UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to accompany:

Open-File Report 79-196

COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE COWDREY QUADRANGLE JACKSON COUNTY, COLORADO

By

AAA Engineering and Drafting, Inc.

Prepared for the U.S. Geological Survey
under contract No. 14-08-0001-17457

1980

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Purpose

These maps were complied to support the land-use planning work of the Bureau of Land Management and to provide a systematic coal resource inventory of Federal coal lands in the McCallum Known Recoverable Coal Resource Area (KRCRA) in response to the land-use planning requirements of the Federal Coal Leasing Amendments Act of 1976.

Published and unpublished non-proprietary data sources were used for this study. No new drilling or field mapping was done to supplement this study. No confidential or proprietary data were used.

Location

The Cowdrey 7½-minute quadrangle is located in the north central part of Jackson County in northwest Colorado. The quadrangle is 1 mile (1.6 km) north of the town of Walden, the county seat of Jackson County. The Colorado-Wyoming state line is approximately 9 miles (14 km) north of the quadrangle and the Colorado-Utah state line is about 86 miles (138 km) west of the quadrangle.

Accessibility

Colorado State Highway 125 runs through the Cowdrey quadrangle in a north-south direction on the east side of the Michigan River. The highway continues northward 39 miles (63 km) to Riverside, Wyoming, and southward 60 miles (97 km) to Granby, Colorado. A light-duty road runs westward from the village of Cowdrey to the west edge of the quadrangle. Another light-duty road crosses the southwest quarter of the quadrangle in a broad arc from the center of the south edge of the quadrangle to a point near the west central edge. Two other light-duty roads leave highway 125 on each side of the township line between T. 9 N. and T. 10 N. and run eastward to the edge of the quadrangle. Numerous unimproved dirt roads occur in other parts of the quadrangle. The main barriers to travel in the quadrangle are the North Platte, Michigan, and Canadian rivers and their flood plains.

A branch line of the Union Pacific Railroad passes through the central part of the quadrangle in a north-south direction. The Brownlee siding is located in section 5, T. 9 N., R. 79 W. The railroad connects with the main line of the Union Pacific at Laramie, Wyoming. The Walden-Jackson County Airport is located on the south edge of the quadrangle in section 16, T. 9 N., R 79 W.

Physiography

The Cowdrey quadrangle is located on the north central side of a broad intermontane topographic basin called North Park. The basin is almost entirely surrounded by mountains including the Park Range to the west, the Rabbit Ears Range to the south and the Medicine Bow Range on the east side. The quadrangle lies in the lowland area of the basin where there are rolling hills, meandering rivers, and shallow dry washes.

The relief in the quadrangle is approximately 420 ft (128 m). The low points in the quadrangle are about 7,870 ft (2,399 m) in elevation where the North Platte, Michigan, and Canadian rivers leave the north edge of the quadrangle. The high point is about 8,290 ft (2,597 m) in elevation on a hill near the east edge of the quadrangle.

The North Platte River flows northward in the west half of the quadrangle. The Michigan River flows northward through the central part of the quadrangle and joins the North Platte River within a mile north of the quadrangle boundary. The Canadian River flows northwestward through the northeast quarter of the quadrangle toward its confluence with the North Platte River about 1½ miles (2.4 km) north of the quadrangle. All three of these streams flow in meandering channels and have flood plains ranging from ¼ mile (0.4 km) to more than 1 mile (1.6 km) in width.

Climate

The Cowdrey quadrangle has a mid-latitude steppe climate and semi-arid conditions prevail in the area. The normal annual precipitation for the quadrangle ranges from about 11 inches (28 cm) on the southwest corner to 17 inches (43 cm) on the northeast corner (U.S. Department of Commerce, (1964)).

The neareast weather data-recording station is at Walden where a record high temperature of 91° F (33° C) and a record low temperature of -49° F (-45° C) were recorded (Colorado State Climatology Office, personal comunication). The mean annual temperature at Walden is 36.5° F (2.5° C). The temperatures in the Cowdrey quadrangle are expected to be similar to those recorded at Walden.

