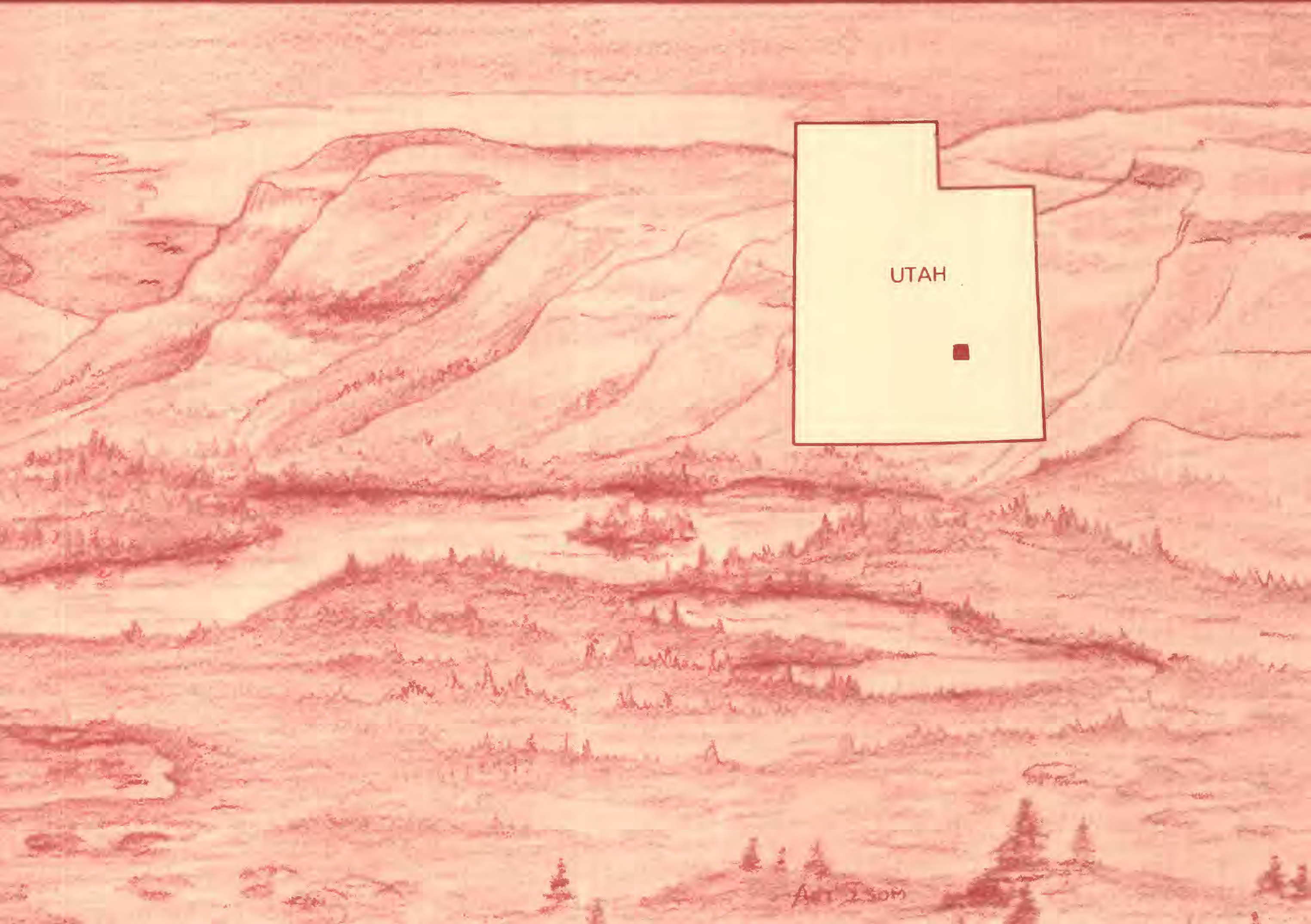
Mineral Resources of the Bull Mountain Wilderness Study Area, Garfield and Wayne Counties, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1751–B



Chapter B

Mineral Resources of the Bull Mountain Wilderness Study Area, Garfield and Wayne Counties, Utah

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U.S. GEOLOGICAL SURVEY BULLETIN 1751

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
HENRY MOUNTAINS REGION, UTAH

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Bull Mountain (UT–050–242) Wilderness Study Area, Garfield and Wayne Counties, Utah.

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PLATE

[Plate is in pocket]

FIGURES

Mineral Resources of the Bull Mountain Wilderness Study Area, Garfield and Wayne Counties, Utah

By Russell F. Dubiel, Calvin S. Bromfield, Stanley E. Church, William M. Kemp, Mark J. Larson, *and* Fred Peterson
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ABSTRACT

The Bull Mountain (UT–050–242) Wilderness Study Area comprises 11,800 acres in the Henry Mountains in Garfield and Wayne Counties, Utah. Field and laboratory investigations were conducted by the USGS (U.S. Geological Survey) from 1981 to 1984 and by the USBM (U.S. Bureau of Mines) in 1986. These investigations indicate that there are no identified resources in the study area. The northern part of the study area has a high potential for undiscovered gypsum resources, and the entire area has a low resource potential for undiscovered copper, lead, zinc, molybdenum, silver, gold, uranium and vanadium, coal, oil and gas, and geothermal resources (fig. 1).

SUMMARY

The Henry Mountains consist of numerous Tertiary (see geologic time chart in the Appendix) igneous stocks, and smaller, subsidiary igneous satellite bodies that were injected radially from the stocks into the adjacent sedimentary strata. Each of these three types of intrusive igneous bodies was intruded into and domed the overlying sedimentary strata. Subsequent erosion by the Colorado River and its tributaries has exposed the igneous intrusive stocks and their subsidiary satellite bodies as five mountains and associated major and minor topographic features. The Bull Mountain Wilderness Study Area is just east of Mt. Ellen, which is the northernmost and one of the largest igneous stocks of the Henry Mountains. The study area includes several subsidiary igneous satellite bodies, including Bull Mountain. Sedimentary rocks ranging in age from Jurassic to Cretaceous were eroded to form a highly dissected topography having narrow and deep canyons and broad, gravel-mantled pediments (benches). Mountain slopes are steep and rugged. There are no perennial streams in the study area; vegetation is sparse and precipitation is low.

