UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

COAL RESOURCE OCCURRENCE

AND

COAL DEVELOPMENT POTENTIAL

MAPS

OF THE

LAREY DRAW QUADRANGLE

CAMPBELL COUNTY, WYOMING

BY

INTRASEARCH INC.

DENVER, COLORADO

OPEN FILE REPORT 79-023
1979

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 ton
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

The report and accompanying maps set forth the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) of coal beds within the Larey Draw Quadrangle, Campbell County, Wyoming. This CRO and CDP map series includes 54 plates (U. S. Geological Survey Open-File Report 79-023). 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 federal coal in Known Recoverable Coal Resource Areas (KRCRA) in the western United States.

The Larey Draw Quadrangle is located in Campbell County, in northeastern Wyoming. It encompasses parts of Townships 54 and 55 North, Ranges 75 and 76 West, and covers the area: 44°37'30" to 44°45' north latitude; 105°52'30" to 106°00' west longitude.

Main access to the Larey Draw Quadrangle is provided by U. S. Highway 14-16 which angles east to west across the northern half of the area. Two maintained gravel roads branch north from U. S. Highway 14-16. Another maintained gravel road branches south intersecting a light-duty road which angles northwest to southeast through the southwest corner of the quadrangle. Minor roads and trails that branch from these gravel roads provide additional access to the more remote areas. The closest railroad is the Burlington Northern trackage, 5 miles (8 km) to the southwest at Leiter, Wyoming.

Drainage patterns generate from high, fairly rugged terrain located in the southeast quarter of the quadrangle. Elevations attain heights of 4575 feet (1394 m) above sea level, 700 to 800 feet (213 to 244 m) above the valley floors. Significant northward drainage is provided by Ivy Creek, South Prong of Spotted Horse Creek, and Spotted Horse Creek. The North and Middle Prongs of Wild Horse Creek drain westward. These intermittent streams drain into the Powder River to the northwest. 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 Arvada, 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 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 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).

Surface and subsurface geological and engineering extrapolations drawn from the current data base suggest the occurrence of approximately 9.8 billion tons (8.9 billion metric tons) of total coal-in-place in the Larey 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 depositonal 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 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 and brown-to-black carbonaceous shales. These sediments are noticeably to imperceptibly coarser than the underlying Fort Union clastics.

The Larey 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, 1975), only 700 to 800 feet (213 to 244 m) are exposed in this area. 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). Kent (1976) named the Norfolk coal bed, and the Smith coal bed was named by Taff (1909). The Swartz coal bed was designated by McKay and Mapel (1973), and Baker assigned names to the Anderson, Canyon, and Wall coal beds. The Cook coal bed was named by Bass (1932), and the Pawnee and Cache coal beds were named by Warren (1959). The Oedekoven and Wildcat coal beds were informally named by IntraSearch (1978a, 1978b). The Moyer coal bed is informally named by IntraSearch in this 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 report to represent a rather consistent, thin, deep coal bed, 150 to 200 feet (46 to 61 m) below the Wildcat coal bed. The name Moyer is derived from outcrop exposures located in the Moyer Springs Quadrangle southeast of the Larey Draw Quadrangle.

Local. The Larey 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 over approximately seventy percent of the 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. 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.

A single, northwest-southeast trending fault occurs in the central portion of the southern half of the quadrangle with a vertical displacement of 5 to 10 feet (1.5 to 3 m). This fault is delineated by IntraSearch and is based upon photogeologic interpretation of color aerial photography (scale 1:24,000). A westward-plunging anticline, present in the central portion of the quadrangle, and two adjacent westward-plunging synclines characterize structural configurations on most of the coal beds.

III. Data Sources

Areal geology of the coal outcrops and associated clinker is derived from the Spotted Horse coal field report (Olive, 1957). The coal bed outcrops are adjusted to the current topographic maps in the area. Outcrop configurations are extended into the western half of the quadrangle from data derived by IntraSearch from the photogeologic interpretation of color aerial photography, scale, 1:24,000.

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.

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 drillholes have no identifier headings, they are not set forth on the Coal Data Sheet (Plate 3). IntraSearch cannot obtain geophysical logs of these drill holes to ascertain the accuracy of horizontal location, topographic elevation, and down-hole data interpretation.

