Text to accompany:

Open-File Report 78-055

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

(Report includes 10 plates)

Prepared for:

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GEOLOGICAL SURVEY

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INTRODUCTION

Purpose

This text is to be used along with the accompanying Coal Resource Occurrence (CRO) maps and Coal Development Potential (CDP) maps of the TE Ranch quadrangle, Carbon County, Wyoming (10 plates; U.S. Geol. Survey Open-File Report 78-055), 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 System (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 Coal Development Potential maps for this quadrangle cover part of the northeastern portion of the KRCRA of the Hanna coal field.

Acknowledgement

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 Union Pacific coal 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 TE Ranch 7½-minute quadrangle is in the northeastern part of Carbon County, Wyoming. The center of the quadrangle is approximately 25 miles (40 km) northeast of Walcott and 13 miles (21 km) north of Hanna, Wyoming (Figure 1).

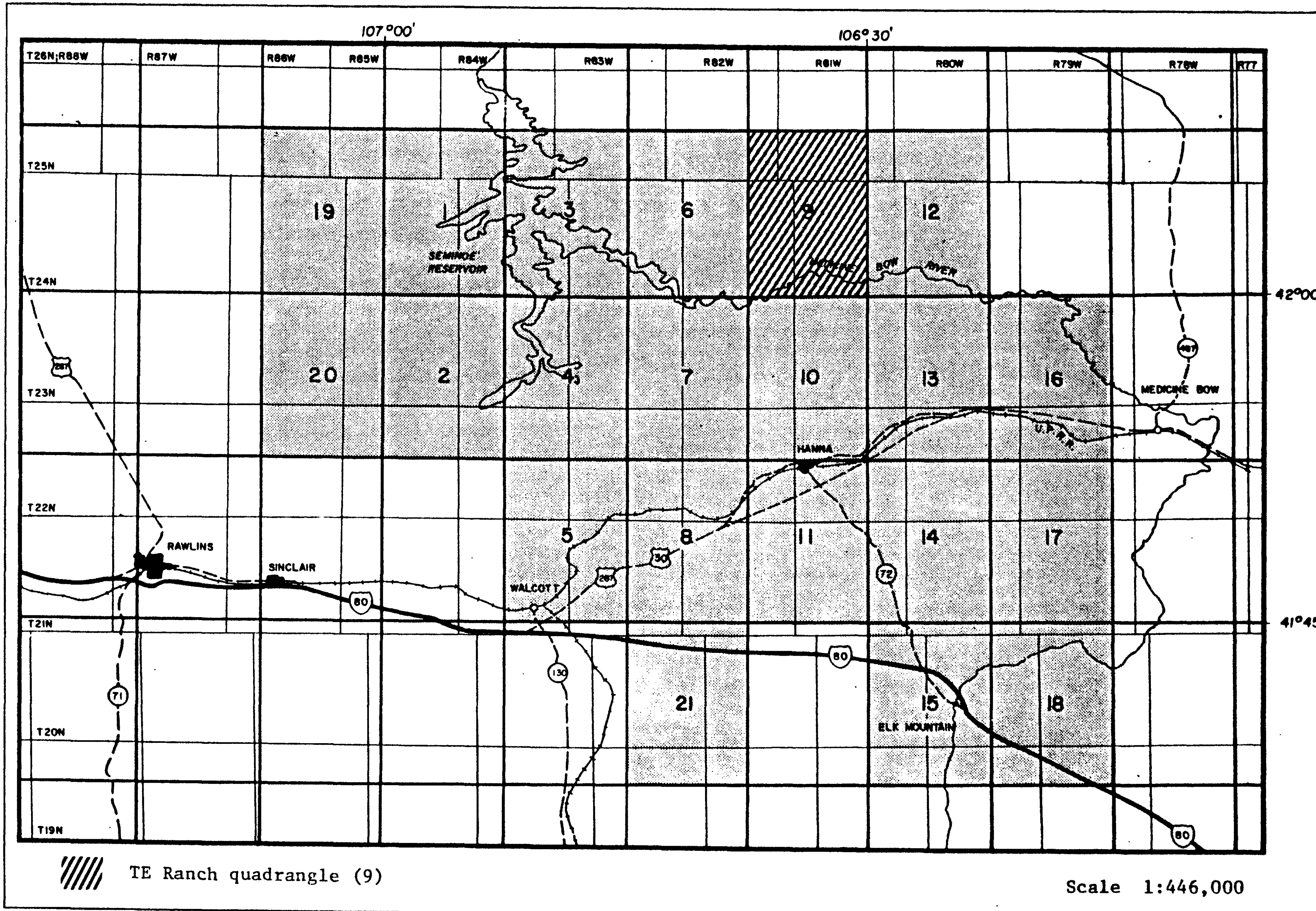

Figure 1. — Map of Hanna and Carbon Basins Study Area

Accessibility

The TE Ranch quadrangle is serviced by three light-duty roads. The access road to the Seminoe Dam site from the town of Medicine Bow crosses the southern third of the quadrangle from east to west. From this road near Campbell Ranch, a second light-duty road runs south to the Medicine Bow River, crosses the river, and continues south beyond this quadrangle to the towns of Elmo and Hanna. The third light-duty road leaves the Seminoe Dam access road at a junction immediately west of Campbell Ranch, and runs northwest to the TE Ranch in the center of the quadrangle. Numerous unimproved roads and trails provide access from the three main roads to the ranches, water sources, and major tributary valleys located in or near the upland plains of the quadrangle.

The main east-west track of the Union Pacific Railroad is 14 miles (23 km) south of the center of the quadrangle.

Physiography

The quadrangle is located on the north rim of the Hanna structural basin. In this area, the Hanna Basin is bounded by the Shirley Mountains whose southern flanks occupy the north third of the quadrangle. Bald Mountain, with a maximum elevation of 8,895 feet (2,711 m) and a local relief of nearly 2,000 feet (610 m), is the most prominent topographic feature. In the southern two-thirds of the quadrangle the terrain