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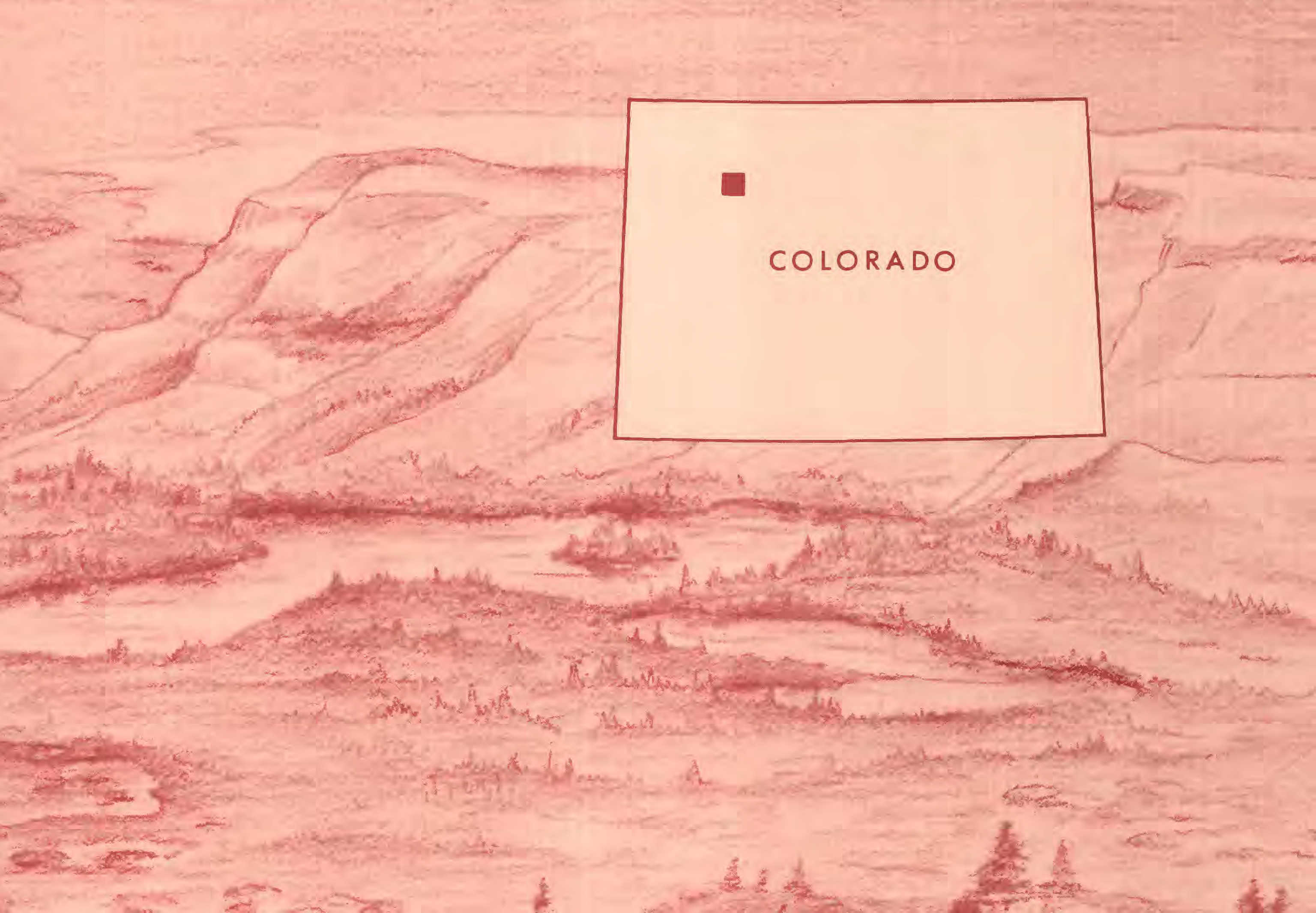
Mineral Resources of the Bull Gulch Wilderness Study Area, Eagle County, Colorado

U.S. GEOLOGICAL SURVEY BULLETIN 1717–C



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.

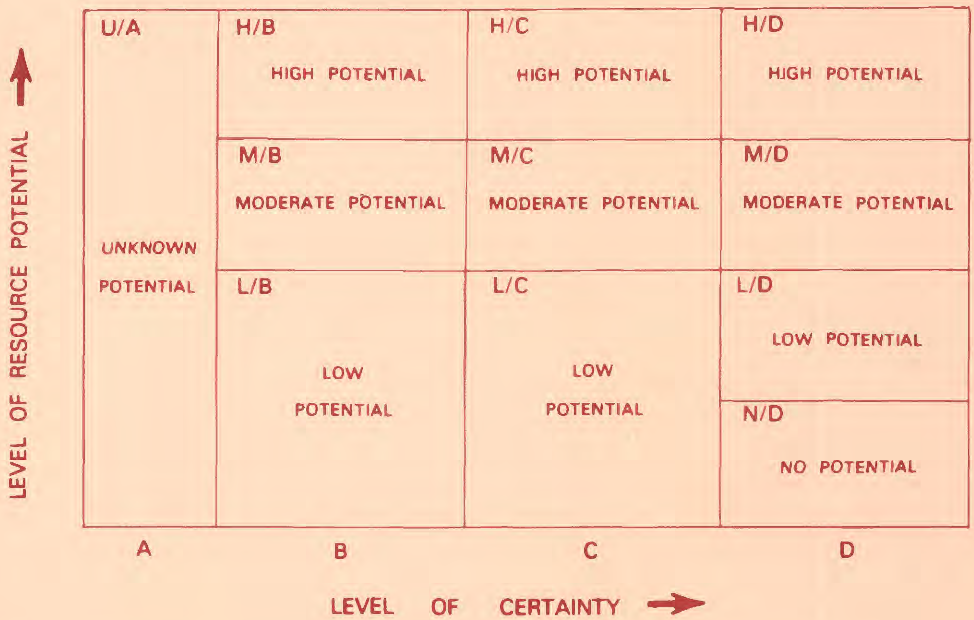
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application 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:

Taylor, R. B., and Steven, T. A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268–1270.

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–0787, p. 7, 8.

Chapter C

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
NORTH-CENTRAL COLORADO

Mineral Resources of the Bull Gulch Wilderness Study Area, Eagle County, Colorado

By Sandra J. Soulliere, Mark A. Arnold,
Jerry R. Hassemer, and Ronny A. Martin
U.S. Geological Survey and

Steven E. Kluender and Jeanne E. Zelten
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1717–C

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1986

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

Library of Congress Cataloging in Publication Data

Mineral resources of the Bull Gulch Wilderness Study Area, Eagle County, Colorado.
(Mineral resources of wilderness study areas—north-central Colorado ; ch. C) (U.S. Geological Survey bulletin ; 1717–C)
Bibliography: p.
Supt. of Docs. No.: I 19.3:1717–C
1. Mines and mineral resources—Colorado—Bull Gulch Wilderness. 2. Geology—Colorado—Bull Gulch Wilderness. 3. Bull Gulch Wilderness (Colo.)
I. Soulliere, Sandra J. II. Series. III. Series: U.S. Geological Survey bulletin ; 1717–C.
QE75.B9 no. 1717–C 557.3 s 86–600383
[TN24.C6] [553'.09788'44]

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 Bull Gulch (CO-070–430) Wilderness Study Area, Eagle County, Colorado.

