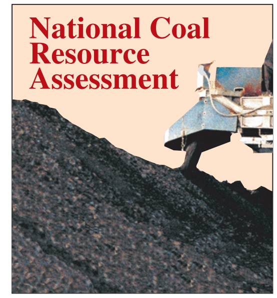
Chapter N

Assessment of the Distribution and Resources of Coal in the Deserado Coal Area, Lower White River Coal Field, Northwest Colorado



Click here to return to Disc 1 Volume Table of Contents

By M.E. Brownfield,[1] L.N.R. Roberts,[1] E.A. Johnson,[1] *and* T.J. Mercier[2]

Chapter N *of*

Geologic Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah

Edited by M.A. Kirschbaum, L.N.R. Roberts, *and* L.R.H. Biewick

U.S. Geological Survey Professional Paper 1625–B*

[1] U.S. Geological Survey, Denver, Colorado 80225

[2] U.S. Geological Survey contract employee, Denver, Colorado 80225

* This report, although in the USGS Professional Paper series, is available only on CD-ROM and is not available separately

U.S. Department of the Interior
U.S. Geological Survey

Contents

Plate

Figures

Tables

Metric Conversion Factors

[Data in this volume are reported in customary inch-pound units because the metric system is not currently in use by the coal industry of the United States. Readers wishing to convert measurements to the International System of units (SI) may use the following factors]

U.S. customary unit	SI conversion
Acre	= 4,046.87 square meters
Acre-foot	= 1,233.49 cubic meters
British thermal unit (Btu)	= 1,055.056 joules
Btu/lb	= 2,326 joules per kilogram
Foot (ft)	= 0.3048 meters
Inch (in.)	= 0.0254 meters
Mile (mi)	= 1.609 kilometers
Pound (lb)	= 0.4536 kilograms
Short ton (ton)	= 0.9072 metric tons
Square miles (mi^2)	= 2.59 square kilometers
Short ton/acre-foot	= 0.7355 kilograms per cubic meter

Assessment of the Distribution and Resources of Coal in the Deserado Coal Area, Lower White River Coal Field, Northwest Colorado

By M.E. Brownfield, L.N.R. Roberts, E.A. Johnson, *and* T.J. Mercier

Abstract

The assessment of coal resources of the coal unit in the Lower White River coal field, Moffat and Rio Blanco Counties, Colorado, is part of the U.S. Geological Survey's (USGS) "National Coal Resource Assessment" (NCRA) Project, a 5-year program to identify and characterize coal deposits that could potentially provide fuel for the Nation's coal-derived energy needs during the first quarter of the 21st century. For this project, the Nation is divided into nine regions, one of which encompassed the Rocky Mountains and Colorado Plateau. One of the priority subareas for resource assessment in the Rocky Mountains and Colorado Plateau region is the Lower White coal field that is located along the northern margin of the Piceance Basin.

Coal beds targeted in the Deserado coal area, Lower White River coal field, are contained in the coal unit of the Upper Cretaceous Mesaverde Group. The coal beds in this unit are laterally discontinuous, are considered to be low sulfur (0.55 percent), and have an apparent rank of high-volatile C bituminous when compared to many other coal-bearing regions in the United States. The coal resources estimated for the Deserado area are only in the identified resource category and represent the total net coal in beds greater than 1.2 ft thick.

The Deserado coal area contains an estimated coal resource of 440 million short tons of which more than 80 percent of the total coal resource is contained in two coal zones. More than 97 percent of the total is federally owned. The coal resources estimated for the Deserado area do not include the area inside the Deserado coal leases nor do they reflect economic, land-use, environmental, technological, and geologic constraints that may ultimately affect the availability and recovery of the coal. The amount of recoverable coal was not estimated in this study. Important factors affecting recoverability are (1) a significant amount of the coal is found at depths greater than 1,000 ft and (2) many of the coal beds are in close proximity stratigraphically, which may restrict underground mining of some beds. Coal can be bypassed due to longwall mining methods related to reduced thickness from partings and splits. Currently, coal is being mined at the Deserado mine by longwall methods and is transported by rail line to the Deseret Generation and Transmission power plant in northeastern Utah.

Introduction

Purpose and Scope

The assessment of the distribution and resources of the coal in the Lower White River coal field of northwest Colorado is part of the U.S. Geological Survey's National Coal Resource Assessment (NCRA) Project, which was initiated in 1994. The primary goal of the NCRA project is to characterize the resource potential and quality of coal resources for areas in the United States that will be utilized for the next few decades. The Lower White River coal field (fig. 1), in Garfield, Moffat, and Rio Blanco Counties, is one of the priority areas within the Rocky Mountains and Colorado Plateau region. To restrict the resource assessment in the context of a 10- to 20-year development period, only coals in the northern part of the Lower White River coal field the Upper Cretaceous Mesaverde Group were assessed for this study (figs. 2 and 3)—this area was designated the Deserado coal area. The coal unit of the Mesaverde Group contains many of the thickest and potentially economic coal beds in the Lower White River coal field (figs. 4 and 5). Study areas were determined by analyzing current mining activity, coal ownership, and by discussions with the U.S. Bureau of Land Management (BLM). This study area was selected because it contains active mining, large amounts of federally administered lands, and has potential for future development. Mineral rights to more that 99 percent of coal within the study area are owned by the U.S. Government. One mine (Deserado mine) is presently operating in the study area and produces coal from the coal unit.

The assessment of the coal unit in the Lower White River coal field is based largely on data derived from geologic

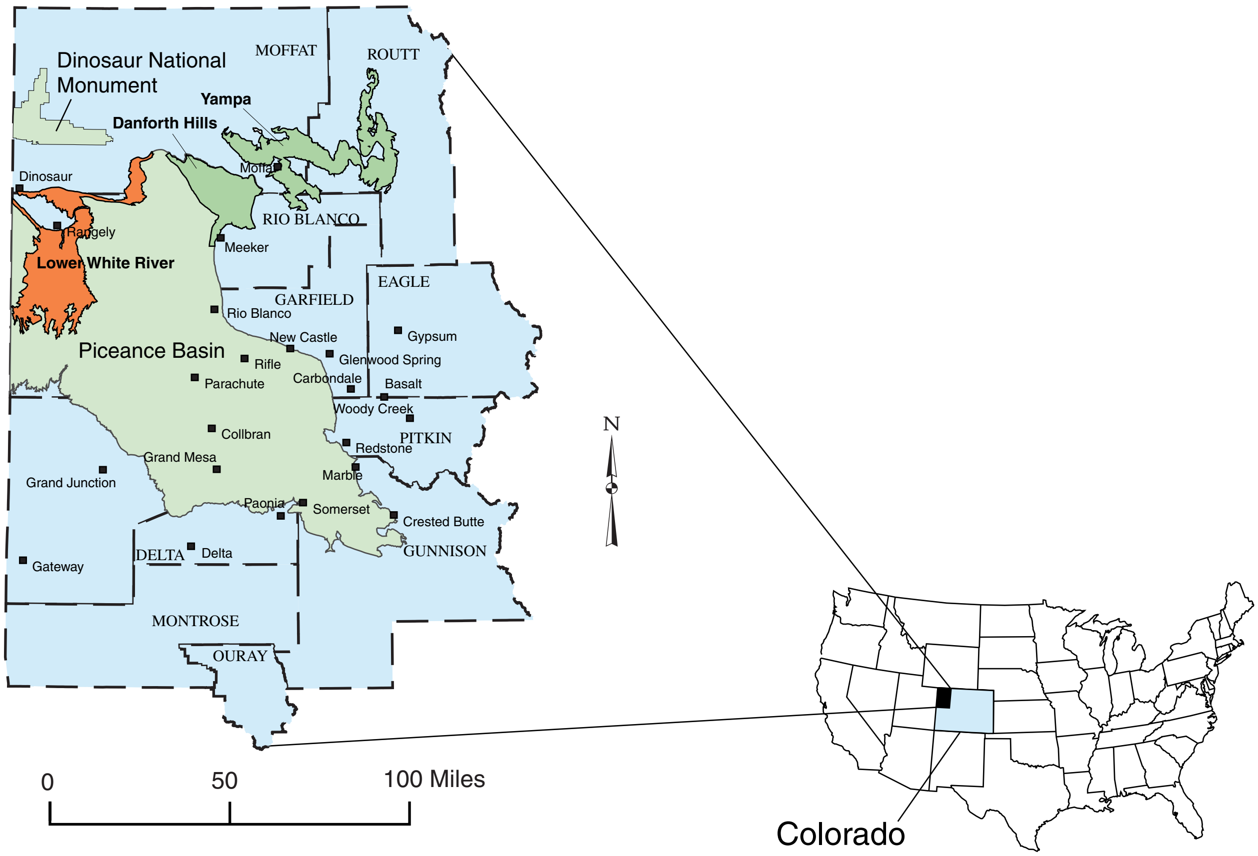


Figure 1. Location map for the Lower White River, Danforth Hills, and Yampa coal fields, northern Piceance Basin, Moffat, Rio Blanco, and Routt Counties, Colorado.

mapping, outcrop measurements, and drilling conducted in the study area by the U.S. Geological Survey (USGS) since the early 1900's. The coal resource data has been stored digitally and manipulated in a Geographic Information System to calculate coal resources within a variety of spatial parameters that were deemed useful for land-use planning and potential mining. The major coal deposits in the Lower White River coal field are present in the coal unit of the Mesaverde Group (figs. 2 and 4). Coal resources reported in this study are for total net coal and assessed coal zones in the coal of the Mesaverde Group and represent only a part of the total in-place coal for the Lower White River coal field. The Deserado coal mine's Federal and State coal leases were excluded in this study (fig. 3).

Location

The Lower White River coal field is located in the northwest part of Colorado and occupies parts of Garfield, Moffat, and Rio Blanco counties (fig. 1). The coal field is located in the northern part of the Piceance Basin, which is part of the Uinta region of the Rocky Mountain Coal Province (Tully, 1996). In this study, the area of interest is restricted to the northern part of the Lower White River coal field and is referred to as the Deserado coal area where there is active coal mining (fig. 2). The Deserado coal area is located north of Rangely, Colo., and south of Dinosaur National Monument.

Previous Geologic Studies and Mining Activity

Since the early 1900's the USGS has conducted investigations to study the geology and to assess the coal, oil and gas, and oil-shale resources in northwest Colorado. Gale (1910) was the first to investigate the coal resources in northern part of the Lower White River coal field. Cullins (1968, 1969, 1971) conducted the first detailed geologic investigations in the Lower White River. Detailed geologic mapping in the Deserado coal study area was completed by Barnum and Garrigues (1980) and Garrigues and Barnum (1980). Additional mapping in the Lower White River coal field was conducted by Hail (1974), Hail and Barnum (1993), and Barnum and Hail (1996).

During the late 1800's and early 1900's, several mines produced coal in the Lower White River coal field for local

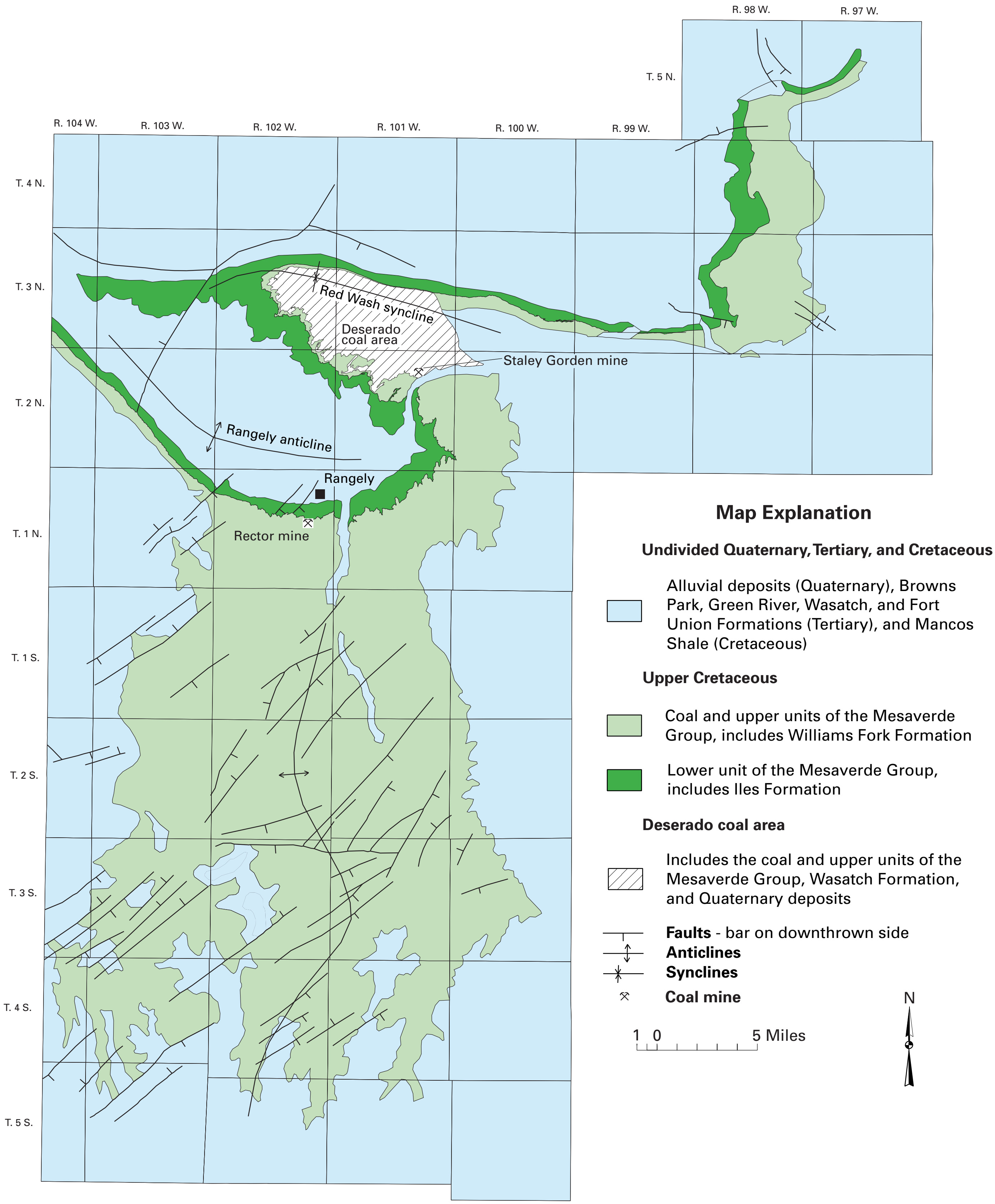


Figure 2. Location map showing the Deserado coal area, Lower White River coal field, Moffat, and Rio Blanco Counties, Colorado. Modified after Barnum and Garrigues (1980), Garrigues and Barnum (1980), and Tweto (1979).

