UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TEXT TO ACCOMPANY:

COAL RESOURCE OCCURRENCE

AND

COAL DEVELOPMENT POTENTIAL

MAPS

OF THE

ARVADA NE QUADRANGLE,

SHERIDAN AND CAMPBELL COUNTIES, WYOMING

BY

INTRASEARCH INC.

ENGLEWOOD, COLORADO

OPEN FILE REPORT 79-167

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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/ metric ton
acre-feet	0.12335	hectare-meters
British thermal units/pound (Btu/lb)	2.326	kilojoules/kilogram (kj/kg)
British thermal units/pound (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 Arvada NE Quadrangle, Sheridan Campbell Counties, Wyoming. This CRO and CDP map series includes 55 plates (U. S. Geological Survey Open-File Report 79-167). 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 a 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 Arvada NE Quadrangle is located in Sheridan and Campbell Counties in northeastern Wyoming. It encompasses all or parts of Townships 54 and 55 North, Ranges 76 and 77 West, and covers the area: 44°37'30" to 44°45' north latitude; 106°00' to 106°07'30" west longitude.

Main access to the Arvada NE Quadrangle is provided by east-west oriented U. S. Highway 14-16, which bisects the area. Several maintained gravel roads provide additional access to the area, especially in the western and southeastern quadrants. Minor roads and trails branch from these gravel roads providing access to the more remote areas. The maintained gravel roads converge at Arvada, Wyoming, immediately west of the quadrangle. Burlington Northern railroad trackage extends across the southern portion of the study area.

The northward-flowing Powder River meanders along the western edge of the quadrangle. Wild Horse Creek, an intermittent tributary to the Powder River, flows westward and drains the southern half of the study area. Elevations attain maximum heights of 4,390 feet (1,338 m) above sea level along the eastern boundary of the quadrangle. These higher elevations rise 700 to 800 feet (213 to 244 m) above the Powder River valley floor to the west.

The 13 to 14 inches (33 to 36 cm) of annual precipitation falling in this semi-arid region accrue principally in the springtime. Summer and fall precipitation usually originates from thunderstorms, and infrequent snowfalls of 6 inches (15 cm) or less generally characterize winter precipitation. Although temperatures ranging from less than -25°F (-32°C) to more than 100°F (38°C) have been recorded near Arvada, 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 Sheridan and Campbell County Courthourses in Sheridan and Gillette, Wyoming, respectively. 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 (resources), as well as recoverable tons (reserves). These coal tonnages are then categorized in measured, indicated, and inferred parts of identified 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 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 6.3 billion tons (5.7 billion metric tons) of total, unleased federal coal-in-place resources in the Arvada NE Quadrangle.

The suite of maps that accompanies 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 overlying Wasatch Formation. Approximately 3,000 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 the 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. 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 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 member subdivisions 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 2 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 and in-filling of these areas 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 of 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 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 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 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 noticably to imperceptibly coarser than the underlying Fort Union clastics.

The Arvada NE Quadrangle is located in an area where surface rocks are classified within the Wasatch Formation. Although the Wasatch Formation is reportedly up to 1,800 feet (549 m) thick (Denson and Horn, 1975),

Olive (1957) mapped 700 to 800 feet (213 to 244 m). Only 750 to 800 feet (229 to 244 m) of Wasatch Formation are exposed in the quadrangle. Olive (1957) correlated coal beds in the Spotted Horse coal field with coal beds in the northward extension of the Sheridan coal field, Montana (Baker, 1929), and Gillette coal field, Wyoming (Dobbin and Barnett, 1927), 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 and Arvada coal beds were named by Stone and Lupton (1910). The Smith and Roland coal beds were named by Taff (1909), and McKay and Mapel (1973) assigned the name to the Swartz coal bed. Baker (1929) named the Anderson, Canyon, and Wall coal beds. The Cook coal bed was named by Bass (1932) and Warren (1959) named the Pawnee coal bed. IntraSearch (1979 and 1978) informally named the Moyer and Oedekoven coal beds. Baker (1929) incorrectly correlated his Roland coal bed with the Roland coal bed of Taff (1909); hence, the name Roland of Baker. The Roland of Baker coal bed is about 125 feet (38 m) stratigraphically higher than the Roland coal bed of Taff (1909).

The CRO/CDP report on Larey Draw, the quadrangle adjacent to and east of Arvada NE Quadrangle, was published in 1979 (IntraSearch, 1979). Since that time, additional subsurface data have been open-filed (Correia, 1980). The new drill hole information prevents the continuity of subsurface contours between the two quadrangles on the Felix, Arvada, Roland of Baker, and Smith coal beds. The Arvada coal bed in the Arvada NE Quadrangle is equivalent to the Norfolk coal bed in the Recluse Quadrangle (Kent, 1976) and in the Larey Draw Quadrangle as mapped by IntraSearch (1979).

