UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Mineral Resources of the Mount Ellen-Blue Hills (Addition) Wilderness Study Area, Wayne County, Utah

By

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This report is preliminary and has not been reviewed
for conformity with U.S. Geological Survey editorial standards
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CONTENTS

FIGURES

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 Mount Ellen-Blue Hills (Addition) (UT-050-238) Wilderness Study Area, Wayne County, Utah.

ABSTRACT

The Mount Ellen-Blue Hills (Addition) (UT-050-238) Wilderness Study Area comprises 7,324 acres in Wayne County, Utah. Field and laboratory investigations were conducted by the U.S. Geological Survey from 1981 to 1985 and by the U.S. Bureau of Mines in 1988. Field investigations disclosed no evidence of mineral occurrences, mining activity, or industrial commodities in the study area. The entire study area has a low mineral resource potential for oil and gas, coal, uranium and vanadium, metals, and geothermal resources.

SUMMARY

At the request of the U.S. Bureau of Land Management, the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM) studied the Mount Ellen-Blue Hills (Addition) (UT-050-238) Wilderness Study Area to determine both the identified (known) resources and the mineral resource potential (undiscovered resources) of the area. The Mount Ellen-Blue Hills (Addition) Wilderness Study Area represents an addition of 7,324 acres to the Mount Ellen-Blue Hills (UT-050-238) Wilderness Study Area, which comprises about 58,480 acres in the northern Henry Mountains and adjacent plateaus. The geology, mineral resources, mining activity, and mineral resource potential of the Mount Ellen-Blue Hills Wilderness Study Area were reported in Gese (1984) and in Dubiel and others (1985). The present report discusses the geology, identified resources, and mineral resource potential of the additional acreage, referred to herein as the Mount Ellen-Blue Hills (Addition) Wilderness Study Area or simply as the study area.

The Mount Ellen-Blue Hills (Addition) Wilderness Study Area is about 15 mi (miles) southwest of Hanksville in Wayne County, Utah (fig. 1). The study area lies south of the Fremont River and encompasses South Caineville Mesa, a large mesa that adjoins the northwest boundary of the Mount Ellen-Blue Hills Wilderness Study area in the northern Henry Mountains. Field and laboratory investigations were conducted by the USGS from 1980 to 1984 and completed by the USBM in 1988.

The study area primarily contains sedimentary rocks of Late Cretaceous age (see geologic time chart in Appendix). The flanks of South Caineville Mesa consist of marine shales and minor thin sandstones of the Upper Cretaceous Blue Gate Member of the Mancos Shale, and the mesa top is formed by the marginal-marine sandstones of the Upper Cretaceous Emery Sandstone Member of the Mancos Shale. In the northern part of the study area, areas of Holocene alluvium are in small tributary drainages to the Fremont River and in the main valley of the Fremont River. Field investigations disclosed no evidence of mineral occurrences, mining activity, or industrial commodities in the study area.

Stream-sediment and rock samples were collected by the USGS from the Henry Mountains region for geochemical analysis as part of the appraisal of the mineral resource potential of several wilderness study areas in the Henry Basin. No significant geochemical anomalies are present in the samples collected in the vicinity of the study area. Oil and gas have been produced from rocks in basins adjacent to the study area; these same strata occur in the subsurface of the Henry Basin, but they remain mostly untested. Factors detrimental to oil and gas accumulation include the extensive dissection of the region by the Colorado River and its tributaries and the emplacement of the Henry Mountains igneous intrusions. The study area has low mineral resource potential for oil and gas.

The study area is within the Henry Mountains coal field. The Ferron and Emery Sandstone Members of the Upper Cretaceous Mancos Shale are important coal-bearing strata within the coal field; the Upper Cretaceous Dakota Sandstone also contains some thin coal seams, but these are laterally discontinuous. The study area has low mineral resource potential for coal on the basis of

