UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TEXT TO ACCOMPANY:

COAL RESOURCE OCCURRENCE

AND

COAL DEVELOPMENT POTENTIAL

MAPS

OF THE

NORTHWEST QUARTER OF NORTH STAR SCHOOL 15' QUADRANGLE,

CAMPBELL COUNTY, WYOMING

BY

INTRASEARCH INC.

DENVER, COLORADO

OPEN FILE REPORT 79-059
1979

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

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

CONVERSION TABLE

TO CONVERT	MULTIPLY BY	TO OBTAIN
inches	2.54	centimeters (cm)
feet	0.3048	meters (m)
miles	1.609	kilometers (km)
acres	0.40469	hectares (ha)
tons (short)	0.9072	metric tons (t)
cubic yards/ton	0.8428	cubic meters per metric tons
acre feet	0.12335	hectare-meters
Btu/lb	2.326	kilojoules/kilogram (kJ/kg)
Btu/lb	0.55556	kilocalories/kilogram (kcal/kg)
Fahrenheit	5/9 (F-32)	Celsius

I. <u>Introduction</u>

This report and accompanying maps set forth the Coal Resource Occurrence (CRO) and Coal Development Potential (CDP) of coal beds within the Northwest Quarter of North Star School 15' Quadrangle, Campbell County, Wyoming. This CRO and CDP map series (U. S. Geological Survey Open-File Report 79-059) includes 40 plates. The project is compiled by IntraSearch Inc., 5351 South Roslyn Street, Englewood, Colorado, under KRCRA Eastern Powder River Basin, Wyoming Contract Number 14-08-0001-17180. This contract is part of a program to provide an inventory of unleased federal coal in Known Recoverable Coal Resource Areas (KRCRAs) in the western United States.

The Northwest Quarter of North Star School 15' Quadrangle is located in Campbell County, in northeastern Wyoming. It encompasses all or parts of Townships 45, 46 and 47 North, Ranges 73 and 74 West, and covers the area: 43°52'30" to 44°00' north latitude; 105°37'30" to 105°45' west longitude.

Principal access to the Northwest Quarter of North Star School 15' Quadrangle is provided by Wyoming State Highway 50 which extends from the north to the southwest across the northwest quarter of the study area. An improved light-duty road extends north to south across the eastern half of the quadrant, intersecting State Highway 50 approximately 11 miles (18 km) to the north and 12 miles (19 km) southwest of Gillette, Wyoming. Minor roads and trails that branch from these two improved roads provide access to the more remote areas. The closest railroad is the Burlington Northern trackage, 15 miles (24 km) to the east.

The primary drainage is provided by eastward-flowing Wild Horse Creek which extends across the southern half of the quadrangle, and collectively, with the tributaries, drains the majority of the southern three-fourths of the study area. The northern fourth is drained by eastward-flowing Threemile Creek. Wild Horse Creek and Threemile Creek both flow into the Belle Fourche River to the east. Pinette Draw, located in the northwest corner of the quadrangle, is the only westward-flowing stream draining into the Powder River to the west. Elevations attain heights of 5278 feet (1609 m) above sea level in the northwest quarter of the quadrangle, 400 to 500 feet (122 to 152 m) above the valley floors to the southeast. The somber grays, yellows and browns of outcropping shales and siltstones contrast strikingly with the brilliant reds, oranges and purples of "clinker," and deep greens of the juniper and pine tree growth.

The 12 to 14 inches (30 to 36 cm) of annual precipitation falling in this semi-arid region accrue principally in the springtime. Summer and fall precipitation usually originates from thunderstorms, and infrequent snowfalls of 6 inches (15 cm) or less generally characterize winter precipitation. Although temperatures ranging from less than -25°F (-32°C) to more than 100°F (38°C) have been recorded near Gillette, Wyoming, average wintertime minimums and summertime maximums range from +5° to +°15F (-15° to -9°C) and 75° to 90°F (24° to 32°C), respectively.

Surface ownership is divided among fee, state, and federal categories with the state and federal surface generally leased to ranchers for grazing purposes. Details of surface ownership are available at the Campbell County Courthouse in Gillette, Wyoming. Details of mineral ownership on federal lands are available from the U. S. Bureau of Land Management in Cheyenne, Wyoming. Federal coal ownership is shown on Plate 2 of the Coal Resource Occurrence maps. The non-federal coal ownership comprises both fee and state coal resources.

The Coal Resource Occurrence and Coal Development Potential program pertains to unleased federal coal and focuses upon the delineation of lignite, subbituminous coal, bituminous coal, and anthracite at the surface, and in the subsurface. In addition, the program identifies total tons of coal in place, as well as recoverable tons. These coal tonnages are then categorized into units of measured, indicated, and inferred reserves and resources, and hypothetical resources. Finally, recommendations are made regarding the potential for surface mining, underground mining, and in-situ gasification of the coal beds. This report evaluates the coal resources of all unleased federal coal beds in the quadrangle which are 5 feet (1.5 m) or greater in thickness and occur at depths down to 3000 feet (914 m). No resources or reserves are computed for leased federal coal, state coal, fee coal, or lands encompassed by coal prospecting permits and preference-right lease applications.

Surface and subsurface geological and engineering extrapolations drawn from the current data base suggest the occurrence of approximately 10.9 billion tons (7.9 billion metric tons) of unleased federal coal resources in the Northwest Quarter of North Star School 15' Quadrangle.

The suite of maps that accompany this report sets forth and portrays the coal resource and reserve occurrence in considerable detail. For the most part, this report supplements the cartographically displayed information with minimum verbal duplication of the CRO-CDP map data.

II. Geology

Regional. The thick, economic coal deposits of the Powder River Basin in northeastern Wyoming occur mostly in the Tongue River Member of the Fort Union Formation, and in the lower part of the Wasatch Formation. Approximately 3000 feet (914 m) of the Fort Union Formation, including the Tongue River, Lebo, and Tullock Members of Paleocene age, are unconformably overlain by approximately 700 feet (213 m) of the Wasatch Formation of Eocene age. These Tertiary formations lie in a structural basin flanked on the east by the Black Hills uplift, on the south by the Hartville and Casper Mountain uplifts, and on the west by the Casper Arch and the Big Horn Mountain uplift. The structural configuration of the Powder River Basin originated in Late Cretaceous time, with episodic uplift thereafter. The Cretaceous Cordillera was the dominant positive land form throughout the Rocky Mountain area at the close of Mesozoic time.