is typical of the high plains grasslands of the Hanna and Carbon Basins. Near the Medicine Bow River at the south boundary of the quadrangle, the descent to the valley of the river is across heavily dissected slopes of minor tributary valleys. Elevations in the quadrangle range from 6,380 feet (1,945 m) in the west part of the valley of the Medicine Bow River to 8,895 feet (2,711 m) at the summit of Bald Mountain.

The principal drainage of the quadrangle is the southerly flowing Troublesome Creek and its many tributaries. Minor streams in the southern third of the quadrangle also flow into the Medicine Bow River which meanders westward to Seminoe Reservoir.

Climate

Climate data for the TE Ranch quadrangle were obtained by evaluating and averaging the data recorded at two nearby weather stations. The Seminoe Dam station is located 18 miles (29 km) west-northwest of the center of the quadrangle at an elevation of 6,838 feet (2,084 m); precipitation and temperature records are available for 33 years to 1970. The Medicine Bow station is located 23 miles (37 km) southeast 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 climate is semiarid with a mean annual temperature of 42°F (6°C) and extremes ranging from 98° to -38°F (37° to -39°C). July is the warmest month with a mean monthly temperature of 67°F (19°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 12 inches (30 cm) with 57 percent of this total falling in the five months of March to July. Part of the precipitation in March, April, and May is in the form of snow. Average annual snowfall is 102 inches (259 cm) with 63 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). Snowfall data were obtained by averaging figures from Elk Mountain and Seminoe Dam stations; no data on snowfall were available from the Medicine Bow station. The Elk Mountain station is located 28 miles (45 km) south-southeast of the center of this quadrangle.

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 northern 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 10 percent of the area of the quadrangle is included in the KRCRA, and within this region about 45 percent of the land is federally owned. Plate 2 of the CRO maps illustrates the ownership status of land in the quadrangle and the boundary of the KRCRA.

The abandoned underground mine in sec. 33, T. 24 N., R. 81 W. is the Rock Crossing mine, which mined a narrow bed of Hanna coal prior to 1906 (Glass, 1972). There are no known active leases, permits, or licenses in the quadrangle, nor are there any producing mines.

