UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TEXT TO ACCOMPANY:

COAL RESOURCE OCCURRENCE

AND

COAL DEVELOPMENT POTENTIAL

MAPS

OF THE

BOX ELDER DRAW QUADRANGLE,

SHERIDAN COUNTY, WYOMING

AND

BIG HORN AND POWDER RIVER COUNTIES, MONTANA

BY

INTRASEARCH INC.

ENGLEWOOD, COLORADO

OPEN FILE REPORT 79-162
1980

TABLE OF CONTENTS

		PAGE
I.	INTRODUCTION	1
II.	GEOLOGY	4
III.	DATA SOURCES	9
IV.	COAL BED OCCURRENCE	11
V.	GEOLOGICAL AND ENGINEERING MAPPING PARAMETERS	17
VI.	COAL DEVELOPMENT POTENTIAL	20
	Table 1.-- Strippable Coal Reserve Base and Hypothetical Resource Data (in short tons) for Federal Coal Lands in the Box Elder Draw Quadrangle, Sheridan County, Wyoming, and Big Horn and Powder River Counties, Montana.	24
	Table 2.--Coal Reserve Base and Hypothetical Resource Data (in short tons) for Underground Mining Methods for Federal Coal Lands in the Box Elder Draw Quadrangle, Sheridan County, Wyoming, and Big Horn and Powder River Counties, Montana.	25
	Table 3.--Coal Reserve Base and Hypothetical Resource Data (in short tons) for In-Situ Gasification for Federal Coal Lands in the Box Elder Draw Quadrangle, Sheridan County, Wyoming, and Big Horn and Powder River Counties, Montana.	26
	SELECTED REFERENCES	27

TABLE OF CONTENTS (continued)

MAPS	PLATES
1. Coal Data Map	1
2. Boundary and Coal Data Map	2
3. Coal Data Sheet	3
4. Isopach and Mining Ratio Map of Arvada Coal Bed	4
5. Structure Contour Map of Arvada Coal Bed	5
6. Isopach Map of Overburden of Arvada Coal Bed	6
7. Areal Distribution of Identified Resources of Arvada Coal Bed	7
8. Identified and Hypothetical Resources of Arvada Coal Bed	8
9. Isopach and Mining Ratio Map of Roland of Baker Coal Bed	9
10. Structure Contour Map of Roland of Baker Coal Bed	10
11. Isopach Map of Overburden of Roland of Baker Coal Bed	11
12. Areal Distribution of Identified Resources of Roland of Baker Coal Bed	12
13. Identified and Hypothetical Resources of Roland of Baker Coal Bed	13
14. Isopach and Mining Ratio Map of Waddle Coal Beds	14
15. Structure Contour Map of Waddle Coal Beds	15
16. Isopach Map of Overburden of Waddle Coal Beds	16
17. Areal Distribution of Identified Resources of Waddle Coal Beds	17
18. Identified and Hypothetical Resources of Waddle Coal Beds	18
19. Isopach and Mining Ratio Map of Anderson Coal Bed	19
20. Structure Contour Map of Anderson Coal Bed	20

TABLE OF CONTENTS (continued)

MAPS PLATES

21. Isopach Map of Overburden of Anderson Coal Bed 21

22. Areal Distribution of Identified Resources of Anderson Coal Bed 22

23. Identified and Hypothetical Resources of Anderson Coal Bed 23

24. Isopach and Mining Ratio Map of Dietz Coal Bed 24

25. Structure Contour Map of Dietz Coal Bed 25

26. Isopach Map of Overburden of Dietz Coal Bed 26

27. Areal Distribution of Identified Resources of Dietz Coal Bed 27

28. Identified and Hypothetical Resources of Dietz Coal Bed 28

29. Isopach and Mining Ratio Map of Canyon Coal Zone 29

30. Structure Contour Map of Canyon Coal Zone 30

31. Isopach Map of Overburden of Canyon Coal Zone 31

32. Areal Distribution of Identified Resources of Canyon Coal Zone 32

33. Identified Resources of Canyon Coal Zone 33

34. Isopach Map of Cook-Otter-Wall-Local Coal Bed Composite 34

35. Structure Contour Map of Cook-Otter-Wall-Local Coal Bed Composite 35

36. Isopach Map of Overburden of Cook-Otter-Wall-Local Coal Bed Composite 36

37. Areal Distribution of Identified Resources of Cook-Otter-Wall-Local Coal Bed Composite 37

38. Identified Resources of Cook-Otter-Wall-Local Coal Bed Composite 38

39. Isopach Map of Brewster-Arnold and King Coal Beds 39

40. Structure Contour Map of Brewster-Arnold and King Coal Beds 40

TABLE OF CONTENTS (continued)

