Text to accompany:

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

(Report includes 41 plates)

Prepared for:

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GEOLOGICAL SURVEY

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INTRODUCTION

Purpose

This text is to be used along with accompanying Coal Resource Occurrence (CRO) maps and the Coal Development Potential (CDP) maps of the Como West quadrangle, Carbon County, Wyoming (41 plates; U.S. Geol. Survey Open-File Report 78-047), 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 northeastern portion of the KRCRA of the Hanna coal field.

Acknowledgment

Texas Instruments Incorporated acknowledges the cooperation of the Rocky Mountain Energy Company, 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 Como West 7½-minute quadrangle is in the northeast part of Carbon County, Wyoming. The center of the quadrangle is in the northeast part of Carbon County, Wyoming. The center of the quadrangle is approximately 8 miles (13 km) northeast of Hanna and 13 miles (21 km) west-northwest of Medicine Bow, Wyoming (Figure 1).

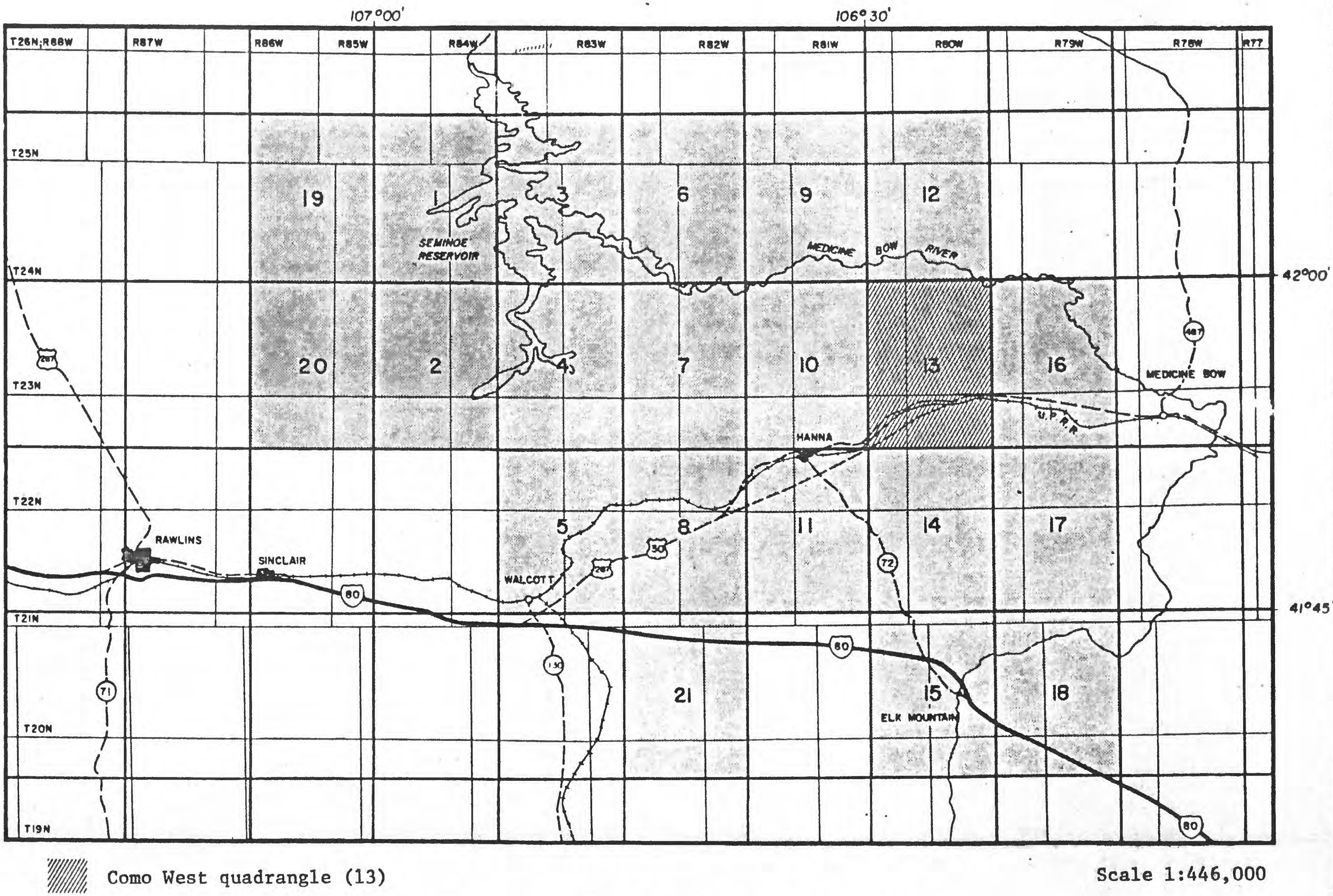

Figure 1. Map of the Hanna and Carbon Basin Study Area

Accessibility

U.S. Highway 30/287 and the main line of the Union Pacific Railroad cross the southern third of the quadrangle, providing access from the town of Medicine Bow 13 miles (21 km) to the east, and from the town of Hanna 8 miles (13 km) to the southwest, of the center of the quadrangle.