Land Status

The Cowdrey quadrangle lies in the north part of the McCallum Known Recoverable Coal Resource Area (KRCRA). The KRCRA covers approximately 25,760 acres (10,425 ha) of the quadrangle. Plate 2 shows areas of non-Federal land and the KRCRA boundary. There were no existing Federal coal leases in the quadrangle when the land check for this report was made on the date shown on plate 2. There are approximately 15,000 acres (6,071 ha) of non-Federal land in the quadrangle and about 21,280 acres (8,612 ha) are Federal coal ownership lands which may or may not be underlain by coal.

Previous Work

Beekly (1915) made a geological study of North Park and published a report which included a description of the coal occurrences. Guidebooks by the Wyoming Geological Association and the Rocky Mountain Association of Geologists contain papers on the geology of North Park (Severy and Thompson, 1953; Henkes, 1957; Montagne and Barnes, 1957). Hail (1965, 1968) published studies of the areal geology of the west side of North Park and Middle Park basins, Jackson and Grand counties, Colorado. Madden (1975, 1976) and Madden and others (1977, 1978) studied the coal geology of North Park and completed seven unpublished maps and reports describing the coal occurrence and coal-bed correlations of the entire North Park basin. Exploratory drilling in the McCallum coal field was reported by Madden (1977).

Miller (1934) described the north and south McCallum anticlines. Kinney (1970a, 1970b, 1971), Kinney and Hail (1970a, 1970b) and Kinney and others (1970) mapped the geology of the eastern part of North Park. Tweto (1976) compiled the geology of the Craig 1^{o} x 2^{o} quadrangle.

GENERAL GEOLOGY

Stratigraphy

The oldest rocks exposed in the Cowdrey quadrangle are those of the Colorado Group of Cretaceous age. These crop out in a small area on the north side of Government creek in the northeast quarter of the quadrangle

(Tweto, 1976). The Colorado Group consists of the Upper Cretaceous Niobrara Formation (calcareous shale and marly limestone) and Upper and Lower Cretaceous Benton Shale (dark bentonitic shale; calcareous sandstone and siliceous shale near the base) (Tweto, 1976). The thickness of the Colorado Group in the area ranges from 1,000 - 1,300 ft (305 - 395 m) but only part of the Group occurs in the quadrangle.

The Colorado Group is overlain by the Pierre Shale of Late Cretaceous age. This formation crops out in the northeast quarter of the quadrangle northeast of the Canadian River and on the east-central side of the quadrangle in the North McCallum anticline. The Pierre Shale is composed of dark-gray marine shale, a few thick beds of fine-grained sandstone, and minor lenticular coal beds (D. H. Madden, personal communication). Tweto (1976) reports that the maximum preserved thickness of the Pierre Shale beneath the pre-Coalmont Formation or pre-Middle Park Formation unconformity in North and Middle Parks is 5,300 ft (1,615 m).

The Coalmont Formation of Paleocene and Eocene age overlies the Pierre Shale and includes the important coal beds in the quadrangle. In the northeast part of North Park, the Coalmont Formation has been divided into two informal members: the arkosic member at the base, and the volcanic member above (Kinney and others, 1970). Only part of the arkosic member is preserved in the Cowdrey quadrangle. The volcanic member and part of the arkosic member have been removed by erosion. The arkosic member is composed of fine-grained, tan, micaceous sandstone; gray, tuffaceous siltstone; coarse, brown, crossbedded, lenticular, conglomeratic lenses; brown, carbonaceous claystone or mudstone and shale; and coal (Kinney and others, 1970). Estimates of the maximum aggregate thickness of the Coalmont

Formation in North Park area range from 9,000 + ft (2,743 m) (Steven, 1960) to 12,000 ft (3,658 m) (Hail, 1968).

