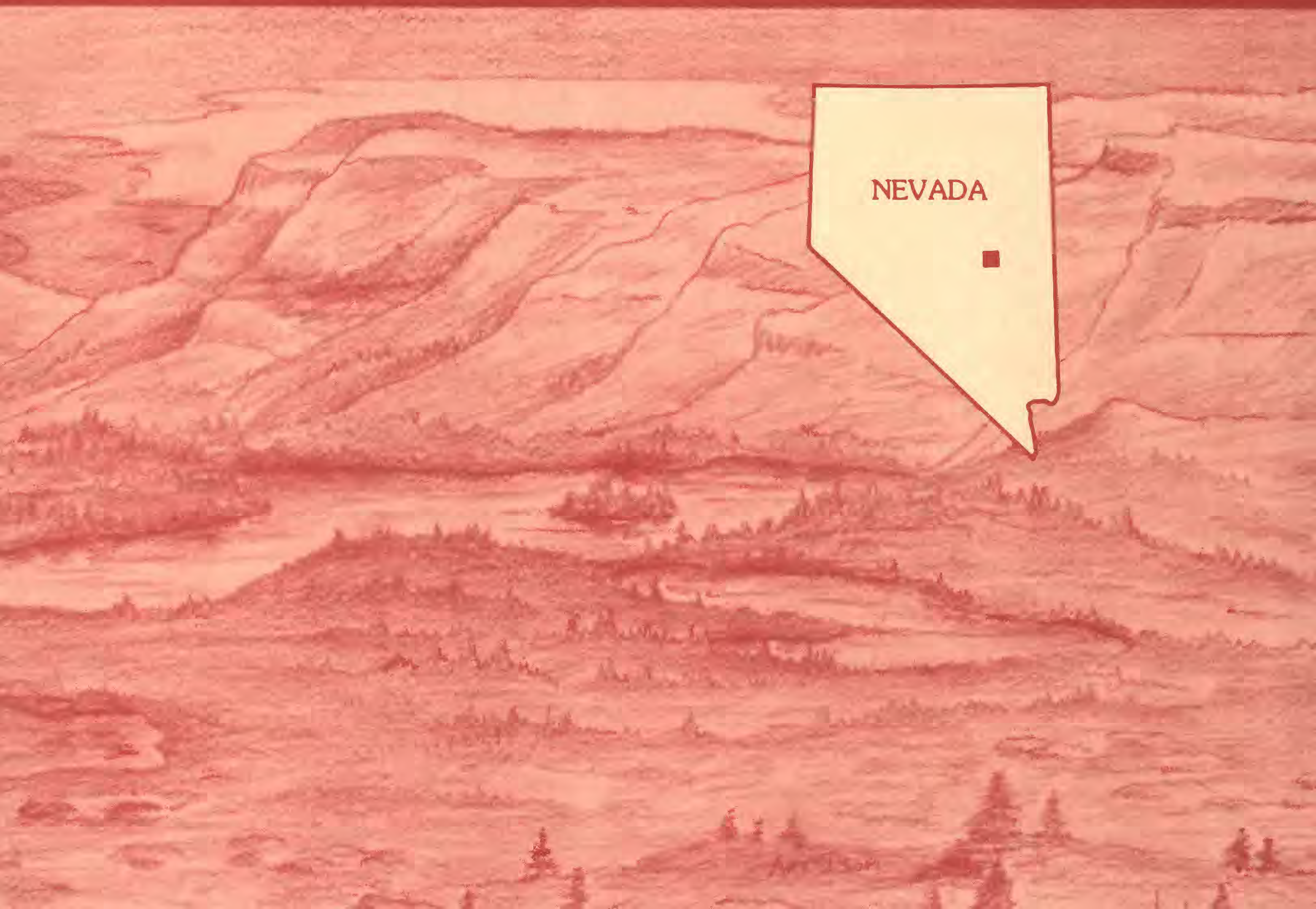
# Mineral Resources of the Park Range Wilderness Study Area, Nye County, Nevada

U.S. GEOLOGICAL SURVEY BULLETIN 1731–F



Chapter F

# Mineral Resources of the Park Range Wilderness Study Area, Nye County, Nevada

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U.S. GEOLOGICAL SURVEY BULLETIN 1731

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
CENTRAL NEVADA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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## STUDIES RELATED TO WILDERNESS

### Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of a part of the Park Range (NV–040–154) Wilderness Study Area, Nye County, Nevada.

# CONTENTS



## PLATE

[Plate is in pocket]



## FIGURES

# Mineral Resources of the Park Range Wilderness Study Area, Nye County, Nevada

*By* William E. Brooks, Robert E. Tucker, Christopher Goodhue, Gordon W. Day, Donald Plouff, *and* Joseph S. Duval
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**SUMMARY**

The Park Range Wilderness Study Area (NV–040–154) is about 45 mi (miles) south of Eureka, Nev., and encompasses 47,268 acres including 46,831 acres on which mineral surveys were conducted. Much of the study area is easily accessible by unpaved roads and four-wheel-drive trails. Elevations range from 6,400 ft (feet) at Hot Creek Valley to 9,131 ft in the central part of the range.