A search was made for mines, prospects, and mineralized areas in and within 0.5 mi (mile) of the study area; none were found within the study area. The USBM collected and analyzed rock, panned-concentrate, and stream-sediment samples to determine the extent of mineralized areas. Samples were analyzed for gold and 25 additional elements. Selected samples were analyzed for copper, lead, vanadium, and uranium. Additionally, five gypsum samples were analyzed for purity. Hydrocarbon leases cover approximately one third of the Bull Mountain Wilderness Study Area. No drilling has been done for hydrocarbons in the study area.

Sedimentologic studies of the Upper Jurassic Morrison Formation and geologic mapping indicate that gypsum beds as much as 30 ft (feet) thick occur in the Tidwell Member at the base of the Morrison Formation and underlie the northern part of the Bull Mountain Wilderness Study Area. The northern part of the study area has a high mineral resource potential for gypsum.

Stream-sediment and rock samples were collected by the USGS from the Henry Mountains region for geochemical analysis as part of an investigation of several wilderness study areas in the region. Geochemical analyses of the samples collected in and around the Bull Mountain Wilderness Study Area indicate that there are anomalous concentratons of metals in the stream sediment (copper and molybdenum) and panned concentrates (gold, silver, copper, lead, and zinc) from Bromide Basin, which is about 1 mi southwest of the study area. However, these geochemical studies do not indicate an extension of the Bromide Basin anomaly northeast into the Bull Mountain Wilderness Study Area. Five to ten miles north of Bromide Basin two isolated sample localities 0.5–1.5 mi outside of the study area have

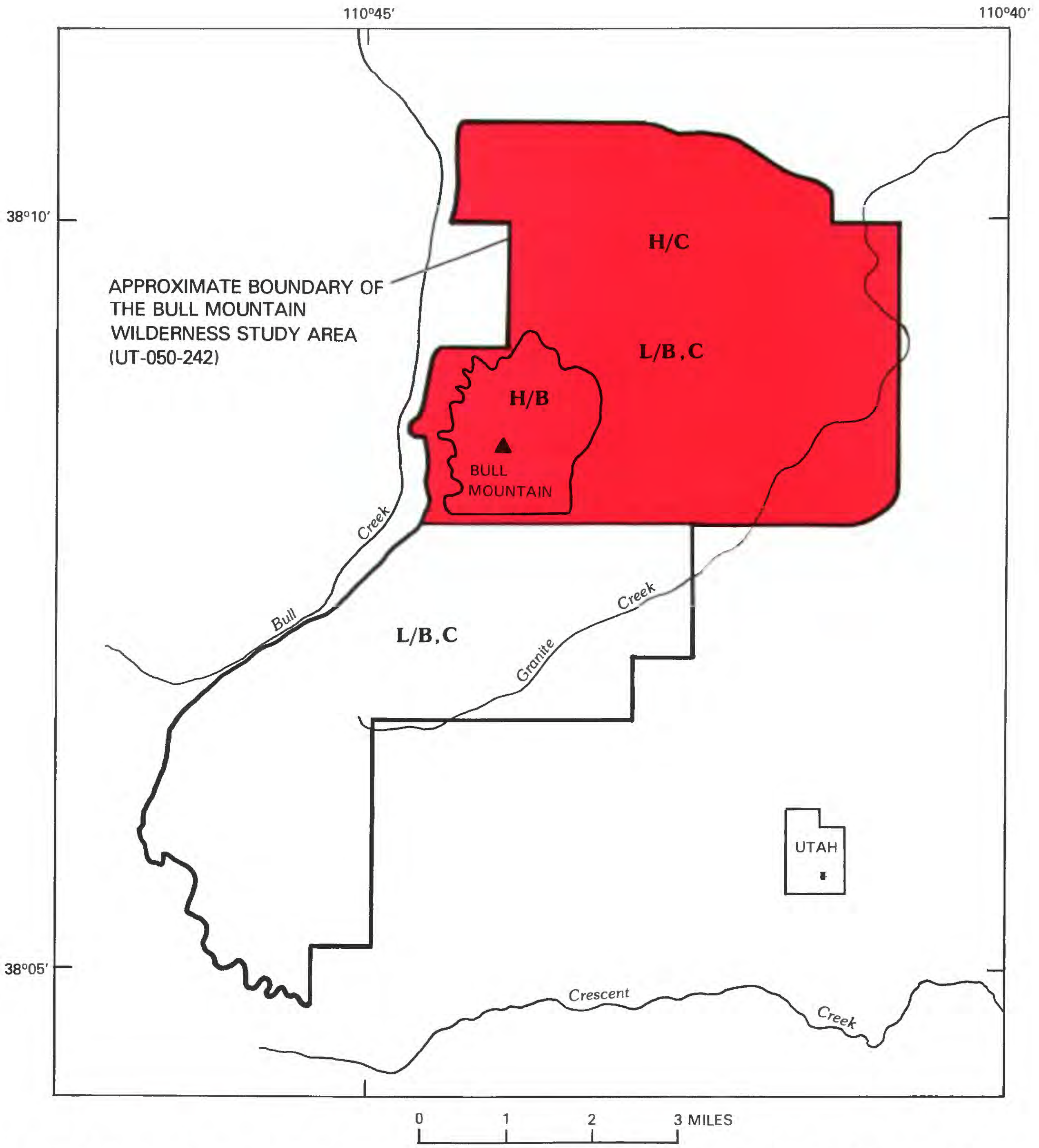

Figure 1 (above and facing page). Summary map showing mineral resource potential of the Bull Mountain Wilderness Study Area, Garfield and Wayne Counties, Utah.

anomalous gold values and are associated with areas of slightly altered rock. These two localities are widely separated and appear to represent small, isolated mineral occurrences. The mineral resource potential is low for these metals.

The entire Bull Mountain Wilderness Study Area is within the Henry Mountains coal field. The Emery and Ferron Sandstone Members of the Cretaceous Mancos Shale are important coal-bearing strata that occur within the coal field.The coal-bearing Emery Sandstone Member has been eroded from the study area, and the coal-bearing Ferron Sandstone Member intermittently crops out in the southern part of the study area. Sections of the Ferron Sandstone Member contain thin, discontinuous coal seams that range in thickness from 0 to 5 ft. The Dakota Sandstone also contains thin, discontinuous coal seams less than 1 ft thick. The potential for undiscovered coal resources is low

EXPLANATION OF MINERAL RESOURCE POTENTIAL

H/C Geologic terrane having high mineral resource potential for gypsum, with certainty level C

H/B Geologic terrane having high mineral resource potential for gypsum, with certainty level B

L/B Geologic terrane having low mineral resource potential for uranium and vanadium, with certainty level B—Applies to entire study area

L/C Geologic terrane having low mineral resource potential for copper, lead, zinc, molybdenum, silver, gold, coal, oil and gas, and geothermal energy, with certainty level C—Applies to entire study area

Levels of certainty

B Data indicate geologic environment and suggest level of resource potential

C Data indicate geologic environment, indicate resource potential, but do not establish activity of resource-forming processes

throughout the study area because of the probable thin, discontinuous nature of the coal beds.

