde Formation in the southwestern part of the basin (Erdmann, 1934). It is correlative with the Fairfield coal zone and the Wheeler coal zone in the eastern part of the basin (Collins, 1976) and with an unnamed coal zone in the north and northwest parts of the basin. For simplicity, the combined name Cameo and Fairfield is used for the first major coal zone above the Rollins and Trout Creek. We are not suggesting that the name Cameo and Fairfield should be applied to those areas of the basin where neither name is presently being used.

The coal-rank map of the Cameo and Fairfield zone was constructed using a variety of sources. Published coal-rank data from coal mines were used in areas where the Cameo and Fairfield coal zone crops out. Many of these analyses were listed in British thermal units (BTU) and were converted to coal rank using the ASTM (1977) classification for coals (table 1). Vitrinite reflectance (Ro) was used to determine coal rank in samples from wells (fig. 2). Vitrinite reflectance has long been used to rank coals. Vitrinite changes from a dull gray to a brilliant white with increasing rank or maturity.

A coal-rank map for this zone in the southern part of the basin based on vitrinite reflectance has been published (Freeman, 1979). Freeman's vitrinite-reflectance map was extended into the northern part of the basin for this study by analyzing cuttings and core obtained from the American Stratigraphic Company, Rio Blanco Natural Gas, Cities Service Gas, Fuelco, and other companies; these samples were donated to the U.S. Geological Survey core library. Several new control points were also acquired in Freeman's area in the southern part of the basin. These samples were from wells recently drilled for oil and gas by Exxon, Snyder Oil, and CER Corporation. To construct the cross sections, vitrinite-reflectance profiles for the entire Cretaceous Mesaverde were obtained for many of the wells by analyzing several coals and organic-rich shales. The position of the top of the Mesaverde on the cross sections was determined using a structure contour map by Granica and Johnson (1980). For the top of the Rollins and Trout Creek, a structure contour map by Johnson (unpublished data) was used.

In general, organic material can be divided into two types: sapropelic or fatty and humic or coaly. Marine source rocks tend to be sapropelic and continental source rocks tend to be humic. The nonmarine Mesaverde or that part of the Mesaverde above the Rollins and Trout Creek should contain mainly humic organic material; whereas, the underlying intertonguing marine and nonmarine Mesaverde contains a mixture of sapropelic and humic material. Humic source rocks tend to generate mainly gas, whereas sapropelic source rocks tend to generate oil and gas while undergoing thermal metamorphism. Figure 1, from Hunt (1979) is a modified chart (Connan, 1974) showing vitrinite reflectance (Ro) lines as related to time and temperature in determining maximum oil, condensate, and gas-generation zones. From this chart, the approximate zone for maximum oil generation is around a Ro of 0.8, for condensate it is around a Ro of 1.2, and for gas it is around a Ro of 2.0. Because of the differences in kerogen composition, these numbers may vary depending on the particular situation. Although this chart shows no gas above a vitrinite reflectance of around 3.5, some would debate that the upper limit for gas could go as high as a Ro of 4.0 or above.

We are not saying that oil or gas will be found everywhere the rank of coal falls in the area of petroleum generation. Too many other conditions, such as migration problems, structural requirements, and reservoir quality, must be considered in exploring for oil and gas.

ACKNOWLEDGMENT

A special thanks to Mark Pawlewicz whose help and knowledge in coal petrology and reflected-light microscopy was invaluable in preparation of this map.

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Table 1.--ASTM Classification of Coals[a]

[From ASTM, 1977]

Class	Group	Fixed Carbon Limits percent (Dry, Mineral-Matter-Free Basis): Equal or Greater Than	Fixed Carbon: Less Than	Volatile Matter Limits percent (Dry, Mineral-Matter-Free Basis): Greater Than	Volatile Matter: Equal or Less Than	Calorific Value Limits, Btu per pound (Moist[b] Mineral-Matter-Free Basis): Equal or Greater Than	Calorific Value: Less Than	Agglomerating Character
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.

