Text to accompany:

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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE HANNA QUADRANGLE, CARBON COUNTY, WYOMING

(Report includes 12 plates)

Prepared for:

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GEOLOGICAL SURVEY

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[Plates are in pocket]

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INTRODUCTION

Purpose

This text is to be used along with the accompanying Coal Resource Occurrence (CRO) maps and the Coal Development Potential (CDP) maps of the Hanna quadrangle, Carbon County, Wyoming (12 plates; U.S. Geol. Survey Open-File Report 78-054),prepared by Texas Instruments Incorporated under contract to the U.S. Geological Survey. This report was prepared to support the land planning work of the U.S. Bureau of Land Management's Energy Minerals Activities Recommendation Systems (EMARS) program, and to contribute to a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA) in the western United States. The Coal Resource Occurrence maps and the Coal Development Potential maps for this quadrangle cover part of the south-central portion of the KRCRA of the Hanna coal field.

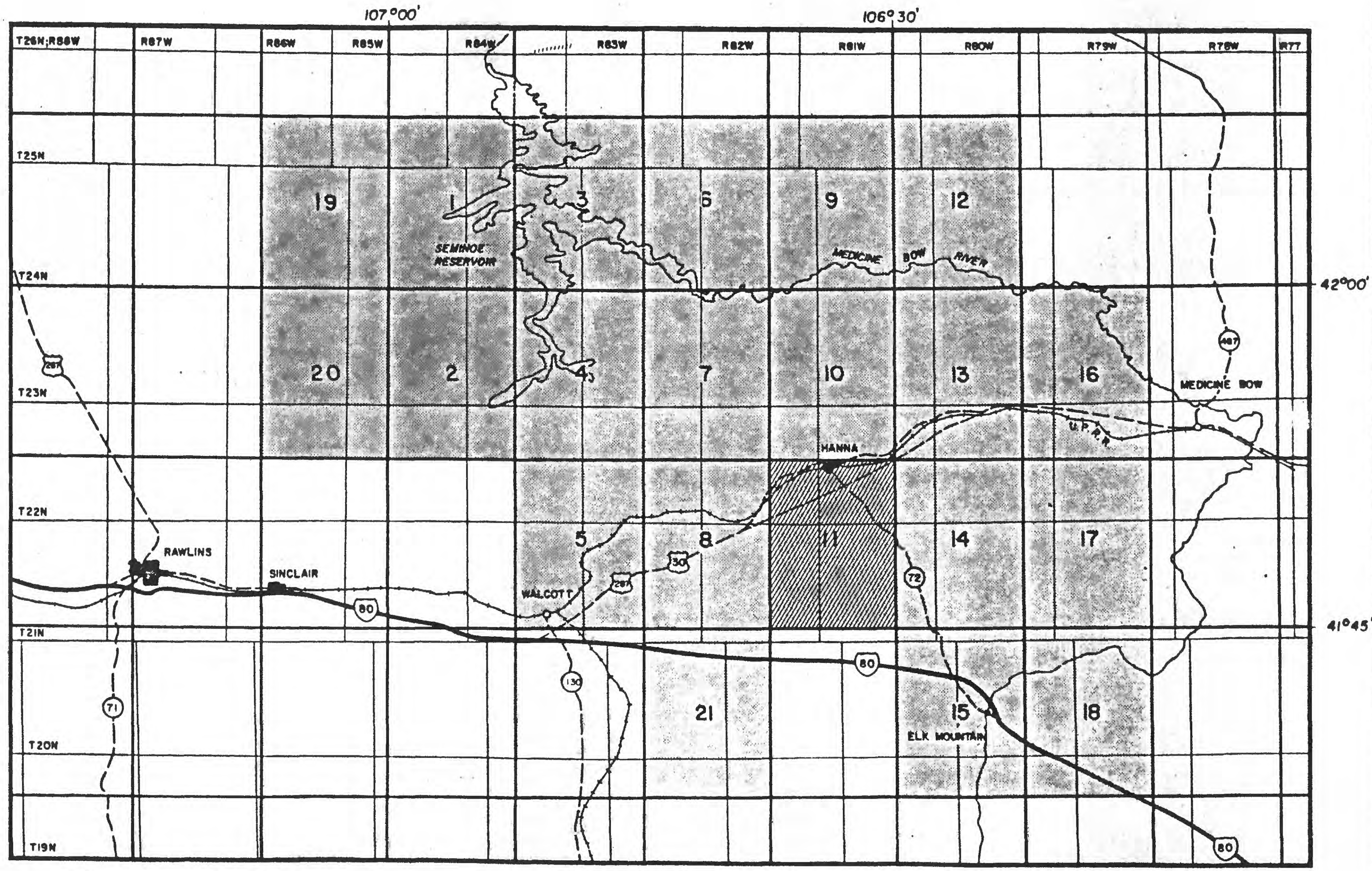
Acknowledgment

Texas Instruments Incorporated acknowledges the cooperation of the Rocky Mountain Energy Company, a wholly owned subsidiary of the Union Pacific Railroad Company, in supplying copies of survey sheets, drillers reports, electric logs, and coal analyses from the Union Pacific coal inventory program.

The Hanna and Carbon coal basins were studied as part of the inventory program and test drilling was conducted in 1970-1971. More than 650 Union Pacific coal drill holes have been evaluated as part of this contract study of 21 quadrangles in Carbon County, Wyoming, and the results and 230 coal analyses have been incorporated into these reports.