Known uranium and vanadium occurrences in the region are restricted to fluvial sandstone of the Salt Wash Member of the Upper Jurassic Morrison Formation. Although the Salt Wash Member is present in the study area, carbonaceous lacustrine mudstone that indicates a favorable environment for uranium-vanadium deposits in the Salt Wash is not present in the Bull Mountain Wilderness Study Area. The Upper Triassic Chinle Formation is known to contain uranium and vanadium in the White Canyon area southeast of the study area, near Fiddler Butte to the east of the study area, and in the vicinity of Capitol Reef National Park west of the study area. The uranium deposits of the Chinle Formation in those areas are restricted to fluvial sandstone of the Shinarump and Monitor Butte Members. Sedimentologic study of these fluvial systems indicates that they probably do not underlie the study area. The study area has a low mineral resource potential for uranium and vanadium.

Geologic investigations of the study area indicate that the study area has a low energy resource potential for oil and gas and a low resource potential for geothermal energy.

INTRODUCTION

The Bull Mountain (UT–050–242) Wilderness Study Area comprises about 11,800 acres encompassing Bull Mountain in the northern Henry Mountains in Garfield and Wayne Counties, Utah (fig. 2, pl. 1). The high, rugged laccolithic mountains, surrounded by pediment gravel surfaces, rise from intricately dissected, sparsely vegetated plateaus. Elevations in the region range from about 4,800 ft along the Fremont River to 11,522 ft on North Summit Ridge of Mt. Ellen. Bull Mountain attains a height of 9,187 ft. The Bull Mountain Wilderness Study Area is about 20 mi southwest of Hanksville and about 25 mi northwest of Lake Powell. The study area is accessible on the north from Hanksville by the Sawmill Basin road, which defines the western boundary of the area. The east, south, and north boundaries of the study area are accessible by unimproved dirt roads extending westward from paved State Highway 95, which extends south from Hanksville.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the U.S. Bureau of Mines and the U.S. Geological Survey. 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 in the Appendix of this report. Identified resources are studied by the USBM. Mineral resource potential is the likelihood of occurrence of undiscovered concentrations of metals and nonmetals, industrial rocks and minerals, and of undiscovered energy sources (coal, uranium, oil, gas, oil shale, and geothermal sources). Mineral resource potential and the level of certainty of the resource assessment were classified according to the system of Goudarzi (1984; see Appendix). The potential for undiscovered resources is studied by the USGS.

Previous Work

G.K. Gilbert (1877) was the first geologist to examine, describe, and interpret the laccoliths and processes of igneous intrusions in the Henry Mountains. Between 1935 and 1939, C.B. Hunt and his associates reinterpreted the geology of the Henry Mountains and later published a detailed report (Hunt and others, 1953). Doelling (1972) mapped several 7½-minute quadrangles as part of a study of the Henry Mountains coalfield. Uranium has been the most important mineral commodity to be mined in this region, and many investigations were conducted by, or done under contract to, the Atomic Energy Commission in the 1940's and 1950's. These reports are available through the Grand Junction, Colo., Office of the Nuclear Regulatory Commission. Butler (1920) was the first to describe the mineral resources of the Henry Mountains region. Reports published on the uranium deposits of the Henry Mountains include Johnson (1959), Doelling (1967, 1975), Peterson (1977, 1980a, b), and Chenoweth (1980). Doelling (1980) also described the various metal deposits of the region.

