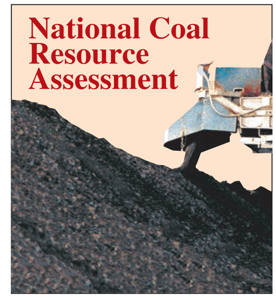
Chapter I

A Summary of the Stratigraphy, Coal Resources, and Coal-Bed Methane Potential of Northwest Colorado



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Chapter I *of*

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

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

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A Summary of the Stratigraphy, Coal Resources, and Coal-Bed Methane Potential of Northwest Colorado

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Introduction

The assessment of the coal resources of northwest Colorado, is part of the U.S. Geological Survey's (USGS) National Coal Resource Assessment (NCRA) project to identify and characterize coal deposits that could potentially provide fuel for the Nation's coal-derived energy needs during the first quarter of the 21st century. Twelve priority assessment units were designated in the Rocky Mountains and Colorado Plateau region (Kirschbaum, chap. A, this CD-ROM) because they are areas of active mining, contain large amounts of federally administered lands, have coal-bed gas production, and have potential for future development (fig. 1). Northwest Colorado contains 5 of the 12 priority assessment units (fig. 1). This paper summarizes the stratigraphy of coal-bearing rocks, coal resources, and coal-bed methane potential in northwest Colorado's priority assessment units.

Danforth Hills, Lower White River, and Yampa assessment units (fig. 1) contain 56 billion short tons of coal in beds greater than 1.2 ft thick and under less than 3,000 ft of overburden. The Southern Piceance Basin assessment unit contains an estimated 48 billion short tons of coal in beds greater than 1 ft thick and under less than 3,000 ft of overburden. Coal resources were not calculated within coal leases. Although northwest Colorado contains a significant coal resource, the resource does not reflect economic, land-use, environmental, technological, and geologic constraints that might affect the availability and recoverability of the coal.

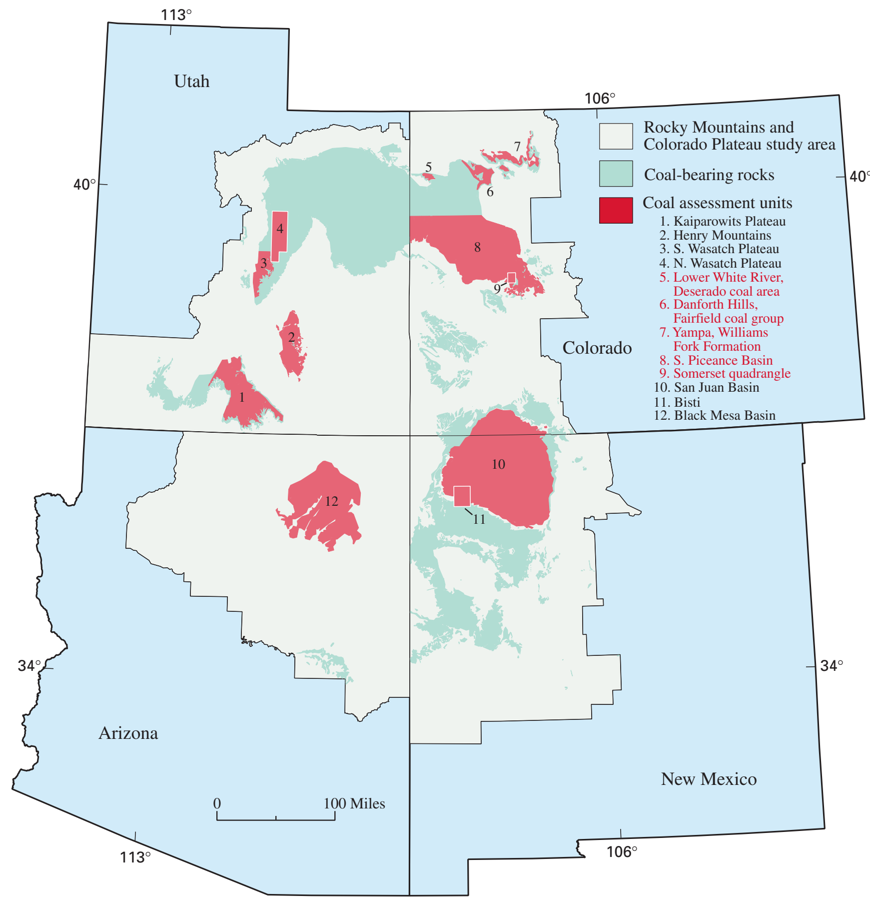

Figure 1. Priority coal assessment areas, shown in red, in the Rocky Mountains and Colorado Plateau region, National Coal Resource Assessment Project. Northwest Colorado assessment units highlighted in red in explanation. Modified after Kirschbaum (chap. A, this CD-ROM).

Coal Fields of Northwest Colorado

Northwest Colorado (fig. 2) has been designated as a priority area for resource assessment because it has a large amount of federally owned coal lands and high coal production. The assessment units include the Deserado coal area in the Lower White River coal field, the Williams Fork Formation in the Yampa coal field, the Fairfield coal group in the Danforth Hills coal field, the Southern Piceance Basin coal area (including the Book Cliffs, Grand Mesa, Somerset, Carbondale, southern Grand Hogback, and Crested Butte coal fields), and the Somerset quadrangle. The Somerset quadrangle was part of the USGS Coal Availability Program and was assessed in cooperation with the Colorado State Geological Survey (Rohrbacher and others, chap. F, this CD-ROM). The percent of federally owned assessed coal in each of the five areas is: Deserado coal area, 99; Danforth Hills, 80; Yampa coal field, 76; and southern Piceance Basin (includes Somerset quadrangle), 88. The northern part of the Grand Hogback coal field was not assessed because there is no coal production from the coal field.

Geoscientists with knowledge about each coal area have developed digital coal thickness and geographical databases and geologic maps to assess the coal resources in each major coal field. Brownfield and others (chap. M and chap. N, this CD-ROM) have evaluated the coal resources in the Danforth Hills and Lower White River coal fields. Hettinger and others (chap. O, this CD-ROM) and Johnson and others (chap. P, this CD-ROM) have integrated geologic and drill-hole data to assess the Yampa coal field and Southern Piceance Basin coal area, respectively.

