Coal Resources and Coal Resource Potential

By R.D. Hettinger, L.N.R. Roberts, and M.A. Kirschbaum

Chapter M of

Resource Potential and Geology of the Grand Mesa, Uncompahgre, and Gunnison (GMUG) National Forests and Vicinity, Colorado

Edited by Viki Bankey

U.S. Geological Survey Bulletin 2213–M

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

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Abstract

Upper Cretaceous strata are known to contain coal in the vicinity of the Grand Mesa, Uncompahgre, and Gunnison (GMUG) National Forests, Colorado, and these coal-bearing rocks extend under some areas of the forests. Forest areas are assigned a high, moderate, or low coal resource potential where coal-bearing strata have less than 6,000 feet of overburden. Areas of high potential have nearby outcrop or drill hole data that substantiate the presence of coal. Areas of moderate 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 to be present. Areas of low potential have no information to substantiate the presence of coal; however, the presence of coal is inferred from regional data. The Uncompahgre National Forest has a low to moderate coal resource potential in areas underlain by the Dakota Sandstone, and it also has a moderate to high coal resource potential in areas underlain by the Fruitland Formation. The Grand Mesa National Forest has a low coal resource potential where it is underlain by the Dakota Sandstone, and it has a high coal resource potential in areas underlain by the Mesaverde Group and Mesaverde Formation. The Gunnison National Forest also has a high coal resource potential in areas underlain by the Mesaverde Group and Mesaverde Formation.

Introduction

Purpose and Scope

Upper Cretaceous rocks in the GMUG greater study area (map area, fig. M1) contain coal-bearing strata that extend under parts of the Grand Mesa, Uncompahgre, and Gunnison (GMUG) National Forests, Colorado. The coal-bearing strata are in the Upper Cretaceous Dakota Sandstone, Fruitland Formation, Mesaverde Formation, and Mesaverde Group. Although some of the coal has been mined since the late 1800's, only the West Elk mine is currently operating within the three national forests of this study area (herein called the GMUG forests). The purpose of this chapter is to summarize the coal geology, and assess the coal resource potential for the GMUG forests. We estimate coal resources in the GMUG forest areas underlain by economically significant deposits of coal in the Mesaverde Group and Mesaverde Formation, and this main coal assessment unit is referred to as Area 1 (fig. M1) in this chapter. We also describe less significant deposits of coal that underlie other parts of the GMUG forests.

The areas of high coal resource potential in the Grand Mesa and Gunnison National Forests are contiguous, and they are estimated to have a combined coal resource of about 38 billion short tons, as determined in this study. That tonnage is reported for all beds of coal more than 1 ft thick and having less than 6,000 ft of overburden. This study does not attempt to estimate coal reserves that are the subset of the resource which can be economically produced at the present time. The coal resource is in the regionally extensive Cameo-Fairfield coal group of the Mesaverde Formation and Mesaverde Group. The Cameo-Fairfield has as much as 97 ft of net coal, and individual beds are as much as 30 ft thick. The Grand Mesa and Gunnison National Forests contain an additional 26 billion short tons of non-resource coal that is also in the Cameo-Fairfield coal group at depths greater than 6,000 ft.[1]

The large coal resource reported for the Grand Mesa and Gunnison National Forests must be regarded with caution because the figure does not take into account economic, land-use, environmental, technological, and geologic restrictions that affect the coal's availability and recoverability. The coal would have to be mined using underground methods, and technological and economical constraints generally limit current longwall mining to depths of less than 3,000 ft, beds more than 3.5 ft thick, and strata inclined by less than 12°; additionally, only about 14 ft of coal can be mined even if the bed is of greater thickness (Timothy J. Rohrbacher, U.S.

[1]Measurements originally made and reported in feet, in miles, in square miles, and in short (2,000-lb) tons are included here in their original units for clarity and to avoid misstatement of precision in conversion. To convert feet to meters, multiply by 0.3048; to convert short tons to metric tons, multiply by 0.91; to convert miles to kilometers, multiply by 1.61; to convert square miles to square kilometers, multiply by 2.6.

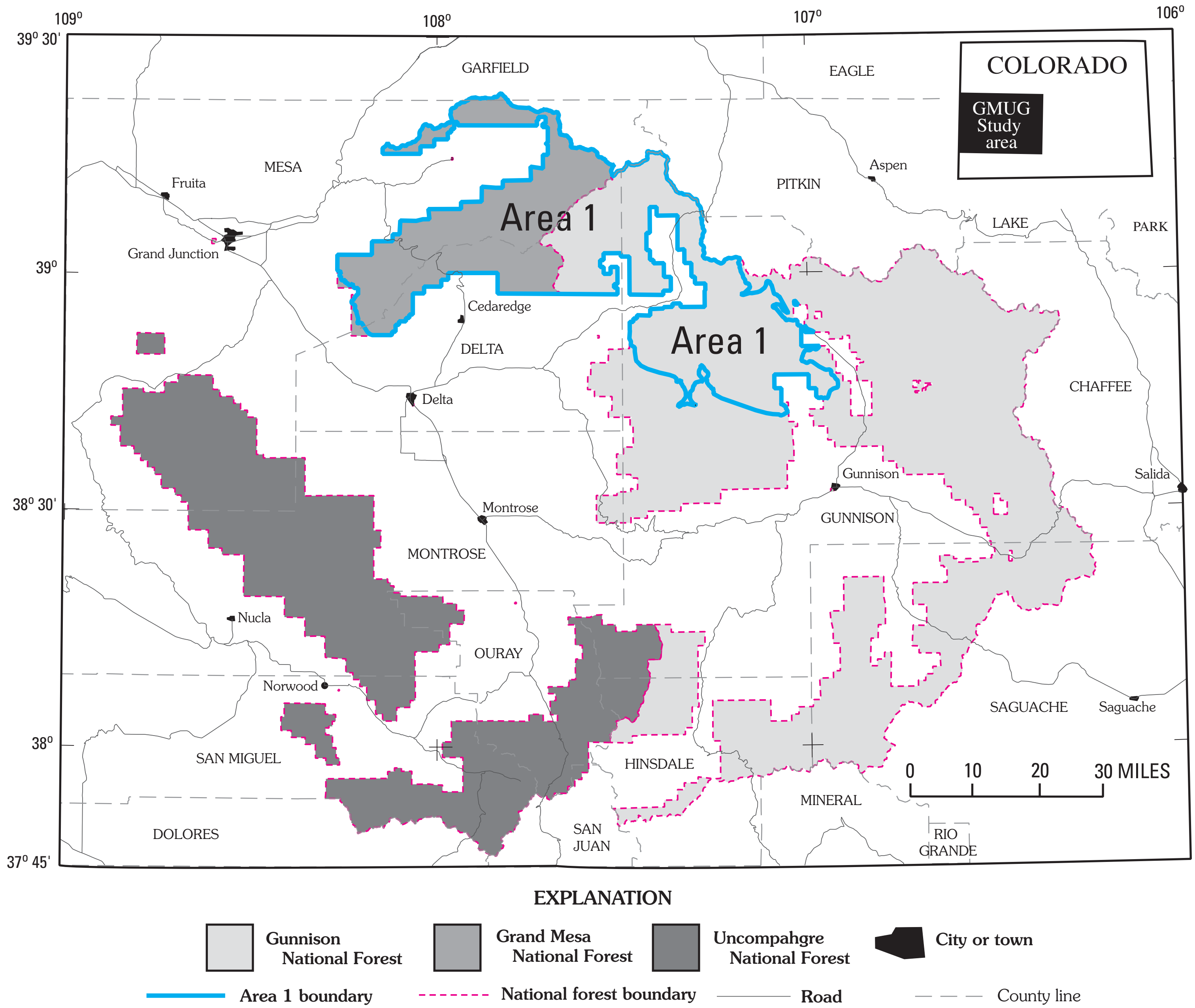


Figure M1. Location of Grand Mesa, Uncompahgre, and Gunnison National Forests, and southern Piceance Basin coal assessment unit (Area 1) within GMUG greater study area. Study area is located in western Colorado (inset) between lat 37°45′ and 39°30′ N. and long 106° and 109° W.

Geological Survey, oral commun., 1996). Only an estimated 37 percent of the coal resource estimated for the Cameo-Fairfield coal group in the Grand Mesa and Gunnison National Forests meets favorable underground mining criteria regarding depth of burial (less than 3,000 ft). Furthermore, only a fraction of that coal could be mined economically because many beds are either less than 3.5 ft thick or more than 14 ft thick and because many localities 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 strata.

Location

The greater study area and GMUG forests are located in western Colorado (fig. M1, index) between lat 37°45′ and 39°30′ N. and long 106° and 109° W. (map area, fig. M1). The study area is situated on and adjacent to the northeastern part of the Colorado Plateau, and major structural features include the Sawatch and Uncompahgre uplifts, and the Piceance and Paradox Basins (fig. M2). The Uncompahgre uplift separates the Piceance Basin from the Paradox Basin to the south.

The GMUG forests contain lands located within or adjacent to several coal fields of western Colorado (fig. M3). The coal field boundaries have been variously defined by Landis (1959), Hornbaker and others (1976), and Tremain and others (1996); and the boundaries shown in figure M3 represent a best-fit approximation of their various descriptions. The Grand Mesa National Forest extends across part of the Grand Mesa coal field and lies in close proximity to the Book Cliffs and Somerset coal fields. The northwestern part of the Gunnison National Forest extends across the Carbondale, Crested Butte, and Somerset coal fields. Farther south, parts of the Uncompahgre National Forest lie within the Tongue Mesa coal field and adjacent to the Nucla-Naturita coal field. The geology and resources of each coal field were described in Landis (1959) and are updated annually by the Colorado Geological Survey (for example, Hornbaker and others, 1976; Tremain and others, 1996).

Acknowledgments

We thank Ted Dyman, Tom Judkins, and Brad Van Gosen for their thorough reviews of the manuscript.

Upper Cretaceous and Tertiary Rocks

The GMUG forests are underlain by coal-bearing strata in the Dakota Sandstone, Mesaverde and Fruitland Formations, and Mesaverde Group (table M1). These Upper Cretaceous rocks were deposited in continental and nearshore marine settings along the western margin of the Western Interior seaway. Shoreline positions and depositional systems during the Late Cretaceous are shown in Roberts and Kirschbaum (1995). Although the Dakota Sandstone has a wide distribution throughout the GMUG forests, the Mesaverde Formation and Mesaverde Group are confined to areas where the Gunnison and Grand Mesa National Forests extend across the Piceance Basin, and the Fruitland Formation is confined to an isolated area where the Uncompahgre National Forest extends across the Tongue Mesa coal field (fig. M4).

The Dakota consists of conglomerate, sandstone, mudrock, carbonaceous shale, and coal deposited in alluvial and coastal plain settings during the initial incursion of the Western Interior seaway during the Cenomanian Stage of the Cretaceous Period. The Dakota is about 30–200 ft thick (Young, 1960, his fig. 16) and is overlain by the Mancos Shale. The Mancos consists of about 4,000–5,000 ft of mudrock deposited in an offshore marine environment that persisted from the Cenomanian through Campanian in the study area, when the shoreline was located in Utah.

As the shoreline moved back into the study area during the late Campanian, strata were deposited in a complex system of continental, coastal plain, and shoreface environments. At the Tongue Mesa coal field (fig. M3), about 200 ft of Upper Cretaceous coal-bearing strata is assigned to the Fruitland Formation by Dickinson (1987a, 1987b, 1988) and Hornbaker and others (1976). These rocks are part of a 1,000-ft thick stratigraphic interval that was referred to as the Mesaverde Formation by Landis (1959). In the southern part of the Piceance Basin, about 2,100–5,600 ft of strata has been assigned to the 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 and Grand Mesa coal fields. In the Book Cliffs coal field, the Mesaverde Group was divided into (in ascending order) the Castlegate Sandstone, Sego Sandstone, Mount Garfield Formation, and Hunter Canyon Formation (Erdmann, 1934; Fisher and others, 1960). In the Grand Hogback and Carbondale coal fields, the Mesaverde Group was divided into (in ascending order) the Iles and Williams Fork Formations (Collins, 1976). The stratigraphy and nomenclature of the Mesaverde are shown in figure M5; a more detailed discussion of Mesaverde stratigraphy is provided by Johnson (1989) and Hettinger and others (2000).

Depositional systems of continental origin prevailed throughout the study area from the latest part of the Cretaceous Period to the middle part of the Eocene Epoch of the Tertiary Period. The later part of the Tertiary was characterized by basalt flows and intrusions of igneous stocks, dikes, sills, and laccoliths. Volcanic activity was especially prevalent along the southeastern flank of the Piceance Basin and in the San Juan volcanic field (fig. M2).

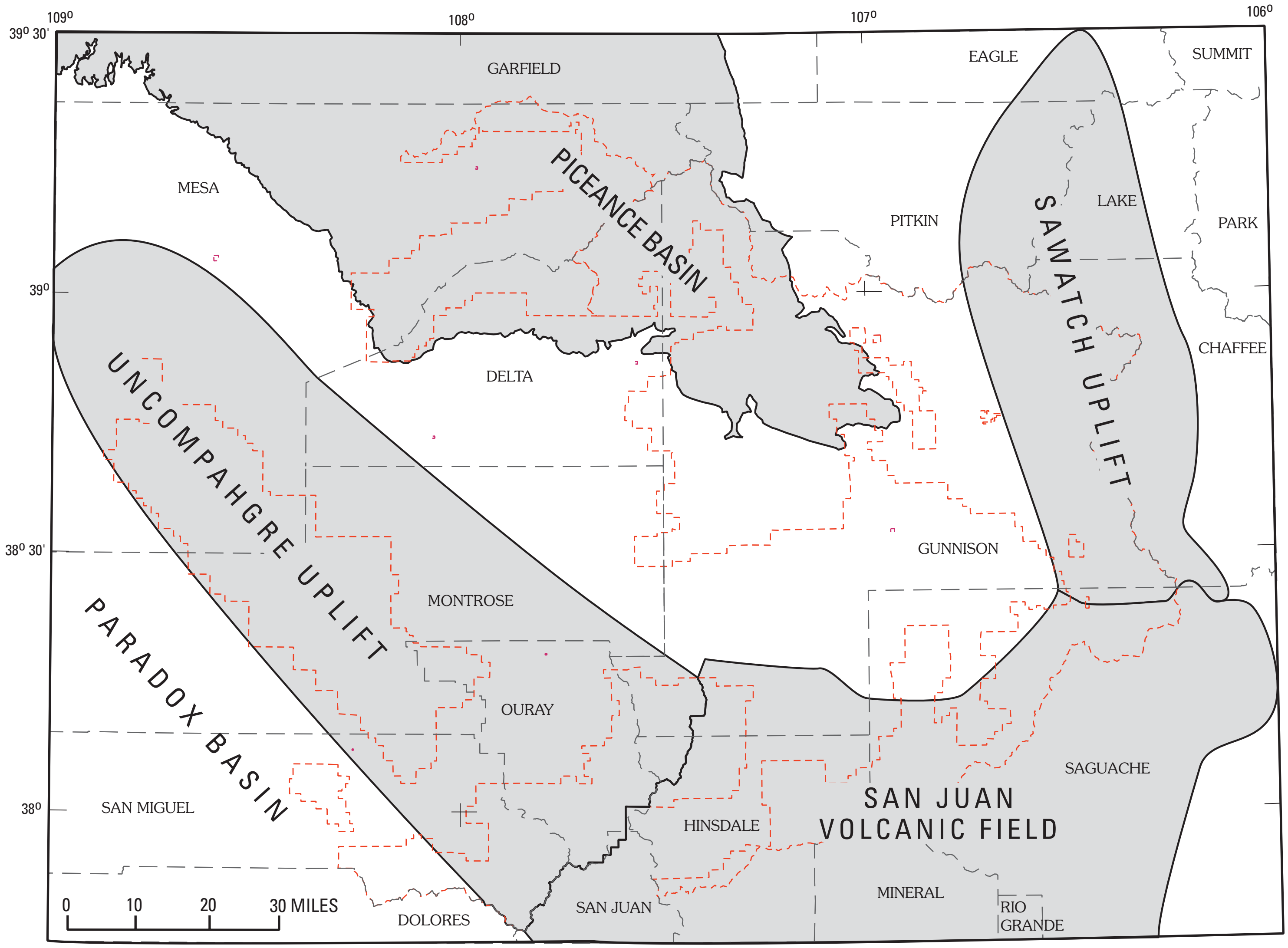
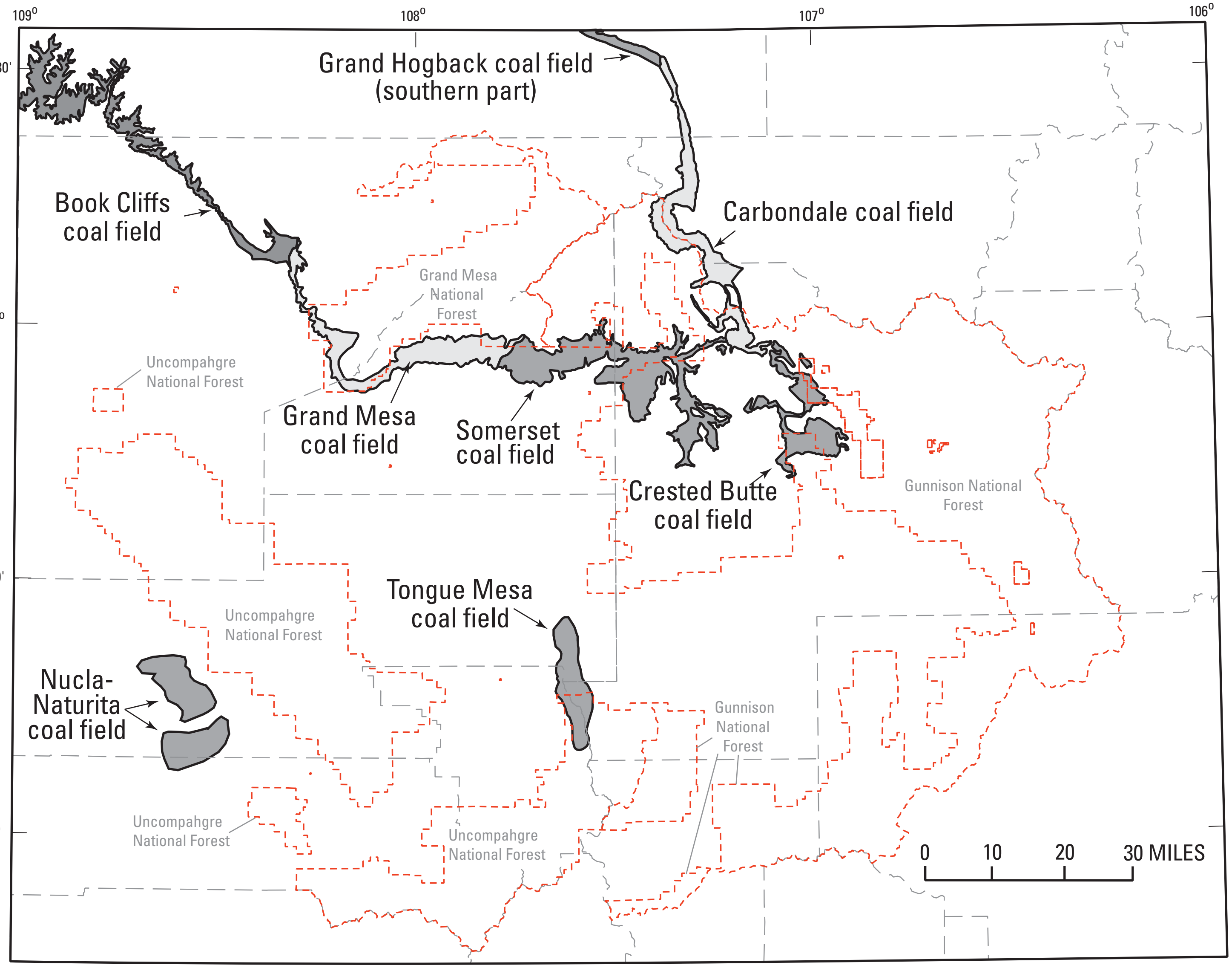


