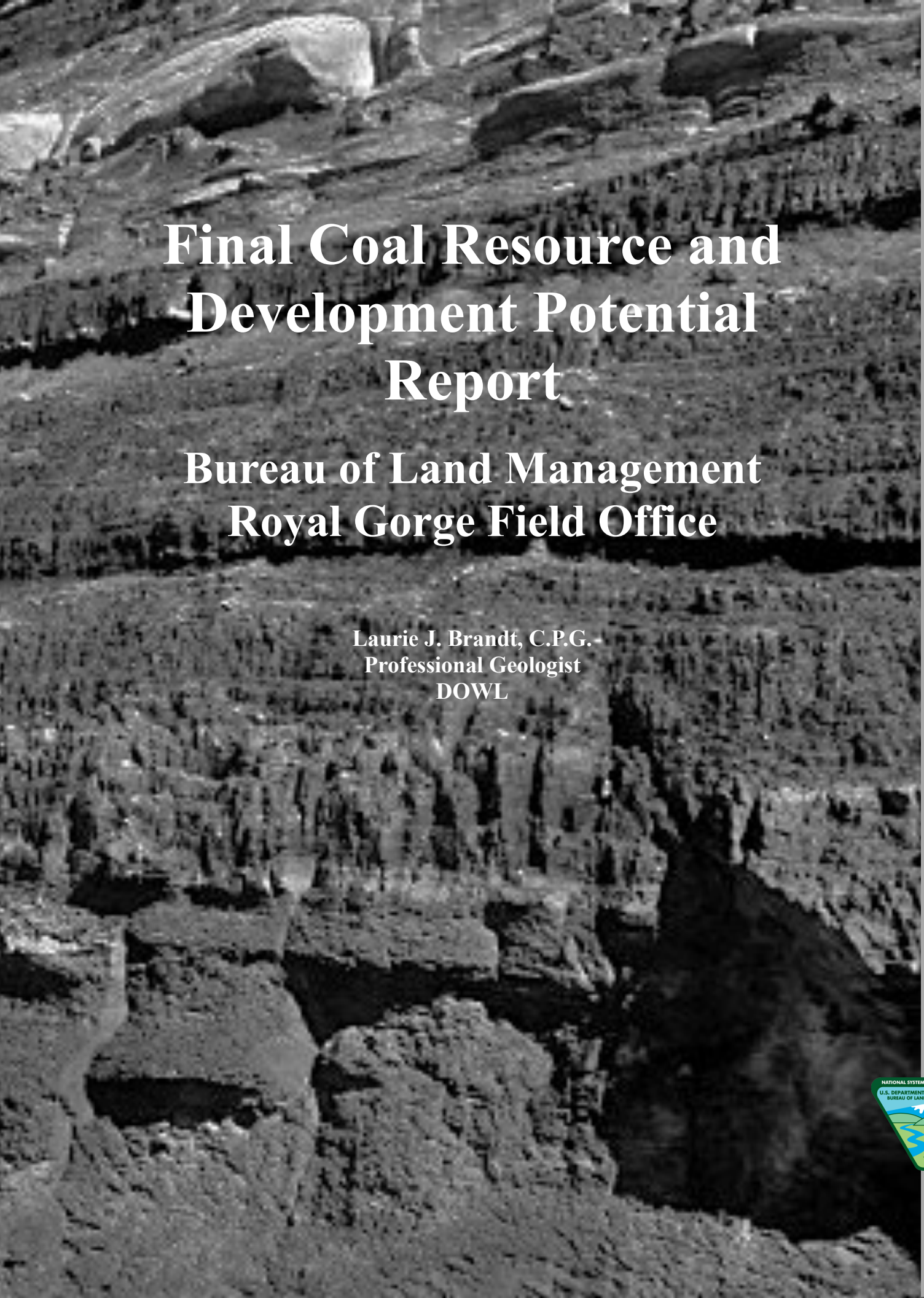

Final Coal Resource and Development Potential Report

Bureau of Land Management
Royal Gorge Field Office

Laurie J. Brandt, C.P.G.
Professional Geologist
DOWL

BLM

Royal Gorge Field Office • COLORADO

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June 2015

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ACRONYMS

BLM	Bureau of Land Management
Btons	Billion short tons
Btu	British Thermal Unit
CARS	Coal Availability and Recoverability Studies
CBM	Coalbed Methane
CDRMS	Colorado Division of Reclamation Mining & Safety
CF&I	Colorado Fuel & Iron Company
CFR	Code of Federal Regulations
CGS	Colorado Geological Survey
COGCC	Colorado Oil & Gas Conservation Commission
COR	Contracting Officer's Representative
EIA	Energy Information Administration (U.S.)
FCEL	Federal Coal Exploration Lease
FCL	Federal Coal Lease
GIS	Geographic Information System
hvA	high volatile A rank coal
hvB	high volatile B rank coal
hvC	high volatile C rank coal
KCRLA	Known Coal Resource Leasing Area (USGS)
KRCRA	Known Recoverable Coal Resource Area (USGS)
MBtu	Million Brittish Thermal Units
MER	Maximum Economic Recovery
MPR	Mineral Potential Report
Mtons	Million short tons
NCRA	National Coal Resource Assessment (USGS)
NECC	New Elk Coal Company
OTA	Office of Technology Assessment
PI	Project Inspector
PPM	Parts Per Million
PRLA	Preference Right Lease Area
RGFO	Royal Gorge Field Office
RMP	Resource Management Plan
TOCC	Texas & Oklahoma Coal Company
UCG	Underground Coal Gasification
US	United States
USBOM	United States Bureau of Mines
USFS	United States Forest Service
USGS	United States Geological Survey

Executive Summary

There are four coal regions in the 45 million acre Planning Area in the eastern half of Colorado managed by the U.S. Bureau of Land Management's Royal Gorge Field Office in Cañon City. These coal regions are the Denver, Raton Mesa, Cañon City and South Park Coal Regions. They range in size from roughly 7,600 square miles in the Denver Coal Region to 50 square miles in the Cañon City Coal Region. The four regions are located in post-Laramide structural basins on the east side of the Continental Divide and contain Upper Cretaceous subbituminous and bituminous coal to Paleocene lignite, subbituminous coal and bituminous coal. The federal resources for these coal regions are summarized in Table 15 and the development potential is summarized in Table 16.

For the Denver Coal Region, composed of both the Denver and Cheyenne Basins, the Laramie Formation contains subbituminous coal and the Denver Formation contains lignite. Most (85%) of the federal Laramie coal in the Denver and Cheyenne Basins is at depths of 150-2,000 feet and is concentrated in the southeastern and eastern portion of the Denver Basin. Most (80%) of the federal Denver lignite is at depths of less than 200 feet (making it a strippable resource) and it is located in the east-central portion of the Denver Basin. Our analysis of Laramie coal determined 31.3 Btons of original coal (27.3 Btons of quasi-available coal) and 11.0 Btons of original lignite (9.5 Btons of quasi-available lignite). "Quasi-available" coal refers to coal where specific "obvious" restrictions are applied to the original coal resource such as city boundaries, 150-foot radius setbacks from gas wells, and extensively mined areas. Intensive gas well drilling and urban development in the Denver and Cheyenne Basins makes coal development of the limited federal coal unlikely unless mine-mouth energy generation or gasification is performed locally to minimize transportation costs and surface disturbance. Also, low sulfur and high Btu coal from the western slope of Colorado and the Powder River Basin of Wyoming are less expensive, more abundant and higher quality than Denver Region coal, so regional competition for the steam coal market is dominated by those sources.

For the Raton Mesa Coal Region, the two formations that contain coal are the deeper Vermejo Formation that outcrops along the eastern margin of the asymmetric Raton Basin and the younger Raton Formation that is concentrated in the southern half of the basin. The northern one-third of the basin (Huerfano County) contains the Walsenburg Field which has historically produced bituminous steam coal, while the southern two-thirds of the basin (Las Animas County) contains the Trinidad Coal Field which has produced coal from both the Vermejo and the Raton Formations, but production has been dominated by bituminous coking coal from the Raton Formation. Our analysis of the federal coal resource in the Walsenburg Field indicates 268 Mtons of original federal coal; however, little historic mining occurred in the areas of federal coal estate, which suggests these areas have relatively low potential for coal development. Our analysis of the federal coal resource in the Trinidad Field, which has had extensive, nearly continuous commercial mining since the 1870's, involved a more extensive study to evaluate the federal coal resource. We used electronic database files generated by the Colorado Geological Survey (CGS) to perform a coal availability assessment of the 7 main coal zones (6 zones in the Raton and 1 zone in the Vermejo) within the Trinidad Field. We added the additional natural gas wells that had been drilled since the CGS study and increased the setback radius to 150 feet for all gas wells. The analysis resulted in an estimated 1.109 Btons of federal coal in the Trinidad Field and maps were produced that show the location and thickness of available coal for each of the 7 zones, with the famous Allen zone containing the most coal.

The Raton Formation coking coals have the greatest potential of federal coal development in the entire RGFO Planning Area, but it will take significant improvements in demand for metallurgical coal to make economic extraction feasible. The extensive coalbed methane development in the Trinidad Field would require accommodation in coal mine plans to either fill and cap the wells or remain outside of the 150-radius setback from each well. Both longwall and room and pillar underground mining methods have been used successfully in this coal field and could be used again for federal coal. Some surface mining is also possible for the shallower coal beds. A local powerplant is not likely due to competition from abundant natural gas in the Raton Basin, but regional consumption in local cement or metallurgical industries would be necessary to keep transportation costs to a minimum. During the Plan Life of the Eastern Colorado Resource Management Plan, these domestic industries are not likely to develop to the point of driving the metallurgical coal industry. Also, international metallurgical coal markets are being serviced by coking coal closer to steel production and to ports with less rail transport distances than from Raton Basin coal.

The Cañon City Coal Field is a small field (50 square miles) and we estimate it contains roughly 181 Mtons of remaining original Vermejo bituminous coal. Since there is no federal coal ownership in the Cañon City Coal Field, there is currently no federal coal resource. In general for the field, minor underground mining of the Vermejo coals is possible if used in local steam coal or industrial uses; however, competition with inexpensive and available natural gas on the Front Range will likely continue to suppress the demand for steam coal.

For the South Park Coal Region, Laramie subbituminous coal is known to be present, but it is not an extensive or high quality resource and there is essentially no infrastructure to support any mining other than for local domestic use. We determined there is 23.9 Mtons of coal resource in the region with 5.48 Mtons of original federal coal.

Improving costs and networks of transporting coal from the RGFO Planning Area would be necessary to improve competitiveness of coal from this region. Rail transport has high fuel surcharges and development of a coal slurry pipeline would have high capital costs that the coal industry could not likely bear in the immediate future. The high costs of the underground mining of relatively thin and lenticular coal beds and the abundance of natural gas are also limiting factors that make coal from these four coal regions not as competitive with other western coal and gas. Until metallurgical coal prices improve significantly, fuel for local powerplants and gasification plants have the greatest potential for the Raton Basin as well as for the Denver and Cañon City Coal Regions. The low sulfur coal in all three basins increases its potential use as a clean and compliant to super-compliant coal in the near future.

I. Introduction

Purpose and Scope

The goal of this report is to summarize the known coal resources for the U.S. Bureau of Land Management (BLM) Royal Gorge Field Office (RGFO) Planning Area, and to assess the geographic areas where there is potential for coal resource development in support of the current Eastern Colorado Resource Management Plan (RMP) process. This report includes published and publically available information on the geologic units that contain coal, current coal quality data, reserve estimates, and current production data, as well as identifying areas in the Eastern Colorado RMP Planning Area with coal development potential.

Acknowledgments

Throughout the preparation of this Federal Coal Report, the primary author, Laurie Brandt of DOWL, interacted with geologists and coal mining specialists from the BLM, the Colorado Geological Survey, the U.S. Geological Survey (USGS), as well as several coal industry representatives who provided input on coal resource data and activity forecasts. Regarding the Raton Mesa Coal Region, Ron Thompson of the New Elk Mine and Dominic Hill and Mark Sykes of the Texas and Oklahoma Coal Company provided additional perspective as coal industry representatives. We worked directly with BLM geologist Melissa Smeins as the Project Inspector (PI) and Glenda Torres as the Contracting Officer's Representative (COR). Permission was granted by Chris Carroll (formerly with the CGS, but currently with the Wyoming Geological Survey) to use an uncompleted and unpublished Coal Availability report and GIS files for the Raton Mesa Coal Region (Carroll et al, 2007). The GIS files from the Carroll et al (2007) study were provided by the CGS. Mr. Carroll, Colorado coal expert, also provided valuable insight as to coal resources in the RGFO Planning Area. We were also given permission from Melissa Smeins, geologist with the RGFO to directly use information from the Draft RGFO Mineral Potential Report (BLM 2015b) prepared by Rare Earth Science, LLC. Since this MPR is a BLM document, we used content of that report without attributing the source as the MPR or Rare Earth Science; however, we verified data prior to inclusion.

Electronic data for map production was supplied by the Colorado Geological Survey and the Bureau of Land Management directly and on various disc and online sources listed in the References section of this report. Most maps were produced in-house by DOWL, unless otherwise noted. The map projection used is UTM, Zone 13 and the datum is NAD1983.

Eastern Colorado RMP Planning Area

The Royal Gorge Field Office's Planning Area encompasses a total of 45,100,000 acres, of which 668,000 acres are public (BLM-administered) land and 3,895,000 acres have federal mineral estate. As seen in Figure 1, the Planning Area covers roughly the eastern half of the State of Colorado and extends from Wyoming to New Mexico and from west of the Front Range to Kansas. It includes the entire Great Plains of Colorado and a portion of the Southern Rocky Mountains. The Planning Area contains four Coal Regions with a total of 13 counties, as follows:

1. **Denver Coal Region** - Adams, Arapahoe, Boulder, Douglas, Elbert, El Paso, Jefferson, Larimer, and Weld Counties
2. **Raton Mesa Coal Region** - Huerfano and Las Animas Counties
3. **Cañon City Coal Region** - Fremont County
4. **South Park Coal Region** - Park County

The Planning Area includes 631,306 acres of federal (subsurface) mineral estate that includes coal (Table 1). This report considers the coal resource that is included as part of the federal mineral estate under all BLM-administered surface lands as well as those under all other surface ownership.

Mineral Estate	acres per coal region				Total acres in Four Coal Regions
	Denver	Raton Mesa	Cañon City	South Park	
Total federal minerals in each Coal Region (acres)*	423,252	187,970	0.25	20,083	631,306
Total area in 4 coal regions (acres)	4,838,285	796,709	31,837	55,030	5,721,861
(sq miles)	7,560	1,245	50	86	8,940

*does not include areas of "No Minerals" and "Oil and Gas Only"

Table 1. Mineral Estate in the Planning Area
(Source: BLM GIS database)

As seen in Table 1, three of the coal regions contain significant amounts of federal mineral estate except for the Cañon City Coal Region, which has only ¼-acre. Figure 1 (Planning Area map) shows the surface ownership of land within the Planning Area, which includes federal ownership (Bureau of Land Management, Forest Service, National Park Service, Department of Defense, and U.S. Fish & Wildlife Service), State, County, City and private lands.

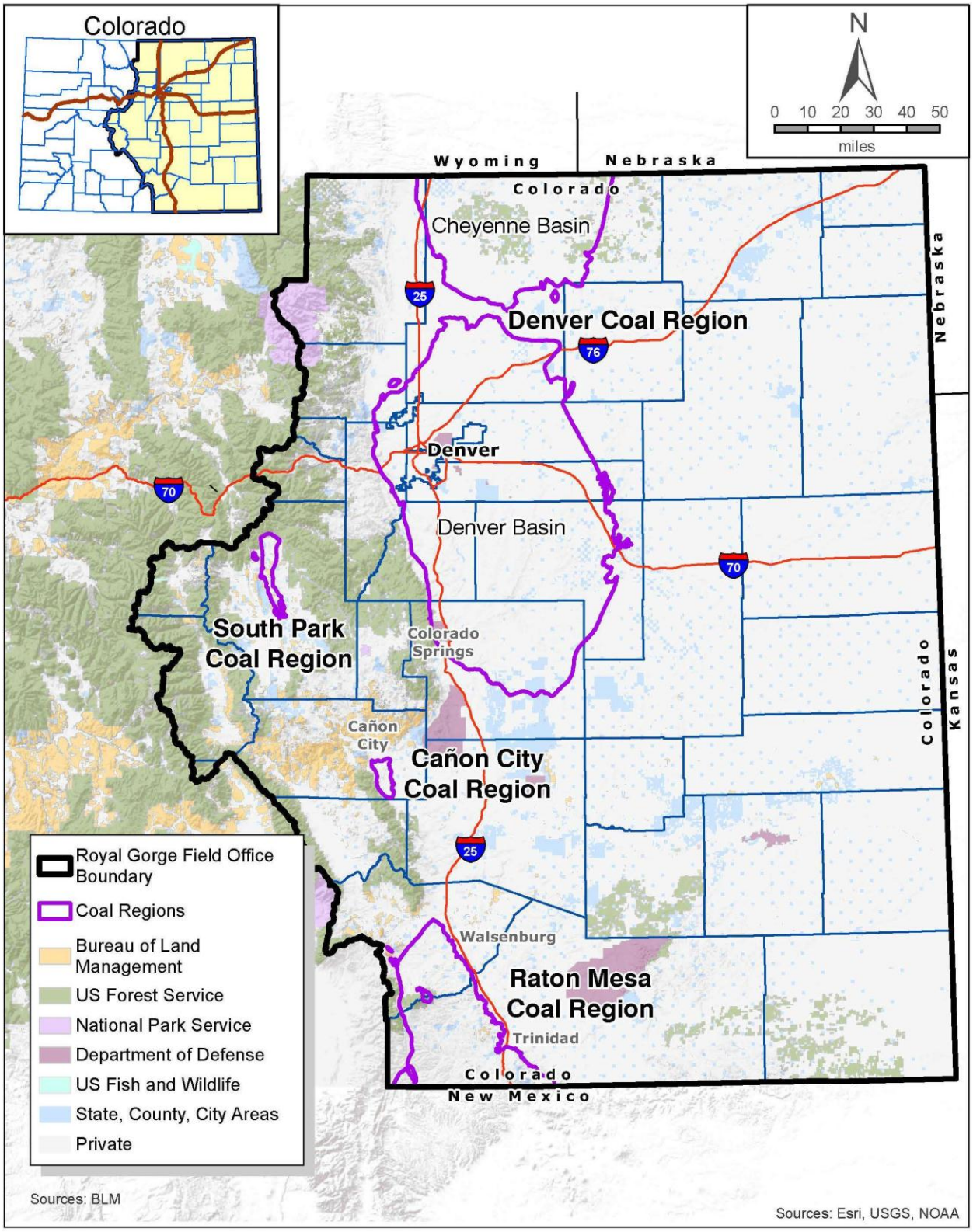


Figure 1. Royal Gorge Field Office Planning Area with Coal Regions

The four designated coal regions within the RGFO Planning Area (Carroll, 2006) are as follows (Fig. 1):

1. **Denver Coal Region** - lies in the Colorado Piedmont section of the Great Plains physiographic province, east of the Front Range. It extends from near Colorado Springs on the south, north to the Wyoming border, and east to near the Town of Limon. The Denver Coal Region consists of the Cheyenne and Denver Basins and is the largest coal region in the RGFO Planning Area and covers about 7,500 square miles. There is one active coal permit in this coal region (i.e. Keenesburg strip mine), but it is not currently mined and is in a state of reclamation. This coal region is not currently mined.
2. **Raton Mesa Coal Region** - is in the Raton section of the Great Plains physiographic province and lies east of the Sangre de Cristo Mountains, straddling the Colorado-New Mexico state line and covering about 1,250 square miles, which makes it the second largest coal region in the RGFO. This region has both steam and coking coal and, of the four coal regions managed by the RGFO, it has the only recently active coal mine. However, this mine is under "Temporary Cessation" status at this time.
3. **Cañon City Coal Region** - is in the Colorado Piedmont section of the Great Plains province. It occupies a relatively small area (roughly 50 square miles) in the Cañon City Embayment in the vicinity of Cañon City. The Wet Mountains are to the south and west and the Great Plains are to the east. This coal region is not currently mined.
4. **South Park Coal Region** – is the smallest and historically least-productive coal region, located in an intermontane basin in the Southern Rocky Mountains province between the Mosquito Range and Front Range. This coal region extends across an estimated 86 square miles, based on the boundaries shown by Carroll (2006), but may be as small as 20 square miles according to Hornbaker et al (1976). This coal region is not currently mined and has not been mined since the late 1800s.

Coal has not been produced from the Denver, South Park and Cañon City Coal Regions for at least 30 years, but mining in the Trinidad Coal Field within the Raton Mesa Coal Region has been active with the Lorencito Canyon surface mine in 2001-2002 (producing 168,124 tons) and the New Elk underground mine in 2011-2014, producing 367,214 tons of coal (CDRMS 2015). Both mines are located in the Purgatoire River valley near Las Animas County Road 12, roughly 20-25 miles west of Trinidad. The Lorencito Canyon Mine has not produced coal since 2002 and is in the final stages of reclamation and is under "Permanent Cessation" status with the CDRMS. The New Elk Mine produced coal from 2011 to October 2014, with a hiatus in 2013, and is currently idle with a "Temporary Cessation" permit status with the CDRMS (2015). Both the Lorencito Canyon and the New Elk mines are located in areas with private mineral estate. The New Elk Coal Company (subsidiary of Cline Mining Corporation), submitted a Federal Coal Lease application in December 2007, but the BLM is waiting for information from the Company to complete the application (personal communication, Melissa Smeins, December 31, 2014). The RGFO is also currently reviewing an application for a Federal Coal Exploration License called "Left Fork," filed in August 2012 by the Texas & Oklahoma Coal Company (TOCC 2014). These will be discussed later in this report. The RGFO therefore currently does not manage any federal coal leases in any of the four coal regions.

A comprehensive coal resource and development potential report has not been completed to date for the Eastern Colorado RMP Planning Area. This report has been written to assist in evaluating areas with coal lease potential under the revised RMP for the Planning Area.

II. Geologic Setting & Formations of Planning Area

All four coal regions are structural basins at the boundary of the Southern Rocky Mountains and the Great Plains, with the South Park Coal Region in the Southern Rocky Mountains Province and the Denver, Raton Mesa and Cañon City Coal Regions in the Great Plains Province, as seen in Figure 2 below.

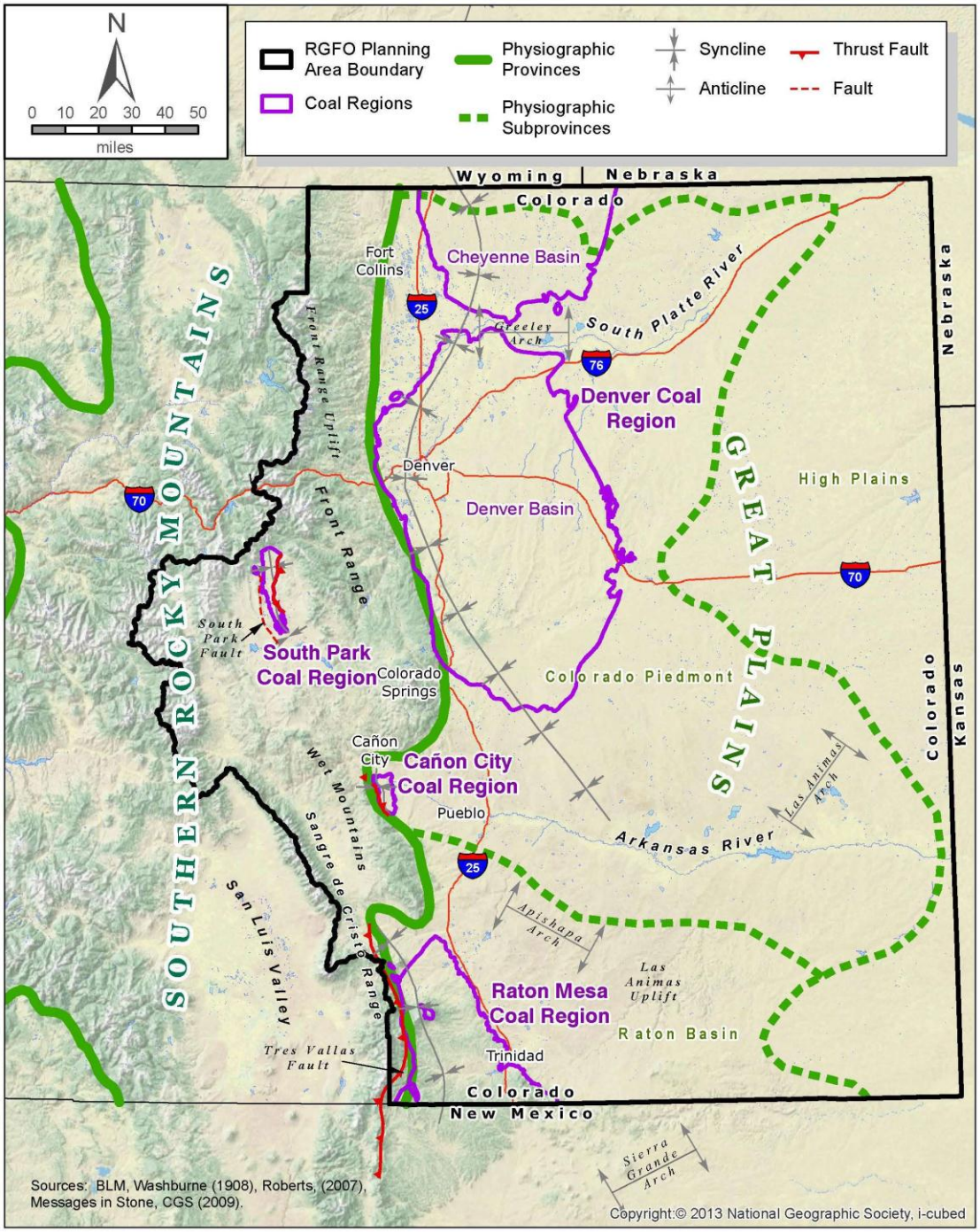


Figure 2. Location of Major Geologic Structural Features

A common theme in all four coal regions is that the coal-bearing basins are elongated, asymmetric synclines due to predominant uplifts adjacent to a portion of the basin. Various thrust faults, arches, uplifts and ranges bound the basins and are shown on Figure 2.

As seen in the stratigraphic chart of Figure 3, below, the economically significant coal beds in all four regions are Late Cretaceous through early Tertiary (Paleocene) in age. In the Denver Coal Region, coal is found in the Laramie and Denver Formations. In the South Park Coal Region coal has been found in the Laramie Formation. For the Raton Mesa Coal Region coal is found in the Vermejo and Raton Formations and for the Cañon City Coal Region, coal is found in the Vermejo Formation. The Denver Basin and South Park Coal Regions are located in the "Front Range" stratigraphic area and the Raton Mesa and Cañon City Coal Regions are in the "Southeast" stratigraphic area depicted in Figure 3.

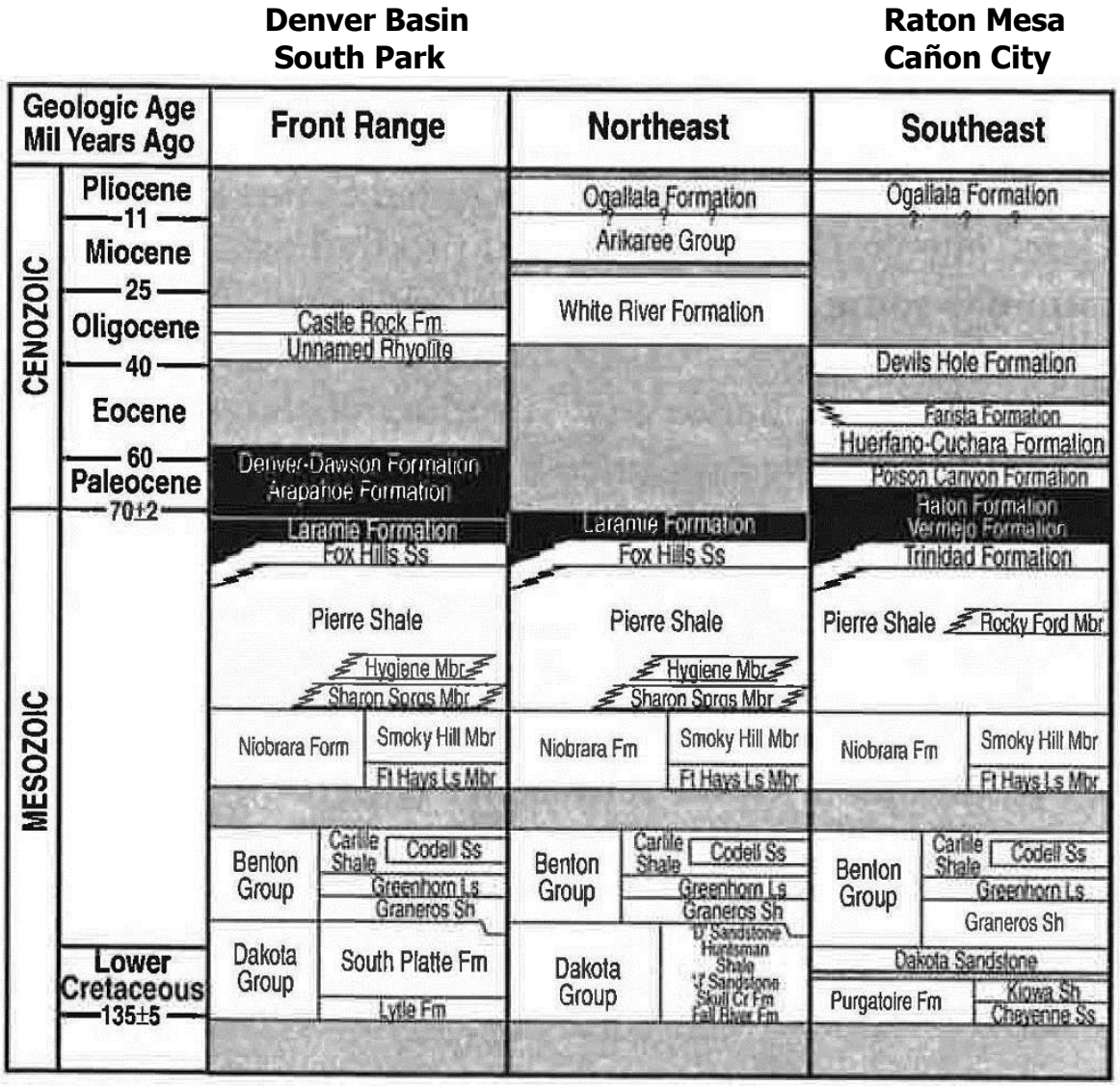


Figure 3. Stratigraphic correlation chart for the coal-bearing strata (shown in black) for RGFO Planning Area Coal Regions
Source: Carroll (2004)

Figure 4 shows the general geology of the Planning Area based on age of formations. Note that the coal-bearing formations are in Late Cretaceous to early Tertiary units.

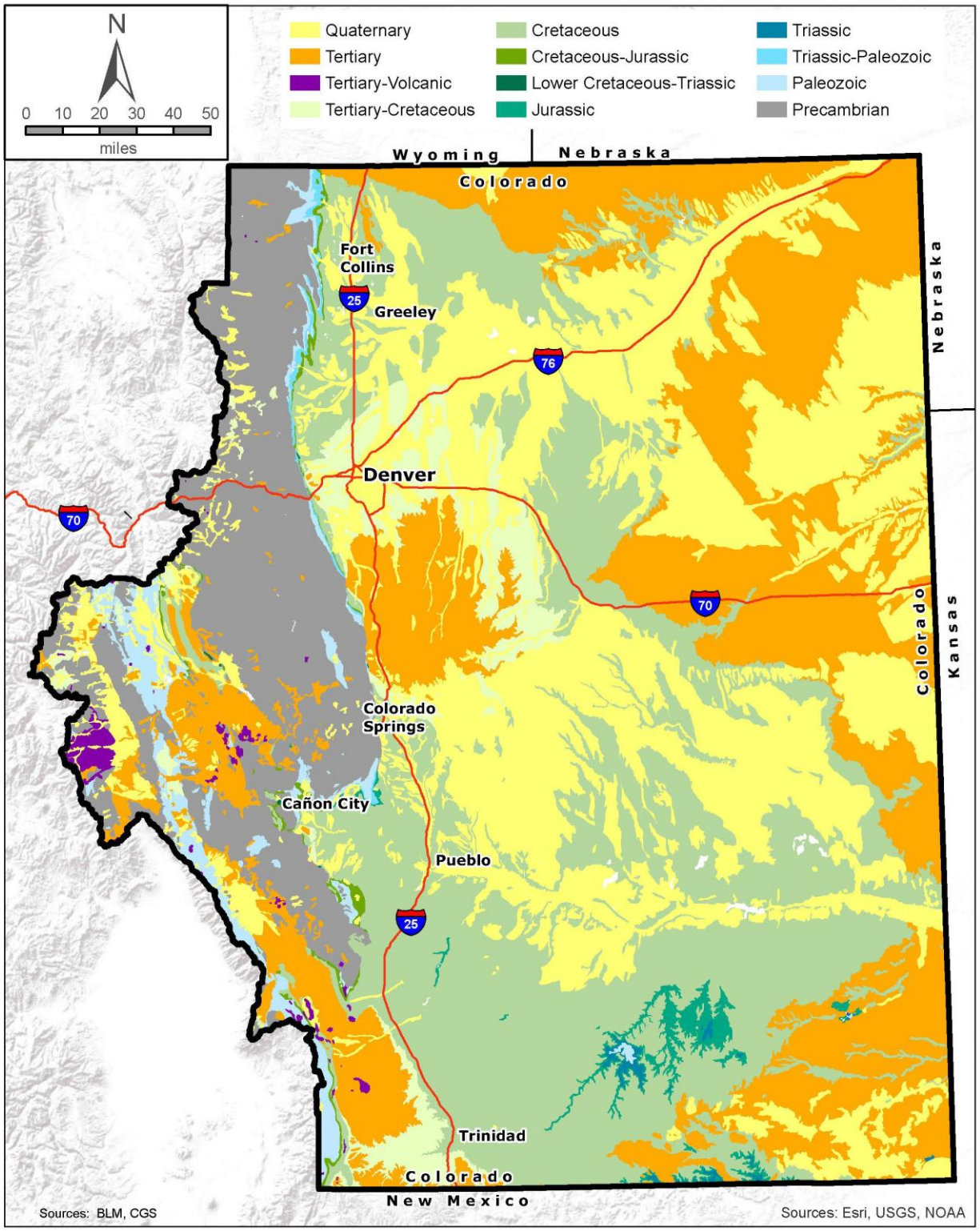


Figure 4. General Geology of the Planning Area

Figure 5 shows the specific coal-bearing formations in the four coal regions. In general, the Laramie, Vermejo and Raton formations contain bituminous and subbituminous coal, while the Denver Formation contains lignite due to its younger age and shallower depth. The geology of each coal region is discussed in the discussions of each basin.