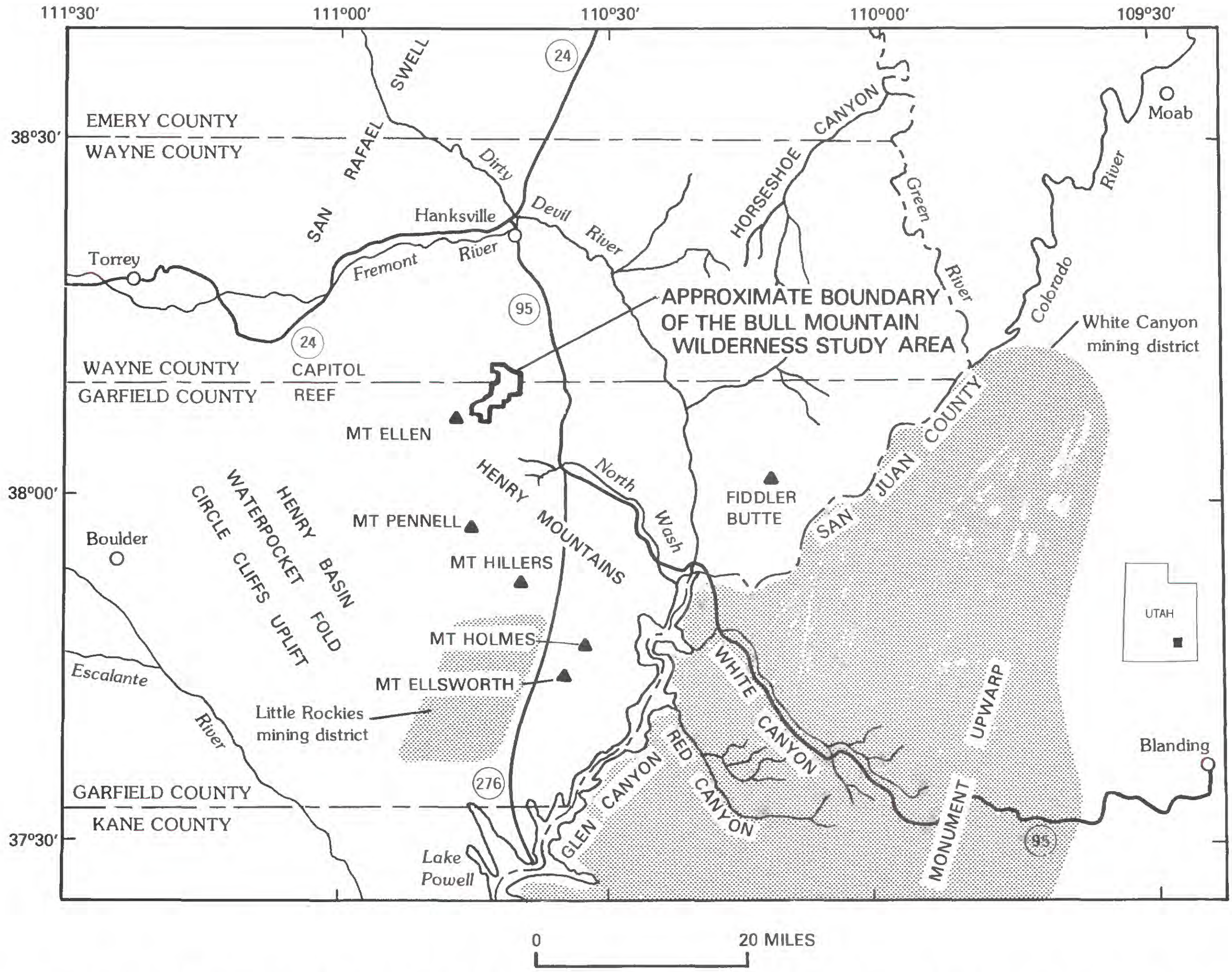

Figure 2. Index map showing location of the Bull Mountain Wilderness Study Area, Garfield and Wayne Counties, Utah.

Investigations by the U.S. Bureau of Mines

In 1986, the USBM conducted a mineral investigation to evaluate the identified mineral resources of the Bull Mountain Wilderness Study Area as part of a joint effort with the USGS. Field studies by USBM personnel during July of 1986 included a search for mines, prospects, and mineralized areas in and within 0.5 mi of the study area boundary; none were found within the study area (Neubert, 1987). The USBM collected samples and determined assay values and investigated past exploration activity in the study area. Minerals and oil and gas information was gathered from published and unpublished literature, USBM files, and oil and gas lease and mining-claim records of Wayne and Garfield Counties and the U.S. Bureau of Land Management State Office in Salt Lake City, Utah (Neubert, 1987).

USBM personnel collected rock, panned-concentrate, and stream-sediment samples from within the study area. Neutron activation analyses for gold and 25 other elements were done by Bondar–Clegg, Inc., Denver, Colorado. Uranium content was determined by fluorometric analysis. Five gypsum samples were analyzed for purity by the USBM Reno Research Center. A complete sample data set can be found in Neubert (1987) and is available for public inspection at the USBM, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

Investigations by the U.S. Geological Survey

From 1981 to 1984, the USGS conducted field and laboratory studies to assess the potential for undiscovered mineral resources of the Bull Mountain Wilderness Study Area, Garfield and Wayne Counties, Utah. The studies consisted of geologic mapping (Patterson and others, 1985); a search for mines, prospects, and mineralized areas; sedimentologic studies (Dubiel, 1982, 1983a, b); rock and stream-sediment sampling for geochemical analysis (Detra and others, 1984); and a search of previously published studies on the geology (Peterson, 1977, 1980a) and mineral resources of the study area. Models developed for the occurrence of uranium (Peterson, 1980b; Dubiel, 1983b) were applied to the evaluation of mineral resource potential for uranium in the study area.

Acknowledgments.—The development of a mineral resource potential summary of a study area is dependent upon the expertise and contributions of many people. The USGS acknowledges the assistance of our helicopter pilots, Leonard Smith and the late Jaxon Ruby, whose skill as pilots made many of the field tasks in remote areas considerably easier. We would also like to thank all of the USGS personnel who assisted in the field on all aspects of this interdisciplinary study: Brad Esslinger, James Faulds, Joseph Fontaine, Darlene Francis, David Hammond, Carl Harris, Paul Milde, Denise Mruk, Charles Patterson, Richard Reeves, Michael Rendina, David Scott, William Thoen, Ann Tirrell, Bruce van Brundt, Shawn Yasataki, and Christine Yee.

APPRAISAL OF IDENTIFIED RESOURCES

By John T. Neubert
U.S. Bureau of Mines

Mining Activity

Gold, silver, and copper were mined in the Henry Mountains in the late 1890's (Butler, 1920). However, within the Bull Mountain Wilderness Study Area, no metal mining has taken place. Most of the precious metals and copper production in the Henry Mountains was from Bromide Basin about 1 mi south of the Bull Mountain Wilderness Study Area. The deposits in Bromide Basin were discovered in 1889 or 1890 (Doelling, 1975). A total of 700 oz (ounces) of gold, 3,000 oz of silver, and 17,500 lb (pounds) of copper has been produced from Bromide Basin (Doelling, 1975). The ore minerals occur in quartz-breccia veins within the diorite stock surrounding Mt. Ellen (Gese, 1984a).

Crescent Creek, which has its source in Bromide Basin and flows within 0.5 mi of the southern boundary of the study area, has been worked for placer gold intermittently from 1914 to the present and has a recorded production of 300 oz of gold (Doelling, 1975).

Several unpatented mining claims exist in and near the study area (Neubert, 1987). No mineral production has been reported from the study area.

Mining Districts, Mineralized Areas, and Identified Resources

The Bull Mountain Wilderness Study Area is near two uranium mining districts: the White Canyon district and the Little Rockies district. The White Canyon mining district is about 20 mi southeast of the study area, across Lake Powell in San Juan County, Utah. Uranium was discovered in this area in 1950, in paleochannels of the Shinarump Member of the Upper Triassic Chinle Formation. In the 1970's, Texasgulf, Inc., Minerals Exploration Division, projected Shinarump paleochannel trends westward into the area east of the Little Rockies and drilled and identified a subsurface uranium deposit (Dubiel and others, 1987). No part of the White Canyon mining district is within the Bull Mountain Wilderness Study Area.

The Little Rockies mining district is about 20 mi south of the Bull Mountain Wilderness Study Area on the west side of Utah State Highway 276. Uranium in the district occurs in paleochannels of the Salt Wash Member of the Upper Jurassic Morrison Formation. No part of the Little Rockies mining district is within the study area.

Oil and Gas

The Bull Mountain Wilderness Study Area is in the Henry basin, a Laramide (Late Cretaceous to Eocene) structural basin near the northwestern part of the Pennsylvanian Paradox basin. The Henry basin is one of the few Rocky Mountain basins that has not produced oil and gas (Irwin and others, 1980). Oil and gas production within the Paradox basin has been primarily from bioherms and structural traps within carbonate rocks of the Pennsylvanian Hermosa Group, although there has been minor production from Permian and Triassic rocks (Irwin and others, 1980). These formations underlie the Henry Mountains and the Bull Mountain Wilderness Study Area but remain untested. Approximately one third of the Bull Mountain Wilderness Study Area (fig. 3) has been leased for oil and gas, but no drilling for hydrocarbons has taken place in the study area.

