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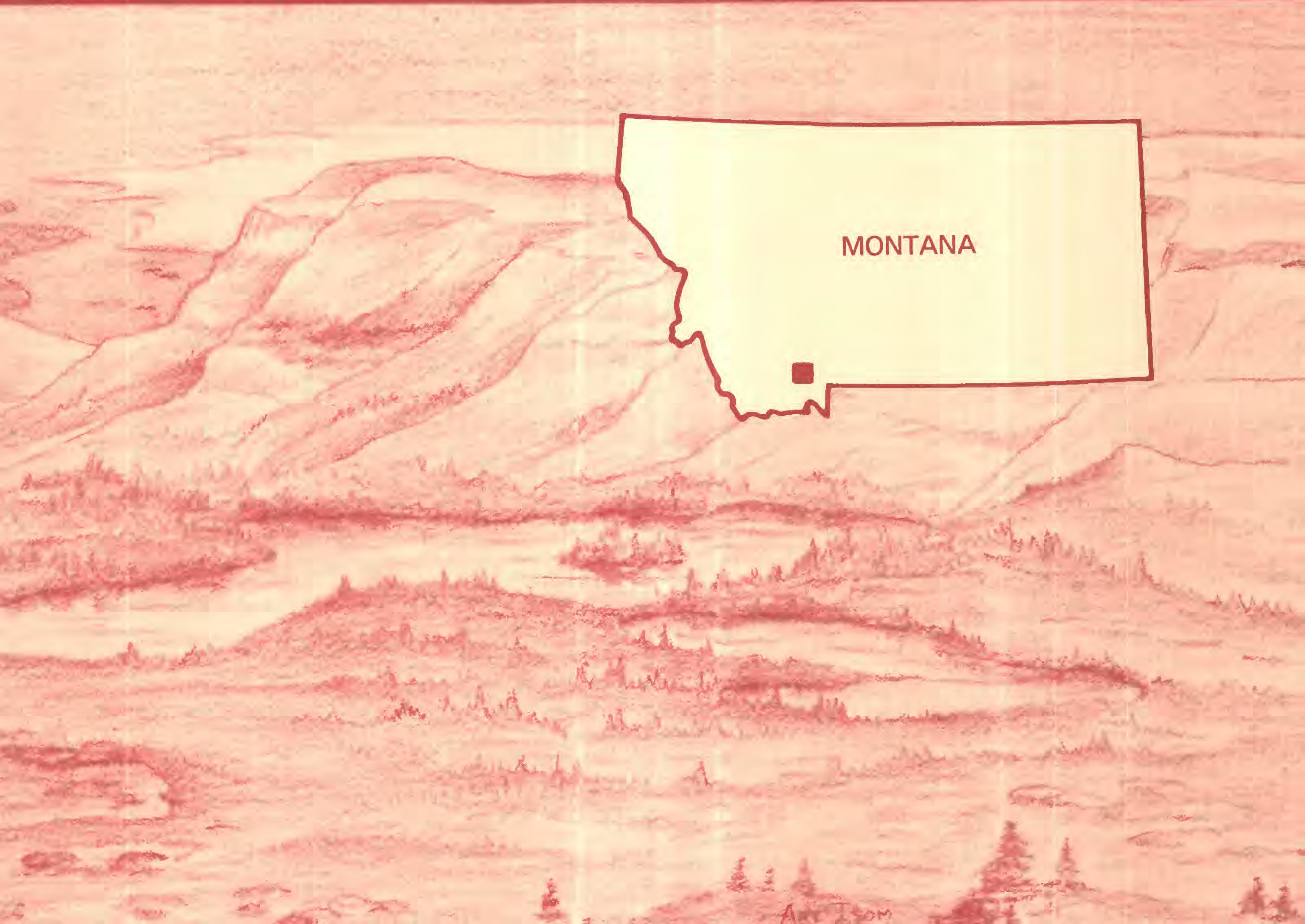
Mineral Resources of the Blacktail Mountains Wilderness Study Area, Beaverhead County, Montana

U.S. GEOLOGICAL SURVEY BULLETIN 1724–B



Chapter B

Mineral Resources of the Blacktail Mountains Wilderness Study Area, Beaverhead County, Montana

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U.S. Geological Survey

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U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1724

MINERAL RESOURCES WILDERNESS STUDY AREAS—
SOUTHWESTERN, MONTANA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
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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 their 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 Blacktail Mountains Wilderness Study Area (MT–076–002), Beaverhead County, Montana.

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Mineral Resources of the Blacktail Mountains Wilderness Study Area, Beaverhead County, Montana

By R. G. Tysdal, G. K. Lee, J. H. Hassemer, *and* W. F. Hanna
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SUMMARY

A mineral resource survey of a 10,610-acre part of the Blacktail Mountains Wilderness Study Area (MT–076–002) was conducted in 1984–85. Identified subeconomic resources of barite exist in the area at the northernmost boundary, and a zone partly within the area along the northeastern boundary has a moderate mineral resource potential for silver and barite, and associated gold, copper, lead, and zinc. No producing mines occur in or adjacent to the area. The area lies within a region that is rated as having moderate energy resource potential for oil and for gas.

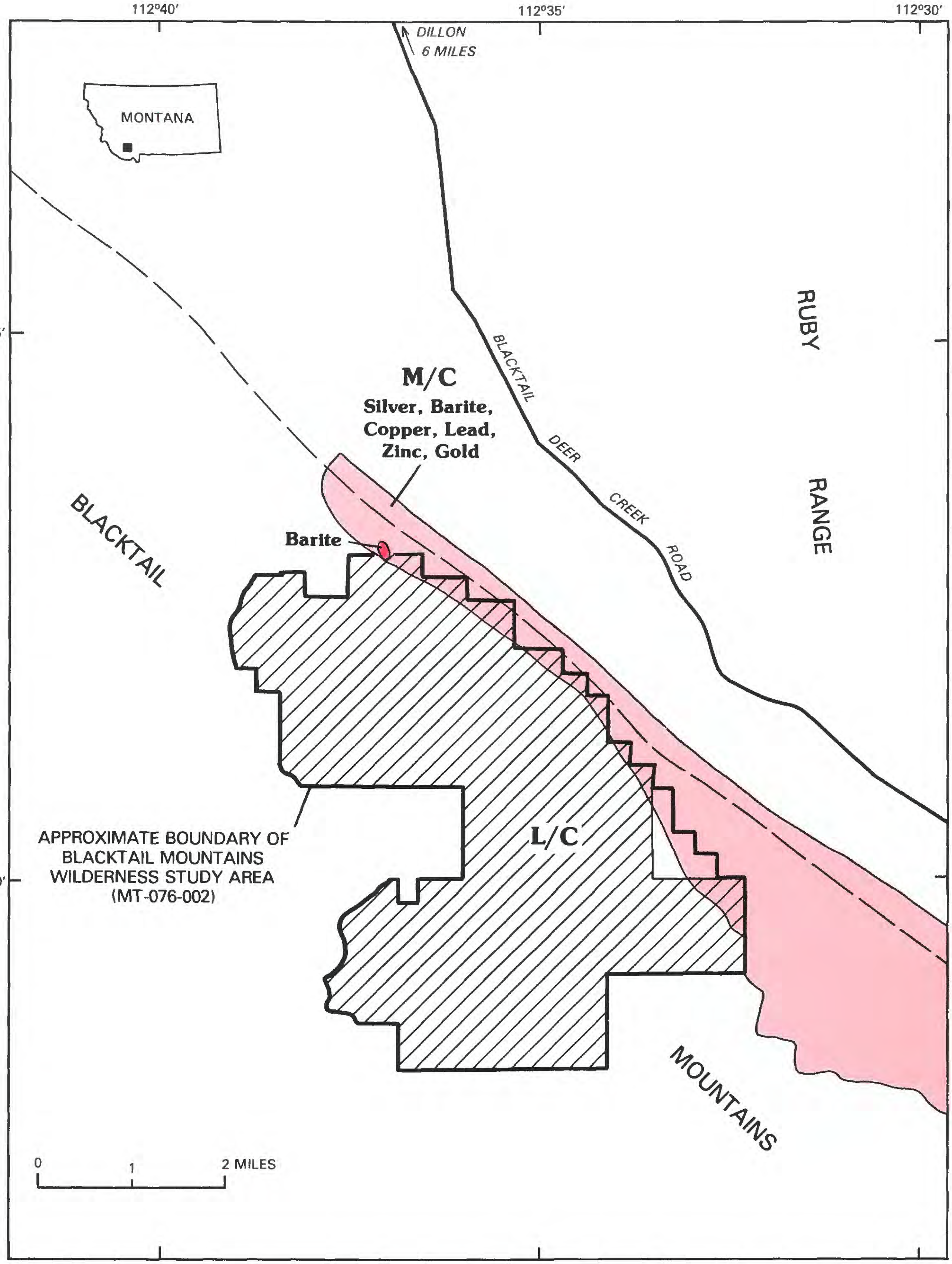
The study area is in the northwest-trending Blacktail Mountains of Beaverhead County, Mont. (fig. 1), and ranges in elevation from about 6,000 to 9,500 feet (ft). The mountains rise abruptly from the valley of Blacktail Deer Creek on the northeast, form a steep northeast flank that reaches to the crest of the range, then slope gently southward. The study area is located about 12 miles (mi) southeast of Dillon, Mont. The main access is by lanes that lead south from a county road, which extends along the axis of the valley of Blacktail Deer Creek.

The study area consists of a basement of Precambrian age rocks, metamorphosed 2,750 and 1,600 million years (m.y.) ago, which are overlain by 65- to 550-m.y.-old sedimentary rocks (see geologic time chart at end of report). The sedimentary rocks are composed mainly of carbonate strata (limestone and dolomite) and have an aggregate thickness of as much as 4,500 ft. Volcanic rocks that are about 30 m.y. old are present locally in the area.

Mountain-building forces deformed this part of the Rocky Mountains during the Laramide orogeny, approximately 60–80 m.y. ago. A series of westward-dipping thrust faults caused repetition (stacking) of some of the sedimentary formations. At about the same time, or shortly thereafter, an eastward-dipping reverse fault developed along what is now the northeast flank of the Blacktail Mountains. The range itself began to emerge as a discrete mountainous mass a few million years later, when a system of down-to-the-basin faults developed along the northeast flank of the range. Displacement on these faults served to separate the rising Blacktail Mountains from the downdropped strata of the basin that underlies the valley of Blacktail Deer Creek.

Field and laboratory studies were conducted to assess the identified resources and mineral resource potential of the study area. Detailed geologic mapping was carried out along the front of the mountains to ascertain the style and significance of deformation that controls location of the zone of mineralized rock. Gravimetric data collected during the course of the study proved useful in delimiting the range-margin fault system. A geochemical study was based on spectrographic and chemical analysis of stream sediments, heavy-mineral concentrates, and rock samples collected by the U.S. Geological Survey (USGS). The U.S. Bureau of Mines (USBM) examined and sampled prospects, mining claims, and mineral occurrences.