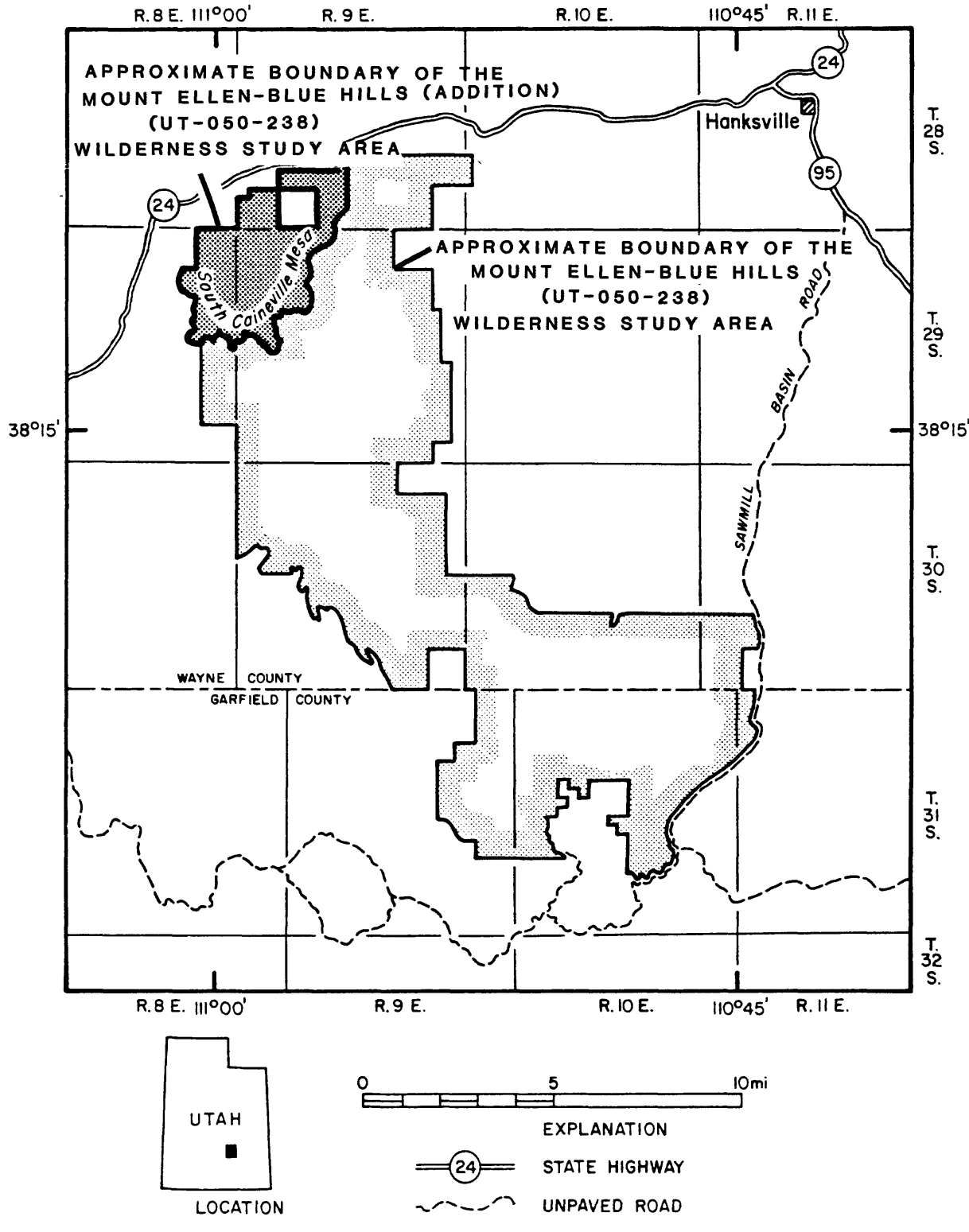

Figure 1. Map showing location of the Mount Ellen-Blue Hills (Addition) Wilderness Study Area

geologic mapping, the lack of significant coal in stratigraphic sections measured adjacent to the study area, and the weathered nature of the Emery Sandstone in the study area.

Uranium and vanadium occurrences in the Henry Basin are restricted to fluvial sandstones of the Salt Wash Member of the Upper Jurassic Morrison Formation. Although the Salt Wash Member probably underlies the study area, favorable belts for uranium deposits in the Salt Wash that are indicated by carbonaceous, lacustrine mudstones probably do not underlie the study area. The Upper Triassic Chinle Formation, which underlies the study area, contains uranium deposits in several regions near the study area, and recent drilling has discovered uranium in the Chinle in the southern part of the Henry Mountains. Sedimentologic analysis of fluvial systems that host Chinle uranium deposits indicates that these fluvial systems probably do not underlie the study area. The study area has low mineral resource potential for uranium and vanadium in the Chinle and Morrison Formations, because the fluvial channel systems that host Chinle uranium deposits and the favorable belt of carbonaceous, lacustrine mudstones associated with Morrison uranium-vanadium deposits probably do not underlie the study area.

Deposits of base (copper, lead, zinc, molybdenum, and related metals) and precious (silver and gold) metals in the sparsely mineralized Henry Mountains are almost entirely restricted to the central intrusions of the five mountain centers. Sedimentary rocks adacent to the central intrusions and associated laccoliths exhibit only slight induration and baking within a few inches to a few feet of the intrusions. On the basis of geologic mapping and geochemical sampling, the study area has a low mineral resource potential for metals.

There is no evidence, such as heated waters or associated mineral deposits, to suggest any occurrence of geothermal sources in the study area, and the study area has low resource potential for geothermal energy.

INTRODUCTION

The The Mount Ellen-Blue Hills (Addition) (UT-050-238) Wilderness Study Area represents an addition of 7,324 acres to the Mount Ellen-Blue Hills (UT-050-238) Wilderness Study Area, which comprises about 58,480 acres in the northern Henry Mountains and adjacent plateaus. The geology, resources, mining activity, and mineral resource potential of the Mount Ellen-Blue Hills Wilderness Study Area were reported in Gese (1984) and in Dubiel and others (1985). The present report discusses the geology, identified resources, and mineral resource potential of the additional acreage, referred to herein as the Mount Ellen-Blue Hills (Addition) Wilderness Study Area or simply as the study area.