Four light-duty roads provide general access in the southern third of the quadrangle as follows:

- A light-duty road leaves U.S. Highway 30/287 near the southeastern border, proceeds south across the railroad tracks to the Chace Ranch, turns east, and leaves the quadrangle. Immediately east of the quadrangle, this road turns south and continues to the town of Elk Mountain, 18 miles (29 km) south of the center of this quadrangle.
- A second light-duty road leaves U.S. Highway 30/287 in the south-central area of the quadrangle; it closely follows the main railroad tracks on their north side, to the town of Como, less than 2 miles (3.2 km) west of the southwest corner of this quadrangle.
- At the southwest border of the quadrangle is part of the mine access road from Como to the Rosebud 5 open-pit mine of the Rosebud Coal Sales Company.
- In the same area is part of the mine access road from Como to the two abandoned Hanna Basin strip mines of the Hanna Basin Coal Company.

Numerous unimproved dirt roads provide access from the main highway and the light-duty roads to the ranches, water sources, grazing areas, mine prospects, and gravel pits in the remainder of the quadrangle. General access to the northeastern part of the quadrangle is restricted by the badlands topography bordering the Medicine Bow River.

In addition to the main line of the Union Pacific Railroad there is the branch railroad of the Arch Mineral Corporation, which leaves the main tracks in sec. 14, T. 22 N., R. 81 W. and proceeds westward to service the company's mining property in the adjoining quadrangle to the west. The 1:24,000 topographic map (1971 edition) shows, in the southeast corner, the location of the right-of-way of an abandoned Union Pacific Railroad spur line that served the company's Carbon No. 4 and No. 5 underground mines. The geologic map of Dobbin, Bowen, and Hoots (1929) shows the location of the old tram road that connected the Sampo underground mine in sec. 2, T. 22 N., R. 81 W. with the main railroad tracks.

Physiography

The Como West quadrangle is located in the eastern part of the Hanna structural basin, and the general topography of rolling upland grasslands is typical of this part of southern Wyoming. The only distinctive physiographic features in the quadrangle are the heavily dissected badlands south of the Medicine Bow River in the northeast, and Hi Allen Ridge in the south-central area. Hi Allen Ridge, with a local relief of less than 500 feet (152 m), is a prominent landmark formed by northwesterly dipping conglomerates and sandstones of the Ferris Formation.

Elevations within the quadrangle range from 6,480 feet (1,975 m) at the Medicine Bow River in the northeast corner to 7,426 feet (2,263 m) at the crest of Hi Allen Ridge. Drainage within the quadrangle is, in places, internal to several small lakes, or in general, to the Medicine Bow River. In the north half of the quadrangle streams flow north to the Medicine Bow River located immediately north of the quadrangle; in the south half, streams flow southeasterly and easterly, but to the upper reaches of the same river, or to closed basin lakes immediately east of the quadrangle.

Climate

Climate data for the Como West quadrangle were obtained from the nearby Medicine Bow weather station. Because no figures on snowfall were available at Medicine Bow, data from Elk Mountain station were used. The Medicine Bow station is located 13 miles (21 km) east of the center of the quadrangle at an elevation of 6,570 feet (2,003 m); precipitation and temperature records are available for 23 years to 1970. The Elk Mountain station is located 18 miles (29 km) south of the center of the quadrangle at an elevation of 7,270 feet (2,216 m); snowfall records are available for 29 years to 1960.

The climate is semiarid, with a mean temperature of 42°F (6°C) and extremes ranging from 97° to -46°F (36° to -43°C). July is the warmest month, with a mean monthly temperature of 65°F (18°C), and January is the coldest month with 21°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 10 inches (25 cm) with 51 percent of this total falling in the four months of April through 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 through 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 eastern part of the KRCRA of the Hanna and Carbon Basins. The Federal Government owns approximately 40 percent of the coal rights in the quadrangle; the remaining 60 percent is non-federally owned. Approximately 75 percent of the area of the quadrangle is included in the KRCRA, and within this region about 30 percent of the land is federally owned, with 7 percent of this Federal land currently 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 three abandoned underground coal mines, two abandoned strip mines, and two active strip mines in the quadrangle (Plate 1).