Location

The Hanna 7½-minute quadrangle is in the northeast part of Carbon County, Wyoming. The center of the quadrangle is approximately 15 miles (24 km) northeast of Walcott and 20 miles (32 km) southwest of Medicine Bow, Wyoming (Figure 1). The town of Hanna is located in the north-central part of the quadrangle.



Hanna quadrangle (11)

Scale 1:446,000

Figure 1. — Map of the Hanna and Carbon Basin study area

Accessibility

Access to the Hanna quadrangle is by three major highways and the main line of the Union Pacific Railroad. U.S. Interstate Highway 80 enters the southeastern corner of the quadrangle from the town of Rawlins to the west, and continues beyond the quadrangle to the town of Laramie to the southeast. U.S. Highway 30/287 crosses the north half of the quadrangle from east to west, providing access from Medicine Bow, 20 miles (32 km) to the northeast, and from Walcott, 15 miles (24 km) to the southwest. State Highway 72 leaves U.S. Highway 30/287 at Hanna Junction, traverses southeasterly to the east-central border, and continues southeasterly beyond this quadrangle for an additional 11 miles (18 km), to the town of Elk Mountain. A secondary paved highway connects Hanna Junction, Hanna, and the town of Como, immediately north of the northeast boundary of the quadrangle.

Numerous light-duty roads lead from Hanna to Hanna Reservoir, to the south-southwest; to the coal mines of Arch Mineral Corporation and Energy Development Company, west and northwest of this quadrangle; to the strip mines of Rosebud Coal Sales Company and Arch Mineral Corporation, north and northeast of this quadrangle; and to the north, to connect with the Medicine Bow-Seminoe Dam service road near Troublesome Creek, north of the Medicine Bow River. Numerous unimproved roads provide ready access from the highways and light-duty roads to the remaining areas of the quadrangle.

The main east-west tracks of the Union Pacific Railroad pass through the town of Hanna, from Medicine Bow to the east, to Sinclair and Rawlins to the west. Two mining company branch lines leave the main tracks near Hanna. The rail spur of Energy Development Company branches west of the town and serves the company's mines located west of this quadrangle. The rail spur of Rosebud Coal Sales Company leaves the main tracks 1 mile (1.6 km) east of Hanna and services the open-pit mines to the northeast.

Physiography

The Hanna quadrangle is located on the south-central rim of the Hanna structure basin and the physiography of the area closely reflects the bedrock and structural geology.

The southwestern area is underlain by flat-lying sands, clays, and marls of the North Park Formation, of Tertiary age. This grassy upland area, only lightly dissected, is drained by the Saint Marys, Martinez Springs, Dana Springs, and Kinney Creeks. Elevations vary from 6,900 to 7,100 feet (2,100 to 2,160 m) over Dana Meadows and the low hills to the south. The northern and eastern limits of this area are the ridges north of Saint Marys Creek and east of Kinney Creek. The more gentle dip slopes of these ridges face south and east to Dana Meadows and the area south of Kinney Reservoir; the steeper north- and east-facing ridge slopes, marking the limits of the North Park Formation, overlook the lower ground which is underlain by the Late Cretaceous-Tertiary sedimentary sequence of the Hanna Basin. Maximum elevation on Wilson Ridge is 7,460 feet (2,274 m) and the local relief is 100 to 250 feet (30 to 76 m).

The southeastern area is underlain by the oldest formations within the quadrangle; the sediments dip north and northwest on the nose and west flank of the Elk Mountain anticline. In the extreme southeast corner the high ground is underlain by resistant strata of the Mesaverde Formation; the top of the formation is marked by the north- and northwest-facing dip slopes of Halleck Ridge. Maximum elevation at the locality is 7,701 feet (2,347 m) and the local relief of Halleck Ridge is more than 300 feet (91 m). The overlying Lewis Shale occupies the valley immediately north of Halleck Ridge, at elevations of 7,120 to 7,250 feet (2,170 to 2,210 m). The lightly dissected upland area further north, as far as the north bank of Percy Creek, is underlain by the more resistant sediments of the Medicine Bow and Ferris Formations.

The east-central and northern areas of the quadrangle are underlain by Hanna sediments which, regionally, dip north toward the center of the Hanna Basin. Locally, dip of the sediments is toward the Hanna syncline; the northeast trending axial trace of this structure extends from the center of sec. 6, T. 21 N., R. 81 W. to the northwest quarter of sec. 21, T. 22 N., R. 81 W. Thus, the topography of the northern area is one of dissected upland grasslands, and prominent arcuate ridges whose dip slopes face inwards to the center of the Hanna syncline. The Sand Hills in the east-central part of the quadrangle and the prominent ridges west of Hanna are typical of the terrain that results from the differential weathering of resistant sandstones and conglomerates in the Hanna Formation. Elevations over the northern half of the quadrangle range from 6,700 to 7,260 feet (2,040 to 2,210 m).

Tributary drainage within the quadrangle is to the two major westerly flowing creeks, Big Ditch in the north half and Saint Marys Creek in the south half.

Climate

Climate data for the Hanna quadrangle were obtained from the Elk Mountain weather station located 12 miles (19 km) southeast of the center of the quadrangle at an elevation of 7,270 feet (2,216 m). Precipitation records are available for 65 years to 1970 and temperature records are available for 22 years to 1970.