MAPS | PLATES

41.	Isopach Map of Overburden of Brewster-Arnold and King Coal Beds	41
42.	Areal Distribution of Identified Resources of Brewster-Arnold Coal Beds	42
43.	Identified Resources of Brewster-Arnold and King Coal Beds	43
44.	Isopach Map of Knobloch-Local-Roberts-Kendrick Coal Bed Composite	44
45.	Structure Contour Map of Knobloch-Local-Roberts-Kendrick Coal Bed Composite	45
46.	Isopach Map of Overburden of Knobloch-Local-Roberts-Kendrick Coal Bed Composite	46
47.	Areal Distribution of Identified Resources of Knobloch-Local-Roberts-Kendrick Coal Bed Composite	47
48.	Identified Resources of Knobloch-Local-Roberts-Kendrick Coal Bed Composite	48
49.	Coal Development Potential for Surface-Mining Methods	49

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 Box Elder Draw Quadrangle, Sheridan County, Wyoming, and Big Horn and Powder River Counties, Montana. This CRO and CDP map series includes 49 plates (U. S. Geological Survey Open-File Report 79-162). 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 Box Elder Draw Quadrangle is located in Sheridan County, in northeastern Wyoming, and in Big Horn and Powder River Counties, in southeastern Montana. It encompasses all or parts of 57 and 58 North, Ranges 78 and 79 West in Wyoming, and Township 9 South, Ranges 44 and 45 East in Montana, and covers the area: 44°52'30" to 45°00' north latitude; 106°15' to 106°22'30" west longitude.

Main access to the Box Elder Draw Quadrangle is provided by a graveled road, which extends northwestward across the southern portion of the quadrangle. Unimproved roads and trails provide access to the more remote areas. The closest railroad is the Burlington Northern trackage approximately 11 miles (18 km) to the south near Leiter, Wyoming.

Drainage is provided by the northwestward-flowing Hanging Woman Creek which flows into the northward-flowing Tongue River approximately

23 miles (37 km) to the northwest. Seventysix Creek and Iron Springs Creek flow northwestward into Hanging Woman Creek. The southeast portion of the quadrangle is drained by the headwaters of the southeastward-flowing North Buffalo Creek. The terrain attains elevations of 4,480 feet (1,366 m) above sea level in the southeast portion of the quadrangle. The lowest elevation in the quadrangle is about 3,760 feet (1,146 m) on the western boundary along Hanging Woman Creek. Topographic relief in the quadrangle is 720 feet (220 m).

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 County Courthouse in Sheridan, Wyoming, the Big Horn County Courthouse in Hardin, Montana, and the Powder River County Courthouse in Broadus, Montana. Details of mineral ownership on federal lands in Wyoming and Montana are available from the U. S. Bureau of Land Management in Cheyenne, Wyoming, and Billings, Montana, respectively. 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 5.5 billion tons (5.2 billion metric tons) of total, unleased federal coal-in-place resources in the Box Elder Draw 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 Box Elder Draw Quadrangle is located in an area where surface rocks are classified within the Wasatch Formation and the Tongue River Member of the Fort Union 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 400 to 500 feet (122 to 152 m) of Wasatch Formation and approximately 60 feet (18 m) of the underlying Tongue River Member of the Fort Union 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 Roland of Baker, Anderson, Canyon, Wall, and Brewster-Arnold coal beds were named by Baker (1929). The Knobloch coal bed was named by Bass (1932 and 1924). Stone and Lupton (1910) named the Arvada coal bed. Taff (1909) named the Dietz coal bed. The Cook coal bed was named by Bass (1932), and the Otter coal bed was named by Bryson and Bass (1973). The King coal bed was named by Warren (1959). Culbertson and Klett (1975) named the Roberts coal bed. The Waddle and Kendrick coal beds were named by Culbertson and Klett (1979). The Roland coal bed was named by Taff (1909) in the Sheridan coal field, Wyoming. A coal bed assumed to be the same bed was called the Roland coal bed in the northward extension of the Sheridan coal field, Montana, by Baker (1929). Subsequent work in the Sheridan coal field has shown that the Roland coal bed named by Baker (1929) lies approximately 125 feet (38 m) above the Roland coal bed named by Taff (1909).

