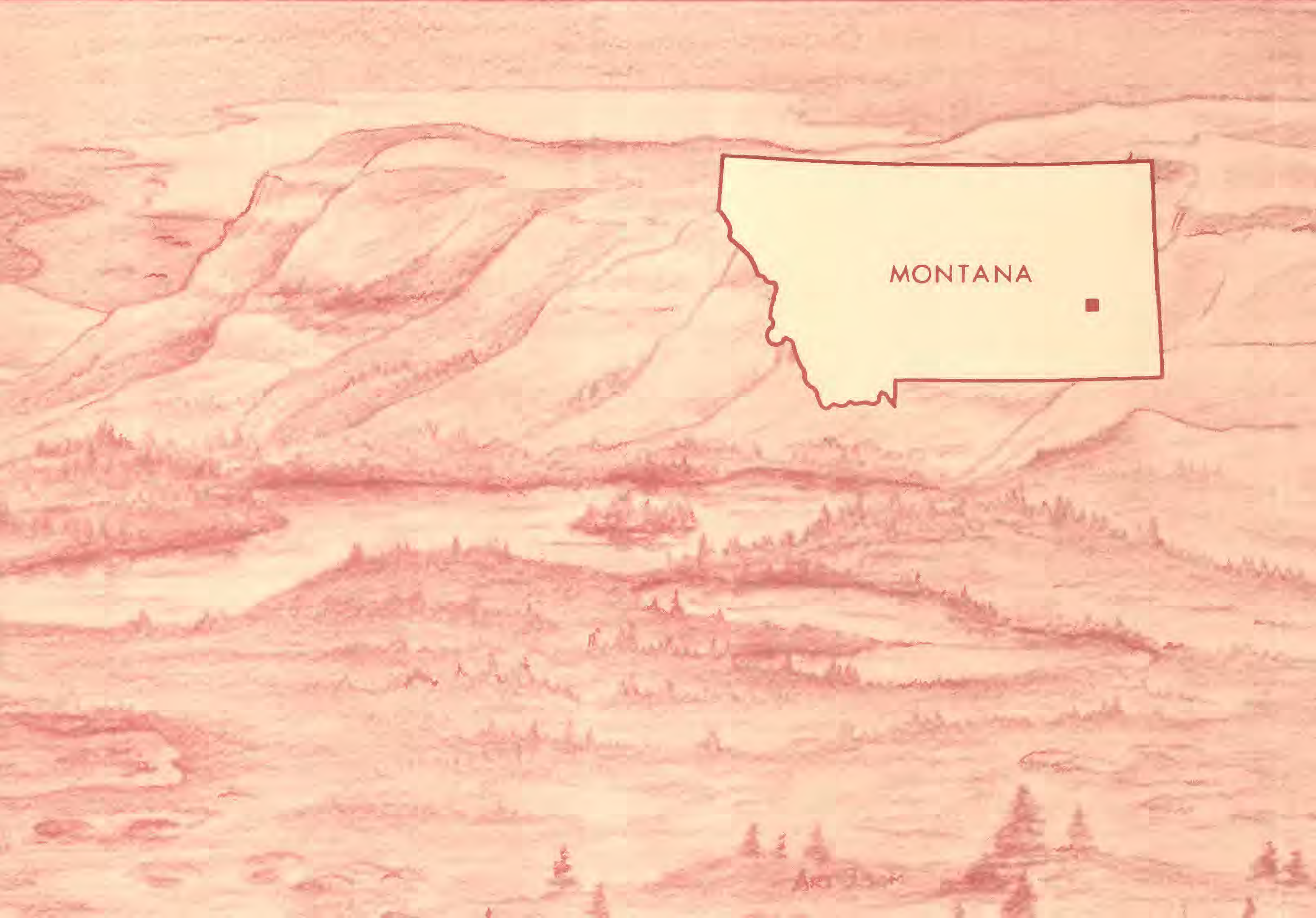
Mineral Resources of the Terry Badlands Wilderness Study Area, Prairie and Custer Counties, Montana

U.S. GEOLOGICAL SURVEY BULLETIN 1722–B



Chapter B

Mineral Resources of the Terry Badlands Wilderness Study Area, Prairie and Custer Counties, Montana

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U.S. GEOLOGICAL SURVEY BULLETIN 1722

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—EASTERN MONTANA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of a part of the Terry Badlands (MT-024–684) Wilderness Study Area, Custer and Prairie Counties, Montana.

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PLATE

[Plate is in pocket]

FIGURES

TABLES

Mineral Resources of the Terry Badlands Wilderness Study Area, Prairie and Custer Counties, Montana

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SUMMARY

In 1984 the U.S. Bureau of Mines and U.S. Geological Survey conducted investigations to appraise the identified resources and assess the mineral resource potential of 29,020 acres of the Terry Badlands Wilderness Study Area (MT–024–684). These investigations revealed 14.45 million short tons of demonstrated subeconomic and 34.65 million short tons of inferred subeconomic resources of coal. The study area has moderate resource potential for undiscovered oil and gas (fig. 1) and low mineral resource potential for undiscovered metals, sand and gravel, geothermal energy, and bentonite.