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.

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Mineral Resources of the Bull Gulch Wilderness Study Area, Eagle County, Colorado

By Sandra J. Soulliere, Mark A. Arnold,
Jerry R. Hassemer, *and* Ronny A. Martin
U.S. Geological Survey *and*
Steven E. Kluender *and* Jeanne E. Zelten
U.S. Bureau of Mines

SUMMARY

The USGS (U.S. Geological Survey) and the USBM (U.S. Bureau of Mines) studied 10,414 acres of the Bull Gulch (CO–070–430) Wilderness Study Area in Eagle County, Colorado. The area has identified, minable sand and gravel deposits; there are no other identified resources. It has moderate mineral resource potential for gypsum and anhydrite, and low potential for all metals, including uranium, coal, oil and gas, and geothermal resources (fig. 1).

Intermittent streams drain the study area and flow into the Colorado River, which forms part of the western boundary. Elevations range from 6,400 ft (feet) along the Colorado River to nearly 10,000 ft along the eastern boundary. Eagle County Road 301, an unpaved road that parallels the Colorado River between Dotsero and Burns, provides access. The prominent cliffs and incised gulches that characterize the topography of the study area are the result of the erosion of the mostly flat lying Pennsylvanian through Cretaceous (see geologic time chart at end of this report) sedimentary rocks. A large breccia pipe (Tertiary?) at Jack Flats intrudes the sedimentary rocks and contains clasts of Proterozoic and Paleozoic formations from the surrounding region. Evaporitic rocks crop out to the south and west and may extend below the surface of the study area. Geologic structure is characterized by a gently dipping anticline and two synclines, all of which trend to the northeast. Two faults terminate at or near the southern edge of the study area.

No mines, prospects, patented mining claims, or mineral leases are in the study area, nor is the study area a part of any recognized mining district. Almost the entire study area is covered by oil and gas leases. An exploration well drilled 0.75 mi (mile) east of the study area was dry and abandoned. Placer gold has been mined to the north and west, but there is no record of gold occurrences within the study area. Uranium prospecting in the Morrison Formation has been conducted in and near the study area, but no uranium discovery has been reported. Sand, gravel, and industrial rock resources exist in the study area; however, sufficient quantities are available elsewhere to satisfy current local needs.

To the south and west of the study area, the Middle and Upper Pennsylvanian Eagle Valley Formation (also called Eagle Valley Evaporite at some localities) contains gypsum and anhydrite. This formation probably extends beneath the surface into the study area. The Eagle Valley intertongues with the upper part of the Belden (Lower and Middle Pennsylvanian), Minturn (Middle Pennsylvanian), and Maroon (Middle and Upper Pennsylvanian and Permian) Formations. The mineral resource potential for gypsum and anhydrite is moderate in the southwestern part of the study area.

A geochemical survey identified anomalous amounts of lead, zinc, molybdenum, silver, barium, and copper in some stream-sediment and rock samples, but no source (or parent) metallic minerals were identified in hand specimens. A few small gold flakes were identified by hand lens in some panned-concentrate samples taken from sediments along the Colorado River. Gold was not present in any of the samples from the tributary streams that drain the study area, however, indicating that the outcropping rocks of the study area are not the source of the gold. Data from the geochemical survey suggest that the anomalous concentrations may be the result of low-temperature processes similar to those that form stratabound mineral deposits. The anomalous concentrations are confined to samples taken from streams that drain the Minturn Formation. However, the data do not exclude a hydrothermal (higher temperature) origin,

