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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE JOHNNY MOORE MOUNTAIN QUADRANGLE JACKSON AND LARIMER COUNTIES, COLORADO

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INTRODUCTION

Purpose

These maps were compiled 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Published and unpublished non-proprietary data sources were used for this study.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 were done to supplement this study. No confidential or proprietary data were used.

Location

The Johnny Moore Mountain 7½-minute quadrangle is located on the east side of Jackson County in north-central Colorado. A small part of the northeast corner of the quadrangle lies in Larimer County. The town of Walden, the county seat of Jackson County, is approximately 8½ miles (13.7 km) west of the Johnny Moore Mountain quadrangle. The city of Denver is 77 miles (124 km) southeast, and the Colorado-Wyoming state line is 17 miles (27 km) north of the quadrangle.

Accessibility

Colorado State Highway 14 passes through the extreme southwest corner of the Johnny Moore Mountain quadrangle. The highway runs northwestward approximately 12 miles (19 km) to the town of Walden and southeastward to the villages of Lindland and Gould. Light-duty roads on the north and south sides of Elk Mountain join on the west side of Elk Mountain and the single road continues westward to Walden. A light-duty road begins at a ranch near the center of the quadrangle and runs northwestward to join the Elk Mountain-Walden road near the west side of the quadrangle. Another light-duty road runs from the center of the south edge of the quadrangle northeastward along Meadow Creek approximately 2½ miles (4 km) to the Rogerson ranch.

Numerous unimproved dirt roads provide accessibility to the lowland area of the quadrangle. The high mountainous areas on the east side of the quadrangle are generally inacessible because of the steep grades and ruggedness of the canyons.

Physiography

The Johnny Moore Mountain quadrangle lies on the east 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 and the Medicine Bow Range on the east. Except for the mountainous east side, the quadrangle lies in the lowland area of the basin which consists of rolling hills, shallow creeks and dry washes. The highest peak in the northeast corner of the quadrangle is 10,950 ft (3,338 m) above sea level. The low point is approximately 8,050 ft (2,454 m) above sea level where the Canadian River intersects the northern border of the quadrangle. The relief is approximately 2,900 ft (884 m).

The Medicine Bow Range rises sharply on the east side of the quadrangle. The mountains are steep and the canyons are narrow. The surface drainage is toward the Canadian River which flows northward in a meandering channel through the central part of the quadrangle. The river flows northwestward from the quadrangle to its confluence with the North Platte River at the north end of the basin.

Climate

The Johnny Moore Mountain 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 15 inches (38 cm) on the southwest corner to 26 inches (66 cm) on the high mountainous area in the northeast corner of the quadrangle (U.S. Department of Commerce, (1964)).

The nearest weather data-recording station is at Walden where a record high temperature of 91° F (33° C) and a record low temperature of - 45° (- 45° C) were recorded (Colorado State Climatology Office, personal communication). The mean annual temperature at Walden is 36.5° (2.5 C). Except in the high mountainous area on the east side, the temperatures in the Johnny Moore Mountain quadrangle are expected to be in the range of those recorded at Walden. The temperature in the higher mountainous area will be lower than at Walden which is at an elevation of about 8,100 ft (2,469 m).

Land Status

The quadrangle lies in the east part of the McCallum Known Recoverable Coal Resource Area (KRCRA). The KRCRA covers approximately 17,140 acres (6,937 ha) of the quadrangle. The areas of non-Federal land and the KRCRA boundary are shown on plate 2. There were no existing Federal coal leases or preference right lease applications in this quadrangle at the date of the land check for this report as shown on plate 2. Approximately 74 percent of the quadrangle area is non-Federal land and 26 percent is Federal coal ownership land.

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 on the areal geology of the west side of North Park and part of Middle Park basins, Jackson and Grand Counties, Colorado. Madden (1976) and Madden and others (1977) studied the geology of the McCallum coal field and completed two unpublished reports with maps describing coal occurrences and coal bed correlations. Exploratory drilling in the McCallum coal field was reported by Madden (1977) who also reported on the coal geology of the entire North Park basin (Madden, 1978).

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 a geologic map of the Craig 1° x 2° quadrangle. Behrendt and others (1969) made a geophysical study of the North Park area. Hail and Leopold (1960) published a paper on the age of the Coalmont Formation.