Most of the prospects, mining claims, and mineral occurrences are located along the northeast margin of the study area, in a zone rated as having a moderate potential for existence of silver and barite (fig. 1). Silver-


112°40′
112°35′
112°30′
DILLON
6 MILES
MONTANA
45°05′
45°00′
BLACKTAIL DEER CREEK ROAD
RUBY RANGE
M/C
Silver, Barite, Copper, Lead, Zinc, Gold
BLACKTAIL
Barite
L/C
APPROXIMATE BOUNDARY OF BLACKTAIL MOUNTAINS WILDERNESS STUDY AREA (MT-076-002)
MOUNTAINS
0
1
2 MILES

EXPLANATION

[Entire wilderness study area has moderate potential for oil and gas at certainty level B. Gold in Archean metamorphic rocks, and nickel and platinum in Archean ultramafic metamorphic rocks, where concealed beneath Mesozoic and (or) Paleozoic strata, are rated as unknown potential, at certainty level A(U/A)]

	Area of identified barite resources
M/C	**Geologic terrane having moderate resource potential for barite, silver, gold, copper, lead, and zinc**
L/C	**Geologic terrane having low resource potential for:** Uranium; low-temperature (<90 C) geothermal water; and quartzite as road metal—For entire area Silver, barite, copper, lead, zinc, and gold—Except as shown above Gold, nickel, and platinum—In exposed Archean metamorphic rocks

Figure 1 (above and facing page). Summary map showing mineral resource potential and identified resources in the Blacktail Mountains study area, Beaverhead County, Montana. Pattern (diagonal lines) shows area of oil and gas leases. Dashed line shows northern edge of Blacktail Mountains.

bearing ore was reportedly shipped in the 1930's from the Noble Mine, (loc. 4P, pl. 1) about one-quarter mile outside the study area, but no records of such production are known. The ore likely was from the Silver Queen mine, located about 3 mi south of the wilderness study area.

The Noble mine and associated prospects occur near the eastward-dipping reverse fault that exists along the northeast flank of the mountain range. Movement along this fault juxtaposed Precambrian metamorphic rock upon rocks as young as Mississippian along the northeast flank of the range. During the reverse movement, the metamorphic rocks immediately northeast of the fault were intensely fractured. Hot mineral-bearing fluids later moved through the fractured and porous rock, altered its character, and deposited local concentrations of silver, barite, and associated minerals. Some of the fluid seeped into the rocks beneath the reverse fault and deposited metals in the immediately subjacent limestone.

The study area lies within a geologic terrane rated as having a moderate energy resource potential for oil and for gas (fig. 2). The resource potential for uranium, coal, and geothermal energy is rated as low. No potential exists for phosphate deposits in the study area because the phosphate-bearing sedimentary formation has been eroded.

INTRODUCTION

The USGS and the USBM studied 10,610 acres of the Blacktail Mountains Wilderness Study Area (MT–076–002), at the request of the U.S. Bureau of Land Management. In this report the studied area is called the "wilderness study area" or simply the "study area." The study area is located in the central part of the Blacktail Mountains in Beaverhead County, Mont. (fig. 2; pl. 1). It is about 12 mi southeast of Dillon and, by road, is accessible only by crossing private land. Access roads that do not require four-wheel-drive vehicles extend south from the road, along Blacktail Deer Creek northeast of the wilderness study area, which is locally referred to as the Blacktail Road.

The north side of the wilderness study area is a steep mountain flank that rises abruptly from the valley of Blacktail Deer Creek. Elevation of the wilderness study area at the foot of the mountain flank is about 6,000 ft, and it reaches a maximum of about 9,500 ft at the head of the south fork of Ashbough Canyon in the core of the wilderness study area. On the south, the mountains slope gently into foothills that lead to the valley of Sage Creek several miles south of the wilderness study area.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is a product of several separate studies by the USBM and the USGS. Identified resources are classified according to the system of the U.S. Bureau of Mines and the U.S. Geological Survey (1980), which is shown on p. IV of this report. Mineral resource potential is the likelihood of occurrence of undiscovered concentrations of metals and nonmetals, of unappraised 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 is shown in the appendix of this report. The field work was carried out during the summers of 1984 and 1985.

Investigations by the U.S. Bureau of Mines

The USBM examined mining claim records of Beaverhead County and the U.S. Bureau of Land Management (BLM). Field studies were conducted during 1984 to examine, map, and sample all known mines, prospects, and mineralized zones. Results of these studies are presented in Benham (1986) and are summarized in this report.

Investigations by the U.S. Geological Survey

New mapping by the USGS was carried out along the eastern part of the wilderness study area to determine the geologic controls of the mineral deposits. Stream-

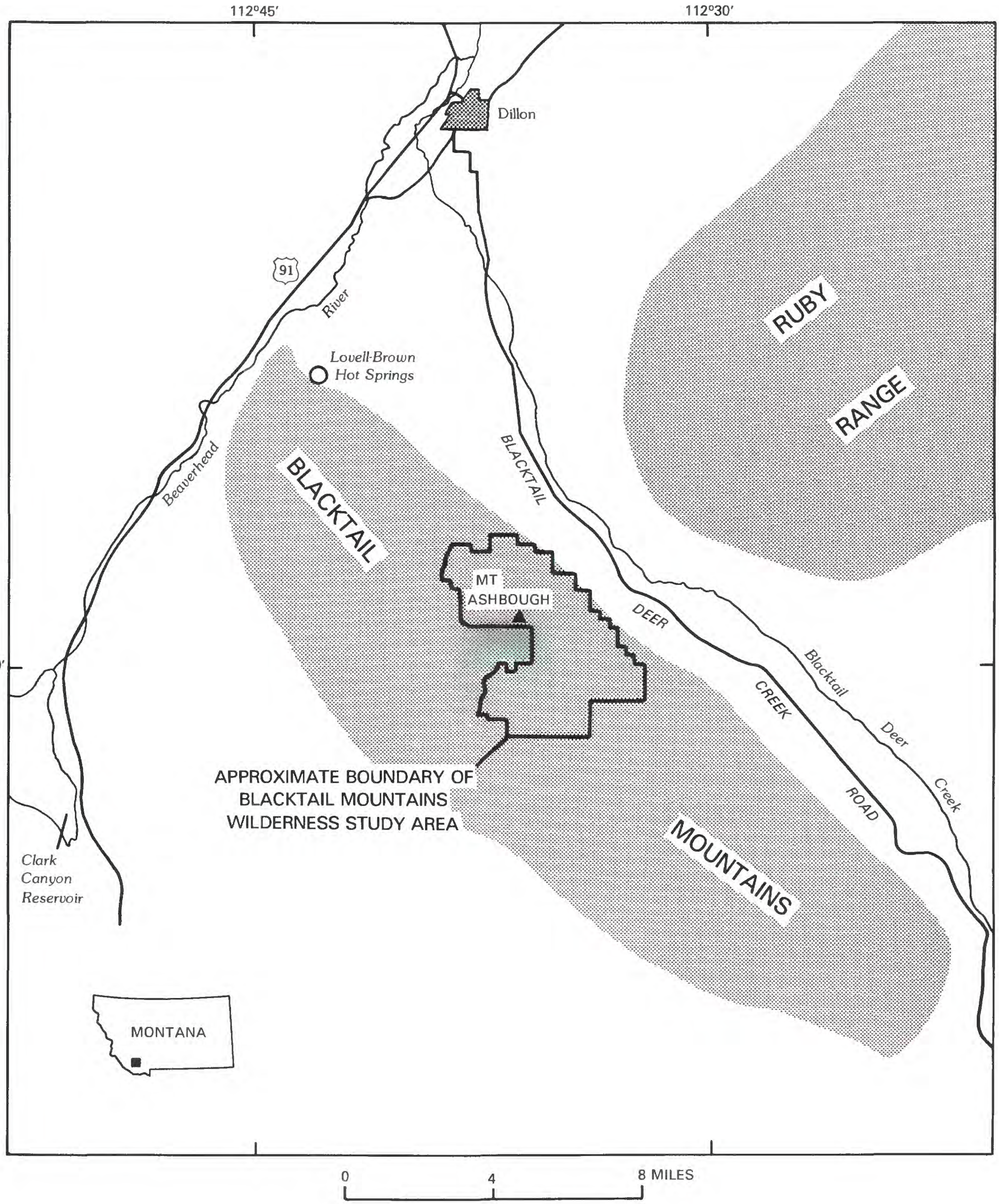


Figure 2. Index map showing location of the Blacktail Mountains study area, Beaverhead County, Montana.

sediment and heavy-mineral pan-concentrate samples were collected from streams that drain the wilderness study area and were analyzed spectrographically and chemically to detect anomalous values of elements. Rocks from selected locations also were analyzed to aid in the interpretation of stream-sediment and concentrate data. New gravity measurements were made in and adjacent to the area.

Acknowledgments.—We wish to thank land owners in the area for permission to cross their land to gain access to the wilderness study area. Mr. Julian Davis, Mining Engineer, Delamar Silver Mines, Jordan Valley, Oregon, kindly supplied numerous documents relating to the mining history, maps of underground workings, and pertinent assay information on the Emil and Silver Queen properties in and adjacent to the wilderness study area. Mr. John Conover kindly gave us permission to examine barite claims on land adjacent to the wilderness study area, and to publish geochemical data on rocks therefrom.

APPRAISAL OF IDENTIFIED RESOURCES

By J. R. Benham
U.S. Bureau of Mines

Mining and Mineral Exploration History

Mining claims and prospects shown on plate 1 were examined by the USBM and are described in table 1. The earliest recorded activity in the area was the location of coal claims in 1879. Local residents described a very small coal mining operation near Mt. Ashbough, the source for coal used in a blacksmith shop in Dillon. (Mt. Ashbough is a local name obtained from the name of a benchmark atop a peak in the SE¼ sec. 29, T. 9 S., R. 8 W.) The coal is bituminous, occurs in the Mississippian Lombard Limestone, and forms a seam that is 1 ft thick or less. The seam is present only locally, is not of high quality, and was found only in landslide blocks and fault zones. No production records are available, but apparently a few hundred feet of the seam was mined by hand (from a landslide block) (Pecora, 1981, p. 84).

Limestone was quarried in Sheep Canyon in 1885, and other lode claims for limestone were located in the 1880's and 1890's. Although limestone in Paleozoic formations is widespread in the wilderness study area, the same formations occur over a broad region outside the study area and are more readily accessible. In 1901, three claims were located for gilsonite (a black, shiny, solidified hydrocarbon) and resulted in the development of underground workings. Also in 1901, 200 oil placers were located, but lapsed because they were not drilled.

From 1907 through 1917, the Noble and contiguous claims were located and developed. Some ore may have been mined from the Noble (loc. 4P, pl. 1) workings in the 1930's. In 1933, two claims were located and developed on the present site of the Emil claim group (loc. 8P, pl. 1). The Golden Fleece claims (nos. 1–16) for barite were located in 1981. Only the Noble Claim and its associated claims and the Golden Fleece claim block were active in 1984.

Quality and Quantity of Identified Resources

Barite-rich material at the Golden Fleece No. 9 claim (loc. 1P, pl. 1 and table 1) has an average specific gravity of 3.8 and an inferred barite resource of 9,000 tons at this density. The present industry standard for barite in drilling mud is 4.0 or greater. The identified subeconomic resources of the Golden Fleece prospect do not contain sufficient barite to justify the cost of mining and building a concentration mill.

The entire study area is leased for oil and gas. Out of 10,610 acres comprising the study area, 9,098.62 acres (86 percent) are currently (1984) encumbered by eight noncompetitive oil and gas leases. The remaining 1,487.38 acres are held in the simultaneous-bidding oil and gas leasing system managed by the BLM.

No outside interest or leasing of lands for their geothermal potential has taken place, and no hot springs or other geothermal phenomena exist in the wilderness study area.