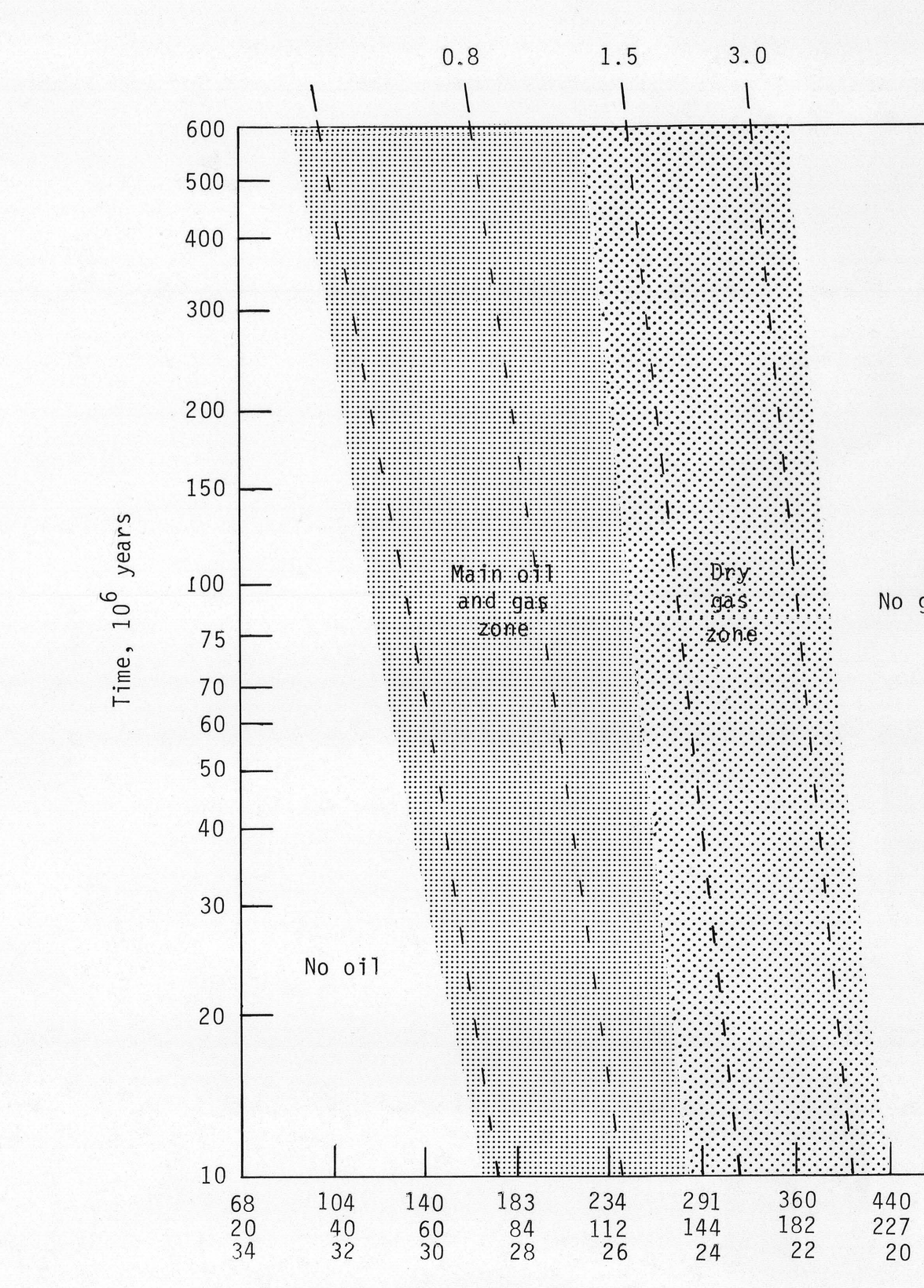

Figure 1. -- Chart showing vitrinite reflectance as related to time and temperature, used in determining maximum oil, condensate, and gas-generation zones.

