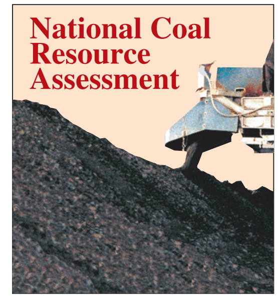
Chapter B

A Summary of the Coal Deposits in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah



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Chapter B *of*

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

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A Summary of the Coal Deposits in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah

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Introduction

This report provides an overview of the geologic setting, distribution, and quality of coal deposits of the Colorado Plateau. The Colorado Plateau contains more than 40 individual coal fields within the four-State region of Arizona, Colorado, New Mexico, and Utah (fig. 1). This chapter summarizes data for 47 coal fields of the Colorado Plateau and provides basic information on the location, general geology, coal resources and quality, and what we consider the most useful references for these areas. Each summary is essentially an annotated bibliography of the coal field. The coal fields can be accessed individually by scrolling through the text, by selecting from the bookmarks provided in Acrobat Reader 4.0 or higher, or by clicking on the appropriate heading in the chapter B table of contents. The summaries can also be accessed from the Colorado Plateau ArcView project, which resides on both disc 1 and disc 2 of this 2-CD-ROM set (the ArcView project on disc 1 may be queried by means of ArcView Data Publisher; the ArcView project on disc 2 provides for full functionality for users who own ArcView 3.1 or later versions).

Acknowledgments

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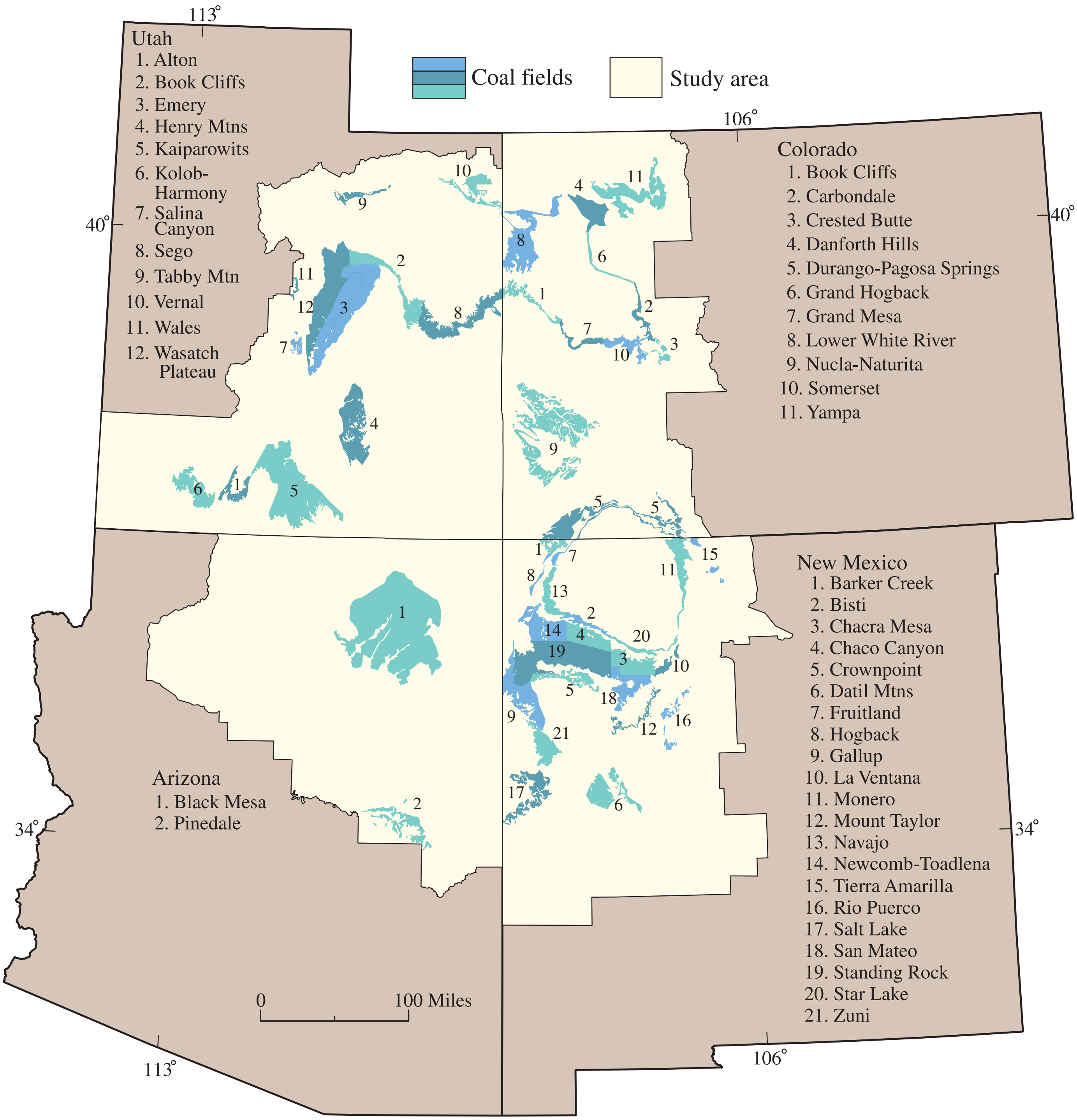

Figure 1. Map showing location of study area and selected coal fields within Arizona, Colorado, New Mexico, and Utah. Different colors are used for the coal fields to clearly delineate boundaries between the fields.

Coal-Field Summaries

Arizona

Black Mesa Coal Field

Location

Black Mesa is located in northeast Arizona within Apache, Coconino, and Navajo Counties and is entirely within the Navajo and Hopi Indian Reservations.

Stratigraphy

Early work on the stratigraphy was by Gregory (1917), and the preliminary coal geology work was by Campbell and Gregory (1911) and Repenning and Page (1956). Biostratigraphic relationships were studied by Peterson and Kirk (1977). The stratigraphic nomenclature and thickness of units are from Eaton and others (1987); depositional environments are from Eaton and others (1987) and Franczyk (1988).

Table. Stratigraphy—Black Mesa coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Yale Point Sandstone	nearshore marine	0-300
Wepo Formation	coastal plain; major coal	300-750
Rough Rock Sandstone	nearshore marine/tidal	0-60
Toreva Formation	nearshore marine; coastal plain, minor coal; fluvial	100-300
Mancos Shale	marine shale	600
Dakota Sandstone	fluvial; nearshore marine; minor coal	45-100

Coal Deposits

Coal is present in the Dakota, Toreva, and Wepo Formations. Extensive work on the coal deposits was completed by Williams (1951) as summarized in Peirce and others (1970). Carr (1991) studied the depositional environments of the Wepo coals. Eight coal zones are mined from the Wepo and are between 4 and 30 ft thick (Moore, 1977; Fellows, 1998).

Coal Quality

Most of the coal in all three formations is high-volatile bituminous C, although some samples in the Dakota are subbituminous C or, in higher ash samples, lignite (Peirce and others, 1970). Proximate/ultimate analyses were compiled by Peirce and others (1970, table 1, p. 20: analysis of 11 coals from the Dakota show ash contents between 10.0 and 30.74 percent, sulfur contents between 0.7 and 2.29 percent, and heating values between 5,119 and 10,550 Btu/lb; analysis of 7 coals from the Toreva show ash contents between 8.8 and 19.0 percent, sulfur contents between 0.9 and 1.3 percent, and heating values between 9,807 and 11,200 Btu/lb; analysis of 11 coals in the Wepo show an ash content between 3.4 and 8.7 percent, sulfur contents between 0.4 and 0.9 percent, and heating values of between 10,450 and 12,060 Btu/lb). The table below is compiled from seven analyses from Wepo coals collected at the Kayenta and Black Mesa mines (Moore, 1977).

Table. Coal in Wepo Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
4.7-9.1	0.3-0.5	9,490-11,560

Resources

Original resource estimates for the Dakota, Toreva, and Wepo are 9.6, 6, and 5.65 billion short tons, respectively (Peirce and others, 1970, p. 27). All estimates are from beds greater than 1 ft thick and down to a maximum depth of 1,700 ft of overburden (this minimum thickness is assumed from discussion in Peirce and others, 1970, p. 26–34). Strippable coal in the Wepo equals about 800 million short tons in areas with less than 130 ft of overburden (Peirce and others, 1970).

Production History

Ten small underground mines have produced about 300,000 short tons of coal since the early 1900's (Pierce and others, 1970). The Kayenta and Black Mesa surface mines have been active since the early 1970's and produced about 12 million short tons of coal in 1995.

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Pinedale Coal Field

Location

The small Pinedale coal field is located in the southern part of Navajo and Apache Counties, Arizona. (Only the Navajo County part of the coal field is shown on figure 1).

Stratigraphy

The first and probably only detailed study of the coal was by Veatch (1911). He placed the coal within the Cretaceous System. The ages of these rocks were further documented by Kirkland (1982), who also provides thickness data.

Table. Stratigraphy—Pinedale coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Tertiary rocks Undifferentiated Cretaceous rocks Triassic rocks	alluvial to marine	200+

Coal Deposits

The field contains two coal beds separated by about 15 ft of non-coaly rock. The lower bed is generally only 2–3 ft thick, and the upper bed is as much as 12 ft thick but contains at least 50 percent non-coal material (Veatch, 1911).

Coal Quality

The rank of the coal is assumed to be subbituminous by Averitt and O'Sullivan (1969). The chemistry data is from three analyses by Cooper and others (1947); samples are from the Merwin coal prospect.

Table. Coal in undifferentiated Cretaceous rocks.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
16.6-41.1	2.2-3.3	7,100-10,430

Resources

Averitt and O'Sullivan (1969) made a provisional estimate of 25 million short tons of coal in the field based on the data of Veatch (1911).

Production History

The Merwin prospect was opened to obtain coal-thickness and quality information in the early 1900's (Veatch, 1911), and there is no known production from the field.

References

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Colorado

Book Cliffs Coal Field

Location

The Book Cliffs coal field is located in Mesa and Garfield Counties in western Colorado, north of the towns of Fruita and Grand Junction. The coal field is located on the southwestern margin of the Piceance Basin. The field is bounded on the west by the Utah/Colorado State line, on the east by the Colorado River, and on the south by the limit of outcrop.

Stratigraphy

A reconnaissance study of the coal in this field was conducted by Richardson (1909). The first detailed mapping of the geology and coal deposits was by Erdmann (1934). Other stratigraphic studies of the coal interval have been conducted by Fisher and others (1960), Gill and Hail (1975), and Kirschbaum and Hettinger (1998). Thickness information is from Fisher and others (1960).

Table. Stratigraphy—Book Cliffs coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Hunter Canyon Formation	alluvial plain	375-1,400
Mount Garfield Formation	nearshore marine/coastal plain; major coal	970-1,070
Sego Sandstone	nearshore marine/tidal	0-110
Mancos Shale	marine	3,800

Coal Deposits

The main coal zones are the Anchor Mine, Palisade, Cameo, and Carbonera of the Mount Garfield Formation. Presently, the most important beds for mining are in the Cameo/Carbonera zone. The Cameo/Carbonera zone is generally poorly exposed due to extensive burning of the beds on outcrop. Where the coals are exposed, individual beds of the Cameo are as thick as 23 ft (Erdmann, 1934). The coal contains abundant methane gas, which has been a problem for the mines in the area since the early 1900's (Murray and others, 1977).

Coal Quality

The table below includes data from the Anchor Mine, Palisade, Carbonera, Cameo, and Thomas coal zones in the Mount Garfield Formation. The information was compiled by Hettinger and others (chap. O, this CD-ROM) based on data in Hornbaker and others (1976), Murray and others (1977), Tremain and others (1996), and R.H. Affolter (written commun., 1998).

Table. Coal in Mount Garfield Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
4.9-23.3	0.4-1.7	9,833-13,560

Resources

Landis (1959) estimated about 2.3 billion short tons of bituminous coal as an original resource down to a depth of 3,000 ft in an area of 255 mi^2. He included all coals greater than 14 inches thick in the measured, indicated, and inferred categories. This estimate was obtained from Richardson (1907, 1909) and Erdmann (1934), who derived their coal-thickness data from outcrops and mines. Hornbaker and others (1976) estimated another 1.3 billion tons from an additional 145 mi^2 of the field with 3,000 ft of overburden and estimated 3.6 billion short tons in areas with 3,000–6,000 ft of overburden for a total of 7.2 billion short tons of coal for the field.

Production History

Numerous mines have operated in the Book Cliffs coal field since 1888, producing from the Anchor Mine, Palisade, Carbonera, and Cameo coal beds (Erdmann, 1934; Murray and others, 1977). Currently, only the north portal of the Roadside mine is operating in the Book Cliffs field (south portal of the Roadside mine is discussed under the Grand Mesa coal field). The north portal has been producing coal since 1994, and production averages about 300,000 short tons of coal per year. The coal is transported to a unit train loadout on-site and provides coal for its mine-mouth power plant.

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Carbondale Coal Field

Location

The field is located on the eastern side of the Piceance Basin within Garfield, Gunnison, and Pitkin Counties. The field stretches from Redstone, Colo., northward for about 25 mi to near the town of Carbondale. The Coal Basin area in the south part of the field is an eroded anticline formed by the intrusion of a small laccolith (Collins, 1977).

Stratigraphy

The coal-bearing rocks are within the Iles and Williams Fork Formations of the Mesaverde Group. Thickness of the units is from Collins (1977), measured in the Coal Basin area.

Table. Stratigraphy—Carbondale coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Williams Fork Formation		
undifferentiated	alluvial plain	2,350
Paonia Shale Member	alluvial plain; major coal	500
Bowie Shale Member	marine-coastal plain; major coal	475-605
Iles Formation		
Rollins Sandstone Member	nearshore marine	84-145
Tongue of Mancos Shale	marine	800-1,000
Cozzette Sandstone Member	nearshore marine	40-45
Mancos Shale	marine	4,000+

Coal Deposits

The coals are present in three zones in the Williams Fork Formation, all located above major nearshore marine sandstones and each of which are separated by 100–200 ft of section (Collins, 1977). In ascending order, the coal zones are the Wheeler, South Canyon, and Coal Ridge, and individual coal beds within the zones are as much as 25 ft thick (Hettinger and others, chap. O, this CD-ROM).

Coal Quality

In the northern part of the field, the coals are high-volatile B bituminous and non-coking, whereas in the southern part of the field, the coals are metamorphosed by igneous intrusions to high-volatile A bituminous, medium-volatile bituminous, and locally to semianthracite and anthracite and strongly coking (Hornbaker and others, 1976). The coal contains high methane levels, ranging from 1,000–4000 cubic ft gas per ton (Murray and others, 1977). The following table is from Hettinger and others (chap. O, this CD-ROM), summarizing data from Hornbaker and others (1976) and Murray and others (1977).