Outcrops of the Wasatch Formation and the Tongue River Member of the Fort Union Formation cover most of the areas of major coal resource occurrence in the Powder River Basin. The Tongue River Member is composed of very fine-grained sandstones, siltstones, claystones, shales, carbonaceous shales, and numerous coal beds. The Lebo Member of the Fort Union Formation consists of light- to dark-gray very fine-grained to conglomeratic sandstone with interbedded siltstone, claystone, carbonaceous shale and thin coal beds. Thin bedded calcareous ironstone concretions interbedded with massive white sandstone and slightly bentonitic shale occur throughout the unit (Denson and Horn, 1975). The Lebo Member is mapped at the surface northeast of Recluse, Wyoming. Here, the Lebo Member is east of the principal coal outcrops and associated clinkers (McKay, 1974), and it presumably projects into the subsurface beneath much of the basin. One of the principal characteristics for separating the Lebo and Tullock Members (collectively referred to as the Ludlow Member east of Miles City, Montana) from the overlying Tongue River Member is the color differential between the lighter-colored upper portion and the somewhat darker lower portion (Brown, 1958). Although geologists are trying to develop criteria for subsurface recognition of the Lebo-Tullock and Tongue River-Lebo contacts through the use of subsurface data from geophysical logs, no definitive guidelines are known to have been published. Hence, for subsurface mapping purposes, the Fort Union Formation is not divided into its members for this study.

During the Paleocene epoch, the Powder River Basin tropical to subtropical depositional environment included broad, inland flood basins with extensive swamps, marshes, freshwater lakes, and a sluggish, but active, northeastward-discharging drainage system. These features were superimposed on an emerging sea floor, near base level. Much of the vast area where organic debris collected was within a reducing depositional environment. Localized uplifts began to disturb the near sea-level terrain of northeastern Wyoming following retreat of the Cretaceous seas. However, the extremely fine-grained characteristics of the Tongue River Member clastics suggest that areas of recurring uplift peripheral to the Powder River Basin were subdued during major coal deposit formation.

The uplift of areas surrounding the Powder River Basin created a structural basin of asymmetric character, with the steep west flank located on the eastern edge of the Big Horn Mountains. The axis of the Powder River Basin is difficult to specifically define, but it is thought to be located in the western part of the Basin and to display a north-south configuration some 15 to 20 miles (24 to 32 km) east of Sheridan, Wyoming. Thus, the sedimentary section described in this report lies on the east flank of the Powder River Basin, with gentle dips of two degrees or less disrupted by surface structure thought to relate to tectonic adjustment and differential compaction.

Some coal beds in the Powder River Basin exceed 200 feet (61 m) in thickness. Deposition of these thick, in-situ coal beds requires a delicate balance between subsidence of the earth's crust and in-filling by tremendous volumes of organic debris. These conditions in concert with a favorable ground water table, non-oxidizing clear water, and a climate amenable to the luxuriant growth of vegetation produce a stabilized swamp critical to the deposition of coal beds.

Deposition of the unusually thick coal beds of the Powder River Basin may be partially attributable to short-distance water transportation of organic detritus into areas of crustal subsidence. Variations in coal bed thickness throughout the basin relate to changes in the depositional environment. Drill hole data that indicate either the complete absence or extreme attenuation of a thick coal bed probably relate to location of the drill holes within the ancient stream channel system draining this lowland area in Early Cenozoic time. Where thick coal beds thin rapidly from the depocenter of a favorable depositional environment, it is not unusual to encounter a synclinal structure over the maximum coal thickness due to the differential compaction between organic debris in the coal depocenter and fine-grained clastics in the adjacent areas.

The Wasatch Formation of Eocene age crops out over most of the central part of the Powder River Basin and exhibits a disconformable contact with the underlying Fort Union Formation. The contact has been placed at various horizons by different workers; however, for the purpose of this report, the contact is positioned near the top of the Roland coal bed as mapped by Olive (1957) in northwestern Campbell County, Wyoming, and it is considered to descend disconformably in the stratigraphic column to the top of the Wyodak-Anderson coal bed (Roland coal bed of Taff, 1909) along the eastern boundary of the coal measures. No attempt was made to differentiate the Wasatch and Fort Union Formations on geophysical logs or in the subsurface mapping program for this project.

Although Wasatch and Fort Union lithologies are too similar to allow differentiation in some areas, most of the thicker coal beds occur in the Fort Union section on the east flank of the Powder River Basin. Furthermore, orogenic movements peripheral to the basin apparently increased in magnitude during Wasatch time causing the deposition of friable, coarse-grained to gritty, arkosic sandstones, fine- to very fine-grained sandstones, siltstones, mudstones, claystones, brown-to-black carbonaceous shales, and coal beds. These sediments are noticeably to imperceptibly coarser than the underlying Fort Union clastics.

The Northwest Quarter of North Star School 15' Quadrangle is located in an area where surface rocks are classified as the Wasatch Formation. Olive (1957) correlated coal beds in the Spotted Horse coal field with coal beds in the Sheridan coal field (Baker, 1929) and Gillette coal field (Dobbin and Barnett, 1927), Wyoming, and with coal beds in the Ashland coal field (Bass, 1932) in southeastern Montana. This report utilizes, where possible, the coal bed nomenclature used in previous reports. The Ulm and Felix coal beds were named by Stone and Lupton (1910). The Smith coal bed was named by Taff (1909). IntraSearch's correlation of thick coal beds from the Spotted Horse coal field to Gillette points out that the Wyodak coal bed, named the "D" coal bed by Dobbin and Barnett (1927), is equivalent to the Anderson, Canyon and, all or part of, the Cook coal beds to the north and west of Gillette, Wyoming. Correlation of this suite of coal beds with the Wyodak coal bed south and southwest of Gillette suggest that the Anderson and Canyon coal beds equate with the upper 10 to 25 percent of the thick Wyodak coal bed, and the Cook and Wall, or Upper Wall, coal beds are equivalent to the major part of the Wyodak coal bed. Due to problematic correlations outside of the Gillette area, the name Wyodak has been informally used by many previous authors to represent the coal beds in the area surrounding the Wyodak coal mine. The Pawnee coal bed was named by Warren (1959). The Wildcat, Moyer, and Oedekoven coal beds were informally named by IntraSearch (1978b, 1979, and 1978a).