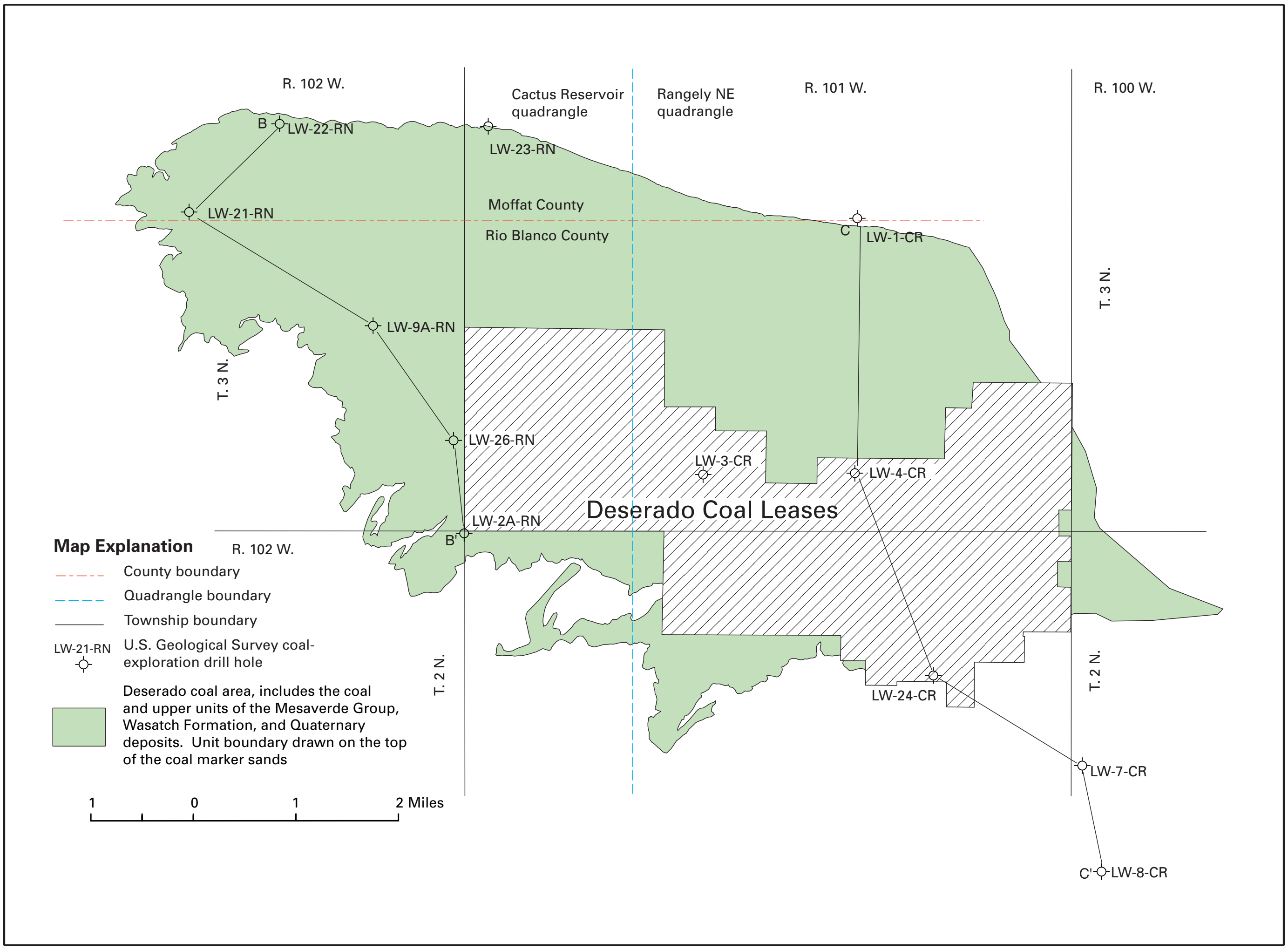


Figure 3. Index map showing location of U.S. Geological Survey drill holes and cross sections (B, fig. 7; C, fig. 8) in the Deserado coal area, the outcrop of the coal marker sands, and the Deserado coal leases, Lower White River coal field, Colorado.

consumption (Gale, 1910). In addition to local heating uses, some of the coal was used to provide fuel for drilling wells in the early days of the Rangely oil field. Gale (1910) sampled and reported analyses of coal from the Rector mine (fig. 2), southwest of the Deserado coal study area. Within the study area, the Staley Gordon mine (fig. 2) produced an unknown amount of coal from the main coal zone of the coal unit of the Mesaverde Group (fig. 5).

Coal is currently mined in the Lower White River coal field by underground methods at the Deserado mine, operated by Western Fuels, Inc. Coal is mined from two coal zones in the coal unit of the Mesaverde Group, then transported over a dedicated electric railroad to the Deseret Generation and Transmission power plant in northeastern Utah. Coal production averaged 1.44 million short tons per year from 1989 to 1994 (Resource Data International, Inc., 1998). Future coal production in the Deserado mine will be limited to the coal unit and potential new mines in the Lower White River coal field are expected to be located in the coal unit as well.

Methods

In order to assess the coal resources of the Lower White River coal field, we created digital files for storing data on various geologic and other features such as outcrop lines, elevation data, coal thickness, faults, fold axes, and extent of Federal coal leases and mined-out areas within the study area. Drill-hole data have been stored and analyzed in a relational stratigraphic database and graphics software package (Stratifact, GRG Corporation, Denver, Colo., 1997). Digital files of the publicly available drill holes are provided in Appendix 1 on disc 2 of this CD-ROM. Mean coal-zone thicknesses and elevation data, derived from the Stratifact drill-hole database,

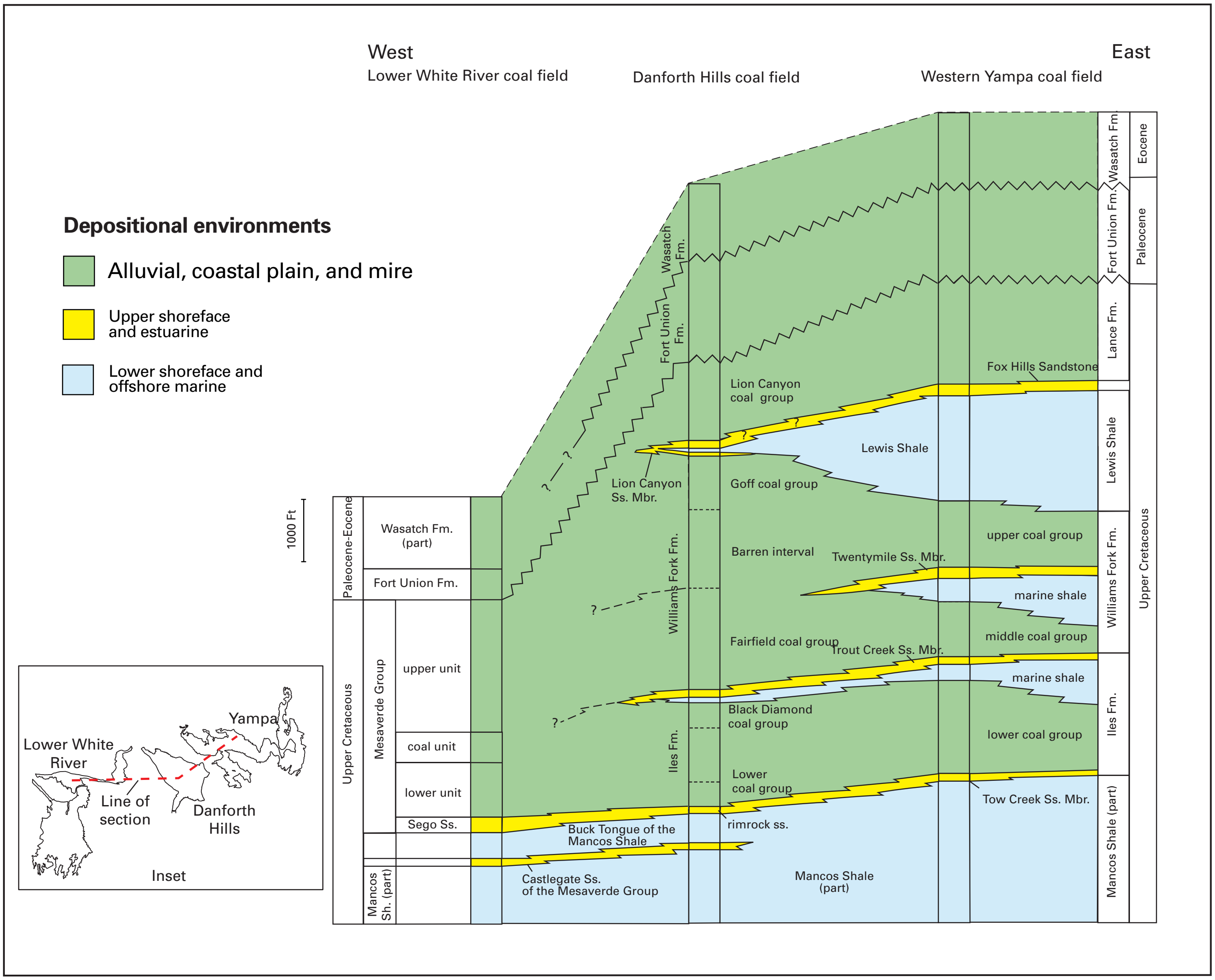


Figure 4. Generalized regional cross section showing depositional environments for part of the Upper Cretaceous and Tertiary rocks in the Lower White River, Danforth Hills, and Yampa coal fields, northwest Colorado. Modified after Brownfield and Johnson (1984).

were integrated with digital elevation data to derive the B and D coal-zone outcrop lines (Roberts and others, chap. C, this CD-ROM). These outcrop lines were then used to define assessment areas for the study. The drill-hole data were analyzed by USGS computer program (G.D. Stricker, written commun., 1998) to determine net-coal-bed thickness, after Wood and others (1983). The digital files were stored, analyzed, and manipulated in a Geographic Information System (GIS) using ARC/INFO (Environmental Systems Research Institute, Inc.) software. Gridding and subsequent generation of contour and isopach maps were done with EarthVision (Dynamic Graphics, Inc.) software, and the contours were converted to ARC/INFO coverages using custom programs ISMARC and Convert-ISM.AML (Roberts and others, 1998). This software integrated the various coverages, allowing us to calculate coal resources and characterize coal distribution within a variety of geologic and geographic parameters. The various digital coverages used in this report are available in the ArcView project in Appendix 2 of this report, and they are explained by Biewick and Mercier (chap. D, this CD-ROM). The methodology for reporting the estimated coal resources is from Wood and others (1983) and is described in more detail by Roberts and others (chap. C, this CD-ROM).