Sand, Gravel, and Stone

Materials suitable for construction purposes are present in the Bull Mountain Wilderness Study Area. Sand and gravel are present in terrace deposits along stream courses, and most of the Jurassic and older rocks could be sources of building stone. Development of

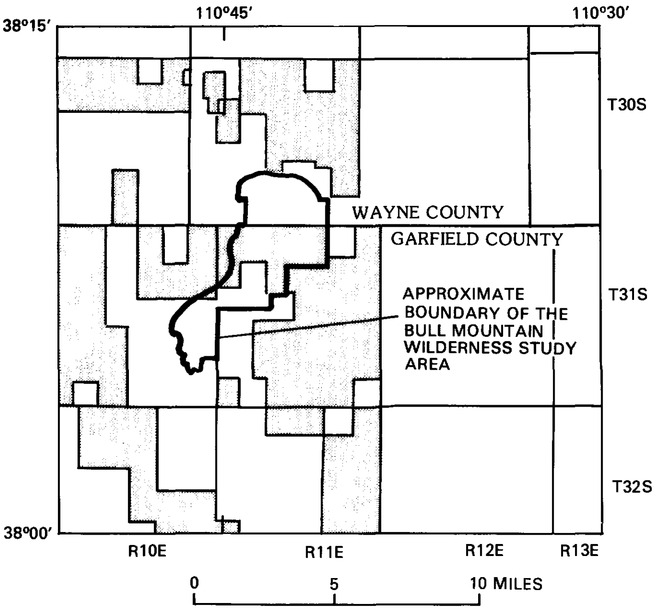

Figure 3. Map showing oil and gas leases in and near the Bull Mountain Wilderness Study Area, Garfield and Wayne Counties, Utah. Oil and Gas lease areas as of 1985 are shaded.

these materials is unlikely due to the lack of local markets, and they are not classified as an identified resource.

Gypsum

A 30-ft-thick gypsum bed crops out within 400 ft of the northern boundary of the Bull Mountain Wilderness Study Area. The bed is within the Tidwell Member of the Upper Jurassic Morrison Formation and occurs just below the Salt Wash Member of the Morrison Formation (Patterson and others, 1985). The purity of the gypsum is variable (Neubert, 1987), but the gypsum could be used as a soil conditioner or as a retarder for portland cement. Distance to markets and availability of gypsum sources closer to markets precludes the gypsum from being classified as an identified resource at this time.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Russell F. Dubiel, Calvin S. Bromfield, Stanley E. Church, William M. Kemp, Mark J. Larson, and Fred Peterson
U.S. Geological Survey

Geology

The Bull Mountain Wilderness Study Area is in and adjacent to the northern Henry Mountains (fig. 2). The study area is on the northeastern flank of the Henry basin, a north-south-trending topographic feature about 100 mi long and 50 mi wide. The structural axis of the Henry basin also trends nearly north-south. The western flank of the asymmetric basin is formed by the steeply eastward dipping rocks of the Waterpocket fold, a monocline that separates the basin from the adjacent Circle Cliffs uplift farther to the west. Strata in the gently dipping east flank of the basin gradually rise eastward toward the crest of the Monument upwarp. The intrusive centers of the Henry Mountains (pl. 1) locally interrupt the gradual eastward rise of the sedimentary strata.

The Henry Mountains consist of five distinct intrusive centers that form large structural domes. Mt. Ellsworth, Mt. Holmes, Mt. Hillers, Mt. Pennell, and Mt. Ellen extend in a north-northwest line for about 35 mi. The core of each igneous intrusive center is a separate diorite porphyry stock that is discordant to the sedimentary rocks. Each stock is bordered by an irregular zone of shattered sedimentary rock that is intricately intruded by the porphyry (pl. 1). The summit of Mt. Ellen and its associated intrusive center, both just west of the study area, are surrounded by a cluster of satellite laccoliths, bysmaliths, and sills. The laccoliths and related intrusions were radially injected into the adjacent sedimentary strata from the igneous stocks. Whereas the laccoliths raised the overlying strata by arching, the bysmaliths raised their roofs by faulting. Bull Mountain is formed from one of these bysmaliths and is one of the largest of the floored intrusive bodies in the Henry Mountains.

Surrounding the intrusive centers are several thousand feet of exposed sedimentary rocks, ranging in age from Middle Jurassic to Late Cretaceous (pl. 1), that are arched into large domes. Mt. Ellen, the largest of the five structural domes composing the Henry Mountains, is 12–15 mi in diameter and has a structural relief of nearly 5,000 ft. Superimposed on this large dome are smaller anticlinal crenulations that reflect the presence of individual, underlying laccoliths and bysmaliths that were intruded radially from the stock into the adjacent sedimentary rocks. The Mt. Ellen stock is southwest of the study area, whereas the actual summit of Mt. Ellen is just west of the study area.

The age of the igneous intrusions is not known with certainty. The youngest sedimentary rock that is intruded by the stocks in the Henry Mountains is Late Cretaceous in age. Potassium-argon ages of 44 and 48 million years were determined for hornblende from diorite porphyry of the Bull Mountain bysmalith (Armstrong, 1969); these age determinations indicate an Eocene age for the intrusion. However, on the basis of their similarity to other intrusive complexes on the Colorado Plateau, Hunt (1980) suggested that a mid-Tertiary age for the intrusions of the Henry

Mountains is more likely. This contention is supported by four fission track ages ranging from 21.2 to 29.2 million years from zircon and sphene from diorite and quartz diorite in the Henry Mountains (Sullivan, 1987).

Geochemistry

A reconnaissance geochemical survey of the study area was conducted during the summers of 1982 and 1983 to assist in the mineral resource potential assessment. This geochemical survey was part of a larger program designed to examine the geochemistry of several wilderness study areas in the region. Stream-sediment samples, heavy-mineral concentrates panned from stream sediments, and rock samples were collected for geochemical analysis. A total of 126 stream-sediment samples, 124 panned-concentrate samples, and 128 rock samples collected within and in the vicinity of thė Bull Mountain Wilderness Study Area were analyzed by semiquantitative emission spectrography (Grimes and Marranzino, 1968). Mineralogic identifications of the heavy-mineral concentrates were made. A sample location map and a list of the data are in Detra and others (1984).