During 1969 and 1970 reconnaissance geologic mapping of the Park Range and adjacent areas was carried out by the USGS (U.S. Geological Survey) in cooperation with the U.S. Atomic Energy Commission. Remapping, reinterpretation, and sampling of problematic areas were carried out during 1983 to 1985 as part of a cooperative study by the USGS and the USBM (U.S. Bureau of Mines). Mineralized zones were examined and evaluated by the USBM, and geologic mapping, geophysical studies, and a stream-sediment geochemical survey were conducted by the USGS.

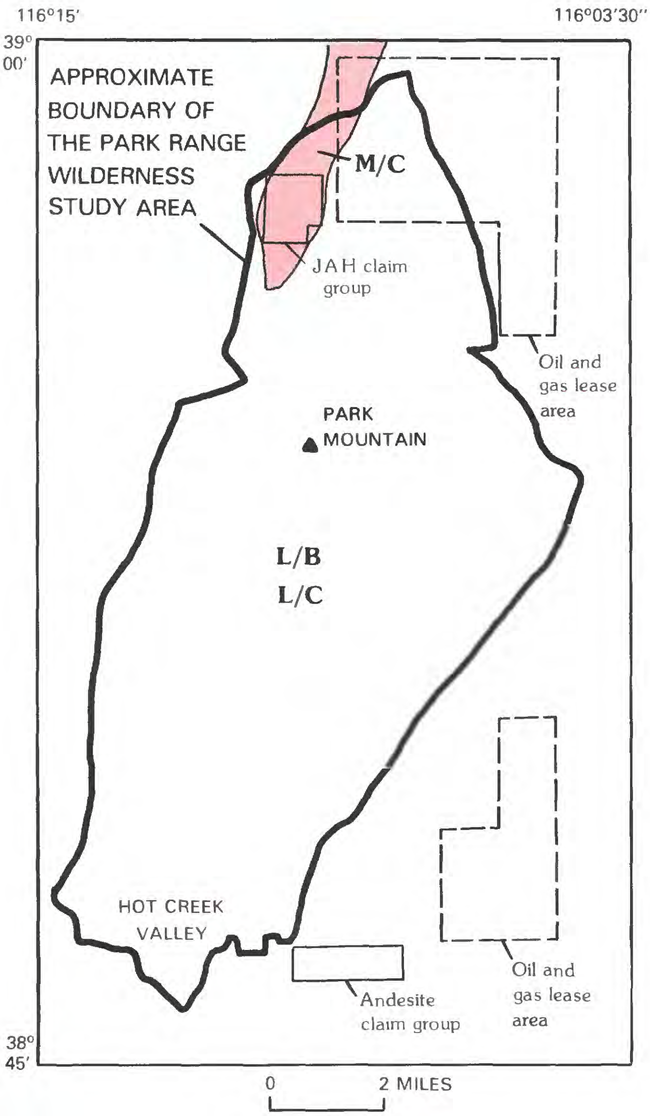
Tertiary (see geologic time chart in Appendix) volcanic rocks that include intermediate-composition lavas and ash-flow tuffs constitute most of the rock exposed in the Park Range. Paleozoic sedimentary rocks that have been faulted and silicified and contain anomalous concentrations of gold, silver, arsenic, and mercury are exposed in a small, wedge-shaped area in the northern part of the wilderness study area. No mineral resources were delineated, and no workings were found during the investigation. However, American Smelting and Refining Co. was actively exploring (1985) the hydrothermally altered sedimentary rocks that crop out in the north end of the study area for hot-spring-type, low-grade, large-tonnage gold deposits. The nearest area having recorded mineral production is the Morey mining district, about 7 mi southwest of the wilderness study area, where small amounts of silver, gold, and lead were sporadically produced from 1865 to 1966.

The mineral resource potential for undiscovered gold, silver, mercury, and arsenic is moderate in the altered, brecciated, and faulted sedimentary rocks exposed in the northern part of the study area and extending north of the study-area boundary (fig. 1). However, the mineral resource potential for these metals in the rest of the study area is low based on the absence of secondary silicification and hydrothermal alteration in the Tertiary volcanic rocks that constitute most of the study area. The mineral resource potential for all other metals in the study area is also low. The resource potential for oil and gas and geothermal energy is low. However, oil and gas leases extend into the northern part of the study area.

Sand and gravel occurrences within the study area are suitable for construction purposes. However, transportation costs to current markets would far exceed their value.