Geologic Maps

Digital geologic maps of the study area were generated using ARC/INFO coverages that included stratigraphic unit boundaries and elevations, faults, fold axes, and coal thick-

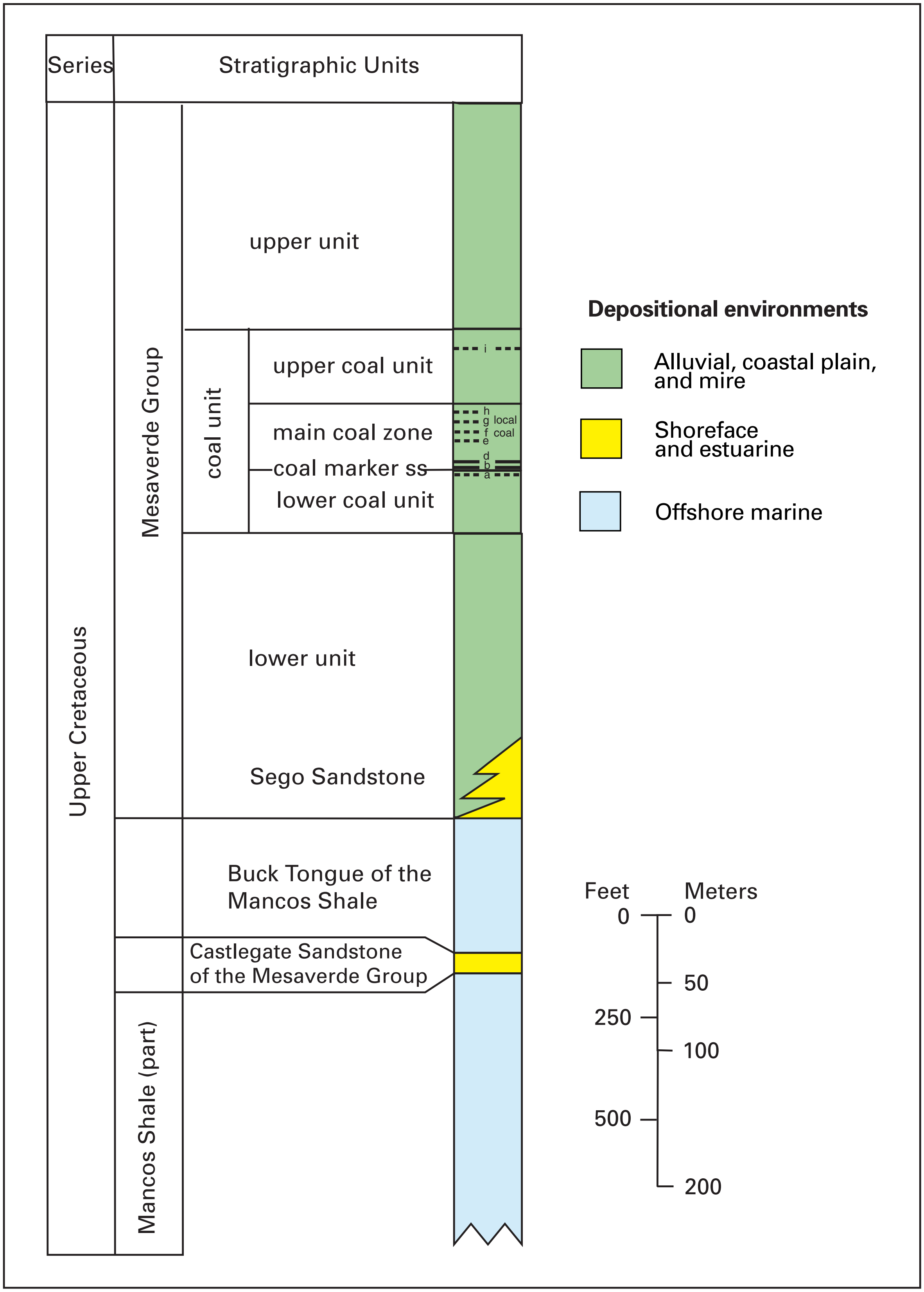


Figure 5. Generalized stratigraphic column showing depositional environments for a portion of the Upper Cretaceous rocks for the Deserado coal area, Lower White River coal field, Colorado. Shown are the major divisions of the coal unit of the Mesaverde Group and the Western Fuels, Inc., coal-zone names. Coal beds and coal marker sands not drawn to scale. Modified after Barnum and Garrigues (1980).

nesses. Data from the 1:500,000-scale geologic map of Colorado (Tweto, 1979; Green, 1992) were used to generate digital regional maps of northwest Colorado (fig. 2). The study-area portion of Colorado geologic map was compiled from 1:250,000-scale geologic maps (Tweto 1975, 1976; Rowley and others, 1979) and published at a scale of 1:500,000. The generalized geologic map for the Lower White River coal field was compiled at a scale of 1:500,000 and was modified using outcrop data from 1:24,000-scale geologic maps by Barnum and Garrigues (1980), Garrigues and Barnum (1980), and Barnum and Hail (1996). The 1:500,000-scale map was then reduced to the map shown on plate 1 (see fig. A on pl. 1)

Geographical Boundaries

Geographical boundaries were imported as ARC/INFO coverages from existing public databases. Township boundaries were digitized from the Rangely NE and Cactus Reservoir 7.5-minute quadrangles. Areas of surface and mineral ownership were obtained from 1:24,000-scale digital compilations completed by the Craig District Office, BLM. County and State lines were obtained from 1:100,000-scale Topologically Interrogated Geographic Encoding and Referencing (TIGER) files produced by the U.S. Bureau of the Census in 1990. Surface topography was obtained from 1:24,000-scale Digital Elevation Model (DEM) files for the Rangely NE and Cactus Reservoir 7.5-minute quadrangles. Coal-lease boundaries and mine plan maps were obtained from the U.S. Bureau of Land Management and compiled digitally by the USGS.

Geophysical Logs

More than 225 borehole geophysical logs, supplied in part by the BLM, were used in this study. Table 1 lists information on 23 of the publicly available exploratory drill holes. Ten of these holes were drilled in 1976 by the U.S. Geological Survey in the Deserado coal area. Figure B on plate 1 shows drill hole locations with index numbers that are cross-referenced with the hole number in table 1. Data on the other drill holes in the Lower White River coal field are proprietary and were obtained over a 25-year drilling period by several different operators and organizations, commonly at different scales. Coal and other lithologic units are readily identified on the geophysical logs because good natural gamma and density traces are recorded on them. The log quality allowed unit boundaries generally to be picked to the nearest one-half foot. A few of the older, lower quality logs allowed interpretations to the nearest foot, but a few of the most recent, well-calibrated logs allowed unit picks to the nearest one-tenth of a foot.

As in most coal studies, the degree of certainty in establishing coal-bed correlations varies with distance between control points (the higher the drilling density, the better the correlation), local stratigraphy, presence or absence of stratigraphic markers, and log quality. Although correlations of individual coal beds should generally be regarded as indications of stratigraphic position within coal zones, the lithologic and stratigraphic log interpretations resulting from the present study are considered to reflect an accurate representation of the stratigraphic framework of coal beds that exist within the Deserado coal area.

Acknowledgments

We would like to thank Janet Hook, Craig District Office, BLM for supplying geophysical logs of coal exploration drill holes and maps showing active and inactive coal leases, and Matt McMcolm of the Colorado State Office of the BLM for confirming the lease maps. We want to gratefully acknowledge Bruce Barnum (Sage Discovery, Golden, Colo.) for his geologic data and valuable discussions on the study area. We also would like to thank USGS employees Ron Affolter for contributing coal quality data, Laura Biewick for providing GIS support, Dorsey Blake for computer programming support, and Gary Stricker for computer programming support. USGS contract employees Tim Gognat, Al Heinrich, Jon Haacke, and Marin Popov are acknowledged for their technical support with drill-hole databases and computer graphics. In addition, we would like to thank USGS employees Mark Kirschbaum and Edwin Landis for their peer reviews of the manuscript, and Rick Scott for his editorial work.

Geologic Setting

Stratigraphy of the Cretaceous and Tertiary Strata of the Lower White River Coal Field

A generalized geologic map of the Lower White coal field is shown in figure A on plate 1. A generalized stratigraphic column for a portion of the Upper Cretaceous rocks of northwest Colorado including the Lower White River coal field is shown in figure 4, and a columnar section for the Deserado coal area is shown in figure 5. The Lower and Upper Cretaceous Mancos Shale has a maximum thickness of 5,100 ft within and adjacent to the Lower White River coal field and outcrops north and south of the Deserado coal area and north and west of Rangely, Colo. (fig. A on pl. 1 and fig. 2). Only the upper part of the unit is shown in the stratigraphic columns. All the coal-bearing units considered in this study are included in the Mesaverde Group of Late Cretaceous age. Within the Deserado coal area, the Mesaverde Group is approximately 5,000 ft thick and is composed of a thick succession of mostly nonmarine rocks that overlie the marine Mancos Shale. The Mesaverde Group has been divided into three informal formation-equivalent stratigraphic units (fig. 5) by the U.S. Geological Survey (Barnum and Garrigues, 1980). These three units are designated the lower unit, coal unit, and upper unit (fig.

Table 1. Locations of coal-exploration holes drilled by the U.S. Geological Survey, in 1976, in the Lower White River coal field.

[Also shown for the holes are surface elevations, depth drilled, and depth logged. All measurements are in feet; to convert feet to meters, multiply by 0.3048]

Drill hole no.	Location	Surface elevation	Depth drilled	Depth logged
LW-1-CR	SE1/4SE1/4SE1/4 sec. 15, T.3 N., R. 101 W.	5,700	300	290
LW-3-CR	NE1/4NE1/4SW1/4 sec. 33, T.3 N., R. 101 W.	5,800	520	519
LW-4-CR	SW1/4SE1/4NE1/4 sec. 34, T.3 N., R. 101 W.	5,710	1,120	1,115
LW- 7-CR	NW1/4SW1/4NW1/4 sec. 18, T.2 N., R. 100 W.	5,630	920	918
LW-8-CR	NW1/4SE1/4NW1/4 sec. 19, T. 2 N., R. 100 W.	5,830	940	925
LW-24-CR	SW1/4SE1/4NE1/4 sec. 11, T. 2 N., R. 101 W.	5,330	280	279
LW-12-GD	SE1/4NW1/4SE1/4 sec. 31, T. 2 N., R. 100 W.	6,150	640	614
LW-13-GD	NW1/4SE1/4NE1/4 sec. 7, T. 1 N., R. 100 W.	5,900	620	610
LW-14-GD	SW1/4NE1/4SW1/4 sec. 1, T. 1 N., R. 101 W.	6,530	500	500
LW-15-GD	NE1/4NW1/4NW1/4 sec. 11, T. 1 N., R. 101W.	6,420	380	380
LW-16-GD	SW1/4NE1/4NW1/4 sec. 14, T. 1 N., R. 101 W.	5,700	420	420
LW-17-GD	SW1/4SW1/4NW1/4 sec. 16, T. 1 N., R. 101 W	5,840	260	256
LW-18-GD	NE1/4SE1/4NE1/4 sec. 20, T. 1 N., R. 101 W.	5,964	460	459
LW-18B-GD	NE1/4SE1/4SW1/4 sec. 21, T. 1 N., R. 101 W.	5,910	400	393
LW-19-GD	NW1/4NE1/4NE1/4 sec. 32, T. 1 N., R. 101 W.	6,020	480	476
LW-25-GD	SW1/4SW1/4NW1/4 sec. 30, T. 2 N., R. 100 W.	6,090	640	636
LW-2A-RN	NW1/4NW1/4NW1/4 sec. 6, T. 2 N., R. 101 W.	6,365	400	400
LW-9A-RN	NW1/4NW1/4NW1/4 sec. 25, T. 3 N., R. 102 W.	6,005	400	366
LW-21-RN	SW1/4SE1/4SW1/4 sec. 15, T. 3 N., R. 102 W	6,051	400	400
LW-22-RN	NE1/4NW1/4NW1/4 sec. 14, T. 3 N., R. 102 W.	6,073	360	350
LW-23-RN	NE1/4NW1/4NW1/4 sec. 18, T. 3 N., R. 101 W.	5,815	320	318
LW-26-RN	SE1/4NE1/4NE1/4 sec. 36, T. 3 N., R. 102 W.	6,174	400	397
LW-10-DC	SE1/4SE1/4SE1/4 sec. 21, T. 3 N. R. 100 W.	5,950	480	445

5). The lower unit is roughly equivalent to the Iles Formation of the Danforth Hills coal field, about 60 mi to the east of the study area, and averages 690 ft in thickness. The top of the lower coal unit is marked by persistent sandstone beds mapped as the "coal marker sands" by Barnum and Garrigues (1980). The coal unit and upper unit are generally equivalent to the Williams Fork Formation of the Danforth Hills and average about 2,130 ft in thickness (fig. 4). The coal unit was informally subdivided into the lower and upper coal units and the main coal zone (fig. 5) by Barnum and Garrigues (1980).

Overlying the Cretaceous Mesaverde Group within the Deserado coal area is a Tertiary section of fluvial and lacustrine rocks assigned to the Fort Union(?) and Wasatch Formations of Paleocene and Eocene age (fig. 4). This section has been divided into the lower member and the main body of the Wasatch Formation by Barnum and Garrigues (1980). The lower member consists of shale; mudstone; thin, persistent, light-brown sandstone interbeds; carbonaceous shale with coaly lenses; and local lenses of brown clay-pebble conglomerate. Locally, a white, massive, clay-cemented basal sandstone, possibly equivalent to the Ohio Creek Formation, is present (Barnum and Garrigues, 1980). The lower member is about 360 ft thick and is probably at least partially correlative with the Fort Union Formation about 10 mi east of the study area (Hail, 1974; Hail and Barnum, 1993). Approximately 980 ft of the main body is exposed in the study area. The main body consists of lacustrine shale and claystone and sandstone interbeds. The Eocene Green River and Miocene Browns Park Formations were mapped east of the Deserado coal area by Hail (1974) and Hail and Barnum (1993). Quaternary deposits consisting of alluvium, colluvium, and terrace gravels are also present throughout the coal field.