The climate is semiarid with a mean annual temperature of 41°F (5°C) and extremes ranging from 95° to -42°F (35° to -41°C). July is the warmest month with a mean monthly temperature of 63°F (17°C) and January is the coldest month with 22°F (-6°C). For seven months of the year, April to October, the mean monthly temperature exceeds 32°F (0°C). Average annual precipitation is 15 inches (38 cm) with 50 percent of this total falling in the five months from March to July. Part of the precipitation in March, April, and May is in the form of snow. Average annual snowfall is 108 inches (274 cm) with 64 percent falling in the four months of January to April. Snow rarely falls in July and August but an inch or more of snow may fall in any other month. March is the month of maximum snowfall (18 inches or 46 cm).

High winds are common throughout most of the year. The prevailing wind direction, as recorded at four weather stations around the perimeter of the Hanna and Carbon Basins, is westerly for all twelve months of the year. The growing season is restricted to less than 100 days between late May and early September which are the average times of the last killing spring frost and the first killing fall frost, respectively.

Land Status

The quadrangle is in the southern part of the KRCRA of the Hanna and Carbon Basins. The Federal Government owns approximately 35 percent of the coal rights in the quadrangle; the remaining 65 percent is non-federally owned.

Approximately 45 percent of the area of the quadrangle is included in the KRCRA, and within this region about 33 percent of the land is federally owned, with about 40 percent of the Federal land leased for coal. Plate 2 of the CRO maps illustrates the ownership status of land in the quadrangle and the boundary of the KRCRA.

There are seven abandoned underground coal mines and two inactive strip mines in the quadrangle (Plate 1). The seven underground mines of the Union Pacific Coal Company operated between 1889 and 1946, mining the coal beds H1, H2, and H5 in the Hanna syncline. The Hanna No. 1, Hanna No. 2, Hanna No. 3, Hanna No. 3½, Hanna No. 4, Hanna No. 5, and Hanna No. 6 mines produced about 280 million short tons (254 million t) of coal over than 58-year period, with 90 percent of the production from the Hanna No. 1, No. 2, and No. 4 mines (Glass, 1972). The inactive strip mines are: The Rosebud No. 1 pit of the Rosebud Coal Sales Company, which mined coal bed H5 from 1961 to recently; the Rimrock No. 3 pit in secs. 10 and 15, T. 22 N., R. 82 W. of Energy Development Company, which mined coal bed BB (the Brooks Bed) from 1970 to recently.

GENERAL GEOLOGY

Previous Work

Dobbin, Bowen, and Hoots (1929) mapped the Hanna quadrangle as part of their study of the geology and coal and oil resources of the Hanna and Carbon Basins. Weitz and Love (1952) compiled a geologic map of Carbon County which incorporates available data, published and unpublished, to that date. Gill, Merewether, and Cobban (1970) provide a detailed description and discussion of the more important sedimentary rock formations of the area.

Stratigraphy

Rocks exposed in the Hanna quadrangle range in age from Late Cretaceous to Quaternary. Coal beds are found in the Medicine Bow Formation of Late Cretaceous age, in the Ferris Formation of Late Cretaceous/Paleocene age, and in the Hanna Formation of Paleocene age.

The oldest unit exposed in the quadrangle is the Mesaverde Formation of Late Cretaceous age as mapped by Dobbin, Bowen, and Hoots (1929). Later studies by Gill, Merewether, and Cobban (1970) have resulted in elevating the

Mesaverde to group status and measuring and defining four separate formations within the group. Surface mapping delineating the formations of the Mesaverde Group has not been extended into the Hanna quadrangle, however, and the group is considered in this report as a unit.

The Mesaverde sediments are exposed in the extreme northeastern corner of the Hanna quadrangle on the west flank of the Elk Mountain anticline (also called the Bloody Lake anticline, Beckwith, 1949). Dobbin, Bowen, and Hoots (1929) give a thickness of 2,700 feet (823 m) for the Mesaverde in this area. They describe the formation as containing a lower unit, of marine origin, which consists of indurated white to gray massive to thin-bedded and cross-bedded sandstones, alternating with thinner beds of gray shale. A middle member of the formation, which is of fresh to brackish water origin, consists of gray to brown thin-bedded to massive sandstones, alternating with beds of gray carbonaceous shale and thin irregular beds of coal. The top member of the formation is predominantly nonmarine and consists of white to gray sandstones, alternating with beds of gray shales and thin beds of carbonaceous shale and coal.

The Upper Cretaceous Lewis Shale conformably overlies the Mesaverde with a gradational contact. In the Hanna quadrangle it is exposed in a band across the southeastern corner. The thickness for the unit in this area is approximately 3,300 feet (1,006 m). The formation consists for the most part of dark-gray marine shales with numerous intercalated beds of sandy shale and gray ripple-marked and cross-bedded to massive sandstone. Dobbin, Bowen, and Hoots (1929) state that the Fox Hills Sandstone is represented in the upper part of the Lewis Shale but they did not differentiate it in their mapping of the Hanna quadrangle.