The Mount Ellen-Blue Hills (Addition) Wilderness Study Area is about 15 mi (miles) west of Hanksville in Wayne County, Utah (fig. 1). The study area lies south of Utah State Highway 24 and the Fremont River. Access to the study area may be gained from Utah State Highway 24 by crossing the Fremont River on foot or by floating the Fremont River. The study area is in the northern part of the Henry Basin, which is dominated by badlands topography. The study area encompasses South Caineville Mesa, a large mesa immediately adjacent to the northwest boundary of the Mount Ellen-Blue Hills Wilderness Study area in the northern Henry Mountains. South Caineville Mesa comprises steep slopes of marine shale and a caprock of marginal-marine sandstone.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is a product of separate studies by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Identified resources are classified according to the system of the U.S. Bureau of Mines and the U.S. Geological Survey (1980), which is shown in the Appendix of this report. Identified resources were 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 (oil, gas, coal, oil shale, uranium, and geothermal sources). Mineral resource potential and the level of certainty of the resource assessment were classified according to the system of Goudarzi (1984), which is also shown in the Appendix. The potential for undiscovered resources was 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 intrusion 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 7 1/2-minute quadrangles as part of a study of the Henry Mountains coal field. Uranium has been the only mineral commodity of any importance in the region, and many investigations were conducted by, or done under contract to, the Atomic Energy Commission (now the U.S. Department of Energy) in the 1940's and 1950's. These reports are available through the U.S. Geological Survey, Books and Open-File Reports Section, Denver Federal Center, Box 25046, Denver, CO 80225. 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, 1980b), and Chenoweth (1980). Doelling (1980) described the various metal deposits of the region.

Several reports describe the mineral resources (Gese, 1984), geology (Patterson and others, 1985) and mineral resource potential (Dubiel and others, 1985) of the Mount Ellen-Blue Hills Wilderness Study Area, which is adjacent to and immediately southeast of the study area.

Investigations by the U.S. Bureau of Mines

In 1988, the USBM completed a mineral investigation to evaluate the identified mineral resources of the Mount Ellen-Blue Hills (Addition) Wilderness Study Area as part of a joint effort with the USGS. Field studies by USBM personnel included a search for mines, prospects, and mineralized areas in and near the study area boundary.

Investigations by the U.S. Geological Survey

From 1980 to 1984, the USGS conducted field and laboratory studies to assess the potential for undiscovered mineral resources of the Mount Ellen-Blue Hills Wilderness Study Area, which adjoins and is immediately southeast of the Mount Ellen-Blue Hills (Addition) Wilderness Study Area. The studies encompassed the acreage of the Mount Ellen-Blue Hills Wilderness Study Area and a belt surrounding that study area that was large enough to include the Mount Ellen-Blue Hills (Addition) Wilderness Study Area. Because the study area adjoins the Mount Ellen-Blue Hills Wilderness Study Area and is in the same geographic and geologic setting, the present evaluation of the mineral resource potential of the Mount Ellen-Blue Hills (Addition) Wilderness Study Area is based on the geologic studies and the data collected for that region. Individual studies consisted of geologic mapping (Patterson and others, 1985), a search for mines, prospects, and mineralized areas, sedimentologic studies (Dubiel, 1982, 1983a, 1983b), rock and stream-sediment sampling for geochemical analysis (Detra and others, 1984), and a search of previously published studies on the geology (Hunt and others, 1953; Peterson, 1977, 1980a, 1980b) and mineral deposits of the area (Doelling, 1972; Lupe and others, 1982; Molenaar and others, 1983; Molenaar and Sandberg, 1983). Models developed for the occurrence of uranium (Peterson, 1980b; Dubiel, 1983b) and base and precious metals (Cox and Singer, 1986) were applied to the evaluation of mineral resource potential in the study area.

Acknowledgements.-This assessment of the mineral resource potential of the area was aided by the expertise and contributions of many people. The USGS thanks 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. I thank each of the USGS personnel who assisted in the field on all aspects of this interdisciplinary study in the Henry Mountains: Calvin Bromfield, Stanley Church, Brad Esslinger, James Faulds, Joseph Fontaine, Darlene Francis, David Hammond, Carl Harris, William Kemp, Mark Larson, Paul Milde, Denise Mruk, Charles Paterson, Fred Peterson, Charles Pierson, Richard Reeves, Michael Rendina, David Scott, William Thoen, Ann Tirrell, Bruce van Brundt, Shawn Yasataki, and Christine Yee.

APPRAISAL OF IDENTIFIED RESOURCES

by Diann D. Gese
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Gold, silver, and copper were produced in the 1890's from fissure veins within the igneous stocks of Mount Ellen, Mount Pennell, and Mount Hillers (Hunt and others, 1953; Dubiel and others, 1988; Dubiel and others, 1990), all of which are a considerable distance south of the study area. No igneous rocks crop out or are known to lie in the subsurface of the study area.

Uranium and vanadium occur in the Chinle Formation in the White Canyon mining district about 50 mi southeast of the study area and in the Morrison Formation in the Little Rockies mining district about 45 mi south of the study area. No part of the White Canyon or Little Rockies mining districts are within the study area. The Chinle Formation and the Morrison Formation do not crop out within the study area, but both formations are present in the subsurface.

The Mount Ellen-Blue Hills (Addition) Wilderness Study Area is within the Henry Mountains coal field (Doelling, 1972). This coal field is 48 mi long and 18 mi wide and contains minable reserves in the Emery and Ferron coal zones and contains thin, discontinuous coal in the Dakota Sandstone (Doelling, 1972). Coal was first mined in the Henry Basin at the Stanton mine, about 40 mi south of the study area, around 1890. The Factory Butte mine about 10 mi northeast of the study area opened in 1908 and operated intermittently until about 1945. Sections measured by Doelling (1972) indicate that the Ferron Sandstone, which underlies the study area, contains thin and discontinuous coal less than 1 foot thick near Factory Butte about 10 mi north of the study area. In this region north of the study area, thin and discontinuous coal 3- to 4-feet thick is in the Dakota Sandstone. Doelling's (1972) sections do not indicate any coal in sections measured south of Factory Butte and near the study area. Coal in the Emery Sandstone occurs in the upper part of the unit on the west side of the Henry Basin about 15 to 40 mi south of the study area. The Emery Sandstone that caps South Caineville Mesa in the study area includes only the lower, non-coal-bearing part of the unit, is thin, and probably has been severely weathered as a result of the exposed position at the top of the mesa. No evidence of any mining activity was found in the Mount Ellen-Blue Hills (Addition) Wilderness Study Area.