Figure M2. Location of major structural features in GMUG greater study area, and their relationship to Grand Mesa, Uncompahgre, and Gunnison National Forests. GMUG forest boundaries are shown as red dashed lines, and the forests are identified in figure M1.



EXPLANATION

Boundaries of Grand Mesa, Gunnison, and Uncompahgre National Forests

County line

Figure M3. Location of coal fields in GMUG greater study area.

Table M1. Summary of Cretaceous strata in Grand Mesa, Uncompahgre, and Gunnison (GMUG) National Forests.

Age	Group or Formation	Thickness (ft)	Description
Late Cretaceous	Mesaverde Group and Mesaverde Formation and	2,150-5,600	Sandstone, mudrock, carbonaceous shale, and coal. Sandstone is very fine grained to medium grained, and locally coarse grained. Upper part is fine grained to coarse grained and conglomeratic. Lower part intertongues with Mancos Shale. The Mesaverde Group or Mesaverde Formation underlies the Grand Mesa and Gunnison National Forests and is exposed in the Book Cliffs, Carbondale, Crested Butte, Grand Hogback, Grand Mesa, and Somerset coal fields (figs. M3 and M4). In the Book Cliffs coal field, the Mesaverde Group is divided into the Castlegate Sandstone, Sego Sandstone, Mount Garfield Formation, and Hunter Canyon Formation. In the Grand Hogback and Carbondale coal fields, the Mesaverde Group is divided into the Iles and Williams Fork Formations. Coeval strata are assigned to the Mancos Shale and Mesaverde Formation in the Grand Mesa and Crested Butte coal fields. Stratigraphic correlations are shown in figures M5 and M7.
	Fruitland Formation	200	The Fruitland Formation underlies areas in the Uncompahgre National Forest, and it is exposed in the Tongue Mesa coal field (figs. M3 and M4).
	Mancos Shale	4,000-5,000 (maximum)	Dark-gray shale with minor sandstone and siltstone; includes thin lenses of limestone, sandy limestone, and limy shale. The Mancos intertongues with the lower part of the Mesaverde Group and Mesaverde Formation.
	Dakota Sandstone	30-200	Light-gray and tan, fine- to coarse-grained sandstone or quartzite; minor interbeds of dark-gray shale, shaly sandstone, conglomeratic sandstone, and thin and lenticular beds of coal.

Dakota Sandstone Coal in the Grand Mesa, Gunnison, and Uncompahgre National Forests

Geologic investigations by Young (1960,1973) indicate that the Dakota Sandstone is widely distributed throughout much of the greater study area. It underlies all of the Grand Mesa National Forest and is present within parts of the Uncompahgre and Gunnison National Forests (fig. M4). The Dakota is gently dipping where it is exposed along the flanks of the Uncompahgre uplift; it abuts the San Juan volcanic field to the south and is locally disrupted by Tertiary intrusions in the Gunnison area.

Coal beds in the Dakota are generally thin and discontinuous, and they contain numerous partings of carbonaceous and coaly shale. Beds as thick as 7.7 ft are found locally in the study area, but they also contain many partings (Eakins, 1986). Numerous studies have been conducted to evaluate the coal in the Dakota; the best and most current summary of Dakota coal is by Eakins (1986). Dakota coal is being produced currently at the New Horizon mine in the Nucla-Naturita coal field (fig. M3) and burned at the Nucla power plant. The power plant uses a fluidized-bed combustion process and can therefore burn a lower quality coal than is used at most power plants (Eakins, 1986). The Dakota coals are high-volatile B and C bituminous in apparent rank (Murray, 1981). Coal in the Nucla-Naturita coal field has an ash yield from 6.1 to 12.8 percent and a sulfur content from 0.5 to 1.1 percent on an as-received basis (Murray, 1981). Haines (1978) analyzed 21 coal samples from three beds in the Nucla-Naturita coal field and reported an ash yield of about 11–28 percent and sulfur content of about 0.3–0.7 percent, with calorific values between 7,370 and 11,550 Btu/lb.

Grand Mesa National Forest

The Dakota Sandstone does not crop out within the Grand Mesa National Forest, but it is widespread in the subsurface (fig. M4). Most of the Dakota is buried at depths greater than 4,000 ft, based on its stratigraphic position below younger units within the forest. Dakota coals crop out 6–10 mi south and west of the forest, between the towns of Grand Junction and Delta, Colo. These coals were measured by

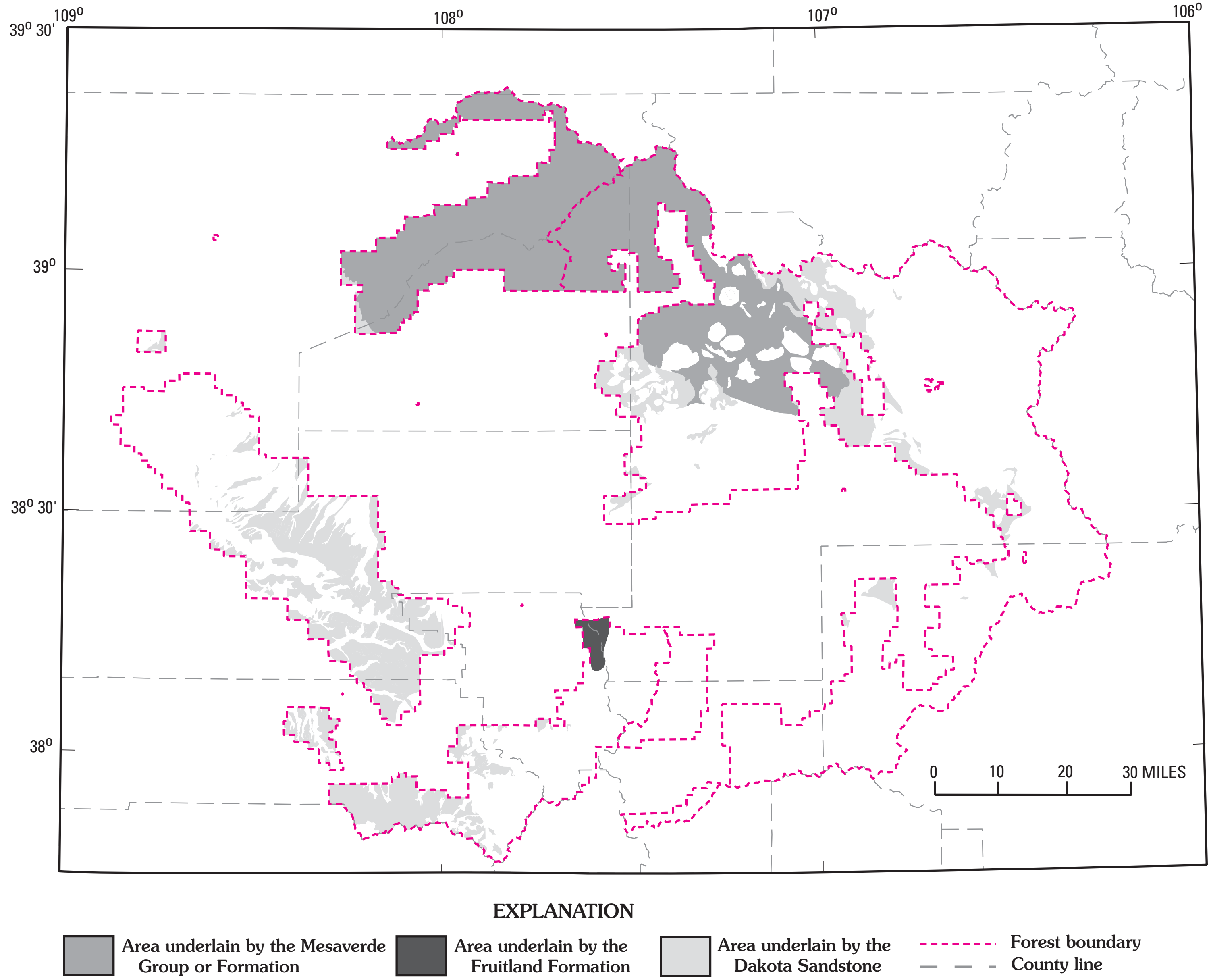


Figure M4. Areas in Grand Mesa, Uncompahgre, and Gunnison National Forests underlain by the Dakota Sandstone, Fruitland Formation, Mesaverde Formation, or Mesaverde Group. Dakota Sandstone also underlies areas covered by the Fruitland and Mesaverde. Tertiary volcanic rocks in Gunnison National Forest might also be underlain by the Dakota Sandstone or Mesaverde Formation. National forests and counties are identified in figure M1.

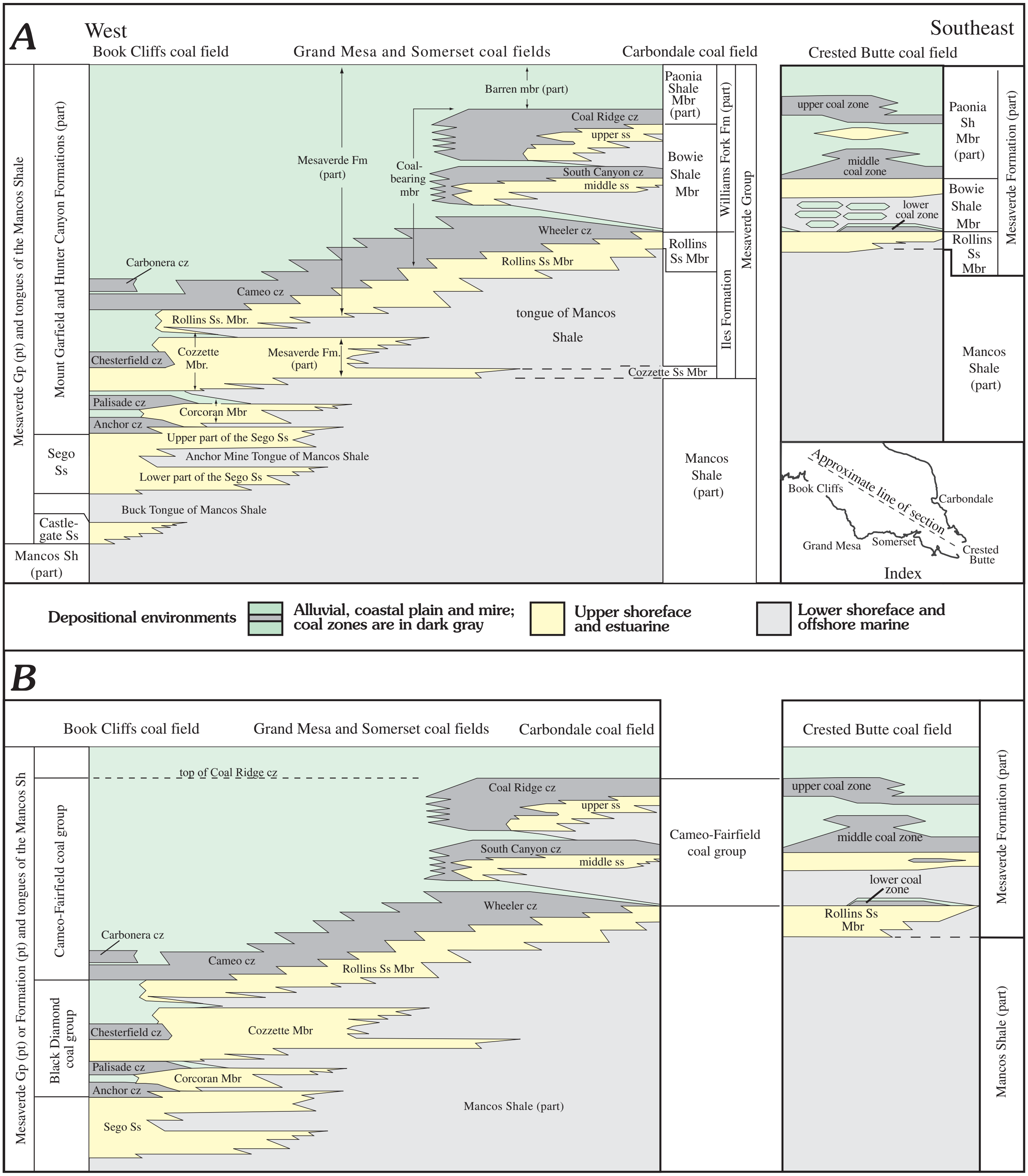


Figure M5. Stratigraphic nomenclature used for the Mesaverde Group and Mesaverde Formation in southern part of Piceance Basin, Colo.; modified from Hettinger and others (2000). *A*, Facies relationships along a line of section that is perpendicular to depositional strike. Index shows line of section in relation to coal fields. *B*, Stratigraphic position and nomenclature used in this report for coal groups and coal zones in the Mesaverde Group and Mesaverde Formation. Line of section is shown in *A*. Ss, ss, sandstone; Mbr, mbr, member; cz, coal zone; Sh, Shale; Gp, Group; Fm, Formation; pt, part.

Woodruff (1912) and Lee (1912). The thickest single bench of coal measured was 20 in. thick; at another locality 6 ft of coal was described within 11 ft of coal-bearing strata (Woodruff, 1912). The poor quality and thin discontinuous nature of the coal precluded development in the area (Woodruff, 1912). The presence of coal within the forest is unknown, but any coal that might be present is likely to be of similar poor quality, quantity, and character.

Gunnison National Forest

Although the Dakota Sandstone is widely distributed in the Gunnison National Forest (fig. M4), data by Gaskill and Godwin (1966a, 1966b), Gaskill and others (1967, 1986, 1987), and Godwin (1968) suggest that the Dakota lacks coal in the eastern and southern parts of the forest. Young (1960, his fig. 6) showed a thin carbonaceous interval within the Dakota at localities east of Delta, Colo., but he did not indicate that this interval contains coal.

Uncompahgre National Forest

The Dakota Sandstone crops out in the Uncompahgre National Forest; however, it is generally poorly exposed, concealed by thick vegetation, or covered by Quaternary landslide deposits. No published reports list precise thicknesses of Dakota coal in the forest; however, a 2.1-ft thick coal bed was measured in the forest about 12 mi northeast of the town of Nucla (fig. M1) (W.W. Boyer, USGS, unpub. data, 1926). Landis (1959) evaluated the Dakota coal as part of a statewide compilation. His generalized maps and descriptions indicate that Dakota coal beds in the forest are likely to be thin, impure, and discontinuous, but that minable reserves might be found locally.

