UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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# COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE MAC FARLANE RESERVOIR QUADRANGLE JACKSON COUNTY, COLORADO

By

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This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

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# INTRODUCTION

## Purpose

These maps were compiled to suport 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Published and unpublished non-proprietary data sources were used for this study.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 Mac Farlane Reservoir 7½-minute quadrangle lies in the south-central part of Jackson County in northwestern Colorado. The quadrangle is 26 miles (42 km) south of the Colorado-Wyoming state line and 7 miles (11 km) south of Walden, the county seat. The towns of Hebron and Coalmont are 2 and 4 miles (3 and 6) west of the quadrangle. The city of Denver is approximately 81 miles (130 km) southeast of the quadrangle.

## Accessibility

Colorado State Highway 125 passes through the northeast part of the Mac Farlane Reservoir quadrangle. This highway continues northward to the town of Walden and into Wyoming. The highway runs southeast from the quadrangle to the towns of Rand and Granby. A light-duty road crosses the southwest part of the quadrangle along Buffalo Creek. Numerous unimproved dirt roads provide accessibility to the other areas of the quadrangle except a mountainous area in the northeast corner of quadrangle called Owl Ridge.

A branch line of the Union Pacific Railroad crosses the north side of the quadrangle. The railroad provides rail service to Laramie, Wyoming. The Walden-Jackson County airport is approximately 8½ miles (13.7 km) north of the quadrangle.

## Physiography

The Mac Farlane Reservoir quadrangle lies in the south central part 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 to the east. The quadrangle lies in the lowland area of the basin where there are rolling hills, shallow creeks, and dry washes.

The relief in the quadrangle is approximately 780 ft (238 M). The low point is 8,070 ft (2,460 m) above sea level where an intermittent stream bed leaves the northwest corner of the quadrangle. The high point is approximately 8,850 ft (2,697 m) above sea level on Owl Ridge at the eastern edge of the quadrangle. Owl Ridge is a prominent resistant ridge that projects into the northeast part of the quadrangle from the adjoining quadrangle on the east.

The main drainage in the northeastern part of the quadrangle is the Illinois River which flows northward along the western base of Owl Ridge. Mac Farlane Reservoir is in the east-central part of the quadrangle and impounds the flow of Soap Creek. The excess water which flows over the Mac Farlane Reservoir dam flows northwestward through the quadrangle in the Soap Creek channel. The southwestern part of the quadrangle is drained by Buffalo Creek which flows northwestward to its confluence with Grizzly Creek in the Coalmont quadrangle.

## Climate

The Mac Farlane Reservoir 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 13 inches (33 cm) on the north side to 16 inches (41 cm) on the south side (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 -49° F (-45° C) were recorded (Colorado State Climatology Office, personal communication). The mean annual temperature at Walden is 36.5° F(2.5° C). The temperatures in the Mac Farlane Reservoir quadrangle are expected to be in the range of those recorded at Walden.

## Land Status

The Mac Farlane Reservoir quadrangle lies in the south central part of of the McCallum Known Recoverable Coal Resource Area (KRCRA). The KRCRA covers approximately 24,250 acres of the quadrangle. Plate 2 shows areas of non-Federal land, leased Federal land, and the KRCRA boundary. There was one existing Federal coal lease in this quadrangle when the land check for this report was made on the date shown on plate 2. A comparison of the area of Federal coal ownership and the non-Federal lands in the quadrangle area is shown in table 1.

Table 1.--Approximate distribution of Federal and non-Federal land areas in the Mac Farlane quadrangle, Jackson County, Colorado

| Category | Approximate area (acres)[1] | Percent of quadrangle area |
|---|---|---|
| Leased Federal coal land | 30 | 0.1 |
| Non-Federal land | 16,970 | 46.9 |
| Unleased Federal coal ownership [2] | 19,180 | 53.0 |
| Total | 36,180 | 100.0 |

[1] To convert acres to hectares, multiply acres by 0.4047
[2] Coal is known to be present in only part of this area.

## 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 Middle Park basins, Jackson and Grand Counties, Colorado. Madden (1976) studied the coal geology of the McCallum coal field and completed two unpublished reports describing the coal occurrence and coal-bed correlations. Madden and others (1977, 1978) described the coal geology of the entire North Park basin. Exploratory drilling in the Coalmont 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 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 (1969) published a paper on the age of the Coalmont Formation.

# GENERAL GEOLOGY

## Stratigraphy

The oldest formation exposed in the Mac Farlane Reservoir quadrangle is the Coalmont Formation of Paleocene and Eocene age. This formation is overlain by the White River Formation, North Park Formation and Quaternary gravels (Tweto, 1976). The Quaternary gravel deposits occur in large areas on the east half of the quadrangle and the White River and North Park Formations are only present in the northeast corner of the quadrangle in the Owl Ridge and Peterson Ridge areas. The Coalmont Formation underlies the entire quadrangle and contains the important coal deposits.

