UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TEXT TO ACCOMPANY:

COAL RESOURCE OCCURRENCE

AND

COAL DEVELOPMENT POTENTIAL

MAPS

OF THE

SOUTHWEST QUARTER OF NORTH STAR SCHOOL 15' QUADRANGLE,

CAMPBELL COUNTY, WYOMING

BY

INTRASEARCH INC.

DENVER, COLORADO

OPEN FILE REPORT 79-066
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This report is preliminary, and has not been edited or reviewed for conformity with United States Geological Survey standards or stratigraphic nomenclature.

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CONVERSION TABLE

TO CONVERT	MULTIPLY BY	TO OBTAIN
inches	2.54	centimeters (cm)
feet	0.3048	meters (m)
miles	1.609	kilometers (km)
acres	0.40469	hectares (ha)
tons (short)	0.9072	metric tons (t)
cubic yards/ton	0.8428	cubic meters per metric tons
acre feet	0.12335	hectare-meters
Btu/lb	2.326	kilojoules/kilogram (kJ/kg)
Btu/lb	0.55556	kilocalories/kilogram (kcal/kg)
Fahrenheit	5/9 (F-32)	Celsius

I. Introduction

This report and accompanying maps set forth the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) of coal beds within the Southwest Quarter of North Star School 15' Quadrangle, Campbell County, Wyoming. This CRO and CDP map series (U. S. Geological Survey Open-File Report 79-066) includes 40 plates. The project is compiled by IntraSearch Inc., 5351 South Roslyn Street, Englewood, Colorado, under KRCRA Eastern Powder River Basin, Wyoming Contract Number 14-08-0001-17180. This contract is part of a program to provide an inventory of unleased federal coal in Known Recoverable Coal Resource Areas (KRCRAs) in the western United States.

The Southwest Quarter of North Star School 15' Quadrangle is located in Campbell County, in northeastern Wyoming. It encompasses all or parts of Townships 44 and 45 North, Ranges 73 and 74 West, and covers the area: 43"45' to 43°52'30" north latitude; 105°37'30" to 105°45' west longitude.

Main access to the Southwest Quarter of North Star School 15' Quadrangle is provided by several maintained gravel roads. The most important of these gravel roads extends north to south bisecting the quadrangle into nearly two equal halves. Other gravel roads branch from this road and extend into the southwestern, southeastern, and extreme northeastern portions of the quadrangle. Minor roads and trails provide additional access to the more remote areas. The closest railroad is the Burlington Northern trackage, 14 miles (23 km) to the east, north of the Black Thunder coal mine.

The Belle Fourche River flows northward across the eastern half of the quadrangle. Mud Spring Creek and Fourmile Creek, tributaries of the Belle Fourche River, drain the west-central and southwestern portions of the study area. Elevations attain heights of 5220 feet (1591 m) above sealevel in the southeastern quarter of the quadrangle, 300 to 350 feet (91 to 107 m) above the valley of the Belle Fourche River in the northeastern quarter of the quadrangle.

The 13 to 14 inches (33 to 36 cm) of annual precipitation falling in this semi-arid region accrue principally in the springtime. Summer and fall precipitation usually originates from thunderstorms, and infrequent snowfalls of 6 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 range from +5° to +°15F (-15° to -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 the delineation of lignite, subbituminous coal, bituminous coal, and anthracite at the surface, and in the subsurface. In addition, the program identifies total tons of coal in place, as well as recoverable tons. These coal tonnages are then categorized into units of measured, indicated, and inferred reserves and resources, and hypothetical resources. Finally, recommendations are made 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 8.4 billion tons (7.6 billion metric tons) of unleased federal coal resources in the Southwest Quarter of North Star School 15' Quadrangle.