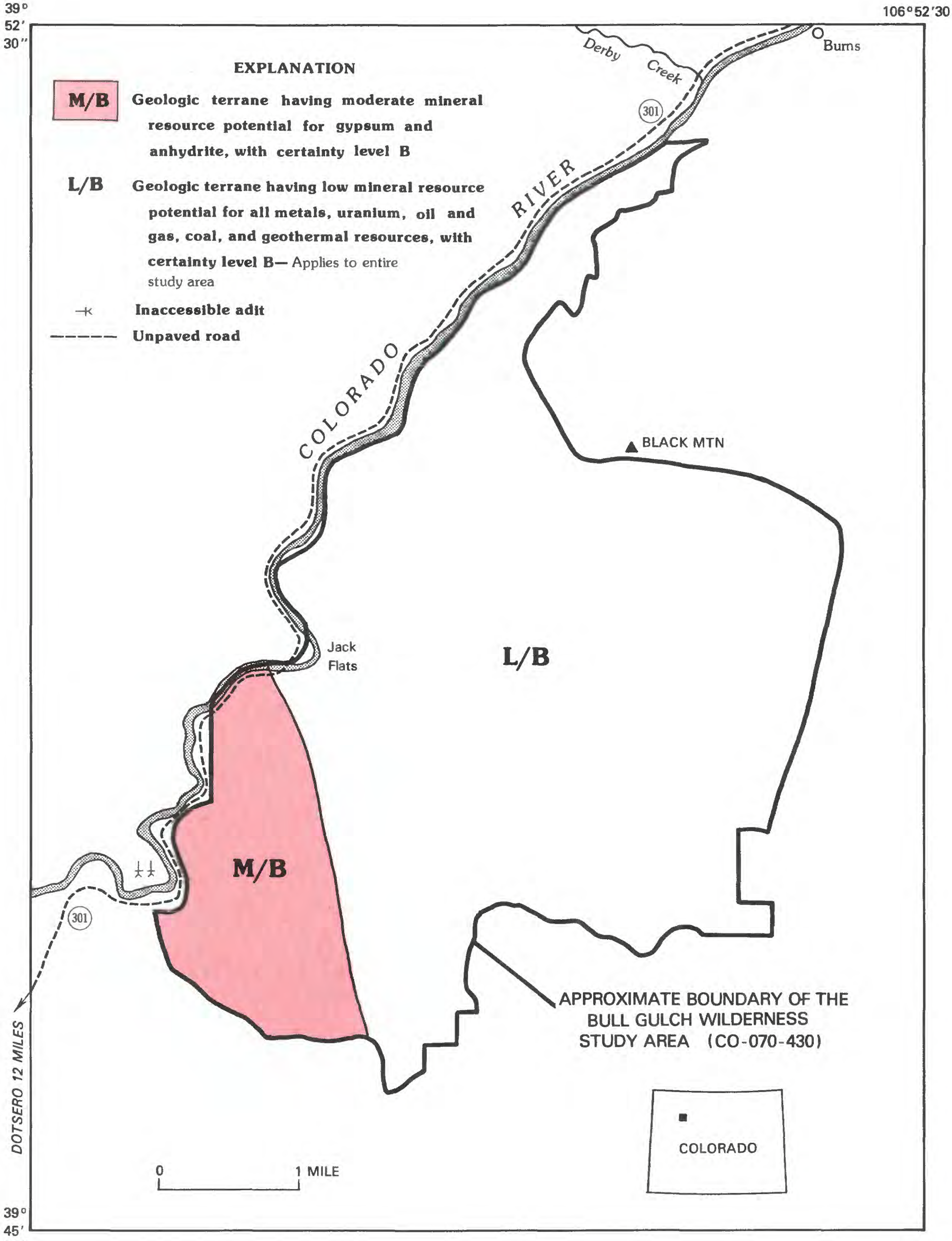

Figure 1. Mineral resource potential map of the Bull Gulch Wilderness Study Area, Eagle County, Colorado.

which is suggested by the presence of the Jack Flats breccia pipe and a rhyolite dike. Lead, zinc, molybdenum, copper, and silver may occur at depth in association with the Jack Flats breccia pipe. Regardless of the origin, the mineralizing processes probably operated only weakly in the vicinity of the study area. The processes were sufficient to cause anomalous concentrations but insufficient to create a deposit, and the mineral resource potential is low for all metals.

The Upper Jurassic Morrison Formation is present in the study area and is a favorable host rock for uranium elsewhere in Colorado. However, no uranium minerals were identified at the surface of the study area, and uranium was not detected in samples taken for geochemical analyses. The mineral resource potential for uranium is low. Geophysical data indicate that the subsurface geology consists of a thick sequence of sedimentary rocks. Some of these formations may be favorable reservoirs for oil and gas. However, the potential for oil and gas is low, and the presence of hydrocarbons in these sedimentary rocks is untested. More information is needed regarding the hydrocarbon content of the sedimentary rocks and the presence of subsurface structures as possible traps. The Belden Formation may contain beds of coaly shale beneath the study area, but the potential for coal resources is low. Thin coal beds in the Belden outside the study area are discontinuous. There is no evidence of geothermal activity in the study area; the potential is low for geothermal resources.

INTRODUCTION

The USGS and the USBM studied 10,414 acres of the Bull Gulch Wilderness Study Area (CO–070–430). The study of this acreage was requested by the BLM (U.S. Bureau of Land Management). In this report the studied area is called the "wilderness study area" or simply the "study area". The Bull Gulch Wilderness Study Area is 1.2 mi southwest of Burns (fig. 1), along the east side of the Colorado River in Eagle County, Colorado. Deeply incised gulches and canyons characterize the rugged topography. Elevations range from 6,400 ft along the Colorado River, which forms the western boundary, to nearly 10,000 ft along the eastern boundary. Intermittent streams drain the study area and flow into the Colorado River. Eagle County Road 301, an unpaved road that parallels the Colorado River between Dotsero and Burns, provides access (fig. 1).

Investigations by the U.S. Bureau of Mines

Prior to field investigation in 1983, USBM geologists reviewed published and unpublished literature for minerals information regarding the Bull Gulch Wilderness Study Area. Local residents and personnel from the USBM and the BLM were interviewed regarding minerals in the area. BLM and county records were examined for locations of mining claims and mineral leases in and near the study area. A 7-day field examination of the study area and its immediate surroundings was made in October 1983 by two USBM geologists.

Investigations by the U.S. Geological Survey

The USGS reviewed published and unpublished information about the region, field mapped and compiled the geology of the study area, collected stream-sediment and rock samples for geochemical analyses, and reviewed aeromagnetic data from a regional geophysical survey. Using this information, the mineral resource potential of the study area was assessed and classified according to the system of Goudarzi (1984; see inside front cover of this report).

APPRAISAL OF IDENTIFIED RESOURCES

By Steven E. Kluender and Jeanne E. Zelten
U.S. Bureau of Mines

No mineral resources have been identified in the Bull Gulch Wilderness Study Area (see resource/reserve classification chart on p. IV of this report), and mining and prospecting have been minimal. A breccia pipe is exposed in the western side of the study area. A gypsum pod occurs in the Eagle Valley Evaporite west of the study area. Uranium is present in the Morrison Formation outside the study area. Sand and gravel are present throughout the study area.

No mines, prospects, patented mining claims, or mineral leases are in the Bull Gulch Wilderness Study Area, nor is it a part of any recognized mining district. As of September 1984, BLM files showed six unpatented lode mining claims within 2 mi of the northernmost part of the study area, and five unpatented placer claims within 2 mi of the southwestern part of the study area. A block of patented claims is within 2 mi of the southern boundary (pl. 1). Since the early 1900's, small-scale gold-placer mining has occurred sporadically along the Colorado River to the north and west, and along Derby Creek to the north. No production records are available for the placers. There is no record of gold occurrences or of production from the study area. Two inaccessible adits are in a gypsum pod about 0.5 mi west of the study area. Uranium prospecting in and near the study area did not result in a uranium discovery. Almost the entire study area is covered by oil and gas leases (fig. 2). An exploration well drilled during 1955–56 by the California Co., 0.75 mi east of the area, was dry and abandoned (pl. 1).

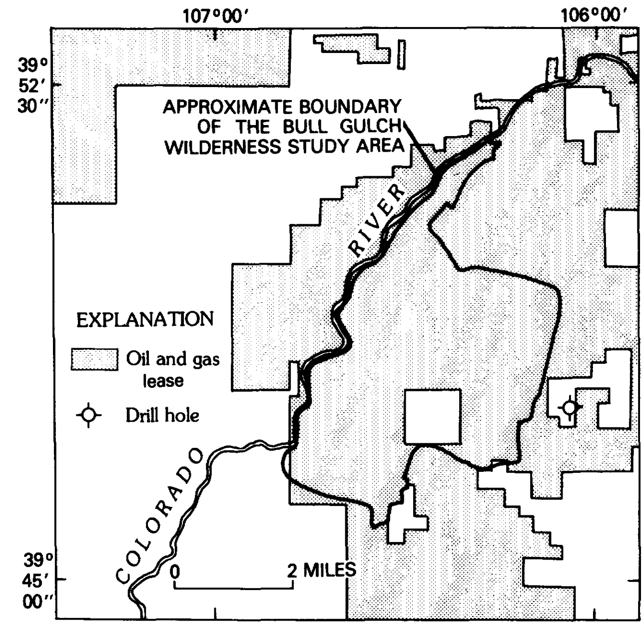

Figure 2. Oil and gas lease map of the Bull Gulch Wilderness Study Area, Eagle County, Colorado. Oil and gas lease data from U.S. Bureau of Land Management, September 1984.