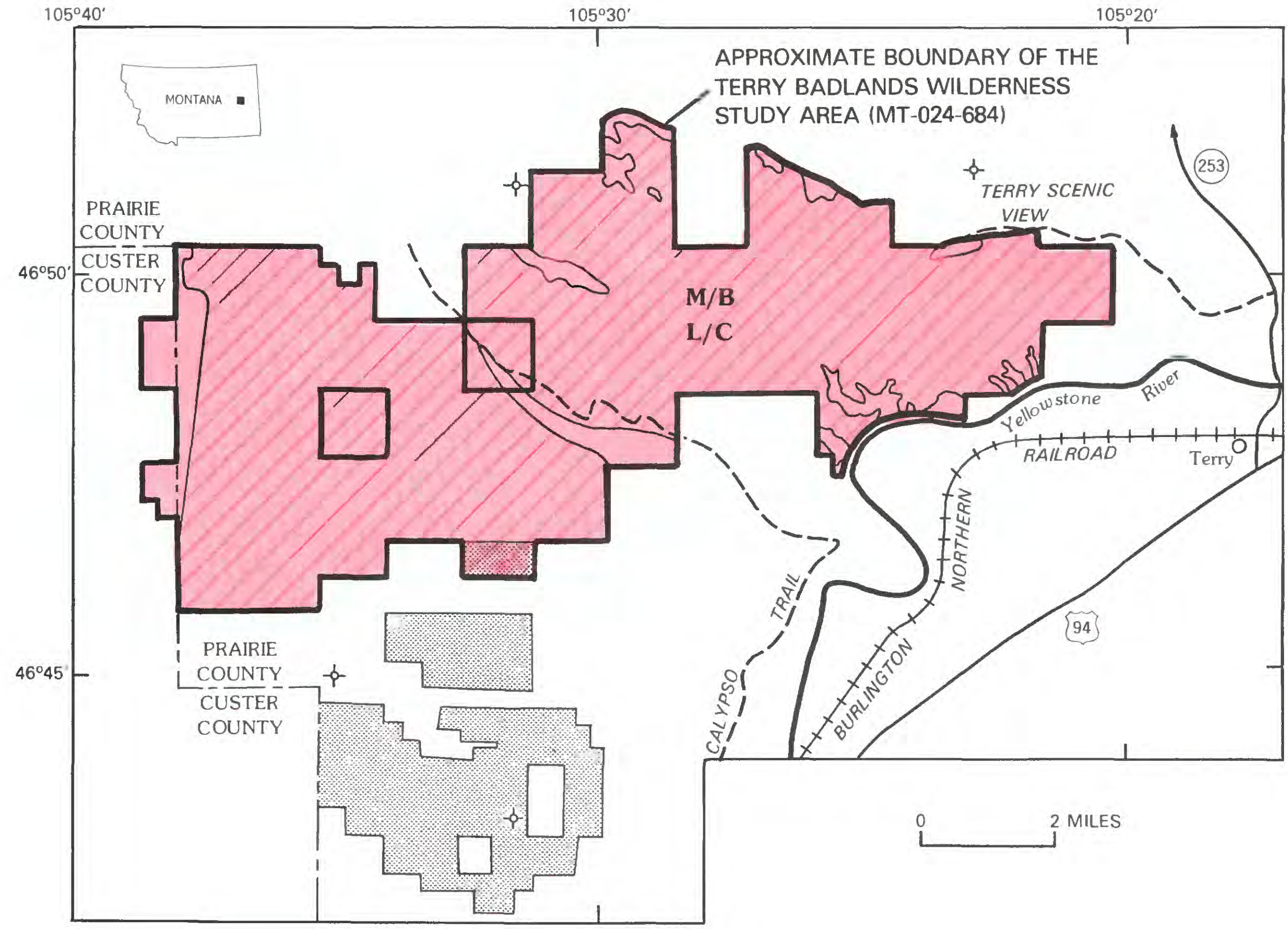
The Terry Badlands Wilderness Study Area in Prairie and Custer Counties, Montana, is 5 mi (miles) northwest of the small town of Terry. Deeply incised, dry canyons with little vegetation typify the badland topography of the wilderness study area. Access to the study area is by dirt roads which approach the western, northern, and southern boundaries.

On the southwestern edge of the Williston basin, the wilderness study area contains flat-lying sedimentary rocks of Paleocene to Holocene age (see geologic time chart in Appendix). The Fort Union Formation is the predominant unit in the area and consists of interbedded sandstone, shale, and mudstone of the Tullock, Lebo Shale, and Tongue River Members. Sixteen coal beds are exposed in this formation in the study area, but only two beds, the H and U beds, are greater than 30 in. (inches) in thickness.

Regional gravity data indicate that the wilderness study area is on the northwestern edge of a broad gravity high. This anomaly may be caused by high-density crystalline rocks, or it may reflect a thick sequence of carbonate rocks. A magnetic anomaly coincides with the gravity anomaly and supports both of these interpretations. Other magnetic anomalies may be caused by heterogeneity in the basement rock.

There is no known mineral production from the wilderness study area. Just south of the wilderness study area, three preference right lease applications for coal are held. One-half of a section in the southern part of the wilderness study area is also covered by a preference right lease application. The U and H coal beds in the wilderness study area contain 2.45 million short tons of measured subeconomic coal resources, 12.0 million short tons of indicated subeconomic coal resources, and 34.65 million short tons of inferred subeconomic coal resources (see coal classification chart, fig. 2, for explanation of terminology). Because of the rank (degree of metamorphism) of the coal (lignite), thickness of overburden, and relative thinness of coal beds, none of the coal resources in the study area meet the specifications for coal reserves at this time.

Geochemical analyses of stream-sediment and rock samples from the wilderness study area did not contain anomalous concentrations of any elements. The geologic environment, lack of geochemical anomalies, and lack of mines or prospects indicate that the mineral resource potential for all metals is low. Sand and gravel deposits are thin and discontinuous, and the mineral resource potential for these commodities is also low. Bentonitic shale beds in the Fort Union Formation are less than 5 ft (feet) thick; mineral resource potential for bentonite is low. There are no known geothermal energy sources in or near the study area. The resource potential for geothermal energy is low.



EXPLANATION

(pink hatched box)	Areas underlain by subeconomic and inferred subeconomic coal resources: coal beds at least 30 in. thick and under less than 500 ft overburden; and geologic terrane having moderate mineral resource potential for oil and gas, with certainty level B
M/B	Geologic terrane having moderate mineral resource potential for oil and gas with certainty level B—Applies to entire study area
L/C	Geologic terrane having low mineral resource potential for all metals, sand and gravel, geothermal energy, and bentonite—Applies to entire study area
⌖	Drill hole for oil and gas
(stippled box)	Area covered by preference right lease applications for coal
— — —	Unpaved road
	Certainty levels
B	Data indicate geologic environment and suggest level of resource potential
C	Data indicate geologic environment and resource potential but do not establish activity of resource-forming processes

Figure 1. Map showing location, identified resources, and mineral resource potential of the Terry Badlands Wilderness Study Area, Montana.