The Mount Ellen-Blue Hills (Addition) 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). Within the Paradox basin, oil and gas production 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 Basin and the study area, but they remain untested.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

by Russell F. Dubiel
U.S. Geological Survey

Geology

The Mount Ellen-Blue Hills (Addition) Wilderness Study Area is in the northern Henry Mountains, on the northern flank of the Henry Basin, a north-south-trending topographic and structural basin about 100 mi long and 50 mi wide. The western flank of this asymmetric basin is formed by the steeply eastward dipping rocks of the Waterpocket Fold, a monocline that separates the Henry Basin from the adjacent Circle Cliffs uplift to the west. Strata of the gently dipping east flank of the basin gradually rise eastward toward the crest of the Monument upwarp. The five intrusive complexes of the Henry Mountains locally interrupt the gradual eastward rise of the sedimentary strata.

The Henry Mountains consist of five distinct intrusive centers that form large structural domes: Mount Ellsworth, Mount Holmes, Mount Hillers, Mount Pennell, and Mount Ellen extend in a north-northwest line for about 35 mi. The core of each igneous complex is a separate diorite porphyry intrusion that is discordant to the surrounding sedimentary rocks. The igneous stocks are surrounded by laccoliths as well as sedimentary strata that have been deformed by the igneous bodies.

Surrounding the intrusive centers are several thousand feet of sedimentary strata ranging in age from Late Triassic to Late Cretaceous that are arched into large domes. The sedimentary rocks have been eroded to form a highly dissected topography. On the north flank of Mount Ellen, fine-grained sedimentary rocks of the Blue Gate Member of the Upper Cretaceous Mancos Shale have been eroded to form an extensive area of badlands known as the Blue Hills. In the northeastern part of the Blue Hills lies South Caineville Mesa, a large mesa whose flanks are eroded in the Blue Gate Member and whose top is composed of caprock of the Upper Cretaceous Emery Sandstone Member of the Mancos Shale (fig. 2). The Mount Ellen-Blue Hills (Addition) Wilderness Study Area encompasses the major portion of South Caineville Mesa (fig. 2). The southeastern boundary of the study area adjoins and is coincident with the extreme northwestern boundary of the Mount Ellen-Blue Hills Wilderness Study Area (Dubiel and others, 1985).

Geochemisry

A reconnaissance geochemical survey of the area including the Mount Ellen-Blue Hills (Addition) Wilderness Study area was conducted during the summers of 1982 and 1983 to assist in the assessment of the mineral resource potential. A sample locality map and a list of the data are in Detra and others (1984). A total of 126 stream-sediment samples, 124 panned-concentrate samples, and 128 rock samples were analyzed by semiquantitative emission spectrography (Grimes and Marranzino, 1968). The data indicate that there are no apparent geochemical anomalies associated with any of the samples collected from the vicinity of the study area.

Mineral and Energy Resources

Oil and gas

Oil and gas have been produced from Pennsylvanian, Permian, and Triassic rocks in Laramide structural 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 igneous intrusions,