GENERAL GEOLOGY

Stratigraphy

The oldest rocks exposed in the Johnny Moore Mountain quadrangle are the granitic rocks of Precambrian-X age in the core of the Medicine Bow Range which crosses the northeast part of the quadrangle. These rocks are composed of quartz monzonite, granodiorite, and quartz diorite and are in part migmatitic and gneissic (Tweto, 1976). Along the foothill area of the Medicine Bow Range, successively younger rocks crop out in northwest-trending bands parallel to the mountain front. These rocks include the formations shown in table 1.

The Coalmont Formation of Paleocene and Eocene age includes the important coal beds in the quadrangle. In the northeast part of North Park, the Coalmont Formation has been divided into two 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 Johnny Moore Mountain 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).

Old glacial-drift deposits (pre-Bull Lake) occur in the southeast part of the quadrangle (Tweto, 1976). These deposits consist of boulders and gravels.

Table 1.--Description of rock units (younger than Precambrian) in the Johnny Moore Mountain quadrangle, Jackson and Larimer Counties, Colorado

Formation	Age	General Description	Estimated Thickness (ft)[2]
Old glacial drift	Quaternary	Unsorted bouldery glacial deposits and associated gravels.	
Coalmont Formation	Paleocene & Eocene	Sandstone, congolmerate, carbonaceous shale, and coal beds.	1,100+
Pierre Shale	Upper Cretaceous	Dark gray marine shale and a few thick beds of fine-grained sandstone. Minor lenticular coal beds.	5,300
Colorado Group			
Niobrara Formation	Upper Cretaceous	Calcareous shale and marly limestone	1,000--1,300
Benton Shale	Upper & Lower Cretaceous	Dark bentonitic shale; calcareous sandstone and siliceous shale near base.	
Dakota Sandstone	Lower Cretaceous	Light-gray and tan sandstone or quartzite; some interbedded dark shale and shaly sandstone.	100--250
Morrison Formation	Upper Jurassic	Varigated shale and mudstone, light-gray sandstone, and beds of fine-grained gray limestone. Locally conglomeratic near base.	300-500

[1] After Tweto (1976)
[2] To convert feet to meters, multiply feet by 0.3048.

Table 1.-- Description of rock units (younger than Precambrian) in Johnny Moore Mountain quadrangle, Jackson and Larimer Counties, Colorado (Continued)

Formation	Age	General Description	Estimated Thickness (ft)[2]
Chugwater Formation	Triassic	Red and gray sandstone, siltstone, shale, and conglomerate	800
Forelle Limestone Member of the Goose Egg Formation	Permian	Gray limestone	< 20
Satanka Shale	Permian	Red Shale	<135

[1] After Tweto (1976)
[2] To convert feet to meters, multiply feet by 0.3048

Structure

The most prominent structural feature in the Johnny Moore Mtn. quadrangle is the Johnny Moore Mountain syncline which trends in a southeast direction across tthe west and south-central parts of the quadrangle (pl. 1). Dips on the flanks of the syncline range to at least 80^{0}. Northeast of the synclinal axis, the beds rise toward the Medicine Bow Range high area with intervening folding and faulting in the northeast part of the quadrangle (Tweto, 1976). These structural elements do not involve coal-bearing strata and are not shown on plates 1 and 4. Southwest of the synclinal axis, the rocks rise sharply toward the axis of the South McCallum anticline which crosses the southwest part of the quadrangle.

Several minor faults occur on the west central side of the quadrangle (pl. 1). The fault traces are inferred by dashed lines on plate 1 and it is assumed that the fault displacements are not large.

COAL GEOLOGY

The Sudduth coal bed is the most important coal bed in the Johnny Moore Mountain quadrangle. The bed is higher grade, thicker, and more extensive than the other beds. The Capron coal zone occurs above the Sudduth bed and is lower grade, thinner, and less persistent than the Sudduth.

In this quadrangle a lenticular coal bed of very limited lateral extent is called a "local" coal bed and has been designated by the letter "L" on plates 1 and 3 (index no. 19).

Sudduth Coal Bed

The Sudduth coal bed occurs in the lower part of the Coalmont Formation in the Johnny Moore Mountain quadrangle (pl. 3). The Sudduth is the thickest coal bed in the area and contains the best quality coal. It is the only coal that is being mined in the quadrangle at the date of this report. The Sudduth bed occurs near the contact between the Coalmont Formation and the underlying

Pierre Shale. The coal bed crops out on both sides of the Johnny Moore syncline in the northwest and central parts of the quadrangle (pl. 1).