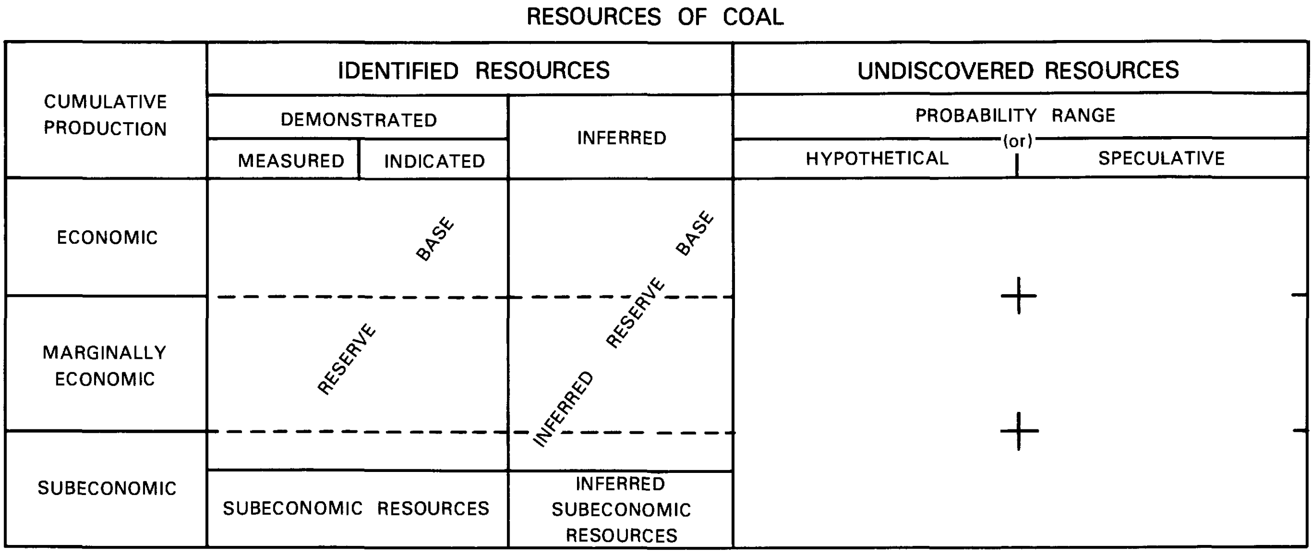


Figure 2. Format and classification of coal resources by reserve and inferred reserve bases and subeconomic and inferred subeconomic resources categories.

Although the wilderness study area is on the edge of the oil- and gas-producing Williston basin, five drill holes adjacent to the study area were dry. Geophysical data suggest that structural and stratigraphic traps may be present along the western edge of the study area, but none are presently known. The energy resource potential for oil and gas is therefore moderate.

INTRODUCTION

The Terry Badlands Wilderness Study Area (MT–024–684) is on the northern bank of the Yellowstone River in eastern Montana about 5 mi northwest of the small town of Terry. A dirt road from Montana State Highway 253 to the Terry Scenic View provides access to the northern and eastern sides of the study area. The Calypso Trail, a dirt road which crosses the study area, provides access to the western and eastern sides of the study area. Rains, which are common in spring and summer, make many of the roads impassable.

Badland topography is typical of the area and extends from the northern bank of the Yellowstone River, rising in elevation to the northern boundary of the wilderness study area. Deeply incised, dry canyons with little vegetation drain southward into the Yellowstone River. Elevations in the study area range from 2,196 ft along the Yellowstone River to 2,920 ft at the northwestern corner of the study area.

At the request of the U.S. Bureau of Land Management (BLM), 29,020 acres of the Terry Badlands Wilderness Study Area were studied. In this report the studied area is called the "wilderness study area" or simply "study area."

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Identified resources are classified according to the system of the U.S. Bureau of Mines and U.S. Geological Survey (1980), which is shown in the Appendix of this report, and coal resources are classified according to Wood and others (1983) (fig. 2). Identified resources are usually studied by the USBM; however, identified coal resources are studied by the USGS. Mineral resource potential is the likelihood of occurrence of undiscovered metals and nonmetals, industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984) and also is shown in the Appendix. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

The USBM study included the collection of information relating to current and past mining activities in and near the study area. Library research was done using USBM files and the Mineral Industry Location System, a computerized data base. Claim-location data were taken from U.S. Bureau of Land Management mining-claim indices, BLM land-status and use records, and county claim records.

Field studies by the USBM encompassed 14 employee-days during June and July of 1984. A scintillometer was used to check coal-bearing units for enrichment in radioactive elements. Forty-five samples of rocks and stream sediments were collected for geochemical analyses and other tests.

Investigations by the U.S. Geological Survey

Office and field studies by the USGS included the compilation of photogeologic maps by R.B. Colton (USGS) and E.L. Heffern (BLM). The geology was field checked by Colton, Heffern, and Susan Cook (USGS) in 1981. This unpublished mapping was used by Gassaway in 1984 while measuring sections and field checking the geology.

Acknowledgments.—Gratitude is expressed to local ranchers Verlin Hines and Dan and Mary Haughian for permission to cross private land during the course of the field work. E.L. Heffern, Gordon Cormier, and Chris Roholt of the BLM, Miles City, Mont., were especially helpful during the field study. E.S. Belt, Amherst College and U.S. Geological Survey, collaborated with Heffern and Colton in the geologic mapping. M.S. Miller, U.S. Bureau of Mines, assisted Causey in his field work.

APPRAISAL OF IDENTIFIED RESOURCES

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Mining and Mineral-Exploration History

There has been no known mineral production from the Terry Badlands Wilderness Study Area. However, just south of the study area is an area with a postulated large quantity of lignite. This area of lignite is covered by three preference right lease applications (PRLA) for coal which are held by Meadowlark Farms, Inc. (a subsidiary of AMAX Coal Co.) (fig. 1). One-half section (320 acres) of the wilderness study area is covered by PRLA No. 2734 (N½ sec. 26, T. 12 N., R. 49 E.) (fig. 1). The entire study area is leased for oil and gas.

Coal

Terminology

Rogers (1913), in his report on the Little Sheep Mountain Coal Field, mapped and named coal beds which were greater than 24 in. (inches) thick. The Terry Badlands, in the eastern part of Rogers' field area, contains coal beds which were named, in descending alphabetical order, beds H through W. Four of Rogers' coal beds have been discussed by more recent workers (Cook, 1979; Roberts, 1982; and Heffern, 1981). These four beds have been given letter designations, some of them similar to Rogers' original labels (table 1). Letter designations used in this report are in table 1.