ASSESSMENT OF POTENTIAL FOR MINERAL RESOURCES

By R. G. Tysdal, G. K. Lee, J. H. Hassemer, and W. F. Hanna
U.S. Geological Survey

Geology

Geologic Setting

The central part of the Blacktail Mountains, in which the wilderness study area lies, consists of a basement of Archean metamorphic rocks overlain by Paleozoic sedimentary strata which, depending on structural interpretations, range from about 3,500 to 4,500 ft thick. The Paleozoic rocks consist largely of limestone and minor quantities of sandstone and shale. Mesozoic sedimentary

Table 1. Mining claims and prospects in and adjacent to the Blacktail Mountains study area, Beaverhead County, Montana

[Asterisk (*) indicates location outside boundary of wilderness study area; ppm, parts per million; <, less than; (table, including sample and resource data, from Benham, 1986)]

Locality no. (plate 1)	Prospect name (commodity)	Summary	Workings and production	Sample and resource data
1P	Golden Fleece No. 9 Claim (barite)	Barite pods as large as 3x4x1.5 ft occur in Mississippian limestone. The barite is massive with radiating plates and has iron staining on fracture surfaces.	One dozer cut 54 ft long by 14 ft high. No production.	One grab and one chip sample yielded 79.4 and 76.1 percent $BaSO_4$, respectively. Specific gravity of five samples ranged from 3.50 to 4.17. Inferred subeconomic barite resource of 9,000 tons averaging 3.8 specific gravity. Present industry standard (1984) for barite used in drilling mud is 4.0 or greater specific gravity.
2P	Unnamed (copper)	Quartzite (possibly jasperoid) is fractured and contains iron-oxide stain and calcite coatings.	Three cuts ranging from 8x7x2 ft to 6x4x3 ft deep. One pit 6 ft in diameter and 3 ft deep. No production.	The following samples were taken: a channel sample of colluvium of limestone, quartzite, and clay; a chip sample of fractured quartzite; and three grab samples. Two samples were analyzed for copper, yielding values of 44 and 63 ppm. No sample contained gold or silver.
3P	Jenkins Canyon Prospect	Mississippian Lodgepole Limestone with shear zones exposed in adit. Three prospect pits explored gossan consisting of a boxwork of limonite and hematite.	A 65-ft-long adit and two caved adits; three prospect pits less than 25 ft in diameter and less than 3 ft deep. No record of production.	Six chip samples were cut across gouge within the sheared zone. Of ten grab samples, five were of gossan, three of limestone, and two of fractured iron-stained quartzite. Two samples contained a trace of gold, four samples contained silver ranging from 0.1 to 0.3 oz/ton. Of three samples analyzed for copper, lead, and zinc, one sample contained 0.12 percent copper, 49 ppm lead, and 650 ppm zinc; the other three samples had negligible values.

rocks likely were deposited across the area and, except locally, later removed by erosion. The Permian Phosphoria Formation is not preserved within the wilderness study area, but the type section of the phosphate-bearing Retort Phosphatic Shale Member is located at Retort Mountain about 1 mi west of the area (Cressman and Swanson, 1964).

Metamorphic basement rocks of the Blacktail Mountains have been correlated with those of the Ruby Range to the north (Klepper, 1950; Heinrich, 1960). Rock units and foliation trends in the two ranges are similar. Rb/Sr dating showed the rocks of the Ruby Range originally were metamorphosed about 2,750 m.y. ago (James and Hedge, 1980); K/Ar dating of rocks from both the Ruby Range and Blacktail Mountains showed that a second metamorphic event occurred about 1,600 m.y. ago (Giletti, 1966).

Deformation during the Late Cretaceous–Tertiary Laramide orogeny generated low-angle thrust faults within the wilderness study area. Mississippian and younger rocks moved eastward with respect to the underlying older rocks and occur in an imbricate stack of thrusts that are particularly well displayed in the Mt. Ashbough area. Upper plates of major thrust faults of the stack are accompanied by east-verging overturned folds (Pecora, 1981).

The thrust faults and associated folds subsequently were deformed along the northeast flank of the mountains by a northwest-trending, northeast-dipping reverse fault,

Table 1. Mining claims and prospects in and adjacent to the Blacktail Mountains study area, Beaverhead County, Montana—Continued

Locality no. (plate 1)	Prospect name (commodity)	Summary	Workings and production	Sample and resource data
*4P	Noble, Bluebird, Mammoth, Iron Queen, Old Weston, Old Pine Claims (silver, copper, gold)	Workings have extended through quartzite (jasperoid) to intersect a fault that contains gouge and quartzite fragments. Argentite and tetrahedrite may exist within the gouge. Upslope (west) from the fault are Paleozoic shales that are fractured and stained with iron. The pits are in colluvium consisting of weathered limestone and dolomite that contain some secondary calcite.	Two caved adits: one about 240 ft long, the other about 70 ft long. One 25-ft shaft connects with the longer adit. Three prospect pits. Geach (1972, p. 159) reported production from the Nevada Mine in 1934 and 1935 as 988 lbs copper, 8,214 oz silver, and 7 oz gold. His description of the workings matches that of the Noble Mine, but it is probable that the production is from the Silver Queen Mine, which is located 6 mi to the southeast, about 3 mi outside the boundary of the wilderness study area.	Fourteen chip samples cut across the fault and ten grab samples from mine dumps, stockpiles, and prospect pits. Seven samples contained a trace of gold. Nineteen samples contained silver ranging from 0.1 to 1.0 oz/ton. Copper ranged from 0.01 percent to 1.3 percent in 20 samples. Zinc ranged from <1 to 140 ppm in 20 samples. Lead ranged from <0.003 percent to 0.11 percent.
5P	Last Chance, Sullivan, and Jumbo Claims (petroliferous shale; thought to be gilsonite by claimants)	Workings are cut into thin-bedded fissile shales of the Mississippian and Devonian Three Forks Formation. At the end of the adit is an exposure of black petroliferous shale.	One 45-ft adit, slightly sloughed at the portal, and two cuts. No production records.	Four chip and two grab samples collected. One chip sample was analyzed for gilsonite, but none was detected. No gold was detected in the four samples analyzed, but two of them contained 0.1 oz of silver per ton.
6P	Ashbough Ridge (copper)	A 0.7- to 1.0-ft thick zone parallel to beds in the Mississippian Mission Canyon Limestone. The zone contains calcite with limonite, hematite, and jasper and is exposed for 50 ft.	One pit, 10 ft diameter by 4 ft deep. No production.	One grab sample contained 26 ppm copper, but no gold or silver.
7P	Ashbough Canyon (gold)	Workings dug through Archean gneiss to intersect the Cambrian Flathead Sandstone. Material in the dump is a hematite- and chlorite-enriched schist. The pit is in light-green fissile shale enclosed in quartzite and limestone.	One caved adit, probably 50 to 70 ft long; one cut; and a pit about 1,500 ft from the dump near the adit. No record of production.	One chip and four grab samples. A trace of gold, but no silver, was detected in four samples.
8P	Emil Claim Group (copper, silver)	Adit cut into quartzite that is banded, massive, competent, and has iron-oxide staining on joint and fracture surfaces. Chrysocolla was seen on some fracture planes. All of the workings above 7,300 ft explored small shear zones in the Archean gneisses.	One 96-ft adit, one 37-ft adit, one 12-ft adit, one caved adit, and eight small prospect pits. No record of production.	Collected three chip samples across shear zones; and sixteen grab samples of schist, gneiss, and quartzite. A trace of gold was found in two samples. Six samples contained silver of 0.1 oz/ton. Eleven samples assayed <2 to 58 ppm copper.

here named the Jake Canyon fault (pl. 1) for its exposure near Jake Canyon about 3 mi south of the wilderness study area. The fault dips at a moderate to steep angle to the northeast and juxtaposes Archean metamorphic rocks upon Paleozoic strata in and immediately northeast of the wilderness study area. In the southeastern part of the wilderness study area, the Jake Canyon fault cuts into the mountains and juxtaposes Archean rocks over other Archean rocks. Within the southeasternmost part of the wilderness study area and farther southeast, the Jake Canyon fault may have subsequently undergone down-to-the-basin (northeast) movement during Tertiary extensional faulting. The Blacktail fault, a basin-and-range normal fault that forms the boundary of the Blacktail Mountains and the valley of Blacktail Deer Creek (pl. 1), later cut through the metamorphic rocks northeast of the Jake Canyon fault and downdropped most of them to below the valley.

Rocks immediately adjacent to the Jake Canyon fault are brecciated, particularly eastward from the fault. These fractured rocks provided a passageway for hydrothermal fluids that altered the rocks, producing gossan, along most of the length of the fault. Masses of jasperoid were formed locally along the fault where silica-rich hydrothermal fluids caused replacement of Archean gneiss. Prospects in and adjacent to the wilderness study area, along the north flank of the Blacktail Mountains, are associated with the mineralized rock of the Jake Canyon fault.

Description of Rock Units

The following rock units were mapped within or immediately adjacent to the wilderness study area and are shown on plate 1 of this report. Descriptions of the Archean rocks are from field studies for this report. Descriptions of the younger units are mainly from Pecora (1981, 1987), supplemented by data from Huh (1967) and Hanson (1952).

Archean gneiss, undivided (unit Agn*)*—The most common rock type of this unit is light-gray, well-foliated, medium- to coarse-grained, biotite-plagioclase-quartz gneiss, locally containing hornblende. Common accessory minerals include zircon, magnetite, apatite, and garnet. Hornblende-rich gneiss layers a few tens of feet thick occur locally within the light-gray gneiss and range in composition from quartz-plagioclase-hornblende gneiss to almost entirely hornblende. Present in some parts of the wilderness study area, and increasing in abundance to the east, is pink to pale-orange, medium- to coarse-grained, foliated quartz-microcline gneiss to plagioclase-quartz-microcline gneiss. The rock contains sparse biotite in some areas. Common accessory minerals include zircon, apatite, and magnetite. Potassium feldspar-quartz pegmatites were observed in some areas of this gneiss. No ultramafic intrusives, such as the nickel-bearing sill-like body at Jake Creek (Sinkler, 1942; Heinrich, 1960) 2 mi southeast of the wilderness study area, were observed in the metamorphic rocks of the wilderness study area.

Cambrian sedimentary rocks, undivided (unit Ꞓu*)*—The formations that make up this unit are composed chiefly of limestone and dolomite, lesser shale and sandstone, and are described from oldest to youngest. The Flathead Sandstone is the basal formation of the map unit and consists of light-colored, medium- to coarse-grained, quartzose sandstone; locally it contains glauconite, rounded quartz pebbles, and is crossbedded. The Flathead ranges from about 30 to 100 ft thick and unconformably overlies Archean metamorphic rocks. The overlying Wolsey Shale is a poorly exposed unit of olive-green finely micaceous clay shale and siltstone; its estimated thickness is 50–150 ft. The Meagher Limestone, about 575 ft thick, is yellowish-brown to gray dolomite that is made prominent by grayish-red-purple mottles. The dolomite is medium to coarse grained, medium to thick bedded, and forms cliffs. The Park Shale is poorly exposed but consists mainly of olive-green clay shale and minor interbeds of limestone in the middle; its thickness ranges from about 100 to 200 ft thick. The Pilgrim Dolomite is the uppermost formation and is mainly gray to pinkish-gray, sugary, thick-bedded, cliff-forming dolomite; it is about 100–125 ft thick.