## INTRODUCTION

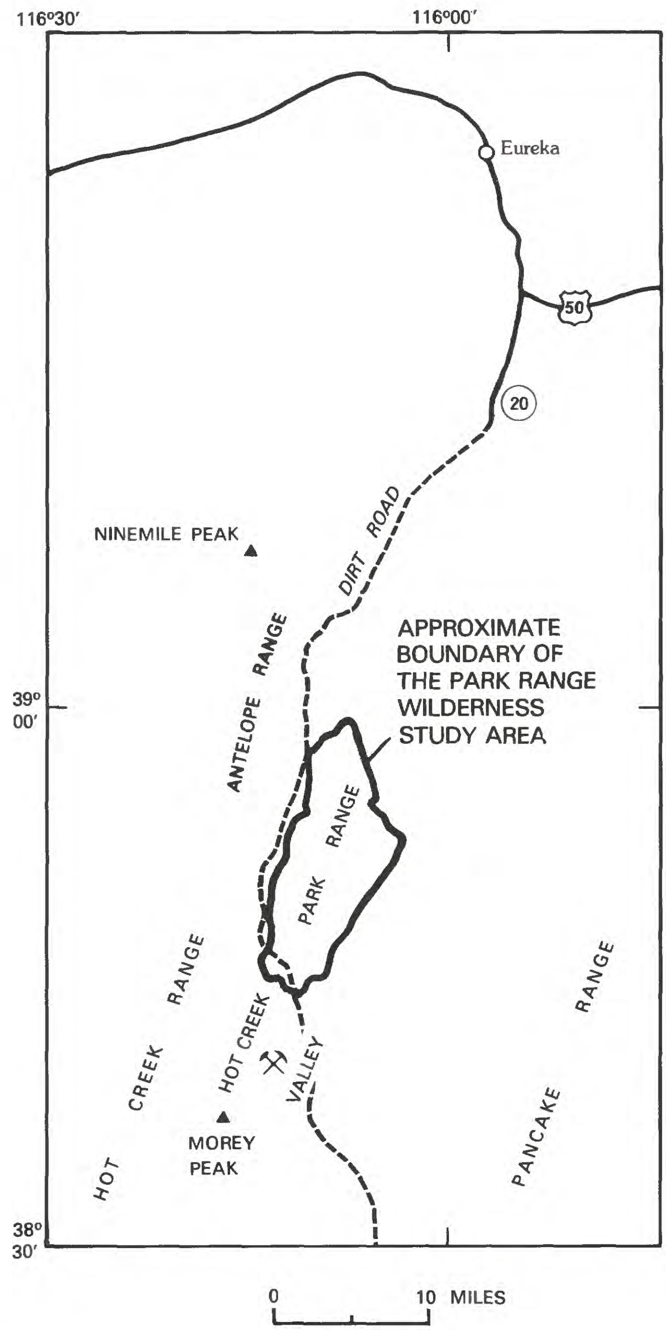
The Park Range Wilderness Study Area (NV–040–154) in central Nevada, about 45 mi south of Eureka, is east of the Hot Creek and Antelope Ranges and northwest of the Pancake Range (fig. 2). Access is by improved dirt roads that extend south from U.S. 50 and




EXPLANATION

| | |
|---|---|
| M/C | Geologic terrane having moderate mineral resource potential for gold, silver, arsenic, and mercury, with certainty level C |
| L/B | Geologic terrane having low mineral resource potential for oil and gas, with certainty level B |
| L/C | Geologic terrane having low mineral resource potential for all metals, except as noted above, and geothermal energy, with certainty level C |

**Figure 1.** Summary map showing mineral resource potential, active claims, and oil and gas leases in the Park Range Wilderness Study Area, Nevada.




**EXPLANATION**

⚒ **Approximate location of Morey district**

**Figure 2.** Index map showing the location of the Park Range Wilderness Study Area, central Nevada.

unpaved roads and four-wheel-drive trails that provide entry to many parts of the study area. Elevations range from 6,400 ft in the south part of the range near Hot Creek Valley to 9,131 ft in the central part of the study area (pl. 1).

The mineral resource potential of the Park Range Wilderness Study Area was assessed by compiling information from earlier published studies as well as more recent studies carried out by the USBM and the USGS. 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 USBM and the USGS. Identified resources are classified according to the system of the U.S. Bureau of Mines and U.S. Geological Survey (1980), which is shown in the Appendix of this report. Identified resources are studied by the USBM. Mineral resource potential is the likelihood of occurrence of undiscovered metals and nonmetals, industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984) and is shown in the Appendix. Undiscovered resources are studied by the USGS.

At the request of the U.S. Bureau of Land Management, 46,831 acres of the 47,268-acre Park Range Wilderness Study Area were studied. In this report the studied area is called the "wilderness study area" or simply "study area."

### Investigations by the U.S. Bureau of Mines

During 1984 and 1985, personnel from the USBM Western Field Operations Center investigated the mineral resources of the Park Range Wilderness Study Area. All available information on geology, mining, and exploration in the area, including county mining-claim records, was reviewed prior to field work.

Claimants were contacted, when possible, for permission to examine properties and publish the results. Field studies involved searches for all mines, prospects, and claims indicated by prefield studies to be within the study area. Those found were examined and, where warranted, mapped and sampled. In addition, ground and air reconnaissance was done in areas of obvious rock alteration.

One hundred twenty-five samples were taken. They were of three types: (1) chip samples, a regular series of rock chips taken in a continuous line across a mineralized zone or other exposure; (2) random chip samples, an unsystematic series of chips taken from an exposure of apparently homogeneous rock; and (3) grab samples, rock pieces taken unsystematically from a dump or stockpile, or loose rock lying on the ground. Details of analytical procedures are described in Johnson and Benjamin (1986). Additional information is available from the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

### Investigations by the U.S. Geological Survey

Geologic mapping, geochemical sampling, and geophysical studies were used to evaluate the mineral resource potential of the Park Range Wilderness Study Area based upon the types of deposits likely to be found in this geologic environment. Assessment of the mineral resource potential is based upon Goudarzi (1984) (see Appendix).