The suite of maps that accompany this report sets forth and portrays 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, including 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 Tongue River Member is composed of very fine-grained sandstones, siltstones, claystones, shales, carbonaceous shales, and numerous coal beds. The Lebo Member of the Fort Union Formation consists of light- to dark-gray very fine-grained to conglomeratic sandstone with interbedded siltstone, claystone, carbonaceous shale and thin coal beds. Thin bedded calcareous ironstone concretions interbedded with massive white sandstone and slightly bentonitic shale occur throughout the unit (Denson and Horn, 1975). The Lebo Member is mapped at the surface northeast of Recluse, Wyoming. Here, the Lebo Member is east of the principal coal outcrops and associated clinkers (McKay, 1974), and it 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 are trying to develop criteria for subsurface recognition of the Lebo-Tullock and Tongue River-Lebo contacts through the use of subsurface data from geophysical logs, no definitive guidelines are known to have been published. Hence, for subsurface mapping purposes, the Fort Union Formation is not divided into its members for this study.

During the Paleocene epoch, the Powder River Basin tropical to subtropical depositional environment included broad, inland flood basins with extensive swamps, marshes, freshwater lakes, and a sluggish, but active, northeastward-discharging drainage system. These features were superimposed on an emerging sea floor, near base level. Much of the vast area 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 character, 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 it 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 delicate 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 of the drill holes within the ancient stream channel system draining this lowland 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 a 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, the contact is positioned near the top of the Roland coal bed as mapped by Olive (1957) in northwestern Campbell County, Wyoming. It is considered to descend disconformably 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 was made to differentiate the Wasatch and Fort Union Formations on geophysical logs or in the subsurface mapping program for this 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 Southwest Quarter of North Star School 15' Quadrangle is located in an area where the surface rocks are classified within the Wasatch Formation. 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. The Felix coal bed was named by Stone and Lupton (1910). The Smith coal bed was named by Taff (1909). The Wildcat, Moyer, and Oedekoven coal beds were informally named by IntraSearch (1978b, 1979, and 1978a).

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 Gillette, Wyoming. Correlation of this suite of coal beds with the Wyodak coal bed south and southwest of Gillette suggest that the Anderson and Canyon coal beds equate with the upper 10 to 25 percent of the thick Wyodak coal bed, and the Cook and Wall or Upper Wall coal beds are equivalent to the major part of the Wyodak coal bed. 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 Pawnee coal bed was designated by Warren (1959).

Local. The Southwest Quarter of North Star School 15' Quadrangle lies on the eastern flank of the Powder River Basin, where the strata dip gently westward. The Wasatch Formation crops out over the entire quadrangle, and is comprised 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.

III. Data Sources

Areal geology of the coal outcrops and associated clinker is derived from Wegemann and others (1928). The coal bed outcrops are adjusted to the current topographic map in the area. The Upper Felix and Lower Felix coal beds of this report are stratigraphically equivalent to the "D" and "E" coal beds of Wegemann and others (1928), respectively.

Geophysical logs from oil and gas test bores and producing wells comprise the source of subsurface control. 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 80 percent of the logs include resistivity, conductivity, and self-potential curves. Occasionally the suite of geophysical logs includes 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 and interpreted, and coal intervals are annotated. Maximum accuracy of coal bed indentification 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.

In some parts of the Powder River Basin, additional subsurface control is available from U. S. Geological Survey open-file reports that include geophysical and lithologic logs of shallow holes drilled specifically for coal exploration. A sparse scattering of subsurface data points are shown on unpublished CRO-CDP maps compiled by the U. S. Geological Survey, and where these data are utilized, the rock-coal intervals are shown on the Coal Data Map (Plate 1). Inasmuch as these drill holes have no identifier headings, they are not set forth on the Coal Data Sheet (Plate 3). The geophysical logs of these drill holes were not available to IntraSearch to ascertain the accuracy of horizontal location, topographic elevation, and downhole data interpretation.