Mississippian and Devonian sedimentary rocks, undivided (unit MDu*)*—These rocks are chiefly dolomite. The lower part is the Devonian Jefferson Formation, a yellowish-brown, medium- to thick-bedded, rubbly weathering dolomite; grayish-black, thick-bedded, fetid dolomite; and yellowish calcareous siltstone. The Jefferson is about 100–120 ft thick. The upper part is the Devonian and Mississippian Three Forks Formation, of which poor exposures reveal grayish-orange siltstone, silty limestone, and evaporite-solution breccia; the Three Forks is about 60 ft thick.

Early and Late Mississippian Madison Group (unit Mm*)*—The lower two-thirds of the Lodgepole Limestone, the basal formation of the Madison, consists of light-gray, fine-grained, thin- to medium-bedded, finely laminated limestone; the upper third of the Lodgepole is light-gray, thin- to medium-bedded limestone and interlayered reddish calcareous siltstone. The formation is as much as 1,000 ft thick. The Mission Canyon Limestone, the upper formation of the Madison, consists of light-gray, medium-bedded limestone, but locally is composed of indistinct to massive layers that form cliffs. Chert stringers occur in the lower part of the Mission Canyon, and zones of evaporite-solution breccia occur in the middle and upper part. The formation is about 800–1,000 ft thick.

Late Mississippian Snowcrest Range Group (unit Mu*)*—The three formations that make up this map unit were recently named and described by Wardlaw and Pecora (1985). The basal formation of the group, the Kibbey Sandstone, is mainly pale-yellowish-brown to pale-orange, fine- to medium-grained, thin- to medium-bedded quartz sandstone; the lowermost beds contain as much as 5 percent black chert grains. Limestone and evaporite-solution breccia are present in the middle of the formation, which is 100–160 ft thick. The stratigraphic sequence for the overlying Late Mississippian Lombard Limestone was reconstructed by Pecora (1981) from outcrops of three tectonically deformed sequences in the Blacktail Mountains. The lower tectonic sequence of the Lombard contains an informal lower member of the formation that is olive-gray to pale-red-purple, thin- to thick-bedded, ostracod-rich limestone; it is about 125 ft thick. The middle tectonic sequence contains pale-brown to light-gray, thin- to thick-bedded limestone; interbeds of siltstone, claystone; and a discontinuous 1-ft-thick bituminous coal seam; this sequence is 220–580 ft thick, depending on tectonic reconstruction assumptions. In the upper tectonic sequence, the Lombard is pale-brown to gray, thin- to thick-bedded, crinoidal limestone; argillaceous limestone; and dark-gray petroliferous limey shale. The thickness is about 300 ft. The upper formation of the group, the Conover Ranch Formation, consists of brick-red shale, siltstone, and sandstone, as well as minor green shale and gray limestone. It is about 100 ft thick.

Early Pennsylvanian and Late Mississippian Quadrant Sandstone (unit ℙMq*)*—This formation is white to tan, fine- to medium-grained, medium- to thick-bedded, well-sorted quartz sandstone. Trough crossbedding is common. The formation is about 680–725 ft thick.

Permian Phosphoria Formation (unit Pp*)*—From bottom to top, the formation consists of pale-brown, thin-bedded mudstone and interbedded sandstone; pale-brown phosphatic mudstone; light-gray dolomite that contains nodular chert and chert stringers; dark-gray to black finely layered phosphatic mudstone; and yellowish-brown, fine- to medium-grained, glauconitic quartz sandstone. The formation, about 350 ft thick, does not exist within the boundaries of the wilderness study area, but crops out about 0.5 mi west of the area of the map of plate 1.

Early Triassic Dinwoody Formation (unit ₸d*)*—This formation consists of moderate- to dark-brown, thin-bedded limestone that contains abundant fossil debris. The formation is about 200 ft thick.

Late Cretaceous Beaverhead Group (unit Kb*)*—This unit is an orange conglomerate. Rounded clasts are pebbles and cobbles derived from the Proterozoic Belt Supergroup (which crops out several miles west of the wilderness study area) set in an orange matrix of quartz-rich sandstone. Poorly exposed; only a few tens of feet thick in the wilderness study area.

Tertiary intrusive rocks (unit Ti*)*—This rock type is light-gray porphyry. It is hydrothermally altered, weathered, and the feldspar phenocrysts have been destroyed. The composition may have been dacitic or more felsic.

Tertiary jasperoid (unit Tj*)*—This unit is cream to white, massive, vuggy rock that forms resistant outcrops. Commonly contains fractures that show evidence of mineralization. The unit formed by replacement of Archean gneiss along the Jake Canyon fault.

Oligocene volcanic rocks (unit Tcr*)*—This unit consists of cream, pink, and pale-green ash-flow tuff and tuff breccia of rhyolitic composition. The unit has a maximum thickness of about 25 ft within the boundary of the wilderness study area. According to Scholten and others (1955), these rocks correlate with the Cook Ranch Formation of Wood (1934, p. 254).

Quaternary sediments, undivided (unit Qal*)*—This unit consists of alluvium, alluvial fans, and colluvium.

Holocene landslide deposits (unit Qls*)*—This unit consists of landslide deposits, many of which are still active.

Geochemistry

Analytical Methods

Stream-sediment samples were collected from most of the active first order drainages, as well as from all second order and larger drainages. At each site a composite sample of fine detritus from several places within the stream bed was taken and later air dried for sieving and analysis. Heavy-mineral concentrates of stream sediments were collected by panning near the stream-sediment site but from coarser detritus believed to represent a relatively high-energy depositional environment.

Rock samples were collected to (1) identify and evaluate places where obvious mineralized or altered rock occurred within the study area, and (2) determine background abundances of elements to help evaluate the stream-sediment samples. The samples usually were taken as representative composites of chips from outcrops, except where altered or mineralized rock was collected preferentially.

All samples were analyzed semiquantitatively for 31 elements using a six-step, direct-current arc, optical-emission, spectrographic method (Grimes and Marranzino, 1968). Stream-sediment samples were sieved through an 80-mesh (177 micron) screen, and was analyzed. A split of each crushed and finely ground rock sample and a small split of each panned-concentrate sample also were analyzed by this method. Atomic-absorption analyses for gold were made on the remainder of each panned-concentrate and rock sample, using the method of Thompson and others (1968). Splits of the rock samples also were analyzed for antimony, bismuth, cadmium, lead, and zinc using the partial extraction, atomic-absorption method of Viets and others (1984).

Table 2. Semiquantitative spectrographic analyses of stream-sediment samples, Blacktail Mountains study area,

[N. M. Conklin, L. A. Bradley, and M. J. Malcolm, USGS, analysts. Values are reported in the six-step classification, at midpoints 1, 1.5, in parentheses; all values given in parts per million except Fe, Mg, Ca, and Ti]

Locality no. (plate 1)	Sample no.	Latitude deg-min-sec	Longitude deg-min-sec	Fe % (.05)	Mg % (.02)	Ca % (.05)	Ti % (.002)	Mn (10)	Ag (.5)	As (700)	Au (15)	B (10)	Ba (30)	Be (1)	Bi (10)
1S	BM001AS	45-02-54	112-34-59	3	2	3	0.3	1000	L	L	L	70	700	1.5	L
2S	BM002AS	45-01-47	112-35-48	1.5	1.5	7	0.15	300	L	L	L	70	150	L	L
3S	BM003AS	45-01-55	112-35-21	3	2	10	0.3	300	L	L	L	70	150	1	L
4S	BM004AS	45-02-06	112-35-06	2	3	10	0.3	1000	L	L	L	70	300	1	L
5S	BM006AS	45-02-32	112-38-58	0.5	0.15	0.3	0.15	150	L	L	L	30	150	L	L
6S	BM007AS	45-02-22	112-38-14	0.5	0.15	0.7	0.15	300	L	L	L	30	300	L	L
7S	BM008AS	45-00-03	112-32-55	2	5	7	0.15	300	L	L	L	70	300	1	L
8S	BM009AS	45-58-25	112-34-27	0.7	7	10	0.07	150	L	L	L	30	100	L	L
9S	BM010AS	44-58-20	112-35-56	2	1	7	0.3	700	L	L	L	70	500	1	L
0S	BM011AS	45-01-16	112-38-29	1.5	1.5	15	0.15	700	L	L	L	20	300	L	L
11S	BM012AS	45-01-24	112-38-26	1	0.7	5	0.15	300	L	L	L	30	150	L	L
12S	BM001GS	45-02-17	112-34-42	1.5	1.5	5	0.15	700	L	L	L	50	500	L	L
13S	BM002GS	45-01-41	112-34-26	2	3	10	0.3	700	L	L	L	70	500	1.5	L
14S	BM003GS	45-01-51	112-34-36	3	3	3	0.3	1000	L	L	L	70	500	1.5	L
15S	BM004GS	45-00-35	112-34-33	1.5	3	5	0.3	500	L	L	L	70	500	1	L
16S	BM005GS	45-00-37	112-34-40	2	1.5	3	0.3	700	L	L	L	70	500	1	L
17S	BM001PS	45-02-56	112-36-34	1	1	10	0.15	300	L	L	L	30	200	L	L
18S	BM002PS	45-02-25	112-36-49	1.5	1	15	0.15	300	L	L	L	50	100	L	L
19S	BM003PS	45-02-31	112-35-36	2	0.7	10	0.3	300	L	L	L	70	700	1	L
20S	BM004PS	45-00-44	112-35-35	1	0.7	15	0.15	300	L	L	L	20	200	L	L
21S	BM005PS	45-00-40	112-35-20	2	0.7	1.5	0.3	1000	L	L	L	100	700	1.5	L
22S	BM006PS	45-01-05	112-33-50	3	2	1.5	0.3	700	L	L	L	70	700	2	L
23S	BM007PS	44-59-55	112-32-30	3	0.7	0.7	0.3	500	L	L	L	100	300	1.5	L
24S	BM008PS	44-59-18	112-36-25	1.5	7	10	0.2	300	L	L	L	100	300	L	L
25S	BM009PS	44-59-22	112-37-25	1.5	1.5	7	0.15	700	L	L	L	70	200	L	L
26S	BM010PS	44-59-08	112-37-18	1	3	7	0.15	300	L	L	L	30	300	L	L
27S	BM011PS	45-00-55	112-37-56	2	1.5	15	0.2	700	L	L	L	50	100	L	L
28S	85MTz610	45-00-01	112-35-15	0.7	0.7	15	0.05	150	L	L	L	L	100	L	L

Results of Study

Samples from within and adjacent to the northeast edge of the study area locally are enriched in silver or gold and associated metals (tables 2, 3, 4) as discussed below. Elevated values of some metals occur in a few places within the interior of the study area, but none are considered to be significant.

Stream-sediment samples from canyon mouths along the northeast flank of the mountain range contain high values only for barium, reflecting mineralized rock associated with the Jake Canyon fault. Heavy-mineral concentrate samples from the same localities show elevated values of arsenic, manganese, chromium, and nickel. Upstream (southwest) from canyon mouths, and away from the mineralized fault, stream-sediment and heavy-mineral concentrate samples generally do not show elevated values.

Heavy-mineral concentrate samples from the southwestern part of the wilderness study area show some very low values of gold. The only known possible source of this element is from the conglomeratic strata of the Cretaceous Beaverhead Group. This unit is in part composed of pebbles and cobbles eroded from the Middle Proterozoic Belt Supergroup, and the conglomerate is known to contain traces of gold throughout its outcrop area in southwestern Montana. Sample localities in the southwestern part of the wilderness study area are mainly in stream courses that drain outcrop areas of the Beaverhead, but drainages from which Beaverhead strata are now absent probably were covered previously by these deposits.