The abandoned underground mines are the Carbon No. 5 mine in the southeast corner, owned by the Union Pacific Railroad Company, worked coal bed C5 before closing in 1881; the Sampo mine in sec. 2, T. 22 N., R. 81 W., owned by the Sampo Cooperative Coal Company, worked coal bed 79 from 1908 to 1909(?); an unnamed mine, also in sec. 2, worked coal bed 79, dates unknown.

The abandoned strip mines are the two open pits of the Hanna Basin Coal Company in sec. 36, T. 23 N., R. 81 W., which worked coal bed 79 between 1959 and 1964(?).

The operating strip mines are the Rosebud Pit 5 and Pit 7 of the Rosebud Coal Sales Company, near the southwest border of the quadrangle. Both mines have been operating since 1961; the No. 5 pit is mining coal bed 80 and the No. 7 pit is mining coal bed 79.

GENERAL GEOLOGY

Previous Work

Dobbin, Bowen, and Hoots (1929) mapped the Como West quadrangle as part of their study of the geology and coal and oil resources of the Hanna and Carbon Basins. Knight (1951) mapped Eocene sediments in the northwest area of the quadrangle. 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 this quadrangle range in age from Late Cretaceous through Quaternary. Coal beds are found in the lower part of the Medicine Bow Formation of Late Cretaceous age, and in the Hanna Formation of Paleocene age. The mapping of Knight (1951) shows that the youngest Hanna coal beds mapped by Dobbin, Bowen, and Hoots (1929) are certainly of Eocene age.

The oldest formation exposed in the quadrangle is the Steele Shale, a marine formation of Late Cretaceous age. The formation crops out south of the Medicine Bow River in the northeast corner of the quadrangle; the unit is about 1,500 feet (457 m) thick, dips to the south at 40° to 50°, and consists of dark-gray shales that contain sparse layers of gray-weathering limestone concretions and thin beds of gray, very fine grained sandstones and siltstones.

Conformably overlying the Steele Shale is the Mesaverde Formation of Late Cretaceous age. Dobbin, Bowen, and Hoots (1929) originally mapped these rocks as the Mesaverde Formation, but Gill, Merewether, and Cobban (1970) elevated the formation to group status, and they defined and measured four formations in the Mesaverde Group. However, these formations have not as yet been mapped in the Como West quadrangle, so the Mesaverde rocks are regarded as a single formation in this report. The Mesaverde rocks crop out in the northeast corner of the quadrangle, dip to the southwest at 13° to 40°, and are about 2,200 feet (671 m) thick in this area of the Hanna Basin, according to Dobbin, Bowen, and Hoots (1929). They describe the formation as consisting of three units, as follows:

- A lower unit of marine origin; white to gray indurated massive to thin-bedded and cross-bedded sandstones, alternating with thinner beds of gray shale.
- A middle unit from a fresh to brackish water environment; gray to brown thin-bedded to massive sandstones, alternating with beds of gray carbonaceous shale and thin irregular beds of coal. No Mesaverde coal beds crop out in the Como West quadrangle.
- An upper unit, primarily of nonmarine origin but grading into shallow-water marine at the top; white to gray sandstones alternating with beds of gray shale and thin beds of carbonaceous shale and coal.

The Upper Cretaceous Lewis Shale of marine origin conformably overlies the Mesaverde Formation. The shales crop out in the northeast corner of the quadrangle and also at the southeast border where they are exposed in the core of the Saddleback Hills anticline. In this quadrangle, the formation is about 800 feet (244 m) thick and 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 quadrangle.

Conformably overlying the Lewis Shale is the Medicine Bow Formation of Late Cretaceous age. The formation crops out in the northeast part of the quadrangle, dips to the southwest at 50°, and is about 2,000 feet (610 m) thick. The formation also crops out on the flanks of the northeasterly plunging Saddleback Hills anticline in the southeast part of the quadrangle. Here, the formation is between 2,000 and 3,000 feet (610 and 914 m) thick, and the sediments dip northwest, northeast, and southeast at 20° to 55°. Dobbin, Bowen, and Hoots (1929) 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.

The Ferris Formation conformably overlies the Medicine Bow Formation and crops out in this quadrangle at the east-central border and in an arcuate belt at the northern limits of the Saddleback Hills anticline. The formation is about 6,500 feet (1,981 m) thick at its type locality near the old Ferris Ranch on the North Platte River, nearly 50 miles (80 km) west of the center of this quadrangle, but the formation thickness at the eastern border of the Hanna Basin is probably less than 3,000 feet (914 m). At the type locality, 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. Coal beds do not crop out in the Como West quadrangle, nor were they detected in the subsurface.