The reliability of correlations, set forth by IntraSearch in this report, varies depending on: 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's 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 North Star School 15' Quadrangle is published by the U. S. Geological Survey, compilation date 1959. Expansion of the topographic base of the North Star School 15' Quadrangle (1:62,500 scale) into seven and one-half minute quadrangle maps (1:24,000 scale) was performed by the U. S. Geological Survey for Coal Resource Occurrence - Coal Development Potential mapping purposes. Land network and mineral 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

Wasatch and Fort Union Formation coal beds that are present in all or parts of the Southwest Quarter of North Star School 15' Quadrangle include, in descending stratigraphic order: the Upper Felix, the Lower Felix, the Smith, an unnamed local, the Upper Wyodak, the Middle Wyodak, the Lower Wyodak, the Pawnee, a second unnamed local, a third unnamed local, the Wildcat, the Moyer, the Oedekoven, and a fourth unnamed local coal bed. A complete suite of maps (coal isopach, structure, overburden isopach, areal distribution of identified resources, identified, and where applicable, hypothetical resources) is prepared for the Upper Felix, Lower Felix, Smith, Upper Wyodak, and Pawnee coal beds, and for the Middle-Lower Wyodak and Wildcat-Moyer-Oedekoven coal zones. Mining-ratio contours are presented on the isopach maps of the Upper Felix, Lower Felix, and Smith coal beds. Insufficient data and areal extent precludes detailed mapping of the local coal beds.

Physical and chemical analyses are published regarding the Upper Felix and Lower Felix coal beds in the Southwest Quarter of North Star School 15' Quadrangle. The "as received" basis analyses for the Smith, Wyodak, Pawnee, and Wildcat coal beds are from surrounding quadrangles in central and southern Campbell County and northern Converse County. These proximate analyses are as follows:

COAL BED NAME			ASH %	FIXED CARBON %	MOISTURE %	VOLATILES %	SULFUR %	BTU/LB
(Upper Felix) "D"	(**)		6.2	29.7	35.5	30.5	1.2	7348
(Lower Felix) "E"	(**)		7.8	31.1	29.0	32.0	1.4	8215
Smith	(U)	Hole 7312C	6.167	33.340	29.610	30.883	1.068	8215
Wyodak	(U)	Hole 757	6.024	32.831	26.907	34.237	0.336	8366
Pawnee	(U)	Hole 7424C	7.880	31.029	31.910	29.183	0.386	7344
(Wildcat) "D"	(*)	Sample 11447	4.3	38.5	27.8	29.4	0.27	8410

(**) - Wegemann and others, 1928
(*) - Winchester, 1912
(U) - U. S. Geological Survey & Montana Bureau of Mines and Geology - 1974, 1976.

The Coal Data Sheet, Plate 3, shows the down hole identification of coal beds within the quadrangle as interpreted from geophysical logs 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. Inasmuch as the Wildcat coal bed underlies the entire quadrangle, it is designated as datum for the correlation diagram. The Upper Wyodak coal bed and the Middle-Lower Wyodak coal zone show the thickest coal occurrences throughout the quadrangle. The Upper Felix, Lower Felix, Smith and Pawnee coal beds, and the Wildcat-Moyer-Oedekoven coal zone show relatively uniform, thin coal occurrences throughout the quadrangle.

Eroded from approximately 40 percent of the study area, the Upper Felix coal bed crops out along the Belle Fourche River valley. The Upper Felix coal bed attains a maximum thickness of over 8 feet (2.4 m) in the southeastern quarter of the study area (Plate 4). Structure contours drawn on top of the Upper Felix coal bed indicate a northwestward-plunging anticline in the east-central portion of the quadrangle (Plate 5). The nose of the anticline is in the area of eroded Upper Felix coal and is not shown. The maximum overburden above the Upper Felix coal bed, approximately 350 feet (107 m), occurs in the northwestern quadrant (Plate 6).

