UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TEXT TO ACCOMPANY:

COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE FORTIN DRAW QUADRANGLE, CAMPBELL COUNTY, WYOMING

BY

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I. Introduction

This report and accompanying maps set forth the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) of coal beds within the Fortin Draw Quadrangle, Campbell County, Wyoming. This CRO and CDP map series includes 20 plates (U. S. Geological Survey Open-File Report 79-043). The project is compiled by IntraSearch Inc., 1600 Ogden Street, Denver, Colorado, under KRCRA Northeastern Powder River Basin, Wyoming Contract Number 14-08-0001-17180. This contract is a part of a program to provide an inventory of unleased federal coal in Known Recoverable Coal Resource Areas (KRCRA) in the western United States.

The Fortin Draw Quadrangle is located in Campbell County, in northeastern Wyoming. It encompasses all or parts of Townships 49, 50 and 51 North, Ranges 70 and 71 West, and covers the area: 44° 15' to 44° 22' 30" north latitude 105° 15' to 105° 22' 30" west longitude.

Main access to the Fortin Draw Quadrangle is provided by U. S. Highway 14-16 which extends east-west across the southern third of the quadrangle. Two maintained gravel roads branch southward from U. S. Highway 14-16, and another maintained road angles northeast to southwest through the northwest quarter of the area. Minor roads and trails that branch from the aforementioned roads provide additional access to the Fortin Draw Quadrangle. The Burlington Northern railroad extends east to west across the southern third of the quadrangle and parallels U. S. Highway 14-16 between Gillette and Newcastle, Wyoming. The Burlington Northern railroad also extends southward through the southeast quarter of the quadrangle providing access to several coal mines.

The major drainage is provided by eastward-flowing Donkey Creek which extends across the southern half of the Fortin Draw Quadrangle and drains into the Belle Fourche River. Dry Donkey Creek drains the rugged

terrain found in the southeast quarter of the quadrangle. High, rugged terrain is present in the Rochelle Hills area in the southeast quarter and in the Deer Creek Breaks area of the northeast portion of the quadrangle. Elevations attain a maximum height of 4781 feet (1457 m) above sea level, 400 to 500 feet (122 to 152 m) above the valley floors. The somber grays, yellows, and browns of outcropping shales and siltstones contrast strikingly with the brilliant reds, oranges, and purples of "clinker", and deep greens of the juniper and pine tree growth.

The thirteen to fourteen inches (33 to 36 cm) of annual precipitation that falls in this semi-arid region accrues principally in the springtime. Summer and fall precipitation usually originates from thunderstorms, and infrequent snowfalls of six inches (15 cm) or less generally characterize winter precipitation. Although temperatures ranging from less than -25°F (-32°C) to more than 100°F (38°C) have been recorded near Gillette, Wyoming, average wintertime minimums and summertime maximums approach +5° to +15°F (-15° and -9°C) and 75° to 90°F (24° to 32°C), respectively.

Surface ownership is divided among fee, state, and federal categories with the state and federal surface generally leased to ranchers for grazing purposes. Details of surface ownership are available at the Campbell County Courthouse in Gillette, Wyoming. Details of mineral ownership on federal lands are available from the U. S. Bureau of Land Management in Cheyenne, Wyoming. Federal coal ownership is shown on Plate 2 of the Coal Resource Occurrence maps. The non-federal coal ownership comprises both fee and state coal resources.

The Coal Resource Occurrence and Coal Development Potential program pertains to unleased federal coal and focuses upon: 1) the delineation of lignite, subbituminous, bituminous and anthracite coal at the surface and in the subsurface on federal land; 2) the identification of total tons in place as well as recoverable tons; 3) categorization of these tonnages into measured, indicated, and inferred reserves and resources, and hypothetical resources; and 4) recommendations regarding the potential for surface mining, underground mining, and in-situ gasification of the coal beds. This report evaluates the coal resources of all unleased federal coal beds in the quadrangle which are 5 feet (1.5 m) or greater in thickness and occur at depths down to 3000 feet (914 m). No resources or reserves are computed for leased federal coal, state coal, fee coal or lands encompassed by coal prospecting permits and preference right lease applications.