Examples of coal deposits in the Dakota Sandstone are provided from two areas located 5–6 mi outside of the forest. One area is located near the town of Norwood (fig. M1); the other area is less than 5 mi from the town of Nucla in the Nucla-Naturita coal field (figs. M1 and M3). Coal beds in the Norwood area are about 2–11 ft thick including partings (Eakins, 1986). Eleven small mines operated 1–2 mi west of Norwood. The mines worked in beds that were 2.6–5.5 ft thick, and about 25,000 short tons of coal was produced between 1925 and 1979. Coal beds in the Nucla area are reported to be 1.3 to 9.0 ft thick; they contain numerous partings, and they can only be mapped over short distances (Eakins, 1986). Landis (1959) estimated that a 15 mi^2 part of the Nucla-Naturita coal field contained about 114 million short tons of coal. Another small area in the NW¼ sec. 31, T. 47 N., R. 15 W., near the town of Nucla, was estimated to contain about 278,900 short tons of coal (Haines, 1978). Twelve small underground mines and one strip mine operated within 4 mi of Nucla, and they produced more than 2 million short tons of coal between 1915 and 1983 (Eakins, 1986). Currently, the New Horizon strip mine supplies the Nucla Power Plant with coal, and about 400,000 short tons of coal was mined in 1995 (G. Sullivan, written commun., 1997, compiled from Mine Safety and Health Administration data). The New Horizon mine is about 1 mi west of Nucla.

Fruitland Formation Coal in the Uncompahgre National Forest

Approximately 200 ft of coal-bearing strata is present in a small part of the Uncompahgre National Forest at the Tongue Mesa coal field (figs. M3 and M4). The coal-bearing rocks were assigned to the Fruitland Formation by Hornbaker and others (1976) and Dickinson (1987a, 1987b, 1988), and they are part of a 1,000-ft thick interval that was originally thought to be equivalent to the Mesaverde Formation by Landis (1959). Both Landis (1959) and Dickinson (1987a, 1987b, 1988) described the coal-bearing interval as being concealed by heavy vegetation, landslides, talus, and glacial deposits. Coal in the Tongue Mesa coal field is reported to have an ash yield of 6.7–8.4 percent, a sulfur content of 0.5–0.9 percent, and a calorific value of 9,350–10,200 Btu/lb on an as-received basis (Hornbaker and others, 1976). The apparent rank of the coal is subbituminous B (U.S. Bureau of Mines, 1937, p. 110–111) and subbituminous C (Dickinson, 1987a, 1987b, 1988). Some of the coal is reported to be oxidized and bony (Hornbaker and others, 1976).

The geology of the Tongue Mesa coal field was mapped in the vicinity of the Uncompahgre National Forest at a 1:24,000 scale by Dickinson (1987a, 1987b, 1988). Dickinson's maps show the Fruitland cropping out at only a few small and widely spaced localities, and depth to the top of the formation ranges from 0 to 2,500 ft within the forest. The Fruitland contains one laterally extensive coal bed that is about 20–40 ft thick, and three to five coal beds that are about 5–13 ft thick. 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 debris. The faulting and landslide cover have also made the coal resources difficult to assess (Dickinson, 1987a, 1987b). Dickinson stated that the coal-bearing strata were drilled extensively for Federal permits and leases, but the drilling data had not been released at the time of his publications.

Some minor underground mining took place in the Tongue Mesa coal field intermittently between the 1890's and 1940's (Murray, 1981). The Lou Creek, Economy, Tyler, and Kennedy mines operated within the forest in T. 46 N., R. 7 W.; the Lou Creek mined a 40-ft thick bed, and the Economy and Tyler each mined a 30-ft thick bed (Dickinson, 1987a, 1988). Additionally, four small mines operated less than 3 mi from the forest and produced from beds that were 6–23 ft thick (Dickinson, 1987a).

Landis (1959) estimated the 58 mi^2 Tongue Mesa coal field to contain a coal resource of about 2,355 million short tons. Hornbaker and others (1976) thought the resources could be as high as 4,000 million short tons, apparently on the basis of core drilling information available to them. However, the forest lands are only partially within the coal field (fig. M3), and no estimate is available for the portion of this resource that is within the forest.

Mesaverde Group and Mesaverde Formation Coal in the Grand Mesa and Northwestern Part of the Gunnison National Forests (Area 1)

Coal-bearing strata in the Mesaverde Group and Mesaverde Formation underlie approximately 620 mi^2 of the Gunnison National Forest and 520 mi^2 of the Grand Mesa National Forest (fig. M4). These forest lands form a contiguous region that is designated as Area 1 in this report (fig. M1). The coal-bearing Mesaverde Group and Mesaverde Formation extend throughout the subsurface of the Piceance Basin (fig. M2) and are exposed in the Book Cliffs, Carbondale, Crested Butte, Grand Hogback, Grand Mesa, and Somerset coal fields (fig. M3). Numerous mines have produced from these coal fields since the late 1800's, and several mines are currently operating near the southern forest boundaries (see section, "Coal Production"). Some of the coal is also considered to be an important source for natural gas (Johnson, 1989). Because of the ongoing economic interest, the coal resources of Area 1 are evaluated in this report.

Data

The evaluation of Area 1 is based primarily on data and digital files used by Hettinger and others (2000) to describe the geology and estimate coal resources in the southern part of the Piceance Basin, an area included in the USGS National Coal Resource Assessment. The digital files were manipulated in a Geographic Information System (GIS) using ARC/INFO software to report coal resources within various parameters in Area 1. With the exception of files of national forest boundaries, all digital files were prepared in-house or imported from the existing public domain, and they have been made available by Biewick and Mercer (2000). Methods regarding the generation and use of the digital files have been provided by Biewick and Mercer (2000), Hettinger and others (2000), and Roberts and others (2000).

Lithologic and stratigraphic data used to assess coal resources in Area 1 are from 94 drill holes and outcrops located in Area 1 (table M2; fig. M6). Additional data were also used from a much larger data base by Hettinger and others (2000), and those data points are also shown in figure M6. Lithologic interpretations were made using a combination of responses from natural-gamma (gamma ray), density, resistivity, neutron, spontaneous potential, and caliper logs. Coal bed thicknesses were rounded to the nearest foot, and beds less than 1 ft thick were not included in the assessment. Because coal thicknesses were rounded, we used a minimum thickness of 1 ft rather than the 14-in. cutoff for bituminous coal as suggested by Wood and others (1983).

Geologic coverages used to assess Area 1 include (1) a geologic map that shows outcrops of rock units, (2) a structure contour map of the base of each coal resource interval, and (3) isopach maps that show the thickness, net coal, and overburden for each coal resource interval. Outcrops of rock units in Area 1 were obtained from a digital geologic map of Colorado by Green (1992) that was compiled from the 1:500,000-scale geologic map of the State of Colorado by Tweto (1979). Structure contour and isopach maps were prepared using lithologic and stratigraphic information gathered from drill holes and outcrops. These spatial data were gridded using Earth Vision [Dynamics Graphics, Inc.], and the resulting contour lines were then converted into ARC/INFO polygon coverages (Roberts and others, 2000).

Coal Geology

In Area 1, the Mesaverde Group and Mesaverde Formation contain coal within the Black Diamond and Cameo-Fairfield coal groups as referred to by Hettinger and others (2000) (fig. M5). The stratigraphic distribution of Mesaverde coal in Area 1 is demonstrated on cross section *A–A′* (fig. M7). The cross section is oriented nearly perpendicular to shorelines of the Cretaceous Western Interior seaway. The datum used for the cross section is a bentonite bed located stratigraphically near the base of a tongue of Mancos Shale that underlies the Rollins Sandstone Member of the Mount Garfield, Mesaverde, and Iles Formations.

Black Diamond Coal Group

The Black Diamond coal group is located stratigraphically below the Rollins Sandstone Member, and contains (in ascending order) the Anchor, Palisade, and Chesterfield coal zones (fig. M5). Individual beds of coal are generally less than 6 ft thick where they are exposed in the Book Cliffs and Grand Hogback coal fields, and they pinch out southeast of those localities. The Black Diamond coal group underlies Area 1 in Tps. 7, 8, 9 S., Rs. 94, 95, 96 W.; drill hole data show that the coal group lies 3,500–10,500 ft deep and has less than 6 ft of net coal in those areas. Resources were not estimated for the Black Diamond coal group in Area 1 because the coal beds are too thin and too deep to be economically significant.

Cameo-Fairfield Coal Group

The Cameo-Fairfield coal group overlies the Rollins Sandstone Member and contains the thickest and most

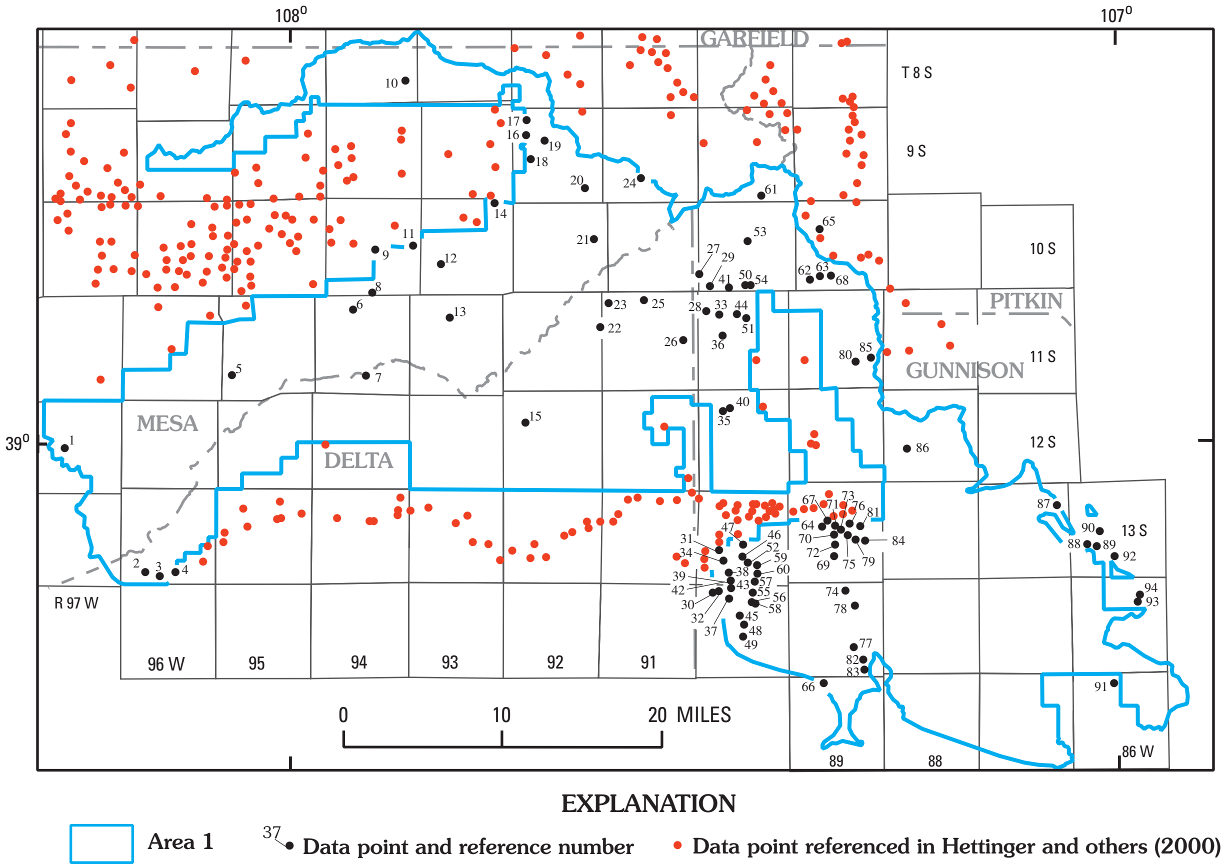


Figure M6. Location of data points used to assess coal resources of Area 1. Area 1 is located where the Mesaverde Formation and Mesaverde Group underlie the Gunnison and Grand Mesa National Forests (figs. M1 and M4). Labeled data points in Area 1, and near its eastern boundary, are referenced in table M2.

extensively mined coals in the Piceance Basin; the coal group is also an important source for natural gas (Johnson, 1989). The coal group is about 1,000 ft thick in the northeastern part of Area 1, and it is less than 200 ft thick in the southwestern and southeastern parts of Area 1. The Cameo-Fairfield extends throughout most of the subsurface of Area 1, and it is exposed near the forest boundaries in the Carbondale, Crested Butte, Grand Mesa, and Somerset coal fields (fig. M3). Exploratory coal drilling in the Grand Mesa and Somerset coal fields has been reported by Eager (1978, 1979), Dunrud (1989a, 1989b), Johnson (1948), and Toenges and others (1949, 1952). Exploratory coal drilling and outcrop measurements in the southern part of the Carbondale coal field have been reported by Collins (1976), Donnell (1962), Dunrud (1989a), Ellis and others (1988), and Kent and Arndt (1980a, 1980b). Coal bed thicknesses in the Crested Butte coal field have been reported in geologic maps by Lee (1912), Gaskill and Godwin (1966a, 1966b), Godwin (1968), and Gaskill and others (1967, 1986). References to coal zones and coal bed thicknesses in those areas are based on our interpretations of their data.

Following the nomenclature of Hettinger and others (2000), the Cameo-Fairfield group contains (in ascending order) the Cameo-Wheeler, South Canyon, and Coal Ridge coal zones in areas located west of long 107°15′ W. (figs. M5, M7; table M1). East of long 107°15′ W., the Cameo-Fairfield group is simply divided into the lower, middle, and upper coal zones (figs. M5, M7, and table M1). Coal zone nomenclature was not extended across long 107°15′ W., owing to structural and stratigraphic complexities, and a paucity of data east of the longitudinal line. Coal-bearing strata in the southern part of the Carbondale and Crested Butte coal fields are poorly exposed, steeply inclined, displaced by numerous faults, and intruded by sills, dikes, and laccoliths. Additionally, coal beds underlie many of the laccoliths.

Net coal in the Cameo-Fairfield coal group ranges from about 50 to 97 ft in a 20- to 30-mi wide belt that extends north to south across the central part of Area 1 (fig. M8). Net coal decreases to less than 50 ft in the remaining parts of Area 1.

Coal distribution in the Cameo-Wheeler, South Canyon, and Coal Ridge coal zones is shown in a series of net coal isopach maps in figures M9, M10, and M11, respectively.

Table M2. Drill hole and outcrop data in Area 1.

[Information is provided for each data point shown in Area 1 in figure M6. Map number (Map No.) refers to the data point in figure M6. Point Identification (ID) is the 10-digit American Petroleum Information (API) number of an oil or gas hole, or the original number of a coal exploration hole or measured section. Type refers to oil and gas hole (O&G); measured section (MS); lithologic log (LL); rotary hole (ROT); rotary and core hole (R/C); undefined (UND). Source refers to the lease operator, well name, data collector, or a U.S. Geological Survey (USGS) or U.S. Bureau of Mines (USBM) publication. The type of publication is an Open-File Report (OF), Bulletin (Bull), Professional Paper (PP), Geologic Quadrangle Map (GQ), or Technical Paper (TP). Latitude and longitude of data point are in decimal degrees. Elevation is measured in feet above sea level to the Earth's surface (or to Kelly bushing of the drill rig) at the data point. The total thickness of coal (Total coal) is provided for the Cameo-Fairfield coal group and includes all coal beds in the group that are more than 1 ft thick. The total thickness of coal and number of coal beds (# beds) are also provided for Cameo-Wheeler, South Canyon, and Coal Ridge coal zones, which are within the Cameo-Fairfield group. Total coal and number of beds includes all coal beds that are more than 1 ft thick. Blank space indicates (1) the coal zones had no coal at the data point, (2) data were not provided (map numbers 31 and 34), or (3) the coal zones were not identified at location of data point (map numbers 86 through 94)]

