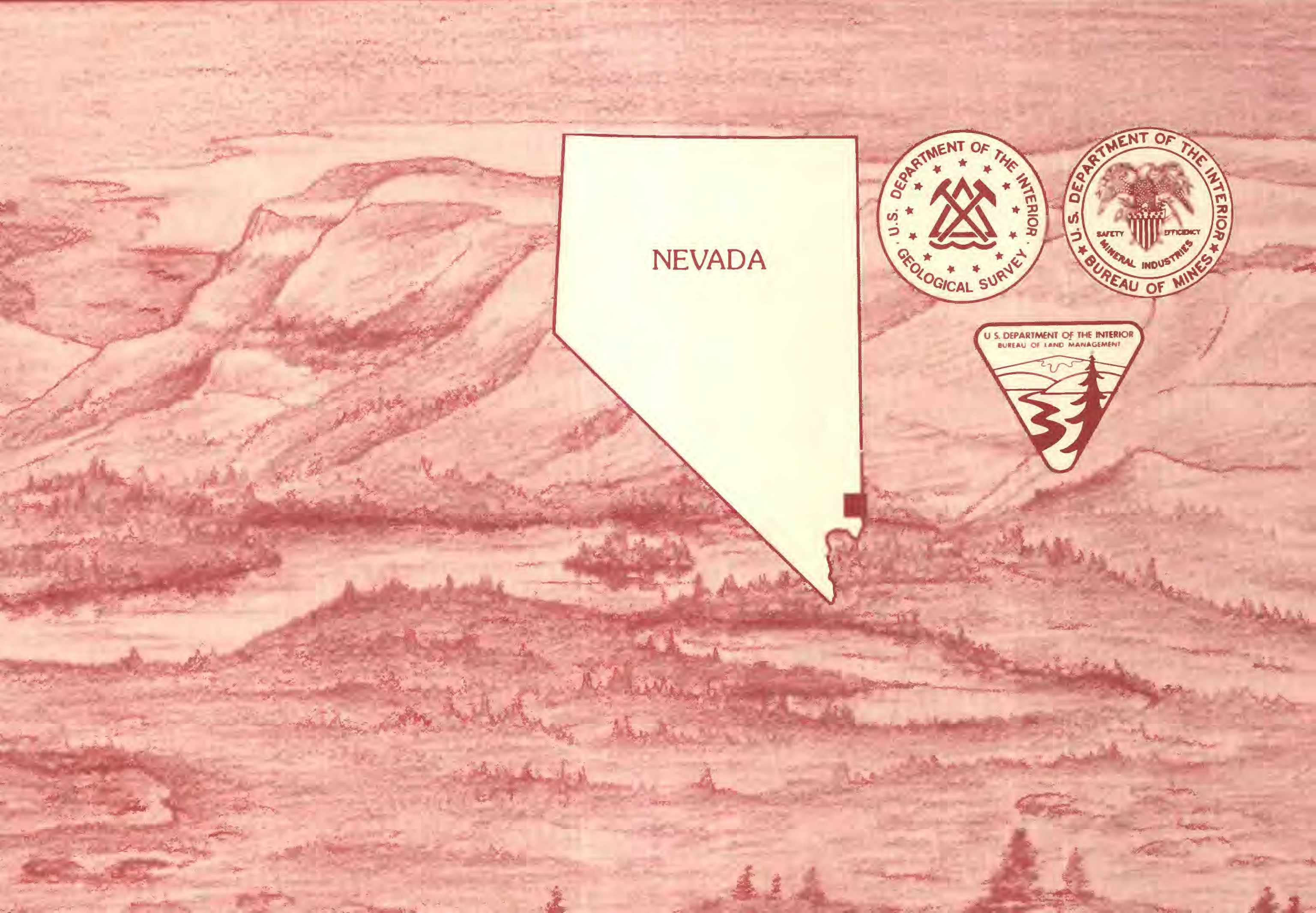
# Mineral Resources of the Million Hills Wilderness Study Area, Clark County, Nevada

U.S. GEOLOGICAL SURVEY BULLETIN 1730-E



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Chapter E

# Mineral Resources of the Million Hills Wilderness Study Area, Clark County, Nevada

By JOEL R. BERGQUIST, GARY A. NOWLAN, and
H. RICHARD BLANK, JR.
U.S. Geological Survey

J. DOUGLAS CAUSEY
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1730

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
SOUTHERN NEVADA

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director



UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1994

For sale by
U.S. Geological Survey, Map Distribution
Box 25286, MS 306, Federal Center
Denver, CO 80225

**Library of Congress Cataloging-in-Publication Data**

Mineral resources of the Million Hills Wilderness Study Area, Clark County,
Nevada /by Joel R. Bergquist ... [ et al.]
p. cm. — (Mineral resources of wilderness study areas—southern
Nevada ; ch. E) (U.S. Geological Survey bulletin ; 1730-E)
Includes bibliographical references.
Supt. of Docs. no.: I 19.3:1730
1. Mines and mineral resources—Nevada—Million Hills Wilderness.
2. Million Hills Wilderness (Nev.) I. Bergquist, Joel R. II. Series. III. Series:
U.S. Geological Survey bulletin ; 1730-E.
QE75.B9 no. 1730-E
[TN24.N3]
557.3 s—dc20
[553'.09793'13] 94-12114
CIP

## 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 Million Hills (NV–050–233) Wilderness Study Area, Clark County, Nevada.

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# Mineral Resources of the Million Hills Wilderness Study Area, Clark County, Nevada

*By* Joel R. Bergquist, Gary A. Nowlan, *and* H. Richard Blank, Jr.
*U.S. Geological Survey*

J. Douglas Causey
*U.S. Bureau of Mines*

## SUMMARY

### Abstract

At the request of the U.S. Bureau of Land Management, 9,599 acres of the Million Hills Wilderness Study Area (NV-050-233) in Clark County, southern Nevada, were evaluated for identified mineral resources (known) and mineral resource potential (undiscovered). Throughout this report, "wilderness study area" and "study area" refer to those acres for which a mineral survey was requested. Fieldwork for this report was carried out in 1987 and 1988.

The study area is at the east edge of the Gold Butte mining district. The Quartz claim, in the northwestern part of the study area, has inferred subeconomic resources of copper, lead, zinc, cobalt, gold, and silver. The Azure Ridge mine, located on the northwest boundary of the study area, contains inferred subeconomic resources of copper, lead, zinc, and lesser amounts of cobalt, gold, silver, gallium, and germanium. The study area includes occurrences of carbonate rocks, and sand and gravel.

A large part of the study area has high potential for undiscovered copper, lead, zinc, cobalt, gold, silver, gallium, and germanium. Most of the study area has low potential for oil and gas. There is no potential for geothermal resources.

### Character and Setting

The Million Hills Wilderness Study Area is located in the eastern Basin and Range physiographic province in southern Nevada about 60 mi east of Las Vegas (fig. 1). The eastern boundary of the study area is the Arizona-Nevada border, and Lake Mead is about 1.5 mi south of the south boundary of the study area. The terrain is characterized by rugged hills etched by deeply incised stream drainages. The western parts of the hills are in many places faulted and eroded to cliffs and ledges. Bedrock in the study area mostly consists of layers of Paleozoic (see "Appendixes" for geologic time chart) sedimentary rocks that have been faulted and steeply tilted toward the east. The sedimentary rocks consist of limestone, dolomite, sandstone, quartzite, and shale. Underlying the sedimentary rocks are Precambrian gneiss and schist. About 40 percent of the study area is covered by alluvium and colluvium. The region has been broken by a succession of arcuate faults; the Gold Butte fault, a major northeast trending structure, crosses the northern part of the study area.

### Identified Resources

Inferred subeconomic resources (see "Appendixes" for resource/reserve classification) of copper, lead, zinc, cobalt, gold, silver, gallium, and germanium are present in the study area. The Quartz claim is in the northern part of the study area and has inferred subeconomic resources of copper, lead, zinc, cobalt, gold, and silver. The nearby Azure Ridge mine, on the northwest boundary of the study area, produced minor amounts of copper and zinc in the early 1900's and contains inferred subeconomic resources of copper, lead, zinc, cobalt, gold, silver, gallium, and germanium along a north-trending fault. The Esperanta group of claims, which includes the Azure Ridge mine (formerly named Bonelli mine), was actively maintained in 1987.

Carbonate rocks, which in other areas may constitute a resource, are here classified as only occurrences. The

Manuscript approved for publication April 1, 1994.

carbonate strata in the study area are thin bedded, cherty, dolomitized, and contain interbeds of sandstone and shale, all of which militate against the usefulness of the carbonate rocks for industrial purposes. The sand and gravel in the area are also classified as only an occurrence because of a near-surface layer of caliche (undesirable in commercial sources) and the distance to current markets. No anomalous radioactivity was measured during field studies.

There were six oil and gas leases as of 1988 in or near the study area, although there has been no production from these leased areas or from the vicinity of the study area.

## Mineral Resource Potential

A large part of the Million Hills Wilderness Study Area has high resource potential for copper, lead, zinc, cobalt, gold, silver, germanium, and gallium in Kipushi-type deposits (see fig. 2 for specific location of area). There is low resource potential for oil and gas, and no potential for geothermal energy in the study area.