A Tertiary(?) breccia pipe, exposed near Jack Flats on the western side of the study area, exhibits some of the characteristics of stockwork molybdenum deposits. Tweto and others (1978) mapped the structure as a rhyolite plug, but Schneider (1980) described the structure as a zoned intrusive breccia pipe. Stockwork molybdenum deposits typically occur in hydrothermally altered rock in or adjacent to such porphyritic intrusives. The breccia pipe is about 30 mi west of the Colorado mineral belt, an area of known stockwork molybdenum deposits. The pipe is somewhat similar to these deposits in structure and composition, but fluorite, copper, and other minerals characteristically associated with these molybdenum deposits were not identified in surface materials in or around the pipe.

Gypsum occurs as discontinuous pods and lenses in the Eagle Valley Evaporite outside the study area. A lenticular 60-ft-thick by 150-ft-long gypsum pod in the Eagle Valley Evaporite is exposed in a cliff face about 0.5 mi west of the study area (Kluender and Zelten, 1985). Two now-inaccessible adits were driven into the gypsum (fig. 1). No production has been recorded from these adits. Exploratory drilling would be necessary to locate possible gypsum deposits and their distribution in the Eagle Valley Evaporite beneath the study area.

The Morrison Formation, exposed along the northern and eastern boundaries of the study area, has been the source of about 85 percent of the uranium mined in Colorado, mostly in the Colorado Plateaus physiographic province (U.S. Senate Committee on Interior and Insular Affairs, 1968). Uranium prospecting in the Morrison in and around the study area has not resulted in a uranium discovery. Local residents report that uranium prospecting was done along the southwest slope of Black Mountain in the northern part of the study area. No uranium workings and no surface evidence of uranium minerals were noted on Black Mountain during the USBM field investigation. Scintillometer readings, taken by the USBM along traverses of Black Mountain, showed background-level radiometric values. The reported prospects could be covered by talus because the ground surface is steep and the bedrock is highly fractured in this area.

Sand, gravel, and industrial rock resources exist in the study area. Almost the entire surface of the area is composed of sandstone. Sand and gravel are found in drainages and along the Colorado River, and talus covers the southeast corner of the study area. Unless there is a local demand for sand and gravel, these resources will probably not be developed. Sufficient quantities of sand and gravel are available elsewhere to satisfy current local needs.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Sandra J. Soulliere, Mark A. Arnold, Jerry R. Hassemer, and Ronny A. Martin
U.S. Geological Survey

Geology

Geologic Setting

The Bull Gulch Wilderness Study Area is in the Southern Rocky Mountains physiographic province. The cliffs, canyons, and gulches that characterize the study area are cut in gently dipping to broadly folded sedimentary rocks of Pennsylvanian to Cretaceous age. At Jack Flats, a large oval breccia pipe intrudes the sedimentary rocks (pl. 1). Alluvial sand and gravel deposits and landslide deposits cover parts of the study area.

The geologic structure of the southern half of the study area is characterized by a gently dipping anticline and two synclines, all of which trend and plunge to the northeast. Tweto and others (1978) mapped two faults, which terminate at or near the southern edge of the study area (pl. 1). No mineralized rocks were found near the faults.

Description of Rock Units

The following description of rock units was modified from Tweto and others (1978). In the subsurface of the study area, the Eagle Valley Formation (Pennsylvanian), also called Eagle Valley Evaporite at some localities, intertongues with the Belden (Pennsylvanian), Minturn (Pennsylvanian), and Maroon (Middle and Upper Pennsylvanian and Permian) Formations. The Eagle Valley Formation is exposed to the south and west of the study area where it consists of gray and reddish-gray siltstone, shale, sandstone, and carbonate rocks, and local lenses of gypsum. The formation is transitional between the coarse clastic rocks of the Minturn and Maroon Formations and the purely evaporitic rocks. Thickness of the formation is variable, depending on intertonguing relations. Locally, gypsum occurs at the surface of the study area as small scattered patches and as thin coatings on the Minturn and Maroon Formations. The evaporite rocks crop out to the south and west of the study area where they consist of gypsum and anhydrite interbedded with siltstone and minor dolomite; they may contain salt at depth. Thickness of the evaporite cannot be measured due to flowage of the gypsum and consequent folding, but Mallory (1971) estimated that its thickness was greater than 3,000 ft in the study area.

The Belden Formation does not crop out in the study area but may intertongue with the Eagle Valley Evaporite in the subsurface. The Belden consists of dark-gray to black shale, carbonate rocks, and sandstone. Its thickness is approximately 900 ft. The Minturn Formation crops out in the study area and consists of gray, pale-yellow, and red sandstone, conglomerate, and shale, and scattered beds of carbonate rocks. The Minturn may intertongue with the Eagle Valley Evaporite locally. The Maroon Formation and Weber Sandstone (Permian and Pennsylvanian) are shown as one map unit (pl. 1). The Maroon Formation consists of approximately 1,400 ft of even-bedded maroon and grayish-red sandstone, conglomerate, and mudstone. Its lower part intertongues with the Eagle Valley Formation (or Evaporite), which underlies the Maroon Formation in places. The Weber Sandstone conformably overlies the Maroon Formation and consists of massive, light-gray to buff sandstone, approximately 50–75 ft thick.

The State Bridge Formation (Lower Triassic and Permian) consists of orange-red to red-brown siltstone, sandstone, and mudstone. It is distinguished from the conformably overlying Chinle Formation (Upper Triassic) by its slightly brighter orange color. The Chinle Formation consists of red-brown to dark-red siltstone, mudstone, conglomerate, and sandstone, and interbeds of green-blue shale and mudstone. The Chinle is approximately 160–200 ft thick.

The Entrada Sandstone and the Curtis Formation (Upper Jurassic) form steep cliffs in the study area and were mapped together. The Entrada Sandstone conformably overlies the Chinle and consists of 80–100 ft of white to light-gray, massive, crossbedded sandstone interbedded with thin-bedded, limy sandstone. The Curtis Formation conformably overlies the Entrada and consists of massive yellowish-gray sandstone, approximately 50–100 ft thick. The Morrison Formation (Upper Jurassic) consists of variegated shale and mudstone, light-gray sandstone, and local beds of gray and green-gray limestone. Approximately 200–500 ft thick, the Morrison Formation is conformable with the overlying Dakota Sandstone. The Dakota Sandstone (Lower Cretaceous) consists of light-gray and tan sandstone or quartzite and some interbedded dark shale and shaly sandstone. The Dakota beds are massive and resistant and have vertical jointing and a desert varnish stain.