The Upper Cretaceous Medicine Bow Formation conformably overlies the Lewis Shale in this quadrangle; it is exposed in a band across the southeast part. Dobbin, Bowen, and Hoots (1929) give a thickness of 6,200 feet (1,890 m) for the Medicine Bow Formation in this area. They describe the formation as consisting of yellow, gray and carbonaceous shales, beds of coal, and gray and brown sandstones. The lower part of the formation is made up of brown massive to cross-bedded sandstones that contain numerous beds of coal. These sandstones are overlain by an intermediate group of gray shales and brown fine-grained thin-bedded sandstones with some beds of massive white sandstone. The sandstones at the top of the formation are coarse grained, massive, and friable and are interbedded with thick beds of dark-gray shale. The depositional environment of the formation is dominantly fresh-water with occasional brackish-water elements, except in the lower part where there are sandstone beds with a marine fauna of Fox Hills type.

Conformably overlying the Medicine Bow Formation is the Ferris Formation. This latter formation is exposed in a band across the southeastern portion of the quadrangle and along the northwestern border. The Ferris Formation is about 6,500 feet (1,981 m) thick at its type locality near the old Ferris Ranch on the North Platte River, 18 miles (29 km) northwest of the center of the Hanna quadrangle. The formation consists of a thick sequence of continental rocks that can be divided into two parts: a lower unit of Late Cretaceous age which is about 1,100 feet (335 m) thick and an upper unit of Paleocene age which is about 5,400 feet (1,646 m) thick. The basal 300 feet (91 m) of the lower unit consists of dark-gray shales and buff to yellow coarse-grained friable massive sandstones with irregular thin beds of conglomerate. The overlying 800-foot (244-m) portion of the lower unit is made up largely of conglomerate which occurs as pockets, lenses, and thin beds irregularly distributed throughout the sandstone. The upper unit of the Ferris Formation consists of gray, brown and yellow sandstones interbedded with numerous thick beds of coal.

The Hanna Formation of Paleocene age unconformably overlies the Ferris Formation. The Hanna Formation is exposed across the northern half of the quadrangle, and in this area Dobbin, Bowen, and Hoots (1929) give a thickness of 7,000 feet (2,134 m) for the unit. The formation consists of conglomerates, conglomeratic sandstones, sandstones, shales, and many thick beds of coal. The conglomerate occurs throughout the formation but is most abundant in the lower half. Thick conglomeratic sandstone and, locally, massive conglomerate mark the base of the formation. The sandstones of the formation range from coarse-grained massive or thick-bedded varieties to fine-grained thin-bedded sandstones which weather brown and split into thin slabs. The coarse-grained varieties are buff to grayish-white, commonly conglomeratic, and highly feldspathic. The conglomerates of the Hanna Formation differ from those of the Ferris in color and in the size and composition of the clasts.

The North Park Formation unconformably overlies older rock units in the Hanna quadrangle. It is exposed in the southwestern part of the quadrangle where it onlaps the Medicine Bow, Ferris, and Hanna Formations. Dobbin, Bowen, and Hoots (1929) state that the formation in this area does not exceed a few hundred feet in thickness and they tentatively assign it a Miocene age. McGrew (1951), on the basis of mammalian fauna, assigns an early Pliocene age to the formation. The North Park Formation consists chiefly of white fine-grained unconsolidated sands, sandy clays, and marls, with occasional intercalated thin beds of gray limestone.

Quaternary alluvium has been mapped along the Big Ditch drainage channel in the north part of the quadrangle.

Structure

The Hanna quadrangle is on the south-central rim of the intermontane Hanna Basin. This structural basin is comparatively small in areal extent, 40 miles (64 km) east-west and 25 miles (40 km) north-south, but very deep. In its central portion, the southeast part of T. 24 N., R. 82 W., about 14 miles (22 km) north of the center of this quadrangle, there are 30,000 to 35,000 feet (9,140 to 10,670 m) of sediments overlying crystalline basement. The confines of the present basin were defined during the Laramide Orogeny when the bordering highlands of the basin were raised and deformed while sedimentary fill accumulated rapidly in the basin. Today the borderlands are characterized by complex folding and faulting while within the basin only mild deformation is expressed by a few broad folds and normal faults. The Late Cretaceous sea retreated temporarily from southern Wyoming in Mesaverde time and made its final withdrawal in Fox Hills time, with the depositional environment changing from marine to continental.

In the north half of the quadrangle, the southern portion of the Hanna syncline is defined by beds of the Hanna Formation. Dips on the east flank and southern end of the syncline are 8° to 12°; dips on the west flank are 12° to 25°. The Hanna syncline is a subsidiary structure in the Hanna structural basin. The northeasterly axial trend of the syncline is parallel to the Saddleback Hills anticline to the east of the quadrangle.

In the southeast corner of the Hanna quadrangle the Mesaverde and Lewis Shale outcrops lie at the northern limit of the Elk Mountain (or Bloody Lake) anticline. This structure has a northeast trend and its axial trace is immediately to the east of this quadrangle. Dips on the west flank of the anticline are 37^{o} to 63^{o} to the northwest.

In the southwest part of the quadrangle the North Park Formation rests on older rocks with an angular unconformity. Beds in the North Park dip southwest at 37^{o} to 45^{o}.

In the northeast part of the quadrangle a series of northwest trending, parallel, normal faults displace the Hanna sediments. The faults extend across the axis of the Hanna syncline and are predominantly downthrown on the northeast. The local coal beds show vertical displacements ranging from 100 to 600 feet (30 to 183 m).

COAL GEOLOGY

Previous Work

The coal deposits of the Hanna and Carbon Basins have been studied by Veatch (1907), Dobbin, Bowen, and Hoots (1929), Berryhill and others (1950), and Glass (1972 and 1975).