Surface and subsurface geological and engineering extrapolations drawn from the current data base suggest the occurrence of approximately 250 million tons(226 million metric tons) of total unleased federal coal-in-place in the Fortin Draw Quadrangle.

The suite of maps that accompany this report set forth and portray the coal resource and reserve occurrence in considerable detail. For the most part, this report supplements the cartographically displayed information with minimum verbal duplication of the CRO-CDP map data.

II. Geology

Regional. The thick, economic coal deposits of the Powder River Basin in northeastern Wyoming occur mostly in the Tongue River Member of the Fort Union Formation, and in the lower part of the Wasatch Formation. Approximately 3000 feet (914 m) of the Fort Union Formation, that includes

the Tongue River, Lebo, and Tullock Members of Paleocene age, are unconformably overlain by approximately 700 feet (213 m) of the Wasatch Formation of Eocene age. These Tertiary formations lie in a structural basin flanked on the east by the Black Hills uplift, on the south by the Hartville and Casper Mountain uplifts, and on the west by the Casper Arch and the Big Horn Mountain uplift. The structural configuration of the Powder River Basin originated in Late Cretaceous time, with episodic uplift thereafter. The Cretaceous Cordillera was the dominant positive land form throughout the Rocky Mountain area at the close of Mesozoic time.

Outcrops of the Wasatch Formation and the Tongue River Member of the Fort Union Formation cover most of the areas of major coal resource occurrence in the Powder River Basin. The Lebo Member of the Fort Union Formation is mapped at the surface northeast of Recluse, Wyoming, east of the principal coal outcrops and associated clinkers (McKay, 1974), and presumably projects into the subsurface beneath much of the basin. One of the principal characteristics for separating the Lebo and Tullock Members (collectively referred to as the Ludlow Member east of Miles City, Montana) from the overlying Tongue River Member is the color differential between the lighter-colored upper portion and the somewhat darker lower portion (Brown, 1958). Although geologists working with subsurface data, principally geophysical logs, in the basin are trying to develop criteria for subsurface recognition of the Lebo-Tullock and Tongue River-Lebo contacts, no definitive guidelines are known to have been published. Hence, for subsurface mapping purposes, the Fort Union Formation is not divided into its member subdivisions for this study.

During the Paleocene epoch, the Powder River Basin tropic to subtropic depositional environment included broad, inland flood basins with

extensive swamps, marshes, freshwater lakes, and a sluggish but active northeastward discharging drainage system, superimposed on a near base level, emerging sea floor. Much of the vast areas where organic debris collected was within a reducing depositional environment. Localized uplifts began to disturb the near sea level terrain of northeastern Wyoming, following retreat of the Cretaceous seas. However, the extremely fine-grained characteristics of the Tongue River Member clastics suggest that areas of recurring uplift peripheral to the Powder River Basin were subdued during major coal deposit formation.

The uplift of areas surrounding the Powder River Basin created a structural basin of asymmetric characteristic, with the steep west flank located on the eastern edge of the Big Horn Mountains. The axis of the Powder River Basin is difficult to specifically define, but is thought to be located in the western part of the Basin, and to display a north-south configuration some 15 to 20 miles (24 to 32 km) east of Sheridan, Wyoming. Thus, the sedimentary section described in this report lies on the east flank of the Powder River Basin, with gentle dips of two degrees or less disrupted by surface structure thought to relate to tectonic adjustment and differential compaction.

Some coal beds in the Powder River Basin exceed 200 feet (61 m) in thickness. Deposition of these thick, in-situ coal beds requires a discrete balance between subsidence of the earth's crust and in-filling by tremendous volumes of organic debris. These conditions in concert with a favorable ground water table, non-oxidizing clear water, and a climate amenable to the luxuriant growth of vegetation produce a stabilized swamp critical to the deposition of coal beds.