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: The thrust of the IntraSearch intent focuses upon the suggestion of a regional nomenclature 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 Larey Draw Quadrangle is published by the U. S. Geological Survey, compilation date, 1971. Land ownership data is compiled from land plats obtained 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 part of the Larey Draw Quadrangle include, in descending stratigraphic order, the Felix, Norfolk, Smith, Swartz, Anderson, Upper Canyon, Lower Canyon, Cook, Wall, Pawnee, Cache, Wildcat, Moyer, and Oedekoven 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, except for the Wildcat, Moyer, and Oedekoven coal beds, where insufficient data, and areal extent preclude detailed mapping.

No physical and chemical analyses are known to have been published regarding the coal beds in the Larey Draw Quadrangle. However, the general "as received" basis proximate analyses for northern Campbell County coal beds are as follows:

COAL BED NAME		ASH	FIXED CARBON	MOISTURE	VOLATILES	SULPHUR	BTU/LB
Felix (U)	Hole 7345	5.223	34.181	30.280	30.316	0.338	8111
Smith (P)		6.440	31.390	35,370	26.800	0.450	7125
Swartz (U)	Hole 7334	6.442	34.001	29.260	30.297	0.707	7738
Anderson (U)	Hole 7406	6.317	31.113	32.583	29.986	0.327	7498
Canyon (P)		4.290	32.852	35.100	27.758	0.307	7298
Cook (P)		4.620	34.410	33.640	27.330	0.250	7766
Wall (U)	Hole 7426	9.542	29.322	32.150	28.985	0.500	7279
Pawnee (U)	Hole 7424	7.880	31.029	31.910	29.183	0.386	7344
Cache (U)	Hole 741	9.481	30.517	31.420	28.582	0.488	7271

(P) - Proprietary Data

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

The Coal Data Sheet, Plate 3, shows the downhole identification of coal beds within the quadrangle as interpreted from geophysical logs from oil and gas test bores and producing sites. Inasmuch as the Anderson coal bed underlies the entire quadrangle, it is designated as datum for the correlation diagram. The Smith, Anderson, Upper Canyon, Cook, and Wall coal beds show the thickest single coal bed occurrences throughout the quadrangle. The Felix, Norfolk, Swartz, Lower Canyon, Pawnee, and Cache coal beds are relatively thin throughout most of the area. Three deep coal beds beneath the Cache coal bed are identified as the Wildcat, Moyer, and Oedekoven coal beds; however, neither the amount of existing data nor the coal thicknesses indicate full-scale mapping of these coal beds to be appropriate. The Canyon, Cook, Wall, Pawnee, Cache, Wildcat, Moyer, and Oedekoven coal beds occur more than 500 feet (152 m) beneath the surface throughout the Larey Draw Quadrangle.

The Felix coal bed is eroded from approximately sixty percent of the quadrangle. Due to the absence of subsurface data for structure and isopach maps, mapping control is derived from outcrop elevations and surface measured sections. The Felix coal bed varies in thickness from 12 to 24 feet (4 to 7 m) with maximum thicknesses occurring in the southeast quarter of the quadrangle. The lack of surface measured sections results in an insufficient data area along the western edge of the study area (Plate 4). Structure contours on the Felix coal bed top define a broad, southeast-plunging anticline located in the northwest quarter of the quadrangle, and a closed structural high in the east-central portion of the quadrangle. These two anticlinal features are separated by a north-to-south trending synclinal feature. The Felix coal bed lies less than 500 feet (152 m) beneath the surface throughout the quadrangle.

The Norfolk coal bed crops out in the northeast corner of the quadrangle, and is separated from the overlying Felix coal bed by 300 to 400 feet (91 to 122 m) of clastic debris. Thicknesses range from 2 to 12 feet (0.6 to 4 m) with maximum thicknesses occuring in the northeast quarter of the area. An insufficient data area in the western portion of the quadrangle results from the absence of subsurface control (Plate 9). The main structural configuration on this coal bed is a westward-plunging anticline which occurs in the central portion of the quadrangle. A westward-plunging syncline is present in the lower third of the quadrangle, with another westward-plunging anticline occurring south of the syncline (Plate 10). The Norfolk coal bed is less than 500 feet (152 m) beneath the surface throughout approximately seventy-five percent of the quadrangle.

The Smith coal bed lies approximately 80 to 130 feet (24 to 40 m) beneath the Norfolk coal bed, and crops out in the northeast corner of the quadrangle along Spotted Horse Creek. The coal bed thickness varies from 19 to 45 feet (6 to 14 m) with maximum thicknesses occurring in the east and southeast portions of the area. The lack of subsurface data in the western portion of the quadrangle requires an insufficient data line for this area (Plate 14). Localized partings occur through the quadrangle with interburdens ranging from 5 to 12 feet (1.5 to 4 m) thick. A westward-plunging anticline occurs in the central portion of the quadrangle. Two less prominent, westward-plunging synclines are located in the northern and southern thirds of the area. The Smith coal bed is less than 500 feet (152 m) beneath the surface throughout approximately sixty percent of the Larey Draw Quadrangle.