Rock samples from the mountain front area show highconcentrations of copper, lead, zinc, chromium, nickel, barium, iron, arsenic and, from the Noble Mine, silver (table 4). Not all of these elements are in high concentration in each rock sample, however. Within the wilderness study area, one of the samples that showed a significant concentration of elements, especially zinc and arsenic, was collected from locality 5R (table 4, sample no. 84MTz27), about one-half mile east of Mt. Ashbough.

2, 3, 5, 7, 10, and so forth; L, detected but less than limit of determination shown in parentheses; N, not detected at limit of detection shown

Cd (30)	Co (5)	Cr (10)	Cu (5)	La (30)	Mo (5)	Nb (20)	Ni (5)	Pb (10)	Sb (100)	Sc (5)	Sn (10)	Sr (100)	V (10)	W (50)	Y (10)	Zn (200)	Zr (10)	Th (200)
L	7	70	50	50	L	L	30	30	L	15	L	300	70	L	30	L	300	L
L	7	50	20	L	L	L	30	15	L	10	70	500	30	L	15	L	70	L
L	7	70	15	L	L	L	30	15	L	15	50	500	70	L	30	L	150	L
L	7	50	20	L	L	L	30	15	L	10	30	300	70	L	15	L	150	L
L	L	10	7	L	L	L	7	10	L	L	L	L	L	L	L	L	300	L
L	L	15	15	L	L	L	7	30	L	L	L	L	15	L	L	L	300	L
L	7	70	30	70	L	L	30	15	L	7	30	200	70	L	30	L	100	L
L	L	20	15	L	L	L	10	L	L	L	L	L	30	L	10	L	30	L
L	7	70	30	50	L	L	30	30	L	10	L	L	70	L	30	L	300	L
L	5	50	15	L	L	L	20	10	L	7	L	500	30	L	15	L	100	L
L	5	50	15	L	L	L	20	10	L	7	30	300	30	L	15	L	200	L
L	7	50	30	50	L	L	20	30	L	7	L	300	70	L	30	L	150	L
L	7	70	30	50	L	L	30	30	L	10	L	300	70	L	30	L	150	L
L	7	70	30	50	L	20	30	30	L	15	L	300	70	L	30	L	200	L
L	7	70	30	50	7	L	30	20	L	10	L	300	150	L	20	L	150	L
L	7	70	30	50	L	L	30	20	L	7	L	200	70	L	30	L	150	L
L	5	70	15	L	L	L	20	L	L	7	L	300	30	L	15	L	70	L
L	5	50	15	L	L	L	30	15	L	7	L	300	30	L	15	L	70	L
L	7	70	30	L	L	L	20	10	L	10	L	300	70	L	30	L	150	L
L	L	50	15	L	L	L	15	10	L	7	L	300	30	L	20	L	70	L
L	7	70	30	70	5	L	50	30	L	15	L	300	150	L	30	L	300	L
L	15	100	30	100	L	20	70	20	L	15	L	300	150	L	30	L	200	L
L	10	100	30	70	L	L	50	30	L	15	L	200	70	L	30	L	300	L
L	7	30	20	L	L	L	15	10	L	5	L	L	30	L	15	L	200	L
L	7	70	30	L	L	L	20	15	L	10	30	300	30	L	20	L	100	L
L	L	50	15	L	L	L	10	10	L	7	L	150	30	L	30	L	300	L
L	7	70	15	L	L	L	30	15	L	10	20	300	30	L	20	L	150	L
L	L	30	5	L	L	L	L	15	L	5	L	150	30	L	10	L	70	L

This sample is representative of a tiny body of clinker-like, weathered Mississippian Kibbey Sandstone. No such clinker-like rock was found elsewhere along the outcrop of this porous formation. Stream-sediment and panned-concentrate samples from streams that head in this area do not contain unusual amounts of metals.

Geophysics

Methods

Gravity data within and surrounding the Blacktail Mountains consist of 65 measurement points (stations) established or compiled by J. H. Hassemer and H. E. Kaufmann (fig. 3). All stations were surveyed with LaCoste and Romberg geodetic gravimeters[1]. The principal facts for these gravity stations are available in a report by Hassemer and others (1986). Nineteen of these stations are located within or immediately adjacent to the wilderness study area. Measurements are referenced to gravity values at base stations (Kaufmann and others, 1983) consistent with the International Gravity Standardization Net 1971.

Observed gravity values were computed using calibration coefficients established by laboratory bench and mountain loop calibrations, and corrections for earth tide and instrumental drift were made using a computer program developed by M. W. Webring, R. R. Wahl, and G. I. Evenden of the USGS. Bouguer gravity anomalies with respective terrain and earth curvature corrections were computed relative to theoretical gravity values derived for Geodetic Reference System 1967 (Woollard, 1979). Equations used in this gravity reduction are summarized in Cordell and others (1982) and are implemented in a computer program of R. H. Godson, USGS. Terrain corrections to a distance of 175 ft (Hammer, 1939) from each station were visually estimated during the field work.

[1]Use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

Table 3. Semiquantitative spectrographic and chemical analyses of heavy-mineral concentrate samples, Blacktail

[R. T. Hopkins, spectrographic analyst; M. A. Pokorny and T. A. Roemer, chemical analysts, USGS. Values are reported in the six-step classification, N, not detected at limit of detection shown in parentheses; all values in parts per million except Fe, Mg, Ca, and Ti]

Locality no. (plate 1)	Sample no.	Latitude deg-min-sec	Longitude deg-min-sec	Fe % s(.1)	Mg % s(.05)	Ca % s(.1)	Ti % s(.005)	Mn s(20)	Ag s(1)	As s(500)	Au s(20)	B s(20)	Ba s(50)	Be s(2)	Bi s(20)	Cd s(50)
1S	BM001AC	45-02-54	112-34-59	5	0.7	15	0.15	700	N	1000	N	150	300	L	N	N
2S	BM002AC	45-01-47	112-35-48	1.5	1	30	0.07	700	N	N	N	20	N	N	N	N
3S	BM003AC	45-01-55	112-35-21	3	1	30	0.07	500	N	N	N	30	N	N	N	N
4S	BM004AC	45-02-06	112-35-06	2	3	30	0.1	700	N	L	N	50	L	L	N	N
5S	BM006AC	45-02-32	112-38-58	3	0.15	1.5	0.1	100	N	N	N	70	N	N	N	N
6S	BM007AC	45-02-22	112-38-14	0.1	L	L	0.07	L	N	N	N	N	N	N	N	N
7S	BM008AC	45-00-03	112-32-55	7	7	7	0.5	2000	N	N	N	150	200	2	N	N
8S	BM009AC	45-58-25	112-34-27	2	10	15	0.1	300	N	N	N	150	50	L	N	N
9S	BM010AC	44-58-20	112-35-56	5	0.7	20	0.2	500	N	N	N	L	L	N	N	N
10S	BM011AC	45-01-16	112-38-29	3	1	30	0.1	1000	N	N	N	30	N	L	N	N
11S	BM012AC	45-01-24	112-38-26	1.5	0.2	10	0.07	200	N	N	N	70	N	L	N	N
12S	BM001GC	45-02-17	112-34-42	2	0.7	30	0.1	500	N	N	N	50	50	L	N	N
13S	BM002GC	45-01-41	112-34-26	5	2	30	0.15	700	N	500	N	100	150	2	N	N
14S	BM003GC	45-01-51	112-34-36	5	0.5	15	0.3	700	N	500	N	200	200	3	N	N
15S	BM004GC	45-00-35	112-34-33	5	5	20	0.7	700	N	500	N	150	70	L	N	N
16S	BM005GC	45-00-37	112-34-40	3	0.3	15	0.2	1000	N	N	N	150	200	2	N	N
17S	BM001PC	45-02-56	112-36-34	2	0.5	20	0.2	300	N	N	N	50	200	N	N	N
18S	BM002PC	45-02-25	112-36-49	1.5	0.5	30	0.1	300	N	N	N	20	L	L	N	N
19S	BM003PC	45-02-31	112-35-36	5	0.7	20	0.2	700	N	500	N	150	300	2	N	N
20S	BM004PC	45-00-44	112-35-35	1	0.7	30	0.03	300	N	N	N	L	N	N	N	N
21S	BM005PC	45-00-40	112-35-20	7	2	10	0.2	2000	N	N	N	150	500	2	N	N
22S	BM006PC	45-01-05	112-33-50	10	5	3	1	3000	N	N	N	N	200	L	N	N
23S	BM007PC	44-59-55	112-32-30	5	5	0.5	1	500	N	N	N	70	300	L	N	N
24S	BM008PC	44-59-18	112-36-25	2	2	10	0.15	700	N	N	N	50	50	N	N	N
25S	BM009PC	44-59-22	112-37-25	2	1.5	20	0.07	1000	N	N	N	20	70	N	N	N
26S	BM010PC	44-59-08	112-37-18	2	1	20	0.15	500	N	N	N	30	200	N	N	N
27S	BM011PC	45-00-55	112-37-56	2	1	30	0.07	700	N	N	N	50	L	N	N	N

Terrain corrections beyond the 175-ft radius, extending to a distance of 103 mi from each station were computed using a modification of the method of Plouff (1977) and incorporating U.S. Department of Defense terrain data digitized at a 15-second grid interval. For purposes of editing and display, gravity station locations were projected to x-y coordinates and Bouguer gravity anomaly values corresponding to these points were gridded using a minimum curvature algorithm (Webring, 1981). The gridded anomaly data were subsequently contoured using an algorithm for splining under tension (Godson and Webring, 1982) and were machine plotted.

The aeromagnetic anomaly map (fig. 4) is an enlargement of part of a map of southwestern Montana and east-central Idaho (U.S. Geological Survey, 1975) compiled from data acquired at a barometric elevation of 12,000 ft along east-west flight lines spaced approximately 2 mi apart.

Regional Geophysical Setting

The regional geophysical setting consists of gravity highs over mountainous terranes of high-grade metamorphic rocks and magnetic highs over some parts of the metamorphic rocks. Gravity lows tend to occur over surficial and basin-fill deposits of valleys, and magnetic lows or areas of low gradient are associated with the nonmagnetic rocks.

Discussion of Anomalies

The gravity anomaly map (fig. 3) is dominated by the northern and western flanks of a 20-mgal high, which conspicuously noses northwestward diagonally across the area of figure 3. Most of the curvature of this nose, and approximately 9 mgal of its 20-mgal relief, occur within the boundaries of the wilderness study area. The high is flanked on the northeast by a gravity low, much of which forms a narrow trough bordered by an ascending gradient shown in the northeastern corner of the map. The high is flanked on the west by a uniform gradient marked by north-trending contours.