The Deserado coal area includes the coal marker sands, rocks of main coal zone, upper coal unit of the coal unit, upper unit of the Upper Cretaceous Mesaverde Group, the main body and lower member of the Wasatch Formation, and Quaternary deposits. The northern, southern, and western boundaries of the Deserado coal area were drawn on the top of the coal marker sands. The eastern boundary was drawn the base of the Tertiary rocks, and the southeastern boundary was drawn at the contact between the Upper Cretaceous rocks and the Quaternary deposits.

Structure

The Lower White River coal field lies on the northern margin of the Piceance Basin south of Dinosaur National Monument (fig. 1). The Deserado coal area lies on the northeast flank of the Rangely anticline (fig. A on pl. 1 and fig.

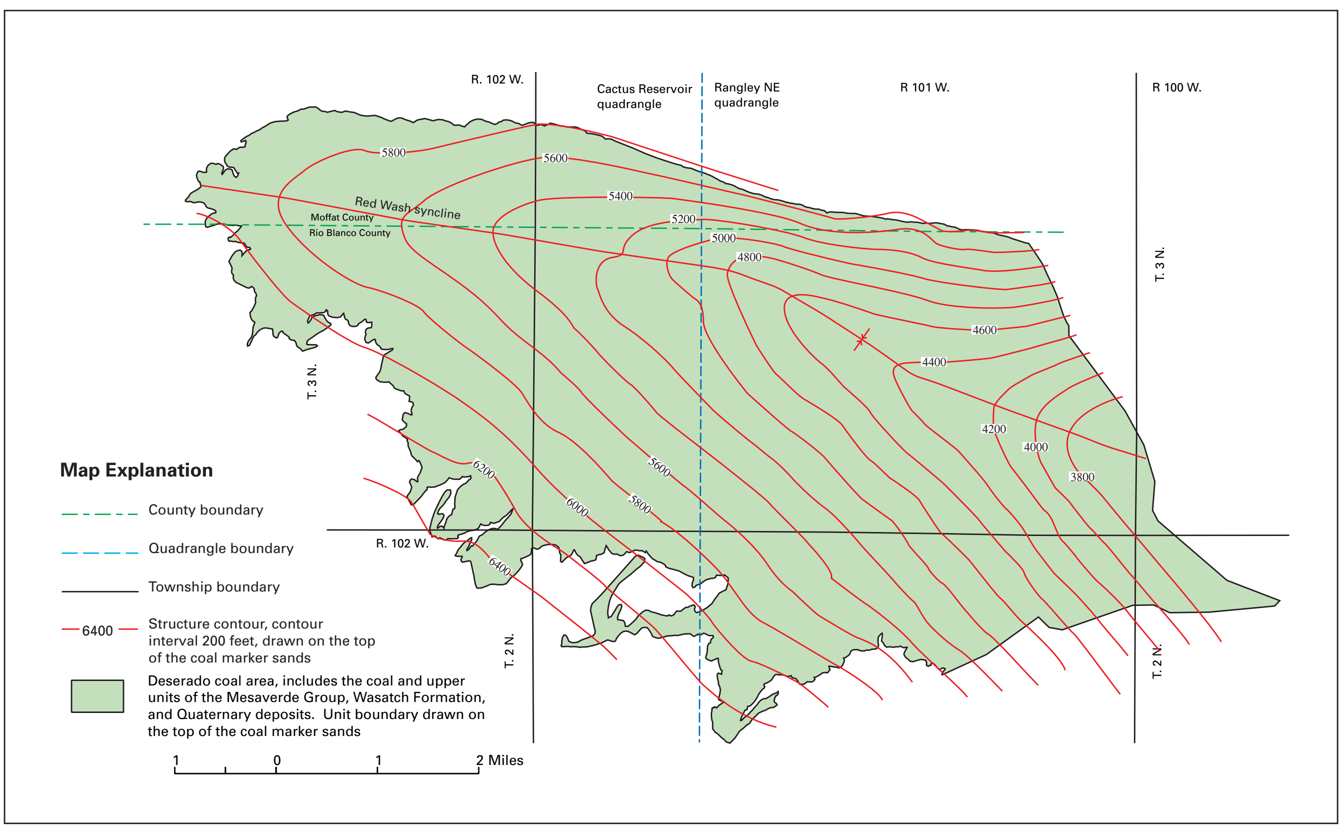


Figure 6. Structure contour map drawn on the top of the coal marker sands, coal unit, Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field, Colorado. Modified after Barnum and Garrigues (1980) and Garrigues and Barnum (1980).

2). The axis of the Red Wash syncline passes through the northern part of the coal area (fig. A on pl. 1 and fig 2). A structure map drawn on the top of the coal marker sands (fig. 6) was constructed using data from geophysical logs (Garrigues, 1976) and outcrop data from 7.5-minute quadrangle geologic maps (Barnum and Garrigues, 1980; Garrigues and Barnum, 1980). The coal-bearing units in the study area dip regularly to the northeast between 5 and 9 degrees through most of the southern part of the area (fig. 6). At the northeastern margin of the coal area, north of the axis of the Red Wash syncline, the rock units dip more steeply to the south. No significant faulting is known to occur in the study area.

Coal Geology of the Deserado Coal Area

Stratigraphy

The coal unit (fig. 5) of the Mesaverde Group (Barnum and Garrigues, 1980) in the Lower White River coal field (fig. A on pl. 1) ranges in thickness from 300 to 600 ft and is divided into three informal subunits (B.E. Barnum, U.S. Bureau of Land Management, written commun., 1988). Within the Deserado coal area, the coal unit averages about 490 ft thick. The subunits are, in ascending order, the lower coal unit, the main coal zone, and upper coal unit. These three subunits were used as regional zones to help with the correlation of stratigraphic units obtained from geophysical logs in the study area.

The lower coal unit (fig. A on pl. 1 and fig. 5) averages about 150 ft thick, but the complete unit is rarely penetrated in the drill holes studied. The lower coal unit is predominately a transitional unit between the lower unit of the Mesaverde Group (fig. 5), which is dominated by thick, fluvial, channel-sandstone successions, and the overlying main coal zone, which was deposited in a coastal-plain environment. The lower coal unit consists primarily of mudstone and shale with interbedded fine-grained sandstone and was deposited in a coastal-plain environment. Thin lenticular coals occur throughout the lower coal unit and are more locally persistent near the top of the subunit.

The uppermost part of the lower coal unit is marked by an interval containing from one to three thin but persistent ledges of white, planar-bedded, ripple-marked, fine-grained to very fine grained, well-sorted sandstone that contain abundant carbonaceous fragments. Gale (1910) first mapped these persistent sandstones, which he called the “white rock unit,” and stated that they marked the base of the minable coals. These sandstone ledges were mapped as the “coal marker” sands (fig. 5) by Barnum and Garrigues (1980), and they can usually be identified on geophysical logs (fig. C on pl. 1, and figs. 7 and 8). The coal marker sands are an important regional marker within the Lower White River coal field. The sands of the coal-marker are interpreted to represent deposition in a low-energy beach environment, probably a lagoonal beach behind an active barrier-island system. The coal marker sands range in thickness from 0 to 35 ft.

The main coal zone of the coal unit (fig. C on pl. 1 and fig. 5) contains all of the thicker and economically important coal beds in the Deserado coal area. Data from drill holes and geologic mapping indicate that the main coal zone averages about 160 ft thick and is predominantly composed of mudstone, sandstone, and coal deposited in a coastal-plain environment. The thicker and more persistent coal beds occur in the lower part of the zone. The coals present in the upper part of the zone tend to be thin and lenticular. The lower part of the main coal zone contains two thin units consisting of altered ash-fall tuff. When exposed on the surface or observed in drill core, the unit is a white to grayish white, structureless, claystone. In the subsurface, these tonstein units were used as marker beds when correlating drill hole geophysical logs. The main coal zone appears to represent one period of nearshore deposition favorable to coal formation. The environment of deposition became progressively less favorable for coal formation as the shoreline retreated eastward. The main coal zone is equivalent to the lower part of the Fairfield coal group of the Williams Fork Formation in the Danforth Hills coal field (Hancock and Eby, 1930; Brownfield and others, chap. M, this CD-ROM). It is correlated to the Cameo-Wheeler coal zone in the southern part of the Piceance Basin, to the Wheeler-Fairfield coal zone along the southern part of the Grand Hogback (Hettinger and others, chap. O, this CD-ROM), and to the Fairfield coal group of Collins (1976) along the northern part of the Grand Hogback.

The upper coal unit averages about 180 ft thick in the study-area drill holes, although the thickness varies considerably. This unit represents a transition from coastal to a fluvial environment of deposition similar to the lower coal unit. Coal is present throughout the upper coal unit, but the coals are generally thin and lenticular. One persistent coal bed, which is as thick as 5 ft, occurs near the top of the unit and may represent the landward vestige of a second period of nearshore coal deposition. If so, this part of the stratigraphic section could be expected to contain a second major coal zone a few miles east of the study area.

Coal Distribution

In the Deserado coal area, the coal unit of the Mesaverde Group has been subdivided into nine coal zones, eight of which are shown in figure 5. Western Fuels, Inc. has named these coal zones A, lower B, upper B (includes C), D, E, F, G, H, and I in ascending order within the Deserado mine area (B.E. Barnum, U.S. Bureau of Land Management, written commun., 1988). Coal zone A is below and coal zones lower B through I are above the coal marker sands. For this report, lower B, upper B, and C were combined as the B coal zone (fig. 5).

Although nine coal zones have been recognized in the

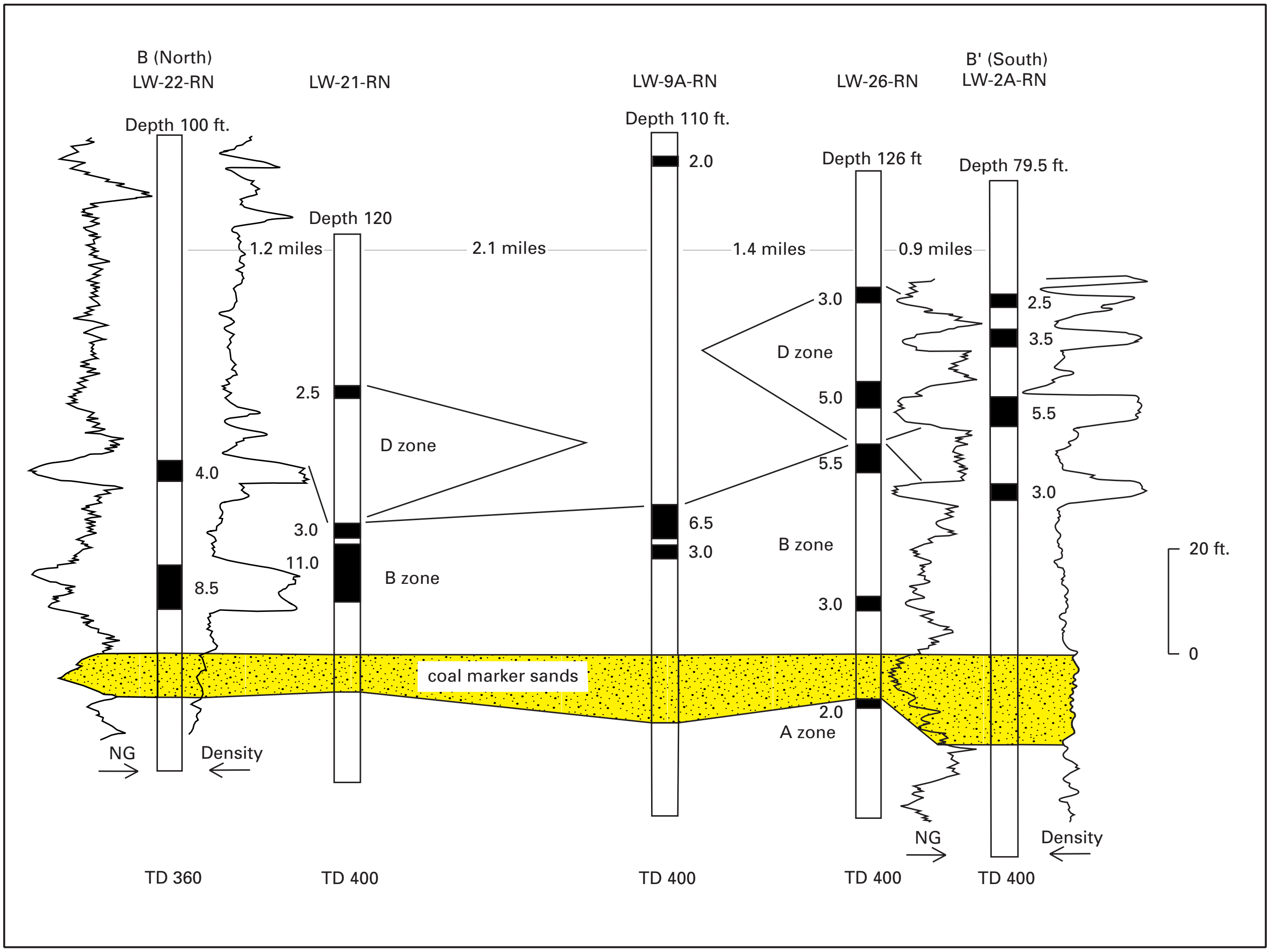


Figure 7. Cross section B-B′ (fig. 3) showing a portion of selected geophysical log traces (natural gamma (NG) and gamma-gamma density) and lithologic units of B and D coal zones and the coal marker sands for selected exploratory bore holes, Deserado coal area, Lower White River coal field, Colorado. Location of cross section shown in figure 3. Coal beds shown in black; coal marker sands in stippled yellow. Total depth (TD) shown at bottom of column (in feet), depth of upper limit of selection shown at top of the column. Thickness of coal beds shown in feet.

coal unit, most coal resources in the Deserado coal area are contained within two coal zones, the B and D, respectively. The B and D zones occur in the lower part of the main coal zone just above the coal marker sands (fig. C on pl. 1 and figs. 5, 7, and 8). The B coal zone rests directly on the coal marker sands, contains one to three coal beds, and averages about 55 ft thick. The top of the B coal zone contains a volcanic-ash unit that can be traced throughout the study area and was used to correlate the major coal zones. The base of the D coal zone is approximately 55 ft above the coal marker sands. The D zone contains as many as two beds and averages about 30 ft thick.