A large oval breccia pipe (Tertiary?) intrudes the sedimentary rocks at Jack Flats. Tweto and others (1978) mapped the structure as a rhyolite plug; Kluender and Zelten (1985) stated that it exhibits some of the characteristics of stockwork molybdenum deposits. The following description of the pipe is from Schneider (1980). The contact of the breccia pipe with the surrounding country rocks is sharp. The pipe is zoned in a crudely concentric pattern: a fine-grained core of volcanic tuff is surrounded by a coarser grained phase of intrusive breccia. The majority of the clasts (rock fragments) in the breccia pipe were derived from Paleozoic sedimentary rocks (mainly the Minturn Formation), but scattered clasts of Proterozoic granitic and metamorphic rocks are also present. All of these clasts were derived from rocks through which the pipe intruded. Clasts of Permian rocks or younger are not found in the breccia. The matrix of the intrusive breccia consists of mineral grains, fine-grained carbonate minerals, and clay. Extensive alteration of the matrix to kaolinite and calcite obliterated any original textures and changed the original composition of the matrix. Calcite, dolomite, quartz, and gypsum are present as open-space fillings in the breccia.

One small rhyolite dike (Tertiary?) intrudes the Maroon Formation north of Jack Flats. The rhyolite is pink to buff and contains biotite and hornblende crystals. In outcrop, the dike is severely weathered and exhibits limonitic alteration. Quaternary alluvium and landslide deposits consisting of sand, gravel, and talus cover parts of the study area.

Geochemistry

Analytical Methods

In 1984, stream-sediment and rock samples were collected from 28 sites in the study area (samples beginning with the letters "BG", pl. 1; Detra and others, 1986). In 1985, an additional 20 panned-concentrate samples were collected to aid in interpretation (samples labeled "AD", pl. 1; Detra and others, 1986); some of these 20 samples were collected from the original 28 sites. Stream-sediment samples were collected from active and intermittent streams that drain the study area. Two types of stream-sediment samples were collected at each site. A sieved fraction of silt and clay was collected to be analyzed for the presence of fine-grained "ore" minerals and metals that may have been absorbed onto clay minerals. A panned, heavy-mineral concentrate was collected because the selective concentration of heavy minerals, many of which may be ore related, permits determination of some elements that are not easily detected in sieved stream-sediment samples. Only panned-concentrate samples were collected during the 1985 supplemental sampling program. Rock samples were collected from the Jack Flats breccia pipe and from the rhyolite dike 1 mi north of the pipe (pl. 1).

To obtain the silt and clay fraction, stream-sediment material was sieved to minus 100 mesh (0.15 mm (millimeter)). The fine-fraction samples were analyzed by neutron activation for uranium and thorium (Millard and Keaton, 1982) and by semiquantitative emission spectrography for 31 elements (Detra and others, 1986).

Each panned-concentrate sample represents a composite collection of coarse stream sediment that was first panned to reduce the amount of common rock-forming minerals, such as quartz and feldspar. In the laboratory, the "BG" panned-concentrate samples were sieved using a U.S. Standard 14 (1.4 mm) stainless-steel sieve, and the coarse fraction was discarded after visual examination. The remaining fraction was further processed by bromoform separation (2.8 specific gravity) to remove the remaining quartz and feldspar. The "AD" panned-concentrate samples were treated somewhat differently: coarse stream sediment was sieved in the field through a U.S. Standard 10 (2.0 mm) stainless-steel screen prior to panning, and the panned concentrate sieved through a U.S. Standard 35 (0.5 mm) screen prior to bromoform separation. The resultant heavy-mineral sample was separated electromagnetically into three fractions using a large, modified, Frantz Isodynamic Separator[1] set at a slope of 15° and a tilt of 10°. The most magnetic fraction was produced by setting the separator at a current of 0.1 ampere to remove the magnetite and ilmenite; the remainder of the sample was then split into paramagnetic and nonmagnetic fractions by setting the separator at a current of 1.0 ampere.

The most magnetic fraction was found to be primarily magnetite and was not analyzed. Only a few paramagnetic-fraction samples, composed largely of ferromagnesian silicates and iron oxides, were analyzed (table 1). The least magnetic material (the nonmagnetic fraction) was split using a Jones splitter. One split was hand-ground for spectrographic analysis; the other split was saved for mineralogic analysis. The spectrographic

[1]Any use of trade names in this report is for descriptive purposes only and does not imply endorsement by the USGS.

Table 1. Concentrations of selected elements in paramagnetic fraction of panned-concentrate samples from the Bull Gulch Wilderness Study Area, Colorado

[Analyzed by six-step semiquantitative spectrographic methods by D. E. Detra, and reported in the series 1, 1.5, 2, 3, 5, 7, 10, etc. Values in parts per million; N, not detected at value shown; <, detected but below value shown. Threshold value for anomaly in parentheses; D, detected]

Sample number	Silver (D)	Copper (150)	Molybdenum (10)	Lead (150)	Zinc (D)
BG23	N 1	200	50	300	N 500
BG24	N 1	100	50	150	N 500
BG27	10	70	20	1,500	N 500
BG31	2	100	30	200	N 500
AD1	1	200	70	200	N 500
AD4	<1	300	100	300	N 500
AD17	1	50	<10	50	N 500

analysis was an optical-emission six-step semiquantitative analysis for 31 elements (Grimes and Marranzino, 1968). Results of this analysis are presented in table 2. In general, the mineralogic analysis consisted of a brief scan of mineralogy under the microscope; however, some grains were selected for identification by X-ray diffraction analysis and for metal-content analysis by laser microprobe (a qualitative to semiquantitative analysis) (Detra and others, 1986).

All rock samples were crushed and pulverized in the laboratory to minus 100 mesh (0.15 mm) and analyzed for 31 elements by semiquantitative emission spectrography (table 3). In addition, the rock samples were analyzed by atomic-absorption spectroscopy for antimony, arsenic, cadmium, bismuth, and zinc (modification of method of Viets, 1978).

Results of Survey

Selected data show that the samples from streams that drain the area underlain by the Minturn Formation in the southwestern part of the study area contain anomalous amounts of silver, lead, molybdenum, and copper in the paramagnetic fractions (table 1) and silver, lead, and molybdenum in the nonmagnetic fractions (table 2). The combination of the original and supplemental sampling show that these anomalies are related to the Minturn Formation.