The Hanna Formation overlies the Ferris Formation, crops out over the central portions of the Hanna and Carbon Basins, and contains many of the thick coal beds of the region, particularly near the towns of Elmo and Hanna. In this quadrangle, the Hanna sediments lie unconformably on the Ferris and older formations, and the Hanna outcrops occupy three-quarters of the total area. The sediments dip north, northwest, and west toward the center of the Hanna Basin near the northwest corner of the quadrangle; dip angles range from 8° to 42°, with a local steepening to 85° in the northeastern area. Bowen (1918) named the Hanna Formation when mapping outcrops north and west of the town of Hanna; he does not report a type section locality but states that the formation is about 7,000 feet (2,134 m) thick. The formation, of continental origin, consists of conglomerate, conglomeratic sandstone, sandstone, shale, 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 range from coarse-grained massive to thick-bedded varieties to fine-grained thin-bedded sandstones which, in weathered outcrops, are a brown color and readily break into thin slabs. The coarse-grained varieties of sandstone are buff to grayish-white, commonly conglomeratic, and highly feldspathic. The age of the Hanna Formation is in doubt; fossils from the Hanna indicate a late Paleocene age, but in the center of the Hanna Basin the formation may be as old as late-early Paleocene or middle Paleocene.

Sediments younger in age than those of the Hanna Formation crop out in the northwestern part of the Como West quadrangle. Knight (1951, p. 49) maps a sequence of coarse conglomerates, arkosic sandstones, siltstones, and shales, to which he assigns an Eocene age.

Alluvial deposits of Quaternary age occur in the valley bottom of the Medicine Bow River. Terrace deposits of similar age mantle the high ground in the vicinity of Wildcat Top, in the northeast corner of the quadrangle. The terrace gravels lie more than 300 feet (92 m) above the present elevation of the Medicine Bow River.

Structure

The Como West quadrangle is located near the eastern limits of the intermontane Hanna Basin. This basin is comparatively small in areal extent, but it is one of the deeper structural basins in the Rocky Mountain region. The basin extends about 40 miles (64 km) east-west, 25 miles (40 km) north-south, and in its deepest portion in the southeastern part of T. 24 N., R. 82 W., contains approximately 30,000-35,000 feet (9,140-10,670 m) of sediments overlying crystalline basement. The Saddleback Hills anticline in the southeast part of this quadrangle is the structural feature that separates the Hanna Basin from the Carbon Basin.

The principal deformation defining the present structural basin occurred during the Laramide Orogeny. The bordering highlands were raised and deformed, and sediments accumulated rapidly in the basin; consequently, the present Hanna Basin has complexly folded and faulted borders but only mild deformation within the basin, as evidenced by a few broad folds and minor faults.

The highlands that define the northern limit of the Hanna Basin are less than 2 miles (3 km) north of the Como West quadrangle; the base of the Mesaverde Formation, which is accepted as defining the eastern limit of the Hanna Basin, is less than 4 miles (6 km) east of this quadrangle. Consequently, the Late Cretaceous and younger sediments within the quadrangle dip generally west, northwest, and north toward the center of the structural basin. The sinuous and frequently interrupted traces of the surface outcrops of Hanna coal beds in the west-central, central, and north-central areas of the quadrangle reflect the shallow folding and minor faulting that characterize deformation within the basin. The minor faults are northwest-trending; their normal vertical displacements and horizontal separations are generally less than 200 feet (61 m), according to Dobbin, Bowen, and Hoots (1929, p. 69).

The major structural feature in the quadrangle is the Saddleback Hills anticline. The structure trends northeast into the southeastern part of the quadrangle and plunges to the northeast beneath the unconformable cover of Hanna sediments. Dips of the sediments on the eastern flank and at the nose of the structure are 20° and 30°; dips on the western flank increase to 55°.

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 have also been calculated for 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 physical and chemical 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 amount of trace elements of environmental concern than is found in the 42 samples collected in six other Wyoming coal fields.

General Features

In the Como West quadrangle, 30 coal beds and 67 local coal lenses either have been mapped by Dobbin, Bowen, and Hoots (1929) or have been identified in the subsurface (Plates 1, 3, and 3A). No coal beds have been located in the Mesaverde sediments of this quadrangle; three coal beds occur in the Medicine Bow Formation; no coal beds have been located in the Ferris sediments; 27 coal beds and 67 local coal lenses occur in the Hanna Formation, as mapped by Dobbin, Bowen, and Hoots (1929). U.S. Geological Survey selected one coal bed in the Medicine Bow Formation, one coal zone and six coal beds in the Hanna Formation, for coal resource evaluation.

