UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TEXT TO ACCOMPANY:

COAL RESOURCE OCCURRENCE

AND

COAL DEVELOPMENT POTENTIAL

MAPS

OF THE

CROTON QUADRANGLE,

CAMPBELL COUNTY, WYOMING

BY

INTRASEARCH INC.

DENVER, COLORADO

OPEN FILE REPORT 79-028
1979

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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

This report and accompanying maps set forth the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) of coal beds within the Croton Quadrangle, Campbell County, Wyoming. This CRO and CDP map series includes 65 plates (U. S. Geological Survey Open-File Report 79-020). 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 Croton Quadrangle is located in Campbell County, in northeastern Wyoming. It encompasses all or parts of Townships 52, 53, and 54 North, Ranges 75 and 76 West, and covers the area: 44°30' to 44°37'30" north latitude; 105°52'30" to 106°00' west longitude.

The main access is the Echeta Road, a maintained gravel road which parallels Wild Horse Creek and angles southeastward through the quadrangle. The Echeta Road continues 10 miles (16 km) west to Arvada, and 29 miles (47 km) southeast to Gillette. Another improved road traverses the northeast corner of the study area. Minor roads and trails that branch from these improved roads provide access to much of the Croton Quadrangle. The Burlington Northern trackage angles southeastward through the southwestern corner of the quadrangle.

Wild Horse Creek flows northwestward through the southwestern quadrant, providing the major drainage for the area. The Middle Prong of Wild Horse Creek flows northwestward through the northern portion of the quadrangle. Both of these creeks eventually drain into the Powder River to the northwest. A maximum elevation of about 4640 feet (1414 m) above sea level occurs in the extreme southwestern part of the study area. Minimum elevations of approximately 3830 feet (1167 m) above sea level occur in the valley floor of Wild Horse Creek on the western quadrangle boundary. 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 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 3,000 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 10.4 billion tons (9.4 billion metric tons) of total unleased federal coal-in-place in the Croton quadrangle. This estimate includes about 167 million tons (151 million metric tons) of Hypothetical Resources.

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 of the drill holes 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-CTP 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 Croton Quadrangle is located in an area where surface rocks are classified into the Wasatch Formation. Although the Wasatch Formation is reportedly 700 to 800 feet (213 to 244 m) thick (Olive, 1957), 855 feet (261 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 fields (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 Truman and Parnell coal beds were named by Maddock and others (1976). The Scott coal bed was named by Olive (1957), and McLaughlin and Hayes (1973) named the Daly coal bed. Stone and Lupton (1910) named the Felix coal bed, 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 Barker (1929) 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 Wildcat, Moyer, and Oedekoven coal beds were informally named by IntraSearch Inc. (1978b, 1979, and 1978a).

Local. The Croton Quadrangle lies on the eastern flank of the Powder River Basin, where the strata dip gently westward. The Wasatch Formation crops out throughout the Croton Quadrangle, and is comprised of friable, corase-grained to gritty, arkosic sandstones, fine-to very fine-grained sandstones, siltstones, mudstones, claystones, brown-to-black carbonaceous shales, and coal beds.

A single, northeast-southwest trending fault occurs in the southeast corner of the quadrangle with a vertical displacement of 5 to 10 feet (1.5 to 3m).

III. Data Sources

Areal geology of the coal outcrops and associated clinker is derived from the Geologic Map and Coal Sections of the Croton Quadrangle by Maddock, Kent, and Bohor (1976).

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 only relate 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-CPP 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). The geophysical logs of these drill holes were unavailable to IntraSearch 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 Croton Quadrangle is published by the U. S. Geological Survey, compilation date, 1972. 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

Wasatch and Fort Union Formation coal beds that are present in all or part of the Croton Quadrangle include, in descending stratigraphic order, the Truman, Parnell, Scott, Daly, Felix, Norfolk, Smith, Swartz, Anderson, Canyon, Cook, Wall, Pawnee, Cache, Wildcat, Moyer, and Oedekoven coal beds. A complete suite of maps (structure, isopach, mining ratio, overburden, identified and hypothetical resources, areal distribution of identified resources) is prepared for each of these coal beds except for the Truman, Parnell, Norfolk, Wildcat and Oedekoven coal beds, where insufficient thickness and lack of areal extent preclude mapping in this quadrangle.