Analyses of the stream-sediment samples taken for this study revealed strong correlations among the elements and provide evidence of carbonate-hosted Kipushi-type copper-lead-zinc mineralization. The geochemical signature for Kipushi-type mineralization is a suite of elements that consists of copper, lead, zinc, arsenic, cobalt, silver, germanium, gallium, molybdenum, tungsten, tin, bismuth, uranium, and vanadium (Cox and Bernstein, 1986). The geochemical data obtained from sampling the study area fit this model quite well. The Apex mine about 50 mi northeast of the study area is the nearest known Kipushi-type deposit. The Apex mine produced copper, lead, zinc,

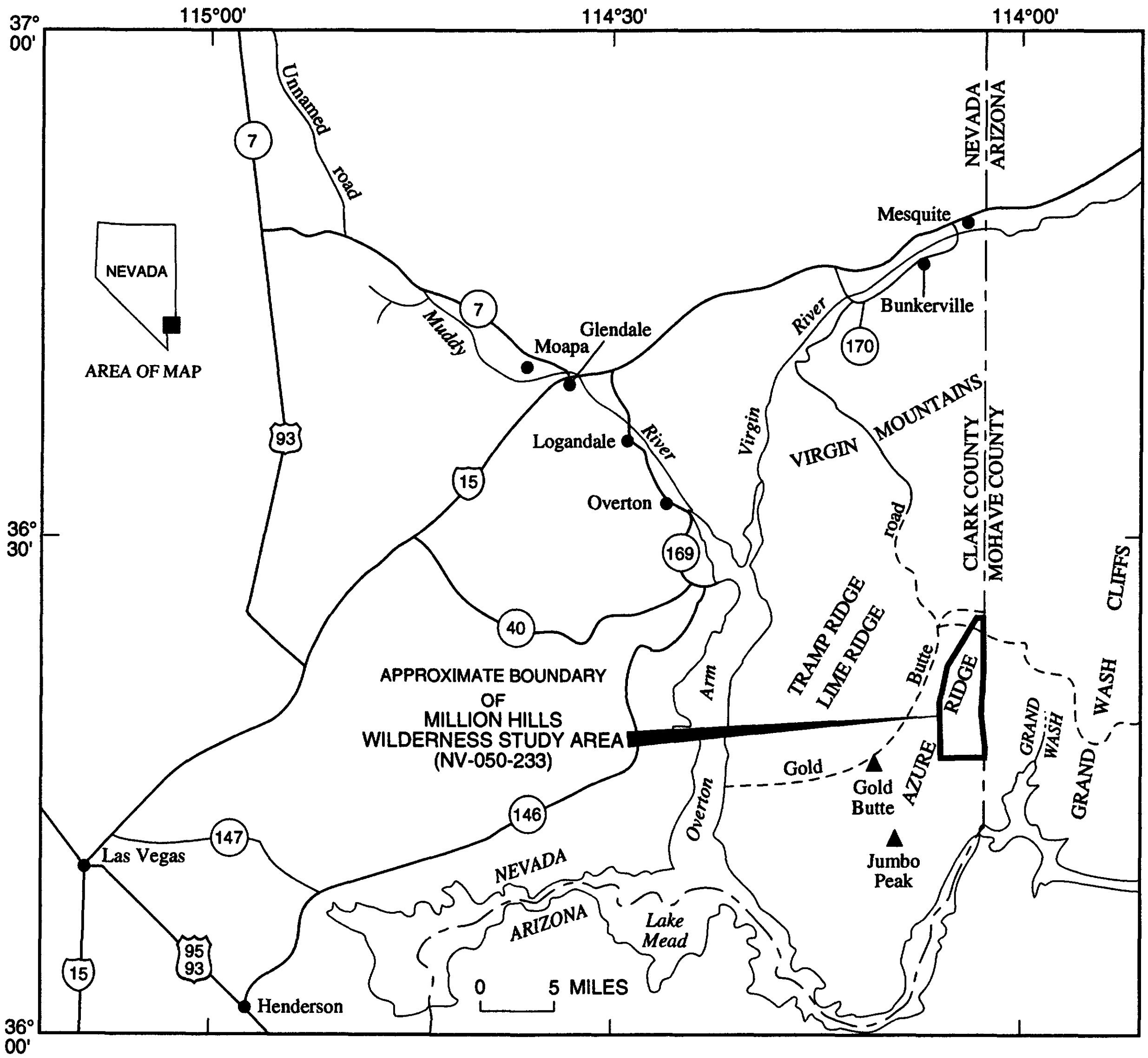
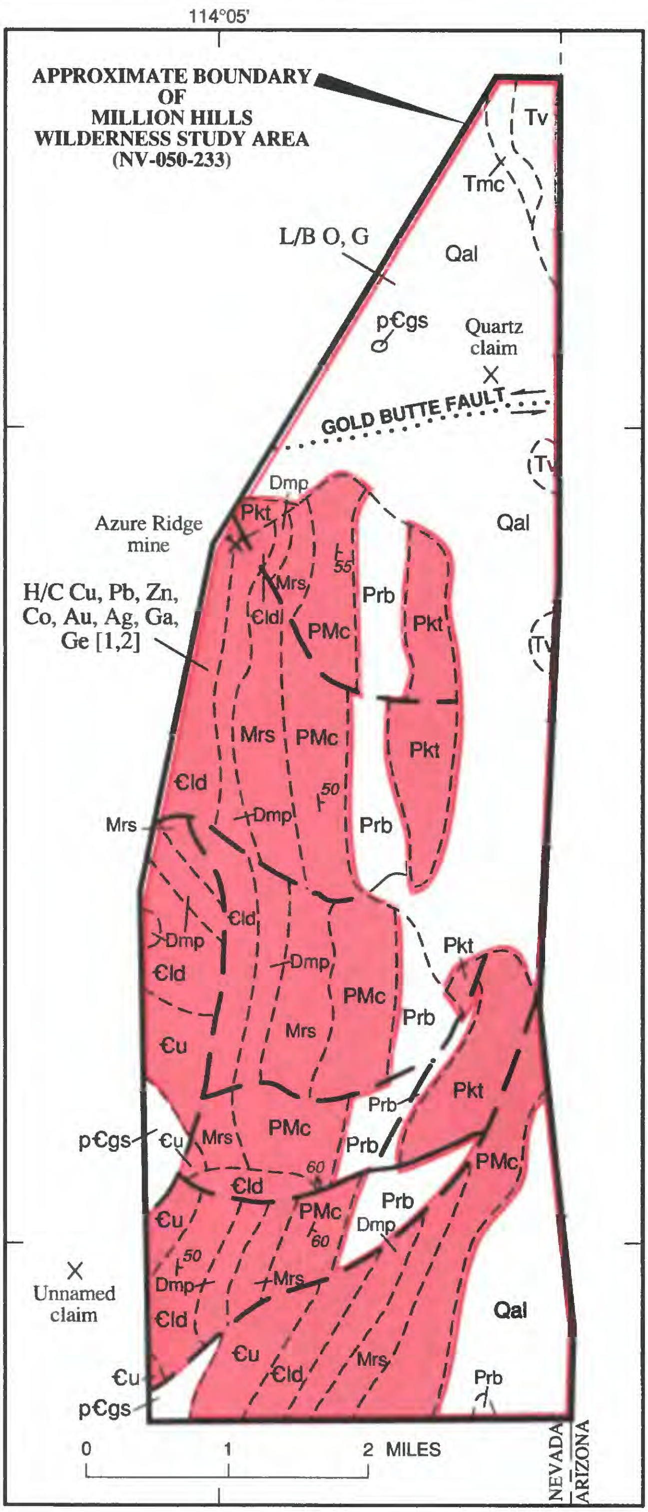



**Figure 1.** Index map showing location of principal geographic features near Million Hills Wilderness Study Area, Clark County, Nevada.

gold, and silver in the period 1884–1962. The mine was closed for a period, then reopened in 1985 for production of germanium and gallium (Bernstein, 1986). The Callville Limestone hosts the Apex deposit and is also one of the bedrock units in the study area. On the basis of (1) the Kipushi-type geochemical signature found for this study,




EXPLANATION

Area having high mineral resource potential (H)

Area having low energy resource potential (L)

Levels of certainty of assessment

- B — Data only suggest the level of mineral resource potential
- C — Data give good indication of the level of mineral resource potential

Commodities

- Ag — Silver
- Au — Gold
- Co — Cobalt
- Cu — Copper
- Ga — Gallium
- Ge — Germanium
- Pb — Lead
- Zn — Zinc
- O,G — Oil and gas

[ ] — Deposit types

- 1 — Kipushi-type copper-lead-zinc
- 2 — Mississippi Valley-type lead-zinc

Geologic map units

- Qal — Alluvium (Quaternary)—Unconsolidated gravel, sand, and silt
- Tv — Volcanic rocks (Tertiary)—Olivine basalt
- Tmc — Muddy Creek Formation (Tertiary)—Weakly indurated gravel, sand, and silt
- Pkt — Kaibab and Toroweap Formations, undivided (Permian)—Limestone and dolomitic limestone; shale, sandstone, and gypsum
- Prb — Red beds (Permian)—Sandstone and shale
- PMc — Callville Limestone (Permian, Pennsylvanian, and Mississippian)—Sandy, silty limestone, dolomitic limestone, dolomite, shale, and siltstone
- Mrs — Rogers Spring Limestone (Mississippian)—Limestone and dolomitic limestone
- Dmp — Muddy Peak Limestone (Devonian)—Limestone and dolomitic limestone
- €ld — Limestone and dolomite (Cambrian)
- €u — Quartzite, shale, sandstone, and limestone (Cambrian)
- p€gs — Gneiss and schist (Precambrian)

Contact—Dashed where approximately located

60 — Fault, showing dip—Dashed where approximately located; dotted where concealed

50 — Strike and dip of beds

**Figure 2.** Mineral resource potential and generalized geology of Million Hills Wilderness Study Area, Clark County, Nevada. Geology modified from Longwell and others (1965). Arrows along fault show relative direction of movement.

(2) the mineralogy of the mine and claims examined by the Bureau of Mines, (3) the proximity and setting of the Apex mine, and (4) the similarity of geology at the Apex mine and the study area, the Million Hills Wilderness Study Area has high resource potential for copper, lead, zinc, gold, silver, cobalt, germanium, and gallium.

Most of the study area was determined to have a low resource potential for oil and gas by Sandberg (1983a, b). This determination was made on the basis of possible source rocks and reservoir rocks in the study area and the presence of favorable areas to the north and west. Part of one oil and gas lease covers about 340 acres in the study area, and contiguous lands are covered by additional oil and gas leases (Bureau of Land Management, 1988).

The study area is in an area of relatively low heat flow, and there are no known warm or hot springs in the region surrounding the study area (Muffler, 1979). The study area has no potential for geothermal resources.

## INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is the result of a cooperative effort by the U.S. Geological Survey and the U.S. Bureau of Mines. An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was provided by Beikman and others (1983). The U.S. Bureau of Mines evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas. Identified resources are classified according to a system that is a modification of that described by McKelvey (1972) and U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey are designed to provide a reasonable scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Goudarzi (1984) discussed mineral assessment methodology and terminology as they apply to these surveys. See "Appendixes" for the definition of levels of mineral resource potential and certainty of assessment and for the resource/reserve classification.

### Location and Physiography

The Million Hills Wilderness Study Area consists of 9,599 acres in Clark County, southern Nevada, along the Arizona border about 2 mi north of Lake Mead. The regional setting is the eastern margin of the Basin and Range physiographic province that is characterized by elongate, north-trending, fault-bounded ranges separated by wide alluviated valleys. The Grand Wash Cliffs, about 12 mi east of the study area, are considered to be the boundary between this province and the Colorado Plateau physiographic province. The study area is located along the northern part of Azure Ridge, a 12-mi-long, north- to northeast-trending ridge. Azure Ridge and two other ridges to the northwest, Tramp Ridge and Lime Ridge, are geologically and structurally similar. The Lime Canyon Wilderness Study Area (NV-050-231) includes most of Lime Ridge, about 10 mi west of this study area.