GENERAL GEOLOGY

Previous Work

Dobbin, Bowen, and Hoots (1929) mapped the TE Ranch quadrangle as part of their study of the geology and coal and oil resources of the Hanna and Carbon Basins. Berta (1951) reviewed the general stratigraphy and structure of the Hanna coal field. Weitz and Love (1952) compiled a geologic map of Carbon County, Wyoming, which incorporates available data, published and unpublished, to that date. Gill, Merewether, and Cobban (1970) defined and correlated the upper Cretaceous and lower Tertiary rocks of south-central Wyoming, including the stratigraphic units that are exposed in this quadrangle.

Stratigraphy

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

Granite is the dominant rock type of the Precambrian rocks that form the core of the Shirley Mountains. Precambrian outcrops are confined to the highest part of Bald Mountain above the 8,000 feet (2,438 m) elevation, and to a larger area in the northwest part of the quadrangle. The Shirley Mountains granite is cut by pegmatites, basic dikes, quartz veins, and fault zones (Finnell, 1951). No significant mineral deposits are reported from the Precambrian rocks in this quadrangle.

Sediments older than Cretaceous age crop out in the northern one-third of the quadrangle. The outcrops are partially mantled by younger deposits of Late Tertiary and Quaternary age, but it is most probable that the older sediments are in faulted contact with the Precambrian outcrops. These pre-Cretaceous age sediments include: Cambrian rocks, undivided; the Mississippian Madison Limestone; the Pennsylvanian Tensleep and Amsden Formations, undivided; Permian rocks, undivided; Triassic rocks, undivided; Jurassic rocks, undivided; and the Jurassic Morrison Formation. The approximate thickness of pre-Cretaceous sediments is 3,200 feet (975 m).

The marine sediments of pre-Cretaceous age are conformably overlain in the northern one-third of the quadrangle by marine sediments of Cretaceous age, totaling about 6,500 feet (1,981 m). Included are the Lower Cretaceous Cloverly, Thermopolis, and Mowry Formations and the Upper Cretaceous Frontier, Niobrara and Steele Shale Formations.

In the Hanna Basin, the Steele Shale is conformably overlain by the essentially nonmarine Mesaverde Formation, followed conformably by the marine Lewis Shale. The geologic map of Weitz and Love (1952) shows these two formations of Late Cretaceous age to be concealed by later Quaternary deposits; Dobbin, Bowen, and Hoots (1929) map a small outcrop of Lewis Shale faulted against Precambrian rocks in sec. 3, T. 24 N., R. 82 W. The Lewis Shale is about 3,000 feet (914 m) thick in the adjoining quadrangle to the west, and consists mainly of dark gray shales interbedded with gray to brown fine-grained sandstones, yellowish-gray siltstones, and bentonite lenses.

The nonmarine Medicine Bow Formation, also of Late Cretaceous age, conformably overlies the Lewis Shale in the west-central area of the quadrangle. Dobbin, Bowen, and Hoots (1929) map an easterly trending belt of vertical to steeply overturned continental sediments that contains a single coal bed, SRL 1a, near its base. Knight (1951, p. 50) measured a stratigraphic section of 3,950 feet (1,204 m) for the Medicine Bow Formation in sec. 9, T. 24 N., R. 82 W., immediately west of this quadrangle. He restricts the formation to the basal, non-conglomeratic part of a thick sequence of conformable continental sediments overlying the Lewis Shale in this part of the Hanna Basin. Medicine Bow sediments consist of yellow, gray and carbonaceous shale, beds of coal, and gray and brown sandstone. The lower part of the formation is made up of massive to cross-bedded brown sandstones, which usually form a conspicuous group of ledges and contain beds of coal. These sandstones are overlain by an intermediate group of dark-colored shales and thin-bedded fine-grained brown sandstones, with some beds of massive white sandstone. The sandstones at the top of the formation are coarse-grained, massive, friable, and easily eroded, and are interbedded with thick beds of dark gray shale. The geologic map of Weitz and Love (1952) shows the belt of Medicine Bow sediments, as mapped by Dobbin, Bowen, and Hoots (1929), to be almost completely concealed by Quaternary terrace deposits; but an additional Medicine Bow outcrop in sec. 18, T. 24 N., R. 81 W., on the left bank of Dry Creek, exposes the major fault that defines the limit of the Hanna Basin on its north side. The stratigraphic log of drill hole 13 (Plate 3) reports 3,800 feet (1,158 m) of Medicine Bow sediments in the subsurface in the southeast corner of the quadrangle, but the total thickness of the formation is more than this because the drill hole was completed when still in the formation.