Local. The Arvada NE 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 composed 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 structure contours drawn on the tops of the coal beds depict a gentle, regional dip to the southwest. Minor flexures and broad, shallow folds occur on some of the coal bed structure maps.

III. Data Sources

Areal geology of the coal outcrops is derived from a publication, the Powder River coal field, Wyoming, (Stone and Lupton, 1910). The coal bed outcrops are adjusted to fit the current topographic maps of the area.

Geophysical logs from oil and gas test bores and producing wells compose 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 and its 3-mile perimeter area were scanned to select those with data applicable to Coal Resource Occurrence mapping. Paper copies of the logs

were obtained and interpreted, and coal intervals were annotated. Maximum accuracy of coal bed identification was accomplished where gamma, density, and resistivity curves were available. Coal bed tops and bottoms were identified on the logs at the midpoint between the minimum and maximum curve deflections. The correlation of coal beds within and between quadrangles was achieved utilizing a fence diagram to associate local correlations with regional coal occurrences.

The reliability of correlations, set forth by IntraSearch in this report, varies depending on: the density and quality of lithologic and geophysical logs; the details, 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 Arvada NE Quadrangle is published by the U. S. Geological Survey, compilation date 1971. 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 Formation and Fort Union Formation coal beds that are present in all or part of the Arvada NE Quadrangle include, in descending stratigraphic order: the Felix, Arvada, Roland of Baker, Upper Smith, Lower Smith, Swartz, Anderson-Upper Canyon, Lower Canyon, Cook, Wall, Pawnee, Moyer, Local, Oedekoven, and Local coal beds. The Upper Smith and Lower Smith coal beds are mapped as a coal zone. A suite of maps composed of: coal isopach and mining-ratio, where appropriate; structure; overburden isopach; areal distribution of identified resources; identified resources and hypothetical resources, where applicable, is prepared for each of these coal beds or coal zones. Mining ratios are presented on the isopach maps of the Felix, Arvada, Roland of Baker, Swartz, and Anderson-Upper Canyon coal beds, and the Smith coal zone.

The Arvada and Anderson-Upper Canyon coal beds were cored within this quadrangle in U. S. Geological Survey drill-hole number 78-3. The unpublished proximate analyses on these coal beds are set forth in this report. No physical or chemical analyses are known to have been published regarding samples of the other coal beds in the Arvada NE Quadrangle. For western Campbell County and eastern Sheridan County coal beds, the "as received" proximate analysis; the Btu value computed on a moist, mineral-matter-free basis;* and the coal rank are as follows:

COAL BED NAME		DATA SOURCE IDENTIFICATION	AS RECEIVED BASIS						MOIST, M-M-F BTU/LB	COAL RANK
			ASH %	FIXED CARBON %	MOISTURE %	VOLATILES %	SULFUR %	BTU/LB		
Felix	(**)	Lab.No. 6432	5.6	35.7	25.8	32.9	0.39	8465	9010	Subbtm. C
Arvada	(1)	Hole 78-3	8.2	32.4	29.8	29.6	1.40	7736	8483	Subbtm. C
Roland of Baker	(2)	Hole SH-7029	4.7	27.8	30.2	37.3	0.24	8086	8518	Subbtm. C
Smith	(1)	Hole 78-2	6.4	36.3	28.9	28.4	0.80	8084	8682	Subbtm. C
Swartz	(U)	Hole 7338	5.7	34.1	31.2	28.9	0.70	7735	8239	Lignite A
Anderson-Upper Canyon	(1)	Hole 78-3	4.2	37.9	27.8	30.1	0.20	8709	9123	Subbtm. C
Cook	(2)	Hole SH-64	3.1	36.2	30.8	29.9	0.15	7948	8223	Lignite A
Wall	(U)	Hole 7426	9.5	29.3	32.2	29.0	0.50	7279	8108	Lignite A
Pawnee	(U)	Hole 7424	7.9	31.0	31.9	29.2	0.39	7344	7674	Lignite A

* The moist, mineral-matter-free Btu values are calculated in the manner stipulated in the publication by American Society for Testing and Materials (1971).

** Stone, R.W., and Lupton, C. T. (1910).

(1) Correia, G. A. (U. S. Geological Survey, unpublished data).

(2) Matson, R. E., and Blumer, J. W. (1973).

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

Except for the Arvada, Smith and Anderson-Upper Canyon coal beds, the proximate analyses presented above are from core hole or outcrop locations in excess of 20 miles (32 km) from this quadrangle. For simplification of tonnage computations, all coal beds in the Quadrangle are tentatively classified as subbituminous C in rank.

The Coal Data sheet, plate 3, shows the down-hole 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 from producing sites. 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 Moyer coal bed underlies the entire quadrangle, it is designated as datum for the correlation diagram. The Anderson-Upper Canyon coal beds show the thickest coal bed occurrences throughout the study area. The Arvada, Roland of Baker, Smith, Swartz, Lower Canyon, Cook, Wall, Pawnee, Moyer, Local, and Oedekoven coal beds are relatively thin throughout the Arvada NE Quadrangle.