The net-coal thickness and overburden (fig. 9) and the coal-thickness-categories (fig. 11) maps of the B coal zone display a thinning of the total coal to the east, with a thickening to the west within the Deserado coal area. The thickest net coal in the B zone is found in the center of the study area south of the axis of the Red Wash syncline and in the western part of the study area. The net-coal thickness and overburden (fig. 10) and the net-coal-thickness-categories (fig. 12) maps of the D coal zone display a thinning of the total coal to the north and a thickening to the east and west. The variability in coal-zone thickness within the study area is due in part to the lenticularity and number of beds within each coal zone.

Coal Quality

Gale (1910) reported coal-analysis data from the Rector mine in the southeastern part of the Deserado coal area. The calorific value ranged from 11,080 to 11,490 Btu/lb, sulfur content from 0.4 to 0.46 percent, and ash yield from 5.53 to 8.06 percent on an as-received basis. The apparent rank of the

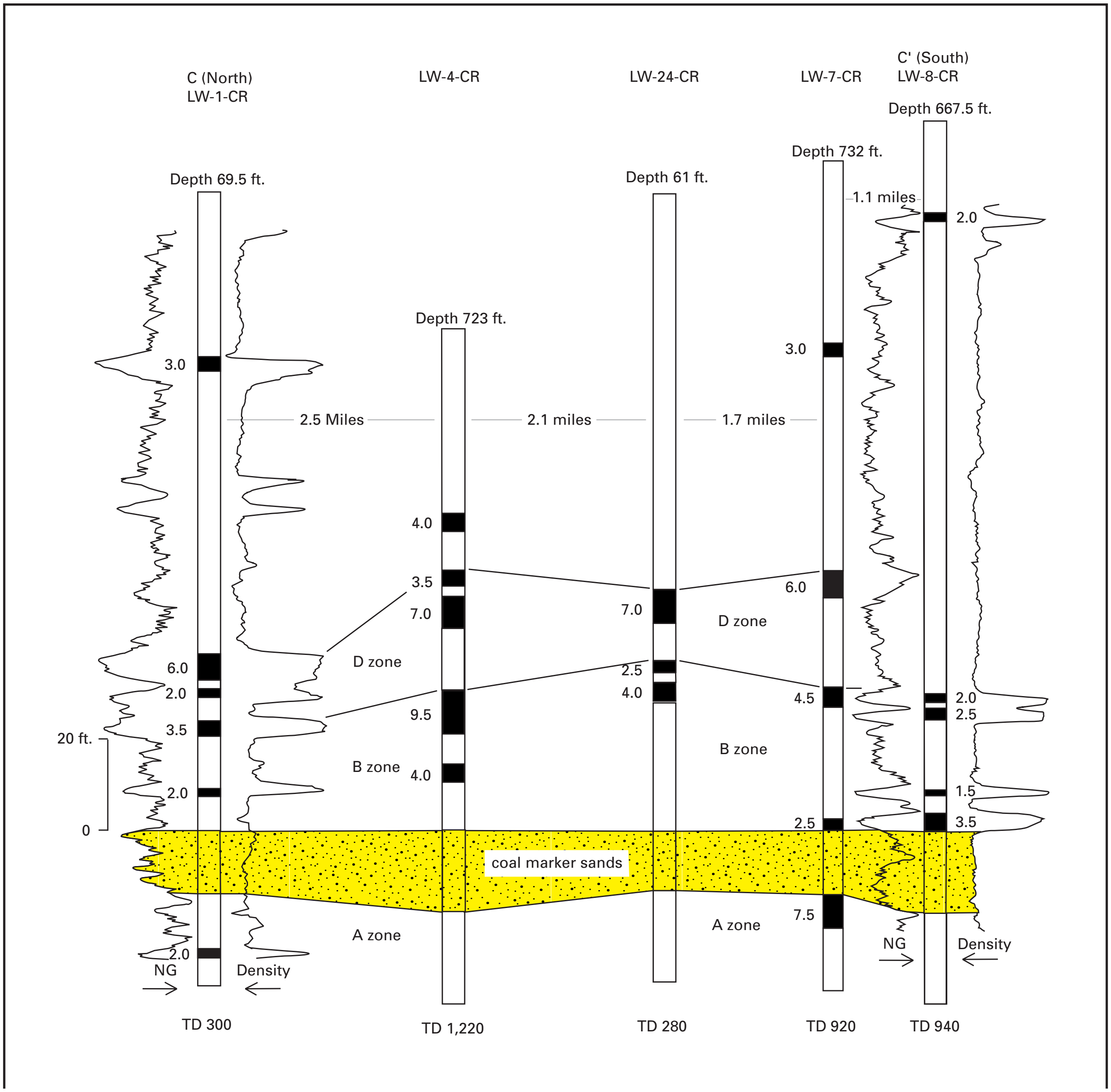


Figure 8. Cross section C-C′ (fig. 3) showing a portion of selected geophysical log traces (natural gamma (NG) and gamma-gamma density) and lithologic units of B and D coal zones and the coal marker sands for selected exploratory bore holes, Deserado coal area, Lower White River coal field, Colorado. Location of cross section shown in figure 3. Coal beds shown in black; coal marker sands in stippled yellow. Total depth (TD) shown at bottom of column (in feet), depth of upper limit of selection shown at top of the column. Thickness of coal beds shown in feet.

coal was determined to be high-volatile C bituminous. Hildebrand and Garrigues (1981) reported proximate and ultimate data on nine coal samples from the Lower White River coal field. The coal has a average heat of combustion of 10,490 Btu/lb, moisture content of 10.4 percent, a sulfur content of 0.5 percent, and an ash yield of 13.0 percent on an as-received basis. The apparent rank for nine samples from the Lower White River coal field was determined to be high-volatile C bituminous, and the calculated mean calorific value (moist, mineral-matter-free basis) is 12,210 Btu/lb. The apparent rank was calculated using the Parr formula (American Society for Testing and Materials, 1997, D388).

In the present study, the 13 coal samples listed (table 2) from the Deserado coal area of the Lower White River

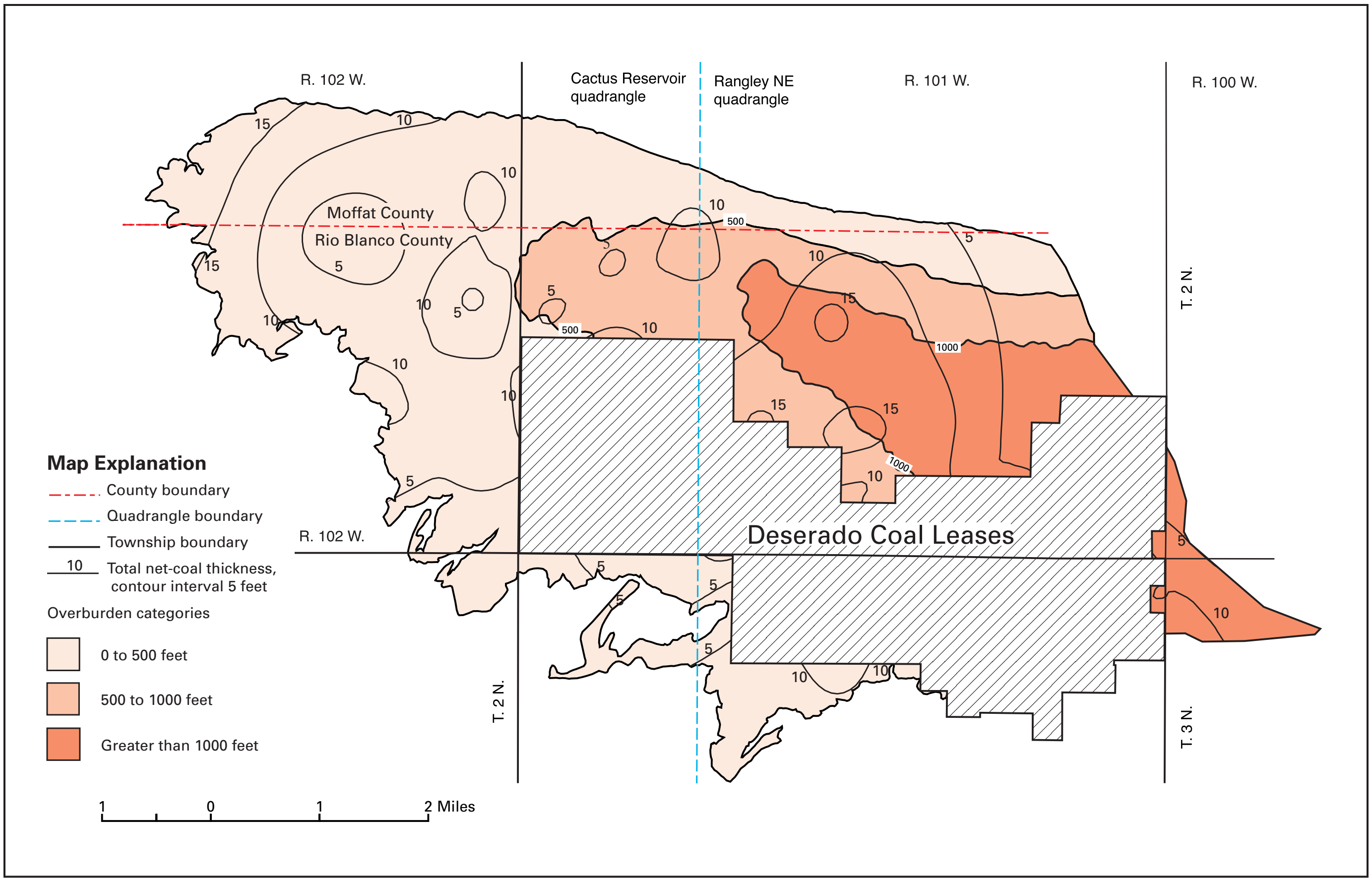


Figure 9. Map showing total net-coal thickness and overburden thickness categories for the B coal zone, Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field, Colorado. Data not shown for Deserado coal leases.

coal field were determined to be high-volatile C bituminous in apparent rank. Two samples were collected at outcrops and the rest were from drill cores within the Lower White River coal field and the B and D zones in the Deserado coal area. The coal has a average calorific value of 10,090 Btu/lb, a sulfur content of 0.55 percent, and an ash yield of 11.6 percent on an as-received basis. Ranges in values for proximate and ultimate analyses are given in table 2. Means and ranges of selected trace-element data for 17 coal samples from the Lower White River coal field and the B and D zones of the Deserado coal area are given in table 3 on a whole-coal basis. The methods for sampling and inorganic analysis of coal used to determine the element contents listed are discussed in Golightly and Simon (1989).

Methodology

Digital files or coverages of various geologic and other features such as outcrop lines, elevation data, coal thickness, faults, fold axes, Federal coal leases, and mined-out areas were created within the study area. The coal benches and parting thicknesses were determined from geophysical logs using the natural gamma and density traces. Coal-bed thicknesses from the log traces are calculated using a USGS program (G.D. Stricker, written commun., 1998) that follows the methodology of Wood and others (1983) and excludes bituminous coal beds less than 1.2 ft thick. The total net-coal thickness values for each zone were used in the resource calculations (see Roberts and others, chap. C, this CD-ROM).