The salient nose (fig. 3) is a feature of the Archean metamorphic rocks. The absence of gradients along contacts separating exposed metamorphic rocks and less dense at midpoints 1, 1.5, 2, 3, 5, 7, 10, and so forth; s, spectrographic; c, chemical; L, detected but less than determination shown in parentheses;

Co s(10)	Cr s(20)	Cu s(10)	La s(50)	Mo s(10)	Nb s(50)	Ni s(10)	Pb s(20)	Sb s(200)	Sc s(10)	Sn s(20)	Sr s(200)	V s(20)	W s(100)	Y s(20)	Zn s(500)	Zr s(20)	Th s(200)	Au c(.05)
10	50	50	N	20	N	50	20	N	N	N	300	150	N	N	N	30	N	L
N	L	L	L	N	N	10	N	N	N	N	500	L	N	N	N	N	N	L
N	30	L	N	N	N	30	L	N	N	N	500	30	N	N	N	N	N	L
N	30	10	N	N	N	15	N	N	N	N	700	50	N	N	N	L	N	0.15
N	N	100	N	N	N	15	N	N	N	N	N	30	N	N	N	100	N	N
N	N	N	N	N	N	L	N	N	N	N	N	N	N	N	N	1000	N	L
10	300	20	300	N	N	100	50	N	10	N	N	150	N	150	N	200	N	0.15
L	20	15	N	N	N	15	L	N	N	N	N	30	N	N	N	50	N	L
L	50	30	N	N	N	50	20	N	N	N	N	100	N	L	N	150	N	0.25
N	20	15	N	N	N	30	L	N	N	N	700	50	N	L	N	200	N	0.1
N	N	L	L	N	N	15	N	N	N	N	300	20	N	N	N	700	N	0.05
N	50	L	N	N	N	20	L	N	N	N	500	50	N	N	N	70	N	N
N	70	50	L	N	N	50	70	N	N	N	300	100	N	L	N	70	N	N
L	70	50	L	N	N	70	70	N	L	N	N	150	N	20	N	70	N	N
L	30	50	L	N	N	70	70	N	N	N	L	150	N	L	N	50	N	N
N	50	30	L	L	N	70	50	N	N	N	200	150	N	N	N	70	N	L
N	20	L	N	N	N	20	L	N	N	N	500	30	N	N	N	300	N	L
N	N	L	N	N	N	20	L	N	N	N	500	30	N	N	N	70	N	L
N	70	50	N	N	N	30	20	N	N	N	500	150	N	L	N	50	N	L
N	L	15	L	N	N	20	N	N	N	N	N	20	N	20	N	N	N	N
10	20	50	N	30	N	200	50	N	L	N	300	500	N	30	N	200	N	N
20	300	20	500	N	N	100	30	N	50	N	N	300	N	500	N	500	N	N
15	200	20	50	N	N	100	20	N	L	N	L	150	N	50	N	1500	N	N
N	70	10	N	N	N	10	L	N	N	N	N	20	N	N	N	50	N	L
N	30	L	L	N	N	15	N	N	N	N	700	30	N	L	N	L	N	L
N	L	50	N	N	N	20	L	N	N	N	300	30	N	N	N	300	N	0.1
N	20	L	N	N	N	20	N	N	N	N	700	30	N	N	N	N	N	L

Mesozoic and Paleozoic sedimentary rocks implies that the sedimentary rocks are underlain by metamorphic rocks at shallow depths. The uniform gradient on the western flank of the prominent nose is associated with a lateral contrast of metamorphic rocks—exposed and overlain by sedimentary rocks—with less dense rhyolitic tuffs to the west. The gradient on the northeastern flank of the nose is associated with similar metamorphic rocks—both exposed and buried—in contact with very low density alluvial and basin-fill deposits. The axis of the narrow gravity trough follows the deepest part of the basin fill (of the valley of Blacktail Deer Creek), which is parallel to the Jake Canyon fault; the gradient ascending to the northeastern corner of the map reflects the occurrence of buried and exposed metamorphic rocks. None of the regionally spaced gravity observation points appears to be influenced by scattered occurrences of high density barite.

The aeromagnetic anomaly map (fig. 4) is dominated by a continuous steep gradient marking the northern flank of paired highs in the southern quarter of figure 4. This gradient becomes much gentler in the northern part. A low-amplitude magnetic trough trends generally northeastward in the northwestern part of the figure.

The wilderness study area is situated largely in a quiet zone of otherwise active magnetic patterns and appears to be underlain at shallow depth by metamorphic rocks that are devoid of magnetic bodies of potential economic interest. The conspicuous gradient flanking the paired high-amplitude magnetic highs marks the edge of occurrences of magnetic bodies within exposed or shallowly buried metamorphic and volcanic rocks. Although the generally silicic volcanic rocks do contain minor amounts of magnetic basalt (outside wilderness study area) having field-measured susceptibilities of as much as 5×10^{-3} SI (the international system of units), the sources of the magnetic anomalies are inferred to be contained within the metamorphic-rock terrane. These bodies are most probably either iron-formation, such as that which occurs in the nearby Ruby Range, or amphibolite, which occurs in massive form in some gneissic terranes in southwestern Montana. Although ultramafic rocks and their serpentinized equivalents cannot be dismissed as possible magnetic source rocks, they ordinarily occur as bodies too small to be detected in a regional aeromagnetic survey such as used for this study. Whatever the lithologic nature of the sources, all of the magnetic bodies occur well out-

Table 4. Semiquantitative spectrographic and chemical analysis of rock samples, Blacktail Mountains study area, Beaverhead County, Montana

[N. M. Conklin, L. A. Bradley, and M. J. Malcolm, spectrographic analysts, USGS; P. H. Briggs and J. G. Crock, chemical analysts, USGS. Values are reported in the six-step classification at midpoints 1, 1.5, 2, 3, 5, 7, 10, and so forth; s, spectrographic; c, chemical; L, detected but less than limit of determination shown in parentheses; >, greater than value shown; –, not determined; all values in parts per million except Fe, Mg, Ca, and Ti]

Locality no. (plate 1)	Sample no.	Latitude deg-min-sec	Longitude deg-min-sec	Rock type	Fe % s(.05)	Mg % s(.02)	Ca % s(.05)	Ti % s(.002)	Mn s(10)	Ag s(.5)
1R	84MTz1A	45-03-06	112-37-04	barite	0.3	0.7	3	0.05	70	L
2R	84MTz1B	45-03-06	112-37-04	limestone	0.5	7	7	0.07	200	L
3R	84MTz13	45-01-08	112-36-18	sandstone	0.7	2	3	0.1	300	L
4R	84MTz18	45-02-15	112-35-07	jasperoid	1.5	0.1	0.05	0.1	100	15
5R	84MTz27	45-01-11	112-35-43	gossan	>20	0.15	0.15	0.07	100	L
6R	84MTz39	45-00-32	112-33-30	shale	3	0.3	0.07	0.3	70	L
7R	84MTz40	45-00-17	112-33-43	shale	3	3	3	0.3	200	L
8R	84MTz43	45-00-01	112-34-06	calcite in fault zone	L	0.15	>20	0.002	500	L
9R	84MTz46	45-01-00	112-33-38	amphibolite gneiss	7	5	5	0.3	1000	L
10R	84MTz47	44-59-41	112-32-12	sheared gneiss	3	0.2	3	0.15	300	L
11R	84MTz54	44-59-12	112-33-24	rhyolite tuff	0.3	3	5	0.1	150	L
12R	84MTz59	45-03-08	112-37-02	oxidized limestone breccia	3	3	0.3	0.2	200	L
13R	84MTz65	45-02-48	112-36-10	oxidized jasperoid breccia	0.7	0.7	1.5	0.05	150	L
14R	84MTz69	45-02-10	112-38-28	limonitic sandstone	2	L	L	0.02	70	L
15R	84MTz96	44-58-55	112-36-50	red siltstone	0.7	0.5	10	0.1	300	L
16R	84MTz106	45-00-05	112-33-10	amphibolite gneiss	1.5	0.2	0.7	0.15	300	L
17R	84MTz126	45-03-10	112-37-13	limestone	0.7	1.5	>20	0.03	500	L
18R	84MTz127	45-03-16	112-37-20	barite	1.5	10	15	0.003	3000	L
19R	84MTz138	44-58-44	112-31-53	oxidized gneiss	3	1.5	1.5	0.07	200	L
20R	84MTz140	44-58-36	112-32-09	oxidized gneiss	0.7	0.05	0.15	0.15	70	L
21R	84MTz178	45-00-43	112-33-10	oxidized gneiss	5	0.15	0.15	0.15	300	L
22R	84MTz181	45-00-54	112-33-21	oxidized gneiss	15	0.1	L	0.15	700	L
23R	85MTz427	45-02-27	112-35-43	gossan	L	0.15	0.03	50	L	5000
24R	85MTz614	45-00-21	112-36-00	oxidized intrusive	2	0.07	7	0.03	150	L
25R	85MTz615	45-00-50	112-36-06	red siltstone	0.7	1.5	3	0.03	100	L
26R	BM005AR	45-02-15	112-35-11	calcite	0.3	0.05	0.15	0.03	15	20

Locality no. (plate 1)	As s(700)	Au s(15)	B s(10)	Ba s(30)	Be s(1)	Bi s(10)	Cd s(30)	Co s(5)	Cr s(10)	Cu s(5)	La s(30)	Mo s(5)	Nb s(20)	Ni s(5)	Pb s(10)	Sb s(100)
1R	L	L	L	>5000	L	L	L	L	L	L	L	L	10	L	L	L
2R	L	L	L	2000	L	L	L	L	30	5	L	L	L	5	L	L
3R	L	L	L	300	L	L	L	L	70	7	L	L	L	5	10	L
4R	L	L	L	>5000	L	L	L	L	15	1500	50	L	L	10	300	L
5R	700	L	L	1000	L	L	L	15	30	20	L	L	L	150	10	L
6R	L	L	70	1000	L	L	L	7	70	15	50	L	L	30	10	L
7R	L	L	150	500	3	L	L	15	100	30	70	L	L	30	15	L
8R	L	L	20	L	L	L	L	L	L	L	L	L	L	L	L	L
9R	L	L	L	500	1	L	L	50	300	70	L	L	L	100	L	L
10R	L	L	L	500	1	L	L	7	50	7	L	L	L	70	L	L
11R	L	L	L	30	L	L	L	L	20	20	30	L	L	7	30	L
12R	L	L	L	150	L	L	L	15	30	20	L	L	L	20	L	L
13R	L	L	L	50	L	L	L	L	200	70	L	L	L	10	L	L
14R	L	L	L	70	L	L	L	L	L	5	L	L	L	5	L	L
15R	L	L	L	150	L	L	L	L	20	7	L	L	L	5	10	L
16R	L	L	L	3000	1	L	L	L	L	7	L	L	L	L	30	L
17R	L	L	L	3000	L	L	L	10	30	7	L	L	L	30	L	L
18R	L	L	L	L	L	L	L	L	L	L	L	L	L	7	L	L
19R	2000	L	10	1500	1.5	L	L	15	1500	7	L	L	L	150	L	L
20R	L	L	L	1000	1	L	L	L	15	15	70	L	L	10	L	L
21R	L	L	15	1000	3	L	L	15	70	15	L	L	20	70	30	L
22R	L	L	L	70	1.5	L	L	20	150	30	L	L	L	70	15	L
23R	L	L		100	2	L	L	100	30	200	L	L	L	100	L	L
24R	L	L	L	100	L	L	L	L	15	15	L	L	L	15	10	L
25R	L	L	L	70	L	L	L	L	10	L	L	L	L	7	L	L
26R	L	L	L	>5000	L	L	L	5	10	20000	L	L	L	L	30	L

Table 4. Semiquantitative spectrographic and chemical analysis of rock samples, Blacktail Mountains study area, Beaverhead County, Montana—Continued