Anomalous concentrations of metals were found in stream sediments (copper and molybdenum) and panned concentrates (gold, silver, copper, lead, and zinc) from Bromide Basin, which is just southwest of the Bull Mountain Wilderness Study Area. Our geochemical studies do not indicate an extension of the Bromide Basin anomaly north into the study area. Five to ten miles north of Bromide Basin and 0.5–1.5 mi west of the study area two isolated sample localities having anomalous gold values are associated with areas of slightly altered rock. These sample localities are widely separated and are west of the study area; they probably represent small, localized mineral occurrences. Analyses of igneous rocks from stocks and satellite laccoliths and bysmaliths throughout the Henry Mountains region indicate that all of the samples that contain anomalous values of metals came from the stocks. Rarely do metal amomalies occur in the laccoliths (Detra and others, 1984).

Mineral and Energy Resources

Evaluation of the mineral resource potential of the Bull Mountain Wilderness Study Area is based on: (1) geologic investigations (pl. 1; Patterson and others, 1985); (2) geochemical investigations (Detra and others, 1984); (3) development of and comparison to mineralization models (fig. 4; Peterson, 1977, 1980b; Dubiel, 1983b); and (4) previously published studies on the geology and mineral occurrences of the study area (Hunt and others, 1953; Doelling, 1972; Molenaar and others, 1983; Molenaar and Sandberg, 1983).

Although there are no mining districts within or near the Bull Mountain Wilderness Study Area, gold, silver, copper, coal, uranium, and vanadium occurrences have been found within or near the study area.

Metals other than Uranium and Vanadium

Base- (copper, lead, zinc, molybdenum) and precious- (silver and gold) metal deposits in the North American Cordillera commonly are associated with igneous plutons. The sparse metallic mineralization in the Henry Mountains is almost entirely restricted to the igneous stocks and the complex intrusive shatter zones that border them. For reasons not well understood, the igneous rocks associated with the laccolithic centers on the Colorado Plateau, including those of the Henry Mountains, generally do not contain significant amounts of copper, lead, silver, and gold.

Placer gold occurs along both sides of Crescent Creek, which is on the east side of Mt. Ellen just south of the study area (Doelling, 1980; Gese, 1984a). These placer gold deposits were discovered around 1900 and produced 300–350 ounces of gold from 1914 to the 1940's (Gese, 1984a). In 1984, several placer gold operations were active on Crescent Creek south of the Bull Mountain Wilderness Study Area.

Gold, silver, and copper have been produced from fissure veins in the diorite porphyry stock of Mt. Ellen, 1 mi south of the study area in Bromide Basin (Hunt and others, 1953; Doelling, 1980; Gese, 1984a). Approximately 700 ounces of gold, 3,000 ounces of silver, and 9 tons of copper have been produced from the Bromide Basin area since 1889 (Doelling, 1972; Gese, 1984a). Although the gold-bearing structures strike toward the study area, no mineralized fissure veins similar to those in Bromide Basin have been found within the study area.

Analyses of stream sediments, panned concentrates from stream sediments, and whole-rock samples were made to assess the potential for metallic resources other than uranium and vanadium in the study area. The sparse areas of metallic mineralization in the Henry Mountains are believed to be related to hydrothermal processes associated with the emplacement of the intrusive stocks around which the laccoliths are clustered. Occurrences of base and precious metals are almost entirely restricted to the stocks and the complexly intruded contact or shattered zones that border them. The stock associated with the Mt. Ellen intrusive center is 1–2 mi south and west of the study area. As noted by Hunt and others (1953, p. 165), the intrusions were nearly devoid of volatiles, temperatures at the time of emplacement were low, and, as a result, contact

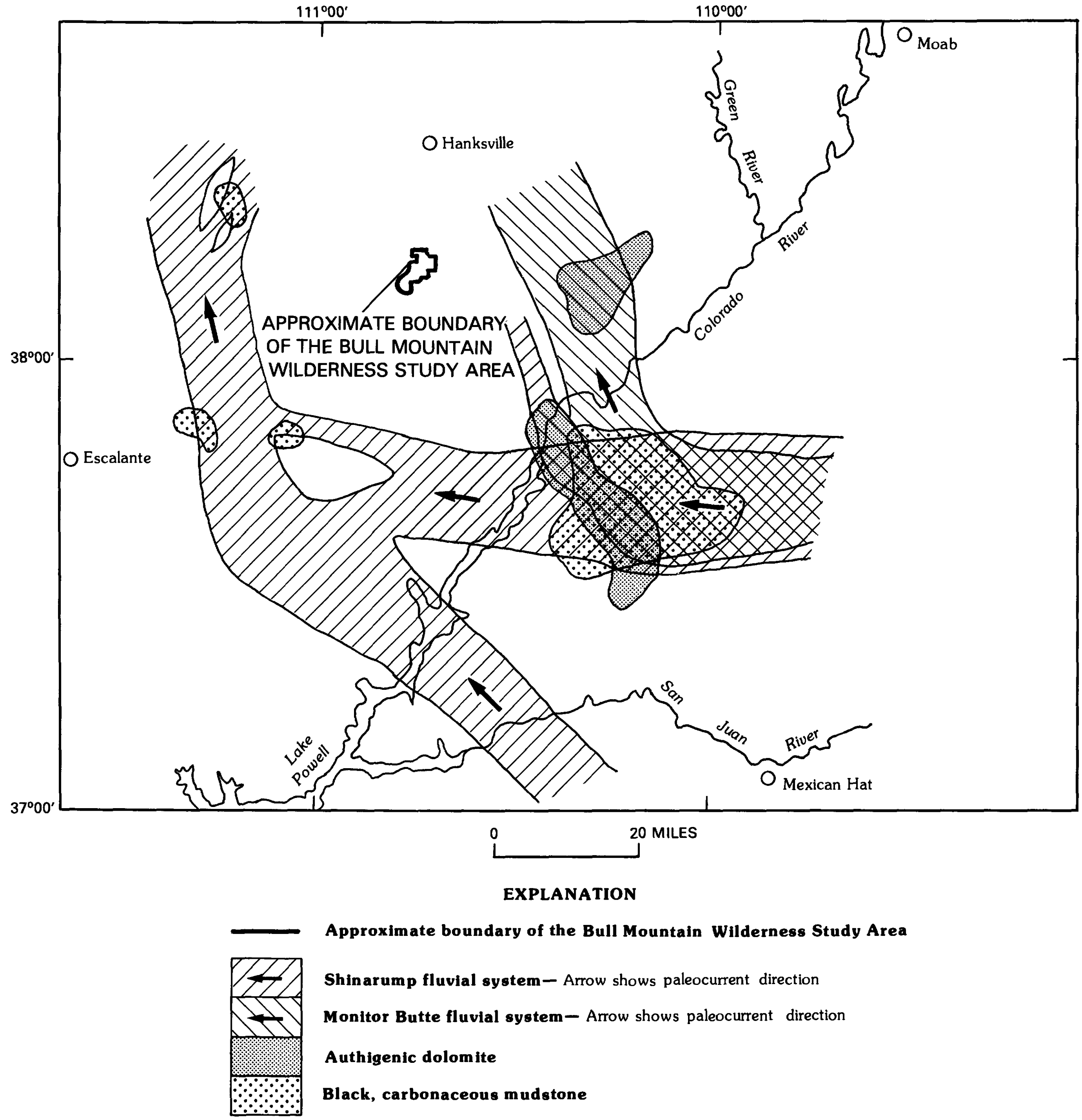

Figure 4. Map showing distribution of Shinarump and Monitor Butte fluvial systems, authigenic dolomite, and black carbonaceous mudstone used to evaluate uranium potential in the Bull Mountain Wilderness Study Area and vicinity. (Modified from Dubiel and others, 1985.)