Table. Coal in Williams Fork Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
1.9-16.2	0.3-2.1	10,160-15,190

Resources

Original in-place resources for coal with as much as 6,000 ft of overburden were estimated to be 5.2 billion short tons for the field (Hornbaker and others, 1976).

Production History

At least 13 major coal mines have operated in the Carbondale field from 1888 to 1990 (Murray and others, 1977).

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Crested Butte Coal Field

Location

This coal field is located at the southeastern edge of the Piceance Basin in Gunnison County, Colorado. The field, which comprises the Ohio Creek and Crested Butte coal districts, lies east of Grand Mesa and the West Elk Mountains along the Ohio Creek and Slate River valleys.

Stratigraphy

The coal-bearing unit is the Mesaverde Formation. The area and the coals have been structurally disrupted by numerous igneous intrusions, which have caused extensive folding and faulting (Lee, 1912; Gaskill and others, 1986).

Table. Stratigraphy—Crested Butte coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mesaverde Formation	nearshore marine; coastal plain; major coal	1600-1700
Mancos Shale	marine	3,600

Coal Deposits

The coals are poorly exposed on outcrops that are between about 9,000 and 11,500 ft above sea level (Lee, 1912). There are as many as four major coal beds as thick as 25 ft and numerous thin beds (Gaskill and others, 1986). Beds are named 1, 2 (Kubler), 3, 4, 5, and 6 in the Crested Butte district and A–B in the Ohio Creek district.

Coal Quality

The coal is reported as high volatile bituminous C through anthracite and is of coking quality (Gaskill and others, 1986). The following table is from Hettinger and others (chap. O, this CD-ROM) summarizing data from Hornbaker and others (1976) and Murray and others (1977).

Table. Coal in Mesaverde Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
3.2-9.1	0.4-1.9	11,080-14,440

Resources

Hornbaker and others (1976) reported about 1.5 billion short tons of coal from beds with less than 6,000 ft of overburden in an area of about 240 mi^2.

Production History

Historically, 11 major mines and numerous smaller mines operated in the Crested Butte coal field from 1881 into the late 1970's (Gaskill and others, 1986; Murray and others, 1977). Most of the coal produced from the area was of coking grade. Cumulative production from the Crested Butte #1 and #2 mines was more than 10 million short tons of coking coal from 1883 until 1952. Most was mined from the number 2 (Kubler) and number 3 beds (Hornbaker and others, 1976).

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Danforth Hills Coal Field

Location

The Danforth Hills coal field is located within Rio Blanco and Moffat Counties in northwestern Colorado.

Stratigraphy

The first major mapping of the geology with detailed descriptions of the coal was by Gale (1910). More detailed mapping and measurements of the coal deposits were completed by Hancock (1925) and by Hancock and Eby (1930). Thicknesses of units are from Hancock and Eby (1930).

Table. Stratigraphy—Danforth Hills coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mesaverde Group	nearshore marine; coastal plain	
Williams Fork Formation	major coal	4,500-5,000
Iles Formation	minor coal	1,350-1,600
Mancos Shale	marine	5,000

Coal Deposits

The Black Diamond coal group of the Iles Formation contains coal as thick as 14 ft (Hancock and Eby, 1930). The Williams Fork contains three major coal zones (groups). In ascending order, these are the Fairfield coal group (as thick as 29 ft with a parting), and the Goff and Lion Canyon coal groups (each generally less than 10 ft thick, but as thick as 18 ft) (Hancock and Eby, 1930). The Fairfield is the most important coal group and contains seven coal zones. The Fairfield coal group contains at least 26 coal beds greater than 5 ft thick; 20 of these coal beds have a maximum thickness greater than 12 ft (Brownfield and others, chap. M, this CD-ROM).

Coal Quality

The coals are mainly high-volatile B and C bituminous; average ash contents are 3.7–10.0 percent in the Iles and 2.2–9.6 percent in the Williams Fork; average sulfur contents are 0.4–0.6 percent in the Iles and 0.3–1.4 percent in the Williams Fork (Murray, 1981). Brownfield and others (chap. M, this CD-ROM) contains a detailed discussion of the quality of the Fairfield coal group coals.

Resources

Hancock and Eby (1930) reported an estimated original coal resource on a coal-group basis of 10.6 billion short tons in areas with less than 3,000 ft of overburden for the Meeker quadrangle. Landis (1959) reported an estimated original coal resource on an individual-bed basis of 7.9 billion short tons in areas under less than 3,000 ft of overburden for the Danforth Hills coal field. Hornbaker and others (1976) reported an estimated original coal resource of 10.5 billion short tons in areas under less than 6,000 ft of overburden for the Danforth Hills coal field.

The Fairfield coal group of the Williams Fork Formation (Hancock and Eby, 1930) contains many potentially economic coal beds in the Danforth Hills coal field and was the only unit newly assessed during the present study (see Brownfield and others, chap. M, this CD-ROM). The Fairfield coal group contains an estimated original coal resource of about 21 billion short tons in the identified and hypothetical resource categories.

Production History

Coal is currently mined by surface methods in the Danforth Hills coal field at the Colowyo mine, operated by Kennecott Corporation. Coal production averaged about 4.5 million short tons per year from 1991 to 1995 from the upper part of the Fairfield coal group (G. Sullivan, written commun., 1997—compiled from Mine Safety and Health Administration data).

References

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Durango–Pagosa Springs Coal Field

Location

The field is located in Archuleta, La Plata, and Montezuma Counties in southwestern Colorado. The field is located on the northern edge of the San Juan Basin (Murray, 1980). Part of the field is within the Southern Ute Indian Reservation (Sandberg, 1990).

Stratigraphy

The geology of the coal deposits was mapped in detail in three separate studies: Zapp (1949) completed the western part of the area (Durango field), Barnes (1953) completed the central part of the area (Los Pinos River field), and Wood and others (1948) completed the geology of the eastern part of the area. Thicknesses of units are from Zapp (1949) and Wood and others (1948); the coal-bearing Fruitland and Menefee Formations thin toward the eastern part of the area.

Table. Stratigraphy—Durango-Pagosa Springs coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Fruitland Formation	coastal plain; major coal	0-310
Pictured Cliffs Sandstone	nearshore marine	0-220
Lewis Shale	marine	1,830-2,400
Cliff House Sandstone	nearshore marine	maximum 320
Menefee Formation	coastal plain; major coal	maximum 200
Point Lookout Sandstone	nearshore marine	maximum 400
Mancos Shale	marine	1,890-2,370
Dakota Sandstone	alluvial/coastal plain; minor coal	160-270

Coal Deposits

Coal is present in the Dakota Sandstone and the Menefee and Fruitland Formations. In the Dakota, an individual coal bed reaches a maximum thickness of 8 ft (Shomaker and Holt, 1973). In the Menefee, there are as many as nine coal zones (Tremain and others, 1996) that are as thick as 9 ft (Zapp, 1949). In the Fruitland, there are numerous beds, and the maximum composite thickness is thought to be as much as 40 ft of coal in an 80-ft-thick zone (Zapp, 1949).

Coal Quality

The Menefee coals are high volatile A and B bituminous and the Fruitland coals are high volatile B and C bituminous (Murray, 1980). The ash, sulfur, and heating contents in the following tables are from (Murray, 1981).

Table. Coal in Fruitland Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
19.5-26.6	0.7-0.8	11,230-12,140

Table. Coal in Menefee Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
3.4-16.6	0.6-1.3	10,860-14,700

Resources

For the Ute Mountain Ute and Southern Ute Indian Reservations (both Tribal and non-Tribal ownership), Shomaker and Holt (1973) estimated total coal resources in all overburden categories: 12 billion short tons of coal in the Dakota Sandstone; 16 billion short tons in the Menefee; and 35 billion short tons in the Fruitland. Sandberg (1990) estimated 16 billion short tons for the Fruitland in the Southern Ute Reservation alone. Within the rest of the Durango field north of the reservations, Zapp (1949) estimated 13 billion short tons in the Menefee, of which about 3 billion short tons are in beds greater than 14 inches thick and under less than 3,000 ft of overburden. No reliable estimates were found for the eastern part of the area near Pagosa Springs, but the coals are generally thinner and the dips of strata are steeper than in the western part of the area (Shomaker, 1971).

Production History

As of 1981, 9.5 million short tons of coal have been produced from the combined area (called San Juan River region in some reports) from about 200 mines (Murray, 1981).

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Grand Hogback Coal Field

Location

The Grand Hogback coal field is located on the east side of the Piceance Basin in Garfield and Rio Blanco County, Colorado. The field extends along the Grand Hogback monocline from Meeker to Glenwood Springs, Colo. The monocline dips steeply to the west, ranging from about 40° to almost vertical.

Stratigraphy

The best synopsis of the stratigraphy and coal geology of the area is by Collins (1976).

Table. Stratigraphy—Grand Hogback coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Williams Fork Formation	nearshore marine/coastal plain: major coal	3,600-5,155
Iles Formation	nearshore marine/coastal plain: minor coal	915-1,060

Coal Deposits

Most of the coal mined from the area came from the Fairfield (Middle) coal group of the Williams Fork Formation. As many as nine individual coal beds are present within a stratigraphic interval of about 470 ft (Collins, 1976, p. 26, Rifle Gap section). Beds are identified, in ascending order: A, B, C, D, Allen, Anderson, Wheeler, E, and F (Hornbaker and others, 1976). The Wheeler coal bed is the thickest (as thick as 50 ft) near New Castle, Colo. (Collins, 1976). Coal is also present in the South Canyon coal group in the upper part of the Williams Fork Formation.

Coal Quality

The following table is from a compilation by Hettinger and others (chap. O, this CD-ROM) summarizing data from Hornbaker and others (1976), Murray and others (1977), and Tremain and others (1996).

Table. Coal in Williams Fork Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
3.1-11.3	0.3-0.9	11,020-13,270

Resources

Total original resources to a depth of 6,000 ft of overburden were estimated by Hornbaker and others (1976) at 3.1 billion short tons.

Production History

At least nine major mines operated in the area from 1888 to 1968, producing mainly from the Wheeler and Allen coal beds (Murray and others, 1977). In the 1990's, only the Eastside mine was operating in the coal field. As of 1994, the Eastside produced less than 4,000 short tons of coal.

References

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Grand Mesa Coal Field

Location

The Grand Mesa coal field extends from the Colorado River to Leroux Creek, located near the town of Cedaredge within Mesa and Delta Counties, Colorado. Numerous mines produced coal in the area just northwest of Cedaredge since the 1920's (Murray and others, 1977).

Stratigraphy

The stratigraphy of the field was first studied in detail by Lee (1912). Few studies have followed, probably because of the generally poor exposures of the coal. Approximate thicknesses of units in the following table are from Lee (1912).

Table. Stratigraphy—Grand Mesa coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mesaverde Formation		
undifferentiated	alluvial plain	1,500
Paonia Shale Member	coastal plain	400
Bowie Shale Member	coastal plain; major coal	400
Rollins Sandstone Member	nearshore marine	100
Mancos Shale	marine	3,000+

Coal Deposits

Coal is present in a zone within about 200 ft above the Rollins Sandstone Member of the Mesaverde Formation. The coals are named A through F in ascending order, and generally only a couple of the seams are of minable thickness at any one place (Hornbaker and others, 1976).

Coal Quality

The table below includes data from the Palisade and Cameo coal zones in the Mount Garfield Formation. The information was compiled by Hettinger and others (chap. O, this CD-ROM) and is based on data collected from Hornbaker and others (1976), Murray and others (1977), Tremain and others (1996), and R.H. Affolter (written commun., 1998).

Table. Coal in Mount Garfield Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
2.1-23.3	0.4-2.2	8,300-13,490

Resources

Hornbaker and others (1976) estimated about 8.6 billion short tons of coal resource in beds greater than 5 ft thick and having as much as 6,000 ft of overburden.

Production History

Presently, only the south portal of the Roadside mine, in the extreme northwestern part of the field, produces coal. Ten major mines operated from 1914 to 1972 around the town of Cedaredge, Colo. (Murray and others, 1977).

References

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Lower White River Coal Field

Location

The coal field is located in Moffat and Rio Blanco Counties and in a small portion of Garfield County in northwestern Colorado. The field is part of two basins: the northwestern margin of the Piceance Basin and the northeastern margin of the Uinta Basin.

Stratigraphy

The coal geology of the area was first studied in detail by Gale (1910). Subsequent detailed mapping of the coal at a scale of 1:24,000 was conducted in the late 1960's to early 1980's (e.g., Barnum and Garrigues, 1980) and part of the field (Deserado area) is summarized in Brownfield and others (chap. N, this CD-ROM). The following average thicknesses of units are from Barnum and Garrigues (1980).

Table. Stratigraphy—Lower White River coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mesaverde Group		
upper unit	alluvial plain	1,750
coal unit	coastal plain; major coal	100-180
lower unit	coastal plain	200

Coal Deposits

The coal unit of the Mesaverde Group contains as many as nine coal zones, named in ascending order as the A, B, upper B, D, E, F, G, H, and I beds. The two main zones in the Deserado mine area are the B and D—in this area the coals have a combined thickness as much as 14 ft in two benches (Brownfield and others, chap. N, this CD-ROM).

Coal Quality

The coals are high-volatile bituminous C in rank; ash contents range from 4.4 to 8.5 percent and sulfur contents range from 0.4 to 0.5 percent (Hornbaker and others, 1976). Information in the following table is from Brownfield and others (chap. N, this CD-ROM) and is based on 13 analyses.

Table. Coal in Mesaverde Group.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
4.1-23.9	0.4-1.1	7,240-11,720

Resources

About 7 billion short tons of coal was estimated to be originally present in about 550 mi^2 of the field in areas where the coal is under less than 1,000 ft of overburden (Landis, 1959). The two main zones in the Deserado area contain about 440 million short tons of identified coal resources in beds greater than 1.2 ft thick in areas where the maximum overburden is about 1,500 ft (Brownfield and others, chap. N, this CD-ROM).

Production History

There is one active mine in the area, the Deserado mine, a longwall operation that has produced an average of about 1.3 million short tons of coal per year between 1991 and 1995 (G. Sullivan, written commun., 1997—compiled from Mine Safety and Health Administration data).

References

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

Nucla-Naturita Coal Field

Location

This is a small coal field located in Montrose County in western Colorado. The coal-bearing formation also extends into Dolores, Mesa, Montezuma, Ouray, and San Miguel Counties in western Colorado (Jones and others, 1978; Eakins, 1986), but these coals are presently of little importance for exploitation because they are generally thin and discontinuous.

Stratigraphy

Coal is present in the Dakota Sandstone. Thickness of units is from Tremain and others (1996).