Coal resources for the Deserado coal area are reported in the identified resource category (Wood and others, 1979). Identified resources are located within a 3-mile radius of a data point and include the reliability categories of measured, indicated, and inferred. The measured resource category has the highest degree of geologic assurance and is located within a 0.25-mile radius of a data point. The indicated resource category has a more moderate degree of geologic assurance and is located within an area bounded by a 0.25- to 0.75-mile radius from a data point. The inferred resource category has a lower degree of geologic assurance and is located within an area bounded by a 0.75- to 3-mile radius from a data point. Coal resources estimated in this study do not include

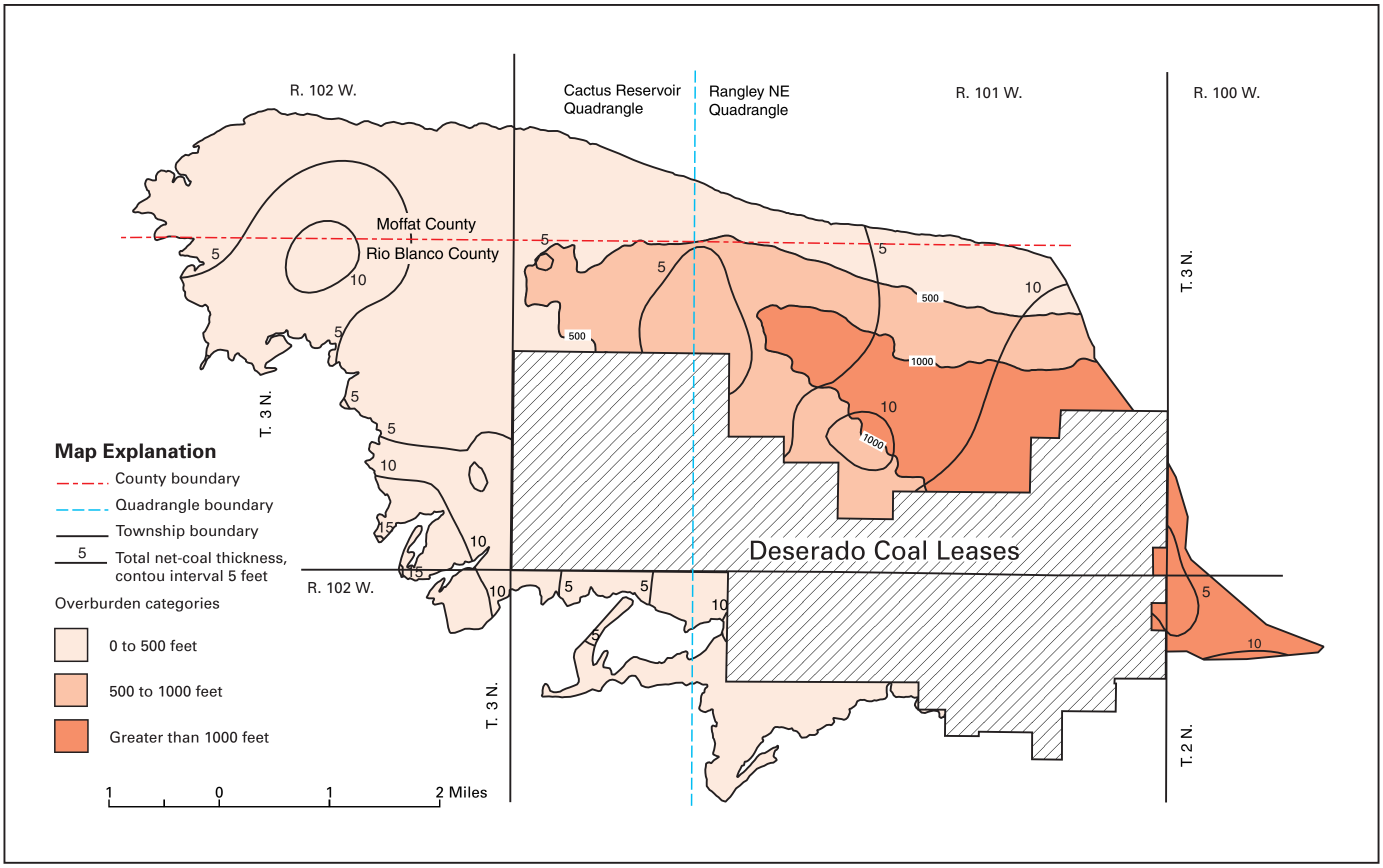


Figure 10. Map showing total net-coal thickness and overburden thickness categories for the D coal zone, Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field, Colorado. Data not shown for Deserado coal leases.

the area inside the Deserado mine Federal and State coal leases. Estimated coal resource tonnages were rounded to two significant figures. Therefore, totals may not equal the sum of individual categories because of independent rounding.

Estimates of coal resource tonnages for the B and D coal zones are based on the methodology of Wood and others (1983), which uses a mean density of 1.32 g/cm3 or 1,800 short tons/acre-ft for bituminous coal. Also, following this methodology (1) calculations were made for the 0–500 ft, 500–1,000 ft, and > 1,000 ft overburden categories by integrating the overburden maps, net-coal isopach maps, and the areal extent of each zone (figs. 9 and 10)and (2) isopach maps that show total net coal in the thickness categories of 1.2–2.3, 2.3–3.5, 3.5–7.0, 7.0–14.0, and greater than 14.0 ft were constructed for each of the two coal zones in the coal unit (figs. 11 and 12).

The maximum overburden for the B and D coal zones was determined by integrating structure contours drawn on the top of the coal marker sands of coal unit (fig. 5), basal elevations for each coal zone, and surface elevations imported from 1:24,000 Digital Elevation Models for the quadrangles within the Deserado coal area (fig. 3). The areal extent of each zone was determined by integrating structure contours drawn on top of the coal marker sands, the mean base elevation for each zone above the coal marker sands, and the Digital Elevation Models for the quadrangles to determine a zero overburden line. The zero overburden line is equivalent to a basal crop line for the coal zone (see Roberts and others, chap. C, this CD-ROM).

Coal Resources

Landis (1959) reported an estimated original coal resource on an individual bed basis of 7.0 billion short tons to an overburden depth of 3,000 ft for the Lower White River coal field (553 mi2). Hornbaker and others (1976) reported an estimated original coal resource of 11.8 billion short tons to an overburden depth of 6,000 ft for the Lower White River coal field.

Based on data derived from the present study, coal resources of about 440 million short tons (table 4) in the identified resource reliability category (Wood and others, 1983) are

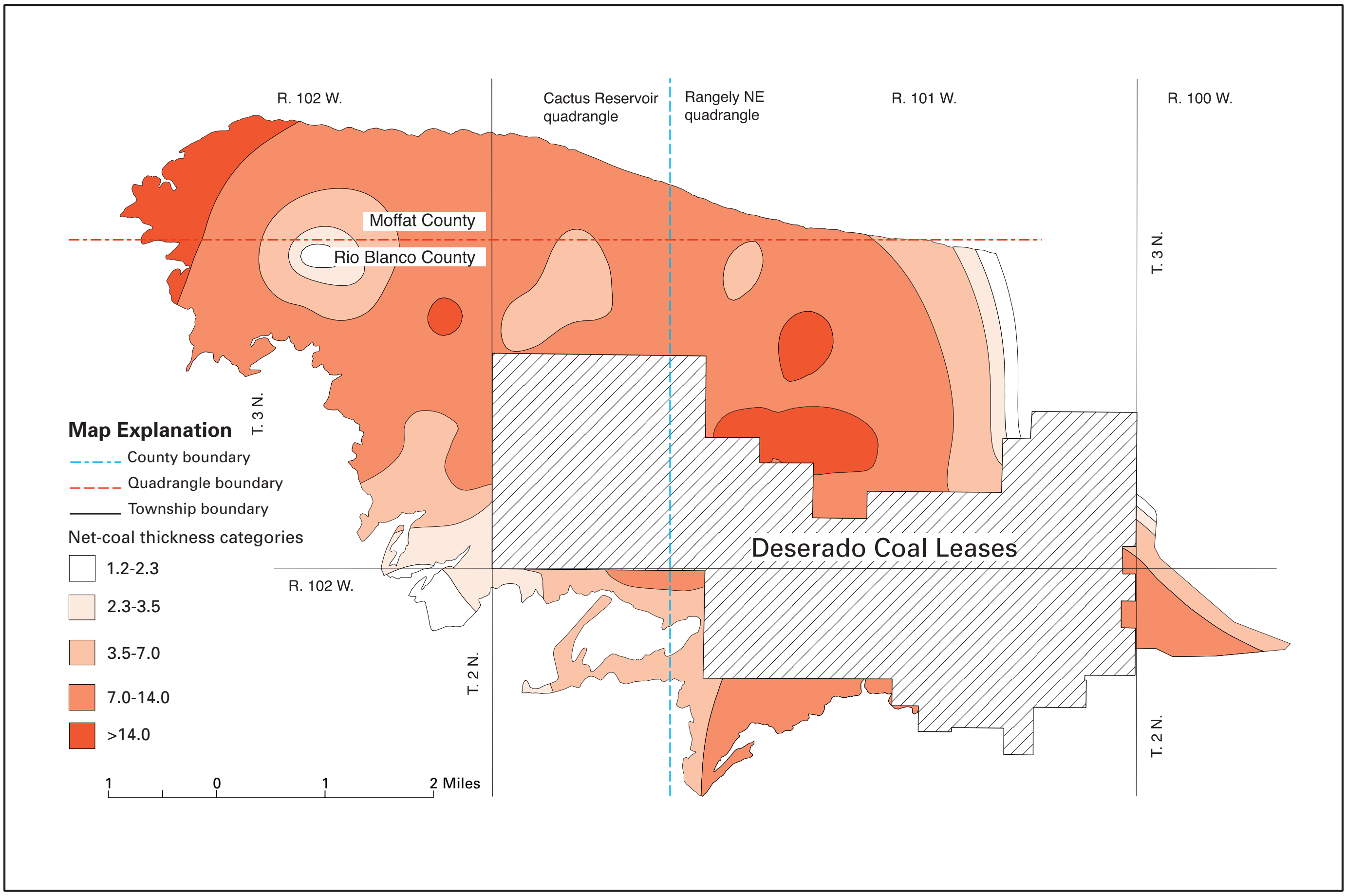


Figure 11. Map showing bituminous net-coal thickness categories for the B coal zone, Deserado coal area, Upper Cretaceous Mesaverde Group, Lower White River coal field, Colorado. Thickness categories from Wood and other (1983). Data not shown for Deserado coal leases.

estimated for the coal unit in the Deserado coal area. This estimate includes all coal beds greater than 1.2 ft thick to an overburden depth of more than 1,500 ft. The total net-coal thickness map (fig. 13) and cross sections (fig. C on pl. 1 and figs. 7 and 8) demonstrate the variability in coal accumulation within the coal unit of the Mesaverde Group in the Deserado coal area. The total net-coal thicknesses range from less than 5 ft to more than 35 ft thick, and the number of coal beds varies from 1 to 10. The calculated total coal resources are shown for various categories (coal and overburden thickness; resource type, county, township, and quadrangle location; coal ownership) in table 4, and coal resources for the B and D coal zones are shown in tables 5–10. More than 97 percent of the coal in the coal unit in the Deserado coal area is federally owned, with more than 90 percent administrated by the U.S. Bureau of Land Management. More than 77 percent of the total coal is found within the 1,000-ft overburden category (250 million short tons), with more than 57 percent within the 500-ft overburden category (250 million short tons). More than 84 percent of the total coal resource is contained in the B and D coal zones in the main coal zone, 220 and 150 million short tons, respectively. The coal resources estimated for this study do not include the area inside the Deserado coal leases.

Although the Deserado coal area contains estimated original resources of 440 million short tons of coal, this resource figure does not reflect economic, land-use, environmental, technological, and geologic constraints that may affect coal availability and recoverability (T.J. Rohrbacher, written commun., 1998). Some of the economic constraints involve costs to build or move infrastructures such as railroads, highways, and primary electrical transmission lines. Environmental restrictions include river valleys, towns and communities, wildlife habitat, and air-quality issues. Geologic constraints include faulting, coal-bed thickness, and the dip of the strata. Any combination of these constraints and (or) restrictions can reduce the amount of coal that is available and recoverable to 10 to 20 percent of the original resource (Rohrbacher and others, 1994).

Within the Deserado coal area, the recoverable coal will be restricted because the two assessed coal zones (B and

