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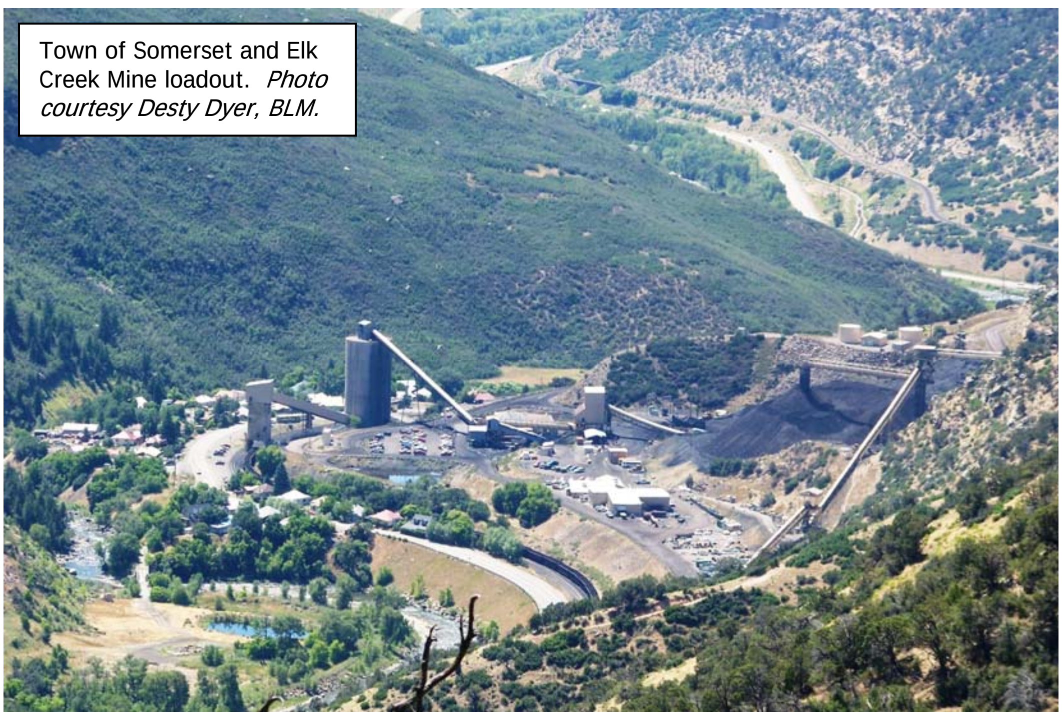
Bureau of Land Management
Uncompahgre Field Office, Colorado

Resource Management Plan Revision and Environmental Impact Statement

COAL RESOURCE AND DEVELOPMENT POTENTIAL REPORT

APRIL 2010



Town of Somerset and Elk Creek Mine loadout. *Photo courtesy Desty Dyer, BLM.*

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ACRONYMNS

BLM	Bureau of Land Management
Btu	British Thermal Unit
FBC	Fluidized Bed Combustion
LDx	lower Dakota x
RMP	Resource Management Plan
UD1	upper Dakota 1
UFO	Uncompahgre Field Office
US	United States
USFS	United States Forest Service
USGS	United States Geological Survey

I. Introduction

Purpose and Scope

The goal of this report is to summarize the known coal resources for the United States (US) Bureau of Land Management (BLM) Uncompahgre Field Office (UFO) planning area, and to assess the geographic areas where potential coal resource development may occur in the next 20 years in support of the UFO Resource Management Plan (RMP) process. This report includes current 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 Uncompahgre RMP planning area with coal development potential for the 20-year time period.

Acknowledgments

Throughout the preparation of this Coal Resource and Development Potential report, the primary author, Laurie Brandt of Buckhorn Geotech, interacted with geologists and coal mining specialists from the BLM, the Colorado Geological Survey, the US Forest Service (USFS), and the US Geological Survey (USGS), who provided input on coal resource data and activity forecasts. Much of the specific coal resource information for the Grand Mesa and Somerset coal fields came directly from two sources: 1) the 2006 Grand Mesa, Uncompahgre, and Gunnison National Forests Coal Resource and Development Potential report (USFS 2006); and 2) the USGS report prepared for the Grand Mesa, Uncompahgre, and Gunnison National Forests entitled, "Coal Resources and Coal Resource Potential" (Hettinger et al. 2004), which is Chapter M of USFS Bulletin 2213 (Bankey 2004). Permission was granted by Ryan Taylor (USFS) to use the structure and content, as needed, of the Grand Mesa, Uncompahgre, and Gunnison National Forests Coal Resource and Development Potential report, of which he was a primary author (USFS 2006). The USGS Professional Paper 1625-B (Kirschbaum et al. 2000), which studied coal deposits of the Colorado Plateau, was also an invaluable resource.

Electronic data for map production was supplied by Mark Kirschbaum (USGS), Chris Carroll (Colorado Geological Survey), and David Sinton (BLM), and on various disc and online sources listed in Section XIII, References. Most maps were produced by David Sinton (BLM) unless otherwise noted. George O'Hara of Western Fuels Association provided valuable information on the Nucla-Naturita coal field, Dakota coal, and coal industry standards. Regarding the Somerset and Grand Mesa coal fields and Mesaverde coal, the following coal industry representatives also provided valuable information: Steve Weist (Oxbow Mining, LLC), James Kiger (Oxbow Mining, LLC), Wendell Koontz (Mountain Coal Company), and Joe Brinton (Bowie Resources).

Uncompahgre RMP Planning Area

The Uncompahgre RMP planning area encompasses 675,677 acres of public (BLM-administered) land in six Colorado counties: Montrose, Delta, Mesa, Gunnison, Ouray and San Miguel (Figure 1). It excludes the Gunnison Gorge and Dominguez-Escalante National Conservation Areas. The planning area includes 2.2 million acres of federal (subsurface) mineral estate, including coal (Table 1). This report considers the coal resource underlying all lands identified in Table 1, including under all BLM-administered surface lands, as well as the federal (BLM) minerals under other surface ownership (such as USFS, private, or State lands).

Table 1. Mineral Estate in the Planning Area

Acres of BLM Surface with Federal Minerals	669,309
Acres of Federal Minerals under Other Federal Surface	1,270,401
Acres of Federal Minerals under Private, State or City Lands	294,952
Total Acres of Federal Minerals	2,234,662

The UFO currently manages several active federal coal leases related to three coal mines in the North Fork Valley near Paonia. The Bowie #2, West Elk and Elk Creek mines are actively producing underground (longwall, continuous) coal mines with a combined annual production of 13,950,859 tons in 2008 and 11,801,437 tons in 2009 (Colorado Division of Recalmation Mining and Safety 2010b). A fourth active mine within the planning area, the New Horizon Mine located near Nucla, is strip mining coal from privately owned mineral estate. Annual production from the New Horizon Mine in 2008 and 2009 was 403,230 and 373,758 tons, respectively (Colorado Division of Recalmation Mining and Safety 2010b). The four mines in the planning area produced 44.4% of the coal in Colorado in 2008 and 42.6% of the coal in 2009.

A comprehensive coal resource and development potential report has not been completed to date for the Uncompahgre RMP planning area. A Known Recoverable Coal Resource Area (KRCRA) map was created by the USGS in the 1970s, but there is no associated report or other documentation (Lewis 2010). This map had been used for management of coal resources in the planning area, as documented in the San Juan/San Miguel and Uncompahgre Basin RMPs and Environmental Impact Statements (BLM 1984, 1988). This report has been written to assist in evaluating areas with coal lease potential under the revised RMP for the planning area.

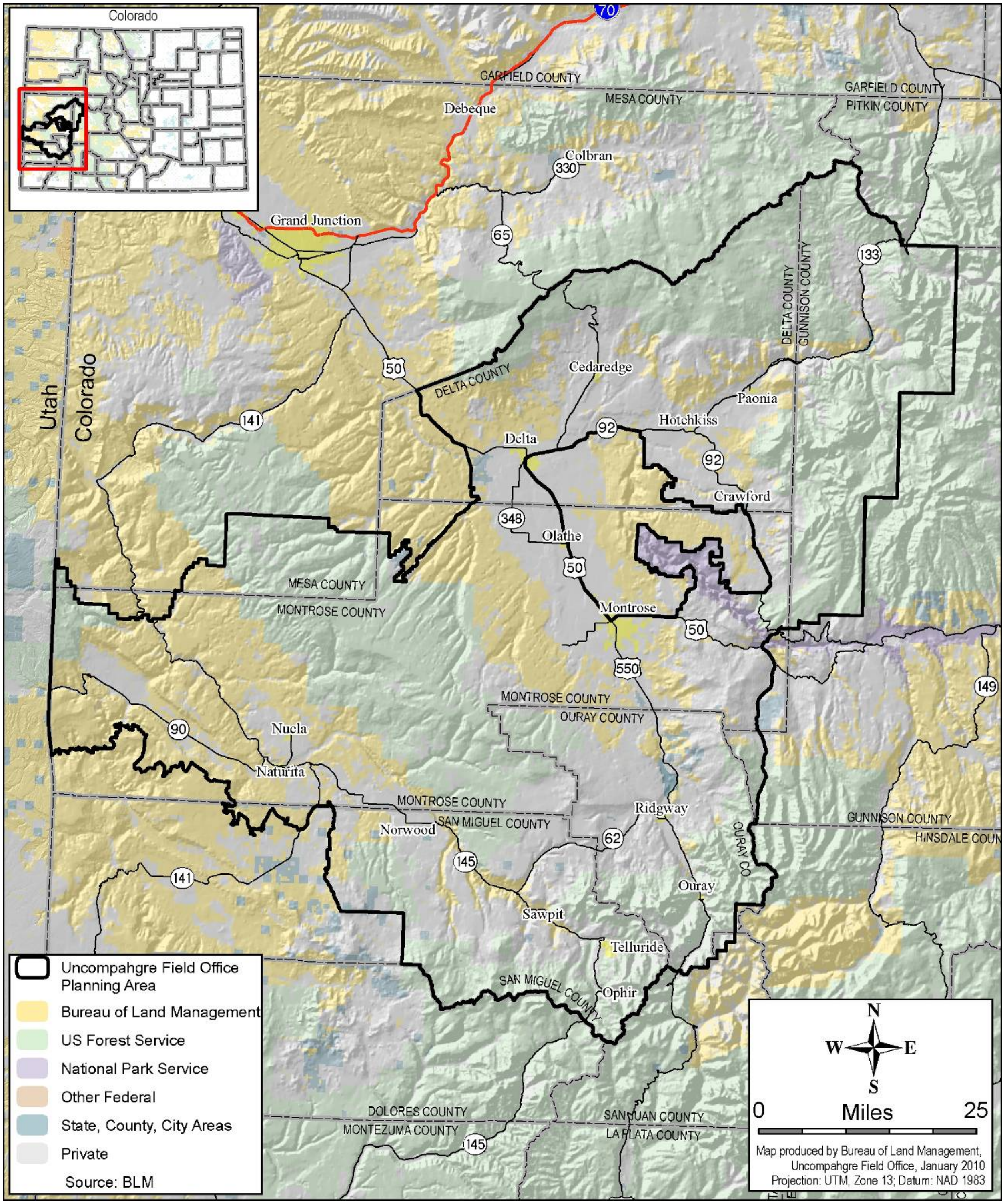


Figure 1. Uncompahgre Planning Area

II. Geologic Setting/Coal Geology

The planning area contains several major structural features that contain and control coal resources, such as the Piceance Basin, Uncompahgre Uplift, and San Juan Volcanic Field (Figure 2). Most of the rocks underlying the planning area are Mesozoic Era in age (Triassic, Jurassic and Cretaceous Periods), with smaller areas of Cenozoic Era aged rocks (Tertiary and Quaternary Periods, also known as Paleogene and Neogene Periods), and minor areas of older rocks (Paleozoic Era and Precambrian Eon) (Figure 3). Coal resources in the planning area are found primarily in the Upper Cretaceous Dakota Formation, Fruitland Formation, and Mesaverde Formation/Group (Figure 4). These rock units were deposited in continental and nearshore marine settings along the western margin of an ancient interior seaway, the Cretaceous Sea.

The Dakota Sandstone has a wide distribution throughout the planning area and is the caprock associated with the Uncompahgre Uplift. The Mesaverde Formation and Mesaverde Group are located the northern portion of the planning area in an east-west band near the base of Grand Mesa. This area is at the southern end of the Piceance Basin. The Fruitland Formation is confined to an isolated area along Cimarron Ridge southeast of Montrose. This area has been impacted by both the Sawatch/Gunnison Uplifts and the San Juan Volcanic Field, resulting in extensive faulting and disruption of the coal seams. Figure 2 shows the major structural features of the region, Figure 3 is the general geology of the planning area, Figure 4 shows the locations of coal-bearing formations, and Table 2 provides information on stratigraphic position, thickness, and a brief description of the Upper Cretaceous and coal-bearing rock units within the planning area.

The Dakota Formation consists of conglomerate, sandstone, mudstone, carbonaceous shale, and coal deposited in alluvial and coastal plain settings during the initial incursion of the Western Interior seaway during the Cenomanian Age of the Cretaceous Period (98 to 93 million years ago). The Dakota Formation is about 30 to 200 feet thick (Young 1960) and is overlain by the Mancos Shale. The Mancos Shale, which is barren of coal, consists of about 4,000 to 5,000 feet of material deposited in an offshore marine environment that persisted from the Cenomanian through Campanian in the study area (93 to 71 million years ago), when the shoreline was located in Utah. The Mesaverde Formation was formed as the shoreline moved back into the area during the late Campanian (83 to 71 million years ago). In the southern part of the Piceance Basin within the planning area, about 2,100 to 5,600 feet of strata has been assigned to the Mesaverde Group and Mesaverde Formation. The Mesaverde consists of sandstone, mudstone, carbonaceous shale, and coal deposited in a complex system of continental, coastal plain, and shoreface environments. The Fruitland Formation has a similar environment of deposition and is essentially contemporaneous with the Mesaverde Formation (Haun and Weimer 1960). In the Cimarron Ridge area near the southeast edge of the planning area, about 200 feet of Upper Cretaceous coal-bearing strata is assigned to the Fruitland Formation (Dickinson 1987a, 1987b, 1988; Hornbaker et al. 1976).

Methane (CH_4) is a natural component of coal stored in the micropore structure of coal seams, and is typically referred to as coalbed methane when produced in association with coal (Colorado Geological Survey 2000). It is a highly explosive gas and is considered a hazard in coal mining. As a safety precaution, ventilation (degasification) systems are required in mines that have detectable levels of methane, but the Mine Safety and Health Administration currently does not allow for flaring of methane from mines. Although coalbed methane is both a hazard and a potential resource, the quantification, management and/or mitigation of methane gas is beyond the scope of this coal resource assessment.

Table 2. Summary of Cretaceous Strata in the Planning Area

Age	Group or Formation	Thickness (feet)	Description
Late Creta-ceous	Mesaverde Group and Mesaverde Formation	2,150–5,600	Sandstone, mudstone, siltstone, carbonaceous shale, and coal. Upper Ohio Creek Member is barren of coal and consists of fine- to coarse-grained sandstone and conglomerate as it grades into the overlying Tertiary Wasatch Formation with lenticular, interbedded mudstone and shale. Coal-bearing member contains 6 to 8 coal beds and zones in the Bowie Shale and Paonia Shale Members. Basal unit is massive Rollins Sandstone Member that overlies the Mancos Shale. Sandstone is very fine grained to medium grained, and locally coarse grained. Cozzette Member (sandstone and siltstone) locally intertongues between Rollins Sandstone and Mancos Shale. The Mesaverde Group/Formation underlies the Grand Mesa and is exposed in the Grand Mesa and Somerset coal fields within the Uncompahgre RMP planning area.
	and		
	Fruitland Formation	200	White to yellow fine-grained sandstone interbedded with subbituminous coal, brown carbonaceous shale, and olive to black shale. The Fruitland Formation is present as isolated exposures in the Tongue Mesa coal field within the planning area.
	Mancos Shale	4,000–5,000 (maximum)	Dark gray, olive to black shale with minor sandstone and siltstone; includes thin lenses of limestone, sandy limestone, and limey shale. The Mancos intertongues with the lower part of the Mesaverde and Fruitland Formations. It does not contain coal. Mancos Shale is extensive throughout the planning area, but has been eroded from the upper surface of the Uncompahgre Plateau in the western half of the planning area.
	Dakota Sandstone	30–200	Light gray and tan, fine- to coarse-grained sandstone or quartzite; minor interbeds of dark gray and carbonaceous shale, shaly sandstone, conglomeratic sandstone, and up to three thin and lenticular beds of coal. Massive sandstone in upper portion of formation forms caprock of Uncompahgre Plateau and mesas west of US Highway 550.

Source: modified from Hettinger et al. 2004; Dunrud 1989

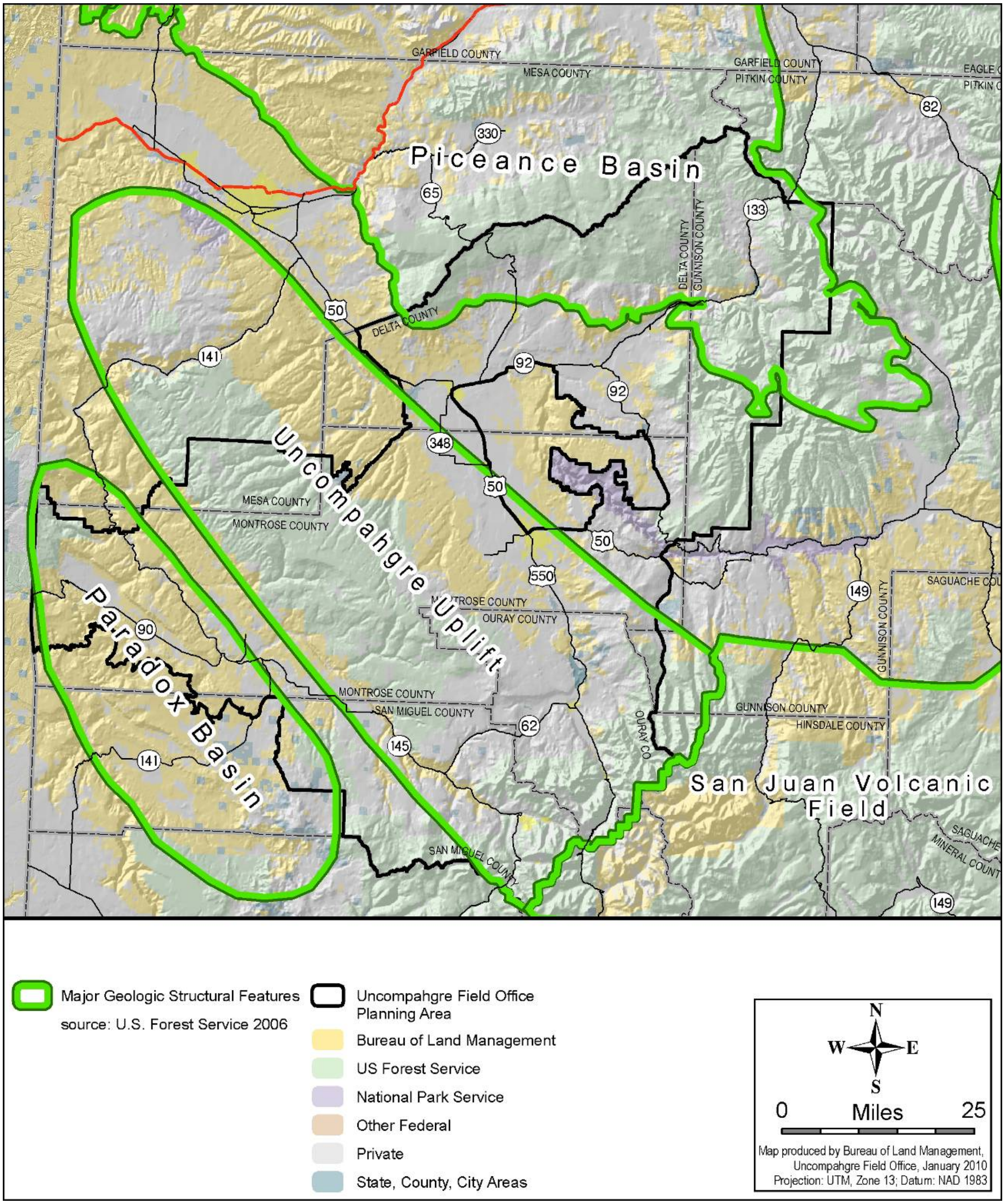


Figure 2. Location of Major Geologic Structural Features
Source: USFS 2006; Hettinger et al. 2004

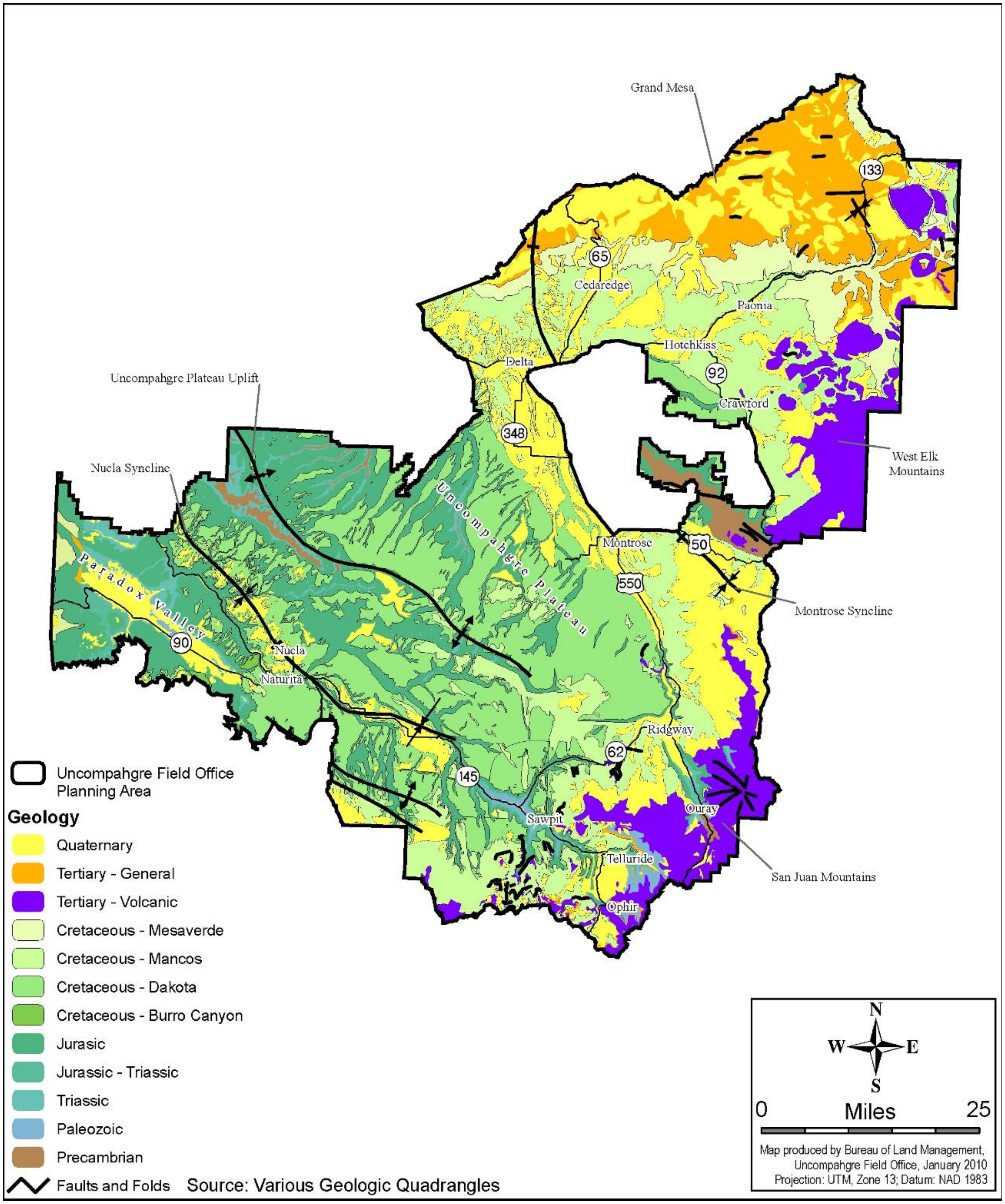


Figure 3. General Geology of the Planning Area

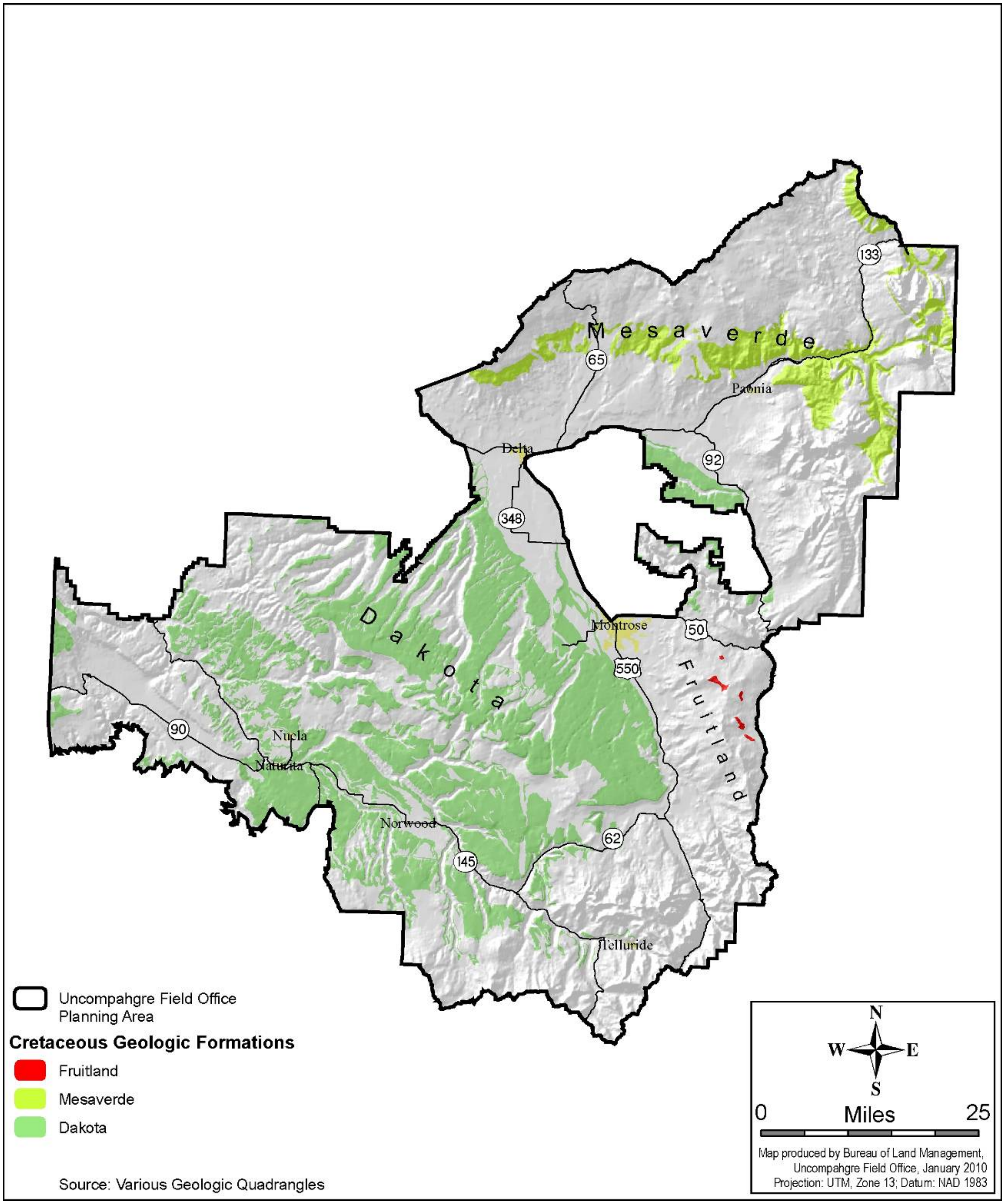


Figure 4. Coal-bearing Geologic Formations in the Planning Area

III. Coal Regions and Coal Fields

The planning area contains two coal regions, the Uinta coal region that is associated with the Piceance Basin, and the San Juan River coal region associated with the Colorado Plateau physiographic province (Figure 5). Within or adjacent to the planning area are seven coal fields within these coal regions (Figure 5). The planning area includes the Grand Mesa and Somerset coal fields, which are within the Uinta coal region, and the Tongue Mesa and Nucla-Naturita coal fields, which are within the San Juan River coal region. Only the Somerset and Nucla-Naturita coal fields are currently being mined. Located in close proximity to the planning area are the Book Cliffs coal field to the northwest, the Carbondale coal field to the northeast, and the Crested Butte coal field to the east (Figure 5). The Carbondale coal field extends into the northeast corner of the planning area. Where this coal field is not located in the Raggeds Wilderness, it has been mostly mined out; access to the coal outcrop in this region is outside the planning area and within an area where the surface is mostly managed by the USFS (Dyer 2010a). Consequently, the coal resource in this area is either outside the planning area or inaccessible due to wilderness status. Therefore, the coal resource potential for the Carbondale coal field is not further analyzed in this report. The coal region and coal field boundaries are explained by Landis (1959), Hornbaker et al. (1976), Murray (1980a), and Carroll (2010). The general characteristics of each coal field within the planning area are discussed below.