Approximately 46 to 197 feet (14 to 60 m) below the Upper Felix coal bed, the Lower Felix coal bed also crops out along the Belle Fourche River valley. The Lower Felix coal bed is eroded from approximately 10 percent of the quadrangle. Maximum Lower Felix coal bed thicknesses of over 25 feet (8 m) are located in the northeast portion of the study area (Plate 9). The non-coal interburden contained within the Lower Felix coal bed ranges in thickness from 0 to 5 feet (0 to 1.5 m). The Lower Felix coal bed dips one to two degrees to the north-northwest (Plate 10), and lies 0 to 450 feet (0 to 137 m) beneath the surface (Plate 11).

A non-coal interval of approximately 325 to 405 feet (99 to 123 m) separates the Smith coal bed from the overlying Lower Felix coal bed. The Smith coal bed varies in thickness from less than 5 feet (1.5 m) in the northwestern corner to more than 15 feet (5 m) in the northeastern and southern portions of the quadrangle (Plate 14). Structure contours drawn on top of the Smith coal bed indicate a northeast-southwest trending anticline in the southeastern quadrant, and a dip of less than two degrees to the northwest throughout the remainder of the quadrangle (Plate 15). The Smith coal bed occurs at depths of less than 400 feet (122 m) to greater than 750 feet (229 m) throughout the study area (Plate 16).

The Upper Wyodak coal bed lies approximately 134 to 274 feet (41 to 84 m) below the Smith coal bed. A minimum of less than 15 feet (5 m) thick in the northeastern corner, the Upper Wyodak coal bed attains a maximum thickness of over 75 feet (23 m) in the southwestern quadrant along the western boundary of the quadrangle (Plate 19). The most prominent structural feature of the Upper Wyodak coal bed is a northeast-southwest trending anticline located in the south-central region of the quadrangle (Plate 20). The thickness of overburden above the Wyodak coal bed varies from less than 750 feet (229 m) to more than 1000 feet (305 m) throughout the study area (Plate 21).

The Middle-Lower Wyodak coal zone occurs approximately 130 to 434 feet (40 to 132 m) below the Upper Wyodak coal bed. The combined thickness of coal beds in the Middle-Lower Wyodak coal zone ranges from less than 10 feet (3 m) in the central portion of the quadrangle to more than 80 feet (24 m) in the southeastern quadrant along the eastern quadrangle boundary (Plate 24). Non-coal interburden within the Middle-Lower Wyodak coal zone ranges from 0 to 221 feet (0 to 67 m) thick. The structure contour map of the Middle-Lower Wyodak coal zone is drawn on top of the Middle Wyodak coal bed in the northeastern quadrant and along the extreme eastern boundary of the quadrangle. Structure contours are drawn on top of the Lower Wyodak coal bed throughout the remainder of the quadrangle where the Middle Wyodak coal bed is absent. The structure contours indicate minor flexures superimposed on a dip of one to two degrees to the northwest (Plate 25). The Middle-Lower Wyodak coal zone lies from less than 1000 feet (305 m) to greater than 1250 feet (381 m) beneath the surface (Plate 26).

The Pawnee coal bed lies 178 to 443 feet (54 to 135 m) below the Middle-Lower Wyodak coal zone. Pinched out in the north-central and east-central portions of the quadrangle, the Pawnee coal bed attains a maximum thickness of over 30 feet (9 m) along the western quadrangle boundary (Plate 29). Structure contours drawn on top of the Pawnee coal bed indicate a broad northeast-southwest trending anticline located in the southeastern quadrant (Plate 30). A small, narrow anticline extends east-west across the northern one-third of the quadrangle. The Pawnee coal bed occurs at depths from less than 1250 feet (381 m) to greater than 1750 feet (533 m).