The geologic map of Dobbin, Bowen, and Hoots (1929) shows the continental rocks of the Ferris Formation conformably overlying the Medicine Bow Formation in the northwest, west, southwest, and south of the Hanna Basin. In these areas, Ferris coal beds are thick and numerous but, as the formation extends northeasterly across the east arm of Seminoe Reservoir, the coal beds thin rapidly and become lens-like, before disappearing as mappable units in outcrops 10 miles (30 km) west-southwest of the center of this quadrangle. Continuing northeast from this locality, the outcrop of the formation narrows appreciably as the beds dip more steeply and ultimately become vertical; they extend into the west-central part of this quadrangle in T. 24 N., R. 82 W. Dobbin, Bowen, and Hoots (1929) map Ferris sediments in secs. 10 and 11; Weitz and Love (1952) map them in secs. 10 through 15; Knight (1951) does not map the formation but considers the Ferris sediments may be the part of a conformable sequence of continental sediments, 13,300 to 17,500 feet (4,054 to 5,334 m) thick, that rests on Medicine Bow sediments but terminates at an erosion surface, and is therefore incomplete. The stratigraphic log of drill hole 13 (Plate 3) reports 3,225 feet (983 m) of Ferris sediments in the subsurface in the southeastern corner of the quadrangle.

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, 20 miles (32 km) southwest of the center of the TE Ranch quadrangle. Here, the formation 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 crops out over the southern one-third of the TE Ranch quadrangle. Throughout the Hanna coal field, the Hanna Formation is normally not only unconformable on the underlying Ferris Formation but also transgresses across all underlying formations, including the Precambrian basement rocks. However, the measured sections of Knight (1951) in this quadrangle and the adjacent quadrangle to the west, show the Hanna sediments to be the upper part of a thick sequence of conformable continental sediments that conformably overlie the Medicine Bow sediments. In the southeast corner of this quadrangle the base of the Hanna Formation is 2,563 feet (781 m) in the subsurface, according to the stratigraphic log of drill hole 13 (Plate 3).

Bowen (1958) named the Hanna Formation when mapping outcrops 13 miles (21 km) south of the center of this quadrangle, 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 Hanna Formation 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 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. Gill, Merewether, and Cobban (1970) therefore suggest that, apparently, the conglomerates of the Ferris were derived from a distant source and those of the Hanna from a nearby source. 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.

No other sediments of Tertiary age were mapped by Dobbin, Bowen, and Hoots (1929) but Knight (1951) maps a conglomeratic succession of probable Eocene age that crop out in the southeast corner of the quadrangle, extending east and south from the valley of Troublesome Creek into the adjoining quadrangles. Detailed mapping shows that these sediments rest unconformably on the older conglomeratic succession of equivalent Ferris-Hanna age. Coal occurs in these Eocene sediments; therefore, it is certain that the coal beds mapped by Dobbin, Bowen, and Hoots (1929) in the southeastern part of this quadrangle are of Eocene age and thus younger than Hanna coal beds.

Knight (1951) and Weitz and Love (1952) map a small outcrop of Miocene-Pliocene sediments in sec. 11, T. 24 N., R. 82 W. Knight (1951, p. 53) states that this conspicuous erosional remnant of flat-lying light-colored sands rests unconformably on the older conglomeratic succession of equivalent Ferris-Hanna age. A similar Miocene-Pliocene deposit is mapped by Weitz and Love (1952) in secs. 32 and 33, T. 25 N., R. 81 W. between Roaring Creek and Troublesome Creek.

Alluvial deposits of Quaternary age occur in the valley bottoms of the Medicine Bow River, Troublesome Creek, and Mud Spring Draw. Terrace deposits of Tertiary age are mapped on many upland slopes in the northern two-thirds of the quadrangle. On the western slopes of Bald Mountain the terrace gravels are mapped at elevations above 8,000 feet (2,438 m), or 1,600 feet (488 m) and more above the present day Medicine Bow River.