Table. Stratigraphy—Nucla-Naturita coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mancos Shale	marine	not recorded
Dakota Sandstone	coastal plain; minor coal	330
Burro Canyon Formation	alluvial plain	not recorded

Coal Deposits

In Montrose County, three minable coal beds 3–5 ft thick are present. In ascending order, they are the Drott, Oberding, and No. 3 coal zones (Murray, 1980). Haines (1978) describes a lower zone (No. 3) and an upper zone (No. 2); the lower zone is composed of two thin beds less than 2 ft thick each and the upper zone is as much as 6.3 ft thick.

Coal Quality

The following table of coal quality data is from Murray (1981).

Table. Coal in Dakota Sandstone.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
6.1-12.8	0.5-1.1	10,010-13,380

Resources

In the main part of the field, near the only presently active mine, a 15-mi^2 area was estimated to have an original resource of about 114 million short tons of coal (Landis, 1959).

Production History

One surface mine is active in the field, and produced 361,500 short tons of coal in 1996 (Resource Data International, 1998). All of the coal is provided to the nearby Nucla power plant located near the mine (Murray, 1981).

References

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Somerset Coal Field

Location

The Somerset coal field is located in Delta (Paonia area) and Gunnison (Somerset area) Counties in west-central Colorado, and lies in the valley of the North Fork of the Gunnison River and its tributaries.

Stratigraphy

The first comprehensive study of the stratigraphy and coal geology of the coal field was by Lee (1912). Thicknesses given below are from Dunrud (1989a, 1989b).

Table. Stratigraphy—Somerset coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mesaverde Formation		
Ohio Creek Member	alluvial plain	500-900
Barren member	alluvial plain	750-1,000
Paonia Shale and Bowie Shale Mbrs undivided	coastal plain; major coal	250-650
Rollins Sandstone Member	nearshore marine	80-200
Mancos Shale	marine	4,000-4,500

Coal Deposits

Coals from the Bowie Shale Member of the Mesaverde Formation are mined from beds whose individual thicknesses range between 8.5 and 18 ft; mined beds from the Paonia Shale Member of the Mesaverde Formation range in thickness from 12 to 13 ft (Hornbaker and others, 1976). Individual coal beds reach a maximum thickness of between 25 and 30 ft (Murray, 1980). A major longwall operation, the West Elk mine, is producing coal from the B seam and taking 12 ft out of a 23-ft bed (Fiscor, 1998). The main beds are named the A (Old King), B (Somerset), C (Bear), D (Oliver), and E, with historical production coming from all beds.

Coal Quality

The coals in the Somerset area are of good coking quality and are reported to be of marginal to premium high-volatile A and B bituminous (Goolsby and others, 1979). The table below includes data from the Coal Ridge, South Canyon, and Cameo-Wheeler coal zones of the Mesaverde Formation and was compiled by Hettinger and others (chap. O, this CD-ROM) based on data collected from Toenges and others (1949, 1952), Hornbaker and others (1976), Murray and others (1977), Tremain and others (1996), and R.H. Affolter (written commun., 1998).

Table. Coal in Mesaverde Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
2.4-29.9	0.3-3.2	8,160-14,380

Resources

About 8 billion short tons of coal are estimated for this field down to a depth of 6,000 ft (Hornbaker and others, 1976).

Production History

Historically, nine major mines operated between 1902 and 1974 in the Somerset coal field (Murray and others, 1977). Five mines (Bear, Hawks Nest, #2 and #3, Orchard Valley, and Somerset) were active as of 1977 (Murray, 1977). As of 1995, there were three active mines in the area (Bowie mine #1, Sanborn Creek, and West Elk), and together these mines produced about 6.5 million short tons of coal that year. The West Elk mine is a longwall operation in the B seam with a 12-ft high cut and a 950-ft-wide panel. It is one of five underground mines in the United States that produced more than 5 million short tons of coal in 1997 (Fiscor, 1998).

References

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Tongue Mesa Coal Field

Location

The field is located in parts of Gunnison, Montrose, and Ouray, Counties, in southwestern Colorado and is partly within the Uncompahgre National Forest. The following information is taken from Hettinger and others (in press).

Stratigraphy

The coal is present within an isolated remnant of Upper Cretaceous rocks in the northern San Juan Mountains. These strata were referred to as the Mesaverde Formation by Landis (1959). The geology of the field was mapped by Dickinson (1987a, 1987b, 1988) and he reassigned about 200 ft of coal-bearing strata to the Fruitland Formation. Landis (1959) described the area as being concealed by heavy vegetation, landslides, talus, and glacial deposits.

Table. Stratigraphy—Tongue Mesa coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Kirtland Shale	alluvial plain	1,000
Fruitland Formation	coastal plain; major coal	200
Pictured Cliffs Sandstone	nearshore marine	50-250

Coal Deposits

The Fruitland is exposed at a few localities and is buried to a depth of as much as 2,500 ft (Dickinson, 1987a, 1987b, 1988). The Fruitland contains one laterally extensive coal bed that ranges from about 20 to 40 ft in thickness, and the formation contains 3 to 5 additional coal beds that are about 5 to 13 ft thick. Dickinson states that the coal-bearing strata were drilled for Federal permits and leases but the data was not available to him.

Coal Quality

Coal in the Tongue Mesa coal field has an ash yield of 6.7 to 8.4 percent, a sulfur content of 0.5 to 0.9 percent, and a calorific value of 9,350 to 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).

Resources

Landis (1959) estimated that a 58-square-mile area of the Tongue Mesa field contained 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 based on drilling information.

Production History

Underground mining took place in the Tongue Mesa coal field between the 1890's and 1940's (Murray, 1981) and numerous small mines operated in the area (Dickinson, 1987a, 1988).

References

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Yampa Coal Field

Location

The field is located in parts of Moffat, Routt, and Rio Blanco Counties in northwestern Colorado. The field is located on the southern margin of the Sand Wash Basin, which is part of the Greater Green River Basin. The stratigraphy is closely related to rocks in the Piceance Basin.

Stratigraphy

The first major reconnaissance report on coal in the Yampa coal field was published by Fenneman and Gale (1906). They introduced the term Mesaverde to the area and named the coal groups in what would later become the Iles and Williams Fork Formations. The geology, stratigraphy, and coal geology were studied in detail by Campbell (1923), Hancock (1925), and Bass and others (1955). A bibliography of the geology of the area was completed by Johnson and Brownfield (1984). Thicknesses of units are from Bass and others (1955) from measurements taken on the eastern side of the coal field.

Table. Stratigraphy—Yampa coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Fort Union Formation	fluvial; coal	1,400
Lance Formation	fluvial; minor coal	800-1,250
Fox Hills Sandstone	nearshore marine	250
Lewis Shale	marine	1,500
Mesaverde Group	nearshore marine; coastal plain	
Williams Fork Formation	major coal	1,100-2,000
Iles Formation	minor coal	1,500
Mancos Shale	marine	4,900

Coal Deposits

Coal is present in the Cretaceous Iles, Williams Fork, and Lance Formations and in the Tertiary Fort Union Formation (Bass and others, 1955). The main coal groups were named the lower, middle, and upper by Fenneman and Gale (1906). The lower coal group is in the Iles, and the middle and upper coal groups are in the Williams Fork. The most economically important coal is restricted to the middle and upper groups. Thick beds are present in the Fort Union but are not currently being mined.

Upper Coal Group.—The upper coal group consists of about nine coal zones, in ascending order K–S, in a succession of strata from 200 to 850 ft thick (Bass and others, 1955; Johnson and others, chap. P, this CD-ROM).

Middle Coal Group.—In outcrops on the eastern side of the field, Bass and others (1955) defined three coal beds within the middle coal group; in ascending order, Wolf Creek, Wadge, and Lennox. On the western side of the field, subsurface studies indicate that there are more than six major zones named A through H within a succession of strata as thick as 1,000 ft (Johnson and Brownfield, 1988).

Coal Quality

Most coal beds in the lower and middle coal groups have apparent ranks of high-volatile bituminous C, and coals in the upper coal group are subbituminous A (Hornbaker and others, 1976). Coal in the Lance and Fort Union are thought to be subbituminous B and C (Murray, 1981). The following table gives averages for the Cretaceous coal-bearing units in the field from Murray (1981). Within the Williams Fork Formation, the middle coal group has ash contents that range from 3.0 to 20.2 percent and sulfur contents that range from 0.3 to 0.9 percent; the upper coal group has ash contents that range from 4.1 to 6.5 percent and sulfur contents that range from 0.5 to 0.7 percent.

Table. Coal in Lance Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
4.1-17.2	0.5-0.7	9,660-9,720

Table. Coal in Williams Fork Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
3.0-20.3	0.3-1.8	9,800-12,440

Table. Coal in Iles Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
4.3-11.3	0.3-0.9	11,090-12,560

Resources

Total original resources for all coal-bearing units, ranging in rank from subbituminous C to high-volatile bituminous B, in areas with less than 6,000 ft of overburden equal about 58 billion short tons (Hornbaker and others, 1976). Landis (1959) estimated about 24 billion short tons of coal for beds in areas under less than 3,000 ft of overburden.

Production History

More than 70 coal mines produced coal historically from the Yampa field (Hornbaker and others, 1976). Numerous small mines produced from the lower coal group of the Iles, mainly in the Oak Creek area (Bass and others, 1955). Mines have produced from surface and underground operations in the middle and upper coal group since the early 1900’s (Fenneman and Gale, 1906).

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New Mexico

Barker Creek Coal Field

Location

The Barker Creek field is located in San Juan County in northwestern New Mexico and extends from the Colorado/New Mexico State line to the line between T. 30 N. and T. 31 N. (Hoffman, 1996) where the dip of the strata steepens near the Hogback monocline.

Stratigraphy

The area was mapped and the stratigraphy and coal geology were studied by Hayes and Zapp (1955), who provided thickness data for the northern part of the area. All units thicken to the south.

Table. Stratigraphy—Barker Creek coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Cliff House Sandstone	nearshore marine	350
Menefee Formation		
upper	coastal plain; major coal	250
middle	alluvial plain	280
lower	coastal plain; major coal	100
Point Lookout Sandstone	nearshore marine	<350

Coal Deposits

Hayes and Zapp (1955) recognized lower and upper coal zones. Composite thicknesses are as much as 17.3 ft for the lower zone and as much as 19.2 ft for the upper zone as reported by Shomaker (1971).

Coal Quality

The apparent rank of these coals is high-volatile bituminous C. The average sulfur content is 0.9 percent, and the average ash content is about 7 percent (Hoffman, 1996).

Table. Coal in Menefee Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	7.03	0.9	11,497
Standard deviation	4.06	0	689
Number of analyses	3	1	3

Resources

Hoffman (1996) reported a demonstrated resource of about 20 million short tons for the lower zone and a resource of 48 million short tons for the upper coal zone (within 200 ft of the surface and greater than 2.33 ft thick). Hayes and Zapp (1955) provided a more detailed breakdown of the resource in the Menefee by township and range in categories greater than 1.2 ft thick to a depth of 3,000 ft of overburden.

Production History

The area had one mine and a few prospect pits in the years between 1882 and 1905 (Nickelson, 1988).

References

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Bisti Coal Field

Location

The Bisti field is located in San Juan County, northwestern New Mexico. The field extends from the boundary of the Navajo Indian Reservation on the west to the boundary between R. 8 W. and R. 9 W. on the east (Shomaker, 1971). The Bisti and De-Na-Zin Wilderness areas are located within the field.

Stratigraphy

The first detailed study of the stratigraphy and coal geology of the field was by Bauer and Reeside (1921). The thickest coals are in the Fruitland Formation. Thickness of the Pictured Cliffs Sandstone was measured at Meyers Creek and Escavada Wash; the Fruitland thickness is from the Meyers Creek area; and the Kirtland Shale thickness is from Escavada Wash (Bauer and Reeside, 1921).

Table. Stratigraphy—Bisti coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Kirtland Shale	alluvial plain	700
Fruitland Formation	coastal plain; major coal	196
Pictured Cliffs Sandstone	nearshore marine	70-91

Coal Deposits

There are three main beds (zones)—named lower, middle, and upper—in the lower 150 ft of the Fruitland in the Bisti area (Shomaker, 1971, fig. 50). Within a four-quadrangle (7.5′) area within the Bisti field, four recognizable coal zones are present. In ascending order, they are the red, green, blue, and yellow (Hoffman and Jones, 1998). These coals were first named by Conpaso for that company's Burnham mine area (G.K. Hoffman, New Mexico Bureau of Mines and Economic Geology, written commun., 1999). The thickest coals are 3.9 to 32.0 ft thick (Shomaker, 1971, based in part on Bauer and Reeside, 1921).

Coal Quality

The coal is subbituminous in rank, and is relatively high in ash (10.1–35.1 percent as-received) and low in sulfur content (0.3–0.8 percent as-received) (Shomaker, 1971, table 11). Average ash, sulfur, and heat contents in the following table are from Hoffman (1996).

Table. Coal in Fruitland Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	19.29	0.52	8,754
Standard deviation	5.42	0.09	883
Number of analyses	44	44	44

Resources

The Fruitland Formation in the Bisti area is estimated to contain about 1,870 million short tons of coal under less than 250 ft of overburden (Shomaker, 1971). A coal-availability study of a four-quadrangle area within the field demonstrates that there is about 5.1 billion shorts tons of coal present in four zones, and, of that amount, about 60 percent is available for mining consideration (Hoffman and Jones, 1998).

Production History

The field has had a number of leases and permits issued since 1961. Two mines, the De-Na-Zin and the Gateway have operated in the area but became inactive in 1988 (Hoffman, 1996). The De-Na-Zin mine had peak production of about 230,000 short tons of coal in 1982 (Nickelson, 1988).

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Chaco Canyon Coal Field

Location

The field is located in San Juan and McKinley Counties, New Mexico, in the southern part of the San Juan Basin. The southern edge of the field is defined by the limit of upper Menefee Formation coal outcrops, which are just below the overlying Cliff House Sandstone (Lease, 1971). The western boundary is the edge of the Navajo Indian Reservation coincident with the west edge of R. 13 W. The eastern boundary is shared by the Chacra Mesa coal field at the west edge of R. 8 W. The field has two subareas, from west to east: La Vida mission and Chaco Canyon (encompassing Chaco Culture National Historic Park).

Stratigraphy

The eastern part of the area was first mapped in detail by Dane (1936), and the Chaco Canyon area was later mapped in detail by Scott and others (1984). Subsurface mapping of the coal in the La Vida Mission area is shown by Lease (1971, fig. 21). The coals are in the upper coal member of the Menefee Formation, which changes facies into the La Ventana Tongue of the Cliff House Sandstone to the east. Coals are also present in the subsurface in the Cleary Coal Member of the Menefee (called Gibson Coal Member of the Mesaverde Formation by Dane, 1936). Thickness of the Cliff House Sandstone is from Dane (1936); thickness of the Menefee is from Scott and others (1984).