The Swartz coal bed occurs 75 to 115 feet (23 to 35 m) beneath the Smith coal bed and varies in thickness from 0 to 20 feet (0 to 6 m). A maximum thickness is attained in the lower third of the quadrangle, with gradual thinning in all directions to a pinchout in the northern third of the quadrangle (Plate 19). A broad, westward-plunging anticline warps the coal bed in the central portion of the quadrangle. A smaller, southwest-plunging syncline is present in the southeast quarter of the quadrangle. Within approximately half of this quadrangle, the Swartz coal bed lies more than 500 feet (152 m) beneath the surface.

The Anderson coal bed lies 55 to 155 feet (17 to 47 m) beneath the Swartz coal bed and 190 to 300 feet (58 to 91 m) below the Smith coal bed where the Swartz coal bed is absent. Thicknesses range from 20 to 40 feet (6 to 12 m) with maximums occurring along the southern edge and northeast quarter of the quadrangle (Plate 24). Structure contours depict a broad, westward-plunging anticline across the central portion of the quadrangle. Two similarly plunging synclines are present in the northwest and southeast quarters of the quadrangle. The Anderson coal bed is greater than 500 feet (152 m) beneath the surface throughout the quadrangle, except for the northeast and extreme northwest areas.

Approximately 0 to 120 feet (0 to 37 m) of clastic debris separate the Anderson coal bed from the Canyon coal bed. The Anderson and Canyon coal beds merge in three drill holes in Section 24, T. 55 N., R. 76 W., Section 29, T. 55 N., R. 75 W., and Section 6, T. 54 N., R. 75 W. The thickness and structural elevation for each coal bed are derived by examining isopach and structural trends in areas surrounding these drill holes. The Canyon coal bed is divided into two units throughout the entire quadrangle with non-coal intervals between the units ranging from 75 to 250 feet (23 to 76 m). The upper portion of this coal bed varies from 0 to 38 feet (0 to 12 m) thick. It is absent from the southern portion of the quadrangle and thickens to the north. The lower unit of the Canyon coal bed occurs 80 to 250 feet (24 to 76 m) beneath the upper unit, and ranges from 0 to 32 feet (0 to 10 m) thick. Maximum thicknesses for the lower unit are located in the southeastern portion of the quadrangle with thinning trends to the north and west. The lower unit is absent along the northern edge of the quadrangle (Plate 29). Structure contours on the upper unit portray a westward-plunging anticline across the central portion of the quadrangle. Two plunging synclines parallel this anticline to the north and south. The lower unit has a gradual south-westward dip with a northwest-trending anticline occurring in the northeast quarter of the Larey Draw Quadrangle.

The Cook coal bed occurs 50 to 250 feet (15 to 76 m) beneath the Lower Canyon coal bed, and 235 to 300 feet (72 to 91 m) below the Upper Canyon coal bed where the Lower Canyon coal bed is absent. The thickness ranges from 0 to 51 feet (0 to 16 m) with maximum thicknesses occurring in the northeast corner of the quadrangle. The Cook coal bed is absent from a small area in the southeast quarter of the quadrangle (Plate 34). A westward-plunging anticlinal feature distorts the coal bed in the central portion of the quadrangle and is paralled by adjacent synclines to the north and south. An area of insufficient data occurs along the southwestern edge of the quadrangle due to inadequate subsurface control (Plates 35, 36).

The Wall coal bed lies 10 to 190 feet (3 to 58 m) beneath the Cook coal bed and varies in thickness from 18 to 30 feet (5 to 9 m). Maximum thicknesses occur along the eastern edge and the far southeast corner of the study area (Plate 39). A southwest-plunging anticline, present across the central portion of the quadrangle, is flanked by two similarly plunging synclines in the northwest and southeast quarters of the quadrangle. A portion of the southwestern quarter of the quadrangle is designated as an insufficient data area due to the lack of subsurface control.

The Pawnee coal bed is separated from the Wall coal bed by a sedimentary interval of 15 to 146 feet (5 to 45 m). Coal bed thicknesses vary from 10 to 20 feet (3 to 6 m) with maximum thicknesses occurring along the eastern and western edges of the quadrangle. Near the western edge of the quadrangle an insufficient data area is designated because of the lack of subsurface control (Plate 44).