Local. The Northwest Quarter of North Star School 15' Quadrangle lies on the eastern flank of the Powder River Basin, where the strata dip gently westward. The Wasatch Formation crops out over the entire quadrangle and is comprised of friable, coarse-grained to gritty arkosic sandstones, fine- to very fine-grained sandstones, siltstones, mudstones, claystones, brown-to-black carbonaceous shales, and coal beds.

III. Data Sources

Areal geology of the coal outcrops is derived from the Pumpkin Buttes coal field report (Wegemann and others, 1928). The coal outcrops are adjusted to current topographic maps in the area.

Geophysical logs from oil and gas test bores and producing wells comprise the source of subsurface control. Some geophysical logs are not applicable to this study, for the logs relate only to the deep, potentially productive oil and gas zones. More than 80 percent of the logs include resistivity, conductivity, and self-potential curves. Occasionally the suite of geophysical logs includes gamma, density, and sonic curves. These logs are available from several commercial sources.

All geophysical logs available in the quadrangle are scanned to select those with data applicable to Coal Resource Occurrence mapping. Paper copies of the logs are obtained and interpreted, and coal intervals are annotated. Maximum accuracy of coal bed indentification is accomplished where gamma, density, and resistivity curves are available. Coal bed tops and bottoms are picked on the logs at the midpoint between the minimum and maximum curve deflections. The correlation of coal beds within and between quadrangles is achieved utilizing a fence diagram to associate local correlations with regional coal occurrences.

The reliability of correlations, set forth by IntraSearch in this report, varies depending on: the density and quality of lithologic and geophysical logs; the detail, thoroughness, and accuracy of published and unpublished surface geological maps; and interpretative proficiency. There is no intent on the part of IntraSearch to refute nomenclature established in the literature or used locally by workers in the area. IntraSearch's nomenclature focuses upon the suggestion of regional coal bed names applicable throughout the eastern Powder River Basin. It is expected, and entirely reasonable, that some differences of opinion regarding correlations, as suggested by IntraSearch, exist. Additional drilling for coal, oil, gas, water, and uranium, coupled with expanded mapping of coal bed outcrops and associated clinkers will broaden the data base for coal bed correlations and allow continued improvement in the understanding of coal bed occurrences in the eastern Powder River Basin.

The topographic map of the North Star School 15' Quadrangle is published by the U. S. Geological Survey, compilation date, 1959. Expansion of the topographic base of the North Star School 15' Quadrangle (scale 1:62,500) into 7 1/2' quadrangle maps (scale 1:24,000) was performed by the U. S. Geological Survey for Coal Resource Occurrence - Coal Development Potential mapping purposes. Land network and mineral ownership data are compiled from land plats available from the U. S. Bureau of

Land Management in Cheyenne, Wyoming. This information is current to October 13, 1977.

IV. Coal Bed Occurrence

Wasatch and Fort Union Formation coal beds that are present in all or part of the Northwest Quarter of North Star School 15' Quadrangle include in descending stratigraphic order: the Ulm, Upper Felix, Lower Felix, Smith, Upper Wyodak, Middle Wyodak, Lower Wyodak, Pawnee, local, Local, Wildcat, Moyer, and Oedekoven. A complete suite of maps (coal isopach, mining ratio as indicated, structure, overburden/interburden isopach, areal distribution of identified resources and identified resources) is prepared for the Ulm, Upper Felix, Lower Felix, Smith, Upper Wyodak, and Pawnee coal beds and for the Middle-Lower Wyodak and Local-Wildcat-Moyer-Oedekoven coal zones. Insufficient thickness and areal extent preclude any detailed mapping of a local coal bed.

No physical and chemical analyses are known to have been published regarding the coal beds in the Northwest Quarter of North Star School 15' Quadrangle. However, the proximate analysis performed on an "as received" basis for Campbell County coal beds is as follows:

COAL BED NAME			ASH %	FIXED CARBON %	MOISTURE %	VOLATILES %	SULFUR %	BTU/LB
Ulm	(U)	Hole 7323	7.288	33.626	30.070	29.016	1.309	7730
Felix	(U)	Hole 7315	6.757	32.934	28.714	31.595	0.548	8093
Lower Smith	(U)	Hole 7312C	6.167	33.340	29.610	30.883	1.068	8215
Wyodak	(U)	Hole 757	6.024	32.831	26.907	34.237	0.336	8366
Pawnee	(U)	Hole 7424	7.880	31.029	31.910	29.183	0.386	7344

(U) - U. S. Geological Survey and Montana Bureau of Mines and Geology - 1974, 1976a, and 1976b.

The Coal Data Sheet, Plate 3, shows the downhole identification of coal beds within the quadrangle as interpreted from geophysical logs from oil and gas test bores and producing sites. A datum coal bed is utilized to position columnar sections on Plate 3. This portrayal is schematic by design; hence, no structural or coal thickness implications are suggested by the dashed correlation lines projected through no record (NR) intervals. Inasmuch as the Lower Wyodak coal bed underlies the entire quadrangle, it is designated as datum for the correlation diagram. The Upper Wyodak and Lower Wyodak coal beds show the thickest single coal bed occurrences throughout the quadrangle. The remainder of the coal beds are relatively thin throughout most the area.

The Ulm coal bed crops out in the northwest corner of the quadrangle and is eroded from approximately 95 percent of the study area. The coal bed thickness averages approximately 10 feet (3.0 m). The maps of the Ulm coal bed presented in this report (Figures 1, 2, 3) are derived from outcrop data (Wegemann and others, 1928). Limited structural control suggest a gentle regional dip to the north. The Ulm coal bed lies approximately 0 to 150 feet (0 to 46 m) in depth beneath the surface throughout areas of occurrence.

The thin Upper Felix coal bed lies approximately 500 feet (152 m) below the overlying Ulm coal bed in the northwest quarter of the quadrangle. The coal bed crops out in the southern half of the quadrangle along Wild Horse Creek and is eroded from approximately 10 percent of the study area. The coal bed thickness ranges from 4 to 8 feet (1.2 to 2.4 m) with maximum thicknesses occurring in the northern half of the quadrant. Structure contours drawn on top of the Upper Felix coal bed indicate a regional dip to the north with a broad anticline extending across the southern half of the quadrangle. The Upper Felix coal bed occurs approximately 0 to 680 feet

(0 to 207 m) beneath the surface and lies less than 500 feet (152 m) in depth throughout approximately 95 percent of the quadrangle.