Table. Stratigraphy—Chaco Canyon coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Cliff House Sandstone	nearshore marine; coastal plain; minor coal	340+
Menefee Formation		1,500
upper coal member	coastal plain; coal	
Allison Member	alluvial plain	
Cleary Coal Member	coastal plain; coal	

Coal Deposits

Coals in the field are as thick as 6.5 ft in the Chaco and La Vida Mission areas (Lease, 1971). In the La Vida Mission subarea, a pod of coal greater than 6 ft thick extends across parts of four sections under less than 150 ft of overburden (Lease, 1971, fig. 21)

Coal Quality

The upper-member coals are subbituminous A in apparent rank (Hoffman, 1996). The following table is from Hoffman (1996).

Table. Coal in upper coal member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	7.88	1.63	10,210
Standard deviation	2.00	1.13	17
Number of analyses	4	4	4

Resources

The Chaco Canyon field contains about 16 million short tons of coal in beds greater than 2.5 ft thick and within 200 ft of the surface (Hoffman, 1996; also see Lease, 1971). The field also contains an additional 83 million short tons of underground resource; 51 million short tons in the upper coal member and 32 million short tons in the Cleary Coal Member (Hoffman, 1996).

Production History

The Chaco Canyon field contained two small mines that operated sometime between 1900 and the 1920's (Nickelson, 1988).

References

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Chacra Mesa Coal Field

Location

The field is located in McKinley and Sandoval Counties, New Mexico, in the southern part of the San Juan Basin. The southern edge of the field is defined by the limit of upper Menefee Formation coal outcrops, which are just below the overlying Cliff House Sandstone (Speer, 1971). The western boundary is the Chaco Canyon coal field. The eastern boundary is shared with the La Ventana field at R. 3 W.

Stratigraphy

The areas were first mapped in detail by Dane (1936). The coals are in the upper coal member of the Menefee Formation, which changes facies into the La Ventana Tongue of the Cliff House Sandstone to the east, and coals are present in the subsurface in the Cleary Coal Member of the Menefee (called upper part of the Gibson Coal Member of the Mesaverde Formation by Dane). Minor coals are present in the Cliff House (Speer, 1971). The thickness of the Cliff House Sandstone is from Dane (1936). The thicknesses of the Menefee units are from Tabet and Frost (1979).

Table. Stratigraphy—Chacra Mesa coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Cliff House Sandstone	nearshore marine; coastal plain; minor coal	360
Menefee Formation		
upper coal member	coastal plain; coal	650
Allison Member	alluvial plain	400-550
Cleary Coal Member	coastal plain; coal	200-300

Coal Deposits

The coals are as thick as 13.7 ft in the Chacra Mesa field, but they are generally less than 6 ft thick (Tabet and Frost, 1979). The maximum thickness observed on outcrop was 3.8 ft (Speer, 1971).

Coal Quality

The Cleary and upper-member coals are subbituminous A to high-volatile C bituminous in apparent rank. The following table is from Hoffman (1996) and is based on data collected in Roybal and others (1987, 1988).

Table. Coal in upper coal member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	9.69	0.72	10,207
Standard deviation	3.29	0.41	615
Number of analyses	14	14	14

Table. Coal in Cleary Coal Member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	11.05	0.45	10,898
Standard deviation	2.57	0.11	1,605
Number of analyses	2	2	2

Resources

The Chacra Mesa field contains an estimated 269 million short tons of demonstrated underground resources (Hoffman, 1996).

Production History

Four small mines operated in the field between 1933 and 1958 (Nickelson, 1988).

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Crownpoint Coal Field

Location

The Crownpoint coal field is located on the south side of the San Juan Basin in McKinley County, New Mexico. The Crownpoint field encompasses the outcrops of the Crevasse Canyon Formation from the northeastern edge of the Gallup field to the west edge of the San Mateo field.

Stratigraphy

The first comprehensive study of the coal geology and stratigraphy was by Sears (1934). The Gibson Coal Member of the Crevasse Canyon Formation was studied in the subsurface by Campbell and Roybal (1987) and Hoffman (1993). Thicknesses of units are from Sears (1934, text and plate 1).

Table. Stratigraphy—Crownpoint coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Crevasse Canyon Formation		
Gibson Coal Member	coastal plain; major coal	140-300
Bartlett Barren Member	alluvial plain	0-270
Dalton Sandstone Member	nearshore marine	180
Mancos Shale		
Mulatto Tongue	marine	0-220
Crevasse Canyon Formation		
Dilco Coal Member	coastal plain; coal	148-200
Gallup Sandstone	nearshore marine; coastal plain; coal	80-320

Coal Deposits

Numerous thin beds are present in the Dilco Coal Member of the Crevasse Canyon Formation and Gallup Sandstone (Sears, 1934). The thickest coals are in the Gibson Coal Member of the Crevasse Canyon Formation. Within the Gibson, coals are as thick as 12 ft on outcrop (Sears, 1934, plate 13). In the subsurface, the Gibson coals are in zones of 3 to 13 beds, and individual beds are as thick as 6 ft (Campbell and Roybal, 1987; Hoffman, 1993).

Coal Quality

The Gibson coals are subbituminous B–A and average about 12 percent ash and about 1.4 percent sulfur on an as-received basis (Hoffman, 1996). The table below is from Hoffman (1996).

Table. Coal in Gibson Coal Member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	11.95	1.44	10,037
Standard deviation	5.29	0.73	923
Number of analyses	13	13	13

Resources

The Gibson Coal Member contains about 663 million short tons of demonstrated resources in areas with less than 200 ft of overburden (Hoffman, 1996). The Gibson may contain as much as 15 million short tons of strippable coal (Shomaker, 1971).

Production History

Eleven mines or prospects operated in the coal field between 1918 and 1963 (Nickelson, 1988).

References

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Datil Mountains Coal Field

Location

The Datil Mountains coal field is located on the southeastern edge of the Colorado Plateau in Catron, Cibola, and Socorro Counties, New Mexico.

Stratigraphy

An early study of the coal geology was by D.E. Winchester of the USGS, but this work was never published according to Pike (1947). Winchester (1920) did place the coal into a stratigraphic context and called the coal-bearing unit the Chamiso Formation. The stratigraphy in current usage was worked out by Pike (1947) and modified by Maxwell (1976). Coal is present in the Dilco Coal Member of the Crevasse Canyon Formation (Frost and others, 1979).

Table. Stratigraphy—Datil Mountains coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mancos Shale (Mulatto Tongue)	marine	100
Crevasse Canyon Formation (part)		
Dilco Coal Member	coastal plain; coal	173
Gallup Sandstone	nearshore marine	27

Coal Deposits

Most coal beds are generally less than 3 ft thick (Hoffman, 1996) but can be as thick as 4.5 ft (Frost and others, 1979).

Coal Quality

The coal in this field has an average apparent rank of subbituminous A; average ash content is about 13 percent, and average sulfur is about 0.7 percent on an as-received basis (Hoffman, 1996).

Table. Coal in Dilco Coal Member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	12.84	0.72	11,465
Standard deviation	6.34	0.54	869
Number of analyses	10	10	10

Resources

About 47 million short tons of coal are estimated for the field by Hoffman (1996), who incorporated both new data and data collected by Frost and others (1979) and Osburn (1982).

Production History

Five small mines operated between about 1917 and 1940 (Frost and others, 1979).

References

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Fruitland Coal Field

Location

This coal field is located in San Juan County in northwestern New Mexico and encompasses the outcrops of the Fruitland Formation between the New Mexico–Colorado State line and the San Juan River. The field history is summarized by Beaumont (1971), Nickelson (1988), and Hoffman (1996).

Stratigraphy

The main coal deposits are in the Upper Cretaceous Fruitland Formation. Thicknesses of units are from Hayes and Zapp (1955) and Roberts (1991).

Table. Stratigraphy—Fruitland coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Kirtland Shale	alluvial plain	1,160
Fruitland Formation	coastal plain; major coal	240-380
Pictured Cliffs Sandstone	nearshore marine	235-380

Coal Deposits

Coal studies in the area include Bauer and Reeside (1921), Hayes and Zapp (1955), Shomaker and Holt (1973), and Roberts (1991). Important coal beds in the Fruitland include, in ascending order: the Main bed or lower split, Upper Main or upper split; Main bed or Carbonero bed, and the Ute Canyon or upper bed. The Main coal is located stratigraphically near the top of the underlying Pictured Cliffs Sandstone and ranges in thickness from about 14 ft, near the San Juan River, to about 30 ft thick at the La Plata mine (Nickelson, 1988).

Coal Quality

Coals of the Fruitland coal field are calculated to have an apparent rank of high-volatile C and B bituminous (see discussion by Beaumont, 1971, p. 107). Average analyses of the coal are summarized from Hoffman (1996).

Table. Coal in Fruitland Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	17.95	0.8	9,786
Standard deviation	5.69	0.3	1,954
Number of analyses	105	103	105

Resources

Demonstrated strippable coal resources within the field are about 550 million short tons (defined as thicker than 2.33 ft and beneath less than 200 ft of overburden) (Hoffman, 1996). Underground resources (200–1,000 ft of overburden) equal 861 million short tons (Hoffman, 1996). An estimated 100 million short tons of coal are distributed in three major beds in the Ute Mountain Ute Indian Reservation under less than 500 ft of overburden (Roberts, 1991).

Production History

Two mines presently operate within this coal field: the San Juan mine in the south part of the field and the La Plata mine in the north part of the field. These mines produce coal for the San Juan generating station. The La Plata mine produced an average of about 1.6 million short tons per year during a 5-year period between 1991 and 1995, and the San Juan mine produced an average of about 3.8 million short tons per year during the same period (G. Sullivan, written commun., 1997—compiled from Mine Safety and Health Administration data). The Ute Mountain Ute Tribal Nation owns coal that underlies an area of about 14.5 mi^2 between the two active mining operations. About 17 underground mines operated in the field between 1898–1972 (Nickelson, 1988).

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Gallup Coal Field

Location

This field is located in McKinley County, New Mexico within a southwestern extension of the San Juan Basin called the Gallup sag (Lease and Shomaker, 1971). The town of Gallup is located within the field. The Gallup sag is bounded on the northwest by the Defiance uplift, and on the southeast by the Nutria monocline. The coal field is arbitrarily bounded on the south by the line between T. 11 N. and T. 12 N.

Stratigraphy

The earliest substantial work on the coal and stratigraphy was by Sears (1925). Summaries of the coal field are provided by Lease and Shomaker (1971) and Hoffman (1996). A study of the relationship between the Gibson Coal Member of the Crevasse Canyon Formation and Cleary Coal Member of the Menefee Formation and interpretations of depositional environments is provided in Cavaroc and Flores (1984). Thicknesses of the Gibson Coal, Bartlett Barren, and Dilco Coal Members of the Crevasse Canyon and the Gallup Sandstone are from Sears (1925), based on his study of the Gallup and Zuni Basins. Thicknesses of the Point Lookout Sandstone and Cleary Coal Member are from Cavaroc and Flores (1984), and the thickness of the Dalton Sandstone Member of the Crevasse Canyon is from Sears and others (1941).

Table. Stratigraphy—Gallup coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Menefee Formation		
Cleary Coal Member	coastal plain; major coal	115
Point Lookout Sandstone	nearshore marine	0-65
Crevasse Canyon Formation		
Gibson Coal Member	coastal plain; major coal	150-175
Bartlett Barren Member	coastal and alluvial plain	330-400
Dalton Sandstone Member	nearshore marine	0-180
Dilco Coal Member	coastal plain; major coal	240-300
Gallup Sandstone	nearshore marine; minor coal	180-250

Coal Deposits

Thick coals are present in the Dilco and Gibson Members of the Crevasse Canyon Formation and Cleary Member of the Menefee Formation. The Black Diamond bed of Sears (1925, p. 28) is the most extensive in the Dilco Member. There are four other thick coal zones in the Dilco (Hoffman, 1996). The Gibson and Cleary (combined where the Point Lookout Sandstone is not present) contains four thick coal zones (Hoffman, 1996), and all of the coal produced from the McKinley mine is from these beds—in ascending order, the green, blue, fuchsia, and yellow beds (Wilson, 1977).

Coal Quality

The apparent rank of the coals in the Dilco, Gibson, and Cleary Members are between high-volatile C bituminous and subbituminous A. The coals in the Cleary and Gibson average about 9 percent ash and contain about 0.5 percent sulfur; the Dilco coals contain about 9 percent ash and about 0.8 percent sulfur (Hoffman, 1996).

Table. Coal in Cleary and Gibson Coal Members.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	9.32	0.53	10,507
Standard deviation	4.56	0.13	0.13
Number of analyses	35	35	35

Table. Coal in Dilco Coal Member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	9.08	0.76	10,343
Standard deviation	5.59	0.32	3,220
Number of analyses	14	14	13

Resources

Remaining demonstrated coal resources in the Cleary and Gibson to a depth of 200 ft equal 449 million short tons. Demonstrated coal resources in the Dilco under less than 200 ft of overburden equal 161 million short tons (Hoffman, 1996).

Production History

Coal was produced historically from more than 85 mines in the Gallup coal field from the Dilco, Gibson and Cleary Members and from the Gallup Sandstone (Nickelson, 1988). At present, only the McKinley mine produces significant amounts of coal from strip pits in the western part of the field. The McKinley mine is located about 20 mi northwest of Gallup and has produced an average of 5.8 million short tons of coal per year over the period between 1991–1995 (G. Sullivan, written commun., 1997—compiled from Mine Safety and Health Administration data).

References

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Nickelson, H.B., 1988, One hundred years of coal mining in the San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 111, 226 p.

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Sears, J.D., Hunt, C.B., and Hendricks, T.A., 1941, Transgressive and regressive Cretaceous deposits in southern San Juan Basin, New Mexico: U.S. Geological Survey Professional Paper 193-F, p. 101–121.

Wilson, J.C., 1977, The McKinley mine, *in* Fassett, J.E., ed., Guidebook of San Juan Basin III Northwestern New Mexico: New Mexico Geological Society 28th Field Conference, p. 253–255.

Hogback Coal Field

Location

The Hogback field is located in northwest New Mexico on the flank of the San Juan Basin in San Juan County. The field extends along the structure of the Hogback monocline from about T. 30 N. south to T. 26 N.

Stratigraphy

The coal geology of the northern part of the area was studied by Hayes and Zapp (1955), who provided thicknesses as measured at San Juan River exposures.

Table. Stratigraphy—Hogback coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Cliff House Sandstone	nearshore marine	750
Menefee Formation		1,000
upper	coastal plain; major coal	
middle	alluvial plain	
lower	coastal plain; major coal	
Point Lookout Sandstone	nearshore marine	350

Coal Deposits

Coal is in the lower and upper zones of the Menefee Formation. The lower zone is poorly developed in the area but has a maximum aggregate coal thickness of 11.3 ft, and the upper zone contains as many as 10 individual beds with total coal as thick as 38.2 ft (Lease, 1971).