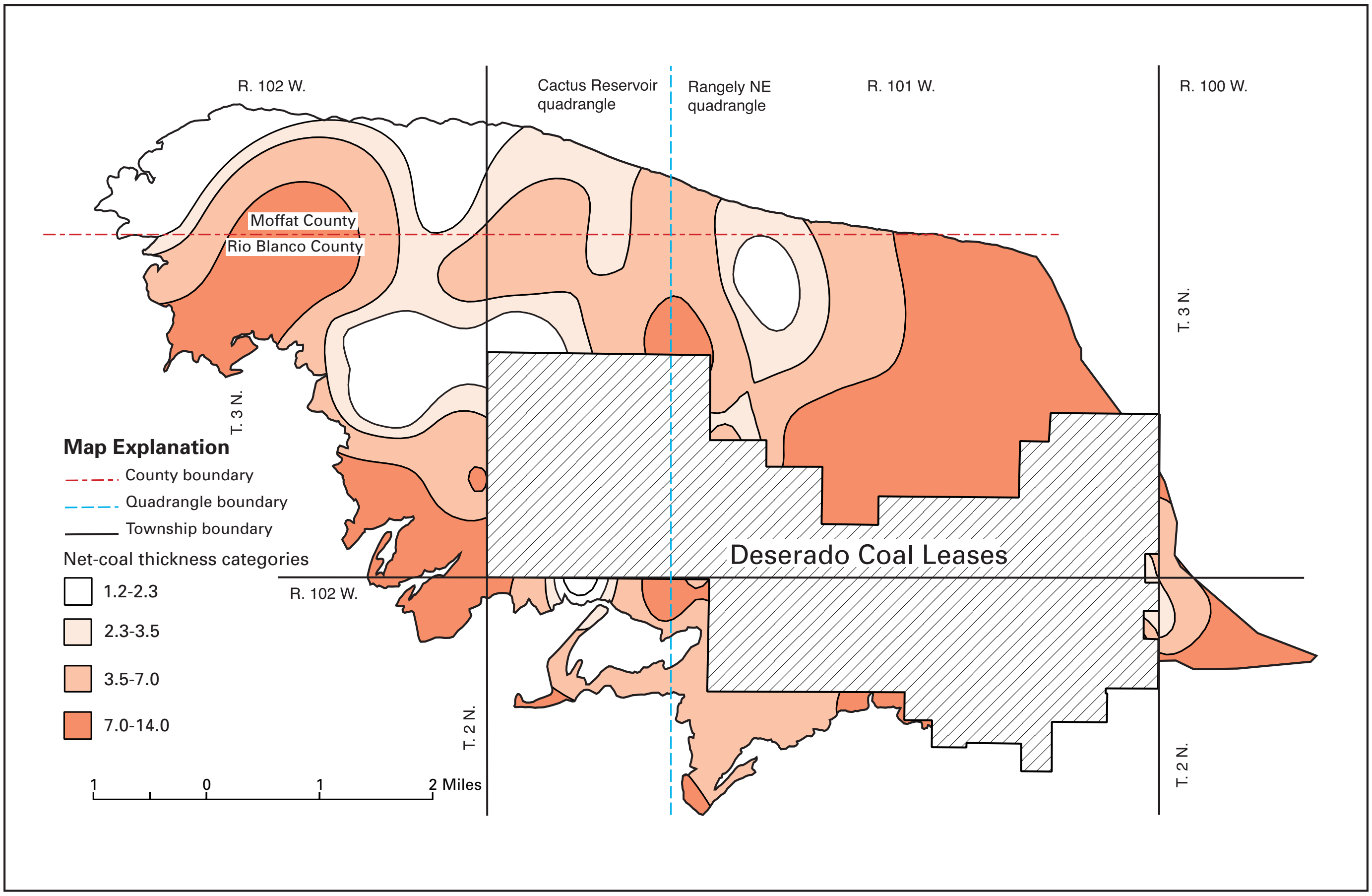


Figure 12. Map showing bituminous net-coal thickness categories for the D coal zone, Deserado coal area, Upper Cretaceous Mesaverde Group, Lower White River coal field, Colorado. Thickness categories from Wood and other (1983). Data not shown for Deserado coal leases.

D) are too close together. Longwall mining methods causes controlled collapsing of overburden, including coal beds, thus reducing the amount of recoverable coal. The thickness of the partings and splits can also limit the recovery of the coal being mined. Mining techniques can reduce the original resource: for example, longwall methods can restrict the recovery of thick beds where mining equipment is engineered for a limited range of coal-bed thicknesses, normally less than 14 ft. Currently the Deserado mine is producing coal by longwall methods from both B and D zones within the mine property at different times. Once the coal is produced from either the B or D zone, the other zone is removed from the resource base because of the current mining process. Future mining in the Lower White River coal field will most likely be restricted to the areas adjacent to the Deserado mine and its rail line. Although the factors just discussed will reduce the amount of coal that can ultimately be recovered, we did not estimate the tonnages that might be affected.

References Cited begins on page 23

Table 2. Number of samples, range, arithmetic mean, and standard deviation of proximate and ultimate analyses, calorific value, forms of sulfur, and ash-fusion temperatures of coal from the Lower White coal field, Colorado.

[All values are in percent except Btu/lb and ash-fusion temperatures, and are reported on the as-received basis]

	Number of samples	Range		Arithmetic mean	Standard deviation
		Minimum	Maximum		
Proximate and ultimate analyses					
Moisture	13	6.7	22.3	12.02	5.17
Volatile matter	13	29.6	36.8	33.39	2.2
Fixed carbon	13	35.6	51.13	42.95	5.69
Ash	13	4.08	23.9	11.64	5.31
Hydrogen	13	4.5	5.6	5.28	0.28
Carbon	13	44.8	66.9	58.22	7.39
Nitrogen	13	1	1.4	1.27	0.12
Oxygen	13	17.7	36.6	23.04	6.34
Sulfur	13	0.4	1.11	0.55	0.19
Calorific value, Btu/lb					
Btu/lb	13	7,240	11,720	10,090	1,490
Forms of sulfur					
Sulfate	12	0.01	0.05	0.02	0.01
Pyritic	13	0.01	0.43	0.18	0.13
Organic	13	0.11	0.63	0.34	0.15
Ash-fusion temperatures, °F					
Initial deformation	13	2,215	2,855	2,595	235
Softening temperature	13	2,305	2,910	2,660	200
Fluid temperature	13	2,415	2,910	2,710	170

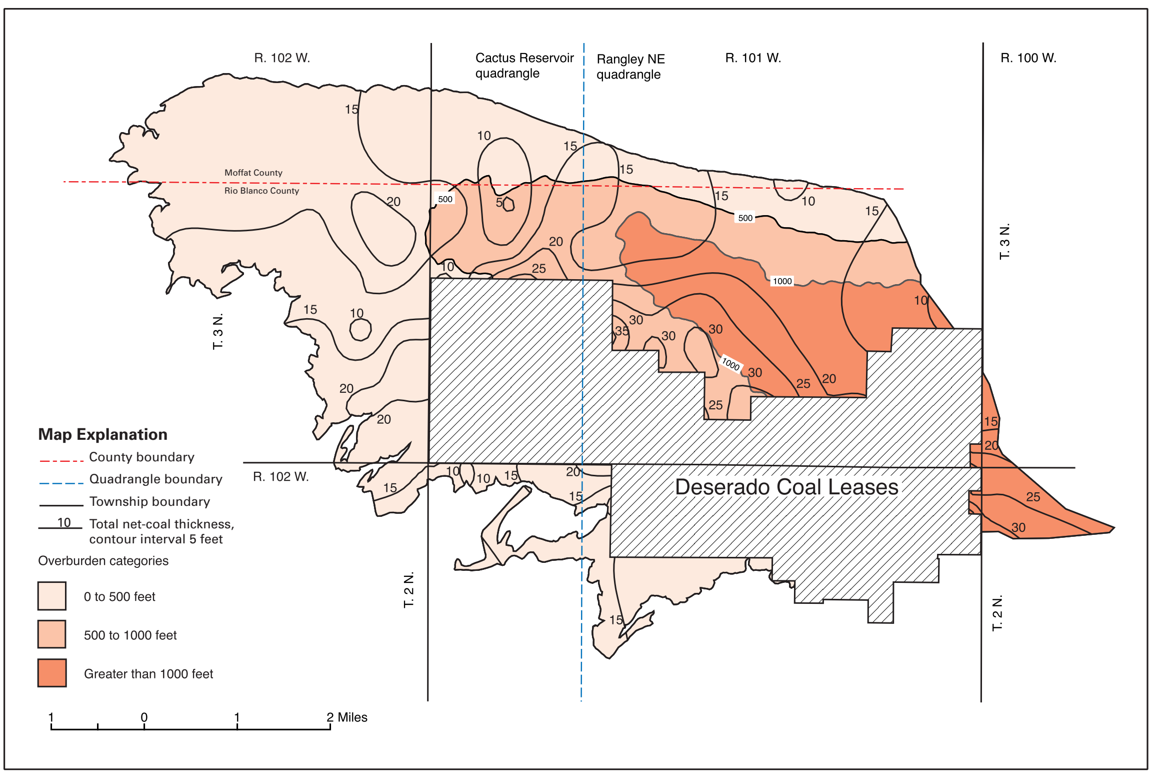


Figure 13. Map showing total net-coal thickness and overburden thickness categories for the coal unit, Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field, Colorado. Data not shown for Deserado coal leases.

Table 3. Number of samples, range, arithmetic mean, and standard deviation of ash and 39 elements in coal from the Lower White River coal field, Colorado.

[All analyses are in percent or parts per million and are reported on a whole coal basis. L, less than value shown]

	Number of samples	Range		Arithmetic mean	Standard deviation
		Minimum	Maximum		
Percent					
Ash	17	4.8	25	13	5.7
Si	17	0.19	7.1	3.3	1.9
Al	17	0.34	2.6	1.5	0.62
Ca	17	0.17	1.4	0.56	0.37
Mg	17	0.046	0.23	0.12	0.061
Na	17	0.077	0.17	0.12	0.023
K	17	0.005	0.21	0.069	0.065
Fe	17	0.094	1.9	0.38	0.42
Ti	17	0.006	0.13	0.079	0.03
Parts per million					
As	16	0.25	0.93	0.47	0.22
B	17	30	84	53	14
Ba	17	110	680	360	170
Be	17	0.26L	1.2	0.66	0.32
Co	17	0.58	4.9	1.6	1
Cr	14	1.4	21	7.5	5.4
Cu	17	2	16	7.2	3.3
F	17	50	210	110	42
Ga	17	0.72	7.7	3.7	1.8
Hg	17	0.01	0.1	0.038	0.026
La	16	6.8L	17	9	3.9
Li	17	1.7	26	11	5.7
Mn	17	2.2	540	40	130
Mo	14	0.48	2.3	1.1	0.6
Nb	17	0.72	13	5	2.7
Ni	17	1.3	11	4.2	2.9
Pb	17	1.4	41	7.5	9.1
Sb	16	0.043	0.63	0.32	0.19
Sc	17	0.58	3.8	2	0.87
Se	17	0.35	2.3	1.1	0.44
Sr	17	30	270	170	67
Th	17	0.24	7.7	3.3	2.2
U	17	0.26L	3.4	1.6	0.99
V	17	2.1	34	15	8
Y	17	4.3	18	8.6	3.8
Yb	17	0.21	1.8	0.78	0.43
Zn	17	2.9	30	13	8.5
Zr	17	3.7	50	27	11

Table 4. Identified total coal resources in millions of short tons, for the coal unit of the Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field.

[Resources are shown by overburden, county, township, quadrangle, and Federal and non-Federal (State and private) ownership categories. Resources do not include area inside the Deserado coal lease boundaries. Coal resources rounded to 2 significant figures]

	Overburden categories, in feet			Total
	0-500	500-1000	>1000	
By county				
Moffat	93	1.8	0	95
Rio Blanco	160	89	95	340
Total	250	91	95	440
By township				
T2N R100W	0	0	19	19
T2N R101W	33	0	1.1	34
T2N R102W	5.6	0	0	5.6
T3N R100W	0	0	3.2	3.2
T3N R101W	46	91	72	210
T3N R102W	170	.41	0	170
Total	250	91	95	440
By 7.5′ quadrangle				
Cactus Reservoir	49	64	95	210
Rangely NE	200	27	0	230
Total	250	91	95	440
By coal-ownership category				
Federal	240	91	95	430
Non-Federal	8.1	.28	0	8.4
Total	250	91	95	440

Table 5. Identified coal resource in millions of short tons for the B coal zone of the Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field by county, coal ownership, and overburden categories.

[Resources do not include area inside the the Deserado coal lease boundaries. Coal resources rounded to 2 significant figures]

	Overburden categories, in feet			Total
	0-500	500-1000	>1000	
By county				
Moffat	58	1.1	0	59
Rio Blanco	72	44	42	160
Total	130	45	42	220
By coal-ownership category				
Federal	120	45	42	210
Non-Federal	5.9	.15	0	6.1
Total	130	45	42	220

Table 6. Identified coal resources in millions of short tons for the B coal zone of the Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field by township, overburden, and net-coal thickness categories.

[Resources do not include area inside the The Deserado coal lease boundaries. Resources rounded to 2 significant figures]

Township	0-500 feet overburden net-coal thickness categories, in feet					0-500 total	500-1000 feet overburden net-coal thickness categories, in feet					500-1000 total	>1000 feet overburden net-coal thickness categories, in feet					>1000 total	Total
	1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0		
T2N R100W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	4.9	0	6.3	6.3
T2N R101W	0	.38	6.1	8.2	0	15	0	0	0	0	0	0	0	0	0	.41	0	.41	15
T2N R102W	.46	.34	0	0	0	.80	0	0	0	0	0	0	0	0	0	0	0	0	.80
T3N R100W	0	0	0	0	0	0	0	0	0	0	0	0	.042	.077	.51	.12	0	.75	.75
T3N R101W	.18	.35	2.8	20	0	23	.12	.23	6.0	31	7.6	45	.18	.39	3.3	23	7.6	35	103
T3N R102W	.17	1.9	10.4	62	16	91	0	0	0	.20	0	.20	0	0	0	0	0	0	91
Total	.81	3.0	19	91	16	130	.12	.23	6.0	31	7.6	45	.22	.47	5.2	28	7.6	42	220

Table 7. Identified coal resources in millions of short tons for the B coal zone of the Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field by overburden, net-coal thickness, and quadrangle categories.

[Resources do not include area inside the The Deserado coal lease boundaries. Coal resources rounded to 2 significant figures]

Quadrangle	0-500 feet overburden net-coal thickness categories, in feet					0-500 total	500-1000 feet overburden net-coal thickness categories, in feet					500-1000 total
	1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0	
Cactus Reservoir	.18	.35	4.9	15	0	20	.12	.23	2.2	21	7.6	31
Rangely NE	.63	2.6	14	76	16	110	0	0	3.8	10	0	14
Total	.80	3.0	19	91	16	130	.12	.23	6	31	7.6	45

Quadrangle	>1000 feet overburden net-coal thickness categories, in feet					>1000 total	Total
	1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0	>14.0		
Cactus Reservoir	.22	.47	5.2	28	7.6	42	94
Rangely NE	0	0	0	0	0	0	124
Total	.22	.47	5.2	28	7.6	42	220

Table 8. Identified coal resources in millions of short tons for D coal zone of the Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field by county, Federal nonfederal (State and private) ownership, and overburden categories.