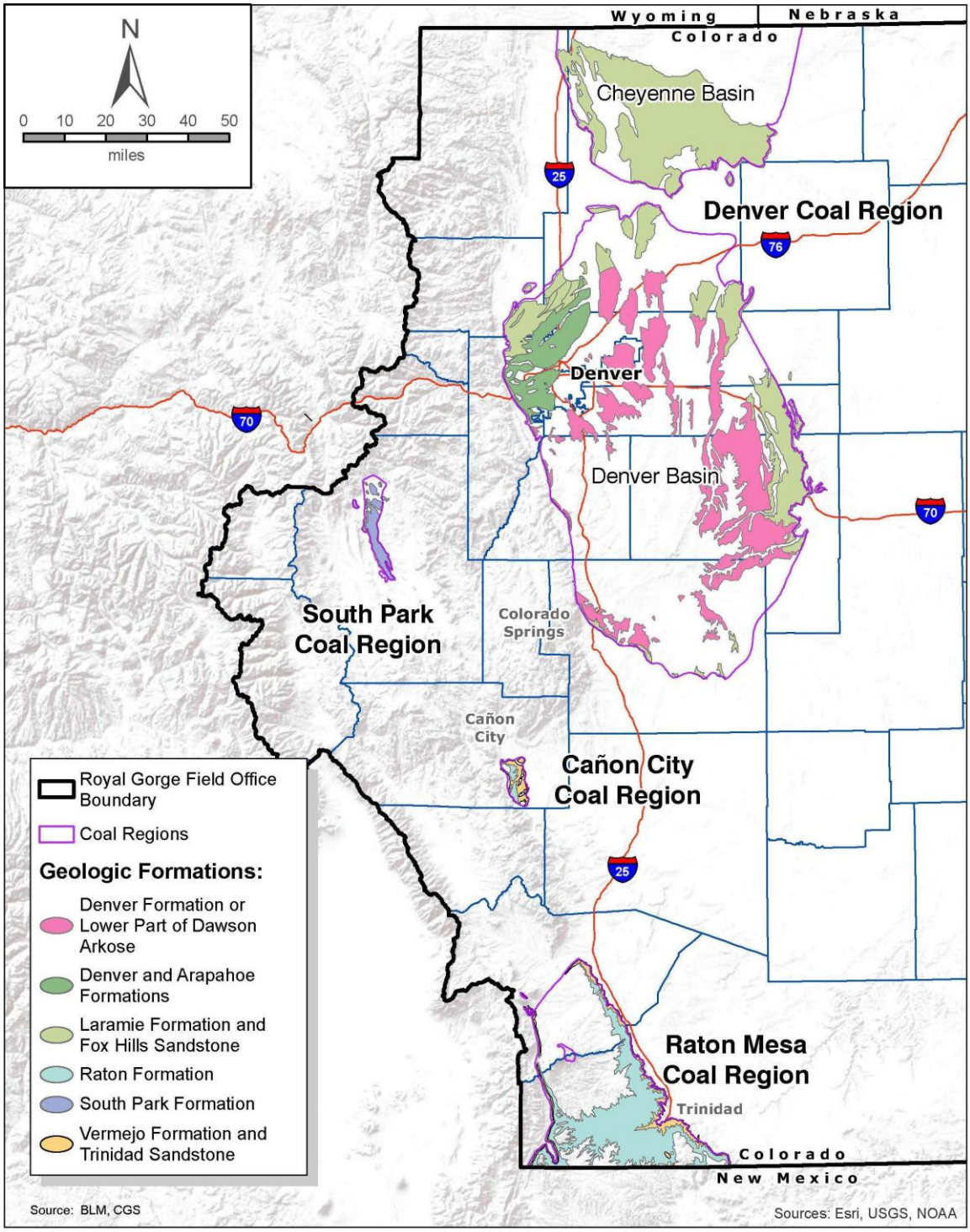


Figure 5. Coal-bearing Geologic Formations in the Planning Area

III. Overview of Coal Regions & Coal Fields

The coal region and coal field boundaries are explained in the 2003 Summary of Coal Resources in Colorado (Carroll 2004) and depicted on maps in Coal Fields and Resources of Colorado (Carroll 2006). The coal fields associated with each coal region are listed in Table 2 below and their locations are shown on the map in Figure 6. This table also contains the coal rank and geologic formations that contain the coal. Coal rank is determined by carbon content (i.e., higher energy content); the higher the carbon content, the higher the rank. The general characteristics of each coal region within the Planning Area are discussed in a separate section for each region. The Denver Coal Region is comprised of 9 coal fields with subbituminous A, B and C rank and lignite coal located in the Denver and Cheyenne subbasins, seen on Figures 5 and 6. There are two coal fields in the Raton Mesa Coal Region, the Walsenburg and Trinidad fields, with hvA, hvB and hvC bituminous and some subbituminous coal. The Trinidad Coal Field is known for high quality coking coal as well as steam coal, as will be discussed in the section for the Raton Mesa Coal Region. The Cañon City Coal Region has one coal field which contains hvC bituminous coal and the South Park Coal Region has one coal field with Subbituminous A and B coal. The coal in the four coal regions are Upper Cretaceous to Paleocene in age. Coal in the Denver and South Park Regions is in the Laramie and Denver Formations, which is stratigraphically similar to the Vermejo and Raton Formations of the Cañon City and Raton Mesa Regions, respectively (see Fig. 3).

Coal Region	Coal Field	Coal Rank	Coal-bearing geologic formations
Denver	Boulder-Weld	Subbituminous A & B	Upper Cretaceous Laramie Fm
	Foothills		
	Colorado Springs		
	Briggsdale (Cheyenne subbasin)	Subbituminous A & B and some Lignite	
	Wellington (Cheyenne subbasin)		
	Eaton (Cheyenne subbasin)		
	Buick-Matheson	Subbituminous B & C	
	Ramah-Fondis	Lignite A and Subbituminous C	Paleocene Denver Fm
	Scranton		
Raton Mesa	Walsenburg	hvB, hvC Bituminous, some subbituminous	Upper Cretaceous/Paleocene Raton Fm and Upper Cretaceous Vermejo Fm
	Trinidad	hvA, hvB Bituminous, mostly coking coal	
Cañon City	Cañon City	hvC Bituminous	Upper Cretaceous Vermejo Fm
South Park	South Park	Subbituminous A & B	Upper Cretaceous Laramie Fm

Table 2. Rank and Coal-Bearing Geologic Formations per Coal Field
(Carroll 2004, Carroll 2006, BLM 2015b)

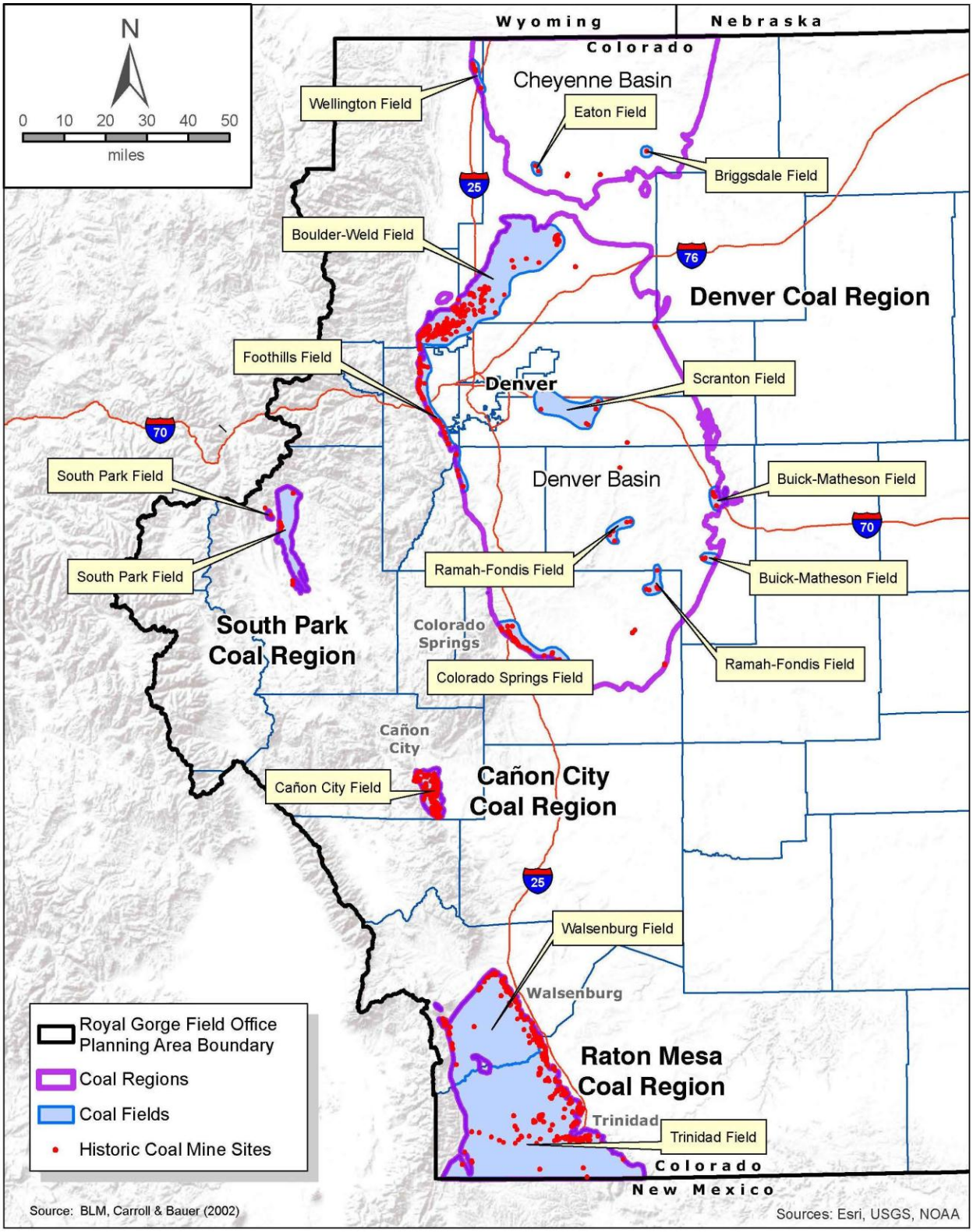


Figure 6. Royal Gorge Field Office Coal Regions & Fields

Coal rank and depth is shown on the following map, Figure 7. This map shows that the four coal regions have subbituminous and bituminous coal of varying depths, with the Denver Basin also containing lignite resources. Coal with less than 150 feet of overburden is generally considered to have potential for surface mining (strippable coal) and coals that have greater than 2,000 feet of overburden are considered to be too deep for subsurface mining given current technological methods. These depths are used in the map below.

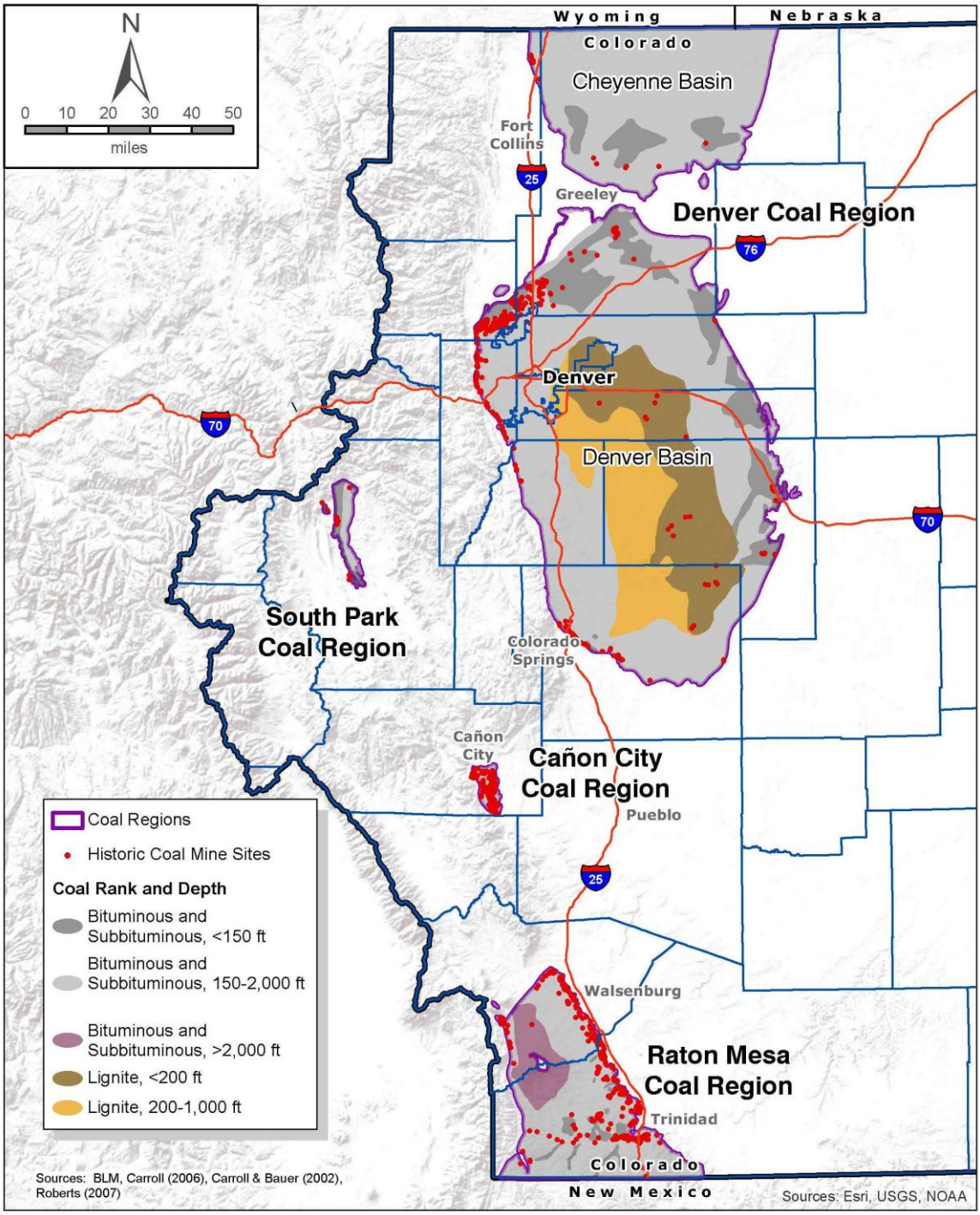


Figure 7. Coal Rank and Depth in the Planning Area

Typical coal quality data is presented in the following Table 3 for each of the formations within the coal fields for the four coal regions. These are "as received" values, not washed samples. In general, the Raton Mesa and Cañon City Coal Regions have the highest quality coal of the four regions, with the consistently highest average heating value (Btu/lb) and lower sulfur and ash. These are coals of the Vermejo and Raton Formations. The coals with the lowest heating value and highest moisture and ash are the lignite coals of the Denver Formation in the Denver Basin. More discussion of coal quality is included under the discussion for each Coal Basin.

Coal Region	Coal Field	Formation	Moisture (%)	Volatile matter (%)	Ash (%)	Sulfur (%)	Mercury (ppm)*	Heating Value (Btu/lb)
Denver	Boulder-Weld	Laramie (beds 1-7)	13.7-29.1	27.3-43.6	3.5-12.7	0.2-0.9	.01-.02*	8,250-10,810
Denver	Colorado Springs	Laramie (beds A,B,C)	19.0-26.2	31.4-45.1	5.6-20.8	0.3-0.7	NA	8,440-9,280
Denver	Southeast/ South-central	Laramie	33.1-35.0	30.8-44.2	7.8-15.7	0.4-1.1	.03-.08*	6,150-7,340
Denver	Southeast/ South-central	Denver (3 beds)	26.4-39.6	19.3-42.7	9.8-44.6	0.2-0.6	.11*	3,636-6,803
Raton Mesa	Trinidad	Raton (11 beds)	1.8-4.5	34.4-40.3	5.3-16.4	0.4-1.1 .58**	.03-.42* .03-.04**	10,169-13,871
Raton Mesa	Trinidad	Vermejo (14 beds)	1.6-7.5	32.2-39.1	7.7-21.8	0.5-1.0	.02-.07*	11,430-13,510
Raton Mesa	Walsenburg	Raton	2.5-4.2	33.4-41.1*	5.3-13.5	0.4-1.0	.09*	12,660-13,340
Raton Mesa	Walsenburg	Vermejo	5.3-10.2	36.4-38.0	7.2-14.4	0.4-1.3	.03-.07*	11,050-12,880
Cañon City	Cañon City	Vermejo (7 beds)	5.4-11.9	31.4-42.9	4.6-14.8	0.3-1.7* .71-2.18**	.01-.16* <.03-.56**	10,400-11,390
South Park	South Park	Laramie (3 beds)	6.3-15.5	NA	1.3-6.4	0.47-0.53	NA	9,780

NA = Not Available

Table 3. Typical Coal Quality Data for Four Coal Regions
(Carroll 2011; Khalsa & Ladwig 1981*; Hatch et al 2006**)

Regarding cumulative coal production (tons) for each of the four coal regions, the following Table 4 summarizes the amount of coal produced in the Planning Area from 1864 to 2014. Of the four coal regions, only the Raton Basin continued to produce coal since 2000 and this was in two mines in Las Animas County: the Lorencito Canyon Mine (a surface mine closed in mid-2002) and the New Elk Mine (an underground mine that has operated sporadically from 2010 to 2014). Most of the coal production for the four regions occurred between the 1860's and the 1980's.

Coal Region	County	County production (tons)	Coal Region Total Produced (tons)	State Production Ranking in 2002*
Cañon City	Fremont	48,004,745	48,004,745	5
Denver	Adams	37,112	134,195,235	4
	Arapahoe	36,259		
	Boulder	43,321,306		
	Douglas	27,367		
	Elbert	108,948		
	El Paso	15,251,246		
	Jefferson	6,697,939		
	Larimer	54,284		
	Weld	68,660,774		
Raton Mesa	Huerfano	75,690,588	262,629,417	3
	Las Animas	186,938,829		
South Park	Park	724,658	724,658	8

**State ranking is out of 8 Coal Regions in Colorado as of 2002.*

Table 4. Coal production for Four Coal Regions (1864 – 2014)
(Carroll 2004 for 1864-2002; CDRMS 2014 for 2002-2014)

According to these statistics, the Raton Mesa Coal Region has produced the most coal of the four coal regions, with 262,629,417 tons of coal and the South Park Coal Region has produced the least, with 724,658 tons of coal. Details of the production for each region will be discussed in more detail below.

IV. Denver Coal Region

Background

As seen in Figure 2, the Denver Coal Region (7,500 mi^2) is in the Colorado Piedmont subprovince of the Great Plains physiographic province. Coal in the Denver Coal Region is preserved within two large, asymmetrical, structural basins that essentially are huge synclines: the Denver Basin and Cheyenne Basin (Kirkham and Ladwig, 1979). The Denver Basin is separated from the Cheyenne Basin by a structural high called the Greeley Arch, shown in Figure 2. Coal-bearing strata have been removed by erosion across the Greeley Arch, resulting in two disconnected coal-bearing areas within the same coal region. Axes of the synclinal basins strike north-south and are located near the mountain front. Coal beds dip moderately to very steeply east along the western margins of the basins and are gently west dipping in the broad eastern flanks of the synclines. Numerous faults disrupt the coal beds in the northwest part of the Denver Basin (Roberts et al., 2001), forming discrete segmented structural blocks that are either upthrown (horsts) or downthrown (grabens). The faults are thought to be listric (concave upwards normal faults) and flatten with depth in strata well below the coal zones.

The Denver Coal Region is one of the major coal and lignite bearing regions in Colorado, with these basins comprising about 36% of the area of Colorado underlain by coal at a depth of less than 3,000 feet (Roberts 2007). The Denver Basin comprises the southern part of the Denver Coal Region and the Cheyenne Basin occupies the northern part of the coal region that extends into Wyoming (Fig. 8). The Denver Basin extends from about Colorado Springs in the south to Greeley in the north, and from the foothills on the west to nearly Limon on the east. Of the approximately 134 million tons (Mtons) of coal produced from historic mines in the Denver Coal Region for 120 years (1859 to 1979), 99% was subbituminous coal of the Cretaceous Laramie Formation, while the remaining 1% was lignite in the Tertiary (Paleocene) Denver Formation (Roberts 2007 and Table 4). The coal field that produced the majority (82%) of coal in the Denver Coal Region came from mines in the Boulder-Weld coal field (see Fig. 6) in the northwest part of the Denver Basin (Kirkham and Ladwig, 1979; Carroll, 2006).

The northern part of the Denver Coal Region is contained within the Cheyenne Basin. Only the southern part of the Cheyenne Basin lies within Colorado; its northern part is within Wyoming. Less than 67,000 tons of coal was recovered from all the known mines in the Cheyenne Basin (Kirkham and Ladwig, 1979), which is 0.05% of the total amount of coal mined in the Denver Coal Region. 82% of the coal in this basin was produced from the Wellington coal field (see Fig. 6) along the western margin of the Cheyenne Basin (Kirkham 1978a).

The following Figure 8 shows the locations of the coal-bearing formations within the Denver Coal Region which includes the Laramie and Denver Formations, with areas of federal coal shown within red polygons. Coal beds in the Cretaceous Laramie Formation are in a zone 50 to 275 feet thick in the lower 300 feet of the Laramie Formation and above the Cretaceous Fox Hills Sandstone (Kirkham and Ladwig 1979). The barren Cretaceous Arapahoe Formation is above the Laramie Formation followed by the Cretaceous to Tertiary (Paleocene) Denver Formation, which contain lignite beds in the upper 300 to 500 feet. The barren Dawson Arkose overlies the Denver Formation. The Denver Formation and Dawson Arkose do not exist in the Cheyenne Basin, as they have been removed by erosion.

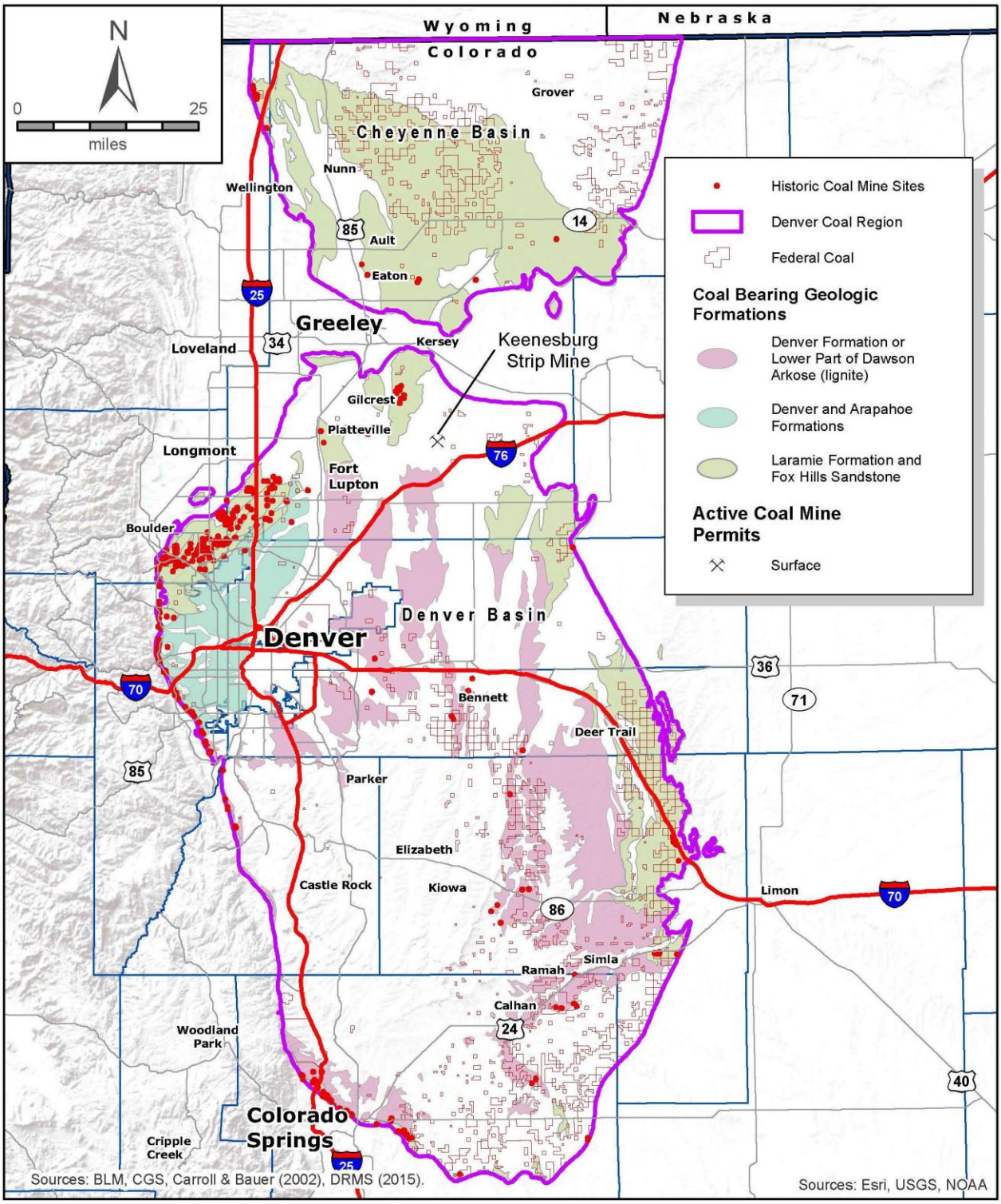


Figure 8. Coal-bearing Formations in the Denver Coal Region

According to Kirkham and Ladwig (1979), most of the Denver and Cheyenne Basins are underlain by coal in the Upper Cretaceous Laramie Formation. Most (99%) of the coal mined in the Denver Basin and all of the coal produced in the Cheyenne Basin came from the Laramie

Formation. The Laramie coal beds crop out around the perimeters of both basins. They lie at depths suitable for surface mining in a zone of varying width on the northern, eastern, and southern sides of the Denver Basin. Coal quality varies significantly throughout the basin, including subbituminous A, B and C for Laramie coals to Subbituminous C and lignite A for Denver Formation coals. Surface mining has not occurred along the west side of the Denver Basin, most likely due to the steep dips of strata in that area. The coal beds in the Cheyenne Basin occur at depths suitable for surface mining in a zone of varying width around the basin and include subbituminous A and B coal and lignite (Table 2).

Stratigraphy

Figure 9 below shows the geologic time scale with formations (stratigraphic units) that contain economically valuable coal highlighted in red with other Denver Basin formations and their descriptions. These coal-bearing and adjacent formations are shown in Figure 10, a generalized east-west cross-section through the Denver Basin. As seen on the cross-section, the Laramie Formation is generally a deep stratum in the Denver Basin and required mostly underground mining except for outcrop locations along the steeply dipping western portion of the basin and along the eastern margin. The lignite coal in the Denver Formation, however, is located closer to the surface and outcrops throughout the central to eastern portion of the basin.

Era	System	Series	Stratigraphic Unit	Unit Thickness (feet)	Physical Description
Cenozoic	Quaternary	Holocene	Alluvium	0–125	Unconsolidated gravel, sand, silt, and clay
		Pleistocene			
	Tertiary	Oligocene	Castle Rock Conglomerate	0–50	Fine to coarse arkosic sandstone and conglomerate
		Eocene	Dawson Formation	0–1,200	Sandstone and conglomeratic sandstone with interbedded siltstone and shale
		Paleocene			
Mesozoic	Cretaceous	Upper Cretaceous	Denver Formation	800–1,000	Shale, silty claystone, and interbedded sandstone; beds of lignite and carbonaceous siltstone and shale common
			Arapahoe Formation	400–700	Sandstone, conglomeratic sandstone, and interbedded shale and siltstone
			Laramie Formation	100–600	Upper part shale, silty shale, siltstone, and interbedded fine sandstone; bituminous coal seams common
					Lower part sandstone and shale
			Fox Hills Sandstone	100–200	Sandstone and siltstone interbedded with shale
			Pierre Shale	4,500–7,000	Shale, calcareous, silty, and dense.

Figure 9. Geologic Time Scale & Description of Denver Coal Basin Formations
(Marsters, 2012)

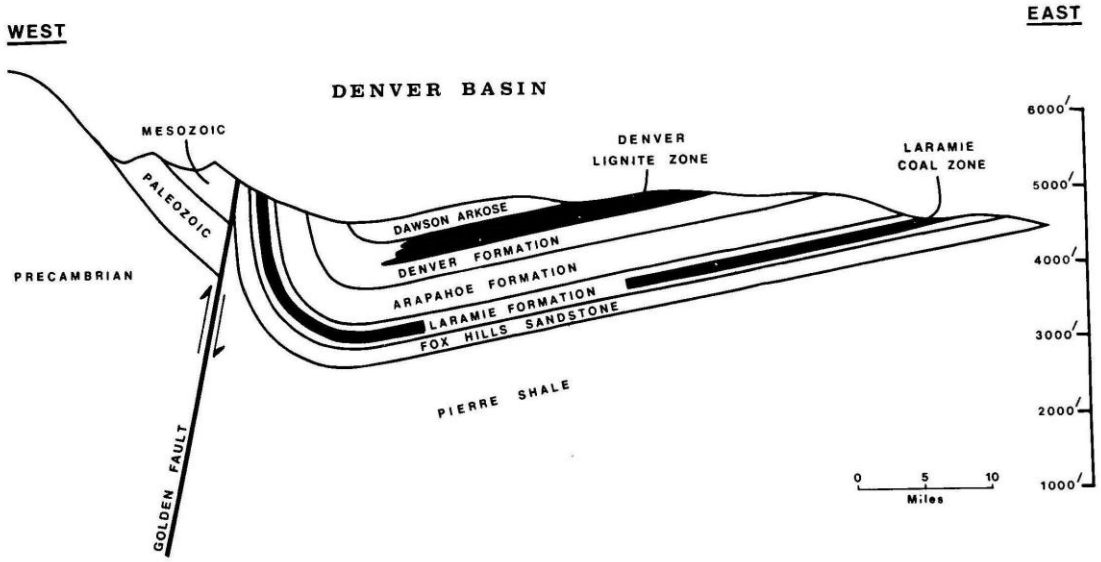


Figure 10. Generalized East-West Cross Section through Denver Basin
(Kirkham and Ladwig, 1980)

Seen in the cross-section above, the basin is asymmetric in the west-east direction, with the axis of the Denver Basin (similar to the Cheyenne Basin) located closer to the mountain front. The coal beds are as much as 2,900 feet deep in the Denver Basin and are over 1,500-feet deep in the Cheyenne Basin (Kirkham and Ladwig, 1979). Although not shown in the above figure, underlying the Pierre Shale is the Dakota Group, which outcrops as a steep hogback known as Dakota Ridge or Dinosaur Ridge in the Morrison area on the west edge of the Denver Basin. Thin, lenticular coal beds are known to exist in the Dakota Group, but it does not contain coal of economic importance in the Denver Basin (Kirkham and Ladwig, 1979).

Laramie Formation

The following stratigraphic sections (Fig. 11) show the coal seams of the Laramie Formation, both from the Boulder-Weld Coal Field (left), located in the northwest portion of the Denver Basin, and the Colorado Springs Coal Field (right), located in the southern portion of the Denver Basin (see locations of fields on Fig. 6). Note the variability across the basin in both the coal bed thickness as well as thickness of the barren, sandstone and mudstone/shale interbeds. This variability is present both in the north-south and east-west directions. Many coal seams and partings are lenticular and discontinuous laterally (Roberts 2005).

As seen in the stratigraphy of the Boulder-Weld Field, there are 7 identified coal beds ranging from 1 to 14 feet thick, with the first bed resting directly on the Fox Hills Sandstone (Fig. 11). Interbeds consist of sandstone and shale of variable thickness (Roberts 2005). For the Colorado Springs Field, there are 3 primary coal beds with multiple minor beds. In general, Laramie coals in the Denver Basin are up to as much as about 20-25 feet in thickness, but typically are less than 10-feet thick (Kirkham and Ladwig, 1979; Tremain et al, 1996). There is no significant coal in the upper part of the Laramie Formation in the Boulder-Weld and Colorado Springs coal fields.

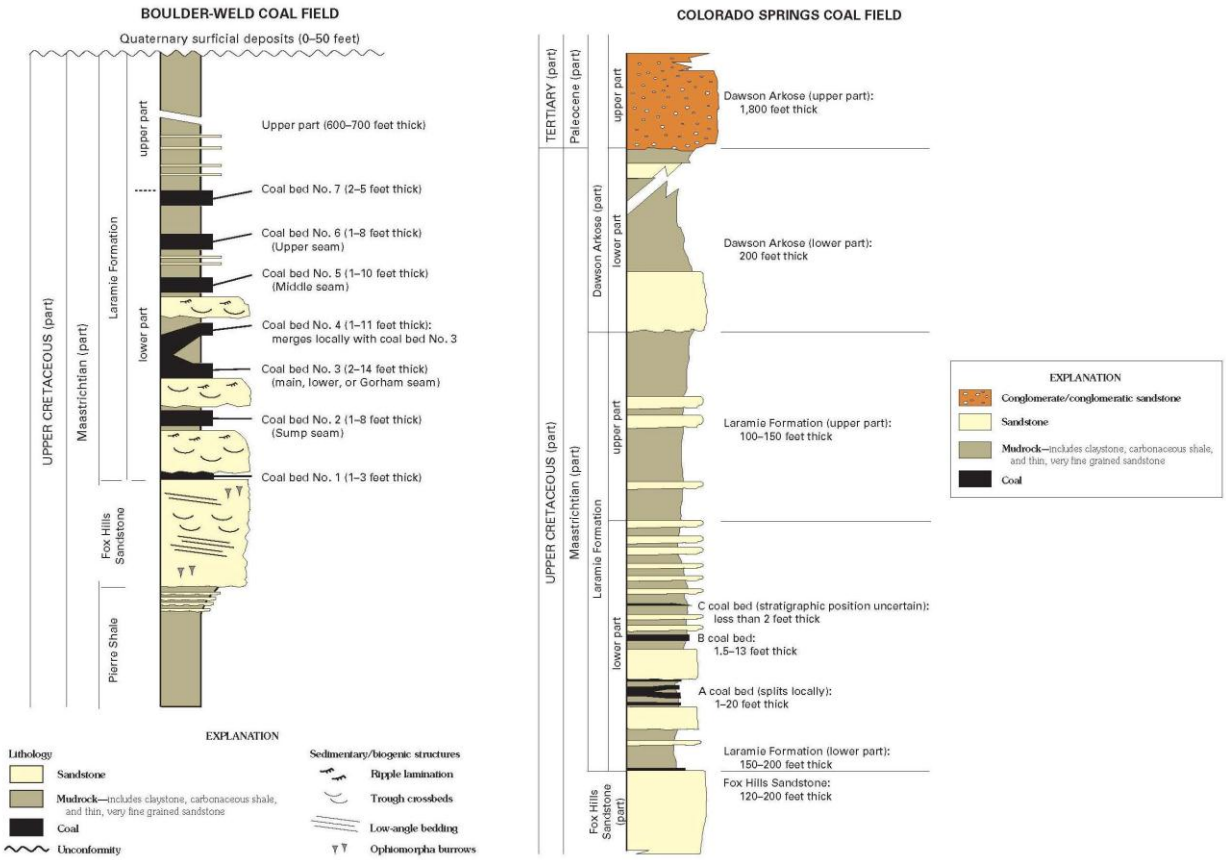


Figure 11. Stratigraphic Columns of Laramie Formation in Boulder-Weld Coal Field (left) and Colorado Springs Coal Field (right) of the Denver Basin
(Roberts, 2005)

The Upper Cretaceous Laramie Formation is a non-marine unit that gradationally overlies the marine Fox Hills Sandstone, which is an important aquifer in the basin. The Laramie consists of brackish water and continental shale, claystone, siltstone, sandstone and coal. The Laramie coals developed in poorly drained swamps in overbank areas adjacent to the channel-margin facies of delta plains. Due to the lenticular nature of the coal and sandstone within the unit, few coal seams can be correlated with other beds for any significant distance, even within a mining district. However, in general, there is a lower (main) coal zone (50 to 275 feet thick) that begins at the contact with the Fox Hills Sandstone. According to Kirkham and Ladwig (1979), some areas contain up to 16 individual coal beds and other areas have only 1 coal bed.

Relatively little is known about the lower Laramie coal zone in the Cheyenne Basin. Mined coal beds are as much as about 8-feet thick, but generally they are 3 to 7 feet thick (Tremain et al, 1996). A minor coal zone locally exists within the upper part of the Laramie Formation in the Cheyenne Basin in the vicinity of the towns of Nunn and Purcell, but it is only about 1.5 feet thick (Kirkham, 1978a).

The following map (Fig. 12) shows coal rank and depth for both the Laramie (bituminous and subbituminous coal) and Denver (lignite) Formations in the Denver Basin.