Where surface and subsurface control are non-existent, the coal isopach and structure contours of a coal bed are projected into the Box Elder Draw Quadrangle by utilizing drill-hole data located in surrounding quadrangles.

Local. The Box Elder Draw Quadrangle lies on the eastern flank of the Powder River Basin, where the strata dip gently westward. The Wasatch Formation is exposed over 95 percent of the 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 Tongue River Member of the Fort Union Formation directly underlies the Wasatch Formation, and is composed of very fine-grained sandstones, siltstones, claystones, shales, carbonaceous shales, and numerous coal beds. The Tongue River Member crops out in two stream valleys along the northern edge of the quadrangle.

Structure contours drawn on the coal beds in the Box Elder Draw Quadrangle depict a gentle, southwestward dip with minor flexures in the northwest quarter of the quadrangle.

A northeast-trending normal fault occurs in the northwest corner of the quadrangle, and has a maximum of 160 feet (49 m) of vertical displacement, downthrown on the south side. The fault is not extended south of the Montana-Wyoming border due to lack of surface control southward.

III. Data Sources

Areal geology of the coal outcrops is derived from the Spotted Horse coal field report (Olive, 1957) and the Moorhead coal field report (Bryson and Bass, 1973). The coal outcrops are adjusted to fit the current topographic map 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 by 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 Box Elder Draw 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, and Billings, Montana. This information is current to October 13, 1977.

IV. Coal Bed Occurrence

The Wasatch Formation and Fort Union Formation coal beds that are present in all or part of the Box Elder Draw Quadrangle include, in descending stratigraphic order: the Arvada, Roland of Baker, Waddle, Smith, Anderson, Dietz, Canyon, Cook, Otter, Local, Wall, Local, Brewster-Arnold, King, Knobloch, Local, Roberts, and Kendrick coal beds. The Canyon coal beds are mapped as a coal zone, and the Cook, Otter, Wall and two Local coal beds are mapped as a coal bed composite. The Knobloch, Local, Roberts, and Kendrick coal beds are also mapped together as a coal bed composite. The Smith coal bed was not mapped due to insufficient thickness and lack of surface control. 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, was prepared for each of these coal beds or coal zones. Mining ratios are presented on the isopach maps of the Arvada, Roland of Baker, Waddle, Anderson, Dietz, and Canyon coal beds.

No physical or chemical analyses are known to have been published regarding coal bed samples from the Box Elder Draw Quadrangle. For coal beds in eastern Sheridan County, Wyoming, and southern Big Horn and Powder River Counties, Montana, 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		
Arvada	(**)	Hole 78-2	10.5	32.9	28.5	28.1	1.6	7575	8538	Subbtm. C
Roland of Baker	(1)	Hole SH-7029	4.7	27.8	30.2	37.3	0.24	8086	8518	Subbtm. C
Waddle	(1)	Hole SH-24	12.1	36.0	23.7	28.2	0.79	7877	9061	Subbtm. C
Anderson	(1)	Hole SM-15	6.7	35.3	28.6	29.4	0.4	7950	8568	Subbtm. C
Dietz	(1)	Hole SH-18	10.0	34.3	25.8	29.9	0.48	7722	8655	Subbtm. C
Canyon	(1)	Hole SH-62	5.6	37.6	24.2	32.5	0.25	8462	8730	Subbtm. C
Cook	(1)	Hole SH-64	3.1	36.2	30.8	30.0	0.15	7948	8225	Lignite A
Wall	(U)	Hole 7426	9.5	29.3	32.2	29.0	0.50	7279	8112	Lignite A
Brewster-Arnold	(U)	Hole 7424	7.9	31.0	31.9	29.2	0.39	7344	8025	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).
** Correia, G. A. (U. S. Geological Survey, unpublished data).
(1) Matson, R. E., and Blumer, J. W. (1973).
(U) U. S. Geological Survey and Montana Bureau of Mines and Geology (1976).