Data point identification				Data point location						Net coal in Cameo-Fairfield group* (ft)	Cameo-Wheeler coal zone		South Canyon coal zone		Coal Ridge coal zone	
Map No.	Point ID	Type	Source	Long W.	Lat N.	Sec.	Township	Range	Elevation (ft)		Total coal (ft)	# beds	Total coal (ft)	# beds	Total coal (ft)	# beds
1	IP-77-1	ROT	USGS OF 78-540	108.24233	38.99503	21	12 S	97 W	7230	31.0	31	8				
2	IP-77-2A	ROT	USGS OF 78-540	108.14739	38.88108	32	13 S	96 W	8700	15.5	15.5	6				
3	IP-77-3	ROT	USGS OF 78-540	108.13039	38.87767	33	13 S	96 W	8450	15.0	15	5				
4	HK-77-1	ROT	USGS OF 78-540	108.11172	38.88131	34	13 S	96 W	8030	34.5	34.5	9				
5	05-077-05011	O&G	PACIFIC-SMITH 1-C	108.04617	39.06228	30	11 S	95 W	10191	31.0	31	4				
6	05-077-05017	O&G	WESTERN FRNTR-BIG CRK 1	107.90175	39.12242	4	11 S	94 W	9464	39.0	39	10				
7	05-029-05031	O&G	APACHE-MACHELSON 2	107.88661	39.06178	34	11 S	94 W	10133	61.0	61	6				
8	05-077-08188	O&G	EXXON-OLD MAN MTN #1	107.87972	39.13839	33	10 S	94 W	10043	43.0	43	12				
9	05-077-08598	O&G	FUELCO-FEE E-22-10-94-S	107.87486	39.17894	22	10 S	94 W	7929	48.0	48	12				
10	05-077-08043	O&G	MOBIL-BEAR CRK 1-25	107.83967	39.33339	25	8 S	94 W	8430	74.0	55	6	14	6	5	3
11	05-077-07360	O&G	ALPINE OIL-GOVT 1	107.83089	39.18153	24	10 S	94 W	8512	71.0	68	9			3	1
12	05-077-05026	O&G	EL PASO-LEON CRK 1	107.79828	39.16478	29	10 S	93 W	9062	37.0	35	5			2	1
13	05-077-08295	O&G	EXXON-KENNY CREEK #1	107.7875	39.11528	9	11 S	93 W	9577	50.0	50	5				
14	05-077-08395	O&G	BV-CARLTON CURRIER 2-1	107.73472	39.22083	2	10 S	93 W	8052	70.0	57	5	9	4	4	3
15	05-077-05001	O&G	SUNRAY-COLO FED C-1	107.69861	39.01908	8	12 S	92 W	9825	81.0	81	10				
16	05-077-05097	O&G	EL PASO CONOCO GOVT 1	107.69756	39.28253	8	9 S	92 W	7665	89.0	70	3	15	3	4	1
17	05-077-05108	O&G	APACHE CORP-RUSHMORE 1	107.69633	39.29686	5	9 S	92 W	7617	87.0	63	2	18	4	6	2
18	05-077-07352	O&G	NORDON-GOVT 1	107.692	39.261	20	9 S	92 W	7610	66.0	54	7	5	3	7	3
19	05-077-08435	O&G	COORS-USA 1-16 SC	107.67528	39.27861	16	9 S	92 W	7850	91.0	68	4	13	3	10	5
20	05-077-08545	O&G	CELERON PORTER MT FD35-1	107.62722	39.23453	35	9 S	92 W	8267	95.0	55	3	24	8	16	2
21	05-077-08575	O&G	AMOCO-RUTH MTN #1	107.61647	39.18703	13	10 S	92 W	8711	97.0	60	7	21	7	16	5
22	05-029-05000	O&G	UNION-OVERLAND GOV'T 1	107.61003	39.106	13	11 S	92 W	9421	66.0	44	3	14	4	8	2
23	05-029-06001	O&G	PAN AM-USA MARVIN WOLF 1	107.60042	39.12897	6	11 S	91 W	8899	82.0	57	5	25	3		
24	05-077-05074	O&G	MTN STATES-28-1 GOV'T	107.56033	39.24308	28	9 S	91 W	9180	94.0	57	6	35	5	2	1
25	05-029-05083	O&G	VICTOR DRLG-GOVT #1	107.55767	39.13117	4	11 S	91 W	8538	94.0	62	4	27	5	5	1
26	05-029-06069	O&G	AMOCO-ELECTRIC MTN U.#1	107.51167	39.09444	13	11 S	91 W	8216	73.0	32	5	29	5	12	4
27	05-051-06043	O&G	PETRO-FED 1-25-10-91	107.49297	39.15547	25	10 S	91 W	8195	74.0	45	3	27	8	2	1
28	05-051-06008	O&G	RALSTON-PETROLWS 11-90-7	107.48417	39.12028	7	11 S	90 W	8181	74.0	40	6	22	6	12	5
29	05-051-06009	O&G	RALSTON-FED 31	107.47939	39.14411	31	10 S	90 W	7901	73.0	45	3	23	4	5	2
30	LEE-MS-47	MS	USGS BULL 510	107.4775	38.86167	5	14 S	90 W		54.0	27	7	10	1	16	2
31	Not provided															
32	DUN-40	LL	USGS MAP C-115	107.47111	38.86278	5	14 S	90 W	8109	76.0	33	6	29	2	14	2
33	05-051-06024	O&G	PIUTE-COAL BSN10-8-11-90	107.46944	39.11742	8	11 S	90 W	7918	78.0	40	7	27	6	11	4
34	Not provided															
35	05-051-06035	O&G	AMOCO-SUMERSET #2	107.46544	39.02875	8	12 S	90 W	8515	85.0	40	4	29	4	16	3
36	05-051-06007	O&G	RALSTON-PETRLWS 11-90-17	107.46533	39.09867	17	11 S	90 W	8101	55.0	26	8	16	4	13	5
37	DUN-41	LL	USGS MAP C-115	107.46	38.85611	9	14 S	90 W	8256	77.0	32	5	29	2	16	3
38	LH-2-33	R/C	USBM TP 721	107.45947	38.87931	33	13 S	90 W	7504	74.9	27.6	4	34.9	6	9.7	2
39	LH-5-33	R/C	USBM TP 721	107.45758	38.87164	33	13 S	90 W	7636	64.5	25.1	5	28.9	3	6.3	1
40	05-051-06021	O&G	AMOCO-SUMERSET #1	107.45756	39.03128	9	12 S	90 W	8441	87.0	39	4	30	4	18	2
41	05-051-06010	O&G	RALSTON-RALSTON 10-90-32	107.45744	39.14203	32	10 S	90 W	7711		9	2	23	4	6	4
42	LH-1-33	R/C	USBM TP 721	107.45739	38.87164	33	13 S	90 W	7643	73.7	27.7	5	33.3	6	7.3	3
43	LH-3-4	R/C	USBM TP 721	107.45667	38.86558	4	14 S	90 W	7765	50.0	13.6	4	23	4	12.3	4
44	05-051-05007	O&G	POOL-HENDERSON 1	107.4485	39.11806	9	11 S	90 W	7532	35.0	30	6	5	1		
45	DUN-42	LL	USGS MAP C-115	107.44667	38.83944	16	14 S	90 W	7678		20	3	17	2		
46	DUN-52	UND	USGS Map C-115	107.44331	38.89461	28	13 S	90 W	7092	81.0	31	4	34	5	16	4
47	DUN-51	UND	USGS Map C-115	107.44272	38.90539	21	13 S	90 W	6765	71.0	35	4	24	2	12	2
48	DUN-43	LL	USGS MAP C-115	107.4425	38.83167	15	14 S	90 W	8442	79.0	43	3	26	2	10	2
49	DUN-44	LL	USGS MAP C-115	107.4425	38.82056	22	14 S	90 W	8484	78.0	34	3	33	3	11	2
50	05-051-06011	O&G	RALSTON-FED33 (10-90-33)	107.43794	39.14511	33	10 S	90 W	7561	55.0	31	5	16	3	8	4
51	05-051-06013	O&G	RALSTON-HENDRSN 11-90-10	107.43764	39.11386	10	11 S	90 W	7550	31.0	25	8	6	2		
52	DUN-53	UND	USGS Map C-115	107.43675	38.88839	27	13 S	90 W	7597	62.0	21	3	28	4	13	3
53	05-051-06023	O&G	PIUTE-RAGGED MTN FED16-4	107.43533	39.18561	16	10 S	90 W	8238	44.0	34	5	6	2	4	2
54	05-051-06014	O&G	RALSTON-10-90-34-SW	107.43203	39.14431	34	10 S	90 W	7490	51.0	30	4	15	1	6	4
55	DUN-57	LL	USGS MAP C-115	107.43167	38.86	3	14 S	90 W	8292	47.0	13	2	27	3	7	2
56	LH-4-10	R/C	USBM TP 721	107.431	38.854	10	14 S	90 W	8041	46.2	10.9	4	18.6	3	15.1	5
57	DUN-56	LL	USGS MAP C-115	107.42917	38.87139	34	13 S	90 W	8051	77.0	31	6	35	4	11	2
58	DUN-58	LL	USGS MAP C-115	107.42889	38.85167	10	14 S	90 W	8156	62.0	22	5	20	2	20	3
59	DUN-54	UND	USGS Map C-115	107.42544	38.88636	27	13 S	90 W	7955	57.0	18	2	20	2	19	5
60	DUN-55	LL	USGS MAP C-115	107.42539	38.87856	34	13 S	90 W	8114	65.0	18	3	33	3	14	2
61	05-051-06001	O&G	SUNRAY-S.WOLF CRK UNIT 1	107.41792	39.22683	34	9 S	90 W	9170	48.0	30	4	12	4	6	3
62	DUN-76	LL	USGS MAP C-115	107.36131	39.14925	31	10 S	89 W	9060	47.0	21	2	18	2	8	1
63	DUN-78	LL	USGS MAP C-115	107.35	39.15222	32	10 S	89 W	9530	51.0	21	3	24	3	6	1
64	LH-11-9	R/C	USBM B-501	107.34992	38.92189	9	13 S	89 W	6385	18.2	12	4	2.4	1	0	0
65	KENT MS-9	MS	USGS OF 80-709	107.34989	39.19494	17	10 S	89 W		54.1	23.1	3	15	2	16	9
66	Lee-MS-71/69/68	MS	USGS BULL 510	107.34833	38.7775	4	15 S	89 W		56.4	29.2	5	21.2	2	6	1

Table M2. Drill hole and outcrop data in Area 1.—Continued

Data point identification				Data point location						Net coal in Cameo-Fairfield group* (ft)	Cameo-Wheeler coal zone		South Canyon coal zone		Coal Ridge coal zone	
Map No.	Point ID	Type	Source	Long W.	Lat N.	Sec.	Township	Range	Elevation (ft)		Total coal (ft)	# beds	Total coal (ft)	# beds	Total coal (ft)	# beds
67	LH-6-16	R/C	USBM B-501	107.34275	38.9275	16	13 S	89 W	6358	24.4	18.5	4	4.2	2	0	0
68	DUN-79	LL	USGS MAP C-115	107.33717	39.15242	33	10 S	89 W	9640	36.0	19	4	13	2	4	1
69	LH-19-28	R/C	USBM B-501	107.33597	38.89428	28	13 S	89 W	6560	18.2	15.6	3	2.4	1		
70	LH-16-21	R/C	USBM B-501	107.33397	38.91314	21	13 S	89 W	6440	19.0	16	2			0	0
71	LH-9-16	R/C	USBM B-501	107.33381	38.92189	16	13 S	89 W	6400	17.7	16	3			1.5	1
72	LH-18-21	R/C	USBM B-501	107.33353	38.90431	21	13 S	89 W	6500	18.5	14.8	3	3.1	1		
73	LH-14-15	R/C	USBM B-501	107.32722	38.91856	15	13 S	89 W	6534	23.2	17.6	3	1.5	1	2.4	2
74	DUN-68	LL	USGS MAP C-115	107.32167	38.8625	3	14 S	89 W	7236	24.5	13.5	3			11	2
75	LH-15-22	R/C	USBM B-501	107.31953	38.91344	22	13 S	89 W	6650	19.7	18.1	2			0	0
76	LH-20-15	R/C	USBM B-501	107.316	38.924	15	13 S	89 W	7635	21.9	17.2	2	2.6	2	1	1
77	LEE-MS-64	MS	USGS BULL 510	107.31278	38.81083	26	14 S	89 W		40.5	16.1	3	6	1	18.4	3
78	DUN-69	LL	USGS MAP C-115	107.31111	38.84917	11	14 S	89 W	7600	20.0	11	5			9	2
79	LH-17-23	R/C	USBM B-501	107.30906	38.90922	23	13 S	89 W	6740	24.7	18.8	3	2.2	1	0	0
80	ELLIS-MS-129	MS	USGS MAP C-97-B	107.30806	39.07333	26	11 S	89 W		13.0					13	4
81	LH-25-14	R/C	USBM B-501	107.304	38.922	14	13 S	89 W	7540	22.2	15.2	2	5.3	3	0	0
82	DUN-71	LL	USGS MAP C-115	107.30167	38.79861	35	14 S	89 W	8562	20.5	13.5	4	3	1	4	1
83	DUN-72	LL	USGS MAP C-115	107.3	38.78917	35	14 S	89 W	8854	26.0	13	2	5	2	8	3
84	LH-21-23	R/C	USBM B-501	107.29878	38.90811	23	13 S	89 W	6940	18.7	14.7	2	2.1	2	0	0
85	ELLIS-MS-128	MS	USGS MAP C-97-B	107.29	39.07667	25	11 S	89 W		5.0					5	3
86	GASKILL-MS-1	MS	USGS MAP GQ-1604	107.24917	38.99333	29	12 S	88 W		7.1						
87	LEE-MS-125	MS	USGS BULL 510	107.07139	38.93917	12	13 S	87 W		3.0						
88	LEE-MS-123	MS	USGS BULL 510	107.03722	38.90333	20	13 S	86 W		4.0						
89	LEE-MS-122	MS	USGS BULL 510	107.02583	38.90056	29	13 S	86 W		6.0						
90	LEE-MS-127	MS	USGS BULL 510	107.02167	38.91472	20	13 S	86 W		11.0						
91	GASKILL-MS-4	MS	USGS MAP GQ-1604	107.00667	38.775	4	15 S	86 W		14.0						
92	LEE-MS-121	MS	USGS BULL 510	107.00444	38.89139	28	13 S	86 W		10.0						
93	LEE-MS-115	MS	USGS BULL 510	106.97778	38.84972	11	14 S	86 W		26.8						
94	LEE-MS-117	MS	USGS BULL 510	106.97528	38.85611	11	14 S	86 W		23.7						

*Cameo-Fairfield group = Cameo-Fairfield coal group of the Mesaverde Group or Formation. The coal group contains the Cameo-Wheeler, South Canyon, and Coal Ridge coal zones west of long 107° 15′ W.

Data used to construct the maps are identified in table M2 and figure M6.

Cameo-Wheeler Coal Zone (West of Long 107°15′ W.)

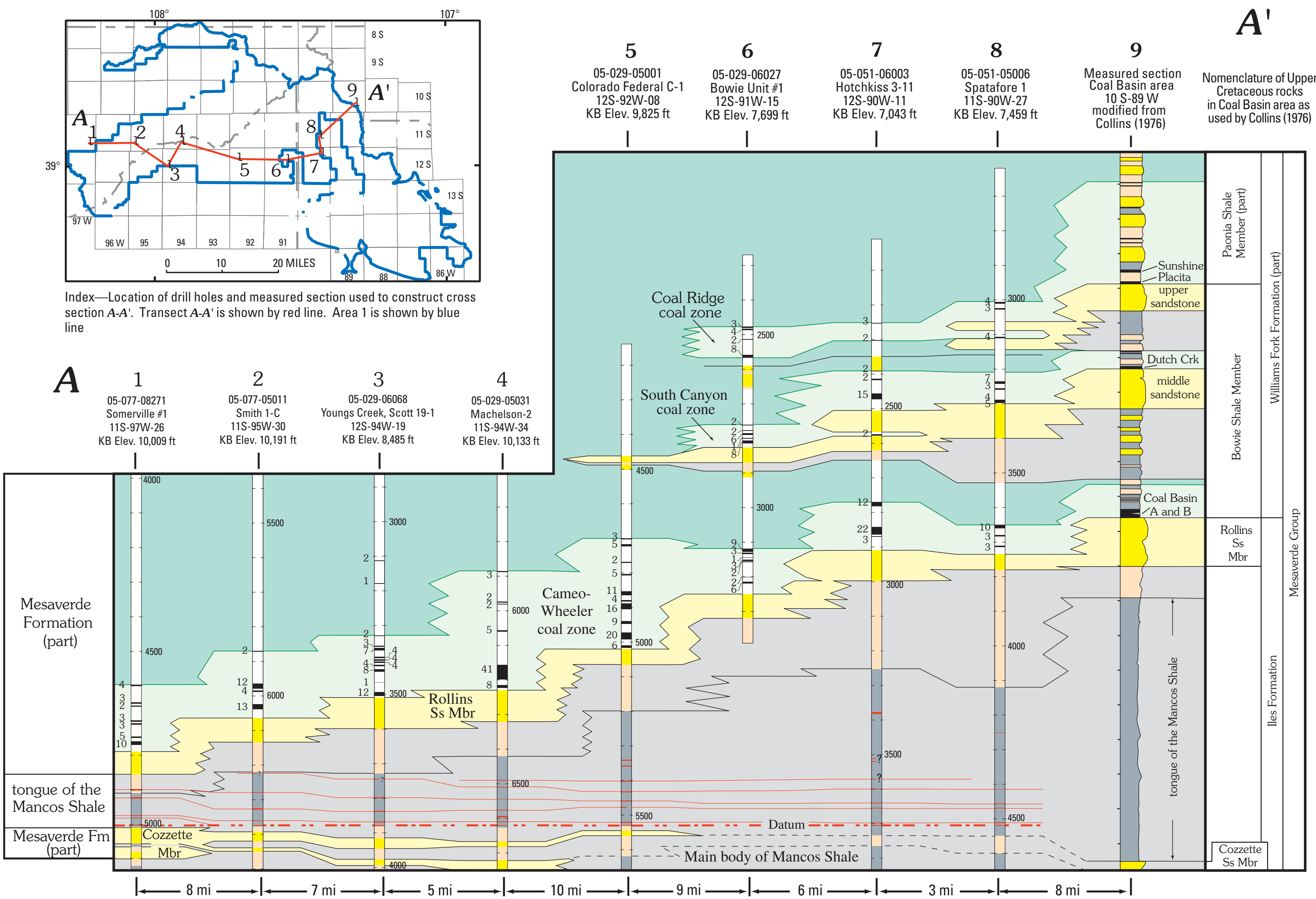
The Cameo-Wheeler coal zone (fig. M5) underlies a 925 mi^2 area that includes all parts of Area 1 west of long 107°15′ W. The coal zone overlies the Rollins Sandstone Member and is about 100–400 ft thick. The Cameo-Wheeler coal zone has approximately 5–80 ft of net coal, and net coal exceeds 50 ft throughout the central part of Area 1 (fig. M9). Near the southern boundary of Area 1, in the Grand Mesa and Somerset coal fields, the Cameo-Wheeler has 10–70 ft of net coal in as many as 15 beds that are 1–30 ft thick. Principal coals in the Somerset coal field include the Old King Coal (A) bed, Somerset (B) bed, Bear (C) bed, and Orchard Valley (D) bed (Dunrud, 1989a, 1989b). Near the eastern boundary of Area 1, in the Carbondale coal field, the Cameo-Wheeler contains about 7–27 ft of net coal in one to three beds that are 3–18 ft thick. Principal coal beds in the southern part of the Carbondale field are the Coal Basin A, B (Somerset), and C (Bear) (Dunrud, 1989a; Ellis and others, 1988).