Analyses of 37 coal samples that were collected as part of the Union Pacific coal inventory program, are shown in Appendix 3. Eleven of these samples are from the selected coal zone 78A, 78B, 79; 9 samples are from the selected coal beds 80, 87, 88, 89; and 17 samples are from local coal lenses. No analyses are available for the selected coal beds 96 and C4. The calculated average calorific value (moist, mineral-matter-free basis) for the 37 coal samples is 10,838 Btu/lb (25,209 kJ/kg), indicating an apparent rank of subbituminous A or high volatile C bituminous for these coal beds, depending on their agglomerating characteristics. This average calorific value for 37 coal samples is 7 percent less than the average calorific value for 87 Hanna coal samples collected throughout the Hanna and Carbon Basins (Appendix 2).

Medicine Bow Coal Beds

The three Medicine Bow coal beds, 95A, 96A, and 96, crop out in the southeast corner of the quadrangle in an arcuate pattern around the nose of the Saddleback Hills anticline. Dip of the coal beds varies from 30° to 45°. Measured thicknesses of the two lower coal beds are less than 4 feet (1.2 m); these coal beds were not intersected in the subsurface by drill holes. Measured thicknesses of the upper coal bed 96 range from 2 to 6 feet (0.6 to 1.8 m), and this selected coal bed was intersected in the subsurface by drill holes 2 and 3.

Hanna Coal Beds

The coal bed C4, located near the base of the Hanna Formation, crops out in the extreme southeast corner of the quadrangle and dips to the southeast at 20° to 25°. Two measured sections show 1.8 feet (0.5 m) of coal with 1.5 feet (0.5 m) of interburden, and 14.5 feet (4.4 m) of coal with 10.2 feet (3.1 m) of interburden; a drill hole intersection shows 7 feet (2.1 m) of coal with 4 feet (1.2 m) of interburden.

The selected coal zone 78A, 78B, 79, is about 1,500 feet (457 m) above coal bed C4 in the stratigraphic succession. The coal zone crops out in the west-central, central, and north-central areas of the quadrangle and dips to the northwest and west at 8° to 12°, except in the north-central area where the dip steepens to 27° to 42°. Coal content of the zone and the amount of interburden are both variable. Where all three coal beds in the zone have been mapped, the coal content is at least 12 feet (3.7 m) and may exceed 39 feet (12 m), and the interburden thickness varies from 124 to 276 feet (38 to 84 m). At the north-central border of the quadrangle, where only coal beds 78A and 79 are present in the outcrops, the coal content is less than 6 feet (2 m) and the interburden thickness is less than 160 feet (49 m).

Coal bed 80, the next younger coal bed selected for evaluation, is about 180 feet (55 m) above the top of the coal zone 78A, 78B, 79. This coal bed crops out to the north and west of the coal zone in the west-central and central areas of the quadrangle; the bed dips to the north and west at 8°, and the coal content ranges from 3.3 to 19.3 feet

(1.0 to 5.9 m). Northwest-trending normal faults displace the bed from 10 to 400 feet (3 to 122 m) vertically.

Selected coal bed 85 is about 3,200 feet (975 m) above coal bed 80, and the interval between the two selected coal beds contains five coal beds and at least 10 local coal lenses. Coal bed 85 crops out in the northwest part of the quadrangle, dips northerly at 14° to 17°, and varies in thickness from 2 to 11 feet (0.6 to 3.4 m). Two faults each vertically displace this coal bed by 50 feet (15 m).

The mapping of Knight (1951) shows the northwestern area of the Como West quadrangle to be partially covered by Eocene sediments lying unconformably on sediments of the Hanna Formation. Knight (1951) notes the presence of coal and carbonaceous shales in the Eocene sediments; therefore, it is certain that the coal beds, 86, 87, 88, and 89 of Dobbin, Bowen, and Hoots (1929) are of Eocene age and younger than Hanna coal beds. For this project study, however, the complete geologic map of Knight (1951) and a mapping of the Eocene coal beds are not available; therefore, the mapping of Dobbin, Bowen, and Hoots (1929) is used for the coal evaluation of the TE Ranch, Difficulty, Elmo, and Como West quadrangles.

Coal bed 87 crops out with a semi-elliptical pattern in the northwestern area of the quadrangle, with northerly and westerly dips of 12° to 17°. Coal thicknesses range from 2.9 to 20 feet (0.9 to 6.1 m).

Coal bed 88 also crops out in the northwestern area with a similar outcrop pattern and similar dip and strike. The stratigraphic interval between coal beds 87 and 88 is 300 to 400 feet (91 to 122 m). Measured thicknesses of coal bed 88 range from 4.2 to 12 feet (1.3 to 3.7 m).