Nucla-Naturita Coal Field

The Nucla-Naturita coal field is near the southwest corner of the Uncompahgre RMP planning area in the vicinity of the towns of Nucla and Naturita (Figure 5). The San Miguel River Canyon bisects the field into a northern and a southern lobe. Highway 145 also passes through the field, which is roughly 18 miles long and 4 to 12 miles wide. The field is mostly in Montrose County, but the southern edge extends into San Miguel County. The northern portion of the field (Figure 5) includes mesas called First Park (containing the town of Nucla), Second Park, and Third Park, progressing from southeast to the northwest. The southern portion of the field is mostly on the south side of the San Miguel River and extends south towards Dry Creek Basin along Naturita Ridge. Although not included in the Nucla-Naturita coal field, Wrights Mesa (the mesa containing Redvale and Norwood [Figure 4]) has had historic coal mining and has a similar geologic setting as the mesas around Nucla (Williams 1983).

Although there are 24 historic surface and underground coal mines in the Nucla-Naturita coal field, the only active coal mine is at the New Horizon Mine, operated by Western Fuels Association, and currently located on private land with private mineral estate. This is a strip mining operation that supplies coal by truck (because no rail line is available in this area) to the Nucla Station, a 100-megawatt power plant owned by Tri-State Generation & Transmission Association. This power plant is a Fluidized Bed Combustion (FBC) type plant that removes sulfur in the combustion process with the addition of limestone (Eakins 1986). Nitric oxides are also reduced due to the lower combustion temperature. Byproducts of this process include gypsum, lime, and other compounds in the fly ash. According to O'Hara (2009), these waste products are currently disposed of in cells south of Naturita on private land. The Nucla plant can burn lower-grade coals, requiring coal with a minimum of 8,000 British Thermal Units (Btu) per pound. Coals higher in sulfur, ash, and rock material can be more efficiently burned in this process, which would be otherwise too "dirty" for combustion in a conventional coal power plant (Eakins 1986).

Stratigraphy

The coals in the Nucla-Naturita coal field are in the Middle Carbonaceous Shale Member of the Dakota Sandstone Formation. The Upper and Lower Sandstone Members contain massive sandstone, while the Middle Carbonaceous Shale Member contains coal, carbonaceous shale, and siltstone. Coal beds within the Middle Member are lenticular, discontinuous, and difficult to correlate across the field (Speltz 1976). In the Nucla-Naturita area, however, there are three beds of mineable thickness ranging from 1 to 5 feet (Landis 1959). Due to the weak nature of Mancos Shale, most of it has been eroded from above the Dakota Sandstone. The Burro Canyon Formation, which underlies the Dakota Sandstone, is a massive sandstone and conglomerate that is often mapped as part of the lower member of the Dakota Sandstone. The rock types and thickness of formation within the coal field are as follows.

Stratigraphic Units	Depositional Environment	Rock Types	Thickness (feet)
Mancos Shale	Marine	Shale and mudstone with thin sandstone, limestone, and bentonite beds; barren	Remnant outliers
Dakota Sandstone	Coastal plain	Sandstone above and below middle coal member with three coal beds and interbedded carbonaceous shale and siltstone	330
Burro Canyon	Alluvial plain	Massive sandstone and conglomerate; barren	Not recorded

Source: Lee 1912; Eakins 1986; Speltz 1976; Kirschbaum and Biewick 2000

Within the Middle Carbonaceous Shale Member of the Dakota Sandstone Formation, there are three coal beds. In ascending order, they are the Drott #3 or Nucla Seam (Western Fuels Association nomenclature), which is 1 to 4 feet thick and lies at the base of this Middle Member; the Oberding #2 or lower Dakota x (LDx) coal seam (Western Fuels Association nomenclature), which is the main seam that ranges from 3 to 8 feet thick; and the #3 or upper Dakota 1 (UD1) coal seam (Western Fuels Association nomenclature), that is typically 1 to 3 feet thick (Landis 1959; Murray 1980a). This is typical of what is found at the New Horizon Mine (O'Hara 2009). Drill hole data obtained by the USGS in 1977 at Peabody Coal Company's Nucla Strip lease application on Second Park indicated the upper coal bed averaged 6.3 feet thick under 20 feet of overburden, there was 29 feet of interburden, and the lower seam was split by 2.5 feet of rock into a 1.4- to 1.9-foot seam and a 1- to 1.3-foot seam (Haines 1978). These variations in bed thickness when compared to the New Horizon Mine, which is on nearby First Park, show the lateral variability of the coal seams within the Dakota Formation in the Nucla-Naturita coal field.

Quality and Rank

The apparent rank of the coal (Figure 6) is high-volatile A to C bituminous (George 1937; Murray 1981; Eakins 1986) to low-volatile B bituminous (O'Hara 2009). According to O'Hara (2009), the middle LDx seam is the thickest seam with the highest quality (low sulfur and ash),

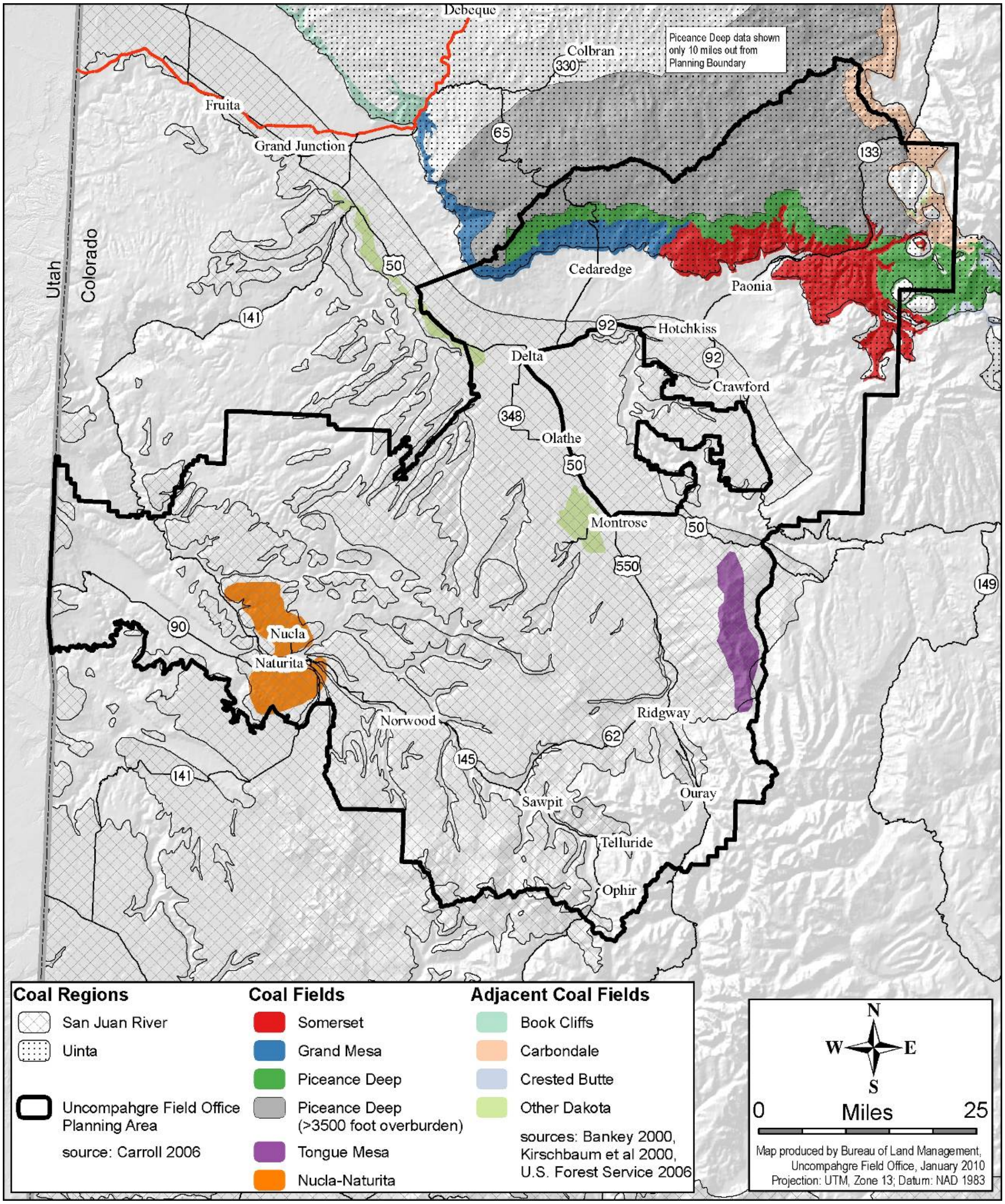


Figure 5. Location of Coal Regions and Coal Fields in the Planning Area

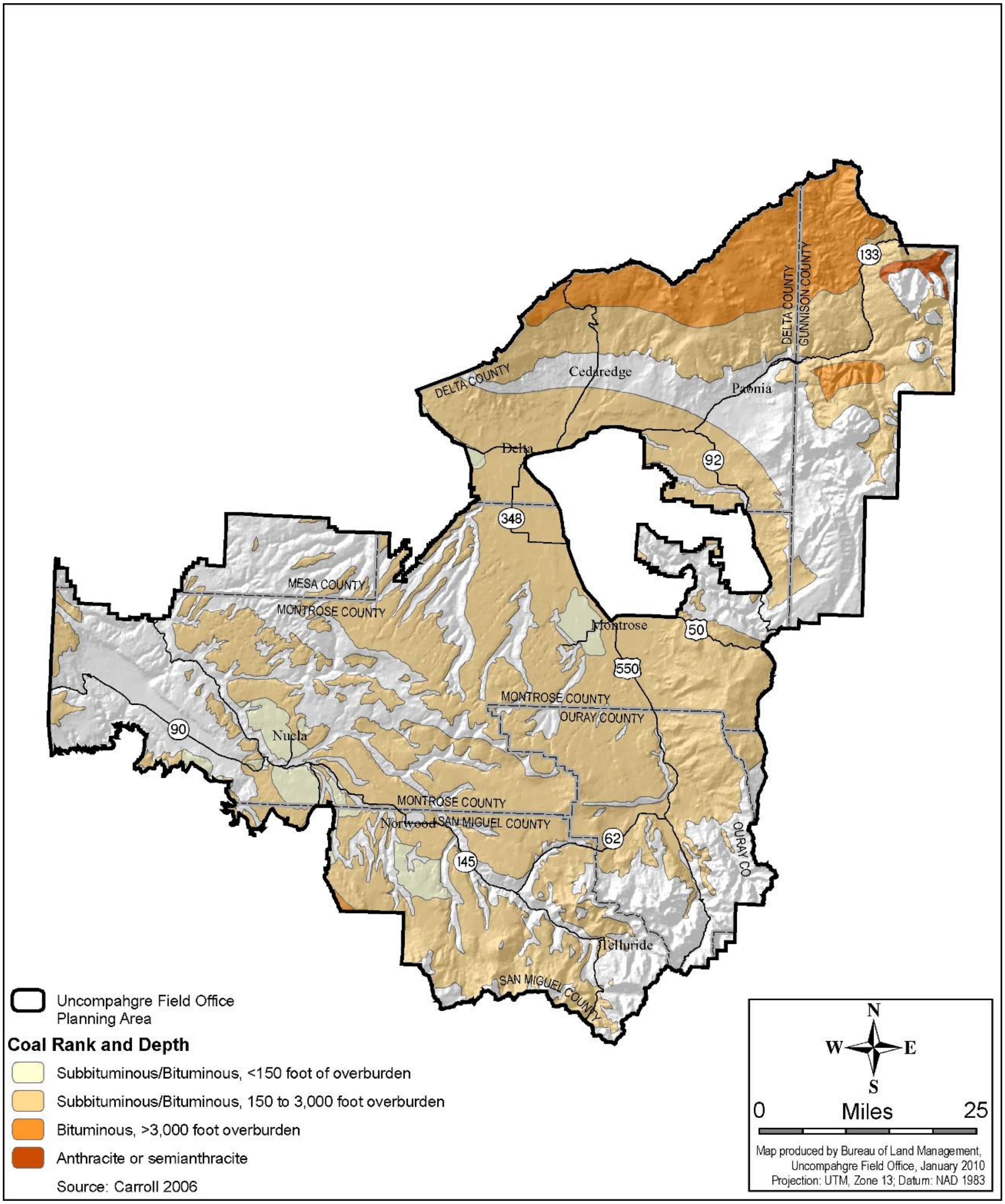


Figure 6. Coal Rank and Depth in the Planning Area

while the upper UD1 seam is often oxidized, producing a lower Btu coal, and it is higher in sulfur and ash. As a consequence, coal from these two seams is blended as they are fed into the FBC power plant at Nucla in order to maximize the capacity of the coal. The following table includes the coal quality data from a range of samples acquired from different mines and seams over the years within the Nucla-Naturita coal field.

Ash Content (percent)	Sulfur Content (percent)	Moisture content (percent)	Heating Value (Btu/pound)
6.1–12.8	0.5–1.1	2.5–13.5	10,010–13,380

Source: George 1937; Kirschbaum and Biewick 2000; Hettinger et al. 2000; Hornbaker et al. 1976; Murray 1981; Ambrose et al. 2001; Carroll 2010

The lenticular and discontinuous nature of Dakota coal in the Nucla-Naturita field, as well as the presence of partings (thin interbeds of impurities) and clastic dikes, has limited the quality and economic viability of this coal. In addition, thickness of overburden plays a role in coal quality and accessibility. If the overburden is too thin, the coal is oxidized and the Btu content is low. If the overburden is too thick and the seams are too thin, it is not cost-effective to strip the excess overburden to obtain coal from thin beds. According to O'Hara (2009), if the overburden thickness is less then 20 feet, the coal is too oxidized and wet (called "bug dust" by industry), but if it is greater than 100 to 120 feet, the coal is not economically feasible to extract. The optimum overburden thickness to effectively strip mine high-quality coal for the Western Fuels Association's New Horizon Mine is currently around 35 to 40 feet. O'Hara (2009) adds that the cost-effectiveness of strip mining is based on a "stripping ratio," which is the thickness of overburden divided by the thickness of coal expressed in cubic yards per ton. Optimum stripping ratios are on the order of 8:1 to 10:1; however, the maximum acceptable ratio is 20:1.

Coal quality tests performed during the 1977 drilling on Second Park, indicated an average Btu of 7,373 in the upper 6-foot coal seam and 9,667 to 11,546 in the lower 1.4- to 1.9-foot seams (Haines 1978). The upper seam was ranked as subbituminous C coal, while the lower split seams were ranked as high-volatile A bituminous coal.

Tongue Mesa Coal Field

The Tongue Mesa coal field is along Cimarron Ridge, a prominent ridge southeast of Montrose between the Uncompahgre River and Cimarron Creek (Figure 5). It extends from south of Cerro Summit (Highway 50) in the vicinity of Coal Hill, south along the Cimarron Ridge to Owl Creek Pass east of Ridgway. Most of the historic mining in this field was on the west side of Cimarron Ridge from Buckhorn Lakes south to the Lou Creek drainage, but no active mining has occurred since 1950. It is roughly 18 miles long from north to south and generally 2 to 3 miles wide. The field spans Montrose, Ouray, and Gunnison Counties.

Stratigraphy

The Fruitland Formation is the primary coal-bearing formation in the Tongue Mesa coal field. It is poorly consolidated, typically forming side slopes, and is exposed mostly in landslide scarps (Dickinson 1987a, 1987b). It is a white to yellowish-gray, fine-grained sandstone interbedded with subbituminous coal, brown carbonaceous shale, and green to black shale (Dickinson 1965, 1987b). The base of the formation, where it lies on the Pictured Cliffs Sandstone, is placed at the lowest coal bed. Below the Pictured Cliffs Sandstone is the Mancos Shale, a thick marine shale formation that does not contain coal. In the Tongue Mesa coal field, most of the Kirtland Shale, which overlies the coal-bearing Fruitland Formation, has been stripped off of the area by erosion. The rock types and thickness of the formations within the coal field are shown below.

Stratigraphic Units	Depositional Environment	Rock Types	Thickness (feet)
Kirtland Shale	Alluvial plain	Shale interbedded with sandstone, siltstone, carbonaceous shale; barren	1,000
Fruitland Formation	Coastal plain	Sandstone interbedded with coal, carbonaceous shale, and shale	200
Pictured Cliffs Sandstone	Nearshore marine	Massive sandstone interbedded with siltstone and shale; barren	50–250
Mancos Shale Formation	Marine	Shale and mudstone with thin sandstone, limestone, and bentonite beds; barren	3,000+

Source: Lee 1912; Dickinson 1988; Kirschbaum and Biewick 2000

The Fruitland Formation contains one extensive coal bed that ranges in thickness from 20 to 40 feet. The formation contains additional coal beds that are about 5 to 13 feet thick. The coal beds in the northern portion of the field are typically 3 feet thick, subbituminous, and bony (Dickinson 1965). “Bone” is impure coal. In the middle of the field, there is one coal bed 26 to 40 feet thick and three to five coal beds 5 to 13 feet thick (Dickinson 1987a, 1987b). In the southern end of the field, three abandoned coal mines reported coal seam thicknesses of 30 to 40 feet (Dickinson 1988).

Coal-bearing strata are located in the lower 200 feet of the Fruitland Formation (Murray 1981) and correlate with the Fruitland-Kirtland Formation of the San Juan Basin section (south of Durango, Colorado) and with the Paonia Shale section in the Grand Mesa area (Hornbaker et al. 1976). Early USGS geologic quadrangle mapping by Dickinson (1965) identified the coal-bearing units as belonging to the Fruitland Formation, which was carried into the more recent mapping (Dickinson 1987a, 1987b, 1988). However, others include the Tongue Mesa coal field as being in the Uinta Coal Region and consider the units to be the Mesaverde Formation (Hornbaker et al. 1976). The Cimarron Ridge area is an outlier of Upper Cretaceous age coal-bearing rocks capped and protected by Upper Cretaceous and early Tertiary volcanic and volcaniclastic rocks (Murray 1980a). Due to the proximity of the Tongue Mesa coal field to the Somerset and Grand Mesa coal fields, it is likely more closely associated with the stratigraphy and local variations of the Uinta Coal Region. For the purposes of this report, it is included in the San Juan River Coal Region.

Quality and Rank

The apparent rank of the coal (Figure 6) is high-volatile B subbituminous (George 1937; Murray, 1980a; Carroll 2010) and subbituminous C (Dickinson 1987a, 1987b, 1988). Some of the coal is reported to be considerably oxidized and bony (Hornbaker et al. 1976; Dickinson 1965; Murray 1980a). As with most Cretaceous coal in western Colorado, the coal is of high quality, with typically low ash and sulfur content and moderately high to high energy value, as seen in the following table, which includes a range of samples acquired from different mines and seams within the Tongue Mesa coal field.

Ash Content (percent)	Sulfur Content (percent)	Moisture content (percent)	Heating Value (Btu/pound)
6.7–8.4	0.5–0.9	14.2–16.0	9,350–10,220

Source: George 1937; Kirschbaum and Biewick 2000; Hettinger et al. 2000; Hornbaker et al. 1976; Murray 1981; Ambrose et al. 2001; Carroll 2010

Somerset Coal Field

The Somerset coal field is located on the lower, southeastern flank of Grand Mesa, extending from the east side of the Leroux Creek drainage (where it abuts the Somerset coal field to the west), past Paonia and Somerset, and east to drainages near Paonia Reservoir in the North Fork of the Gunnison Valley (Figure 5). Many historic mines are distributed throughout this field; currently there are three active mines: Bowie #2 Mine (operated by Bowie Resources), Elk Creek Mine (operated by Oxbow Mining, LLC), and West Elk Mine (operated by Mountain Coal Company). Highway 133 passes through the eastern end of this field. The field is roughly 38 miles long and 2 to 10 miles wide. Most of this field is in Delta County, with the eastern portion extending into Gunnison County.

Early work by Lee (1912) separated the Coal Creek district from the Somerset district; both were located in the Grand Mesa coal field. The Coal Creek district included the coal beds that were accessible from Coal Creek canyon south of Paonia Reservoir. These coal beds underlie Coal Creek Mesa to the west and Snowshoe Mesa to the east. At least four historic coal mines were located in this area (Carroll and Bauer 2002), but there is no recent mining, primarily due to the lack of a rail spur. Toenges et al. (1952) studied the coal quality, reserves, and coking properties of the Coal Creek district. Later work by Landis (1959) redefined the coal fields and districts in the area and combined the Coal Creek with the Somerset district, renaming it the Somerset coal field. The Grand Mesa district became the Grand Mesa coal field, and the region was renamed the Uinta Coal Region. Although some literature refers to the Coal Creek field or district, for the purposes of this report, it is included in the Somerset coal field (Figure 5).

Detailed studies of the Somerset coal field were performed by many authors including Dyni and Gaskill (1980), Eakins et al. (1998a, 1998b), George (1937), Hettinger et al. (2004), Landis (1959), Lee (1912), Schultz et al. (2000), Toenges (1949, 1952), and USFS (2006). In addition to the band of Mesaverde along the southern flank of Grand Mesa that is defined by the east-west upper northern portion of the Somerset coal field, there are extensive areas on the south side of the North Fork of the Gunnison River that have proven coal resource and are also within the Somerset coal field. These area include the Minnesota Creek basin (including the Dry Fork and Lion Mesa) east of Paonia (Toenges 1949), Coal Creek Mesa and east to Snowshoe Mesa (Toenges et al. 1952), and the area east of Jumbo Mountain where the Mountain Coal Company is operating the West Elk Mine.

Stratigraphy

The coals in the Somerset coal field are in the Paonia Shale and Bowie Shale Members of the Mesaverde Formation. The alluvial plain deposits of the Barren and Ohio Creek Members overlie the coal-bearing members. The Rollins Sandstone Member, a tan, massive sandstone unit, underlies the coal-bearing members and overlies the Mancos Shale Formation. The rock types and thickness of the formations within the coal field are shown below.

Stratigraphic Units	Depositional Environment	Rock Types	Thickness (feet)
Mesaverde Formation			
Ohio Creek Member	Alluvial plain	Interbedded sandstone (fine to coarse grained), mudstone, and shale	500–900
Barren Member	Alluvial plain	Interbedded fine-grained sandstone, mudstone, and shale; lenticular; some thin, noncommercial coal beds	750–1,000
Paonia Shale and Bowie Shale Member	Coastal plain	Interbedded sandstone, mudstone, shale, and siltstone with coal beds and zones as thick as 30 feet	250–650
Rollins Sandstone Member	Nearshore marine	Massive sandstone, finer at base with gradational contact with Mancos Shale	80–200
Mancos Shale Formation	Marine	Shale and mudstone with thin limestone beds	4,000–4,500

Source: Lee 1912; Dunrud 1989a, 1989b; Kirschbaum and Biewick 2000

According to Hornbaker et al. (1976), coals from the Bowie Shale Member are mined from beds ranging from 8.5 to 18 feet thick, and coals from the Paonia Shale Member are mined from beds ranging in thickness from 12 to 13 feet. Individual coal beds can reach a maximum thickness of 25 to 30 feet (Murray 1980a). The six major coal seams are named A through F in ascending order.

Quality and Rank

The apparent rank of the coal in the Somerset coal field (Figure 6) is high-volatile B and C bituminous (Carroll 2010; Hornbaker et al. 1976; Landis 1959). In the eastern portion of the field where the coal has been exposed to laccoliths and other intrusions, the rank of coal is marginal to premium high-volatile A and B bituminous, and some are of good coking quality (Goolsby et al. 1979). In 1977, four mines (Bear, Hawk's Nest #2 and #3, and Somerset) in the Somerset coal field produced coking coal (Murray 1980b). In several places in the southeastern part of the field, igneous intrusions have metamorphosed the coal to semi-anthracite, but this is a minor component of the overall coal and is included in reserve estimates as bituminous (Landis 1959). As with most Cretaceous coal in western Colorado, the coal is of high quality, with typically low ash and sulfur content and moderately high to high energy value, as shown in the following table, which includes a range of samples acquired from different mines and seams within the Somerset coal field. Because this is a large and active coal field, coal quality data were provided from a variety of sources due to the volume of available data.

Ash Content (percent)	Sulfur Content (percent)	Moisture content (percent)	Heating Value (Btu/pound)
2.0–13.9	0.3–0.9	2.3–22.4	8,160–13,900
Source: Hornbaker et al. 1976			
3.2–11.4	0.5–0.8	3.2–13.6	10,040–13,453
Source: Murray 1981; Ambrose et al. 2001; Carroll 2010			
2.4–29.9	0.3–3.2	2.3–10.7	8,160–14,380
Source: Kirschbaum and Biewick 2000; Hettinger et al. 2000, Murray et al. 1977; Toenges 1949, 1952			

Grand Mesa Coal Field

The Grand Mesa coal field is located as a narrow band on the lower flanks of Grand Mesa from the Leroux Creek drainage on the east (where it abuts the Somerset coal field), through the town of Cedaredge, and west and north to the town of Palisade, where it abuts the Book Cliffs coal field (Figure 5). Most of the historic mining in this field was centered west of Cedaredge (Highway 65), but no active mining has occurred since 1984. The field is roughly 55 miles long and 1 to 3 miles wide with a total of 96 square miles. The field spans Delta and Mesa Counties.

Stratigraphy

The coals in the Grand Mesa coal field are in the Mt. Garfield Formation of the Mesaverde Group. The coal is found in the Paonia Shale and Bowie Shale Members. The Rollins Sandstone Member, which is a whitish, massive sandstone unit, underlies the coal-bearing members and overlies the Mancos Shale Formation, a marine shale and mudstone that forms the Adobe badlands on the lowest slopes of Grand Mesa. The rock types and thickness of the formations within the coal field are shown below.

Stratigraphic Units	Depositional Environment	Rock Types	Thickness (feet)
Mesaverde Group			
Undifferentiated	Alluvial plain	Sandstone and shale, barren	1,000
Paonia Shale Member	Coastal plain	Coal, carbonaceous shale, sandstone	400
Bowie Shale Member	Coastal plain	Major coal, carbonaceous shale, sandstone	400
Rollins Sandstone Member	Nearshore marine	Massive sandstone, shale, barren	100
Mancos Shale Formation	Marine	Shale and mudstone with thin bentonite beds	3,000+

Source: Lee 1912; Kirschbaum and Biewick 2000

Coal is present in a zone roughly 200 feet above the Rollins Sandstone Member (Kirschbaum and Biewick 2000). The six to eight coal beds are in the Bowie Shale and Paonia Shale Members of the Mesaverde Group and are named A through F in ascending order. Generally, only two or three of the seams are of mineable thickness (i.e., 4 to 14 feet thick) at any one locality, with the lowest seams the most persistent and productive (Hornbaker et al. 1976; Murray 1981). Review of isopach maps produced by Grand Mesa Coal Company for their Red Canyon Mine #1 and #2, located in the vicinity of Colby and Brimstone Corner (northwest of

Cedaredge), indicates coal thicknesses of 3.4 to 7.6 feet in the E seam (Grand Mesa Coal Company 1984). At the Red Canyon Mine #2, the D and E seams were the thickest, and the beds dip 5 to 6 degrees to the northwest.