The Felix coal bed crops out in small areas near hilltops in the south-central part of the area, and along the eastern boundary of the quadrangle. The coal bed is eroded from more than 95 percent of the quadrangle. The Felix coal bed thickness ranges from 6 to 8 feet (1.8 to 2.4 m). Elevations on the Felix coal bed outcrop indicate a gentle, westward dip. The Felix coal bed is buried a maximum of 180 feet (55 m) beneath the surface of the quadrangle.

The Arvada coal bed, 340 to 430 feet (104 to 131 m) beneath the Felix coal bed is eroded from the Powder River valley and some of its tributary valleys. The Arvada coal bed ranges in thickness from 5 to 10 feet (1.5 to 3 m). Structure contours drawn on top of the Arvada coal bed depict southwestward dip. The overburden above the coal bed attains a maximum thickness of 580 feet (177 m).

The Roland of Baker coal bed lies 68 to 130 feet (21 to 40 m) below the Arvada coal bed and is eroded from the Powder River valley in the northwestern part of the quadrangle. The Roland of Baker coal bed is present throughout the quadrangle, except where it is eroded. The coal bed thickness ranges from 1 to 7 feet (0.3 to 2.1 m); however, it is mapped only where the thickness is 5 feet (1.5 m) or greater (figure 1). Structure contours drawn on top of the Roland of Baker coal bed depict gentle, southwestward dip. In the area of economic Roland of Baker coal bed occurrence, the overburden ranges from 0 to 290 feet (0 to 88 m) in thickness.

The Smith coal zone is eroded from a small part of the Arvada NE Quadrangle in the northwestern corner and lies approximately 100 feet (30 m) beneath the Roland of Baker coal bed. The coal zone thickness ranges from 10 to 35 feet (3 to 11 m), and thins to the northwest. A south-plunging syncline is located along the western quadrangle boundary in the southwest quadrant. Southwestward dip with minor flexures dominates the remainder of the study area. The Smith coal zone contains 2 to 3 separate coal beds with a total of 22 to 34 feet (7 to 10 m) of clastic sediments separating the coal beds. The Smith

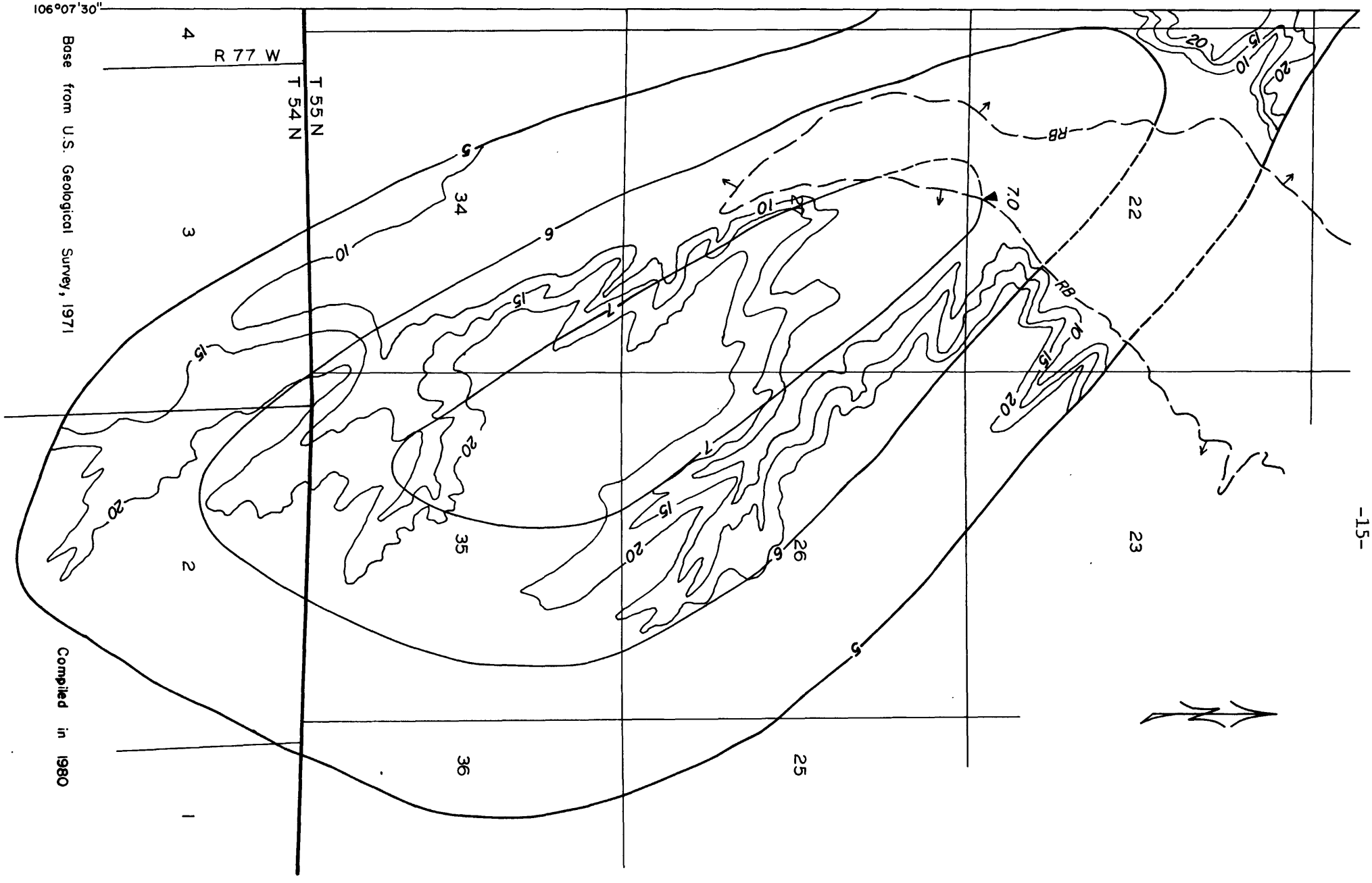
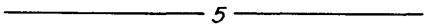
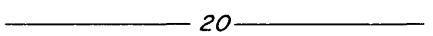