South Canyon Coal Zone (West of Long 107°15′ W.)

The South Canyon coal zone underlies a 530 mi^2 region in Area 1. This coal zone overlies and intertongues with the middle sandstone of the Bowie Shale Member of the Williams Fork Formation (fig. M7). It extends west from long 107°15′ W. and pinches out along a sinuous line that trends about N. 20° W. from sec. 31, T. 12 S., R. 92 W. to sec. 30, T. 8 S., R. 95 W. (fig. M10). The coal zone is 1–200 ft thick and contains 1–30 ft of net coal (fig. M10). Net coal exceeds 20 ft along a 5- to 10-mi wide belt that trends N. 20° W. throughout the central part of Area 1. In the Somerset coal field, the South Canyon has 15–35 ft of net coal in two to five beds that are 1–25 ft thick, and important coal beds include the Oliver (D), D-1, and D-2 beds (Dunrud 1989a). In the southern part of the Carbondale field, at Coal Basin, the South Canyon contains the 3–20 ft thick Dutch Creek coal bed (Collins, 1976; Dunrud, 1989a).

Coal Ridge Coal Zone (West of Long 107°15′ W.)

The Coal Ridge coal zone overlies and intertongues with the upper sandstone in the Bowie Shale Member of the Williams Fork Formation (fig. M7), and the coal zone occupies about the same area as the underlying South Canyon coal zone. The Coal Ridge is 100–400 ft thick near the line of long 107°15′ W., is less than 100 ft thick throughout most of its west half, and pinches out near the same line as the underlying South Canyon coal zone (fig. M11). The Coal Ridge generally has less than 10 ft of net coal, although a small area with about 20 ft of net coal is located near the Somerset coal field (figs. M3 and M11). In the Somerset coal field, the Coal Ridge coal zone contains 10–26 ft of net coal in two to seven beds that are 1–10 ft thick; important beds include the Hawksnest (E) and E-2 (Dunrud, 1989a). In the southern part of the Carbondale coal field, the Coal Ridge coal zone has 2–10 beds of coal that are 1–23 ft thick, and named beds include the Placita, Sunshine, North Rim, and Lake Ridge coal beds (Ellis and others, 1988).



Index—Location of drill holes and measured section used to construct cross section *A-A'*. Transect *A-A'* is shown by red line. Area 1 is shown by blue line

Figure M7 (above and following page). Stratigraphy of continental and marine rocks in the Upper Cretaceous Mesaverde Group and Mesaverde Formation, along cross section *A–A'*, in Area 1. Location of cross section *A–A'* is shown in index.

EXPLANATION

Lithologic and depositional interpretations

Rock type (indicated by color in drill hole column)

- **Sandstone**
- **Siltstone or interbedded sandstone and mudrock**
- **Mudrock**
- **Coal**
- **Bentonite**—Queried where uncertain
- **Lithology not interpreted**—Interval does not contain coal

Depositional environments (indicated by background pattern)

- **Coastal plain and alluvial**—Coal zones are light green
- **Upper shoreface and estuarine**
- **Lower shoreface and offshore marine**

Drill hole information

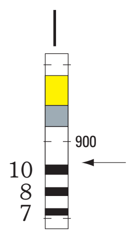
2 ← **Drill hole identification number as shown on cross section**

05-077-08271 ← **American Petroleum Information (API) number**

Somerville #1 ← **Drill hole name**

11S-97W-26 ← **Location (township, range, section)**

KB Elev. 10009 ft ← **Drill hole elevation (Kelly bushing)**



Columnar section showing selected rock types penetrated by drill hole; down-hole depths are reported in 500 ft intervals on right side of column. Rock types were interpreted from geophysical logs. Thickness of coal (black) is shown in feet on left side of column

Abbreviations

Fm	**Formation**
Mbr	**Member**
Ss	**Sandstone**
Sh	**Shale**
pt	**part**

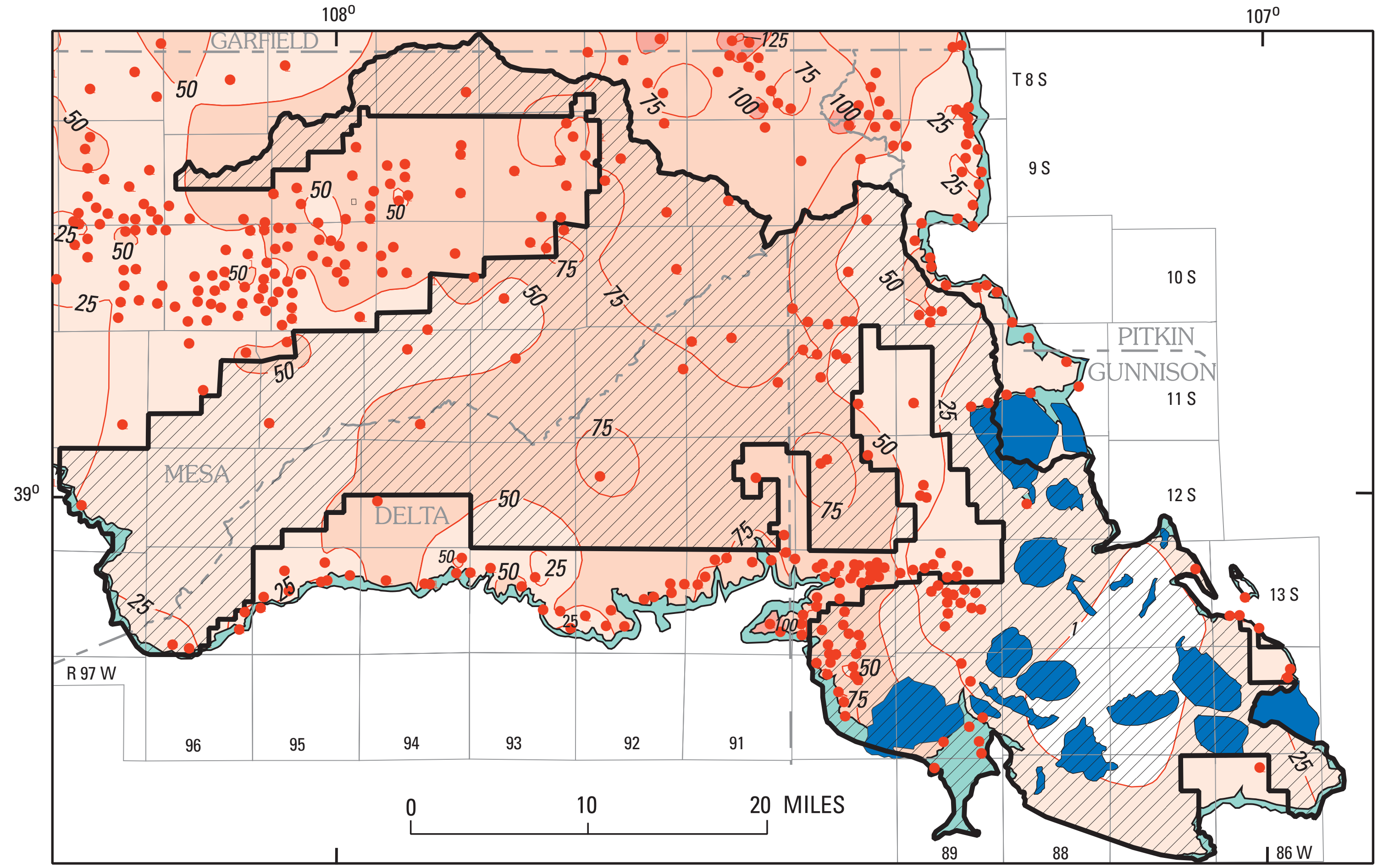
Contacts

- **Facies contact**—Dashed where approximate
- **Facies contact that rises stratigraphically**—Dashed where approximate
- **Datum; dashed where approximate**—Represents a surface of maximum marine transgression
- **Bentonite marker bed**

Scale

4 mi — **Distance between drill holes and measured sections**

Vertical scale (ft): 500, 400, 300, 200, 100, 0



EXPLANATION

Thickness of net coal (in feet) in Cameo-Fairfield coal group: No coal | 1–50 | 50–100 | 100–140

Outcrop of Cameo-Fairfield coal group

Area 1

Tertiary laccolith or stock

Data point location

100 Isoline showing thickness (in feet) of net coal in Cameo-Fairfield coal group—Contour interval 25 ft

Figure M8. Isopach map of net coal in Cameo-Fairfield coal group in Area 1. Net coal values represent all beds of coal more than 1 ft thick.

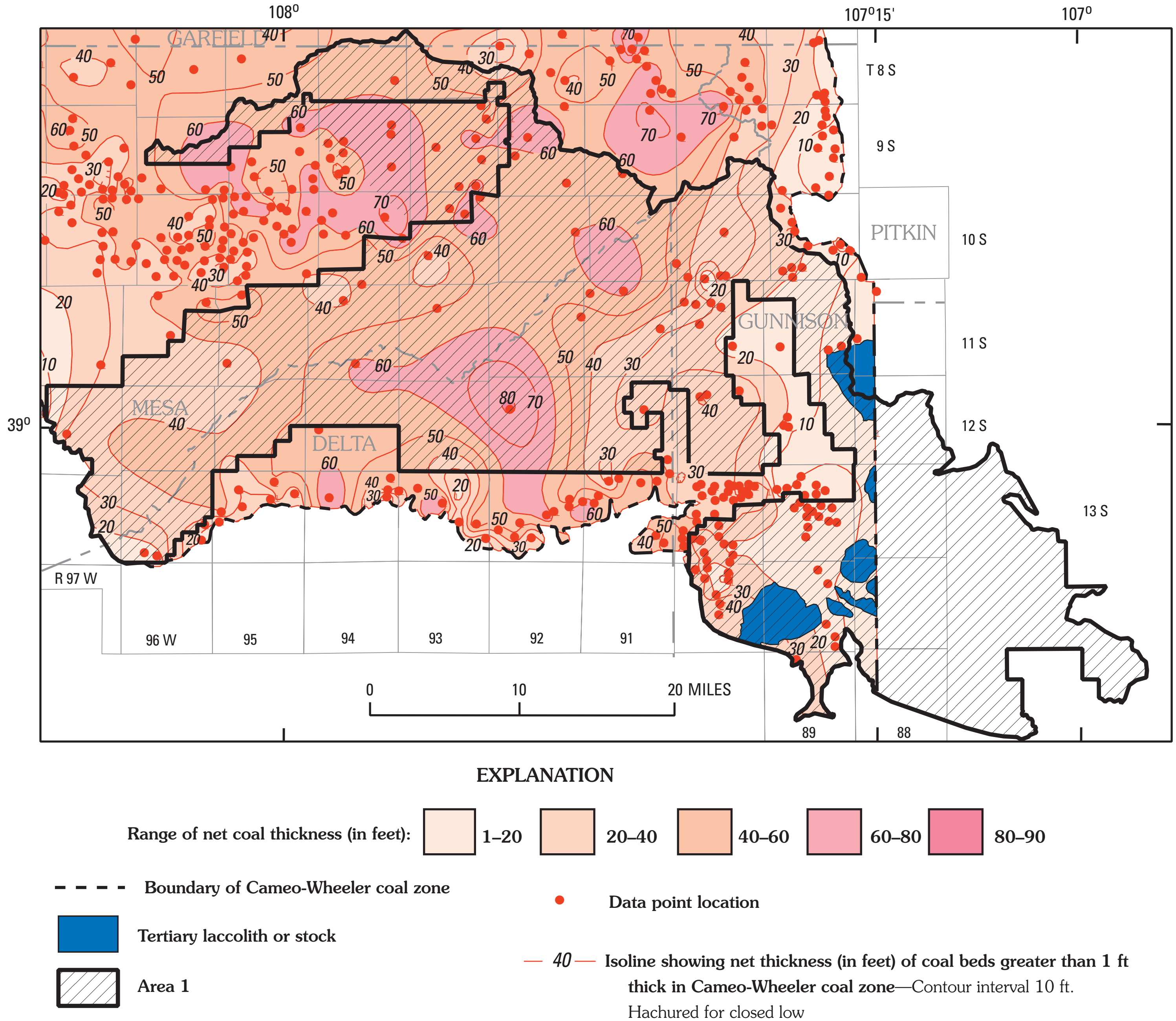
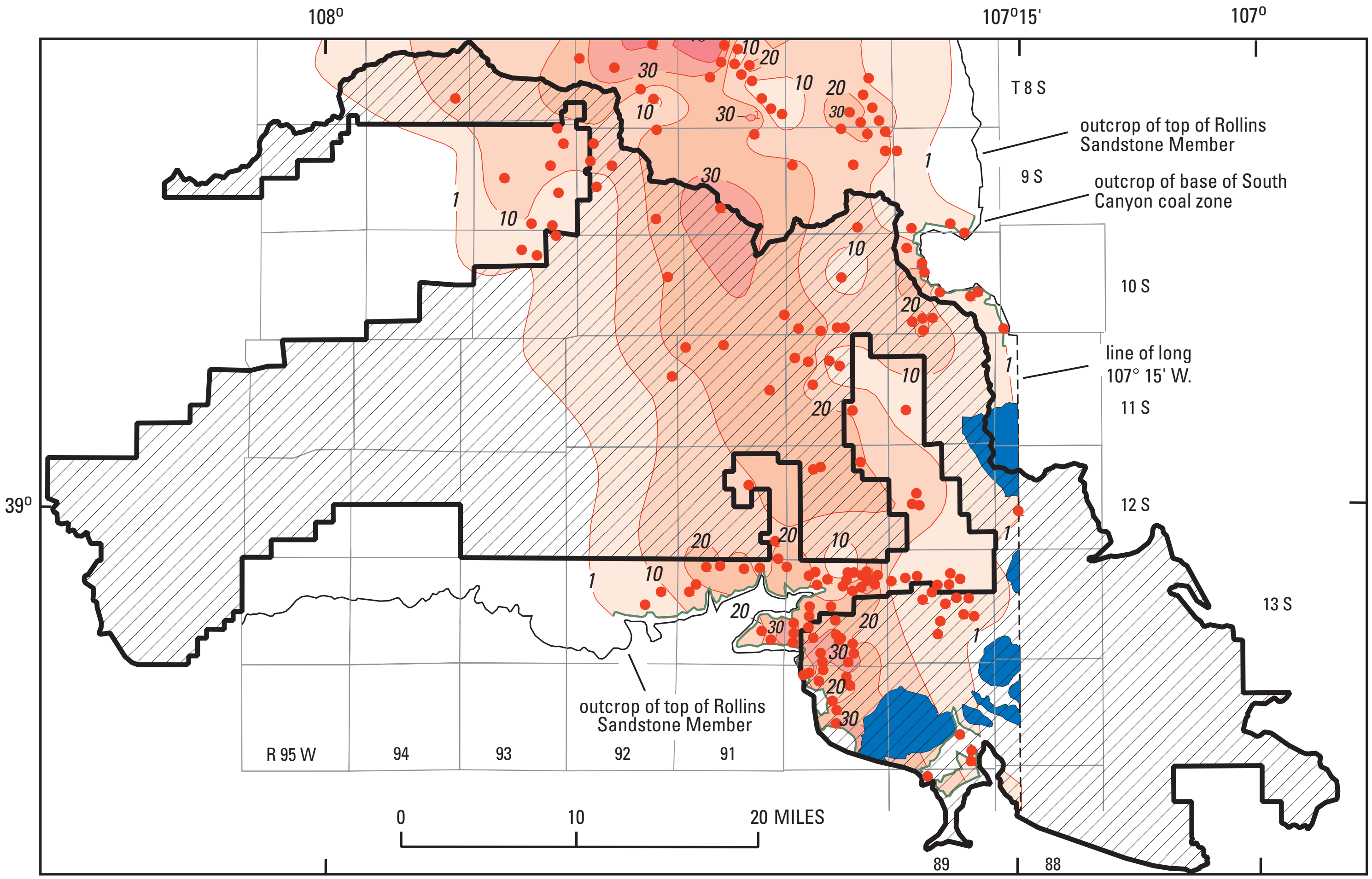


Figure M9. Isopach map of net coal in Cameo-Wheeler coal zone in Area 1. Net coal values represent all coal beds more than 1 ft thick. Cameo-Wheeler coal zone is defined only for areas located west of long 107°15′ W.



EXPLANATION

Range of thickness (in feet) of net coal in South Canyon coal zone: No coal | 1–10 | 10–20 | 20–30 | 30–40 | 40–50

Tertiary laccolith or stock

Area 1

Outcrop of South Canyon coal zone

Data point location

10 **Isoline showing thickness of net coal**—Contour interval 10 ft; 1 ft contour also shown

Figure M10. Isopach map of net coal in South Canyon coal zone in Area 1. Net coal values represent all coal beds more than 1 ft thick. South Canyon coal zone is defined only for areas located west of long 107°15′ W.