Deposition of the unusually thick coal beds of the Powder River Basin may be partially attributable to short distance water transportation of organic detritus into areas of crustal subsidence. Variations in coal bed thickness throughout the basin relate to changes in the depositional environment. Drill hole data that indicate either the complete absence or extreme attenuation of a thick coal bed probably relate to location within the ancient stream channel system servicing this low land area in Early Cenozoic time. Where thick coal beds thin rapidly from the depocenter of a favorable depositional environment, it is not unusual to encounter synclinal structure over the maximum coal thickness due to the differential compaction between organic debris in the coal depocenter and fine-grained clastics in the adjacent areas.

The Wasatch Formation of Eocene age crops out over most of the central part of the Powder River Basin and exhibits a disconformable contact with the underlying Fort Union Formation. The contact has been placed at various horizons by different workers; however, for the purpose of this report, in northwestern Campbell County, Wyoming, the contact is positioned near the top of the Roland coal bed as mapped by Olive (1957) and is considered to disconformably descend in the stratigraphic column to the top of the Wyodak-Anderson coal bed (Roland coal bed of Taff, 1909) along the eastern boundary of the coal measures. No attempt is made to differentiate the Wasatch and Fort Union Formations on geophysical logs or in the subsurface mapping program that is a part of this CRO-CDP project.

Although Wasatch and Fort Union lithologies are too similar to allow differentiation in some areas, most of the thicker coal beds occur in the Fort Union section on the east flank of the Powder River Basin. Furthermore, orogenic movements peripheral to the basin apparently increased in magnitude during Wasatch time causing the deposition of friable, coarse-grained to

gritty arkosic sandstones, fine-to very fine-grained sandstones, siltstones, mudstones, claystones, brown-to-black carbonaceous shales and coal beds. These sediments are noticeably to imperceptibly coarser than the underlying Fort Union clastics.

The Fortin Draw Quadrangle is located in an area where surface rocks are classified into the Tongue River Member of the Fort Union Formation and the Wasatch Formation. Although the Tongue River Member is reportedly 1200 to 1300 feet (366 to 396 m) thick (Olive, 1957), only 400 to 500 feet (122 to 152 m) are exposed in this area. Approximately 50 to 180 feet (15 to 55 m) of the Wasatch Formation crop out in the quadrangle. Olive (1957) correlated coal beds in the Spotted Horse coal field with coal beds in the Sheridan coal field (Baker, 1929) and Gillette coal field (Dobbin and Barnett, 1927), Wyoming, and with coal beds in the Ashland coal field (Bass, 1932) in southeastern Montana. This report utilizes, where possible, the coal bed nomenclature used in previous reports.

IntraSearch's correlation of thick coal beds from the Spotted Horse coal field to Gillette points out that the Wyodak coal bed, named the D coal bed by Dobbin and Barnett (1927), is equivalent to the Anderson, Canyon and all or part of the Cook coal beds to the north and west of the Fortin Draw Quadrangle. Due to problematic correlations outside of the Gillette area, the name Wyodak has been informally used by many previous authors to represent the coal beds in the area surrounding the Wyodak coal mine. The Wildcat and Moyer coal beds were informally named by IntraSearch (1978 and 1979).

Local. The Fortin Draw Quadrangle lies on the eastern flank of the Powder River Basin, where the strata dip gently westward. The Wasatch Formation caps the higher elevations in the southwest quarter of the quadrangle, and is comprised of fine-to very fine-grained sandstones, brown-to-black

carbonaceous shales, and very thin, lenticular coal beds. The Tongue River Member of the Fort Union Formation crops out over the remaining area. The Fort Union Formation is composed of very fine-grained sandstones, siltstones, claystones, shales, carbonaceous shales, and numerous coal beds. Metamorphosed overburden (clinker) covers approximately eighty-five percent of the surface in this quadrangle.

III. Data Sources

Areal geology of the coal outcrops and associated clinker is derived from the Preliminary Geologic Map and Coal Resources of the Fortin Draw Quadrangle by Law (1974).

The major source of subsurface control, particularly on deep coal beds, is the geophysical logs from oil and gas test bores and producing wells. Some geophysical logs are not applicable to this study, for the logs relate only to the deep potentially productive oil and gas zones. More than eighty percent of the logs include resistivity, conductivity, and self-potential curves. Occasionally the logs include gamma, density, and sonic curves. These logs are available from several commercial sources.

