UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TEXT TO ACCOMPANY:

COAL RESOURCE OCCURRENCE

AND

COAL DEVELOPMENT POTENTIAL

MAPS

OF THE

ORIVA QUADRANGLE,

CAMPBELL COUNTY, WYOMING

BY

INTRASEARCH INC.

DENVER, COLORADO

OPEN FILE REPORT 79-040
1979

This report is preliminary, and has not been edited or reviewed for conformity with United States Geological Survey standards or stratigraphic nomenclature.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

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 Oriva Quadrangle, Campbell County, Wyoming. This CRO and CDP map series (U. S. Geological Survey Open-File Report 79-040) includes 52 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 Oriva Quadrangle is located in Campbell County, in northeastern Wyoming. It encompasses all or parts of Townships 49, 50 and 51 North, Ranges 73 and 74 West, and covers the area: 44°15' to 44°22'30" north latitude; 105°37'30" to 105°45" west longitude.

Main access to the Oriva Quadrangle is provided by two maintained light-duty roads. Echeta Road traverses northwest to southeast across the central part of the quadrangle. Montgomery Road extends east to west across the southern half of the study area. Echeta Road and Montgomery Road merge along the southeastern boundary of the quadrangle. Minor roads and trails that branch from these maintained gravel roads provide additional access to the more remote areas. Interstate Highway 90 traverses northeast to southwest across the southeast corner of the quadrangle, however, no access to the study area is provided. Gillette, Wyoming is approximately 6 miles (9.7 km) to the east of the quadrangle boundary. The closest railroad is the Burlington Northern trackage which traverses northwest to southeast across the central part of the quadrangle.

Drainage patterns generate from the moderately rugged topographic high which extends northwest to southeast across the central part of the quadrangle. Elevations attain heights of 4950 feet (1509 m) above sealevel in the southeast quarter of the quadrangle, 500 to 600 feet (152 to 183 m) above the valley floors to the north and west. Drainage to the southwest of this topographic high is provided by westward-flowing Wild Horse Creek, the East Fork of Wild Horse Creek, and S Bar Creek. The drainage in this area flows into the Powder River to the northwest. Hay Creek drains the northwest part of the quadrangle, flowing into Wild Horse Creek and eventually the Powder River to the northwest. The major drainage northeast of the topographic high is provided by Rawhide Creek. Rawhide Creek flows northward draining into the Little Powder River. Bennor Draw, Durky Draw, and additional intermittent streams supplement the drainage throughout the quadrangle. The somber grays, yellows, and browns of outcropping shales and siltstones contrast strikingly with the brilliant reds, oranges, and purples of "clinker," and the deep greens of the juniper and pine tree growth.

The 12 to 14 inches (30 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 + 15°F (-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 9.8 billion tons (8.9 billion metric tons) of unleased federal coal resources in the Oriva 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 Oriva Quadrangle is located in an area where 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). Kent (1976) named the Norfolk coal bed, and the Smith and Ulm coal beds were named by Taff (1909). Baker (1929) assigned names to the Anderson, Canyon, and Wall coal beds. The Cook coal bed was named by Bass (1932), and the Pawnee coal bed was named by Warren (1959). 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 suggests 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.

Local. The Oriva 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. The Fort Union Formation unconformably underlies the Wasatch Formation, and is composed of very fine-grained sandstones, siltstones, claystones, shales, carbonaceous shales, and numerous coal beds.

Structure contours drawn on top of the various coal beds within the quadrangle indicate a regional dip to the west. The most dominant structural feature is a broad westward-plunging anticline which extends across the central part of the quadrangle. Two significant synclines extend into the northern and southern parts of the study area. Additional anticlinal and synclinal features disrupt the gentle westward dip.

III. Data Sources

Areal geology of the coal outcrops and associated clinker is derived from Law (1975) and Buck (1977).