The proximate analyses presented above are from core hole and outcrop locations beyond the boundaries of this quadrangle. In order to simplify tonnage computations, all coal beds in the Box Elder Draw Quadrangle are tentatively classified as subbitminous C in rank.

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 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 Brewster-Arnold coal bed underlies the entire quadrangle, it is designated as datum for the correlation diagram. The Anderson and Roberts coal beds show the thickest coal bed occurrence throughout the study area. The other coal beds are relatively thin throughout the Box Elder Draw Quadrangle.

The Arvada coal bed ranges in thickness from 2 to 5 feet (0.6 to 1.5 m), with maximum thickness in the north-central area of the quadrangle. The Arvada coal bed has been eroded from 50 percent of the quadrangle, mostly in the northern half of the Box Elder Draw Quadrangle. The coal bed is separated into two coal beds at one location by a clastic interval 4.5 feet (1.4 m) thick. Coal isopach and structure contour maps of the Arvada coal bed in the eastern half and along the northern edge of the quadrangle are based on surface measured sections and coal outcrop elevations (Olive, 1957; and Bryson and Bass, 1973). Subsurface control in the Shuler Draw Quadrangle to the southwest allows projection of contours over the western half of the quadrangle. Structure contours drawn on the top of the Arvada coal bed depict gentle, southwestward dip. The Arvada coal bed occurs from 0 feet (0 m) to greater than 500 feet (152 m) beneath the surface.

The Roland of Baker coal bed lies 140 to 260 feet (43 to 79 m) beneath the Arvada coal bed. The Roland of Baker coal bed is absent along the eastern edge of the quadrangle, and attains a maximum thickness of 18 feet (5 m) in the southwestern corner. The Roland of Baker coal bed has been eroded in the northern part of the study area. Coal isopach and structure contour maps of the Roland of Baker coal bed are based on surface measured sections and coal outcrop elevations (Bryson and Bass, 1973) along the northern edge of the quadrangle, and by utilizing drill-hole data located in surrounding quadrangles. Structure contours drawn on the top of the Roland of Baker coal bed depict gentle, southwestward dip with minor flexures in the northwest. The Roland of Baker coal bed lies from 0 feet (0 m) to greater than 550 feet (168 m) beneath the surface.

The Waddle coal beds lie 40 to 200 feet (12 to 61 m) beneath the Roland of Baker coal bed, and 160 to 260 feet (49 to 79 m) beneath the Arvada coal bed where the Roland of Baker coal bed is absent. The Waddle coal beds have been eroded in the northern area of the Box Elder Draw Quadrangle, and are absent in the northeastern corner. The coal beds range to a maximum thickness of 12 feet (4 m) in the southwestern quarter. A non-coal interval of 39 feet (12 m) occurs between the two Waddle coal beds. Structure contours drawn on the top of the Waddle coal beds depict gentle, southwestward dip with minor flexures in the northern part of the quadrangle. The Waddle coal beds occur from 0 feet (0 m) to greater than 700 feet (213 m) beneath the surface.

The Anderson coal bed is located 160 to 260 feet (49 to 79 m) beneath the Waddle coal beds, and approximately 300 feet (91 m) beneath the

Roland of Baker coal bed where the Waddle coal beds are absent. The Anderson coal bed ranges in thickness from 5 feet (1.5 m) in the southeastern area to 25 feet (8 m) in the northwestern corner of the quadrangle. Structure contours drawn on the top of the Anderson coal bed depict gentle, southwestward dip with minor folds. The Anderson coal bed lies from less than 200 feet (61 m) to greater than 900 feet (274 m) beneath the surface.