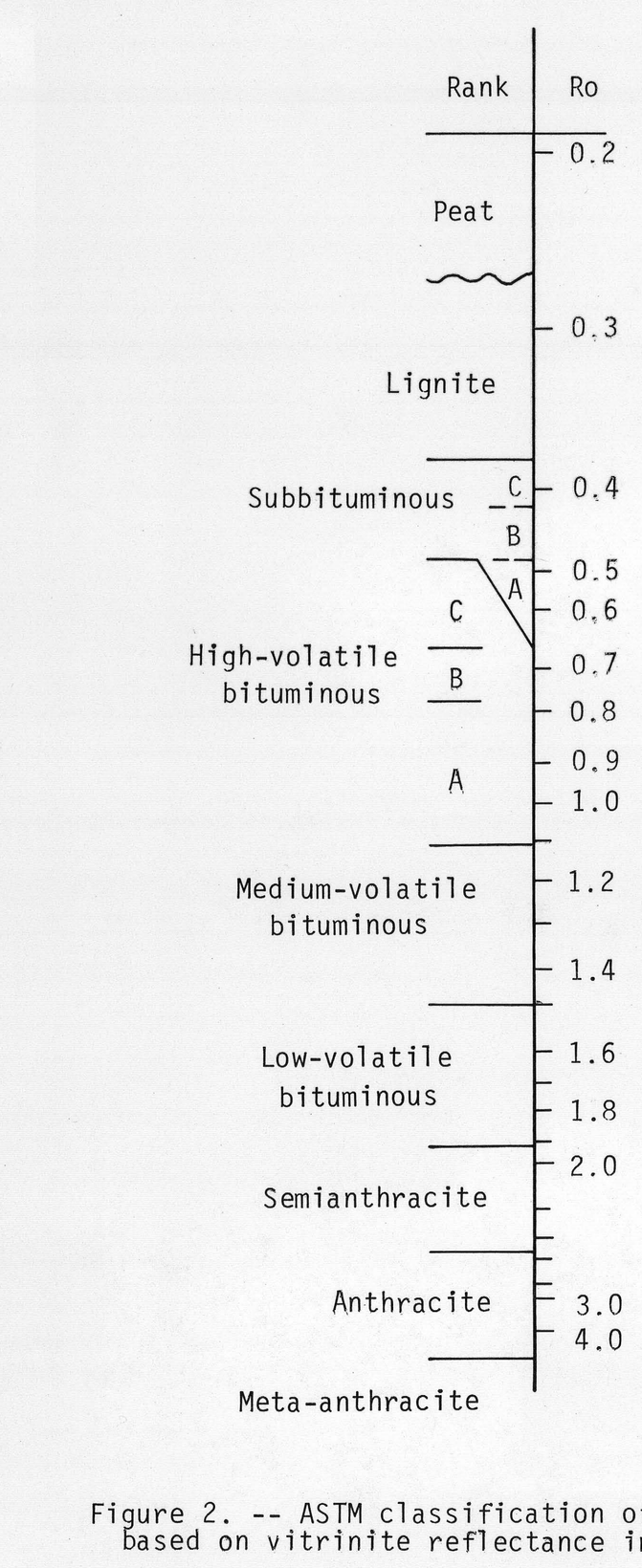

Figure 2. -- ASTM classification of coal based on vitrinite reflectance in oil (Ro).