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 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 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 down hole 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 Oriva Quadrangle is published by the U. S. Geological Survey, compilation date 1972. 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 part of the Oriva Quadrangle include, in descending stratigraphic order: the Ulm, Scott, local, Felix, Norfolk, local, Smith, Anderson, Canyon, Cook, Wall, Pawnee, Wildcat, Moyer, local, Oedekoven, and local coal beds. A complete suite of maps (coal isopach, mining ratio, where appropriate, structure, overburden/interburden isopach, areal distribution of identified resources, and identified resources) was prepared for the Ulm, Felix, Norfolk, Smith, Anderson, Wall and Pawnee coal beds, and for the Canyon-Cook coal beds and the Wildcat-Moyer-Oedekoven coal beds which were mapped as coal zones. Insufficient data, thickness, and areal extent preclude detailed mapping of the Scott and numerous unnamed local coal beds.

The Felix coal bed is the only coal bed in the quadrangle that is known to have published physical and chemical analyses. The general proximate analyses performed on an "as received" basis for the Felix coal bed, and for selected coal beds in adjacent areas of northern Campbell County are as follows:

COAL BED NAME			ASH %	FIXED CARBON %	MOISTURE %	VOLATILES %	SULFUR %	BTU/LB
Felix	(U)	Hole 7343	4.910	34.699	27.243	32.393	0.479	8488
Smith	(U)	Hole 7340	3.505	38.036	29.980	28.474	0.309	8371
Anderson	(U)	Hole 738	4.546	34.783	31.540	29.131	0.250	7770
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

(U) - U. S. Geological Survey & Montana Bureau of Mines & 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 Smith coal bed underlies the entire quadrangle, it is designated as datum for the correlation diagram. The Anderson and Canyon coal beds show the thickest single coal bed occurrences throughout the quadrangle. The remaining coal beds show a thin to moderately thick coal bed occurrence throughout most of the study area.

The Ulm coal bed has been eroded from approximately 96 percent of the quadrangle, and is present only at the higher elevations scattered throughout the quadrangle. Due to limited subsurface data available, the majority of the coal bed data is derived from coal bed outcrop elevations and surface measured sections (Buck, 1977). The coal bed thickness ranges from 12 to 20 feet (4 to 6 m) with maximum thicknesses occurring in the southeast quarter of the study area. Structure contours drawn on top of the Ulm coal bed indicate a northwest-plunging anticline extending across the central part of the quadrangle. The Ulm coal bed lies approximately 0 to 170 feet (0 to 52 m) below the surface of the quadrangle.

The Felix coal bed lies approximately 400 feet (122 m) below the Ulm coal bed, and has been eroded from a small area along the northeast boundary of the quadrangle. The thickness of the coal bed ranges from 18 to 33 feet (5 to 10 m), with maximum thickness occurring in the northeast and southeast quarters of the quadrangle, and with thinning to the southwest. A non-coal interval ranging from 0 to 9 feet (0 to 2.7 m) locally separates the coal bed. Structure contours drawn on top of the Felix coal bed indicate a broad westward-plunging anticline extending across the central part of the quadrangle. A smaller, westward-plunging anticline occurs in the northeast corner of the study area. Two synclinal features also occur in the northern and southern halves of the quadrangle. The Felix coal bed lies approximately 0 to 500 feet (0 to 152 m) beneath the surface throughout 98 percent of the study area.

The Norfolk coal bed occurs approximately 310 to 360 feet (95 to 110 m) beneath the overlying Felix coal bed, and is present only in the northeast part of the quadrangle. The coal bed thickness ranges from 0 to 11 feet (0 to 3 m), averaging approximately 7 feet (2.1 m) in thickness. The Norfolk coal bed shows a gentle dip to the west of one to two degrees. Approximately 30 percent of the area of Norfolk coal bed occurrence lies 350 to 750 feet (107 to 229 m) in depth beneath the surface of the quadrangle.