The Cache coal bed occurs 65 to 140 feet (20 to 43 m) beneath the Pawnee coal bed and ranges from 0 to 10 feet (0 to 3 m) thick. Minimum thicknesses occur along the northern edge of the quadrangle with gradual thickening southward. The Cache coal bed, absent from a small area along the northeastern edge of the quadrangle, folds to form a westward-plunging anticline across the center of the area with small, synclinal features occurring to the north and south.

V. Geological and Engineering Mapping Parameters

Subsurface mapping is based on geologic data within and adjacent to the Larey 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), and where non-federal coal exists.

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 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. North of the Larey Draw Quadrangle in the Montana portion of the Powder River Basin, a recovery factor of eighty-five percent is utilized because of the general northward thinning of economic coal beds. 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 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:

$$MR = \frac{t_o \ (0.922)}{t_c \ (rf)}$$

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

A surface mining potential map is prepared utilizing the following mining ratio criteria for coal beds 40 feet (12 m) thick or less:

*Conversion factor of 0.911 is used for subbituminous coal; 0.922 is used for lignite.

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 surface mining potential is moderate to high for most of the Larey Draw Quadrangle. The majority of moderate to high surface mining potential areas are located in the eastern half of the quadrangle. The Felix, Norfolk, and thick Smith coal beds crop out with low overburden-to-coal ratios, which accounts for the high surface mining potential in this area. Moderate to low surface mining potential areas are located in the western half of the quadrangle, where the coal beds are beneath increasing overburden thicknesses due to the westward dip of the coal beds. Table 1 sets forth the strippable reserve base tonnages per coal bed for the quadrangle.

Underground Mining Coal Development Potential. Subsurface coal mining potential throughout the Larey Draw Quadrangle is considered low. Table 2 sets forth the 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. <u>Low development</u> potential relates to a total coal section less than 100 feet (30 m) thick, or coal beds that lie 500 feet (152 m) to 1000 feet (305 m) beneath the surface.
2. <u>Moderate development</u> potential is assigned to a total coal section from 100 to 200 feet (30 to 61 m) thick, and from 1000 to 3000 feet (305 to 914 m) beneath the surface.
3. <u>High development</u> 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 Larey Draw Quadrangle is low, hence no CDP map is generated for this map series. The resource tonnage for in-situ gasification with low development potential totals 8.1 billion tons (7.4 billion metric tons; Table 3). None of the coal beds in the Larey 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 Larey 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
Felix	195,540,000	32,020,000	5,810,000	233,370,000
Norfolk	63,150,000	65,240,000	141,070,000	269,460,000
Smith	316,650,000	403,560,000	57,750,000	777,960,000
Swartz	-	400,000	165,810,000	166,210,000
Anderson	21,680,000	66,660,000	40,080,000	128,420,000
Canyon	5,390,000	39,320,000	-	44,710,000
Total	602,410,000	607,200,000	410,520,000	1,620,130,000

Table 2.--Coal Reserve Base Data (in short tons) for underground mining methods for Federal Coal Lands in the Larey Draw Quadrangle, Campbell County, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Felix	-	-	-	-
Norfolk	-	-	149,020,000	149,020,000
Smith	-	-	940,210,000	940,210,000
Swartz	-	-	315,480,000	315,480,000
Anderson	-	-	1,383,180,000	1,383,180,000
Canyon	-	-	1,362,530,000	1,362,530,000
Cook	-	-	1,415,010,000	1,415,010,000
Wall	-	-	1,336,520,000	1,336,520,000
Pawnee	-	-	936,540,000	936,540,000
Cache	-	-	284,090,000	284,090,000
Total	-	-	8,122,580,000	8,122,580,000

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

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Felix	-	-	-	-
Norfolk	-	-	149,020,000	149,020,000
Smith	-	-	940,210,000	940,210,000
Swartz	-	-	315,480,000	315,480,000
Anderson	-	-	1,383,180,000	1,383,180,000
Canyon	-	-	1,362,530,000	1,362,530,000
Cook	-	-	1,415,010,000	1,415,010,000
Wall	-	-	1,336,520,000	1,336,520,000
Pawnee	-	-	936,540,000	936,540,000
Cache	-	-	284,090,000	284,090,000
Total	-	-	8,122,580,000	8,122,580,000

Baker, A. A., 1929, The northward extension of the Sheridan coal field, Big Horn and Rosebud Counties, Montana: U. S. Geol. Survey Bull. 806-B, P. 15-67.