The Dietz coal bed occurs 40 to 220 feet (12 to 67 m) beneath the Anderson coal bed. The Dietz coal bed is absent in the southeastern corner, and ranges to a maximum thickness of 10 feet (3 m) in the south-central area of the quadrangle. A non-coal interval of 3 to 9 feet (0.9 to 2.7 m) is present in the south-central area. Structure contours drawn on the top of the Dietz coal bed depict gentle, southwestward dip with minor flexures in the north. The Dietz coal bed occurs from less than 300 feet (91 m) to greater than 1,000 feet (305 m) beneath the surface.

The Canyon coal zone lies 40 to 300 feet (12 to 91 m) beneath the Dietz coal bed, and 300 to 340 feet (91 to 104 m) beneath the Anderson coal bed where the Dietz coal bed is absent. Total coal zone thicknesses range from 8 to 25 feet (2.4 to 8 m) with maximum thicknesses along the eastern edge of the quadrangle. In the northeastern corner, the Canyon coal zone consists of two coal beds with a non-coal interval of 93 feet (28 m). The main structural configuration on the Canyon coal zone is a southwestward-plunging anticline through the central portion of the quadrangle, flanked by a southwestward-plunging syncline to the east. The Canyon coal zone lies from less than 400 feet (122 m) to greater than 1,250 feet (381 m) beneath the surface.

The <u>Cook-Otter-Wall-Local</u> coal bed composite occurs 100 to 400 feet (30 to 122 m) beneath the Canyon coal zone. Total coal thicknesses range from 4 feet (1.2 m) along the southeastern edge to 24 feet (7 m) along the western edge of the quadrangle, where all the coal beds in this coal composite are present. The Local coal bed occurs above and another Local coal bed is below the Wall coal bed in this area. The Cook coal bed is absent from the southwestern portion of the quadragle into the east-central area. In the northern half of the quadrangle, the Wall and Local coal beds are absent. The non-coal interval ranges from 5 to 324 feet (1.5 to 99 m). Structure contours drawn on the top of the Cook coal bed depict gentle, southwestward dip with minor flexures. Where the Cook coal bed is absent, the structure contours drawn on the top of the Otter coal bed depict a gentle, westward dip. The Cook-Otter-Wall-Local coal bed composite occurs from less than 700 feet (213 m) to greater than 1,500 feet (457 m) beneath the surface. Where the Cook coal bed is absent, the coal beds lie from 900 to 1,450 feet (274 to 442 m) beneath the surface.

The <u>Brewster-Arnold and King</u> coal beds lie 100 to 450 feet (30 to 137 m) beneath the Cook-Otter-Wall-Local coal bed composite, and total thicknesses range from 5 to 18 feet (1.5 to 5 m) with maximum thicknesses in the west-central area of the quadrangle. The total non-coal interval ranges from 121 to 129 feet (37 to 39 m). The King coal bed is absent in the northern half of the quadrangle. Structure contours drawn on top of the Brewster-Arnold coal bed depict gentle, southwestward dip with minor flexures. The Brewster-Arnold-King coal bed composite lies from less than 1,000 feet (305 m) to greater than 1,750 feet (533 m) beneath the surface.

The Knobloch-Local-Roberts-Kendrick coal bed composite occurs 140 to 330 feet (43 to 101 m) beneath the Brewster-Arnold and King coal beds. Total coal thicknesses range from 29 feet (9 m) in the northeastern corner to 52 feet (16 m) in the southwestern quarter of the quadrangle. The total non-coal interval within the coal composite ranges from 512 to 557 feet (156 to 170 m). Structure contours drawn on top of the Knobloch-Local-Roberts-Kendrick coal bed depict a broad, southwestward-plunging anticline through the east-central area of the quadrangle. The coal bed composite lies from less than 1,400 feet (427 m) to greater than 2,250 feet (686 m) beneath the surface.