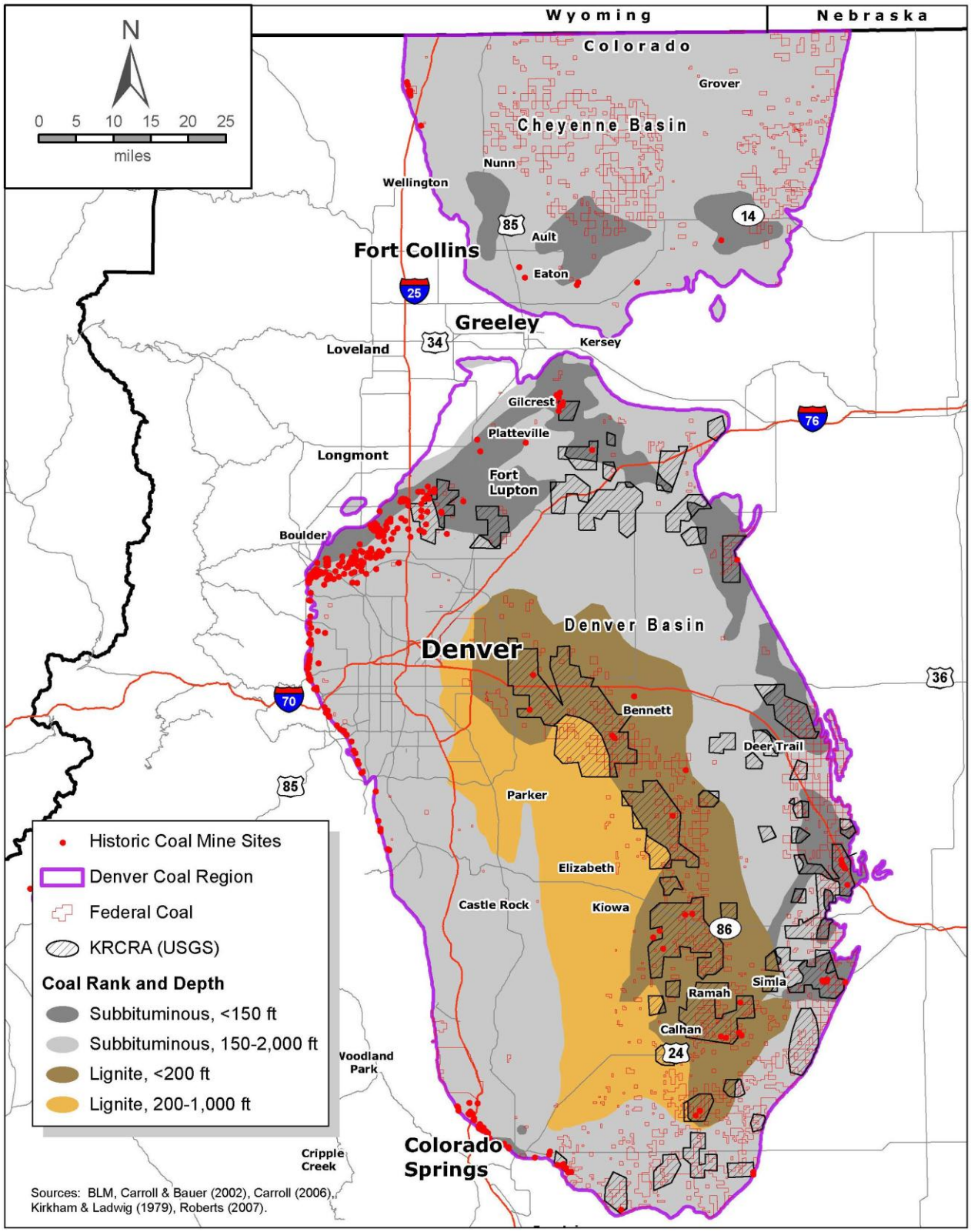


Figure 12. Coal Rank and Depth in the Denver Basin

Denver Formation

The following stratigraphic sections (Fig. 13) show the coal beds of the Denver Formation, both the Northern or Scranton Mining District (left) and Southern or Ramah-Fondis Mining District (right) lignite areas (see locations of fields on Fig. 6). Note the variability from north to south in the lignite deposits of the basin in terms of coal bed thickness and thickness of the barren, sandstone and mudstone/shale interbeds (Roberts 2005). This variability is present both in the north-south and east-west directions. Many coal seams and partings are lenticular and discontinuous laterally.

As seen in the stratigraphy of the Northern Lignite area (including the Scranton District), there are 5 identified coal beds (Lignite Beds A-E) ranging from 10 to 30 feet thick, including partings, with the uppermost bed (Bed A) located beneath the Dawson Arkose. Including partings, Beds A-D have a maximum thickness of 30 feet and Bed E has a maximum thickness of 55 feet locally. Interbeds consist of sandstone, claystone, and carbonaceous shale of variable thickness (Roberts 2005). Bed B is also known as the Lowry Bed, Bed C is also known as the Bennett Bed, and Bed E is also known as the Watkins Bed, based on their type localities near these towns.

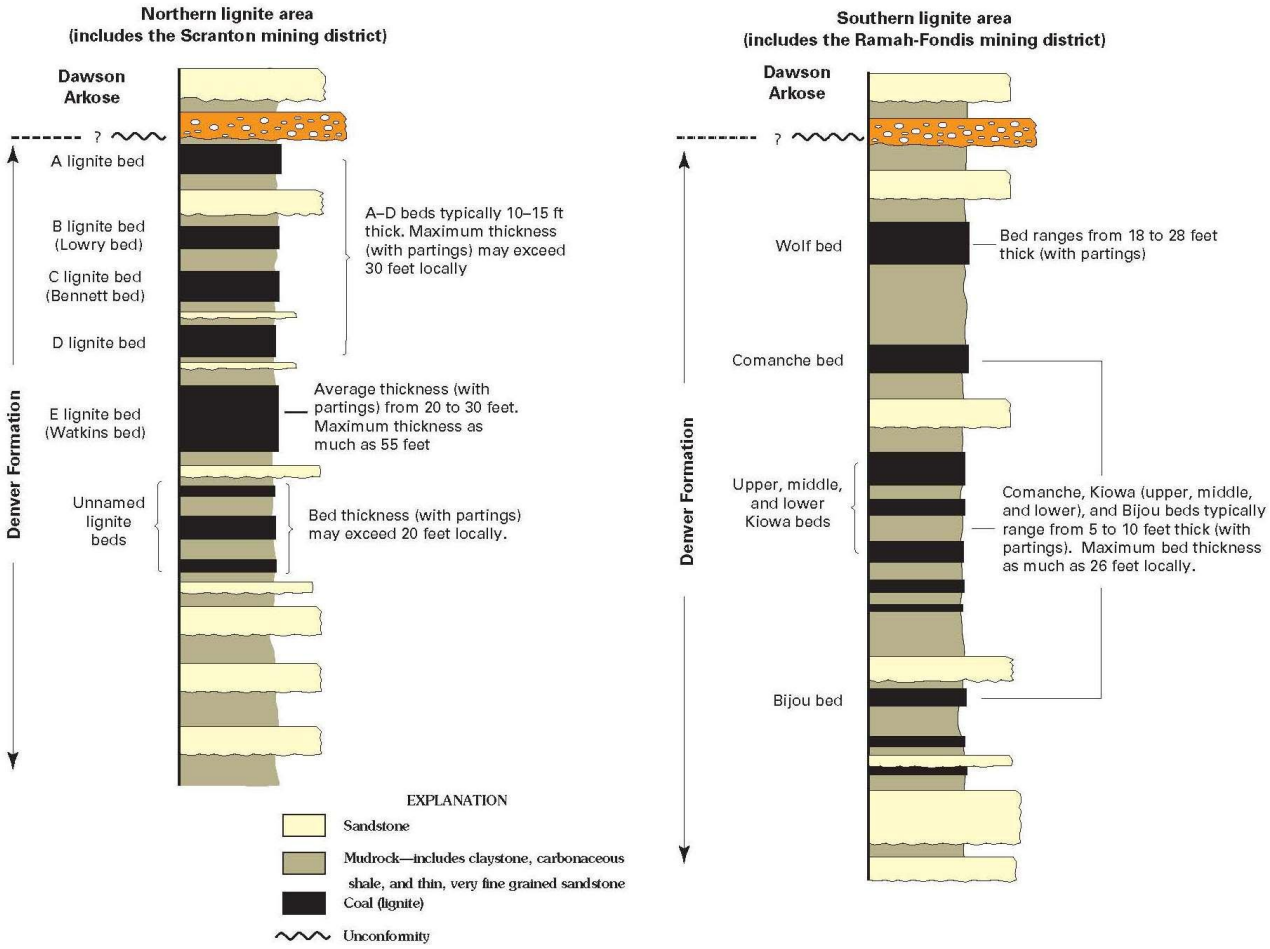


Figure 13. Stratigraphic Columns of the Denver Formation in the Denver Coal Field
(Roberts, 2005)

For the Southern Lignite area (Ramah-Fondis Mining District), there are 4 primary lignite beds with multiple minor beds (Roberts 2005). The lignite beds from top (near the Dawson Arkose) are the Wolf, Comanche, Kiowa and Bijou beds. Including partings, the Wolf Bed is 18 to 28 feet thick and the Comanche, Kiowa and Bijou Beds are 5 to 10 feet thick, with a maximum thickness of 26 feet locally. Although Denver lignites in the southern portion of the basin are up to 28 thick, they are typically less than 10-feet thick (Kirkham and Ladwig, 1979).

The Denver Formation is younger than the Laramie Formation and is separated from it by the Arapahoe Formation, and it lies beneath the Paleocene and Eocene Dawson Arkose. Denver Formation lignite beds are present only in the central and eastern parts of the Denver Basin and they are not present in the Cheyenne Basin (Fig. 12). Studies based on examining borehole logs, field mapping of outcrops, and historic mine data indicates Paleocene-age lignite beds, some attaining thicknesses in excess of 50 feet, exist in the upper 300 to 500 feet of the Denver Formation within the Denver Basin (Soister, 1972, 1974; Kirkham and Ladwig, 1979, 1980; Brand and Eakins, 1980). The lignite zone is 800 to 1,500 feet above the top of the Laramie coal zone (Soister, 1974). The lignite beds are at depths suitable for surface mining in several areas, and most of the lignite resources are less than 1,000-feet deep, as seen in the cross-section of Figure 10 and in the map of coal rank and depth (Fig. 12). Also seen on Figure 12 is that the eastern half of the lignite beds are at depths of less than 200 feet where all of the historic mining has occurred.

The following photograph (Figure 14) is of an outcrop of a lignite bed of the Denver Formation located in the Ramah-Fondis (southern) mining district in Elbert County. Note the prominent non-coal (sandstone) parting at the level of the person in the photograph as well as the numerous, thinner claystone, siltstone or sandstone partings above and below this level.

Figure 14. Lignite bed of the Denver Formation in Big Gulch (Elbert County)
(Source: Nichols 1999)

The Denver Formation lignite is brownish-black to black and weathers, slacks and disintegrates rapidly upon exposure (Kirkham and Ladwig, 1979). As such, it is typically not observed in outcrop except where recent incision has exposed it, such as in the previous photograph. Kirkham and Ladwig (1979) indicate that low hills capped by clinker (baked and fused lignite) are not uncommon in the region. The environment of deposition for Denver lignite was swamps east of the distal end of the alluvial plain piedmont or braided stream complex which extended eastward from the Front Range as it eroded during the early Paleocene (Kirkham and Ladwig, 1979). Due to the migrating nature of alluvial fan and braided stream environments as well as the evidence that uplift and related sedimentation were episodic, the lateral extent and thickness of lignite beds and partings is highly variable in the basin. The northern and southern lignite areas (Scranton and Ramah-Fondis Fields) previously described indicate there were two distinct swamp areas formed in the lower, poorly drained areas adjacent to the alluvial channels. These lignite coal fields are in the thicker, eastern portion of the lignite region.

Most lignite beds contain numerous non-coal partings, ranging from 0.1 inch to over 2 feet, and consist of sandstone, claystone (kaolin), altered volcanic ash, and siltstone layers. Consequently, Soister (1974) refers to gross bed thickness (lignite plus partings) and net lignite thickness. Kirkham and Ladwig (1979) indicate that partings can be as much as 30% of the gross lignite thickness. One of the common partings is kaolin, a kaolinite-rich rock, which weathers to a light or off-white color and can be 2 to 5 feet thick overlying individual lignite beds (Kirkham and Ladwig, 1979). They indicate that analysis of kaolin partings in the basin contain about 24% alumina (Al_2O_3), which could be extracted if commercially feasible to be co-mined with the lignite. Speltz (1976) suggests this is "of extraordinary interest," as his research indicated that about 20% of the total lignite thickness contains kaolin with greater than 31% alumina. He cited a Bureau of Mines estimate that suggests there are more than 400 Mtons of kaolin in the Denver lignite resource. When the kaolin is removed from the lignite, the heating value increases dramatically, as illustrated in Speltz's (1976) sample that increased from 6,905 Btu/lb to 11,874 Btu/lb with the clay partings removed. Including the partings, Kirkham and Ladwig (1979) conclude that much of the Denver lignite in the eastern part of the basin that is 5 feet or thicker could be mined using current strip-mining technology.

Coal Quality and Rank

Previous Tables 2 and 3 show ranges in coal quality and rank for Laramie and Denver Formation coals compared to the other three coal regions. Table 5 (below) is a summary of coal quality data for the Denver Coal Region. In general, Denver Basin coal is lower in coal rank than coal in the Raton Mesa and Cañon City Coal Regions, but similar to coal in the South Park Coal Region. Coal in the Laramie Formation usually is classified as low-sulfur, subbituminous A or B coal. Laramie coal with higher heat values (~8,300 to 10,800 Btu/lb) is found along the northwestern side of the Denver Basin in the Boulder-Weld Field (Carroll, 2011). The highest heat values within this field are in coal found in the southwest part of the Boulder-Weld coal field near the mountain front where much of the historic mining was concentrated (Kirkham, 1978a). In the eastern portion and along the margin of the Denver Basin (Buick-Matheson Field) some Laramie coal is subbituminous B and C, having heat values averaging about 6,100 to 7,300 Btu/lb and in the Colorado Springs Field coal is ranked subbituminous A and B with heat values of 8,400 to 9,300 Btu/lb (Carroll, 2011). Table 5 summarizes coal quality data for the various fields in the Denver Basin.

Coal Region	Coal Field	Formation and Coal Rank	Moisture (%)	Volatile matter (%)	Ash (%)	Sulfur (%)	Mercury (ppm)*	Heating Value (Btu/lb)
Denver	Boulder-Weld	Laramie Fm (beds 1-7) Subbit A & B	13.7-29.1 21.0-30.0**	27.3-43.6	3.5-12.7	0.2-0.9	.01-.02*	8,250-10,810
Denver	Foothills	Laramie Fm Subbit A & B	26.0**	NA	7.0**	0.6**	NA	8,500**
Denver	Colorado Springs	Laramie Fm (beds A,B,C) Subbit A & B	19.0-26.2 23.0**	31.4-45.1	5.6-20.8 7.0**	0.3-0.7 0.5**	NA	8,440-9,280 8,500**
Denver	SE/S-central; Buick-Matheson	Laramie Fm Subbit A,B,C	33.1-35.0 34.0**	30.8-44.2	7.8-15.7 9.0**	0.4-1.1 0.4**	.03-.08*	6,150-7,340 6,500**
Denver	Ramah-Fondis & Scranton	Denver Fm (3 beds) Lignite	26.4-39.6	19.3-42.7	9.8-44.6	0.2-0.6	.11*	3,636-6,803
Denver (Cheyenne)	Briggsdale	Laramie Fm Subbit A & B	33.0**	NA	8.0**	0.4**	NA	7,200**
Denver (Cheyenne)	Wellington	Laramie Fm Subbit A & B	32.0**	NA	8.0**	1.7**	NA	7,500**
Denver (Cheyenne)	Eaton	Laramie Fm Subbit A & B	NA	NA	NA	NA	NA	8,000**

NA = Not Available

Table 5. Coal Quality Data for Denver Coal Region
(Carroll 2011; Khalsa & Ladwig 1981*; Kirkham & Ladwig 1979**)

Laramie coal in the Cheyenne Basin ranks as subbituminous A and B with some lignite and contains slightly lower heat values than most Laramie coal in the Denver Basin (Table 2). For example, in the Wellington Field along the western margin of the Cheyenne Basin the heat values averaged 7,500 Btu/lb, on the southern Eaton Field heat values averaged 8,000 Btu/lb, and on the eastern Briggsdale Field they averaged 7,200 Btu/lb (Kirkham and Ladwig, 1979).

As seen in Table 5, other coal quality factors for Laramie coal indicate that sulfur concentrations in the Wellington Coal Field (Cheyenne Basin) were high (1.7%) relative to other areas in both basins, which were on the order of 0.2 to 1.1% in the other fields (Kirkham and Ladwig, 1979; Carroll, 2011). Ash content of Laramie coal ranged widely throughout the basin from 3.5 to 21%, moisture content ranged from 14 to 35%, and volatile matter content ranged from 27 to 45%. For ash, moisture and volatile matter, the Boulder-Weld Field values were generally the lowest and the Colorado Springs Field values were generally the highest. Carroll (2006) evaluated 727 coal samples from Laramie coal and found an average of 11.2% ash, 0.3% sulfur, and 9,072 Btu/lb. Other chemical analyses of Laramie coal samples indicate the following typical ranges: 0.4 to 1.7 ppm arsenic, 0.4 to 2.9 ppm cobalt, 2.1 to 15 ppm chromium, 0.01 to 0.11 ppm mercury, 0.9 to 3.8 ppm selenium, 0.5 to 1.9 ppm uranium, <25 to 40 ppm lead, and 22-80 ppm zinc (Khalsa and Ladwig, 1981).

Denver lignite ranges from about 3,600 to 7,000 Btu/lb, 8 to 45% ash, 22 to 40% moisture content, 19 to 43% volatile matter, and low sulfur concentrations of 0.2 to 0.6% (Kirkham and Ladwig, 1979; Carroll 2011). Most analyses show the lignite ranks as lignite A; however, some of the highest quality Denver lignite beds (thin intervals between thick lignite beds) may rank as high as subbituminous C coal (Kirkham and Ladwig, 1979). The highest quality lignite bed in the entire Denver Formation appears to be the Comanche bed of the Southern lignite area (Ramah-Fondis Mining District). Kirkham (1978a) suggests that the high ash content varies widely due to the clayey (kaolin) non-coal partings that are prevalent in the lignite beds.

Historic Mining

Approximately 385 mostly underground mines have produced coal in the Denver Coal Region (Carroll and Bauer, 2002). Most of these mines worked the coal beds in the lower Laramie coal zone. Relatively few mines have produced coal from the upper Laramie coal zone or lignite from the Denver Formation (see "Historic Production" below). As shown in Figure 6 and Table 2, there are a total of 9 mining districts, coal fields, or coal areas in the Denver Coal Region, with 7 coal fields that mined the Laramie subbituminous coal (Fig. 15) and 2 districts that mined the Denver lignite (Fig. 16). Of the 7 coal fields that historically produced coal from the Laramie Formation, 4 are in the Denver Basin and 3 are in the Cheyenne Basin. The coal fields are described below under the formations that were mined in those districts.

Mining Subbituminous Coal in the Laramie Formation

The following map (Figure 15) shows the historic coal fields that mined the Laramie Formation in the Denver Coal Region and basic information about each field's characteristics. Each field on this map is discussed briefly below, in order of production, from largest to smallest.

Boulder-Weld Field - This coal field, located in the northwest part of the Denver Basin, produced the majority (~107 Mtons) of coal in the Denver Coal Region from 160 mines for 120 years (Kirkham and Ladwig, 1979; Carroll, 2006). It is located mostly in Boulder and Weld Counties, but extends slightly into northwestern Adams County. Coal mining initiated in 1859 in the Marshall area and it is not only the oldest mining area in the basin, but also it is one of the oldest in the western United States (Kirkham and Ladwig, 1979; Roberts, 2005).

Peak production in the Boulder-Weld Field was in 1929, when 2.7 Mtons of coal were mined (Kirkham 1978a). In 1979, when Kirkham and Ladwig (1979) produced their coal resource assessment of the basin, one mine (Lincoln Mine) still operated, producing 100,000 tons/year. Early mines in the Boulder-Weld field worked adits into coal outcrops in the southwestern portion of the field, but as mining progressed to the northeast, mostly vertical shafts with some slopes were required to access the subbituminous coal beds (Kirkham and Ladwig, 1979). This contrasts with most other underground coal mines within the RGFO that were drift or slope mines, with portals (i.e., mine entrances) that were constructed at or near coal outcrops. This coal field has complex geology and is interrupted by numerous normal faults, some of which have coal bed offsets of up to 300 feet (Kirkham and Ladwig, 1979). Coal beds range from 1 to 14 feet thick and have heating values of 8,200-9,900 Btu/lb (Roberts, 2005). Future development in this field is limited due to urban development, significant mined out areas, and complex geology.

Colorado Springs Field – This coal field, located in the southwest edge of the Denver Basin, produced approximately 16 Mtons of coal from 65 mines for 75 years, from 1882 to 1957 (Kirkham and Ladwig, 1979; Carroll, 2006). It is located in El Paso County and much of the area is now within the Colorado Springs urbanized area. One of the mines was a strip mine, but all the others were underground mines. Coal bed thickness ranged from less than 2 to 20 feet and heating values averaged 8,500 Btu/lb (Roberts, 2005). Future development in this area is limited due to urban development.

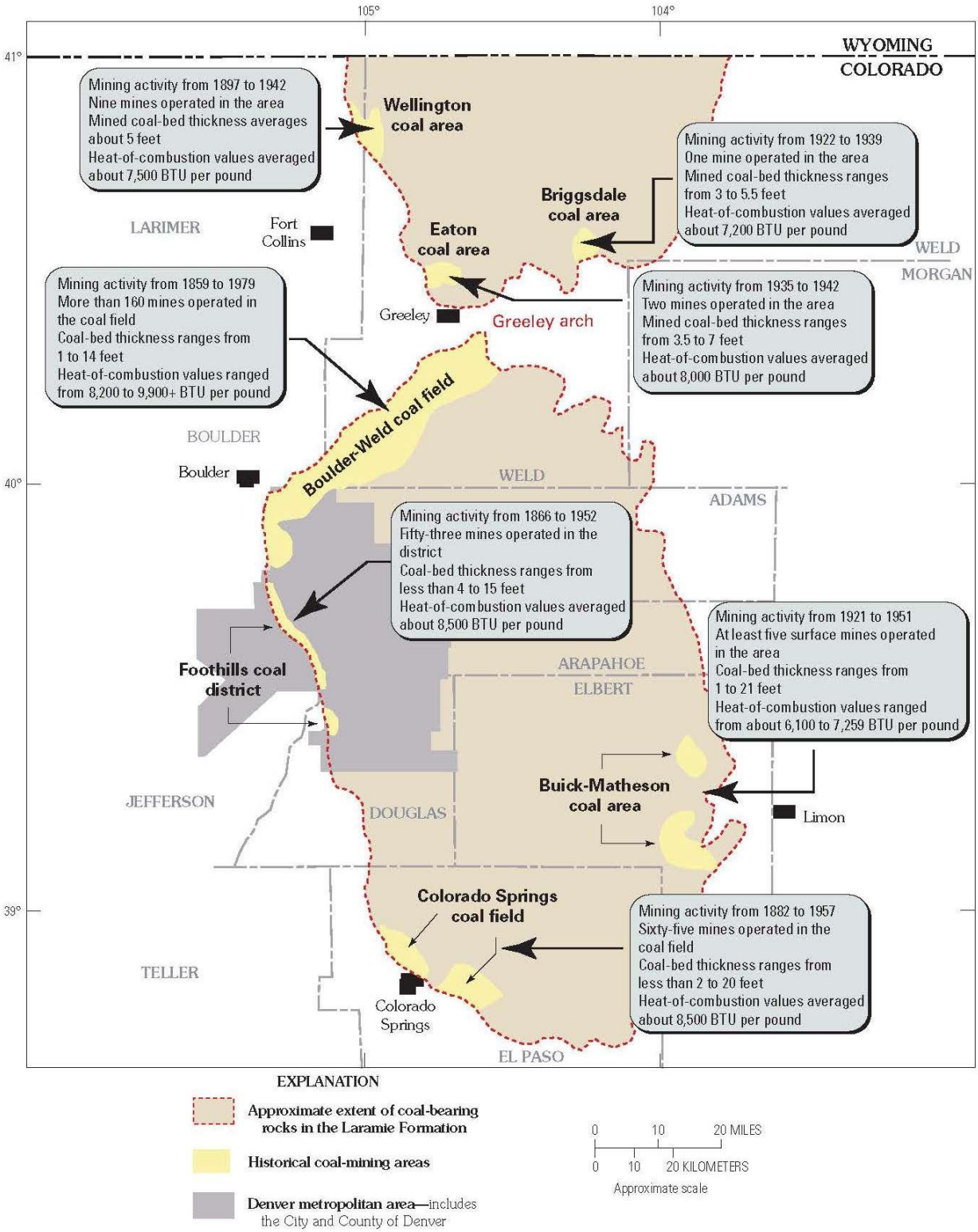


Figure 15. Historic Coal Mining from the Laramie Formation in the Denver Basin
(Roberts, 2005)

Foothills Field - This coal district, located along the western edge of the Denver Basin, directly west of downtown Denver in Jefferson and Douglas Counties, produced about 7 Mtons of coal from 53 underground mines for 86 years, from 1866 to 1952 (Kirkham and Ladwig, 1979; Carroll, 2006). Coal bed thickness ranged from less than 4 to 15 feet and heating values averaged 8,500 Btu/lb (Roberts, 2005). Future development in this area is limited due to urban development and the difficulty of mining steeply dipping coal beds, which range from 30-40° to vertical or overturned because of the Front Range uplift at the basin margin.

Buick-Matheson Field - This coal field, located along the east-southeast edge of the Denver Basin in Elbert County, produced roughly 107,000 tons of coal from 5 surface mines for 30 years, from 1921 to 1951 (Kirkham and Ladwig, 1979; Carroll, 2006). Coal bed thickness ranged from 1 to 21 feet and heating values ranged from 6,100-7,300 Btu/lb (Roberts, 2005).

Wellington coal area - This coal area, located along the western margin of the Cheyenne Basin in Larimer County, produced roughly 55,000 tons of coal from 9 underground mines for 45 years, from 1897 to 1942 (Kirkham and Ladwig, 1979; Carroll, 2006). Coal bed thickness averaged 4 to 5 feet for one seam and heating values were about 7,500 Btu/lb (Roberts, 2005).

Eaton coal area - This coal area, located in the southern portion of the Cheyenne Basin in Weld County, produced roughly 8,000 tons of coal from 2 underground mines for 7 years, from 1935 to 1942 (Kirkham and Ladwig, 1979; Carroll, 2006). Coal bed thickness averaged 3.5 to 7 feet for one seam and heating values were about 8,000 Btu/lb (Roberts, 2005).

Briggsdale coal area - This coal area, located in the southeastern portion of the Cheyenne Basin in Weld County, produced roughly 3,000 tons of coal from 1 underground mines for 17 years, from 1922 to 1939 (Kirkham and Ladwig, 1979; Carroll, 2006). Coal bed thickness averaged 3 to 5.5 feet for one seam and heating values were about 7,200 Btu/lb (Roberts, 2005).

Mining Lignite in the Denver Formation

The following map (Fig. 16) shows the historic coal fields or districts that mined the Denver Formation in the Denver Coal Region. Mining in these areas was from 1886 to 1940. There are basically two lignite fields, the Northern or Scranton District and the Southern or Ramah-Fondis District, discussed below.

Northern Lignite (Scranton) District - This lignite field, located in the Denver Basin east of Denver in Adams County, produced roughly 36,000 tons of lignite from up to 3 mines for 14 years, from about 1886 to 1900 (Kirkham and Ladwig, 1979; Carroll, 2006). Gross lignite thickness averaged 20 to 30 feet, with maximum thickness of 55 feet (Roberts, 2005).

Southern Lignite (Ramah-Fondis) District – This lignite field, located in the Denver Basin northeast of Colorado Springs in Elbert County, produced roughly 3,000 tons of lignite from 9 mines for 31 years, from 1909 to 1940 (Kirkham and Ladwig, 1979; Carroll, 2006). The main lignite bed averaged 18 to 28 feet thick while other beds averaged 5 to 10 feet thick (Roberts, 2005).

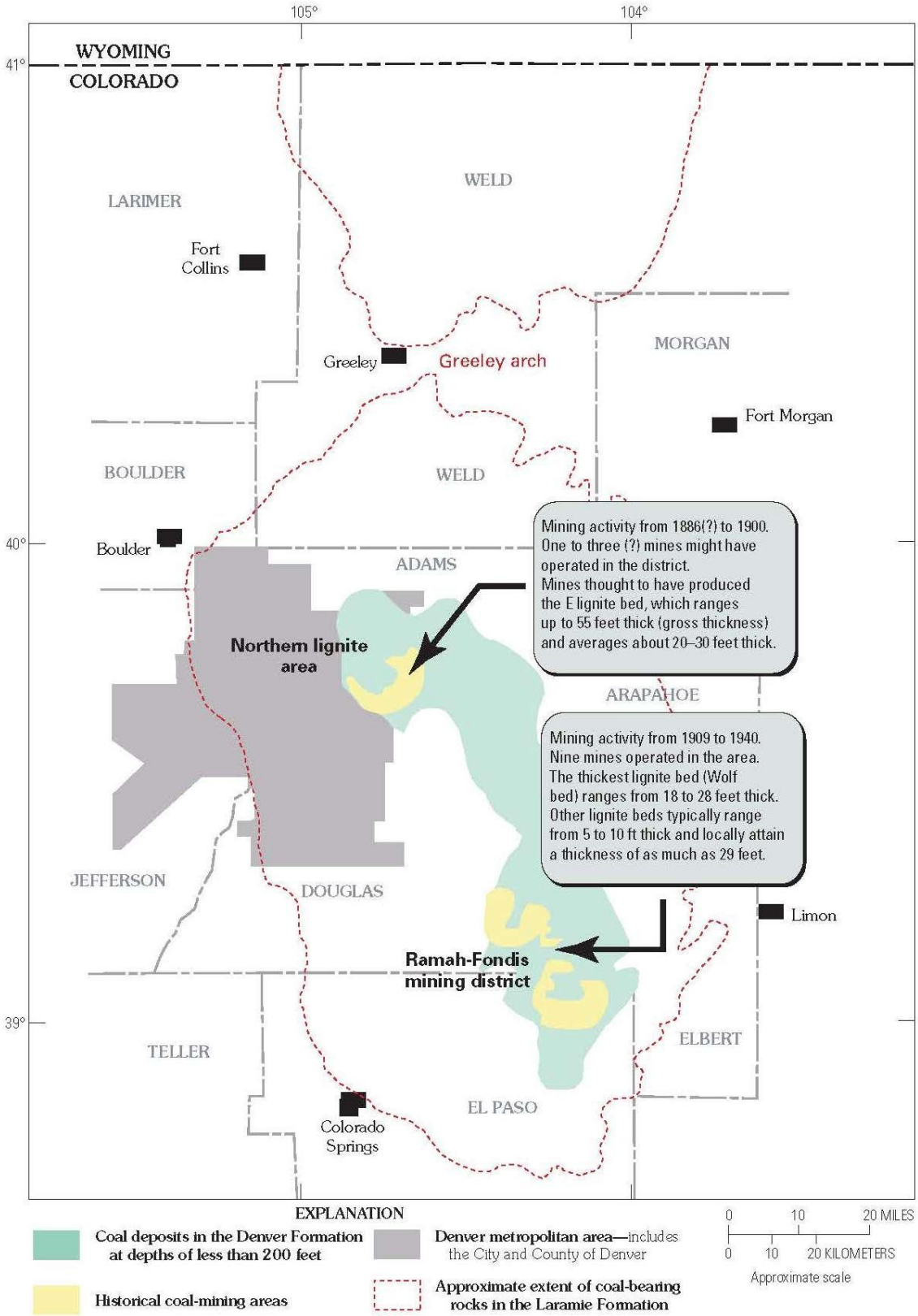


Figure 16. Historic Coal Mining from the Denver Formation in the Denver Basin
(Roberts, 2005)

Historic Production

The production of coal for each county within the Denver Coal Region was previously presented in Table 4. Basically, the counties with the largest production were Weld County (68.7 Mtons) and Boulder County (43.3 Mtons). A total of 134.2 Mtons of coal were mined in 9 counties (Carroll 2004). In 2002, this was the 4th largest coal producing region in Colorado. According to Kirkham (1978a), roughly 99.9% of the coal was produced in the Denver Basin and 0.1% was produced in the Cheyenne Basin. Also, greater than 99.9% of the coal was Laramie subbituminous coal, while less than 0.1% was Denver lignite, and 99.8% of the coal production was from underground mines and 0.2% was from surface mines.

Where Laramie coal beds are relatively flat lying or gently dipping, most underground mines used room-and-pillar mining methods, with the pillars typically being 20 to 30 ft wide, and access to the these mines was primarily via vertical shafts or slope entries (Roberts, 2007; Speltz, 1976). Shafts were typically 250 to 500 feet deep and coal was mined at depths of 50 to 500 feet deep (Carroll, 2004; Myers et al, 1975). Some amount of retreat mining (pillar pulling) upon completion of coal extraction was also used. Roberts (2007) indicates that room and pillar mines extracted 25-75% of the coal, with average coal extraction being 50-60%; retreat mining extracted 70-95% of the coal, with the average being 80-85%.

Where Laramie beds are steeply dipping, such as in the Foothills District, "stope" mining was used to access coal up to 100 feet above haulageways that were positioned parallel to the strike of the coal beds (Roberts 2007). Mine cars were pulled by mules to haul coal until the 1940s and then electric motors and continuous mining machines with conveyor systems were typically used post WWII. Longwall mining equipment was not used in this region because of the variable extent and quality of Laramie coal and the Denver lignites are "discontinuous, lenticular and impure" (Speltz, 1976). Most Laramie coal was mined underground, but there were a few strip mines in the eastern portion of the Denver Basin; most Denver lignite was mined at or near the surface with open pits and shallow shafts, tunnels, and slopes (Speltz, 1976; Soister et al, 1977).

Natural Gas Operations

Fender and Murray (1978) and Kirkham (1978a) document gas explosions, gassy mines and mine fires in more than a dozen mines in Boulder, Weld, Jefferson and El Paso Counties from the early 1900s to 1956 and Kirkham and Ladwig (1979) concluded that the data indicates that there appears to be "appreciable amounts" of coal gas in Laramie coal, but no data for Denver lignites. However, as of 1978, they indicate that none of the natural gas wells were producing from coalbed methane (CBM). John Axelson, East Environmental Supervisor of the COGCC, confirmed that this is still the case that there are no CBM gas wells in the Denver and Cheyenne Basins (personal communication, February 18, 2015). Instead, the extensive oil and gas drilling in the Denver and Cheyenne Basins is for conventional hydrocarbons, not CBM. The reason for this is that the Laramie and Denver Formation coals were not buried deep enough in the Denver Basin to achieve significant diagenesis and gas production. The two basins have formed structural traps for oil and gas in sandstone units due to thick sequences of low permeability Cretaceous shales. However, the use of hydraulic fracturing has allowed for more complete development of the gas resources trapped in the shales and sandstones.

Figure 17 shows the 26,600 active gas wells in the Denver Coal Region from the COGCC database for the end of 2014. Note the general distribution of wells throughout Denver Coal Region as well as the concentration of wells in the northern one-third of the Denver Basin and southern tip of the Cheyenne Basin.