The processes that resulted in the anomalous silver, lead, molybdenum, and copper concentrations in the study area are not known, but several possibilities are suggested. Favored is the precipitation of metals from relatively cold fluids passing through the Minturn Formation after deposition. This process is indicated by the metal-bearing, apparently postdepositional calcite and marcasite

Table 2. Concentrations of selected elements in nonmagnetic fraction of panned-concentrate samples from the Bull Gulch Wilderness Study Area, Colorado

[Analyzed by six-step semiquantitative spectrographic methods by D. E. Detra, and reported in the series 1, 1.5, 2, 3, 5, 7, 10, etc. Values in parts per million; G, greater than 10,000 parts per million; N, not detected at value shown; <, detected but below value shown. Threshold value for anomaly in parentheses; D, detected]

Sample number	Silver (D)	Barium (5,000)	Copper (150)	Molybdenum (10)	Lead (150)	Zinc (D)
BG05†*	N 1	G	N 10	N 10	100	N 500
BG06†*	N 1	G	100	10	20,000	N 500
BG07†*	N 1	G	N 10	30	1,000	N 500
BG08†*	N 1	G	N 10	500	3,000	N 500
BG09†*	N 1	G	10	200	2,000	N 500
BG10	N 1	G	<10	N 10	500	N 500
BG11*	15	G	20	N 10	15,000	N 500
BG12	N 1	G	N 10	N 10	50	N 500
BG13	N 1	G	N 10	N 10	70	N 500
BG14	N 1	G	<10	N 10	20	N 500
BG15	N 1	G	N 10	N 10	30	N 500
BG16	N 1	G	N 10	N 10	50	N 500
BG17	N 1	G	N 10	N 10	N 20	N 500
BG18	N 1	G	N 10	N 10	20	N 500
BG19	N 1	G	N 10	30	N 20	N 500
BG20	N 1	G	N 10	N 10	150	N 500
BG21	N 1	G	N 10	N 10	100	N 500
BG22	N 1	G	N 10	N 10	70	N 500
BG23	N 1	G	N 10	70	300	N 500
BG24	N 1	G	N 10	100	300	N 500
BG25	N 1	G	N 10	N 10	100	N 500
BG26	N 1	G	N 10	N 10	150	N 500
BG27	200	G	N 10	50	200	N 500
BG31	15	G	N 10	100	10,000	1,500
AD1	N 1	10,000	50	N 10	150	N 500
AD2	N 1	10,000	30	100	700	N 500
AD3†	N 1	10,000	70	30	300	N 500
AD4	N 1	10,000	20	N 10	100	N 500
AD5	N 1	2,000	<10	N 10	300	N 500
AD6	N 1	5,000	<10	N 10	70	N 500
AD7*	N 1	G	30	N 10	1,000	N 500
AD8	N 1	G	15	N 10	100	N 500
AD9	N 1	G	N 10	N 10	100	N 500
AD10	N 1	G	20	N 10	300	N 500
AD11	N 1	G	<10	N 10	70	N 500
AD12	N 1	10,000	50	N 10	2,000	N 500
AD13	N 1	G	<10	N 10	100	N 500
AD14	N 1	G	10	N 10	200	N 500
AD15	N 1	G	20	N 10	200	N 500
AD16	N 1	G	15	N 10	100	N 500
AD17	10	G	70	N 10	2,000	N 500
AD18	2	G	150	N 10	1,500	N 500
AD19	7	G	150	15	2,000	N 500
AD20	N 1	G	<10	N 10	100	N 500

†Sample contains visible gold.

*Sample contains visible lead shot or slug fragments.

Table 3. Concentration of selected elements in rock samples from the Bull Gulch Wilderness Study Area, Colorado

[Analyzed by six-step semiquantitative spectrographic methods by M. J. Malcolm, and reported in the series 1, 1.5, 2, 3, 5, 7, 10, etc. Values in parts per million; N, not detected at value shown; <, detected but below value shown; value in parentheses is average value for rock type (average values taken from Levinson, 1980)]

Sample number	Rock type	Silver	Arsenic	Barium	Copper	Manganese	Molybdenum	Lead	Antimony	Zinc
BG2RS	Rhyolite dike	5 (0.04)	N 5 (1.5)	3,000 (600)	500 (10)	300 (400)	5 (2)	30 (20)	N 2 (0.2)	45. (40)
BG6RS	Breccia, Minturn Fm.	2 (<0.01)	18 (1)	100 (100)	100 (10)	1,500 (400)	N 5 (0.2)	15 (7)	6 (<0.1)	78 (16)
BG7RS	Breccia, Minturn Fm.	N 0.5 (0.01)	N 5 (1)	300 (100)	50 (10)	1,500 (400)	N 5 (0.2)	10 (7)	4 (<0.1)	38 (16)
BG10RS	Breccia, Minturn Fm.	N 0.5 (<0.01)	18 (1)	300 (100)	20 (10)	500 (400)	5 (0.2)	150 (7)	3 (<0.1)	140 (16)
BG28R	Breccia, Minturn Fm.	N 0.5 (<0.01)	9 (1)	700 (100)	15 (10)	500 (400)	N 5 (0.2)	15 (7)	N 2 (<0.1)	66 (16)
BG29R	Breccia, Minturn Fm.	N 0.5 (<0.01)	11 (1)	700 (100)	30 (10)	500 (400)	-- (0.2)	15 (7)	2 (<0.1)	76 (16)
BG30R	Breccia, Minturn Fm.	N 0.5 (<0.01)	N 5 (1)	1,500 (100)	7 (10)	1,000 (400)	-- (0.2)	30 (7)	6 (<0.1)	250 (16)
BG31R	Mn-stained sandstone.	N 0.5 (<0.01)	N 5 (1)	500 (100)	15 (10)	1,500 (400)	-- (0.2)	10 (7)	3 (<0.1)	17 (16)

found in some of the samples (Detra and others, 1986). The sediment-hosted copper deposits found in the Minturn Formation of the Sangre de Cristo Range, Colorado (Taylor and others, 1984), are deposits that formed in a geologic environment similar to that of the study area.

Data from the survey do not exclude a hydrothermal origin for the anomalous element concentrations, which is suggested by the presence of a large breccia pipe and a rhyolite dike (pl. 1). The igneous event that led to the formation of the breccia pipe and the emplacement of the rhyolite dike would be the likely source for any hydrothermal fluids. However, samples from the breccia pipe, which would be expected to be a major conduit or pathway for such metal-rich fluids, do not seem to be any more anomalous than samples from the Minturn Formation.

Another possible origin is the incorporation of detrital grains from pre-Pennsylvanian mineralized rocks into the Minturn Formation. The variation in results seen in the data for similar sites (for example, compare samples BG31 and AD1, tables 1 and 2) could be explained by this model. However, such data variation is explained by any mechanism whereby only a few isolated metal-rich grains are present; for example, on the outer fringes of an ore deposit or where the processes of mineralization operated only weakly.

Regardless of the geochemical model or combination of models, it is likely that the mineralizing processes operated only weakly in the vicinity of the study area, sufficiently to cause a geochemical anomaly but insufficiently to create a deposit. The breccia pipe has in effect acted as a giant drill, bringing to the surface samples of the underlying rocks, but none of the rocks tested proved to be more than weakly anomalous.