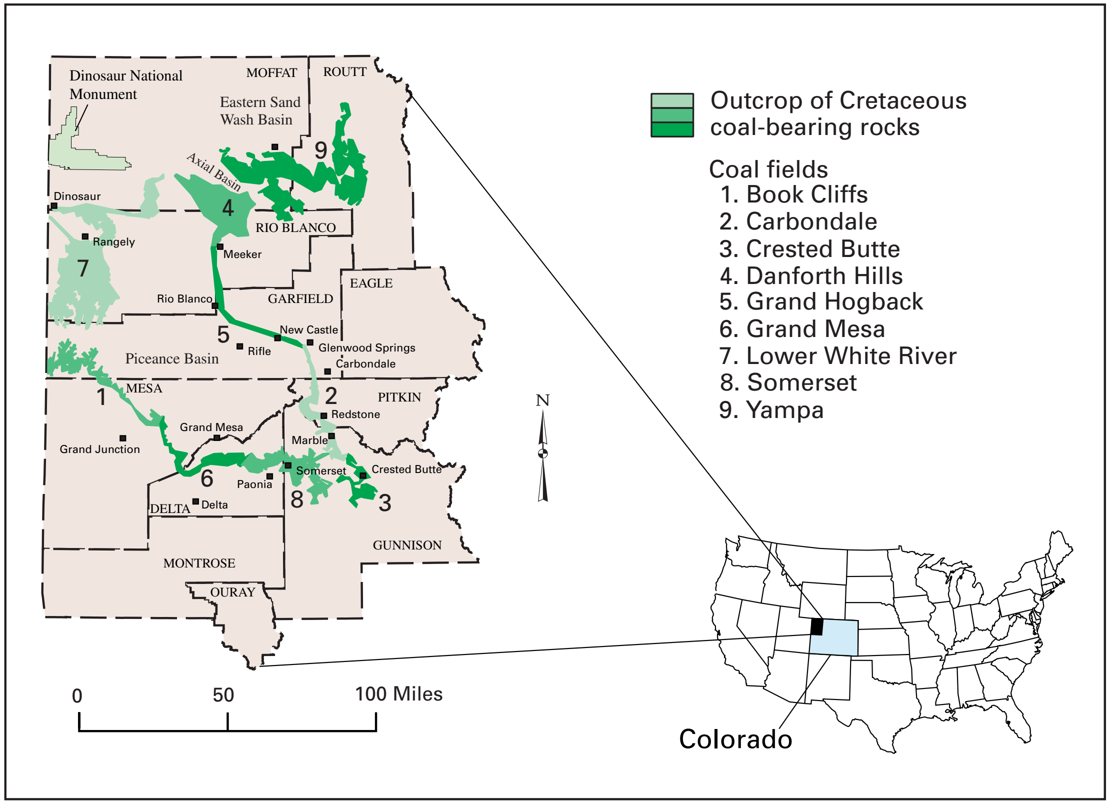

Figure 2. Major coal fields in northwest Colorado. Approximate boundaries of the coal field fields are shown in shades of green.

Coal in Northwest Colorado

The coal-bearing rocks in northwest Colorado (fig. 3) include the Upper Cretaceous Mesaverde Formation in the southern Piceance Basin, the Mount Garfield, Hunter Canyon, Iles, and Williams Fork Formations of the Mesaverde Group in the southern Piceance Basin, and Iles and Williams Fork Formations of the Mesaverde Group, the lower, coal, and upper units of the Mesaverde Group, Upper Cretaceous Lance Formation, and Paleocene Fort Union Formations in the eastern Sand Wash and northern Piceance Basins. The stratigraphic terminology and facies relations vary from coal field to coal field within the study area.

Only one mine, the Colowyo (Kennecott Mining Company) was producing coal in the Danforth Hills coal field at the end of 1999, while in the Lower White River coal field the only mine producing coal was the Deserado. In the Yampa coal field, four mines operated at the end of 1999 and included the Foidel Creek, Seneca II West, Trapper, and Yoast mines. Six mines were producing coal in the southern Piceance at the end of 1997; these include the Bowie No. 1, Bowie No. 2, McClane Canyon, Roadside North Portal, Sanborn, and West Elk mines. In 1997, coal production in northwest Colorado was about 24 million short tons of subbituminous and bituminous coal (Resource Data International, Inc.).

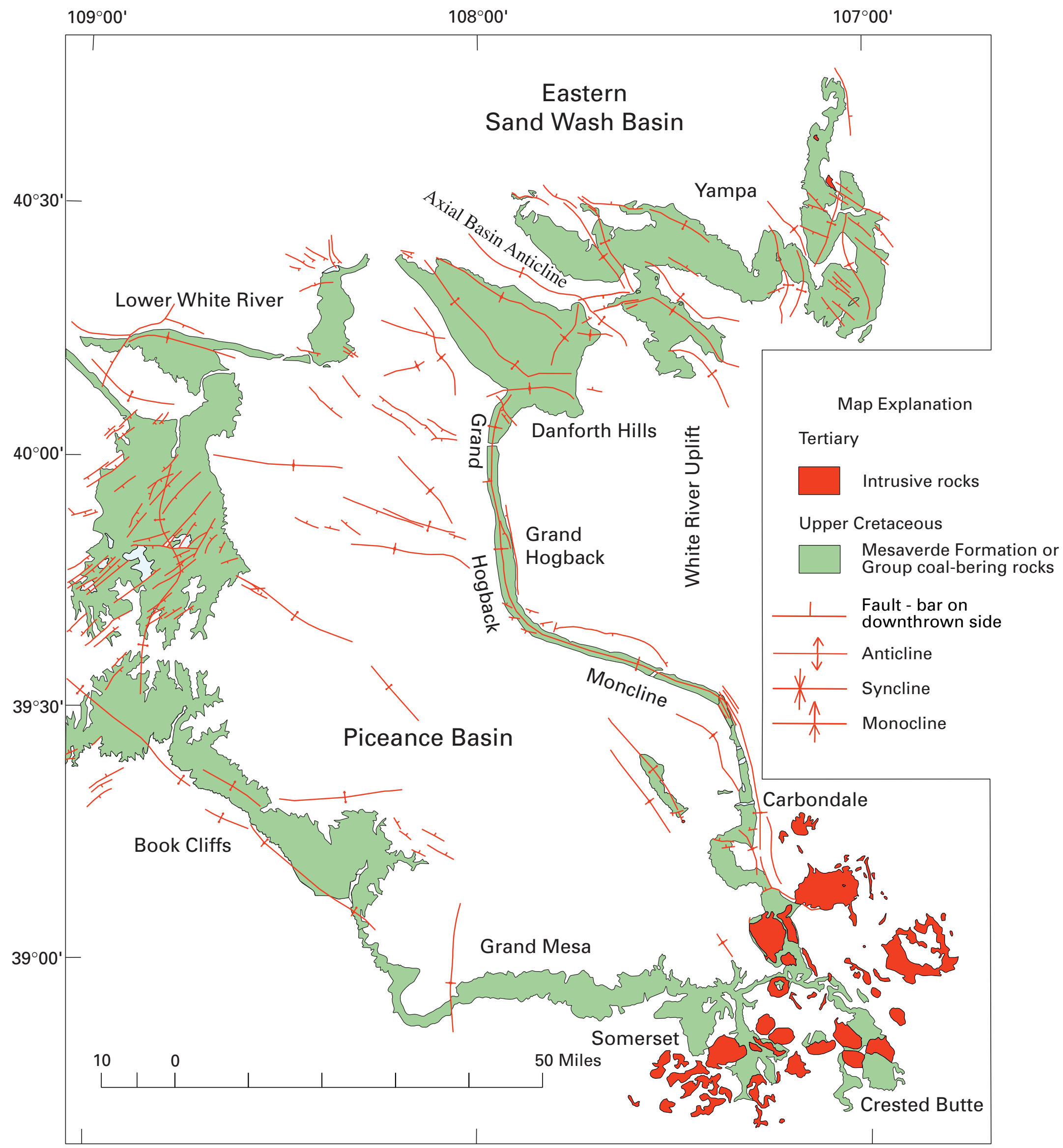

Figure 3. Generalized geologic map of northwest Colorado showing outcrops of the coal-bearing Mesaverde Formation and Group and major coal fields within the eastern Sand Wash and Piceance Basins. Modified from Brownfield and others (chaps. M and N, this CD-ROM) Hettinger and others (chap. O, this CD-ROM), and Johnson and others (chap. P, this CD-ROM).

Lower White River Coal Field

Location

The Lower White River coal field (figs. 2 and 3) occupies parts of Garfield, Moffat, and Rio Blanco Counties. The coal field is located in the northern part of the Piceance Basin, which is part of the Uinta Region of the Rocky Mountain Coal Province (Tully, 1996). In this study, the area of interest is restricted to the northern part of the Lower White River coal field where there is active coal mining. This area is referred to as the Deserado coal area (Brownfield and others, chap. N, this CD-ROM). The Deserado coal area is located north of Rangely, Colo., and south of the Dinosaur National Monument.