The Wildcat-Moyer-Oedekoven coal zone occurs 304 to 440 feet (93 to 134 m) beneath the Pawnee coal bed and is comprised of two to five rather uniformly thin coal beds. The combined coal bed thicknesses vary from less than 10 feet (3 m) in the extreme southeastern corner to a maximum of 70 feet (21 m) in the northeast quadrant (Plate 34). The total non-coal interburden between these coal beds ranges from 11 to 309 feet (3 to 94 m) in thickness. Generally, the Wildcat-Moyer-Oedekoven coal zone dips to the west (Plate 35). The overburden above the Wildcat-Moyer-Oedekoven coal zone varies from less than 1750 feet (533 m) to greater than 2000 feet (610 m) throughout the Southwest Quarter of North Star School 15' Quadrangle (Plate 36).

V. Geological and Engineering Mapping Parameters

The correct horizontal location and elevation of drill holes utilized in subsurface mapping are critical to map accuracy. Intra-Search Inc., plots the horizontal location of the drill hole as described on the geophysical log heading. Occasionally this location is superimposed on or near to a drillsite shown on the topographic map, and the topographic map, horizontal location is utilized. If the ground elevation on the geophysical log does not agree with the topographic elevation of the drillsite, the geophysical log ground elevation is adjusted to conformance. If there is no indication of a drillsite on the topographic map, the "quarter, quarter, quarter" heading location is shifted within a small area until the ground elevation on the heading agrees with the topographic map elevation. If no elevation agreement can be reached, the well heading or data sheet is rechecked for footage measurements and ground elevation accuracy. Inquiries to the companies who provided the oil and gas geophysical logs frequently reveal that corrections have been made in the original survey. If all horizontal location data sources have been checked and the information accepted as the best available data, the drillsite elevation on the geophysical log is modified to agree with the topographic map elevation. IntraSearch Inc., considers this agreement mandatory for the proper construction of most subsurface maps, but in particular, the overburden isopach, the mining ratio, and Coal Development Potential maps.

Subsurface mapping is based on geologic data within, and adjacent, to the Southwest Quarter of North Star School 15' 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 surface 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, they are not reflective of total coal thickness. Isopach lines extend to the coal bed outcrops, the projections of coal bed outcrops, and the contact between porcellanite (clinker) and unoxidized coal in place. Attenuation of total coal bed thickness is known to take place near these lines of definition; however, the overestimation of coal bed tonnages that results from this projection of total coal thickness is insignificant to the Coal Development Potential maps. Structure contour maps are constructed on the tops of the main coal beds. Where subsurface data are 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 above a particular coal bed under study. Mining ratio maps for this quadrangle are constructed utilizing a 95 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 at the intersections of coal bed and overburden isopach contours 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 1750, or 1770--the number of tons of lignite A or subbituminous C coal per acre-foot, respectively (12,874 or 13,018 metric tons per hectare-meter, respectively), to determine 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 resource category boundaries. Where these relationships occur, generalizations of complexly curvilinear lines are discretely utilized, and resources and/or reserves are calculated within an estimated 2 to 3 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 for subbituminous coal is as follows:

$$MR = \frac{to\ (0.911)^*}{tc\ (rf)}$$

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

*A conversion factor of 0.922 is used for lignite.

A surface mining development potential map (Plate 39) was prepared utilizing 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 are 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 development potential is high for approximately 30 percent of the Southwest Quarter of North Star School 15' Quadrangle. The high potential areas are located in the east-central and northeastern portions of the quadrangle and result from low overburden-to-coal thickness ratios for the Upper and Lower Felix coal beds. A moderate potential rating covers approximately 10 percent of the quadrangle. The moderate potential areas occur adjacent to the high potential areas. Approximately 40 percent of the study area is classified as having low development potential for surface mining methods. Much of the low development potential area occurs along the Belle Fourche River where the Upper and Lower Felix coal beds are eroded away. The remainder of the quadrangle either is considered to have no development potential for surface methods, or is non-federal coal land.