The Lower Felix coal bed occurs approximately 20 to 288 feet (6.1 to 88 m) beneath the Upper Felix coal bed where the Upper Felix coal bed is present, and is composed of a highly split, moderately thick coal bed. The coal bed thickness ranges from 5 to 27 feet (1.5 to 8 m), with thickest occurrences extending from the north through the central area of the quadrangle, and with thinning to the east and southwest. The clastic interval separating the coal bed varies in thickness from 0 to 73 feet (0 to 22 m). The Lower Felix coal bed dips gently to the northwest showing a small northwest-plunging anticline in the southwest quarter of the quadrant. The Lower Felix coal bed is buried approximately 10 to 740 feet (3.0 to 226 m) beneath the surface and occurs less than 500 feet (152 m) in depth throughout approximately 90 percent of the study area.

The Smith coal bed occurs 377 to 441 feet (115 to 134 m) below the Lower Felix coal bed, and ranges in thickness from 3 to 20 feet (0.9 to 6 m). Maximum thicknesses occur in the northeast quarter of the quadrant, thinning to the west. Structure contours drawn on top of the Smith coal bed indicate a regional northwest dip showing minor anticlinal and synclinal configurations in the western half of the quadrangle. The Smith coal bed lies approximately 380 to 1220 feet (116 to 372 m) beneath the surface and occurs at depths exceeding 500 feet (152 m) throughout approximately 98 percent of the quadrangle.

The Upper Wyodak coal bed lies approximately 139 to 283 feet (42 tc 86 m) below the Smith coal bed. The coal bed thickness ranges from 15 to 65 feet (4.6 to 20 m) with maximum thicknesses occurring in the western half of the quadrant, and with thinning to the east. Structurally, the Upper Wyodak coal bed dips gently to the northwest. A broad syncline plunges southwest extending across the northern half of the quadrangle. The Upper Wyodak coal bed lies approximately 620 to 1320 feet (189 to 402 m) beneath the surface throughout the entire quadrangle.

The Middle-Lower Wyodak coal zone occurs approximately 150 to 347 feet (46 to 106 m) beneath the Upper Wyodak coal bed, and is composed of a thin Middle Wyodak coal bed overlying a moderately thick Lower Wyodak coal bed. The total coal-zone thickness ranges from 30 to 130 feet (9 to 40 m) with thickest occurrences located in the northeast corner of the quadrangle, thinning to the west. The thin Middle Wyodak coal bed extends from the east into the eastern half of the study area and is absent from approximately 75 percent of the quadrangle. The clastic interval separating the various coal beds composing the coal zone varies from near 0 to 246 feet (0 to 75 m) depending on the localized occurrence of the various coal beds. Structure contours drawn on top of the Middle Wyodak coal bed where present, and on top of the Lower Wyodak coal bed elsewhere, depict a broad northwest-plunging anticline in the southwestern quarter of the quadrangle. In addition, a broad, westward-plunging syncline extends into the northwest quarter of the quadrant. The eastern half of the quadrangle is characterized by a gentle dip to the west and northwest. The Middle-Lower Wyodak coal zone lies approximately 830 to 1650 feet (253 to 503 m) in depth beneath the surface throughout the entire quadrangle.

The Pawnee coal bed ranges between 93 and 310 feet (28 to 95 m) below the Middle-Lower Wyodak zone, and varies in coal bed thickness from 5 to 40 feet (1.5 to 12 m) with maximum thicknesses occurring along the north-central boundary of the quadrangle. It thins significantly to the southwest. Structure contours drawn on top of the Pawnee coal bed indicate a broad, northwest-plunging anticline extending across the southern half of the study area. In the northern portion of the quadrangle, contours

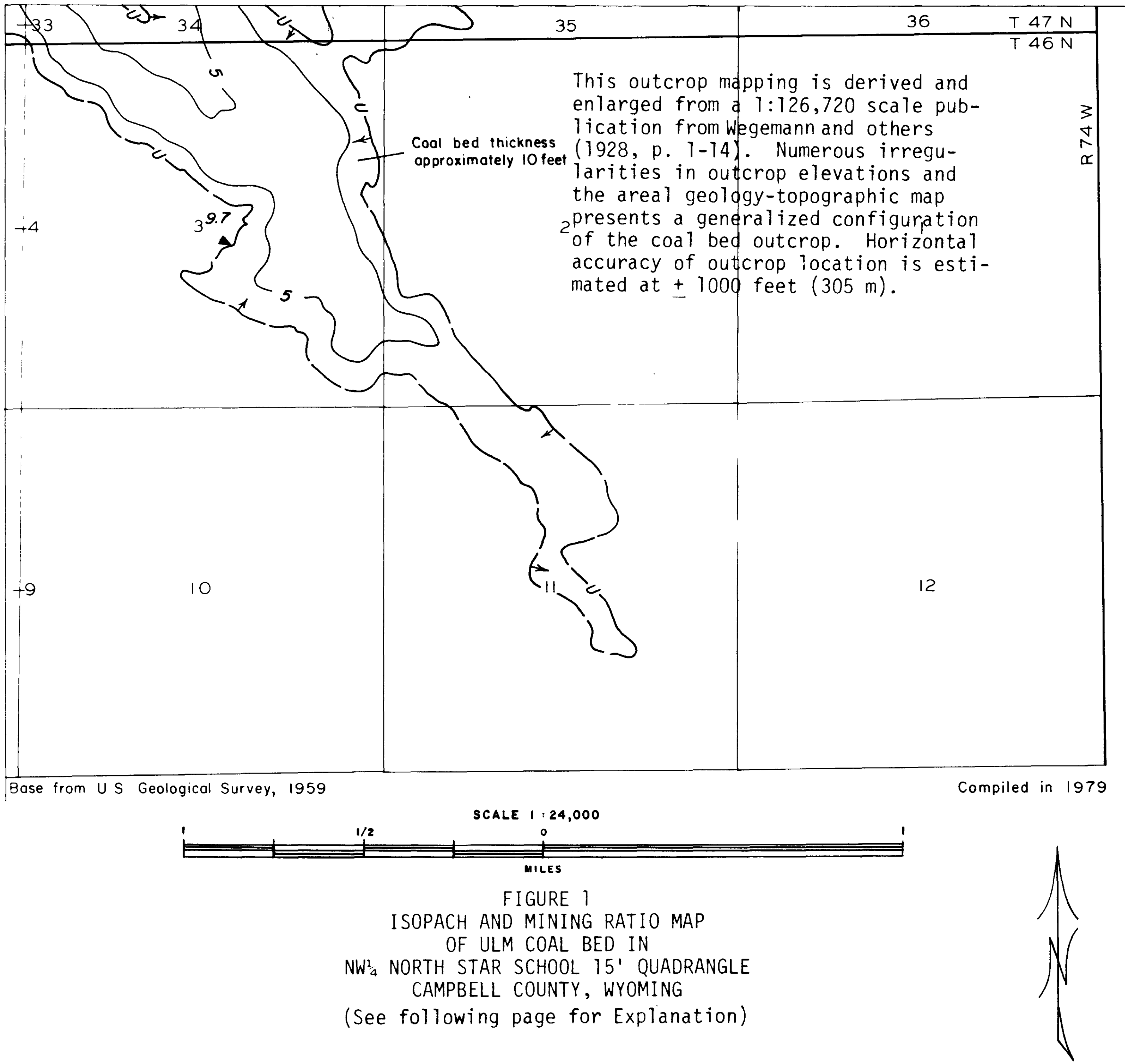
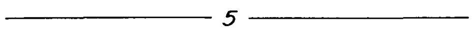
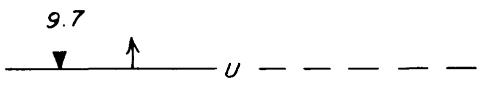