Stratigraphy of Cretaceous and Tertiary Strata

A generalized stratigraphic column showing a portion of the Upper Cretaceous rocks in northwest Colorado and the regional correlations between the Lower White River, the Danforth Hills, and Yampa coal fields is shown in figure 4.

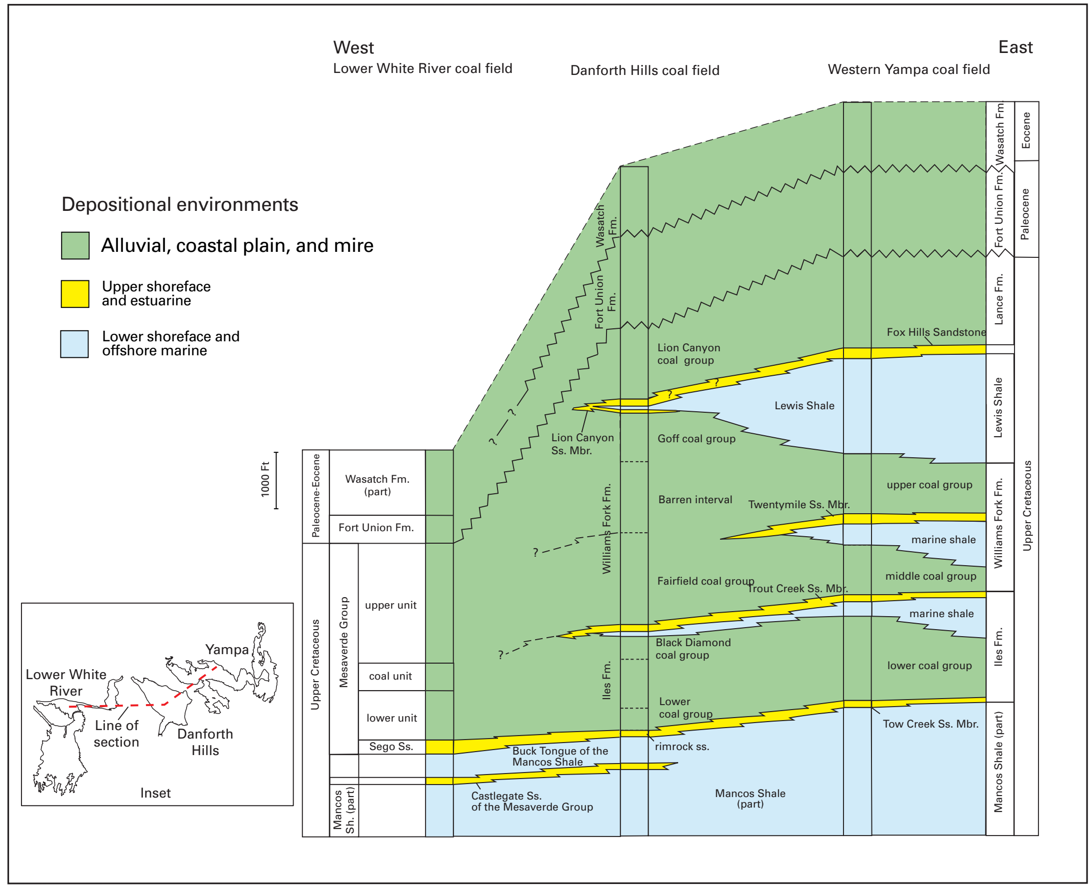

Figure 4. Stratigraphic correlations and facies relationships for part of the Upper Cretaceous and Tertiary rocks in the Lower White River, Danforth Hills, and Yampa coal fields, Colorado. Named sandstones are in yellow. After Brownfield and others (chap. N, this CD-ROM). Abbreviations include: Sandstone (Ss.), sandstone (ss.) Member (Mbr.), and Formation (Fm.).

All the coal-bearing units considered in this study are part of the Mesaverde Group of Late Cretaceous age. Within the Deserado coal area, the Mesaverde Group is approximately 5,000 ft (1,500 m) thick and is composed of a thick succession of mostly nonmarine rocks, which overlie approximately 5,100 ft (1,570 m) of marine mudrock in the Upper Cretaceous Mancos Shale. The Mesaverde Group has been divided into three informal formation-equivalent stratigraphic units (fig. 5) by the USGS (Barnum and Garrigues, 1980). These three units are designated the lower unit, coal unit, and upper unit. The lower unit is roughly equivalent to the Iles Formation in the Danforth Hills coal field about 60 mi to the east of the study area (fig. 4) and averages 690 ft (210 m) thick. The coal unit and upper unit, with a combined average thickness of 2,130 ft (650 m) are correlated to the Williams Fork Formation in the Danforth Hills (fig. 4).

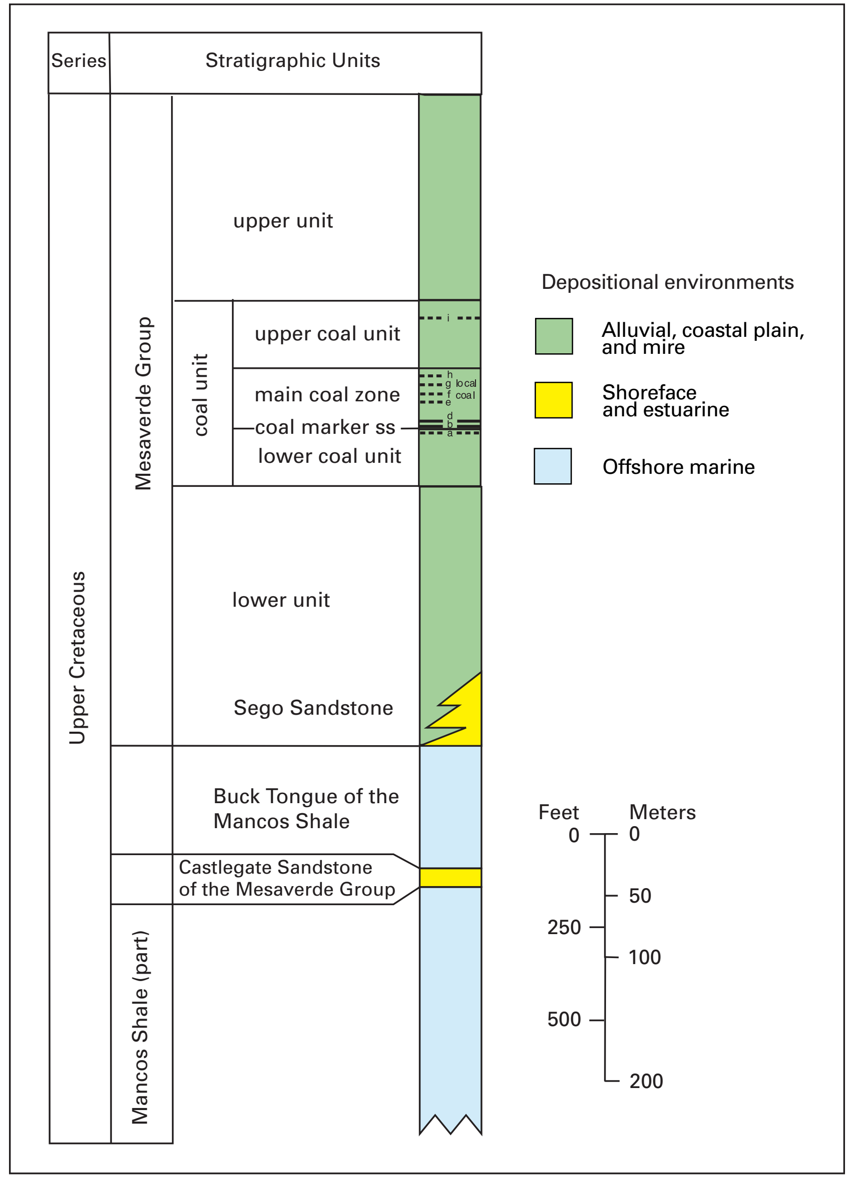

Figure 5. Generalized stratigraphic column for a portion of the Upper Cretaceous rocks for the Deserado coal area, Lower White River coal field, Colorado. Shown are the major divisions of the coal unit of the Mesaverde Group and the Western Fuels, Inc., coal-zone names. Coal beds and coal marker sandstones not drawn to scale. Named sandstones are shown in yellow. After Brownfield and others (chap. N, this CD-ROM).