Structure

The TE Ranch quadrangle is on the northern edge 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 (65 km) east-west, 25 miles (40 km) north-south, and in its deepest portion in the southwestern area of this quadrangle contains approximately 30,000-35,000 feet (9,140-10,670 m) of sediments overlying the Precambrian basement. It is bounded on the north by the Sweetwater Arch, which in this quadrangle is represented by the Shirley Mountains.

The principal deformation defining the present structural basin occurred during the Laramide Orogeny. The bordering highlands were raised and deformed, and the sediments accumulated rapidly in the basin; consequently, the present Hanna Basin has complexly folded and faulted borders, with mild deformation within the basin expressed by a few broad folds and normal faults. With the retreat of the sea in late Cretaceous time, the depositional environment changed from marine to continental as exemplified by the sediments that crop out over the southern half of this quadrangle.

One of the two major fault systems developed in the Hanna Basin crosses the central part of this quadrangle in a west-northwesterly direction. From its exposure south of the Oil Springs anticline in the northeast part of T. 23 N., R. 79 W., the fault trends west-northwest at the boundary of the basin to enter the TE Ranch quadrangle at its east boundary in sec. 23, T. 24 N., R. 81 W. (Weitz and Love, 1952). Within the quadrangle, the surface trace of the fault is almost completely concealed by Quaternary deposits; the only exceptions are on the hillslopes west of Troublesome Creek at Watkins Ranch, where Steele Shale on the north is faulted against Hanna sediments to the south, and on the north bank of Dry Creek in sec. 18, T. 24 N., R. 81 W., where the fault is exposed at an outcrop of Medicine Bow sediments. The fault continues in a west-northwesterly direction to the west-central boundary of the quadrangle, and the geologic map of Weitz and Love (1952) shows the fault system continuing in the same direction for at least six townships. Dobbin, Bowen, and Hoots (1929) suggest that the vertical displacement of this fault may be as much as 30,000 feet (9,140 m) and subsequent investigations in the area confirm their supposition. Precambrian rocks are exposed in the southwestern part of sec. 2, T. 24 N., R. 82 W., in the valley of Dry Creek at an elevation of 7,200 feet (2,195 m). Less than 3 miles (5 km) to the south, in sec. 23, T. 24 N., R. 82 W., is the deepest part of the Hanna structural basin where, from the results of exploratory oil well drilling in the Hanna and Carbon Basins and the surrounding areas, the Precambrian basement is considered to be deeper than the -29,000-foot (-8,840 m) elevation.

South of this major fault system the Medicine Bow, Ferris-Hanna, and Eocene sediments are relatively undisturbed by faulting or folding. Dips in the sediments progressively decrease southward toward the center of the basin, from overturned and vertical Medicine Bow beds near the fault to southerly dips of less than 25° in Ferris-Hanna sediments in sec. 30, T. 24 N., R. 81 W. The shallow dips of less than 10° mapped by Dobbin, Bowen, and Hoots (1929) in the southeast corner of the quadrangle, are in the younger and unconformable Eocene sediments. Knight (1951), when mapping these Eocene sediments, shows shallow east-trending folds with local dips varying from 2° to 38°. He suggests that this folding "represents the final effects of the compressional forces which operated during the development of the Basin. Regional evidence leads to the belief that this folding took place before Oligocene time."

Dobbin, Bowen, and Hoots (1929) did not complete the detailed geologic mapping in the quadrangle north of the major fault system. Weitz and Love (1952) record a complex of generally east-trending and north-trending faults in the Shirley Mountains as far east as the western slopes of Bald Mountain. This fault complex displaces all the older units of the stratigraphic succession from the Precambrian crystalline rocks to the Niobrara Formation. Folding is also prominent north and northwest of TE Ranch and south of Bald Mountain.

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 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). An apparent rank has been calculated from the average analysis for coal in each of the four stratigraphic units. A standard rank determination (ASTM, 1977, p. 216, sec. 6.2.2) cannot be made because some of the published analyses are from weathered coal samples, and 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 TE Ranch quadrangle, 5 coal beds and 10 local coal lenses in the Medicine Bow and Hanna Formations have been mapped by Dobbin, Bowen, and Hoots (1929) or have been identified in the subsurface (Plates 1 and 3). Of the 15 coal beds and local coal lenses identified, coal bed 88 of the Hanna Formation was selected for the production of derivative maps.