Coal bed 89, the youngest bed selected for coal evaluation, crops out in the same area with a similar outcrop pattern to coal beds 87 and 88. The stratigraphic interval between coal beds 88 and 89 is 260 to 600 feet (79 to 183 m). Measured thicknesses of coal bed 89 range from 2 to 8 feet (0.6 to 2.4 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), an oil well log, and coal drill holes (written communications, Rocky Mountain Energy Company, 1977, and U.S. Geological Survey, 1978) were used to construct the coal data map (Plate 1) and coal data sheets (Plates 3 and 3A). U.S. Geological Survey reviewed these three plates and on the basis of Reserve Base criteria, selected seven coal beds and one coal zone for the calculation of coal resources in the Como West quadrangle. In addition, calculation of coal resources was requested for isolated or noncorrelatable data points.

The coal data map and coal data sheets were used to construct structure contour, coal isopach, overburden isopach, and cumulative interburden maps of the correlatable coal beds and coal zone (Plates 4-13, 16-21, 24-26, 29-31, 34-36). 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. For the coal zone consisting of beds 78A, 78B, and 79, cumulative thickness of these three beds plus the thicknesses of the intervening coal bed CWL8 and local coal lenses were used. Control points were generated from surface data and from drill holes by combining outcrop and subsurface thicknesses of individual beds to produce a single, cumulative coal thickness of the entire zone.

Plates 4-13, 16-21, 24-26, 29-31, 34-36 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 25 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 96, C4, 80, 85, 87, 88, and 89; the coal zone 78A, 78B, and 79; 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. An 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, and of multiple coal beds at least 5 feet (1.5 m) thick and having 500 feet (152 m) or less of combined overburden and interburden.
- 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 (0.4 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 thickness 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 mile (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 within 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 Plates 14, 22, 27, 32, and 37 for four of the seven selected coal beds and for the selected coal zone. Evaluation of coal beds 96, C4, and 80 showed that no mappable coal resources are present beneath unleased Federal land; therefore, the coal beds are excluded from Reserve Base and reserve calculations.

The coal resource acreage within each area of unleased Federal land was determined 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 or coal zone in that area, 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 beds 85, 87, 88, and 89 and coal zone 78A, 78B, 79: 15.84 million short tons (14.37 million t); assigned to measured, indicated, or inferred categories; shown on Plates 14, 22, 27, 32, and 37; included in the Coal Reserve Base totals shown on Plate 2.
- From isolated or noncorrelatable data points: 5.30 million short tons (4.81 million t) of strippable resources and 15.90 million short tons (14.42 million t) of nonstrippable resources, assigned to the inferred resource category, included in the coal Reserve Base total shown on Plate 2.

In summary, the total Reserve Base for 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 Como West quadrangle is 37.04 million short tons (33.60 million t).

Coal reserves for the quadrangle are calculated by applying recovery factors to the measured, indicated, and inferred resources of coal beds 85, 87, 88, and 89, and coal zone 78A, 78B, 79. The inferred resources determined from isolated or noncorrelatable data points are excluded. 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 Plates 14, 22, 27, 32, 37. Total coal reserves for unleased Federal land within the KRCRA in the Como West quadrangle are 11.24 million short tons (10.20 million t), consisting of 8.58 million short tons (7.78 million t) recoverable by strip mining or by underground mining and 2.66 million short tons (2.41 million t) recoverable by underground mining only.

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 Como West 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) for points of intersection of coal isopachs (Plates 11, 20, 25, 30, and 35), and overburden isopachs (Plates 12, 21, 26, 31, and 36), or combined overburden and cumulative interburden isopachs (Plate 13).
- 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 at least 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, only 12 feet (3.7 m) of the total thickness is used for Reserve Base calculations.
- 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 (Plates 15, 23, 28, 33, and 38) were prepared for the coal zone and for coal beds 85, 87, 88, and 89. A mining-ratio map is omitted for coal beds 96, C4, and 80 because of insufficient data within the unleased Federal land of the KRCRA in this quadrangle.

Development potential acreages were then blocked out, as shown on CDP Plates 39 and 40. Acreage for strippable and nonstrippable resources of selected coal beds is shown in Table 1 for each of the four development potential categories. 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.

Additionally, at the direction of the U.S. Geological Survey, an unknown development potential is assigned to coal resources calculated for any coal bed that, although not selected for coal resource evaluation, is (a) wholly or partly of Reserve Base thickness, or (b) of unknown thickness.