Table 1. Coal-bed terminology used in previous reports and in this report

[Letters denote coal beds; leaders indicate coal beds not discussed in these reports]

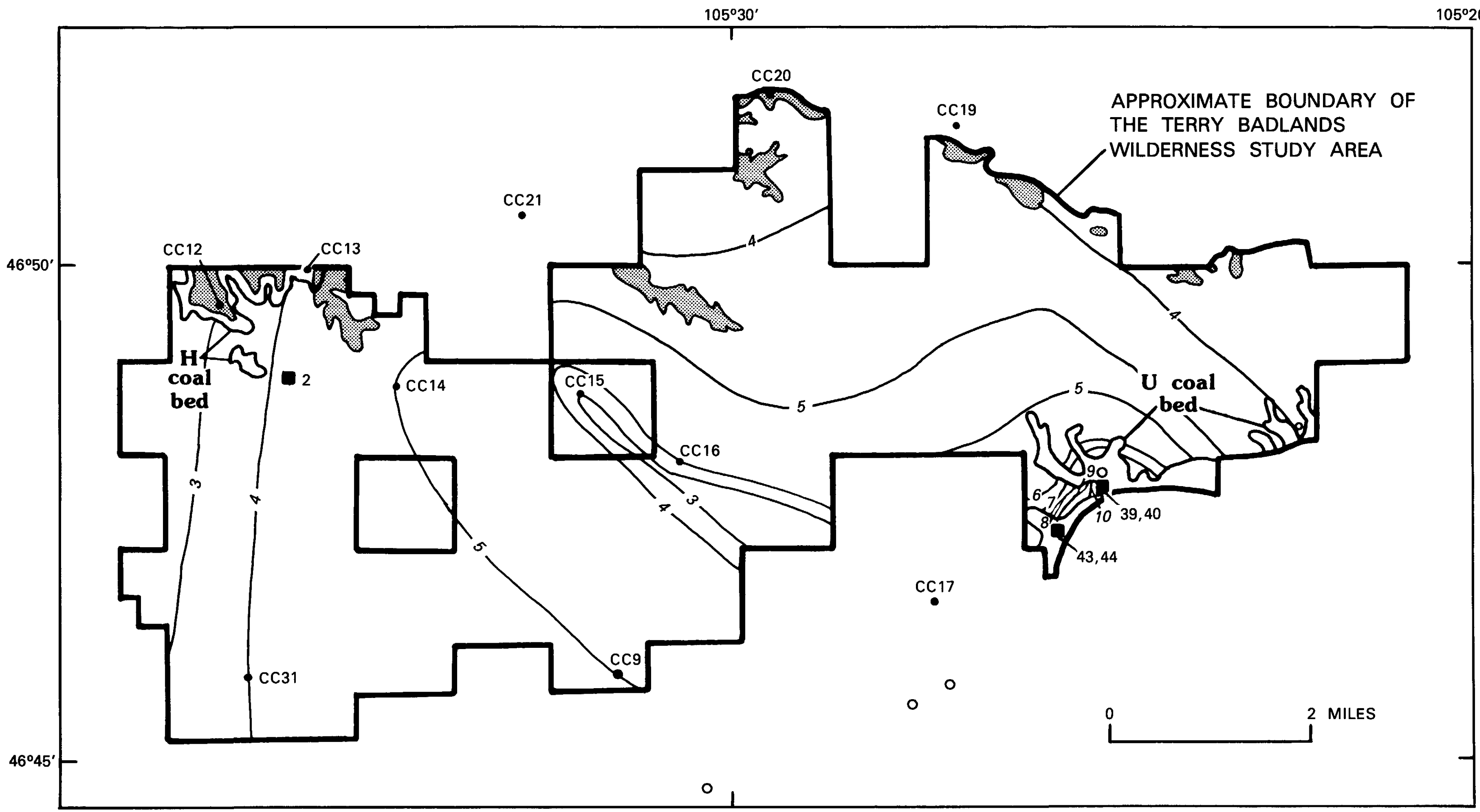
Rogers (1913)	Cook (1979)	Roberts (1982)	Heffern (1981)	This report
--	--	H (Haughian)	--	--
H	H	G	H	H
I	--	--	--	--
J	--	--	--	--
K	--	--	--	--
L	--	--	--	--
M	--	--	--	--
N	--	--	--	--
O	--	--	--	--
P	--	--	--	--
Q	V-1	--	--	--
R	R	R	--	R
S	--	--	--	--
T	--	--	--	--
U	U	U	U	U
V	--	--	--	--
W	L	L	--	W

Only two coal beds in the study area consistently average 30 in. or greater in thickness: the H and the U bed. The thickness of these beds is taken from Rogers (1913) and Roberts (1982) and measured sections and well logs. The coal in the H bed averages 3 ft thick. Coal in the U bed averages 3 ft thick and is as much as 10 ft thick in the southeastern part of the study area (fig. 3). The U bed splits into several coal stringers towards the northern part of the study area, separated from one another by an average of 5 ft of shale in the middle of the study area to more than 20 ft of shale in the northern part.

Cook (1979) and Roberts (1982) discussed the R bed and the L bed (bed W of Rogers) in detail. Where they studied these beds south of the wilderness study area, the beds were greater than 30 in. in thickness. However, within the study area, the R coal bed is 1 ft or less in thickness, and the L bed is less than 2 ft in thickness.

Analyses

Coal samples in this report were taken from outcrops, and their analyses do not represent unweathered coal. Analyses of one sample of the H bed and four samples of the U bed are in table 2, and sample localities



EXPLANATION

——	Outcrop of U and H coal beds
▒	Areas where overburden of U coal bed is greater than 500 ft
—3—	Isopach showing thickness of U coal bed in feet
•CC14	Drill hole (U.S. Bureau of Land Management)
o	Measured section (U.S. Geological Survey)
■39	Coal-sample locality for U and H coal beds (U.S. Bureau of Mines)

Figure 3. Map showing outcrop patterns of the H and U coal beds, thickness of the U coal bed, and localities of measured sections, coal samples, and coal drill holes in the Terry Badlands Wilderness Study Area, Montana.

Table 2. Analyses of coal samples from the Terry Badlands Wilderness Study Area, Montana

[Air dried coal, as received]

Sample No. (fig. 3)	2	39	40	43	44
Coal bed	H	U	U	U	U
Sample thickness (ft)	2.25	3.1	6.5	6.8	3.2
PROXIMATE ANALYSIS (percent)					
Moisture	37.51	28.61	13.37	12.45	21.32
Volatile matter	29.48	28.93	30.72	29.92	30.84
Fixed carbon	22.74	30.21	31.62	27.58	32.51
ULTIMATE ANALYSIS (percent)					
Ash	10.27	12.25	24.29	30.05	15.33
Hydrogen	6.46	5.83	4.25	4.13	5.02
Carbon	34.60	39.53	40.56	35.90	40.26
Nitrogen	.40	.38	.56	.43	.45
Oxygen	47.47	41.69	29.81	29.13	38.61
Sulfur forms (percent):					
Sulfate	.62	.05	.17	.07	.05
Pyritic	.05	.04	.08	.08	.07
Organic	.13	.24	.30	.21	.20
HEAT CONTENT (Btu per pound)					
Air dried as received	5311	6287	6258	5504	6137
Moist, mineral-matter-free*	5958	7242	8481	8146	7351
ASH					
Initial deformation (°F)	2185	2130	2295	2300	2080
Softening temperature (°F)	2290	2350	2415	2395	2195
Fluid temperature (°F)	2500	2475	2685	2690	2400
Hardgrove grindability index.	100	50	73	77	69

*Values calculated using the Parr formula (Wood and others, 1983).