FIGURE 1
ISOPACH AND MINING-RATIO MAP
OF ROLAND OF BAKER COAL BED IN
ARVADA N E QUADRANGLE
SHERIDAN AND CAMPBELL COUNTIES, WYOMING.
(See following page for Explanation)

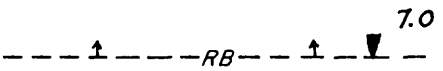
EXPLANATION FOR FIGURE 1



ISOPACHS OF COAL BED-Showing thickness in feet. Isopach interval 1 foot. Dashed where coal is burned or eroded.



MINING-RATIO CONTOUR-Number indicates cubic yards of overburden per ton of recoverable coal by surface mining methods. Contours shown only in area suitable for surface mining within the stripping limit.



TRACE OF COAL BED OUTCROP-Showing coal thickness, in feet, measured at triangle. Arrow points toward the coal-bearing area. Coal bed dashed where inferred or projected.

To convert feet to meters, multiply feet by 0.3048.

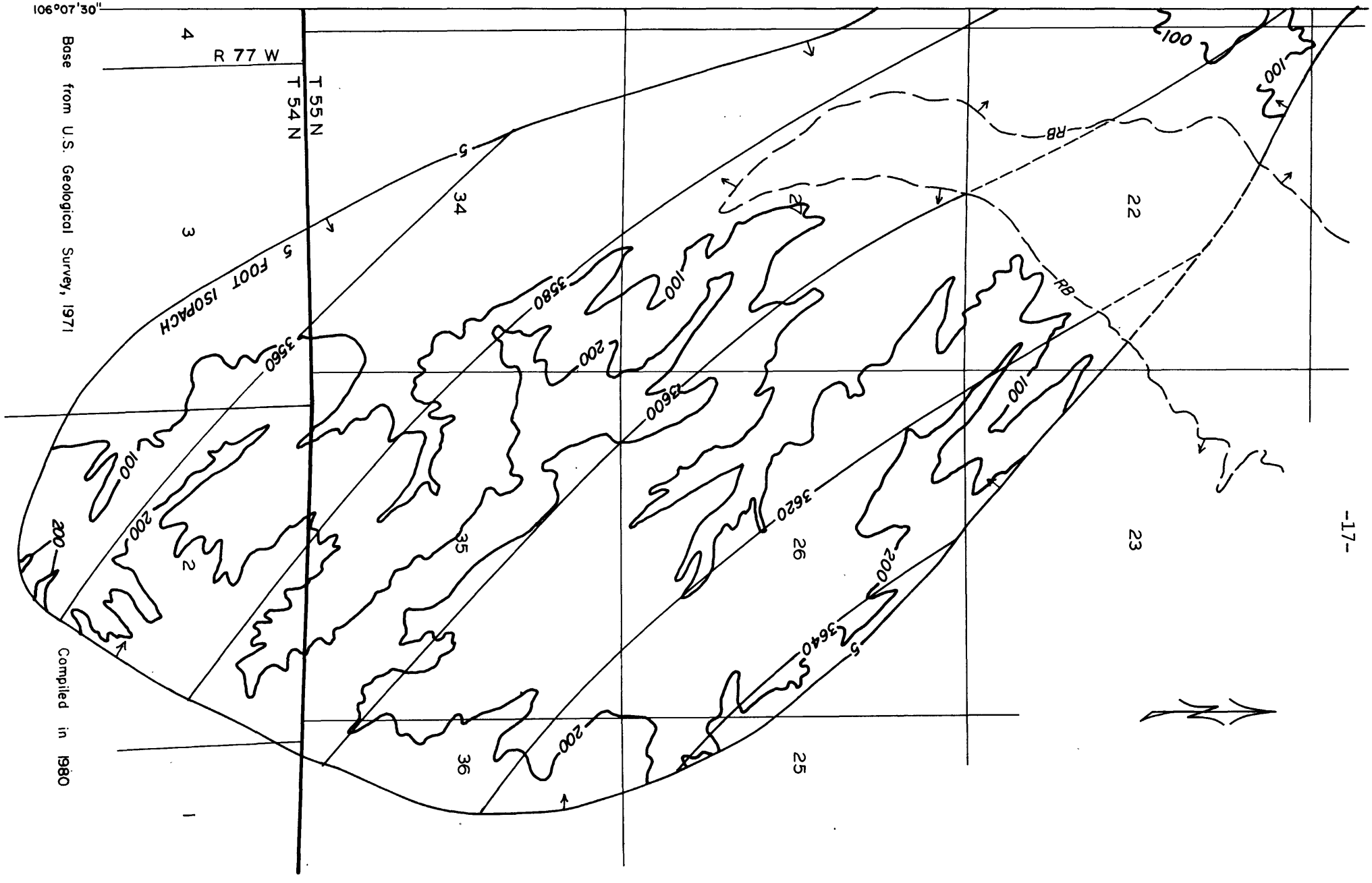
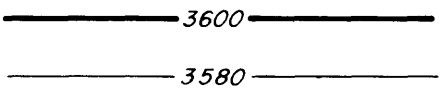