The study area is about 16 mi from north to south, and ranges in width from about 0.5 mi at the north end to 5 mi wide on the south boundary. Most of the study area is along the rugged bedrock of Azure Ridge, but alluvial aprons cover areas of gentler topography along the eastern margin and northern parts. Elevations range from about 3,946 to 1,770 ft. The topography of most of the area is exceedingly rugged, with cliffs, ledges, deeply incised stream drainages, and broken blocks. The carbonate rocks have developed rough weathering surfaces typical of these kinds of rock in desert climate. Flora in the area include cacti, grasses, yucca, and sagebrush.

Access to the northern and western parts of the study area is by dirt road from the north. A road to the Azure mine is the only one that enters the study area; and there is no road access to the eastern or southern parts of the area.

### Previous and Present Investigations

One of the earliest studies of the geology and mineral resources of the area is by Longwell (1928). His 1:250,000-scale map shows Azure Ridge in a generalized way. Other studies of the geology and resources are by the Intermountain Association of Petroleum Geologists (1952) (map scale 1:380,365); Bowyer and others (1958) (map scale 1:200,000); Longwell and others (1965) (geologic map scale 1:250,000); Morgan (1968) (map scale 1:31,680), Ledbetter (1970) (no map), and Bohannon (1978) (map scale 1:250,000). Volborth (1962) studied the Precambrian rocks west of the study area and those rocks were dated by Wasserburg and Lanphere (1965). Paleozoic stratigraphy of the region is discussed in McNair (1951). Tertiary rocks in the region were studied by Anderson and others (1972), Brenner and Glanzman (1979), and Bohannon (1984). Studies of tectonics and structure in the region were done by Anderson (1973), Longwell (1974), Bohannon (1979), and Wernicke and others (1982).

Brief discussions of the Gold Butte mining district, which includes Azure Ridge, are found in Lincoln (1923), Hill (1916), Hewett and others (1936), and Couch and Carpenter (1943). Reports on exploration and development in the district are given in Yale (1906, 1907, 1908), Naramore and Yale (1909), and Naramore (1911). Production of gold from the district is discussed by Heikes (1913, 1914, 1916, 1917, 1919, 1921a, b), but there is no mention of production from the Azure Ridge mine in these reports. Production from the mine is reported for the year 1918 by Vanderburg (1937, p. 36). Causey (1988) reported on the mineral resources of the Million Hills Wilderness Study Area.

Results of a sampling program which the Nevada Bureau of Mines and Geology did for the Bureau of Land Management were reported by Smith and Tingley (1983a, b). Descriptions of wilderness study areas that include geology and mineral resources are given in a publication of the Bureau of Land Management (1988). Evaluations of the potential for oil and gas in wilderness lands were prepared by Sandberg (1983a, b).

The U.S. Geological Survey visited the study area in the 1986 and 1987 field seasons. Fieldwork included geochemical sampling and checking of existing geologic maps. Geophysical data covering the area were obtained and interpreted. Geochemical samples of stream sediments and panned concentrates were taken from the study area and analyzed in U.S. Geological Survey laboratories. The analytical results are reported in McHugh and Nowlan (1989) and McHugh and others (1989).

The mineral investigation of the study area by the U.S. Bureau of Mines included collection of information related to current and past mining activity. A library search was made for information on mines and prospects located in and near the study area. This search included checking U.S. Bureau of Land Management mining claim recordation indices, Clark County, Nevada, mining claim records, and the U.S. Bureau of Mines Mineral Industry Location System (MILS). U.S. Bureau of Land Management land status and land use records, and U.S. Bureau of Mines files were also examined.

The U.S. Bureau of Mines field investigation was conducted during March 1987. Active claims in the study area were examined, and 48 rock samples were collected within and around the claims for geochemical analysis. The methods and results of the U.S. Bureau of Mines mineral investigation of the study area were reported by Causey (1988). An investigation of the Quartz claim was done by Moyle and Buehler (1990) as a follow up to the work by Causey (1988). Additional information is available from the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

## Acknowledgments

The authors would like to thank Brent Turrin of the U.S. Geological Survey and John Benham and Bill Hale of the U.S. Bureau of Mines Western Field Operations Center for their assistance in the field.

# APPRAISAL OF IDENTIFIED RESOURCES

*By* J. Douglas Causey
*U.S. Bureau of Mines*

## Mining History

The study area is on the east edge of the Gold Butte mining district south of the Virgin Mountains. Longwell and others (1965) described the boundaries of this district as bounded on the west and south by Lake Mead, on the east by the Colorado River and state boundary, and on the north by an east-west line approximately 6 mi north of the study area.

Mining activity in the district began in 1873 with the discovery of mica. Over 6 short tons of sheet mica (muscovite) were produced before 1900. More recent industrial mineral interest has centered on a vermiculite occurrence. These minerals are in granitic rocks, which are only exposed west of the study area.

In 1905, gold was discovered in metamorphic and granitic rocks west of the study area. In 1907, argentiferous copper and zinc ores were discovered in Paleozoic limestone and a limited amount of mining occurred at three mines in the district. Total production of gold, silver, copper, and zinc ore from the three mines, one of which is in the study area, was less than $100,000 (Longwell and others, 1965, p. 126–128).

The Azure Ridge mine was active in 1918; two carloads of hand-sorted zinc ore averaging 40 percent zinc and one carload of copper ore averaging 35 percent copper were shipped from the mine (Vanderburg, 1937, p. 36). The property is now covered by the Esperanta claims (nos. 1–4), which were located November 17, 1934 and are owned by Laura Gentry, according to 1987 claim records. No information was found concerning two other claims examined.

## Mines and Prospects

Three mineral properties were evaluated in this study (table 1). Results of sampling and mapping of the properties, two of which are in the study area and one just outside, were reported in Causey (1988). Additional information on the Quartz claim, and the Azure Ridge mine including the somewhat larger area of the Esperanta claims (nos. 1–4) is given in Moyle and Buehler (1990) and in unpublished files at the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202. Resource classifications for all properties and commodities evaluated are listed in table 2.

The Azure Ridge mine and an associated group of workings, located at the northwest edge of the study area, extend south about 1 mi. There are indications of high-grade copper-lead-zinc mineralization along Azure Ridge on the Esperanta claims (nos. 1–4). Gold, silver, cobalt, gallium,

**Table 1.** Mines and prospects in and near Million Hills Wilderness Study Area, Clark County, Nevada

[pct, percent; ppm, parts per million; cps, counts per second]

| Name | Description | Workings and production | Sample and resource data |
|---|---|---|---|
| Quartz claim | Alluvium-covered area containing aragonite, travertine, and sinter with manganese coatings. The manganese-rich crust and veins contain high concentrations of cobalt, nickel, lead, zinc, barium, and copper. Small outcrops of carbonate rock exposed locally. | Two small prospect pits and a 100-ft-long trench. No production. | Four samples taken. Manganese-rich samples contain as much as 9.07 pct manganese, 6,096 ppm cobalt, 546 ppm copper, 4,860 ppm barium, 107 ppm molybdenum, 1,698 ppm nickel, 1,874 ppm lead, 80 ppm thallium, and 3,732 ppm zinc. Because of limited exposure, no resources were calculated. However, elemental and geologic associations are similar to descriptions of Kipushi- or Mississippi Valley-type deposits. Claim is classified as having inferred subeconomic resources of copper, lead, zinc, and cobalt. |
| Azure Ridge mine (Bonelli mine, Esperanta claims nos. 1–4). | Cambrian(?) gray dolomite hosts deposit. Mineralized rock occurs along bedding-plane faults. Ore minerals are mainly base-metal carbonates such as malachite, smithsonite, and aurichalcite. Cerussite may also be present. Mine is near and south of Gold Butte fault. | Five adits (180+ ft, 60+ ft, 97 ft, 25 ft, and 15 ft); one shaft, 11 ft deep; two open cuts; and 10 pits. Production of two carloads averaging 40 pct zinc, and one carload averaging 35 pct copper in 1918 (Vanderburg, 1937, p. 36). | Forty-three samples taken. Select samples contain as much as 8.99 pct copper, 33.0 pct lead, 30.8 pct zinc, 471 ppm cobalt, 3,300 ppm gold, and 142 ppm silver, 150 ppm germanium, and 75 ppm gallium. Mineralized rock occurs sporadically over an area about 5,000 ft long by 1,100 ft deep. The structure is as thick as 9 ft in outcrop. There is an inferred subeconomic resource of copper- lead- zinc- cobalt- gold- silver- gallium- germanium-bearing material. The occurrence of the mineralized rock in small podlike bodies makes it unrealistic to attempt to quantify resources on the basis of limited sampling. |
| *Unnamed prospect | Precambrian locally schistose gneiss, mostly granitic with some garnets. Scintillometer readings of 75 to 120 cps were obtained. | Bulldozed road and a stone monument. No production. | One sample taken. No economic concentrations of metals detected. There is less than 10 ppm uranium and only 12 ppm thorium in the sample. There are no identified resources on this property. |

* Outside study area.

**Table 2.** Resource classification of properties and commodities evaluated in Million Hills Wilderness Study Area, Clark County, Nevada

| Property name | Resource classification | Commodities |
|---|---|---|
| Quartz claim | Inferred subeconomic resources. | Copper, lead, zinc, cobalt. |
| Azure Ridge mine (Bonelli mine, Esperanta claims nos. 1–4). | Inferred subeconomic resources. | Copper, lead, zinc, cobalt, gold, silver, gallium, germanium. |
| Unnamed prospect | — | None. |
| Alluvial deposits* | Occurrence | Sand, gravel. |
| Carbonate deposits* | Occurrence | Limestone, dolomite. |

* See figure 2 for formations containing these rock and mineral types.

and germanium[1] are minor constituents. Mining would require underground methods because mineralized rock is in a narrow, steeply dipping fault. Because of the podlike nature of the mineralized structure and the lack of data regarding the frequency, size, and distribution of the pods, resources were not quantified. However, the mineralized rock crops out sporadically over an area about 5,000 ft long and as much as 9 ft thick. Within this area there may be other high-grade pods. The Esperanta claims were determined to contain inferred subeconomic resources of copper, lead, zinc, cobalt, gold, silver, gallium, and germanium. The high grade reported by Vanderburg (1937, p. 36) is probably not continuous along the fault because these analyses were from material that was hand sorted from selected mining areas.

Because of limited exposures, no resources could be quantified on the Quartz claim. The prospect on the Quartz claim probably is about 0.5 mi south of the Gold Butte fault (Moyle and Buehler, 1990). The geologic association of faults, impure limestone and dolomite, aragonite, travertine, and sinter with manganese-rich encrustations, which contain unusually high concentrations of cobalt, nickel, lead, zinc, barium, molybdenum, thallium, and copper and average to low concentrations of gallium and germanium,[2] suggests a Mississippi Valley-type lead-zinc deposit or a Kipushi-type copper-lead-zinc deposit. Whereas the Azure Ridge mine does not have concentrations of cobalt and nickel as high as those found on the Quartz claim, many of the high-grade samples from the Azure Ridge mine are enriched in most of the same elements. This correlation indicates a deposit similar to that at the Azure Ridge mine. The Quartz claim is determined to contain inferred subeconomic resources of copper, lead, zinc, cobalt, gold, and silver. No large lead-zinc mines have been discovered in the region; however, exploration apparently has been limited to digging on surface exposures and little geophysical work and drilling have been done. Also, gold and silver seem to have drawn more of the mineral industry's attention and exploration money.