DESCRIPTION OF SAMPLES

2. Dull-black crumbly lignite.
39. Black fissile lignite.
40. Black fissile coal with vitreous layers.
43. Slightly vitreous black lignite.
44. Slightly vitreous black lignite.

are shown on figure 3. Based upon heat content, the coal samples ranked as lignite, except for sample 40 (U bed), which ranked as subbituminous C (see Wood and others (1983) for a description of coal ranks).

Ash content of the sample from the H bed was 10.27 percent, and samples from the U bed ranged from 12.25 to 30.05 percent. Carbon content in the H bed sample was 34.60 percent, and in the U bed samples ranged from 35.90 to 40.56 percent. Volatile matter in the H-bed sample was 29.48 percent and in the U bed samples was 28.93 to 30.84 percent.

Resources

Wood and others (1983) outlined the criteria for determining coal resources. Demonstrated lignite resources consist of beds greater than 30 in. thick, exclusive of partings of 1 in. or greater, and overburden less than 6,000 ft. Coal reserves are defined as coal beds greater than 5 ft thick with less than 500 ft overburden. Subeconomic coal resources are determined by summing tonnages of demonstrated resources that do not meet the criteria for the reserve base and have less than 500 ft overburden. Demonstrated subeconomic resources are further divided into measured subeconomic resources, where coal tonnages are calculated as much as 0.25 mi away from data points, and indicated subeconomic resources, where coal tonnages are calculated from 0.25 to 0.75 mi from data points. Inferred subeconomic resources are coal tonnages calculated from 0.75 to 3 mi from data points. Coal beds with more than 33 percent ash are excluded from resource consideration.

The coal resources for the wilderness study area are based on field measurement of coal outcrops, drill-hole information (fig. 3), and coal analyses (table 2). All resources are calculated for coal beds 30 in. or more in thickness and overburden of less than 500 ft. An acre-foot of coal was assumed to weigh 1,750 tons.

Two coal beds, the U and H beds, in the Terry Badlands Wilderness Study Area meet the thickness and overburden criteria of Wood and others (1983) for demonstrated and inferred subeconomic coal resources. The U bed underlies the entire study area and is exposed at the southeastern corner of the study area above the Yellowstone River. The overburden increases from 0 ft to greater than 500 ft along the northern boundary of the study area. The H bed is exposed only in the northwestern part of the study area because of its stratigraphic position and higher elevations in the north; the bed has been eroded away in the rest of the study area.

The Terry Badlands Wilderness Study Area is calculated to contain 2.45 million short tons of measured subeconomic coal resources, 12.0 million short tons of indicated subeconomic coal resources, and 34.65 million short tons of inferred subeconomic coal resources (table 3).

Wood and others (1983) indicated that a reserve base consists of lignite greater than 5 ft thick and overburden of less than 500 ft. Because of the low rank of the coal (lignite), the amount of overburden, the high ash content, and the relative thinness of the coal beds, no coal reserves are considered to exist in the study area at this time. The badlands character of the area would also result in major problems in reclamation.

Industrial Minerals

The USBM sampled bentonite in the study area, and the analyses are presented in Causey (1985). No special or unique properties were identified in the clay samples. Much of the material is suitable for making structural clay products or lightweight aggregate. Because of the distance to market, the overburden of 50 to 100 ft, and the thinness of the beds (5 ft or less), the bentonite does not constitute a mineral resource.

Clinker from burned coal beds is present along the northern part of the study area (pl. 1) and is as much as 60 ft thick. Clinker is most commonly used as road metal. The rugged topography of the area and distance to existing road systems make it unlikely that clinker from this area will be used; therefore, the clinker does not constitute a mineral resource.

Table 3. Calculated coal resources in the Terry Badlands Wilderness Study Area, Montana

[In millions of short tons]

U BED Overburden 0 to 500 ft	
Subeconomic:	
Measured	1.6
Indicated	10.7
Inferred	34.6
H BED Overburden 0 to 100 ft	
Subeconomic:	
Measured	0.85
Indicated	1.3
Inferred	.05

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

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Geology

Geologic Setting

The Terry Badlands Wilderness Study Area is on the southwestern edge of the Williston basin, the largest depositional basin of the North American continental interior. Underlain by a thick sequence of Paleozoic and Mesozoic rocks, the basin is one of the most important oil-producing basins in North America. None of these rocks, however, are exposed in the study area. The study area is on the southwestern limb of the Sheep Mountain syncline. The regional dip is 1°–2° to the northeast, but locally rocks dip as much as 5°. No faults were observed.

Description of Exposed Rock Units

The oldest and most predominant unit exposed in the study area is the Fort Union Formation (Paleocene) (pl. 1). Three members are exposed in the study area, and contacts between the members are sharp.

Tullock Member (unit Tft*).*—This basal unit is composed of gray to tan sandstone beds with interbeds of buff, tan, and green shale and minor lenses of lignite. The Tullock member crops out only in the southeastern part of the study area. The base of the member is not exposed in the study area; maximum exposure is 50 ft.

Lebo Shale Member (unit Tfl*).*—The base of this member is marked by the U coal bed. The Lebo is composed of gray, tan, brown, yellow, and buff fine- to medium-grained sandstone beds with lesser amounts of gray and brown shale and mudstone. A channel fill of fine-grained sandstone, which trends northwest, cuts through nearly the entire member. This channel contains intraformational conglomerate (clasts of the host shale) and was observed at the head of Crooked Creek to the north of the wilderness study area and near the southern debouchment of the Calypso Trail. Maximum thickness of the member is 200 ft.

Tongue River Member (unit Tfr*).*—The Tongue River Member is composed of beds of yellow-weathering fine-grained sandstone with interbeds of gray mudstone. This member contains the H coal bed. The exposed thickness is about 50 ft, and the top of the member is eroded away.