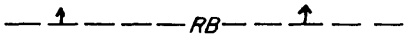
FIGURE 2
STRUCTURE CONTOUR AND ISOPACH OF OVERBURDEN MAP
OF ROLAND OF BAKER COAL BED IN
ARVADA N E · QUADRANGLE
SHERIDAN AND CAMPBELL COUNTIES, WYOMING
(See following page for Explanation)

EXPLANATION FOR FIGURE 2



STRUCTURE CONTOURS-Drawn on top of coal bed. Contour interval 20 feet. Datum is mean sea level. Dashed where coal is burned or eroded.

OVERBURDEN ISOPACH-Showing thickness of overburden, in feet, from the surface to the top of the coal bed. Isopach interval 200 feet.



TRACE OF COAL BED OUTCROP-Arrow points toward the coal-bearing area. Coal bed dashed where inferred or projected.

To convert feet to meters, multiply feet by 0.3048.

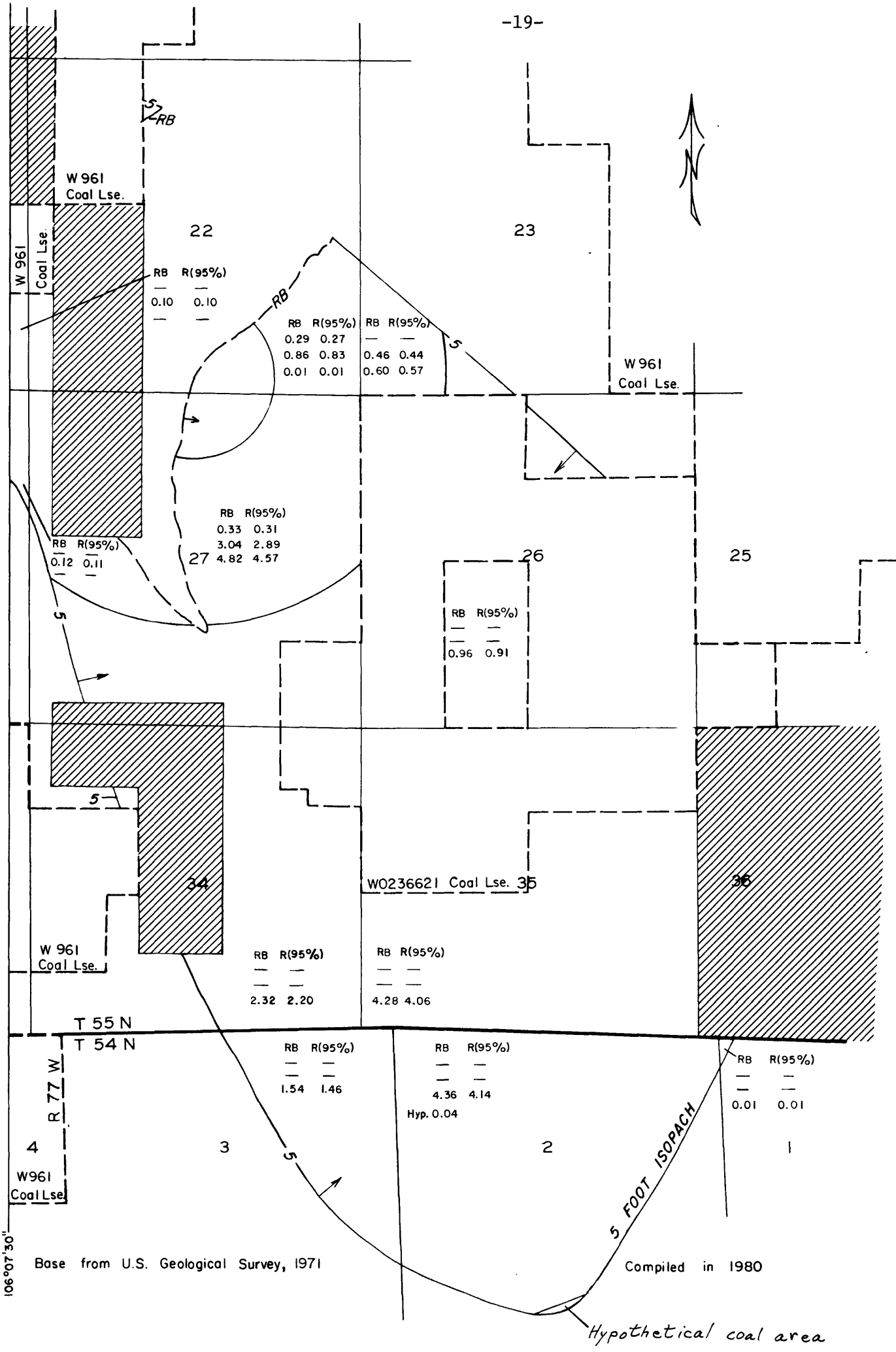
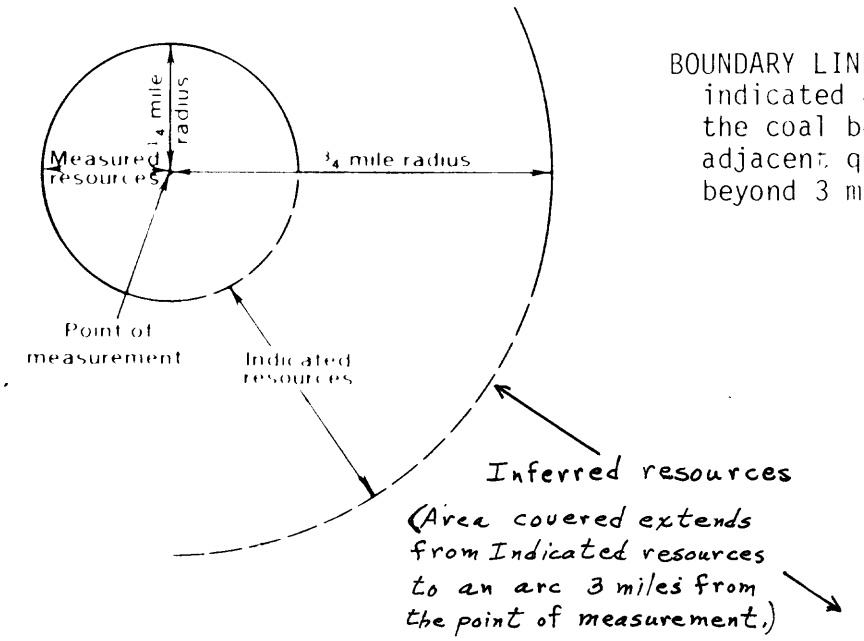


FIGURE 3
AREAL DISTRIBUTION OF IDENTIFIED RESOURCES
AND IDENTIFIED AND HYPOTHETICAL RESOURCES MAP
OF ROLAND OF BAKER COAL BED IN
ARVADA NE QUADRANGLE
SHERIDAN AND CAMPBELL COUNTIES, WYOMING
(See following page for Explanation)

EXPLANATION FOR FIGURE 3

NON-FEDERAL COAL LAND-Coal tonnages not evaluated.



BOUNDARY LINES-Enclosing areas of identified measured, indicated and inferred parts resources of the coal bed. Dashed where projected from adjacent quadrangles. Hypothetical resources beyond 3 miles from point of measurement.

TRACE OF COAL BED OUTCROP-Arrow points toward the coal-bearing area. Coal bed dashed where inferred or projected.

RB	R(95%)	
—	—	(Measured)
—	—	(Indicated)
4.36	4.14	(Inferred)
Hyp. 0.04		(Hypothetical)

IDENTIFIED AND HYPOTHETICAL RESOURCES OF COAL BED--In millions of short tons. Dash indicates no resources in that category. Reserve Base (RB) x the recovery factor (95) = Reserves (R).

W961 Coal Lse.

COAL LEASE-Coal Lse. Coal tonnages not evaluated.

Reserves are not calculated for coal beds greater than 500 feet in depth.

To convert miles to kilometers, multiply miles by 1.609.

To convert short tons to metric tons, multiply short tons by 0.9072.

coal zone lies from 0 to 760 feet (0 to 232 m) beneath the surface.