Twenty-six coal analyses have been published since 1913 for coal beds of the Mesaverde Group and the Medicine Bow, Ferris, and Hanna Formations within the Hanna and Carbon Basins (Appendices 1 and 2). Samples collected and analyzed prior to 1913 have not been considered in this report (American Society for Testing and Materials, 1977, p. 218). An average analysis and apparent rank of coal beds in each of these four stratigraphic units has also been calculated for the 230 analyses from the Union Pacific coal inventory program (Appendices 1 and 2). A standard rank determination (ASTM, 1977, p. 216, sec. 6.2.2) cannot be made because (a) some of the published analyses are from weathered coal samples, and (b) the procedure and quality of sampling for the Union Pacific coal evaluation program are not known.

Glass (1975) and U.S. Department of Interior (1975) published not only proximate coal analyses for 17 samples collected in the Hanna Basin, but also assays for 10 major and minor oxides, 12 major and minor elements, and up to 32 trace elements. Glass (1975, p. 1) stresses that his assay data are insufficient to characterize the chemical and physical properties of any individual coal bed, but that this will be possible at a later date as the study continues. Assay results of the 17 Hanna Basin samples show that these coals contain no significantly greater amounts of trace elements of environmental concern than are found in the 42 samples collected in six other Wyoming coal fields.

General Features

In this quadrangle 29 coal beds and 12 local coal lenses have either been mapped by Dobbin, Bowen, and Hoots (1929) or identified in the subsurface (Plates 1 and 3).

Three coal beds occur in the Medicine Bow Formation, 2 coal beds and 3 local coal lenses in the Ferris Formation, and 24 coal beds and 9 local coal lenses in the Hanna Formation. Two coal beds, 65 and H1, were selected by U.S. Geological Survey for resource evaluation.

Medicine Bow Coal Beds

Outcrops of Medicine Bow coal beds are restricted to the southeast corner of the quadrangle. The three coal beds mapped on Plate 1 (95, 96, and 97), dip to the northwest at angles exceeding 50°. Measured thicknesses range from 1.9 to 4 feet (0.6 to 1.2 m).

Ferris Coal Beds

Of the two coal beds and three local coal lenses identified in the Ferris Formation, only coal bed 65 was selected for evaluation. Coal bed 66 and the three local coal lenses are below Reserve Base thickness at all measured locations. Coal bed 65 dips northeast at 21° and is 8.5 to 15 feet (2.6 to 4.6 m) thick. Only a short segment of the coal bed crops out in this quadrangle, in sec. 3, T. 21 N., R. 82 W.

Hanna Coal Beds

Coal bed and local lens thicknesses vary widely in the Hanna Formation, ranging from 0.1 to 24.8 feet (0.03 to 7.6 m). Dip directions also vary, depending upon the location of outcrops relative to the axis of the Hanna syncline. Dip angles range from 8° to 25° and dip directions vary from southeast, to north, to northwest.

Of the Hanna Formation coal beds, only coal bed H1 was selected for resource evaluation. Coal bed H1, located near the top of the formation, forms an elliptical outcrop pattern around the axis of the Hanna syncline and dips toward the axis at 8° to 12°. Measured thicknesses range from 5 to 21.5 feet (1.5 to 6.6 m).

COAL RESOURCES AND RESERVES

Previous Work

Coal reserves of the Hanna and Carbon Basins have been estimated or calculated by Dobbin, Bowen, and Hoots (1929), Berryhill and others (1950), and Glass (1972).

Method of Calculating Resources and Reserves

Data from Dobbin, Bowen, and Hoots (1929) and coal drill holes (written communications, Rocky Mountain Energy Company, 1977, and U.S. Geological Survey, 1978) were used to construct a coal data map (Plate 1) and a coal data sheet (Plate 3). U.S. Geological Survey reviewed these two plates and on the basis of Reserve Base criteria, selected two coal beds for the calculation of coal resources in the Hanna quadrangle. In addition, calculation of coal resources was requested for isolated or noncorrelatable data points.

The coal data map and coal data sheet were used to construct structure contour, coal isopach, and overburden isopach maps of the correlatable coal beds (Plates 4-9). For single coal beds, the maps were drawn using, as control points, thicknesses measured at outcrop and subsurface data from drill hole information. Where coal beds are split, cumulative coal thicknesses were used, excluding non-coal partings.

Plates 4-9 provide the data for calculating the coal resources and reserves within the KRCRA boundary of the quadrangle in accordance with the classification system given in U.S. Geological Survey Bulletin 1450-B and the instructions provided by U.S. Geological Survey on approval of these six plates. Calculation of the resources and reserves is in accordance with the following criteria:

- Identified coal resources of the quadrangle, as selected by U.S. Geological Survey, are contained within coal beds 65 and H1, and the resources defined by isolated or noncorrelatable data points.

- Coal bed thicknesses from surface mapping are true thicknesses; thicknesses from subsurface data are apparent thicknesses. Apparent thickness is corrected to true thickness if the dip of the selected coal bed exceeds 25°.

- Strippable coal resources (the resources capable of being extracted by strip-mining methods) are composed of single coal beds at least 5 feet (1.5 m) thick and having 200 feet (61 m) or less of overburden.