Coal Quality

The average apparent rank of the coals in the Hogback field is high-volatile C bituminous; the average ash content is about 16 percent and the average sulfur content is about 0.7 percent on an as-received basis (Hoffman, 1996).

Table. Coal in Menefee Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	15.68	0.7	10,053
Standard deviation	11.08	0.2	1,533
Number of analyses	3	3	3

Resources

The field is estimated to have about 45 million short tons of coal in areas where the overburden is less than 200 ft; however, these resources may not be recoverable because of the steep dips of the strata (Lease, 1971; Hoffman, 1996).

Production History

The Hogback field was mined between 1907 and 1976. More than 17 separate mines operated in the area until 1976. The largest, Hogback No. 13, produced less than 100,000 short tons during its lifetime (Nickelson, 1988).

References

Hayes, P.T., and Zapp, A.D., 1955, Geology and fuel resources of the Upper Cretaceous rocks of the Barker dome–Fruitland area, San Juan County, New Mexico: U.S. Geological Survey Oil and Gas Investigations Map OM-144, scale 1:62,500.

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Nickelson, H.B., 1988, One hundred years of coal mining in the San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 111, 226 p.

La Ventana Coal Field

Location

This coal field is located in Sandoval County, New Mexico, on the southeastern edge of the San Juan Basin.

Stratigraphy

The first comprehensive study of the geology and the coal deposits of this coal field was by Dane (1936), and the complex intertonguing of the units was worked out by Beaumont and Hoffman (1992). The most up-to-date study of the area, concentrating on subsurface geology, is by Beaumont and Hoffman (1992), who show a maximum thickness of about 950 ft for the La Ventana. The thickness of the La Ventana Tongue given in the table below is based on Dane (1936, p.108). Thickness of the Menefee is also derived from Dane (1936), and is in good agreement with subsurface measurements reported by Beaumont and Hoffman (1992, fig. 4). The thickness of the Point Lookout is from a sandstone measured and referred to by Dane (1936, p.99) as the Hosta sandstone member of the Mesaverde Formation.

Table. Stratigraphy—La Ventana coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Cliff House Sandstone		
La Ventana Tongue	nearshore marine	650-1,256
Menefee Formation		667
upper coal member	coastal plain; coal	
Allison Barren Member	alluvial plain	
Cleary Coal Member	coastal plain; coal	
Point Lookout Sandstone	nearshore marine	84

Coal Deposits

Coal as thick as 8.5 ft is present mainly in the upper coal member of the Menefee Formation (Hoffman, 1993).

Coal Quality

The coals of the Cleary Coal Member of the Menefee Formation and the upper member are subbituminous in rank (Hoffman, 1996). Coals in the Cleary average about 11 percent ash and about 1 percent sulfur (as-received), and coals in the upper member average about 8 percent ash and about 1.4 percent sulfur (Hoffman, 1996).

Table. Coal in upper coal member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	8.14	1.36	10,171
Standard deviation	4.34	0.55	696
Number of analyses	20	20	20

Table. Coal in Cleary Coal Member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	11.06	1.01	10,400
Standard deviation	3.31	0.62	620
Number of analyses	28	20	27

Resources

The upper coal member has about 130 million short tons of demonstrated resources with about 75 million short tons having less than 200 ft of overburden (Hoffman, 1996).

Production History

About 36 mines were operating in the La Ventana field between 1884 and 1984 (Nickelson, 1988; Hoffman, 1996).

References

Beaumont, E.C., and Hoffman, G.K., 1992, Interrelationships between the upper coal member of the Menefee Formation, the La Ventana Tongue, and the Lewis Shale in the southeastern San Juan Basin, New Mexico, *in* Lucas, S.G., Kues, B.S., Williamson, T.E., and Hunt, A.P., eds., San Juan Basin IV: New Mexico Geological Society Guidebook, 43rd Field Conference, p. 207–216.

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Hoffman, G.K., 1993, Description of coal-bearing sequences, *in* Hoffman, G.K., Campbell, F.W., and Beaumont, E.C., eds., Quality Assessment of Strippable Coals in Northwestern New Mexico: Fruitland, Menefee, and Crevasse Canyon Formation Coals in the San Juan Basin, and Moreno Hill Formation Coals in Salt Lake Field: New Mexico Bureau of Mines and Mineral Resources Bulletin 141, p.17–49.

Hoffman, G.K., 1996, Coal resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources Resource Map 20, 22 p., 1 plate, scale 1:1,000,000.

Nickelson, H.B., 1988, One hundred years of coal mining in the San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 111, 226 p.

Monero Coal Field

Location

The Monero coal field is located in Rio Arriba County and a small portion extends into Sandoval County in north-central New Mexico. The field is structurally situated on the northeastern margin of the San Juan Basin.

Stratigraphy

A reconnaissance study of the coal was completed by Gardner (1909); however, the earliest detailed geology of the area was by Dane (1948) and the most recent work is by Hoffman (1991). Thicknesses of units are from Hoffman (1991), except for the Mancos Shale which is from Dane (1948).

Table. Stratigraphy—Monero coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mesaverde Group		
Cliff House Sandstone	nearshore marine	125
Menefee Formation	coastal plain; coal	0-110
Point Lookout Sandstone	nearshore marine	65-200
Mancos Shale	marine shale	2,060

Coal Deposits

Individual coal beds attain a maximum thickness of about 5 ft (Hoffman, 1991, fig. 8).

Coal Quality

The coals are high-volatile bituminous C to A in apparent rank, average about 10 percent ash, and have about 1.8 percent sulfur on an as-received basis (Hoffman, 1991).

Table. Coal in Menefee Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	10.16	1.85	12,373
Standard deviation	3.10	1.01	963
Number of analyses	14	14	13

Resources

Only about 8 million short tons of demonstrated resource is estimated for this field in areas under less than 200 ft of overburden (Hoffman, 1996); the estimated original resource is 17 million short tons (Hoffman, 1991).

Production History

About 40 mines operated in the field between 1882–1963, producing 1.6 million short tons of coal (Hoffman, 1991).

References

Dane, C.H., 1948, Geologic map of part of eastern San Juan basin, Rio Arriba County, New Mexico: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 78, 1 sheet.

Gardner, J.H., 1909, The coal field between Gallup and San Mateo, New Mexico, *in* Campbell, M.R., ed., Contributions to Economic Geology 1907: U.S. Geological Survey Bulletin 341, p. 364–378.

Hoffman, G.K., 1991, Geology and quality of Menefee Formation coals, Monero coal field, Rio Arriba County, New Mexico: New Geology, v. 13, no. 1, p. 1–21.

Hoffman, G.K., 1996, Coal resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources Resource Map 20, 22 p., 1 plate, scale 1:1,000,000.

Mount Taylor Coal Field

Location

This coal field is located on the south and east side of the Mount Taylor volcanic complex in McKinley, Sandoval, and Cibola Counties, New Mexico. The original usage of the name Mount Taylor by Hunt (1936) also encompasses several other fields (see San Mateo and Rio Puerco fields). Much of the coal in the field is overlain by lava flows associated with Mount Taylor.

Stratigraphy

The first detailed mapping of the geology was completed by Hunt (1936) And the latest compilation of the geology and coal resources is by Dillinger (1989, 1990). Thicknesses of the units are from a compilation by Dillinger (1990).

Table. Stratigraphy—Mount Taylor coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Crevasse Canyon Formation		
Gibson Coal Member	coastal plain; minor coal	64-492
Dalton Sandstone Member	nearshore marine	40-213
Mancos Shale		
Mulatto Tongue	marine shale	60-400
Crevasse Canyon Formation		
Dilco Coal Member	coastal plain; minor coal	80-200

Coal Deposits

Coals are present in the Gibson Coal and Dilco Coal Members of the Crevasse Canyon Formation in the southern Mount Taylor field and only in the Gibson in the eastern part of the Mount Taylor field. The beds are between 2.5 and 7.0 ft thick and are lenticular in nature (Kottlowski and Parkhill, 1971; Hoffman, 1996). Discontinuous coal beds in the eastern part of the Mount Taylor field are as thick as 6.5 ft (Kottlowski and others, 1971).

Coal Quality

The coal is subbituminous A to high-volatile C bituminous (Kottlowski and Parkhill, 1971; Hoffman, 1996). The Gibson and Dilco coals have a sulfur content of about 0.6 percent and an ash content of about 6 percent based on only a few analyses (Hoffman, 1996).

Resources

In the southern Mount Taylor field, the Gibson contains about 14 million short tons of coal under less than 200 ft of overburden (Hoffman, 1996); the member contains about 37 million short tons under less than 1,000 ft of overburden and in beds greater than 3.5 ft thick (Dillinger, 1989). The Dilco contains no resources in beds greater than 3.5 ft thick (Dillinger, 1989). No strippable coal is reported from the eastern Mount Taylor field (Kottlowski and others, 1971).

Production History

The East Mount Taylor coal field had four mines or prospects in operation between 1924 and 1954, and the area showed some potential in the 1960's; however, exploration drilling showed insufficient coal to allow further development (Nickelson, 1988).

References

Dillinger, J.K., 1989, Coal resources maps of the Grants 30'x60' quadrangle, west-central New Mexico: U.S. Geological Survey Coal Investigations Map C118-B, scale 1:100,000.

Dillinger, J.K., 1990, Geologic map of the Grants 30'x60' quadrangle, west-central New Mexico: U.S. Geological Survey Coal Investigations Map C118-A, scale 1:100,000.

Hoffman, G.K., 1996, Coal resources of New Mexico: New Mexico bureau of Mines and Mineral Resources Resource Map 20, 22 p., 1 plate, scale 1:1,000,000.

Hunt, C.B., 1936, The Mount Taylor coal field, *in* Sears, J.D., Hunt, C.B., and Dane, C.H., eds., Geology and Fuel Resources of the Southern Part of the San Juan Basin: U.S. Geological Survey Bulletin 860-B, p. 31–80.

Kottlowski, F.E., and Parkhill, T.A., 1971, South Mount Taylor Crevasse Canyon area, *in* Shomaker, J.W., Beaumont, E.C., and Kottlowski, F.E., eds., Strippable Low-Sulfur Coal Resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, p. 87–89.

Kottlowski, F.E., Beaumont, E.C., and Parkhill, T.A., 1971, East Mount Taylor Crevasse Canyon area, *in* Shomaker, J.W., Beaumont, E.C., and Kottlowski, F.E., eds., Strippable Low-Sulfur Coal Resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, p. 89–92.

Nickelson, H.B., 1988, One hundred years of coal mining in the San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 111, 226 p.

Navajo Coal Field

Location

The Navajo coal field is located on the Navajo Indian Reservation within San Juan County in northwestern New Mexico. The field extends from the San Juan River on the north to the eastern edge of the Navajo Reservation at the boundary between R. 14 W. and R. 13 W. (Shomaker, 1971).

Stratigraphy

The stratigraphy and coal geology was first studied in detail by Bauer and Reeside (1921). The thickness of the Pictured Cliffs Sandstone was measured at Brimhall Wash, and the thickness of the Fruitland Formation was obtained at Cottonwood Arroyo (Bauer and Reeside, 1921).

Table. Stratigraphy—Navajo coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Kirtland Shale	alluvial plain	~1,000
Fruitland Formation	coastal plain; major coal	330
Pictured Cliffs Sandstone	nearshore marine	49

Coal Deposits

Bauer and Reeside (1921) mapped two continuous coal beds in the northern part of the field and as many as five fairly continuous coal beds in the central and southern parts of the field. The coals dip at about 1 degree to the east into the San Juan Basin (Bauer and Reeside, 1921). The low dips keep the coal within 1,000 ft of the surface in a band about 10 mi wide, east of the outcrop belt.

Coal Quality

Coals are subbituminous A to high-volatile C bituminous (Hoffman, 1996). Average ash, sulfur, and heat contents in the table below are from Hoffman (1996).

Table. Coal in Fruitland Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	19.29	0.79	9,124
Standard deviation	3.23	0.27	647
Number of analyses	39	37	39

Resources

Demonstrated surface minable coal resources in the field are about 1.3 billion short tons for beds greater than 2.5 ft and less than 200 ft of overburden (Hoffman, 1996).

Production History

The Navajo mine opened in 1963 and has produced high volumes of coal each year since (Hoffman, 1996) (average of 8.3 million short tons between 1991–1995—G. Sullivan, written commun., 1997—compiled from Mine Safety and Health Administration data). One other major operation, the Burnham mine, operated in the area from 1978–1984.

References

Bauer, C.M., and Reeside, J.B., Jr., 1921, Coal in the middle and eastern parts of San Juan County, New Mexico: U.S. Geological Survey Bulletin 716-G, p. 155–237.

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Shomaker, J.W., 1971, Navajo Fruitland field, *in* Shomaker, J.W., Beaumont, E.C., and Kottlowski, F.E., eds., Strippable Low-Sulfur Coal Resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, p. 108–110.

Newcomb-Toadlena Coal Field

Location

These coal fields are located within San Juan County, New Mexico, on the western margin of the San Juan Basin and entirely within the Navajo Indian Reservation. The location is best shown by Shomaker (1971, his fig. 17, p. 49).

Stratigraphy

Coal is present in the Menefee Formation. The geology of the Newcomb area was mapped and coal sections were measured by O'Sullivan (1955) and Beaumont and O'Sullivan (1955). Thickness measurements of the formations are not available for the following table.

Table. Stratigraphy—Newcomb-Toadlena coal field.

Stratigraphic units	Depositional environment
Cliff House Sandstone	nearshore marine sandstone
Menefee Formation	coastal plain; coal
Point Lookout Sandstone	nearshore marine sandstone

Coal Deposits

In the Toadlena area, the coals are less than 2.5 ft thick in beds dipping as much as 12 degrees, making them unsuitable for strip mining (Lease, 1971). In the Newcomb area, the coals have a maximum cumulative thickness in the range of 32–38 ft in 7 to 10 beds (Beaumont and O'Sullivan, 1955), with a maximum individual bed thickness of about 7 ft (Shomaker, 1971). The coals are generally lenticular and unevenly distributed in the stratigraphic section (Shomaker, 1971).

Coal Quality

The coal is subbituminous A or B rank and generally contains less than 1 percent sulfur (Shomaker, 1971). The table below is summarized from Shomaker (1971, table 3, p. 54).

Table. Coal in Menefee Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Range	6.6-22.7	0.5-1 .4	7,660-10,410
Number of analyses	6	6	6

Resources

No resource estimates are available for the Toadlena area. The Newcomb area contains resources of about 72 to 78 million short tons of surface-minable coal under less than 200 ft of overburden and another 54 million short tons under less than 1,000 ft of overburden that are potentially minable by underground methods (Shomaker, 1971; Hoffman, 1996).