Clinker (pl. 1).—These units consist of red, orange, and yellow shale and sandstone that were baked and (or) fused by burning of an underlying coal bed; they commonly form resistant caps on buttes and ridges. The units formed when the H coal bed in the Tongue River Member and the U coal bed in the Lebo Shale Member burned. The maximum thickness of each unit is about 60 ft.

Sand and gravel deposits (unit Qg, *pl. 1).*—This unit consists of crudely stratified sand and gravel in terraces cut and filled by the Yellowstone River when it was at higher topographic levels. The thickness averages 10 ft.

Alluvium and colluvium (unit Qac, *pl. 1).*—This unit consists of poorly stratified sand, silt, and clay deposited by sheetwash and gravity processes on slopes. It may include and interfinger with alluvium. The thickness is a maximum of 15 ft.

Alluvium (unit Qal, *pl. 1).*—This unit contains unconsolidated sand, silt, and clay found in active stream and river channels. The thickness is generally less than 15 ft.

Landslide deposits (unit Qls, *pl. 1).*—This unit consists of masses of unsorted and jumbled rock which have moved downslope. The lithology and texture reflect that of the parent rock.

Geochemistry

Four sediment samples from alluvial deposits were collected from within the study area by members of the Los Alamos National Laboratory in 1978 as a part of the U.S. Department of Energy National Uranium Resource Evaluation program (U.S. Department of Energy, 1981). The samples were analyzed for uranium content by fluorescence spectrometry and neutron activation, and for 32 additional elements by plasma emission spectrometry. None of the four sediment samples contained anomalous concentrations of any elements.

Causey (1985) collected 14 rock samples and 8 alluvial (placer) samples for analysis. Rocks were analyzed for gold and silver by fire assay; one of the samples was analyzed for uranium by X-ray fluorescence, and one other sample was analyzed for iron and manganese by atomic absorption. Rock samples were additionally analyzed by semiquantitative spectrophotometric methods for 40 elements. None of the samples contained anomalous concentrations of any elements. Trace amounts of gold were found in the sediment samples.

Geophysics

Gravity and magnetic anomaly reconnaissance data (figs. 4 and 5) provide information about the geologic setting and structural framework of the region of the Terry Badlands Wilderness Study Area.

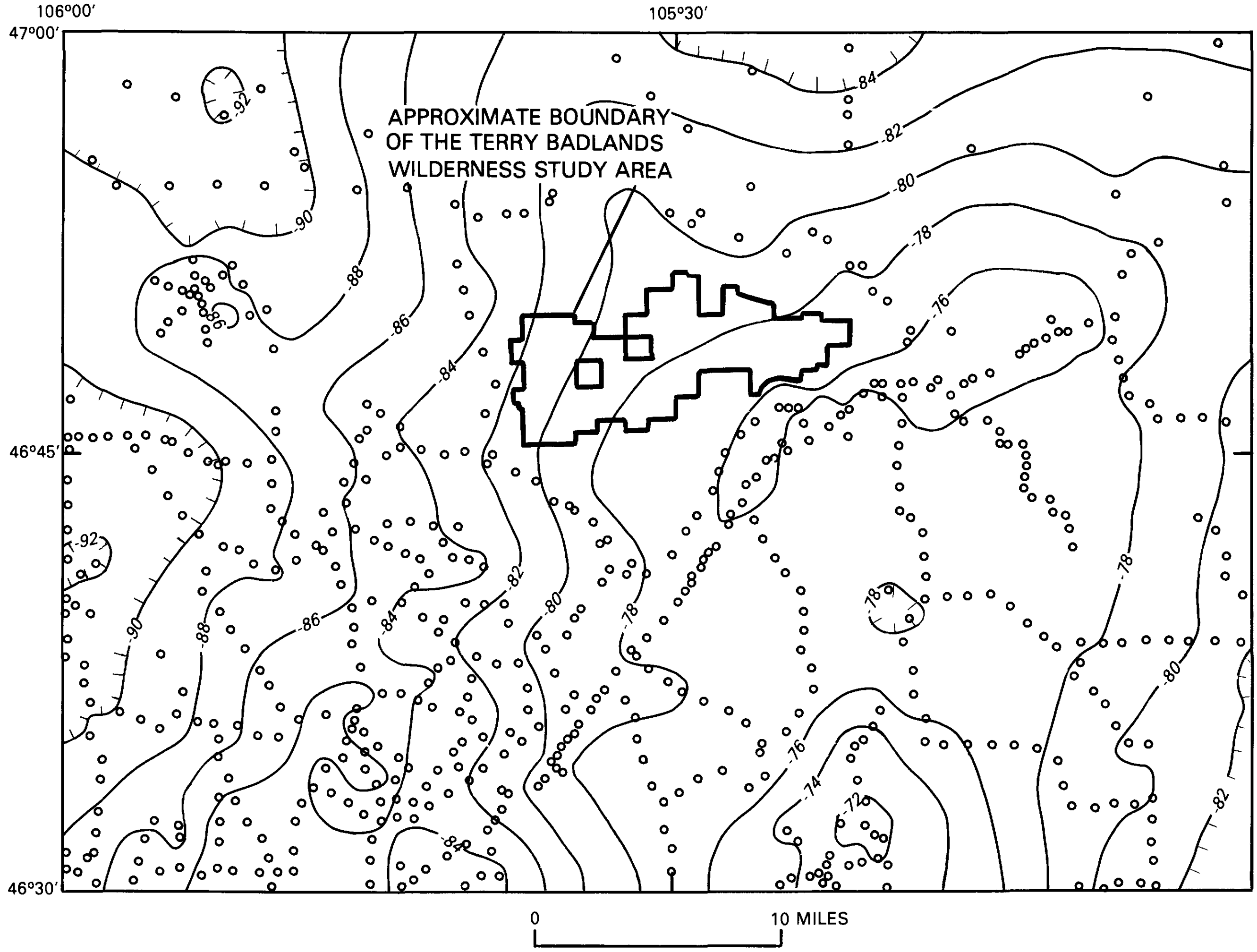
Gravity Data

A complete Bouguer gravity anomaly map (fig. 4) was generated using data collected by the USGS (Bankey and McCafferty, 1986) augmented with U.S. Department of Defense data. These gravity data were reduced using the 1967 formula and a density of 2.67 grams per cubic centimeter, were gridded at a 1-kilometer (0.6-mi) spacing, and were contoured at 2 mGals (milligals) using computer programs by Webring (1981) and Godson and Webring (1982). The wide station spacing and lack of stations within the study area preclude detailed interpretation within the study area but show the regional structural setting.