Cobalt is of particular interest because it is a strategic mineral and is not being produced in the United States. One of the last U.S. producers was a lead mine in Missouri where cobalt was recovered as a byproduct. Only in the Blackbird mining district of Idaho is cobalt a primary commodity—the grade there averages 0.6 percent (Kirk, 1985, p. 3). All of the United States' cobalt resources (1.4 million short tons) are considered subeconomic at $13.00/lb (Engineering and Mining Journal, 1993).

Indications of other mineral resources were not found in the study area. Sand and gravel, while widespread, are partly cemented with caliche, which lowers the commercial value. The study area is also remote from population centers and major transportation systems. The sand and gravel are not currently needed for construction, and they have no qualities that would make them valuable for any other purpose. There is no indication of uranium or thorium in the vicinity. There are no known oil or gas shows, but exploration has been too limited to draw any conclusions at this time. As of 1987, there was limited oil and gas leasing interest, mostly in the north half of the study area.

[1]Unpublished analyses of samples from the Azure Ridge mine and the Esperanta claims (nos. 1-4) showed concentrations of 4, 6, 25, 120, 145, and 150 parts per million germanium; and 5, 8, 25, 26, 63, 65, and 75 parts per million gallium.

[2]Unpublished analyses of samples from the Quartz claim showed three samples with concentrations of <1 part per million and one sample with 1 part per million germanium and 2, 2, 3, and 11 parts per million gallium.

## ASSESSMENT OF RESOURCE POTENTIAL

*By* Joel R. Bergquist, Gary A. Nowlan, *and*
H. Richard Blank, Jr.
*U.S. Geological Survey*

### Geology

The study area is located north of Lake Mead along the Arizona border and includes the eastern half of Azure

Ridge. Azure Ridge is separated from geologically and structurally similar Tramp Ridge and Lime Ridge to the northwest by an alluviated valley. The study area is in the eastern margin of the Basin and Range physiographic and structural province. The Grand Wash Cliffs, about 12 mi to the east, mark the boundary with the Colorado Plateau physiographic province. Azure Ridge, Tramp Ridge, and Lime Ridge are all predominantly composed of Paleozoic sedimentary rocks. The area immediately west and southwest of Azure Ridge is a highland composed almost wholly of Precambrian granite, gneiss, and schist that has been deeply dissected. The Paleozoic rocks of Azure Ridge rest unconformably on these Precambrian crystalline rocks. Jumbo Peak, approximately 5 mi southwest of the study area, is composed mainly of Precambrian granite and is the highest point in the area with an elevation of 5,763 ft.

Azure Ridge comprises most of the Million Hills Wilderness Study Area and is not a single ridge, but rather a 3-mi-wide series of roughly linear, north-trending ridges and valleys. These ridges were formed by the uplift, faulting, and erosion of the now steeply east-dipping strata. The dips of these beds generally range from about 50° to 60° E. The ridges reflect the eastward tilting along northeast trending faults that have caused repetition of the stratigraphic section in adjacent ridges. Excellent exposures of the strata occur along the fault-bounded west sides of the ridges.

Structurally, Azure Ridge is a fault block that has been tilted eastward. The ridge is broken by two sets of faults: one that trends northeast and a second that trends roughly east-west. The Paleozoic section of sedimentary rocks is partly in depositional contact and partly in fault contact with the underlying Precambrian crystalline rocks along the west side of the ridge. The Paleozoic rocks of the study area are broken by both normal and bedding-plane faults, which partly control the topography and also provide pathways for mineralizing fluids. The northern part of Azure Ridge is truncated by the northeast-trending Gold Butte fault, which is a major structural feature of the region. Tramp Ridge and Azure Ridge are lithologically and structurally similar, though separated by a distance of about 7 mi along the Gold Butte fault. This similarity led Longwell and others (1965) to conclude that Tramp Ridge and Azure Ridge were previously continuous but were separated by a large component of left-lateral strike-slip movement along the Gold Butte fault.

## Stratigraphy

A Precambrian metamorphic suite of gneiss and schist (p€gs) forms the basement rocks of the study area and is exposed only in the western part of the study area. The gneiss and schist are the oldest rocks in the region and underlie the Paleozoic strata. This suite comprises quartz-mica schist, chlorite schist, amphibolite, and banded gneiss. In places, interbedded mica schists and quartzose gneisses suggest that they are metamorphosed interbeds of sandstone and shale (Longwell and others, 1965). The metamorphic rocks are locally strongly deformed by folding and shearing that suggest deformation occurred at great depths and pressures. The metamorphic suite was intruded by Precambrian granite (not exposed in the study area) and associated dikes and stringers, which pervade the metamorphic rocks.

Unconformably overlying the Precambrian basement rock is a sequence of Paleozoic stratified sedimentary rocks. Many of the Paleozoic rocks in the study area are lateral equivalents of strata exposed in the Grand Canyon.

The lowermost Paleozoic unit in the study area (€u) comprises undivided Cambrian quartzite, shale, sandstone, and limestone. In the Virgin Mountains, laterally equivalent strata consist of the (ascending) Prospect Mountain Quartzite, Pioche Shale, Lyndon Limestone, and the Chisholm Shale, all of McNair (1951) (McNair, 1951; Longwell and others (1965). The base of the section, there, is the Prospect Mountain Quartzite, which consists of quartzite and sandstone that are light gray to reddish gray, thin to thick bedded, locally pebbly, and locally crossbedded (McNair, 1951). The Pioche Shale is olive-green or gray shale with thin interbeds of sandstone and fossiliferous limestone (McNair, 1951). The Lyndon Limestone is a gray-weathering, massive bedded, fine- to medium-grained limestone that locally has shaly limestone mottling (McNair, 1951). The Chisholm Shale is green to brown, fissile to thin-bedded shale that grades upward into a coarse-grained, mottled limestone lying at the base of the Peasley Limestone of McNair (1951) (McNair, 1951; Longwell and others, 1965).

In the study area, the Cambrian limestone and dolomite, of unit €ld, which overlies unit €u, includes in ascending order, the strata laterally equivalent to Peasley Limestone and an unnamed unit composed of limestone and dolomitic limestone in the Virgin Mountains. The Peasley Limestone there consists of limestone, dolomitic limestone, and interbeds of shale. These limestones and dolomitic limestones are typically dark gray, brown weathering to light gray, fine grained, thin to medium bedded, and mottled tan to yellowish-brown (McNair, 1951). The overlying unnamed unit consists of limestone and dolomitic limestone that is brown, tan, or gray on fresh and weathered surfaces, thin to thick bedded and contains thin beds of oolitic limestone, intraformational conglomerate, and shaly limestone (McNair, 1951).

The Devonian Muddy Peak Limestone (Dmp) overlies the Cambrian limestone and dolomite (€ld) in the study area and consists of limestone and dolomitic limestone that is light to dark gray or tan to brown, fine to very coarse grained, thin to thick bedded or massive, and typically weathering to tan and gray (McNair, 1951). Some of its beds contain fossils, ripple marks, and sandy horizons. The fossil gastropods, brachiopods, *Stromatopora*, horn corals, and fish fragments that occur sparingly in the fossiliferous beds indicate that the rocks are Late Devonian in age (McNair, 1951).

The contact between the Mississippian Rogers Spring Limestone (Mrs) and the underlying Devonian Muddy Peak Limestone in the study area is marked by an erosional unconformity and by a change in the weathering colors of the rocks at the contact from brown gray to light gray (McNair, 1951). The Rogers Spring Limestone consists of limestone and dolomitic limestone that is whitish to dark gray, light to dark gray weathering, very fine to coarse grained, and medium to thick or massive bedded. Some beds are fossiliferous with crinoids, horn corals, brachiopods, gastropods, and *Syringopora;* and some contain nodules or bands of brown-weathering chert (McNair, 1951).

In the Muddy Mountains, strata laterally equivalent to those present in the study area that make up the interval between the Mississippian Rogers Spring Limestone and the Permian redbeds (unit Prb, discussed below) were originally assigned by Longwell (1921) to the Callville Limestone. Subsequent workers have subdivided the strata that constitute Longwell's Callville Limestone into three separate formations. Ledbetter (1970), using the terminology of Bissell (1962), mapped and described the Illipah Formation below the Callville Limestone as described by Welsh (1959) at Azure Ridge. McNair (1951) referred to the rocks of the upper part of Longwell's Callville Limestone as the Pakoon Limestone in the Virgin Mountains and elsewhere on the basis of their contained Permian fossil fusulinids but not on the basis of lithologies of these two units, which are similar. In this part of Arizona, no physical boundary has been observed between the Pennsylvanian and Permian beds (Longwell and others, 1965). Ledbetter (1970) described the Pakoon Formation of McNair (1951) in the Azure Ridge area. Longwell and others (1965) reported that on the basis of a reexamination of fusulinids in the section, the lowermost part of the section (that is, the rocks which make up the Illipah Formation) may actually be Late Mississippian and Early Pennsylvanian in age. The Callville Limestone (PMc) in the study area, therefore, consists of (1) the undivided Mississippian and Pennsylvanian Illipah Formation of Bissell (1962) and Ledbetter (1970), (2) strata laterally equivalent to the Pennsylvanian Callville Limestone of McNair (1951), and (3) the Permian Pakoon Formation of McNair (1951). Herein the rocks of this section at Azure Ridge are called the Mississippian to Permian Callville Limestone as used by Longwell and others (1965), which follows the original definition of the Callville by Longwell (1921).

The Callville Limestone as mapped in the area of this report consists of three parts. The lowermost is a 15-ft-thick Mississippian and Pennsylvanian section consisting of carbonaceous shale, siltstone, and sandy limestone that constitutes the Illipah Formation of Bissell (1962) and Ledbetter (1970). The middle part (wholly Pennsylvanian) of the Callville lying above the basal part of the formation consists of basal limestones and dolomitic limestones that are typically thick bedded, cliff forming, and oolitic. These rocks are generally fine grained but range to coarse grained. They are mostly gray where fresh and tan to gray where weathered. There are a few scattered, thin bands of red chert near the top of the middle unit of the Callville at Azure Ridge. Fossil gastropods occur in the middle part of the sequence that consists wholly of Pennsylvanian limestones. The uppermost (Permian) part of the Callville as mapped in this report, the Pakoon Formation of McNair (1951), typically is silty and, in many places, crossbedded limestone that weathers to subdued slopes. The Permian rocks in the Callville consist of limestone, dolomitic limestone, and pure dolomite all of which are fine grained, gray or tan, fossiliferous, and brown, tan, or pink weathering. Some of the Permian strata contain oolites or thin chert beds. The Permian fossils found in these rocks consist mostly of horn corals, brachiopods, and fusulinids.