Production History

No mining has taken place in either coal field.

References

Beaumont, E.C., and O'Sullivan, R.B., 1955, Preliminary geologic map of the Kirtland quadrangle, San Juan County, New Mexico: U.S. Geological Survey Coal Investigations Map C-32.

Hoffman, G.K., 1996, Coal resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources Resource Map 20, 22 p., 1 plate, scale 1:1,000,000.

Lease, R.C., 1971, Toadlena Upper Menefee area, *in* Shomaker, J.W., Beaumont, E.C., and Kottlowski, F.E., eds., Strippable Low-Sulfur Coal Resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, p. 47.

O'Sullivan, R.B., 1955, Preliminary geologic map of the Naschitti quadrangle, San Juan County and McKinley Counties, New Mexico: U.S. Geological Survey Coal Investigations Map C-31.

Shomaker, J.W., 1971, Newcomb Upper Menefee area, *in* Shomaker, J.W., Beaumont, E.C., and Kottlowski, F.E., eds., Strippable Low-Sulfur Coal Resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, p. 47–52.

Rio Puerco Coal Field

Location

The Rio Puerco coal field is located at the southeastern edge of the San Juan Basin in Sandoval and Bernalillo and in parts of Cibola and Valencia Counties, New Mexico. Hunt (1936, plate 19) showed the area to be highly faulted and included the field with the Mount Taylor coal field.

Stratigraphy

Resources and coal information from Hunt (1936) is summarized by Shomaker (1971) and Hoffman (1996). The coal is thought to be in the Gibson Coal Member of the Crevasse Canyon Formation (Shomaker, 1971; Hoffman, 1996) although Hunt (1936) placed most of the coal in the upper Gibson member (Cleary Coal Member of the Menefee Formation according to present usage). Stratigraphic table (below) is, in part, from Sears and others (1941); thicknesses of units are approximated from Sears and others (1941, plate 26).

Table. Stratigraphy—Rio Puerco coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Menefee Formation		
Cleary Coal Member	coastal plain; coal	300+
Mancos Shale		
Satan Tongue	marine shale	0-350
Mesaverde Formation		
Hosta Sandstone Member	nearshore marine	0-200
Gibson Coal Member	coastal plain; coal	0-200
Dalton Sandstone Member	nearshore marine	0-100
Mancos Shale		
Mulatto Tongue	marine shale	200-500
Mesaverde Formation		
Dilco Coal Member	coastal plain; minor coal	0-100
Gallup Sandstone Member	nearshore marine	0-50

Coal Deposits

Coal is present in the Gibson Coal Member and is as thick as 9.6 ft with two partings (Hunt, 1936, plate 37), but individual coal beds generally average 3.8 ft thick (Hoffman, 1996).

Coal Quality

The rank of coals in the Gibson is subbituminous A to high-volatile C bituminous; the average ash content is about 8 percent and sulfur content is about 0.9 percent based on as-received analyses of just four samples (Hoffman, 1996).

Table. Coal in Gibson Coal Member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	8.35	0.93	9,445
Standard deviation	1.71	0.41	203
Number of analyses	4	4	4

Resources

The Gibson is estimated to have demonstrated coal resources of about 25 million short tons (Hoffman, 1996).

Production History

Six small mines operated from the 1920's into the 1940's (Hoffman, 1996).

References

Hoffman, G.K., 1996, Coal resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources Resource Map 20, 22 p., 1 plate, scale 1:1,000,000.

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Salt Lake Coal Field

Location

The field is located in Cibola and Catron Counties in west-central New Mexico.

Stratigraphy

Regional stratigraphic relationships were worked out in detail by Hook and others (1983). Thickness of the Atarque Sandstone is from Hook and others (1983), and thickness of the Moreno Hill Formation is from McLellan and others (1983), Roybal and Campbell (1981), and Campbell (1987). The geology and distribution of coal was comprehensively mapped by Campbell (1981, 1989) and Roybal and Campbell (1981). The lower member of the Moreno Hill is equivalent to the Carthage member of the Tres Hermanos Formation.

Table. Stratigraphy—Salt Lake coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Moreno Hill Formation	coastal/alluvial plain; coal	519-844
upper member	alluvial plain; minor coal	350
middle member	alluvial plain	60
lower member	coastal plain; coal	490
Atarque Sandstone	nearshore marine	50-80

Coal Deposits

The major coal-bearing unit is the Moreno Hill Formation, although minor coal is present in the Dakota Sandstone (Campbell, 1987). There are four zones in the Moreno Hill: the Antelope, the Cerro Prieto, the Rabbit in the lower member, and the Twilight in the upper member (Campbell, 1987, 1989). The coals are as thick as 14 ft and average about 5 ft (Hoffman, 1996).

Coal Quality

The apparent rank of coal in the Moreno Hill is subbituminous A; the average ash content is about 17 percent and average sulfur content is about 0.7 percent on an as-received basis (Hoffman, 1996).

Table. Coal in Moreno Hill Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	17.07	0.69	9,166
Standard deviation	4.07	0.22	837
Number of analyses	58	52	56

Resources

Resource estimates are summarized by Hoffman (1996) using data from Campbell (1981, 1989) and Roybal and Campbell (1981). The Moreno Hill contains about 323 million short tons of coal in beds greater than 2.5 ft thick and under less than 200 ft of overburden.

Production History

The field has had extensive exploration and some lease sales in the 1980's. A test mine, the Fence Lake #1, was opened and produced about 100,000 short tons of coal but was shut down during 1987 (Hoffman, 1996).

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San Mateo Coal Field

Location

The San Mateo coal field is located in Ciboal, McKinley, and Sandoval Counties of northwestern New Mexico on the southeastern edge of the San Juan Basin (Pierce and Shomaker, 1971).

Stratigraphy

The first coal reconnaissance work was by Gardner (1909), but the first detailed geologic and stratigraphic study was by Hunt (1936). Hunt (1936) referred to the Cleary Coal Member of the Menefee Formation as the upper Gibson Coal Member. Thicknesses of units are from Hunt (1936) and Hoffman (1993, p. 37–38).

Table. Stratigraphy—San Mateo coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Menefee Formation		
Cleary Coal Member	coastal plain; coal	300±
Point Lookout Sandstone	nearshore marine	200+

Coal Deposits

Coal is present in the Cleary Coal Member of the Menefee Formation, and the main coal beds are named blue and purple. The thickest coals are more than 15 ft (Beaumont, 1987).

Coal Quality

Coal in the field is subbituminous A in rank and averages about 13 percent ash and about 1 percent sulfur (Hoffman, 1996).

Table. Coal in Cleary Coal Member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	13.14	0.93	9,865
Standard deviation	3.46	0.35	1,088
Number of analyses	45	45	45

Resources

Demonstrated resources are estimated at about 450 million short tons in areas with less than 200 ft of overburden (Hoffman, 1996).

Production History

Historically there has been very little mining in the San Mateo coal field; however, in 1984 the Lee Ranch mine opened and produced about 250,000 short tons in its first year of operation (Nickelson, 1988). Cumulative production from 1984–1995, was around 32 million short tons of coal (G. Sullivan, written commun., 1997—compiled from Mine Safety and Health Administration data).

References

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Standing Rock Coal Field

Location

The Standing Rock coal field is located in McKinley County, New Mexico, in the southern part of the San Juan Basin. The field is arbitrarily separated from the San Mateo field at T. 8 W.

Stratigraphy

Coal was studied on outcrop by Hunt (1936) and in the subsurface by Hoffman (1993).

Table. Stratigraphy—Standing Rock coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Menefee Formation		
Cleary Coal Member	coastal plain; coal	~290
Point Lookout Sandstone	nearshore marine	~80

Coal Deposits

Coals in the Cleary Coal Member of the Menefee Formation are generally thin but can be as thick as 24 ft in one area of the field near the Standing Rock Trading Post (Shomaker, 1971, fig. 27).

Coal Quality

Coal in the field is subbituminous A in rank, and averages about 13 percent ash and 1.0 percent sulfur (Hoffman, 1996).

Table. Coal in Cleary Coal Member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	13.32	1.06	9,429
Standard deviation	3.35	0.38	552
Number of analyses	27	27	27

Resources

Demonstrated resources, estimated from limited data, total about 392 million short tons in areas with less than 200 ft of overburden (Hoffman, 1996).

Production History

Coal has been produced for domestic use only from small mine openings (Hoffman, 1996).

References

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Star Lake Coal Field

Location

The Star Lake coal field is located in McKinley, San Juan, and Sandoval Counties in northwestern New Mexico (Shomaker and Lease, 1971, fig. 55). The field is on the southern edge of the San Juan Basin and is defined by the limit of Fruitland Formation outcrops on the south, by the boundary between R. 8 W. and R. 9 W. to the west and by the thinning of the unit and change in trend near Cuba, N. Mex. to the east.

Stratigraphy

The area was studied in detail by Dane (1936). The Fruitland Formation, and coals within it, thin in the eastern part of the field.

Table. Stratigraphy—Star Lake coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Kirtland Shale	alluvial plain	200
Fruitland Formation	coastal plain; major coal	217
Pictured Cliffs Sandstone	nearshore marine	40-100

Coal Deposits

Coals in the Fruitland are as thick as 15.9 ft but generally contain numerous thin partings (Shomaker and Lease, 1971). The coal thins toward the eastern part of the field.

Coal Quality

The coals are subbituminous A to high-volatile bituminous C in rank, and contain 15 to 20 percent ash and 0.4 to 0.7 percent sulfur (Shomaker and Lease, 1971). The following table showing averages for ash, sulfur, and heat content is from Hoffman (1996).

Table. Coal in Fruitland Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	22.42	0.55	8,636
Standard deviation	4.43	0.12	702
Number of analyses	52	52	52

Resources

Demonstrated surface-minable coal resource estimates for the area are 946 million short tons in beds greater than 2.5 ft thick and with less than 200 ft of overburden (Hoffman, 1996).

Production History

Interest in leasing coal has been ongoing since the 1960's, and several exploration projects have been conducted in the area (Nickelson, 1988). No active mines are currently in operation.

References

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Tierra Amarilla Coal Field

Location

The Tierra Amarilla is located on the east flank of the Chama Basin within Rio Arriba County, New Mexico.

Stratigraphy

The stratigraphy and thicknesses of units in the table below are from Landis and Dane (1969).

Table. Stratigraphy—Tierra Amarilla coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Lewis Shale	marine	1,000
Menefee Formation	coastal plain; coal	99-120
Point Lookout Sandstone	shoreface	40-67

Coal Deposits

Landis and Dane (1969) recognized nine separate, thin coal beds in the Menefee Formation. The thickest individual bed is 4.1 ft thick and it is located stratigraphically in the lower part of the formation (Landis and Dane, 1969, fig. 3).

Coal Quality

The Menefee coals have an apparent rank of between subbituminous A and high-volatile C bituminous (Landis and Dane, 1969). Coal samples were collected from the tipple of the Dandee mine and analyzed by the U.S. Bureau of Mines; the results of the analyses are reported in the following table from Landis and Dane (1969).

Table. Coal in Menefee Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Range	7.7	1.0-1.1	9,640-10,110
Number of analyses	1	2	2

Resources

Not enough data are available to provide a meaningful estimate of the resources; however, most coal beds are less than 2.5 ft thick and will probably remain uneconomical for development (Nickelson, 1988).

Production History

Three small mines operated in the area between 1935 and 1955 (Nickelson, 1988)

References

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Zuni Coal Field

Location

The Zuni coal field in McKinley and Cibola Counties, in western New Mexico, is a continuation of the Gallup coal field. The coal field is entirely within the Zuni Indian Reservation and is part of the Zuni Basin, a northwest-trending asymmetric syncline (Anderson, 1987).

Stratigraphy

The stratigraphy was first worked out in detail by Sears (1925), and was later placed into a regional context by Hook and others (1983). Geologic mapping and coal geology was refined by Anderson (1987) and Anderson and Stricker (1987). Approximate thicknesses of units are from Hook and others (1983, Pescado Creek section).

Table. Stratigraphy—Zuni coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Crevasse Canyon Formation		
Dilco Coal Member	coastal plain; coal	175 (part)
Gallup Sandstone		
Torrivio Member	fluvial	125
Ramah unit	coastal plain; minor coal	75
F sandstone	nearshore marine	60
Mancos Shale		
Pescado Tongue	marine	55
Tres Hermanos Formation		
Fite Ranch Member	nearshore marine	40
Carthage Member	coastal plain; coal	150
Atarque Sandstone Member	nearshore marine	50

Coal Deposits

Coal is present within the Dilco Coal Member of the Crevasse Canyon Formation, the School mine coal group in the Gallup Sandstone, and in the Harper and Shoemaker Canyon coal zones in the Carthage Member of the Tres Hermanos Formation (Anderson and Stricker, 1987). The Harper coals in the Carthage are 3 to 4 ft thick, and the upper zone in the Gallup is as thick as 7 ft (Anderson and Stricker, 1987).

Coal Quality

The coal in the Zuni field has an apparent rank of high-volatile C bituminous (Anderson, 1987). The sulfur content of the Gallup Ramah unit is between 0.6 and 1.5 percent, and ash content is between 8.8 and 36.0 percent (Anderson and Stricker, 1987).

Table. Coal in Ramah unit.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
8.8-36.0	0.6-1.5	10,470-11,250

Resources

Three areas in the middle of the field are thought to have strippable resources totaling about 6 million short tons (Kottlowski, 1971). Anderson (1987) estimated coal resources in the Gallup Sandstone at about 49 million short tons in the southeastern part of the field.

Production History

Three small mines operated in the coal field between 1905 and 1958 (Nickelson, 1988).

References

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Utah

Alton Coal Field

Location

The Alton coal field is located in Kane and Garfield Counties in southern Utah and encompasses about 175 mi^2; about 28,000 acres were originally leased for coal. The field lies adjacent to Bryce Canyon National Park, and the coal is likely present in the subsurface beneath the Park. The easternmost part of the field is within the boundary of the Grand Staircase–Escalante National Monument.

Stratigraphy

The major coal-bearing unit in the Alton coal field is the Cretaceous Dakota Sandstone. Thickness of Dakota Sandstone is from Kauffman and others (1987); thickness of the Tropic Shale is from Cashion (1961).

Table. Stratigraphy—Alton coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Tropic Shale	marine	1,200
Dakota Sandstone		
upper member	nearshore marine	75
middle member	alluvial plain; major coal	150
lower member	fluvial	0-150

Coal Deposits

There are two major coal zones in the Dakota: the Smirl (or upper coal zone), which has a maximum coal thickness of 18 ft in T. 39 S., R. 6 W. (Cashion, 1961, section 45); and the Bald Knoll (or lower coal zone), which has a maximum coal thickness 8.7 ft including three partings in T. 39 S., R. 6 W. (Cashion, 1961, section 44).