The Terry Badlands are on the northwestern edge of a broad, low-amplitude gravity high. This broad anomaly may be caused by high-density crystalline rocks in the basement rocks or may reflect a broad shelf of thick carbonate rocks in the lower Paleozoic sequence. A 10- to 20-mGal horseshoe-shaped gradient zone trends east-west across the Terry Badlands. It may define the boundary of the inferred mass of high-density rocks along the minus-80- and minus-82-mGal contours.

Magnetic Data

Regional aeromagnetic data (fig. 5) were obtained from a National Uranium Resource Evaluation survey of the Miles City 1°×2° quadrangle (Bendix Field Engineering Corporation, 1983). These data were collected along



EXPLANATION

—-82— **Gravity anomaly contour**—Contour interval 2 milligals. Hachures show closed areas of lower gravity values

o **Gravity station**

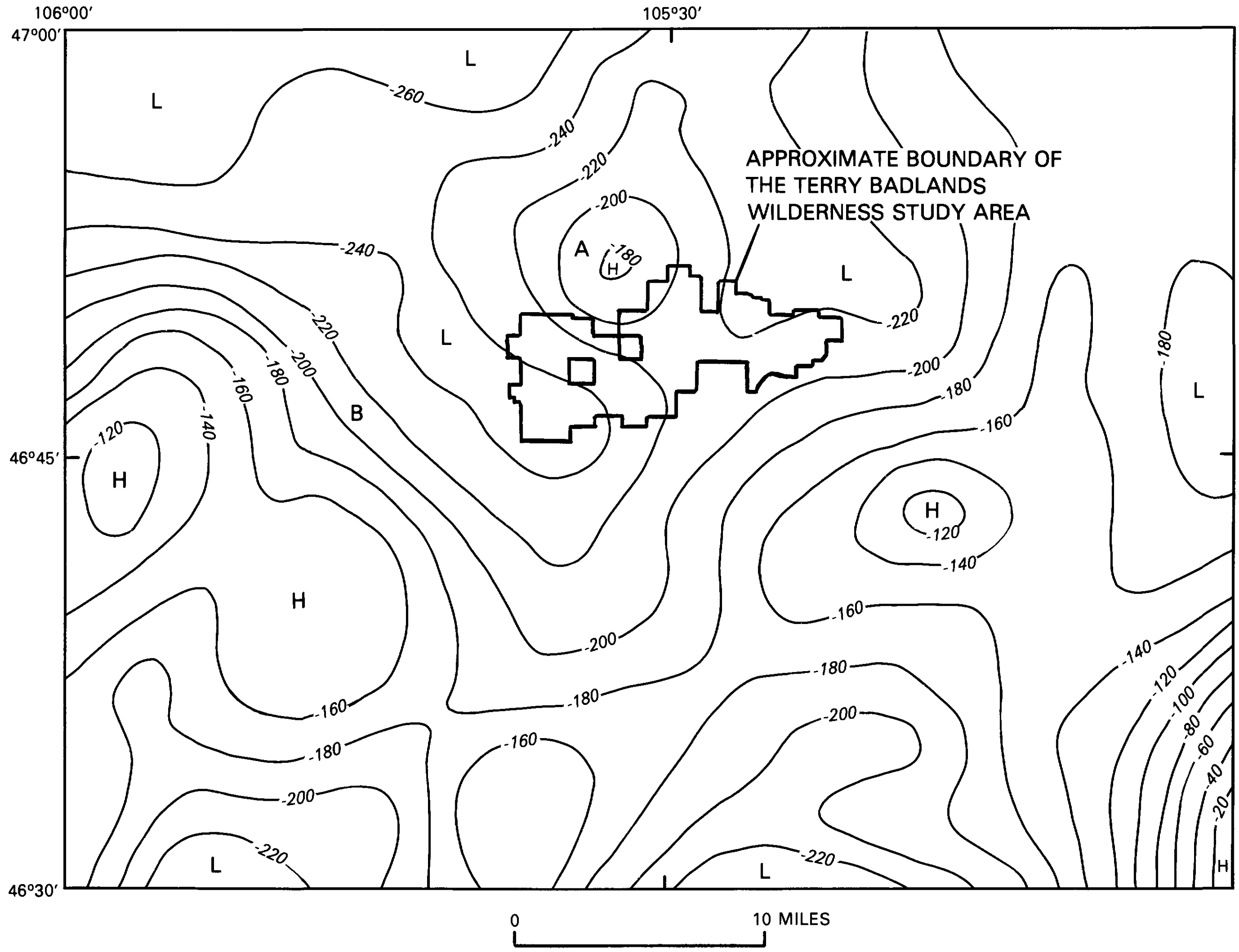
Figure 4. Complete Bouguer gravity anomaly map of the Terry Badlands Wilderness Study Area, Montana.

traverses flown 3 mi apart east-west at an elevation 400 ft above terrain. The 1975 International Geomagnetic Reference Field, updated to the survey date, was removed and the resulting data were gridded and contoured at a 20-nT (nanotesla) contour interval.

The small 80-mGal gravity high (fig. 4) just north of the wilderness study area roughly coincides with a small positive anomaly in the magnetic data (fig. 5, letter A). Magnetic gradient B, southwest of the study area, also coincides with a positive deflection in the gravity data. These anomalies may arise from the heterogeneous basement rocks. However, if a thick section of Paleozoic carbonates generated the broad gravity high, discussed previously, in the gravity data, then stratigraphic and possible structural traps for oil and gas could occur along the gravity gradient on the western boundary of the wilderness study area.

The other gravity-gradient zones (fig. 4) do not correspond to gradient zones on the magnetic map (fig. 5). This lack of correspondence suggests that the gravity sources of these gradients are not closely related to the magnetic sources. The gravity anomalies are probably caused by both nonmagnetic sedimentary rocks and basement rocks, and the magnetic anomalies are probably caused by basement rocks alone.