Structure

A prominent fold in the quadrangle is the Walden syncline whose axial trace crosses the western side of the quadrangle (pl. 1). The flanks of the syncline dip from 10-20° (Madden, 1976). The large central area of the quadrangle extending from the northwest corner to the southeast corner is characterized by beds dipping generally southwest about 10° toward the axis of the Walden syncline. The northwest-plunging nose of the north McCallum anticline occurs on the east-central side of the quadrangle (pl. 1). The southwest flank of the anticline dips from 15° to 30° (Madden, 1976).

Tweto (1976) and Kinney and others (1970) show several faults in the Cowdrey quadrangle. One crosses the northeast corner of the quadrangle; two east-west trending faults occur on the east-central side of the quadrangle; and two northwest-southeast trending faults are shown on the southwest side of the axial trace of the Walden syncline. The diplacements of the faults are unknown.

COAL GEOLOGY

The named coal beds in the quadrangle include the Sudduth, Capron, and Hill beds. Other lenticular coal beds of limited areal extent are called "local" beds and are designated by the symbol "L" on plates 1 and 3.

Sudduth Coal Bed

The Sudduth coal bed occurs near the base of the Coalmont Formation in the Cowdrey quadrangle. The coal bed is less than 5 ft (1.5 m) thick in the area of the North McCallum anticline on the east side of the quadrangle, but thickens eastward into the Eagle Hill quadrangle where the bed reaches nearly 30 ft (9.1 m) in thickness (AAA Engineering and Drafting, Inc., 1980). A hole drilled in section 25, T. 10 N., R. 80 W. encountered 8 ft (2.4 m) of coal at index number 4 (pl. 1). Because of the lack of coal-bed measurements west of index number 4, it is not known whether the bed thickens or thins toward the west side of the quadrangle. Likewise, the absence of drilling north and south of index number 4 prohibits estimations of thickness trends in those directions. Because only one thickness measurement of the Sudduth coal bed in the quadrangle is greater than 5 ft (1.5 m) (index number 4), coal isopach, structure, and overburden maps were not made for that bed.

Capron Coal Bed

In the Cowdrey quadrangle the Capron coal bed is approximately 1,800 ft (549 m) above the base of the Coalmont Formation and about 1,700 ft (518 m) above the Sudduth coal bed. The Capron coal bed was encountered in four drill holes in the quadrangle and ranges from 3.0 to 12.5 ft (0.9 to 3.8 m) in thickness (pl. 1 and 3). The bed is missing at index number 3 near the center of the quadrangle, but is 3.0 ft (0.9 m) thick at index number 5. The bed thickens southwestward to 10.0 ft (3.0 m) at index number 4 and southeastward to 12.5 ft (3.8 m) at index number 6. The coal bed at index number 6 is split by rock intervals from 1.0 to 2.0 ft (0.3 to 0.6 m) thick (pl. 1), but the total coal thickness is 12.5 ft (3.8 m) thick. At the south side of the quadrangle at index number 8, the Capron bed is 12.0 ft (3.7 m) thick with no rock splits.

Hill Coal Bed

Beekley (1915) measured a coal bed at index number 1 (pl. 1) at an abandoned coal mine opening. The combined coal thickness was 2.4 ft (0.7 m) which was split by a combined rock thickness of 1.2 ft (0.4 m). Beekley (1915) reported that although the bed appears to be somewhat higher in the section than the Capron coal, the stratigraphic position of the bed is very uncertain.

Isolated Data Points

In instances where isolated measurements of coal beds greater than 5 ft (1.5 m) thick are encountered, the standard criteria for construction of isopach, structure contour, mining ratio, and overburden isopach maps are not available. The lack of data concerning these beds limits the extent to which they can be reasonably projected in any direction and usually precludes correlation with other coal beds. For this reason, an isolated data point map was prepared on a separate sheet (in U.S. Geological Survey files) for the non-isopachable 8 ft (2.4 m) thick Sudduth coal bed, and an 8 ft (2.4 m) thick local coal bed encountered in the drill hole located at index number 4 on plate 1. The resource tonnages for these isolated data points were calculated to be 3.6 million short tons (3.3 million metric tons for the area within ¼ mile (0.4 m) of the point of measurement. The resource tonnage is shown by an asterisk on plate 2.