Coal Quality

Coal in the Alton field has a range of apparent rank of from subbituminous C to high-volatile bituminous C (Doelling, 1972). The range of selected proximate/ultimate analyses of nine coal samples from the Smirl zone are compiled below from Affolter and Hatch (1980). Averages are from R.H. Affolter, (written comm., 1997).

Table. Coal in Dakota Sandstone.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	10.2	1.2	8,796
Range	4.8-20.9	0.5-3.5	6,260-9,780

Resources

Original coal reserves from the field have been estimated by Cashion (1961) and by Doelling (1972). Doelling estimated 2.1 billion short tons of reserves, of which 200 million short tons are under less than 200 ft of overburden and are considered strippable. Part of the field (T. 40 S., Rs. 4.5–5 W.) was studied under the Energy Mineral Rehabilitation Inventory and Analysis project that provided data on soils, vegetation, hydrology, coal distribution, and reclamation potential of the area (Bureau of Land Management, 1975). As part of that study, approximately a 30-mi^2 area was determined to have about 90 million short tons of coal in beds greater than 10 ft thick and with less than 200 ft of overburden (Bowers and others, 1976).

Production History

There is no active production in the Alton field. Eight mines operated historically in the southwestern part of the field with less than 50,000 short tons produced (Doelling, 1972). Five leases from State and Federal Governments have been granted in the field.

References

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Book Cliffs Coal Field

Location

The Book Cliffs coal field is located in Emery, Carbon, and Utah Counties in east-central Utah and lies on the northeast-dipping flank of the Uinta Basin. The coal field was historically, and is presently, one of the most important coal fields in Utah. The field extends for about 70 mi in length, extending from a few miles west of Price, Utah, southeastward to the canyon of the Green River. The area contains four mining districts—from west to east, the Castlegate, Soldier Canyon, Sunnyside, and Woodside districts (Doelling, 1972).

Stratigraphy

The coal-bearing unit in the Book Cliffs field is the Blackhawk Formation. The stratigraphy and coal geology were first studied in detail by Clark (1928). The Blackhawk is about 1,500 ft thick in the western part of the field and thins to as little as 450 ft toward the southeastern part of the field (Balsley, 1980; Young, 1955).

Table. Stratigraphy—Book Cliffs coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Castlegate Sandstone	fluvial	150-500
Blackhawk Formation	coastal plain; major coal	450-1,150
Star Point Sandstone	nearshore marine	0-300

Coal Deposits

The coal geology of the eastern part of the Book Cliffs was studied in detail by Clark (1928). A comprehensive summary of the field was compiled by Doelling (1972) and is further updated by Tabet (in press). The main coal zones are, in ascending order, Spring Canyon (4–10 ft), Castlegate A, B, C, D (4–18 ft), Kennilworth (4–28 ft), Gilson (4–18 ft), Rock Canyon (4–12 ft), and Sunnyside, (4–16 ft) (Tabet, in press).

Coal Quality

A summary of seven beds in the table below is based on more than 900 samples compiled from data of Tabet (in press). Details of the Spring Canyon (Subseam), Castlegate A and B, Kenilworth, Gilson, Rock Canyon, and Lower Sunnyside are available in Tabet (in press).

Table. Coal in Blackhawk Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
5-8	0.38-0.98	12,512-12,910

Resources

Original in-place resources for the Book Cliffs coal field are about 3.5 billion short tons for beds greater than 4 ft thick beneath less than 3,000 ft of overburden (Tabet, in press, modified from Doelling, 1972, and Anderson, 1983).

Production History

The Book Cliffs coal field has produced coal since the 1870's and, as of 1997, about 270 million short tons of coal were mined from the area (Jahanbani, 1996). More than 50 major mines have operated in the Book Cliffs from 1896 to the present (Doelling, 1972). The Book Cliffs coal field has produced about 2–3 million short tons of coal per year for the last 15 years (Jahanbani, 1996). Three major mines produced 3.15 million short tons in 1996. The opening of the Willow Creek mine will add about 2 million short tons of production to the Book Cliffs in the coming years (Jahanbani, 1996).

References

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Emery Coal Field

Location

The Emery coal field is located within Emery County in central Utah. The field extends for about 35 mi in a northeast-southwest direction. The eastern edge of the field is bounded by good exposures called the Coal Cliffs. The field is bounded on the south by volcanic rocks on the Fish Lake Plateau, and is limited to the west by excessive depth beneath the Wasatch Plateau. The coal deposits extend into the subsurface to the north and the field boundary is arbitrarily chosen near Price, Utah. We include the Ferron coal-bed gas play (fig. 1) in this summary—(play 2052 Uinta Piceance–Emery of Rice, 1995).

Stratigraphy

Thicknesses of the Tununk and Ferron Sandstone Members of the Mancos Shale are from isopach maps from Ryer and McPhillips (1983) for the Emery coal field and the Ferron play. Sequence stratigraphic studies of the unit have been completed by Gardner (1993).

Table. Stratigraphy—Emery coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mancos Shale		
Blue Gate Member	marine	(part)
Ferron Sandstone Member	coastal plain/nearshore marine; coal	55-830
Tununk Member	marine	300-790

Coal Deposits

The coal was first described by Lupton (1916) and named, in ascending order, the A, B, C, D, G, I, J, L, and M. Isopach maps of the A, C, G, J, and I are shown in Ryer (1981), who also provides an excellent summary of the associated depositional environments of the Ferron coal-bearing interval in the Emery field. These isopachs show a pod shape for most of the Ferron coal deposits.

Coal Quality

The rank of the coal is high-volatile bituminous B, and mean values of ash and sulfur contents are summarized below (Tabet, in press). The data, based on about 75 samples, are from the A, C, G, and I beds.

Table. Coal in Ferron Sandstone Member.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
8.20-14.54	0.78-1.26	11,275-12,179

Resources

The Ferron coals in the Emery coal field proper are estimated to contain about 1.4 billion short tons (Doelling, 1972, p. 437). An additional undetermined resource is present in the area around Price, Utah, where coal-bed methane is currently being produced in the Drunkard's Wash field (Gloyn and Sommer, 1993). The Drunkard's Wash field contains coal beds as much as 28 ft thick with overburden depths of between 100 and 2,500 ft (Bunnell and Hollberg, 1991).

Production History

As of 1996, cumulative production from the Emery field was 270 million short tons; however, there has been no active mining since 1990 (Jahanbani, 1996).

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Henry Mountains Coal Field

Location

The Henry Mountains coal field is located in south-central Utah in parts of Emery, Garfield, and Wayne Counties. The field is within a structural basin, and the coal is limited to an area of about 450 mi^2. The basin is bounded on the west by the Waterpocket fold where the beds generally dip 20°–30°. The east side of the basin is bounded by numerous laccolithic igneous intrusions that locally alter the coal (Hunt and others, 1953).

Stratigraphy

Coal is present in three units, in ascending order, the Dakota Sandstone, Ferron Sandstone Member of the Mancos Shale, and Masuk Formation (Emery Sandstone Member of the Mancos Shale of Hunt and others, 1953; sometimes referred to as Muley Canyon Sandstone Member of Mancos Shale—see discussion of stratigraphy by Eaton, 1990). Although the older formations have the greatest areal extent, the greatest resource and best quality coal is in the youngest coal-bearing unit—the Masuk Formation (Doelling, 1972). The stratigraphy and unit thickness are from Hunt and others (1953) and Eaton (1990).

Table. Stratigraphy—Henry Mountains coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Tarantula Mesa Sandstone	continental	270-400
Masuk Formation	coastal plain; major coal	600-750
Muley Canyon Sandstone	nearshore marine	270
Mancos Shale		
Blue Gate Member	marine	1,400
Ferron Sandstone Member	nearshore marine/coastal plain; coal	150-300
Tununk Member	marine	525-650
Dakota Sandstone	alluvial to marginal marine; minor coal	1-75

Coal Deposits

Coals in the Dakota Sandstone are thin and discontinuous. Coals in the Ferron are as much as 9 ft thick, but only over a 5-mi^2 area in the north part of the Henry Mountains coal field (Factory Butte area; Doelling and Smith, 1982). The thickest coal in the Masuk Formation is 13.4 ft, and the maximum cumulative thickness of coal is about 23 ft in three to four beds (Law, 1979, measured section 27; Law, 1980). The most up-to-date report on coal in the Henry Mountains is by Tabet (1999) and Tabet (chap. R, this CD-ROM).

Coal Quality

The Ferron coals have an apparent rank of high-volatile bituminous C, and the Masuk (Emery) coals have a range of apparent rank of subbituminous A to high-volatile bituminous C (Hatch and others, 1980; Doelling and Smith, 1982). Proximate/ultimate analyses for coal of the Henry Mountains are summarized in the tables below from Doelling (1972) for one sample in the Dakota and from Tabet (1999) for four samples in the Ferron and 37 samples in the Masuk (Muley Canyon).

Table. Coal in Masuk Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Mean	11.74	0.9	10,086

Table. Coal in Ferron Sandstone Member.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Mean	14.5	2.5	11,038

Table. Coal in Dakota Sandstone.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Mean	1.7	2.92	13,478

Additional data on chemical analyses from the coal-bearing units are given by Hatch and others (1980), who reported proximate and ultimate analyses for 16 core and abandoned-mine samples in the central part of the Henry Mountains coal field. For the Masuk Formation (Emery), ash content ranges from 7.1 to 27.3 percent and the sulfur content ranges from 0.4 to 1.0 percent.

Resources

The Ferron Sandstone Member and Masuk Formation have significant coal resources in the area. For coal beds greater than 6 ft thick, the Ferron is reported to contain about 219 million short tons of in-place resources; the Masuk (Muley Canyon) is estimated to have at least 1,388 million short tons of in-place resources (Tabet, 1999).

Production History

As of 1982, only about 59,000 short tons of coal were mined from the Henry Mountains Basin (Doelling and Smith, 1982). The majority of the production was from the Ferron in the far northern part of the field (Factory Butte area).

References

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Kaiparowits Plateau

Location

The Kaiparowits Plateau coal field is located in Kane and Garfield Counties of south-central Utah. The margins of the field are defined on the east by the Straight Cliffs Escarpment, on the west by the Kaibab monocline and Joes Valley anticline, on the north by the Aquarius Plateau, and on the south by the Gray Cliffs. The northern part of the field is within the Dixie National Forest, and the southern part is in the Grand Staircase–Escalante National Monument.

Stratigraphy

The stratigraphy and thickness data are from Hettinger and others (chap. T, table 2, this CD-ROM), based on Sargent and Hansen (1982) and Peterson (1969a, 1969b).

Table. Stratigraphy—Kaiparowits coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Straight Cliffs Formation		
Drip Tank Member	fluvial	140-400
John Henry Member	coastal plain/nearshore marine; major coal	600-1,500
Smoky Hollow Member	fluvial/coastal plain: minor coal	20-300
Tibbet Canyon Member	nearshore marine	60-185
Tropic Shale	marine	600-900
Dakota Sandstone	fluvial/nearshore marine; minor coal	15-250

Coal Deposits

The main coal-bearing unit in the Kaiparowits Plateau field is the John Henry Member of the Straight Cliffs Formation. Coal zones within the John Henry include, in ascending order, the Henderson (or lower), Christensen, Rees, and Alvey. The John Henry contains as many as 30 individual beds as thick as 59 ft (Hettinger and others, chap. T, this CD-ROM). Minor amounts of coal are also present in the Smoky Hollow Member of the Straight Cliffs Formation and the Dakota Sandstone, but the beds are thin and lenticular.

Coal Quality

The apparent rank of the John Henry coals changes systematically from subbituminous B in the northern part of the plateau to high-volatile bituminous B in the southern part of the Plateau (Kohler and others, 1997). The proximate/ultimate analysis of about 100 samples from mines and outcrops provide the data for the table below, derived from Doelling and Graham (1972, p. 123–127).

Table. Coal in John Henry Member of the Straight Cliffs Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
5.0-6.6	0.6-2.1	9,890-12,270

Resources

Coal resources for the Kaiparowits equal about 60.5 billion short tons for beds greater than 1 ft thick beneath less than 600 ft of overburden (Hettinger and others, chap. T, table 6, this CD-ROM). About 30 billion short tons were calculated for areas where the overburden is less than 3,000 ft, the strata dip less than 12 degrees, and the beds are between 3.5 and 14 ft thick (beds thicker than 14 ft thick were calculated as 14 ft thick) (Hettinger and others, chap. T, this CD-ROM).

Production History

Between 1910 and 1970, less than 50,000 short tons of coal were produced from about 15 small mines (Hettinger and others, chap. T, his table 1, this CD-ROM).

References

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Kolob-Harmony Coal Fields

Location

The Kolob-Harmony coal fields are located in parts of Kane, Iron, and Washington Counties in southwestern Utah. The Kolob field is the larger of the two fields, and is separated from the Harmony field by the Hurricane fault, and from the Alton field by the Sevier fault.

Stratigraphy

The coal is present in the Dakota Sandstone in the Kolob field (called the Tropic Formation by Averitt, 1962) or in the Iron Springs Formation in isolated outcrops of the Harmony field. The thickness of the Dakota is from Gustason (1989), Kauffman and others (1987) and Averitt (1962); the thickness of Tropic is from Cashion (1961) and Averitt (1962).

Table. Stratigraphy—Kolob-Harmony coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Tropic Shale	marine	0-250
Dakota Sandstone		
upper member	nearshore marine/coastal plain; coal	150
middle member	alluvial plain; minor coal	1,025
lower member	fluvial	50

Coal Deposits

Coal in the lower member of the Dakota Sandstone is called the lower coal zone, and the coal in the upper member of the Dakota Sandstone is called the upper or Culver coal zone. The lower coal is as much as 4 ft thick, and the Culver zone averages about 5–6 ft thick but can be as thick as 10 ft (Averitt, 1962; Doelling and Smith, 1982).

Coal Quality

The coal in the Kolob-Harmony fields is subbituminous A to bituminous C in rank (Doelling 1972). Locally in the Harmony field, some coal is metamorphosed by igneous intrusions to an apparent rank of semianthracite. Coal analyses for the Kolob and Harmony fields in the table below are from Doelling and Smith (1982).

Table. Coal in Dakota Sandstone—Kolob.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Range of mean	10.8-11.5	2.21-5.76	10,344-10,500

Table. Coal in Dakota Sandstone—Harmony.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Mean	26.6	3.31	9,100

Resources

Doelling and Smith (1982) report about 2.0 billion short tons of coal in the Kolob field in beds greater than 4.0 ft thick, most of which (about 95 percent) is in the upper zone. Insignificant resources are present in the Harmony field (Doelling and Smith, 1982).

Production History

About 25 mines have operated in the area between 1852 and 1966, and, cumulatively, they have produced less than a million short tons of coal (Doelling, 1972).