Coal Geology of the Deserado Coal Area

The coal unit (fig. 6) of the Mesaverde Group in the Lower White River coal field ranges in thickness from 300 to 600 ft (90 to 180 m) and is divided into three informal subunits (B.E. Barnum, U.S. Bureau of Land Management, written commun., 1988). The subunits are, in ascending order, the lower coal unit, the main coal zone, and the upper coal unit. A group of persistent sandstones is located at the top of the lower unit (fig. 7). These sandstones were named the coal marker sands by Barnum and Garrigues (1980). Within the Deserado coal area the coal unit averages about 490 ft (150 m) thick.

In the Deserado coal area the coal unit of the Mesaverde Group has been subdivided into nine coal zones, eight of which are shown in figure 5. Western Fuels, Inc., has named these coal zones A, lower B, upper B (C), D, E, F, G, H, and I, in ascending order, within the Deserado Mine area (B.E. Barnum, U.S. Bureau of Land Management, written commun., 1988). Although nine coal zones have been recognized in the coal unit, most coal resources in the Deserado area are contained within two zones, the B (includes the lower B, upper B, and C) and the D (Brownfield and others, chap. N, this CD-ROM). Only the B and D coal zones were assessed for this study. The B and D occur in the lower part of the main coal zone just above the coal marker sands (fig. 5).

Figure 6. Looking north across the Rangely Reservoir at the Deserado coal area. Coal unit and coal marker sands of the Mesaverde Group in center of photo (see fig. 5). Photo by Bruce E. Barnum, Sage Discovery.

Figure 7. Coal marker sands of the coal unit of the Mesaverde Group in the Deserado coal area. The unit consists of well-sorted, fine-grained, planar-bedded, ripple-marked sandstone beds located at the top of the lower coal unit (see fig. 5). Photo by Bruce E. Barnum, Sage Discovery.

Coal Resources

The Deserado coal area contains an estimated original coal resource of about 440 million short tons (Brownfield and others, chap. N, this CD-ROM) with more than 80 percent of the total coal resource contained in the B and D coal zones (fig. 8). Coal resources were not calculated within the Deserado mine lease boundaries. Coal is presently mined by underground methods at the Deserado mine operated by Western Fuels, Inc. Coal from the Deserado mine is transported about 20 mi over a dedicated electric railroad to the Deseret Generation and Transmission power plant in northeastern Utah. Coal production averaged 1.44 million short tons per year from 1989 to 1994. In 1997 the Deserado mine produced 1.1 million short tons of coal, accounting for 5 percent of the total coal produced in northwest Colorado (Resource Data International, Inc., 1998). Within the Deserado coal area, the actual amount of coal that can be recovered will be less than the assessed resource because the two major zones are close together and contain partings and splits restricting underground mining.

Figure 8. The D coal zone of the main coal zone in the Deserado coal area. Photo by Bruce Barnum, Sage Discovery.

Danforth Hills Coal Field

Location

The Danforth Hills coal field (figs. 2 and 3) is situated in northwest Colorado in Moffat and Rio Blanco Counties within the Rocky Mountain Coal Province of Tully (1996). The coal field lies north of the White River in the northeastern part of the Piceance Basin. The western boundary of the coal field is northern extension of the Grand Hogback and the northern part of the coal field is bounded by the Axial Basin.

The northern part of the Danforth Hills coal field is characterized by north- and east-trending ridges that are separated by steep canyons. The southwestern part of the Danforth Hills is characterized by steeply dipping, long, narrow hogbacks. Elevations in the coal field range from 6,200 to 8,700 ft.

Figure 9. Contact between the Upper Cretaceous Iles Formation and the Mancos Shale along the northern part of the Danforth Hills coal field.

Stratigraphy of Cretaceous and Tertiary Strata

All of the coal-stratigraphic units exposed within the Danforth Hills coal field are of Cretaceous and Tertiary age (fig. 10). All the coal-bearing rocks considered in this study are included in the Upper Cretaceous Mesaverde Group. The lowest unit is the thick marine Mancos Shale of Upper Cretaceous age, which is overlain by the mostly nonmarine, coal-bearing Iles and Williams Fork Formations of the Mesaverde Group. The Mesaverde in this area generally consists of a thin to thick interbedded succession of shale, siltstone, and sandstone. Carbonaceous rocks are common, and thick beds of coal occur throughout the Mesaverde Group. The Mesaverde Group was deposited largely in a terrestrial environment, although regional relations indicate that this sedimentation was directly influenced by sea-level changes.

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Rocks of marine or marginal-marine origin do occur within the Mesaverde, most notably the Trout Creek Sandstone Member of the Iles Formation. This persistent marginal marine sandstone is one of the best stratigraphic markers in the area. It is directly overlain by the Fairfield coal group (Hancock and Eby, 1930), which contains the most extensive coal resources in the area.

The Williams Fork Formation rocks were deposited along the western margin of the late Campanian to Maastrichtian Western Interior Seaway (Roberts and Kirschbaum, 1995). The area was located in a very favorable position for coal deposition, at or near the margin of the sea, resulting in the stacking of several thousand feet of coal-bearing strata along the coastal plain. These coal-bearing rocks typically show a cyclic pattern of coal deposition, which is reflected in the coal zones assessed in this study. Sedimentary processes associated with near-shore and fluvial deposition in this area have influenced the geometry and distribution of these coal deposits.

Coal Geology

The coal-bearing intervals in the Iles and Williams Fork Formations of the Mesaverde Group in the Danforth Hills were stratigraphically subdivided into five coal groups by Hancock and Eby (1930). The Iles Formation was subdivided into two units, the lower and the Black Diamond coal groups (fig. 10). The Williams Fork was subdivided into three coal units and one barren interval in this study. The units are, in ascending order, the Fairfield coal group, the barren interval, and the Goff coal group, and the Lion Canyon coal group (fig. 10).

The Williams Fork Formation contains the thick and economically important coal beds in the Danforth Hills coal field. Data from drill hole geophysical logs and geologic maps indicates that the Williams Fork is about 3,000 to 3,500 ft thick.