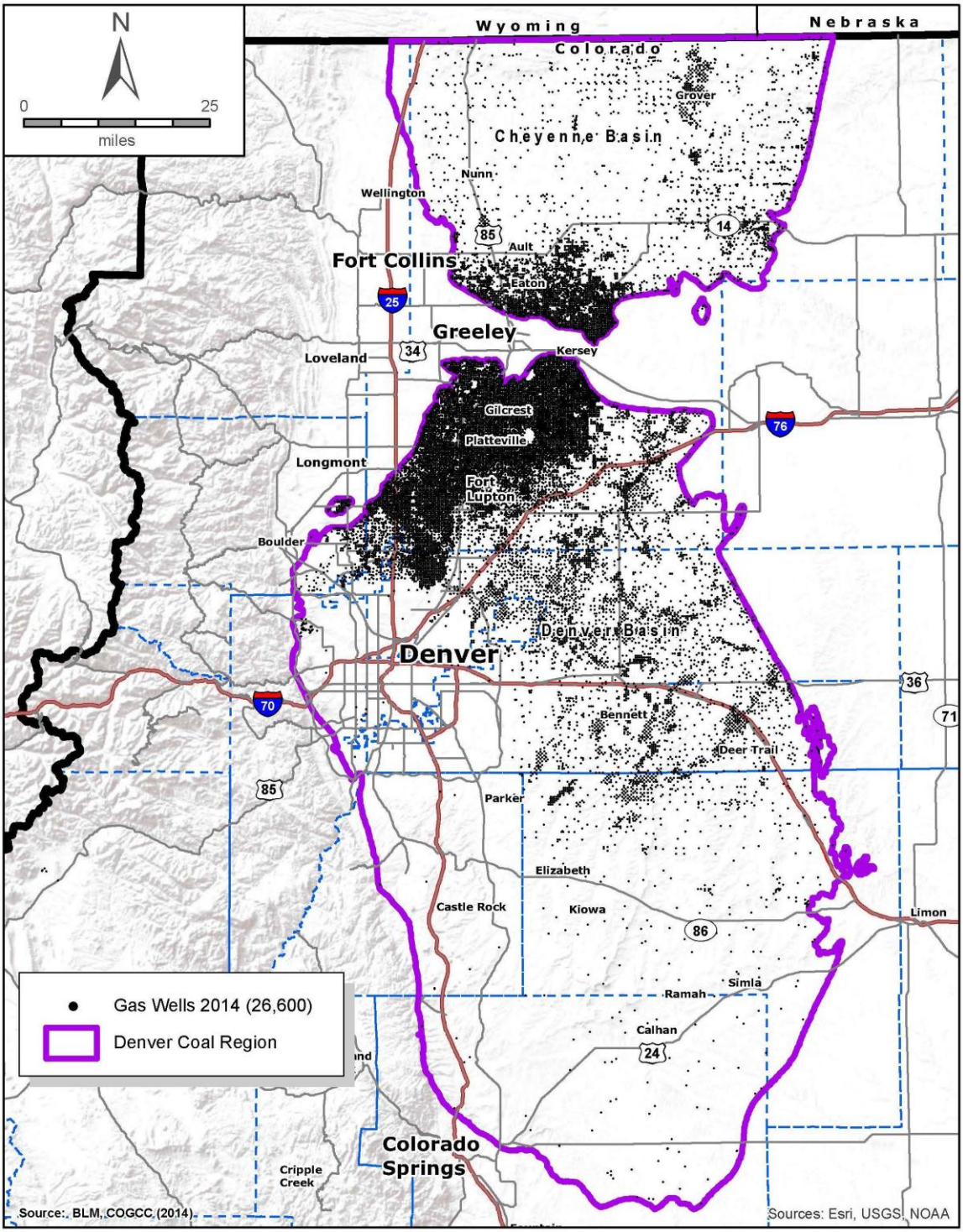


Figure 17. Gas Wells in the Denver Coal Region

As will be further discussed, the presence of natural gas wells does not preclude coal mining, but it does impact the availability of coal and the cost of coal development. The COGCC gas well database was used in our analysis of the coal resource for federal coal.

Current Mining Operations and Production

According to the online CDRMS database, there is one active coal mine permit in the Denver Coal Region: the Keenesburg Strip Mine, operated by Coors Energy Company (Permit No. C1981028). This mine is located in Weld County in the northeastern part of the Denver Basin (Fig. 8). It was a strip mine that produced lignite coal from 1983-1988, but currently is undergoing reclamation, according to Daniel Kipp, Site Superintendent (personal communication, February 18, 2015). Mr. Kipp, who has worked at this site for 35 years, indicated that the lignite was not of high quality, so mining was ceased in 1988. He indicated that fly ash from the coal-fired Trigen Colorado Steam & Electric Plant at the Coors Brewery in Golden, Colorado is currently hauled to the Keenesburg site and used to backfill the strip mine pit and that operations will continue for another 6 to 7 years.

Other than the Keenesburg Strip Mine, there has been no other coal mining in the Denver Coal Region since the 1980s and, in most cases, not since the 1940s. Therefore, there are no current mining operations or production figures for the region. Urban development and lack of demand for subbituminous or lignite coal were the main driving forces that ended the coal mining in this region. Other areas in Colorado have higher quality coal and larger resources, such as bituminous coal in the Uinta, Green River and San Juan Coal Regions and coking coal in the Raton Basin.

Restrictions to Mining Operations in Coal Region

There are many surface and subsurface restrictions to coal mining including areas where the coal is already mined out, environmental and societal protections, and technological/geological considerations. According to Rohrbacher et al (2000), the unsuitability criteria from Federal Regulations 43 CFR §3461.5 include the following social and environmental categories: federal lands; rights of ways and easements; dwellings, roads, cemeteries, public buildings; Wilderness Study Areas (WSA); lands with outstanding scenic quality; lands used for scientific study; historical lands and sites; natural areas; critical habitat for threatened or endangered species; state listed threatened/endangered species; bald or golden eagle nests, roosts and concentration areas; federal lands containing active falcon cliff nesting sites; habitat for migratory bird species; fish and wildlife habitat for resident species; flood plains; municipal watersheds; national resource waters; alluvial valley floors; and State or Indian Tribe criteria.

Other applicable land use restrictions identified by Rohrbacher (2000) include towns, pipelines and powerlines, industrial sites, archaeological areas, ownership issues, wetlands, streams, lakes and reservoirs. Technological restrictions relate to both the geology and limitations to mining operations, and they include: burned or oxidized coal; coal beds too thin to mine; coal bed discontinuities; coal beds too close (<40 ft apart); coal beds too steep to mine; roof or floor problems; minimum and maximum depth limitations on underground mining; too much overburden for surface mining; too close to intrusives or faults; beds offset by faults; active mines and barrier pillars; mined-out and abandoned mine areas; subsidence over abandoned

mines; slopes too steep to reclaim; unstable slopes; oil and gas development; and minimum resource block size.

Regarding overburden restrictions in the Denver Coal Region, it is generally accepted that lignite within 200 feet of the surface is considered strippable and coal deeper than 1,000 feet is not economically feasible to mine for this rank of coal (Brand and Eakins, 1980; Kirkham and Ladwig, 1979; Murray, 1980). This is why we chose the categories of "lignite <200 ft" and "lignite 200-1,000 ft" for coal rank and depth in our evaluation (Fig. 12). Similarly, for Laramie subbituminous coal in the region, it is strippable if less than 150 feet of overburden is present and for underground mining, roughly 150 feet of overburden is needed for roof support (Speltz, 1976). Laramie underground mines are well-documented as having subsidence issues when overburden thickness is not sufficient to support the mined-out areas, especially in the Boulder-Weld Field (Roberts et al, 2001; Myers et al, 1975; Noe et al, 1999; Amundson et al, 2009; Marsters, 2012). The maximum overburden generally accepted for the underground mining of Laramie coal, based on historic mining, is 2,000 feet (Kirkham and Ladwig, 1979; Murray, 1980; Roberts, 2005). Therefore, we chose the categories of "subbituminous <150 ft" and "subbituminous 150-2,000 ft" for coal rank and depth in our evaluation (Fig. 12).

Due to the large amount of oil and gas wells in the Denver Coal Region, as previously discussed, it is worth mentioning that the presence of these wells does not prohibit coal development in the region, but it does create restrictions that are long-lasting, but not permanent. In other words, the two industries are not mutually exclusive, but they affect each other. If oil or gas wells exist in an area proposed for coal mining, the wells would either need to be completely avoided within a 150-foot radius in the mine plan or they would need to be officially abandoned, filled with cement/grout and capped so they are not a pathway for oil, gas or groundwater. Once filled, they could be "mined through" in a surface or underground mine.

Although not an officially recognized restriction, but which should be considered as a limiting factor to coal development in the Denver Coal Region is water, both surface water rights and groundwater impacts (Kirkham and Ladwig, 1979). Surface water is appropriated and limited in the arid high plain and would require the acquisition of water rights for water-consuming projects such as mining or gasification plants. Important regional groundwater aquifers are the Laramie-Fox Hills aquifer at the base of the Laramie Formation coals and the Dawson Arkose at the top of the Denver lignites and, to a lesser extent, the sandstones below the lignite zone in the Denver Formation. Potential pollution of and disruption to water flow within the aquifers with coal and lignite mining activities would need to be considered prior to mining.

Previous Estimates of Coal Resources

An analysis of Coal Availability has not been performed for the Denver Coal Region to date, according to Joe East, USGS Project Chief for NCRDS, National Coal Resources Data Systems (personal communication, December 9, 2014). However, there have been numerous studies that have evaluated coal resources and coal quality of this coal region. These include Landis (1959), Landis and Cone (1971), Soister (1972, 1974), Speltz (1976), Soister et al (1977), Kirkham (1978a, 1978b, 1978c), Kirkham and Ladwig (1979, 1980), Brand and Eakins (1980), Nichols (1999), and Roberts (2005, 2007). The following Table 6 is a summary of the estimates of coal resources for the Denver Coal Region.

Reference	Total coal Denver & Cheyenne Basins		Laramie coal		Denver lignite	
	Btons	Square miles	Btons	Square miles	Btons	Square miles
Landis (1959)	5.3	836	4.3	649	1	187
Kirkham & Ladwig (1979)	30-40	7,500	20-25	5,600-6,400	10-15	1,700
Hornbaker et al (1976)	39.8	7,500	29.8	NR	12.5	NR
Brand & Eakins (1980)	29.5	NR	16.6*	NR	12.9*	NR
Speltz (1976)	NR	NR	NR	NR	13	NR
Soister (1978b)	NR	NR	NR	NR	10	2,250

**For the Denver East ½° x 1° Quadrangle only* *NR=Not Reported*

Table 6. Previous Estimates of Coal Resource in Denver Coal Region

Laramie Formation Subbituminous Coal – As seen in Table 6, estimates of coal resources vary considerably. However, the differences can be explained by different researcher's area of study, assumed bed thickness and extent, and amount of acceptable overburden. For example, Kirkham and Ladwig (1979) concluded that significant areas of both the Denver and Cheyenne Basins are virtually coal-free and that most of the Cheyenne Basin has considerably less coal than estimated by Landis (1959), although Landis surveyed a much smaller area. The Kirkham and Ladwig (1979) estimate of remaining in-place resources of subbituminous coal beds in the Laramie Formation greater than 2.5 feet thick at depths of less than 3,000 feet in the Denver Coal Region is approximately 20 to 25 billion tons.

Denver Formation Lignite – As mentioned, there is no Denver Formation in the Cheyenne Basin, although minor amounts of lignite were reported (Carroll 2004), so all estimates listed are just for the Denver Basin. Landis (1959) produced an early estimate of the lignite resource in the Denver Basin for just the Scranton and Ramah-Fondis mining areas, while most other researchers regarded a larger area of Denver lignite. Kirkham and Ladwig (1979) concluded that in-place resources of Denver Formation lignite at least 4 feet thick and less than 1,000 feet deep in the Denver Basin is likely 10 to 15 billion tons.

Analysis of Federal Coal Resources in the Denver Coal Region

The Federal Government owns the coal estate in numerous tracts scattered across the Denver Coal Region (Fig. 8). Most of the tracts within the Denver Basin are concentrated along the eastern, southeastern and southern part of the basin in areas underlain by Laramie Formation coal, or they are in the central to southern part of the basin in areas where the Denver Formation lignites are at relatively shallow depths. Other small tracts with federal coal are scattered in other areas of the Denver Basin. Within the Cheyenne Basin, the tracts with federal coal are in the central and eastern margins of the basin.

The USGS has studied coal resources in most coal regions, including the Denver Coal Region, and has identified "Known Recoverable Coal Resource Areas (KRCRAs)." A KRCRA is "an administrative and technical classification established by the U.S. Geological Survey to designate areas where the location and amount of minable coal deposits have been reasonably well-defined by geologic mapping and coal exploration" (OTA, 1981). The Office of Technology Assessment (OTA) publication goes on to say that "minable coal reserves are found outside of KRCRAs, but generally there is less information available about the extent of the reserves and little or no commercial coal mining in these areas." KRCRAs are often delineated as *Known Coal Resource Leasing Areas* (KCRLAs) on maps to identify areas for potential coal leasing. For the Denver Coal Region, KRCRAs were identified on the *Coal Resources and Development Map of Colorado* (Jones et al, 1978), discussed in Soister et al (1977), and are shown on the Denver Coal Region Coal Rank and Depth Map (Fig. 12). The criteria for the Denver KRCRA were the following: (1.) Only parts of the basin with concentrations of federally-owned coal were considered; (2.) Lands within KRCRA must be underlain by coal with a minimum thickness of 4 feet and maximum depth of 2,000 feet, as determined by mine records, coal prospect boreholes, water wells, and some oil/gas wells; (3.) a 1-mile radius was used for known data points and inferences were made within a 5-mile radius of that point; and (4.) the Laramie coal could be worked via surface or underground methods and Denver lignite was suitable mostly for surface mining.

In the absence of Coal Availability studies, KRCRA mapping is a valuable tool for evaluating coal resources and was used as the basis for our analysis of coal resources for land with federal coal estate. For our analysis, we digitized the KRCRA polygons and overlaid them on coal rank and depth (Fig. 12) to determine area in acres for strippable (<150 ft) and subsurface (150-2,000 ft) bituminous/subbituminous Laramie coal as well as strippable (<200 ft) and subsurface (200-1,000 ft), based on depths suggested by Roberts (2005). We did not perform a Coal Availability study to remove all land use and technological restrictions, as sufficient mined-out areas are not well documented electronically, but we did remove several obvious larger restrictions that would impact coal availability in the Denver and Cheyenne Basins. These restrictions include urban areas (cities, as per CDOT GIS data), 150-foot radius buffer zones around gas wells (per COGCC data), an "extensive mining area" of the Boulder-Weld Field that has been essentially mined-out (per Kirkham and Ladwig, 1979), the Air Force Academy, and the Rocky Mountain Arsenal.

We then applied those modified polygons (with above restrictions applied) to the federal coal estate to determine areas of "quasi-available" federal coal within KRCRAs and outside of KRCRAs, as seen in Table 7 below. To determine tonnage, we assumed for Laramie subbituminous coal an average bed thickness of 5 feet and a density of 1,770 tons/ac-ft. For Denver lignite we assumed an average bed thickness of 5 feet and a density of 1,750 tons/ac-ft. The conversion factors for determining tonnage of the different coal ranks is based on Wood et al. (1983). The average bed thickness of 5 feet was selected from Tremain et al (1991, 1996) and Kirkham and Ladwig (1979), discussed earlier. We felt the 5-foot thickness was conservative within coal fields, where some Laramie beds could be as thick as 20 feet (more typically 5-10 feet in Denver Basin and 3-7 feet in Cheyenne Basin) and some Denver lignite beds could be as thick as 30-55 feet (typically 10-30 feet in Northern zone and 5-10 feet in Southern zone), but also accounted for the discontinuous and lenticular nature of all of the coal and lignite beds across the region.

	Federal Coal within KRCRA (assumed thickness of 5 ft and minus some restrictions*)		Federal Coal outside KRCRA (assumed thickness of 5 ft and minus some restrictions*)		Total Federal Coal	
Coal Rank and Depth	Area (acres)	Tonnage**	Area (acres)	Tonnage**	Area (acres)	Tonnage**
Subbituminous coal 150-2,000 ft	24,905	220,409,250	211,883	1,875,164,550	236,788	2,095,573,800
Subbituminous coal <150 ft	16,219	143,538,150	26,452	234,100,200	42,671	377,638,350
Lignite 200-1,000 ft	6,949	60,803,750	12,373	108,263,750	19,322	169,067,500
Ligninte <200 ft	39,144	342,510,000	40,397	353,473,750	79,541	695,983,750
Total	87,217	767,261,150	291,105	2,571,002,250	378,322	3,338,263,400

* Restrictions only include cities (per CDOT GIS), 150' radius from gas wells (COGCC), and "extensive mining" area (Kirkham & Ladwig 1979).

** Tonnage is based on the assumption that Bituminous/Subbituminous coal is 1,770 tons/ac-ft, and Lignite is 1,750 tons/ac-ft.

Table 7. Federal Coal Resource in Denver Coal Region

For our analysis, we used Figure 12 as our base map, which shows the four coal categories based on rank and depth, with two depth categories for subbituminous coal and two depth categories for lignite, and the KRCRAs. Appendix A contains our maps showing the progression of applying restrictions to this base map in our analysis. The first map (Fig. A-1) shows the areas of the three main restrictions (cities, gas wells, and extensive mining) and the in-place known coal for the entire region. The second map (Fig. A-2) shows the federal coal with the 3 restrictions applied. It also shows where federal coal is located both inside and outside of KRCRAs. The Air Force Academy and Rocky Mountain Arsenal properties have also been removed from this map because the federal minerals associated with these properties are not available for leasing. The third map (Fig. A-3) shows the coal with federal ownership for both KRCRAs and non-KRCRAs. This map is helpful to see where the federal coal resource is better known (i.e. within KRCRAs) and likely thicker and of better quality than in the non-KRCRA areas. The fourth map (Fig. A-4) shows the rank and depth of the federal coal in the Denver and Cheyenne Basins. This final map shows virtually no federal coal in the northern, western and southwestern portions of the Denver Basin. For Laramie subbituminous coal (shown in shades of gray), there is some shallow (<150 ft) strippable federal coal along the eastern margin of the Denver Basin and small amount in the south-central portion of the Cheyenne Basin. There is deeper (150-2,000 ft) Laramie coal in the southeastern and eastern portions of the Denver Basin and a small amount in the northeastern portion of the Denver Basin. The Cheyenne Basin contains deeper Laramie coal in the central and eastern portions of the basin. For Denver lignite (shown in shades of brown), there is shallow (<200 ft) strippable federal lignite throughout the lignite region (Fig. 12) in the east-central portion of the basin; however, much of it is in non-contiguous parcels. There is a lesser amount of deep lignite (200-1,000 ft) to the west of the shallow lignite.

As a sensitivity analysis, we calculated the amount of coal in the four categories of rank and depth for the Denver Coal Region, assuming the same average bed thickness as used in our analysis for federal coal, to compare our coal resource quantities with other published resource estimates. We determined the following total original coal (no restrictions applied) shown in Table 8. These results indicate approximately 31.3 billion tons of Laramie subbituminous coal and 11.0 billion tons of Denver lignite in the Denver Coal Region.

Coal Rank and Depth	Original Coal (Btons)		Quasi-available coal	
			Restrictions (Btons)	Total (Btons)
Laramie subbituminous coal (150-2,000 ft)	26.6	31.3	-4.024	27.3
Laramie subbituminous coal (<150 ft)	4.7			
Denver lignite (200-1,000 ft)	4.9	11.0	-1.556	9.5
Denver lignite (<200 ft)	6.1			

Table 8. Results of Original vs. Quasi-Available Coal in Denver Coal Region

When we correct for our restrictions, shown above, to determine "quasi available" coal on a region-wide basis, we calculate 27.3 billion tons of Laramie coal and 9.5 billion tons of Denver lignite. These results indicate we are in the "ballpark" of the prior estimates of 20-30 billion tons for subbituminous coal and 10-15 billion tons for lignite shown in Table 6. This indicates that our assumed average bed thicknesses of 5 feet are close to reality for the basin. Our federal coal analysis was based on this same assumption of bed thickness. When we attempted to apply coal beds of 2.5 feet to the non-KRCRA coal, our estimates for both Laramie coal and Denver lignite were severely underestimated when compare with published resource estimates.

According to Table 7, there are 2.47 billion tons of available federal Laramie subbituminous coal and 865 Mtons of available federal Denver lignite with in the Denver Coal Region. To put these numbers into perspective, the two largest mines in Colorado produced between 6.3 and 6.7 Mtons each in 2014 and the total 2014 production for all 8 producing mines in the state was 23 Mtons (CDRMS, 2015).

It should be mentioned that our numbers are an over-estimate of "available" coal since not all mined out areas, land use (societal and environmental), and technological restrictions have been removed from the study area (Luppens et al, 2009). Actual economically recoverable coal would also have to take into account mining and processing losses, compliance ($S0_2$ content) of the coal, and resources that are too costly to extract. The number is higher for underground mining and lower for surface mining. Regarding mining methods, longwall operations are the predominant method of coal extraction in the Colorado Plateau region (of which the Denver Coal Region is most similar), except where room and pillar is required due to geologic conditions, and longwall methods recover more coal than room and pillar mining (Luppens et al 2009).

Comparing the Denver Coal Region with another western coal region with both surface and underground mining of similar age, coal rank, mining methods and significant land use restrictions, the San Juan Basin of New Mexico (Bisti Coal Field) had recoverable coal resources that were 47% of the original coal resource (Rohrbacher et al, 2000). Another similar underground region in Colorado is the Somerset coal field of the Piceance Basin, which has a recoverable resource of 64% and an economically recoverable resource that is 22% of the original resource Luppens et al (2009). Desty Dyer, BLM Mining Engineer, indicated that the actual recoverable coal in western Colorado coal mines is typically on the order of one-third to

one-half of the original coal (personal communication, October 23, 2014). In other words, 50-67% of the coal is unusable, left behind or wasted, so estimates of actual recoverable coal should multiply the original coal resource by .50 to .33. According to Rohrbacher et al (1994), the mineable coal resource tonnage can be about 60% of the calculated Available Coal.

Potential for Federal Coal Development during Plan Life

In viewing the results of our coal analysis (Fig. 8, Fig. 12 and Appendix A) and the previous section, we offer the following summaries of the potential for federal coal development during the Plan Life of the Eastern Colorado Resource Management Plan. Relevant to the discussion of the potential for federal coal development is the economic climate that determines the value of both thermal and metallurgical coal. In other words, if there is market demand for the coal, then there is potential for future development of the coal, but if the market demand is poor, even if coal quality and availability is good, then the potential for coal development is poor. A discussion of the current domestic and international markets for both thermal (steam) coal and metallurgical (coking) coal is presented in Section IX (Coal Resource Potential and Reserve Estimates) of this report. It may be helpful to read that section first if unfamiliar with the status of current coal markets for the types of coal located in each coal region.

Subbituminous coal of the Laramie Formation – As previously discussed, there is an estimated 20-25 billion tons of subbituminous coal within 3,000 feet of the surface in the Denver Basin. Our calculations of "available" federal subbituminous coal are 1.2 billion tons and if we assume that the actual recoverable coal is 40-60% of available coal, the amount of subbituminous coal is reduced to 480-720 Mtons. The heating value of Laramie coal averages 9,072 Btu/lb, but can vary across the basin from 5,000 to 10,800 Btu/lb, has subbituminous rank, low average sulfur content of 0.3%, and moderate average ash content of 11.2% (Kirkham and Ladwig, 1979; Carroll 2011). Although the low sulfur content is desirable from an emissions compliance standpoint, the relatively low rank of this coal and its' highly variable heating value make it less desirable, especially when compared to other Colorado coals. For example, it takes twice as much subbituminous coal that has 6,500 Btu/lb heating value than a bituminous coal that has 13,000 Btu/lb, which is a substantial competitive advantage for the higher ranked coal (Luppens et al, 2009). In other words, Laramie coal in the Denver and Cheyenne Basins is not as high quality as the bituminous coal that is currently mined in Colorado and would not be competitive with that coal especially that which is transported out of state. If it is burned locally, due to its' super compliance sulfur content, then it could be more economic when compared with other Colorado coal, even if it has lower heating value. However, over-riding factors will be the land use restrictions due to urban and suburban development and the socio-economic acceptance of surface or subsurface coal mining.

Historically, the mining of Laramie subbituminous coals in the Denver and Cheyenne Basins was concentrated in the Boulder-Weld Field (82% of total production) with minor production in the Foothills and Colorado Springs Fields. In the Boulder-Weld Field, the highest quality coal was in the western portion of the district, where urban development has been concentrated. The Buick-Matheson Field in the eastern margin of the Denver Basin and in the three small fields of the Cheyenne Basin were very minor producers of coal. Due to the major urban and suburban development of the Denver Metropolitan area in the past 30 years, virtually the entire area of the north Denver Basin between Denver and Greeley has been developed for residential, commercial and agricultural use. Land use conflicts and hazards associated with coal mining,

such as coalbed fires, subsidence, and surface and subsurface water contamination affect the potential for possible coal mining (Fishman et al, 2005). This is also an area of intense gas well production (Fig. 17). Although there is a fair amount of KRCRAs and both shallow (<150 ft) and deep (15-2,000 ft) coal identified for this region of the basin (Fig. 12), there is not much federal coal estate. However, there is private coal ownership that could fill in the "gaps" of federally-owned coal. Due to all these factors, especially urban sprawl and the high density of gas wells, there is little potential for federal Laramie coal development in the northern portion of the Denver Basin. For the western (Foothills Field) and southern (Colorado Springs Field), there is virtually no federal coal and these areas are highly urbanized; therefore, the potential for federal coal in these areas is also very low.

For the eastern portion of the basin where the Laramie coal is known to be relatively shallow and there is both more federal coal estate and more KRCRAs, the potential for federal coal resource is somewhat greater. There is a significant amount of shallow (<150 ft) resource, as well as underground mining due to the underlying coal resource, as was historically mined. However, it is worth noting that the federal estate is a patchwork of many non-contiguous or small clusters of parcels rather than large blocks of federal coal ownership (see Fig. A-2). This is important because there would need to be essentially universal "buy in" by the privately owned coal estate for large-scale, economic development of the coal in this region to take place. Development of infrastructure (roads, railroads, utilities) would require the dedication of larger tracts and, possibly, a single large mine to make this a profitable endeavor. However, due to the lenticular nature of the coal beds with many partings, subbituminous B and C and lignite rank, and the relatively low heat value of the eastern margin Laramie coal (6,100-7,000 Btu/lb), this resource is not as desirable as the more massive and higher heat value coals in the Uinta, Green River and San Juan Coal Regions of Colorado. Consequently, the potential for federal Laramie coal development in the eastern portion of the Denver Basin is considered low.

For the Cheyenne Basin, there is a significant amount of federal coal ownership, but this land is entirely outside of the three small historic coal fields and is not generally within the areas mapped as having Laramie subbituminous coal less than 150 feet. Therefore, any mining of Cheyenne Basin coal would likely be done by underground mining methods, as was done historically. However, since historic mining never concentrated in the areas with federal coal ownership, it is likely that the coal is not generally regarded as high quality or economic to extract in these areas. Average heat values of 7,200-8,000 Btu/lb, subbituminous A and B to lignite rank, and relatively high sulfur contents of 1.7% were recorded for this region. These do not indicate high quality coal competitive with super compliant coals of the western slope of Colorado. If the coal resource was to be developed, it would face the same issues at the eastern margin of the Denver Basin such as scattered federal coal ownership, marginal coal quality, infrastructure development needed, and lack of market demand for this type of coal. The potential for federal Laramie coal development in the Cheyenne Basin is considered low.

It should be mentioned that Kirkham and Ladwig (1979) suggest that in situ and surface gasification may become a viable method to extract energy from coal and lignite beds in the Denver and Cheyenne Basins. Underground Coal Gasification (UCG) requires much less disturbance to landscape and allows for the conversion of methane to carbon dioxide, a less potent greenhouse gas. However, although there are pilot and demonstration plants elsewhere in the world, there are none in the United States. Therefore, this is a technology that is not yet mainstream and the environmental consequences would need to be evaluated. It is possible

that this technology could be advanced sufficiently to be commercially viable for the Denver Coal Region within the Plan Life of the Eastern Colorado Resource Management Plan. However, we conclude that its' potential is low since it would likely take many more years to develop this technology for U.S. standards and the suitability of the Laramie and Denver lignites in terms of gas quality/quantity has yet to be determined.

Lignite of the Denver Formation – As previously discussed, the literature estimates 10-15 billion short tons of lignite within 3,000 feet of the surface in the Denver Basin. It is not present in the Cheyenne Basin. Our calculations of "available" federal lignite are 433 Mtons and if we assume that the actual recoverable coal is 40-60% of available coal, the amount of lignite is reduced to 173-260 Mtons. The heating value of Denver lignite is relatively low (3,600-7,000 Btu/lb), and ash and moisture content are highly variable, but generally relatively high (8-45% and 22-40%, respectively) (Kirkham and Ladwig, 1979; Carroll 2011). However, sulfur content is low (0.2-0.6%), which is desirable from an emissions compliance standpoint. The variations in lignite quality are primarily due to the number and presence of clay (principally kaolinite) partings, which can comprise 5-30% of a given lignite bed. Although the kaolinite can negatively impact lignite quality, it can also be a source of alumina (i.e. averages 24% alumina in the kaolinite in this basin). Therefore, the presence of clay partings composed of kaolinite allows for the potential for dual-resource (lignite and alumina) recovery (Murray, 1980a; Speltz, 1976). The technological and economic feasibility of alumina extraction from kaolinite mined concurrently with lignite was beyond the scope of this report.

Although the lignite region of the Denver Basin is outside of the major urban centers of the Denver Metropolitan area, suburban and rural residential development and agriculture use dominate the region. The more rural and low density residential land use and relatively gentle terrain lends itself to potential surface mining and "rolling" reclamation, as is being successfully executed in the Nucla area that has a similar rural agrarian setting. In that area, immediate reclamation of the mined out areas in a rolling mine face has minimized visual and economic impacts to the irrigated farm lands. They also have the advantage of having a nearby fluidized bed combustion chamber powerplant within short (less than 10 miles) trucking distance of the Dakota Group coals. These "dirty" coals (i.e. high sulfur coals with many shale and sandstone partings) can be burned in this type of powerplant more efficiently than in a conventional plant. This "mine-mouth" powerplant situation, where little transportation costs are incurred, would be the only way to make this lignite resource economically viable. A similar scenario may be possible in the Denver lignite region with a specially designed powerplant and alumina processing facility. However, the demand for low heat value coal would need to increase significantly to make lignite mining in this region a viable option. Due to the abundance of high Btu and low sulfur coal in the Uinta, Green River and San Juan Coal Regions in Colorado, the development potential for lignite coal in the Denver Basin is considered low.

V. Raton Mesa Coal Region

Background

As seen in Figure 2, the Raton Mesa Coal Region is in the Raton Basin subprovince of the Great Plains Physiographic Province. The Raton Basin is an asymmetrical synclinal basin that is over 4,000 square miles that straddles the Colorado-New Mexico line, with the Colorado portion of the basin covers about 2,200 square miles (Landis, 1959; Flores and Bader, 1999). The following map (Fig. 18) shows the Raton Basin and its' major structural features.

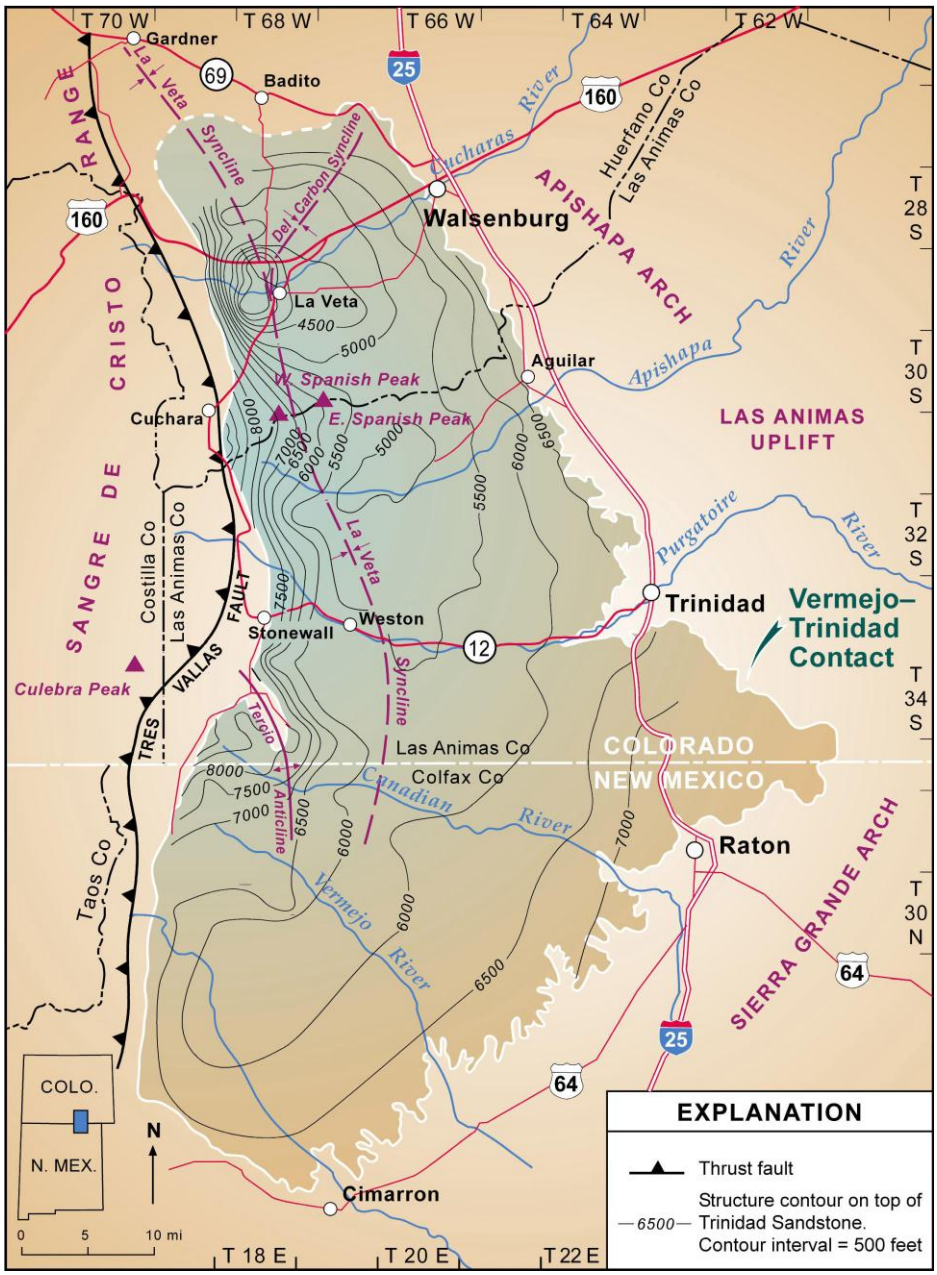


Figure 18. Regional map of the Raton Mesa Coal Region
(Carroll et al, 2007; modified from Hemborg, 1998)

The Raton Basin, formed during Laramide compression, is bounded on the west by the faulted Sangre de Cristo uplift (Culebra Range) and extends eastward to Trinidad and Walsenburg. The Wet Mountains are to the north and the Apishapa Arch, Las Animas Uplift and Sierra Grande Arch are located to the northeast to southeast, respectively (Fig. 18). The west side of the basin is determined by the west-dipping, Laramide-aged thrust and reverse fault system called the Tres Vallas Fault. As seen in Figure 18, the roughly north-south striking La Veta Syncline forms the axis of the basin and the steep topographic contours on the western portion of the basin indicate its' asymmetric shape. Local anticlines such as the Tercio Anticline located south of Stonewall and the Del Carbon Syncline northwest of Walsenburg, as well as numerous faults in the western portion of the basin, also deform the coal (Johnson, 1961). In contrast, on the east side of the Raton Basin, the Cretaceous and Tertiary coal-bearing strata are mostly flat-lying or gently dipping (less than 5°) to the west, and they are seldom disrupted by faults and folds (Carroll et al, 2007). The Raton Basin has more than 3,500 feet of Cretaceous strata and over 2,000 feet of Tertiary strata.

As seen on Figure 18, the main town in the region is Trinidad along the eastern margin of the basin and it has a population of roughly 9,000 people, which is half of what was present in 1930 during the peak of coal mining in the region (Carroll et al, 2007). The towns of Aguilar and Walsenburg are also located along the I-25 corridor on the eastern margin of the basin north-northwest of Trinidad. The towns of Weston and Stonewall are located near the west-central edge of the basin and La Veta is located near the northwest edge of the basin. Former mining towns of Cokedale and Starkville are west and southwest of Trinidad, respectively, in the Purgatoire River valley, which is the main drainage in the basin that flows east towards Trinidad (Fig. 18 and 19). Land ownership in the basin is primarily private (Fig. 1) with severed minerals. The large Maxwell Land Grant, which has both private surface and subsurface ownership, is located south of the Purgatoire River. Figure 19 below shows the areas with federal mineral estate, which is the focus of this study.

In the northwest corner of the Trinidad Coal Field along the western portion of the Huerfano/Las Animas county line, the Spanish Peak stocks intrude the coal-bearing strata. West Spanish Peak is 13,626 feet and the nearby East Spanish Peak is 12,683 feet (Hemborg, 1998). Late Tertiary (Miocene aged) igneous sills, dikes, flows, plugs and laccoliths radiate from the two stocks and are located across much of the Raton Mesa Coal Region. Hundreds of dikes, 2 to 60 feet thick radiate from the 23-27 Ma Spanish Peak stocks (Hemborg, 1998). These gabbroic to rhyolitic igneous rocks range from about 3 to 33 Ma (Wallace, 1996). The metamorphic effects of heat from the igneous intrusions locally increased the coal rank and even coked the coal (Carroll et al, 2007). The dikes typically caused only localized alteration of the coal beds, but the sills, which often intruded along coal beds, did cause alteration, assimilation, and local destruction of the coal beds (Flores and Bader, 1999). Hundreds of millions of tons of coal may have been destroyed by the sills, which can be up to 300 feet thick; however, the heat associated with the sills had the beneficial effect of locally increasing the rank of the coal to coke (Pillmore, 1969; Tremain, 1980).