One coal mine is located within the quadrangle in sec. 33, T. 24 N., R. 81 W. The abandoned Rock Crossing underground mine once worked an unnamed coal bed in the Hanna Formation (Glass, 1972).

Analyses of samples collected during the Union Pacific coal inventory program along with published analyses are shown in Appendices 1, 2, and 3. In this quadrangle, 2 coal samples were collected from coal bed 88 in the Hanna Formation.

Medicine Bow Coal Beds

In sec. 3 of T. 24 N., R. 82 W., a single coal bed, SRL 1a, crops out in the Medicine Bow Formation. This coal bed occurs in the lower part of the formation and is the only mapped coal in the Medicine Bow Formation within the TE Ranch quadrangle. Dip of coal bed SRL 1a is vertical and its thickness is reported to be 7 feet (2.1 m). No analyses of coal samples are available for this coal bed.

Hanna Coal Beds

As noted in a preceding section of this report, Knight (1951) mapped Eocene sediments in the southeast corner of this quadrangle. Carbonaceous shales and coal beds occur in the upper part of the Eocene stratigraphic section; therefore, it is certain that the coal beds 86, 88, and 89 of Dobbin, Bowen, and Hoots (1929) are of Eocene age and thus 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; instead, the mapping of Dobbin, Bowen, and Hoots (1929) is used in the coal evaluation of the TE Ranch, Difficulty, Elmo, and Como West quadrangles.

Outcrops of 4 coal beds and 2 local coal lenses occur in the southeast corner of the quadrangle (Plate 1). Also, 8 additional local coal lenses are identified in the subsurface (Plate 3). Dips are shallow, less than 10° to the south, and coal bed thicknesses range from 1 to 32.8 feet (0.3 to 10 m). The oldest coal bed, 86, and the two local coal lenses that crop out adjacent to the Medicine Bow River, are thin and associated with greater thicknesses of carbonaceous shale. Coal bed 88 was selected for coal resource evaluation and it also is part of a thick zone of carbonaceous shales with thin beds of coal and bony coal. Dobbin, Bowen, and Hoots (1929, Plate 19) measured three sections of coal bed 88 and their measured section 1173 in this quadrangle is a zone more than 104 feet (32 m) thick that includes coal beds 88 and EL7. Only 31 percent of the zone is coal and bony coal; of the 36 individual beds of coal and bony coal only 3 exceed 2 feet (0.6 m) thickness, with the thickest bed being 3.2 feet (1 m). The coal zone can be subdivided into four coal-bearing units separated by three carbonaceous shale units that are 30, 8, and about 14 feet (9.1, 2.4, and 4.2 m) thick. In fact, the coal zone is considerably thicker than the 104.3 feet (31.8 m) recorded on Plate 3. An additional 2.5 feet (0.8m) of bony coal occurs above the top coal in the measured section but the thickness of the interbedded carbonaceous shale and bone is not given by Dobbin, Bowen, and Hoots (1929). It is known, however, to exceed 16 feet (4.9 m). Drill holes 2, 3, and 16 (Plate 3) show a similar zoning, with coal bed 88 as part of a thick zone of relatively thin coal beds and local coal lenses separated by carbonaceous shales.

Coal bed 89 crops out in the southeastern corner of the quadrangle. Measured sections in the adjoining quadrangle to the east show that this coal bed is also a thick zone of coal and bony coal with interbedded carbonaceous shales.

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), oil and gas well logs, 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 the coal data sheet (Plate 3). U.S. Geological Survey reviewed these two plates and on the basis of Reserve Base criteria, selected coal bed 88 for the calculation of coal resources in the TE Ranch 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 bed (Plates 4-6). For the single coal bed, the maps were drawn using, as control points, thicknesses measured at outcrop and subsurface data from drill hole information. Where the coal bed is split, cumulative coal thicknesses were used, excluding non-coal partings.

Plates 4-6 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 3 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 bed 88, 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°. In this quadrangle the selected coal bed dips at less than 25°.

- Strippable coal resources (the resources capable of being extracted by strip-mining methods) are comprised 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 (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 thickness location on a mapped outcrop.

- Coal resources from isolated or noncorrelatable data points are calculated from 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 the maps which show 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 Plate 7 for the selected coal bed.