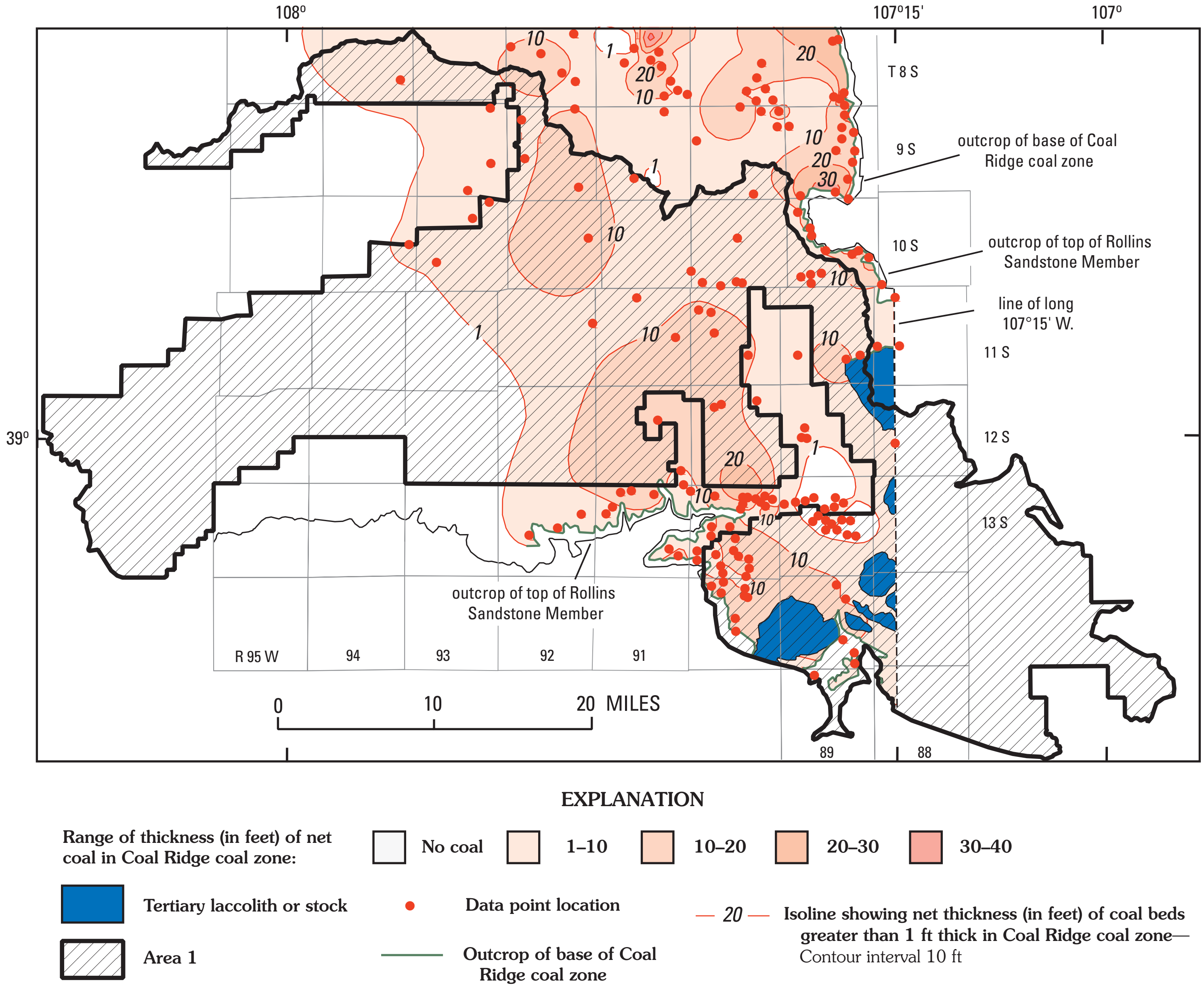


Figure M11. Isopach map of net coal in Coal Ridge coal zone in Area 1. Net coal values represent all coal beds more than 1 ft thick. Coal Ridge coal zone is defined only for areas located west of long 107°15′ W.

Lower, Middle, and Upper Coal Zones (East of Long 107°15′ W.)

East of long 107°15′ W., the Cameo-Fairfield coal group is divided into the lower, middle, and upper coal zones. The collective coal zones have about 1–30 ft of net coal (fig. M12) in one to five beds, and individual beds are 1–25 ft thick.

The lower coal zone overlies a basal marine sandstone that was considered to be equivalent to the Rollins Sandstone Member by Gaskill and Godwin (1966a, 1966b), Godwin (1968), and Gaskill and others (1967, 1986, 1987). The lower coal zone contains only one or two coal beds that were measured locally along outcrops in the Crested Butte coal field. The only important coal in the lower zone is the 0–4.0 ft thick A bed, which is located 7–10 mi south of the town of Crested Butte in the Ohio Creek district (T. 15 S., R. 86 W.) (Gaskill and others, 1987).

The middle coal zone overlies a second marine sandstone that is about 100–200 ft stratigraphically above the Rollins equivalent sandstone. The middle coal zone contains two to six coal beds that range from 1 to 25 ft thick. Included in the middle zone are four beds near the town of Crested Butte; these are bed I (1.5–6.5 ft thick), bed II (5.0–10.0 ft thick), bed III (2.0–25.0 ft thick), and bed IV (0–6.0 ft thick) (Gaskill and others, 1986). Other important beds include the B bed, which is 5.6–8.6 ft thick in the Ohio Creek district, and several unnamed beds that have been mined on Anthracite Mesa in T. 13 S., R. 86 W. (Gaskill and others, 1967).

The upper coal zone is about 300 ft stratigraphically above the Rollins equivalent sandstone, and it contains several lenticular coal beds in the Crested Butte coal field. Important beds include the C bed, which is about 5 to 6 ft thick in the Ohio Creek district, and a 3.5-4.5 ft thick anthracite bed that has been mined 7 mi southwest from the town of Crested Butte (Gaskill and others, 1987).

Coal Quality

The Cameo-Fairfield coal group has an ash yield of 1.9–29.9 percent, a sulfur content of 0.3–3.2 percent, and calorific values of 8,160–15,190 Btu/lb, based on values in the Grand Mesa, Somerset, Carbondale, and Crested Butte coal fields (table M3). The coal has an apparent rank that varies from subbituminous A to anthracite in the southern part of the Piceance Basin (Hornbaker and others, 1976). The coal's apparent rank generally increases to the southeast along the basin's southern and eastern flanks owing to the increase in depth of burial (Johnson, 1989), and it also increases near igneous intrusions owing to local heating (Hornbaker and others, 1976). The apparent rank of coal is subbituminous A to high volatile B bituminous along the basin's southern flank, and high volatile C bituminous to medium volatile bituminous along the basin's eastern flank; some beds have been metamorphosed to semianthracite and anthracite in the Carbondale and Crested Butte coal fields. Coal with coking properties has been identified in the eastern part of the Somerset coal field, the southern part of the Carbondale coal field, and the Crested Butte coal field (Hornbaker and others, 1976; Murray and others, 1977).

Coal Resources

Methods

Coal resources were estimated using the methodology of Wood and others (1983). Coal quantities reported as resources represent, as accurately as data allow, all coal in the ground in beds greater than 1 ft thick and under less than 6,000 ft of overburden. 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 study does not attempt to estimate coal reserves which are that subset of the resource that can be economically produced at the present time. Coal resources were estimated by multiplying the volume of coal by the average density of coal (Wood and others, 1983, p. 36). For this study, we used an average density of 1,800 short tons per acre-ft for bituminous coal.

Coal tonnages were reported within overburden categories of 0–500, 500–1,000, 1,000–2,000, 2,000–3,000, and 3,000–6,000 ft. Overburden was determined by subtracting

Table M3. Ash yield, sulfur content, and calorific values of coal in Cameo-Fairfield coal group in vicinity of Area 1, southern part of the Piceance Basin, Colo.

[Coal field locations are shown in figure M3. Modified from Hettinger and others (2000). Values are based on ranges of proximate and ultimate analyses summarized by Hornbaker and others (1976), Murray and others (1977), and Tremain and others (1996); values in the U.S. Geological Survey USCHEM database provided by R.H. Affolter (written commun., 1998), and include values summarized by Toenges and others (1949, 1952) for the Somerset coal field. Coal from the C.M.C. mine had an ash yield of 23.3 percent and was included in the Book Cliffs coal field by Tremain and others (1996); we included that ash value in the Grand Mesa coal field because the C.M.C mine was located in the Grand Mesa coal field as defined by Landis (1959)]

Coal field	Ash (pct)	Sulfur (pct)	Btu/lb
Grand Mesa	2.1–23.3	0.4–2.2	8,300–13,490
Somerset	2.4–29.9	0.3–3.2	8,160–14,380
Crested Butte	3.2–9.1	0.4–1.9	11,080–14,440
Carbondale	1.9–16.2	0.3–2.1	10,160–15,190

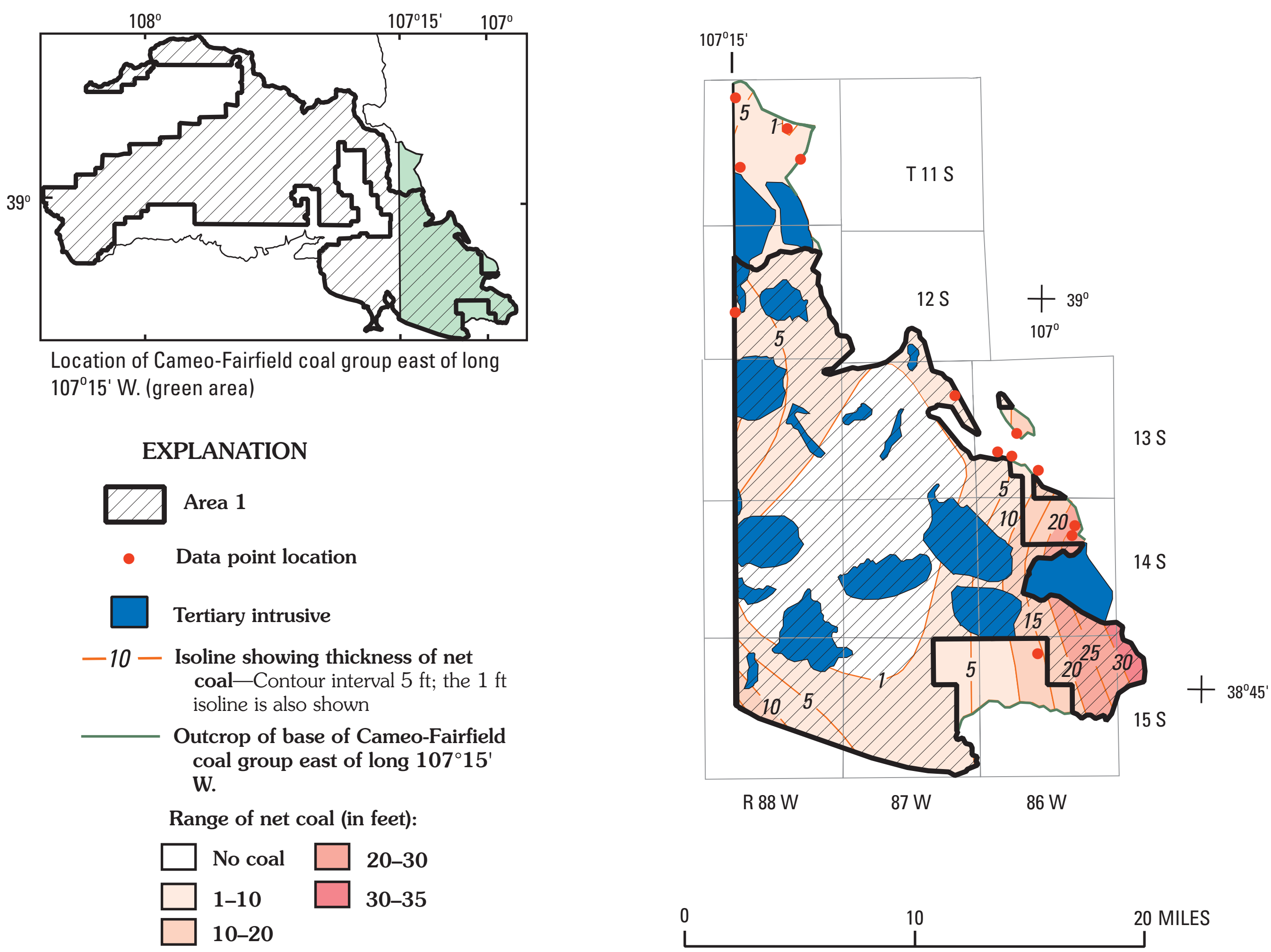


Figure M12. Isopach map of net coal in Cameo-Fairfield coal group east of long 107°15′ W., in Area 1. Net coal values represent all coal beds more than 1 ft thick.

elevations at the base of the specified coal interval from surface elevations; the difference therefore represents the maximum overburden on the specified coal interval. Elevations at the base of the Cameo-Fairfield coal group and Cameo-Wheeler coal zone were determined from a structure contour map of the top of the Rollins Sandstone Member (Hettinger and others, 2000). Similarly, elevations at the base of the South Canyon and Coal Ridge coal zones were determined from structure contour maps that represent the base of those respective coal zones. Maximum overburden thicknesses on the Cameo-Wheeler, South Canyon, and Coal Ridge coal zones are shown in figures M13, M14, and M15, respectively, and the maximum overburden thickness on the base of the Cameo-Fairfield coal group east of long 107°15′ W. is shown in figure M16.

Coal tonnages are also reported by identified and hypothetical reliability categories as defined by Wood and others (1983). Identified resources are located less than 3 mi from a coal measurement (data point), and hypothetical resources are located more than 3 mi from a coal measurement.

Results

Area 1 has an original coal resource of about 38 billion short tons in the Cameo-Fairfield coal group. That resource represents coal beds more than 1 ft thick and under less than 6,000 ft of overburden. The resource figure does not include coal folded over the flanks of laccoliths or buried beneath laccoliths. Approximately 32 percent of the resource is in the Grand Mesa National Forest, and 68 percent of the resource is in the Gunnison National Forest. Area 1 also contains about 34 billion short tons of non-resource coal in the Cameo-Fairfield group that is covered by 6,000–11,500 ft of overburden. 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 Cameo-Fairfield group where it is located west of long 107°15′ W. (tables M4, M5, and M6, respectively), and tonnages are reported for the entire Cameo-Fairfield coal group where it is located east of long 107°15′ W. (table M7).

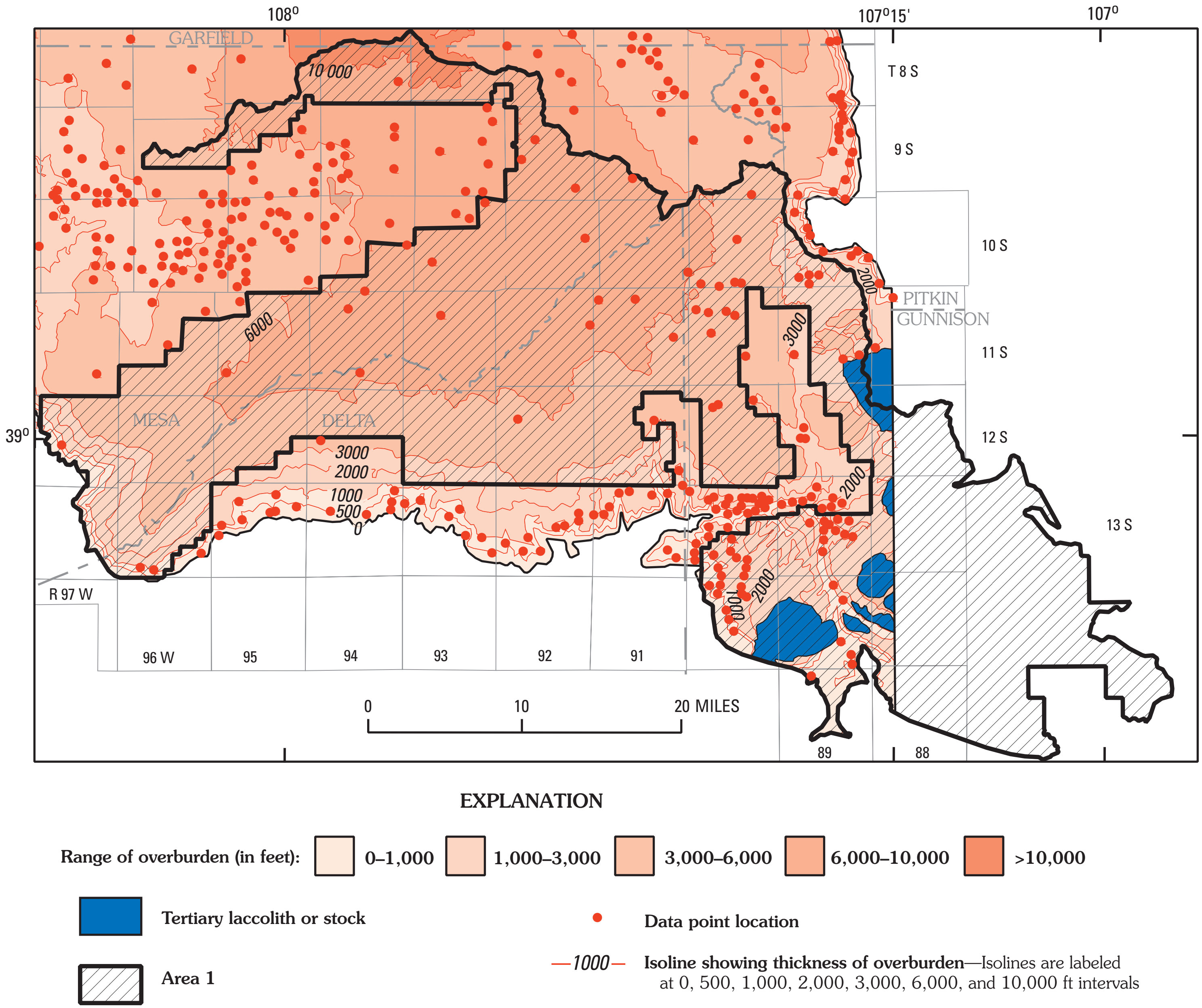


Figure M13. Isopach map of overburden on base of Cameo-Wheeler coal zone in Area 1. Cameo-Wheeler coal zone is defined only for areas located west of long 107°15′ W.