Table 1. - Development potential for identified resources of the selected coal beds and coal zone within the KRCRA of the Como West quadrangle

Coal bed or coal zone	Development potential (acres)							
	Strippable resources			Nonstrippable resources			Unknown category	
	High	Moderate	Low	High	Moderate	Low	Strippable	Nonstrippable
78A,78B,79	240	40	80	0	0	0	320	3,160
80	0	40	0	0	0	0	0	2,880
85	120	0	80	200	0	0	120	1,760
87	560	0	0	360	0	0	0	1,080
88	480	0	80	400	0	0	0	600
89	400	80	160	400	0	0	0	400
Totals	1,800	160	400	1,360	0	0	440	9,880

To convert acres to hectares, multiply by 0.4046.

Development Potential for Strippable Resources

Development potential for strippable coal resources within unleased Federal land in the KRCRA of this quadrangle is shown in Table 1 for each selected coal bed and coal zone. Plate 39 and Table 2 show the highest surface development potentials for the selected coal beds and coal zone. The totals are obtained after assigning the highest assessed development potential for any coal bed within the smallest legal subdivision to each subdivision.

Table 2. - Highest development potential for identified resources of the selected coal beds and coal zone within the KRCRA of the Como West quadrangle

Development potential (acres)							
Strippable resources			Nonstrippable resources			Unknown category	
High	Moderate	Low	High	Moderate	Low	Strippable	Nonstrippable
1,540	160	400	1,260	0	0	1,640	4,160

To convert acres to hectares, multiply by 0.4046.

There are approximately 8,240 acres (3,334 ha) of unleased Federal land within the KRCRA of this quadrangle. Of this area, 3,800 acres (1,537 ha) or 46 percent of the total, are estimated to be underlain by coal resources for the selected coal beds and coal zone with development potential for surface mining. Of the 3,800 acres (1,537 ha), a high development potential is assigned to 1,540 acres (647 ha), a moderate development potential to 160 acres (65 ha), a low development potential to 400 acres (162 ha), and an unknown development potential to 1,640 acres (664 ha).

Of the 8,240 acres (3,334 ha) of unleased Federal land, there are 2,275 acres (920 ha) or 28 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 within unleased Federal land in the KRCRA of this quadrangle is shown in Table 1 for each selected coal bed and coal zone. Plate 40 and Table 2 show the highest subsurface development potentials for the selected coal beds and coal zone. The totals are obtained after assigning the highest assessed development potential for any coal bed within the smallest legal subdivision to each subdivision.

Of the 8,240 acres (3,334 ha) of unleased Federal land within the KRCRA of this quadrangle, 5,480 acres (2,217 ha), or 66.5 percent of the total, are estimated to be underlain by coal resources from the selected coal beds and coal zone with development potential for underground mining. Of the 8,240 acres (3,334 ha), a high development potential is assigned to 1,260 acres (509 ha), and an unknown development potential is assigned to 4,040 acres (1,635 ha).

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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						Moist, mineral-matter-free basis (2)	
		Ft	in	Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb		
Published analyses	26	318	6	12.5	7.1	36.2	44.2	0.6	10,553	11,438	sub A or 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 or 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 Ft	Total footage in	Average analyses — as-received basis: Percent: Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb	Calorific Value, Btu/lb: Moist, mineral-matter-free basis (2)	Apparent rank of coal (3)
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, Como West Quadrangle