Quality and Rank

The apparent rank of coal in the Grand Mesa coal field (Figure 6) grades from high-volatile C bituminous to subbituminous A (Hornbaker et al. 1976; Murray 1981). Lee (1912) indicated that the Grand Mesa coal field (known at that time as the Rollins District of the Grand Mesa coal field) produced coal that was typically subbituminous and had lower energy than the bituminous coal in the "Somerset District" to the east. As with most Cretaceous coal in western Colorado, the coal is of high quality, with typically low ash and sulfur content and moderately high energy value, as seen in the following table, which includes a range of samples acquired from different mines and seams within the Grand Mesa coal field.

Ash Content (percent)	Sulfur Content (percent)	Moisture content (percent)	Heating Value (Btu/pound)
2.1–23.3	0.4–2.2	9.8–20.0	8,300–13,490
Source: George 1937; Kirschbaum and Biewick 2000; Hettinger et al. 2000; Hornbaker et al. 1976; Murray 1981			
2.1–17.9	0.5–2.2	3.1–19.5	8,298–13,489

Source: Ambrose et al. 2001; Carroll 2010

IV. Coal Stratigraphy

Coal in the Uncompahgre RMP planning area is found in three Upper Cretaceous formations (Figure 7). From oldest to youngest, they are the Dakota Sandstone Formation, the Mesaverde Formation and Mesaverde Group, and the Fruitland Formation. The Mancos Shale Formation lies between the Dakota Sandstone and the Mesaverde/Fruitland Formations. The following generalized stratigraphic column shows the relationship of the three formations and the coal regions found in the planning area.

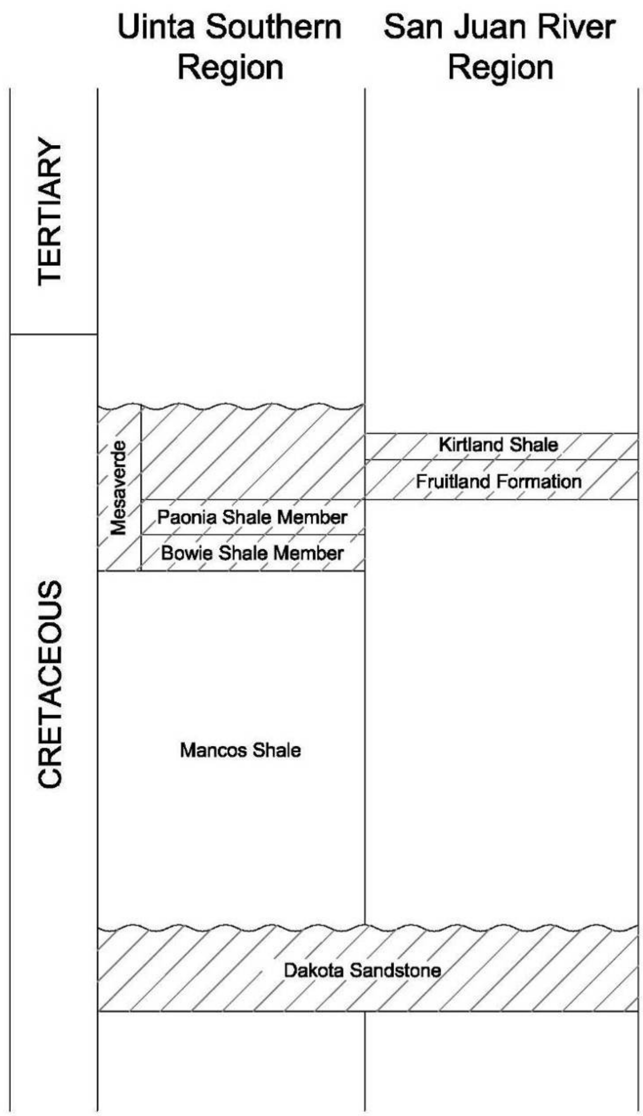


Figure 7. Stratigraphic Relationship of Coal-bearing Formations in Planning Area
Source: modified from Landis 1959

Dakota Sandstone

The Dakota Sandstone Formation underlies the entire planning area. The Dakota in the region is divided into an upper sandstone unit, a middle carbonaceous shale and coal-bearing unit, and a lower conglomeratic sandstone unit. Although coal beds can occur throughout the Dakota, the thicker seams are concentrated in the middle unit. The sandstone units are predominately fine to medium grained; light brown to dark gray; thin-bedded to massive; and generally cross-bedded, friable to quartzitic fluvial sandstone and conglomeratic sandstone (Eakins 1986; Williams 1983). The upper sandstone unit grades conformably and gradationally into the Mancos shale with alternating sandstone and carbonaceous shale beds. The lower sandstone unit disconformably overlies either the Brushy Basin Shale Member (green mudstones) of the Morrison Formation or the conglomeratic sandstones of the Burro Canyon Formation (Eakins 1986).

The thickness of the Dakota varies, but it is generally 150 to 200 feet thick. The Dakota is best exposed on canyon rims, where it forms one to two resistant ledges and a weak side slope composed of the weaker middle unit of carbonaceous shale and coal. The following photograph shows a typical outcrop of the Dakota Sandstone Formation.

Typical outcrop of Dakota Sandstone near Nucla, Colorado. Note the upper and lower resistant sandstone ledges. The coal is located in the 20- to 30-foot sloping hillside below the sandstone outcrop at the top of the photograph. Due to the weakness of the coal, it can only be seen darkening the surface soils. *Photo courtesy of Western Fuels Association.*

Coal beds in the Dakota Formation are generally thin, lenticular, and discontinuous, and contain numerous partings of sandstone, mudstone, carbonaceous shale, and shaly coal. Coal beds as thick as 7.7 feet are found locally in the Nucla-Naturita coal field, but they also contain many partings (Eakins 1986). The three coal seams, discussed in the Nucla-Naturita coal field section, are shown in Figure 8. The middle (LDx) seam is the thickest seam with the highest quality. The New Horizon Mine is currently strip mining the upper two seams (UD1 and LDx). The lowest (Nucla) seam is too deep and thin to be effectively strip mined. Eakins (1986), Haines (1978), and Speltz (1976) all discuss borehole logs, water well logs, and outcrop data that document the presence and thickness of coal seams within the Dakota Formation throughout the Uncompahre planning area. The photograph following the stratigraphic column shows the nature of Dakota coal on outcrop.

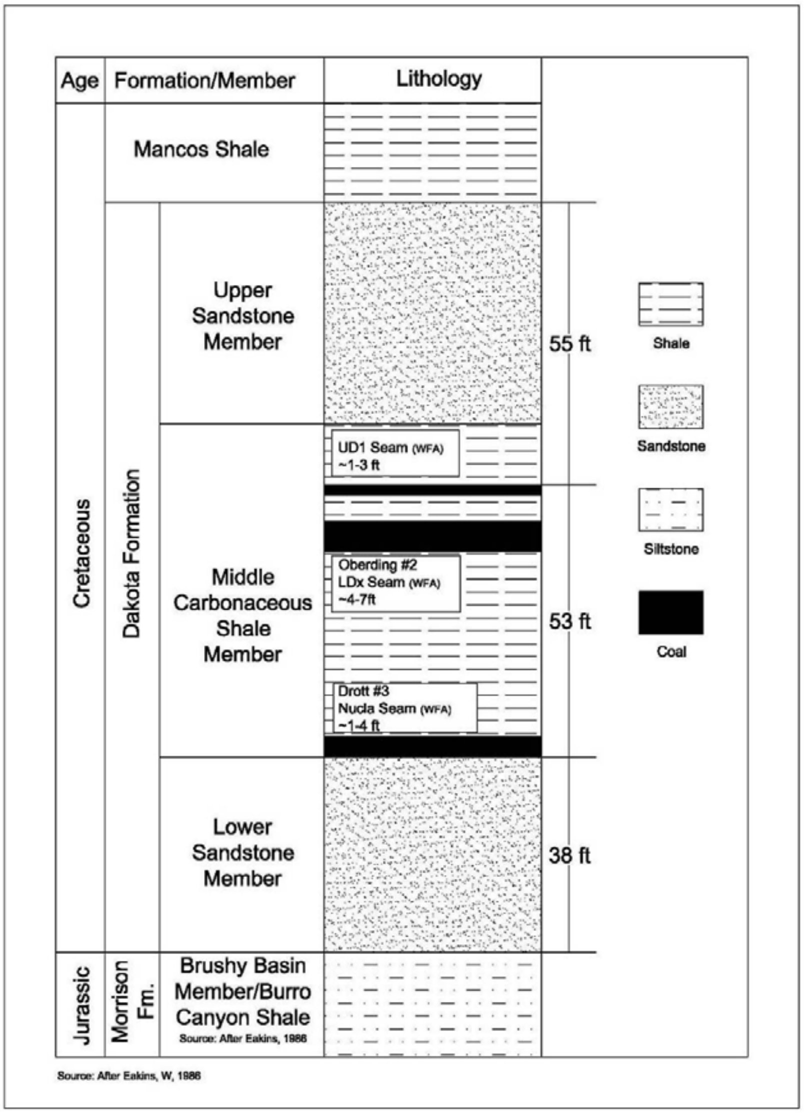


Figure 8. Stratigraphic Column of Dakota Sandstone in Nucla-Naturita Coal Field
Source: Western Fuels Association

Outcrop of Dakota coal near Nucla. Note the ledge-forming sandstone bed overlying the LDx coal seam that is roughly 4 to 5 feet thick in this outcrop. The coal is oxidized and bony. Note also the cross bedding in the sandstone and joints. *Photo courtesy Western Fuels Association.*

The Nucla-Naturita coal field sits astride the Nucla Syncline (Figure 3), a structural feature that strikes northwest and extends from east of Norwood to near Gateway, northwest of Nucla (Williams 1983). This trough-like feature sits between the Uncompahgre Plateau to the northeast and the Paradox Basin anticline to the southwest (Figure 2). This linear basin explains the trapping of Quaternary eolian (wind-blown) deposits on the mesas around Nucla, Redvale, and Norwood. Although the regional folding post-dated the coal deposition within the Dakota Sandstone, it has impacted the depth of coal and local dip of the beds. At the margins of the Paradox Basin anticline, for example, Dakota beds are steeply dipping and eroded along the lower flanks, with coal diving steeply underground. Along the axis of the syncline between Nucla and Norwood, the beds are almost level with the ground surface.

In addition to thin, lenticular, discontinuous, and low-quality coal with partings, clastic dikes are another characteristic of Dakota coal that adds to difficulty in mining this resource (O'Hara 2009). Clastic dikes are a specific type of sandstone parting that was emplaced or injected during the coalification process and at relatively shallow burial depths (Hardie 1999). The dike material migrates laterally and vertically for distances of over 500 feet in some places. Of the three types of clastic dikes, Hardie (1999) indicates that by far the most common type are joint-sourced dikes. These dikes follow fractures or joints created in the young, poorly consolidated floor and roof sediments that enclosed the peat beds and commonly penetrate entire coal seams. Dewatering of the overlying or underlying shale provides a medium to carry the clastic sands into the coal beds along joints. The joint-sourced dikes can be up to 10 feet thick and often intersect at right angles. Clastic dikes are hard, well-cemented, and often continuous through the coal seam. Consequently, they are problematic for mining, causing slowed production, increased wear on or damage to coal excavation equipment, and increased ash and impurities in the mined coal.

In the northeast portion of the planning area in the vicinity of Grand Mesa and the North Fork of the Gunnison River, the Dakota Sandstone is only exposed at the surface southwest of Highway 92, Crawford, and Hotchkiss (Figures 1 and 4). This is in the area of Fruitland and Scenic Mesa, where portions of the Smith Fork and North Fork have incised deep canyons, exposing the hard Dakota Sandstone caprock. This is an area with primarily private subsurface mineral estate. Coal in this area has not been exploited on a commercial level. Coal seams can be seen within the Dakota Sandstone Formation in the vicinity of Pleasure Park, located downstream of the town of Lazear in the North Fork of the Gunnison Canyon (within the Gunnison Gorge National Conservation Area), but this is excluded from the Uncompahgre RMP planning area. This indicates that coal may be present in the nearby Fruitland and Scenic Mesa areas, but the isolated federal subsurface rights would make mining the resource unviable.

Speltz (1976) discusses an area of Dakota coal called the Montrose Deposit. This area is shown on the west side of the city of Montrose on Figure 6. Based on six water well logs, there is 10 feet of coal from 90 to 97 feet deep and a “coal zone” from 121 to 156 feet deep. However, Speltz (1976) is careful to say that water well logs can be very unreliable indicators of coal presence, as the water well loggers often identify carbonaceous shale as coal, partings are not recorded, and they are not generally logged by a geologist or with coal identification in mind. Speltz (1976) adds that no other supporting data could be found and that even if coal is found in this area, he would not expect the coal beds to be of significant thickness or laterally extensive. Later work by Eakins (1986) in the Montrose area, which was based on water well and borehole logs, indicate typical seams of 0.4 to 1.1 feet at depths of 45 to 80 feet, with some very deep 5- to 7-foot seams at depths of greater than 460 feet. Many seams are split with multiple partings of 0.3 to 0.6 feet thick. Partings are interbeds of impurities such as carbonaceous shale, impure coal, pyrite, and mineral-rich layers such as sandstone and shale. The only mine in Dakota coal on the east side of the Uncompahgre Plateau was the Happy Canyon underground coal mine southwest of Montrose, which mined a 2.3-foot coal seam from 1923 to 1928 (Carroll and Bauer 2002). Other areas where Eakins (1986) evaluated logs and outcrops east of the Uncompahgre Plateau, he found 0.2- to 2-foot seams with partings from 70 to 95 feet west and northwest of Delta (Figure 6) and 0.5- to 1.7-foot seams with partings to 152 feet in the Ridgway/Colona area. Woodruff (1912) also evaluated the coal potential of the Dakota Formation west and northwest of Delta and found the coal to be in thin seams with partings, lenticular and limited in extent, high in ash and sulfur, and impure with poor combustion qualities.

Due to the Dakota Sandstone’s deep burial under Mancos Shale and the Mesaverde Formation in the Somerset and Grand Mesa coal fields, the Dakota Sandstone is not considered a coal resource in that region. According to the USFS (2006), most of the Dakota is buried at depths greater than 4,000 feet, based on its stratigraphic position below younger units within the Grand Mesa National Forest. Dakota coals crop out between the cities of Grand Junction and Delta, outside of the planning area, but work by Lee (1912) indicated only thin and poor quality coal in this area. The presence of Dakota coal in the planning area north and northeast of

Delta is unknown, but any coal that might be present is likely to be of similar poor quality, quantity, and character. Similarly, the Dakota Sandstone is deeply buried under the Mancos Shale southeast of Montrose in the Tongue Mesa coal field (Figures 4 and 5) and is not considered a coal resource in that region.

For much of the remainder of the planning area, west of Highway 50 and 550, the Dakota Sandstone is extensively exposed near the surface. The Dakota Sandstone forms the caprock of the Uncompahgre Plateau, the dominant structure of the western half of the planning area, and the caprock of many mesas west of Telluride and on the flanks of the Paradox Valley anticline. It is gently dipping where it is exposed along the flanks of the Uncompahgre Plateau and where it abuts the Tertiary San Juan volcanic field to the south and the Tertiary intrusions of the West Elk Mountains, east of Highways 50, 92, and 133 (Figure 3). Hogbacks and cuestas are formed by the Dakota where it is more steeply dipping, such as along salt anticlines in the Paradox Valley and other similar structures in the region (Eakins 1986). As shown on Figure 4, the Dakota is extensively exposed on the Uncompahgre Plateau and western mesas, but according to the USFS (2006), it is generally poorly exposed, concealed by thick vegetation, or covered by Quaternary land-slide deposits within the Uncompahgre National Forest. No published reports list precise thicknesses of Dakota coal in that forest; however, a 2.1-foot-thick coal bed was measured on the Uncompahgre Plateau about 12 miles northeast of the town of Nucla. Landis (1959) evaluated the Dakota coal, and his generalized maps and descriptions indicate that Dakota coal beds in the Uncompahgre National Forest are likely to be thin, impure, and discontinuous. However, minable reserves might be found locally. Although the Dakota Sandstone is exposed extensively throughout the western half of the planning area, the only area with proven coal resource is in the vicinity of the towns of Nucla and Naturita.

Fruitland Formation

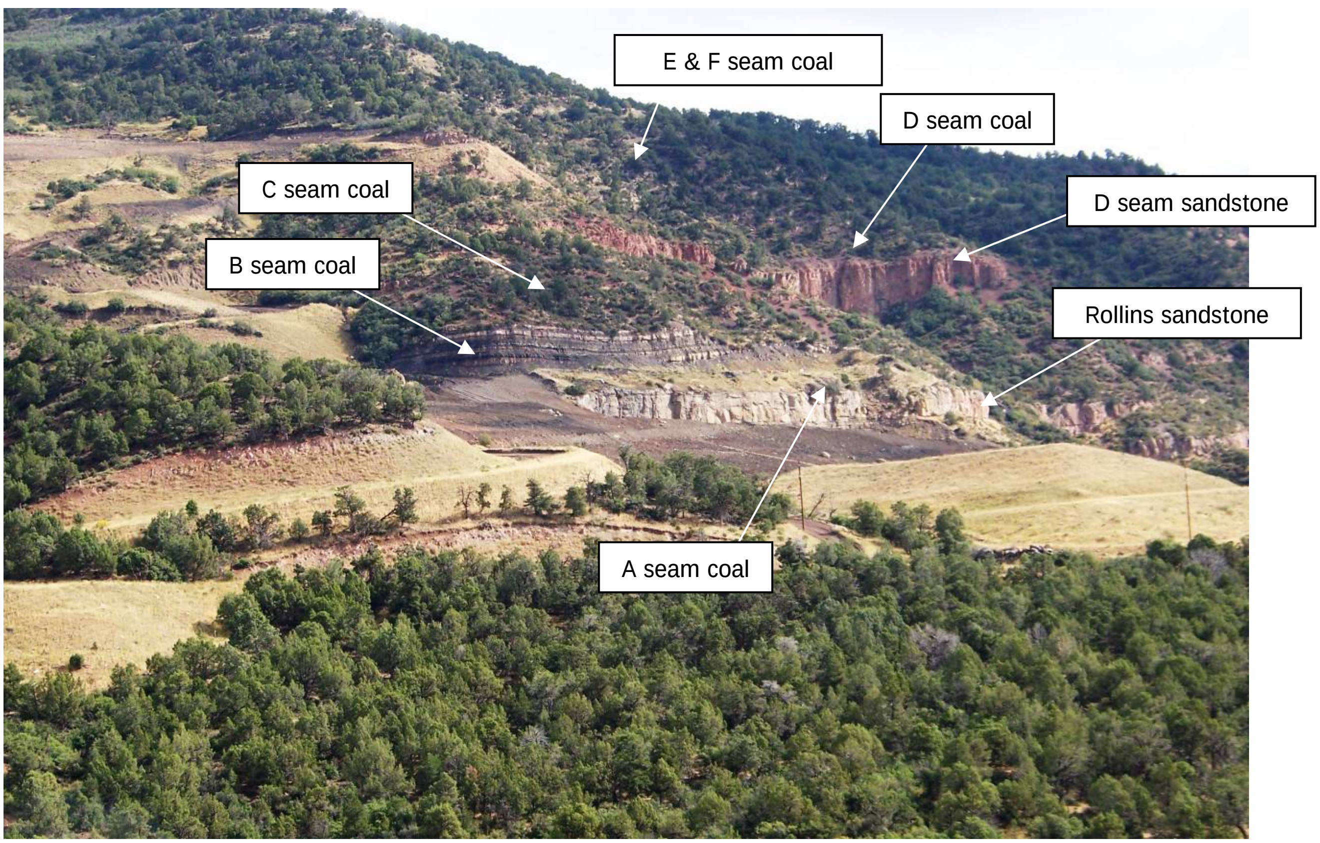
Tongue Mesa Coal Field (Montrose, Gunnison, and Ouray Counties)

Approximately 200 feet of coal-bearing strata is present at the Tongue Mesa coal field, an isolated erosional remnant of upper Cretaceous strata capped by late Cretaceous to early Tertiary volcanic rocks (Figures 2 and 3) (Murray 1981). The coal-bearing rocks were assigned to the Fruitland Formation by Hornbaker et al. (1976) and Dickinson (1965, 1987a, 1987b, 1988). They are part of a 900-foot-thick interval that was originally thought to be equivalent to the Mesaverde Formation by Landis (1959). These coal-bearing strata correlate to the Paonia Shale in the Grand Mesa area (Hornbaker et al. 1976). Both Landis (1959) and Dickinson (1965, 1987a, 1987b, 1988) described the coal-bearing interval as being concealed by heavy vegetation, landslides, talus, and glacial deposits. In his 1:24,000-scale USGS geologic quadrangles, Dickinson (1965, 1987a, 1987b, 1988) mapped the Fruitland Formation cropping out at only a few small and widely spaced localities, primarily at landslide scarps. Depth to the top of the formation ranges from 0 to 2,500 feet within the field.

The Fruitland Formation contains one principal and persistent coal seam that is 8 to 40 feet thick, referred to as the Cimarron or Lou Creek seam, which has been mined on both sides of the ridge and three to five stratigraphically higher coal seams that are about 5 to 13 feet thick (Hornbaker at al. 1976). The beds of coal are gently inclined and disrupted by numerous faults; however, the precise location and displacement of the faults cannot be determined from surface mapping because the area is extensively covered by landslide deposits.

Mesaverde Group and Mesaverde Formation

The Mesaverde has been assigned group status in the Book Cliffs, Grand Hogback, and Carbondale coal fields, but is considered a formation in the Crested Butte, Grand Mesa, and Somerset coal fields. For the purposes of this report, they will be considered one in the same. The Mesaverde is located in the southern Piceance Basin (Figure 2), which is in the northeastern portion of the planning area on the flanks of Grand Mesa (Figure 4) and is the source of coal mined in the Grand Mesa and Somerset coal fields (Figure 5). The Mesaverde is essentially divided into upper barren sandstone and shale members, the coal-bearing Paonia and Bowie Shale Members, and the lower Rollins Sandstone Member. The upper barren members consist of interbedded sandstone, mudstone, and shale. The basal Rollins Sandstone Member is a tan to very light gray, massive sandstone, and fine to very fine grained, becoming coarser and more quartzose in the upper part and grading into the Mancos Shale in the lower part (Dunrud 1989b). The Paonia and Bowie Shale Members contain six to eight coal seams or zones, named A through F in ascending order. These members range in thickness from 250 to 650 feet. Total thickness of the Mesaverde ranges from 2,000 to 2,700 feet. The following photograph is of a hillside near the town of Paonia where distinctive sandstone units and coal seams are visible due to disturbance of the hillside.



Exposure of Mesaverde Formation near Paonia, including the Rollins Sandstone Member at the base and the Paonia and Bowie Shale (coal-bearing) Members above it. This photographic was taken looking northeast from Steven's Gulch Road. The prominent coal seams near the middle of the photograph are of the B seam coal. *Photo courtesy Desty Dyer, BLM.*

As seen in the previous photograph, the more-resistant sandstone beds of the Mesaverde form distinctive vertical ledges or cliffs on the canyon walls above the North Fork of the Gunnison River Valley. The coal-bearing strata form vegetated sideslopes, and the coal is rarely seen cropping out due to its weak nature.

In the Grand Mesa and Somerset coal fields, the geologic literature and mining industry label the coal beds as six major units. These coal beds, as previously discussed and as labeled in the above photograph, are labeled A through F, with A being the lowest (oldest) bed in the stratigraphic section and F being the highest (youngest). The location of the six coal seams within the Mesaverde Formation are shown in the generalized stratigraphic column (Figure 9).

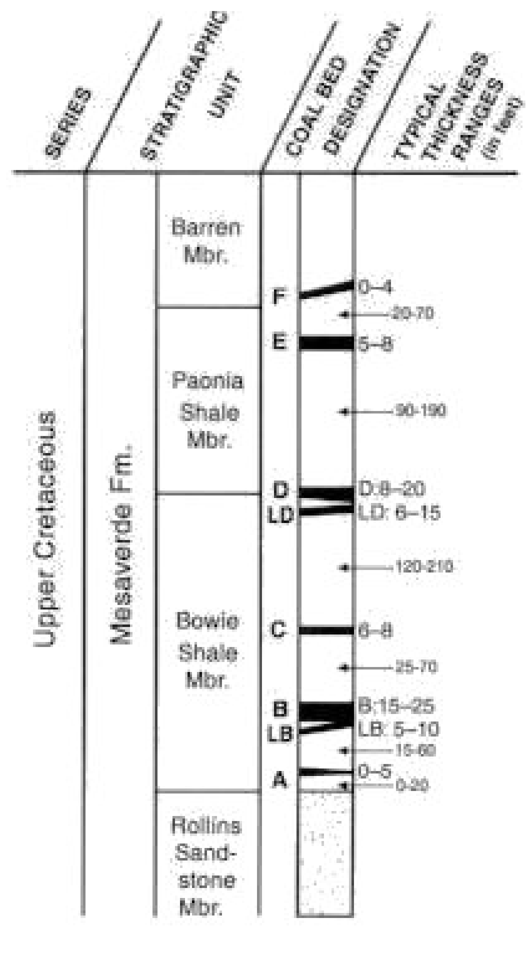


Figure 9. Generalized Stratigraphic Column Showing Coal Beds in the Somerset, Colorado, Area
Source: Rohrbacher et al. 2000

Studies of the Piceance Basin have further categorized these coal seams into groups that can be generally correlated across the basin and between coal fields. The A through F seams are within the Cameo-Fairfield coal group, which is further divided into three coal zones: Cameo-Wheeler Coal Zone (A, B, and C seams), South Canyon Coal Zone (D and E seams), and Coal Ridge Coal Zone (F seam), as shown in Figure 10. According to the USFS (2006), these correlations were made by examining cross-sections developed from drill holes throughout the region. They qualify this information considering that coal seams and interburden thickness can vary dramatically over a relatively short lateral extent, and the best correlations were made when comparing available non-proprietary data. This report conforms to the coal industry convention of referring to the seam names rather than the coal zones and the Mesaverde rather than the Cameo-Fairfield coal group. It is understood that when the report refers to the Mesaverde, it refers to the coal-bearing members above the Rollins Sandstone, and when referring to the Mesaverde Formation or Group, it refers to the entire column defining that formation.