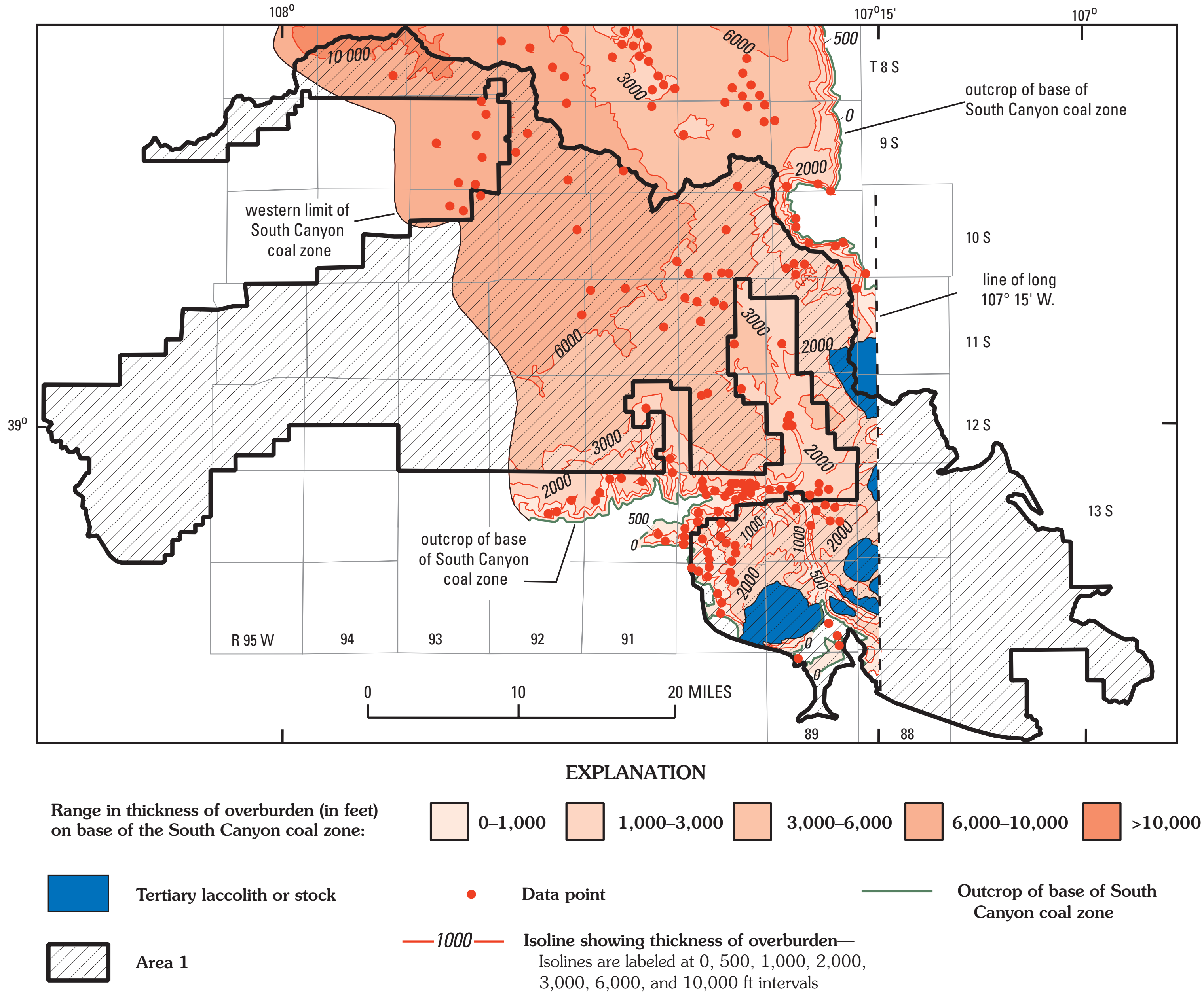


Figure M14. Isopach map of overburden on base of South Canyon coal zone in Area 1. South Canyon coal zone is defined only for areas located west of long 107°15′ W.

Table M4. Original coal resources (*A*) and other occurrences of non-resource coal (*B*) in Cameo-Wheeler coal zone, Area 1.

[Coal tonnages were rounded to two significant figures, and categories that show total tonnage may not equal the sum of the components because of independent rounding]

A. Original coal resources (in millions of short tons) in Cameo-Wheeler coal zone, Area 1.

Forest	Reliability	Overburden (ft)					Total
		0-500	500-1,000	1,000-2,000	2,000-3,000	3,000-6,000	
Grand Mesa	Identified	140	130	420	940	5,500	7,100
	Hypothetical	78	94	290	440	3,900	4,800
Grand Mesa Total		210	220	710	1,400	9,300	12,000
Gunnison	Identified	940	820	2,200	2,600	8,100	15,000
	Hypothetical	80	15	0.058	200	1,800	2,100
Gunnison Total		1,000	830	2,200	2,800	9,900	17,000
Grand Total		1,200	1,100	2,900	4,100	19,000	29,000

B. Other occurrences of non-resource coal (in millions of short tons) in Cameo-Wheeler coal zone at depths greater than 6,000 ft in Area 1.

Forest	Reliability	Overburden (ft)		Total
		6,000-10,000	>10,000	
Grand Mesa	Identified	16,000	790	17,000
	Hypothetical	4,400	450	4,900
Grand Mesa Total		21,000	1,200	22,000
Gunnison	Identified	5,400	0.00	5,400
	Hypothetical	1,300	0.00	1,300
Gunnison Total		6,700	0.00	6,700
Grand Total		27,000	1,200	28,000

Table M5. Original coal resources (*A*) and other occurrences of non-resource coal (*B*) in South Canyon coal zone, Area 1.

[Coal tonnages were rounded to two significant figures, and categories that show total tonnage may not equal the sum of the components because of independent rounding]

A. Original coal resources (in millions of short tons) in the South Canyon coal zone, Area 1.

Forest	Reliability	Overburden (ft)					Total
		0-500	500-1,000	1,000-2,000	2,000-3,000	3,000-6,000	
Grand Mesa	Identified	0.00	0.00	0.00	0.00	0.25	0.25
	Hypothetical	0.00	0.00	0.00	0.47	26	26
Grand Mesa Total		0.00	0.00	0.00	0.47	26	27
Gunnison	Identified	180	350	840	740	2,500	4,600
	Hypothetical	0.2	2.5	20	59	410	490
Gunnison Total		180	350	860	790	2,900	5,100
Grand Total		180	350	860	790	2,900	5,100

B. Other occurrences of non-resource coal (in millions of short tons) in South Canyon coal zone at depths greater than 6,000 ft in Area 1.

Forest	Reliability	Overburden (ft)		Total
		6,000-10,000	>10,000	
Grand Mesa	Identified	2,000	100	2,100
	Hypothetical	300	48	340
Grand Mesa Total		2,300	150	2,500
Gunnison	Identified	1,100	0.00	1,100
	Hypothetical	170	0.00	170
Gunnison Total		1,300	0.00	1,300
Grand Total		3,600	150	3,800

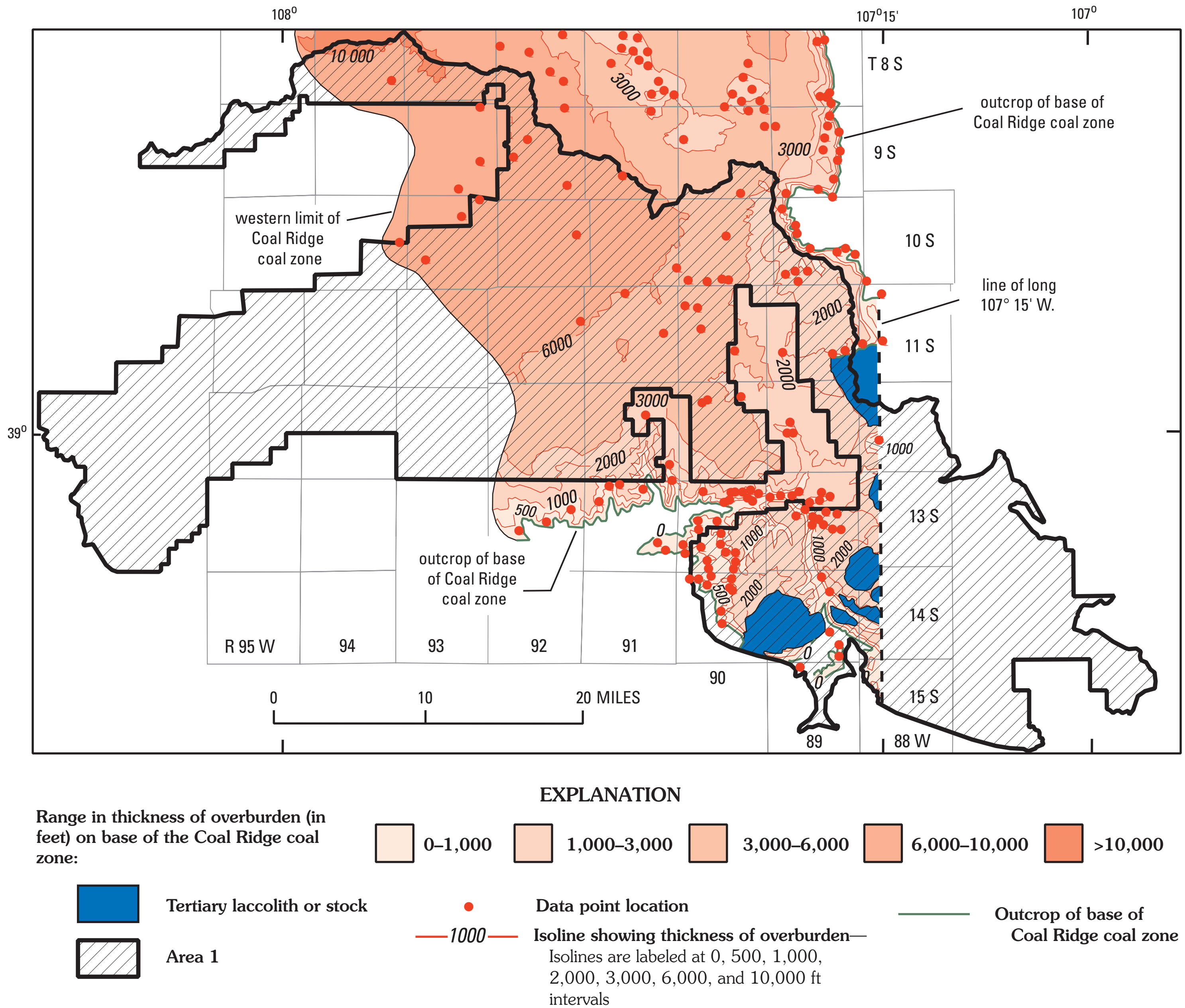


Figure M15. Isopach map of overburden on base of the Coal Ridge coal zone in Area 1. Coal Ridge coal zone is defined only for areas located west of long 107°15′ W.

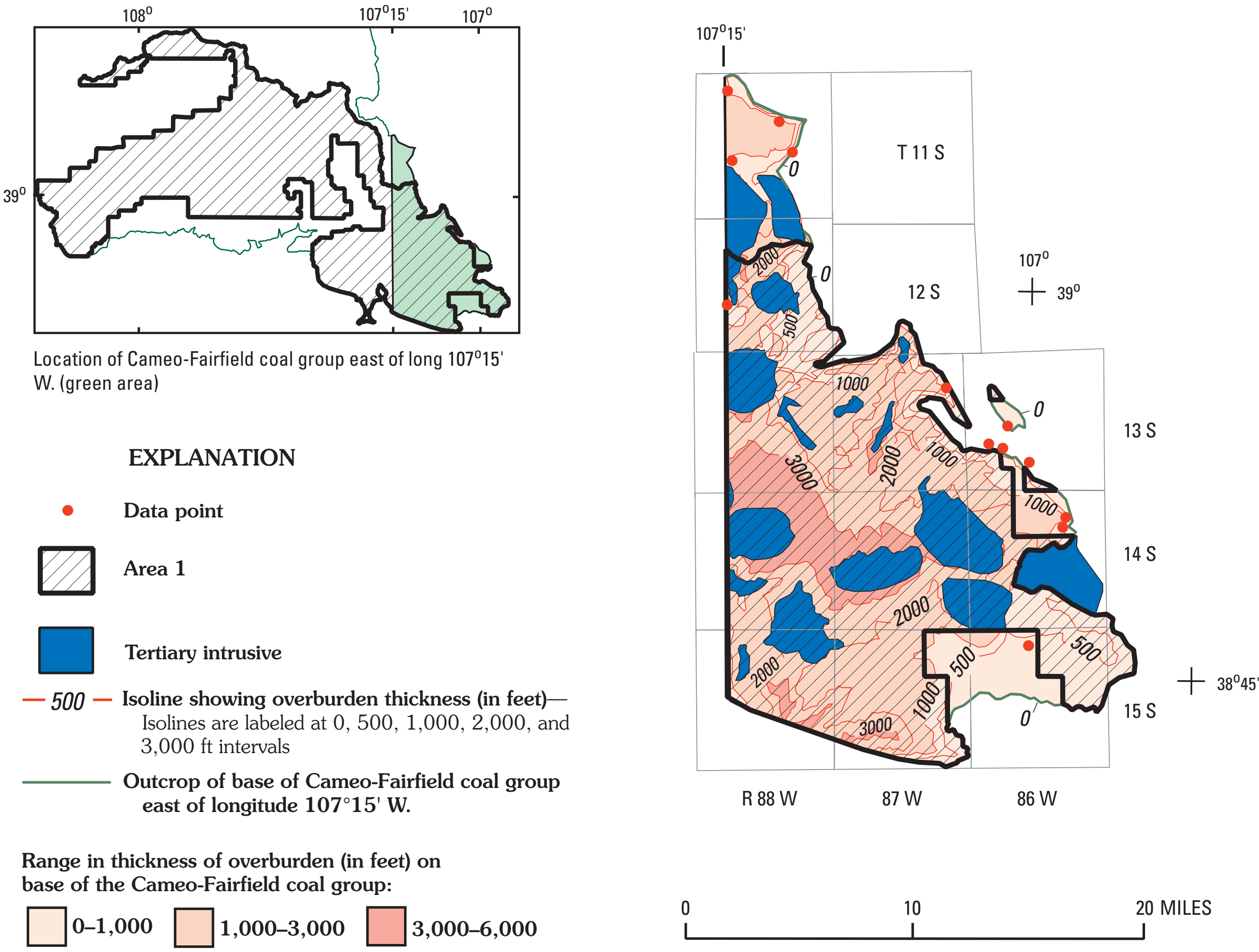


Figure M16. Isopach map of overburden on base of Cameo-Fairfield coal group east of long 107°15′ W., in Area 1.

The large coal resource figure reported for Area 1 must be regarded with caution because it does 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 ft, (2) beds more than 3.5 ft thick, and (3) strata inclined by less than 12°; additionally, only about 14 ft of coal can be mined even if the bed is of greater thickness (Timothy J. Rohrbacher, oral commun., 1996). These overburden and bed thickness limits are supported by a summary of 81 longwalls operating in the United States by 30 companies (Merritt and Fiscor, 1995, p. 32–38). Only an estimated 14 billion short tons of coal in Area 1 meets favorable underground mining criteria regarding depth of burial (less than 3,000 ft), and only a fraction of that coal could be mined economically because many beds are either less than 3.5 ft thick or more than 14 ft 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 strata.

Cameo-Wheeler Coal Zone

The Cameo-Wheeler zone has an original coal resource of 29 billion short tons in Area 1 (table M4*A*). The resource is distributed across 560 mi^2 where the coal is covered by less than 6,000 ft of overburden (fig. M13). Approximately 9.3 billion short tons is under less than 3,000 ft of overburden, and 5.2 billion short tons is under less than 2,000 ft of overburden. The Cameo-Wheeler contains an additional 28 billion short tons of non-resource coal in Area 1 (table M4*B*). The non-resource coal is covered by 6,000–11,500 ft of overburden.

South Canyon Coal Zone

The South Canyon zone has an original coal resource of approximately 5.1 billion short tons in Area 1 (table M5A). The resource is distributed across a 320 mi^2 area where the

Table M6. Original coal resources (*A*) and other occurrences of non-resource coal (*B*) in Coal Ridge coal zone, Area 1.

[Coal tonnages were rounded to two significant figures, and categories that show total tonnage may not equal the sum of the components because of independent rounding]

A. Original coal resources (in millions of short tons) in Coal Ridge coal zone, Area 1.

Forest	Reliability	Overburden (ft)					Total
		0-500	500-1,000	1,000-2,000	2,000-3,000	3,000-6,000	
Grand Mesa	Identified	0.00	0.00	0.00	0.27	0.00	0.27
	Hypothetical	0.00	0.00	0.18	5.8	27	33
Grand Mesa Total		0.00	0.00	0.18	6.1	27	34
Gunnison	Identified	170	230	670	540	1,400	3,000
	Hypothetical	0.96	0.82	0.22	38	330	370
Gunnison Total		170	230	670	580	1,700	3,300
Grand Total		170	230	670	580	1,700	3,400

B. Other occurrences of non-resource coal (in millions of short tons) in Coal Ridge coal zone at depths greater than 6,000 ft in Area 1.