The Sudduth coal bed ranges from 10.8 to 58.0 ft (3.3 to 17.7 m) thick at various points in the quadrangle. Based on the coal isopach map (pl. 4) the bed thins northward from index no. 4 where it is 56.0 ft (17.1 m) thick and thins southward from index no. 9 where it is 58.0 ft (17.7 m) thick. Because of the lack of control points in the southwest part of the quadrangle and insufficient data line was drawn about ½ mile from the outcrop trace in that area. The Reserve Base tonnage (discussed below) was calculated for the area between the outcrop trace and the insufficient data line.

Capron Coal Zone

The Capron coal zone occurs in the Coalmont Formation approximately 1,850 ft (564 m) stratigraphically above the base of the formation. Capron coal zone exposures occur at the points of measurement located at index numbers 20, 21, and 22 on plate 1. Madden (1976) reports that "The Capron coal is shaly and weathered at the surface". In this quadrangle the zone consists of several thin coal beds less than 2 ft (0.6 m) thick interbedded with rock.

PROXIMATE ANALYSES OF THE COAL

Tables 2 and 3 show the proximate analyses of coal samples taken from the Sudduth coal bed in two mines located in the quadrangle.

On the basis of the analyses shown in tables 2 and 3, the Sudduth coal at the sampling sites ranges from subbituminous B to high volatile C bituminous in rank (American Society for Testing and Materials, 1977). The average of the above analyses represents a rank of subbituminous A coal.

Table 2.--Proximate analyses of coal (as-received) from the Sudduth bed in the Kerr strip mine, sec. 35, T. 9 N., R. 78W., Jackson County, Colorado (Madden, 1976)[1]

Lab Sample No.	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulphur %	Heat Value Btu/lb
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 3.--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 %	Sulphur %	Heat Value 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	3.2	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 the Kj/kg multiply by 2.326

MINING OPERATIONS

Coal mining in North Park dates back to the late 1800's and 1900's. Many of the early mines were located in the Coalmont area about 18 miles (29 km) southwest of the Johnny Moore Mountain quadrangle.

Table 4 lists the known mines and prospects in the Johnny Moore Mountain quadrangle.

Table 4.--Coal mines in the Johnny Moore Mountain quadrangle, Jackson and Larimer Counties, Colorado

Mine Name(s)	Approximate Location	Coal Bed Name	Coal Thickness (ft)[1]	Production[2] (s.t.)[3]	Periods of Operation
Marr (undergrounded and strip mines)	Sec. 26 and 35 T. 9 N., R. 78 W.	Sudduth	49-53	102,393	1919-20, 1923-44 1945-54, 1955-59
Marr No. 1 (Kerr Strip)	Sec. 25, 26, 35 T. 9 N., R. 78 W.	Sudduth	49-56	1,256,664	1974-80
Canadian	SW¼ sec. 2, T. 8 N., R. 78 W.	Sudduth	29-39	380,852	1974-80
Lange Shaft	SW¼ sec. 25, T. 9 N., R. 78 W.	Sudduth	50	---	---
Unnamed Prospect	NE¼ sec. 14, T. 8 N., R. 78 W.	Capron Coal Zone	3.5	---	---

1 To convert feet to meters, multiply feet by 0.3048
2 Production through 1978 (Colorado Division of Mines)
3 To convert short tons to metric tons, multiply short tons by 0.9072.

The Marr No. 1 strip mine and the Canadian strip mine were operating in January of 1980. The coal from these mines has been used in steam-electric generating plants.

COAL RESOURCES

The principal source of data used in the construction of the coal isopach, structure contour, and coal data maps was Madden (1977a and 1977b). The logs of oil and gas test wells drilled in the area were inspected for reliable coal-bed data, but the logs were generally non-definitive for coal, or the wells were drilled in non-coal-bearing areas.

The coal isopach map was constructed by using a point-data net derived from coal-thickness measurements of the Sudduth coal bed obtained from surface exposures and correlated well logs located within the quadrangle boundary and a 3-mile (4.8-km)-wide zone around the quadrangle. Measured coal thickness values were used directly in the point-data net where the rocks dip less than 25°. In the drill holes at index numbers 2, 3, 4, 13, 14, 15, 16, 18, and 19 (pl. 1) the rocks dip greater than 25° and adjusted coal-bed thicknesses were calculated by multiplying the apparent, vertically-measured coal-bed thickness by the cosine of the dip. 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 by using a point-data net derived from well logs and surface exposures. The elevation of the top of the contoured coal bed was based on surface altitude and the measured depth to the top of the coal bed encountered in drill holes and referenced to mean sea level.