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

COAL BED NAME	HOLE #	ASH	FIXED CARBON	MOISTURE	VOLATILES	SULFUR	BTU/LB.
Felix (U)	7345	5.223	34.181	30.280	30.316	0.338	8111
Smith (U)	7312C	16.323	29.797	25.376	28.503	2.598	7273
Swartz (U)	7334	6.442	34.001	29.260	30.297	0.707	7738
Anderson (U)	7406	6.317	31.113	32.583	29.986	0.327	7498
Canyon (U)	744	4.290	32.852	35.100	27.758	0.307	7298
Cook		4.620	34.410	33.640	27.330	0.250	7766
Wall (U)	7426	9.542	29.322	32.150	28.985	0.500	7279
Pawnee (U)	7424	7.880	31.029	31.910	29.183	0.386	7344
Cache (U)	741	9.481	30.517	31.420	28.582	0.488	7271

All analyses except BTU/LB are reported in percent

(U) - U.S. Geological Survey & Montana Bureau of Mines & Geology - 1973, 1974, 1975.

The Coal Data Sheet, Plate 3, shows 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 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 Anderson coal bed underlies the entire quadrangle, it is designated as datum for the correlation diagram. The Smith, Anderson, Canyon, and Wall coal beds show the thickest single coal bed occurrence, and the Felix, Norfolk, Swartz, Cook, Pawnee, Cache, Wildcat, Moyer, and Oedekoven coal beds are relatively thin throughout the Croton quadrangle.

The Scott coal bed crops out throughout the quadrangle, and lies less than 380 feet (116 m) beneath the surface. Thicknesses for the Scott coal bed average 5 feet (1.5 m), and range from 4 feet (1.2 m) in the central portion to 7 feet (2.1 m) in the northeast corner of the study area. Minor east-west trending folds distort the gentle westward dip of the Scott coal bed.

Approximately 100 feet (30 m) of clastic sediment separates the Daly coal bed from the overlying Scott coal bed. The Daly coal bed crops out throughout the Croton Quadrangle, and averages 6 feet (1.8 m) thick. A minimum thickness of 3.4 feet (1.0 m) occurs in the southeast portion, with maximum thicknesses of 8 feet (2.4 m) in the northeast and southwest corners of the study area. Structural contours on top of the Daly coal bed portray a westward dip of less than one degree. The Daly coal bed lies less than 480 feet (146 m) beneath the surface throughout the Croton Quadrangle.

The Felix coal bed crops out throughout the study area, lies approximately 100 to 140 feet (30 to 43 m) below the Daly coal bed, and averages 17 feet (5 m) thick. Maximum thicknesses of 26 feet (8 m) occur in the east-central portion and thin westward to a minimum thickness of 12 feet (4 m) in the western area of the quadrangle. Non-coal intervals of 10 to 73 feet (3 to 22 m) separate upper and lower units of the Felix coal bed in Sections 21, and 31, T. 53 N., R. 75 W., respectively. Southwest-northeast trending folds distort structural contours on top of the Felix coal bed which lies less than 580 feet (177 m) beneath the surface throughout the Croton Quadrangle.

From 361 to 584 feet (110 to 178 m) of clastic sediment separates the Smith coal bed from the overlying Felix coal bed. The Smith coal bed averages 35 feet (11 m) thick, and ranges from 24 to 42 feet (7 to 13 m) in thickness. Non-coal intervals ranging from 2 to 13 feet (0.6 to 4 m) thick divide the Smith coal bed into two units. Structural contours on top of the Smith coal bed indicate a westward dip of less than two degrees. An insufficient data line extending southeast across the southwestern portion of the quadrangle delimits an area to the west where the lack of subsurface data precludes mapping. The Smith coal bed lies less than 500 feet (152 m) below the surface throughout approximately fifty percent of the Croton Quadrangle.

The Swartz coal bed lies 110 to 157 feet (34 to 48 m) beneath the Smith coal bed, and averages approximately 6 feet (1.8 m) thick. Absent from the eastern portion of the study area, the Swartz coal bed attains a maximum thickness of 15 feet (5 m) in the north-central section of the quadrangle. Structural contours on top of the Swartz coal bed define a westward dip of one to two degrees. The Swartz coal bed lies 500 to 1300 feet (152 to 396 m) below the surface throughout most of the study area.

From 32 to 184 feet (10 to 56 m) of interburden separate the Anderson coal bed from the overlying Swartz coal bed. The Anderson coal bed varies in thickness from 25 feet (8 m) in the southeast corner to 60 feet (18 m) in the east-central portion of the quadrangle, and averages 47 feet (14 m) thick. Although the Anderson coal bed is undivided in the western portion of the study area, non-coal intervals from 2 to 26 feet (0.6 to 8 m) thick divide the coal bed into two units in the eastern part of the Croton Quadrangle. A westward dip of one to two degrees is portrayed by the structural contours on top of the Anderson coal bed. The Anderson coal bed lies 500 to 1580 feet (152 to 482 m) beneath the surface throughout the Croton Quadrangle.