Many elements occur in anomalous amounts in the heavy-mineral concentrates. These include boron, barium, lanthanum, strontium, thorium, and yttrium throughout the study area, and cobalt, chromium, niobium, nickel, and tin sporadically (Detra and others, 1986). These elements are interpreted as related to normal heavy-mineral occurrences in sedimentary rocks. Some of the grains (for example, barite, celestite, dolomite, pyrite, and marcasite) were observed under the microscope to be in crystal forms strongly suggestive of having been formed in place. Other grains (such as apatite, zircon, calc-silicates, barite, and dolomite) showed crystalline shapes indicative of sediments derived from a nearby source area, whereas still other grains were highly rounded and strongly frosted, indicating they had been reworked, possibly several times. In this latter category, apatite, diopside, barite, rutile, and monazite were identified by X-ray diffraction; tourmaline and thorite were suspected, but not confirmed. Laser-microprobe analysis showed that the monazite contained large amounts of calcium, lanthanum, thorium, and yttrium (Detra and others, 1986).

Sieving the 1985 panned-concentrate samples at a finer grain size than the 1984 panned-concentrate samples resulted in an increase in the concentration of some elements (for example, boron, lanthanum, and thorium) at the expense of other elements (barium, strontium). This is interpreted as concentrating smaller minerals such as monazite relative to larger grains such as barite, celestite, and dolomite. Although some of the elements may be anomalous in part as the result of the same processes (deposition from formation brines, ground water, or weak hydrothermal fluids) that created the silver-lead-molybdenum-copper anomalies, most of the elements are anomalous because the original source area of the sediments that formed the Minturn and overlying formations contained resistate minerals (for example, monazite) enriched in those elements. The results of the sampling show these elements to be present regardless of the formation or formations that occur in the stream drainage basin.

Stream-sediment samples collected during this study were not anomalous in uranium, and no sample exceeded 5 ppm (parts per million) uranium. Samples collected in and near the study area during the NURE (National Uranium Resource Evaluation) program did not exceed 8 ppm uranium (Planner and others, 1981).

Many of the panned-concentrate samples, collected where terrace gravels of the Colorado River provided part of the sediment, were found to contain native gold (table 2), generally in amounts of one color per pan. Repeat sampling (1985 sampling) found that these gold occurrences are restricted to the gravels of the Colorado River and were not derived from the study area. The NURE sampling program (Planner and others, 1981) reported gold in a sample site near the site of sample BG14. It is believed that this occurrence is also derived from the river gravels.

Many of these samples derived in part from the terrace gravels were also found to contain recognizable lead shot and slug fragments. These lead artifacts caused some very high lead values in the analyses (table 2) but are of no significance in the mineral appraisal.

Geophysics

Aeromagnetic data were from a regional survey flown at a line spacing of 5 mi and a barometric elevation of 14,500 ft (Zietz and Kirby, 1972). These data showed low-intensity magnetic anomalies caused by variations in the lithology of the crystalline basement beneath the thick sedimentary rock cover in the Bull Gulch Wilderness Study Area. Magnetic intensity increases from east to west along two NURE profiles that cross the study area. This increase suggests that either the basement rocks dip to the east or the magnetic susceptibility of the basement rocks increases to the west. The profiles were flown at about 400 ft above the ground and show no high-frequency magnetic change indicative of near-surface magnetic sources within the study area, but high-frequency anomalies of 20 to 30 gammas do occur about 0.5 mi east of the study area on profile 5 and about 2 mi east of the study area on profile 4 (see pl. 1, Bendix Field Engineering Corp., 1983). The high-frequency aeromagnetic anomalies are caused by near-surface magnetic sources.

Magnetic traverses across a breccia pipe at Jack Flats, with the magnetometer sensor about 8 ft above the surface (Schneider, 1980), show little magnetic contrast between the wall rock and the breccia. Magnetic variation (about 50 gammas) along the profiles is not sufficient to suggest a mafic intrusion at depth but does suggest that the rock material in the pipe is similar to the enclosing rocks.

Gravity measurements were made along the northwest boundary of the study area, but none were made within the study area. Regional control (Behrendt and Bajwa, 1974) shows that the study area lies on the flank of a strong northwest-trending gravity low that possibly indicates a basement structure that dips to the southeast. The low (fig. 3) is probably produced by a thickening of low-density sedimentary rock units.

Mineral and Energy Resource Potential

Gypsum and anhydrite pods and lenses are found in the evaporite facies rocks of the Eagle Valley Formation (Mallory, 1971). Rocks of the evaporite facies crop out to the south and west of the study area where they intertongue with sandstone and shale from the Belden, Minturn, and Maroon Formations. It may be inferred from the geologic mapping of the region (Mallory, 1971; Tweto and others, 1978) that the formations exist beneath the study area. No gypsum or anhydrite beds were observed in the study area, but gypsum occurs at the surface locally as patches and coatings on rocks of the Minturn and Maroon Formations in the southwestern part of the study area. Most of the study area is in a facies transition zone where gypsum beds give way to clastic beds. So if gypsum beds extend into the study area, they would probably be discontinuous and contain clay and mud impurities. The mineral resource potential (classified according to the system of Goudarzi, 1984) for gypsum and anhydrite is moderate in the southwestern part of the Bull Gulch Wilderness Study Area; certainty level is B (fig. 1; pl. 1).

On the basis of geochemical analyses, geophysical surveys, geologic mapping, and the absence of mineralized areas, the Bull Gulch Wilderness Study Area