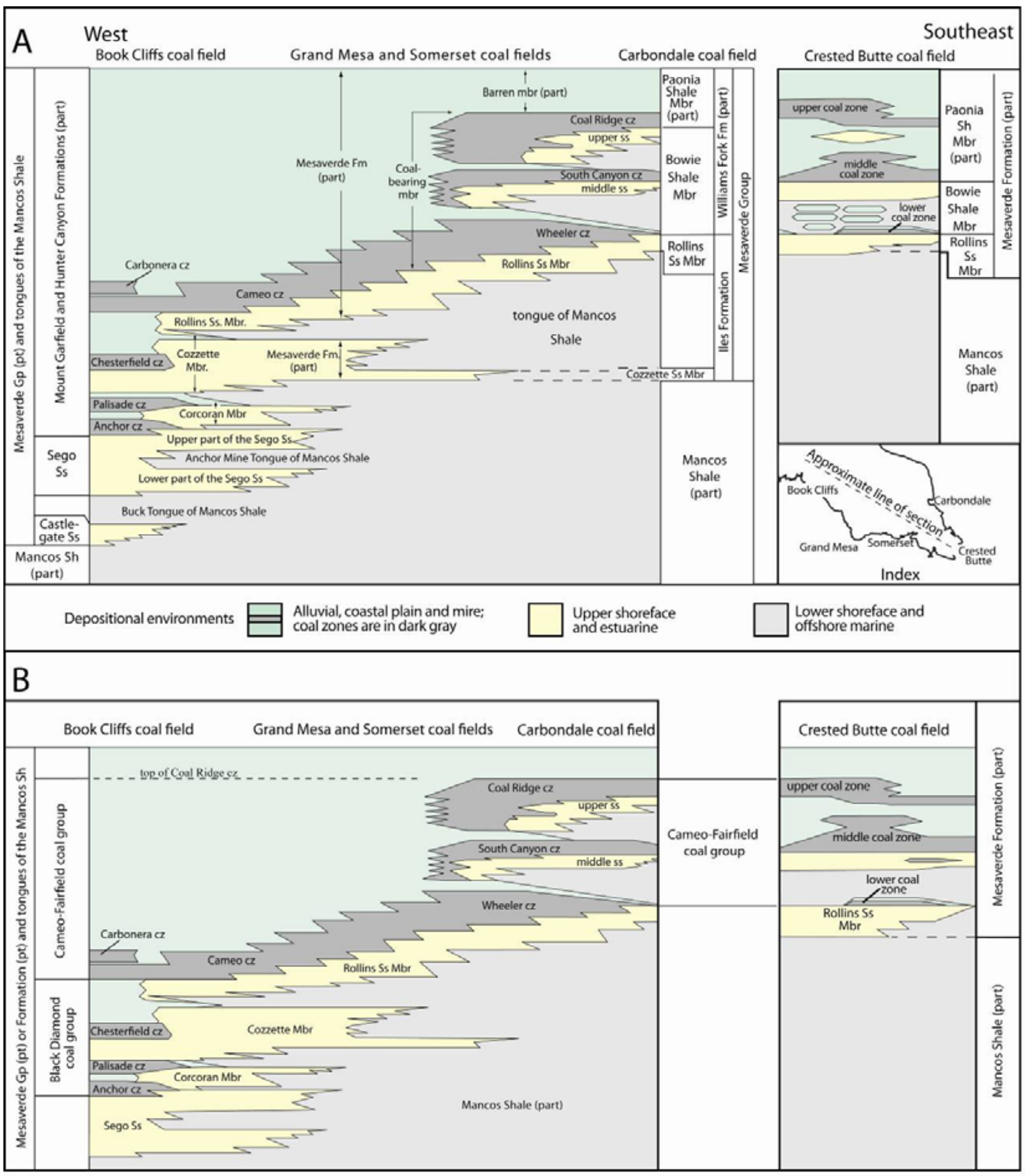


Figure 10. Stratigraphic Section of Mesaverde Group and Mesaverde Formation in the Southern Piceance Basin
Source: modified from Hettinger et al. 2000

The coal-bearing Mesaverde Group and Mesaverde Formation extend throughout the subsurface of the Piceance Basin and are exposed in the Book Cliffs, Carbondale, Crested Butte, Grand Hogback, Grand Mesa, and Somerset coal fields (Figure 5). In the Somerset coal field, the Mesaverde is generally dipping to the northeast. Consequently, the coal seams are getting deeper under Grand Mesa as elevations increase on the mesa. According to Carroll (2005), the coal beds at the West Elk Mine dip 3 to 5 degrees to the northeast, and the seams at both Bowie #2 and Elk Creek Mines dip 2 to 5 degrees to the northeast. Numerous mines have produced from these coal fields in the Southern Piceance Basin since the late 1800s. Some of the coal is also considered to be an important source for natural gas (Johnson 1989; Murray 1977). Methane is a hazard for underground mining due to its explosive potential, so gas is currently ventilated rather than recovered.

The coal-bearing portion of the Mesaverde (above the Rollins Sandstone Member) contains the thickest and most extensively mined coals in the Piceance Basin (Murray 1977). According to work by Hettinger et al. (2000) that focused on “Area 1,” which contained parts of the Grand Mesa and Gunnison National Forests, net coal in the Mesaverde ranges from about 50 to 97 feet in a 20- to 30-mile-wide belt that extends north to south across the central part of Area 1 (Figure 11). Area 1 includes the Grand Mesa and Somerset coal fields within the planning area. Net coal decreases to less than 50 feet in the remaining parts of Area 1. Coal distribution in the A through F coal seams is shown in a series of net coal isopach maps in Figures 12, 13, 14, and 15. Coal distribution and thickness for each of the seams, based on Hettinger et al. (2000), are discussed below.

A, B, and C Seams

The A, B, and C seams underlie a 925 square mile area that includes all parts of Area 1 west of longitude 107°15’ W. This coal zone overlies the Rollins Sandstone Member and is about 100 to 400 feet thick. The A, B, and C seams have approximately 5 to 80 feet of net coal, and net coal exceeds 50 feet throughout the central part of Area 1 (Figure 12). Near the southern boundary, in the Grand Mesa and Somerset coal fields, the A, B, and C seams have 10 to 70 feet of net coal in as many as 15 beds that are 1 to 30 feet thick.

D and E Seams

The D and E seams underlie a 530 square mile region in Area 1 (Figure 13). This coal zone overlies and intertongues with the middle sandstone of the Bowie Shale Member of the Williams Fork Formation (Figure 10). The coal zone is 1 to 200 feet thick and contains 1 to 30 feet of net coal. Net coal exceeds 20 feet along a 5- to 10-mile-wide belt that trends N. 20° W. throughout the central part of Area 1. In the Somerset coal field, the D and E seams have 15 to 35 feet of net coal in 2 to 5 beds that are 1 to 25 feet thick.

F Seam

The F seam overlies and intertongues with the upper sandstone in the Bowie Shale Member of the Williams Fork Formation (Figure 10). The F seam (Figure 14) occupies about the same area as the underlying D and E seams. The F seam coal zone is 100 to 400 feet thick near the line of longitude 107°15’ W., is less than 100 feet thick throughout most of its west half, and pinches out near the same line as the underlying D and E seams (Figure 13). The F seam generally has less than 10 feet of net coal, although a small area with about 20 feet of net coal is located near the Somerset coal field. In the Somerset coal field, the F seam contains 10 to 26 feet of net coal in 2 to 7 beds that are 1 to 10 feet thick.

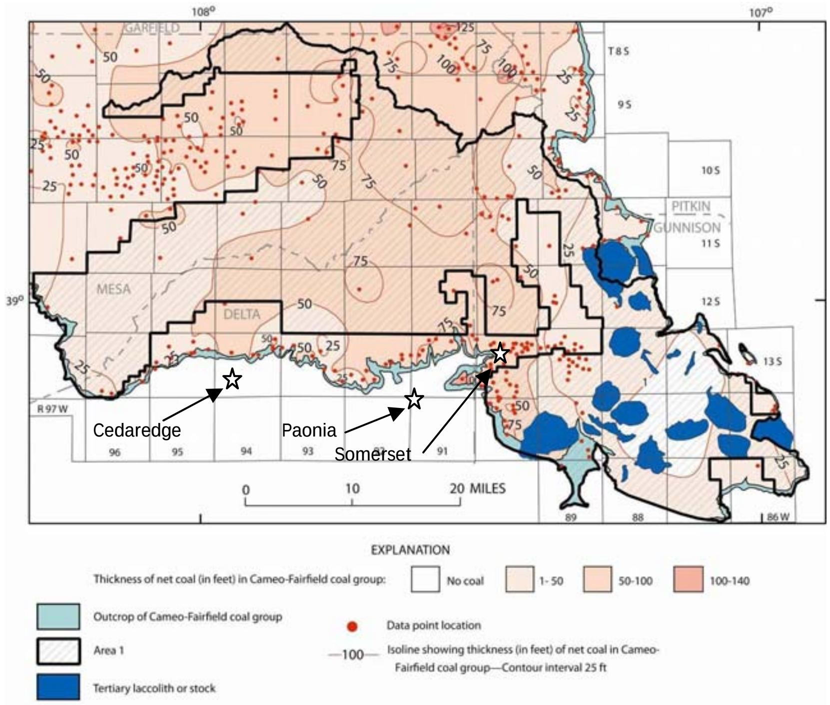


Figure 11. Isopach Map of Net Coal in the Mesaverde Coal-bearing Units
Net coal represents all beds over 1 foot thick (Source: Hettinger et al. 2004)

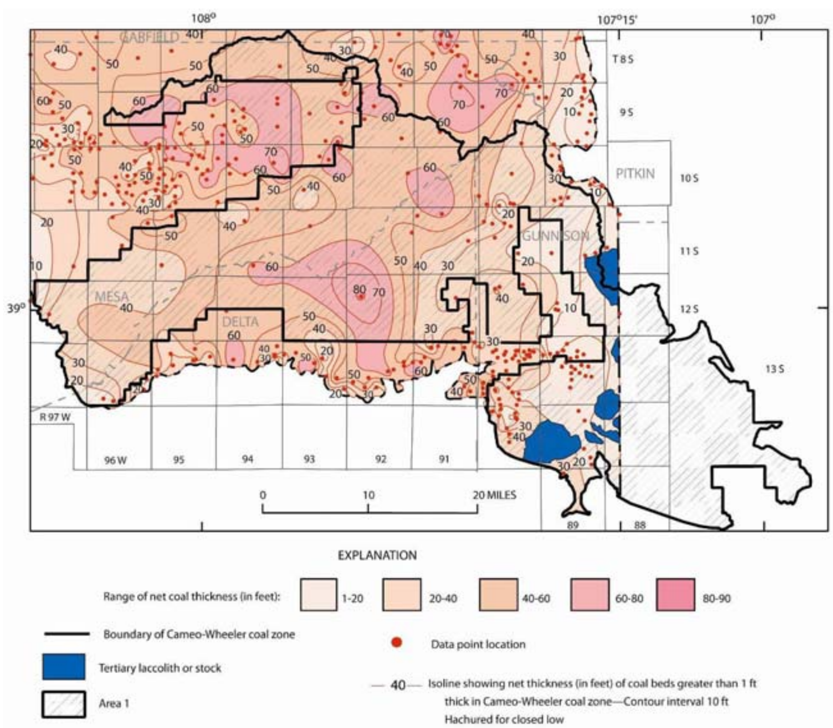


Figure 12. Isopach Map of Net Coal in the Mesaverde A, B, and C Seams
Net coal represents all beds over 1 foot thick (Source: Hettinger et al. 2004)

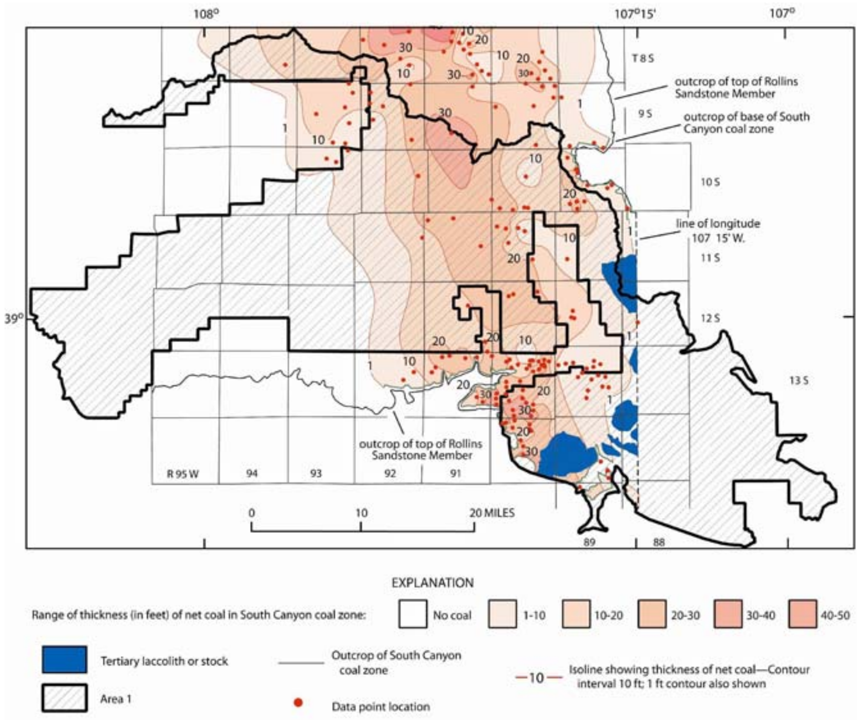


Figure 13. Isopach Map of Net Coal in the Mesaverde D and E Seams
Net coal represents all beds over 1 foot thick (Source: Hettinger et al. 2004)

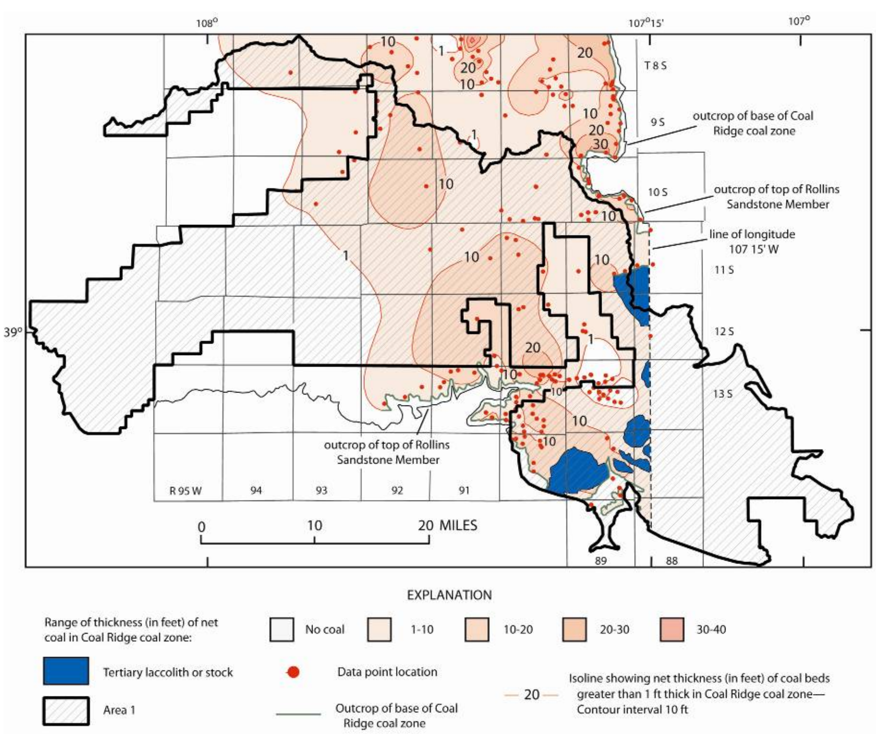


Figure 14. Isopach Map of Net Coal in the Mesaverde F Seam
Net coal represents all beds over 1 foot thick (Source: Hettinger et al. 2004)

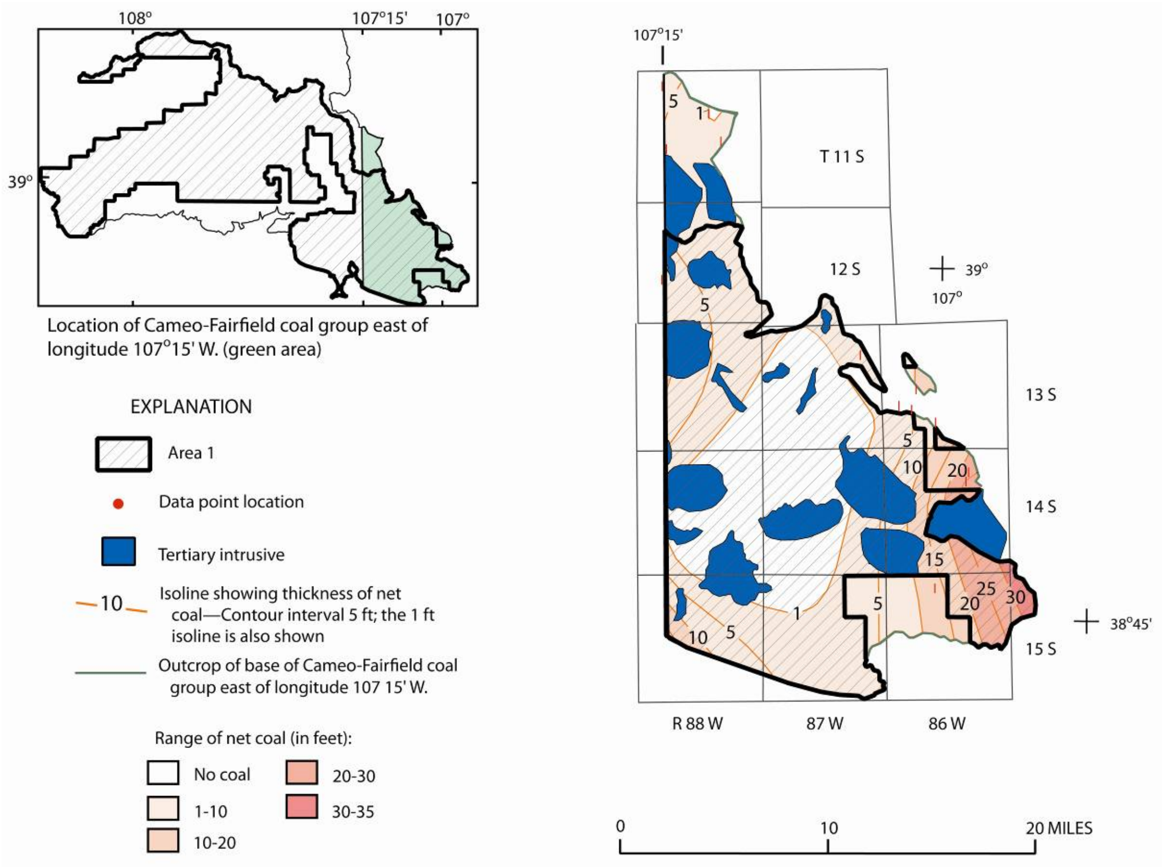
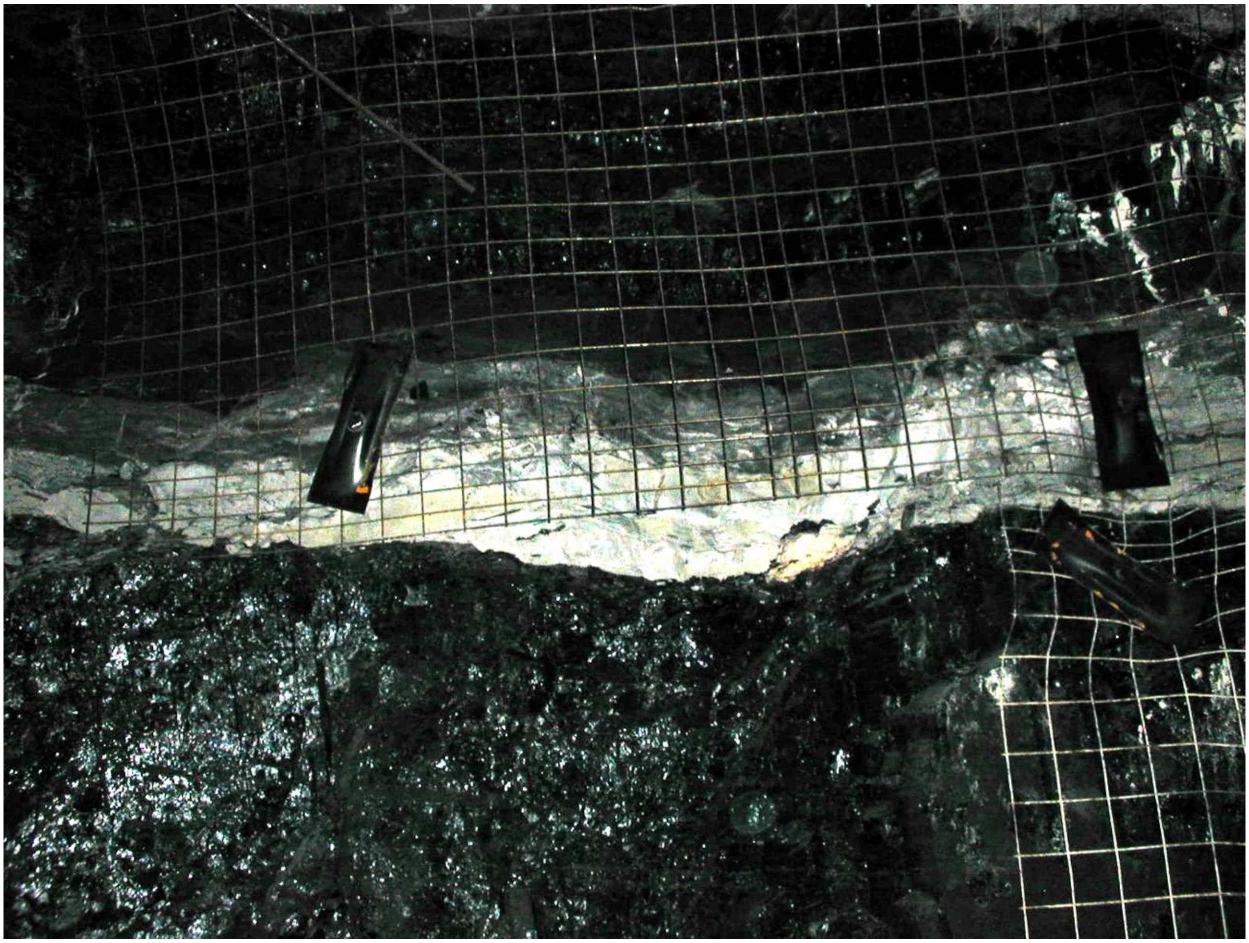


Figure 15. Isopach Map of Net Coal in Mesaverde in Eastern Intrusive Area
Net coal represents all beds over 1 foot thick (Source: Hettinger et al. 2004)

Mesaverde in Eastern Intrusive Area

East of longitude 107°15' West, the Mesaverde is divided into the lower, middle, and upper coal zones. The collective coal zones have about 1 to 30 feet of net coal (Figure 15) in 1 to 5 beds, and individual beds are 1 to 25 feet thick. The Mesaverde is often covered, poorly exposed, steeply included, displaced by faults, and intruded by sills, dikes, and laccoliths throughout the West Elk Mountains (Hettinger et al. 2000). As a consequence, the coal zones are difficult to correlate. Murray et al. (1977) indicate that the complex of Tertiary intrusions played a role in the genesis of the coking-grade coals and associated methane gas found in this region of the Piceance Basin. As seen in Figure 15, the Mesaverde coal is concentrated in the extreme eastern portion of Hettinger's study area (Hettinger et al. 2000) in the vicinity of the Crested Butte coal field, which is outside of the planning area.

Coal partings are common occurrences in the mining of all Cretaceous coals, including Dakota and Mesaverde coals. The following is a photograph of a parting of sandstone in one of the underground mines in the Somerset area.



Parting of sandstone in the Mesaverde Formation. This photo was taken in an underground mine in the Somerset area. The wire mesh and bolts are used to secure the coal in this area prior to covering with a coating of lime to control dust. *Photo courtesy Desty Dyer, BLM.*

Just as clastic dikes are an issue in the Dakota Sandstone Formation, they are also an issue in the Mesaverde Formation. Hardie (1999) studied clastic dikes in the Palisade and Somerset areas and found that joint-source dikes are very common in the southern Piceance Basin. He found that the predominant orientation of dikes in the West Elk Mine near Somerset is N35°W, with a secondary orientation of dikes being N65°E. The dominant orientation is perpendicular to the general dip of the Mesaverde Formation, which is 2 to 5 degrees to the northeast. As previously mentioned in the Dakota Sandstone Formation, these dikes are hard and well-cemented, making mining through them challenging. Igneous intrusive dikes are also present in the Somerset coal field. These are hard and continuous features much like clastic dikes, and provide an impediment to mining operations. In addition to the issues discussed for strip mining when clastic dikes are encountered, underground mining operations also can experience unstable roof conditions, infiltration of mine water or methane, and roof vibration when cut (Hardie 1999).

V. Historic Mining and Production

Historic Mining

Historic coal mining in the planning area occurred in five coal fields: Nucla-Naturita, Tongue Mesa, Somerset, Grand Mesa, and Carbondale (Figure 5). Historic mines are shown relative to the coal fields on Figures 16, 17, and 18. The history of coal mining in each of the coal fields is discussed below. The Carbondale coal field produced mainly coking coals, but it is not discussed because the former Mid-Continent Mine and other historic workings depleted the accessible known reserves or the coal is inaccessible due to either Wilderness status (refer to Section III) or thick overburden.

Nucla-Naturita Coal Field

The earliest mining of Dakota coals in the Nucla-Naturita coal field was in the 1880s, but the peak period for mining was from about 1920 to 1950 (Eakins 1986; Carroll and Bauer 2002). All Dakota coal mines in this region were underground mines with the exception of the Nucla Strip Mine (operated by Peabody Coal Company intermittently from 1959 to 1988), the Hamilton Strip Mine (operated by Honeywood Coal Company from 1992 to 1993), and the New Horizon Mine (operated by Western Fuels Association from 1993 to present). The New Horizon Mine is the only mine currently in operation. It supplies coal to the FBC power plant in Nucla (Section III).

As seen in Figure 16, most of the mines (including the currently active New Horizon Mine) are northwest of the town of Nucla, locally known as First Park and Second Park. Another cluster of historic underground mines is located southwest of Nucla (northwest of Naturita) along the outcrop of the Dakota Sandstone in the San Miguel River Canyon. Mine adits in the canyon slopes followed gently-dipping beds of coal under First Park. A few other mines were located upstream of Naturita in the San Miguel Canyon. On Wrights Mesa, just west of Norwood, 10 historic mines were located in the upper slopes of Naturita Canyon. Again, these were underground mines that followed coal seams under Wrights Mesa and operated in the 1920s and 1930s. A lone mine that operated in the 1930s was located near Redvale. These older mines supplied coal for a smelter in Norwood, coke ovens, local power, industrial needs, and household heating (Eakins 1986).

Tongue Mesa Coal Field

According to Carroll and Bauer (2002), there were eight historic coal mines in the Tongue Mesa coal field (Figure 17). The earliest mines, Lou Creek and Economy, which started production in 1917 and 1919, respectively, were in the Lou Creek drainage northeast of Ridgway. The other mines operated between the 1920s and 1950. There have also been a few small abandoned "dog hole" mines at outcrop locations located in landslide scarps (Dickinson 1987a, 1987b). The mostly subbituminous coal that came out of this field was used for local heating for nearby ranches and homes. In 1987, the BLM issued a license to mine on private surface with federal minerals in the field that was used by a charitable organization having a 100 ton annual production ceiling and the license was terminated in 2001 (Dyer 2010b). No commercial mining has occurred in the Tongue Mesa coal field since 1950.