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 Box Elder Draw Quadrangle area. Data from geophysical logs are used to correlate coal beds and control contour lines for the coal thickness, structure, and overburden maps. Isopach lines are also drawn to honor only selected measured sections 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, these surface measurements ~~they~~ are not reflective of true ~~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 as just listed; 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 (reserves). 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) were 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 49) 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 10 percent of the quadrangle. These high development potential areas result from low overburden-to-coal thickness ratios of the Roland of Baker and the Arvada coal beds where they crop out in the western and northern portions of the quadrangle. The surface-mining development potential is moderate for approximately 10 percent of the quadrangle, located primarily in the western and northern areas. The moderate development potential results from moderate overburden-to-coal ratios for the Roland of Baker and Anderson coal beds. Approximately 55 percent of the Box Elder Draw Quadrangle is rated as having a low development potential for surface mining due to thin coal beds overlain by thick overburden. Less than 5 percent of the quadrangle is rated as having no potential for surface-mining development, which results from no known coal beds being 5 feet (1.5 m) or more thick and less than 500 feet (152 m) beneath the surface. The remaining 20 percent of the study area is classified as non-federal coal land. 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 Box Elder Draw Quadrangle is considered low. Inasmuch as recovery factors have not been established for the underground development of coal beds in this quadrangle, reserves (recoverable coal tonnages) are not calculated for coal beds that occur more than 500 feet (152 m) beneath the surface. Table 2 sets forth the estimated underground-minable coal resources in tons per coal bed.

<u>In-Situ Gasification Coal Development Potential</u>. 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 buried from 500 to 3,000 feet (152 to 914 m) beneath the surface. This categorization is as follows:

1. <u>Low development</u> 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. <u>Moderate development</u> 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. <u>High development</u> 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 in the Box Elder Draw Quadrangle is rated as low. This rating results from the coal beds 5 feet (1.5 m) or more thick which occur between

500 feet (152 m) and 1,000 feet (305 m) beneath the surface. The total coal section more than 1,000 feet (305 m) beneath the surface is less than 100 feet (30 m) thick throughout the quadrangle. The coal resource tonnage totals for in-situ gasification are listed by coal bed on table 3.

Table 1.--Strippable Coal Reserve Base and Hypothetical Resource Data (in short tons) for Federal Coal Lands in the Box Elder Draw Quadrangle, Sheridan County, Wyoming, and Big Horn and Powder River Counties, Montana.

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				
Arvada	2,740,000	1,170,000	400,000	4,310,000
Roland of Baker	30,120,000	65,460,000	205,150,000	300,730,000
Waddle	-	-	212,560,000	212,560,000
Anderson	-	41,990,000	187,020,000	229,010,000
Dietz	-	-	37,040,000	37,040,000
Canyon	-	-	11,650,000	11,650,000
Total	32,860,000	108,620,000	653,820,000	795,300,000
Hypothetical Resources				
Arvada	-	-	230,000	230,000
Roland of Baker	-	-	14,110,000	14,110,000
Waddle	-	-	21,290,000	21,290,000
Anderson	-	-	62,480,000	62,480,000
Dietz	-	-	12,070,000	12,070,000
Total	-	-	110,180,000	110,180,000
GRAND TOTAL	32,860,000	108,620,000	764,000,000	905,480,000

Table 2.--Coal Reserve Base and Hypothetical Resource Data (in short tons) for Underground Mining Methods for Federal Coal Lands in the Box Elder Draw Quadrangle, Sheridan County, Wyoming, and Big Horn and Powder River Counties, Montana.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Reserve Base Resources				
Roland of Baker	-	-	3,530,000	3,530,000
Waddle	-	-	20,120,000	20,120,000
Anderson	-	-	253,950,000	253,950,000
Dietz	-	-	142,070,000	142,070,000
Canyon	-	-	666,680,000	666,680,000
Cook-Otter-Wall-Local	-	-	633,060,000	633,060,000
Brewster-Arnold-King	-	-	480,050,000	480,050,000
Knobloch-Local-Roberts-Kendrick	-	-	2,253,330,000	2,253,330,000
Total	-	-	4,452,790,000	4,452,790,000
Hypothetical Resources				
Roland of Baker	-	-	270,000	270,000
Waddle	-	-	3,380,000	3,380,000
Anderson	-	-	79,150,000	79,150,000
Dietz	-	-	12,290,000	12,290,000
Total	-	-	95,090,000	95,090,000
GRAND TOTAL	-	-	4,547,880,000	4,547,880,000