Forest	Reliability	Overburden (ft)		Total
		6,000-10,000	>10,000	
Grand Mesa	Identified	1,200	20	1,200
	Hypothetical	300	11	310
Grand Mesa Total		1,500	31	1,500
Gunnison	Identified	230	0.00	230
	Hypothetical	32	0.00	32
Gunnison Total		260	0.00	260
Grand Total		1,700	31	1,800

Table M7. Original coal resources in Cameo-Fairfield coal group located east of long 107°15′ W., Area 1.

[All of these coal resources are within the Gunnison National Forest. Coal tonnages were rounded to two significant figures, and categories that show total tonnage may not equal the sum of the components because of independent rounding]

Reliability	Overburden (ft)					Total
	0–500	500–1,000	1,000–2,000	2,000–3,000	3,000–6,000	
Identified	160	160	63	51	2.6	440
Hypothetical	160	64	160	100	57	540
Grand Total	320	220	220	150	60	980

coal is covered by less than 6,000 ft of overburden (fig. M14). Approximately 2.1 billion short tons is under less than 3,000 ft of overburden, and 1.4 billion short tons is under less than 2,000 ft of overburden. The South Canyon contains an additional 3.8 billion short tons of non-resource coal in Area 1. The non-resource coal is covered by 6,000–11,200 ft of overburden (table M5B).

Coal Ridge Coal Zone

The Coal Ridge coal zone has an original coal resource of approximately 3.4 billion short tons in Area 1 (table M6*A*). The resource is distributed across 360 mi^2 where the coal is covered by less than 6,000 ft of overburden (fig. M15). Approximately 1.7 billion short tons is under less than 3,000 ft of overburden, and 1.1 billion short tons is under less than 2,000 ft of overburden. The Coal Ridge contains an additional 1.8 billion short tons of non-resource coal in Area 1. The non-resource coal is covered by 6,000–11,000 ft of overburden (table M6*B*).

Coal Resources of the Cameo-Fairfield Coal Group East of Long 107°15′ W.

Area 1 has an original resource of 980 million short tons of coal in the Cameo-Fairfield coal group where it is located east of long 107°15′ W. (table M7). The resource is distributed across 220 mi^2 and is in the lower, middle, and upper coal zones. This resource figure is tenuous because of the complex geology and paucity of coal measurements in the area. Additionally, the resource figure does not include coal that is folded over the flanks of laccoliths or that is buried beneath laccoliths in the region. Maximum overburden on the Cameo-Fairfield coal group east of long 107°15′ W. is shown in figure M16. Approximately 910 million short tons of coal is under less than 3,000 ft of overburden, and 760 million short tons is under less than 2,000 ft of overburden.

Coal Production

About 150 million short tons of coal has been mined since the late 1800's from the Cameo-Fairfield coal group in the Carbondale (southern part), Crested Butte, Grand Mesa (eastern part), and Somerset coal fields. About 99 million short tons was mined in Gunnison County, 30 million tons was mined in Pitkin County, and 21 short million tons was mined in Delta County (Eakins and Coates, 1998). The coal was produced from about 60 mines; the mine areas are shown in figure M17. Mining activity prior to 1977 was compiled by Murray and others (1977), and mining activity from January 1977 to December 1997 was summarized by Hettinger and others (2000). About 83 million short tons has been extracted from 21 mines that operated at various times between January 1977 and December 1997. Only four mines were producing coal at the end of 1997; all four mines are in the Somerset coal field, and they are the Bowie No. 1 (Orchard Valley mine), Bowie No. 2 mine, Sanborn Creek, and West Elk (Mt. Gunnison) mines. In 1997, the Sanborn Creek and West Elk (Mt. Gunnison) mines produced 1.6 million and 5.6 million short tons of coal, respectively.

About 19 mines have produced coal from the Grand Mesa and Gunnison National Forests (fig. M17), and most of the mines are located in the Crested Butte and Somerset coal fields. We did not attempt to determine production from the Grand Mesa and Gunnison National Forests because production records generally reflect operations conducted within and adjacent to the forest lands. Coal production data by Gaskill and others (1986, 1987) show that none of the coal mines in the Crested Butte coal field have operated since the 1950's. Only the West Elk mine in the Somerset coal field was operating within the Gunnison National Forest at the time of this publication.

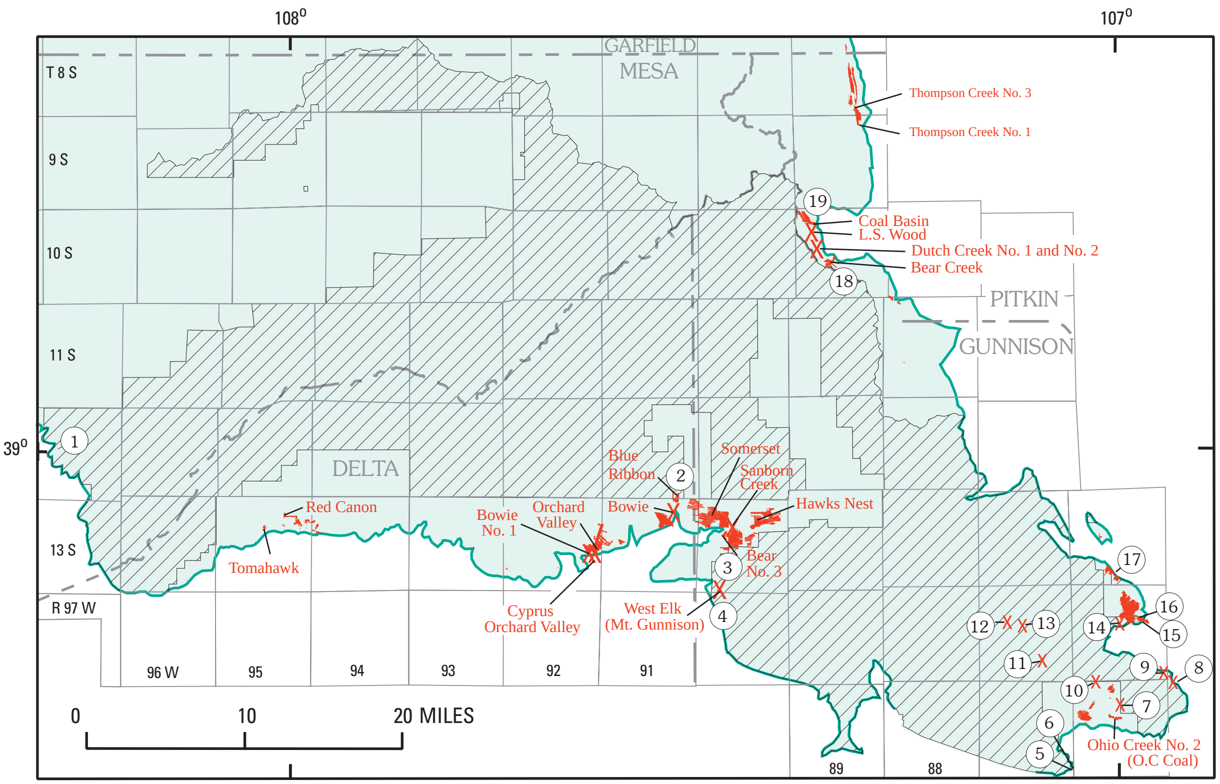
Summary of Coal Resource Potential in the Grand Mesa, Uncompahgre, and Gunnison National Forests

The three GMUG forests are considered to have coal resource potential in areas where underlying strata (1) are likely to have accumulated in a coal-forming environment, and (2) the potential coal-bearing rocks are less than 6,000 ft deep (fig. M18). As summarized in this report, coal-bearing strata are either known or are likely to be in the Dakota Formation, Fruitland Formation, Mesaverde Formation, or Mesaverde Group. Areas of high coal resource potential have nearby outcrop or drill hole data that substantiate the presence of coal. Areas of 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 to be 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.

Coal Resource Potential of the Dakota Sandstone in the Grand Mesa and Uncompahgre National Forests

There are two problems in trying to determine the coal resource potential of the Dakota Sandstone. The first problem is that few data are available for Dakota coal in the GMUG forests. The presence of coal in the Dakota must therefore be inferred from adjacent areas where the Dakota has been described. The second problem is that the Dakota Sandstone and underlying Jurassic strata have been mapped as a single unit at many localities in the Gunnison and Uncompahgre National Forests, and presence of the Dakota is not certain in those areas. Based on published geologic maps, the Dakota is definitely present where mapped separately from the underlying Burro Canyon Formation, and it is likely to be present below areas where younger sedimentary rocks have been mapped at the surface.

The GMUG forests have either a moderate, low, or no resource potential for coal in the Dakota Sandstone (fig. M18*A*). The Uncompahgre National Forest has a low to moderate coal resource potential in areas underlain by the Dakota Sandstone. Although few data are available to substantiate the presence of coal in the forest, the occurrence of minable coals outside of the forest (near the towns of Nucla and Norwood) indicates that isolated deposits of minable coal might also be in the forest. The Dakota Sandstone has a low coal resource potential in a small part of the Grand Mesa National Forest. The Dakota is 5,000 and 6,000 ft deep in that area, and its low resource potential is based on outcrop data that show the Dakota to contain a few thin coal beds about 10 mi outside the forest along the Gunnison River. Any Dakota coal that might be present in the Grand Mesa National Forest would not have current mining potential because it is at depths that exceed the physical or economic limits of present-day mining techniques. The Dakota Sandstone has no coal resource potential in the remaining part of the Grand Mesa National Forest because it is more than 6,000 ft deep. Available data indicate that the Dakota does not contain coal where it is exposed in the vicinity of the Gunnison National Forest, and therefore this forest is not considered to have resource potential for Dakota coal.



MAP NUMBER AND NAME OF MINE

1 Kannah Creek
2 Blue Ribbon
3 Bear No. 3
4 West Elk (Mt. Gunnison)
5 Castle Rock

6 Hinkle
7 K-D (Kozy Draw); S.L. Staples & Son
8 Comstock
9 Robinson (Kochevar)
10 Richardson; Richardson Coal Co.; Mt. Carbon Anthracite Coal Co.; Gomer Dollard and Weaver Brothers

11 Mt. Carbon Anthracite Coal Co., Ohio Creek-Anthracite Coal Co., and W. Hinds
12 Ruby-Anthracite (Floresta No. 1); Caledonia Fuel Co., Union Pacific Coal Co., and Colorado Fuel and Iron Co.
13 Unknown
14 Wheatstone
15 Verzuh

16 Crested Butte, Bulkley No. 1 and 2, and Porter
17 Peanut, Elk Mountain, and Horace
18 Bear Creek
19 Coal Basin

Mines that have produced coal from the GMUG forests. Mines are located by numbers shown on map.

EXPLANATION

Area 1, Grand Mesa and Gunnison National Forests (part)

Area underlain by Cameo-Fairfield coal group

Outcrop of base of Cameo-Fairfield coal group

Hawks Nest
5
Mine location—Named mines have operated since 1977. Numbers refer to mines within GMUG forests, and are listed at right

Approximate mine location

Figure M17. Location of coal mines that have produced from Cameo-Fairfield coal group in vicinity of Area 1. Mines that have produced coal since 1977 are named in red type. Mines that became inactive prior to 1977 are not named. Mines that have operated within the forest are shown in list.

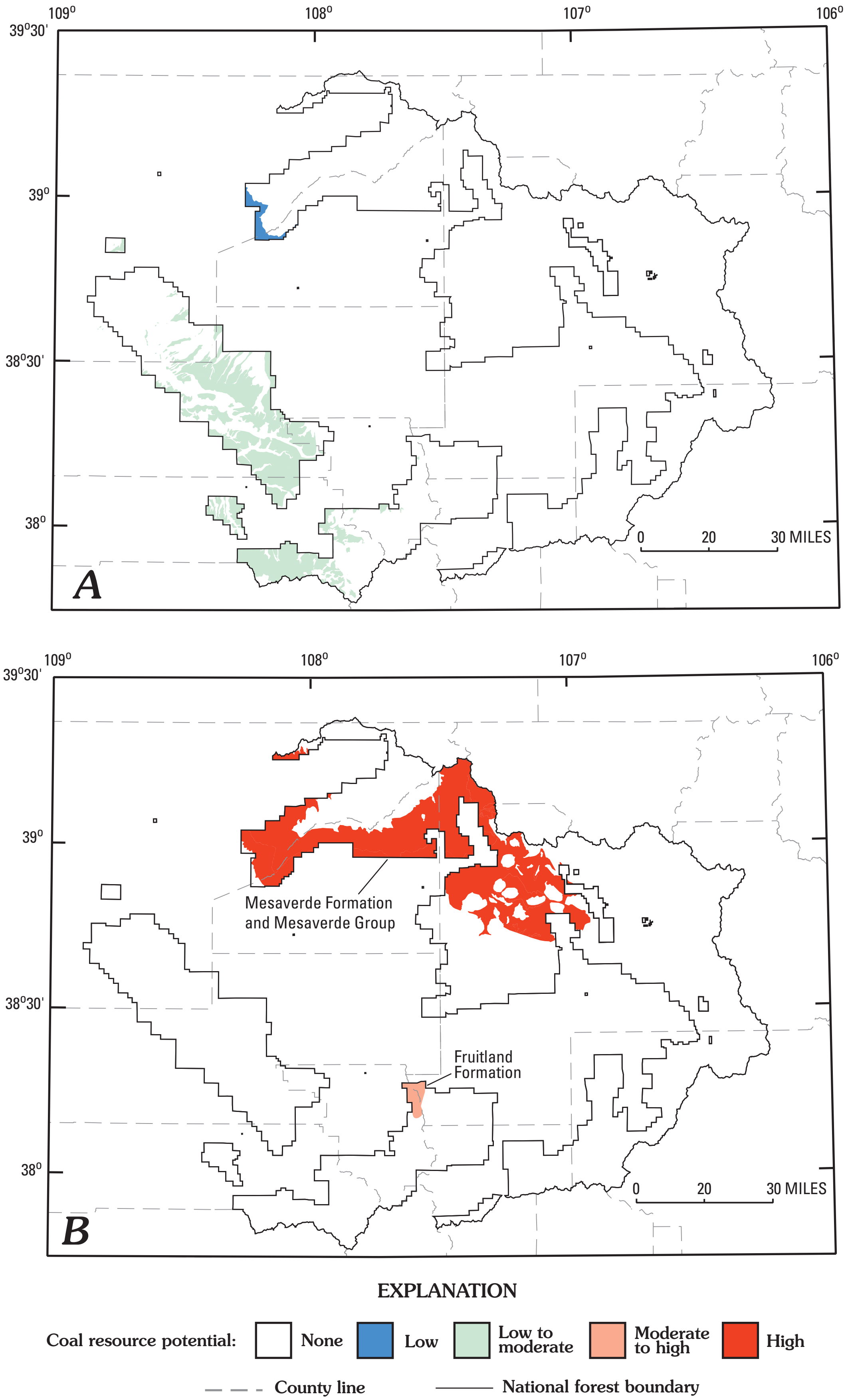

109°
108°
107°
106°
39°30'
39°
38°30'
38°
0
20
30 MILES
A
B
Mesaverde Formation and Mesaverde Group
Fruitland Formation
EXPLANATION
Coal resource potential:
None
Low
Low to moderate
Moderate to high
High
County line
National forest boundary

Figure M18 (previous page). Coal resource potential in Grand Mesa, Uncompahgre, and Gunnison (GMUG) National Forests. GMUG forests are identified in figure M1. *A*, Coal resource potential for GMUG forest areas underlain by the Dakota Sandstone. *B*, Coal resource potential for GMUG forest areas underlain by the Fruitland Formation, Mesaverde Formation, or Mesaverde Group. GMUG forest areas intruded by volcanic rock were not assessed.

Coal Resource Potential of the Fruitland Formation in the Uncompahgre National Forest

The Uncompahgre National Forest has a moderate to high resource potential for coal where it is underlain by the Fruitland Formation in the Tongue Mesa coal field (fig. M18*B*). The area is given a high resource potential because it is known to contain thick beds of subbituminous coal; the area is also assigned a moderate resource potential because coal bed continuity could not be determined, owing to poor exposure and structural complexities. Coal beds were mined locally in the Tongue Mesa coal field between the 1890's and 1940's (Dickinson, 1987a, 1987b, 1988), and there has been some interest to develop the coal since that time (Hornbaker and others, 1976; Dickinson, 1987a, 1987b, 1988). Although the area has a moderate to high resource potential, Hornbaker and others (1976) thought that the coal in the Tongue Mesa area could not compete with better coal in the Somerset field.

Coal Resource Potential of the Mesaverde Group and Mesaverde Formation in the Grand Mesa and Gunnison National Forests

The Grand Mesa and Gunnison National Forests have a high coal resource potential where the Cameo-Fairfield coal group is at depths of less than 6,000 ft (fig. M18*B*). This regionally extensive coal group is in the Mesaverde Group and Mesaverde Formation; it contains as much as 97 ft of net coal, and has individual coal beds as thick as 30 ft within the forest areas. Cameo-Fairfield coal has been mined at several coal fields located in and adjacent to the forests. About 150 million short tons has been produced since the late 1800's, and the West Elk mine is currently operating in the Gunnison National Forest.

The area of high coal resource potential in the Grand Mesa and Gunnison National Forests (fig. M18*B*) is estimated to contain about 38 billion short tons of coal in the Cameo-Fairfield coal group, as determined for Area 1 in this study. This large resource figure does not represent minable reserves, which are a subset of the resource that could be economically produced at the present time. Coal in the Cameo-Fairfield 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 of the coal resource is at depths (less than 3,000 ft) favorable for longwall mining. 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 strata.

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