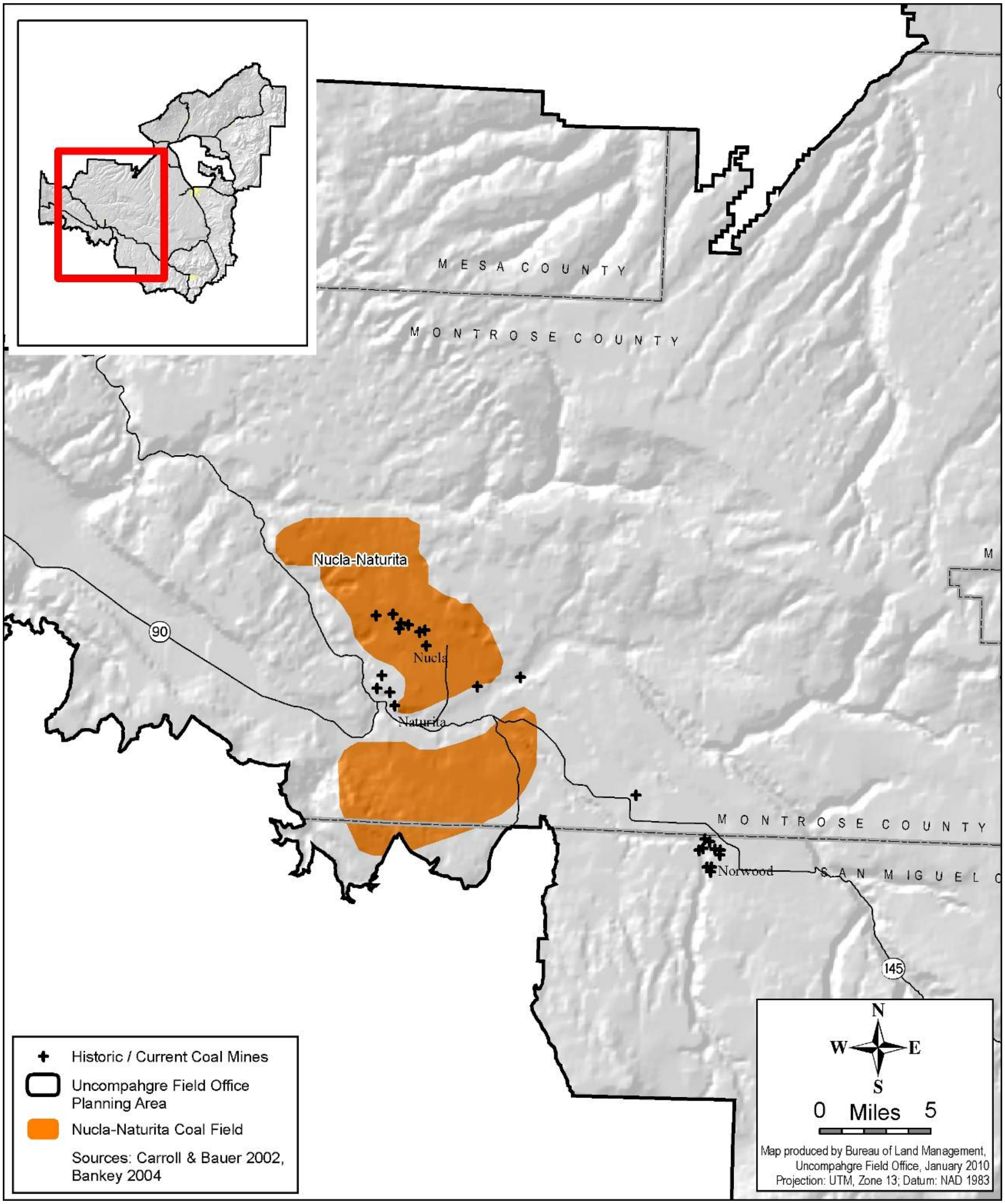


Figure 16. Historic Coal Mines in the Nucla-Naturita Coal Field

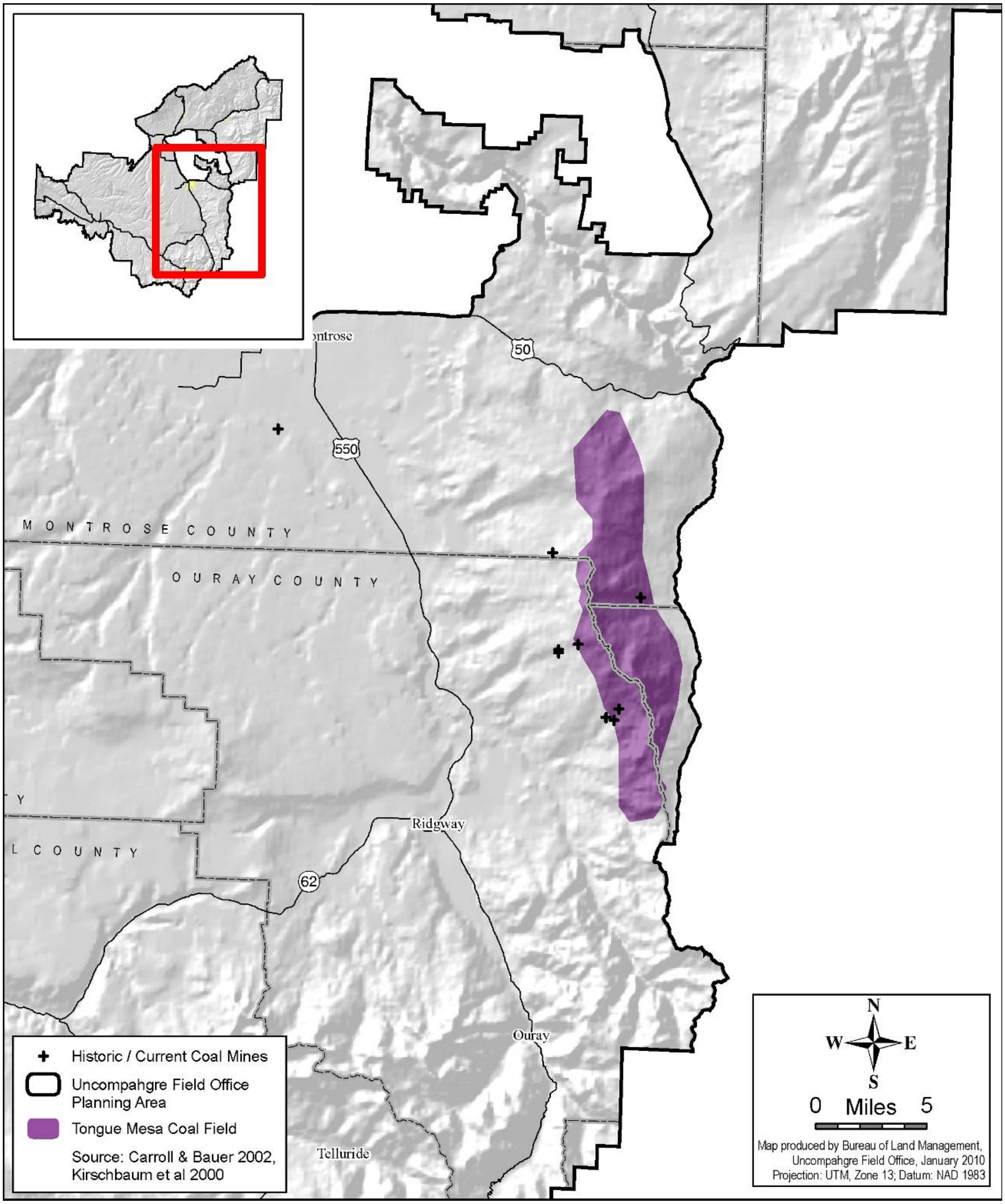


Figure 17. Historic Coal Mines in the Tongue Mesa Coal Field

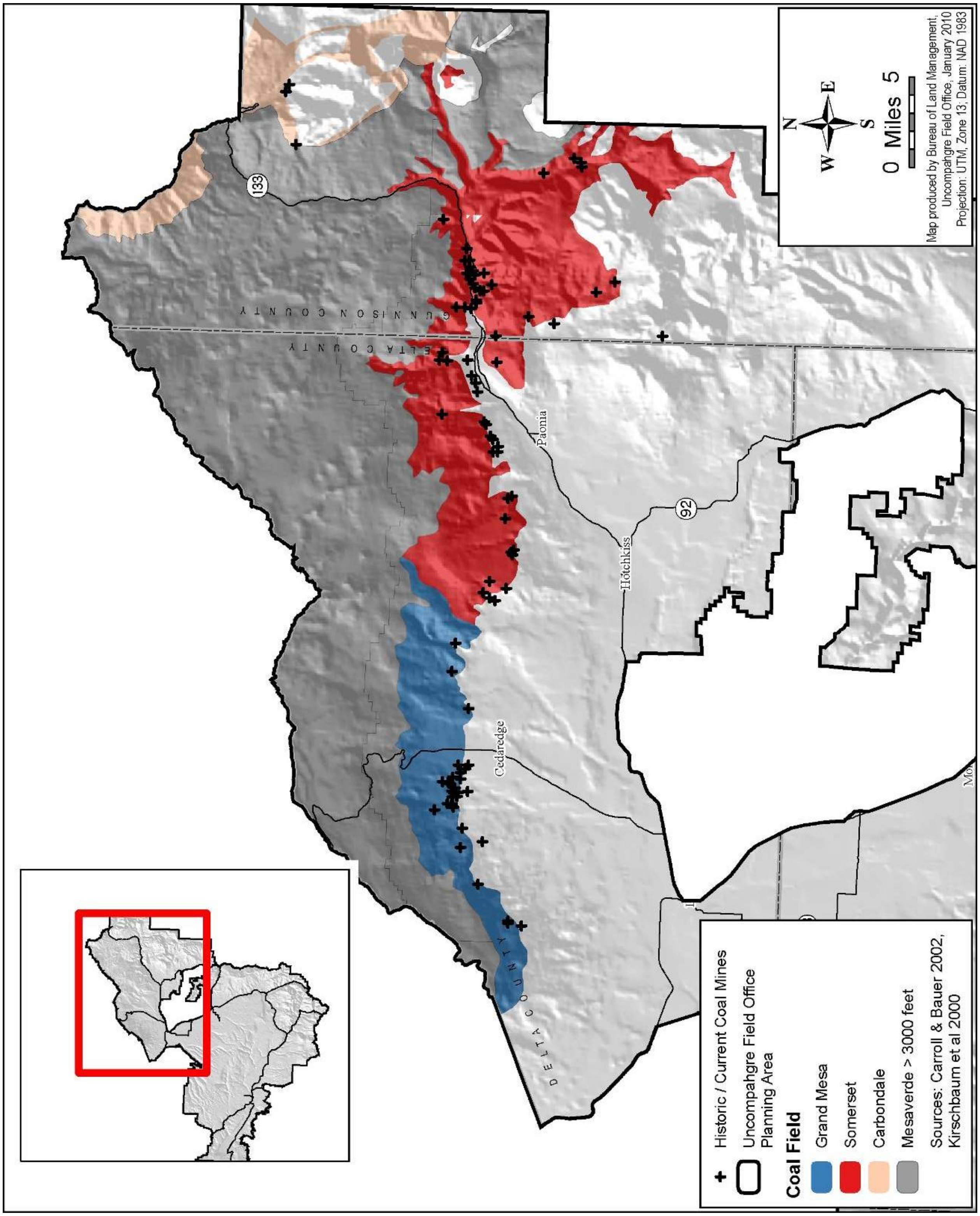


Figure 18. Historic Coal Mines in the Grand Mesa and Somerset Coal Fields

Somerset Coal Field

Coal mining has occurred in the North Fork Valley since the late 1800s. According to Carroll and Bauer (2002), there have been 37 underground coal mines and numerous prospects but no surface mining in the Somerset coal field. The Denver and Rio Grande Railroad constructed a spur from Delta to Somerset and in 1902 established the town of Somerset (Schultz et al. 2000). Volcanic dikes, sills, and laccoliths of the Elk and West Elk intrusive complexes to the south and southeast of the Somerset coal field locally increased the rank of the bituminous coals in the southern portion of the field to coking coals, which made them very desirable for metallurgical uses (Murray et al. 1977; Schultz et al. 2000). Three commercial mines began operation as early as 1903: Cooperative Mine operated until 1910 by the Paonia Coal Company, King Mine operated until 1974 by Adolph Coors Company, and Somerset Mine operated until 1985 by US Steel Corporation. Many of the 37 mines were very productive and operated for 10 to 50 years.

As seen on Figure 18, most of the mines are concentrated in the Somerset area, but they also extend to the west towards Cedaredge and the Grand Mesa coal field at an elevation of roughly 7,000 feet. Historic mines are also found to the southwest and southeast of Somerset in the Little Coal Creek, Minnesota Creek, and Coal Creek drainages. By 1977, there were 10 active mines: West Elk, Bear #3, Hawks Nest East, Sanborn Creek, Somerset, Blue Ribbon, Bowie, Bowie #1, Orchard Valley, and Cyprus Orchard Valley (Hettinger et al. 2004). Currently, there are three active mines: West Elk (operated by Mountain Coal Company, Inc.), Elk Creek (operated by Oxbow Mining, LLC), and Bowie #2 (operated by Bowie Resources).

Grand Mesa Coal Field

Historic underground coal mining started in the Grand Mesa coal field in the 1880s, and many of these mines operating through the 1930s. Without a railroad spur to this area, the coal was hauled by wagon or trucked to Cedaredge, Delta, and other local communities for use as domestic fuel mostly during the winter months (Lee 1912). According to Carroll and Bauer (2002), there were 34 mines in this coal field, most of which were underground mines. Five of the 34 mines were surface strip mines. As seen on Figure 18, most of the mines were concentrated in the area northwest of Cedaredge in the Ward Creek and Cottonwood Creek basins near the town of Colby (Dunrud 1989a). However, a few mines extended to the east near Leroux Creek (north of Hotchkiss) and the Somerset coal field. A few mines were located southwest of Cedaredge along the Mesaverde outcrop containing basal coal lying on top of the Rollins Sandstone (i.e., the Paonia Shale Member) (Lee 1912). The larger mines were the Winton/Tomahawk (1914-1982), Red Canyon #1 and #2 (1923-1984), Green Valley #2 (1949-1972), Top (1938-1970), and States (1914-1951). By 1977, there were two active mines: Tomahawk and Red Canyon (Hettinger et al. 2004). There have been no active mines in the Grand Mesa coal field since 1984.

Historic Production

Nucla-Naturita Coal Field

Most mines in the Nucla-Naturita coal field produced less than 10,000 tons of coal. Only four underground mines exceeded 100,000 tons of production. Three historic mines (US Vanadium, Liberty Bell, and Fiddling Bill), located in the San Miguel Canyon northwest of Naturita, produced a combined total of about 375,000 tons of coal from 1919 to 1950 (Eakins 1986; Carroll and Bauer 2002). The Nucla Strip Mine produced 2,071,766 tons of coal from 1959 to

1988. The New Horizon Mine produced a total of 4,176,510 tons as of 2004 (Carroll 2005) and had a production of 403,230 tons in 2008 and 373,758 tons in 2009 (Colorado Division of Recalmation Mining and Safety 2010b). The New Horizon Mine typically produces about 400,000 tons of coal annually, which is trucked to the FBC power plant in Nucla.

Tongue Mesa Coal Field

The eight mines in the Tongue Mesa coal field that operated between 1917 and 1950 were all small-scale, commercial underground mining operations that produced a total of 14,831 tons (Carroll and Bauer 2002). The largest mine, the Kennedy Mine (in the Lou Creek basin northeast of Ridgway), produced a total of just over 3,000 tons of coal. Although some of the coal seams in this field are 30 to 40 feet thick, the Fruitland Formation along Cimarron Ridge is highly faulted with extensive landslides; therefore, the coal seams are discontinuous and disrupted, producing relatively small amounts of coal. The area is also remote and without a rail line, so accessing and transporting the coal is not viable on a commercial scale.

Grand Mesa and Somerset Coal Fields

Historic production of coal from the Grand Mesa and Somerset coal fields is often lumped into coal produced for the entire Southern Piceance Basin. A summary of mining activity in the southern Piceance Basin prior to 1977 was compiled by Murray et al. (1977). Their study indicates that about 84 million short tons of coal were mined from the Mesaverde in the southern Piceance Basin from 1864 through 1976. From 1977 to 1997, another 94.2 million short tons of coal (1.9 to 8.6 million short tons of coal annually) has been produced from 31 mines in the Southern Piceance Basin (USFS 2006). In the Grand Mesa coal field, much of the early coal mined was hand dug and hauled by wagon to surrounding communities during the winter months to supply domestic fuel (Lee 1912). Most mines produced a few hundred to a few thousand tons per month in the winter. Of the 34 mines in this field, only 6 mines produced a total of more than 100,000 tons. The largest mines were the Tomahawk and Red Canyon Mines, which produced a combined 1.01 million short tons of coal. A railway spur was never extended to this district, so the coal mined since the 1940s had to be trucked for local domestic use. No mines have operated commercially in this field since 1984.

In the Somerset coal field, there were 18 mines that each produced at least 100,000 short tons of coal (Schultz et al. 2000). Of these 18 mines, 15 were concentrated in the Somerset Quadrangle, and 12 produced over 1 million short tons of coal each. The high quality and large volume of coal in this field was recognized early on with the development of a rail line in 1894. Therefore, coal has been hauled by rail for metallurgical uses and steam production for over 100 years. Three mines currently operate in the Somerset coal field: Bowie #2, Elk Creek, and West Elk Mines. Their current production figures are described in Section VI.

VI. Current Mining Operations and Production

Current coal-mining operations within the Uncompahgre RMP planning area include one mine in the Nucla-Naturita coal field (New Horizon Mine) and three mines in the Somerset coal field (Bowie #2, Elk Creek, and West Elk Mines) (Figure 19).

Nucla-Naturita Coal Field

The New Horizon Mine in Nucla is a relatively small surface-mining operation (927 permitted acres) (Colorado Division of Recalmation Mining and Safety 2010a) that produced 403,230 tons of coal in 2008 and 373,758 tons in 2009 from the upper two seams of the Dakota Sandstone (Colorado Division of Recalmation Mining and Safety 2010b). This was 1.2 percent of the coal produced in Colorado in 2008 and 3.1% in 2009. The coal is trucked to the Nucla Station FBC power plant. The New Horizon Mine reclaims about 25 acres per year (Cappa et al. 2007). The following photograph shows nature of the surface mining and associated reclamation.

Oblique aerial photograph looking southwest at the New Horizon Mine in Nucla. The mine pit face is oriented north-south and is 3,400 feet long. Mining is advancing to the right (west), and seeding in the reclaimed area can be seen to the left. *Photo courtesy Western Fuels Association.*

According to Carroll (2005), the New Horizon Mine operated by Western Fuels Association, extracts coal from the upper (UD1) seam that is 0.8 to 1.5 feet thick and the middle (LD1) seam that is 5 to 7.5 feet thick. Interburden thickness is 6 to 10 feet, and overburden thickness is 15 to 100 feet. In 2006, the average heating value of the coal shipped was 11,680 Btu (Cappa et al. 2007). According to O'Hara (2010a), the surface overburden (topsoil, shale, and some sandstone) is excavated with hydraulic shovels (excavator) and trucks as well as blast casting and dozer pushed in the pit floor. When harder material is encountered than cannot be

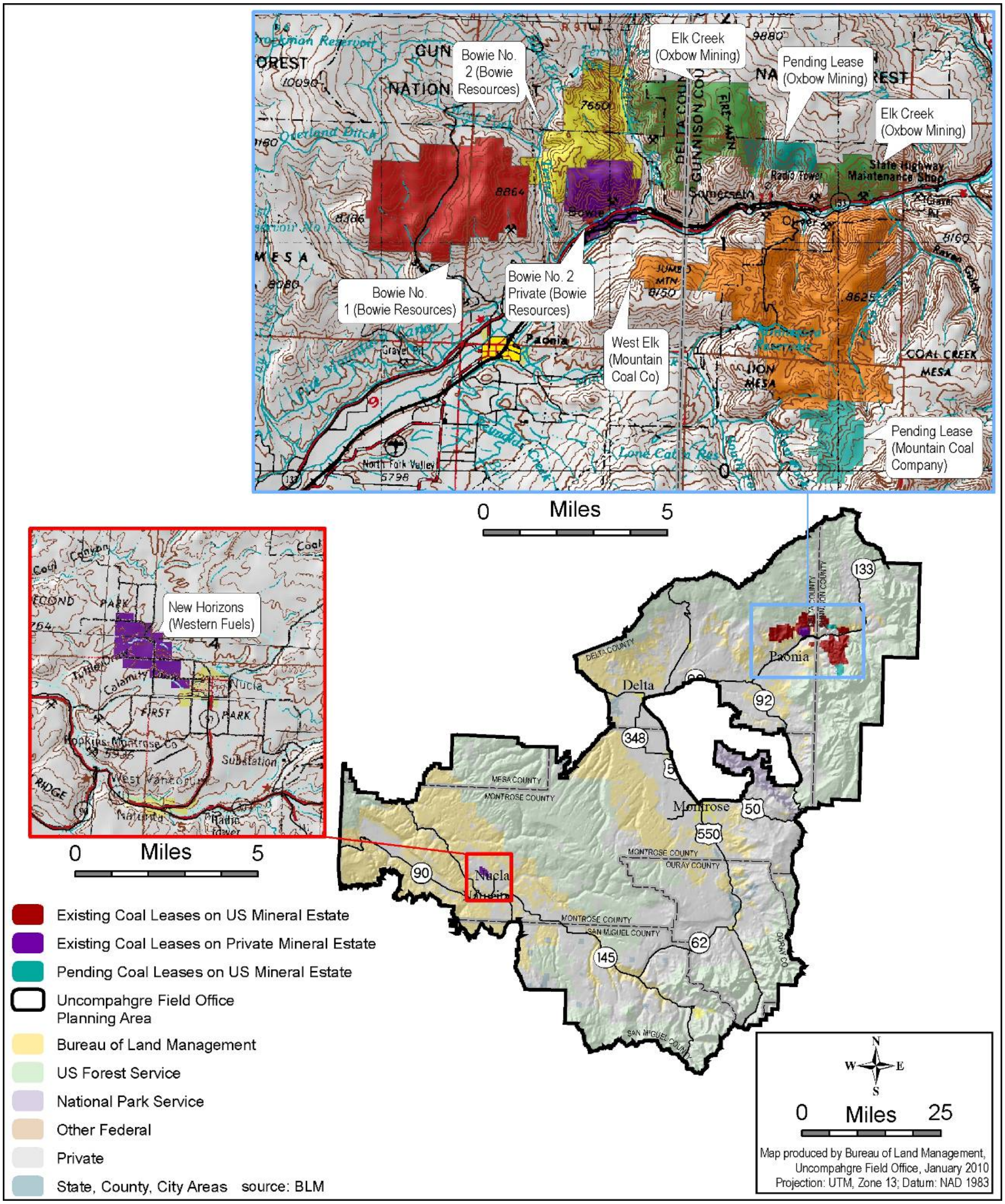


Figure 19. Location of Active Coal Leases in the Planning Area

ripped, it is blast casted. The sandstone of the Dakota is typically a well-cemented sandstone to quartzite, which is very hard and must be drilled and blasted. Coal is loaded with a rubber-tired loader into belly dump highway trucks and hauled to the local power plant. The thin, lower-quality UD1 coal is blended with the thicker, higher-quality LDx coal at the plant to create the optimum burn.

Somerset Coal Field

In 2009, the Elk Creek Mine (operated by Oxbow Mining, LLC) produced 5,702,879 tons of coal, the Bowie #2 Mine (operated by Bowie Resources) produced 1,212,977 tons of coal, and the West Elk Mine (operated by Mountain Coal Company) produced 4,885,581 tons of coal (Colorado Division of Recalmation Mining and Safety 2010b). This is a total of 11,801,437 short tons of coal, which was 41.3 percent of Colorado's coal production in 2009. The West Elk Mine is the seventh largest underground coal mine in the US and the second largest underground mine in Colorado based on production (Carroll 2005). The Elk Creek Mine is the 18th largest underground coal mine in the US. According to the Colorado Division of Recalmation Mining and Safety (2010a), the permitted acreages for the Somerset coal mines, shown in Figure 19, are: Bowie #1 (8,670 acres), Bowie #2 (5,864 acres), Elk Creek (13,429 acres), and West Elk Mine (17,155 acres). All three mines in the Somerset coal field ship the coal by rail, and it is primarily used as steam coal.

In 2005, due to the demand for Colorado's high-quality (low sulfur, low ash, low mercury, high Btu) coal, 67 percent of the coal produced was shipped out of state by rail to 28 other states, mostly to the east where it is blended with high-sulfur coals to reduce pollution at minimally-compliant steam power plants (Cappa et al. 2007). Of those states, Tennessee, Kentucky, and Texas together received almost one-third of the total coal shipped out of Colorado. Somerset coal is highly desirable for blending with high-sulfur coals for electricity production. For example, in 2006, over 15.5 million tons of coal from the Somerset coal field was shipped to the Front Range and further east. The Tennessee Valley Authority uses North Fork coal from all three mines. Although a small percentage of coal from Colorado is used for commercial and industrial plants, no coking coal from Somerset was used for that purpose.

The three active mines in the Somerset coal field are mining coal from the Paonia Shale Member of the Mesaverde. The West Elk Mine mined the F seam of the Mesaverde Formation until 1991 and mined the B seam until recently, but is currently mining the 10- to 11-foot-thick E seam (Carroll 2005; Cappa et al. 2007). Average interburden between the B and E seams is 120 to 130 feet. Although the average overburden depth of the B seam is 1,200 feet, the West Elk Mine has the maximum mining depth in Colorado at 2,300 feet (Carroll 2010). Prior to 2003, Oxbow mined the B and C seams from their Sanborn Creek Mine located east of their currently active Elk Creek Mine, which is in the 14-foot-thick D seam. The Elk Creek Mine workings are above the historic US Steel B and C seam workings. Prior to 2004, Bowie mined the 9- to 12-foot-thick D seam then transitioned to the B seam beneath their D seam workings, having mined-out the D seam in 2007. The Bowie No. 2 Mine currently extracts coal from the 10- to 12-foot-thick 'upper' B seam split. According to Cappa et al. (2007), the average energy value of coal shipped from these three mines was 11,650 Btu for Bowie #3, 12,375 Btu for Elk Creek, and 11,650 Btu for West Elk. All three mines primarily use longwall mining methods with some use of continuous miners. Longwall mining equipment is shown in the following photograph.

Longwall mining operation in Elk Creek Mine. This wall is 825 feet long and produces 10,000 tons of coal per day. *Photo courtesy Oxbow Mining, LLC.*

VII. Coal Resource Potential (Geologic Occurrence)

A coal resource is where concentrations of coal exist in such forms that economic extraction is currently or may become feasible (US Bureau of Mines and USGS 1976). 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. The Uncompahgre RMP planning area is considered to have coal resource potential in areas where (1) underlying strata are likely to have accumulated in a coal-forming environment, and (2) the potential coal-bearing rocks are less than 3,500 feet deep for coals to be extracted by underground mining methods (i.e., Mesaverde or Fruitland coals) or less then 150 feet for coals to be surface mined (i.e., Dakota coals). As discussed in this report, coal-bearing strata are known or are likely to be in the Dakota Formation, Fruitland Formation, or Mesaverde Formation/Mesaverde Group. Since overburden depth is an important factor in determining coal potential once a coal-bearing formation is known, overburden was used as a selection criteria. Figure 20 shows the overburden depths of the three formations in the planning area.

The resource potential was evaluated separately for areas with Dakota coal and Mesaverde/Fruitland coal because they require different mining methods (i.e., surface versus underground) and represent a different kind of resource (e.g., thin-seam, lower-quality coal of the Nucla-Naturita coal field requiring consumption by a local power plant versus thick-seam, high-quality coal of the Somerset coal field). The coal resource potential is shown on Figure 21 (Dakota Formation) and Figure 22 (Mesaverde and Fruitland Formations). The criteria for determining low, low to moderate, and high coal resource potential, based on geologic occurrence is described below for each formation. For this analysis, areas of high coal resource potential have nearby outcrop, mining, or drill hole data that substantiate the presence of coal. Areas of low to moderate coal resource potential do not have drill hole or outcrop data to substantiate the presence of coal; however, data in adjacent areas indicate that coal is likely present. Areas of low coal resource potential have no information to substantiate the presence of coal; however, the presence of coal is inferred from regional data.

Once the coal potential was assessed for the planning area based on geologic factors, a map was generated that removed mined-out and currently leased areas because these areas have no future leasing or permitting coal potential (Figure 27). This Known Potential Coal Resource map (Figure 27) also only includes coal with federal mineral estate. In other words, all private subsurface ownership was removed as being a coal resource, as the purpose of this report is to identify the areas of potential exploration and mining for coal on lands with federal (BLM) mineral ownership and management. It should be mentioned that in mined-out areas in the Somerset coal field, it is likely that not all (six) coal seams may have been removed. Other seams in a lease could have coal potential, but these are in areas with existing leases and no new area would be involved. Areas with pending leases (Figure 19) are shown on Figure 27 as a potential coal area because they have not yet been mined. In the Grand Mesa coal field, no mined-out areas were removed, as none of the mines were very deep (many were only 100 to 300 feet deep) or extensive laterally.