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 a 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 Sudduth coal bed are shown on plate 7 and are rounded to the nearest tenth of a million short tons. The Reserve values are based on a surface mining recoverability factor of 85 percent. The subsurface mining recoverability factor is 50 percent where the dip of the bid is 15° or less. Where the dip is greater than 15° the coal is considered suitable only for situ coal gasification and no Reserves are computed. In this quadrangle there is only a small area of unleased Federal land where the coal Reserve Base tonnage was considered mineable by conventional subsurface mining methods.

The following criteria for coal resource determinations are given in the U.S. Geological Survey Bulletin 1450-B: "Measured.--Resources are computed from dimensions revealed in outcrops, trenches, mine working, and drill holes. The points of observation and measurement 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 no greater than ½ mile (0.4 km) wide belt from the outcrop or points of observation or 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 a geologic evidence. The points of observation are 1½ (2.4 km) to 6 miles (9.5 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 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 (300 m) for subbituminous coal.

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) and 3,000 ft (914 m) below ground level in beds having dips of less than 15° is considered minable by conventional subsurface methods. Coal of Reserve Base thickness lying between 200 ft(61 m) and 3,000 ft (914 m) below ground level with dips greater than 15° is assumed to be suitable for in situ coal gasification.

Reserve Base tonnages of Federal coal per section for the isopached coal bed are shown on plate 2 and total approximately 85.5 million short tons (77.6 million metric tons) for the unleased Federal coal lands within the quadrangle. The Reserve Base tonnage for surface mining methods is all classified as having a high development potential and totals 11.9 million short tons (10.8 million metric tons) for the quadrangle. The only Reserve Base tonnage for conventional subsurface mining methods in the quadrangle has a high-development-potential and totals 1.3 million short tons (1.2 million metric tons). The subsurface Reserve Base tonnage in unleased Federal land where the dip of the beds is greater than 15° is classified as having a low development potential for in situ coal gasification and totals 72.3 million short tons 65.6 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. 8 and 9) so as to coincide with the boundaries of 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) area 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 and were assigned a high-, moderate-, or low-development-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 8. Approximately 4 percent of the unleased Federal land area in this quadrangle is classified as having a high-development-potential using surface mining methods. There are no areas rated for moderate or low development potentials. The remaining Federal land in the quadrangle has 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 (61.0 m) of the surface have no surface-mining development potential.

The tonnage of Reserves recoverable by surface mining methods are calculated on a recoverability factor of 85 percent (specified by the U.S. Geological Survey, unpublished data, 1979) of the Reserve Base tonnage.

Development Potential Using Subsurface Mining Methods and in Situ Coal Gasification

The coal development potential for areas in which subsurface development of coal is assumed possible is shown on plate 9. In this quadrangle, areas where coal beds dip 15° 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 0.5 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. In this quadrangle there are no areas classified with a moderate- or low-development-potential using conventional subsurface mining methods, but a large area has a low-development-potential for in situ coal gasification and is discussed below. 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 in unleased Federal land within the quadrangle where the coal beds are 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. An arbitrary dip limit of 15° is assumed to be the maximum dip suitable for conventional subsurface mining methods.

The development potential using in situ coal gasification applies to areas that contain coal beds 5 ft (1.5 m) or more thick dipping in excess of 15°. The coal beds in much of the area in this quadrangle have dips greater than 15° and are classified as having a low-development-potential for using in situ coal gasification methods. Approximately 5 percent of the unleased Federal land in the quadrangle is so classified.

Table 5.--Sources of data used on plate 1.

Source	Index No.	Drill hole or measured section no. in reference source
Madden, 1977a	1	-----
Madden, 1977b	2	J12B, p.42
Do.	3	J13B, p.44
Do.	4	J14B, p.45
Boreck and others, 1975	5	p. 106
Madden, 1977a	6	-----
Beekly, 1915	7	p. 97
Do.	8	p. 96
Madden, 1977a	9	-----
Do.	10	-----
Boreck and others	11	p. 101-105
Madden, 1977a	12	-----
Madden, 1977b	13	J1A, p. 18
Do.	14	J1B, p. 19
Do.	15	J2, p. 20
Do.	16	J3, p. 22
Do.	17	J6B, p. 27
Madden, 1977a	18	-----
Madden, 1977b	19	J6A, p. 26
Beekly, 1915	20	p. 98
Madden, 1977a	21	-----
Beekly, 1915	22	p. 99

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