The Smith coal bed lies approximately 55 to 177 feet (17 to 54 m) below the Norfolk coal bed, and ranges in thickness from 9 to 27 feet (2.7 to 8 m). Maximum thicknesses occur along the northeastern edge of the quadrangle, with thinning to the west. Structure contours drawn on top of the Smith coal bed depict a northward-plunging anticline extending from the southeast corner through the central and northern parts of the quadrangle. A synclinal low trending north to south extends throughout in the eastern half of the study area. With the exception of small areas along the drainages of the northeast quarter of the quadrangle, the Smith coal bed lies approximately 380 to 1000 feet (116 to 305 m) in depth beneath the surface.

The Anderson coal bed is separated from the overlying Smith coal bed by approximately 9 to 250 feet (2.7 to 76 m) of clastic sediments, The coal bed thickness ranges from 25 to 70 feet (8 to 21 m) with maximum thicknesses occurring in the northeast quarter of the quadrangle. A non-coal interval ranging from 0 to 82 feet (25 m) locally separates the Anderson coal bed in the east-central part of the study area. The most dominant structural feature depicted by structure contours drawn on top of the Anderson coal bed is a broad, westward-plunging anticline extending across the central part of the quadrangle. A smaller, westward-plunging anticline extends across the northern edge of the quadrangle. Two synclinal lows extend across the northern and southern halves of the study area. The Anderson coal bed lies approximately 500 to 1200 feet (152 to 366 m) in depth beneath the entire surface of the quadrangle, except for a small area located in the drainage of the northeast quarter.

The Canyon-Cook coal zone occurs approximately 10 to 326 feet (3.0 to 99 m) below the overlying Anderson coal bed, and is composed of two-to-three, thin to moderately thick coal beds. The total coal zone thickness ranges from 10 to 49 feet (3.0 to 15 m), with thickest occurrences located in the northeast quarter of the quadrangle. The total non-coal interval separating the various coal beds comprising the coal zone varies from 4 to 200 feet (1.2 to 61 m). Structure contours drawn on top of the Canyon coal bed indicate anticlinal features in the southeast and northeast quarters of the quadrangle. A broad, westward-plunging syncline extends throughout the majority of the western half of the quadrangle, disrupting the anticlinal features to the east. The Canyon-Cook coal zone lies approximately 650 to 1350 feet (198 to 411 m) in depth beneath the surface of the quadrangle.

The Wall coal bed lies approximately 135 to 305 feet (41 to 93 m) below the Canyon-Cook coal zone, and ranges in thickness from 0 to 35 feet

(0 to 11 m). Maximum thicknesses occur along the west-central edge of the quadrangle, thinning significantly to the east and south. The Wall coal bed is absent from small areas along the eastern and southern boundaries of the quadrangle. A clastic interval ranging from 0 to 5 feet (0 to 1.5 m) in thickness locally separates the coal bed. Structure contours drawn on top of the Wall coal bed indicate a broad westward-plunging anticline in the southeast quarter of the quadrangle. A less significant anticline occurs along the northeastern edge of the study area. A small synclinal low also occurs in the northeast quarter of the quadrangle. In the western half of the quadrangle the Wall coal bed dips gently to the west. The Wall coal bed lies approximately 975 to 1750 feet (297 to 533 m) in depth beneath the surface of the quadrangle.

The Pawnee coal bed occurs approximately 25 to 133 feet (8 to 41 m) beneath the overlying Wall coal bed, and ranges in thickness from 0 to 25 feet (0 to 8 m). Maximum thicknesses occur along the southwestern edges of the quadrangle. The Pawnee coal bed thins throughout the central area of the quadrangle in a north-to-south trend. The Pawnee coal bed is locally absent from an area in the north-central part of the quadrangle. The Pawnee coal bed dips to the west and shows only minor anticlinal and synclinal features. The Pawnee coal bed lies approximately 980 to 1800 feet (299 to 549 m) in depth beneath the surface of the quadrangle.