FIGURE 1
ISOPACH AND MINING RATIO MAP
OF ULM COAL BED IN
NW¼ NORTH STAR SCHOOL 15' QUADRANGLE
CAMPBELL COUNTY, WYOMING
(See following page for Explanation)

EXPLANATION FOR FIGURE 1



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.

To convert feet to meters, multiply feet by 0.3048.

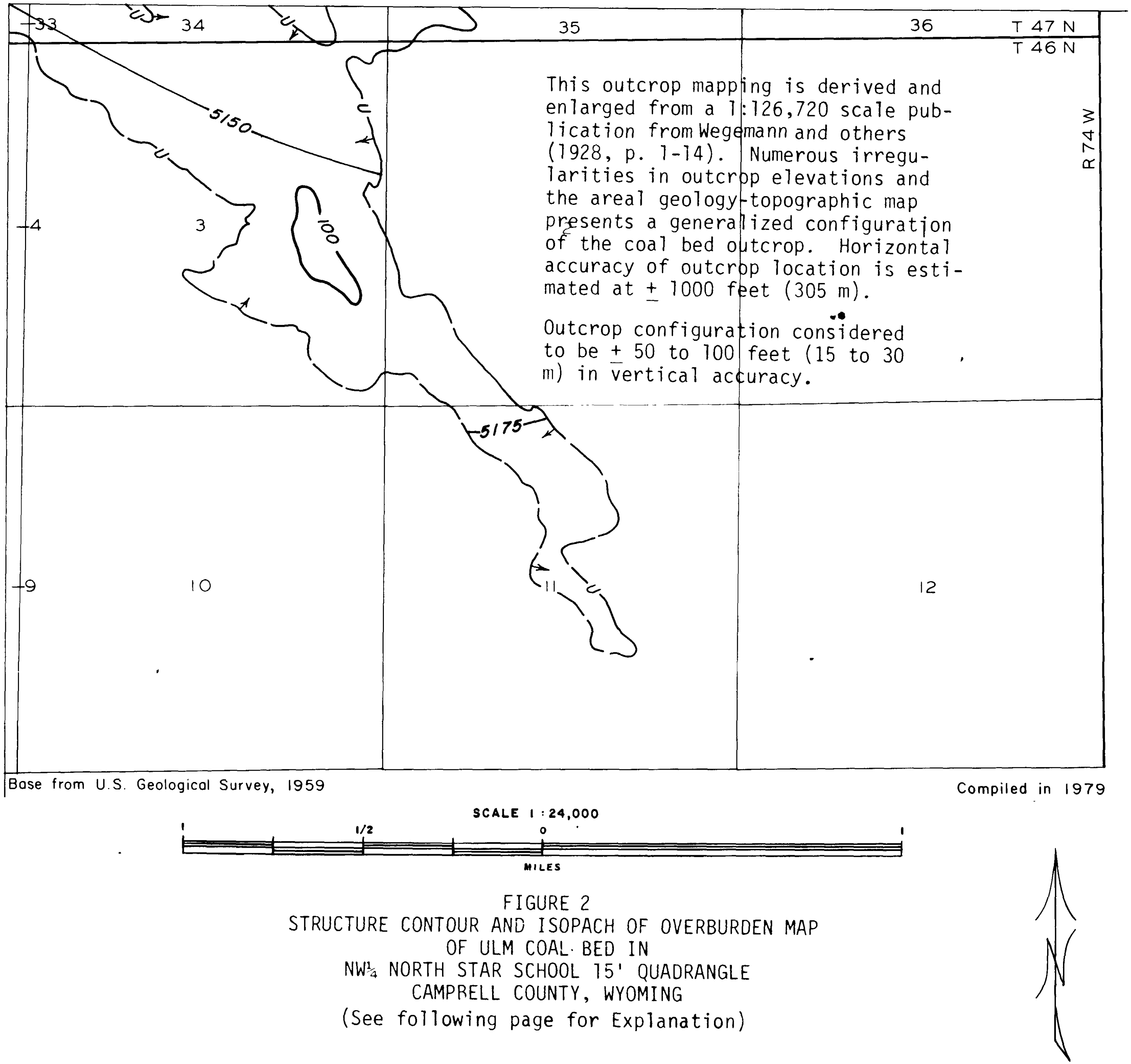
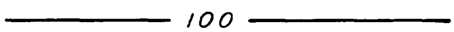


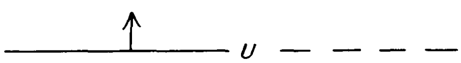
FIGURE 2
STRUCTURE CONTOUR AND ISOPACH OF OVERBURDEN MAP
OF ULM COAL BED IN
NW¼ NORTH STAR SCHOOL 15' QUADRANGLE
CAMPRELL COUNTY, WYOMING
(See following page for Explanation)

EXPLANATION FOR FIGURE 2

STRUCTURE CONTOURS-Drawn on top of coal bed. Contour interval 25 feet. Datum is mean sea level.