PROXIMATE ANALYSES OF THE COAL

Tables 1 and 2 show the proximate analyses of coal samples taken from the Sudduth coal bed in two mines in the Johnny Moore Mountain quadrangle approximately 7 miles (11 km) east of the southeast corner of the Cowdrey quadrangle.

Table 1.--Proximate analyses of coal (as-received) from the Sudduth bed in the Kerr strip mine, sec. 35, T. 9 N., R. 78 W., Jackson County, Colorado (Madden, 1976)

Lab Sample No.	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulfur %	Heat Valve Btu/lb[1]
K-52662	14.2	35.4	48.3	2.1	0.2	11,280
K-52663	14.4	34.4	47.9	3.3	0.2	10,830
K-52664	13.0	35.0	47.8	4.2	0.3	10,900
K-52665	12.4	34.9	41.9	10.8	0.2	10,040
K-52666	11.0	37.1	41.5	10.4	0.2	10,290
K-52667	12.0	36.0	45.5	6.5	0.3	10,790
K-52668	12.0	38.3	46.0	3.7	0.3	11,160
K-52669	12.8	37.3	44.8	5.1	0.7	11,160

[1]To convert Btu/lb to Kj/kg multiply by 2.326

Table 2.--Proximate analyses of coal (as-received) from the Sudduth bed in the Canadian strip mine, SW¼ sec. 2, T. 8 N., R. 78 W., Jackson County, Colorado (Madden, 1976)

Lab Sample No.	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulfur %	Heat Valve Btu/lb[1]
K-50383	14.5	31.9	47.2	6.4	0.2	10,730
K-50384	15.4	32.9	48.5	3.2	0.2	10,990
K-50385	16.1	31.4	43.0	9.5	0.2	9,900
K-50386	14.6	32.6	49.1	3.7	0.2	10,890
K-50387	14.5	27.4	45.5	19.2	0.2	8,580

[1]To convert Btu/lb to Kj/kg multiply by 2.326

Table 3 lists the moisture, ash and heating value for three coal samples obtained from the Capron coal bed in the Gould NW quadrangle which joins the southeast corner of the Cowdrey quadrangle.

Table 3.--Partial analyses of coal from the Capron bed in lots 19 and 20, sec. 19, T. 9 N., R. 78 W., Jackson County, Colorado. (Madden, 1976)

Lab Sample No.	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulfur %	Heat Value Btu/lb[1]
1	43	---	---	7.44	---	4,580
2	11.4	---	---	9.96	---	10,669
			(air-dried)			
3	15.6	---	---	5.08	---	10,750

[1]To convert Btu/lb to Kj/kg multiply by 2.326.

On the basis of the above incomplete analyses, the coal in sample numbers 2 and 3 ranges in rank from subbituminous A to high volatile bituminous C. Sample number 1 was probably a weathered surface sample as indicated by the abnormal moisture content and should not be considered representative of the coal bed.

MINING OPERATIONS

Coal mining in North Park dates back to the late 1880's and early 1900's. Nearly all the coal mines in North Park that operated in the past were located south of the Cowdrey quadrangle. Available information indicates that one coal mine or prospect referred to by Beekley (1915) as the Hill mine is the only instance of coal mining in the quadrangle. The sparcity of mines in the quadrangle is largely due to the thinness of the coal beds and the lack of outcrops.