Bass, N. W., 1932, The Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana: U. S. Geol. Survey Bull. 831-B, p. 19-105.

Brown, R. W., 1958, Fort Union Formation in the Powder River Basin, Wyoming: Wyo. Geol. Soc. Guidebook, Thirteenth Annual Field Conf., p. 111-113.

Dobbin, C. E., and Barnett, V. H., 1927, The Gillette coal field, northeastern Wyoming, with a chapter on the Minturn district and northwestern part of the Gillette field by W. T. Thom, Jr: U. S. Geol. Survey Bull. 796-A, P. 1-50.

Glass, G. B., 1975, Review of Wyoming coal fields, 1975: Wyoming Geol. Survey Public Information circ. 4, p. 10.

IntraSearch Inc., 1978a, Coal resource occurrence and coal development potential of the Cabin Creek Northeast Quadrangle, Sheridan and Campbell Counties, Wyoming and Powder River County, Montana: U. S. Geol. Survey Open-File Report 78-064, 21 p.

________________, 1978b, Coal resource occurrence and coal development potential of the Rocky Butte Quadrangle, Campbell County, Wyoming: U. S. Geol. Survey Open-File Report 78-830, 22 p.

Jacob, A. F., 1973, Depositional environments of Paleocene Tongue River Formation: Am. Assoc. of Petroleum Geologists Bull., vol. 56, no. 6, p. 1038-1052.

Kent, B. H., 1976, Geologic map and coal sections of the Recluse Quadrangle, Campbell County, Wyoming: U. S. Geol. Survey Misc. Field Studies Map MF-732, scale, 1:24,000.

Landis, E. R., and Hayes, P. T., 1973, Preliminary geologic map of the Croton 1 SE (White Tail Butte) Quadrangle, Campbell County, Wyoming: U. S. Geol. Survey Open-File Report, scale, 1:24,000.

McKay, E. J., and Mapel, W. J., 1973, Preliminary geologic map of the Calf Creek Quadrangle, Campbell County, Wyoming: U. S. Geol. Survey Open-File Report, scale, 1:24,000.

McKay, E. J., 1974, Preliminary geologic map of the Bertha 2 NW (Rocky Butte) Quadrangle, Campbell County, Wyoming: U. S. Geol. Survey Open-File Report 74-173, scale, 1:24,000.

Olive, W. W., 1957, The Spotted Horse coal field, Sheridan and Campbell Counties, Wyoming: U. S. Geol. Survey Bull. 1050, 83 p.

Schell, E. M., and Mowat G. D., 1972, Reconnaissance map showing some coal and clinker beds in the Fort Union and Wasatch Formations in the eastern Powder River Basin, Campbell and Converse Counties, Wyoming: U. S. Geol. Survey Open-File Report, scale 1:63,360.

Stone, R. W., and Lupton, C. T., 1910, The Powder River coal field, Wyoming, adjacent to the Burlington Railroad, in Coal Fields of Wyoming: U. S. Geol. Survey Bull. 381-B, p. 115-136.

Taff, J. A., 1909, The Sheridan coal field, Wyoming, in Coal Fields of Wyoming: U. S. Geol. Survey Bull. 341-B, p. 123-150.

U. S. Bureau of Mines and U. S. Geological Survey, 1976, Coal resource classification system of the U. S. Bureau of Mines and U. S. Geological Survey: U. S. Geol. Survey Bull. 1450-B, 7 p.

U. S. Geological Survey and Montana Bureau of Mines and Geology, 1973, Preliminary report of coal drill-hole data and chemical analyses of coal beds in Sheridan and Campbell Counties, Wyoming, and Big Horn County, Montana: U. S. Geol. Survey Open-File Report 73-351, 51 p.

U. S. Geological Survey and Montana Bureau of Mines and Geology, 1974, Preliminary report of coal drill-hole data and chemical analyses of coal beds in Campbell County, Wyoming: U. S. Geol. Survey Open-File Report 74-97, 241 p.

Warren, W. C., 1959, Reconnaissance geology of the Birney-Broadus coal field, Rosebud and Powder River Counties, Montana: U. S. Geol. Survey Bull. 1072-J, p. 561-585.

Weimer, R. J., 1977, Stratigraphy and tectonics of western coals, in Geology of Rocky Mountain Coal, A Symposium, 1976: Colorado Geol. Survey Resource Series 1, p. 9-27.