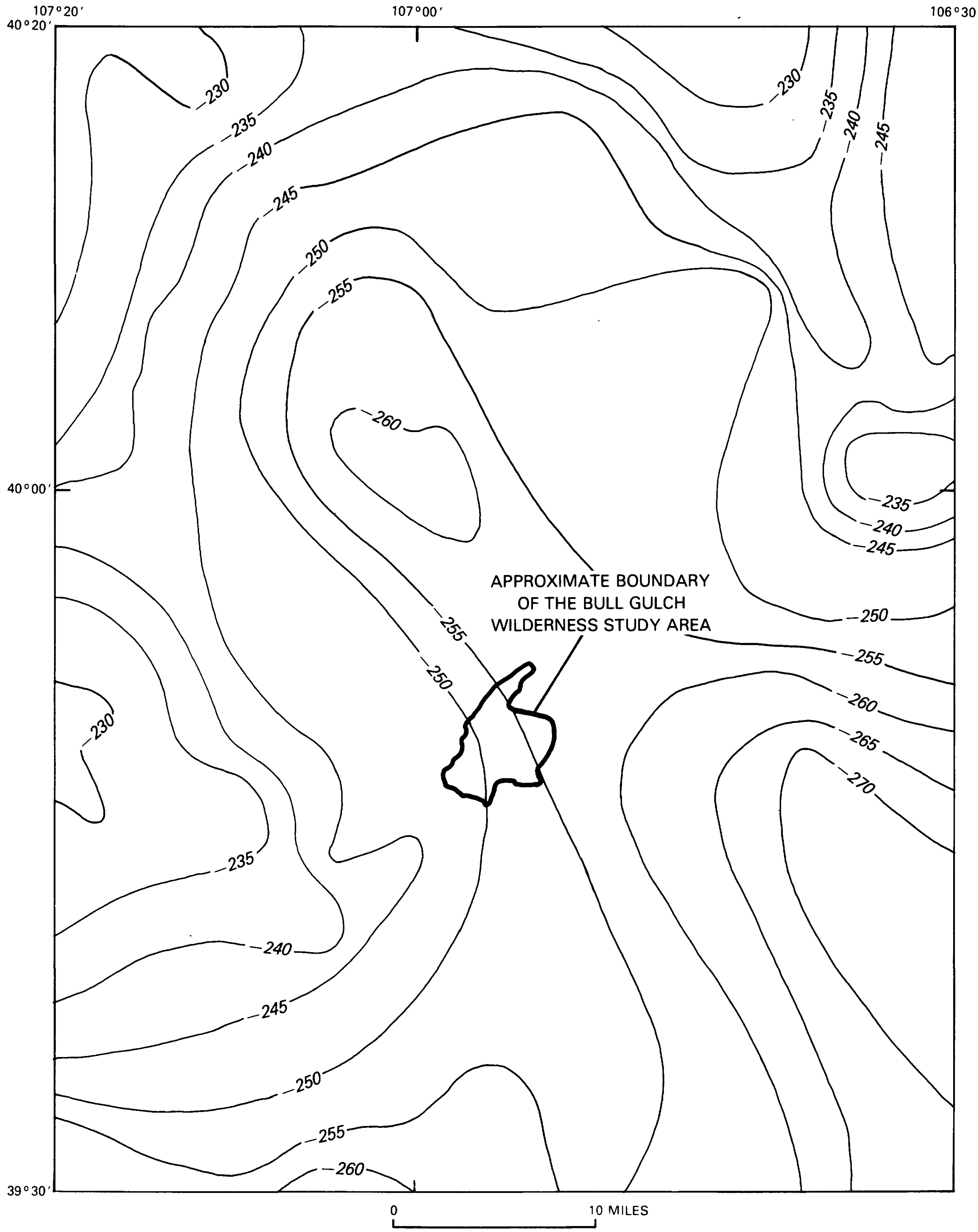

Figure 3. Complete Bouguer gravity anomaly map of the Bull Gulch Wilderness Study Area, Eagle County, Colorado (Behrendt and Bajwa, 1974). Contour interval is –5 milligals; reduction density is 2.67 grams per cubic centimeter.

has low mineral resource potential for all metals at certainty level B. Anomalous amounts of lead, molybdenum, zinc, copper, and silver were detected in some of the rock samples from the breccia pipe at Jack Flats and from the rhyolite dike north of the pipe. However, no metallic minerals were identified in hand specimen. According to Schneider (1980), the association of calcite, kaolinite, dolomite, and gypsum in the alteration suite at the Jack Flats breccia pipe suggests deposition from hydrothermal (hot water) fluids that were a mixture of magmatic and meteoric waters. If the breccia pipe is related to a porphyry system and if hydrothermal fluids mineralized the pipe and the surrounding rocks, then lead, zinc, copper, and molybdenum may occur beneath the surface. The extent of the breccia pipe and the depth to a possible porphyry cannot be estimated from the available data. A granitic intrusion might be present and yet might not manifest itself in the magnetic profile, as its magnetic susceptibility is low (Schneider, 1980).

A few small flakes of gold were identified by hand lens in some panned-concentrate samples taken from alluvial sand and gravel along the banks of the Colorado River outside the study area. No gold was present in samples from streams that drain only the study area; therefore the outcropping rocks of the study area are not the source of the gold. Some small-scale mining of a gold placer has occurred to the north and west, but there is no record of production from within the study area.

The Morrison Formation is exposed along the northern and eastern boundaries of the study area. Although the Morrison Formation is a favorable host for uranium elsewhere, no uranium was detected during the field investigations. Geochemical analyses of stream-sediment samples revealed that uranium was not present in amounts greater than 5 ppm. Although uranium prospecting in the Morrison has been conducted in and around the study area, no uranium discovery has been reported (Kluender and Zelten, 1985). The mineral resource potential for uranium is low for the Bull Gulch Wilderness Study Area. Available information suggests this low level of mineral resource potential; certainty level is B.

Spencer (1983) assigned a "low potential" rating for oil and gas in the Bull Gulch Wilderness Study Area. Regional geophysical surveys suggest that a thick sequence of sedimentary rocks underlies the study area, but the presence of hydrocarbons in these sediments is unknown. The exploratory hole 0.75 mi east of the study area (fig. 2), which penetrated the Belden Formation, was dry and abandoned (Kluender and Zelten, 1985). Although favorable reservoir rocks such as the Belden Formation may be present beneath the study area, more information regarding possible structural traps and hydrocarbon content is needed to fully assess the possibilities for oil and gas. Therefore the mineral resource potential for oil and gas is low in the study area. Available information suggests the level of resource potential; certainty level is B.

Bass and Northrop (1963) noted that coal in the Belden Formation is discontinuous near the study area. The Belden may contain beds of coal or coaly shale beneath the study area, but they also are likely to be discontinuous. Because evaporites from the Eagle Valley Formation may intertongue with the overlying Belden, any coal in the lower part of the Belden would probably be interbedded with shale, clay, and gypsum. The mineral resource potential for coal is low in the study area; certainty level is B.

A group of warm springs is approximately 15 mi southwest of the study area near Dotsero. Barrett and Pearl (1978) postulated that the springs are associated with a fault system at depth and that the heat source is associated with the White River uplift, west of the study area. Geologic mapping indicates that this fault system does not extend into the study area, and there is no evidence of geothermal activity associated with the observed faulting near the southern edge. A local rancher reported hot saline water in a well drilled about 2 mi northwest of the study area (Kluender and Zelten, 1985), but no temperature was recorded. Thermal-water occurrences have not been recorded anywhere else in the vicinity (Kluender and Zelten, 1985). The mineral resource potential for geothermal energy sources is low in the Bull Gulch Wilderness Study Area; certainty level is B.

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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.

Mineral Resources of Wilderness Study Areas— North-Central Colorado

This volume was published
as chapters A, B, and C

U.S. GEOLOGICAL SURVEY BULLETIN 1717

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.

Abstracted with minor modifications from:

Taylor, R. B., and Steven, T. A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268–1270.

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–0787, p. 7, 8.

CONTENTS

[Letters designate the chapters]

*U.S. GOVERNMENT PRINTING OFFICE: 1986-0-773-047/46012