The primary coal bearing formations are the Upper Cretaceous Vermejo and Upper Cretaceous to Paleocene Raton Formations, as shown on Figure 19. These formations are genetically similar to the Laramie Formation and Denver Formation in the Denver Coal Region. The Trinidad Sandstone conformably underlies the Vermejo Formation and forms the basal unit upon which the coal-bearing strata begin. The Trinidad Sandstone also forms a distinctive

marker bed (cliff or bench) on both the east and west sides of the basin due to its resistance to erosion. Figure 19 also shows areas of federal coal estate, historic mines, and the mined out areas mapped by Lewicki (2001).

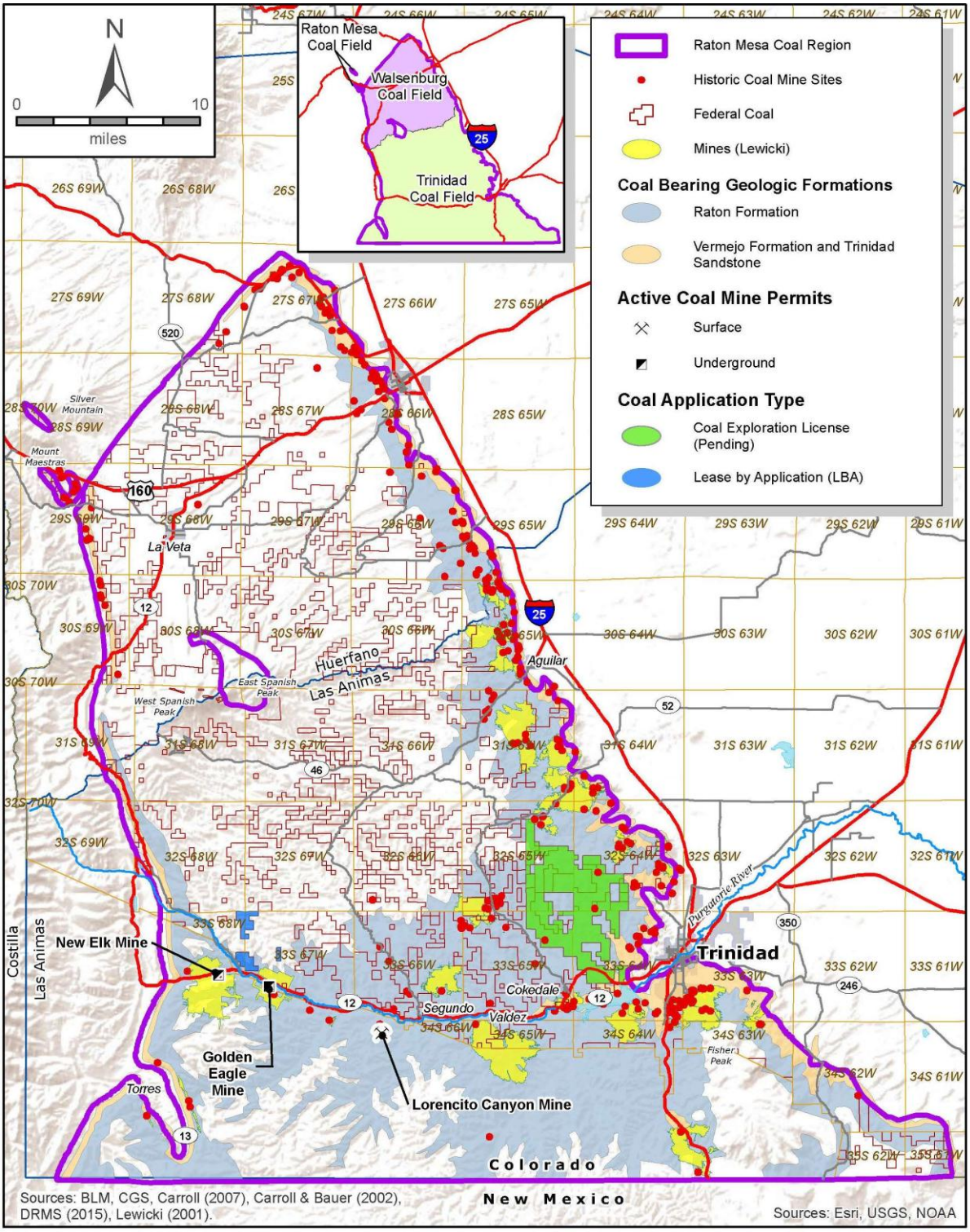


Figure 19. Coal-bearing Formations in the Raton Mesa Coal Region

Landis (1959) subdivided the Colorado part of the Raton Mesa Coal Region into the Walsenburg coal field and the Trinidad coal field. Coal mines within Huerfano County were included in the Walsenburg coal field which produced mostly bituminous coal and some subbituminous coal, while the mines in Las Animas County were included in the Trinidad coal field which produced bituminous coal, mostly high quality coking coal, which is still generally in demand as metallurgical coal (Carroll, 2006). Most mines in the Walsenburg coal field were located at the coal outcrop along the margins of the Raton Basin in the vicinity of the towns of Walsenburg and La Veta. Most coal produced in the Walsenburg coal field came from the Vermejo Formation, while mines in the Trinidad coal field were more widespread and produced from both the Vermejo and Raton Formations.

Stratigraphy

The coal-bearing rocks of the Raton Basin are the Upper Cretaceous Vermejo Formation and the Upper Cretaceous to Paleocene Raton Formation. The Vermejo Formation typically contains more coal beds than the Raton Formation, and they are thicker and laterally more extensive than the Raton coals (Johnson, 1961). Maximum thickness of coal beds in both formations is about 14 feet (Boreck and Murray, 1979). Much of the mined coal has come from relatively shallow depths, but coal beds are over 3,000 feet deep along the axis of the basin and in the troughs of some synclines (Johnson, 1961). The Vermejo coals are over 500 feet deep across much of the entire region (Carroll et al, 2007). The following geologic time scale (Fig. 20) shows the coal-bearing formations and those that are common in the region. The Raton and Vermejo Formations will be described further below under separate headings.

AGE		FORMATION	ROCK UNITS	THICKNESS IN FEET
Tertiary	Eocene	Cuchara	Arkosic Sandstone and conglomerate	200+
	Paleocene	Poison Canyon	Sandstone-Course grained to conglomeratic beds 13-50 ft thick.	2,100-2,500
		Raton	**Upper Coal Zone**- thick coal beds, very-fine grained sandstone, siltstone, and mudstone.	600-1,100
			Barren Series- Fine-grained sandstone with minor mudstone and siltstone.	180-600
Mesozoic	Upper Cretaceous		**Lower Coal Zone**- Thin and discontinuous coal beds with sandstone, carbonaceous shale, and siltstone. Up to 90 ft thick Raton Conglomerate at base is only present locally.	100-250
		Vermejo	Barren Interval- Thick sandstone, siltstone, and mudstone. Locally present throughout study area.	250-800
			Sandstone and mudstone with discontinuous **coal beds**. Thick basal coal beds split but are lenticular.	120-220
		Trinidad Sandstone	Sandstone-Fine to medium grained, O*phiomorpha* casts.	150-550
		Pierre Shale	Shale-silty at top, some limestone concretions.	1,500-2,300

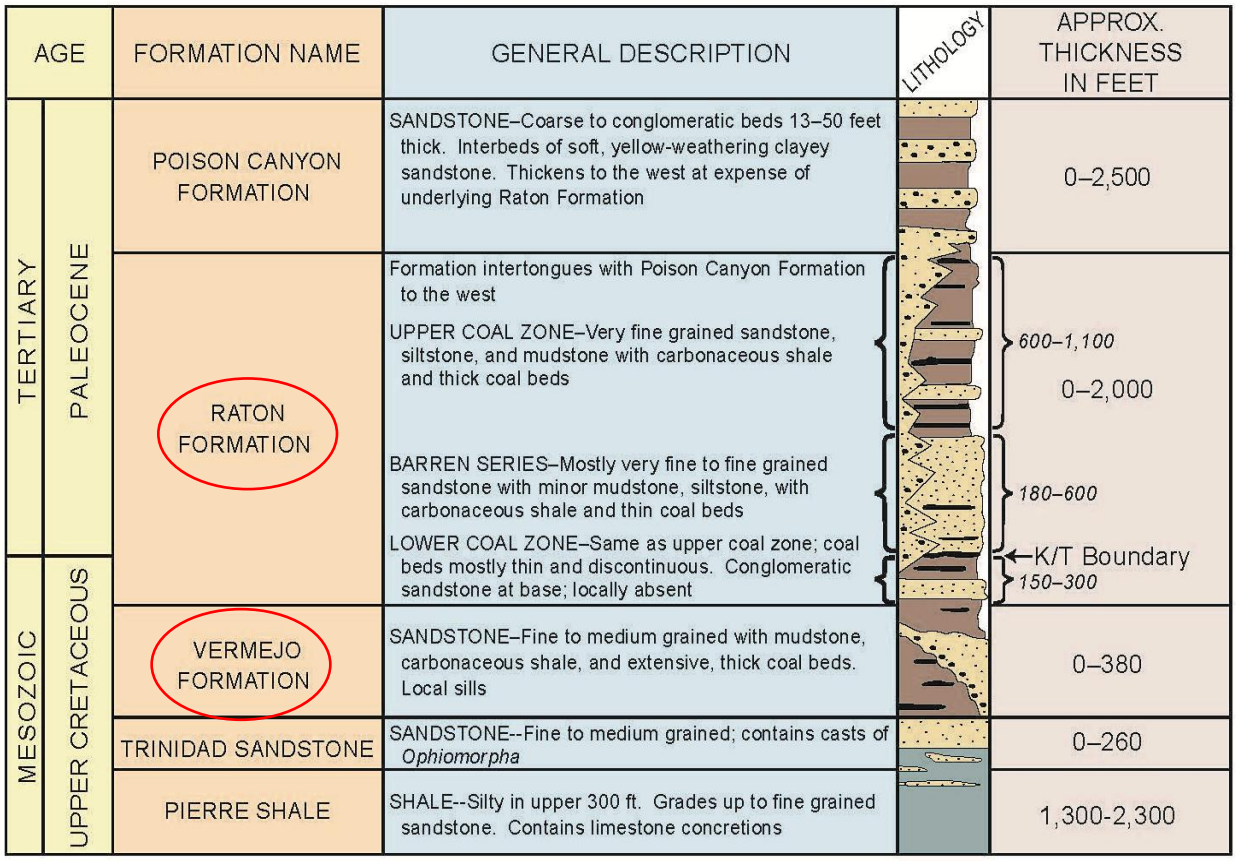
Figure 20. Stratigraphy of the Raton Mesa Coal Region
(Modified by Carroll 2014 from Flores and Bader 1999)

The Trinidad Sandstone (Upper Cretaceous) is at the base of the coal-bearing section and it is a marker bed both stratigraphically in borehole logs and in outcrop, as it resists erosion and forms prominent cliffs or ledges in the central and eastern part of the Raton Basin. It is a light gray, slightly arkosic, fine- to medium-grained sandstone that forms a single, continuous stratum over the entire extent of the Trinidad Coal Field (Carroll et al, 2007). The Trinidad Sandstone thickens westward from 45 feet at Trinidad to 260 feet at Stonewall, where it forms a

prominent hogback (USGS, 1974). Figure 21 offers a graphic depiction of the stratigraphic column of the Raton Basin, including the sedimentary rocks of Cretaceous and Tertiary age.

Vermejo Formation

The Vermejo Formation as both slopes and ledges on the margins of the Raton Basin where it is exposed at the surface and consists of buff, gray and gray-green sandstone beds, with gray to black silty shale, black carbonaceous shale, and black bituminous coal beds that are thin to massive, often lenticular and parallel laminated (Carroll et al, 2007). The Vermejo was deposited in a regressive marginal-marine (coastal plain) environment that rests conformably on the Trinidad Sandstone (Khalsa and Ladwig, 1981). It was formed 69-71 million years ago in alluvial flood basins and extensive mires or coal swamps (Carroll et al, 2007). In the Raton Basin, the thickness of the Vermejo ranges from about 370 to 1,020 feet, with the coal-bearing lower portion of the formation being 120-220 feet thick (Flores and Bader 1999). Tremain (1980) reports Vermejo coals occur in beds up to 14 feet thick and the total coal thickness of the formation is up to 30 feet. There are thick basal coal seams directly overlying the Trinidad Sandstone and Johnson (1961) describes the Vermejo as having 3 to 14 coal beds more than 14-inches thick. Many coal seam names have been used for the Vermejo coal seams such as the Sopris, Cameron, Cokedale, Robinson, Robinson No. 2, Alamo, Starkville, Walsen, and Berwind coal beds. Figure 21 shows the Vermejo Formation in the stratigraphic column.



Adapted from Flores and Bader (1999), Tyler and others (1991), and Tremain (1980).

Figure 21. Stratigraphic Column of Coal Beds of the Raton and Vermejo Formations
Topper (2011)

According to Carroll et al (2007), the Vermejo contains 5 major coal zones that average beds 3-6 feet thick. Vermejo coals are usually thicker than the Raton coals, but they have thick overburden for much of the basin other than at the margins where the formation outcrops.

Raton Formation

The Raton Formation, as depicted on Figure 21, is close to 2,000 feet thick at its maximum and is the bedrock for much of the region, consisting of coal-bearing fine-grained sandstone, siltstone and shale, mostly of freshwater origin with a lower and an upper coal zone separated by a barren sandstone and shaly zone (Flores and Bader, 1999). Most mineable Raton coal is in the upper coal zone, where some lenticular coal beds are up to 12 feet thick. The Raton Formation was formed 64-69 million years ago in alluvial flood basins and extensive coal swamps in a broad coastal plain (Carroll et al, 2007). In the Raton Basin, as shown in Figure 21, the thickness of the Raton ranges from about 880 to 1,950 feet, with the coal-bearing lower coal zone being 100-250 feet thick and the upper coal zone being 600-1,100 feet thick (Flores and Bader, 1999). The Cretaceous-Tertiary (K-T) boundary is located at the top of the lower coal zone and it is preserved as a thin claystone layer with elevated iridium content seen in an outcrop at Trinidad Lake State Park (Carroll et al, 2007). The Raton Formation contains numerous coal beds, often referred to as coal zones, but most mines have produced from six main coal zones identified by Carroll et al (2007) that are sufficiently thick and laterally extensive: the Ciruela, Boncarbo, Primero, Allen/Frederick/ Delagua, Bear Canyon, and Cass. These zones are described further in the Coal Availability section of our analysis for this coal region.

Coal Quality and Rank

The Raton Mesa Coal Region generally contains high quality (high energy and low sulfur and ash), bituminous steam coal and coking coal and it is believed to contain the largest reserves of metallurgical grade coal in the Rocky Mountains (Carroll et al, 2007). Tables 2 and 3 show ranges in coal quality and rank for Vermejo and Raton Formation coals and coal quality compared with the other three coal regions in the Planning Area. Table 9 (below) summarizes coal quality data for the Raton Mesa Coal Region. In general, coal rank increases from north to south in the Raton Basin and these coals are higher in coal rank than those in the Denver and South Park Coal Regions, but similar to those in the Cañon City Coal Region. However, there is no coking or metallurgical coal in the Cañon City Coal Region. Carroll (2006) evaluated 861 coal samples from Raton Mesa and found an average of 16.1% ash, 0.7% sulfur, and 12,541 Btu/lb.

Regarding coal rank in Huerfano County (Walsenburg Coal Field, Fig. 19), also shown in Table 9, both the Vermejo and Raton coals typically rank as high volatile B and C (hvB, hvC) bituminous coal and some subbituminous coal and are non-agglomerating and not suitable for coking (Tremain et al., 1996; Carroll, 2006; Johnson, 1961). In Las Animas County (Trinidad Coal Field, Fig. 19), the coal rank is high volatile A and B (hvA, hvB) bituminous coal, and the coal is nonagglomerating and typically suitable for coking (Tremain et al., 1996; Carroll, 2006; Johnson, 1961). Locally, dikes and sills have replaced or destroyed coal beds in the Walsenburg and Trinidad coal fields, thus altering coal quality in otherwise high quality coal seams.

Coal Region	Coal Field	Formation and Coal Rank	Moisture (%)	Volatile matter (%)	Ash (%)	Sulfur (%)	Mercury (ppm)*	Heating Value (Btu/lb)
Raton Mesa	Trinidad	Raton Fm (11 beds) hvA, hvB bitum mostly coking	1.8-4.5 1.0-5.8+	34.4-40.3 28.6-38.8+	5.3-16.4 7.1-26.3+	0.4-1.1 .58** 0.4-0.8+	.03-.42* .03-.04**	10,169-13,871 10,310-13,880+
Raton Mesa	Trinidad	Vermejo Fm (14 beds) hvA, hvB bitum mostly coking	1.6-7.5 1.0-7.9+	32.2-39.1 27.0-40.5+	7.7-21.8 7.5-26.7+	0.5-1.0 0.5-1.0+	.02-.07*	11,430-13,510 10,640-13,890+
Raton Mesa	Walsenburg	Raton Fm hvB, hvC bitum & subbitum	2.5-4.2	33.4-41.1*	5.3-13.5	0.4-1.0	.09*	12,660-13,340
Raton Mesa	Walsenburg	Vermejo Fm hvB, hvC bitum & subbitum	5.3-10.2	36.4-38.0	7.2-14.4	0.4-1.3	.03-.07*	11,050-12,880

NA = Not Available

Table 9. Coal Quality Data for Raton Mesa Coal Region
(Carroll 2011; Khalsa & Ladwig 1981*; Hatch et al 2006**; Speltz 1976^{+})

The coal in the Trinidad Coal Field is typically brittle and friable with bright luster and impurities mostly consist of pyrite and elemental sulfur (USGS, 1974). Some data on heavy metals, including mercury, are available for the Raton Mesa Coal Region. According to Khalsa and Ladwig (1981), 33 coal samples from mines and exploratory core samples of various formations in the two coal fields indicate the following typical ranges: 0.3 to 5.5 ppm arsenic, <0.04 to 0.90 ppm cadmium, 0.02 to 0.42 ppm mercury, <0.1 to 4.9 ppm selenium, 0.2 to 5.3 ppm uranium, <1.1 to 23 ppm lead, and 1.0 to 88 ppm zinc. According to work by Hatch and others (2006), a sample from the M seam at the Lorencito Canyon Mine contained 0.04 parts per million (ppm) of mercury (dry basis) and a sample from the N-A seam at this mine contained 0.03 ppm of mercury. These samples also had the same mercury content on an as-received, remnant moisture basis. Tewalt et al. (2001) provided summary data for mercury in coal in the Raton Mesa Coal Region, revealing a median value of 0.05 ppm mercury and a mean value of 0.09 ppm based on 40 analyses of as-received whole coal samples. They do not describe details about the sample locations or sampled coal beds.

As pointed out by Goolsby (1979), although the sulfur content of Raton Basin coal is within the bounds of a "premium" grade designation of coal, the ash content falls within a "marginal" grade. However, Goolsby (1979) states that coal preparation (washing) significantly lowers ash content and upgrades the coal to a premium grade coking coal.

Historic Mining

Although coal was used by the early settlers in the mid-1800s, commercial mining didn't began until 1873 and then in earnest in 1884 when CF&I opened multiple mines across the region (Pillmore, 1969). About 387 mines, shown on Figure 19, have worked coal beds in the Raton and Vermejo Formations in the RGFO portion of the Raton Mesa Coal Region, with peak historic production of 71 Mtons of Raton coal from 1911 to 1920 and strong production continuing into the 1950s associated with steel production in Pueblo (Flores and Bader, 1999; Boreck and Murray, 1979; Tremain et al., 1996; Carroll and Bauer, 2002). According to the historic coal mines database by Carroll and Bauer (2002), some mines were small independent mines that

lasted a few years and others were large corporate mines that operated for 20 to 50 years. When the Golden Eagle Mine closed in 1995, it ended 125 years of continuous coal mining activity in the district, a testament to the massive coal reserves in the region and the demand for coking coal (Hemborg, 1998). Mines in the Walsenburg Field were concentrated primarily on the coal outcrops at the eastern, northern and western edges of the Raton Basin via slope and drift mines (Carroll and Bauer, 2002). Flores and Bader (1999) also recognized the Walsenburg and La Veta mining districts within the Walsenburg field, which primarily produced steam coal. Most mines in this field access the coal via slope or drift entrances at the outcrops.

Mines in the Trinidad Field, which produced primarily coking coal, were also concentrated at the coal outcrops along the eastern margin of the basin, but mining also extended west along the Purgatoire River valley and into adjacent tributary canyons (Fig. 19 and 22). Flores and Bader (1999) recognizes 7 historic mining districts in the Trinidad Coal Field, with the Purgatoire district being the largest and centered in the "heart" of the field, with the Aguilar and Trinidad districts along the northeastern and eastern margin of the basin, the Allen district on the west edge of the field, and the Tercio, Morley and Yankee districts in the southwest to southeast portions of the field. Historic mines in the Trinidad Field were typically larger underground mines accessed via slope or drift mine entrances. Some of the mines also accessed coal beds via shafts and there were a few surface strip mines in both fields, most of which operated in the 1970s-1980s. The areal extent of historic mines of the Trinidad Coal Field are shown on Figure 22 prepared by Carroll et al (2007) based on detailed surveying and mine mapping by Lewicki (2001). Names of the larger mines are indicated.

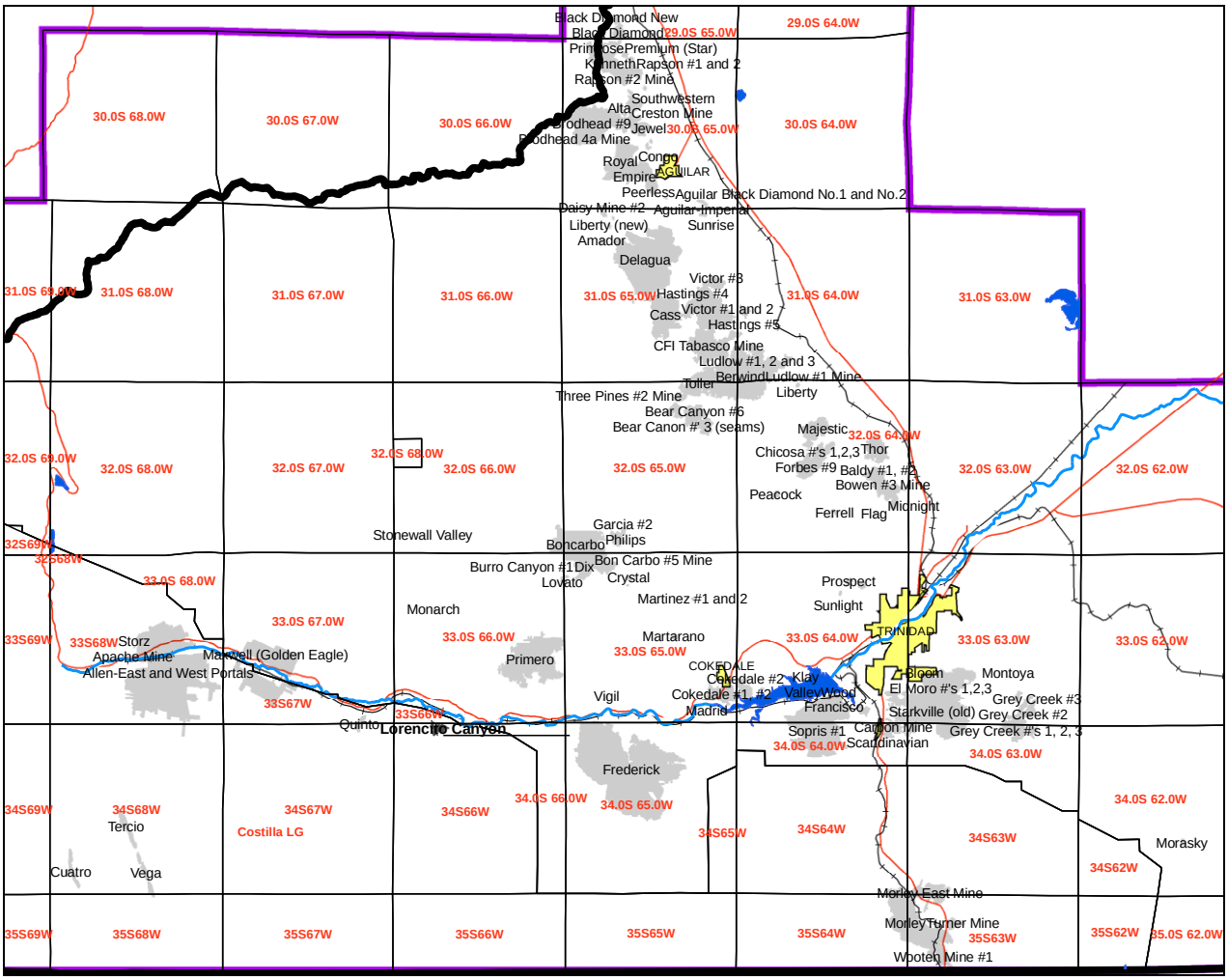


Figure 22. Historic coal mines in Las Animas County of Trinidad Coal Field
(Lewicki, 2001; Carroll et al, 2007)

Farming, ranching and coal mining have all driven the economy of the region and a great deal of the infrastructure development such as roads, utilities, railroads, and towns like Cokedale, owe their existence to coal mining. The following photograph (Fig. 23) shows the relatively large scale of mining in the Trinidad Coal Field during a period of intensive coal development.

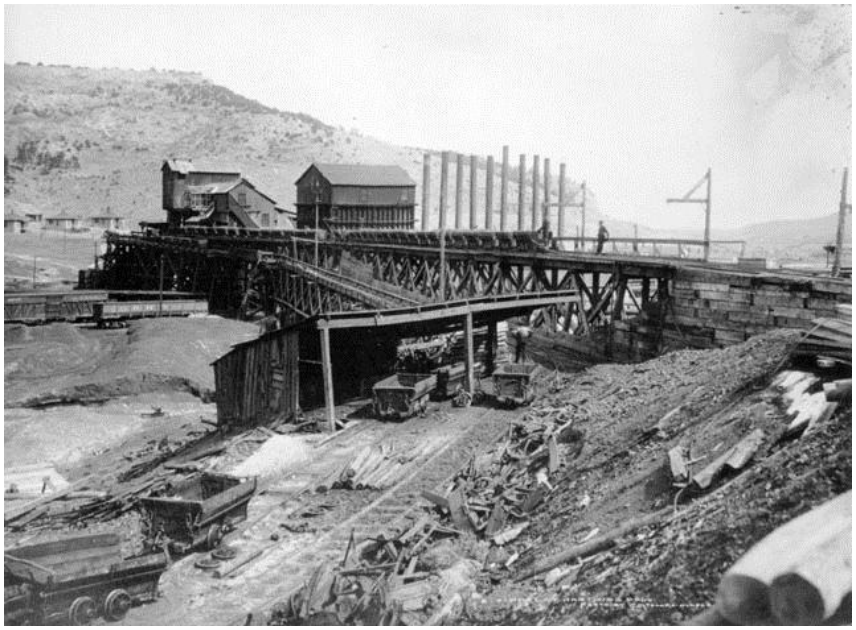


Figure 23. Forbes Coal Mine and Tipple in the Trinidad Coal Field (1913)
(Colorado Historical Society photograph from Carroll et al, 2007)

Historically, the Trinidad coal field has yielded the highest quality coking coal in the western United States (USGS, 1974; Goolsby et al., 1979). In the 1970's, for example, coke from the southern part of the Trinidad coal field along the Purgatoire River valley was used by steel mills of CF&I in Pueblo, Colorado and the Kaiser Steel Corp. in Fontana, California (USGS, 1974). Coking coal also was produced primarily from the Trinidad Field, but there was also some coking coal produced from a few mines in the southern part of the Walsenburg Coal Field. Some coal beds have been converted to natural coke by the intrusion of igneous activity, while other coal beds have been completely replaced by igneous sills (Flores and Bader, 1999). Coke ovens at Cokedale, El Moro, Segundo, Sopris, Tercio and other areas in the coal region were used historically to drive off volatiles from the bituminous coal to produce coke, a higher grade product (Goolsby, 1979). Coke is one of the three essential ingredients, along with iron ore and limestone, in the manufacturing of iron. Coke provides the heat that melts the ore, it forms carbon monoxide that reduces the iron-bearing ore to metallic iron, and it provides a porous but strong physical structure that supports the chemical reactions and allows gases to circulate (Goolsby, 1979). Coke is not only used in steel manufacturing but also in other metallurgical processes such as sintering, pelletizing, zinc retort-smelting, and other blast furnace smelting (Goolsby, 1979). Demand for coking coal for steel production in nearby Pueblo fueled the coal industry in the Trinidad Coal Field for many years. This high quality coking coal of the Trinidad coal field is still sought after by national and international markets.

Historic Production

According to Carroll (2006) about 264 Mtons of coal has been mined in the Raton Mesa Coal Region and, until the 1990s, this area historically had been the most productive coal region in Colorado. However, mining in areas outside the RGFO (mainly in the Uinta and Green River Coal Regions of Colorado) since the 1990s has resulted in cumulative production totals that now

exceed the historic production in the Raton Mesa Coal Region. The following Table 10 summarizes the production from the larger and more recent mines in the Trinidad Coal Field.

Coal Mine	Operator	Years of Production	Tonnage	Seam Name	Btu (as-received)
Lorencito Canyon	Lorencito Coal (B. Addington)	2001-2002	167,922	M, Na, O, Q, R beds surface mineable	13,000
Golden Eagle	KN Energy	1984-1995	9,288,471	Primero	11,400
RimRock	RimRock Coal Co.	1992-1993	7,467	Engleville	unk
Raton Creek	Unk	1988-1990	147,780	Lower Starkville	unk
Trinidad Basin Strip	Trinidad Basin Mining Co.	1981-1984	234,460	Delagua	unk
Animas	Sundance Coal Co.	1983-1984	137,115	Up, Lwr Starkville	HV Bit b
Helen	Sundance Coal Co.	1983-1984	37,830	Up, Lwr Starkville	HV Bit b
Maxwell	CF&I Steel	1977-1982	600,656	Apache	11,400
Allen	CF&I Steel	1951-1982	18,152,789	Allen	11,260
Delagua Strip	Delagua Coal Co.	1977-1980	141,356	Delagua, Cass	Unk
Baldy Cyn Strip	Unk	1979	2,587	unk	Unk
Healy Strip	Horner Coal Co.	1976-1978	127,042	Delagua	unk
Jewell Strip	Unk	1975-1977	17,929	Rapson, Up. Robinson	13,000
Martinez	Al Martinez	1924-1971	5,738	Martinez	12,800
Prosperity #1, #2	George Pantazes	1950-1971	12,376	Gem	12,700
Montoya #3	Ben and Sam Montoya,	1961-1970	2,385	Engle-Starkville	unk
Bisulco	Bisulco Mine Partners	1953-1970	4,575	Robinson	12,656

Table 10. Trinidad Coal Field Mines Operated 1924-2002
(Carroll and Bauer, 2002)

According to CDRMS (2015) records, of the 264 Mtons of coal mined in the Raton Mesa Coal Region, 188 Mtons (71%) of coal was mined in the Trinidad Coal Field and 76 Mtons (29%) of coal was mined in the Walsenburg Coal Field. As mentioned, once the Golden Eagle Mine closed in 1995, there was a hiatus of mining until the Lorencito Canyon contour strip mine operated from 2001-2002, producing 0.168 Mtons of coal. According to Ron Thompson, Mining Engineer with the New Elk Mine, after the Lorencito Canyon Mine closed, the rail line that extended to both the Lorencito Canyon and New Elk Mines was removed (personal communication, October 3, 2014).

There was another hiatus in mining until 2011, when the New Elk Mine opened in the old Allen Mine. The New Elk Mine produced 0.367 Mtons of coal in 2011, 2012, and 2014 (CDRMS, 2015). Production stopped in October 2014 and is in a status of "Temporary Cessation," according to state records. Mr. Thompson indicated that most of the coal had been trucked about 110 miles to a concrete plant in Pueblo due to low prices for metallurgical coal that prohibited longer distance or rail transport (personal communication, October 3, 2014).

When the mining district closed in 1995 with the shuttering of the Golden Eagle Mine, Hemborg (1998) pointed out that this closure was not the result of resource depletion; rather, the district could not compete economically with the lower unit operating costs of other mines in the Rocky Mountain coal regions. Large surface mines with thicker coal seams in Wyoming and northern and western Colorado produced larger volumes of high quality, super compliant (low sulfur) coal with less overhead than the underground mines of the Raton Basin with thinner beds. Also, the domestic demand for metallurgical coal declined as steel production went overseas.

Coalbed Methane Operations

The Raton Mesa Coal Region is one of the major coalbed methane producing areas in the United States. A CGS publication by Tremain (1980) of the coalbed methane potential in the Raton Mesa Coal Region concluded that there is a roughly 180 square mile high potential area within the basin that is estimated to have 1.56 trillion cubic feet of gas in Vermejo coal beds. The Tremain report suggests the Vermejo coals have up to 514 cf of gas per ton of coal that is less than 2,000 feet deep. However, the gassiest coal is medium-volatile rank from greater than 1,000 feet, which generally targets the Vermejo coals. Tremain (1980) concludes that the Raton Formation coals have not been buried deep enough to allow for the genesis of volatiles, so Raton coals are not considered the source coal for the CBM. Since the Vermejo underlies the Raton, gas wells would need to penetrate the entire Raton Formation to reach the Vermejo CBM; therefore, CBM extraction in the Raton Mesa Coal Region is relevant to future development of coal resources in the area due to the sheer numbers of wells drilled. The following Figure 24 shows the gas wells currently drilled in the Raton Basin. In 2007 there were 1,624 gas wells (red dots) and in 2014 there were 4,024 wells (red and black dots). These wells cover a large part of the Trinidad Coal Field and attests to the productivity of the gas field.

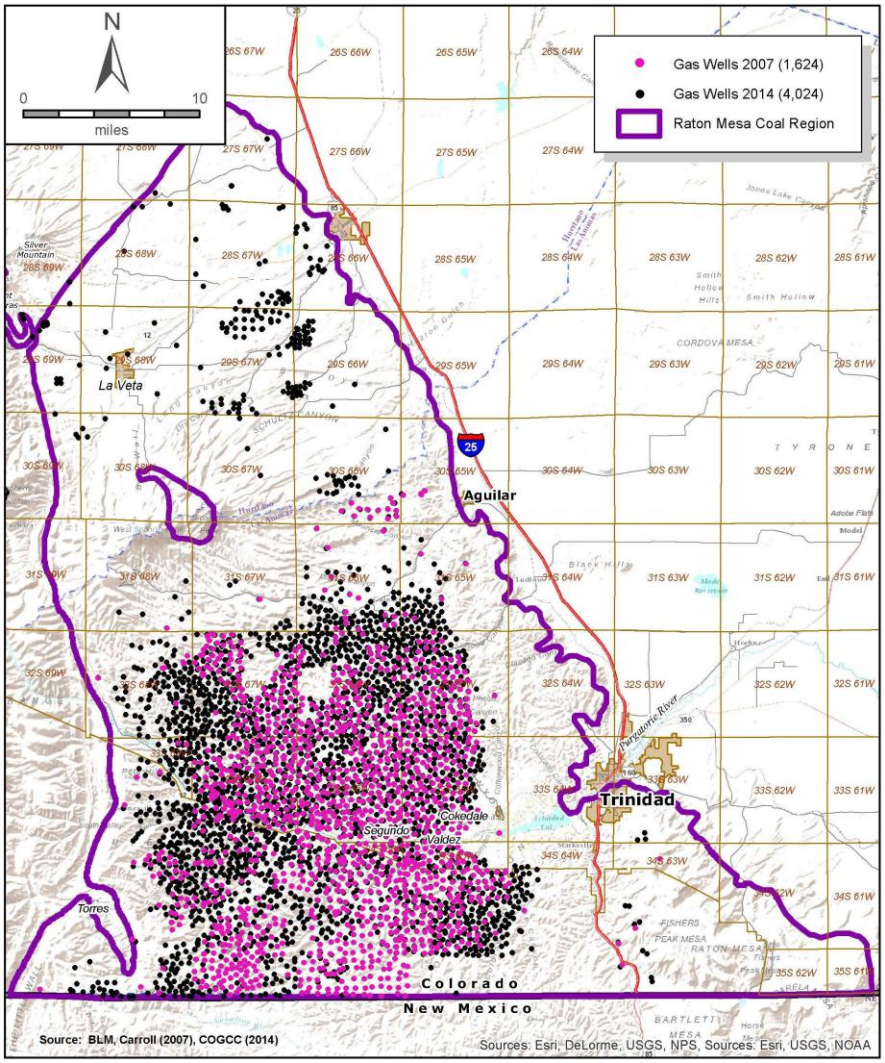


Figure 24. Gas Wells in the Raton Mesa Coal Region

Regarding the impact of CBM wells on commercial coal mining, we interviewed several coal industry representatives. Ron Thompson, Mining Engineer with the New Elk Mine and long-time coal expert in the Raton Mesa Coal Region, indicated that Cline Mining Corporation (owner of New Elk Mine) had hired Raven Rigs to evaluate the value of the gas wells in the federal coal land north of the mine (shown as dark blue areas on Fig. 19), to determine the feasibility of coal mining in that area (personal communication, December 16, 2014). He said that most of the gas wells have greater production in the first few years of operation and are expected to have a lifespan of 15 to 20 more years. The required setback from a gas well for coal mining operations is a 150-foot radius; there is a 300-foot diameter zone within which no mining can occur "in the vicinity of oil and gas wells that penetrate coalbeds or any underground area of a coal mine" (Federal Regulation 30 CFR §75.1700). Mr. Thompson indicated that the company's approach would be to purchase the remaining value on the wells, fill and cap them with cement, and then simply cut out and mine through the capped wells when encountered with their longwall miner. If a continuous miner is used in that portion of the mine, then the mine plan would be set up to avoid the gas wells by adhering to the minimum setback.