The Wildcat-Moyer Oedekoven coal zone lies approximately 140 to 271 feet (43 to 83 m) beneath the Pawnee coal bed, and is composed of 4 to 5, thin-to-moderately thick coal beds. The total coal zone thickness ranges from 18 to 64 feet (5 to 20 m), with maximum thicknesses occurring in the north-central part of the quadrangle. The Wildcat and Oedekoven coal beds comprise the majority of the total coal zone thickness. Both of these coal beds exceed 20 feet (6 m) in thickness. The total clastic interval separating the various coal beds comprising the coal zone varies from 125 to 485 feet (38 to 148 m). Structure contours drawn on top of the Wildcat coal bed indicate a regional dip to the west with only minor anticlinal and synclinal variations. The Wildcat-Moyer-Oedekoven coal zone lies approximately 1325 to 1950 feet (404 to 594 m) beneath the surface throughout the entire quadrangle.

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 Oriva 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 49) 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 for the Oriva Quadrangle is high for approximately 20 percent of the study area, and is primarily attributed to the low overburden to coal ratios for the Ulm and Felix coal beds. The high potential rating generally occurs in conjunction with the significant drainages of the quadrangle, where erosion has decreased the overburden thickness. Moderate and low development potential ratings cover approximately 65 and 5 percent of the quadrangle, respectively. These potential ratings are attributed to increasing overburden to coal ratios for the Ulm, Felix, Norfolk, Smith and Anderson coal beds. The remaining 10 percent of the quadrangle is classified as non-federal coal land and not evaluated for surface mining development potential. Table 1 sets forth the estimated strippable reserve and hypothetical resources base tonnages per coal bed for the quadrangle.

Underground Mining Coal Development Potential. Subsurface coal mining potential throughout the Oriva 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).

A coal development potential map (Plate 50) for in-situ gasification was prepared using the above criteria. The coal development potential for in-situ gasification within the Oriva Quadrangle is low for the majority of the study area. Approximately 70 percent of the quadrangle is covered by the low potential rating. A moderate potential rating covers approximately 20 percent of the quadrangle, primarily along the western boundary of the study area. The remaining 10 percent scattered throughout the quadrangle, is classified as non-federal coal land and not evaluated for in-situ gasification development potential. The coal resource tonnage totals for in-situ gasification with low and moderate development potentials are listed on Table 3.

Table 1.--Strippable Coal Reserve Base and Hypothetical Resource Data (in short tons) for Federal Coal Lands in the Oriva 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				
Ulm	43,400,000	1,810,000	-----	45,210,000
Felix	391,880,000	841,740,000	92,990,000	1,326,610,000
Norfolk	-----	-----	20,220,000	20,220,000
Smith	-----	-----	28,390,000	28,390,000
Anderson	-----	-----	2,270,000	2,270,000
TOTAL	435,280,000	843,550,000	143,870,000	1,422,700,000
HYPOTHETICAL RESOURCES				
Lower Ulm	-----	-----	4,180,000	4,180,000
TOTAL	-----	-----	4,180,000	4,180,000
GRAND TOTAL	435,280,000	843,550,000	148,050,000	1,426,880,000

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

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Felix	-----	-----	1,230,000	1,230,000
Norfolk	-----	-----	36,690,000	36,690,000
Smith	-----	-----	855,300,000	855,300,000
Anderson	-----	-----	2,663,250,000	2,663,250,000
Canyon-Cook	-----	-----	1,270,840,000	1,270,840,000
Wall	-----	-----	741,060,000	741,060,000
Pawnee	-----	-----	681,220,000	681,220,000
Wildcat-Moyer-Oedekoven	-----	-----	2,055,570,000	2,055,570,000
TOTAL	-----	-----	8,305,160,000	8,305,160,000

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

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
	-----	1,091,550,000	7,213,610,000	8,305,160,000
TOTAL	-----	1,091,550,000	7,213,610,000	8,305,160,000

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