Underground Mining Coal Development Potential. Subsurface coal mining potential throughout the Southwest Quarter of North Star School 15' 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 that occur more than 500 feet (152 m) beneath the surface. Table 2 sets forth the estimated coal resources 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 1000 feet (305 m) to 3000 feet (914 m) beneath the surface, or 2) a coal bed or coal zone 5 feet (1.5 m) or more in thickness which lies 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 within the Southwest Quarter of North Star School 15' Quadrangle is moderate and low. The Upper, Middle, and Lower Wyodak, the Pawnee, the Wildcat, and the Moyer coal beds attain a combined coal thickness of approximately 138 feet (42 m) and are buried more than 1000 feet (305 m) in the northwest corner and along the western edge of the quadrangle. Along the northern and eastern boundaries, the Middle and Lower Wyodak, Pawnee, Wildcat, Moyer and Oedekoven coal beds combine for a coal thickness of slightly greater than 100 feet (30 m) at a burial depth greater than 1000 feet (305 m). The moderate potential for in-situ gasification covers an area that is less than 5 percent of the Southwest Quarter of North Star School 15' Quadrangle (Plate 40) and totals approximately 0.7 billion tons (0.6 billion metric tons) (Table 3). The remaining 95 percent of the study area is low development potential because the total coal thickness that is deeper than 1000 feet (305 m) is less than 100 feet (30 m) thick or the coal beds have between 500 to 1000 feet (152 to 305 m) of overburden. The low development potential for in-situ gasification totals 6.9 billion tons (6.3 billion metric tons). None of the coal beds in the quadrangle qualify for a high development potential rating.

Table 1.--Strippable Coal Reserve Base and Hypothetical Resource Data (in short tons) for Federal Coal Lands in the Southwest Quarter of North Star School 15' 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
RESERVE BASE TONNAGE				
Upper Felix	14,540,000	11,080,000	18,180,000	43,800,000
Lower Felix	268,460,000	59,840,000	151,700,000	480,000,000
Smith	-----	-----	261,460,000	261,460,000
TOTAL	283,000,000	70,920,000	431,340,000	785,260,000
HYPOTHETHICAL RESOURCE TONNAGE				
Smith	-----	-----	460,000	460,000
TOTAL	-----	-----	460,000	460,000
GRAND TOTAL	283,000,000	70,920,000	431,800,000	785,720,000

Table 2.--Coal Resource Base and Hypothetical Resource Data (in short tons) for Underground Mining Methods for Federal Coal Lands in the Southwest Quarter of North Star School 15' Quadrangle, Campbell County, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
RESOURCE BASE TONNAGE				
Smith	-----	-----	398,300,000	398,300,000
Upper Wyodak	------	-----	2,671,100,000	2,671,100,000
Lower Wyodak	-----	-----	1,861,460,000	1,861,460,000
Pawnee	-----	-----	677,010,000	677,010,000
Wildcat-Moyer-Oedekoven	-----	-----	1,959,650,000	1,959,650,000
TOTAL	-----	-----	7,567,520,000	7,567,520,000
HYPOTHETICAL RESOURCE TONNAGE				
Smith	-----	-----	110,000	110,000
Upper Wyodak	-----	-----	5,810,000	5,810,000
Lower Wyodak	-----	-----	1,710,000	1,710,000
Pawnee	-----	-----	270,000	270,000
GRAND TOTAL	-----	-----	7,575,420,000	7,575,420,000

Table 3.--Coal Resource Base and Hypothetical Resource Data (in short tons) for In-Situ Gasification for Federal Coal Lands in the Southwest Quarter of North Star School 15' Quadrangle, Campbell County, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
RESOURCE BASE TONNAGE				
	-----	719,590,000	6,847,930,000	7,567,520,000
TOTAL	-----	719,590,000	6,847,930,000	7,567,520,000
HYPOTHETICAL RESOURCE TONNAGE				
	-----	-----	7,900,000	7,900,000
TOTAL	-----	-----	7,900,000	7,900,000
GRAND TOTAL	-----	719,590,000	6,855,830,000	7,575,420,000

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