Similarly, interviews with representatives of the Texas & Oklahoma Coal Company, Dominic Hill and Mark Sykes, who are seeking the Left Fork exploration license (shown as green area on Fig. 19), would mine using the room and pillar method and avoid gas wells with a 200 feet buffer around them (personal communication, December 16, 2014). The Left Fork area of proposed exploration has fewer gas wells, which are mostly concentrated on the west side of the proposed study area, so the CMB wells are less of an issue for their project. However, additional gas drilling in the area may occur in the future, which would require flexible mining methods and adaptable mine plan.

Current Mining Operations and Production

In the past 30 years, coal mining in the Raton Mesa Coal Region has been concentrated in Lorencito Canyon near Segundo, the Animas and Raton Creek areas south of Trinidad, and the Maxwell and Allen Mine areas (Fig. 19). The New Elk Mine, formerly called the Allen Mine, is located on the south side of the Purgatoire River between the towns of Weston and Stonewall. Recently, only the New Elk Mine (Permit No. C1981012) has operated, but activities have been suspended as of December 2014 due to bankruptcy issues with Cline Mining Corporation which owns the New Elk Coal Company (*Denver Post*, December 15, 2014). According to the online DRMS database, the status of the New Elk Mine is "Temporary Cessation." Historically, this underground slope mine was a major coal producer. The mine resumed coal production in May 2011 and has produced 367,214 tons of coal from 2011-2014 out of the Raton Formation. The New Elk Coal Company also holds an exploration permit (No. X201123201) with "Inactive" status with the CDRMS. This "New Elk Mine Exploration Program" includes land adjacent to federal coal parcels north of the existing mine (Fig. 19).

According to the *Denver Post* article about the Cline Mining Corporation bankruptcy (December 15, 2014), the New Elk Mine woes are in large part due to falling global demand of metallurgical coal due to the slowing growth in China and a glut of coal supply. The article went on to say that the projections indicate a 6-year low of $117/metric ton in 2015 for metallurgical coal from a high of $330 in 2011. Additionally, overall coal production in Colorado hit a 20-year low in 2013, primarily due to the massive conversion of coal-fired plants to natural gas, which is

readily available and has lower carbon emissions. In general, coal demand is down domestically and internationally for both metallurgical and steam coal.

The Lorencito Canyon Mine (Permit No. C1996084), located on the south side of the Purgatoire River between the towns of Valdez and Weston, was a contour strip mine that removed coal from the Ciruela coal zone. In the two years it operated (2001-2002), this mine produced 168,124 tons of coal that was processed at the New Elk Mine site. Coal from this mine was processed at the New Elk Mine site and it is in the final stages of reclamation (personal communication, Ron Thompson, October 3, 2014) and it has a status of "Terminated" according to the CDRMS (2015) records.

Restrictions to Mining Operations in Region

The unsuitability criteria for coal mining listed in federal regulations (43 CFR §3461) as well the land use and technological restrictions presented in the "Restrictions" section of this report for the Denver Coal Region generally also apply to the Raton Mesa Coal Region. The restrictions relevant to the Trinidad Coal Field are discussed in great detail in the Coal Availability study of this field by Carroll et al (2007).

Previous Estimates of Coal Resources

Due to the continued value of metallurgical coal and the high quality coking coal produced for roughly 140 years in the Raton Mesa Coal Region, this region has been studied extensively to estimate coal resources. The first study by the USGS in this basin was started in 1948 and it was based on coal outcrops and measured sections, but no subsurface data beyond the coal mines was available at that time. Landis (1959) published this data and the original coal resource was calculated at 12.674 billion tons (Btons) of bituminous coal with less than 3,000 feet of overburden for 1,044 square miles of Las Animas County. Carroll (2006) used the original coal resource estimate by Landis to conclude that, with about 264 Mtons of coal mined out, there is an estimated remaining coal resource of 12.410 Btons. Johnson (1961) estimated the original coal reserves on a coal zone basis for both Las Animas and Huerfano counties to be about 16.367 Btons. He estimated recoverable reserves at 8.184 Btons, based on economic recoverability at the time. Jurich (1984) reported that the USGS estimates in-place coal reserves for mineable coalbeds (i.e. at least 14 inches thick seams with less than 3,000 feet overburden) to be 17 Btons. It should be noted that all reserves reported by the USGS and U.S. Bureau of Mines were for underground mines, as this was the historic mining method for the Raton Basin. For strippable coal, Speltz (1976) estimates 128.05 Mtons of strippable coal in 23,721 acres in the Trinidad Field, mostly along tributary canyons north of the Purgatoire River, and 8.3 Mtons of strippable coal in 1,541 acres of the Walsenburg Field.

Renewed interest in coal in the 1970's, especially for high quality bituminous coal of metallurgical grade, resulted in new studies and mapping by private companies and the federal government. For example, Mobil Oil held a Preference Right Lease Area (PRLA) with the BLM and the U.S. Geological Survey focused on the Raton Basin (USGS, 1974; Weston and Madrid USGS Quadrangles, 1979; Mountain Minerals, 1980). The Mountain Minerals study estimates a reserve base sufficient to support underground mining of about 1 Mtons per year. Amuedo and Bryson (1977) estimated the coal resources of the Raton Formation alone, based on 4-foot thick

beds, are about 5 Btons. The Mobil study determined that there were reserves of 29 million short tons of net coal present in the Boncarbo and Primero beds north of the Cokedale area. The 1979 USGS study was based on field mapping, mine data, and four coalbed methane (CBM) wells. This report indicated three commercially viable coal seams (Primero, Boncarbo, Ciruela) and the potential for methane production and this data became the basis for the current CBM boom (Carroll et al 2007). Using the coking coal classification system, Goolsby (1980) estimated the Raton Basin contains a reserve of at least 1.8 Btons of marginal grade (1.1-1.8% sulfur; 8.1-12% ash) high-volatile A bituminous coking coal and at least 216 Mtons of marginal grade high-volatile B bituminous coking coal. Flores and Bader (1999) conclude there is an estimated 2 Btons of in-place coking coal reserve base in the Raton Basin.

Available Coal Resources in the Trinidad Coal Field

Chris Carroll, coal expert formerly with the Colorado Geological Survey, performed an extensive study of the Raton and Vermejo Formations in the Trinidad Coal Field as part of a cooperative Coal Availability Recoverability Studies project between the CGS and the USGS Energy Resources Team (Carroll et al 2007). The purpose of the CGS/USGS study was to determine coal available for mining in an essentially dormant mining province using new data available from the recent coalbed methane drilling in the basin. The Walsenburg Coal Field was not included in their study due to the greater potential quantity and coking quality of coal known in the Trinidad Coal Field.

A draft of the Carroll et al report was circulated in 2007, but a final report was not officially published. This extensive study involved correlation of coal seams across the coal field based on the analysis of hundreds of coalbed methane wells to determine the coal zones with the most potential. Carroll and his team determined that there are seven coal zones, each composed of numerous coal seams, which contain measurable and potentially minable coal. Figure 25 shows the names of various common coal seams in the region and the names of the coal zones identified by Carroll et al (2007). The zones are as follows, in order from top to bottom, the upper 6 coal zones are in the Raton Formation and the lowest zone is in the Vermejo Formation:

1. **Ciruela** – This zone is the highest zone, 80-240 feet above the Boncarbo zone.
2. **Boncarbo** – Consistent coal zone that has been mined successfully.
3. **Primero** – Carroll et al (2007) considers this the "single-most important mineable coal remaining in the Trinidad Coal Field."
4. **Allen-Delagua-Frederick** – The Allen and Frederick Mines were the largest producing coal mines in the Trinidad Coal Field.
5. **Bear Canyon** – Contains the mineable Bear Canyon #6 and Rigby coal beds.
6. **Cass** – Many historic mines effectively used this zone.
7. **Walsen** – This zone has up to 13 local coal bed splits in the Trinidad Field and is regarded by Carroll et al (2007) was the best mineable coal bed in the Vermejo.

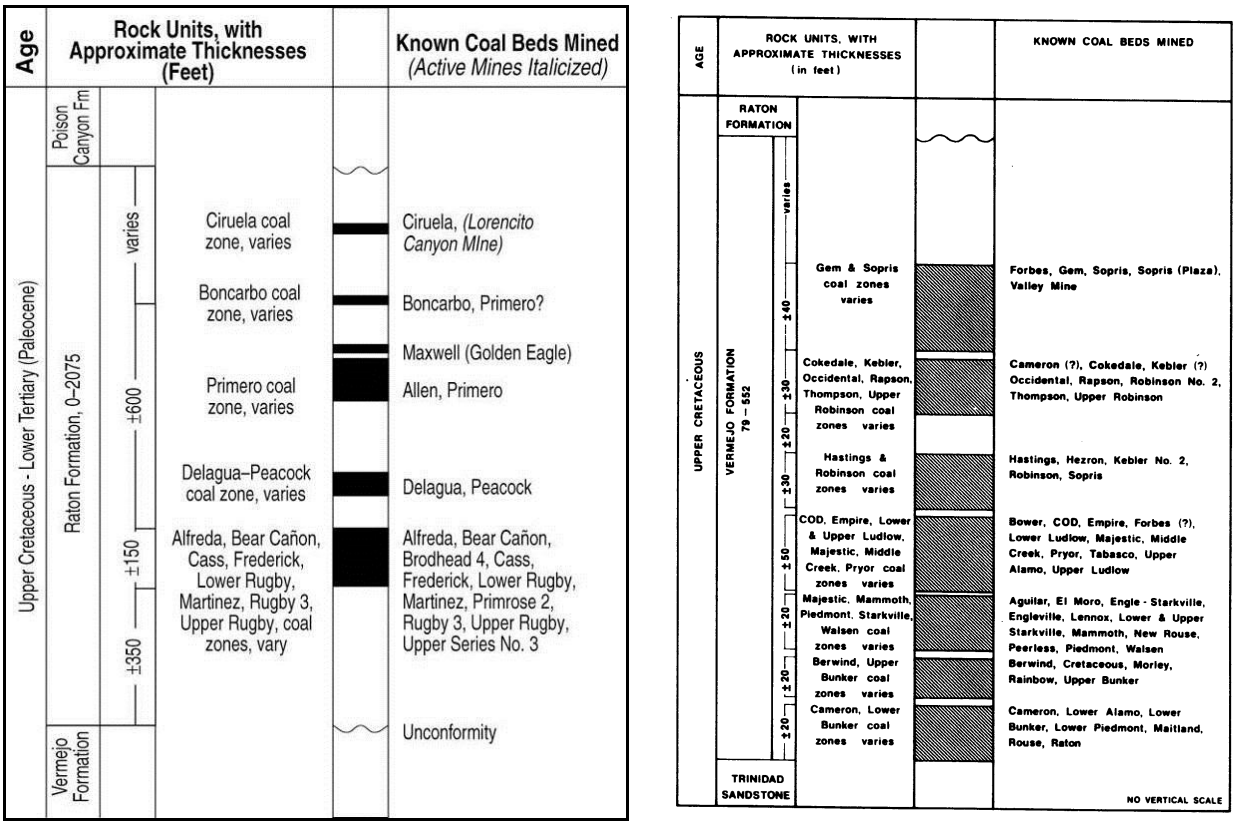


Figure 25. Mineable coal beds in the Raton Mesa Coal Region
(From Carroll et al, 2007; Tremain and others, 1991; Boreck and Murray, 1979)

Carroll et al (2007) used gas well logs to correlate coal bed thickness laterally to other borehole data and created resource reliability polygons for measured (¼ mile radius), indicated (3/4 mile radius), and inferred (3 mile radius) resources. Once the thickness of each coal zone was determined for the entire coal field, technological and land use surface restrictions were removed from the "Original Coal" to arrive at "Available Coal." The tonnage of coal is determined as bed thickness multiplied by area by a density of 1,800 tons/acre-foot for bituminous coal. The Carroll et al (2007) study is intended to be used by the USGS to further refine the estimate of actual coal available using current mining methods, with the assumption of maximum overburden depth of 3,000 feet and minimum coal thickness of 18 inches. "Recoverable coal" is calculated when mineability and economic factors are applied to available coal resources. According to Rohrbacher et al (1994), the resultant resource tonnage can be about 60% of the calculated Available Coal, similar to in the Denver Coal Region.

For our analysis of the federal coal within the Trinidad coal field, we acquired the digital GIS data from the Carroll et al (2007) project (courtesy of the CGS) and processed it to arrive at Available Coal on land with federal mineral estate for the Trinidad Coal Field. The output maps from each of the seven zones produced by this analysis are included in Appendix B. Maps 1 of 2 and 2 of 2 in Appendix B show the extent of the seven coal zones that we evaluated. The analysis results for the Allen/Frederick/Delagua Coal Zone are shown in Appendix B as a series of 6 maps to illustrate the progression of steps used to arrive at available coal and the tabulated results are shown in Table 11 below. All other coal zones have 4 maps in Appendix B. Table 11 summarizes the original coal in the field for both the full coal zone and federal land for each of

the 7 coal zones, presented in acres and thousands of tons. The next two columns show Carroll's 2007 available coal based on a 100-foot radius from CBM wells (which matches well with Carroll's Table 10, page 51 of his 2007 report). The next two columns show the amount of new restrictions caused by an increase in well radius to 150 feet applied to all CBM wells (2007 and 2014 wells). The final two columns are our calculated Available Coal, both for the entire coal zone and for federal coal, with the 150-foot radius from all wells applied to Carroll's data.

coal zone	original coal		Available Coal (Carroll 2007 data)*		2014 CBM Well Restrictions**		Available Coal**	
	acres	(x1,000) tons	acres	(x1,000) tons	acres	(x1,000) tons	acres	(x1,000) tons
Ciruela - full zone	95,568	498,259	89,587	478,167	2,060	11,108	87,527	467,059
- federal land	20,423	116,170	19,245	110,009	555	3,163	18,690	106,846
Boncarbo - full zone	75,920	459,672	68,208	425,174	1,833	11,283	66,375	413,891
- federal land	28,327	188,711	26,111	177,997	702	4,720	25,409	173,277
Primero - full zone	149,942	871,696	139,257	811,550	3,152	18,651	136,105	792,899
- federal land	29,139	180,122	27,508	171,556	743	4,691	26,765	166,865
Allen - full zone	256,608	1,519,514	266,502	1,333,145	44,458	26,610	222,044	1,306,535
- federal land	50,781	293,321	45,540	267,935	1,013	5,957	44,527	261,978
Bear Canyon - full zone	87,965	500,381	80,362	468,717	1,287	7,628	79,075	461,089
- federal land	29,389	165,728	26,232	152,340	437	2,629	25,795	149,711
Cass - full zone	171,892	857,273	156,197	787,373	3,399	16,749	152,798	770,624
- federal land	43,189	207,106	40,159	194,615	899	4,275	39,260	190,340
Walsen - full zone	71,099	432,920	67,178	413,761	1,498	9,283	65,680	404,478
- federal land	10,175	66,471	9,400	62,292	300	1,983	9,100	60,309
Total All Coal Zones								1,109,326

*based on C. Carroll (2007) data with 100' radius buffer from CBM wells

**based on 2014 COGC well data with 150' radius buffer for all CBM wells

Calculations for federal land was not part of Carroll's data, but Carroll's data was used in conjunction with BLM federal minerals data.

Table 11. Federal Available Coal in Trinidad Coal Field

The 6 Allen Coal Zone maps of Appendix B progress as follows:

1.) Overburden Thickness – shows the areas of deeper and shallower coal in this zone;
2.) Reliability and Coal Thickness – shows the measured, indicated and inferred coal bed thickness map, including thickness of bed at each well;
3.) Structure contours – a digital elevation model was integrated with the overburden thickness map to map the coal beds;
4.) Restrictions – this map shows the land use and technical restrictions as well as the federal unsuitability criteria, which includes such features as CBM wells, dikes, faults, mined out areas, lack of bed thickness data, etc.;
5.) Coal Thickness – modeled coal thickness throughout the coal zone; and
6.) Available Federal Coal with Coal Thickness – shows the thickness of available coal in areas with federal coal ownership.

The sixth and final map is the graphical representation of the final two columns of Table 11 for the Allen coal zone. The maps for the other 6 coal zones are overburden thickness, restrictions, coal thickness, and available federal coal for each coal zone.

This analysis resulted in an estimated 1.109 Btons of federal coal in the 7 coal zones in the Trinidad Coal Field. The Allen coal zone has the most federal coal (0.262 Btons) and the Cass coal zone as the second greatest amount of coal (0.190 Btons). The Walsen coal zone has the

least amount of federal coal (0.060 Btons). The final maps of available federal coal for each coal zone are very helpful to see where the thicker beds of coal are located.

It should be mentioned that, even if all 7 coal zones were present in one general location, it would not be likely to mine all 7 zones. First, the beds would need to be a minimum thickness of 5 feet to be economically feasible in this basin, whether room and pillar or longwall methods are used, according to Ron Thompson, mining engineer and long-time coal expert on the Raton Basin (personal communication, December 16, 2014). The Carroll et al (2007) report indicates the coal zone with the most coal in beds greater than 5 feet is the Allen/Frederick/Delagua zone followed by the Primero and Boncarbo zones. This reduces the potential zones to roughly 3 of the 7, given current technology and the assumption of 5-foot bed minimum thickness. Second, there would need to be a minimum thickness of roughly 60 to 70 feet of competent rock between mined seams to create sufficient roof support, so some seams may need to be avoided (personal communication, Desty Dyer, BLM Mining Engineer, April 28, 2015). Third, according to 43 CFR §3482.1(b) a mine must have a "Resource Recovery and Protection Plan" which ensures the "Maximum Economic Recovery (MER)" based on standard industry operating practices so that "all profitable portions of a leased federal coal deposit must be mined." This means the "conservation of the recoverable coal reserves and other resources and to prevent the wasting of coal." Therefore, a proposed mine plan would need to extract all possible beds, not just those that are the thickest and mining methods could not be used that destroy other possible beds that could be mined in the future. Realistically, mining would be top-down, with the shallower seams mined first and it is likely that up to 3 or 4 beds would be mined in any given area due to fragmentation of the underground resource. Deeper beds may be mined at a later time when technological advances allow for more cost-effective methods.

Analysis of Federal Coal in the Walsenburg Coal Field

A Coal Availability study has not been performed for the Walsenburg Coal Field by the USGS, CGS or other entity. This is likely due to the facts that this field does not contain metallurgical grade coal, there is little infrastructure available for commercial development (i.e. rural roads, rugged terrain, lack of railroad into the region, etc.), the beds are relatively thin, extensive mining has already removed the shallower "easy" coal, and there is little demand for steam coal that is expensive to extract. However, for the purposes of this report, we have prepared an analysis similar to that which was done for the South Park Coal Region. We first mapped the extent of the bituminous coal from 150-2,000 feet and greater than 2,000 feet. A database for coal less than 150 feet was not available, but this coal is located along the margins of the basin where the historic mining took place and where the resource is mostly mined out near the surface. Figure 26 shows the locations of these coal depth classes (overburden thickness), the location of historic mines in this field, and the federal coal ownership. From this coal depth map, we cut out the areas of federal coal and determined the area of each of the coal depth classes, shown in Figure 27.

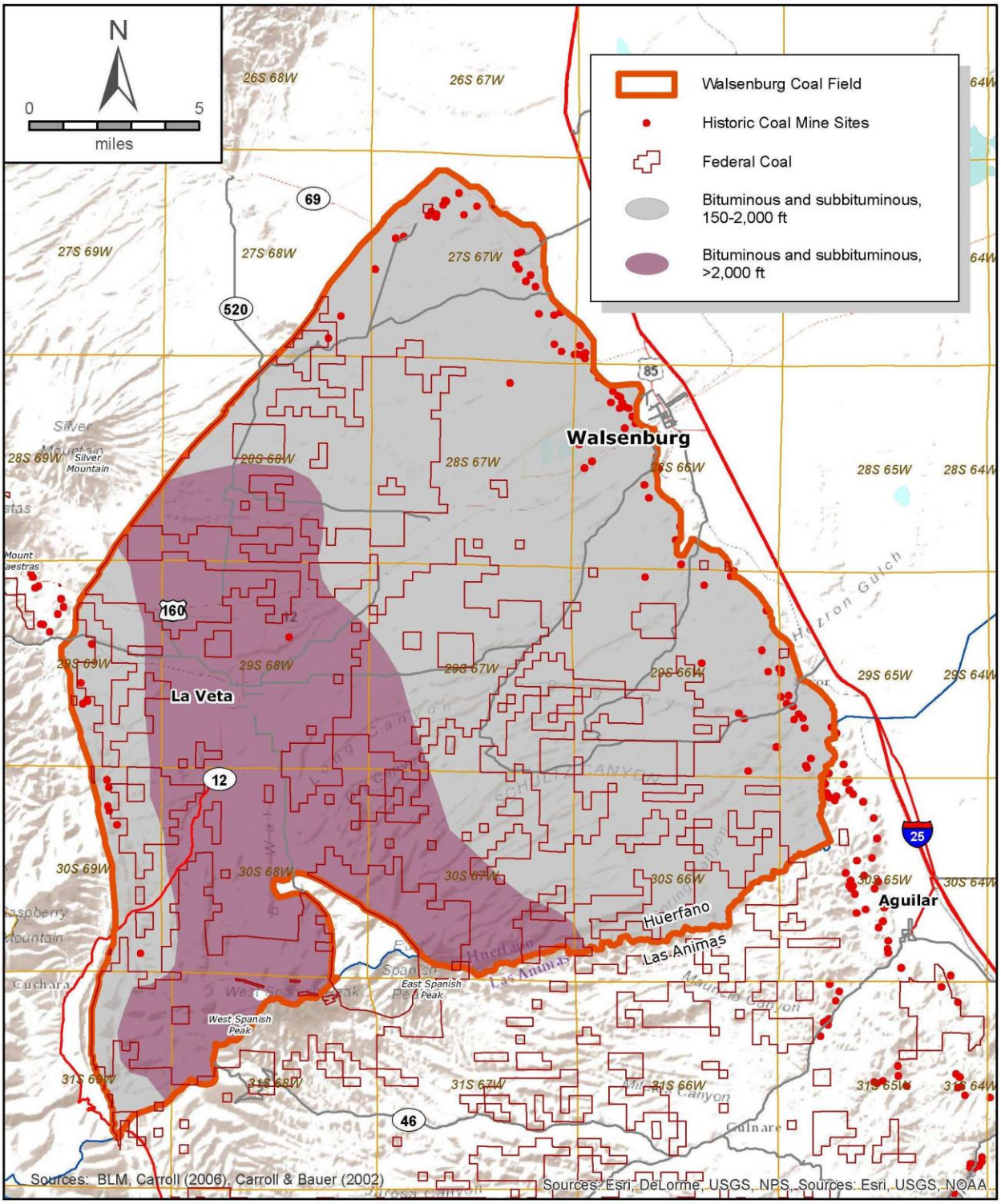


Figure 26. Walsenburg Field Coal Rank and Depth

Note on the above map (Fig. 26) that very few of the historic mines, which are concentrated on the coal outcrop at the basin margins, are located on federal coal. There is a total of 85,921 acres of federal coal in the Walsenburg Field, with 49,697 acres (57.8% of the federal estate) of

coal with an overburden of 150-2,000 feet and 36,224 acres (42.2% of the federal estate) of coal under at least 2,000 feet of overburden. The following map (Fig. 27) shows areas of federal coal for the two coal depth classes.

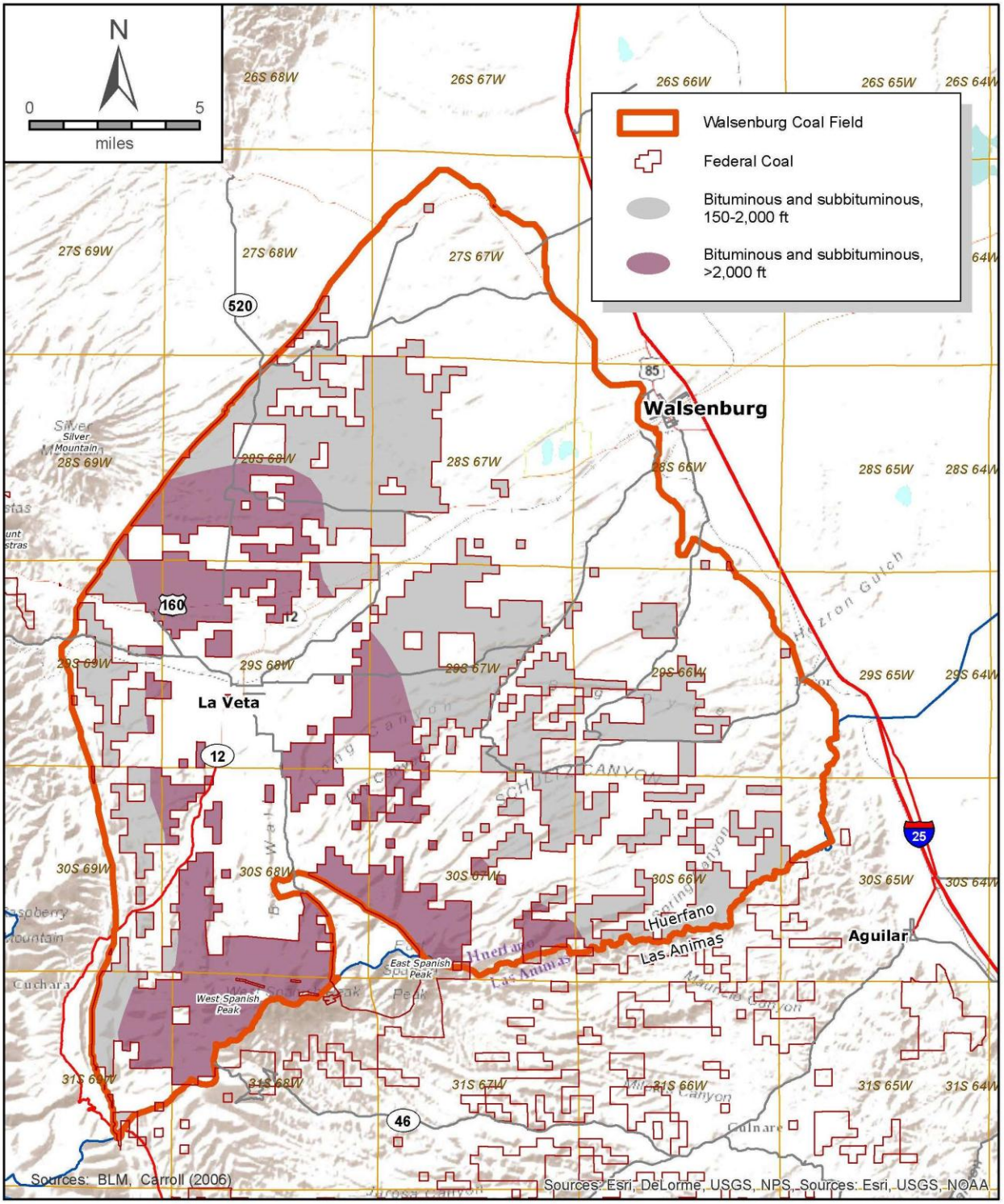


Figure 27. Federal Coal in Walsenburg Field

We reviewed the historic mine database of the CGS (Carroll and Bauer, 2002) to determine an average coal thickness for this field, which almost exclusively mined coals of the Vermejo Formation. Although some beds in the field are as thick as 8 to 10 feet, most beds were 2.5 to 6 feet thick. Considering the coal beds have partings and are lenticular with considerable lateral variability in quality and thickness, we used an average thickness of 3 feet. We also disregarded the coal deeper than 2,000 feet since coal was not mined even close to that depth historically in this field and it is in the region of the field where the Spanish Peak intrusions are located. A value of 1,800 tons/ac-ft was used as the density of bituminous coal applied to the acreage. Given these assumptions, we estimate there is 841 Mtons of original coal and 268 Mtons of federal coal in the Walsenburg Field at depths of less than 2,000 feet. This amount of federal coal is similar to the total amount of coal mined in the Raton Mesa Coal Region, which may be a realistic number, especially considering the estimate of roughly 12 billion tons of coal in the entire region. However, since very little historic mining occurred in areas of federal coal ownership, we speculate that these areas have relatively low potential for coal development.

Potential for Federal Coal Development during Plan Life

The Federal Government owns the rights to the coal in many tracts scattered across the part of the Raton Mesa Coal Region north of the Purgatoire River and north of the Maxwell Land Grant. The Walsenburg Coal Field has relatively low potential for federal coal development due to extensive intrusions, rugged terrain, difficult access, thick overburden, thin and discontinuous coal beds, and lack of transportation infrastructure. This is why historic mining production in this region was relatively low, especially when compared with the Trinidad Coal Field.

The Trinidad Coal Field has low/moderate potential for federal coal development due to 7 known coal zones (6 in the Raton Fm. and 1 in the Vermejo Fm.), the presence of known metallurgical coking coal, low sulfur, high heating value, and some existing infrastructure; however, the potential is not considered high due to lack of a complete rail line, lack of a domestic market (i.e. steel industry is essentially located overseas, which requires significant transportation costs), and relatively thin and discontinuous beds that require extensive site development, mostly underground mining methods that are expensive, and processing to remove waste rock and contaminants. Additionally, the dense, regional gas development has added complexity and costs associated with co-development of the coal such as complying with well setbacks, acquiring and capping wells, and mine methods that may require less extraction of coal (i.e. room and pillar vs. longwall mining). The socio-economic acceptance of coal mining as a way of life has been ingrained in this rural farming/ranching/mining community. When the New Elk Mine opened in 2010, the mine quickly brought its workforce up to 320 employees, with plans to add 150 more jobs until a declining metallurgical market hampered the mining effort (*Denver Post*, December 15, 2014). The main limiting factor to coal development in the Trinidad Coal Field is the depressed market demand for metallurgical coal. Amuedo and Bryson (1977) suggest mine-mouth electric generating powerplants (to reduce transportation and infrastructure costs), creating in-situ gasification plants, or building a coal slurry pipeline to the Gulf coast for export. The coal slurry pipeline and rail transport have high capital and/or transportation costs that the coal industry could not likely bear in the immediate future.

Although CBM development in the basin is extensive, the coal industry is amenable to either acquisition and capping or avoidance with altered mine plans, or a combination of both options. Production from these gas wells will have the added long-term benefit for future coal mining of making the coal field less gassy and presumably safer over time.

VI. Cañon City Coal Region

Background

As seen in Figure 2, the Cañon City Coal Region is at the western edge of the Colorado Piedmont subprovince of the Great Plains physiographic province as it abuts the Southern Rocky Mountain Province. The Cañon City basin is a down-faulted, synclinal basin or embayment bounded on the north by the Front Range uplift, on the south by the Apishapa uplift, on the southwest by the Wet Mountains, and on the east by the Great Plains (Carroll, 2004). The Cañon City region is considered to be a northern extension of the Raton Mesa Region which was cut off by uplift and faulting, causing the removal of coal-bearing sequences once deposited in the entire region (Tremain et al, 1991). Consequently, coal is found in the Upper Cretaceous Vermejo Formation, a northern extension of the lower coal zone of the Raton Mesa region. Although the Raton Formation is present in this basin, it is barren of coal, as the swamp environments did not extend this far north in the Paleocene (Washburne, 1908a). Like the other basins in the Planning Area, it is asymmetric, with the axis of the trough (Chandler Syncline) in the western portion of the basin where beds dip steeply and more gently dipping strata are located on the eastern portion of the basin. The Laramide-age Wet Mountains thrust fault essentially forms the western margin of the basin, where Precambrian basement rocks have been brought to the surface. Although this coal field covers only 50 square miles, there were 185 mines that operated from 1878 to 2000 (Carroll and Bauer, 2002).

Washburne (1908a) provided a detailed description of the Cañon City coal field based on field mapping, interviews and review of available mine data. He noted that the coal was of very high quality and "is one of the best known [regions], producing a high grade, clean, dry domestic fuel." Most of the mines Washburne analyzed were mining 2.5 to 5 foot thick coal beds by hand in room-and-pillar or longwall methods with slope or shaft entries. Washburne noted the relative ease in mining the coal due and the lack of methane gas produced in the mines. Other early work by Whiteside (1912), observed that the coal beds are, in general, thinner in the Cañon City Field than in the similar Walsenburg Field in Raton Mesa, but they are not disturbed by igneous intrusions like they are further south. Whiteside also pointed out that, due to the Wet Mountain Thrust Fault, the coal beds are sharply upturned at the western margin of the field. Stevenson (1881) observed that the dip quickly becomes abrupt on the western side of the field, where the outcrop is measured at Oak Creek to be 40° and then steepens to the west and north until the beds are 90° or even overturned at sharp hogbacks. There are a few historic mines shown along the western edge of the field and these presumably had to deal with steeply tilted coal beds and were probably mined from below in a stope method. The eastern outcrop of the field is marked by low bluffs with dips of 2°-6° (Stevenson, 1881; Washburne, 1908a). Washburne (1908a) concluded that there are indications of coal in the Dakota Sandstone formation, but the beds are thin and of no value.

The following map (Fig. 28) shows the locations of the coal-bearing formations within the Cañon City Coal Region which includes the Vermejo and Raton Formations. Although the Raton Formation is shown because it often contains coal in the Planning Area, no coal was mined in this formation in the Cañon City Region; all coal mined in this region was extracted from the Vermejo Formation. We will describe the coal resource of this region, but since there are no areas of federal coal ownership in the Cañon City Coal Region, no analysis of federal coal estate could be estimated.