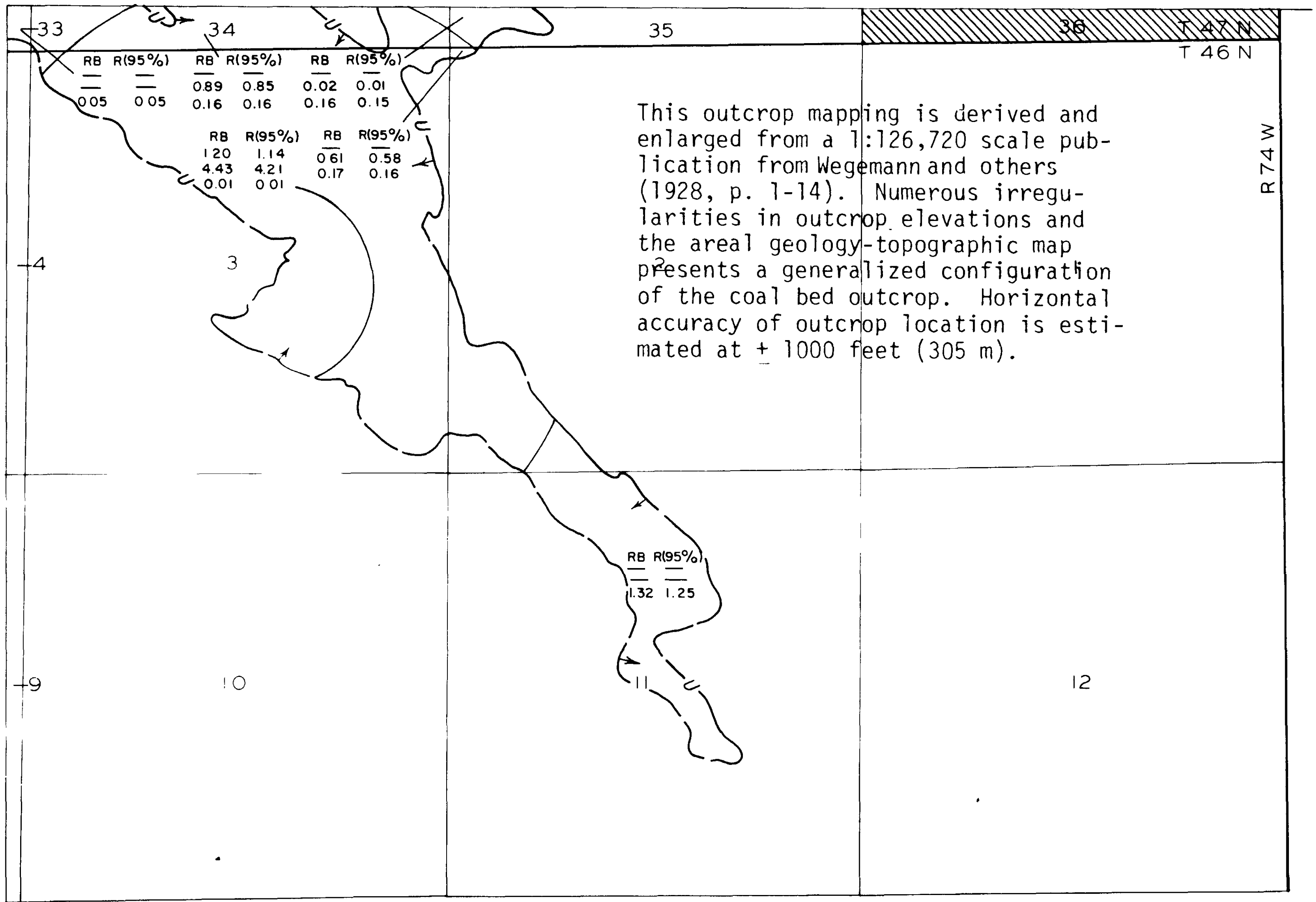


OVERBURDEN ISOPACH-Showing thickness of overburden, in feet, from the surface to the top of the coal bed. Isopach interval 100 feet.



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

To convert feet to meters, multiply feet by 0.3048.



Base from U.S. Geological Survey, 1959

Compiled in 1979

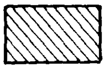
SCALE 1:24,000

1 1/2 0 1

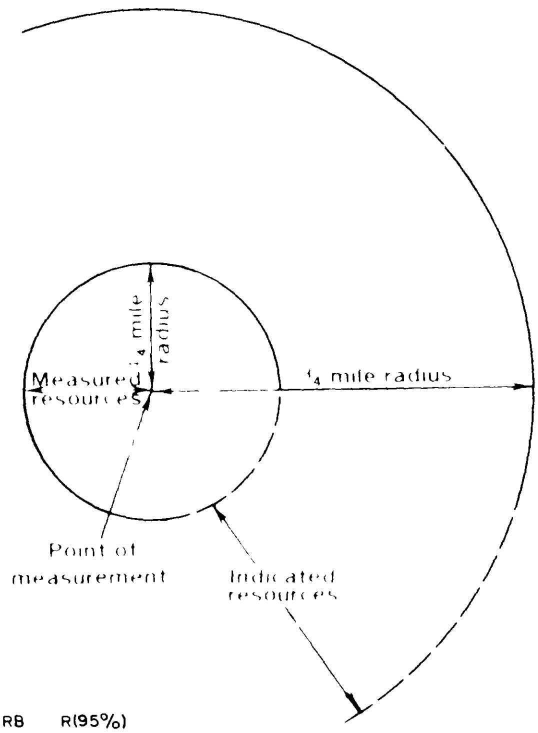
MILES

FIGURE 3
AREAL DISTRIBUTION OF IDENTIFIED RESOURCES
AND IDENTIFIED RESOURCES MAP
OF ULM COAL BED IN
NW¼ NORTH STAR SCHOOL 15' QUADRANGLE
CAMPBELL COUNTY, WYOMING
(See following page for Explanation)

EXPLANATION FOR FIGURE 3



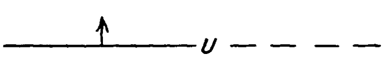
NON-FEDERAL COAL LAND



BOUNDARY LINES-Enclosing areas of measured and indicated coal resources of the coal bed. Inferred resources beyond 3/4 mile.

RB	R(95%)	
—	—	(Measured)
—	—	(Indicated)
1.32	1.25	(Inferred)

IDENTIFIED 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).