Lying above the Callville Limestone in the study area is a sequence of interbedded sandstone and redbeds, here termed the redbeds unit (Prb). The contact of this unit with the underlying limestones of the Callville is sharp and lithologically distinct. The basal bed of this unit is a sandstone whose lateral equivalent in the Virgin Mountains 25 mi north of the study area and elsewhere was termed the Queantoweap Sandstone by McNair (1951). Ledbetter (1970) recognized the Queantoweap at Azure Ridge. The sandstone in the study area is pinkish gray, calcareous, crossbedded and ledge forming. The Queantoweap is overlain by redbeds, which consist of interbedded reddish sandy shale and reddish fine-grained sandstone.

The stratigraphically highest Paleozoic units mapped at Azure Ridge are the undivided Permian Kaibab and Toroweap Formations (Pkt). The Kaibab is the youngest Paleozoic formation in the region. The two units are lithologically similar, although the Kaibab tends to form steeper cliffs than the Toroweap. There is a gypsum bed at the top of the Toroweap that marks the boundary between the two formations (Longwell and others, 1965).

The Toroweap Formation consists of a basal gypsum member, a middle limestone member, and an upper gypsum member (Longwell and others, 1965). The gypsum members are generally gray to white or pinkish, slope forming, and interbedded with a few thin beds of limestone. The upper gypsum member also locally contains some solution breccia (Longwell and others, 1965). The middle limestone member of the Toroweap consists of limestone and dolomitic limestone that is typically gray to dark gray, fine to medium grained, thin to thick bedded, cliff forming, and fossiliferous with crinoids and brachiopods (Longwell and others, 1965). The limestone of the middle member also contains thin bands, lenses, and nodules of chert that in some beds constitute as much as half the rock. The chert is typically gray to pinkish gray on fresh surfaces and weathers brown, giving the rocks a dark color.

The Kaibab Formation consists of limestone and dolomitic limestone, with a solution-collapse breccia at the base of the formation. Above the basal part of the unit are beds of limestone that are typically, gray, fine to medium grained, weathering tan to pinkish gray, and cliff forming. Most parts of the formation contain beds, bands, and nodules of chert.

Tertiary sedimentary and volcanic units are exposed along the eastern edge of the study area. These are separated from the Paleozoic rocks of Azure Ridge by wide expanses of alluvium. The lowermost Tertiary unit is the Muddy Creek Formation (Tmc), exposed beneath volcanic flow rocks at the north end of the study area. The age of the Muddy Creek is constrained by the age of the overlying basalt, which has been radiometrically dated at approximately 2.5 Ma or million years ago (Luedke and Smith, 1981). The formation consists of fluvial and lacustrine deposits that were laid down in interior basins. The beds consist of gravel, sand, and silt that are weakly indurated, weakly bedded, and relatively flat lying. The color of the beds appears generally buff but is varied and not distinctive.

Tertiary volcanic flow rocks (Tv) overlie the Muddy Creek Formation and are also found as outliers in contact with younger Quaternary alluvium. The flows are locally vesicular olivine basalt that is blocky or platy weathering, and dark brown to black on weathered surfaces.

Quaternary alluvium (Qal) covers about 30 to 40 percent of the study area, mostly in the northern and eastern parts. Alluvium in the study area consists of bouldery alluvial fans, coarse gravelly material probably deposited as sheetwash, and generally unsorted sand, silt, and clay. Along its contact with the Paleozoic rocks of the Million Hills, this unit also includes talus deposits.

## Geochemical Studies

A reconnaissance geochemical survey of the Million Hills Wilderness Study Area was conducted in April 1987. Samples of drainage sediment were collected at 28 sites on streams draining the wilderness study area and vicinity (fig. 3). Stream-sediment samples represent a composite of material eroded from the drainage basin of the stream sampled. Panned-concentrate samples derived from stream sediment contain selectively concentrated minerals that may be ore related and may include elements not easily detected in stream-sediment samples.

Three samples were collected at each site. One of the samples was air dried and then sieved through an 80-mesh (0.177-mm) stainless-steel sieve to obtain a stream-sediment sample. The portion that passed through the screen was later pulverized to minus-100-mesh (0.149 mm) size prior to analysis. For the other two samples at each site, enough stream sediment was screened through a 10-mesh (2mm) sieve to obtain about 20 lb. The minus-10-mesh samples were panned to remove most of the quartz, feldspar, clay-sized material, and organic matter. One of these panned-concentrate samples was further concentrated by a series of steps that utilized bromoform (specific gravity 2.8) and magnetic separations to produce a nonmagnetic heavy-mineral-concentrate sample. The nonmagnetic heavy-mineral-concentrate sample includes most nonmagnetic ore minerals and accessory minerals such as sphene, zircon, apatite, and rutile. Prior to analysis the nonmagnetic heavy-mineral-concentrate sample was pulverized to minus-100 mesh size. The raw panned-concentrate samples received no further treatment and were analyzed for gold.

The stream-sediment and nonmagnetic heavy-mineral-concentrate samples were analyzed using a six-step semi-quantitative emission spectrographic method described by Grimes and Marranzino (1968) for calcium (Ca), iron (Fe), magnesium (Mg), titanium (Ti), silver (Ag), arsenic (As), gold (Au), boron (B), barium (Ba), beryllium (Be), bismuth (Bi), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), lanthanum (La), manganese (Mn), molybdenum (Mo), niobium (Nb), nickel (Ni), lead (Pb), antimony (Sb), scandium (Sc), tin (Sn), strontium (Sr), thorium (Th), vanadium (V), tungsten (W), yttrium (Y), zinc (Zn), and zirconium (Zr). In addition, the nonmagnetic heavy-mineral-concentrate samples were analyzed for phosphorus (P), sodium (Na), gallium (Ga), germanium (Ge), palladium (Pd), and platinum (Pt) by emission spectrography. Also, the stream-sediment samples were analyzed for Au by graphite-furnace atomic absorption, for uranium (U) by ultraviolet fluorimetry, and for As, Bi, Cd, Sb, and Zn by inductively coupled plasma spectroscopy. The raw panned-concentrate samples were analyzed for Au by flame atomic absorption. Analytical data, sampling sites, and references to analytical methods are presented in McHugh and others (1989).

Selected elements determined in each sample type, the lower and upper limits of determination, the range of concentrations, the 50th and 90th percentile concentrations, and the threshold (highest background) concentrations are presented in table 3. Threshold concentrations were established by visual and statistical examination of the data, by comparison of the data from this study with data from nearby wilderness study areas (El Dorado, Ireteba Peaks, and Lime Canyon), and by reference to bedrock concentrations (table 4) listed by Rose and others (1979).

Correlations for logs of data obtained from the analysis of minus-80-mesh stream-sediment samples are listed in table 5. Before the correlation analysis, qualified values were replaced by unqualified values. Qualified values are

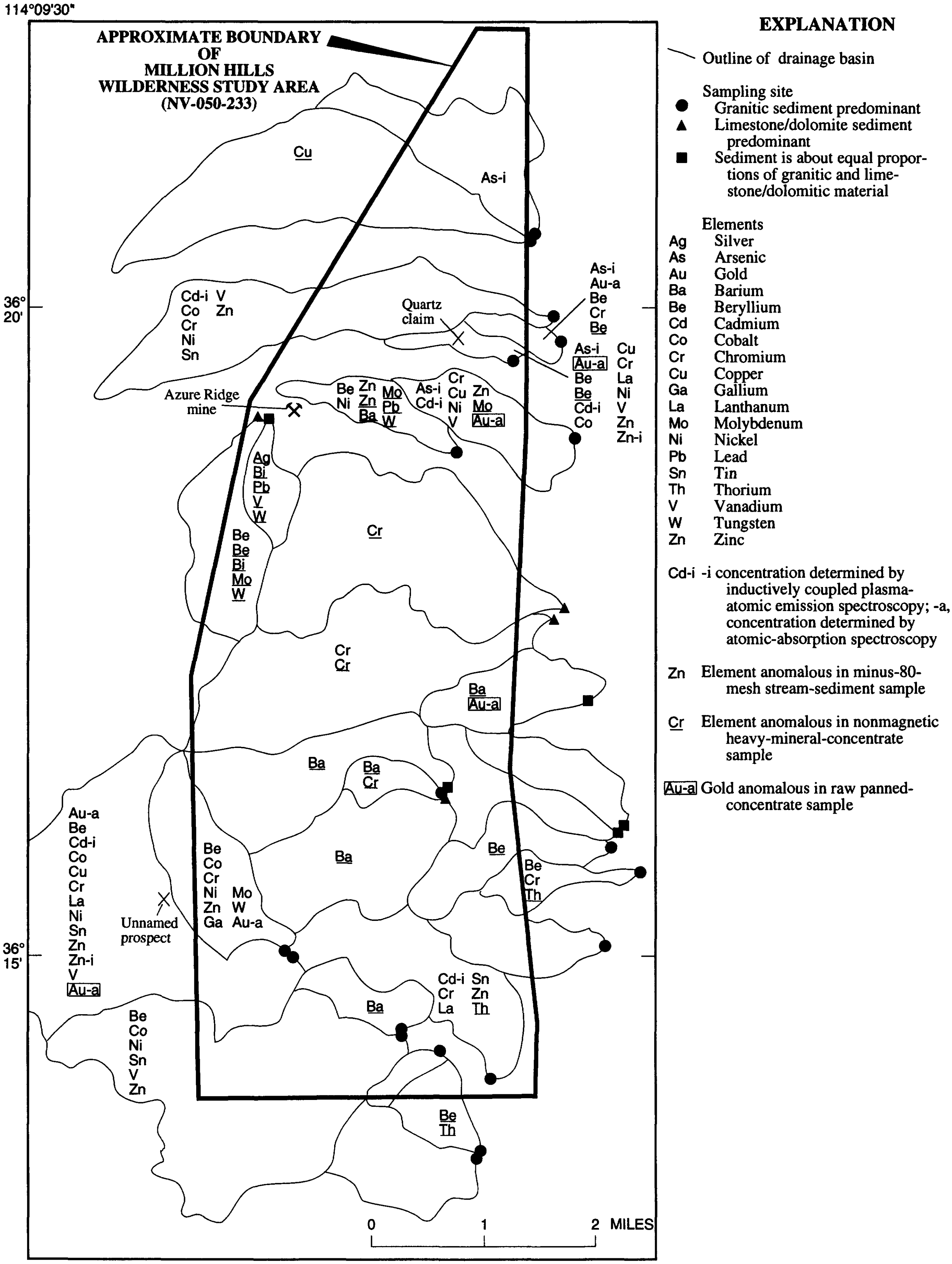



**Figure 3.** Elements present in anomalous concentrations in samples collected from drainage basins in and near Million Hills Wilderness Study Area, Clark County, Nevada.

those less than the lower limit of determination and greater than the upper limit of determination. Reported concentrations qualified by "N" or "<" were replaced by values two emission spectrographic steps below the lower limit of determination (table 3). Concentrations qualified by "L" were replaced by values one emission spectrographic step below the lower limit of determination. No elemental concentrations in minus-80-mesh stream-sediment samples were greater than the upper limit of determination. Any variable with more than 9 samples containing undetected concentrations was omitted from table 5.