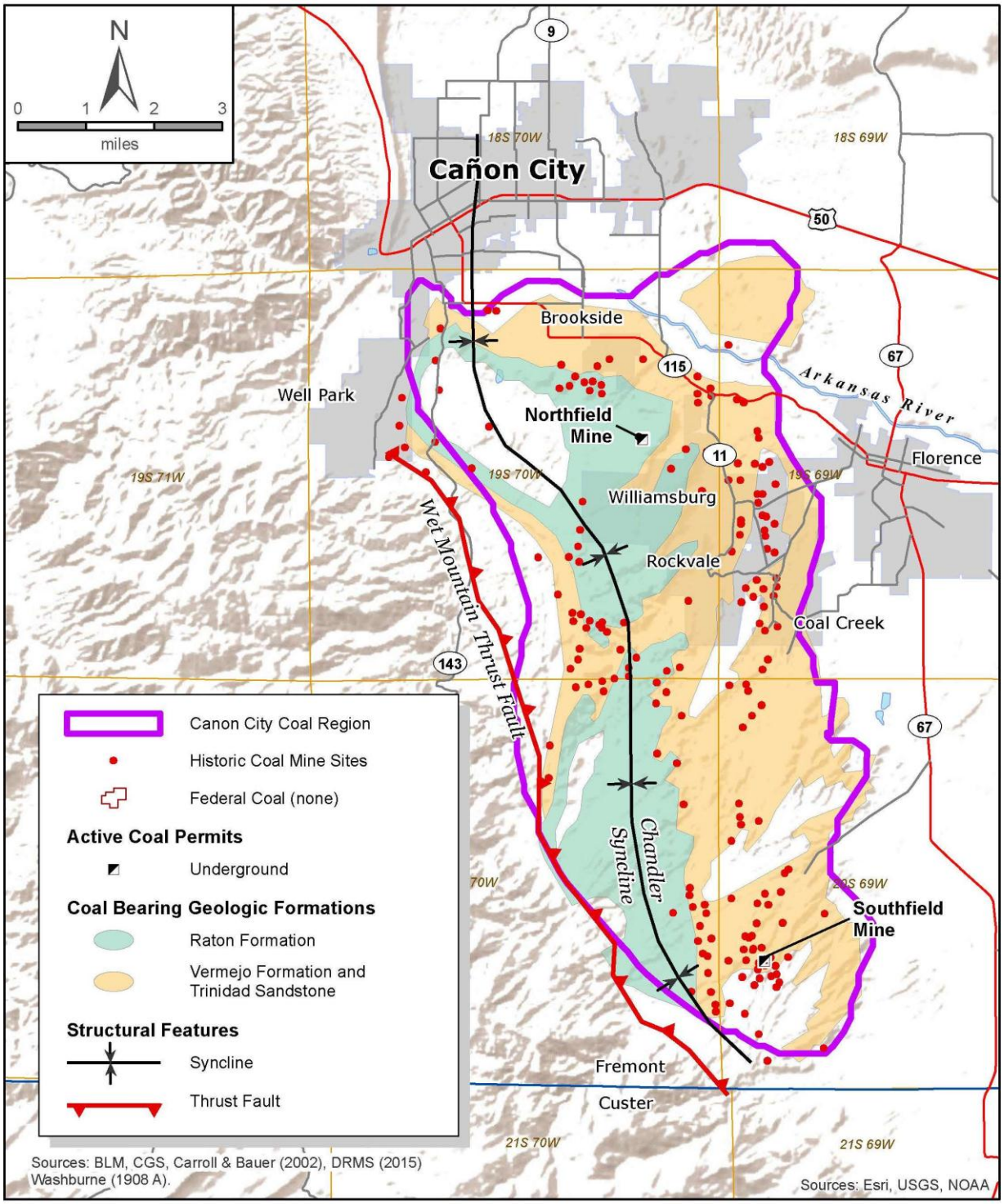


Figure 28. Coal-bearing Formations in the Cañon City Coal Region

The following Figure 29 illustrates the rank and depth of coal and historic mines in the region. The database only supplied coal in the depth range of 150-2,000 feet, but coal <150 feet is known due to the historic strip mines. Shallower coal should be in the general vicinity of the Vermejo Formation shown in Figure 28 above or roughly the western half of the basin.

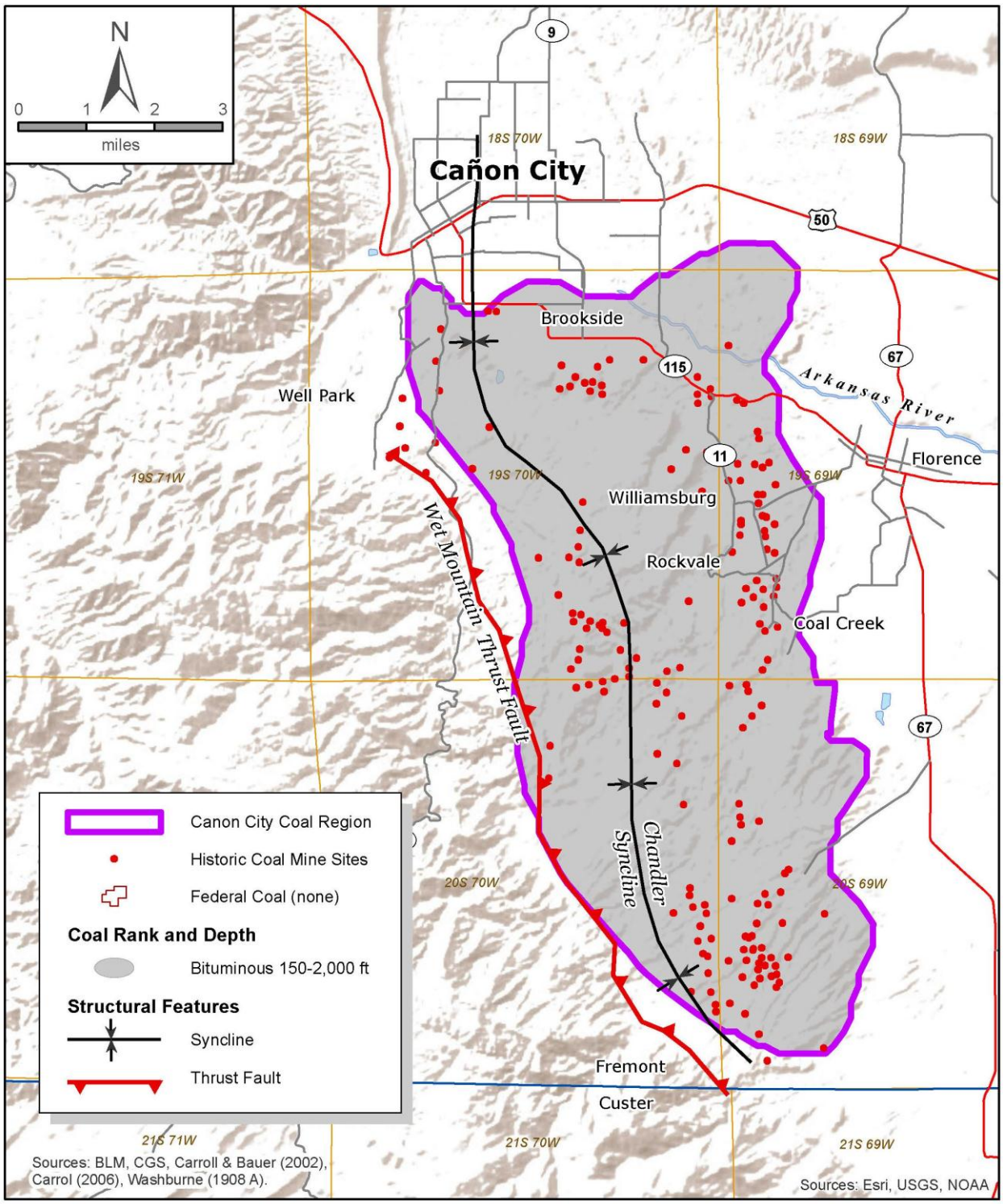


Figure 29. Coal Rank and Depth for Cañon City Coal Region

Stratigraphy

There are as many as 16 coal beds recognized in the Cañon City Coal Region in the Vermejo Formation, but only 7 zones have commercial importance (Speltz, 1976). The overlying Raton Formation is barren of coal. The following Figure 30 shows the stratigraphic column for the region for Mesozoic and Cenozoic formations on the left, and a stratigraphic column for the coal zones within the Vermejo Formation. According to the 2003 Summary of Coal Resources in Colorado (Carroll 2004), there were 7 coal zones mined in the Vermejo that ranged from 2 to 10.5 feet thick, with average thickness of beds on the order of 3 to 4 feet. Just as with the Raton Mesa Coal Region, the first coal zone sits directly on top of the Cretaceous Trinidad Sandstone and it is called the Rockvale Coal Zone. As seen in Figure 30, progressing up from the Rockvale are the Cañon City, Magnet, Radiant, Royal Gorge, Chandler and Brookside Coal Zones and they range from 30 to 165 feet thick. Barren sandstone intervals generally ranged from 50 to 100 feet thick. There is essentially no coal in the upper 200-500 feet of the Vermejo or in the Raton Formation.

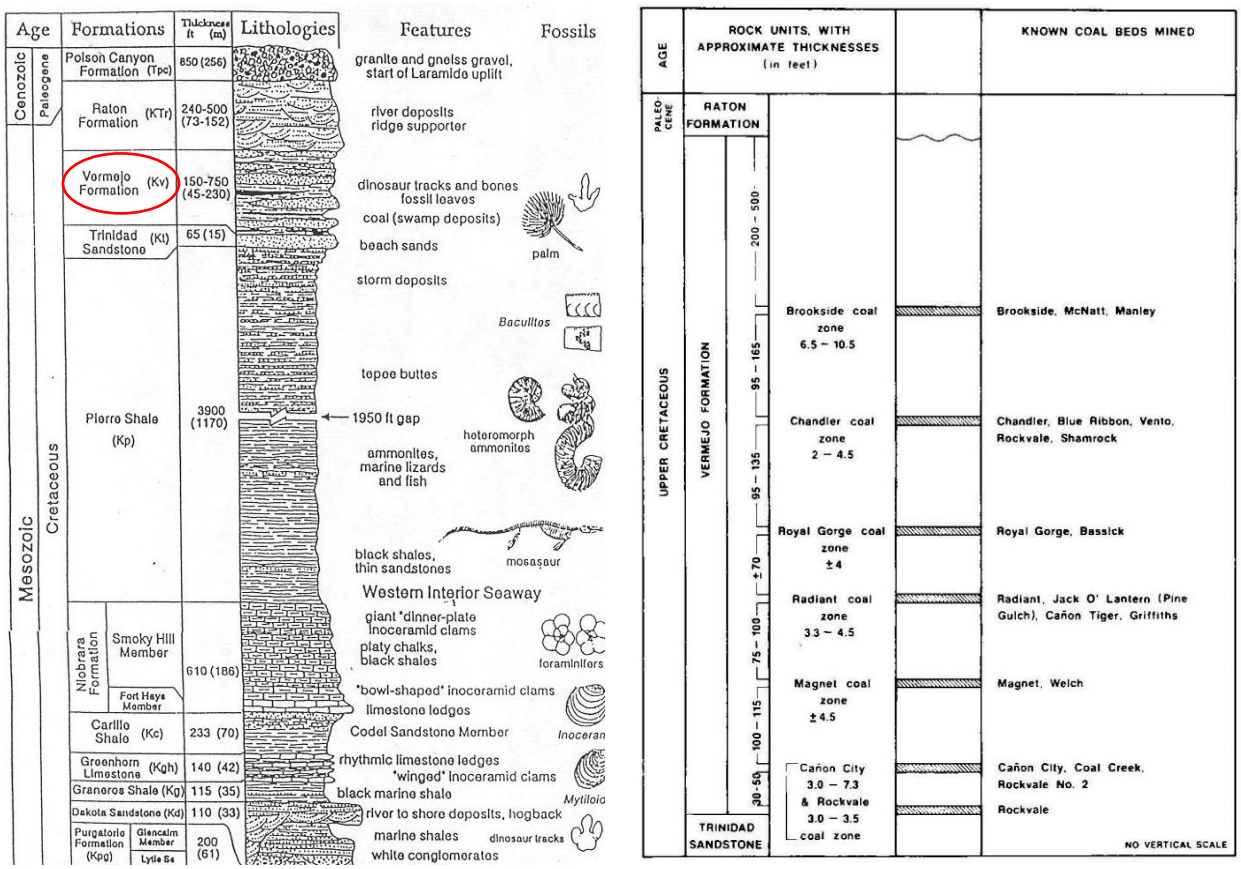


Figure 30. Stratigraphic Columns of Cañon City Coal Region
(Henry et al, 2004; Boreck and Murray, 1979)

The environment of deposition of the Vermejo Formation was river and deltaic channels in a marginal marine-continental environment. The Vermejo is reported to be 750-1,200 feet thick (Washburne, 1908a; Beach, 1983) and contains mostly sandstone with lesser amounts of shale and coal. It is described by Beach (1983) as "tan- to yellowish-orange, thin- to massive-bedded, fine- to coarse-grained, hard, friable, cross-stratified, sandstone interlayered with dark-

to light-gray, thin to thick, blocky to flakey shale and bituminous coal and lignite. Sandstones are both marine and non-marine; 200-750 ft thick, resistant sandstones, cliff and hogback former." The Vermejo lies conformably on the Trinidad Sandstone, a 50-100 foot thick, cliff-forming, marker bed. The Raton Formation that overlies the Vermejo is a yellow-gray to brown, coarser, massive, cliff-forming, non-marine sandstone with thin beds of soft, carbonaceous shaly sandstones, and no coal (Beach, 1983).

Coal Quality and Rank

Tables 2 and 3 show ranges in coal quality and rank for Vermejo coals in the Cañon City Coal Region compared to the other three coal regions in the Planning Area. Table 12 (below) is a summary of coal quality specific to the Cañon City Coal Region. In general, these coals are higher in coal rank than those in the Denver and South Park Coal Regions, but similar to those in the Raton Mesa Coal Region. High-volatile C (hvC) bituminous coal occurs in the Vermejo Formation in the Cañon City Coal Region (Carroll, 2006; Khalsa and Ladwig, 1981). Cañon City coal is relatively low in sulfur, non-weathering (non-slaking), nonagglomerating, and non-coking (Tremain et al, 1991).

Coal Region	Coal Field	Formation and Coal Rank	Moisture (%)	Volatile matter (%)	Ash (%)	Sulfur (%)	Mercury (ppm)*	Heating Value (Btu/lb)
Cañon City	Cañon City	Vermejo Fm (7 beds) hvC Bitum	5.4-11.9	31.4-42.9	4.6-14.8	0.3-1.7* 0.71-2.18**	.01-.16* <.03-.56**	10,400-11,390

Table 12. Coal Quality Data for Cañon City Coal Region
(Carroll 2011; Khalsa & Ladwig 1981*; Hatch et al 2006**)

Carroll (2006) evaluated 684 coal samples from Laramie coal and found an average of 9.8% ash, 0.8% sulfur, and 11,130 Btu/lb. Other chemical analyses of Cañon City coal samples indicate the following typical ranges: 0.3 to 5.5 ppm arsenic, <0.04 to 0.32 ppm cadmium, 0.01 to 0.56 ppm mercury, <0.1 to 4.9 ppm selenium, 0.15 to 5.3 ppm uranium, <1.1 to 20 ppm lead, and 1.0 to 88 ppm zinc (Khalsa and Ladwig, 1981; Hatch et al 2006). Regarding mercury levels tested at the Southfield Mine (Fig. 27), Finkelman (2006) analyzed four coal samples and found as-received raw coal contained 0.58 ppm mercury (dry basis), whereas the product from the preparation (wash) plant contained <0.03 ppm mercury (dry basis). A channel sample collected from a mined seam, which excluded a parting, contained 0.19 ppm of mercury (dry basis) and 0.18 ppm on an as-received (remnant moisture basis).

Historic Mining

185 documented mines have produced coal in this coal region from 1878 to 2000 and most mines were underground shaft, slope or drift mines, but a few were strip mines or combined strip/underground mines (Carroll and Bauer, 2002). Whiteside (1912) indicated that the Littell Mine that, at the time, was the deepest coal shaft in the state, being 1,065 feet deep. Room-and-pillar mining was used primarily. Peak mining activity was between the 1890s and 1940s, with less mining in the 60s and 70s (7 mines in 1972), tapering to 2 mines in 1990, and the last mine closed in 2000 (Carroll and Bauer, 2002; Speltz, 1976; Tremain et al 1991). Until the

1940s, the coal region provided fuel for trains that served gold mining camps and fueled the mills in Florence and Cañon City that processed the ore (Henry et al, 1996). The coal was also used locally for a cement plant, steam-electric powerplants, State Penitentiary, Pueblo State Hospital, and local domestic users (Murray, 1980; Carroll, 2004).

Historic Production

For the 122 years of mining history, this coal region produced 48 Mtons of coal from 185 mines (Carroll 2004). The largest mines according to Carroll and Bauer (2002) were the Southfield (6.36 Mtons), Chandler Creek (5.15 Mtons), Rockvale #1, #2 and #3 Mines (8.28 Mtons combined), and Coal Creek #1 and #2 Mines (4.00 Mtons). Since 1947, ten of the mines were strip mines, but combined, they produced only 0.86 Mtons, which is less than 2% of the total production of the field (Speltz, 1976).

Natural Gas Operations

According to the 2014 COGCC database, there are 99 natural gas wells in the Cañon City Coal Region (Figure 31). Since the coal is located in the Vermejo Formation which is in the upper 750-1,200 feet, this is the only zone of coal from which CBM could be extracted. Since CBM is extracted from Vermejo coals in the Raton Basin, it is possible that methane is also produced from the coals in the Cañon City embayment. However, it is more likely that the wells are extracting conventional gas from the Niobrara and other older Mesozoic formations.

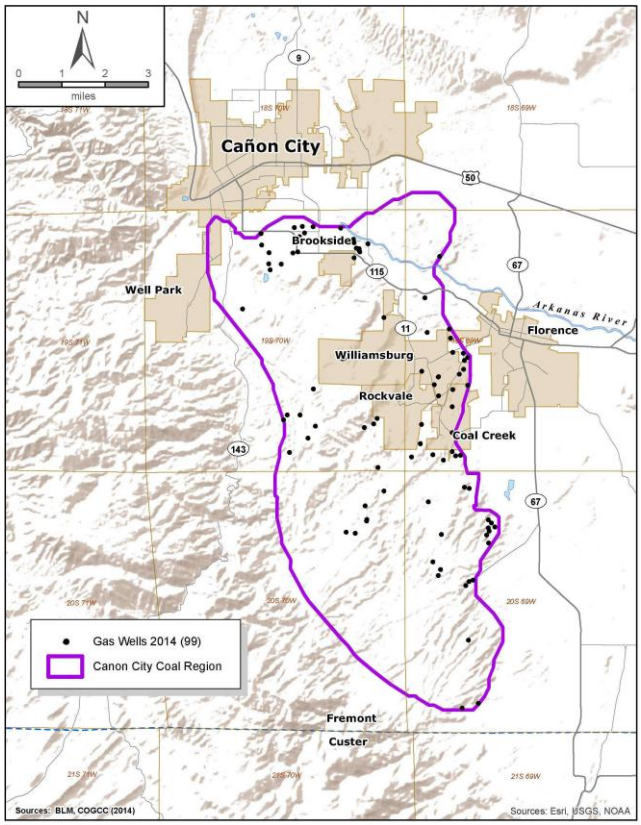


Figure 31. Gas Wells in Cañon City Coal Region

Although the presence of gas wells doesn't necessarily prohibit coal mining, it does cause a restriction during mining of a 150-radius from each well. Gas wells do have the potential benefit of reducing methane within the coals, which makes it safer for coals mining operation due to the reduced risk of explosions. Since the density of wells is not currently high, gas wells in the basin do not likely pose a significant hindrance to future coal mining.

Current Mining Operations and Production

In the early 1970s, there were 7 mines in the coal region of which 2 were surface and 5 were underground (Speltz, 1976). Currently, the only mine in the region with an active permit from the CDRMS is the Northfield Mine (Permit No. C2006085). It is proposed as an underground mine and the application has been approved, but the CDRMS is awaiting receipt of the warranty bond package (personal communication, Dan Hernandez, CDRMS, February 25, 2015). Mr. Hernandez also indicated that the most recent previous mine was the Southfield Mine (Permit No. C1981014) which operated from 1984 to 2000 and produced a total of 6.36 Mtons during that period. The status of the Southfield Mine with the CDRMS is "Permanent Cessation" and reclamation is complete.

Restrictions to Mining Operations in Region

The restrictions to mining coal in the Cañon City Coal Region are primarily related to land use restrictions such as towns, pipelines and powerlines, gas wells, roads, homes (private property), industrial sites, archaeological areas, ownership issues, wetlands, streams, lakes and reservoirs. A railroad is still in place and there are powerplants in the region that could receive the coal. Although the coal quality is relatively good, the thin seams (averaging 3-4 feet thick) create technological restrictions that make this coal less desirable than the thicker bituminous coals of other regions in western Colorado. If used, it would likely only be in the local market.

Previous Estimates of Coal Resources

Early assessments of coal resources estimated 900 Mtons of coal in 40 square miles (Vanderwilt, 1947) and 466 Mtons in 35 square miles (Spencer and Erwin, 1953). Landis (1959) estimated about 295 Mtons of bituminous coal in the 36 square miles he mapped as this coal region. Tremain et al (1991) estimate there are approximately 250 Mtons of coal in this region within 1,000 feet of the surface. Boreck and Murray (1979) estimated the remaining reserve base for this coal region is 107 Mtons from an original demonstrated reserve base of 180 Mtons. Carroll (2006; 2011) estimates 295 Mtons of original in-place coal with 48 Mtons mined, for a total of 247 Mtons remaining. Although none of these authors differentiated between underground and strippable resources, Speltz (1976) concludes that, although strippable coal is "definitely present, there are no deposits of large areal extent." Speltz estimates there are 10.2 Mtons of strippable coal with an average recoverable coal thickness of around 3 feet in 1,911 acres of the field, most of which is located in the transition zone between the foothills and the plains southwest of Florence. The modern estimates of the coal resource range from 107 Mtons to about 250 Mtons of coal in the Cañon City Coal Region. If we assume the average coal thickness is 4 feet, we calculate the field has 229.23 Mtons of original coal at 1,800 tons/ac-ft for the 50 square miles of the basin. With 48 Mtons already mined, that leaves roughly 181 Mtons of coal minus land use and technological restrictions.

Analysis of Federal Coal in Cañon City Coal Region

There is no federal coal ownership in the Cañon City Coal Region, so no analysis of federal coal could be performed.

Potential for Federal Coal Development during Plan Life

Unless coal estate is purchased by the federal government, there is no potential for federal coal development in the Cañon City Coal Region.

VII. South Park Coal Region

Background

The South Park Coal Region is 20-mile long and 2 to 5 mile wide syncline, trending north-south and located in the Southern Rocky Mountain physiographic province in the north-central portion of South Park (Fig. 2). The South Park Basin is an intermontane basin with an average elevation of about 9,000-10,000 feet that consists of generally eastward-dipping Paleozoic and Mesozoic sedimentary rocks preserved between the Laramide Sawatch uplift on the west and the Front Range uplift on the east. The Mosquito Range is to the west, the Ten Mile Range is to the northwest, and the Thirtynine Mile Volcanic Field is to the south. The South Park Coal Region, located about 15 miles east of Fairplay, extends across an estimated 86 square miles, based on the boundaries shown by Carroll (2006), but may be as small as 20 square miles according to Hornbaker et al (1976). South Park coal is preserved in a geologically complex area with many northwest-trending folds and fault systems, creating a complex structural grain (Barkmann et al, 2013). The South Park Fault is located on the west side of the region, the axis of a syncline parallels this fault in the central to eastern portions of the region, and the Laramide-age Elkhorn Thrust Fault, which is a major regional fault that bounds the west side of the Laramide Front Range Uplift, is located on the eastern edge of the coal region (Fig. 30).

According the Washburn (1908b), Landis, (1959), and Carroll (2006), the South Park Coal Region extends generally from north of the town of Jefferson southward nearly to the town of Hartsel and it is roughly 3 to 5 miles wide. The Laramie coal-bearing strata, which correlate with the Denver Basin coals, are only locally exposed around the perimeter of the coal region, with the best exposures limited to the northern and northwestern edge of the region. In many places, alluvium and other surficial deposits conceal the Laramie strata. Also, a major period of uplift eroded an unconformity across the Laramie and older rocks, locally removing the Laramie prior to deposition of the overlying South Park Formation (Fig. 32). This is why the Laramie Formation ranges in thickness from 0 to 425 feet in the region (Landis, 1959). The Laramie Formation is locally cut by faulting and the Laramie strata subcrop in the subsurface beneath or adjacent to the faults. This is another factor that complicates determination of the extent of the coal-bearing strata.

The following Figure 32 shows the locations of the coal-bearing Laramie Formation and the overlying South Park Formation. This map also shows the locations of historic coal mines and the major structural features in the immediate vicinity of this coal region. Areas of federal coal are shown within red polygons.

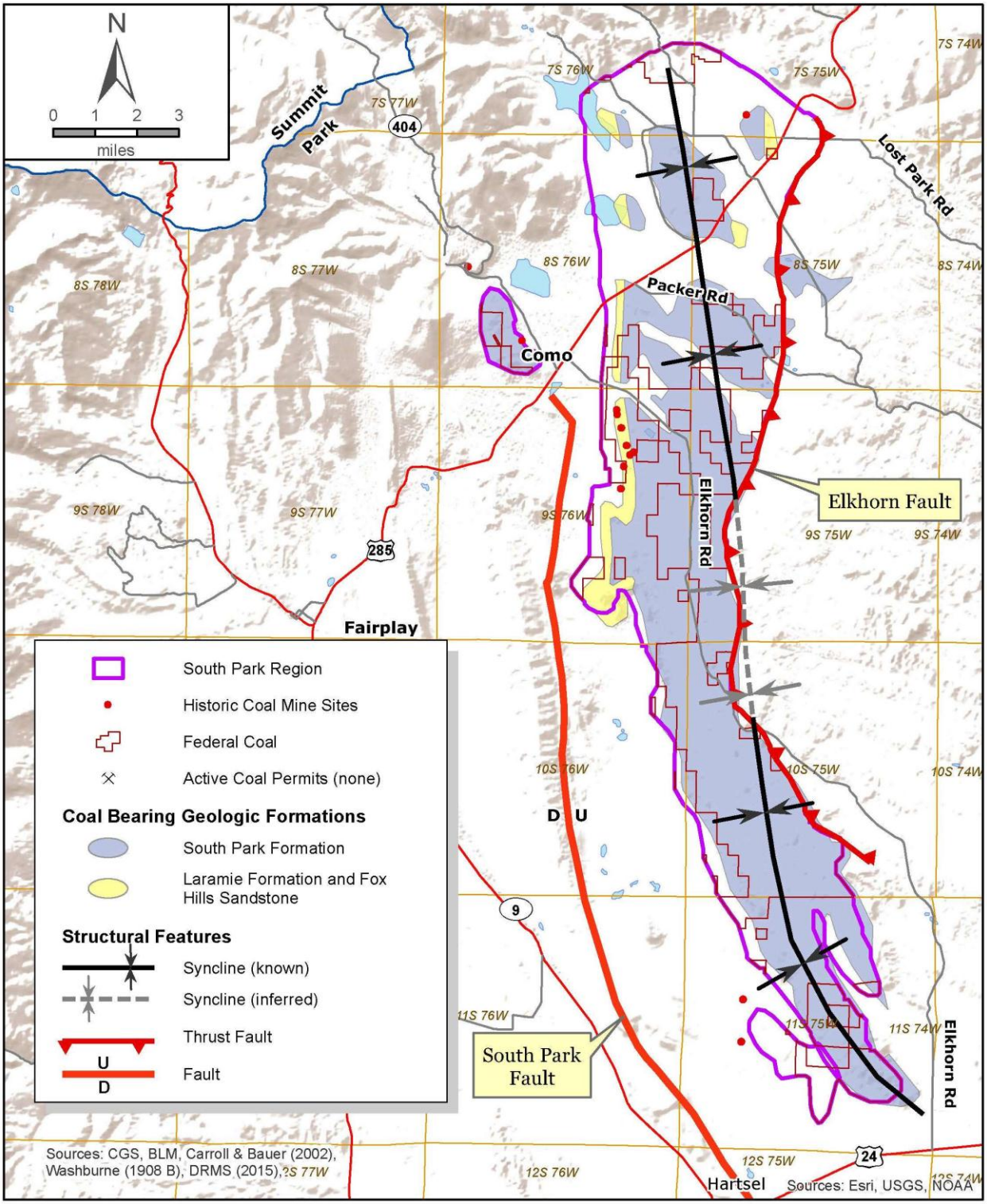


Figure 32. Coal-bearing Formations in the South Park Coal Region

The following Figure 33 shows coal rank and depth for the South Park Coal Region. This map also show the locations of historic coal mines and the major structural features in the immediate vicinity of this coal region. Areas of federal coal are shown within red polygons.

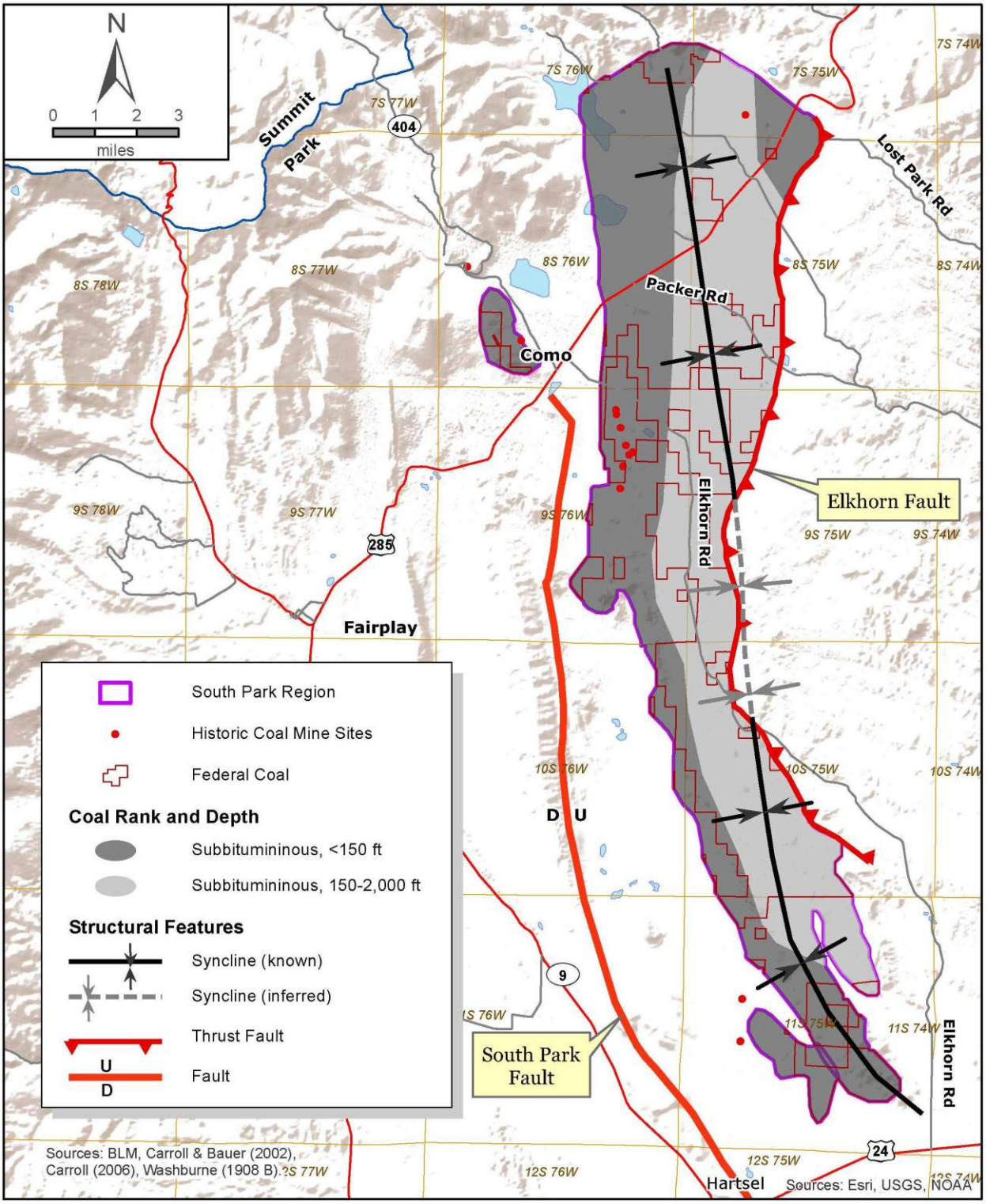


Figure 33. Coal Rank and Depth for South Park Coal Region

As seen in the above map, all the coal in the basin is subbituminous in rank and the shallower coal (<150 feet) is located on the western edge of the region (western limb of the syncline) where it outcrops in steeply dipping beds. It is worth noting that all historic mines are located

in this shallower coal. Although a few mines show as outliers, these are likely mis-mapped. For example, the mine in the northeast corner is the one that mined an outcrop north of Jefferson and the two in the southwest corner should be shown within the region's boundary.

Washburne (1908b) published the only "detailed" report on the South Park Coal Region and by the time he wrote his report, all commercial mining had ceased by 1905. He stated that the northernmost outcrop of coal is on Jefferson Hill about 1 mile north of the town of Jefferson, where there was a small mining operation in a roughly a 12-14 inch thick coal bed. This block of coal-bearing strata, seen in Figure 30, is wedged between two strands of the Elkhorn Thrust, and it dips steeply west (Barker and Wyant, 1976). The Laramie Formation also outcrops as a narrow band along the northwestern to west-central edge of the coal region, as seen on Figure 30, which is where most of the coal mining was concentrated. Coal-bearing strata dip steeply from 25° to 90°, typically 45°, at all outcrops (Washburne, 1908b). A few other isolated mines had worked the Laramie coal at Como and in the southwest corner of the region, north of Hartsel. Deep weathering and steep dips made mining difficult.

The outlines of the coal region as mapped by Washburne (1908b), Landis (1959), and Carroll (2006) assume the central area of the South Park Coal Region is underlain by coal. As shown in Figure 32, it is assumed that the Laramie coal continues under the South Park Formation as it extends towards the axis of the syncline. However, the absence of coal outcrops or other Laramie strata, lack of exploratory coring, and the lack of mines in this area, it is unknown if coal exists in the central portion of the coal region. If coal does not exist in this central area, then the coal region consists of two disconnected areas of the synclinal basin.

Stratigraphy

The coal-bearing rocks are correlated with the Laramie Formation in the Denver Basin and the Cretaceous sequence in the South Park Coal Field is the same as the stratigraphic sequence in the Denver Coal Region, as they were contiguous prior to the Laramide Front Range Uplifts (Washburne, 1908b; Kelso, 1988). The stratigraphy of the South Park Coal Region was first studied by Washburne (1908b) as he attempted to understand the geology and coal resource after the mining had ceased, so he was unable to visit the underground workings to measure the stratigraphy. Many mine entrances had collapsed or the mines were filled with water, so Washburne's analyses were based on available mine records, interviews, and field study of outcrops. Landis (1959) later analyzed the resource and mapped the extent of the field. More recent mapping of quadrangles has taken place, but the extent and quality of the coal resource is not well understood due to complex geology due to intense folding and faulting, thick alluvial and glacial deposits, deep weathering, and erosional sequences that have stripped many layers of strata from the region. Washburne (1908b) states that rocks in the South Park region are so deeply weathered that "it is necessary to penetrate about 50 feet below the surface before reaching fresh coal."

Very little detailed information is available for the coal beds and coal mines in the South Park Coal Region since it hasn't been mined for 110 years and little exploration has been performed. Some of the best information is from the King Mine complex on the west flank of the syncline and Washburne (1908b) reports up to 3 coal beds where most of the coal mining was concentrated: a lower bed on top of the Fox Hills Sandstone about 7 feet thick, locally 40 feet thick; a middle bed about 2.8 feet thick, and an upper bed about 4 feet thick. In the northeast

corner above Jefferson there is one bed roughly 1-foot thick. Many partings of carbonaceous shale make some of the coal in this region unusable. In the northwest corner near Como there are two beds, one about 12 feet thick and one about 6 feet thick. Washburne suspected the thickest coal was apparently a result of shearing and crumpling. The beds dip moderately to very steeply east or northeast, ranging from about 30° to as much as 90°.

The coal beds of the South Park Coal Region occur near the bottom of the Cretaceous Laramie Formation, which sits conformably on the Fox Hills Sandstone, a beach and deltaic sequence that sits atop the marine Pierre Shale (see left column of Fig. 34 below). Three primary coal beds (right column of Fig. 34) sit near the bottom of the Laramie, which also consists of sandstone, shale, carbonaceous shale, and some tuff. The Laramie is capped by the South Park Formation, which consists of sandstone, conglomerate, shale and volcanic flows.