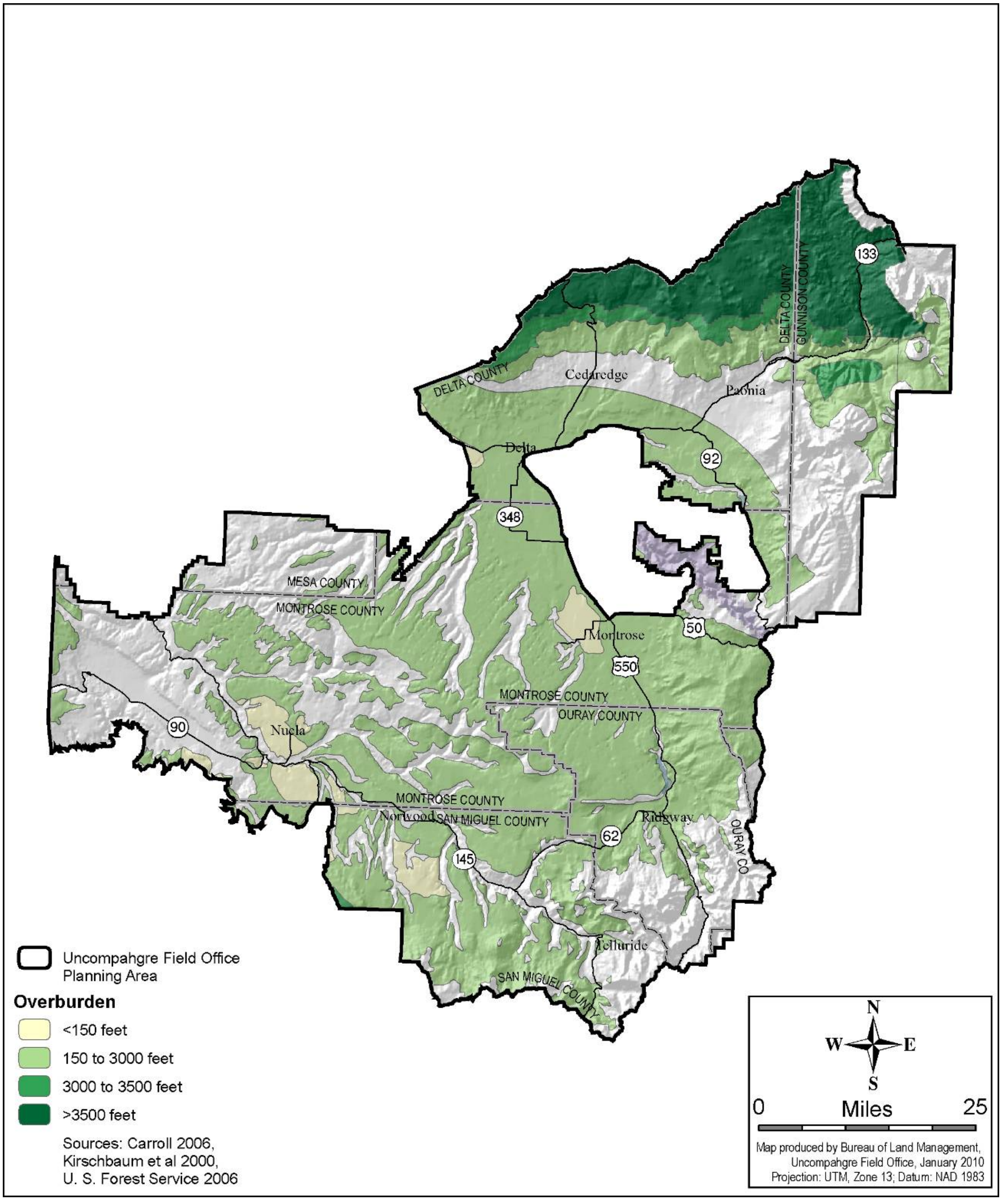


Figure 20. Depth of Overburden within the Planning Area

Coal Resource Potential of the Dakota Sandstone

Methods for Dakota Sandstone Resource Evaluation

Coal thickness isopach maps have not been compiled for the Dakota Sandstone because the lenticular coals cannot be correlated on a regional scale (Eakins 1986). Consequently, the evaluation was based on an assessment of coal resource based on overburden thickness (Figure 20), areas adjacent to existing mines, and areas with drill hole data substantiating the presence (or lack) of viable coal seams.

Previously Estimated Coal Resources

The Nucla-Naturita coal field is the primary area with coal potential within the Dakota Sandstone. In the main part of the Nucla-Naturita coal field (15 square miles), in the vicinity of the New Horizon Mine, Landis (1959) estimated an original resource of about 114 million short tons of coal. Hornbaker et al. (1976) estimated a total of 1.375 billion short tons of Dakota coal in the Nucla-Naturita coal field at a depth of less than 3,000 feet within the 50 square miles of explored area. Using water well logs and assuming a 3-foot thickness of coal where no information exists, Speltz (1976) calculated strippable resources of 2.9 billion short tons of coal within 502,000 acres of southwest Colorado (includes the Cortez and Dove Creek areas). He did not separate out the Nucla-Naturita coals from those in Dolores and Montezuma Counties, but the area defined as having strippable coal in the Dakota Sandstone near Nucla was about one-fifth the size of the more-extensive Cortez-Dove Creek region. With this rough estimate, the strippable Dakota coals in the Nucla region would have about 0.58 billion short tons of coal.

Current Coal Resource Potential

Determining the coal resource potential of the Dakota Sandstone is problematic for at least three reasons. The first reason is that drill hole data is concentrated in some areas of the Nucla-Naturita coal field but is lacking in other areas. The presence of coal in the Dakota must, therefore, be inferred from adjacent areas where the Dakota coal has been described. The second reason is that the Dakota Sandstone is often mapped as including the Burro Canyon Formation, which is barren of coal. Showing areas all of Dakota (including Burro Canyon) would therefore overestimate the extent of the true Dakota Sandstone and its coal-bearing units. The third reason is that the coal seams in the Dakota Sandstone are typically lenticular, discontinuous, and often bony (i.e., impure coal or mineral partings). Because the seams are laterally so variable, it is difficult to accurately calculate the volume of the resource. In addition, even if an area has well less than 120 feet of overburden, which is the current industry limit for strippable coal, the coal could be highly oxidized and of poor quality (O'Hara 2009). The closer the coal is to the surface, the greater the exposure to air and oxidation/degradation of the coal. Therefore, shallow coal is not necessarily a good thing in terms of maintaining quality of the coal.

The criteria used for determining levels of recoverable coal potential in the Uncompahgre RMP planning area mapped as Dakota Sandstone are as follows (Figure 21):

(1.) **High potential** – Dakota Sandstone in Nucla-Naturita and Wrights Mesa (Redvale and Norwood) regions with overburden less than 150 feet (Figure 20), but excluding Third Park (north of Coal Creek) and mined-out (or current lease) areas. This represents the strippable coal resource, such as what is being currently mined.

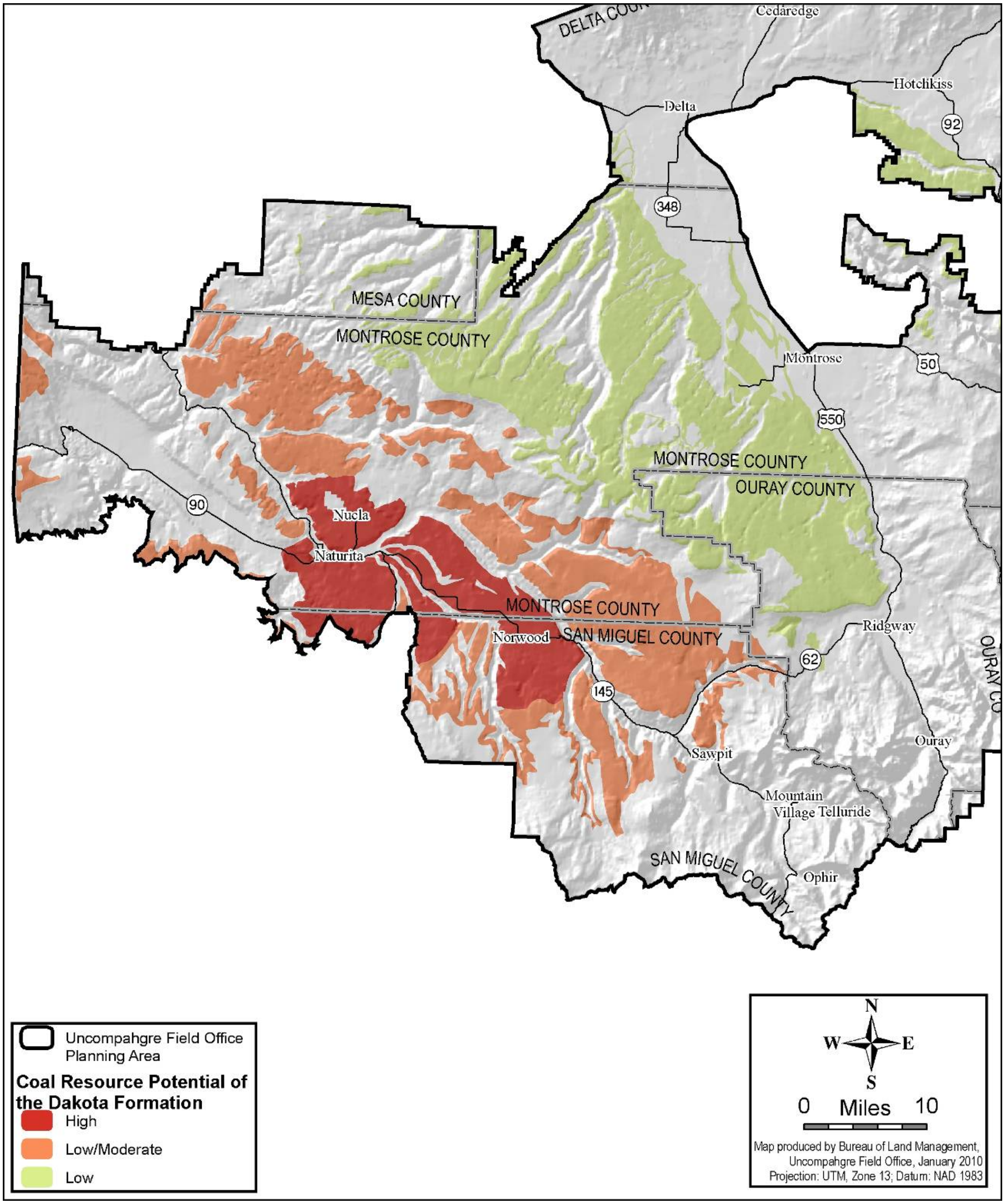


Figure 21. Coal Resource Potential of the Dakota Sandstone

(2.) **<u>Low to moderate potential</u>** – Dakota Sandstone in Nucla-Naturita region outside of the high-potential area with overburden of less than 150 feet, Dakota Sandstone with overburden 150 to 3,000 feet west of Uncompahgre Plateau, and Third Park near Nucla. This represents coal that can either be stripped if drilling confirms viable coal seams or limited underground mining for thicker seams. This resource would still require trucking to the Nucla FBC power plant.

(3.) **<u>Low potential</u>** – This includes all other Dakota Sandstone outside of the Nucla-Naturita region with an overburden of less than 3,000 feet, such as in the Uncompahgre and North Fork Valleys.

Although underground mines have operated in the region in the past, it would require significant infrastructure development that does not currently exist in order to resume this activity. However, there is the potential for thicker seams (on the order of 7 to 9 feet, based on historic mining records), which could warrant the resumption of underground mining if drilling data supports the presence of these types of seams.

All other areas of Dakota Sandstone in the planning area are regarded as having low potential because the formation in these areas appears to have mostly carbonaceous shale or bony coal and not thick, pure, or continuous coal seams. In the northern portion of the planning area, the resource potential is also low for Dakota coals because either the formation is buried by 5,000 to 6,000 feet of overburden or it is isolated and not proven with borehole data. Any deep Dakota coal that might be present in the planning area would not have current mining (development) potential because it is at depths that exceed the physical or economic limits of present-day mining techniques.

Areas showing coal potential do not account for private or federal coal estate or any other limitations such as proximity to roads or homes. It is purely a representation of potential coal underlying the surface.

Coal Resource Potential of the Fruitland Formation

Methods for Fruitland Formation Resource Evaluation

Coal thickness isopach maps have not been compiled for the Fruitland Formation in the planning area because the coal seams are broken by numerous faults and landslides, so they cannot be correlated on a regional scale. Consequently, the evaluation is based on an assessment of coal resource based primarily on overburden thickness (Figure 20) and geologic mapping because there are few historic mines and a lack of drill hole data.

Previously Estimated Coal Resources

The Tongue Mesa coal field is the primary area with coal potential for the Fruitland Formation. Landis (1959) reported an estimated 2.355 billion tons of coal originally in place, but Hornbaker et al. (1976) estimated it as high as 4.000 billion short tons. However, since underground mining would only be feasible in the thicker seams, only one-sixth to one-quarter of this coal is recoverable (Hornbaker et al. 1976). This would indicate a recoverable resource of 0.670 to 1.00 billion short tons. Speltz (1976) indicated that, given the geology, topography, and discontinuous nature of the coal seams, there is no strippable coal resource in the Tongue Mesa coal field.

Current Coal Resource Potential

According to the USGS, the planning area has a moderate to high resource potential for coal where it is underlain by the Fruitland Formation in the Tongue Mesa coal field (Hettinger et al. 2004). The area is given a high resource potential because it is known to contain thick beds of subbituminous coal, some of which are 30 to 40 feet thick (Carroll and Bauer 2002). The area is also assigned a moderate resource potential because coal bed continuity could not be determined, owing to poor exposure and structural complexities. Some exploratory and evaluation drilling was carried out in the mid-1970s (Hornbaker et al. 1976). For example, Kemmerer Coal explored the potential for coal resources of the Fruitland coal in the 1970s but did not pursue mining due to a lack of supporting data (Sharrow 2005). The few outcrops of the Fruitland Formation are surrounded by landslide deposits that are potentially unstable and steep, thus making access difficult. Although the area has a moderate to high resource potential, Hornbaker et al. (1976) concluded that the coal in the Tongue Mesa area could not compete with better coal in the Somerset field.

The following criteria were used for determining levels of recoverable coal potential in the planning area in the Tongue Mesa coal field (Figure 22). Due to the similar age/type of coal and underground mining techniques needed to extract the coal, the potential for both the Fruitland and Mesaverde coals are shown on the same map (Figure 22).

(1.) **High potential** – All of the Fruitland coal with high potential has been mined-out, is too small (isolated), or is too inaccessible to be a viable resource. Consequently, none of the coal resource in the Fruitland Formation within the planning area is considered to have high potential.

(2.) **Low to moderate potential** – Areas with Mesaverde or Fruitland Formation outcrops in the Cimarron Ridge (Tongue Mesa) area. This represents the underground mining coal resource, such as the type of coal that was previously mined in the Tongue Mesa coal field.

(3.) **Low potential** – Includes all Mesaverde or Fruitland Formations within the Cimarron Ridge area with an overburden of less than 3,000 feet.

According to the BLM's letter to the Grand Mesa, Uncompahgre, and Gunnison National Forest Supervisor, which included comments from their review of the Grand Mesa, Uncompahgre, and Gunnison National Forest's draft Coal Resource and Development Potential of 2004, the BLM indicated that the Fruitland coal in the Tongue Mesa field is difficult to access and heavily faulted (Sharrow 2005). In addition to the discontinuous nature of the formation due to faults and landslides in the Tongue Mesa area, there are no railway lines to transport the coal. Without a rail line, this resource would require trucking to the rail line in Montrose or to a currently nonexistent power plant constructed for the specific purpose of burning that local coal, similar to what is being done in the Nucla area. Due to difficult access, the marginal and dispersed nature of the coal resource, and lack of a nearby power plant to the Tongue Mesa coal field, it is not likely that large-scale mining development could be justified over the next 20 years. In fact, even small-scale mining development of this resource would not be expected.

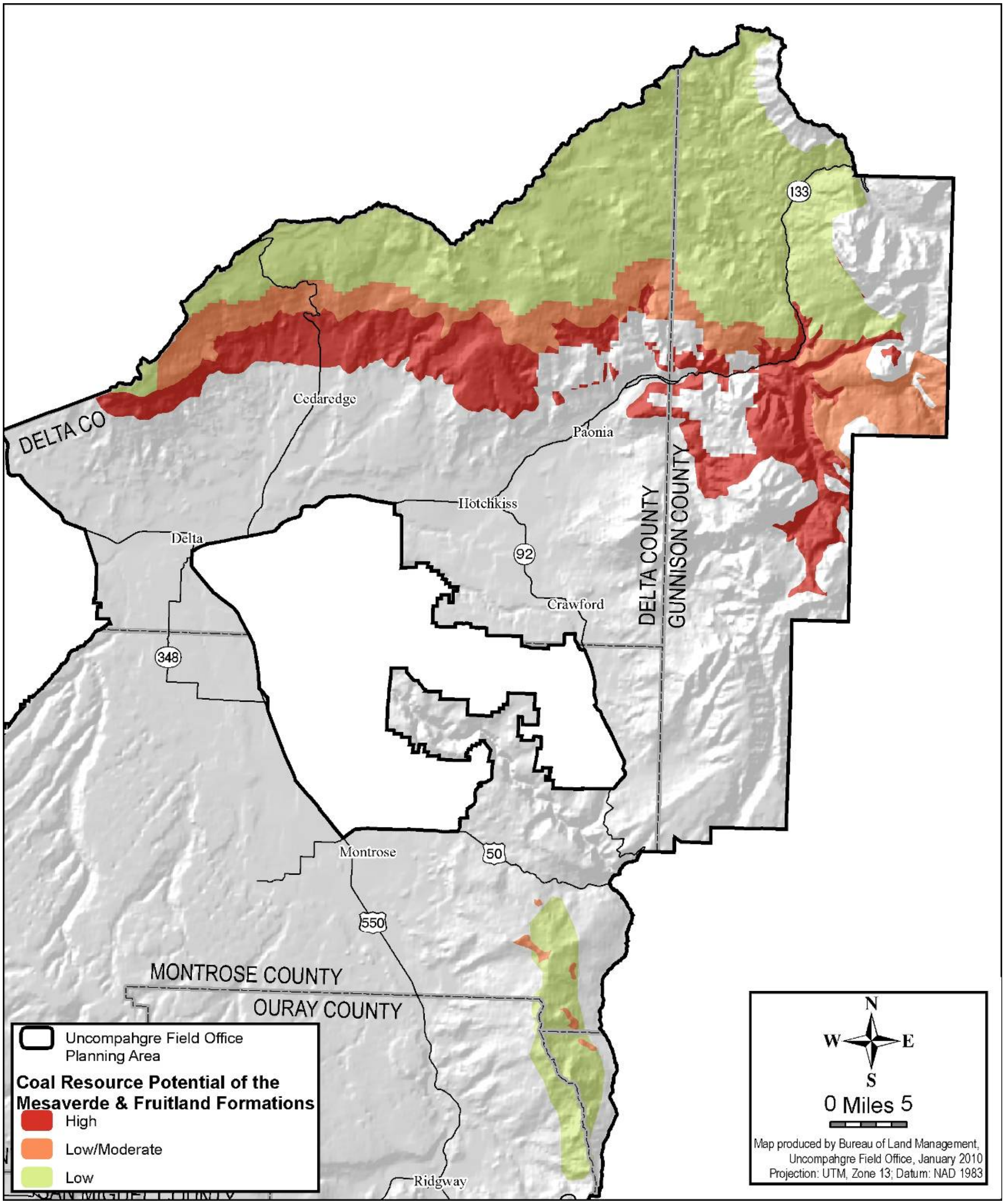


Figure 22. Coal Resource Potential of the Fruitland and Mesaverde Formations

Methods for Mesaverde Coal Resource Evaluation

The resource potential of the Somerset coal field has been studied in much more detail than any of the other coal field in the planning area (Boreck and Murray 1979; Eakins et al. 1998a, 1998b; Hettinger et al. 2000, 2004; Hornbaker et al. 1976; Landis, 1959; Rohrbacher et al. 2000; Schultz et al. 2000; Toenges et al. 1949, 1952; USFS 2006). Gross coal resources were estimated using a modified methodology based on that of Wood et al. (1983) by which all coal in the ground in beds greater than 1 foot thick and under less than 3,500 feet of overburden are reported. The term "original resource" refers to coal in the ground prior to mining. More deeply buried coal is reported as other occurrences of non-resource coal. **This report does not estimate coal reserves that are the subset of the resource that can be economically produced at the present time**. Coal resources for Mesaverde coal were estimated by multiplying the volume of coal by the average density of coal (Wood et al. 1983).

Hettinger et al. (2000) performed an analysis on the Mesaverde coals in the southern Piceance Basin, which includes the Somerset coal field. Maximum overburden thicknesses on the A, B, C, D, E, and F seams are shown in Figures 23, 24, and 25. The maximum overburden thickness on the base of the Mesaverde Formation east of Somerset in the intrusive area (east of longitude 107°15' West) is shown on Figure 26.

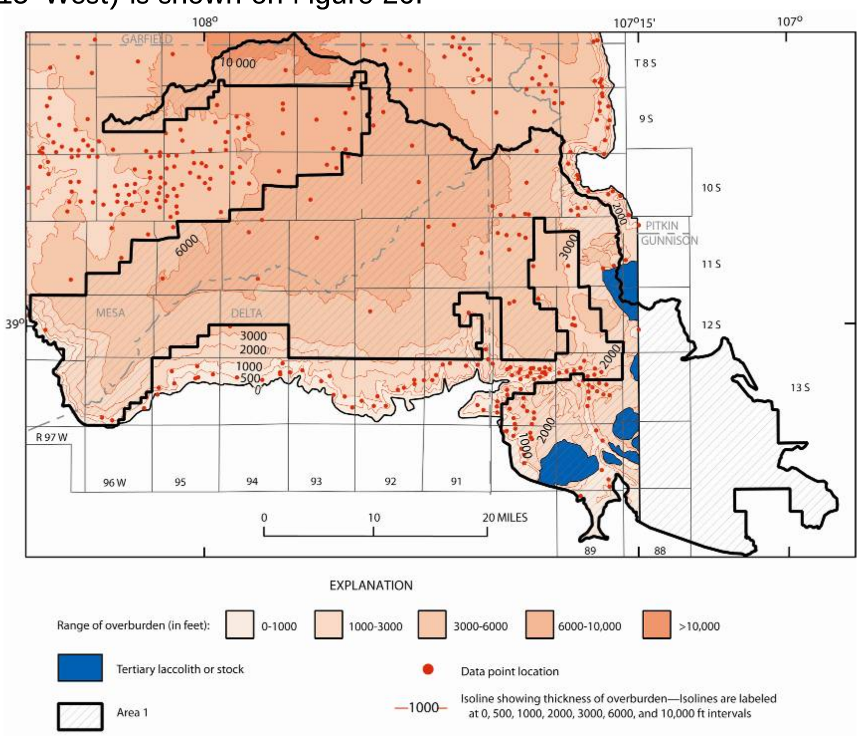


Figure 23. Isopach Map of Overburden on Base of Mesaverde A, B, and C Seams
Source: Hettinger et al. 2004

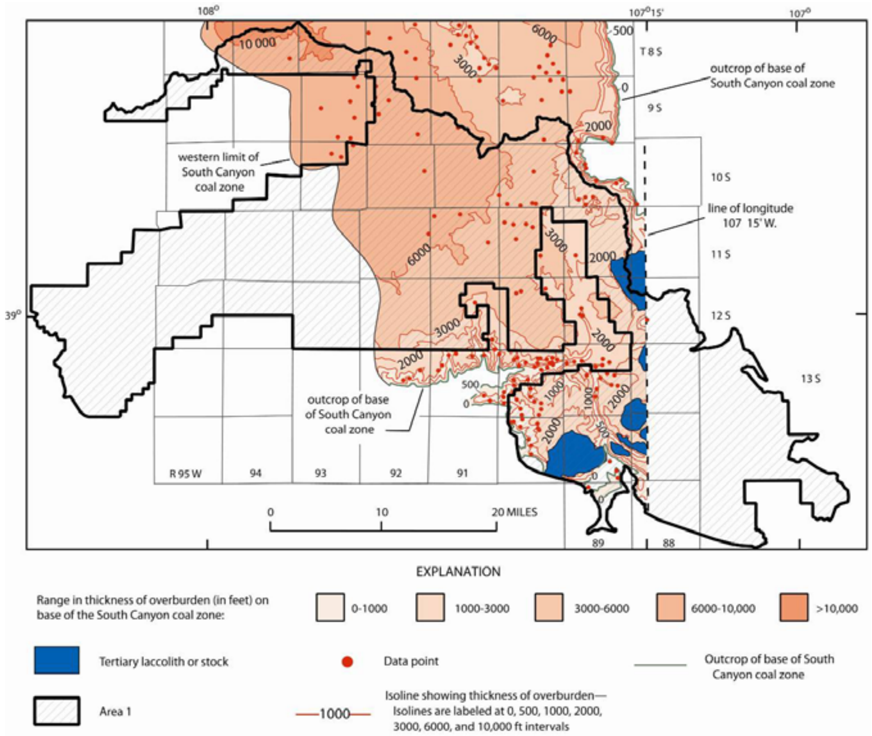


Figure 24. Isopach Map of Overburden on Base of Mesaverde D and E Seams

Source: Hettinger et al. 2004

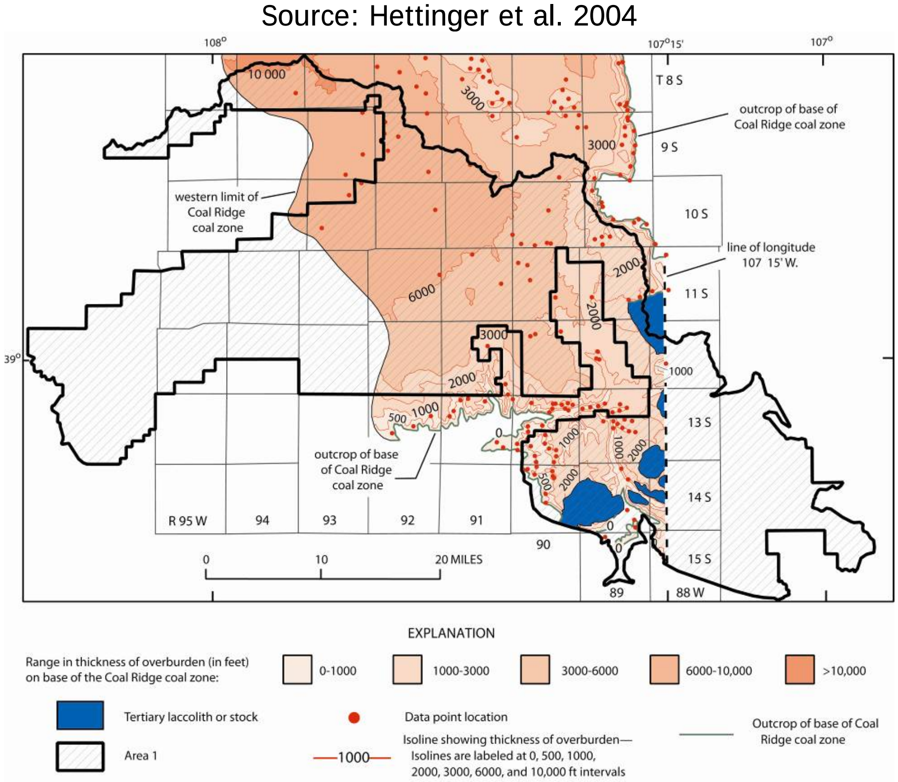


Figure 25. Isopach Map of Overburden on Base of Mesaverde F Seam

Source: Hettinger et al. 2004

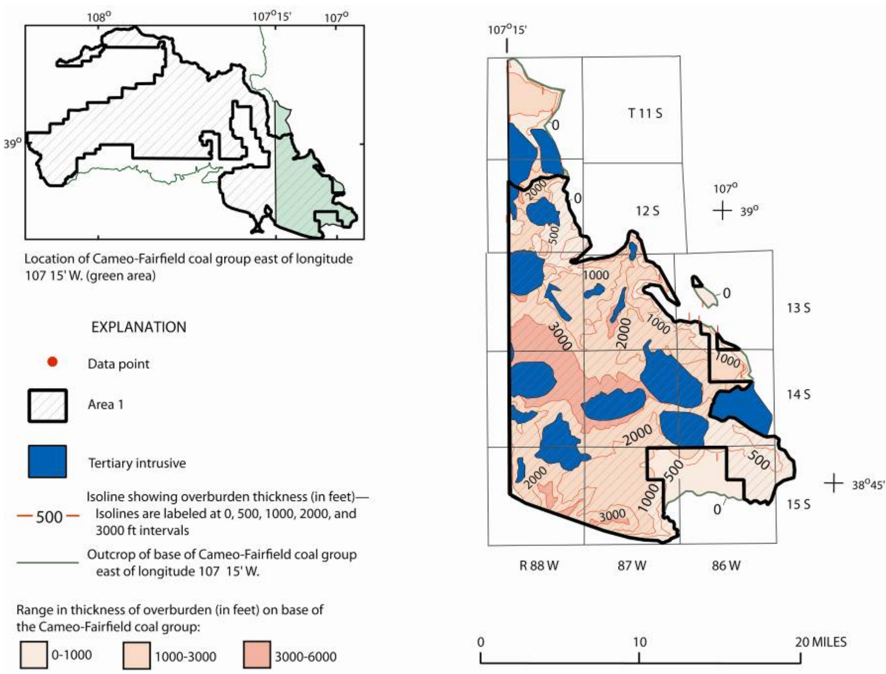


Figure 26. Isopach Map of Overburden on Mesaverde Formation in Eastern Intrusive Area

Source: Hettinger et al. 2004

For the analysis by Hettinger et al. (2000), an average density of 1,800 short tons per acre-foot for bituminous coal was used. Coal tonnages are reported within overburden categories of 0–500, 500–1,000, 1,000–2,000, and 2,000–3,000 feet. Overburden was determined by subtracting elevations at the base of the specified coal interval from surface elevations. The difference represents the maximum overburden on the specified coal interval. Elevations at the base of the A, B, and C seams were determined from a structure contour map of the top of the Rollins Sandstone Member. Similarly, elevations at the base of the D, E, and F seams were determined from structure contour maps that represent the base of those respective seams and their associated zones. These overburden thicknesses are shown in Figures 23–26.