Locality no. (plate 1)	Sc s(5)	Sn s(10)	Sr s(100)	V s(10)	W s(50)	Y s(10)	Zn s(200)	Zr s(10)	Th s(200)	As c(.5)	Bi c(2)	Cd c(.1)	Sb c(2)	Zn c(2)	Au c(.1)
1R	L	L	7000	15	L	10	L	30	L	61	9	0.3	2	150	L
2R	L	L	150	15	L	10	L	100	L	75	4	0.2	8	6	L
3R	L	L	150	20	L	15	L	70	L	8	2	0.4	5	16	L
4R	L	L	500	15	L	20	L	50	L	77	L	L	13	23	L
5R	5	L	150	70	L	10	500	20	L	778	L	5.4	L	201	L
6R	7	L	200	50	L	20	L	300	L	15	L	0.2	L	27	L
7R	20	L	300	150	L	10	L	70	L	46	L	0.3	5	9	L
8R	L	L	150	30	L	10	L	L	L	7	L	L	L	L	L
9R	50	L	300	200	L	15	L	70	L	L	L	0.1	2	17	L
10R	7	L	150	50	L	L	L	20	L	L	L	0.5	L	26	L
11R	L	L	150	30	L	L	L	30	L	28	L	0.2	10	L	L
12R	20	L	50	150	L	L	L	30	L	L	L	0.9	6	15	L
13R	L	L	30	20	L	L	L	20	L	20	L	0.2	L	25	L
14R	L	L	30	10	L	L	700	20	L	117	L	0.4	L	216	L
15R	L	L	30	15	L	L	L	100	L	L	L	0.2	L	8	L
16R	5	L	300	15	L	15	L	30	L	L	L	0.2	L	35	L
17R	L	L	300	30	L	20	L	30	L	219	L	0.5	L	66	L
18R	L	L	L	10	L	L	L	L	L	58	L	0.4	12	8	L
19R	5	L	L	30	L	L	300	15	L	1540	2	0.3	69	19	L
20R	5	L	150	15	L	30	L	200	L	167	L	L	6	4	L
21R	15	L	150	70	L	50	L	150	L	8	L	L	L	23	L
22R	10	30	150	100	L	L	L	50	L	52	5	2.7	L	83	L
23R	7	L	300	50	L	15	1000	15	L	8300	L	4.7	2	500	–
24R	L	L	L	20	L	L	L	70	L	1300	L	2.4	6	45	–
25R	L	L	L	10	L	L	L	70	L	5	L	0.5	7	14	–
26R	L	L	700	10	L	20	L	70	L	160	L	L	20	6	–

side the boundaries of the wilderness study area. A low-amplitude magnetic trough in the northwestern part of figure 4 represents a residual low. The southern flank of a magnetic high in the extreme northwestern corner of the map area probably has a source in buried metamorphic rocks. The region of the residual low thus expresses relatively nonmagnetic rock terrane.

Mineral and Energy Resources

Fault-controlled Mineral Deposits

The model (hydrothermal mineral deposits).—Gossan of hydrothermal origin occurs proximate to the Jake Canyon fault along the northeast flank of the Blacktail Mountains. Samples of the gossan contain elevated concentrations of copper, lead, zinc, chromium, nickel, barium, arsenic and, at the Noble Mine (loc. 4P, pl. 1) immediately outside the wilderness study area, silver. Silver and (or) gold were detected in samples from a few prospects within the wilderness study area. The Noble reportedly produced silver-bearing ore, but no production records were found; the figures given by Geach (1972, p. 159) for the Nevada mine likely represent ore shipped from the Silver Queen mine 3 mi southeast of the boundary of the wilderness study area (table 1). Rock samples collected from the Noble mine contain 0.1 to 1.0 oz of silver per ton, 0.1 to 1.3 percent copper, and less than 1 to 140 parts per million (ppm) zinc (table 1, this report; Benham, 1986).

The Noble mine occurs along the trace of the Jake Canyon fault. Although talus and alluvial deposits conceal the surface exposures in the mine area, samples from the mine workings show that at least some of the mineralized rock is jasperoid. Jasperoid masses are present locally along the trace of the fault, both within the wilderness study area and to the southeast. The Silver Queen mine, for example, is closely associated with a mass of jasperoid that is several tens of feet thick and about 1 mi long. It dips about 40° eastward (about the same inclination as the fault) and is adjacent to the fault on the north. Jasperoid masses show that movement along the zone of the Jake Canyon fault continued after the jasperoid started to form because the jasperoid is fractured and sulfide mineralization took place along the fractures.

The gossan, jasperoid, barite, and other evidence of mineralized rock in the vicinity of the wilderness study

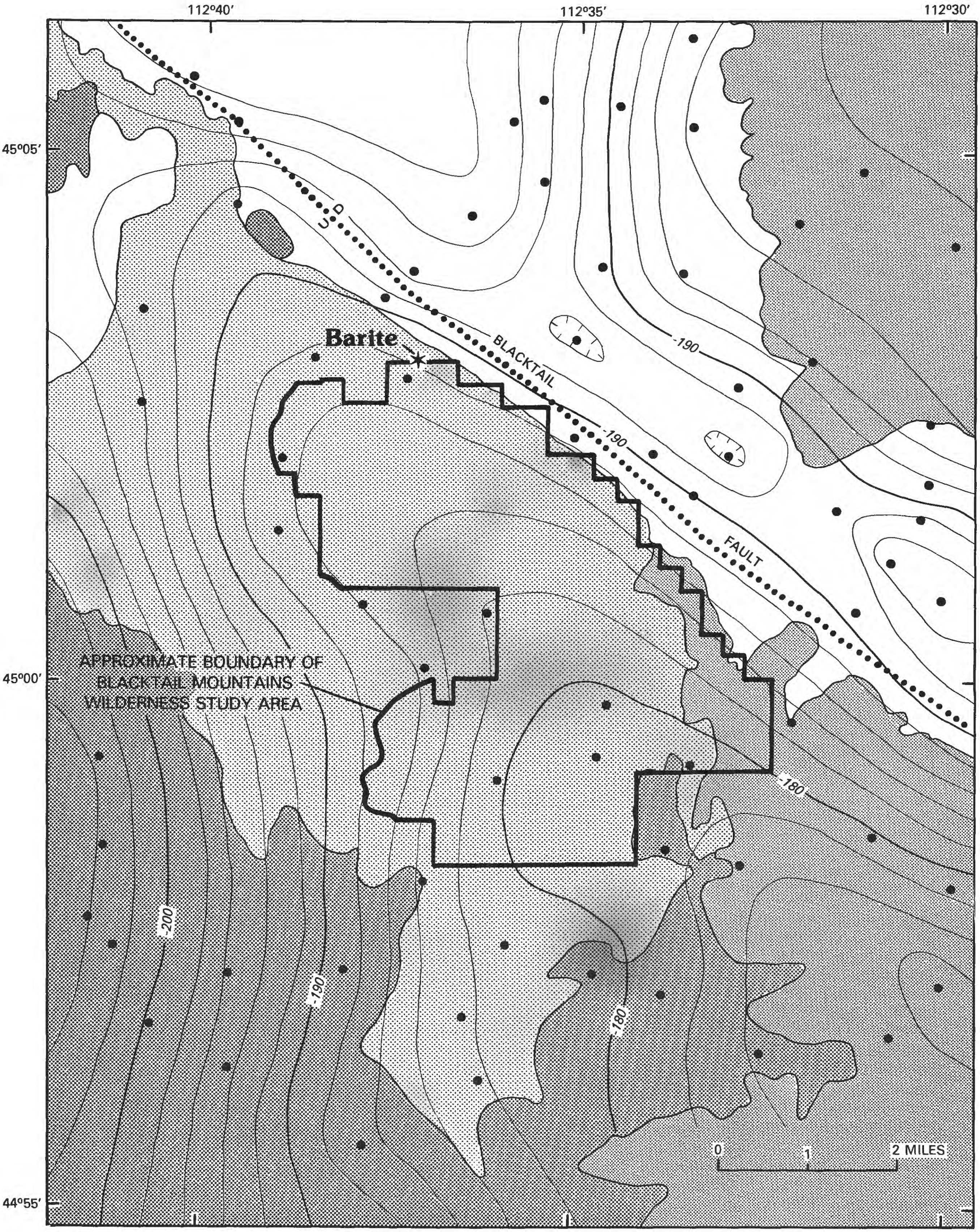


Figure 3 (above and facing page). Complete Bouguer gravity anomaly map and generalized geologic setting in the vicinity of the Blacktail Mountains study area.

EXPLANATION

-190 **Gravity contours**—Contour interval, 2 milligals; hachures indicate depression; dots show location of measurement stations

Contact

U D **Normal fault, concealed**—D, downthrown side; U, upthrown side

Area of identified barite resources

Quaternary and Tertiary basin deposits

Tertiary volcanic rocks

Mesozoic and Paleozoic sedimentary rocks

Archean metamorphic rocks

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area probably formed from hydrothermal fluids that circulated through the fractured and brecciated rock associated with the Jake Canyon fault. The source of the fluids is unknown, but the formation of jasperoid and local deposition of ore minerals suggests that the mineralizing fluids may have been tapped during an episode of extensional deformation, either after down-to-the-basin faulting along the Jake Canyon fault or later during development of the Blacktail fault. The fluids presumably moved up the extension-generated fault(s) and spread into brecciated Archean rocks of the hanging wall of the Jake Canyon fault. Some of the fluid probably flowed into fractured Paleozoic strata immediately beneath (west of) the Jake Canyon fault. Within the wilderness study area, rocks that may have been mineralized by this process are preserved mainly near the Jake Canyon fault along the northeast boundary of the wilderness study area.

The pre-erosion plane of the northeastward-dipping Jake Canyon fault projects over Paleozoic rocks of the wilderness study area, as shown on cross section *A–A'* of plate 1. Beneath the plane existed a minor volume of shale and porous Paleozoic sandstone, as well as carbonate strata fractured during movement along the Jake Canyon fault and older west-dipping thrust faults. Most of the porous rocks that may have been mineralized by hydrothermal fluids seeping beneath (southwest of) the Jake Canyon fault apparently have been eroded. In the interior of the wilderness study area, the few rock samples that show somewhat elevated elemental concentrations are probably remnants of mineralized rock formed by this process. The rock sample of locality 5R (pl. 1; sample no. 84MTz27, table 4), for example, is from the porous Mississippian Kibbey Sandstone; this mineralized rock probably was deposited from fluids that moved upward along the Jake Canyon fault and then seeped laterally along the sandstone unit. In a similar manner, the isolated occurrence of arsenic and zinc at locality 14R (pl. 1; sample no. 84MTz69, table 4) may reflect seepage of fluids into the porous, poorly cemented quartz sandstone of the Pennsylvanian Quadrant Sandstone.

Resource potential.—The northeastern margin of the wilderness study area is considered to have a moderate mineral resource potential for silver and barite, and associated copper, lead, zinc, and gold. Areas of moderate potential have most or all of the following characteristics: (1) hydrothermally altered rock, denoted chiefly by gossan, but also including jasperoid that replaced Archean gneiss; (2) within or immediately associated with the Jake Canyon fault; (3) proximate to normal fault(s) of the basin-and-range fault system; and (4) elevated concentrations of elements in stream-sediment, heavy-mineral concentrate, and rock samples.

Assignment of moderate resource potential for silver, copper, lead, zinc, gold and barite in the study area is made with a certainty level of C: available data give a good indication of potential. More detailed geochemical sampling of rocks, alluvium, and soils, and perhaps drilling or trenching along talus- and alluvium-covered slopes at the northeastern margin of the wilderness study area would be required to define identified resources. A pattern is used on plate 1 to show where alluvium covers bedrock that is judged to have moderate potential for mineral deposits.