metamorphism and rock alteration were slight. In addition, there were neither large nor numerous channelways available for mineralizing solutions. The small production of base and precious metals from Bromide Basin came chiefly from local, narrow, northerly trending fissure veins in the Mt. Ellen stock. Locally, narrow iron-oxide-stained fissures, that in places contain minor copper carbonates, have been prospected in the shatter zone around the Mt. Ellen stock, but no production has resulted from these prospects. The shatter zone does not extend into the study area. Within the study area, small areas in intrusive rocks of the laccoliths are stained with iron oxides, probably from the oxidation of pyrite. Geologic and geochemical evidence suggests that the Bull Mountain Wilderness Study Area has a low potential for copper, lead, zinc, molybdenum, gold, and silver. This low mineral resource potential is assigned a certainty level of C on the basis of the known geologic and geochemical data bases and the relative uncertainty in the understanding of mineralization processes and models for this intrusive igneous terrane.

Minor occurrences of metals that are intimately associated with uranium are discussed in the subsequent section on uranium.

Coal

The entire Bull Mountain Wilderness Study Area is within the Henry Mountains coal field (Gese, 1984b). The Emery and Ferron Sandstone Members of the Cretaceous Mancos Shale are important coal-bearing strata that occur within the coal field. These beds are thickest west and south of the study area along the axis of the Henry basin. The Cretaceous Dakota Sandstone contains black, carbonaceous mudstone and thin, laterally discontinuous coal seams.

The coal-bearing Emery Sandstone Member has been eroded from within the study area. The coal-bearing Ferron Sandstone Member, however, intermittently crops out northwest of the study area (Gese, 1984a) and in the extreme southern part of the study area (pl. 1; Patterson and others, 1985). Sections of coal within the Ferron Sandstone Member, measured by Doelling (1972) at 14 locations near the study area, show thin, discontinuous coal seams that range in thicknesses from 0 to 5 ft (Gese, 1984a). Coal seams in the Dakota Sandstone are discontinuous and are generally less than 1 ft thick.

Jet, a gemstone variety of lignite coal, occurs near the top of the Cretaceous Dakota Sandstone approximately 1 mi north and 4 mi west of the study area in the SE¼ sec. 22, T. 30 S., R. 10 E. (Doelling, 1980; Gese, 1984b). Jet was produced from this area from 1919 to 1925; however, no jet is known to occur within the study area.

The facts that the Emery Sandstone Member has been eroded from the study area and that coal seams in the Ferron Member and Dakota Sandstone are thin and discontinuous indicate that the Bull Mountain Wilderness Study Area has a low energy resource potential for coal because of the thin, discontinuous nature of the coal beds. This low energy resource potential is assigned a certainty level of C on the basis of the known occurrences of coal in the region, the occurrence of similar host rocks in the study area, and geologic studies that indicate the thin and discontinuous nature of the coal beds.

Uranium and Vanadium

In the past, uranium exploration in the Henry basin had been limited to the uranium- and vanadium-bearing Salt Wash Member of the Jurassic Morrison Formation. More recently, a minor effort has been directed toward the exploration of the Upper Triassic Chinle Formation just northeast of Mt. Ellsworth in the southern Henry Mountains. Most of the known uranium and vanadium occurrences in the Salt Wash Member of the Morrison Formation are south of the study area in a north-trending zone known as the Henry Mountains mineral belt. Both the Shootering Canyon mine and the Del Monte mine, south of Mt. Hillers in the southern Henry Mountains, are in this belt.

The known uranium and vanadium occurrences in the area are restricted to fluvial sandstone beds of the Salt Wash Member of the Morrison Formation. Detailed sedimentologic studies of the Salt Wash Member in the Henry basin by Peterson (1980a, b) indicate that, in the Henry basin, uranium-vanadium deposits in the Salt Wash Member of the Morrison Formation are associated with carbonaceous lacustrine mudstone strata interbedded with the sandstone beds. These carbonaceous lacustrine mudstone beds occur in a belt south of the study area and are not present in the Bull Mountain Wilderness Study Area. Geochemical studies of the region (Lupe and others, 1982) indicate that there are no known significant uranium anomalies in the study area.

The Upper Triassic Chinle Formation, which is at depth within the Bull Mountain Wilderness Study Area, is known to contain uranium deposits in the White Canyon area southeast of the study area, in the area near Fiddler Butte east of the study area, and near Capitol Reef National Park west of the study area. In addition, uranium has been discovered by recent drilling northeast of Mt. Ellsworth in the southern Henry Mountains in subsurface paleochannels of the Upper Triassic Chinle Formation (Dubiel and others, 1987). In each of these areas, uranium deposits that contain minor vanadium and copper are restricted to fluvial channel sandstone and conglomerate beds of the Shinarump Member to the east and west, and of the Monitor Butte Member to the north near Fiddler Butte. Sedimentologic analysis of these fluvial systems on the basis of paleochannel trends from nearby outcrops indicates that the fluvial depositional systems of the Shinarump Member trend west from the area of White Canyon and north to northwest through the area of Capitol Reef National Park (fig. 4). The sedimentology study (Dubiel, 1983b) also indicates that the fluvial depositional systems of the Monitor Butte Member trend north in the area of North Wash and Fiddler Butte (fig. 4). Sedimentologic analysis of these fluvial systems (Dubiel, 1983b) indicates that they probably do not underlie the Bull Mountain Wilderness Study Area (fig. 4) on the basis of study of the trend of paleochannel systems in nearby outcrops. However, some uncertainty exists in predicting the exact subsurface trend of the paleochannel systems as distance from the outcrop to the study area increases.