"The Coalmont is largely nonresistant and easily eroded, and forms lowlands, flatlands, or slopes . . . Much of the area underlain by the Coalmont is commonly obscured by a cover of surficial material" (Hail, 1968). In some areas, however, moderately well cemented sandstone or comglomerate beds form cliffs, weak ridges, or hogbacks.

The Coalmont Formation is locally divided into the following three members in ascending order: the Middle Park Member, a middle member, and an upper member. The Middle Park Member has a maximum thickness of 600 ft (183 m) in the Middle Park area southeast of the Mac Farlane quadrangle. The Middle Park Member thins to zero where overlapped by the middle member and may not be present in the quadrangle.

The middle member ranges from 1,765 to 2,740 ft (538 to 835 m) in thickness in drill holes that penetrated the entire unit (Hail, 1968). The member consists of crossbedded arkosic sandstone, conglomeratic sandstone, and gray or green sandy claystone or mudstone; carbonaceous shale and coal are sparse. In the Coalmont-Pole Mountain area, the middle and upper members are separated by an unconformity marked by an abrupt change from sandstone and conglomerate below to carbonaceous shale above. In other areas clear evidence for unconformity is lacking, and the eastward extent of the unconformity is unknown owing to lack of subsurface information (Hail, 1968).

The upper member of the Coalmont Formation consists of sandstone, claystone, mudstone, carbonaceous shale, and coal. Conglomeratic beds are present but are not abundant. The sandstone beds are fine- to coarse-grained, gray to light brownish gray. The beds are mostly soft and nonresistant but locally contain resistant slabs and ledges. The sandstone beds are massive to crossbedded and locally even-bedded. They are arkosic and generally contain much white mica. The claystone and mudstone beds are olive green and gray and are nonresistant. The carbonaceous shale is chocolate brown, silty and fissle to blocky and locally contains abundant ironstone nodules. Coaly beds occur in the lower to middle part of the upper member in the Coalmont area. Hail (1968) states, "Estimates from outcrops indicate that the upper member may be as much as 5,500 feet thick within the northeastern part of the area. . ."

The White River Formation is Oligocene in age and unconformably overlies the Coalmont Formation. The White River Formation occurs as discontinuous lenses at the base of the North Park Formation along Peterson Ridge and Owl Ridge. The White River Formation ranges from 80 ft (24 m) at Owl Ridge to about 200 ft (61 m) along Peterson Ridge. The formation consists of gray, calcareous, tuffaceous claystone, siltstone, and sandstone.

The North Park Formation of Miocene age unconformably overlies the White River Formation. The North Park Formation consists of alternating orange to gray calcareous, nodular, ashy sandstone; conglomeratic sandstone; white, fine- to coarse-grained, hard, calcareous sandstone with intercalated beds of volcanic conglomerate and ash; pink siltstone, limestone, and patches of white, calcareous material with the appearance of spring deposits in some places containing tube-like veins and small irregular cavities filled with bluish-white calcite (Beekly, 1915; Hail, 1968; Kinney, 1970). The maximum thickness of the North Park Formation is about 1,800 ft (550 m) (Tweto, 1976).

## Structure

The axial trace of the North Park syncline passes through the northeast corner of the Mac Farlane Reservoir quadrangle. The synclinal axis is the structural low area of North Park. The axis is offset by a northeast trending fault in the northeast corner of the quadrangle. The axial trace of an unnamed anticline crosses the southwest corner of the quadrangle.

Numerous northwest-southeast trending faults occur in the west central part of the quadrangle (pl. 1 and 5). The faults are roughly parallel and form a series of horst-graben type fault blocks with displacements ranging from a few feet to over 300 ft (91 m). The faulted area is also the area of coal occurrence as determined by drilling. Any coal mining which may be planned for this area will certainly be influenced by these faults.

## COAL GEOLOGY

In the Mac Farlane Reservoir quadrangle, coal beds occur in the middle and the upper members of the Coalmont Formation. Thin, lenticular, local beds of coal and carbonaceous shale occur in the middle member as indicated in the log of the True Oil Company 41-10 Meyring well (pl. 3). The numerous coal beds were reported on an American Stratigraphic Company sample log. The thicknesses of the coal were determined from cuttings samples and geophysical logs and may not be highly accurate.

### Riach Coal Bed

The most important coal bed in the quadrangle is the Riach bed which occurs in the lower to middle part of the upper member of the Coalmont Formation (Hail, 1968). The Riach bed or zone includes a main bed and several thin beds. On plates 1 and 3 of this report the beds have been designated by the symbols R1, R2, R3 etc. The main Riach bed is referred to as the R1 bed and is overlain by the thinner Riach beds.