- Nonstrippable coal resources (subsurface resources capable of being mined by underground methods) are single or multiple coal beds with a minimum thickness of 5 feet (1.5 m); a maximum dip of 15°; an overburden, or combined overburden and interburden, thickness of 0 to 3,000 feet (914 m). To avoid duplicating strippable coal Reserve Base and reserve values, no nonstrippable coal Reserve Base and reserve values are calculated where a coal bed(s) occurs above the stripping limit. When calculating nonstrippable coal Reserve Base values, an average thickness for each coal bed is determined from the coal bed thicknesses at control points within a measured area. When calculating nonstrippable coal reserve values, the average thickness for each coal bed is determined in a like manner after coal bed thicknesses greater than 12 feet (3.7 m) have been reduced to 12 feet (3.7 m).

- All coal deeper than 3,000 feet (914 m) is excluded.

- Reliability or geologic assurance categories (measured, indicated, and inferred resources) are defined according to proximity of the coal to a data point. Measured resources occur within 0.25 mile (402 m) of a data point; indicated resources occur within an area that is 0.25 to 0.75 mile (402 m to 1.2 km) from a data point; inferred resources occur within an area that is 0.75 to 3 miles (1.2 to 4.8 km) from a data point. A data point is either a measured coal thickness in a drill hole or a measured coal location on a mapped outcrop.

- Coal resources from isolated or noncorrelatable data points are calculated for a single coal bed at least 5 feet (1.5 m) thick or for an aggregate thickness of multiple coal beds each at least 5 feet (1.5 m) thick. The single coal bed, or the stratigraphically highest bed in an aggregate of coal beds, is locally projected up dip to the surface to establish an inferred outcrop. Strippable coal resources for the projected bed or beds are considered to occur from surface to a depth of 200 feet (61 m); nonstrippable coal resources are considered to occur from surface to a depth of 3,000 feet (914 m). Only the coal resources underlying an area within 0.5 miles (804 m) of a drill hole or a measured surface outcrop are considered, and they are assigned to the inferred category of reliability.

- Coal resources are calculated for unleased Federal land within the KRCRA boundary (Plate 2). Information pertaining to leased or fee acreage and to non-Federal land is considered proprietary and not for publication.

In preparing a map for evaluating the areal distribution of identified resources for the isolated or noncorrelatable coal beds, some data require a unique solution. For example:

- Where short segments of coal bed outcrop have data points that indicate a coal thickness of 5 feet (1.5 m) or more, an arc with a radius equal to half the outcrop length is drawn down dip from the outcrop, connecting to the ends of the outcrop. The resulting contained area defines the total coal resource, segmented into strippable and nonstrippable resource sections.
- Where a coal bed outcrop has data points with coal thicknesses less than 5 feet (1.5 m), a 5-foot (1.5-m) cut-off point is interpolated and the resulting segments with values greater than 5 feet (1.5 m) are used to generate arcs (radii equal to half the outcrop length) for defining the extent of the coal resources. When several data points occur on the outcrop of a resource area, an average of their coal thickness values is used to calculate a tonnage of coal.
- Where areas within outcrop segment arcs and areas with 0.5 mile (804 m) of a drill hole coincide, the areas are combined and drill hole coal thickness values are averaged with outcrop coal thickness values.
- When evaluating multiple coal beds of an isolated or noncorrelatable data point, the interburden between subsurface coal beds may be too great to allow the aggregate thickness of coal to be considered as one planar unit. In such instances, a conservative judgment is made and the resources for each coal bed are calculated separately and then totaled.

Results

The areal distribution of leasable Federal coal resources within the KRCRA boundary is shown on Plate 10 for one of the two selected coal beds. Evaluation of coal bed 65 showed that no mappable coal resources are present beneath unleased Federal land; therefore, the coal bed is excluded from Reserve Base and reserve calculations.

The coal resource acreage within each area of unleased Federal land was determine by planimeter. Coal Reserve Base values are obtained by multiplying the coal resource acreage for the planimetric portion of each area of unleased Federal land by the average isopach value of the selected coal bed H1, times the conversion factor for subbituminous coal, 1,770 short tons

(1,606 t) of coal per acre-foot. The coal Reserve Base tonnages are recorded as follows:

- from coal bed H1: 0.18 million short tons (0.16 million t); assigned to measured, indicated, or inferred categories; shown on Plate 10; included in the coal Reserve Base totals shown on Plate 2.
- from isolated or noncorrelatable data points: 0.50 million short tons (0.45 million t) of strippable resources, assigned to the inferred resource category, and included in the coal Reserve Base totals shown on Plate 2.

In summary, the total Reserve Base for all coal beds thicker than 5 feet (1.5 m), that lie less than 3,000 feet (914 m) below the ground surface of unleased Federal land within the KRCRA in the Hanna quadrangle, is 0.68 million short tons (0.62 million t).

Coal reserves for the quadrangle are calculated by applying recovery factors to the measured, indicated, and inferred resources of coal bed H1. The inferred resources determined from the isolated or noncorrelatable data points are excluded from coal reserve calculations. For strippable resources, a recovery factor of 0.85 is used; for nonstrippable resources, the recovery factor is 0.50. Reserve tonnages, to the nearest ten thousand short tons, are shown on Plate 10. Total coal reserves for unleased Federal land within the KRCRA in the Hanna quadrangle, are 0.15 million short tons (0.14 million t) recoverable by strip mining or by underground mining.