During 1983 a stream-sediment geochemical survey of the Park Range Wilderness Study Area was conducted as part of the mineral resource evaluation. This study utilized the minus-80-mesh fraction of the stream-sediment sample and the nonmagnetic fraction of panned concentrate from stream-sediment samples. A composite stream-sediment sample was collected at each site, each sample consisting of sediments collected from not less than five points along about 100 ft of the stream channel. Details of sample collection, locations, and analytical procedures are described in Tucker and others (1984).

In 1985 a field check of reconnaissance geologic mapping of the Park Range (Dixon and others, 1972) indicated alternative interpretations of the sedimentary rocks and structures exposed in the northern part of the range (C.H. Thorman, oral commun., 1985). Therefore, remapping and careful sampling of the problematic area that includes faulted and silicified Paleozoic and Tertiary sedimentary rocks was carried out during the summer of 1985. A new geologic map at 1:24,000 scale was prepared by W.E. Brooks and then compiled at 1:50,000 scale using the previous work by Dixon and others (1972) (pl. 1).

*Acknowledgments*.—We thank Bob Bennett, geologist with Long Lac Mineral Exploration (Texas), Inc., for help in familiarizing us with the rock formations, alteration, and mineralization at the Fandango deposit southwest of the study area; ASARCO personnel for providing us with geologic maps and descriptions of their claims in the north part of the study area; Jack Fulton of El Aero Services, Inc., for his expert helicopter flying ability and knowledge of the area; and the Richard McKay family of Snowball Ranch for their gracious hospitality.

## APPRAISAL OF IDENTIFIED RESOURCES

**By Fredrick L. Johnson and David A. Benjamin**
**U.S. Bureau of Mines**

### Mining and Mineral-Exploration History

The Morey mining district, about 5 mi southwest of the wilderness study area near Morey Peak (fig. 2), is the closest area having recorded mineral production.

The first discovery there was in 1865, and the district was organized in 1866. Silver, along with small amounts of gold and lead, was produced sporadically until about 1966. The district was most active from 1866 to 1891 and from 1937 to 1947; total production is valued at less than $1 million (Kleinhampl and Ziony, 1984).

Exploration activity in the Park Range Wilderness Study Area has been limited. A search of the Nye County and BLM mining records revealed that only one block of 41 active mining claims and no historical claims were located in the study area. Many of the location descriptions for historical claims in the area are vague, and some could have been located within the wilderness study area.

The JAH claims, the only active claims in the study area, are held by ASARCO. The company was actively (1985) exploring for hot-spring-type, large tonnage, low-grade gold deposits in the northern part of the study area (fig. 1). Their exploration program has included detailed geologic mapping and geochemical sampling. The Andesite claims, a group of active claims just southeast of the wilderness study area, are held by AMSELCO. They are also exploring for disseminated gold deposits, but their exploration program to date (1985) has been limited to geochemical sampling.

An area leased for oil and gas extends into the northern part of the study area.

## Mineral-Deposit Economics

Although no mineral resources were identified in the Park Range Wilderness Study Area during this study, the JAH claim area has many of the favorable criteria for hot-spring-type, large-tonnage, low-grade gold deposits. The development of heap-leaching gold-recovery methods, combined with recent, relatively high gold prices, about $400 per ounce, and depressed prices for other metals, have made deposits of this type the current vogue in mining. Most new domestic mine openings, many of them in Nevada, have been in deposits of this type that exceed 1 million tons in size and 0.03 troy ounces of gold per ton (1.0 ppm (part per million)) in grade.

Extensive sand and gravel occurrences in the study area are suitable for many construction purposes. However, transportation cost to current markets, a major part of total production cost, would far exceed the value for these high-bulk, low-unit-value commodities. Adequate material is available closer to major markets in the region.

# ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

**By William E. Brooks, Robert E. Tucker, Christopher Goodhue, Gordon W. Day, Donald Plouff, and Joseph S. Duval**
**U.S. Geological Survey**

## Geology

The Park Range is one of the generally north-striking and east-dipping ranges of the eastern half of the Great Basin. Regional studies include those of the Hot Creek Range, Little Fish Lake Valley, and the Antelope Range to the west (Hill and Pakiser, 1966; Stewart, 1971; Ekren and others, 1974; Hardyman and others, in press) and the Eureka volcanic center to the north (Blake and others, 1975).

The oldest rocks in the study area are Paleozoic limestone, dolomite, quartzite, and shale, described by Dixon and others (1972). Correlative rocks adjacent to the study area have been described by Kleinhampl and Ziony (1967) and Hose (1983). Similar Paleozoic assemblages in central Nevada were studied by Nolan and others (1956), Merriam (1963), Lowell (1965), and Quinlivan and Rogers (1974).