Table 3.--Coal Reserve Base and Hypothetical Resource Data (in short tons) for In-Situ Gasification for Federal Coal Lands in the Box Elder Draw Quadrangle, Sheridan County, Wyoming, and Big Horn and Powder River Counties, Montana.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Reserve Base Resources				
Roland of Baker	-	-	3,530,000	3,530,000
Waddle	-	-	20,120,000	20,120,000
Anderson	-	-	253,950,000	253,950,000
Dietz	-	-	142,070,000	142,070,000
Canyon	-	-	666,680,000	666,680,000
Cook-Otter-Wall-Local	-	-	633,060,000	633,060,000
Brewster-Arnold-King	-	-	480,050,000	480,050,000
Knobloch-Local-Roberts-Kendrick	-	-	2,253,330,000	2,253,330,000
Total	-	-	4,452,790,000	4,452,790,000
Hypothetical Resources				
Roland of Baker	-	-	270,000	270,000
Waddle	-	-	3,380,000	3,380,000
Anderson	-	-	79,150,000	79,150,000
Dietz	-	-	12,290,000	12,290,000
Total	-	-	95,090,000	95,090,000
GRAND TOTAL	-	-	4,547,880,000	4,547,880,000

SELECTED REFERENCES

American Society of Testing and Materials, 1971, Standard specifications for classification of coals by rank (ASTM Designation D 388-66) in Gaseous fuels, coal, and coke: American Society for Testing and Materials, pt. 19, p. 57-61.

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

Bass, N. W., 1924, Coal in the Tongue River valley, Montana: U. S. Geological Survey Press Mem. 16748, February 12, 1924.

______1932, The Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana: U. S. Geological Survey Bull. 831-B, p. 19-105.

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

Bryson, R. P., and Bass, N. W., 1973, Geology of Moorhead coal field, Powder River, Big Horn, and Rosebud Counties, Montana: U. S. Geological Survey Bull. 1338, 116 p.

Correia, G. A., 1980, Preliminary results of 1978 coal assessment drilling in Northern and Western Recluse Geologic Analysis Area, northern Campbell County and eastern Sheridan County, Wyoming: U. S. Geological Survey Open-File Report 80-80, 70 p.

Culbertson, W. C., Kent, B. H., and Mapel, W. J., 1979, Preliminary diagrams showing correlation of coal beds in the Fort Union and Wasatch Formations across the northern Powder River Basin, northeastern Wyoming and southeastern Montana: U. S. Geological Survey Open-File Report 79-1201, 11 p.

Culbertson, W. C., and Klett, M. C., 1975 (1976), Preliminary geologic map and coal sections of the Jones Draw Quadrangle, Sheridan County, Wyoming: U. S. Geological Survey Miscellaneous Field Studies Map MF-726, 2 sheets, 1:24,000 scale.

_____1979, Geologic map and coal sections of the Forks Ranch quadrangle, Big Horn County, Montana: U. S. Geological Survey Miscellaneous Field Studies Map MF-1086, 2 sheets, 1:24,000 scale.

Culbertson, W. C., and Robinson, L. N., 1978, Coal resource occurrence and coal development potential maps of the Quietus quadrangle, Big Horn and Powder River Counties, Montana: U. S. Geological Survey Open-File Report 78-654, 20 p.

Denson, N. M., and Horn, G. H., 1975, Geologic and structure map of the southern part of the Powder River Basin, Converse, Niobrara, and Natrona Counties, Wyoming: U. S. Geological Survey Miscellaneous Investigations Series, Map I-877, scale 1:125,000.

Dobbin, C. E., and Barnett, V. H., 1927 (1928), The Gillette coal field, northeastern Wyoming: U. S. Geological Survey Bull. 796-A, 50 p.

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

Matson, R. E., and Blumer, J. W., 1973, Quality and reserves of strippable coal, selected deposits, southeastern Montana: Montana Bureau of Mines and Geology Bull. 91, 135 p.

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

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

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

Taff, J. A., 1909, The Sheridan coal field, Wyoming: U. S. Geological Survey Bull. 341-B, p. 123-150.

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

U. S. Geological Survey and Montana Bureau of Mines and Geology, 1976a, Preliminary report of coal drill-hole data and chemical analyses of coal beds in Campbell and Sheridan Counties, Wyoming: Custer, Prairie, and Garfield Counties, Montana; and Mercer County, North Dakota: U. S. Geological Survey Open-File Report 76-319, 377 p.

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

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