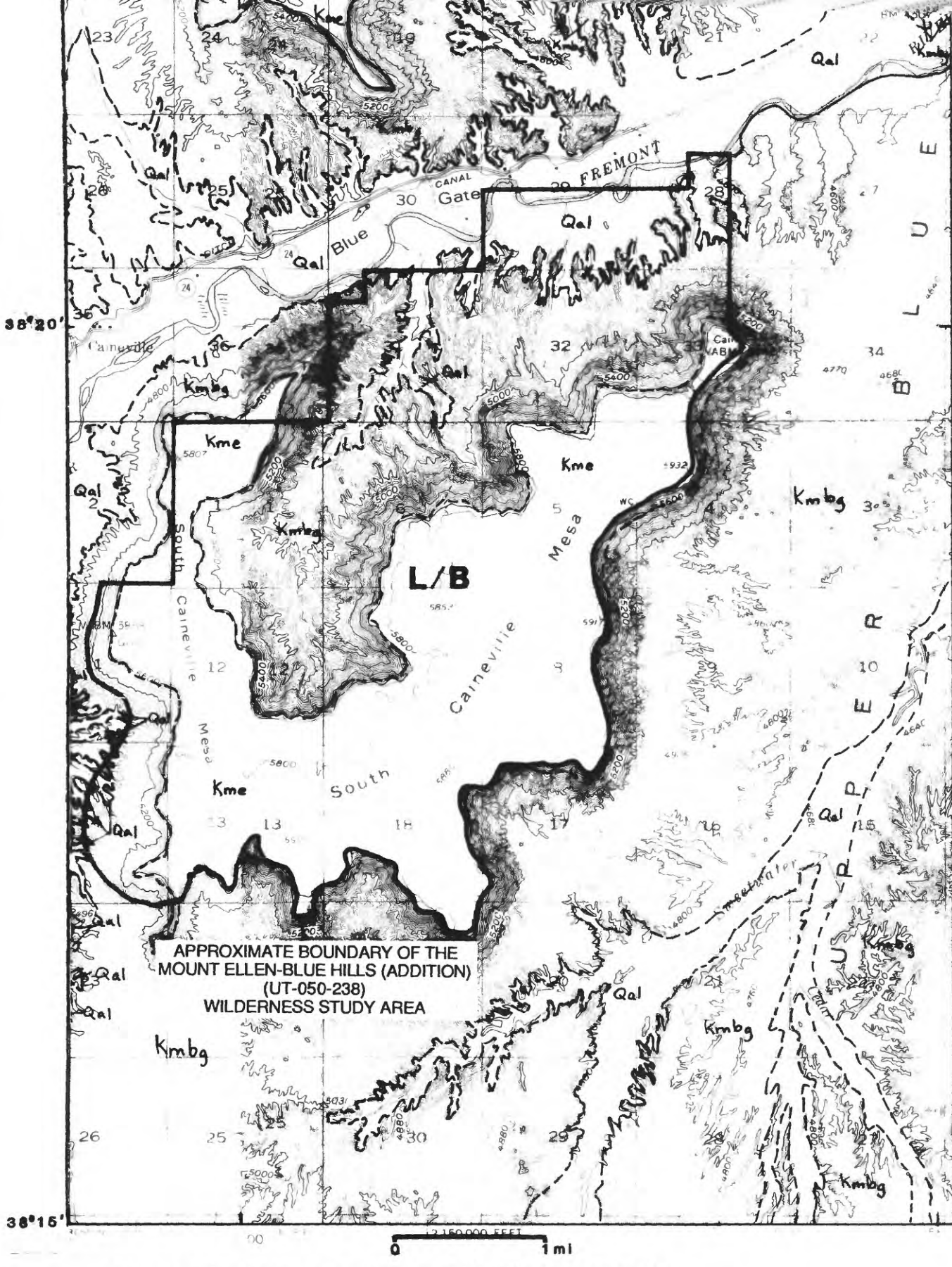


Figure 2. Map showing mineral resource potential and geology ot the Mount Ellen-Blue Hills (Addition) Wilderness Study Area

EXPLANATION OF MINERAL RESOURCE POTENTIAL

L/B **Geologic terrane having low mineral resource potential for oil and gas, coal, uranium and vanadium, metals, and geothermal resources, with certainty level B**

Levels of certainty

B **Data indicate geologic environment and suggest level of resource potential**

DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**--Poorly sorted deposits of clay, silt, sand, and gravel deposited in and along stream courses

Mancos Shale (Upper Cretaceous)--Vertically alternating marine, marginal-marine, and nonmarine units aggregating 3,200-3,600 ft in thickness in the region

Kme **Emery Sandstone Member**--Light- to dark-brown, fine- to medium-grained sandstone; sandstone thinly bedded or cross-stratified; forms steep slopes and cliff; marginal-marine, lagoonal-paludal, and alluvial-plain deposits. Corresponds to Muley Sandstone Member of Mancos Shale of Smith (1984); only the lower part of the Emery Sandstone is in the study area; approximate thickness 120 ft

Kmbg **Blue Gate Member**--Gray to dark-gray bentonitic shale, horizontally laminated to ripple cross-laminated; locally interbedded with minor, thin, very fine grained sandstone; forms steep, broad slope; offshore marine deposits; approximate thickness in the study area is 1,100 ft thick

CORRELATION OF MAP UNITS

Qal	}Holocene	}QUATERNARY
unconformity		
Kme		
	}Upper Cretaceous	}CRETACEOUS
Kmbg		

which have uplifted, domed, and only slightly heated the adjacent sedimentary rocks (Hunt and others, 1953; Molenaar and Sandberg, 1983). The Mount Ellen-Blue Hills (Addition) Wilderness Study Area and vicinity has a low 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 B is assigned on the basis of the regional geology, the occurrence of possible hydrocarbon-bearing strata in the subsurface of the study area, and a lack of knowledge of the exact subsurface distribution of these rocks and their hydrocarbon content.

Coal

The entire study area is within the Henry Mountains coal field (Doelling, 1972). The Ferron and Emery Sandstone Members of the Upper Cretaceous Mancos Shale are important coal-bearing strata that occur within the coal field. The Upper Cretaceous Dakota Sandstone also contains black, carbonaceous mudstone and some thin coal seams, but these are laterally discontinuous and are generally less than 1 foot thick. The Ferron Sandstone contains coal that has been mined at Factory Butte about 10 mi northeast of the study area. Measured sections by Doelling (1972) indicate that south of Factory Butte and near the study area the Ferron Sandstone contains coal beds less than 1 foot thick. The Ferron Sandstone occurs in the subsurface of the study area. In the area near Factory Butte, sections by Doelling (1972) indicate that the Dakota Sandstone contains coal 3 to 4 feet thick, but south of Factory Butte and near the study area, the sections do not indicate any coal in the Dakota. Coal in the Emery Sandstone occurs in the upper part of the unit on the west side of the Henry Basin about 15 to 40 mi south of the study area (Doelling, 1972). The Emery Sandstone crops out in the study area at the top of South Caineville Mesa (fig. 2), but includes only the lower, commonly non-coal-bearing part of the unit, is thin, and probably has been severely weathered as a result of the exposed position at the mesa top. The Mount Ellen-Blue Hills (Addition) Wilderness Study Area has a low mineral resource potential for coal in the Emery Sandstone and the Ferron Sandstone Members of the Mancos Shale and in the Dakota Sandstone on the basis of geologic mapping, the lack of significant coal in sections of these units measured in adjacent areas, and the weathered nature of Emery Sandstone outcrops at the top of South Caineville Mesa. This resource potential is assigned a certainty level of B on the basis of known occurrences of coal in the region, the presence of similar host rocks in the study area, and the apparent lack of coal in sections measured at outcrops adjacent to the study area.