The nearest mines operating in 1979 were the Canadian strip mine and the Marr No. 1 strip mine (formerly the Kerr No. 1 strip mine) located in the Johnny Moore Mountain quadrangle. These mines are approximately 8 miles (13 km) southeast of the Cowdrey quadrangle and produce from the Sudduth coal bed. The coal bed thickness in those mines ranges from 34 to 60 ft (10 to 18 m). Total production from the Marr No. 1 strip mine through 1978 was 1,256,664 short tons (1,140,046 metric tons) (Colorado Division of Mines, personal communication). Total production from the Canadian strip mine through 1978 was 280,852 short tons (345,509 metric tons) (Colorado Division of Mines, personal communication).

COAL RESOURCES

The principal sources of data used in the construction of the coal isopach, structure contour, and coal-data maps were Madden (1975, 1976, and 1977). Several oil and gas test wells have been drilled in the quadrangle and the available logs of these wells were inspected, but either interpretations of coal occurrence were too questionable or the wells were drilled in non-coal areas.

The coal isopach map for the Capron bed was constructed using a point-data net derived from coal-thickness measurements of the individual bed obtained from surface exposures and drill hole measurements within the quadrangle boundary and within a 3-mile (4.8-km)-wide border extending beyond the quadrangle boundary. Measured coal thickness values were used directly in the point-data net. The principle of uniform variation in thickness between data points was used to establish the position of the isopach lines.

The structure contour map was constructed using a point-data net derived from well logs and surface exposures. Elevations for the top of the contoured coal bed were based on surface altitudes and measured depths to the top of the coal bed and referenced to a mean sea level datum.

The overburden isopach map was based on a point-data net derived from stratigraphic-interval thicknesses measured from the ground surface to the top of the isopached coal bed. A secondary set of data-net points was generated by laying the structure contour map over a topographic contour map, and then calculating apparent overburden thickness values at the intersections of structure contour lines and surface topographic contour lines.

Coal thickness data was obtained from the coal isopach map (pl. 4) for resource calculations. The coal-bed acreage (measured by planimeter), multiplied by the average isopach thickness of the coal bed, multiplied by a conversion factor of 1,770 short tons of coal per acre-foot (13,018 metric tons of coal per hectare-meter) for subbituminous coal yields coal resources in short tons. Reserve Base and Reserve values for the Capron coal bed are shown on plate 5 and are rounded to the nearest tenth of a million short tons. The Reserve values are based on a subsurface mining recoverability factor of 50 percent where the coal bed dips 15^{0} of less and a surface mining recoverability factor of 85 percent.

The following criteria for coal resource determinations are given in U.S. Geological Survey Bulletin 1450-B: "Measured.--Resources are computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurements are so closely spaced and the thickness and extent of coals are so well defined that the tonnage is judged to be accurate within 20 percent of true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of the coal differs from region to region according to the character of the coal beds, the points of observation are not greater than ½ mile (0.8 km) apart. Measured coal is projected to extend as a ¼ mile (0.4 km) wide belt from the outcrop or points of measurement.

"Indicated.--Resources are computed partly from specified measurements and partly from projection of visible data for a reasonable distance on the basis of geologic evidence. The points of observation are ½ (0.8 km) to 1½ miles (2.4 km) apart. Indicated coal is projected to extend as a ½ mile (0.8 km) wide belt that lies more than ¼ mile (0.4 km) from the outcrop or points of observation or measurement.

"Inferred.--Quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region and where few measurements of bed thickness are available. The estimates are based primarily on an assumed continuation from Demonstrated coal [a collective term for the sum of coal in both Measured and Indicated Resources and Reserves] for which there is geologic evidence. The points of observation are 1½ (2.4 km) to 6 miles (9.6 km) apart. Inferred coal is projected to extend as a 2¼-mile (3.6 km) wide belt that lies more than 3/4 mile (1.2 km) from the outcrop or points of observation or points of observation or measurement." (U.S. Bureau of Mines and U.S. Geological Survey, 1976, p. B6 and B7).