Strong correlations among an unusually large group of elements that includes Fe, Ti, Be, Co, Cr, Cu, La, Mn, Ni, Pb, Sc, V, Y, Cd, Zn, and U are shown in table 5. A number of mathematical manipulations and procedures such as r-mode factor analysis support this strong correlation. The validity of the correlations is also supported by figure 3, which lists elements present in anomalous concentrations in each sampled drainage basin. Gold is not included in table 5 because half the samples have undetected concentrations. Nevertheless, anomalous concentrations of gold in minus-80-mesh stream-sediment samples appear to be closely associated with anomalous concentrations of other elements. Sampling sites are differentiated on figure 3 on the basis of the rock-type composition of the stream sediment as determined at the time of sample collection. The correspondence between sediment composition and anomalous elemental concentrations is listed in table 3. Most of the samples containing anomalous concentrations were collected from sites where the sediment was 70 percent or greater granitic composition even though, in some cases, bedrock at the sampling site was limestone or dolomite.

Correlations among the ferride elements, Fe, Co, Cr, Cu, Ni, and V, are very strong (table 5). Correlations of the ferride elements with Ti, Mn, and Sc are also very strong. The association of Fe, Co, Cr, Cu, Ni, V, Ti, Mn, and Sc is fairly common in stream-sediment samples from many geologic and climatic environments and usually reflects the presence of common ferromagnesian silicates. However, the association of these elements in stream-sediment samples from the study area is unusually strong, inclusive, and persistent. In addition, some elements (Be, La, Y, Zr, and U), which usually correlate poorly with most of the ferride elements, and elements that are often related to mineralization (Cd, Pb, and Zn) also correlate moderately to strongly with the ferromagnesian group of elements. Magnesium usually correlates positively with the ferromagnesian group, though in samples from the study area, the correlation is negative and poor. This relationship probably reflects the presence of carbonate rocks.

Gneiss and schist underlie parts of the wilderness study area (fig. 2) and contribute sediment or have contributed sediment in the past to most of the sampled stream channels. Material from the gneiss and schist bedrock was probably recorded as granitic material at the time of sample collection (table 3, fig. 3). Although there is good correspondence between granitic sediment and anomalous concentrations of many elements, the inclusive and strong correlations in table 5 suggest a geochemical signature other than one that can be attributed to granitic sediment alone.

The geochemical data from drainage-sediment samples of the wilderness study area and vicinity suggest the geochemical signature for a model of carbonate-hosted mineral deposits termed Kipushi Cu-Pb-Zn deposits (Cox and Bernstein, 1986). The geochemical signature for Kipushi-type mineralization is Cu, Zn, Pb, As, Co, Ag, Ge, Ga, Mo, W, Sn, Bi, U, and V (Cox and Bernstein, 1986). The nearest known Kipushi-type ore deposit, the Apex mine, is about 50 mi northeast of the study area. The Apex mine produced Cu, Pb, Ag, and minor amounts of Zn and Au from 1884 to 1962 (Bernstein, 1986), operated intermittently thereafter, and was reopened in 1990 (Hecla Mining Company, 1990). Apex is the only known mine in the world where the primary products are gallium and germanium. Proven and probable reserves at Apex total about 230,000 short tons with grades of 0.046 percent Ga, 0.105 percent Ge, and 1.6 percent Cu (Hecla Mining Company, 1990). The host rock of the deposit is the Callville Limestone. The ore at the Apex mine is associated with zones of fault breccia. The limestone has been dolomitized and locally silicified within and near the fault zones.

The Azure Ridge mine is a carbonate hosted deposit that produced a few carloads of sorted Zn and Cu ore (Longwell and others, 1965, p. 130). The ore contained minor amounts of Au and Ag. The deposit is associated with faults and is in a stratigraphic setting similar to the Apex mine. Recent analyses of mineralized samples by the U.S. Bureau of Mines reveal Co is present in the deposit (Causey, 1988). The Quartz claim (fig. 3), an inactive mining claim, has Mn and Fe oxides in alluvial fill. Samples of the oxide contain the following approximate concentrations of elements, in parts per million (ppm): Ni-1,700; Mo-110; Pb-1,900; Tl-80; Zn-3,700; Cu-550; Co-6,100; Bi-28; As-140; Ba-4900 (Causey, 1988). Manganese-iron oxides are effective scavengers of many elements (Chao and Theobald, 1976), but a source for the elements must exist in order for them to be available for scavenging.

A possible explanation for the geochemical signature expressed in the drainage samples from the study area and vicinity is that Kipushi-type mineralization is present in the subsurface and is the source of anomalous concentrations of a variety of elements in drainage sediment and is the source for the Mn-Fe oxides and associated elements at the Quartz claim. Mineralogical studies of the nonmagnetic heavy-mineral-concentrate samples might help to establish the residency of many of the elements detected by emission spectrography. Selective leaching of minus-80-mesh stream-sediment samples might establish whether

**Table 3.** Statistics for selected elements in drainage samples collected in and near Million Hills Wilderness Study Area, Clark County, Nevada

[Results based on 28 samples. Concentrations determined by emission spectrography except As-i, Cd-i, and Zn-i determined by inductively coupled plasma spectroscopy and Au-a determined by atomic absorption. N, not detected at lower limit of determination; L, detected below lower limit of determination; G, greater than upper limit of determination; <, less than lower limit of determination; ---, upper limit is open ended. ppm, parts per million; pct, percent]

| Element | Limits of determination, ppm | | Range, ppm | | Percentiles, ppm | | Threshold concentration, ppm | Number of samples with anomalous concentrations | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lower | Upper | Minimum | Maximum | 50th | 90th | | 70 pct granitic sediment, or greater | 70 pct limestone/dolomite sediment, or greater | Approximately equal amounts of granitic and limestone/dolomite sediment |
| Minus-80-mesh stream-sediment samples | | | | | | | | | | |
| As-i | 5 | 20,000 | < | 17 | 5 | 11 | 10 | 4 | 0 | 0 |
| Au-a | 0.001 | — | < | 0.003 | 0.001 | 0.001 | 0.001 | 2 | 0 | 0 |
| Be | 1 | 1,000 | N | 5 | 1 | 3 | 2 | 7 | 0 | 1 |
| Cd-i | 0.1 | 1,000 | 0.2 | 5.6 | 1.2 | 2.6 | 1.9 | 5 | 0 | 0 |
| Co | 5 | 2,000 | N | 50 | 10 | 30 | 20 | 5 | 0 | 0 |
| Cr | 10 | 5,000 | N | 1,000 | 85 | 200 | 100 | 8 | 0 | 1 |
| Cu | 5 | 20,000 | L | 50 | 20 | 40 | 30 | 3 | 0 | 0 |
| La | 20 | 1,000 | N | 500 | 30 | 110 | 100 | 3 | 0 | 0 |
| Ni | 5 | 5,000 | L | 200 | 20 | 70 | 50 | 7 | 0 | 0 |
| Sn | 10 | 1,000 | N | L | N | L | N | 4 | 0 | 0 |
| V | 10 | 10,000 | 15 | 500 | 70 | 150 | 100 | 5 | 0 | 0 |
| Zn | 200 | 10,000 | N | 200 | N | L | N | 8 | 0 | 0 |
| Zn-i | 2 | 18,000 | < | 56 | 37 | 48 | 49 | 2 | 0 | 0 |
| Nonmagnetic heavy-mineral-concentrate samples | | | | | | | | | | |
| Ag | 1 | 10,000 | N | 5 | N | N | N | 0 | 1 | 0 |
| Ba | 50 | 10,000 | 100 | G | 1,250 | 10,000 | 5,000 | 2 | 3 | 1 |
| Be | 2 | 2,000 | N | 50 | N | 2 | N | 4 | 0 | 1 |
| Bi | 20 | 2,000 | N | 20 | N | N | N | 0 | 1 | 1 |
| Cr | 20 | 10,000 | N | 200 | N | 110 | 70 | 0 | 1 | 2 |
| Cu | 10 | 50,000 | N | 30 | L | 17 | 20 | 1 | 0 | 0 |
| Ga | 10 | 1,000 | N | L | N | N | N | 1 | 0 | 0 |
| Mo | 10 | 5,000 | N | 50 | N | L | N | 3 | 0 | 1 |
| Pb | 20 | 50,000 | N | 3,000 | 20 | 60 | 300 | 1 | 1 | 0 |
| Th | 200 | 5,000 | N | 200 | N | N | N | 3 | 0 | 0 |
| V | 20 | 20,000 | 20 | 150 | 50 | 85 | 100 | 0 | 1 | 0 |
| W | 50 | 20,000 | N | 1,000 | N | 200 | L | 3 | 2 | 2 |
| Zn | 500 | 20,000 | N | L | N | N | N | 1 | 0 | 0 |
| Raw panned-concentrate samples | | | | | | | | | | |
| Au-a | 0.05* | — | < | 0.65 | < | 0.05 | < | 4 | 1 | 0 |

*Based on 10-g sample

**Table 4.** Average of median concentrations of selected elements in bedrock from Rose and others, 1979

[Concentrations in parts per million. <, less than value shown; ---, no value given]

| Element | Granite | Basalt and gabbro | Limestone | Sandstone | Shale |
|---|---|---|---|---|---|
| Ag | 0.037 | 0.1 | 0.1 | 0.25 | 0.19 |
| As | 2.1 | 1.5 | 1.1 | 1.2 | 12 |
| Au | 0.0023 | 0.0032 | 0.005 | 0.005 | 0.004 |
| Ba | 840 | 330 | 92 | 170 | 550 |
| Be | 3 | 1 | <1 | <1 | 3 |
| Bi | 0.3 | 0.05 | --- | 0.3 | 1.0 |
| Cd | 0.1 | 0.2 | 0.035 | <0.1 | 0.3 |
| Co | 1 | 48 | 0.1 | 0.33 | 19 |
| Cr | 4.1 | 170 | 11 | 35 | 90 |
| Cu | 12 | 72 | 5 | 10 | 42 |
| La | 55 | 17 | 4 | 7 | 39 |
| Mo | 1.3 | 1.5 | 0.4 | 0.2 | 2.6 |
| Ni | 4.5 | 130 | 20 | 2 | 68 |
| Sn | 3.0 | 1.5 | <1 | 0.6 | 6 |
| Th | 20 | 2.7 | 1.7 | 5.5 | 12 |
| V | 44 | 250 | 20 | 20 | 130 |
| W | 1.5 | 1.0 | 0.5 | 1.6 | 1.8 |
| Zn | 51 | 94 | 21 | 40 | 100 |

the elements present in anomalous concentrations are associated with primary minerals, such as sulfides, or secondary Mn-Fe oxides. These additional studies would help test the applicability of the Kipushi Cu-Pb-Zn model.