All geophysical logs available in the quadrangle are scanned to select those with data applicable to Coal Resource Occurrence mapping. Paper copies of the logs are obtained, interpreted, and coal intervals annotated. Maximum accuracy of coal bed identification is accomplished where gamma, density, and resistivity curves are available. Coal bed tops and bottoms are picked on the logs at the midpoint between the minimum and maximum curve deflections. The correlation of coal beds within and between quadrangles is achieved utilizing a fence diagram to associate local correlations with regional coal occurrences.

The reliability of correlations, set forth by IntraSearch in this report, vary depending upon: the density and quality of lithologic and geophysical logs; the detail, thoroughness, and accuracy of published and unpublished surface geological maps; and interpretative proficiency. There is no intent on the part of IntraSearch to refute nomenclature established in the literature or used locally by workers in the area. IntraSearch nomenclature focuses upon the suggestion of regional coal bed names applicable throughout the eastern Powder River Basin It is expected and entirely reasonable that some differences of opinion regarding correlations, as suggested by IntraSearch, exist. Additional drilling for coal, oil, gas, water, and uranium, coupled with expanded mapping of coal bed outcrops and associated clinkers will broaden the data base for coal bed correlations and allow continued improvement in the understanding of coal bed occurrences in the eastern Powder River Basin.

The topographic map of the Fortin Draw Quadrangle is published by the U. S. Geological Survey, compilation date, 1971. Land ownership data are compiled from land plats available from the U. S. Bureau of Land Management in Cheyenne, Wyoming. This information is current to October 13, 1977.

IV. Coal Bed Occurrence

Only thin, lenticular coal beds occur in the Lower Wasatch Formation in the Fortin Draw Quadrangle. Fort Union Formation coal beds that are present in all or part of the quadrangle include, in descending stratigraphic order, the Wyodak, Wildcat, and Moyer coal beds. A complete suite of maps (structure, isopach, mining ratio, overburden/interburden, identified resources and areal distribution of identified resources) is prepared for each of these coal beds.

A Physical and chemical analysis regarding the Wyodak coal bed in the Fortin Draw Quadrangle was obtained from U. S. Geological Survey and Montana Bureau of Mines and Geology drill hole 7363, located in Section 23, T. 50 N., R. 71 W. The "as received" basis proximate analysis is as follows:

COAL BED NAME	ASH %	FIXED CARBON %	MOISTURE %	VOLATILES %	SULPHUR %	BTU/LB
Wyodak (U) U.S. 7363	6.830	30.574	31.710	30.885	0.652	7807

(U) - U. S. Geological Survey & Montana Bureau of Mines & Geology - 1974.

The Coal Data Sheets, Plate 3a and 3b, show the downhole identification of coal beds within the quadrangle as interpreted from U. S. Geological Survey and Montana Bureau of Mines and Geology drill holes, and from oil and gas test bores and producing sites. A datum coal bed, is utilized to position columnar sections on Plate 3. This portrayal is schematic by design; hence, no structural or coal thickness implications are suggested by the dashed correlation lines projected through no record (NR) intervals. In the southwestern part of the quadrangle, the Wyodak coal bed is designated as datum for the correlation diagram (Plate 3b). Due to the sporadic subsurface coal bed occurrences on Plate 3a, there is no datum.

Clinker, resulting from the burning of the Wyodak coal bed, covers approximately eighty-five percent of the quadrangle except in portions of the southwest quarter. A thin, non-coal interval 3 to 52 feet (0.9 to 16 m) thick divides the Wyodak coal bed into upper and lower units. Aggregate coal bed thicknesses range from 60 to 86 feet (18 to 26 m) with maximum thicknesses occurring along the southwestern edge of the quadrangle. An Upper Wyodak coal bed burn-erosion line extending northwest to south-

east across the southwest quarter of the quadrangle delimits an area to the west where the Upper Wyodak coal bed is partially preserved from burning and erosion. East of this line is insufficient data for mapping of the lower Wyodak coal bed. Where the Wyodak coal bed is present, it lies less than 500 feet (152 m) beneath the surface. The structural configuration of the Wyodak coal bed portrays a westward dip of one to two degrees with no significant structural features superimposed thereon.