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

To convert miles to kilometers, multiply miles by 1.609.

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

show a gentle dip to the west. The Pawnee coal bed lies approximately 1240 to 2025 feet (378 to 617 m) beneath the surface throughout the entire quadrangle.

The Local-Wildcat-Moyer-Oedekoven coal zone is separated from the overlying Pawnee coal bed by 180 to 416 feet (55 to 129 m) of clastic debris, and is composed of four, thin, lenticular coal beds. The total coal zone thickness ranges from 9 to 60 feet (2.7 to 18 m) with maximum thicknesses occurring in the southeast quarter, significant thinning to the northwest. The Wildcat and Oedekoven coal beds show a uniform coal bed occurrence throughout the entire quadrangle, both averaging approximately 7 to 9 feet (2.1 to 2.7 m) thick. The Local and Moyer coal beds show a thin, very lenticular coal occurrence throughout the quadrangle. The clastic interval separating the various coal beds comprising the coal zone varies from 73 to 497 feet (22 to 152 m). Structure contours drawn on top of the Local coal bed, where present, and on top of the Wildcat coal bed elsewhere, show a rolling surface, generally dipping to the west. The Local-Wildcat-Moyer-Oedekoven coal zone lies approximately 1600 to 2300 feet (488 to 701 m) beneath the surface throughout the entire quadrangle.

V. Geological and Engineering Mapping Parameters

The correct horizontal location and elevation of drill holes utilized in subsurface mapping are critical to map accuracy. Intra-Search Inc., plots the horizontal location of the drill hole as described on the geophysical log heading. Occasionally this location is superimposed on or near to a drillsite shown on the topographic map, and the topographic map, horizontal location is utilized. If the ground elevation on the geophysical log does not agree with the topographic elevation of the drillsite, the geophysical log ground elevation is adjusted to conformance. If there is no indication of a drillsite on the topographic map, the "quarter, quarter, quarter" heading location is shifted within a small area until the ground elevation on the heading agrees with the topographic map elevation. If no elevation agreement can be reached, the well heading or data sheet is rechecked for footage measurements and ground elevation accuracy. Inquiries to the companies who provided the oil and gas geophysical logs frequently reveal that corrections have been made in the original survey. If all horizontal location data sources have been checked and the information accepted as the best available data, the drillsite elevation on the geophysical log is modified to agree with the topographic map elevation. IntraSearch Inc., considers this agreement mandatory for the proper construction of most subsurface maps, but in particular, the overburden isopach, the mining ratio, and Coal Development Potential maps.

Subsurface mapping is based on geologic data within, and adjacent, to the Northwest Quarter of North Star School 15' Quadrangle area. Data from geophysical logs are used to correlate coal beds and control contour lines for the coal thickness, structure, and overburden maps. Isopach lines are also drawn to honor selected surface measured sections where there is sparse subsurface control. Where isopach contours do not honor surface measured sections, the surface thicknesses are thought to be attenuated by oxidation and/or erosion; hence they are not reflective of total coal thickness. Isopach lines extend to the coal bed outcrops, the projections of coal bed outcrops, and the contact between porcellanite (clinker) and unoxidized coal in place. Attenuation of total coal bed thickness is known to take place near these lines of definition; however, the overestimation of coal bed tonnages that results from this projection of total coal thickness is insignificant to the Coal Development Potential maps. Structure contour maps are constructed on the tops of the main coal beds. Where subsurface data are scarce, supplemental structural control points are selected from the topographic map along coal outcrops.

In preparing overburden isopach maps, no attempt is made to identify coal beds that occur in the overburden to a particular coal bed under study. Mining ratio maps for this quadrangle are constructed utilizing a 95 percent recovery factor. Contours of these maps identify the ratio of cubic yards of overburden to tons of recoverable coal. Where ratio control points are sparse, interpolated points are computed at the intersections of coal bed and overburden isopach contours using coal structure, coal isopach, and topographic control. On the Areal Distribution of Identified Resources Map (ADIR), coal bed reserves are not calculated where the coal is less than 5 feet (1.5 m) thick, where the coal occurs at a depth greater than 500 feet (152 m), where non-federal coal exists, or where federal coal leases, preference-right lease applications, and coal prospecting permits exist.

Coal tonnage calculations involve the planimetering of areas of measured, indicated, inferred reserves and resources, and hypothetical resources to determine their areal extent in acres. An <u>Insufficient Data Line</u> is drawn to delineate areas where surface and subsurface data are too sparse for CRO map construction. Various categories of resources are calculated in the unmapped areas by utilizing coal bed thicknesses mapped in the geologically controlled area adjacent to the insufficient data line. Acres are multiplied by the average coal bed thickness and 1750, or 1770--the number of tons of lignite A or subbituminous C coal per acre-foot, respectively (12,874 or 13,018 metric tons per hectare-meter, respectively), to determine total tons in place.

Recoverable tonnage is calculated at 95 percent of the total tons in place. Where tonnages are computed for the CRO-CDP map series, resources and reserves are expressed in millions of tons. Frequently the planimetering of coal resources on a sectionized basis involves complexly curvilinear lines (coal bed outcrop and 500-foot stripping limit designations) in relationship with linear section boundaries and circular resource category boundaries. Where these relationships occur, generalizations of complexly curvilinear lines are discretely utilized, and resources and/or reserves are calculated within an estimated 2 to 3 percent, plus or minus, accuracy.

VI. Coal Development Potential

Strippable Coal Development Potential. Areas where coal beds are 5 feet (1.5 m) or more in thickness and are overlain by 500 feet (152 m) or less of overburden are considered to have potential for surface mining and are assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios for subbituminous coal is as follows:

$$MR = \frac{to\ (0.911)^*}{tc\ (rf)}$$

where MR = mining ratio
to = thickness of overburden
tc = thickness of coal
rf = recovery factor
0.911* = conversion factor (cu. yds./ton)

*A conversion factor of 0.922 is used for lignite.

A surface mining development potential map (Plate 39) was prepared utilizing the following mining ratio criteria for coal beds 5 to 40 feet (1.5 to 12 m) thick:

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

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

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

The surface mining development potential is high for approximately 25 percent of the quadrangle, primarily in the eastern half of the study area. A moderate development potential rating covers approximately 15 percent of the quadrant. The high and moderate development potential ratings can be attributed to low-to-moderate, overburden-to-coal ratios for the Ulm, Upper Felix, and Lower Felix coal beds and occur in conjunction with the primary drainages of the quadrangle. The higher overburden-to-coal ratios for these coal beds account for approximately 35 percent of the quadrangle being classified as low development potential for surface mining. The remaining area of the quadrangle is either classified as non-federal coal land or as having no development potential for surface mining. Table 1 sets forth the estimated strippable reserve and hypothetical resources base tonnages per coal bed for the quadrangle.