## Geophysical Studies

Regional aeromagnetic and gravity data for the Million Hills Wilderness Study Area and vicinity assist in establishing the geologic framework essential to evaluation of the resource potential. Two aeromagnetic surveys provide data at 1-mi spacing: a survey of part of part of the Las Vegas 1°×2° quadrangle, flown east-west at 1,000 ft above ground (U.S. Geological Survey, 1983), and a survey of the Gold Butte-Chloride area, flown north-south at 8,000 ft barometric elevation (U.S. Geological Survey, 1972). Gravity data are available from the U.S. National Defense Mapping Agency (through the National Center for Geophysical and Solar-Terrestrial Data, Boulder, Colo.); 16 additional gravity stations were established by the USGS for this project.

A residual total-intensity map was made by merging digital data from the two aeromagnetic surveys, after removal of the International Geomagnetic Reference Field (fig. 4). The contour intervals are 20 and 100 nanoteslas (nT). The area of coverage is much larger than the study area to show regional relations. The anomaly field is complex and is dominated by very intense, relatively short wavelength disturbances. Almost all principal anomaly highs are associated with exposed metamorphic and granitic rock of the Precambrian crystalline basement complex, the only exception being due east of the study area, where the high can be attributed to concealed basement rock on the floor of the Grand Wash depression (fig. 1). Most of this depression is a region of relatively weak anomalies, probably because of the increased depth to sources. Strong aeromagnetic anomaly trends in the region are predominantly northwesterly and northeasterly. A deep west-northwest-trending low is present over the structural depression between the Virgin Mountains and the area that includes Lime Ridge, Tramp Ridge, and Azure Ridge. A low also is present over Grand Wash, where it has an east-northeast trend, possibly reflecting offset on a concealed extension of the Gold Butte fault.

The regional Bouguer gravity anomaly field was computed with data from 123 points of gravity observation in the area (fig. 5). The standard reduction density, 2.67 g/cm$^3$, was used, and terrain corrections were applied for Hayford-Bowie zones A–O (0–167 km). An explanation of these procedures is given in Cordell and others (1982). The principal feature of the gravity field is the down-to-the-east gradient between dense Precambrian crystalline and Paleozoic carbonate rocks of the Virgin Mountains and much less dense Cenozoic fill of the Grand Wash depression. The basin fill of the Grand Wash apparently reaches a maximum thickness in

**Table 5.** Correlation coefficients for analytical data from minus-80-mesh stream-sediment samples collected in and near Million Hills Wilderness Study Area, Clark County, Nevada

[Based on logs of replaced data. Coefficients multiplied by 100. All elements analyzed by emission spectrography except where suffix denotes other methods. -i, inductively coupled plasma spectrometry; -f, x-ray fluorescence. Results based on analyses of 28 samples]

| | Fe | Mg | Ti | B | Ba | Be | Co | Cr | Cu | La | Mn | Ni | Pb | Sc | Sr | V | Y | Zr | As-i | Cd-i | Zn-i | U-f |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ca | -49 | 30 | -56 | -13 | -46 | -53 | -55 | -51 | -34 | -33 | -41 | -52 | 1 | -50 | -37 | -38 | 035 | 032 | 4 | -38 | -29 | -31 |
| Fe | | -16 | 89 | -9 | 57 | 75 | 91 | 78 | 87 | 84 | 90 | 93 | 66 | 93 | 61 | 90 | 88 | 63 | 42 | 93 | 80 | 73 |
| Mg | | | -39 | -30 | -41 | -22 | -22 | -24 | -12 | -20 | -21 | -20 | 8 | -27 | -20 | -27 | -12 | -46 | -11 | -20 | -18 | -14 |
| Ti | | | | 15 | 64 | 69 | 88 | 74 | 75 | 86 | 81 | 88 | 48 | 87 | 62 | 85 | 81 | 72 | 29 | 83 | 68 | 59 |
| B | | | | | 10 | -4 | -14 | -2 | -21 | -23 | -26 | -19 | -17 | -13 | -26 | -12 | -14 | 26 | 2 | -30 | -17 | -4 |
| Ba | | | | | | 51 | 55 | 51 | 40 | 45 | 49 | 54 | 22 | 59 | 70 | 48 | 36 | 39 | 21 | 51 | 48 | 46 |
| Be | | | | | | | 82 | 53 | 69 | 64 | 76 | 78 | 52 | 84 | 74 | 64 | 76 | 39 | 5 | 68 | 73 | 77 |
| Co | | | | | | | | 67 | 85 | 77 | 85 | 93 | 65 | 91 | 68 | 82 | 84 | 65 | 21 | 85 | 78 | 68 |
| Cr | | | | | | | | | 63 | 68 | 65 | 70 | 44 | 65 | 54 | 67 | 76 | 48 | 45 | 72 | 63 | 44 |
| Cu | | | | | | | | | | 73 | 90 | 90 | 82 | 84 | 62 | 80 | 82 | 48 | 32 | 89 | 89 | 76 |
| La | | | | | | | | | | | 79 | 84 | 51 | 83 | 64 | 88 | 84 | 54 | 38 | 84 | 63 | 65 |
| Mn | | | | | | | | | | | | 89 | 73 | 91 | 65 | 87 | 84 | 49 | 32 | 94 | 83 | 78 |
| Ni | | | | | | | | | | | | | 68 | 94 | 73 | 90 | 84 | 57 | 27 | 92 | 83 | 74 |
| Pb | | | | | | | | | | | | | | 60 | 47 | 56 | 70 | 41 | 23 | 71 | 81 | 57 |
| Sc | | | | | | | | | | | | | | | 71 | 89 | 86 | 56 | 24 | 88 | 77 | 78 |
| Sr | | | | | | | | | | | | | | | | 50 | 59 | 22 | 5 | 65 | 69 | 62 |
| V | | | | | | | | | | | | | | | | | 78 | 57 | 47 | 92 | 68 | 69 |
| Y | | | | | | | | | | | | | | | | | | 54 | 25 | 81 | 76 | 65 |
| Zr | | | | | | | | | | | | | | | | | | | 11 | 49 | 38 | 29 |
| As-i | | | | | | | | | | | | | | | | | | | | 49 | 35 | 34 |
| Cd-i | | | | | | | | | | | | | | | | | | | | | 84 | 73 |
| Zn-i | | | | | | | | | | | | | | | | | | | | | | 76 |

the extreme northeast corner of the map area. A deep embayment in the gravity anomaly gradient in the north-central part of figure 5 reflects the structural discontinuity in magnetic basement evident in the north-central part of figure 4.

East-northeast and north to north-northwest aeromagnetic and gravity trends intersect in the vicinity of the Azure Ridge mine in the northern part of the study area. The east-northeast trends are expressions of the Gold

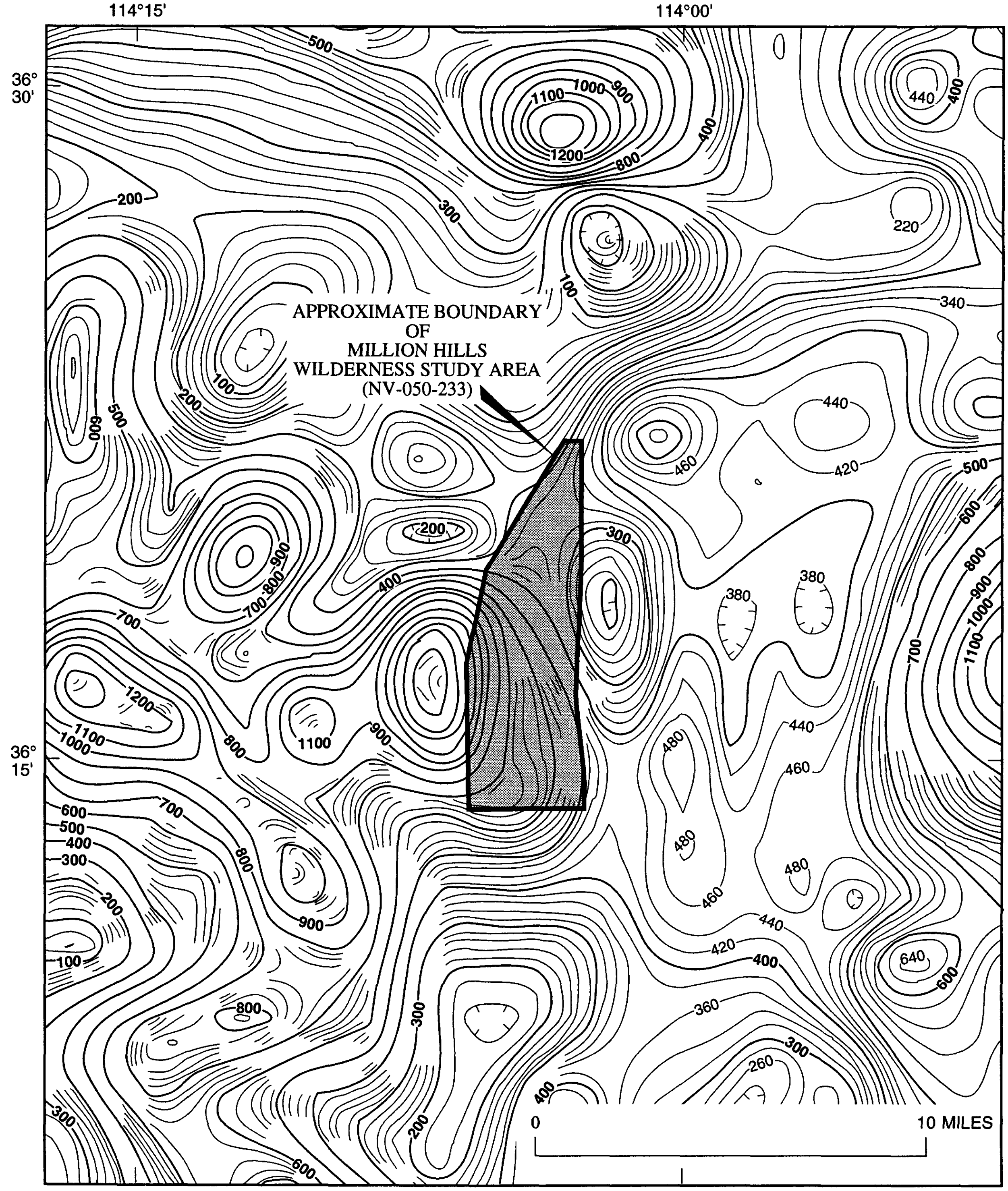



Figure 4. Residual total-intensity aeromagnetic map of Million Hills Wilderness Study Area and vicinity, Clark County, Nevada, and Mojave County, Arizona. Contour intervals, 20 and 100 nanoteslas; hachures denote magnetic low.