The Canyon coal bed lies 29 to 219 feet ([illegible] to 67 m) below the Anderson coal bed and ranges from 10 to 37 feet (3 to 11 m) thick. Averaging [illegible] feet ([illegible] m) thick, the Canyon coal bed attains a maximum thickness of 37 feet (11 m) in the south-central portion of the quadrangle. The minimum thickness of 10 feet (3 m) is located in the extreme northwest corner of the study area. The Canyon coal bed merges with the underlying Cook coal bed in Section 36, T. 54 N., R. 76 W. Individual coal bed thicknesses for mapping purposes are derived from geophysical log information from adjacent drill holes. A non-coal interval of 4 feet (1.2 m) divides the Canyon coal bed in Section 2, T. 53 N., R. 76 W., in the northwest corner of the quadrangle. Structural contours on top of the Canyon coal bed indicate a westward dip of approximately one degree, with a slightly steeper dip on the east-central portion of the quadrangle. The Canyon coal bed lies 700 to 1680 feet (213 to 512 m) beneath the surface throughout the study area.

From 0 to 195 feet (0 to 59 m) of clastic sediment separate the Cook coal bed from the overlying Canyon coal bed. The Cook coal bed varies in thickness from 4 to 32 feet (1.2 to 10 m), and averages approximately 15 feet (5 m) thick. The maximum thickness of 32 feet (10 m) occurs in the northwest corner with thinning trends to the south, northeast, and east. Undivided in the northern portion of the study area, the Cook coal bed separates into two to three units in the northwestern part, and decreases to a single, thin coal bed in the east and southeast sections of the quadrangle. Non-coal intervals of the Cook coal bed range from 9 to 22 feet (2.7 to 7 m) thick. Structural contours on the Cook coal bed top define a minor east-west trending syncline in the central portion of the study area. The Cook coal bed dips approximately one degree to the west and lies 800 to 1700 feet (244 to 518 m) beneath the surface throughout the Croton Quadrangle.

The Wall coal bed occurs 14 to 252 feet (4 to 77 m) below the Cook coal bed, and averages 33 feet (10 m) thick. Maximum thicknesses of 40 feet (12 m) are present in the western, southern, and eastern portions of the quadrangle. A minimum thickness of 19 feet (6 m) occurs in the northeastern part of the study area. The Wall coal bed is divided into two to three units in the northwest and central portions of the quadrangle by non-coal intervals varying from 3 to 43 feet (0.9 to 13 m) thick. An insufficient data line extending southeast across the southwestern portion of the quadrangle delimits an area to the west where the lack of subsurface data precludes detailed mapping. Structural contours on top of the Wall coal bed define a westward dip of one to two degrees. The Wall coal bed lies 1,000 to 2,060 feet (305 to 628 m) below the surface in the Croton Quadrangle.

From 158 to 266 feet (48 to 81 m) of clastic sediment separates the Pawnee coal bed from the overlying Wall coal bed. The Pawnee coal bed averages 12 feet (4 m) thick, and ranges from 5 to 20 feet (1.5 to 6 m) in thickness. Non-coal intervals of 90 to 100 feet (27 to 30 m) divide the Pawnee coal bed into two units in the southeastern portion of the study area. Structural contours on top of the Pawnee coal bed portray a southwestward dip of less than two degrees. An insufficient data line delimits an area in the southwest part of the quadrangle where the paucity of subsurface data precludes mapping. More than 1250 feet (381 m) of sediments and coal beds overlie the Pawnee coal bed.

The <u>Cache</u> coal bed is separated from the Pawnee coal bed by 64 to 126 feet (20 to 38 m) of interburden. Averaging approximately 7 feet (2.1 m) thick, the Cache coal bed varies from 3 to 12 feet (0.9 to 4 m) in thickness. Structural contours on top of the Cache coal bed indicate a southwestward dip of two degrees or less. The Cache coal bed lies 1360 to 2400 feet (415 to 732 m) beneath the surface throughout the study area.