Underground Mining Coal Development Potential. Subsurface coal mining potential throughout the Northwest Quarter of North Star School 15' Quadrangle is considered low. Inasmuch as recovery factors have not been established for the underground development of coal beds in this quadrangle, reserves are not calculated for coal beds that occur more than 500 feet (152 m) beneath the surface. Table 2 sets forth the estimated coal resources in tons per coal bed.

In-Situ Gasification Coal Development Potential. The evaluation of subsurface coal deposits for in-situ gasification potential relates to the occurrence of coal beds more than 5 feet (1.5 m) thick buried from 500 to 3000 feet (152 to 914 m) beneath the surface. This categorization is as follows:

1. Low development potential relates to: 1) a total coal section less than 100 feet (30 m) thick that lies 1000 feet (305 m) to 3000 feet (914 m) beneath the surface, or 2) a coal bed or coal zone 5 feet (1.5 m) or more in thickness which lies 500 feet (152 m) to 1000 feet (305 m) beneath the surface.
2. Moderate development potential is assigned to a total coal section from 100 to 200 feet (30 to 61 m) thick, and buried from 1000 to 3000 feet (305 to 914 m) beneath the surface.
3. High development potential involves 200 feet (61 m) or more of total coal thickness buried from 1000 to 3000 feet (305 to 914 m).

An in-situ gasification potential map (Plate 40) is prepared using the above criteria. The coal development potential for in-situ gasification within the Northwest Quarter of North Star School 15' Quadrangle is moderate to low. The resource tonnage for in-situ gasification with moderate development potential totals approximately 5.7 billion tons (5.2 billion metric tons), with low development potential totals approximately 3.9 billion tons (3.5 billion metric tons) (Table 3).

Table 1.--Strippable Coal Reserve Base and Hypothetical Resource Data (in short tons) for Federal Coal Lands in the Northwest Quarter of North Star School 15' Quadrangle, Campbell County, Wyoming.

Development potentials are based on mining ratios (cubic yards of overburden/ton of recoverable coal).

Coal Bed	High Development Potential (0-10:1 Mining Ratio)	Moderate Development Potential (10:1-15:1 Mining Ratio)	Low Development Potential (>15:1 Mining Ratio)	Total
RESOURCE BASE				
Ulm	8,570,000	-----	-----	8,570,000
Upper Felix	32,370,000	56,060,000	102,520,000	190,950,000
Lower Felix	334,260,000	280,990,000	333,430,000	948,680,000
Smith	-----	-----	13,840,000	13,840,000
TOTAL	375,200,000	337,050,000	449,790,000	1,162,040,000
HYPOTHETICAL RESOURCE				
Upper Felix	-----	-----	4,560,000	4,560,000
Lower Felix	-----	-----	27,240,000	27,240,000
TOTAL	-----	-----	31,800,000	31,800,000
GRAND TOTAL	375,200,000	337,050,000	481,590,000	1,193,840,000

Table 2.--Coal Resource Base and Hypothetical Resource Data (in short tons) for Underground Mining Methods for Federal Coal Lands in the Northwest Quarter of North Star School 15' Quadrangle, Campbell County, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
RESOURCE BASE				
Upper Felix	------	-----	20,190,000	20,190,000
Lower Felix	-----	-----	161,050,000	161,050,000
Smith	-----	-----	685,280,000	685,280,000
Upper Wyodak	-----	-----	2,374,560,000	2,374,560,000
Lower Wyodak	-----	-----	3,956,090,000	3,956,090,000
Pawnee	-----	-----	911,840,000	911,840,000
Local-Wildcat Moyer-Oedekoven	-----	-----	1,513,590,000	1,513,590,000
TOTAL	-----	-----	9,622,600,000	9,622,600,000
HYPOTHETICAL RESOURCES				
Smith	-----	-----	2,290,000	2,290,000
TOTAL	-----	-----	2,290,000	2,290,000
GRAND TOTAL	-----	-----	9,624,890,000	9,624,890,000

Table 3.--Coal Resource Base and Hypothetical Resource Data (in short tons) for In-Situ Gasification for Federal Coal Lands in the Northwest Quarter of North Star School 15' Quadrangle, Campbell County, Wyoming.

Coal Bed Name	High Development Potential	Moderate Development Potential	Low Development Potential	Total
RESOURCE BASE				
	-----	6,403,750,000	3,218,850,000	9,622,600,000
HYPOTHETICAL RESOURCE				
	-----	-----	2,290,000	2,290,000
TOTAL	-----	6,403,750,000	3,221,140,000	9,624,890,000

SELECTED REFERENCES

Allen, D. D., 1977, Preliminary coal resource map of the North Star School NW Quadrangle, Campbell County, Wyoming: U. S. Geological Survey unpublished maps, scale 1:24,000.

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., 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.

Dobbin, C. E., and Barnett, V. H., 1927 (1928), The Gillette coal field, northeastern Wyoming: U. S. Geological Survey Bull. 796-A, p. 1-50.

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

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

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

_____, 1979, Coal resource occurrence and coal development potential of the Larey Draw Quadrangle, Campbell County, Wyoming: U. S. Geological Survey Open-File Report 79-023, 29 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.

McKay, E. J., 1974, Preliminary geologic map of the Bertha 2 NW (Rocky Butte) Quadrangle, Campbell 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, 1974, Preliminary report of coal drill-hole data and chemical analyses of coal beds in Campbell County, Wyoming: U. S. Geological Survey Open-File Report 74-97, 241 p.

_____, 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.

_____, 1976b, Preliminary report of coal drill-hole data and chemical analyses of coal beds in Campbell, Converse, and Sheridan Counties of Wyoming; and Big Horn, Richland, and Dawson Counties, Montana: U. S. Geological Survey Open-File Report 76-450, 382 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.

Wegemann, C. H., Howell, R. W., and Dobbin, C. E., 1929, The Pumpkin Buttes coal field, Wyoming: U. S. Geological Survey Bull. 806-a, p. 1-14.

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