The remainder of the wilderness study area is judged to have a low potential for silver, copper, lead, zinc, gold, and barite deposits: the certainty level is rated C. The remainder of the study area is not close to the faults of the range front and generally lacks elevated values of elements that characterize the area of moderate resource potential.

Other Mineral Resources

No phosphate resources exist in the wilderness study area. The Permian Phosphoria Formation was eroded from the area, and its nearest outcrop is about 0.5 mi to the west.

Gold is widespread in small units of Archean metamorphic rocks in nearby ranges, but none was detected in stream-sediment or heavy-mineral concentrate samples from streams that cross Archean metamorphic rocks of the wilderness study area. Nickel-bearing metamorphosed Archean ultramafic rocks were reported to occur in Jake Canyon about 2 mi south of the wilderness study area (Sinkler, 1942; Heinrich, 1960). The sill-like Archean ultramafic body is about 1,800 ft long and 60 ft wide and according to Sinkler (1942, p. 137) is reputed to contain up to 2 percent nickel and a trace of platinum. Other small Archean ultramafic pods are present in the Jake Canyon area, but none were found in, or immediately adjacent to, the wilderness study area.

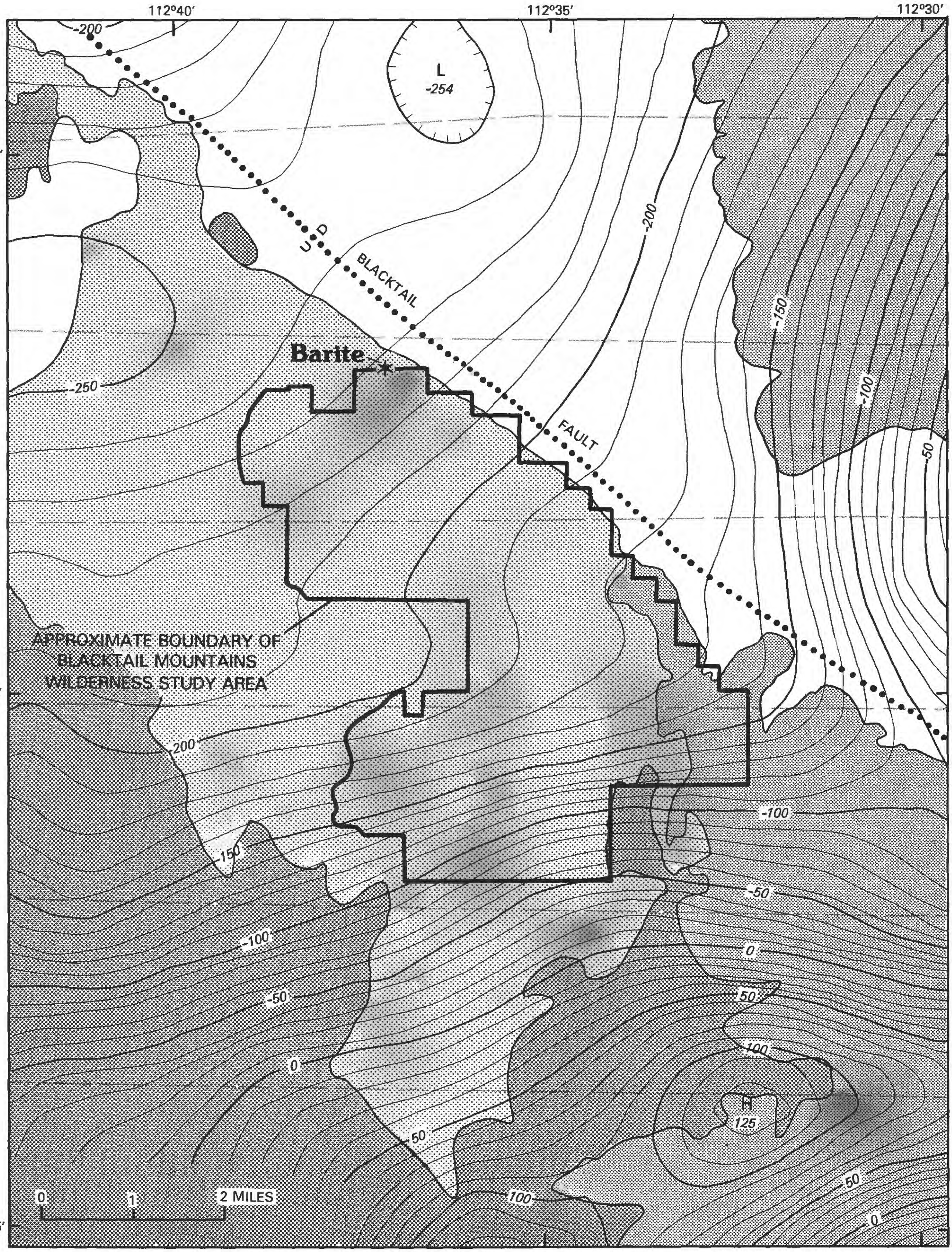

Figure 4 (above and facing page). Map showing aeromagnetic anomalies and generalized geologic setting in the vicinity of the Blacktail Mountains study area.

EXPLANATION

Magnetic contours—Contour interval, 10 gammas; hachures indicate depression; dashed lines show flight paths of airborne survey. H, area of magnetic high and value in gammas; L, area of magnetic low and value in gammas

Contact

Normal fault, concealed—D, downthrown side; U, upthrown side

Area of identified barite resources

Quaternary and Tertiary basin deposits

Tertiary volcanic rocks

Mesozoic and Paleozoic sedimentary rocks

Archean metamorphic rocks

A low mineral resource potential for gold in metamorphic rocks, and nickel and platinum in metamorphosed ultramafic rocks, is assigned to the area of exposed Archean rocks; the certainty level is rated C: available data give a good indication of mineral resource potential.

In the part of the wilderness study area where metamorphic terrane is concealed by Mesozoic and (or) Paleozoic sedimentary strata, the mineral resource potential for gold in metamorphic rocks, and platinum and nickel in metamorphosed ultramafic rocks, is rated as unknown, with a certainty level of A: available information is not adequate for determination of the level of mineral resource potential. Stream-sediment and heavy-mineral concentrate samples are not useful for detection of elements in the concealed metamorphic rocks, and it is unknown if metamorphosed ultramafic rocks like those southeast of the study area lie concealed beneath sedimentary strata of the study area.

Several miles northwest of the study area, sandstone of the Quadrant Sandstone was quarried in recent years and used as road metal. The sandstone at the quarry is near several faults of the range front and has undergone deformation that caused silica to be mobilized and reprecipitated, thus creating a very well cemented sandstone or quartzite. Quadrant sandstone of the wilderness study area generally is not well cemented, is not adjacent to the range front system of faults, and tends to break down into sand grains upon extensive weathering. The potential for quartzite with the properties of that at the road metal quarry northwest of the study area is low, with a certainty level of C: available information gives a good indication of the resource potential.

Energy Resources

A seam of bituminous coal, about 1 ft thick, occurs locally in the Mississippian Lombard Limestone (loc. 9P, pl. 1); a few hundred feet of the coal seam apparently was mined by hand during the early part of the century and used for local consumption (Pecora, 1981, p. 84; John Conover, rancher, oral commun., 1984). The coal bed occurs only locally; is not of high quality; and is 12 in. or less in thickness, which is less than the minimum thickness needed for coal resource calculations (Wood and others, 1983, p. 31). The coal commonly is associated with thrust faults and landslide deposits. The hand-mined coal was from a slide-block at the head of a landslide.

Uranium potential of the area was evaluated by the U.S. Department of Energy during the National Uranium Resource Evaluation (NURE) program, and the area was not classified as favorable for uranium deposits (Wodzicki and Krason, 1981a, b). As part of this program, Broxton (1978; 1979) and LaDelfe (1980) reported no anomalous concentrations of uranium in stream-sediment or stream-water samples from the wilderness study area. The resource potential for uranium is rated as low, with a certainty level of C: available information gives a good indication of the resource potential.

The study area lies within a region that Perry and others (1983a, p. G17) assigned a medium oil potential, and a medium to high gas potential. These ratings are believed to be approximately equivalent to the Goudarzi (1984) classification of "moderate" and "moderate" or "high" potential. The assignment took cognizance of possible source rocks and structural traps associated with thrust faults; Perry and others (1983b) discussed the petroleum potential in more detail within a regional structural setting. Upon a reconsideration of the potential within the region, Perry (oral commun., 1986) assigned a medium potential to both oil and gas. In 1901, three claims were filed for gilsonite (a black, shiny, solidified hydrocarbon) within the study area (loc. 5P, pl. 1), as noted in the USBM section of this report. The USBM had a sample analyzed from the claim workings, but no gilsonite was detected (table 1). The country rock near the claims is shale of the Mississippian and Devonian Three Forks Formation. The shale had a petroliferous odor when freshly broken, a common occurrence for some Three Forks strata and for the underlying Devonian Jefferson Formation in southwestern Montana. The entire area is rated as having a moderate oil potential and a moderate gas potential, each with a certainty level of B: available information suggests the level of resource potential. Seismic exploration and drilling would be required to assign a higher level of certainty. The assignment is made for the entire wilderness study area, not just the area of sedimentary strata, because it is possible that the Blacktail Mountains could be underlain by a thrust fault, thus could overlie potential host rocks for hydrocarbon deposits.

The study area lies about 6 mi southeast of the Lovell–Brown Hot Springs, a known geothermal resource area (KGRA) (fig. 1). The springs are of the low-temperature variety (less than 90 °C), containing geothermal water that ranges from 19 °C to 24 °C (Sammel, 1979, p. 112–113; Sonderegger and Bergantino, 1981). The hot springs occur along the Blacktail fault, a basin-margin fault that cuts into the crust and serves as a conduit for ground water that migrates upward. These waters contain dissolved calcium carbonate, which has precipitated at the ground surface to form tufa deposits.

No hot springs or tufa deposits of former hot springs occur within the study area. The Blacktail fault occurs along the northeast side of the wilderness study area, lying immediately outside the boundary. It is concealed by Quaternary alluvium, although seepage of ground water locally marks its trace. The resource potential for low-temperature (less than 90 °C) geothermal water like that of the Lovell–Brown Hot Springs is rated as low, estimated with a certainty level of B: available information suggests the level of resource potential. The Blacktail fault shows no evidence of movement within historical time, but were it to become active, heated ground water possibly could be tapped, leading to thermal springs along its trace.

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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

<table>
<tr><td rowspan="4">LEVEL OF RESOURCE POTENTIAL →</td><td rowspan="4">U/A
UNKNOWN POTENTIAL</td><td>H/B
HIGH POTENTIAL</td><td>H/C
HIGH POTENTIAL</td><td>H/D
HIGH POTENTIAL</td></tr>
<tr><td>M/B
MODERATE POTENTIAL</td><td>M/C
MODERATE POTENTIAL</td><td>M/D
MODERATE POTENTIAL</td></tr>
<tr><td rowspan="2">L/B
LOW POTENTIAL</td><td rowspan="2">L/C
LOW POTENTIAL</td><td>L/D
LOW POTENTIAL</td></tr>
<tr><td>N/D
NO POTENTIAL</td></tr>
<tr><td></td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
</table>

LEVEL 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.

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RESOURCE / RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	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 by the U. S. Geological Survey, 1986

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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