References

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Salina Canyon Coal Field

Location

The Salina Canyon coal field is a minor field located within Sevier County, Utah, west of the Wasatch Plateau along Interstate 70. The field is highly dissected by north-south-trending normal faults, including the Musinia fault zone (Spieker and Baker, 1928).

Stratigraphy

The stratigraphy and coal geology were first studied in detail by Spieker and Baker (1928). A compilation of the geology of the area is included in (Doelling 1972). Coals are present in the Castlegate Sandstone and Blackhawk Formation.

Table. Stratigraphy—Salina Canyon coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Castlegate Sandstone	fluvial; minor coal	229
Blackhawk Formation	coastal plain; major coal	540 (part)

Coal Deposits

There are three coal beds within the Blackhawk Formation: the Wilson, Sevier, and Ivie beds. Most of the coal beds are about 2–3 ft thick; however, the Ivie bed is reported as between 6 and 10 ft thick on outcrop (Spieker and Baker, 1928). The Ivie bed was found to be 4.7–6.3 ft thick in the subsurface based on three drill holes, and between 4.7 and 7.5 ft thick in the Sevier Valley Mine as reported in Doelling (1972, p. 39).

Coal Quality

Coal quality information in the table below is based on the range of 11 to 13 samples compiled from Doelling (1972, table 16).

Table. Coal in Blackhawk Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
4.2-13.2	0.32-0.6	9,690-12,080

Resources

Spieker and Baker (1928) estimated about 170 million short tons of coal for the Salina Canyon field over an area of about 30 mi^2. They estimated that the Ivie bed may contain as much as 140 million short tons in an aggregate area of about 20 mi^2. Doelling (1972) reports a potential resource of about 69 million short tons for about 7,700 acres west of the Musinia fault.

Production History

Five small mines operated in the coal field between 1910 and 1953, having produced about 430,000 tons of coal (Doelling, 1972).

References

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Spieker, E.M., and Baker, A.A., 1928, Salina Canyon district, Sevier County, Utah: U.S. Geological Survey Bulletin 796-C, p.125–170.

Sego Coal Field

Location

The Sego coal field is situated in the eastern part of the Book Cliffs within Grand County in Utah. The field is on the southern flank of the Uinta Basin, which has gentle dips to the north. The field is about 6 mi in width and about 65 mi in length, covering an area of about 400 mi^2 (Doelling, 1972). The coal-bearing Neslen Formation extends across the Colorado State line, becoming the Mount Garfield Formation (see summary of Book Cliffs coal field, Colorado).

Stratigraphy

The stratigraphy of the coal-bearing Neslen was first worked out in detail by Fisher (1936) and later refined by Fisher and others (1960) and Kirschbaum and Hettinger (1998). Thickness of the formation is from Fisher (1936) and Kirschbaum and Hettinger (1998). The coal deposits present in the easternmost part of the field were studied by Gualtieri (1991a, 1991b)

Table. Stratigraphy—Sego coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Castlegate Sandstone (part)		
Bluecastle Tongue	alluvial	0-150
Neslen Formation	coastal plain; coal	250-410
Sego Sandstone	tidal/nearshore marine	140-213

Coal Deposits

The coal zones in the Neslen Formation were first mapped and named by Fisher (1936) and include, in ascending order, the Palisade, Ballard, Chesterfield, and Carbonera. The most important bed is the Chesterfield coal, which has been extensively mined in the Sego Canyon area (Doelling, 1972; Willis, 1986). The Chesterfield attains a maximum thickness on outcrop of about 5 ft (Fisher, 1936, plates 13–15). Gaultieri (1991a, 1991b) noted in drill holes a maximum thickness of about 7 ft for the Chesterfield in the easternmost part of the field.

Coal Quality

The coal is high-volatile B-C bituminous (Gualtieri, 1991a, 1991b). Ash, sulfur and Btu/lb data in the following table are from Doelling and Smith (1982).

Table. Coal in Neslen Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
4-19	0.37-1.0	9,000-12,000

Resources

Doelling (1972) reported 293.5 millions of short tons of coal in the Neslen in beds greater than 4 ft thick. Gualtieri (1991b) reported about 180 million short tons of coal in the combined lower (Palisade) Ballard, Carbonera, and local beds.

Production History

Eight mines and several prospects operated in the Sego coal field between 1898 and 1953 and produced a total of 2.65 million short tons of coal (Doelling, 1972).

References

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Gualtieri, J.L., 1991a, Map and cross sections of coal zones in the Upper Cretaceous Neslen Formation, north-central part of the Westwater 30’x60’ quadrangle, Grand and Uintah Counties, Utah: U.S. Geological Survey Coal Investigations Map C-133.

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Tabby Mountain Coal Field

Location

The Tabby Mountain coal field is located on the northwestern flank of the Uinta Basin and extends for about 35 mi within Wasatch and Duchesne Counties, Utah (Doelling and Smith, 1982). Strata dip from 24 to 75 degrees, and the western margin of the field is highly deformed from eastward-directed thrusting (Doelling and Smith, 1982). Most of the coal is owned by the Uinta and Ouray Indian Tribes (Doelling and Smith, 1982).

Stratigraphy

Lupton (1912) completed the first fairly detailed study of the stratigraphy and geology of the coal-bearing units. Lupton's study and later stratigraphic and geologic studies were compiled by Doelling (1972). The revised stratigraphy and thickness of the Frontier Formation is from Molenaar and Wilson (1990). Thicknesses of the upper shale member of the Mancos Shale and the Mesaverde Formation are from Lupton (1912).

Table. Stratigraphy—Tabby Mountain coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mesaverde Formation	coastal plain/nearshore marine; coal	3,300
Mancos Group		
upper shale member	marine shale	1,450
Frontier Formation	coastal plain/nearshore marine; coal	760
unnamed shale unit	marine shale	170
Mowry Shale	marine shale	200

Coal Deposits

Coal as thick as 10 ft is present in the Frontier Formation (Doelling and Smith, 1982). As many as 21 beds of coal are present in the Mesaverde Formation and they are as much as 28 ft thick (Lupton, 1912). The main bed is named the Fraughton.

Coal Quality

The coal in the Frontier and Mesaverde is subbituminous C to lignite A in apparent rank. Ash and sulfur content in the following table are from (Doelling and Smith, 1982). Calorific values, based on 27 analyses indicate an apparent rank of lignite (Affolter, chap. G, this CD-ROM); Doelling and Smith (1982) reported values of 8,000 to 10,000 Btu/lb.

Table. Coal in Frontier and Mesaverde Formations.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
6-10	0.7-1.0	3,674-7,784

Resources

The Tabby Mountain field is estimated to have about 1.9 billion short tons of coal in beds greater than 14 inches thick and under less than 3,000 ft of overburden (Lupton, 1912). Of this amount, Doelling (1972) estimated that about 231 million tons are in beds greater than 4 ft thick and under less than 3,000 ft of overburden.

Production History

Four small mines and a few prospects operated in the Tabby Mountain field from the early 1900's until about 1949 (Doelling, 1972).

References

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Lupton, C.T., 1912, The Blacktail (Tabby) Mountain coal field, Wasatch County, Utah, *in* Campbell, M.R., ed., Contribution to Economic Geology 1910: U.S. Geological Survey Bulletin 471, p. 595–628.

Molenaar, C.M., and Wilson, B.W., 1990, The Frontier Formation and associated rocks of northeastern Utah and northwestern Colorado: U.S. Geological Survey Bulletin 1787, 21 p.

Vernal Coal Field

Location

The Vernal field is located on the northeast margin of the Uinta Basin in Uintah County, Utah.

Stratigraphy

A brief summary of the coal deposits of the field was completed by Gale (1910) and Lupton (1912). Kinney (1955) studied the stratigraphy and mapped the geology of part of the field and worked on the Frontier Formation coals. A regional stratigraphic study was completed by Molenaar and Wilson (1990). The most comprehensive report on the coal geology is by Doelling and Graham (1972). Thicknesses of units are from Kinney (1955).

Table. Stratigraphy—Vernal coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Mesaverde Formation	nearshore marine; coastal plain; coal	1,100
Mancos Group		
upper shale member	marine	4,900
Frontier Formation	nearshore marine; coastal plain; coal	140-270
Mowry Shale	marine	30-120

Coal Deposits

Coal beds in this field contain numerous partings and dip steeply. The coal beds are generally thin, although Frontier coals are as thick as 8.1 ft and Mesaverde Formation coals can be as thick as 7.0 ft (Doelling and Graham 1972).

Coal Quality

Both the Frontier and Mesaverde coals have an apparent rank of high-volatile C bituminous. Averages for ash, sulfur, and heat contents are given in the table below (Doelling and Smith, 1982).

Table. Coal in Mesaverde Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
17.5	0.8	8,750

Table. Coal in Frontier Formation.

[Values reported on an as-received basis]

Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
12.5	1.6	11,510

Resources

Inferred resources with as much as 3,000 ft of overburden equal about 164 million short tons in the Frontier and about 13 million short tons in the Mesaverde (Doelling and Graham, 1972, p. 26–27).

Production History

About 52 mines or prospects were opened in the area between the 1870's and 1955, producing a total of about 250,000 short tons of coal (Kinney, 1955; Doelling and Graham, 1972; Doelling and Smith, 1982).

References

Doelling, H.H., and Graham, R.L., 1972, Vernal coal field, *in* Doelling, H.H., and Graham, R.L., eds., Eastern and Northern Utah Coal Fields: Utah Geological and Mineralogical Survey Monograph Series No. 2, p. 1–95.

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Wales Coal Field

Location

The Wales coal field is a minor field located in Sanpete County, Utah. The field is just west of the Colorado Plateau proper and is on the east side of the Gunnison Plateau (San Pitch Mountains) within the Basin and Range Province.

Stratigraphy

A reconnaissance study of the coal was completed by Richardson (1906), and the earliest detailed study of the coal was by Clark (1914). Coal in the Wales coal field is present within the Cretaceous-Tertiary North Horn Formation. The coal is in the Cretaceous part of the unit (Lawton and others, 1993). The stratigraphy and thickness is from Lawton and others (1993).

Table. Stratigraphy—Wales coal field.

Stratigraphic unit	Depositional environment	Thickness (ft)
North Horn Formation		
coal-bearing unit	alluvial/lacustrine	131-374

Coal Deposits

Numerous thin beds as much as 6.6 ft thick (with partings) are present in the coal unit (Doelling, 1972; Lawton and others, 1993).

Coal Quality

Coal chemistry data in the following table are from a compilation by Doelling (1972).

Table. Coal in North Horn Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Average	14.8	4.3	10,119
Range	4.0-29.2	2.88-6.79	6,554-11,857
Number of analyses	13	8	6

Resources

The field contains about 12 million short tons of coal (Doelling, 1972).

Production History

The Wales coal field dates back to 1855. Several small mines operated until 1955, producing a total of 175,000 short tons of coal (Doelling, 1972).

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Wasatch Plateau Coal Field

Location

The Wasatch Plateau is the most important coal field in Utah. The field is located in the center of the State within Carbon, Emery, Sanpete, and Sevier Counties and partially within Utah and Wasatch Counties (Doelling and Smith, 1982). The coal field is about 90 mi long and about 10–20 mi wide. The field is cut by a series of generally north-south-trending normal faults that partition the field into seven distinct coal areas, as defined by Doelling (1972b, his fig. 18, p. 127). Three smaller fields are present west of the main Wasatch Plateau coal field: the Mount Pleasant, Salina Canyon, and Sterling fields (Doelling, 1972a). The Salina Canyon field is included separately in this report.

Stratigraphy

The first comprehensive study of the stratigraphy and coal geology of the Blackhawk Formation was conducted by Spieker (1931). Thicknesses for the members of the Mancos Shale are from the Three States National Gas Co., Joe's Valley No. 3 well, as reported in Roberts and Kirschbaum (1995, p. 90). Thicknesses of upper units are from Spieker (1931).

Table. Stratigraphy—Wasatch Plateau coal field.

Stratigraphic units	Depositional environment	Thickness (ft)
Castlegate Sandstone	fluvial	500
Blackhawk Formation	coastal plain; major coal	700-1,000
Star Point Sandstone	nearshore marine	222-500
Mancos Shale		
Masuk Member	marine	1,590
Emery Sandstone Member	coastal plain; major coal	1,200
Blue Gate Member	marine	2,160

Coal Deposits

Coal is present in two units: the Blackhawk Formation and the Emery Sandstone Member of the Mancos Shale. Coal in the Emery is little known because it is present only in the subsurface and relatively few drill holes penetrate the unit. The Emery contains at least six coal beds in the Joe's Valley No. 3 well that are as much as 11 ft thick.

The Blackhawk Formation contains the most important coal-bearing unit and contains more than 20 individual beds that are greater than 4 ft thick (Tabet, in press). The main beds are the Accord Lakes, Axel Anderson, Blind Canyon (Lower O'Connor), Wattis (Upper O'Connor), Cottonwood, and Castlegate A (Bob Wright). Many of these beds were originally named the Hiawatha bed by Spieker (1931) who did not fully recognize the complex nature of the coal over the 9-mi length of the field.

Coal Quality

The coal in the Blackhawk has an apparent rank of bituminous B and C (Tabet, in press). A summary of selected mean proximate/ultimate values based on about 750 analyses from the Blind Canyon, Castlegate A, Hiawatha, and Upper Hiawatha beds compiled from Tabet (in press) are given in the table below.

Table. Coal in Blackhawk Formation.

[Values reported on an as-received basis]

	Ash content (percent)	Sulfur content (percent)	Heating value (Btu/lb)
Mean Range	6.00-8.99	0.52-0.63	11,503-12,844

Resources

Spieker (1931) estimated 13 billion short tons of coal in beds greater than 14 inches thick for the Wasatch Plateau, and he estimated 7.8 billion short tons for beds greater than 30 inches thick. Original minable reserves were estimated at about 6.4 billion short tons by Doelling (1972b).

Production History

Production from numerous mines between 1870 and 1996 has totaled about 386 million short tons (Jahanbani, 1996) or 5 percent of the resource originally estimated by Spieker (1931) for beds greater than 30 inches thick. As of 1996, there were eight major underground mines operating in the Wasatch Plateau that produced about 24 million short tons of coal (Jahanbani, 1996). Four of the mines are longwall operations: Deer Creek, SUFCO, Skyline, and Trail Mountain, all of which are producing more than 3.5 million short tons a year as of 1996 (Fiscor, 1998; G. Sullivan, written commun., 1997—compiled from Mine Safety and Health Administration data).

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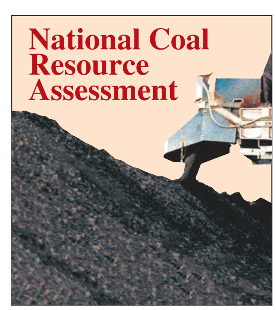

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