The Swartz coal bed is absent from approximately 65 percent of the study area. It is present in the southeastern quarter and in the southwestern corner. The Swartz coal bed lies approximately 120 to 200 feet (37 to 61 m) beneath the Smith coal zone. The coal bed thickness ranges from 0 to 15 feet (0 to 5 m), with the maximum thickness occurring in the southeast corner. The coal bed isopach contours honor drill-hole data located in the Larey Draw Quadrangle to the east. Structure contours drawn on top of the Swartz coal bed depict a gentle, southwestward dip. The Swartz coal bed occurs approximately 360 to 860 feet (110 to 262 m) beneath the surface.

The Anderson-Upper Canyon coal bed lies approximately 200 feet (61 m) below the Swartz coal bed, where the Swartz coal bed is present, and 220 to 400 feet (67 to 122 m) beneath the Smith coal zone. The Anderson-Upper Canyon coal bed ranges from 20 to 50 feet (6 to 15 m) thick with the maximum thicknesses for the study area trending from northeast to southwest. A broad, southwest-plunging anticline dominates the northern half of the coal bed structure map. A small syncline is located in the southern portion of the map. The overburden isopach contours indicate that the Anderson-Upper Canyon coal bed lies approximately 290 to 1,100 feet (88 to 335 m) beneath the surface.

The Lower Canyon coal bed is absent from a small area in the northeastern corner of the quadrangle, and occurs approximately 180 to 340 feet (55 to 104 m) below the Anderson-Upper Canyon coal bed.

The coal bed thickness ranges from 0 to 15 feet (0 to 5 m) with maximum thicknesses occurring in the north-central area. Due to the lack of subsurface information for the Lower Canyon coal bed, the isopach contours are projected into the Arvada NE Quadrangle by utilizing drill-hole data from surrounding quadrangles. Structure contours drawn on top of the Lower Canyon coal bed depict southwestern dip, disrupted by minor flexures. The overburden thickness overlying the Lower Canyon coal bed ranges from 690 to 1,350 feet (210 to 411 m).

The Cook coal beds comprise two, thin coal beds separated by approximately 21 to 36 feet (6 to 11 m) of non-coal sediments. The Cook coal beds lie from 220 to 280 feet (67 to 85 m) below the Lower Canyon coal bed and range in thickness from 12 to 36 feet (4 to 11 m). They thin from northeast to southwest. The coal bed structure map depicts some minor flexures superimposed upon a southwestward regional dip. The Cook coal beds occur approximately 900 to 1,490 feet (274 to 454 m) beneath the surface.

The Wall coal beds lie approximately 80 to 180 feet (24 to 55 m) beneath the Cook coal beds. Three distinct Wall coal beds are separated by 108 to 133 feet (33 to 41 m) of clastic sediments. The three coal beds total 20 to 50 feet (6 to 15 m) in thickness with maximum thicknesses occurring in the extreme southwest corner. A broad, shallow, southwest-plunging anticline is present in the west-central part of the quadrangle. Gentle, southwest dip dominates the remainder of the structure map. The Wall coal beds lie approximately 930 to 1,790 feet (283 to 546 m) beneath the surface.

The Pawnee coal beds lie 100 to 110 feet (30 to 34 m) below the Wall coal beds. Approximately 65 to 74 feet (20 to 23 m) of clastic sediments separate the two-to-three thin, Pawnee coal beds. The total Pawnee coal beds' thickness ranges from less than 8 feet (2.4 m) in the southwestern corner to greater than 20 feet (6 m) along the eastern quadrangle boundary. Structure contours drawn on top of the Upper Pawnee coal beds depict minor flexures superimposed on the regional southwestward dip. The Pawnee coal beds lie approximately 1,280 to 1,970 feet (390 to 600 m) beneath the surface.

The Moyer-Local-Oedekoven coal bed composite comprises one or two Moyer coal beds, a local coal bed, and one or two Oedekoven coal beds. The non-coal interval within the coal bed composite ranges from 256 to 279 feet (78 to 85 m) in thickness. The coal bed composite, absent from the eastern one-third of the Arvada NE Quadrangle, attains a maximum thickness of 33 feet (10 m) in the west-central area. A westward-plunging anticline occurs in the west-central area, with regional, southwest dip throughout the remaining areas. The overburden thickness above the Moyer-Local-Oedekoven coal bed composite ranges from 1,630 to 2,400 feet (497 to 732 m).