Coal resource tonnages were calculated for measured, indicated, and inferred categories in the unleased areas of Federal coal land where the coal is 5 ft (1.5 m) or more thick and lies within 3,000 ft (914 m) of the surface. The criteria cited above were used in calculating Reserve Base and Reserve data in this report and differ from those stated in U.S. Geological Survey Bulletin 1450-B, which calls for a maximum depth of 1,000 ft (305 m).

In this study, coal 5 ft (1.5 m) or more thick lying between the ground surface and a depth of 200 ft (61 m) is considered amenable to surface mining methods; coal 5 ft (1.5 m) or more thick lying between 200 ft (61 m) and 3,000 ft (914 m) below ground level in beds having dips of 15° or less is assumed to be mineable by conventional subsurface mining methods. Coal 5 ft (1.5 m) or more thick lying between 200 ft (61 m) and 3,000 ft (914 m) below ground level in beds dipping greater than 15° is assumed to be suitable for in situ coal gasification methods.

Reserve Base tonnages of Federal coal per section for the isopached coal bed are shown on plate 2 and total approximately 9.2 million short tons (8.3 million metric tons) for the unleased Federal coal lands within the quadrangle. The Reserve Base tonnage (in short tons) for surface mining methods 1.3 million short tons (1.2 million metric tons), and the tonnage for subsurface mining methods is 7.9 million short tons (7.2 million metric tons). There is no Reserve Base tonnage for in situ coal gasification methods in this quadrangle. The coal resource tonnage for the non-isopached coal beds at isolated data points is 3.6 million short tons (3.3 million metric tons).

AAA Engineering and Drafting, Inc. has not made any determination of economic recovery for any of the coal beds described in this report.

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn (pl. 6 and 7) to coincide with boundaries of the smallest legal land subdivisions shown on plate 2. In sections or parts of sections where no land subdivisions have been surveyed by the BLM (U.S. Bureau of Land Management), approximate 40-acre (16-ha) parcels have been used to show the limits of high-, moderate-, or low-development-potential areas.

The designation of a coal-development-potential classification is based on the occurrence of the highest rated coal-bearing area that may occur within any fractional part of a 40-acre (16-ha) BLM land-grid area, lot, or tract of unleased Federal coal land. For example, a certain 40-acre (16-ha) parcel is totally underlain by a coal bed of moderate-development potential. If a small corner of the same 40-acre (16-ha) area is also underlain by another coal bed of high-development potential, the entire 40-acre (16-ha) is given a high-development-potential rating even though most of the area is rated "moderate".

Development Potential Using Surface Mining Methods

Areas where the coal beds 5 ft (1.5 m) or more in thickness are overlain by 200 ft (61 m) or less of overburden are considered to have a surface mining potential on the basis of the mining ratio (cubic yards of overburden per ton of recoverable coal). The following formula is used to calculate mining ratios:

$$MR = \frac{t_o\ (0.911)}{t_c\ (rf)}$$

Where MR = mining ratio (cubic yards of overburden per ton of recoverable coal).

t_o = thickness of overburden (in feet)

t_c = thickness of coal (in feet)

rf = recovery factor

0.911 = factor for subbituminous coal

To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

Areas of high-, moderate-, and low-development-potential for surface mining methods are here defined as areas underlain by coal beds having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15. These mining-ratio values for each development-potential category are based on economic and technological criteria and were provided by the U.S. Geological Survey (1979, unpublished data).

The coal development potential using surface mining methods is shown on plate 6. Approximately 9 percent of the unleased Federal land area in this quadrangle is classified as having a high-development-potential. The remaining Federal land in the quadrangle is classified as having an unknown surface mining development potential or no development potential. Areas of unknown surface mining development potential are those not known to contain coal beds 5 ft (1.5 m) or more thick that are within 200 ft (61.0 m) of the surface; however, coal beds 5 ft (1.5 m) or more thick could be present in the area. Lands where it is known that no coal beds occur within 200 ft (16.0 m) of the surface have no surface-mining potential.