Uranium and vanadium

Uranium and vanadium occurrences in the Henry Basin are restricted to fluvial sandstones of the Salt Wash Member of the Upper Jurassic Morrison Formation, and most of these are south and east of the study area in a north-trending zone known as the Henry Mountains mineral belt (Peterson, 1977, 1980a). Detailed sedimentologic studies of the Salt Wash Member indicate that, in the Henry Basin, uranium-vanadium deposits occur where carbonaceous lacustrine mudstones are interbedded with the sandstones (Peterson, 1980a). Although the Salt Wash Member probably underlies the study area, the carbonaceous lacustrine beds occur only in a north-south-trending belt that lies several miles east of the study area boundary. The favorable belt indicated by the lacustrine mudstones for Salt Wash uranium-vanadium deposits probably does not underlie the study area.

Recently, a minor effort has been directed toward exploration for uranium-vanadium deposits in the basal sandstones of the Chinle Formation in the southeastern part of the Henry Basin. The Chinle Formation underlies the study area. The Chinle is known to contain uranium deposits in the White Canyon area about 60 mi southeast of the study area, near Fiddler Butte about 40 mi southeast of the study area, and near Capitol Reef National Park about 30 mi west of the study area. In addition, recent drilling northeast of Mount Ellsworth in the southern Henry Mountains has discovered uranium in subsurface paleochannels of the Chinle (Dubiel and others, 1987). In these areas, uranium deposits that contain vanadium and copper occur are restricted to

fluvial channels of the Shinarump and Monitor Butte Members of the Chinle Formation. Sedimentologic analysis of these fluvial systems based on paleochannel trends extrapolated from nearby outcrops (Dubiel, 1983b, 1987a, 1987b) indicates that the Shinarump and Monitor Butte fluvial depositional systems probably do not underlie the study area (Dubiel and others, 1985). However, some uncertainty exists in predicting the exact trend of the paleochannel systems, and that uncertainty increases as distance from the outcrop and the study area are increased.

The Mount Ellen-Blue Hills (Addition) Wilderness Study Area has a low mineral resource potential for uranium and vanadium deposits in the Chinle and Morrison Formations, because the fluvial-channel systems that host Chinle uranium-vanadium deposits probably do not underlie the study area and because the favorable belt of carbonaceous lacustrine mudstones associated with fluvial-channel-hosted uranium-vanadium deposits of the Morrison Formation also probably does not underlie the study area. This mineral resource potential is assigned a certainty level of B on the basis of the occurrence of known ore-bearing host rocks in the subsurface of the study area and the lack of certainty of the location in the subsurface of fluvial-channel systems and lacustrine mudstones associated with known uranium-vanadium deposits.

Metals

Deposits of base (copper, lead, zinc, molybdenum, and related metals) and precious (silver and gold) metals in the sparsely mineralized Henry Mountains are almost entirely restricted to the central intrusions of the five mountain centers (Hunt and others, 1953; Dubiel and others, 1990). Sedimentary rocks adjacent to the central and laccolithic igneous intrusions exhibit only slight induration and baking within a few inches, or at most a few feet, of the intrusions (Hunt and others, 1953). The Mount Ellen-Blue Hills (Addition) Wilderness Study Area has a low mineral resource potential for metals, with certainty level B assigned on the basis of the lack of known ore-bearing igneous rocks outcropping in the study area and the lack of knowledge of the subsurface distribution of possible ore-bearing rocks.

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. Hence, the Mount Ellen-Blue Hills (Addition) Wilderness Study Area has a low resource potential for geothermal energy. A certainty level of B is assigned on the basis of the lack of geologic evidence for geothermal sources in the study area.

REFERENCES CITED

Butler, B.S., 1920, Henry Mountains region, *in* The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, p. 622-632.

Chenoweth, W.L., 1980, Uranium-vanadium deposits of the Henry Mountains, Utah, *in* Picard, M.D., ed., Henry Mountains Symposium: Utah Geological Association, Publication 8, p. 299-304.

Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.

Detra, D.E., Erikson, M.S., Kemp, W.M., and Willson, W.R., 1984, Analytical results, mineralogical data, and sample locality map of stream-sediment, heavy-mineral-concentrate, and rock samples from the Bull Mountain and Blue Hills-Mount Ellen Wilderness Study Areas (UT-050-242,238), Wayne and Garfield Counties, Utah: U.S. Geological Survey Open-File Report 84-570, 31 p.

Doelling, H.H., 1967, Uranium deposits of Garfield County Utah: Utah Geological and Mineralogical Survey Special Studies 22, 113 p.