COAL DEVELOPMENT POTENTIAL

Method of Calculating Development Potential

Following the calculation of Reserve Base values and coal reserves, the coal resources of the KRCRA of the Hanna quadrangle, except those coal resources determined from isolated or noncorrelatable data points, are evaluated for their development potential in each of two mining-method categories, surface and subsurface.

Strippable and nonstrippable resources are assigned to one of four development potential categories (high, moderate, low, and unknown) according to the following criteria:

Strippable Resources

- Assignment is based on calculated mining-ratio values for subsurface data points (wells and drill holes) and for points of intersection of coal isopachs (Plates 5 and 8) and overburden isopachs (Plates 6 and 9).

- The formula used to calculate mining ratios was provided by U.S. Geological Survey as follows:

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

where

MR = mining ratio

t_o = thickness of overburden, in feet

t_c = thickness of coal, in feet

rf = recovery factor (0.85 for strip mining)

0.911 = a constant

- If mining ratio is 0-10, resources have high development potential.

  If mining ratio is 10-15, resources have moderate development potential.

  If mining ratio is greater than 15, resources have low development potential.

- If insufficient data prevent the construction of mining-ratio contours, the resources are assigned to unknown development potential category, provided that there is reasonable assurance the coal bed is present in that area.

Nonstrippable Resources

- Coal beds must be more than 5 feet (1.5 m) thick. Coal beds less than 5 feet (1.5 m) thick are excluded from the Reserve Base coal resources; where coal beds are more than 12 feet (3.7 m) thick, thickness values are reduced to 12 feet (3.7 m).

- If the overburden is between 0 and 1,000 feet (0 and 305 m), resources have high development potential; if the overburden is between 1,000 and 2,000 feet (305 and 610 m), resources have moderate development potential; if the overburden is between 2,000 and 3,000 feet (610 and 914 m), resources have low development potential.

- If insufficient data prevent the construction of coal isopachs or overburden isopachs, or if the correlatable coal bed in the area is located completely above the stripping limit, the resources are assigned to the unknown development potential category, provided that there is reasonable assurance the correlatable coal bed is present in the area.

By applying the above criteria, mining-ratio maps were prepared for the selected coal beds 65 and H1. Evaluation of the mining-ratio map for coal bed 65 with respect to Plate 2 showed that this coal bed had no development potential beneath unleased Federal land within the KRCRA boundary.

Development potential acreages for coal bed H1 were then blocked out, as shown on CDP Plates 11 and 12. Acreage for strippable and nonstrippable resources from this selected coal bed are recorded in the following sections of this report. In accordance with a constraint imposed by the U.S. Bureau of Land Management, the highest development potential affecting any portion of a 40-acre (16 ha) parcel is applied to the entire parcel. For example, if 5 acres (2 ha) within a parcel are assigned a high development potential, 25 acres (10 ha) a moderate development potential, and 10 acres (4 ha) a low development potential, then the entire 40 acres (16 ha) are assigned a high development potential.

Development Potential for Strippable Resources

Development potential for strippable coal resources of coal bed H1 within unleased Federal land in the KRCRA of this quadrangle, is shown on Plate 11. Values are obtained after assigning the highest assessed development potential for any coal bed within the smallest legal subdivision to that subdivision.

There are approximately 2,720 acres (1,101 ha) of unleased Federal land within the KRCRA of this quadrangle. Of this area, 80 acres (32 ha) or 2.9 percent of the total, are estimated to be underlain by coal resources from the selected coal bed, with development potential for surface mining. Of the 80 acres (32 ha), a high development potential is assigned to 40 acres (16 ha) and an unknown development potential to 40 acres (16 ha).

Of the 2,720 acres (1,101 ha) of unleased Federal land, there are 560 acres (277 ha) or 21 percent of the total, which are classifiable as of unknown surface mining potential on the basis of both (a) the presence of outcrops of noncorrelatable coal beds of unknown thickness and (b) data gaps on beds selected for coal resource evaluation.

Development Potential for Nonstrippable Resources

Development potential for nonstrippable coal resources of coal bed H1 within unleased Federal land in the KRCRA of this quadrangle, is shown on Plate 12. Values are obtained after assigning the highest assessed development potential for any coal bed within the smallest legal subdivision to that subdivision.

Of the 2,720 acres (1,101 ha) of unleased Federal land within the KRCRA of this quadrangle, 80 acres (32 ha) or 2.9 percent of the total, are estimated to be underlain by coal resources from the selected coal bed, with development potential for underground mining. An unknown development potential is assigned to all 80 acres (32 ha).

Of the 2,720 acres (1,101 ha) of unleased Federal land, there are 640 acres (259 ha) or 24 percent of the total, which are classifiable as of unknown subsurface mining potential on the basis of both (a) the presence of outcrops of noncorrelatable coal beds of unknown thickness and (b) data gaps on beds selected for coal resource evaluation.

Because mining ratio data for beds 65 and H1 on this quadrangle are confined to private lands, the U.S. Geological Survey requested that these two maps not be drafted for open file. The maps are, however, retained on file for reference.

Development Potential for In Situ Gasification

In situ gasification of coal on a commercial scale has not been done in the United States and criteria for rating the development potential of this method are unknown.

The Bureau of Mines authorized a field project to study the technical, environmental, and economic feasibility of underground coal gasification (UCG) in 1972 (Nielson, 1977, p. 286). The Hanna No. 1 coal bed was chosen for experimentation. It is a 30-foot thick subbituminous coal seam ranging in depth from 300 to 400 feet. Location of the experimental site was sec. 29, T. 22 N., R. 81 W., in this quadrangle.