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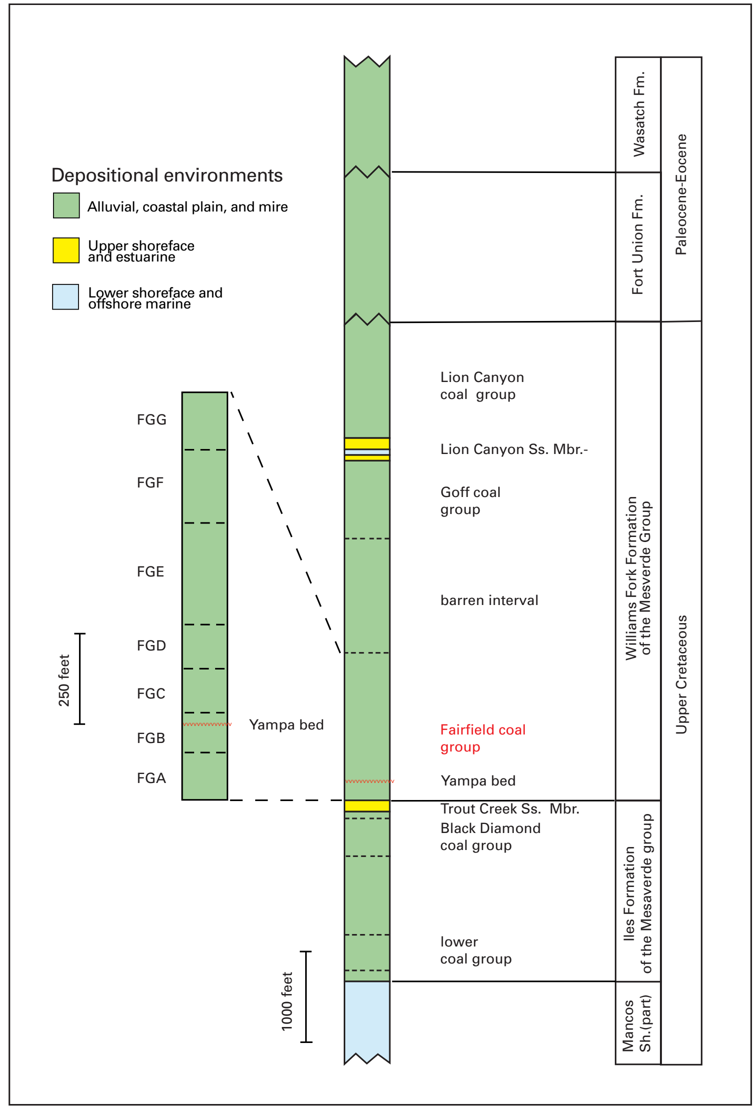

Figure 10. Generalized stratigraphic column showing depositional environments for a portion the Upper Cretaceous and Tertiary rocks in the Danforth Hills coal field, Colorado. Shown are the major divisions of the Fairfield coal group and the Yampa bed (a tonstein) of the Williams Fork Formation. Yampa bed not drawn to scale. Named sandstones are shown in yellow. After Brownfield and others (chap. M, this CD-ROM).

The Fairfield coal group is located at the base of the Williams Fork and has an average thickness of 1,300 ft (Hancock and Eby, 1930). In the lower part of the Fairfield coal group is a regionally persistent unit consisting of altered volcanic ash named the Yampa bed. The Yampa bed, introduced by Brownfield and Johnson (1986), is a regionally extensive tonstein (altered ash-fall tuff) in the lower part of the Williams Fork Formation (fig. 10). The Yampa bed was used to facilitate the correlation of coal beds in the Fairfield coal group throughout the Danforth Hills coal field. The Fairfield coal group is predominately terrestrial in origin and coals developed from peat that accumulated in a coastal-plain environment. The Goff coal group averages 700 ft thick and is separated from the Fairfield group by about 1,000 ft of rock containing little coal. The Lion Canyon coal group (Lance Formation equivalent in this study) of Hancock and Eby (1930) averages 1,000 ft thick and directly overlies the Lion Canyon Sandstone Member of the Williams Fork Formation (Fox Hills Sandstone?) in the southwestern and western part of the Danforth Hills coal field (figs. 4 and 10).

The Fairfield coal group (Hancock and Eby, 1930) contains many potentially economic coal beds in the Danforth Hills coal field (fig. 10) and was the only coal-bearing unit assessed in this study (Brownfield and others, chap. M, this CD-ROM). The Fairfield coal group was divided into seven coal zones, the FGA, FGB, FGC, FGD, FGE, FGF, and FGG (fig. 10). Coal resources were calculated on each of the seven coal zones (table 1). The Fairfield coal group contains at least 26 coal beds that have maximum thicknesses greater than 5 ft; 20 of these coal beds have thicknesses greater than 12 ft. The deeper drill holes, which penetrated most of the Fairfield coal group, consistently indicate a total net-coal thicknesses greater than 100 ft. The most significant deposits of this type occur in the FGB and FGE zones, each of which locally have net-coal bed thicknesses greater than 60 ft.

Table 1. Fairfield coal zones of the Williams Fork Formation showing thickness range, average thickness, number of coal beds, general net-coal thickness range, maximum net-coal thickness, and average stratigraphic distance above the Trout Creek Sandstone Member of the Iles Formation, Mesaverde Group, Danforth Hills coal field.

Fairfield coal zone	Thickness range (feet)	Average zone thickness (feet)	Average stratigraphic distance above Trout Creek Sandstone Member (feet)	Number of coal beds in zone	General net-coal thickness range (feet)	Maximum net-coal thickness (feet)
FGG	2.5-410	160	970	1 to 6	5-20	>30
FGF	3-310	210	760	1 to 7	10-40	>40
FGE	7.5-500	280	480	1 to 9	10-50	>60
FGD	3.5-248	120	360	1 to 4	10-20	>30
FGC	12-195	115	240	1 to 5	10-30	>40
FGB	6-230	110	130	1 to 5	20-30	>60
FGA	17-280	130	0	1 to 5	10-20	>30

Coal Resources

Hancock and Eby (1930) reported an estimated original coal resource on a coal-group basis of 10.6 billion short tons to a depth of 3,000 ft for the Meeker 15′ quadrangle which includes the southern two thirds of the assessment unit. Landis (1959) reported an estimated original coal resource on an individual bed basis of 7.9 billion short tons to a depth of 3,000 ft for the Danforth Hills coal field. Hornbaker and others (1976) reported an estimated original coal resource of 10.5 billion short tons to a depth of 6,000 ft for the Danforth Hills coal field.

This assessment study (Brownfield and others, chap. M, this CD-ROM) determined that the Fairfield coal group contains an estimated original coal resource of about 21 billion short tons in coal beds greater than 1.2 ft thick to a depth of 6,000 ft. About 90 percent of the coal resource (19 billion short tons) is under less than 3,000 ft of overburden. Coal production averaged 4.5 million short tons per year from 1989 to 1996 at the Colowyo mine (fig. 11). In 1997, the Colowyo mine produced 4.3 million short tons of coal, accounting for 18 percent of the total study area production (Resource Data International, 1998).

Figure 11. Colowyo coal mine in the northern part of the Danforth Hills coal field. The mine produces coal from FGF and FGG zones (as many as nine beds) in the Fairfield coal group by dragline and truck-and-shovel methods.

Yampa Coal Field

Location

The Yampa coal field, covering about 520 mi^2, is located in northwest Colorado and occupies parts of Routt and Moffat Counties and a very small part of Rio Blanco County (figs. 2 and 3). The Yampa coal field is bounded by the Park Range uplift to the east, the White River uplift to the south, and the Axial arch to the west. The coal field is also transversed by the west-flowing Yampa and Williams Fork Rivers. Elevations in the coal field range from about 6,000 ft above sea level near the town of Lay to just over 9,800 ft at the top of Pilot Knob in the northeastern part of the coal field. The coal field is characterized by rolling hills and northward-dipping slopes. Along the southern boundary of the coal field are rugged southwestward-facing cliffs deeply incised by gulches extending northward.

Figure 12. View of the Trout Creek Sandstone Member of the Iles Formation (thick sandstone just below red-baked rock unit) and the middle coal group (red-baked rock unit) in the Williams Fork Formation, Yampa coal field.

Figure 13. View of Trout Creek Sandtone Member of the Iles Formation. Middle coal group in the Williams Fork Formation is above the Trout Creek and the lower coal group of the Iles Formation is below the Trout Creek.