_____, 1972, Henry Mountains coal field, *in* Doelling, H.H., and Graham, R.L., eds., Eastern and northern Utah coal fields: Utah Geological and Mineralogical Survey Monograph Series, No. 2, p. 97-190.

_____, 1975, Geology and mineral resources of Garfield County: Utah Geological and Mineralogical Survey Bulletin 107, 175 p.

_____, 1980, Mineral deposits of the Henry Mountains, *in* Picard, M.D., ed., Henry Mountains Symposium: Utah Geological Association Publication 8, p. 287-296.

Dubiel, R.F., 1982, Measured sections of the Shinarump, Monitor Butte, and Moss Back Members of the Chinle Formation (Upper Triassic) in the White Canyon and Red Canyon area, southeastern Utah: U.S. Geological Survey Open-File Report 82-729, 25 p.

_____, 1983a, Stratigraphic sections of the Shinarump, Monitor Butte, and Moss Back Members of the Upper Triassic Chinle Formation in the northern part of the White Canyon, Red Canyon, and Blue Notch Canyon area, southeastern Utah: U.S. Geological Survey Open-File Report 83-188, 30 p.

_____, 1983b, Sedimentology of the lower part of the Upper Triassic Chinle Formation and its relationship to uranium deposits, White Canyon area, southeastern Utah: U.S. Geological Survey Open-File Report 83-459, 48 p.

_____, 1987a, Sedimentology of the Upper Triassic Chinle Formation, southeastern Utah: Boulder, Colo., University of Colorado, Ph.D. Dissertation, 132 p.

_____, 1987b, Sedimentology and new fossil occurrences of the Upper Triassic Chinle Formation, southeastern Utah, *in* Campbell, J.A., ed., Geology of Cataract Canyon and vicinity: Four Corners Geological Society, 10th Field Conference Guidebook, p. 99-107.

_____, Bromfield, C.S., Church, S.E., Kemp, W.M., Larson, M.J., Peterson, Fred, and Gese, D.D., 1985, Mineral resource potential map of the Mt. Ellen-Blue Hills Wilderness Study Area and Bull Mountain study area, Garfield and Wayne Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1756-A, scale 1:50,000.

_____, Bromfield, C.S., Church, S.E., Kemp, W.M., Larson, M.J., Peterson, Fred, and Neubert, J.T., 1988, Mineral resources of the Mt. Hillers Wilderness Study Area, Garfield County, Utah: U.S. Geological Survey Bulletin 1751-C, 14 p.

_____, Bromfield, C.S., Church, S.E., Kemp, W.M., Larson, M.J., Peterson, Fred, Pierson, C.T., and Gese, D.D., 1990, Mineral resources of the Mount Pennell Wilderness Study Area, Garfield County, Utah: U.S. Geological Survey Bulletin 1751-D, 17 p.

_____, Bromfield, C.S., Church, S.E., Kemp, W.M., Larson, M.J., Peterson, Fred, Pierson, C.T., and Kreidler, T.J., 1987, Mineral resources of the Little Rockies Wilderness Study Area, Garfield County, Utah: U.S. Geological Survey Bulletin 1751-A, 11 p., scale 1:50,000.

Gese, D.D. 1984, Mineral investigation of the Blue Hills-Mount Ellen Wilderness Study Area, Wayne and Garfield Counties, Utah: U.S. Bureau of Mines Open-File Report MLA 26-84, 19 p.

Gilbert, G.K., 1877, Geology of the Henry Mountains: U.S. Geographical and Geological Survey of the Rocky Mountain Region (Powell), 160 p.

Goudarzi, G.H. compiler, 1984, Guide to the preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-787, 42 p.

Grimes, D.J., and Marranzino, A.P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Hunt, C.B., Averitt, Paul, and Miller, R.L., 1953, Geology and geography of the Henry Mountains region: U.S. Geological Survey Professional Paper 228, 234 p.

Irwin, C.D., Clark, W.R., and Peabody, W.W., 1980, Petroleum geology of the Henry Mountains basin, *in* Picard, M.D., ed., Henry Mountains Symposium: Utah Geological Association Publication 8, p. 353-366.

Johnson, H.S., 1959, Uranium resources in the Green River and Henry Mountain districts, Utah--A regional synthesis: U.S. Geological Survey Bulletin 1087-C, 104 p.

Lupe, R.D., Franczyk, K.J., Luft, S.F., Peterson, Fred, and Robinson, Keith, 1982, National Uranium Resource Evaluation, Salina Quadrangle, Utah: U.S. Department of Energy Report PGJ/F-053(82), 83 p.

Molenaar, C.M., Sandberg, C.A., and Powers, R.B., 1983, Petroleum potential of wilderness lands, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1545, scale 1:1,000,000.

_____, and Sandberg, C.A., 1983, Petroleum potential of wilderness lands in Utah: U.S. Geological Survey Circular 902-K, 13 p.

Patterson, C.G., Bromfield, C.S., Dubiel, R.F., Faulds, J.E., Larson, M.J., Milde, P.G., and Peterson, Fred, 1985, Geologic map of the Mt. Ellen-Blue Hills Wilderness Study Area and Bull Mountain study area, Garfield and Wayne Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1756-B, scale 1:50,000.

Peterson, Fred, 1977, Uranium deposits related to depositional environments in the Morrison Formation (Upper Jurassic), Henry Mountains mineral belt of southern Utah, in Campbell, J.A., ed., Short papers of the U.S. Geological Survey Uranium-Thorium Symposium, 1977: U.S. Geological Survey Circular 753, p. 45-47.