The Wildcat coal bed lies 400 to 500 feet (122 to 152 m) beneath the Wyodak coal bed and ranges from 0 to 13 feet (0 to 4 m) in thickness. A maximum coal bed thickness is located in the southwest corner of the area. The coal bed thins from this area eastward. Due to the lenticular nature of the Wildcat coal bed, it underlies portions of the western half of the quadrangle. Approximately sixty percent of the Wildcat coal bed lies 500 feet (152 m) or more beneath the surface. The Wildcat coal bed has a westward dip of one to two degrees.

The Moyer coal bed lies 75 to 125 feet (23 to 38 m) beneath the Wildcat coal bed and ranges from 0 to 10 feet (0 to 3.0 m) in thickness. Maximum thicknesses occur in the southwest corner of the quadrangle. The Moyer coal bed is absent from approximately sixty-five percent of the quadrangle, and occurs only in portions of the western half of the study area. The westward dipping Moyer coal bed lies more than 500 feet (152 m) beneath the surface throughout approximately ninety percent of its area of occurrence.

V. Geological and Engineering Mapping Parameters

Subsurface mapping is based on geologic data within and adjacent to the Fortin Draw Quadrangle area. Data from geophysical logs are used to correlate coal beds and control contour lines for the coal thickness, structure,

and overburden maps. Isopach lines are also drawn to honor selected measured sections where there is sparse subsurface control. Where isopach contours do not honor surface measured sections, the surface thicknesses are thought to be attenuated by oxidation and/or erosion, hence not reflective of total coal thickness. Structure contour maps are constructed on the tops of the main coal beds. Where subsurface data is scarce, supplemental structural control points are selected from the topographic map along coal outcrops.

In preparing overburden isopach maps, no attempt is made to identify coal beds that occur in the overburden to a particular coal bed under study. Mining ratio maps for this quadrangle are constructed utilizing a ninety-five percent recovery factor. Contours of these maps identify the ratio of cubic yards of overburden to tons of recoverable coal. Where ratio control points are sparse, interpolated points are computed using coal structure, coal isopach, and topographic control. On the Areal Distribution of Identified Resources Map (ADIR), coal bed reserves are not calculated where the coal is less than 5 feet (1.5 m) thick, where the coal occurs at a depth greater than 500 feet (152 m), where non-federal coal exists, or where federal coal leases, preference right lease applications, and coal prospecting permits exist.

Coal tonnage calculations involve the planimetering of areas of measured, indicated, inferred reserves and resources, and hypothetical resources to determine their areal extent in acres. An Insufficient Data Line is drawn to delineate areas where surface and subsurface data are too sparse for CRO map construction. Various categories of resources are calculated in the unmapped areas by utilizing coal bed thicknesses mapped in the geologically controlled area adjacent to the insufficient data line. Acres are multiplied by the average coal bed thickness and 1770 (the number of tons of subbituminous C per acre-foot; 13,018 metric tons per hectare-meter, to deter-

mine total tons in place. Recoverable tonnage is calculated at 95 percent of the total tons in place. Where tonnages are computed for the CRO-CDP map series, resources and reserves are expressed in millions of tons. Frequently the planimetering of coal resources on a sectionized basis involves complexly curvilinear lines (coal bed outcrop and 500-foot stripping limit designations) in relationship with linear section boundaries and circular resources category boundaries. Where these relationships occur, generalizations of complex curvilinear lines are discretely utilized, and resources and/or reserves are calculated within an estimated two to three percent plus or minus accuracy.

VI. Coal Development Potential

Strippable Coal Development Potential. Areas where coal beds are 5 feet (1.5 m) or more in thickness and are overlain by 500 feet (152 m) or less of overburden are considered to have potential for surface mining and are assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios is as follows:

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

where MR = mining ratio
t_o = thickness of overburden
t_c = thickness of coal
rf = recovery factor
0.911 = conversion factor (cu. yds./ton)

Surface mining potential relates to the following mining ratio criteria for coal beds 5 to 40 feet (1.5 to 12 m) thick:

1. Low development potential = 15:1 and greater ratio.
2. Moderate development potential = 10:1 to 15:1 ratio.
3. High development potential = 0 to 10:1 ratio.