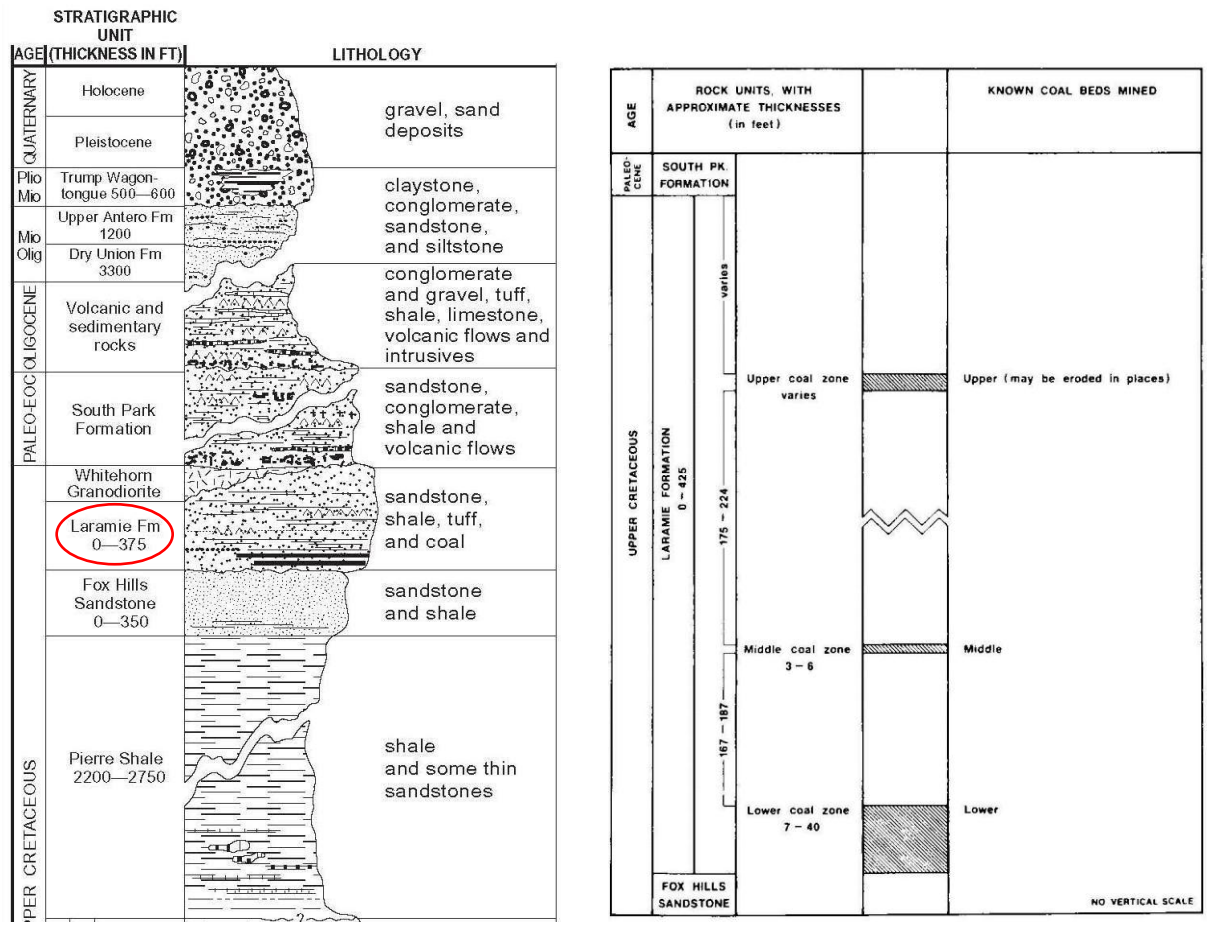


Figure 34. Stratigraphic Columns of South Park Coal Region
[Scarbrough, 2001 (left) and Boreck and Murray, 1979 (right)]

As seen above column to the right, the lower coal zone in the Laramie is the thickest and can range from 7 to up to 40 feet thick. The middle coal zone is 3 to 6 feet thick and the upper coal zone, if present, is less than 4 feet thick. The coal bearing strata are cut off at depth to the west of the Laramie outcrop by the South Park Fault and are presumably destroyed by the Elkhorn Thrust Fault on the east side of the coal region (Fig. 32).

Coal Quality and Rank

Previous Tables 2 and 3 show ranges in coal quality and rank for South Park coals compared to the other three coal regions in the Planning Area. Table 13 (below) shows typical coal quality data for the South Park Coal Region. In general, these coals are lower in coal rank than those in the Raton Mesa and Cañon City Coal Regions, but similar to those in the Denver Coal Region. Limited analytical data from coal samples collected from 3 beds and analyzed when the mines were operating from 1870 to 1905 suggest the Laramie coal in this coal region is subbituminous A and B coal, containing 9,780 Btu/lb, 6.3 to 15.5 % moisture, 1.3 to 6.4% ash, and 0.47 to 0.53% sulfur (Washburne, 1908b; Hornbaker et al., 1978; Carroll and Bauer, 2002; Carroll, 2006). The sulfur values are considered high for Colorado coals and when compared with other coals in the Planning Area; however, ash and moisture contents are relatively low. No other coal quality data, such as for heavy metals, could be found in the literature for this coal region that hasn't been mined for 110 years.

Coal Region	Coal Field	Formation	Moisture (%)	Volatile matter (%)	Ash (%)	Sulfur (%)	Mercury (ppm)*	Heating Value (Btu/lb)
South Park	South Park	Laramie Fm (3 beds) Subbit A & B	6.3-15.5	NA	1.3-6.4	0.47-0.53	NA	9,780

NA = Not Available

Table 13. Average Coal Quality Data for South Park Coal Region
(Hornbaker et al 1978; Carroll & Bauer 2002; Carroll 2006 & 2011)

Historic Mining

The South Park Coal Region was mined from 1870-1905 in nine (9) underground mines and 4 prospects (Carroll and Bauer, 2002). The previous map (Fig. 30) shows the location of these historic mines and prospects within the South Park Coal Field. Two of the historic mines and prospects are in or near Como, one is on Jefferson Hill in the northeast corner of the region north of Jefferson, two are in the southwest corner north of Hartsel, and 8 are clustered in an outcrop belt of Laramie Formation, called the King Mine complex of the Union Pacific Coal Company, that extends from Highway 285 south along the western edge of the region. This mine complex which includes the King Cole, Como Group, Lechner, America, Thompson and Wagon Mines is located along Park Gulch in this outcrop belt (Washburne, 1908b; Carroll and Bauer, 2002). The three main coal beds mined in that complex are described above in the Stratigraphy section. South of this complex, there are no further outcrops of coal and there were only prospects near Hartsel to the south. The coal zone is not exposed on the east limb of the anticline where the Elkhorn Fault abuts Precambrian granite to the Mesozoic strata; therefore, no mining occurred on the east side of the coal region south of Jefferson.

Washburne (1908b) described another area of significant mining in the coal region. The "Old Como Mine" and nearby prospects were located in a narrow, north-northwest-trending zone on the northwest and west sides of the town of Como. Apparently two coal beds were mined in this area. The Old Como Mine was abandoned in 1883, and when visited by Washburne in 1908 it had caved in, filled with water, and was not available for inspection; however, several local residents described the mine as having produced from a 5- to 6-foot-thick coal bed. However, no outcrops of Laramie strata were detected by Widmann et al. (2005) while mapping

the Como Quadrangle at a scale of 1:24,000, but waste dumps from the Old Como Mine and nearby prospects still contained coal fragments and pieces of Laramie sandstone when the geologic mapping was conducted in 2004. Widmann et al. (2005) interpreted the block containing the Laramie coal as a narrow, isolated, fault-bounded block that is not physically connected to the coal outcrop belt at the King Mine complex south of Highway 285.

Historic Production

Only 725,000 tons of coal was produced in 35 years in this region due to the tightly folded and faulted nature of the South Park Basin that disrupted and/or altered coal seams (Carroll, 2006; Boreck and Murray, 1979).

Natural Gas Operations

According to the COGCC database (2014), there are 10 gas well sites in the South Park Coal Region, shown in Figure 35.

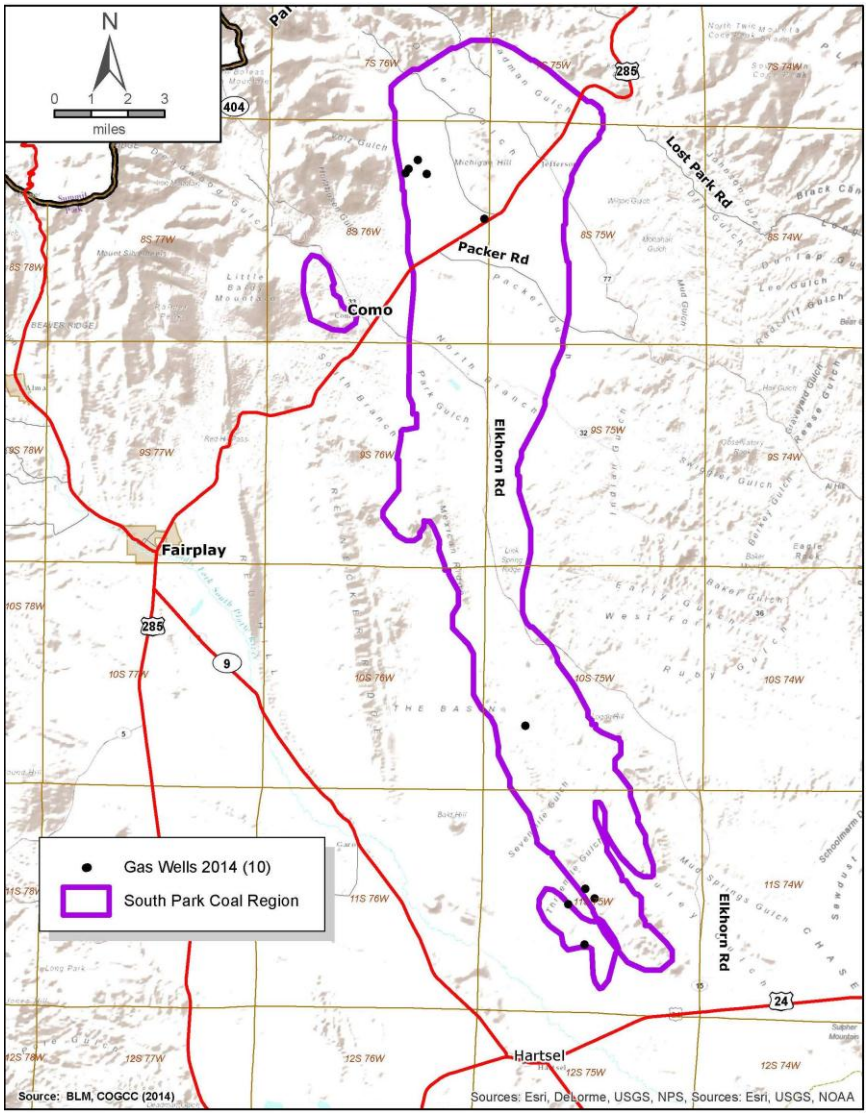


Figure 35. Gas Wells in South Park Coal Region

Due to the limited extent, both vertically and laterally, of Laramie coal in the basin, it is not likely that these wells are obtaining methane from coal. Also, given the locations of the wells, there is no indication of the correlation of the wells with coal beds. There is a cluster of 5 wells in the northwest corner of the basin in the vicinity of an outcrop of Laramie Formation, but these wells would more likely be attempting to access conventional natural gas at depth. Cross sections offered by Barkmann (2013) suggest the wells are obtaining gas from deeper Mesozoic units in the basin such as the Niobrara Formation and the Benton Group. They also indicate that of the 30 gas well sites that were permitted in 2010, 22 of them were abandoned and not in use, 5 had not been drilled, and 3 had no data. Since there were 30 well sites (permits) in 2010 and only 10 in 2014 indicates this basin is not likely a productive region for gas drilling for either conventional gas or CBM.

Current Mining Operations and Production

There is no current mining in the South Park Coal Region and it hasn't been mined since 1905.

Restrictions to Mining Operations in Region

The restrictions to mining coal in the South Park Coal Region are primarily related to the complex geologic setting, disruption of the coal beds by folding and faulting, degradation of the beds by weathering and intrusions, steeply dipping beds, and the relatively thin and discontinuous seams across the region. Washburne (1980b) concludes that the coal outcrops are badly weathered, in some places to depth of at least 50 feet, and they are covered by alluvium and talus to depths ranging from a few feet to several hundred feet. Technological restrictions would include challenges with the steeply dipping beds, thin seams, partings, and lack of infrastructure. Land use restrictions include towns, pipelines and powerlines, industrial sites, archaeological areas, ownership issues, wetlands, streams, lakes and reservoirs.

Previous Estimates of Coal Resources

Hornbaker et al (1976) estimate that the entire South Park basin that was tightly folded and faulted may have contained approximately 227 Mtons (Mtons) of in-place coal resources above a depth of 6,000 feet. Specifically for this coal region, Vanderwilt (1947) estimated 18 Mtons for 80 square miles, Spencer and Erwin (1953) estimated 20 Mtons for an area of 3 square miles, and Del Rio (1960) estimated 32 Mtons within 1,000 feet of the surface. Landis (1959) estimated about 92 Mtons of bituminous coal in the 8 square miles he mapped as this coal region. He speculated that an additional area of 12 square miles may have minable coal reserves with less than 3,000 feet of overburden. This is a smaller area than that which was mapped by later geologists, which ranges from 20 to 86 acres (Hornbaker, 1976; Carroll, 2006). Boreck and Murray (1979) estimated the remaining reserve base for this coal region is 23.9 Mtons from an original demonstrated reserve base of 25.3 Mtons. Carroll (2006) estimates 92 Mtons of resource with 0.7 Mtons mined, for a total of 91.3 Mtons remaining. Although none of these authors differentiated between underground and strippable resources, Speltz (1976) concludes that, due to steep dips and deep weathering, the South Park coal field is considered to have no strippable coal resource. He goes on to say that "additional exploration is unlikely to change this interpretation of the status of the field." Given this assessment of the generally

poor quality of the coal field and lack of interest in mining this area for over 100 years, we conclude the coal resources are on the low end of the estimates, on the order of 20-30 Mtons.

Analysis of Federal Coal in South Park Coal Region

No studies of Coal Availability have been found for the South Park Coal Region. Of the coal resource studies that have included the South Park Coal Region, resource estimates, as indicated above, vary widely due to the varying assumed sizes of the region, quality of coal, and assumed presence or absence of coal due to degradation, faulting, folding, erosion or non-deposition. If we assume only coal less than 150 feet is considered to be present (Fig. 32) and of minable quality, there would be 26,928 acres (49% of the coal field) of original coal. If we assume an average of 1-foot of coal is located in that area, there would be 47.7 Mtons of coal resource (assuming the value of 1,770 tons/ac-ft). However, if we assume that the southern half of the field does not have high enough quality coal to mine, as the historic records indicate, and we use only the northern half of the field along the western edge (as the Laramie Formation outcrop suggests on Fig. 31), this would determine there is 23.9 Mtons of coal resource in this field, which matches closely with Boreck and Murray's (1979) estimate. The federal coal within this area of the field (all subbituminous coal <150 ft and north of Section 36 T9S R76W) is 3,095 acres. Again, using the assumption of 1-foot thick coal and 1,770 ton/ac-ft for subbituminous coal, we calculate 5.48 Mtons of federal coal in this coal region.

Potential for Federal Coal Development during Plan Life

This coal region was mined for 35 years, producing only 0.725 Mtons, and it has not been mined for the past 110 years. The Laramie subbituminous coal outcrops in a highly weathered hogback southeast of Como and in a few isolated (fault block) locations in the region. Based on geologic characteristics, the South Park Coal Region is considered to have low potential for future coal development due to highly weathered rock to depths of around 50 feet, a cover of deep (roughly 100 feet) alluvium, faults, folds, relatively low rank and quality, numerous shaly and sandstone partings, steeply dipping beds, and generally, thin and lenticular coal deposits. The steep (typically 45°) dip of the beds creates difficult mining conditions, as was the case of mining the Foothills District of the Denver Basin. Also, the deep weathering and surficial deposits would require mines to be shaft, slope or stope mines, as there could be a minimum of 50-100 feet of overburden and weathered rock overlying potentially usable coal. Strip mines or shallow mines are not likely.

Based on land use and economic factors, this coal would also have low development potential due to lack of infrastructure (railroad, mine facilities, etc.) and lack of a market for relatively low quality coal. Mine-mouth operations where a powerplant is nearby and coal is trucked short distances to the plant that services the local community or other local commercial/residential uses would be the only viable option for coal development in this area during the next 20-30 years. Competition with established methods of energy and heat production such as natural gas, wood burning, wind and solar would make it difficult for coal products to enter the relatively small local market.

In summary, we consider the development potential of the South Park Coal Region to be low over the Plan Life of the Eastern Colorado Resource Management Plan.

VIII. Current Mining Operations and Production

Of the four coal regions within the Planning Area, only the Raton Mesa Coal Region has current mining operations. There is one mine (New Elk Mine) in the Trinidad coal field of the Raton Mesa Coal Region (Fig. 19), but operations are currently suspended during bankruptcy proceeding of the New Elk Coal Company (NECC), a subsidiary of Cline Mining Corporation.

Raton Mesa Coal Region

The New Elk Mine is 24 miles west of Trinidad and is a relatively small underground mining operation (6,118 acres) that produced 113,825 tons of coal in 2011, 239,151 tons in 2012, 0 tons in 2013 and 14,238 tons in 2014 (CDRMS, 2015). No production has occurred since October 2014. According to the recent New Elk Mine Technical Report (Agapito Associates, 2012), this mine is formerly the Allen Mine operated by the Colorado Fuel & Iron Company (CF&I) from 1951 until 1985 to supply metallurgical coal to its' Pueblo iron and steel production facility. It was closed when the domestic metal markets declined and the mine was allowed to partially flood. The nearby Golden Eagle Mine (aka Maxwell Mine) operated from 1984-1995 and also produced primarily metallurgical coal. According to the 2012 New Elk Mine Technical Report, NECC filed a lease application in 2007 with the BLM for 3 parcels (1,295 acres) located north of and adjacent to the current mine. Coal seams being mined or proposed to be mined are the Allen, Apache, Blue and Maxwell seams of the Raton Formation. The coal from the New Elk mine is trucked to a loadout at Jensen (west of Trinidad) and then taken by rail to metallurgical markets primarily overseas. The following photograph (Fig. 36) shows nature of the surface mine structures at the New Elk Mine.

Figure 36. New Elk Mine in Raton Basin west of Trinidad.
(Photo courtesy L. Brandt)

IX. Coal Resource Potential & Reserve Estimates

General Discussion

A coal resource is where concentrations of coal exist in such forms that economic extraction is currently or may become feasible (U.S. Bureau of Mines and USGS, 1976). As explained by Luppens et al (2009), coal resources include in-place tonnages for identified (demonstrated and inferred) and undiscovered (hypothetical and speculative) coal deposits with a minimum thickness of 14 inches for anthracite and bituminous coal and 30 inches for subbituminous coal and lignite under less than 6,000 feet of overburden. The coal needs to be in thick enough seams without significant partings or other impurities and needs to meet quality standards (i.e., within acceptable ranges of Btu, sulfur, ash, and moisture content) for the market to be supplied. Coal reserves, on the other hand, are a subset of coal resources where the coal "must be considered as economically producible at the time of classification, but facilities for extraction need not be in place and operative" (Wood et al 1983). Typically, "the volume of coal reserves in a given area is significantly smaller than total coal resources" due to technological restrictions such as overburden greater than 3,000 feet, thin coal beds, steeply dipping strata or societal or environmental restrictions such as towns, wetlands, or sensitive areas. Coal availability and recoverability studies are where restrictions and mining/processing losses are applied to determine "Recoverable Resources" (Luppens et al 2009). When economic factors (i.e. sales price is compared with production costs and market demand) and compliance (less than 1.2 lb/MBtu) with emissions standards are applied to the recoverable resource, the coal reserve can be determined.

It is worth noting that coal reserve assessments are a dynamic process, not a "one-time evaluation or static procedure" (Luppens et al 2009). This is because the volume of reserves calculated is dependent on the data and assumptions at the time of the study. Changes in transportation, technology, mining economics, tariffs, political factors, world-wide competition, coal demand and market pricing all potentially affect the reserve estimate.

As projected in the "Annual Energy Outlook 2014 with Projections to 2040" by the U.S. Energy Information Administration, the annual growth of energy consumption from 2012-2040 for industrial metallurgical coal in the U.S. is -0.5% and the annual growth of for this same time period for commercial coal is 0.0% (EIA 2015). For the Rocky Mountain supply region specifically, the average annual growth from 2012 to 2040 is projected to be -2.5%.

Markets for Thermal (Steam) Coal

Thermal (steam) coal is typically subbituminous to bituminous coal with low ash and sulfur content and moderate to high Btu heating values. These qualities are met by coal resources in the Denver, Cañon City and Raton Mesa Coal Regions. However, according to the U. S. Energy Information Administration (2014), both the domestic and international markets for steam coal are decreasing over the next 25 years. Internationally, thermal coal demand is primarily in China, East Asia, India and Europe and those markets are being served by those countries internally and by Australia. Domestically, highly compliant low sulfur coal is being supplied in large quantities (386 Mtons in 2012) primarily by the Powder River Basin of Wyoming (EIA 2014). Additionally, the EIA report indicates the aggressive conversion of existing coal-fueled powerplants to less expensive and readily available natural gas powerplants for electricity

generation. This conversion trend is both in Colorado and nation-wide, due to regulations to reduce greenhouse gas, sulfur dioxide, and heavy metal emissions as well as due to the readily available and cheaper natural gas resources due to the recent gas drilling boom. This competition with natural gas for steam generation as well as increasing production using renewable resources will further reduce the demand for steam coal. There is essentially no international market for steam coal from the RGFO Planning Area and the domestic market would be limited to relatively small production for local powerplants.

Markets for Metallurgical (Coking) Coal

Metallurgical (coking) coal or "met" coal is typically hvA to hvB bituminous coal with low ash and sulfur content and high Btu heating values. Only the Raton Mesa Coal Region has this quality of coal in the RGFO Planning area. According to the "Coal Market Module" of the "Annual Energy Outlook 2014" produced by the U.S. Energy Information Administration, competition with China, Australia, Russia, and India, the largest metallurgical coal producers along with the U.S., has reduced the demand for Colorado metallurgical coal, which is relatively expensive to extract (due to thinner, lenticular beds that are mostly mined underground), longer transportation routes to steel producing countries, and tariffs which are more favorable to China for the Asian and Indian markets (EIA 2014). The next version of the Annual Energy Outlook will be released in June 2015. The demand for coking coal, which is used in the steel smelting process, is directly related to the demand for steel. According to the World Coal Association (2015), 2013 statistics indicate the U.S. is no longer a top steel producer, with China ranked first at 779 Mtons, Japan second at 111 Mtons, U.S. third at 87 Mtons, and India fourth at 81 Mtons. The top coking coal producers in 2013 were China (527 Mtons), Australia (158 Mtons), U.S. (78 Mtons), Russia (73 Mtons) and India (42 Mtons). Given the proximity of the largest steel producers with the largest metallurgical coal producers mostly in Eurasia, it is difficult for American coking coal to be competitive overseas in those markets. The price of metallurgical coal is currently at relatively low values (average of $95/ton at end of 2014) after a peak of just over $200/ton in 2011; however, in 2000 the average price fell to $38/ton, so met coal market values can be highly volatile (EIA 2015).

According to mining engineer in the Trinidad Coal Field, Ron Thompson (personal communication October 3, 2014), the most likely market for metallurgical coal from the Raton Basin is South America, particularly Brazil. In 2014, Brazil was the largest importer of U.S. metallurgical coal at 7.4 Mtons (EIA 2015). Coal would be shipped by rail or possibly slurry pipelines to ports in the Gulf of Mexico and transported via ship to South America. European, Asian, Indian and Japanese markets are currently served by European, Asian and Australian coking coal producers. Domestically in 2012, metallurgical coal was produced in much higher quantities in Central Appalachia (54.9 Mtons), Northern Appalachia (22.4 Mtons) and Southern Appalachia (12.2 Mtons) than in the Rocky Mountain region (0.1 Mtons) and these eastern supply regions are much closer to eastern seaports which allows for more direct ocean transport to Europe and South America ("Coal Market Module" of EIA 2014). Therefore, competition both domestically and internationally from larger metallurgical coal producers and the lack of a domestic coking coal market make the prospects for this resource suppressed for the next several decades.

Coal Resource Potential

Specific to the Royal Gorge Field Office Planning Area, for coal to be considered to have resource potential, the following criteria must be met: (1) underlying strata are likely to have accumulated in a coal-forming environment, and (2) the potential coal-bearing rocks are less than 2,000 feet deep for coals to be extracted by underground mining methods (i.e., Laramie, Vermejo and Raton Formation coals) or less than 150 feet for coals to be surface mined (i.e., Denver lignite). Since overburden depth is an important factor in determining coal potential once a coal-bearing formation is known, maximum overburden thickness was used as a selection criteria. Various maps in this report illustrate overburden depth.

Coal resource estimates for the four coal regions in the Planning Area were determined by Carroll (2006) and are presented in Table 14 below. The remaining coal resource is the original coal resource minus the amount of coal that has been mined. However, as mentioned, the actual coal reserve is much less than the tonnages presented below, as the reserve estimate is a subset of the overall resource. These coal resource results show that the Cañon City and South Park Coal Regions are not only physically very small but also they have very small coal resources when compared to the other two regions. In fact, the total amount of coal already mined in the Raton Mesa Coal Region is slightly more than the total resource remaining in the Cañon City Coal Region. Also, although the Raton Mesa Coal Region is 1/6th the size of the Denver Coal Region, it has more than twice the remaining coal resource, which is 12.4 Btons. The Raton Mesa Coal Region also contains metallurgical grade coal which the other three regions do not, so the high coal rank, coking quality and sulfur compliance make the Raton Mesa coal the most desirable of the regions.

Coal Region	Area (miles^2)	Original Coal Resource (Mtons)	Mined Coal (Mtons)	Remaining Coal Resource	
				Million Tons (Mtons)	Billion Tons (Btons)
Denver	7,560	5,260	134	5,126	5.1
Raton Mesa	1,245	12,674	264	12,410	12.4
Cañon City	50	295	48	247	0.247
South Park	86	92	0.7	91.3	0.091

Table 14. Estimated Coal Resource in Four Coal Regions
(Carroll 2006)

Coal Reserve Estimates

Reserve estimates for Colorado and other western coal have been determined for only select coal-producing basins in the U.S., with the focus of their research on areas under federal coal lease and Preference Right Lease Areas (PRLA), as presented in the "Assessment of Development and Production Potential of Federal Coal Leases" (OTA 1981) and various Coal Availability and Recoverability Studies (CARS) by the USGS and U.S. Bureau of Mines (Luppens et al 2009). Review of the literature indicates that no coal reserve estimates or other detailed recoverability or economic studies have been performed on the Denver, Raton Mesa, Cañon City

or South Park Coal Regions. James Luppens, USGS Project Chief with the U.S. Coal Assessment Project, indicated that the USGS is currently working on the Colorado Plateau area, which will include the Raton Basin, even though it is technically not part of the Plateau physiographic province (personal communications November 26, 2014). He also indicated that, as of November 2014, "the start of our more detailed assessment of the Raton area (which will include a comprehensive assessment of both in-place and recoverable resources) is at least one year away from starting." The series of USGS publications in the 1625-A series, which have been referenced herein in the Denver and Raton Mesa Coal Region sections of this report, are the most recent National Coal Resource Assessment (NCRA) documents for the four coal regions in the Planning Area (Nichols 1999; Flores and Bader 1999).

In Colorado, only a portion of the Somerset Coal Field in the Piceance Basin of western Colorado has been studied at the reserve-level, including coal availability, recoverability, and economic evaluations (Rohrbacher et al, 2000). The OTA (1981) study combined the federal and PRLA leases in the Denver Basin and Raton Mesa Basin in Colorado to arrive at recoverable reserves of 0.05 Btons of surface coal and 0.02 Btons of underground coal. These reserve estimates are a very small fraction of the resource tonnages shown in Table 14. This is likely due to the relatively small amount of leasable federal coal compared to private fee coal in both the Denver and Raton Mesa Coal Regions. For example, the New Elk Mine and the recent Lorencito Canyon Mine, both of which are in the Raton Mesa Coal Region, are entirely under private coal estate. The 1981 OTA study was also very broad-brush and was intended for regional comparisons with other western and eastern coal producing regions, not site-specific determinations of coal reserves.

More realistically, if it is assumed that the reserve for all coal (federal and private fee ownership) is on the order of 35% of the remaining resource, the coal reserves in the Raton Mesa Basin would be 4.3 Btons of coal, the Denver Basin would be 1.8 Btons of coal, the Cañon City Basin would be 0.09 Btons of coal, and the South Park Basin would be 0.03 Btons of coal.

X. Potential for Coal Development during Plan Life

This report was prepared to quantify the coal resource and aid in identifying areas with coal development potential in the RGFO Planning Area in support of the Eastern Colorado RMP revision underway in 2014. The coal resource potential, which is the potential for the presence of coal based on geologic factors, was discussed separately for each of the four coal regions. Coal development potential is the economic feasibility of the coal actually being extracted. Factors such as remoteness, rugged terrain, market demand for the type or quality of coal, and availability of suitable transportation (i.e., rail line) or coal-handling infrastructure all contribute to the development potential of coal. The following criteria were taken into account when assessing the potential for coal development: (1.) Areas with high potential for coal resource occurrence; (2.) Existing coal mining activity occurring nearby; (3.) Areas where the overburden is 150 feet or less; (4.) Advances in mining or energy production technology could occur; and (4.) Coking coal and compliant coal will continue the demand for area coal. Please refer to the more detailed discussions of and maps showing areas of the coal resource and development potential of federal coal for each of the four coal regions earlier in this report. Below are tables summarizing the findings of the federal coal resource (Table 15) and of the federal coal development potential (Table 16).

Coal Region	Formation, Coal Rank and/or Coal Field	Federal Coal Resource (acres)	Federal Coal Resource (tons)
Denver	Subbituminous coal (Laramie Fm)	279,459	2.474 Btons
	Lignite (Denver Fm)	98,863	0.865 Btons
Raton Mesa	Walsenburg Field bituminous coal (Vermejo Fm)	36,224	268 Mtons
	Trinidad Field bituminous & coking coal (Vermejo & Raton Fm)	189,546	1.109 Btons*
Cañon City	Bituminous Coal (Vermejo Fm)	0	0
South Park	Subbituminous coal (Laramie Fm)	3,095	5.48 Mtons

*This estimate is based on the most detailed "available" coal analysis of the 4 coal basins, as it was based on CGS analysis (Carroll et al 2007), while the other acreage and tonnage values are based on "quasi-available" coal as discussed in the report.

Table 15. Summary of RGFO Federal Coal Resources

As seen in the above Table 15, the Denver Coal Region contains the largest amount of coal of the 4 coal regions, but it is primarily subbituminous in rank. The highest quality coal is the bituminous and coking coal of the Trinidad Field of the Raton Basin. The South Park and Cañon City Coal Regions have very small to no federal coal resources.

The following Table 16 summarizes the development potential of coal in the four coal regions with the RGFO Planning Area. As previously discussed, development potential is related to many factors from coal quality to market demand, so this table is intended to provide the main factors contributing to development potential not an exhaustive list.

Coal Region	Coal Type or Coal Field	Development Potential	Reasons
Denver	Laramie coal	low	Low rank (subbituminous coal; variable heating value) Thin and lenticular beds (shale/sandstone partings) Urbanization (metropolitan and suburban land use) Extensive natural gas development in basin Competition with thick, high quality Colorado/Wyoming coal Non-contiguous patchwork of federal coal estate (no large tracts) Lack of transportation or mining infrastructure Lack of market for this low quality coal
	Lignite	low	Low heating value and high ash and moisture content Kaolinite clay partings Suburban and rural residential land use development Lack of market for this low quality coal
Raton Mesa	Walsenburg Field	low	Extensive igneous intrusions Thin and lenticular beds (shale/sandstone partings) Thick overburden Remote location and rugged terrain Lack of railroad, transportation and mining infrastructure Lack of market for this quality of coal
	Trinidad Field	low/moderate	Lack of domestic market demand for metallurgical coal Low international market demand for metallurgical coal Distance from international metallurgical market Competition with Appalachian metallurgical coal Lack of complete rail line or slurry pipeline High cost of underground mining of thin/lenticular beds Extensive natural gas development in basin
Cañon City	Cañon City	none	No current federal coal ownership
South Park	South Park	low	Complex geologic setting (faults, folding, steep dip, lenticular) Deep alluvial overburden, shaly/sandstone partings, thin beds Low rank and quality (subbituminous, deep weathering) No mining in over 100 years Lack of rail line, transportation or mining infrastructure Remote mountainous location Lack of market for this low quality coal

Table 16. Summary of RGFO Federal Coal Development Potential

In summary, until metallurgical coal prices improve significantly, fuel for local powerplants and gasification plants have the greatest potential for the Raton Mesa Coal Region, and lesser so for the Denver and Cañon City Coal Regions. The low sulfur coal in all three basins increases their potential use as a clean and compliant to super-compliant coal in the near future; however, competition with natural gas for power generation has suppressed the demand for all steam coal. There is virtually no potential for commercial coal development in the South Park Coal Region.

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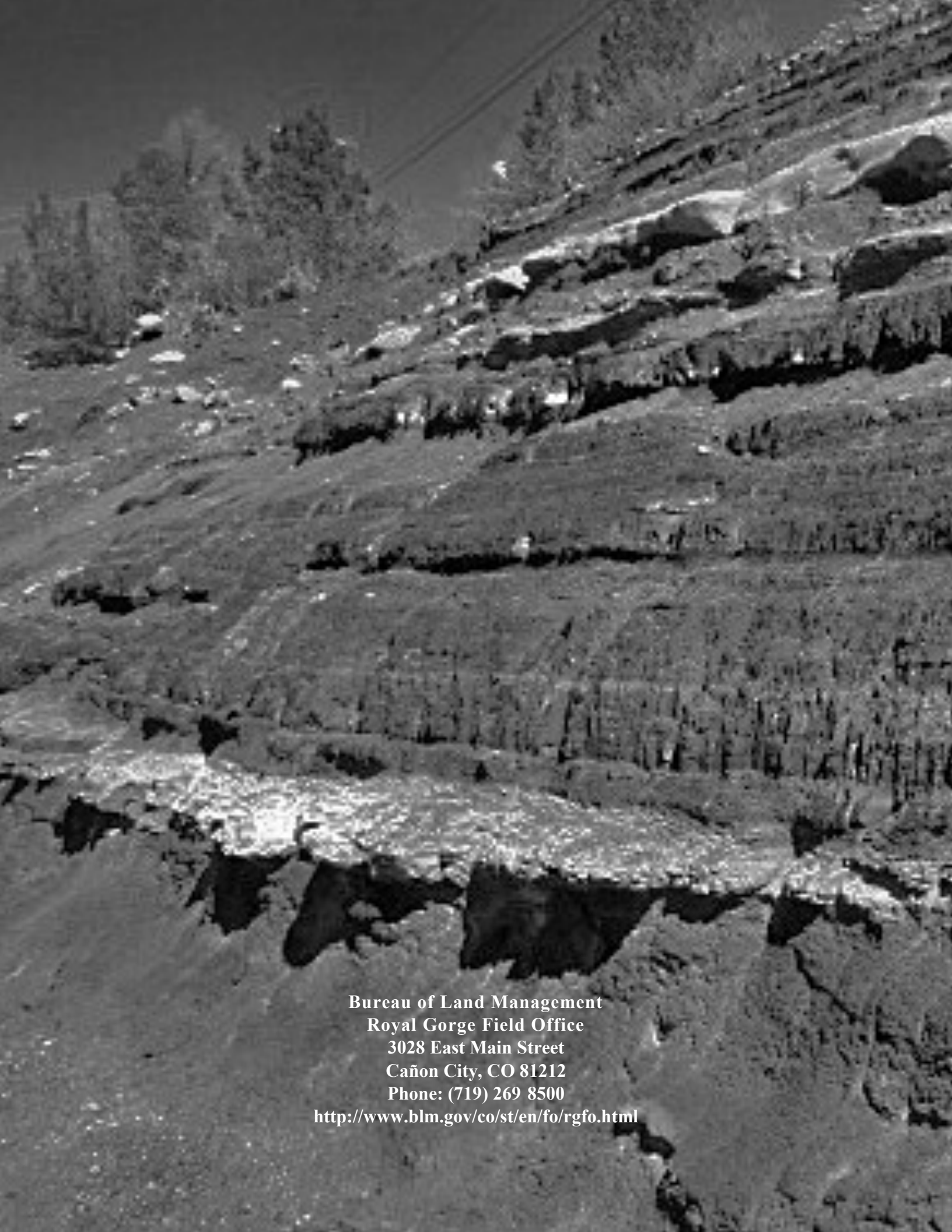

Bureau of Land Management
Royal Gorge Field Office
3028 East Main Street
Cañon City, CO 81212
Phone: (719) 269 8500
http://www.blm.gov/co/st/en/fo/rgfo.html