Detailed mineralogic and geochemical studies by Northrup (1982) of uranium ore deposits in Jurassic rocks of the Henry basin suggest that authigenic dolomite occurs in fluvial sandstone beds that contain uranium and vanadium ore deposits. In a comparative study, rock samples from the lower part of the Chinle Formation, including the Shinarump and Monitor Butte Members, were collected for dolomite analysis where the Chinle crops out around the Henry basin. X-ray diffraction studies indicate that the areas of greatest concentration of authigenic dolomite coincide with the areas of Shinarump and Monitor Butte paleochannel systems (fig. 4), thus supporting the concept that Shinarump and Monitor Butte fluvial systems may have some potential for containing uranium deposits.

Dubiel (1983b) showed that carbonaceous lacustrine mudstones, similar to those reported to be related to Morrison Formation uranium deposits (Peterson, 1977), are abundant in the lower part of the Chinle Formation in the same areas that contain the fluvial systems and the dolomite concentrations (fig. 4). Therefore, all of these factors indicate that the potential for uranium and vanadium resources in the study area, on the basis of sedimentologic studies of both the Salt Wash Member of the Upper Jurassic Morrison Formation and the Shinarump and Monitor Butte Members of the Upper Triassic Chinle Formation, is low (fig. 1, pl. 1). Copper and other metals such as cobalt and nickel are known to occur in uranium deposits in the Shinarump Member in other places on the Colorado Plateau (Shoemaker and others, 1959), although the present data do not indicate their presence in the study area. This designation of low mineral resource potential for uranium and vanadium is assigned a certainty level of B on the basis of the known occurrences of uranium deposits in adjacent areas, the occurrence of similar host rocks within the study area, and the uncertain projection of trends favorable for the formation of uranium deposits into the study area on the basis of models developed for this study.

Oil and Gas

Oil and gas have been produced from Pennsylvanian, Permian, and Triassic rocks in basins adjacent to the Henry basin, and these same strata are known to occur in the subsurface of the Henry basin, but they remain mostly untested. Factors detrimental to oil and gas accumulation in the study area are the extensive dissection of the region by the Colorado River and its tributaries, which would have lowered reservoir pressures by exposing reservoir rocks (Irwin and others, 1980), and the emplacement of the Henry Mountains intrusive igneous bodies, which have uplifted, deformed, and heated the adjacent sedimentary rocks, possibly destroying hydrocarbons that may have been present (Molenaar and Sandberg, 1983). Thus, the Bull Mountain Wilderness Study Area has been assessed as having a low energy resource potential for oil and gas on the basis of data from this study and from studies by Molenaar and others (1983) and Molenaar and Sandberg (1983). A certainty level of C is assigned on the basis of the regional geology and occurrence of possible hydrocarbon-bearing units within the study area coupled with a lack of knowledge on the exact subsurface distribution of these units and their hydrocarbon content.

Gypsum

The Tidwell Member of the Upper Jurassic Morrison Formation occurs immediately below the Salt Wash Member of the Morrison Formation. Geologic mapping for this study (pl. 1; Patterson and others, 1985) included the Tidwell Member with the Salt Wash Member. West of the study area along Sawmill Basin road and east of the study area in the vicinity of Goatwater Point the Tidwell Member contains gypsum in beds as much as 30 ft thick (Peterson, 1980a). Geologic mapping for this study and sedimentologic studies of the Morrison Formation around the Henry basin indicate that the gypsum beds in the Tidwell Member underlie the northern half of the Bull Mountain Wilderness Study Area (pl. 1; Peterson, 1980a; Patterson and others, 1985). But because the exact stratigraphic position within the Morrison Formation of the floor of the Bull Mountain bysmalith is not precisely known, we are uncertain whether the Tidwell Member underlies the bysmalith. The northern half of the Bull Mountain Wilderness Study Area has a high mineral resource potential for gypsum in the Tidwell Member of the Morrison Formation. A certainty level of B is assigned to the area of the Bull Mountain bysmalith on the basis of the uncertainty in the stratigraphic position of the floor of the bysmalith, geologic mapping, and sedimentology studies of the Morrison Formation. A certainty level of C is assigned to the remaining area of the northern part of the study area on the basis of geologic mapping and sedimentology studies of the Morrison Formation.

Geothermal Energy

There is no evidence, such as heated waters or associated mineral deposits, to suggest any occurrence of geothermal sources in the study area. The Bull Mountain Wilderness Study Area has a low resource potential for geothermal energy. A certainty level of C is assigned on the basis of the lack of geologic evidence for geothermal sources in the study area.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

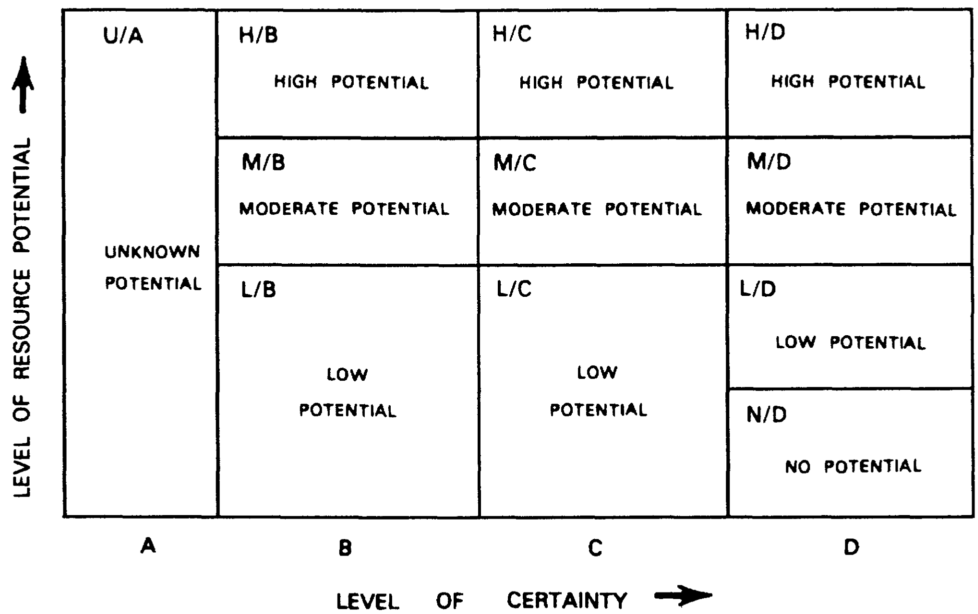
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

Abstracted with minor modifications from:

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RESOURCE / RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

Terms and boundary ages used in this report

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

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

[2] Informal time term without specific rank.

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