Mesaverde Group

In the Yampa coal field, the Mesaverde Group is divided into two formations (fig. 4), the Iles in the lower part and the Williams Fork in the upper part (Hancock, 1925). Included in the Iles is the Trout Creek Sandstone Member (figs. 12 and 13) at the top of the formation, and included in the Williams Fork is the Twentymile Sandstone Member in the middle of the formation. Both of these sandstones are regressive shoreface deposits, each is transitional with an underlying marine shale, and each is overlain by a thick unit of nonmarine rocks including fluvial sandstone, overbank sandstone and mudrock, and carbonaceous shale and coal (fig. 14). Earlier workers (Fenneman and Gale, 1906) defined coal in the Iles as the lower coal group, coal between the Trout Creek and the Twentymile as the middle coal group, and coal above the Twentymile as the upper coal group (fig. 4). The Mesaverde comprises an eastward thinning, wedge-shaped package of marine and nonmarine rocks that overlies and intertongues with the Upper Cretaceous Mancos Shale and underlies the Upper Cretaceous Lewis Shale. Toward the west, the Mesaverde becomes increasingly more nonmarine. In central Utah equivalent strata are composed almost exclusively of conglomerate of terrestrial origin.

Because most of the economic coal is contained in the Williams Fork, resources were calculated for only those coals in the middle and upper coal groups. Several large mines are currently extracting coal from these two groups, and future coal leasing and subsequent mining will undoubtedly be restricted to coal in these two groups.

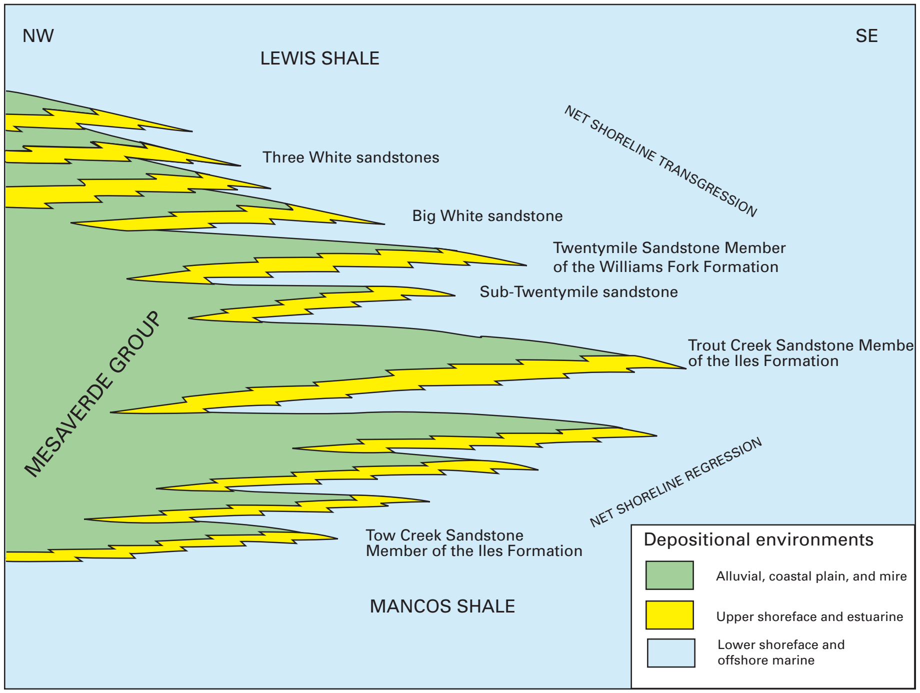

Figure 14. Generalized northwest-southeast cross section of the Mesaverde Group in the Yampa coal field showing depositional environments and the stratigraphic positions of major sandstone units. Modified after Johnson and others (chap. P, this CD-ROM).

Coal Geology

Both Cretaceous- and Tertiary-age coal occurs in the Yampa coal field. The Upper Cretaceous Lance Formation contains a minor amount of coal, and there is a significant amount in the Paleocene Fort Union Formation. However, there is currently no interest in extracting coal from either of these formations, and therefore they were not included in the assessment. Of the three coal groups in the Mesaverde, only the middle and upper groups of the Williams Fork Formation (fig. 4), were considered in this assessment (Johnson and others, chap. P, this CD-ROM). To better define the occurrence of coal, four coal zones and three barren intervals were established (fig. 15). The middle coal group contains the A coal zone (AZ), barren interval A (BIA), the B coal zone (BZ), and barren interval B (BIB), in ascending order. The upper coal group contains the C coal zone (CZ), barren interval C (BIC), and the D coal zone (DZ).

Within the A coal zone is a regional, altered, ash-fall tuff (tonstein) called the Yampa bed (Brownfield and Johnson, 1986). The unit is an important regional marker that is easily identified on drill hole geophysical logs and was used to facilitate correlation of coals in the Williams Fork Formation (fig. 15).

During deposition of the Williams Fork, the area that is now northwestern Colorado was at a latitude of about 42 degrees north (Roberts and Kirschbaum, 1995), and had a humid, subtropical climate. This, coupled with a high water table characteristic of a lower coastal plain depositional setting, was conducive to the development of a complex network of peat swamps.

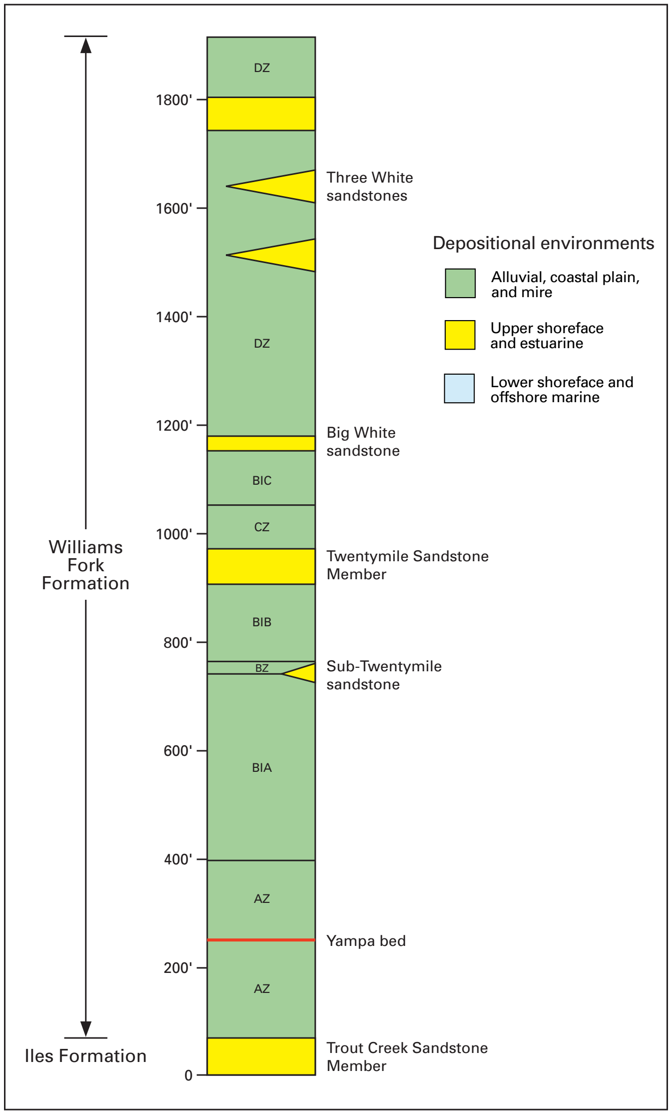

Figure 15. Stratigraphic column showing the middle and upper coal groups of the Williams Fork Formation, Yampa coal field. Modified after Johnson and others (chap. P, this CD-ROM). Yampa bed not drawn to scale.

Coal Resources

The Yampa coal field contains an estimated coal resource of about 76 billion short tons in beds equal to or greater than 1.2 ft (Johnson and others, chap. P, this CD-ROM). Although a significant amount of coal remains in the coal field, this figure must be regarded with caution. For example, of the 76 billion tons, about 52 percent is under more than 3,000 ft of overburden and thus with current technology is unavailable for underground mining. But even more significant, about 90 percent of the coal is under more than 500 ft of overburden, and is thus unavailable for surface mining. It is apparent that only a small percentage of the 76 billion tons of remaining coal resource could be recovered.