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Appendix 1. — Average analyses of coal samples from the Hanna and Carbon Basins

Source of Data	Number of samples (1)	Total footage		Average analyses – as-received basis						Calorific Value, Btu/lb	Apparent rank of coal (3)
				Percent							
		Ft	in	Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb	Moist, mineral-matter-free basis (2)	
Published analyses	26	318	6	12.5	7.1	36.2	44.2	0.6	10,553	11,438	sub A <u>or</u> hvCb
Union Pacific coal inventory program	230	1,605	10	12.48	8.74	35.12	43.68	0.82	10,398	11,494	sub A <u>or</u> hvCb

Notes:

(1) Published data from USBM (1931, p. 40-45, sample nos. 2623, 2624, 22800, 22972, 93486, 93488, 93541, A14123, A14124); Glass (1975, p. 16-19, sample nos. 74-23 to 74-34, inclusive); Dept. of Interior (1975, p. 38, sample nos. D169597-99, D169607-08). Union Pacific coal inventory program data from company files, Rocky Mountain Energy Company (1977).

(2) Moist, mineral-matter-free Btu/lb calculated from average analyses, as-received basis, using Parr formula (ASTM, 1977, p. 216, sec. 8.2).

(3) Sub A – subbituminous A; hvCb – high volatile C bituminous (ASTM, 1977, p. 215, sec 4.2, and p. 217).

[To convert feet and inches to meters, multiply feet by 0.3048 and inches by 0.0254. To convert Btu/lb to kilojoule/kilogram, multiply by 2.326].

Appendix 2. — Average analyses of coal grouped by coal-bearing formations in the Hanna and Carbon Basins

Source of data	Formation or Group	Number of samples (1)	Total footage		Average analyses — as-received basis						Calorific Value, Btu/lb	Apparent rank of coal (3)
					Percent							
			Ft	in	Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb	Moist, mineral-matter-free basis (2)	
Published analyses	Mesaverde	1	4	0	14.1	7.8	36.5	41.6	1.1	10,290	11,251	sub A or hvCb
	Medicine Bow	2	10	1	12.8	3.8	33.3	50.2	0.8	11,050	11,534	hvCb
	Ferris	10	93	1	13.0	8.3	34.3	44.3	0.4	9,970	10,956	sub A or hvCb
	Hanna	13	211	4	12.0	6.6	38.1	43.3	0.7	11,946	11,797	hvCb
Union Pacific coal inventory program	Mesaverde	13	70	5	9.45	8.41	35.42	46.72	0.77	11,112	12,237	hvCb
	Medicine Bow	16	93	4	13.09	4.03	35.46	47.42	0.80	10,927	11,446	sub A or hvCb
	Ferris	114	863	1	12.69	7.96	34.39	44.97	0.44	10,331	11,309	sub A or hvCb
	Hanna	87	579	0	12.51	10.67	35.96	40.85	1.33	10,280	11,640	hvCb

Notes:

(1) Published data from USBM (1931, p. 40-45, sample nos. 2623, 2624, 22800, 22972, 93486, 93488, 93541, A14123, A14124); Glass (1975, p. 16-19, sample nos. 74-23 to 74-34, inclusive); Dept. of Interior (1975, p. 38, sample nos. D169597-99, D169607-08). Union Pacific coal inventory program data from company files, Rocky Mountain Energy Company (1977).

(2) Moist, mineral-matter-free Btu/lb calculated from average analyses, as-received basis, using Parr formula (ASTM, 1977, p. 216, sec. 8.2).

(3) Sub A — subbituminous A; hvCb — high volatile C bituminous (ASTM, 1977, p. 215, sec. 4.2, and p. 217).

[To convert feet and inches to meters, multiply feet by 0.3048 and inches by 0.0254. To convert Btu/lb to kilojoule/kilogram, multiply by 2.326].

Appendix 3. — Coal analyses, Hanna quadrangle

Drill hole	Location			Coal bed	Sample interval						Analyses - as-received basis					
					From		To		Sample width		Percent					
	Sec.	Twp.	Rge.		Ft	in	Ft	in	Ft	in	Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb
1	3	21N	82W	65	214	6	227	0	12	6	16.93	12.87	32.54	37.66	0.63	8,512
1	3	21N	82W	65	229	4	237	6	8	2	16.58	6.16	37.09	40.17	0.23	9,537
2	15	22N	82W	L	72	6	78	6	6	0	12.28	6.13	35.13	46.46	0.31	10,800

Drill hole data from Rocky Mountain Energy Company (1977).

[To convert feet and inches to meters, multiply feet by 0.3048 and inches by 0.0254. To convert Btu per pound to kilojoules per kilogram (kJ/kg), multiply by 2.326].

Appendix 4. — Coal Reserve Base Data for Federal coal lands (in short tons) in the Hanna quadrangle, Carbon County, Wyoming.

Strippable coal Reserve Base data for Federal coal lands (in short tons) in the Hanna quadrangle, Carbon County, Wyoming [Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons, multiply by 0.9072]

Coal Bed	High Development Potential (0-10 mining ratio)	Moderate Development Potential (10-15 mining ratio)	Low Development Potential (>15 mining ratio)	Total
HI	140,000	0	0	140,000
Total	140,000	0	0	140,000