The R1 bed ranges from 2 to 13 ft (0.6 to 4.0 m) in thickness in the drilled area of the quadrangle. The bed thins eastward and was missing in two of the holes drilled in sections 23 and 24, T. 7 N., R 80 W. (pl. 1 and 4). The Riach bed thickens westward toward the Coalmont quadrangle as indicated by the coal isopach map, plate 4. The isopached area shown on plate 4 is restricted because of the limited drilling data and an insufficient data line bounds much of that area.

## 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, isolated data point maps are included on a separate sheet (in U.S. Geological Survey files) for non-isopachable coal beds. Resource data for these isolated data points were calculated for areas within ¼ mile (0.4 km) of the points of measurement and are given in table 2 and are shown by an asterisk on plate 2.

Table 2.--Isolated data points in the Mac Farlane Reservoir quadrangle, Jackson County Colorado

| Index Number (pl. 1,3) | Location | Coal Bed Name | Outcrop or Drill Hole | Coal Thickness (ft)[1] | Measured area (ac)[2] | Resource Tonnage (s.t.)[3] |
|---|---|---|---|---|---|---|
| 1 | NE¼NE¼ sec. 10 T. 6 N., R. 80 W. | Local | Drill Hole | 6.0 | 80 | 800,000 |
| 1 | NE¼NE¼ sec. 10 T. 6 N., R. 80 W. | Local | Drill Hole | 6.0 | 80 | 800,000 |
| 1 | NE¼NE¼ sec. 10 T. 6 N., R. 80 W. | Local | Drill Hole | 6.0 | 80 | 800,000 |

[1] To convert feet to meters, multiply feet by 0.3048
[2] To convert acres to hectares, multiply acres by 0.4047
[3] To convert short tons to metric tons, multiply short tons by 0.9072

## PROXIMATE ANALYSES OF THE COAL

Tables 3 and 4 show the proximate analyses of coal samples taken from the Riach coal bed in two mines located in the adjoining Coalmont quadrangle.

Table 3.--Proximate analysis of coal (as received) from the Riach bed in the Riach mine, sec. 24, T. 7 N., R. 81 W., Jackson County, Colorado (Beekly, 1915)

| Lab Sample No. | Moisture % | Volatile Matter % | Fixed Carbon % | Ash % | Sulphur % | Heat Value Btu/lb[1] |
|---|---|---|---|---|---|---|
| 12601 | 22.8 | 36.2 | 34.1 | 6.90 | 0.70 | 9,010 |

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

Table 4.-- Proximate analysis of coal (as-received) from the Riach bed in the Grizzly Creek strip mine, sec. 32 T. 7 N., R. 80 W., Jackson County, Colorado (Boreck and others, 1977)

| Sample No. | Moisture % | Volative Matter % | Fixed Carbon | Ash % | Sulphur % | Heat Value Btu/lb |
|---|---|---|---|---|---|---|
| 75-H-11 | 14.5 | 29.3 | 24.7 | 31.5 | 0.6 | 6,520 |
| 75-H-12 | 17.2 | 37.3 | 36.9 | 8.6 | 0.6 | 9,520 |
| 75-H-13 | 17.8 | 32.0 | 37.1 | 13.1 | 1.0 | 8,600 |
| 75-H-14 | 19.4 | 33.7 | 41.4 | 5.5 | 0.7 | 9,570 |
| 75-H-15 | 20.2 | 34.5 | 34.1 | 11.2 | 0.9 | 8,630 |

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

On the basis of the analyses shown in tables 3 and 4, the Riach coal at the sampling sites is subbituminous B in rank (American Society for Testing and Materials, 1977). It is assumed that the Riach coal bed in the Mac Farlane Reservoir quadrangle is of similar rank.

## MINING OPERATIONS

Coal mining in North Park dates back to the late 1800's and early 1900's. Available information indicates that no coal mines have been developed in the Mac Farlane Reservoir quadrangle, but a number of mines (now inactive or abandoned) produced coal in the adjoining Coalmont quadrangle. Information pertaining to these mines is listed in table 5.

Coal was first mined commercially in the Coalmont district about 1909 and continued to be mined until near the close of World War II. The district was idle until about 1959 when a surface mine was opened in the NE¼ sec. 23, T. 7 N., R. 81 W. Then in 1975 the Grizzly Creek mine was opened in sec. 32, T. 7 N., R. 80 W. It operated about one year.