Figure 16. View of the Eagle # 5 longwall mine, middle coal group, Williams Fork Formation, Yampa coal field. The Eagle # 5 mine is temporarily closed.

Figure 17. Looking north from the Trapper strip mine at the Tri-State power plant. Cedar Mountain, to the left of the plant, consists of Oligocene and Miocene Browns Park Formation capped by basalt. To the north is the Sand Wash Basin.

Southern Piceance Basin

Location

The Southern Piceance Basin study area is located in west-central Colorado and includes areas south of lat 39°42'30"N. that are underlain by the Mesaverde Group or Mesaverde Formation within the Piceance and Uinta Basins (fig. 3). The eastern boundary of the study area is delineated by the Grand Hogback monocline (fig. 3). The southeasternmost part of the study area is delineated along the beveled edge of the Mesaverde Formation below Oligocene volcanics in the West Elk Mountains. The study area occupies about 4,140 mi^2 within parts of Delta, Garfield, Gunnison, Mesa, Pitkin, and Rio Blanco Counties (fig. 2). Transportation routes include Interstate 70, State and local highways, and the Denver and Rio Grande Western Railroad.

Figure 18. View of the Cameo coal zone (red baked strata) above the Rollins Sandstone Member of the Mount Garfield Formation of the Mesaverde Group, Layton Wash, southern Piceance Basin. Photo by Mark A. Kirschbaum, U.S. Geological Survey.

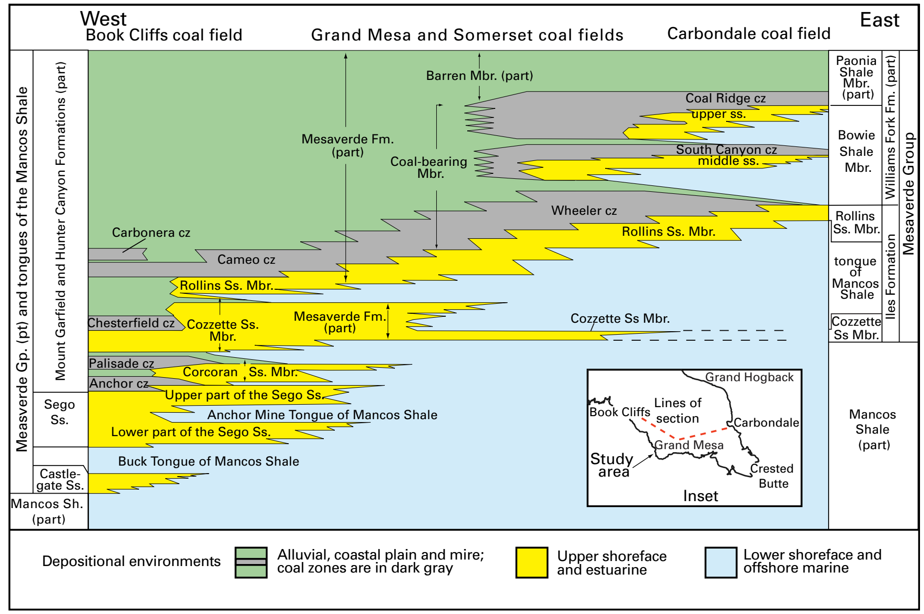

Figure 19. Stratigraphic correlations and facies relationships in the Mesaverde Group and Mesaverde Formation, southern Piceance Basin, Colorado. Abbreviations include: Sandstone (Ss.), sandstone (ss.), Member (Mbr.), coal zone (cz), Shale (Sh.), Group (Gp.), Formation (Fm.), and part (pt.). After Hettinger and others (chap. O, this CD-ROM).

Coal Geology

In the southern part of the Piceance Basin, the coal beds of the Mesaverde Group or Formation are contained in the Black Diamond and Cameo-Fairfield coal groups. Details regarding the stratigraphic position and nomenclature of coal zones in each coal group are provided in Hettinger and others (chap. O, this CD-ROM). The Black Diamond coal group underlies the Rollins Sandstone (fig. 19) and Trout Creek Sandstone Members of the Iles Formation (fig. 21) and contains the Anchor, Palisade, and Chesterfield coal zones. The Cameo-Fairfield coal group overlies the Rollins Sandstone and Trout Creek Sandstone Members and contains the Wheller, South Canyon, and Coal Ridge coal zones. It contains the most extensively

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Figure 20. View of the palisades on the western end of Grand Mesa overlooking the town of Palisade, Colo. Cameo coal zone (burn zone) above Rollins Sandstone Member of the Mount Garfield Formation. The Corcoran Sandstone is the white sandstone in the lower cliff. Photo by Mark A. Kirschbaum, U.S. Geological Survey.

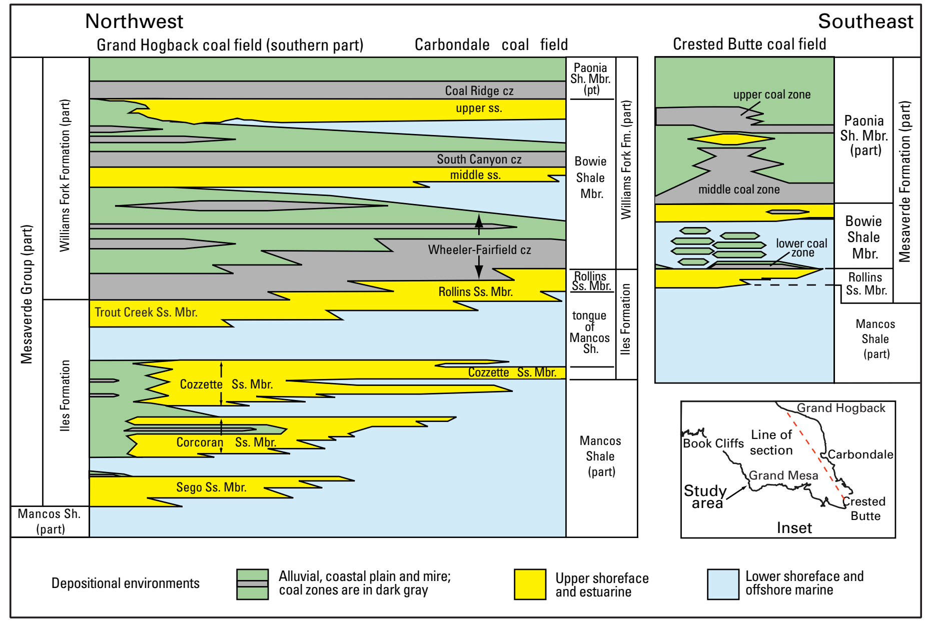

Figure 21. Stratigraphic correlations and facies relationships in the Mesaverde Group and Mesaverde Formation, southern part of the Piceance Basin, Colorado. Abbreviations include: Sandstone (Ss.), sandstone (ss.), Member (Mbr.), coal zone (cz), Shale (Sh.), Group (Gp.), Formation (Fm.), and part (pt.). After Hettinger and others (chap. O, this CD-ROM).

mined coals in the southern Piceance Basin and is also an important source for coal-bed gas (Johnson, 1989). The Cameo-Fairfield coal group is 4 to 1,400 ft thick and covers 4,140 mi^2 in the southern Piceance Basin. It contains the Cameo and Carbonera coal zones (Book Cliffs coal field), the Cameo (figs. 18, 20, and 22) coal zone (Grand Mesa coal field), the coal-bearing member (Somerset coal field), and the Wheeler-Fairfield, South Canyon, and Coal Ridge coal zones (Grand Hogback and Carbondale coal fields) (figs. 19 and 21). In the Crested Butte coal field, the Cameo-Fairfield coal group contains the informally named lower, middle, and upper coal zones (fig. 21).