The following mining ratio criteria is utilized for coal beds greater than 40 feet (12 m) thick:

1. Low development potential = 7:1 and greater ratio.
2. Moderate development potential = 5:1 to 7:1 ratio.
3. High development potential = 0 to 5:1 ratio.

The surface mining potential map for the Fortin Draw Quadrangle delimits some high potential in an area less than ten square miles in size in the west-central and southwest part of the quadrangle. This high potential results from the thick Wyodak coal bed occurring at a shallow depth beneath the surface with low mining ratios. The existing data base indicates either no coal beds or thin, deeply buried coal beds throughout the remaining eighty percent of the area, which produces an area of no surface, underground mining, or in-situ gasification potential. Table 1 sets forth the estimated strippable reserve base tonnages per coal bed for the quadrangle.

Underground Mining Coal Development Potential. Subsurface coal mining potential throughout the Fortin Draw Quadrangle is considered low. Inasmuch as recovery factors have not been established for the underground development of coal beds in this quadrangle, reserves are not calculated for coal beds buried more than 500 feet (152 m) beneath the surface. Table 2 sets forth the estimated coal reserve base in tons per coal bed.

In-Situ Gasification Coal Development Potential. The evaluation of subsurface coal deposits for in-situ gasification potential relates to the occurrence of coal beds more than 5 feet (1.5 m) thick buried from 500 to 3000 feet (152 to 914 m) beneath the surface. This categorization is as follows:

1. Low development potential relates to: 1) a total coal section less than 100 feet (30 m) thick that lies 500 feet (152 m) to 3000 feet (914 m) beneath the surface, or 2) coal

beds 5 feet (1.5 m) or more in thickness that lie 500 feet (152 m) to 1000 feet (305 m) beneath the surface.

2. Moderate development potential is assigned to a total coal section from 100 to 200 feet (30 to 61 m) thick, and buried from 1000 to 3000 feet (305 to 914 m) beneath the surface.

3. High development potential involves 200 feet (61 m) or more of total coal thickness buried from 1000 to 3000 feet (305 to 914 m).

The coal development potential for in-situ gasification on the Fortin Draw Quadrangle is low, hence no CDP map is generated for this map series. The reserve base tonnage for in-situ gasification with low development potential totals approximately 69 million tons (62 million metric tons) (Table 3). None of the coal beds in the Fortin Draw Quadrangle qualify for a moderate or high development potential rating.

Table 1.--Strippable Coal Reserve Base Data (in short tons) for Federal Coal Lands in the Fortin Draw Quadrangle, Campbell County, Wyoming.

Development potentials are based on mining ratios (cubic yards of overburden/ton of recoverable coal).

Coal Bed	High Development Potential (0-10:1 Mining Ratio)	Moderate Development Potential (10:1-15:1 Mining Ratio)	Low Development Potential (>15:1 Mining Ratio)	Total
Wildcat	———	———	6,580,000	6,580,000
Moyer	———	———	———	———
	(0-5:1 Mining Ratio)	(5:1-7:1 Mining Ratio)	(> 7:1 Mining Ratio)	
Wyodak	166,110,000	———	———	166,110,000
TOTAL	166,110,000	———	6,580,000	172,690,000

Table 2.--Coal Resource Base Data (in short tons) for Underground Mining Methods for Federal Coal Lands in the Fortin Draw Quadrangle, Campbell County, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Wyodak	———	———	———	———
Wildcat	———	———	35,130,000	35,130,000
Moyer	———	———	32,620,000	32,620,000
Total	———	———	67,750,000	67,750,000

Table 3.--Coal Resource Base Data (in short tons) for In-Situ Gasification for Federal Coal Lands in the Fortin Draw Quadrangle, Campbell County, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Wyodak	———	———	———	———
Wildcat	———	———	35,130,000	35,130,000
Moyer	———	———	32,620,000	32,620,000
TOTAL	———	———	67,750,000	67,750,000

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