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3. Freeman, V. L., 1979, Preliminary report on rank of deep coals in part of the southern Piceance Creek Basin, Colorado: U.S. Geological Survey Open-File Report 79-725, 11 p.
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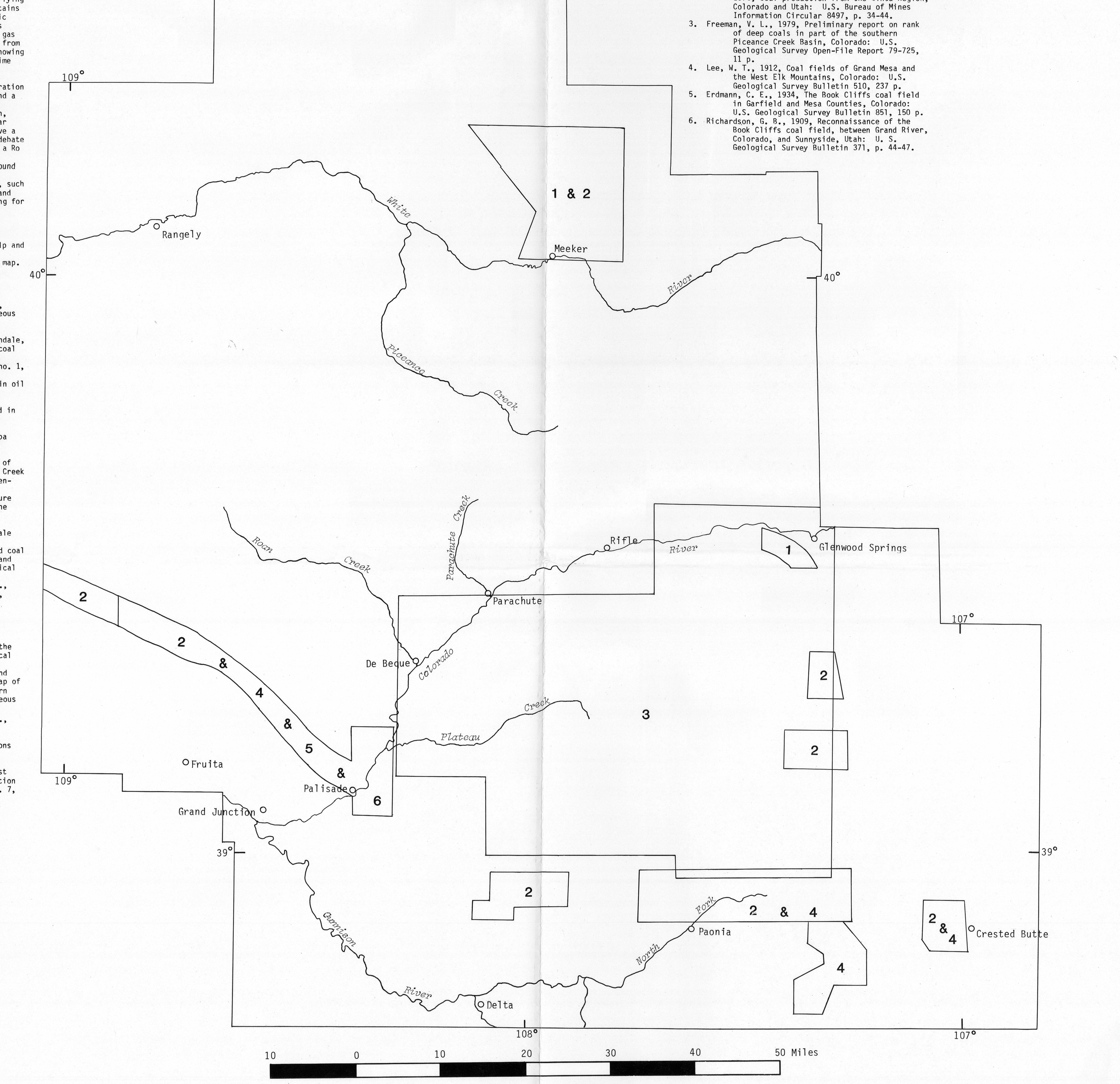

INDEX MAP SHOWING PUBLISHED SOURCES OF DATA USED IN COMPILATION

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1983
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