Table 5.--Coal mines (abandoned) in the Coalmont quadrangle, Jackson County, Colorado

| Mine Name | Approximate Location[1] | Coal Bed Name | Coal Thickness (ft)[2] | Production (s.t.)[3] | Period(s) of Operation |
|---|---|---|---|---|---|
| Coalmont | Sec. 23, 24 T. 7 N., R. 81 W. | Riach | 20-65 | 310,179 | 1909-19 |
| Grizzly Creek | Sec. 32 T. 7 N., R. 80 W. | Riach | 25 | 65,000 | 1975 |
| Moore No. 1 (Rabbit Ear) | Sec. 23-26 T. 7 N., R. 81 W. | Riach | 30-50 | 647,173 | 1922-34, 1938 |
| Moore No. 2 | Sec. 24, T. 7 N., R. 81 W. | Riach | 30-75 | 9,060 | 1922-24 |
| Moore and Moore | Sec 25, 26 T. 7 N., R. 81 W. | Riach | 20-40 | 493,127 | 1915-21, 1935-51 |
| Rosebud | Sec. 14,23,26 T. 7 N., R. 81 W. | Riach | 13 | 313,460 | 1958-60 |

[1] Locations reported by the Colorado Division of Mines (personal communication). Specific locations and outlines of mined areas are unknown.
[2] To convert feet to meters, multiply feet by 0.3048
[3] To convert short tons to metric tons, multiply short tons by 0.9072

## COAL RESOURCES

The principal source of data used in the construction of the coal isopach, structure contour, and coal data maps was Madden (1977). Several oil and gas test wells have been drilled in the area and the available logs of these wells 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 an individual 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°. 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 measured depth 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 Riach 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 subsurface mining recoverability factor of 50 percent and a surface mining recoverability factor of 85 percent.

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 workings, 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 (0.8 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 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 m) and 3,000 ft (914 m) below ground level in beds having dips of less than 15° is considered mineable 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 44.5 million short tons (40.4 million metric tons) for the unleased Federal coal lands within the quadrangle. Reserve Base (in short tons) in the various development potential categories for surface and subsurface mining methods are shown in tables 6 and 7.

Resource tonnages calculated for isolated data points (non-isopached coal beds) are classified as inferred coal and placed in the unknown development potential category. The coal resources for the isolated data points are shown in table 2 and total 2.4 million short tons (2.2 million metric tons). In this quadrangle, coal resources of unknown development potential are projected to extend as a ¼ mile (0.4 km) wide belt from the outcrop or points of measurement at the isolated data points.

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

Table 6.--Coal Reserve Base data for Surface mining methods for Federal coal lands in the Mac Farlane Reservoir quadrangle, Jackson County, Colorado (in short tons)[1]

| Coal Bed Name | High development potential (0-10 mining ratio) | Moderate development potential (10-15 mining ratio) | Low development potential (>15 mining ratio) | Total |
|---|---|---|---|---|
| Riach coal bed | 6,100,000 | 800,000 | 800,000 | 7,700,000 |

[1]To convert short tons to metric tons, multiply by 0.9072.

Table 7.--Coal Reserve Base data for subsurface mining methods and in situ coal gasification for Federal coal lands in the Mac Farlane Reservoir quadrangle, Jackson County, Colorado. (in short tons)[1]

| Coal Bed Name | High Development Potential | Moderate Development Potential | Low Development Potential | Total |
|---|---|---|---|---|
| Riach coal bed | 36,800,000 | -0- | -0- | 36,800,000 |

[1]To convert short tons to metric tons, multiply by 0.9072.

## 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 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 2 percent of the unleased Federal land area in this quadrangle is classified as having a high-development-potential using surface mining methods, less than 1 percent has a moderate-development potential; and 2 percent has a low development potential. 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 13 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. 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 within the quadrangle 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. 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 this quadrangle generally have dips less than 15°

and are not classified as having a development potential for using in situ coal gasification methods.

Reserves have not been calculated for the non-isopached coal beds at isolated data points. The areas controlled by those points have been assigned an unknown development potential. Resource tonnages included in the unknown development potential category for areas within ¼ mile (0.4 km) of isolated data points are shown in table 2. No distinction has been made between surface and subsurface mining resources in the areas controlled by isolated data points.

Table 8.--Sources of data used on plate 1.

| Source | Plate 1 Index No. | Drill Hole or Measured Section No. in Reference Source |
|---|---|---|
| True Oil Co. well logs and American Stratigraphic Co. log D-4693 | 1 | 41-10 Meyring well |
| Madden, 1977 | 2 | M-11, p. 39-41 |
| Do. | 3 | M-100, p. 109-110 |
| Do. | 4 | M 104, p. 119 |
| Do. | 5 | M-41, p. 65-67 |
| Do. | 6 | M-12, p. 42-44 |
| Do. | 7 | M-5, p. 22-24 |
| Do. | 8 | M-108, p. 120 |
| Do. | 9 | M-102, p. 116-118 |
| Do. | 10 | M-6, p. 28-30 |
| Do. | 11 | M-36, p. 62-64 |

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