The tonnage of Reserves recoverable by surface mining methods is calculated on a recoverability factor of 85 percent (specified by the U.S. Geological Survey, unpublished date, 1979) of the Reserve Base tonnage. Reserves have not been calculated for the nonisopached coal beds at isolated data points because the development potential for those beds is unknown.

Development Potential Using Subsurface Mining Methods and In Situ Coal Gasification

The coal development potential for areas in which subsurface mining of coal is possible is shown on plate 7. In this quadrangle, areas where coal beds dip 15^{0} or less, are 5 ft (1.5 m) or more thick and are overlain by 200 to 1,000 ft (61 to 305 m) of overburden are considered to have a high-development-potential for conventional subsurface mining methods. Approximately 31 percent of the unleased Federal land in this quadrangle has a "high" classification. Areas where such beds are overlain by 1,000-2,000 ft (305-610 m) and 2,000-3,000 ft (610-914 m) of overburden are rated as having moderate- and low-development-potentials, respectively. None of the unleased

Federal land in the quadrangle has a "moderate" or "low" coal-development-potential for conventional subsurface mining methods. Areas that contain no known coal in beds 5 ft (1.5 m) or more thick but do contain coal-bearing units at depths between 200 to 3,000 ft (61-914 m) are classified as areas of unknown coal development potential. Areas where it is known that no coal beds occur or where coal beds are present at depths greater than 3,000 ft (914 m) have no coal-development potential.

Reserve Base tonnages have been calculated for all areas of unleased Federal land where the coal beds are known to be 5 ft (1.5 m) or more thick. Reserves are based on a recoverability factor of 50 percent (specified by the U.S. Geological Survey, unpublished data, 1979) and have been calculated for only that part of the Reserve Base considered to be suitable for conventional subsurface mining methods.

Areas where the dip of the beds is greater than 15^{o} are assumed to be suitable for in situ coal gasification. No unleased Federal land in the quadrangle is in this category. The total Reserve Base tonnages per Federal section are shown on plate 2.

Reserves have not been calculated for the nonisopached coal beds at isolated data points. The areas controlled by those points have been assigned an unknown development potential. No distinction has been made between surface and subsurface mining resources in the areas controlled by isolated data points.

Table 4.--Sources of Data Used on Plate 1.

Plate 1 Index No.	Source	Drill Hole or Measured Section No. in Reference Source
1	Beekley, 1915	sec. K, pl. X
2	Madden, 1975	No number used
3	Madden, 1977	C-30, p. 78
4	Madden, 1976	No number used
5	W.C. McBride Corp.	Allard No. 1
6	Madden, 1977	C-31, p. 79
7	Do.	C-32, p. 80
8	Madden, 1978	No number used
9	Monolith Portland Midwest Co.	D.h. 6
10	Madden, 1977	C-18, p. 56
11	Madden, 1975	No number used
12	Do.	Do.
13	Madden, 1977	C-28, p. 76
14	Madden, 1975	No number used
15	Madden, 1977	C-27, p. 74

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10. Kinney, C. M., 1970a, Preliminary geologic map of the Gould quadrangle, North Park, Jackson County, Colorado: U.S. Geol. Survey open-file report.

11. __________ 1970b, Preliminary geologic map of the Rand quadrangle North Park, Jackson and Grand Counties, Colorado: U.S. Geol. Survey open-file report.

12. __________ 1971, Preliminary geologic map of "southwest third" of Kings Canyon quadrangle, North Park, Jackson County, Colorado: U.S. Geol. Survey open-file report.

13. Kinney, D. M., and Hail, W. J., 1959, Upper Cretaceous rock in North Park, Jackson County, Colorado in Symposium on Cretaceous rocks of Colorado and adjacent areas: Rocky Mtn. Assoc. Geologists Guidebook.

14. ___________1970a, Preliminary geologic map of the Walden quadrangle, North Park, Jackson County, Colorado: U.S. Geol. Survey open-file map.

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