Previously Estimated Coal Resources

The Grand Mesa and Somerset coal fields are the primary areas with coal potential for the Mesaverde Formation. About 150 million short tons have been produced since the late 1800s from this region (USFS 2006). The Mesaverde has six regionally extensive coal seams or zones; they contain as much as 97 feet of net coal and have individual coal beds as thick as 30 feet within the USFS areas (Hettinger et al. 2000). According to Landis (1959), a total of 3.348 billion short tons of bituminous coal are estimated to have been originally present in the 133 square miles of the Somerset coal field. He estimates that an additional 87 square miles of land may contain mineable coal reserves with less than 3,000 feet of overburden and could add around 2.19 billion short tons of coal to the resources. Hornbaker et al. (1976) adds that roughly one-half of the original coal in 133 square miles was high-volatile B bituminous and of coking quality. If coal could be mined with an overburden depth of 6,000 feet, Hornbaker et al.

(1976) estimates 8 billion short tons of coal over an additional 100 square miles. Landis (1959) determined that the Grand Mesa coal field contained 1.6 billion short tons of mineable coal, with less than 9 percent being high-volatile C bituminous and the remainder being subbituminous A rank. He indicated that if the overburden depth was increased to 3,000 feet, there should be an additional 184 square miles of coal with possibly 3.1 billion short tons of coal. Hornbaker et al. (1976) estimated 8.6 billion short tons of coal resource in beds greater than 5 feet thick and underlying up to 6,000 feet of overburden with 9 percent being high-volatile C bituminous and the remainder being subbituminous A rank.

Current Coal Resource Potential

The Known Potential Coal Resource map is shown as Figure 27. The USFS (2006) analyzed in detail the Grand Mesa and Gunnison National Forests in the southern Piceance Basin. They found that the area of high coal resource potential in the two forests within the basin is estimated to contain about 38 billion short tons of coal in the Mesaverde Formation. This large resource figure does not represent mineable reserves, which are a subset of the resource that could be economically produced at the present time. Coal in the Mesaverde would have to be mined using underground methods, and technological and geologic restrictions preclude much of the resource from being economically mined. For example, only 37 percent (14 billion short tons) of the coal resource is at depths favorable for longwall mining (i.e., less than 3,000 feet). Some coal would be precluded from mining because the beds are too thin, thick, or steeply inclined. Additional coal would also be restricted from mining because the beds might be discontinuous, left in the ground as pillars for roof support, or bypassed due to mining of adjacent coal seams.

Specific to the recoverable coal potential for Mesaverde coal in the Grand Mesa and Somerset coal fields within the planning area, the following criteria were used for determining levels of potential (Figure 22).

(1.) **High potential** – All Mesaverde in the vicinity of Grand Mesa with an overburden of less than 3,000 feet except for mined-out areas and current leases. It does not include pending leases. High-potential areas include much of the Grand Mesa and Somerset coal fields within the planning area.

(2.) **Low to moderate potential** – All Mesaverde with overburden of 3,000 to 3,500 feet. This is continuous band spanning both coal fields that is known to exist but is at the margin of current mining capabilities.

(3.) **Low potential** – Includes the Deep Piceance coal (Mesaverde with overburden greater than 3,500 feet).

Areas mined-out or under current leasing are excluded from having coal resource potential even if some seams within a lease have not been mined. This is because those seams could be mined under the current leases and require no exploration on new (not previously leased) land. In other words, exploration and mining of these unexploited seams could occur, but these activities would occur within areas of existing leases.

Although the Grand Mesa coal field has not had an active mine since 1984, this was not due to an exhaustion of the coal resource; rather, it was due to a lack of a rail line to export the coal to more-distant markets. Grand Mesa is within the Piceance Basin and is underlain by the

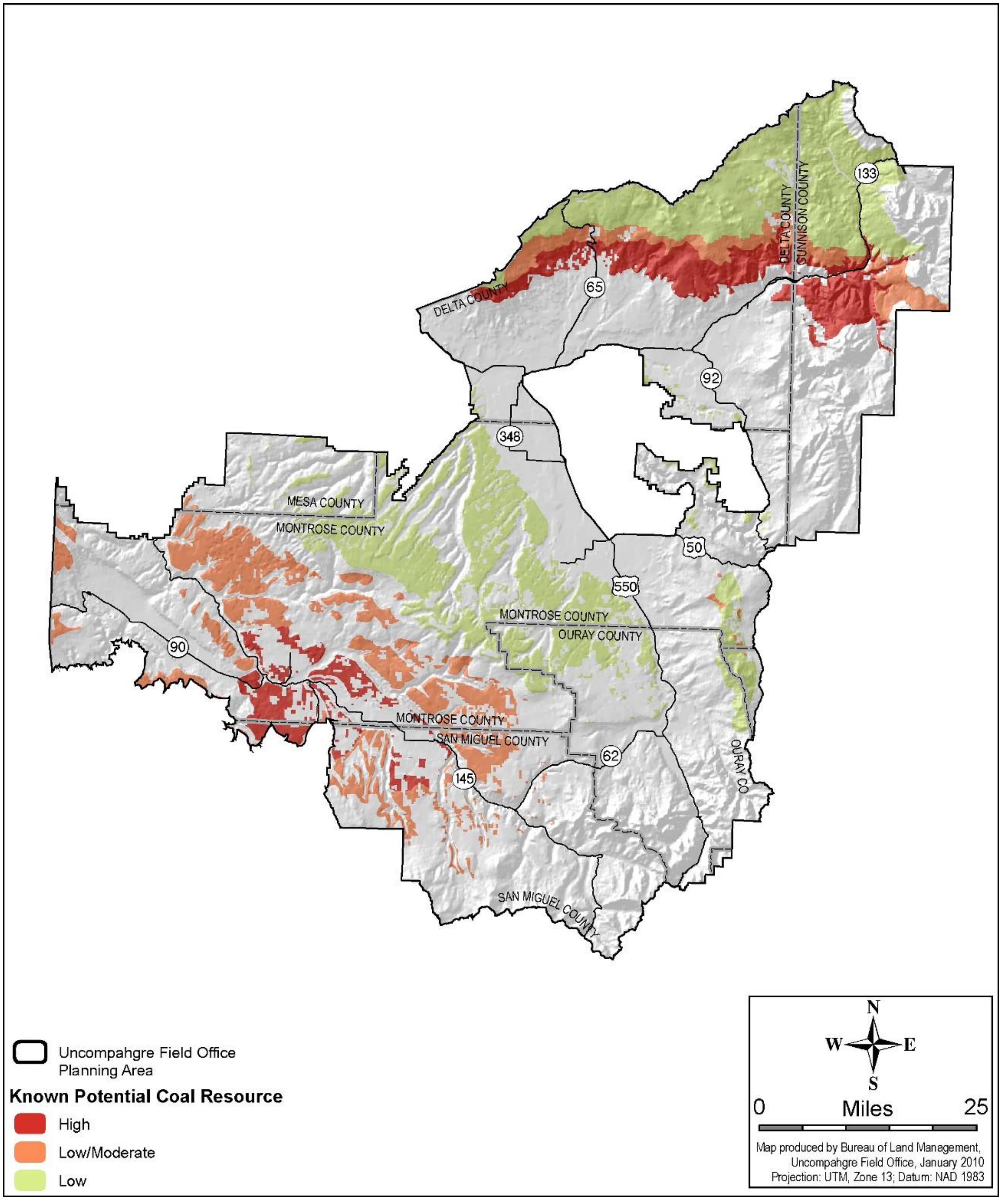


Figure 27. Known Potential Coal Resource in the Planning Area

Mesaverde. As such, coal underlies the entire landform, and the coal potential is significant if it could be accessed by deep-mining methods (Haun and Weimer 1960; Hornbaker et al. 1976; Landis 1959; Murray 1980a).

More detailed information about the coal resource potential of each of the six Mesaverde seams is offered below as a summary of work by Hettinger et al. (2000) and the USFS (2006).

Coal Resource Breakdown of the Mesaverde A to F seams

Based on information from the USGS (Hettinger et al. 2000), Area 1 (defined as the Grand Mesa and Gunnison National Forest within the Piceance Basin) has an original coal resource of about 14 billion short tons in the Mesaverde Formation and Mesaverde Group. This total represents coal beds more than 1 foot thick and under less than 3,500 feet of overburden. The resource figure does not include coal folded over the flanks of laccoliths (dome-shaped igneous intrusions) or buried beneath laccoliths. Approximately 20 percent of the resource is in the Grand Mesa National Forest, and 80 percent is in the Gunnison National Forest.

Area 1 also contains about 58 billion short tons of non-resource coal in the Mesaverde that is covered by 3,000 to 11,500 feet of overburden (Figure 20). Non-resource coal is defined by coal seams that are too thin or of such quality (low Btu or high sulfur/mercury) to make them uneconomical to mine. Approximately 76 percent of the non-resource coal is in the Grand Mesa National Forest, and 24 percent is in the Gunnison National Forest. Coal tonnages are reported by reliability and overburden categories for each coal zone in the Mesaverde where it is located west of longitude 107°15' West (Tables 3, 4, and 5, respectively), and tonnages are reported for the entire Mesaverde where it is located east of longitude 107°15' West (Table 6).

Table 3. Original Coal Resources in the A, B, and C Seams (Area 1) (in millions of tons)

National Forest	Reliability[1]	Overburden				Total
		0–500	500–1,000	1,000–2,000	2,000–3,000	
Grand Mesa	Identified	140	130	420	940	1,600
	Hypothetical	78	94	290	440	900
Grand Mesa Subtotal		**210**	**220**	**710**	**1,400**	**2,700**
Gunnison	Identified	940	820	2,200	2,600	6,900
	Hypothetical	80	15	0	200	300
Gunnison Subtotal		**1,000**	**830**	**2,200**	**2,800**	**7,100**
Total		**1,200**	**1,100**	**2,900**	**4,100**	**10,000**

[1] "Identified" resources are located less than 3 miles from a coal measurement (data point from an exploration drill hole), and "Hypothetical" resources are located more than 3 miles from a coal measurement.

Table 4. Original Coal Resources in the D and E Seams (Area 1)
(in millions of tons)

National Forest	Reliability[1]	Overburden				Total
		0–500	500–1,000	1,000–2,000	2,000–3,000	
Grand Mesa	Identified	0	0	0	0	0
	Hypothetical	0	0	0	0.47	0.47
Grand Mesa Subtotal		**0**	**0**	**0**	**0.47**	**0.47**
Gunnison	Identified	180	350	840	740	2,100
	Hypothetical	0.20	2.5	20	59	80
Gunnison Subtotal		**180**	**350**	**860**	**790**	**2,200**
Total		**180**	**350**	**860**	**790**	**2,200**

[1] "Identified" resources are located less than 3 miles from a coal measurement (data point from an exploration drill hole), and "Hypothetical" resources are located more than 3 miles from a coal measurement.

Table 5. Original Coal Resources in the F Seam (Area 1)
(in millions of tons)

National Forest	Reliability[1]	Overburden				Total
		0–500	500–1,000	1,000–2,000	2,000–3,000	
Grand Mesa	Identified	0	0	0	0.27	0.27
	Hypothetical	0	0	0.18	5.80	6
Grand Mesa Subtotal		**0**	**0**	**0.18**	**6.1**	**7**
Gunnison	Identified	170	230	670	540	1,600
	Hypothetical	0.96	0.82	0.22	38	40
Gunnison Subtotal		**170**	**230**	**670**	**580**	**1,600**
Total		**170**	**230**	**670**	**586**	**1,607**

[1] "Identified" resources are located less than 3 miles from a coal measurement (data point from an exploration drill hole), and "Hypothetical" resources are located more than 3 miles from a coal measurement.

Table 6. Original Coal Resources in the Mesaverde of the Eastern Intrusive Area (Area 1)
(in millions of tons)

Reliability[1]	Overburden				Total
	0–500	500–1,000	1,000–2,000	2,000–3,000	
Identified Subtotal	160	160	63	51	434
Hypothetical Subtotal	160	64	160	100	484
Total	320	224	223	151	918

[1] "Identified" resources are located less than 3 miles from a coal measurement (data point from an exploration drill hole), and "Hypothetical" resources are located more than 3 miles from a coal measurement.

The large gross coal resource figures reported for Area 1 (Grand Mesa and Gunnison National Forests in the Piceance Basin) must be regarded with caution because they do not reflect economic, land use, environmental, technological, and geologic restrictions that affect the availability and recoverability of coal. The coal would have to be mined using underground methods, and technological and economical constraints generally limit current longwall mining to (1) depths of less than 3,000 feet, (2) beds more than 3.5 feet thick, and (3) strata inclined by less than 12 degrees (USFS 2006). Additionally, only about 14 feet of coal can be mined even if the bed is of greater thickness due to limitations of the longwall mining equipment.

An estimated 14 billion short tons of coal in Area 1 meets favorable underground mining criteria regarding depth of burial (less than 3,000 feet), and only a fraction of that coal could be mined economically because many beds are either less than 3.5 feet thick or more than 14 feet thick, and because many localities in the vicinity of the Crested Butte and Carbondale coal fields are steeply inclined. Additional coal would also be restricted from mining because it might be in beds that are discontinuous, left in the ground as pillars for roof support, or bypassed due to mining of adjacent coal seams. The following summarizes the findings:

Area 1, A, B, and C Seams—The A, B and C seams have an original coal resource of 10 billion short tons in Area 1 (Table 3) where the coal is covered by less than 3,000 feet of overburden (Figure 23). Approximately 5.2 billion short tons are under less than 2,000 feet of overburden.

Area 1, D and E Seams—The D and E seams have an original coal resource of approximately 2.2 billion short tons in Area 1 (Table 4) where the coal is covered by less than 3,000 feet of overburden (Figure 24). Approximately 1.4 billion short tons are under less than 2,000 feet of overburden. The D and E seams contain an additional 3.8 billion short tons of non-resource coal (3,000 to 11,500 feet of overburden) in Area 1.

Area 1, F Seam—The F seam has an original coal resource of approximately 1.6 billion short tons in Area 1 (Table 5) where the coal is covered by less than 3,000 feet of overburden (Figure 25). Approximately 1.1 billion short tons are under less than 2,000 feet of overburden. The F seam contains an additional 1.8 billion short tons of non-resource coal in Area 1.

Area 1, Coal Resources of the Mesaverde in Eastern Intrusive Area—Area 1 has an original resource of 918 million short tons of coal in the Mesaverde where it is located east of longitude 107°15’ West (Table 6). The coal resource is distributed across the lower, middle, and upper coal zones. This resource figure is tenuous because of the complex geology and lack of coal measurements in the area. Additionally, the resource figure does not include coal that is folded over the flanks of laccoliths or that which is buried beneath laccoliths in the region. Maximum overburden on the Mesaverde east of longitude 107°15’ West is shown in Figure 26. Approximately 767 million short tons are under less than 2,000 feet of overburden.

VIII. Areas with Potential for Coal Development during Plan Life and Reserve Estimates

This report was prepared to aid in identifying areas with coal development potential in the planning area in support of the RMP revision underway in 2010. The following development potential estimates are for the plan life of 20 years beginning in approximately 2013, and are based on the most current available resource and development information. The coal resource potential was discussed in Section VII, which is the potential for the presence of coal based on geologic factors. 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.

Identification of Areas with Potential for Coal Development during Plan Life

The coal development potential within the planning area was evaluated separately for the Dakota Sandstone Formation and the Mesaverde/Fruitland Formations. In the case of Dakota coals, the seams are relatively thin, lenticular, and near the surface, making them more suitable to strip mining and local marketing. For the Mesaverde Formation, the coal is relatively thick with multiple, continuous seams, and is deep, requiring underground mining methods. The Fruitland Formation would also require underground mining and has potentially thick seams, but they are fragmented by faults. Only the Mesaverde coals in the Somerset coal field are accessible with a rail line via the North Fork Valley, while all other areas with coal potential would require trucking. The following criteria were taken into account when assessing the potential for coal development:

a. Areas with high potential for coal resource occurrence;
b. Existing coal mining activity occurring nearby;
c. Areas where the overburden is 3,500 feet or less in the Somerset Field and 150 feet or less for Dakota coal in the Nucla-Naturita-Norwood area;
d. Advances in mining technology could occur;
e. Coal prices and high-coal quality will continue the demand for area coal; and
f. Areas with private subsurface estate and Wilderness are excluded.

Nucla-Naturita Coal Field Potential Development

Coals in the Dakota Formation occur within the Nucla-Naturita coal field and several adjacent areas. Current mining at the New Horizon Mine will likely extend to the north on First and Second Parks. Also, mining potential exists on other areas of First and Second Parks (i.e., New Horizon Mine North), Wrights Mesa (southeast of Nucla and Naturita in the Redvale and Norwood areas), and south of the San Miguel River towards Naturita Ridge and Dry Creek Basin. Although Eakins (1986) indicated through borehole, water well, and outcrop data that Third Park had coal resource potential, exploratory work by Western Fuels Association found mostly carbonaceous shale, low-quality coal (around 8,000 Btu), and the main LDx coal seam was thin with multiple partings, making it undesirable for current strip mining methods (O'Hara 2009). If mining extends into these additional areas in the vicinity of the Nucla-Naturita coal field, supplying coal to the Nucla FBC power plant is expected for the next 20 years.

Regarding coal potential for other Dakota coals outside of the Nucla-Naturita area, borehole logs, water well logs, and outcrop data all suggest that coal does exist in this formation over a broad area, but it is too deep for strip mining, too thin with many partings, and/or of too poor quality to be a desirable coal resource. The main reason that the Nucla-Naturita coal field is still operating is the proximity of a specialized (FBC) coal power plant that can efficiently process the relatively thin, dirty seams of coal typical of Dakota coal in western Colorado. Because there are no other similar power plants in the planning area, developing Dakota coal outside of the Nucla area is not anticipated over the next 20 years.

Tongue Mesa Coal Field Potential Development

Coals in the Fruitland Formation occur within the Tongue Mesa coal field. Small "dog hole" mines have been used along the coal outcrop for local residential heating, but no commercial mines have operated since 1950 (Carroll and Bauer 2002). The Tongue Mesa field is heavily faulted, is covered with extensive landslide deposits, has no rail line or coal-handling facilities, and is in a remote area with limited access. Therefore, no commercial mining activity is expected in this area over the next 20 years.

Grand Mesa Coal Field Potential Development

The Grand Mesa coal field, located west of Leroux Creek, has significant potential to provide bituminous coal resource, as shown in Figure 22. However, due to the lower coal quality (i.e., lower Btu), deep overburden, and inaccessibility to coal-handling and transportation facilities, coal mining activity in this field has limited potential during the next 20 years (Sharrow 2005). Some exploration may be anticipated in the portions of this field with an overburden of less than 3,000 feet overlying the Mesaverde, but actual mining on a commercial scale is not likely due to a lack of a rail line and related infrastructure, as well as the proven higher-quality coal in the adjacent Somerset coal field. Additionally, the Somerset coal field contains a rail line, loadouts, and other coal handling facilities to accommodate future mining in the vicinity of Paonia and Somerset that do not exist in the Cedaredge area. Consequently, no commercial mining activity is expected in this area over the next 20 years.

Somerset Coal Field Potential Development

The Somerset coal field has the greatest potential for continuing to produce the largest amount of coal in the planning area. Projections by the US Department of Energy's Energy Information Administration (US Department of Energy 2010b) indicate that demand for Somerset's compliant to super-compliant coal will remain high and will likely continue to provide around 40 percent of Colorado's coal. In addition to the areas shown in Figure 28, which is the projection of the areas of recoverable coal resource based on the previously discussed criteria, the USFS (2006) produced a more detailed evaluation of potentially developable coal of the Mesaverde in the Somerset coal field within the Grand Mesa and Gunnison National Forests (Figure 28). The areas labeled A, B, and C (shown in purple on Figure 28) are the areas they determined should be considered for coal leasing in the Grand Mesa and Gunnison National Forests. This area surrounds the currently active coal operations in the North Fork Valley, including the Somerset coal field, and extends to the west into the Grand Mesa coal field (Area A), north of Somerset and Oxbow's lease (Area B), and east and south of Mountain Coal's lease (Area C). Area C is constrained by the North Fork of the Gunnison River on the north, Coal Creek on the east, the West Elk Wilderness boundary on the south, and the coal outcrop on the west. The estimated

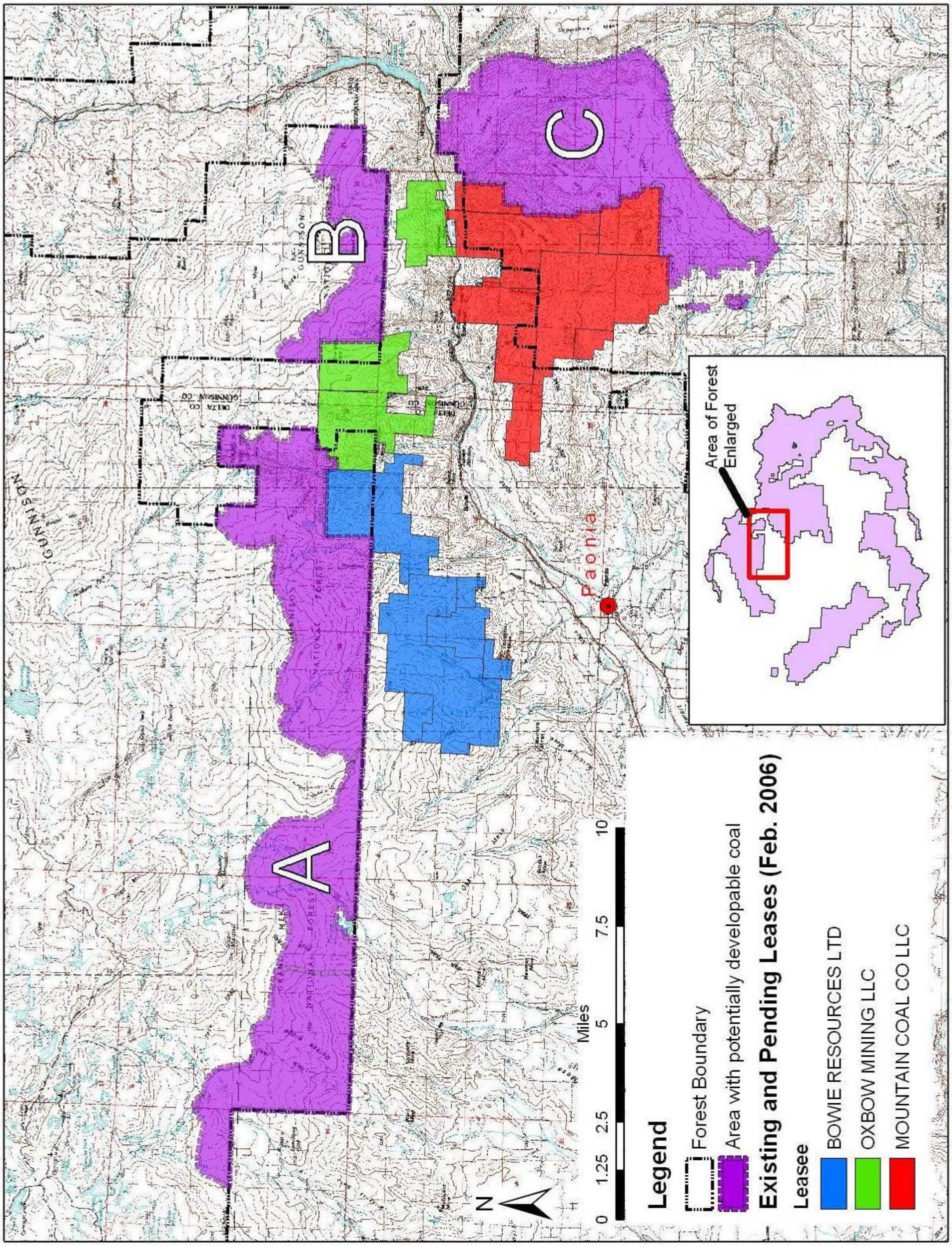


Figure 28. Potentially Developable Coal in the Somerset Coal Field
Source: USFS 2006

area on the Grand Mesa and Gunnison National Forests having a high potential for coal development is 45,280 acres, with Area A containing 24,780 acres, Area B containing 4,675 acres, and Area C containing 15,825 acres.

The limits of developable coal for Areas A, B, and C (Figure 28) have an overburden cut-off at 3,500 feet (rather than the 3,000 feet cited by USGS). This increased overburden limit is considered to allow for improvements in technology and mining techniques. As new equipment and techniques are employed, the depths to which longwall operations are safe and manageable are likely to increase (USFS 2006).

For the deeper coal seams that are currently inaccessible by current underground mining techniques, either conventional gas drilling methods in sandstone reservoirs interbedded with the coal in the Mesaverde or Underground Coal Gasification, also known as in-situ gasification of coal beds, may be an option to obtain energy from the coal beds without removing the coal (Wikipedia 2009). Underground Coal Gasification technology could be used to extract methane from the Piceance Deep coals in the planning area, which are those with an overburden of greater than 3,500 feet (Figure 5). In the Underground Coal Gasification process, wells inject oxidants into coal seams igniting them, and production wells collect the resultant gases to be used as a chemical feedstock or as fuel for power generation. Murray et al. (1977) found that the southeastern part of the Piceance Creek Basin, which includes the Somerset coal field, contains the gassiest coal mines in Colorado as well as the western US. Murray's work indicated that there are multiple thick (approximately 20- to 50-foot) coal beds in the basin at depths of 3,000 to 7,000 feet. Underground Coal Gasification technology has been used in the Appalachian region since the 1970s and could be a viable deep energy resource for this region of Colorado. Neither conventional gas drilling nor Underground Coal Gasification methods could be used close to an active or planned underground coal mine due to the fire and explosion potential within the mines.

Coal potential for other Mesaverde coals in the Somerset coal field outside of the currently leased areas includes Snowshoe Mesa and areas east of Coal Creek (east of Area C on Figure 28) and Coal Creek Mesa west of Coal Creek. Literature suggests the potential for coking and anthracite coal resources in these areas. Other areas of coal potential are Oak Mesa and the Leroux Creek basin near the western edge of the Somerset coal field, areas north to east of Paonia (Terror, Elk, and Minnesota Creek basins), and the area locally known at the Raggeds Field (east of Highway 133 and north of Paonia Reservoir on Figure 22). Viability of these reserves needs further evaluation.

Reserve Estimates for Area with Development Potential

Gross Reserve Estimates

Detailed analyses of coal reserves for the sum of all coal fields within the planning area are not available. There are many estimates of reserves on a per-mine basis, but none are projected beyond the scope of their operation. However, the USGS and others have calculated reserve estimates for the Somerset area coals. Because the majority of the currently active coal operations within the planning area are within the Somerset Quadrangle, data derived from their activities are useful to evaluate the potential coal resource in that area. In 2000, the USGS published a report on the coal reserves within the Somerset 7.5' Quadrangle (Rohrbacher et al. 2000) that was based on work by Eakins et al. (1998a). These reports are summarized in

Table 7, which provides a gross estimate of the coal reserves in the vicinity of the West Elk, Elk Creek, and Bowie #2 mines.