V. Geological and Engineering Mapping Parameters

The correct horizontal location and elevation of drill holes utilized in subsurface mapping are critical to map accuracy. IntraSearch 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 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 Arvada NE 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 in areas where there is sparse subsurface control. Where coal 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 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, 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, and inferred parts of identified 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 1,750, or 1,770--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 tonnages (reserves) are 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 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 54) was prepared utilizing the following mining-ratio criteria for coal beds 5 feet to 40 feet (1.5 to 12 m) thick:

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

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

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

The surface-mining development potential is high for approximately 35 percent of the quadrangle. These high development potential areas result from the moderately thick Arvada coal bed and Smith coal zone occurring at shallow depths. The area of high development potential is located in the western half and southeastern quarter of the Arvada NE Quadrangle. As the overburden thickness above these two coal beds increases, the development potential rating decreases to a moderate rating. The area of moderate development potential covers approximately 25 percent of the study area, primarily in the northeastern quadrant and in the south-central area. Areas of low development potential for surface mining cover 5 percent of the quadrangle, primarily in the central region. The remaining 35 percent of the study

area is underlain by either non-federal coal land or leased federal coal. The coal resources in these areas are not evaluated in this study. Table 1 sets forth the estimated strippable reserve base tonnages per coal bed for this quadrangle.

Underground Mining Coal Development Potential. Subsurface coal mining development potential throughout the Arvada NE Quadrangle is considered low. Inasmuch as recovery factors have not been established for the underground development of coal beds in this quadrangle, recoverable 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 development potential relates to the occurrence of coal beds more than 5 feet (1.5 m) thick and buried from 500 to 3,000 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 1,000 feet (305 m) to 3,000 feet (914 m) beneath the surface, or 2) a coal bed or coal zone 5 feet (1.5 m) or more in thickness that lies 500 feet (152 m) to 1,000 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 1,000 to 3,000 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 1,000 to 3,000 feet (305 to 914 m).

The coal development potential for in-situ gasification (plate 55) on the Arvada NE Quadrangle is moderate for approximately 3 percent of the area. The moderate coal development potential area located in the southwestern quadrant results from the combined coal bed thicknesses of the Lower Canyon and deeper coal beds exceeding 100 feet (30 m) at depths greater than 1,000 feet (305 m). Approximately 62 percent of the study area is given a low development potential rating for in-situ gasification becuase total coal bed thicknesses are less than 100 feet (30 m) at depths of less than 1,000 feet (305 m). The remaining 35 percent of the area involves non-federal coal land or leased federal coal, and therefore, it is not evaluated in this study.

Table 1.--Strippable Coal Reserve Base and Hypothetical Resource Data (in short tons) for Federal Coal Lands in the Arvada NE Quadrangle, Sheridan and Campbell Counties, 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 Resources				
Felix	2,910,000	670,000	-	3,580,000
Arvada	125,490,000	43,870,000	52,940,000	222,300,000
Roland of Baker	5,460,000	5,650,000	11,760,000	22,870,000
Smith	416,900,000	366,280,000	89,390,000	872,570,000
Swartz	-	-	57,270,000	57,270,000
Anderson-Upper Canyon	-	122,710,000	56,640,000	179,360,000
Total	550,760,000	539,180,000	268,000,000	1,357,940,000
Hypothetical Resources				
Felix	-	-	590,000	590,000
Arvada	-	-	2,750,000	2,750,000
Roland of Baker	-	-	40,000	40,000
Smith	-	-	31,390,000	31,390,000
Swartz	-	-	1,210,000	1,210,000
Anderson-Upper Canyon	-	-	30,600,000	30,600,000
Total	-	-	66,940,000	66,940,000
GRAND TOTAL	550,760,000	539,180,000	334,940,000	1,424,880,000

Table 2.--Coal Reserve Base and Hypothetical Resource Data (in short tons) for Underground Mining Methods for Federal Coal Lands in Arvada NE Quadrangle, Sheridan and Campbell Counties, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Reserve Base Resources				
Smith	-	-	67,840,000	67,840,000
Swartz	-	-	14,980,000	14,980,000
Anderson-Upper Canyon	-	-	1,234,820,000	1,234,820,000
Lower Canyon	-	-	171,510,000	171,510,000
Cook	-	-	517,660,000	517,660,000
Wall	-	-	697,780,000	697,780,000
Pawnee	-	-	344,290,000	344,290,000
Moyer-Local-Oedekoven	-	-	366,410,000	366,410,000
Total	-	-	3,415,290,000	3,415,290,000
Hypothetical Resources				
Anderson-Upper Canyon	-	-	39,380,000	39,380,000
Lower Canyon	-	-	158,030,000	158,030,000
Cook	-	-	448,760,000	448,760,000
Wall	-	-	434,400,000	434,400,000
Pawnee	-	-	321,810,000	321,810,000
Moyer-Local-Oedekoven	-	-	46,790,000	46,790,000
Total	-	-	1,449,170,000	1,449,170,000
GRAND TOTAL	-	-	4,864,460,000	4,864,460,000

Table 3.--Coal Reserve Base and Hypothetical Resource Data (in short tons) for In-Situ Gasification for Federal Coal Lands in the Arvada NE Quadrangle, Sheridan and Campbell Counties, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Reserve Base Resources	-	108,320,000	3,306,970,000	3,415,290,000
Hypothetical Resources	-	-	1,449,170,000	1,449,170,000
GRAND TOTAL	-	108,320,000	4,756,140,000	4,864,460,000

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