Tertiary volcanic rocks that include intermediate-composition lavas and ash-flow tuffs constitute most of the rock exposed in the Park Range. Near Ninemile Peak, northwest of the study area (fig. 2), intermediate lavas that probably correlate with those in the study area have been dated at 35.2±1.1 Ma (million years ago) (F.J. Kleinhampl and R.F. Marvin, written commun., *in* Ekren and others, 1974). The widespread Windous Butte Formation, an ash-flow tuff, overlies the intermediate lavas and several thinner tuffs and is 30.7±0.6 Ma (Grommé and others, 1972). The tuff may be as thick as 1,800 ft in the study area (Dixon and others, 1972) but thins westward to about 1,300 ft in Little Fish Lake Valley (Ekren and others, 1974). Younger, less voluminous tuffs include the Shingle Pass Tuff (25.1±1.0 Ma; Sargent and McKee, 1969) and the Bates Mountain Tuff (22.8±0.9 Ma, Sargent and McKee, 1969; 25.1±1.0 Ma, Marvin and others, 1973).

Pre-Tertiary compression has produced small-scale folding of the Paleozoic rocks. Both the Paleozoic sedimentary rocks and the Tertiary sedimentary and volcanic rocks have been affected by younger extensional faulting. The Bates Mountain Tuff has been offset; therefore, the present-day fault pattern must have occurred after 23 Ma and perhaps is part of basin-and-range extension that is considered to have occurred at 17 Ma or more recently (Stewart, 1971).

Rocks in the northern part of the wilderness study area have been hydrothermally altered and silicified. This alteration has resulted in iron and manganese stains and the introduction of silica and minor barite along some of the faults and fractures in the sedimentary rocks near Big Fault Wash (pl. 1). Replacement of limestone by silica has resulted in a red jasperoid breccia of uncertain age, described by Hose (1983). In this area the Mulligan Canyon Rhyolite is bleached and altered, making identification of the phenocrysts difficult. The volcanic rocks in the southern part of the study area, though faulted and fractured, show no evidence of alteration.

## Geochemistry

Analytical data from stream-sediment samples at 59 sampling sites were examined for elemental concentrations above background level that might be related to mineralization. All samples were analyzed by a six-step semiquantitative emission spectrographic method for 31 elements (Grimes and Marranzino, 1968). No anomalous metal concentrations unrelated to lithology were identified within the minus-80-mesh fraction of the stream-sediment samples or the nonmagnetic fraction of the panned concentrate. These analytical results suggest that the Park Range Wilderness Study Area has low potential for metallic mineral deposits. Analyses and sample locations are given in Tucker and others (1984).

In the JAH claim area (fig. 1), seventy-five rock samples were taken by the USBM (Johnson and Benjamin, 1986). Each sample was analyzed for gold and silver content by fire assay and ICP (inductively coupled plasma) methods. The detection limit by these methods is 0.007 ppm gold and 0.3 ppm silver. Arsenic content was determined by ICP and atomic-absorption methods. One of several special methods, determined by rock lithology and mercury concentration, was used for mercury analyses. The detection limit for arsenic and mercury by these methods is 2.0 ppm. Five (7 percent) contained gold (more than 0.007 ppm), twenty-one (28 percent) contained silver (more than 0.3 ppm), twenty-one (28 percent) contained anomalous arsenic (more than 50 ppm), and nine (12 percent) contained mercury (more than 2.0 ppm). Values were as much as 0.14 ppm gold, 8.53 ppm silver, 2,800 ppm arsenic, and 4 ppm mercury. The localities of those samples containing gold, silver, mercury, and anomalous arsenic are concentrated in the central part of the JAH claims. Complete descriptions and analyses for these samples are available at the USBM Western Field Operations Center, Spokane, Wash.

Of twenty-three analyses of select rock samples taken by W.E. Brooks and F.J. Kleinhampl in the JAH claim area near Big Fault Wash, only two analyses showed anomalous concentrations of arsenic (2,000–3,000 ppm, respectively), and nine had zinc concentrations of 55 to 1,400 ppm. However, none of these seemingly anomalous metal values was accompanied by anomalous gold or silver content. These samples were analyzed by a six-step semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). Select samples were analyzed for gold and mercury using atomic absorption. In addition, arsenic, bismuth, cadmium, antimony, and zinc were analyzed by inductively coupled argon plasma-atomic emission spectroscopy (ICP–AES) (Crock and others, 1987). Analytical results, techniques, and sample sites are given in Brooks and others (1987).

## Geophysics

Contour and composite-color maps were prepared at a scale of 1:1,000,000 from aeroradiometric data acquired in regional surveys contracted by the U.S. Department of Energy as part of the National Uranium Resource Evaluation Program. The data provide estimates of the near-surface concentrations of potassium, equivalent uranium, and equivalent thorium. The nominal altitude of the surveys was 400 ft above the ground surface, and data for altitudes exceeding 700 ft were discarded. Five east-west flight lines about 3 mi apart traversed the area.

The following estimates of radioelement concentrations were determined by inspection of the contour maps. The study area has moderate radioactivity with values of 2.5–3.0 percent potassium, 2–4 ppm equivalent uranium, and 13–16 ppm equivalent thorium. The definition of anomalous radioelement concentrations was based upon the composite-color maps prepared by Duval (1983) and assuming that the radioelement concentration as well as its ratio to the other radioelements is relatively high within the context of the map data. According to these criteria, a thorium anomaly exists in the northern part of the area, but there are no potassium or uranium anomalies. The significance of the thorium anomaly is unclear but probably reflects lithologic differences.