_____, 1980a, Sedimentology of the uranium-bearing Salt Wash Member and Tidwell unit of the Morrison Formation in the Henry and Kaiparowits basins, Utah, *in* Picard, M.D. ed., Henry Mountains symposium: Utah Geological Association, Publication 8, p. 305-322.

_____, 1980b, Sedimentology as a strategy for uranium exploration--Concepts gained from analysis of a uranium-bearing depositional sequence in the Morrison Formation of south-central Utah, *in* Turner-Peterson, C.E., ed., Uranium in sedimentary rocks--Application of the facies concept to exploration: Denver, Colo., Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, p. 65-126.

Smith, Curtis, 1984, Geology, depositional environments, and coal resources of the Mt. Pennell 2 NW quadrangle, Garfield County, Utah: Brigham Young University Geology Studies, v. 30, part 1, p. 145-169.

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, 5 p.

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.

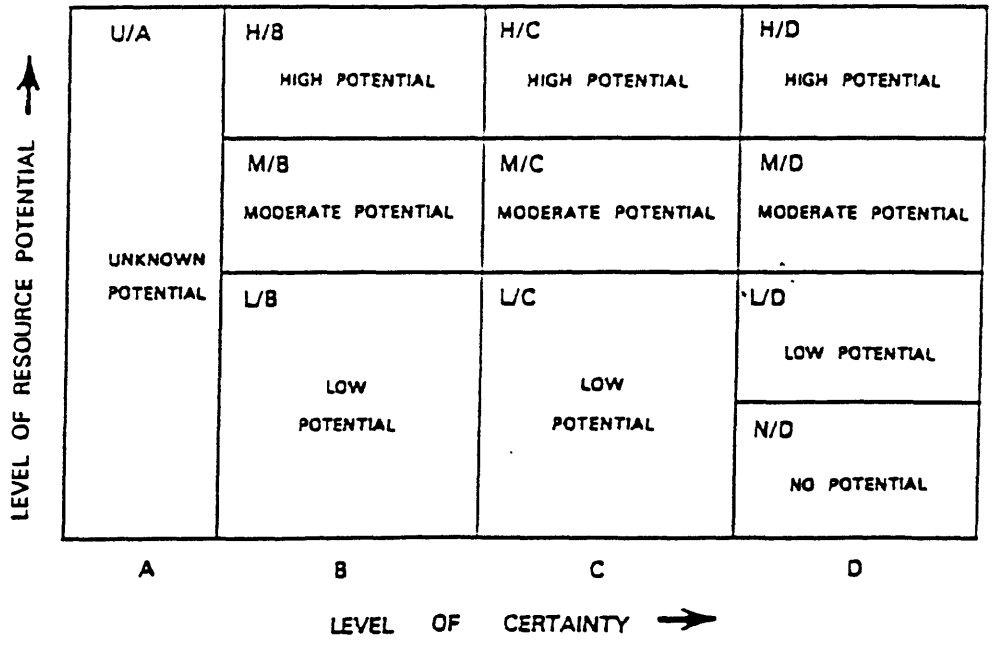
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

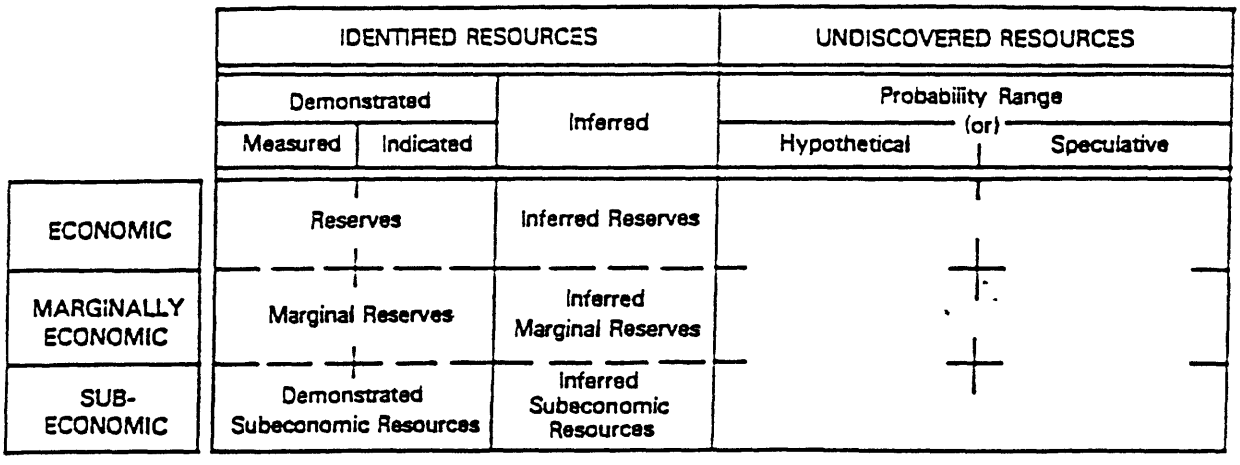
Abstracted with minor modifications from:

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.

RESOURCE/RESERVE CLASSIFICATION



Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from McKelvey, 1972, Mineral resource estimates and public policy: *American Scientist*, v.60, p.32-40, and 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 Early	96 / 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				
pre-Archean[2]		3800?			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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