Coal Resources

Original coal resources have been determined for each coal zone in the Cameo-Fairfield coal group in the southern Piceance Basin, and are reported by overburden, county, township, 7.5' quadrangle, and surface and coal ownership (Hettinger and others, chap. O, this CD-ROM). The Cameo-Fairfield coal group contains about 48 billion short tons of coal that are in beds greater than 1 ft thick and under less than 3,000 ft of overburden. The coal group also has about 72 billion tons of additional coal that are under 3,000 to 6,000 ft of overburden. Underground mining is the most likely method for extracting coal in this part of the Piceance Basin (Speltz, 1976), and historic production compiled by Eakins and Coates (1998) indicates that about 176 million tons of coal has been mined. Hettinger and others (chap. O, this CD-ROM) estimate that only 34 billion tons of coal in the Cameo-Fairfield group meet favorable underground mining criteria of depth less than 3,000 ft and bed thickness greater than 3 ft. In 1997, the southern Piceance Basin produced 32 percent of the total coal production in northwest Colorado or about 7.7 million short tons of coal (Resource Data International, 1998).

Figure 22. View of Cameo-Wheeler coal zone (red-baked rock) above the Rollins Sandstone Member of the Mount Garfield Formation of the Mesaverde Group near Hunter Canyon, southern Piceance Basin. Photo by Mark A. Kirschbaum, U.S. Geological Survey.

Coal-Bed Methane in Northwest Colorado

Piceance Basin

The Piceance Basin is producing coal-bed gas from five fields (fig. 23): the Grand Valley, Parachute, and South Shale Ridge fields in the Southern Piceance study area (fig. 24) and the White River Dome and Pinyon Ridge fields in the northern part of the Piceance Basin (Johnson and Flores, 1998). Gas content for coals in the Piceance Basin is as much as 604 cubic feet per short ton (Tremain, 1990; Reinecke and others, 1991). Scott and others (1996) estimated that the deepest part of the Piceance Basin has a gas-in-place coal-bed methane resource that exceeds 60 billion cubic feet of gas (BCFG) per square mile and that most of that resource is within the Cameo-Fairfield coal group.

The best production rates in the Piceance Basin thus far are from the White River Dome field a few miles southwest of the Danforth Hills coal field. Production rates have been gaged as high as 3,080 Mcf/d of gas and 96 barrels of water per day (Johnson and Flores, 1998). Through 1995, the White River Dome produced 3,656 MMcf of coal-bed gas (Tyler and others, 1995). The field has also produced 2,200 barrels of liquid hydrocarbons. White River Dome produces from the Fairfield coal group (Cameo-Fairfield coal zone in the southern Piceance Basin) of the Williams Fork Formation at depths ranging from about 5,400 to 6,400 ft. North of the White River dome the Pinyon Ridge field also produces gas (at depths greater than 1,300 ft) from the Williams Fork.

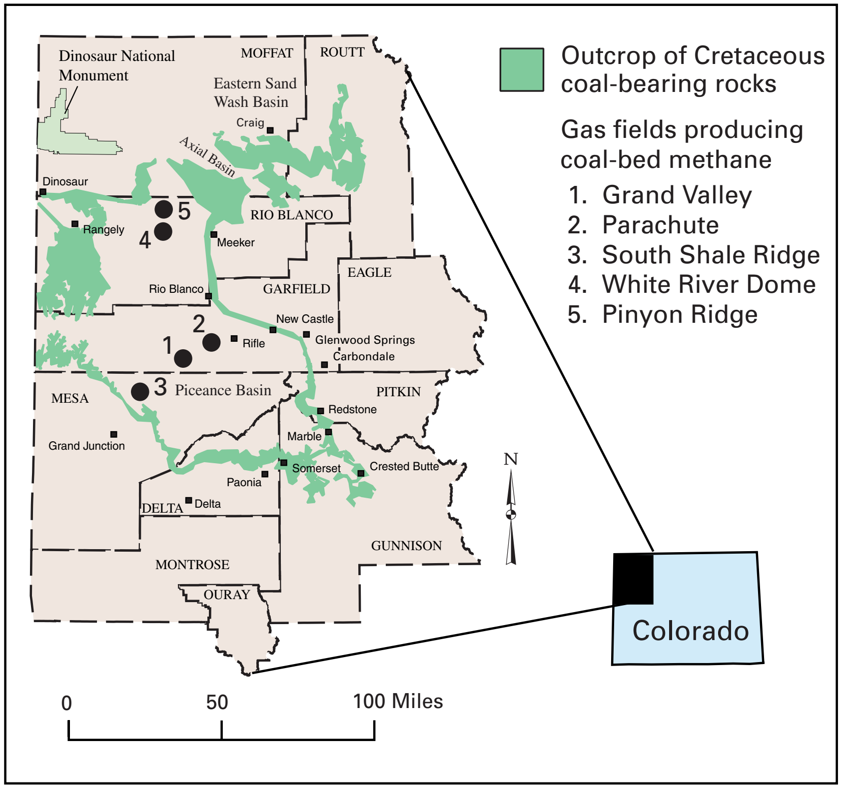

Figure 23. Gas fields producing coal-bed methane in northwest Colorado. Gas fields are approximately located.

Figure 24. Gas well in the southern Piceance Basin. Photo by Ronald Johnson, U.S. Geological Survey.

The coals within Deserado coal area contain methane and must be degassed as part of the mining process (George Ohera, Western Fuels, oral commun., 1998). The potential for commercial production of natural gas in the Piceance Basin remains largely unproven; through 1994, cumulative production of natural gas from coals approached 19 BCFG (Scott and others, 1996).

Sand Wash Basin

Extensive coal resources occur in the Upper Cretaceous Mesaverde Group and Lance Formation, and the lower Tertiary Fort Union Formation in the Sand Wash Basin of northwest Colorado. These coals are mainly subbituminous to high-volatile B bituminous (rank determined by vitrinite reflectance) and have average gas contents of less than 200 cubic feet per short ton. However, some coals have a gas content exceeding 540 cubic feet per short ton (Kaiser and others, 1993). Kaiser and others (1993) estimate that the coal-bed methane resources of the Sand Wash Basin are at least 101 Tcf and that 24 Tcf is estimated to be at depths of less than 6,000 ft. Cumulative gas production has been small, with 84 MMcf through 1992. The potential for commercial production of gas in the Sand Wash Basin is low because of the low gas content and largely unproven because of the large water volumes that are produced along with the gas (Kaiser and others, 1993).

Summary

The Lower White River, Danforth Hills, Yampa, and Southern Piceance Basin assessment units contain an estimated coal resource of about 217.4 billion short tons of coal to a depth of 6,000 ft. About 48 percent, or 104 billion short tons, of coal is under less that 3,000 ft of overburden. Although there is a significant amount of coal in northwest Colorado, this figure should be regarded with caution because it does not reflect economic, land-use, and environmental, technological, and geologic constraints that might limit coal availability and recoverability.

The future of coal mining appears bright. The industry will continue to support the local economy by providing jobs and by purchasing goods and services from local suppliers. However, over the next decade most of the coal produced will come from areas presently under lease and from coal mines already in existence. Coal mining will remain an important social and economic factor in northwest Colorado well into the 21st century.

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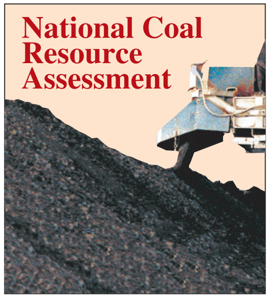

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