Table 7. Summary of Original, Mined, and Available Coal Resources within the Somerset 7.5' Quadrangle as of 1998

Resource Category	Seam*						Total
	Lower B	B	C	Lower D	D	E	
Original coal resource	95.2	1,202.5	417.6	280.7	666.4	425.4	3,087.8
Coal Mined or lost during mining	0.0	222.6	25.6	0.0	5.3	21.9	275.4
Remaining coal	95.2	979.9	392.0	280.7	661.1	403.5	2,812.4
Land use restrictions	0.0	0.1	0.2	0.9	0.4	0.3	1.9
Technological restrictions	36.4	198.3	0.9	175.9	72.8	0.3	484.6
Available coal resource	**58.8**	**781.5**	**390.9**	**103.9**	**587.9**	**402.9**	**2,325.9**

Source: Rohrbacher et al. 2000; Eakins et al. 1998a
*numbers are in millions of tons

Given that Table 7 reflects data as of 1998, it would be a fair estimate that available coal resources within the Somerset 7.5' Quadrangle are still over 2.2 billion short tons. However, these numbers are total for all coal beds greater than 2.3 feet thick. **The USFS (2006) indicates that "only a fraction of that coal could be mined economically because many beds are either less than 3.5 feet thick or more than 14 feet thick (range favorable for longwall mining operations)."** Additional coal would also be restricted from mining because of discontinuous beds, coal left in the ground as pillars for roof support, or coal bypassed due to mining of adjacent strata.

Refined Reserve Estimates

Although the USGS has published many reports calculating the reserves in and around the planning area, a more refined reserve estimate is needed to reflect the reserves within the areas highlighted in Figure 28.

In Hettinger et al. (2000), the USGS included spreadsheet data containing lithologic logs of explorations hole in the Somerset 7.5' Quadrangle. Also included in this report were Geographic Information System layers showing thickness of net coal and overburden. This coal resource data was clipped to the area having a high potential for coal development. Using Geographic Information System allowed the summation of coal reserves only for the area with high potential for coal development. When totaled, the amount of coal reserves for all coal beds (any thickness) is approximately 3.025 billion tons (USFS 2006). However, this estimate, because it contains all coal beds and has no land use restrictions, is not realistic. Since the USGS typically studies large regions with dispersed exploration logs, they typically extrapolate coal bed thickness over large areas. Therefore, their estimates of coal reserves are typically high.

As such, an estimation of recoverable and mineable coal reserves for the area identified in Figure 28 was performed assuming a thickness of mineable coal for the area to be 20 feet (to account for multiple seams of mineable thickness), a value of 1,830 tons per acre per foot of height. Using these parameters, the area in Figure 28 contains an estimated 1.65 billion tons of mineable coal, equating to 829 million tons of recoverable coal (USFS 2006).

IX. Compliant and Super-Compliant Coal Reserves

The existing coal production from mines operating on federal leases within the planning area produce Clean Air Act compliant and super-compliant coal. This means that coal quality meets or exceeds Clean Air Act standards for clean-burning coal (i.e., compliant coal contains between 1.0 and 1.2 pounds of sulfur dioxide per million Btu, and super-compliant coal contains less than 1.0 pound of sulfur dioxide per million Btu). The Energy Policy Act of 2005 contains provisions (Section 437) for the Secretary of Interior, in consultation with the Secretary of Agriculture, to inventory coal resources, including identifying areas where resources of compliant and super-compliant coal exist. Some areas in the US have been inventoried since 2005 for evaluating the presence of compliant and super-compliant coal. However, this level of inventory has not yet been performed by the Secretary of Interior for the planning area.

Recognizing that currently developed coal resources within the planning area meet Clean Air Act standards, available coal quality data were reviewed to generally assess where compliant and super-compliant coal resources may exist in the planning area. According to data presented by Affolter (2000) and summarized in Section III, the four coal fields in the planning area contain the range of non-compliant to super-compliant coals. All of the coal fields contain some coal that would at least be compliant. Colorado is second only to Illinois in bituminous coal reserves, but it is by far the leader in bituminous Clean Air Act-compliant coal reserves (Cappa et al. 2007). For example, coal produced in 2006, including coal from the Somerset coal field, ranges between 0.4 and 0.8 percent sulfur, which is two the three times lower than average eastern bituminous coal.

X. Production Estimates

In 2009, according to the Colorado Division of Minerals and Geology (Colorado Division of Recalmation Mining and Safety 2010b), the Bowie mines, Elk Creek Mine, and West Elk Mine collectively produced a total of 11,801,437 tons of coal, which was over 41.3 percent of coal produced from all Colorado coal mines. The New Horizon Mine produced 373,758 tons of coal in 2009, which was 3.1 percent of the State's coal production that year.

According to the Energy Information Administration's (Department of Energy) *2010 Annual Energy Outlook* with Projections from 2008 to 2035, the demand for low-sulfur bituminous and subbituminous coal from the Rocky Mountain Region is likely to increase annually by 0.2 percent and 0.7 percent, respectively (US Department of Energy 2010b). This is the type of coal produced in the Somerset coal field. The US Department of Energy projects that, on a Btu basis, 60 percent of domestic coal production will originate from states west of the Mississippi River in 2035, which is up from 50 percent in 2008. This is due to lower prices for western mining operations and the low sulfur content of western coals. The population is projected to increase by 0.9 percent per year with the demand for electric power from coal increasing 0.4 percent annually. The difference is projected to be made up by an increased use of renewable energy and natural gas supplies due to lower gas prices, as well as a decline in per capita consumption of electricity due to conservation measures triggered by higher energy prices and environmental concerns (US Department of Energy 2010b). Although there will be fewer new coal-fired power plants constructed in the next 25 years, coal will remain the dominant energy source for electricity generation according to the US Department of Energy's projections.

The BLM forecasts that 5 to 10 percent of coal reserves in the Somerset coal field will be recovered over the next 10 to 15 years (USFS 2006). The USFS report projects that, although demand for coal is projected to increase, yearly production at the mines in the Somerset coal field is likely to remain close to the existing rate of approximately 14 to 16 million tons per year due to several limiting factors. One limiting factor to the amount of coal produced is the capacity of the railway line or spur off of the main line in Delta, operated by Union Pacific, which hauls the coal. This spur's sole purpose is to support the three mines in the Somerset area, but mine production is directly related to the number of coal trains that can move in and out of the one-way valley (Cappa et al. 2007). Currently, due to train availability, it is unlikely that the rail line could support an increase in mine production. According to Oxbow Mining, LLC, each train set typically contains 105 cars, each carrying roughly 108 tons per car, which is a total of 11,400 tons of coal per train (Kiger 2010). This is an average of 2.84 trains per day leaving the valley. Other limiting factors to production include physical bottlenecks at the mine facilities such as conveyor and train load-out capacities, as well as the amount of coal that can be stockpiled at the individual mine sites.

For the Grand Mesa, Tongue Mesa, and Nucla-Naturita coal fields, no rail line spur currently exists to transport coal outside of the fields. The Nucla-Naturita coal field is successful due to the presence of a FBC power plant less than 10 miles from the single strip mine operating in the area. This plant is well suited to use low-quality coal, and the process removes sulfur during combustion. The 100 megawatt Nucla FBC plant can burn up to 420,000 tons of coal per year, with a minimum criteria of 8,000 Btu coal with no limits on ash and sulfur content (Eakins 1986; O'Hara 2010b). According to O'Hara (2010b), as long as this coal can be mined locally, with a maximum trucking distance of 10 miles from the Nucla power plant, production of around 400,000 tons of coal per year can be expected for the next 10 to 20 years. The New Horizon Mine is expected to deplete currently permitted mine reserves in 2013, so other areas will need to be permitted to meet Nucla power plant demand. O'Hara (2010b) indicated that the New Horizon Mine North (currently under review for permitting) would provide seven years of coal similar to the current rate to the Nucla power plant. Beyond 2020, other areas in the Nucla-Naturita coal field will need to be mined, but he is confident, based on their exploratory work, that these resources exist in the Nucla-Naturita coal field for an additional 18 years of production.

Production from the Grand Mesa and Tongue Mesa coal fields is primarily limited by haulage costs, which are currently cost prohibitive to truck coal to a loading station in the Delta or Montrose areas to access the exiting rail lines. An FBC power plant, similar to that which is used in Nucla, could be constructed in these areas, but this would require significant development costs. In addition, substantial costs would be associated with the development of transportation and surface infrastructure to deliver coal to a new plant. These factors make the Grand Mesa and Tongue Mesa coal fields unlikely coal resources to be developed in the next 20 years.

XI. Summary

The planning area contains several geologic formations that contain coal or have a high potential for the geologic occurrence of coal within four coal fields: the Somerset, Grand Mesa, Tongue Mesa, and Nucla-Naturita. The primary coal-bearing rocks are the Upper Cretaceous Dakota Formation, Mesaverde Formation and Group, and the Fruitland Formation. Due to the relatively thin coal seams and thin overburden, the Dakota coals are being strip mined in the Nucla-Naturita area at the New Horizon Mine. Maximum overburden thickness is typically approximately 100 to 120 feet for strip mining of Dakota coal. Due to multiple thick coal seams and thick overburden, the Mesaverde coals are mined underground in the Somerset coal field of the North Fork Valley. The active mines in that field are the Bowie #2, Elk Creek, and West Elk Mines. The current industry overburden limit is around 3,000 feet, but the USGS regards areas of coal potential up to 6,000 feet deep, which is the Piceance Deep coal underlying Grand Mesa.

The BLM estimates that coal development would occur in an area generally surrounding existing operations in the Somerset coal field and into eastern portions of the Grand Mesa coal field in the next 20 years. This area encompasses about 45,280 acres and contains an estimated 829 million tons of recoverable coal reserves (USFS 2006).

Currently, the three mines in the Somerset area collectively produce 12 to 16 million tons of coal per year. This production rate will likely remain stable and could increase slightly over the next 20 years. The demand for the high quality (i.e., high Btu, low sulfur, and low ash) of Somerset coal will likely continue for this coal both within and outside Colorado. The active strip mine in the Nucla-Naturita area will exhaust its current permit in 2013, but if other areas in the region with known coal resource are available for mining, the rate of 350,000 to 420,000 tons of coal per year could be mined for the next 20 years to continue to feed the Nucla Station FBC power plant.

XII. References

Affolter, R.H. 2000. Quality Characterization of Cretaceous Coal from the Colorado Plateau Coal Assessment Area. Chapter G of Geological Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah. USGS Professional Paper 1625-B, CD-ROM Discs 1 and 2, Version 1.0, 136 p.

Ambrose, C.T., W. Eakins, J.E. Schultz, and B.S. Kelso. 2001. Colorado Coal Quality Data. Colorado Geological Survey IS-58, CD-ROM.

Ayers, W.B. and W.R. Kaiser. 1994. Coalbed Methane in the Upper Cretaceous Fruitland Formation, San Juan Basin, New Mexico and Colorado. New Mexico Bureau of Mines and Mineral Resources Bulletin 146.

Bankey, V. 2004. Resource Potential and Geology of the Grand Mesa, Uncompahgre, and Gunnison National Forests and Vicinity, Colorado. USGS Bulletin 2213, 276 p.

BLM (US Bureau of Land Management). 1984. San Juan/San Miguel Resource Management Plan and Environmental Impact Statement, Final.

_____. 1988. Uncompahgre Basin Resource Management Plan and Environmental Impact Statement, Final.

_____. 2010. Red Cliff Mine Draft Environmental Impact Statement. Internet Web site: www.blm.gov/co/st/en/BLM_Programs/land_use_planning-rmp-red_cliff_mine.html. Accessed February 24, 2010.

Boreck, D.L. and D.K. Murray. 1979. Colorado Coal Reserves Depletion Data and Coal Mine Summaries. Colorado Geological Survey OFR 79-1.

Cappa, J.A., G. Young, J.R. Burnell, C. Carroll and B. Widmann. 2007. Colorado Mineral and Energy Industry Activities, 2006. Colorado Geological Survey IS-75, 55 p.

Carroll, C.J. 2003. Coal Geology of Colorado. 2003. Keystone Coal Industry Manual, published by Primedia Business Magazines and Media, Chicago, IL. p. 490-502.

_____. 2004. 2003 Summary of Coal Resources in Colorado, Colorado Geological Survey SP-54.

_____. 2005. Colorado Coal Directory, 2005. Colorado Geological Survey IS-71. 68 p.

_____. 2006. Coal Resource Maps of Colorado. Colorado Geological Survey MS-43. CD-ROM.

_____. 2010. Coal Geology of Colorado. 2010 Keystone Coal Industry Manual, published by Primedia Business Magazines and Media, Chicago, IL. p. 427-439.

Carroll, C.J. and M.A. Bauer. 2002. Historic Coal Mines of Colorado. Colorado Geological Survey Information Series 64, CD-ROM.

Colorado Division of Reclamation Mining and Safety. 2010a. County Operator Mining Data. Internet Web site: http://mining.state.co.us/County%20Operator%20Mining%20Data.htm. Accessed January 8, 2010.

_____. 2010b. Monthly Coal Summary Reports. Internet Web site: http://mining.state.co.us/Coal%20Reports.htm. Accessed February 17, 2010.

Colorado Geological Survey. 2000. Coalbed Methane – Colorado's World Class Commodity, in Rock Talk Vol. 3, No. 3, July 2000. 12 p.

_____. 2005. Colorado Coal: Energy Security for the Future, in Rock Talk Vol. 8, No. 2, Summer 2005. 12 p.

Dickinson, R.G. 1965. Geologic Map of the Cerro Summit Quadrangle, Montrose County, Colorado. USGS Map GQ-486.

_____. 1987a. Geologic Map of the Buckhorn Lakes Quadrangle, Gunnison, Montrose and Ouray Counties, Colorado. USGS Map GQ-1642.

_____. 1987b. Geologic Map of the Washboard Rock Quadrangle, Gunnison, Montrose and Ouray Counties, Colorado. USGS Map GQ-1643.

_____. 1988. Geologic Map of the Courthouse Mountain Quadrangle, Gunnison, Hinsdale, and Ouray Counties, Colorado. USGS Map GQ-1644.

Dunrud, C.R. 1989a. Geologic Map and Coal Stratigraphic Framework of the Cedaredge Area, Delta County, Colorado. Coal Investigation Map. USGS Map C-116.

_____. 1989b. Geologic Map and Coal Stratigraphic Framework of the Paonia Area, Delta Area, Delta and Gunnison Counties, Colorado. USGS Coal Investigations Map C-115.

Dyer, D. 2010a. Personal communication between Laurie Brandt, Buckhorn Geotech, and Desty Dyer, Mining Engineer, BLM UFO. January 11, 2010.

_____. 2010b. Personal communication between Laurie Brandt, Buckhorn Geotech, and Desty Dyer, Mining Engineer, BLM UFO. January 21, 2010.

Dyni, J.R. and D.L. Gaskill. 1980. Relation of the Carbon/Oxygen Ratio in Coal to Igneous Intrusions in the Somerset Coal Field, Colorado. USGS Bulletin 1477-A.

Eakins, W. 1986. Coal Resources of the Dakota Sandstone, Southwestern Colorado. Colorado Geological Survey OFR 86-1A.

Eakins, W. and M.M. Coates. 1998. Focus: Colorado Coal, in Colorado Geological Survey Rock Talk, v. 1, no. 3, 6 p.

Eakins, W., C.M.T. Ambrose, D.C. Scott, and D.D. Teeters. 1998a. Availability of Coal Resources in Colorado: Somerset Quadrangle, West-Central Colorado. Colorado Geological Survey RS-36, 87 p.

Eakins, W., C.M.T. Ambrose, R.C. Phillips, and M.L Morgan. 1998b. Demonstrated Reserve Base for Coal in Colorado Somerset Coal Field. Colorado Geological Survey OFR 98-5.

Ellis, M.S. and V.L Freeman. 1984. Geologic Map and Cross Sections of the Carbondale 30' x 60' Quadrangle, West-Central, Colorado. USGS Coal Investigations Map C-97-A.

Ellis, M.S., D.L. Gaskill and C.R. Dunrud. 1987. Geologic Map of the Paonia and Gunnison Area, Delta and Gunnison Counties, Colorado. USGS Coal Investigations Map C-109.

Ellis, M.S., V.L. Freeman, and J.R. Donnell. 1988. Cross Sections Showing Correlation of Coal Beds and Coal Zones in the Mesaverde Formation in the Carbondale 30' x 60' Quadrangle, West-Central Colorado. USGS Coal Investigations Map C-97-B.

Ellis, M.S. and V. Gabaldo. 1989. Geologic Map and Cross Sections of Parts of the Grand Junction and Delta 30' x 60' Quadrangles, West-Central Colorado. USGS Coal Investigations Map C-124.

Fender, H.B., D.C. Jones and D.K. Murray. 1978. Bibliography and Index of Publications Related to Coal in Colorado 1972-1977. Colorado Geological Survey Bulletin 41.

George, R.D. 1937. Analyses of Colorado Coals. US Bureau of Mines Technical Paper 574. 327 p.

Goolsby, S.M., N.S. Reade, and D.K. Murray. 1979. Evaluation of Coking Coals in Colorado. Colorado Geological Survey RS-7.

Grand Mesa Coal Company. 1984. Application for a Permit to Conduct coal Mining in Colorado for Red Canyon Mine #1 and #2, Mining Plan, and Exploration Data, Volumes 1-3.

Hail, W.J. 1972a. Reconnaissance Geologic Map of the Cedaredge Area, Delta County, Colorado. Scale 1:48,000. USGS Map I-697.

_____. 1972b. Reconnaissance Geologic Map of the Hotchkiss Area, Delta and Montrose Counties, Colorado. Scale 1:48,000. USGS Map I-698.

Haines, D.V. 1978. Core-Hole Drilling and Coal Analysis Report for nine Holes Drilled During 1977 in the Nucla coal Field, Montrose County, Colorado. USGS Open-File Report 78-899, 37 p.

Hardie, J.K. 1999. Clastic Dikes Intruding Cretaceous Coals of Western Colorado. Colorado Geological Survey Bulletin 53.

Haun, J.D. and R.J. Weimer. 1960. Cretaceous Stratigraphy of Colorado, in Weimer, R.J. and J.D Haun, eds., Guide to the Geology of Colorado: Geological Society of America, Rocky Mountain Association of Geologists, and Colorado Scientific Society Guidebook, p. 58-65.

Hettinger, R.D, L.N.R. Roberts, T.A. Gognat. 2000. Investigations of the Distribution and Resources of Coal in the Southern Part of the Piceance Basin, Colorado. Chapter O of Geologic Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah. USGS Professional Paper 1625-B Discs 1 and 2, Version 1.0 (CD ROM).

Hettinger, R.D, L.N.R. Roberts, M.A. Kirschbaum. 2004. Coal Resources and Coal Resource Potential. Chapter M of Resource Potential and Geology of the Grand Mesa, Uncompahgre, and Gunnison National Forests and Vicinity, Colorado. USGS Bulletin 2213-M, p. 191-223.

Hodgson, H.E. 1978. Proceedings of the Second Symposium on the Geology of Rocky Mountain Coal – 1977. Colorado Geological Survey RS-4.

Hornbaker, A.L. and R.D. Holt. 1973. 1972 Summary of Coal Resources in Colorado. Colorado Geological Survey SP-3.

Hornbaker, A.L., R.D. Holt, and K. Murray. 1976. 1975 Summary of Coal Resources in Colorado. Colorado Geological Survey SP-9.

Johnson, R.C., 1989, Geologic History and Hydrocarbon Potential of Late Cretaceous-age, Low-Permeability Reservoir, Piceance Basin, Western Colorado: USGS Bulletin 1787-E, p. E1–E51.

Jones, D.C. and J.E. Schultz. 1978. Coal Resource and Development Map of Colorado. Colorado Geological Survey MS-9, digital TIF image in Coal Resource Maps of Colorado by Carroll (2006).

Khalsa, N.S. and L.R. Ladwig. 1981. Colorado Coal Analyses 1976-1979. Colorado Geological Survey IS-10.

Kiger, J. 2010. Personal communication between Laurie Brandt, Buckhorn Geotech, and Jim Kiger, Oxbow Mining, LLC. February 18, 2010.

Kirschbaum, M.A. 2000. Introduction: Geologic Assessment of Coal in the Colorado Plateau. Chapter A of Geological Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah. USGS Professional Paper 1625-B, CD-ROM Discs 1 and 2, Version 1.0.

Kirschbaum, M.A., L.N.R. Roberts, and L.R.H. Biewick. 2000. Geologic Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah. USGS Professional Paper 1625-B, CD-ROM Discs 1 and 2, Version 1.0, Geographic Information System Shapefiles and metadata.

Kirschbaum, M.A. and L.R.H. Biewick. 2000. A Summary of the Coal Deposits in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah. Chapter B of Geological Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah. USGS Professional Paper 1625-B, CD-ROM Discs 1 and 2, Version 1.0.

Landis, E. R. 1959. Coal Resources of Colorado. USGS Bulletin 1072-C, p. 131-232.

Lee, W.T. 1912. Coal Fields of Grand Mesa and the West Elk Mountains, Colorado. USGS Bulletin 510, 237 p.

Lewis, L. 2010. Personal communication between Laurie Brandt, Buckhorn Geotech, and Lynn Lewis, former Geologist, BLM UFO. February 24, 2010.

Murray, D.K. 1980a. Coal in Colorado, in Kent, H.C. and K.W. Porter, eds., Colorado Geology: Rocky Mountain Association of Geologists, p. 205-216.

_____. 1980b. Coal Resources in Colorado. Colorado Geological Survey Special Publication 13, 24 p.

_____. 1981. Upper Cretaceous (Campanian) Coal Resources of Western Colorado. New Mexico Geological Society Guidebook, 32nd Field Conference, Western Slope Colorado, p. 233-239.

Murray, D.K., H.B. Fender, and D.C. Jones. 1977. Coal and Methane Gas in the Southeastern Part of the Piceance Creek Bain, Colorado, in Veal, H.K., ed., Exploration Frontiers of the Central and Southern Rockies: Rocky Mountain Association of Geologists, 1977 Symposium, p. 379-405.

Morse, J.G. 1979. Energy Resources in Colorado: Coal, Oil Shale, and Uranium. Westview Press, 396 p.

O'Hara, G. 2009. Personal communication between Laurie Brandt, Buckhorn Geotech, and George O'Hara, Geologist, Western Fuels Association. December 16, 2009.

_____. 2010a. Personal communication between Laurie Brandt, Buckhorn Geotech, and George O'Hara, Geologist, Western Fuels Association. February 8, 2010.

_____. 2010b. Personal communication between Laurie Brandt, Buckhorn Geotech, and George O'Hara, Geologist, Western Fuels Association. February 18, 2010.

Rohrbacher, T.J., C.L. Molnia, L.M. Osmonson, M.D. Carter, W. Eakins, G.K. Hoffman, D.E. Tabet, J.E. Schultz, D.C. Scott, D.D. Teeters, G.E. Jones, J.C. Quick, B.P. Hucka and J.A. Hanson. 2000. Coal Availability, Recoverability, and Economic Evaluations, of Coal Resources in the Colorado Plateau: Colorado, New Mexico, and Utah. Chapter F of Geological Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah. USGS Professional Paper 1625-B, CD-ROM Discs 1 and 2, Version 1.0.

Rushworth, P., B.S. Kelso, M.E. Brownfield, and E.A. Johnson. 1988. Selected References on the Geology and Coal Resources of Central and Western Colorado Coal Fields and Regions. Colorado Geological Survey IS-25.

Schultz, J.E., W. Eakins, D.C. Scott and D.D. Teeters. 2000. Availability of Coal Resources in Colorado: Somerset Coal Field, West-Central Colorado. Colorado Geological Survey RS-38, 84 p.

Schweinfurth, S.P. 2002. Coal – A Complex Natural Resource: An Overview of Factors Affecting Coal Quality and Use in the United States. USGS Circular 1143.

Sharrow, B. December 14, 2005. Letter from BLM Uncompahgre Field Office Manager (B. Sharrow) to USFS Forest Supervisor (C. Richmond) regarding formal input on the 2004 Grand Mesa, Uncompahgre, and Gunnison National Forests Coal Resource and Development Potential Report. 3 p.

Smith, S.M., A.B. Wilson, and M.J. Crane. 2001. Cited References and Additional Selected Bibliography for the Grand Mesa, Uncompahgre, and Gunnison National Forests Greater Study Area.

Speltz, C.N. 1976. Strippable Coal Resources of Colorado: Location, Tonnage, and Characteristics of Coal and Overburden. US Bureau of Mines Info Circular 8713.

Streufert, R.K. 1999. Geology and Mineral Resources of Gunnison County, Colorado. Colorado Geological Survey RS-37.

Toenges, A.L., J.J. Dowd, L.A. Turnbull, J.D. Davis, H.L. Smith, and V.H. Johnson. 1949. Reserves, Petrographic and Chemical Characteristics, and Carbonizing Properties of Coal Occurring South of Dry Fork of Minnesota Creek, Gunnison county, near Paonia, Colorado, and the Geology of the Area. US Bureau of Mines Technical Paper 721, 48 p.

Toenges, A.L., L.A. Turnbull, J.D. Davis, D.A. Reynolds, B.C. Parks, H.M. Cooper, and R.F. Abernethy. 1952. Coal Deposit, Coal Creek District, Gunnison County Colorado: Reserves, Coking Properties, and Petrographic and Chemical Characteristics. US Bureau of Mines Bulletin 501, 83 p.

US Bureau of Mines and USGS. 1976. Coal Resource Classification System of the US Bureau of Mines and USGS. USGS Bulletin 1450-B, 9 p.

US Department of Energy. 2010a. Energy Information Administration Annual Coal Report, 2008. Internet Web site: http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html. Accessed January 8, 2010.

_____. 2010b. Energy Information Administration Annual Energy Outlook, 2010. Internet Web site: http://www.eia.doe.gov/oiaf/aeo/page/overview.html. Accessed February 18, 2010.

_____. 2010c. Energy Information Administration Colorado Profile. Internet Web site: http://www.eia.doe.gov/cneaf/coal/statepro/imagemap/co.htm. Accessed January 8, 2010.

_____. 2010d. Energy Information Administration Quarterly Coal Report, July – September 2009. Internet Web site: http://www.eia.doe.gov/cneaf/coal/quarterly/qcr_sum.html. Accessed January 8, 2010.

USFS. 2006. Coal Resource and Development Potential Report: Grand Mesa, Uncompahgre, and Gunnison National Forests, 44 p.

USGS and Colorado Geological Survey. 1977. Energy Resources Map of Colorado. Scale 1:500,000. USGS Map I-1039.

Wikipedia. 2009. Underground Coal Gasification. Internet Web site: http://en.wikipedia.org/wiki/Underground_coal_gasification. Accessed December 17, 2009.

Williams, P.L. 1983. Geology, Structure, and Uranium Deposits of the Moab Quadrangle, Colorado and Utah. Scale 1:250,000. USGS Map I-360.

Wood, G.H. Jr., T.M. Kehn, M.D. Carter and W.C. Culbertson. 1983. Coal Resource Classification System of the USGS, USGS Circular 891, 81 p.

Woodruff, E.G. 1912. Coal Resources of Gunnison Valley, Mesa and Delta Counties, Colorado in Contributions to Economic Geology, Part II – Mineral Fuels, ed. M.R. Campbell. USGS Bulletin 471. P.565-573.

Wray, L.L. 2000. Late Cretaceous Fruitland Formation Geologic Mapping, Outcrop Measured Sections, and Subsurface Stratigraphic Cross Sections, Northern La Plata County, Colorado. Colorado Geological Survey OFR 00-18.

Wray, L.L. and J.E. Schultz. 2001. Coal and Coalbed Methane in Colorado. Colorado Geological Survey SP-51. CD-ROM.

Young, R.G. 1960. Dakota Group of Colorado Plateau: American Association of Petroleum Geologists Bulletin, v. 44, no. 2, p. 156-194.

Zook, J.M. and C.M. Tremain. 1997. Directory and Statistics of Colorado Coal Mines with Distribution and Electric Generation Map, 1995-96. Colorado Geological Survey RS-32.