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 planimeteric portion of each area of unleased Federal land by the average isopach value of the selected coal bed, 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 88: 0.48 million short tons (0.44 million t); assigned to measured, indicated, or inferred categories; shown on Plate 7; included in the coal Reserve Base totals shown on Plate 2.

- from isolated or noncorrelatable points: 2.80 million short tons (2.54 million t) of strippable resources and 1.80 million short tons (1.63 million t) of nonstrippable 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 TE Ranch quadrangle, is 5.08 million short tons (4.61 million t).

Coal reserves for the quadrangle are calculated by applying recovery factors to the measured, indicated, and inferred resources of coal bed 88. 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 7. Total coal reserves for unleased Federal land within the KRCRA in the TE Ranch quadrangle, are 0.41 million short tons (0.37 million t), all 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 TE Ranch 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 (Plate 5) and overburden isopachs (Plate 6).

- 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 prevents 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, a mining-ratio map (Plate 8) was prepared for coal bed 88.

Development potential acreages were then blocked out, as shown on CDP Plates 9 and 10. Acreages for strippable and nonstrippable resources of the selected coal bed 88 are as follows:

Strippable resources, high development potential . . . . . . 200 acres

Nonstrippable resources, high development potential . . . . 80 acres

Nonstrippable resources, unknown development potential . . . 120 acres

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 either: (a) wholly, or partly, of Reserve Base thickness, or (b) of unknown thickness.

Development Potential for Strippable Resources

Development potential for strippable coal resources within unleased Federal land in the KRCRA of this quadrangle, is shown in the preceding section for the selected coal bed. Plate 9 shows the surface development potential for the unleased Federal land in the KRCRA of this quadrangle. The totals are obtained after assigning the highest assessed development potential for any coal bed within the smallest legal subdivision to that subdivision. In practice, there are no moderate and low development potential acreages because all the resources of coal bed 88 are assigned a high development potential.

There are approximately 1,520 acres (615 ha) of unleased Federal land within the KRCRA of this quadrangle. Of this area, 200 acres (81 ha) or 13.2 percent of the total, are estimated to be underlain by coal resources, from the selected coal bed, with development potential for surface mining; a high development potential is assigned to all 200 acres (81 ha).

Of the 1,520 acres (615 ha) of unleased Federal land, there are 680 acres (275 ha) or 45 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 a preceding section for the selected coal bed. Plate 10 shows the subsurface development potential for the unleased Federal land in the KRCRA of this quadrangle. The totals are obtained after assigning the highest assessed development potential for any coal bed within the smallest legal subdivision to that subdivision. In practice, no acreages were assigned moderate or low development potentials.

Of the 1,520 acres (615 ha) of unleased Federal land within the KRCRA of this quadrangle, 200 acres (81 ha) or 13.2 percent of the total, are estimated to be underlain by coal resources, from the selected coal bed, with development potential for underground mining. Of the 200 acres (81 ha), a high development potential is assigned to 80 acres (32 ha), and an unknown development potential to 120 acres (49 ha).

Of the 1,520 acres (615 ha) of unleased Federal land, there are 920 acres (372 ha) or 61 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.

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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 <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 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, TE Ranch quadrangle

Drill hole	Location			Coal bed	Sample interval				Sample width		Analyses - as-received basis					
					From		To				Percent					
	Sec.	Twp.	Rge.		Ft	in	Ft	in	Ft	in	Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Btu/lb
3	33	24N	81W	88	104	3	114	0	9	9	12.31	10.71	37.18	39.80	2.03	10,267
3	33	24N	81W	88	119	6	125	0	5	6	11.76	14.77	35.69	31.78	2.05	9,720

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/lb to kilojoules/kilogram (kJ/kg), multiply by 2.326].

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

Strippable coal Reserve Base data for Federal coal lands (in short tons) in the T.E. Ranch quadrangle, Carbon County, Wyoming [Development potentials are based on mining ratio (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
88	90,000	160,000	210,000	460,000
Total	90,000	160,000	210,000	460,000

Non-strippable coal Reserve Base data for Federal coal lands (in short tons) in the T.E. Ranch 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
88	10,000	0	0	10,000
Total	10,000	0	0	10,000