The <u>Moyer</u> coal bed occurs 161 to 289 feet (49 to 88 m) below the Cache coal bed, and averages 6 feet (1.8 m) thick. Maximum thicknesses of 8 feet (2.4 m) are located in the central portion of the Croton Quadrangle, with thinning trends toward the north, west, and south. A minimum thickness of less than 4 feet (1.2 m) is present along the southern quadrangle boundary. Structural contours on top of the Moyer coal bed define a west-southwestward dip of one to two degrees. Due to the scarcity of subsurface data to the west, an insufficient data line extends southeast across the southwestern portion of the study area. The Moyer coal bed is buried under 1610 to 2410 feet (491 to 735 m) of overburden.

V. <u>Geological and Engineering Mapping Parameters</u>

The correct horizontal location and elevation of drill holes utilized in subsurface mapping are critical to map accuracy. Intra-Search plots the horizontal location of the drill hole as described on the geophysical log heading. Occasionally this location is superimposed 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 of 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 correctness. 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 considers this agreement mandatory for the proper construction of most subsurface maps, but in particular, the overburden isopach, the ratio, and Coal Development Potential maps.

Subsurface mapping is based on geologic data within and adjacent to the Croton 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. 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 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. Contour 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 and preference right lease applications 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 <u>Insufficient</u>

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. Areas 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; 12,874 or 13,018 metric tons per hectare-meter), 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 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 ratio 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)

*This factor applies to subbituminous coal. For computing lignite mining ratios use the factor 0.922.

A surface mining potential map is 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 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 is high for approximately sixty percent of the Croton Quadrangle. High potential areas are due to the occurrence of the thick Felix and Smith coal beds near the surface. Moderate and low surface mining potentials in the remaining forty percent of the study area are the result of increasing amounts of overburden and greater mining ratios in areas of high terrain above the Felix and Smith coal beds. The thick coal beds, that underlie the Smith coal bed, are buried beneath more than 500 feet (152 m) of overburden. 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 Croton 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 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 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 Croton Quadrangle is: moderate for approximately 3.7 billion tons (3.4 billion metric tons) of coal that underlie about sixty percent of the quadrangle; low for ± 3.6 billion tons (3.3 billion metric tons) of coal beneath approximately fifteen percent of the quadrangle. Insufficient data precludes the classification of potential in the remainder of the area in the southwestern quadrant. The moderate potential develops beneath the high terrain between Wild Horse Creek on the southwest and the Middle Prong of Wild Horse Creek on the northeast. Here the 1000 foot (305 m) depth beneath the surface occurs above the thick Anderson, Canyon, Cook, Wall, and Pawnee coal beds. Aggregate thickness of these coal beds varies from 109 to 167 feet (33 to 51 m). Although these coal beds maintain their thicknesses beneath the valley floors, the 1000 foot (305 m) depth beneath the surface depresses to a position underlying the thick coal beds. A low development potential results from this relationship.

Table 1.--Strippable Coal Reserve Base Data (in short tons) for Federal Coal Lands in the Croton 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
Scott	12,410,000	3,070,000	13,250,000	28,730,000
Daly	12,760,000	4,430,000	25,780,000	42,970,000
Felix	361,160,000	142,550,000	50,300,000	554,010,000
Smith	227,050,000	320,700,000	56,290,000	604,040,000
Swartz	--	--	24,230,000	24,230,000
Anderson	--	--	--	--
Canyon	--	--	--	--
Cook	--	--	--	--
Wall	--	--	--	--
Pawnee	--	--	--	--
Cache	--	--	--	--
Moyer	--	--	--	--
TOTAL	613,380,000	470,750,000	170,550,000	1,254,680,000

Table 3.--Coal Resource Base Data (in short tons) for Underground Mining Methods for Federal Coal Lands in the Croton Quadrangle, Campbell County, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Scott	--	--	--	--
Daly	--	--	--	--
Felix	--	--	5,890,000	5,890,000
Smith	--	--	1,273,490,000	1,273,490,000
Swartz	--	--	220,680,000	220,680,000
Anderson	--	--	2,403,840,000	2,403,840,000
Canyon	--	--	1,587,990,000	1,587,990,000
Cook	--	--	638,430,000	638,430,000
Wall	--	--	1,930,560,000	1,930,560,000
Pawnee	--	--	468,240,000	468,240,000
Cache	--	--	237,170,000	227,170,000
Meyer	--	--	249,170,000	249,170,000
TOTAL	--	--	9,073,460,000	9,073,460,000

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

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
	--	3,710,050,000	3,601,400,000	7,311,450,000
TOTAL	--	3,710,050,000	3,601,400,000	7,311,450,000

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