[Resources do not include area inside the The Deserado coal lease boundaries. Coal resources rounded to 2 significant figures]

	Overburden categories, in feet			Total
	0-500	500-1000	>1000	
By county				
Moffat	21	.09	0	21
Rio Blanco	64	31	33	130
Total	85	31	33	150
By coal-ownership category				
Federal	84	31	33	150
Non-Federal	1	.02	0	1
Total	85	31	33	150

Table 9. Identified coal resources in millions of short tons for the D coal zone of the Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field by overburden, net-coal thickness, and township categories.

[Resources do not include area inside the The Deserado coal lease boundaries. Coal resources rounded to 2 significant figures]

Township	0-500 feet overburden net-coal thickness categories, in feet				0-500 total	500-1000 feet overburden net-coal thickness categories, in feet				500-1000 total	>1000 feet overburden net coal thickness categories, in feet				>1000 total	Total
	1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0		
T2N R100W	0	0	0	0	0	0	0	0	0	0	0	.21	1.3	4	5.4	5.4
T2N R101W	.10	.23	9.6	3.2	13	0	0	0	0	0	0	.04	.11	.03	.17	13
T2N R102W	0	0	0	4.1	4.1	0	0	0	0	0	0	0	0	0	0	4.1
T3N R100W	0	0	0	0	0	0	0	0	0	0	0	.01	.93	.2	1.1	1.1
T3N R101W	.58	3.7	6.5	8.2	19	.63	2.2	11	17	31	.15	.98	2	23	26	77
T3N R102W	3.5	4.7	13.7	27	49	0	0	0	0	0	0	0	0	0	0	49
Total	4.2	8.6	30	42	85	.63	2.2	11	17	31	.15	1.2	4.3	27	33	150

Table 10. Identified coal resources in millions of short tons for the D coal zone Upper Cretaceous Mesaverde Group, Deserado coal area, Lower White River coal field by overburden, net-coal thickness, and quadrangle categories.

[Resources do not include area inside the The Deserado coal lease boundaries. Coal resources rounded to 2 significant figures]

Quadrangle	0-500 feet overburden net-coal thickness categories, in feet				0-500 total	500-1000 feet overburden net-coal thickness categories, in feet				500-1000 total	>1000 feet overburden net-coal thickness categories, in feet				>1000 total	Total
	1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0		1.2-2.3	2.3-3.5	3.5-7.0	7.0-14.0		
Cactus Reservoir	.089	.97	9.6	10	21	.55	1.2	7	16	25	.15	1.2	4.3	28	33	79
Rangely NE	4.1	7.7	20	32	64	0.077	1	4.4	.81	6.3	0	0	0	0	0	70
Total	4.2	8.7	30	42	85	.63	2.2	11	17	31	.15	1.2	4.3	28	33	150

References Cited

Barnum, B.E., and Garrigues, R.S., 1980, Geologic map and coal sections of the Cactus Reservoir quadrangle, Rio Blanco and Moffat Counties, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-1179, scale 1:24,000.

Barnum, B.E., Garrigues, R.S., and Dyer, L.E., 1977, Coal sections of holes drilled in 1976 in the Lower White River coal field, Moffat and Rio Blanco Counties, Colorado: U.S. Geological Survey Open-File Report 77-378.

Barnum, B.E., and Hail, W.J., Jr., 1996, Geologic map of the Gillam Draw quadrangle, Rio Blanco County, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-2314, scale 1:24,000.

Brownfield, M.E., and Johnson, E.A., 1984, Selected references on the geology of the Danforth Hills coal field, Moffat and Rio Blanco Counties, Colorado: U.S. Geological Survey Open-File Report 84-768, 28 p.

Collins, B.A., 1976, Coal deposits of the Carbondale, Grand Hogback, and southern Danforth Hills coal fields, eastern Piceance Basin, Colorado: Quarterly of the Colorado School of Mines, v. 71, no. 1, 138 p.

Cullins, H.L., 1968, Geologic map of the Banty Point quadrangle, Rio Blanco County, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-703, scale 1:24,000.

Cullins, H.L., 1969, Geologic map of the Mellen Hill quadrangle, Rio Blanco County, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-835, scale 1:24,000.

Cullins, H.L., 1971, Geologic map of the Rangely quadrangle, Rio Blanco County, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-812, scale 1:24,000.

Gale, H.S., 1910, Coal fields of northwestern Colorado and northeastern Utah: U.S. Geological Survey Bulletin 415, p. 179–203.

Garrigues, R.S., 1976, Geophysical logs of holes drilled in 1976 in the Lower White River coal field, Moffat and Rio Blanco Counties, Colorado: U.S. Geological Survey Open-File Report 76-871, 11 p. and 33 logs.

Garrigues, R.S., and Barnum, B.E., 1980, Geologic map and coal sections of the Rangely NE quadrangle, Rio Blanco and Moffat Counties, Colorado: U.S. Geological Survey Open-File Report OF-80-274, scale 1:24,000.

Golightly, D.W., and Simon, F.O., eds., 1989, Methods for sampling and inorganic analysis of coal: U.S. Geological Survey Bulletin 1823, 72 p.

Green, G.N., 1992, Digital geologic map of Colorado: U.S. Geological Survey Open-File Report OF-92-0425, scale 1:500,000.

Hail, W.J., Jr., 1974, Geologic map of the Rough Gulch quadrangle, Rio Blanco and Moffat counties, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-1195, scale 1:24,000.

Hail, W.J., Jr., and Barnum, B.E., 1993, Geologic map of the Divide Creek quadrangle, Rio Blanco and Moffat counties, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-2232, scale 1:24,000.

Hildebrand, R.T., and Garrigues, R.S., 1981, Geology and chemical analyses of coal, Mesaverde Group (Cretaceous), Lower White River coal field, Moffat and Rio Blanco Counties, Colorado: U.S. Geological Survey Open-Report 81-597, 26 p.

Hornbaker, A.L, Holt, R.D., and Murray, D.K., 1976, 1975 summary of coal resources in Colorado: Colorado Geological Survey Special Publication No. 9, 17 p.

Landis, E.R., 1959, Coal resources of Colorado: U.S. Geological Survey Bulletin 1072-C, p. 131–232.

Resource Data International, Inc., 1998, COALdat database: Boulder, Colorado, Resource Data International, Inc. [database available from Resource Data International, Inc., 1320 Pearl Street, Suite 300, Boulder, CO 80302].

Rohrbacher, T.J., Teeters, D.D., Osmonson, L.M., and Phis, M.N., 1994, Coal Recoverability and the definition of coal reserves, Central Appalachian Region, 1993: U.S Bureau of Mines Coal Recoverability Series Report 10-94, 36 p.

Rowley, P.D, Tweto, Ogden, Hanson, W.R., and Carrara, P.E., 1979, Geologic map of the Vernal 1°×2° quadrangle, Colorado, Utah, and Wyoming: U.S. Geological Survey Miscellaneous Investigations Map I-1526, scale 1:250,000.

Tully, John, 1996, Coal fields of the conterminous United States: U.S. Geological Survey Open-File Report 96-92, 1 plate, scale 1:5,000,000.

Tweto, Ogden, 1975, Preliminary geologic map of the east half of the Vernal 1°×2° quadrangle, Colorado: U.S. Geological Survey Open-File Report 75-788, scale 1:250,000.

Tweto, Ogden, 1976, Geologic map of the Craig 1°×2° quadrangle, northwestern Colorado: U.S. Geological Survey Miscellaneous Investigations Map I-972, scale 1:250,000.

Tweto, Ogden, 1979, Geologic Map of Colorado: U.S. Geological Survey, scale 1:500,000.

Wood, G.H., Kehn, T.M., Carter, M.D., and Culbertson, W.C., 1983, Coal resource classification system of the U. S. Geological Survey: U.S. Geological Survey Circular 891, 65 p.

Appendix 1—Digital Files for Coal Exploration Drill Holes in the Lower White River Coal Field, Northwest Colorado, for which Data are Publicly Available

Appendix 1 contains the publicly available drill-hole database (14 holes—shown in table 1) used to asses coal resources in the Deserado coal area of the Lower White River coal field, northwest Colorado. The location, lithologic, and stratigraphic data are available in ASCII format, DBF, and Excel spreadsheet files on disc 2 of this CD-ROM.

Appendix 2—ArcView Project for the Geologic Assessment of Coal in the Deserado Coal Area, Lower White River Coal Field, Northwest Colorado

The digital files used for the coal resource assessment of the Deserado coal area, Lower Whiter River coal field, northwest Colorado, are presented as views in the ArcView project.

The ArcView project and the digital files are stored on both discs of this CD-ROM set—Appendix 2 of chapter N resides on both discs. Persons who do not have ArcView 3.1 may query the data by means of the ArcView Data Publisher on disc 1. Persons who do have ArcView 3.1 may utilize the full functionality of the software by accessing the data that reside on disc 2. An explanation of the ArcView project and data library—and how to get started using them—is given by Biewick and Mercier (chap. D, this CD-ROM). Metadata for all digital files are also accessible through the ArcView project.

Click on image below to bring up high-resolution image of plate 1.

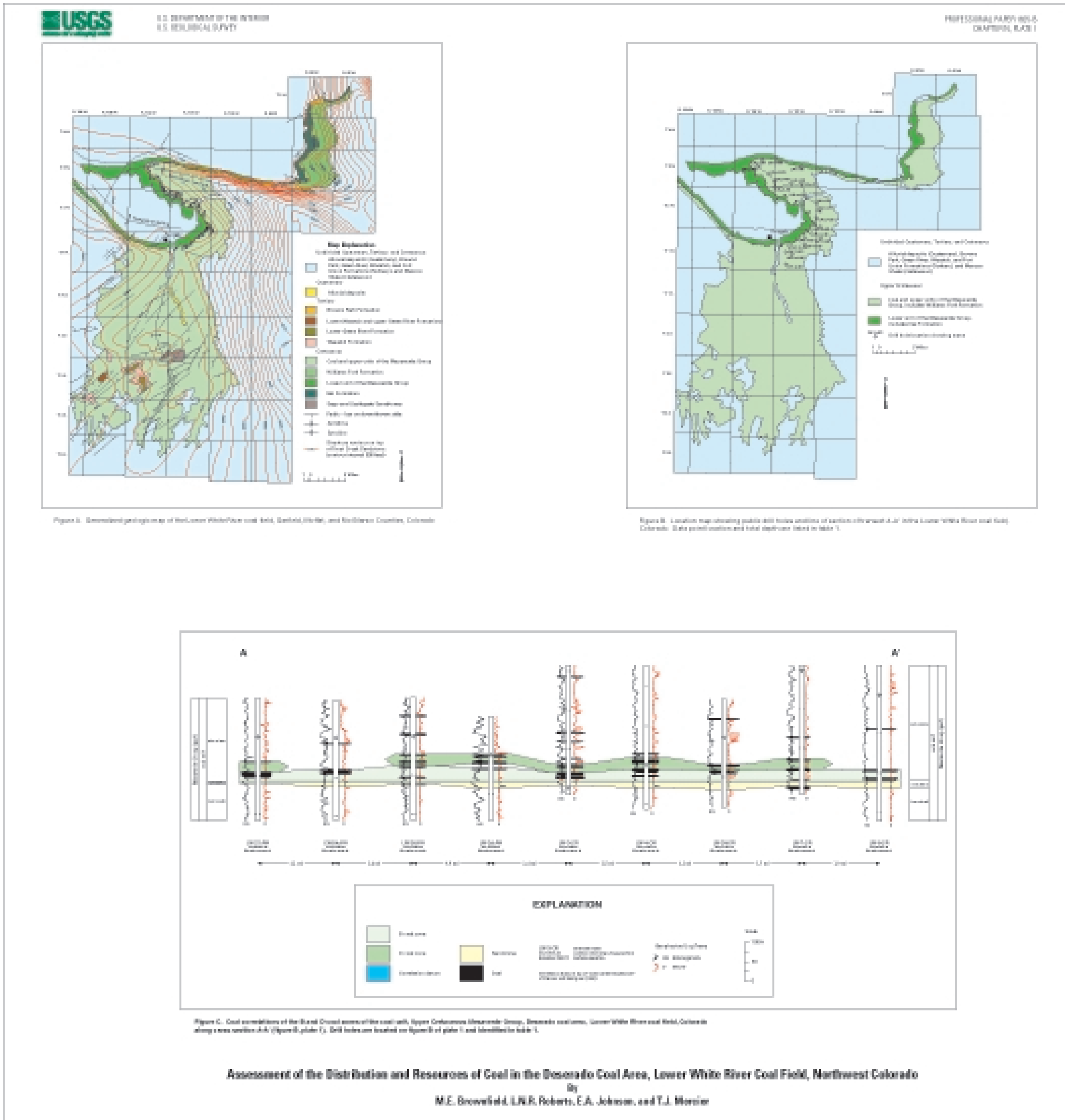
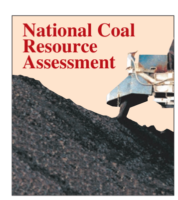


Plate 1. Assessment of the distribution and resources of coal in the Deserado coal area, Lower White River coal field, northwest Colorado.



Click here to return to Disc 1 Volume Table of Contents