Gravity data were compiled from 3 gravity stations on hillcrests in the Park Range and about 40 other stations near roads outside the study area (Healey and others, 1981; Snyder and Healey, 1983; D.B. Snyder, unpub. data, 1982). The pattern of gravity anomalies is nearly featureless in the study area relative to the surrounding area (fig. 3), mostly because of sparse data coverage. A gravity low (L, fig. 3), inside and outside the southern boundary of the study area, may extend northward from Hot Creek Valley to possibly reflect underlying Cenozoic sedimentary deposits at the south flank of the Park Range. A small gravity high (H, fig. 3) in the east corner of the study area may indicate the location of pre-Tertiary rocks concealed at shallow depth.

An aeromagnetic survey of the region was flown at altitudes of 500 and 1,000 ft above mean ground level with east-west flight lines spaced at intervals of about 1 mi (U.S. Geological Survey, 1968). The aeromagnetic map reflects large contrasts in magnetization of rocks in the study area (fig. 4). Many of the intense magnetic anomalies are elongated to the north and are correlated with topography. That is, magnetic highs tend to occur over hilltops and ridges of volcanic rocks, and magnetic lows occur over valleys and saddles. The anomalies are so intense, especially over the Windous Butte Formation along the crest of the Park Range, that the nature of rocks beneath the surface cannot be determined on the basis of magnetic interpretation. Broad magnetic lows, reflecting the thickness of sedimentary deposits, conform to the extent of alluvium in Hot Creek Valley and Big Fault Wash.

An east-west-trending aeromagnetic lineament was interpreted to extend for about 40 mi from Tulle Creek in the southern part of the Monitor Range, west of the study area, to Pritchards Station in the south part of the study area (Ekren and others, 1974). The Andesite claim group is along the extension of the lineament outside the wilderness study area boundary (fig. 1), but the geologic significance of the lineament is unclear.

## Mineral and Energy Resources

### Metallic Minerals

The geology of the region that includes the Park Range Wilderness Study Area (Kleinhampl and Ziony, 1985) has many of the features stated by Silberman (1982) to be associated with hot-spring-type gold and silver deposits. These features in the Park Range include (1) complex high-angle structures such as caldera-rim fracture zones and basin-and-range-type faults; (2) strike-slip faults with high-angle splays near areas of felsic volcanic activity; (3) complex volcanic centers with a variety of flow rocks; (4) evidence of thermal-spring activity; (5) signs of repeated fracturing, veining, and brecciation; and (6) anomalous concentrations of gold, silver, arsenic, and mercury.

Because of the indications of alteration, favorable geologic structures, and anomalous concentration of silver, gold, arsenic, and mercury in rock, moderate mineral resource potential for these metals with certainty level C is assigned to the area of exposed sedimentary rocks in and extending beyond the north part of the wilderness study area.

The volcanic rocks that constitute the rest of the study area are faulted but lack evidence for hydrothermal alteration and silicification. Also, no anomalous concentrations of metals were found by analysis of stream-sediment samples. Therefore, a low mineral resource potential for these metals with certainty level C is assigned to the rest of the wilderness study area. All other metals are considered to have low mineral resource potential, with certainty level C.

### Oil and Gas

The Park Range Wilderness Study Area is one of a cluster of study areas in eastern Nevada that is considered to have no potential for petroleum resources (Sandberg, 1982, 1983). However, exposures of Paleozoic miogeosynclinal rocks, the focus of petroleum exploration in eastern Nevada, suggest that possible oil and gas source and reservoir horizons may be present below the volcanic cover. Therefore, using criteria defined in Goudarzi (1984), the resource potential of the wilderness study area for oil and gas is rated low with certainty level B.

### Geothermal Energy

Areas of anomalous heat flow are known from wells and springs adjacent to the study area. However, there are no hot springs or other evidence of geothermal activity within the wilderness study area. Therefore, the resource potential for geothermal resources is rated low with certainty level C.

## RECOMMENDATIONS FOR FUTURE WORK

The northern part of the Park Range Wilderness Study Area warrants additional study. Areas of exposed Tertiary and Paleozoic sedimentary rock should be carefully mapped and sampled in detail. Those areas determined to contain anomalous concentrations of gold, silver, arsenic, or mercury should be resampled on a closely spaced grid pattern. Drilling would be needed to confirm favorable geochemical results.