Location					Sample interval				Sample width		Analyses - as received basis					
					From		To				Percent					
Drill hole	Sec.	Twp.	Rge.	Coal bed	Ft	in	Ft	in	Ft	in	Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb
8	23	23N	80W	L	245	0	249	0	4	0	14.06	9.08	34.70	42.16	0.41	9,976
9	7	23N	80W	89	43	7	50	0	6	5	15.52	14.91	36.42	33.15	1.20	9,115
11	7	23N	80W	88	109	7	118	5	8	10	13.87	12.52	31.51	42.10	1.45	9,643
11	7	23N	80W	87	339	10	349	2	9	4	12.64	11.03	35.23	41.10	1.19	10,164
14	31	23N	80W	80	46	6	48	9	2	3	14.05	11.09	36.79	38.07	1.59	10,043
14	31	23N	80W	80	48	5	49	10	1	5	14.61	8.69	34.90	41.80	1.84	10,085
14	31	23N	80W	79	227	0	237	7	10	7	15.34	4.94	34.46	45.26	0.91	10,671
15	31	23N	80W	80	127	0	132	4	5	4	14.20	8.54	37.67	39.59	1.94	10,233
20	31	23N	80W	78-A	28	4	37	7	9	3	15.44	5.22	35.67	43.67	0.96	10,586
20	31	23N	80W	L	95	4	99	6	4	2	16.51	5.73	34.44	43.32	2.05	10,386
21	31	23N	80W	78-B	71	7	77	1	5	6	15.10	8.18	37.20	39.52	1.31	10,271
21	31	23N	80W	78-A	172	4	184	8	12	4	15.65	6.75	35.58	42.02	1.02	10,470
21	31	23N	80W	L	238	0	246	2	8	2	15.81	7.18	35.01	42.00	1.83	10,280
22	19	23N	80W	L	665	7	667	0	1	5	13.45	9.12	36.87	40.56	1.82	10,822
27	7	23N	80W	89	52	4	53	0	0	8	15.06	13.29	36.39	35.26	0.99	8,750
32	9	23N	80W	79	71	4	75	2	3	10	19.33	9.33	35.47	35.87	3.46	9,338
32	9	23N	80W	79	105	7	110	0	4	5	17.56	15.68	34.11	32.65	3.19	8,684
32	9	23N	80W	79	110	0	113	0	3	0	17.85	21.51	29.52	31.12	1.09	7,791
32	9	23N	80W	79	119	8	124	6	4	10	20.49	11.21	31.96	36.34	2.11	8,665
32	9	23N	80W	L	229	6	236	0	6	6	16.65	14.66	34.85	33.84	3.15	8,894
32	9	23N	80W	L	237	8	245	4	7	8	17.19	13.36	35.19	34.26	2.81	9,140
32	9	23N	80W	L	262	6	269	0	6	6	19.34	19.43	29.83	31.40	2.35	7,875
32	9	23N	80W	L	269	0	274	0	5	0	17.92	15.04	33.05	33.99	1.13	8,792
32	9	23N	80W	L	320	6	329	0	8	6	15.41	9.80	38.33	36.46	2.79	10,007
32	9	23N	80W	L	339	7	342	7	3	0	15.90	7.77	34.62	41.71	1.67	9,904
32	9	23N	80W	78-B	369	0	374	4	5	4	16.21	10.96	34.27	38.56	1.39	9,540
34	9	23N	80W	L	37	0	40	0								
				L	40	0	44	0	15	0	16.46	21.08	30.42	32.04	3.81	8,006
				79	143	0	151	0								
34	9	23N	80W	L	153	0	159	8	6	8	17.71	8.40	34.52	39.37	2.06	9,652
34	9	23N	80W	L	192	8	197	6	4	10	15.71	19.56	31.60	33.13	2.50	8,357
34	9	23N	80W	L	200	6	203	10	3	4	16.25	15.02	33.17	35.56	1.84	9,015
34	9	23N	80W	L	247	0	253	0	6	0	15.10	17.31	34.79	32.80	2.30	8,940
34	9	23N	80W	L	266	6	271	3	4	9	15.88	10.65	33.50	39.97	2.20	9,547
34	9	23N	80W	78-B	295	0	301	0	6	0	15.65	8.87	34.14	41.34	2.24	9,865
35	7	23N	80W	87	178	0	185	0	7	0	17.15	20.48	29.65	32.72	2.78	7,919
35	7	23N	80W	87	195	7	203	2	7	7	17.00	11.11	33.94	37.95	1.20	9,300
36	7	23N	80W	L	241	0	244	9	3	9	18.19	12.85	31.85	37.11	1.43	8,925
36	7	23N	80W	L	244	9	249	2	4	5	17.39	21.78	29.24	31.59	1.84	7,745

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/kilogram (KJ/Kg), multiply by 2.326.]

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

Strippable coal Reserve Base data for Federal coal lands (in short tons) in the Como West 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
Zone {78A, 78B, 79}	1,240,000	450,000	850,000	2,540,000
85	60,000	70,000	190,000	320,000
87	2,880,000	1,190,000	610,000	4,680,000
88	540,000	320,000	400,000	1,260,000
89	970,000	210,000	20,000	1,200,000
Total	5,690,000	2,240,000	2,070,000	10,000,000

Non-strippable coal Reserve Base data for Federal coal lands (in short tons) in the Como West quadrangle, Carbon County, Wyoming. (To convert short tons to metric tons, multiply by 0.9072)

Coal Bed	High Development Potential (0-1000 ft of overburden)	Moderate Development Potential (1000-2000 ft of overburden)	Low Development Potential (2000-3000 ft of overburden)	Total
Zone {78A, 78B, 79}	730,000	0	0	730,000
85	670,000	0	0	670,000
87	2,010,000	0	0	2,010,000
88	2,040,000	0	0	2,040,000
89	60,000	0	0	60,000
Total	5,510,000	0	0	5,510,000