A 40-nT positive magnetic anomaly (fig. 5, letter A) lies north of the Terry Badlands Wilderness Study Area and is flanked by two low-amplitude, northwest-



EXPLANATION

— *-200* — **Aeromagnetic anomaly contour**— Contour interval 20 gammas

H **Area of aeromagnetic high**

L **Area of aeromagnetic low**

Figure 5. Total-intensity aeromagnetic anomaly map of the Terry Badlands Wilderness Study Area, Montana. Letters A and B are discussed in text.

trending negative anomalies. Other similar low-amplitude positive anomalies are southeast, west, and southwest of the wilderness study area. A rough depth estimate using the straight-line method (Nettleton, 1971) indicated that the source of these anomalies is magnetic bodies at depths of 1.8 mi or more, which is at or below the surface of the crystalline basement rocks. These magnetic bodies probably do not disrupt the overlying sedimentary rocks. The gradient zone along the southwestern boundary of the wilderness study area could indicate a fault or linear boundary between rocks of differing magnetization. This gradient zone changes direction and follows the Yellowstone River valley for nearly 22 mi along the southeastern boundary of the study area.

Mineral and Energy Resource Potential

Metals

No mineralized zones, mines, or prospects were identified in the study area or the surrounding areas. None of the rock or stream-sediment samples from the study area contained anomalous concentrations of any elements.

The study area also lacks the geologic environment favorable for the formation of metallic mineral deposits. The study area therefore has low mineral resource potential for all metals, with certainty level C.

Industrial Minerals

Sand and gravel are present in the stream drainages in the study area, but the deposits are thin and generally discontinuous. The study area has low mineral resource potential for undiscovered sand and gravel, with certainty level C.

Bentonitic shale beds are in the Fort Union Formation but are less than 5 ft thick and are generally discontinuous. The mineral resource potential for bentonite is low, with certainty level C.

Oil and Gas

The study area is on the southwestern edge of the Williston basin, one of the most important oil-producing basins in North America (Perry and others, 1982, 1983), and the entire study area is under lease for oil and gas as of the date of this report. Four oil and gas exploration holes were drilled within 5 mi of the study area (fig. 1), but all of the holes were dry (E.L. Heffern, BLM, 1981, unpub. report). One hole 1 mi south of the study area was completed at a depth of 9,100 ft in the Ordovician Red River Formation. No subsurface traps for oil and gas are known in the study area.

According to Perry and others (1983), the principal oil reservoirs in the area of the Terry Badlands Wilderness Study Area are in the Upper Devonian Birdbear Formation, the Upper Mississippian Charles Formation of the Madison Group, and the overlying Kibbey Formation; these units would be many thousands of feet below the study area. Heffern (1981, unpub. report) indicated that Dome Petroleum found the Madison Group at a depth of 7,600 ft several miles to the west of the study area. Perry and others (1982, 1983) rated the study area as having high oil and medium gas potential.

The Terry Badlands Wilderness Study Area is rated in this study as having moderate resource potential for oil and gas for several reasons. Foremost is that the study area is on the edge of one of the most important oil-producing basins in North America. Favorable source rocks for oil and gas are present in the subsurface of the study area, but five oil and gas wells drilled adjacent to the study area were dry. Geophysical data also suggest that structural and stratigraphic traps for oil and gas may be present along the western edge of the study area. A certainty level of B is given to this rating because of the lack of knowledge concerning the structure of rocks in the subsurface.

Geothermal Energy

There are no known geothermal energy sources in or near the wilderness study area (Sonderegger and Bergantino, 1981), and no warm springs were noted during this study. The resource potential for geothermal energy is low, with certainty level C.

Recommendations for Further Work

Seismic profiles across the Terry Badlands Wilderness Study Area would help determine whether appropriate structural traps for oil and gas exist in the subsurface. Drilling would provide confirmation of this information and provide data about which rock units are present in the subsurface.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

LOW mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics define a geologic environment in which the existence of resources is unlikely. This broad category embraces areas with dispersed but insignificantly mineralized rock as well as areas with few or no indications of having been mineralized.

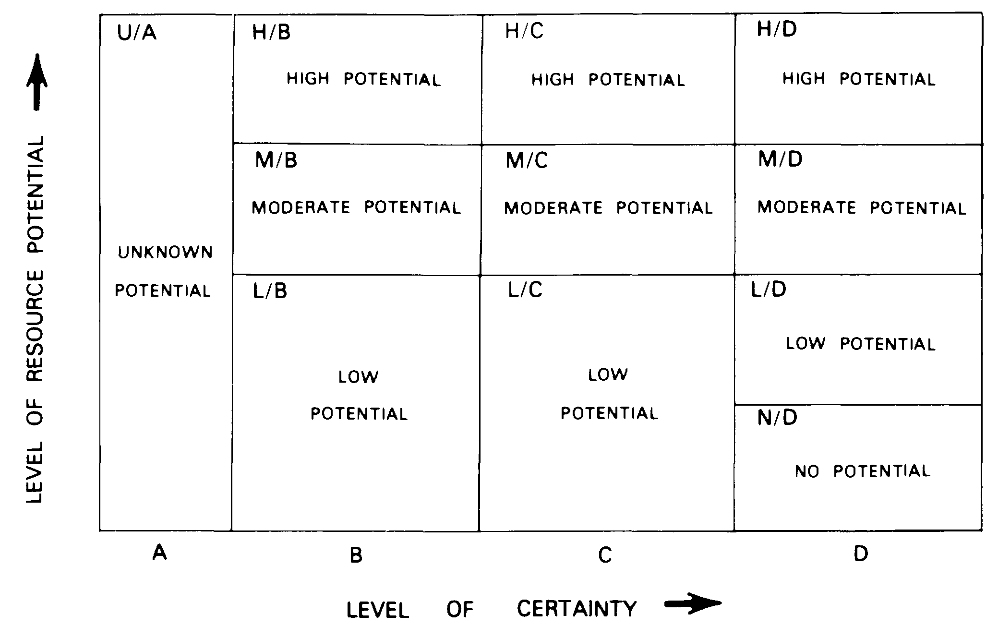
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

HIGH mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data support mineral-deposit models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

NO mineral resource potential is a category reserved for a specific type of resource in a well-defined area.

Levels of Certainty



A. Available information is not adequate for determination of the level of mineral resource potential.
B. Available information suggests the level of mineral resource potential.
C. Available information gives a good indication of the level of mineral resource potential.
D. Available information clearly defines the level of mineral resource potential.

Abstracted with minor modifications from:

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RESOURCE / RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range	
	Measured	Indicated		Hypothetical (or)	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from U. S. Bureau of Mines and U. S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U. S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART
Terms and boundary ages used in this report

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~ 240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~ 330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~ 570[1]
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				3800?
pre-Archean[2]					4550

[1] Rocks older than 570 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.

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