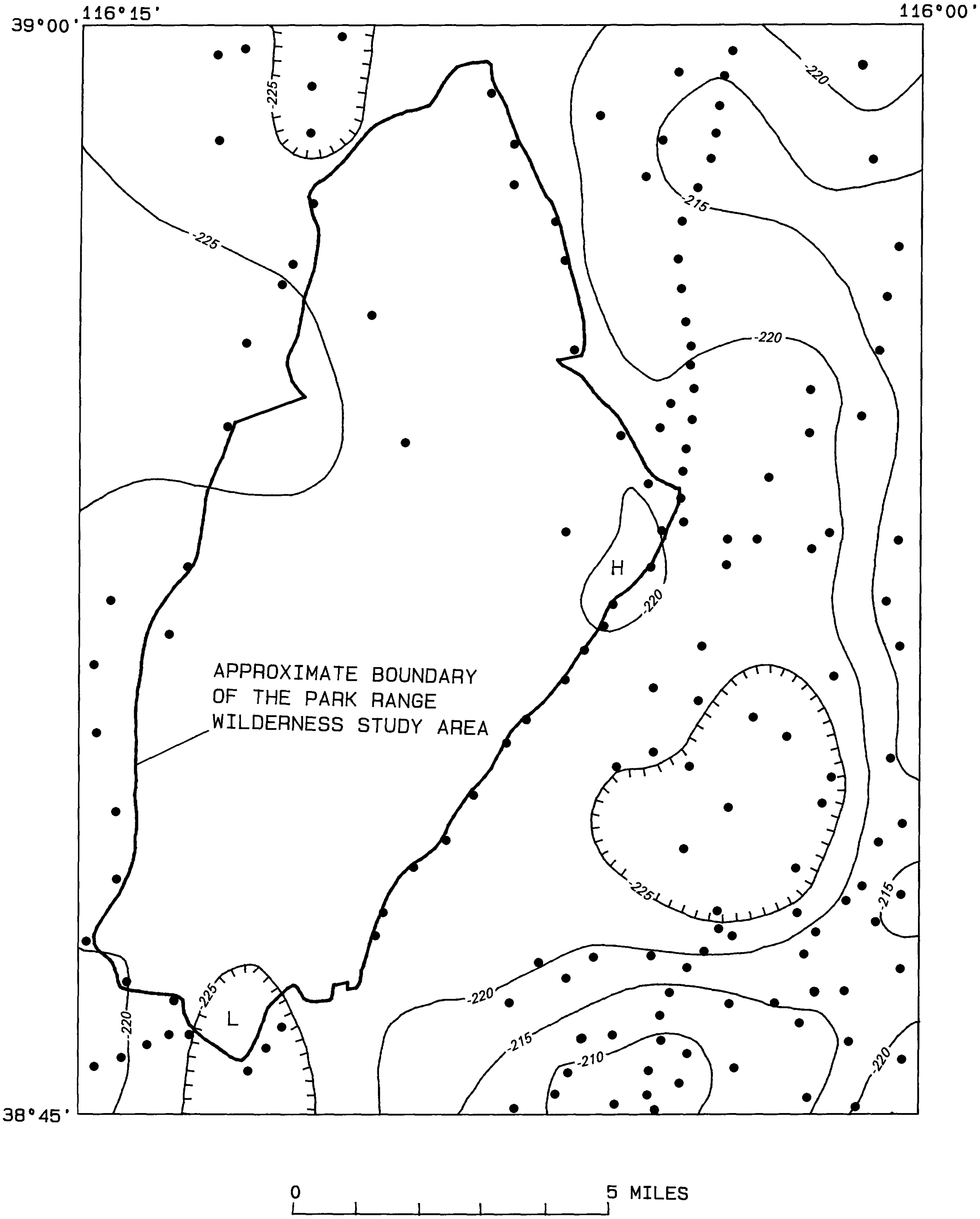



**Figure 3.** Bouguer gravity map of the Park Range Wilderness Study Area, central Nevada. Contour interval, 5 milligals; H, gravity high discussed in text; L, gravity low discussed in text; dots, gravity stations. Hachures indicate closed areas of lower gravity values.

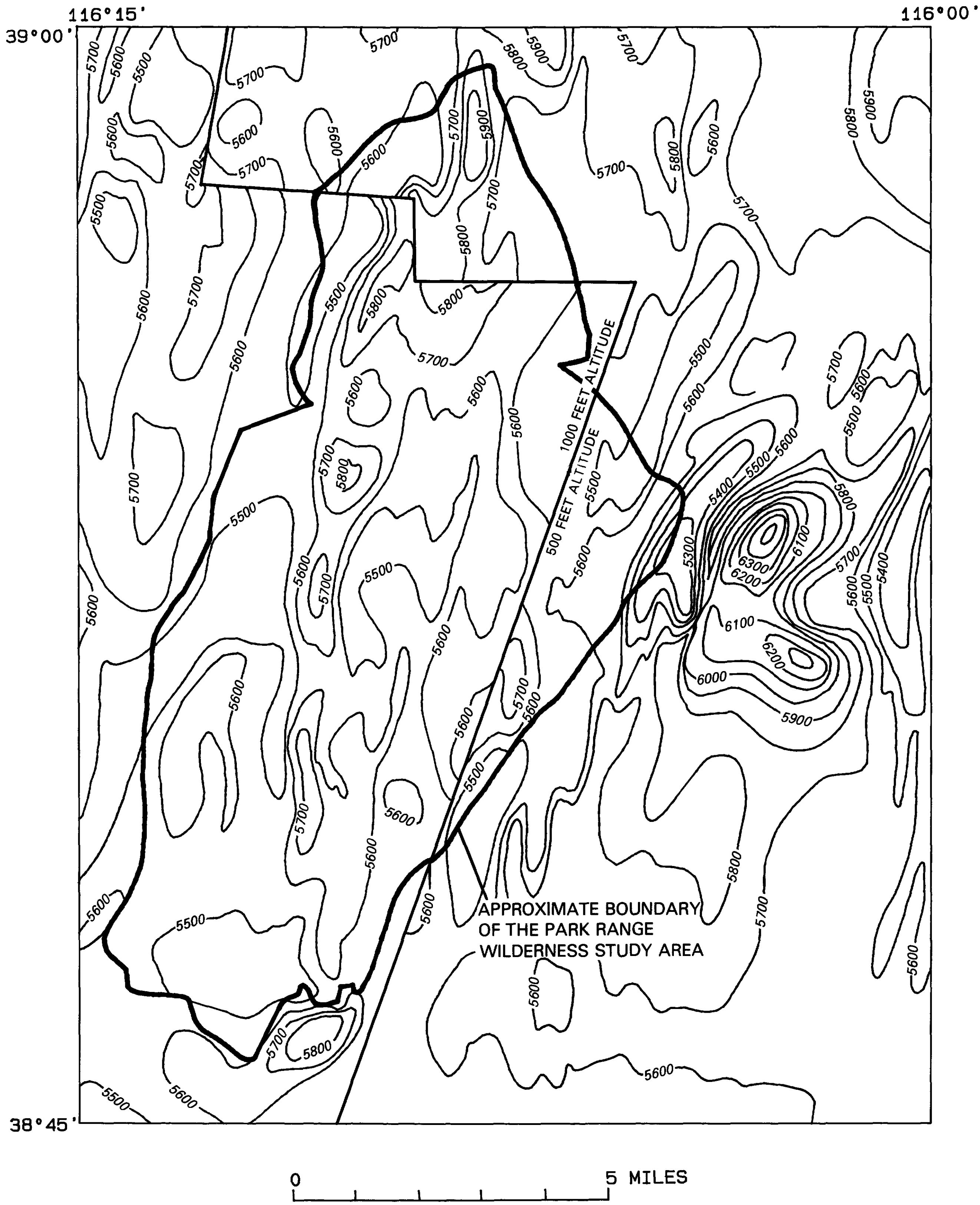



**Figure 4.** Aeromagnetic map of the Park Range Wilderness Study Area, central Nevada. Contour interval, 100 gammas. Heavy line separates aeromagnetic survey flown at 1,000 ft (western part) from 500 ft (eastern part).

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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.

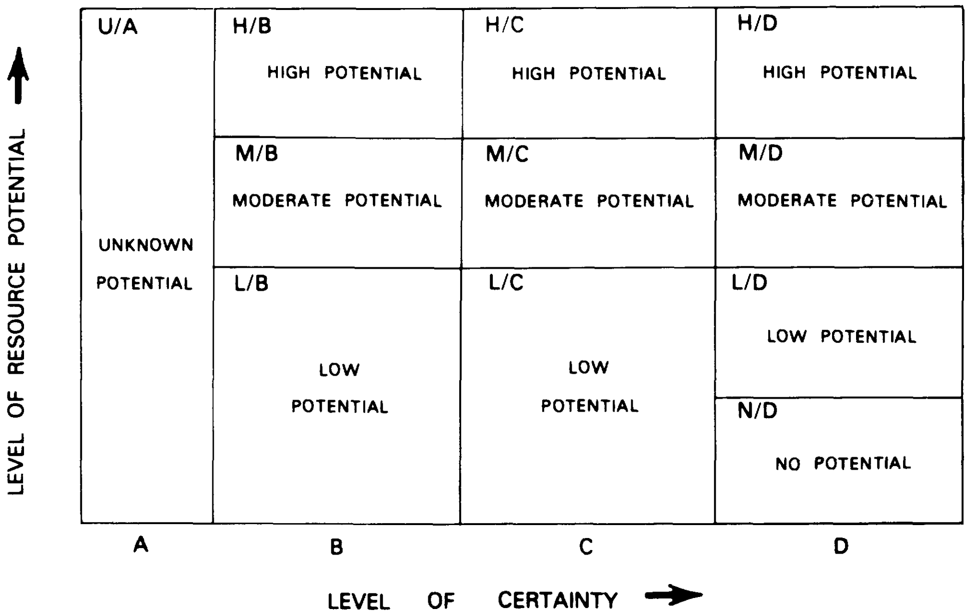
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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## RESOURCE / RESERVE CLASSIFICATION

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

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

## GEOLOGIC TIME CHART

Terms and boundary ages used 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<br>Middle<br>Early | 205 |
| | | Triassic | | Late<br>Middle<br>Early | ~ 240 |
| | Paleozoic | Permian | | Late<br>Early | 290 |
| | | Carboniferous Periods | Pennsylvanian | Late<br>Middle<br>Early | ~ 330 |
| | | | Mississippian | Late<br>Early | 360 |
| | | Devonian | | Late<br>Middle<br>Early | 410 |
| | | Silurian | | Late<br>Middle<br>Early | 435 |
| | | Ordovician | | Late<br>Middle<br>Early | 500 |
| | | Cambrian | | Late<br>Middle<br>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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