Butte fault, but the structural discontinuity reflected by the north to north-northwest trends is concealed. The significance of the structural intersection with regard to possible Kipushi-type copper-lead-zinc mineralization is unclear.

## Mineral and Energy Resource Potential

The Million Hills Wilderness Study Area has high resource potential for copper, lead, zinc, cobalt, gold, silver,

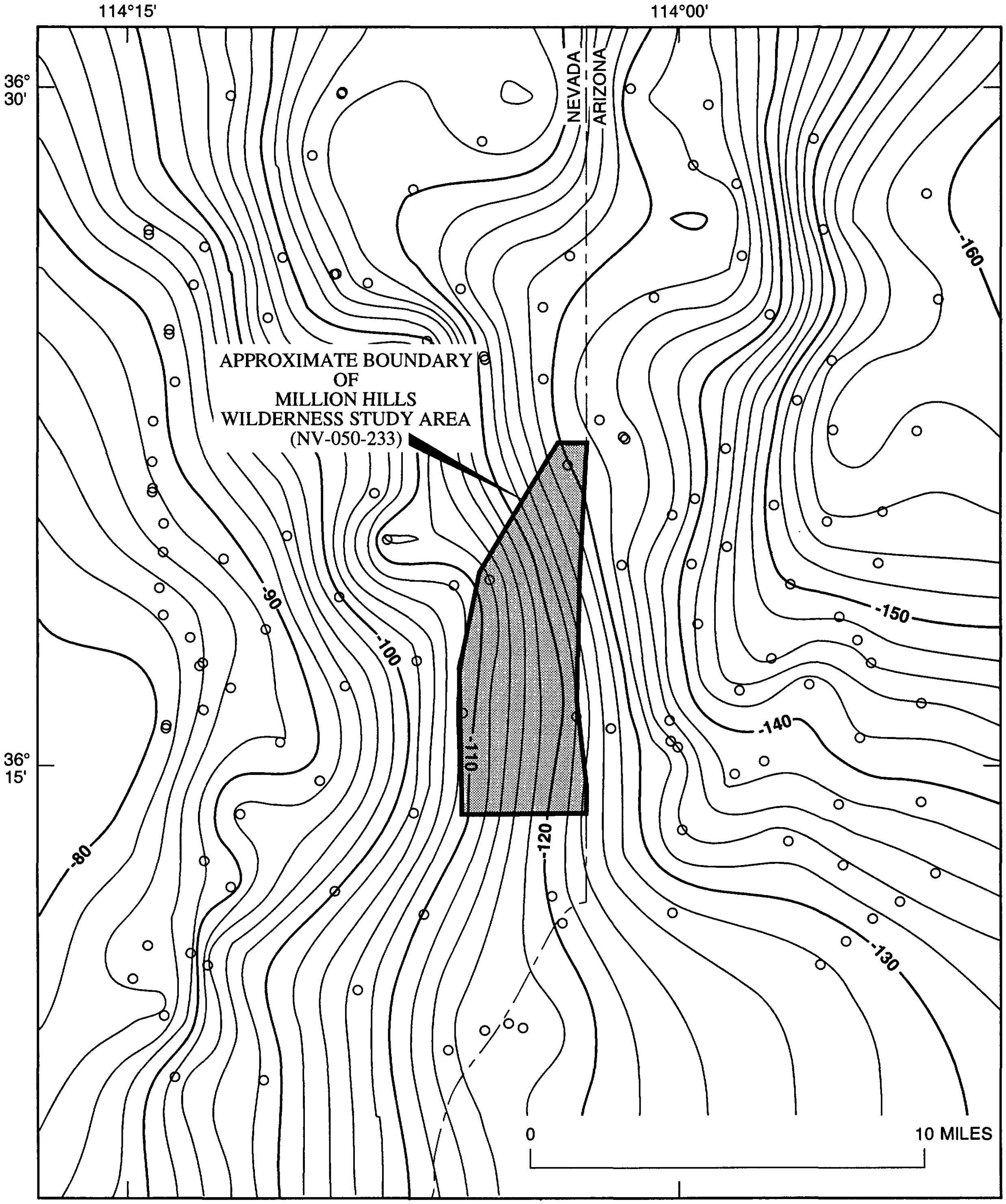



**Figure 5.** Complete Bouguer gravity anomaly map of Million Hills Wilderness Study Area and vicinity, Clark County, Nevada, and Mojave County, Arizona. Contour interval, 2 milligals; circles denote gravity stations.

germanium, and gallium in Kipushi-type deposits. There is low resource potential for oil and gas, and no potential for geothermal energy. There are occurrences of carbonate rocks, and sand and gravel.

Evidence of copper-lead-zinc mineralization in the study area, which can be interpreted to reflect Kipushi-type deposits, was obtained from a geochemical survey that was done by the U.S. Geological Survey for this evaluation of mineral resources, and from a survey by the U.S. Bureau of Mines (Causey, 1988) of the mines, prospects, and mineralized parts of the study area. Kipushi-type deposits are significant because of other metals associated with the copper, lead, and zinc. These metals are cobalt, germanium, and gallium, all of which are relatively scarce in this country, and two of which (cobalt and germanium) are classified as strategic and critical minerals. Cobalt is a metal chiefly used to make magnetic alloys, and alloys that are heat, corrosion, and wear resistant. The end uses are mostly in aircraft, jet engines, cutting tools, electrical equipment, paints, and chemical products. Germanium is a metalloid used chiefly in the electronics and optics industries. It is also used in the manufacture of some semiconductor devices, optical lenses with infrared sensing capabilities, fiber optics, nuclear radiation detectors, alloys, and as a catalyst. Gallium is a metal with a very low melting point (86° F) used in the manufacture of electronic components and optical devices, and as an alloying agent in the preparation of superconductive devices. The United States is a net importer of all three elements. For additional information on supply, demand, and other facts related to cobalt, germanium, and gallium, see Kirk (1985), Plunkert (1985), Petkof (1985), and U.S. Bureau of Mines (1993).

Most cobalt is produced as a byproduct from the mining of other metals. The only primary cobalt producing district in the United States is the Blackbird district in Idaho. The Blackbird district contains relatively high grade ore of about 0.6 percent cobalt. Other world cobalt deposits have ore grades of about 0.1 to 2.0 percent (Kirk, 1985). Data obtained by the U.S. Bureau of Mines in their investigation of the study area revealed the presence of as much as 0.6 percent cobalt associated with manganese at the Quartz claim (Causey, 1988). In their investigation of a cobalt-manganese occurrence in the northern part of the study area, Moyle and Buehler (1990) found concentrations of cobalt ranging from 0.1 to 0.5 percent. These concentrations were detected in samples from fissures, but the volume of cobalt-enriched material at this occurrence is very small. The study area thus has samples that contain percentages of cobalt as high as those mined in the only cobalt producing district in the U.S. This does not necessarily make the cobalt at Azure Ridge mineable, but it does raise the possibility of economically significant mineralization in the study area and makes it an area in which further exploration may be justified.

The geochemical data from drainage-sediment samples from the study area and immediate vicinity suggest the geochemical signature of a carbonate-hosted Kipushi-type copper-lead-zinc mineral deposit such as described by Cox and Bernstein (1986). The geochemical signature of this type of deposit includes the elements: copper, lead, zinc, cobalt, germanium, gallium, silver, arsenic, molybdenum, tungsten, tin, bismuth, uranium, and vanadium (Cox and Bernstein, 1986). The data obtained from analysis of the geochemical samples was compared with a number of possible mineral deposit types, including the Mississippi Valley type of lead-zinc deposit. However, the correlations of the data were by far the strongest for the Kipushi model. The correlations are strong and inclusive with a high number of attributes present, and they strongly indicate Kipushi-type mineralization as the source of the observed geochemical suite of elements. The correlation is empirically observable, but it was also tested and verified by a number of statistical procedures including r-mode factor analysis. The possibility of the geochemical signature coming from underlying Precambrian gneiss and granite was rejected because the correlations of elements with the Kipushi model are so strong and inclusive. The geochemical signature is stronger than what would appear from the Precambrian rocks alone. This then leads to the conclusion that the geochemical signature is derived from mineralized carbonate rocks. The geochemical signature obtained from sampling of the study area can be explained by the presence of subsurface Kipushi-type mineralization, which would be the source of the anomalous concentrations of the suite of elements found in this study.

The only known Kipushi-type deposit in the conterminous United States is the Apex mine, located about 50 mi northeast of the study area and about 12 mi west of St. George, Utah. The Apex mine is active, and is the first in the world to be mined primarily for germanium and gallium (Bernstein, 1986). Between 1884 and 1962 the deposit was mined for copper, lead, silver, and minor amounts of zinc and gold (Bernstein, 1986). Hecla Mining Co. acquired the Apex mine in 1989 and began producing germanium, gallium, and small amounts of byproduct copper in 1990. Proven and probable reserves total 230,200 short tons that grade 0.105 percent germanium, 0.046 percent gallium, and 1.6 percent copper (Hecla Mining Co., 1990). The need for gallium and germanium decreased with the end of the Cold War. The Apex is still active, though now the primary product is cobalt sulfate for the copper industry (Hecla Mining Co., 1993). The host rock at the Apex mine is the Callville Limestone, a stratigraphic unit that is present in the study area. The physical characteristics of the Callville at the Apex mine were described by Bernstein (1986) and are similar to those of the unit as it crops out in the study area. The ore at the Apex mine occurs in breccia, gouge, and fissures along steeply dipping (64°–71° W) subparallel faults in the Apex fault zone that trends north to northeast (Bernstein, 1986). The fault zone apparently controlled the locus of mineralization at the Apex mine. The Azure Ridge mine is in a similar setting of host rocks and structure, and the observed mineralization in the study area similarly occurs along steeply dipping faults.

The study area may contain Kipushi-type copper-lead-zinc mineralization on the basis of: (1) a geochemical suite of anomalous elements from the study area that strongly correlates with the geochemistry of known Kipushi-type deposits, (2) known mineralization in the study area that includes copper, lead, zinc, gold, silver, and cobalt—all minerals associated with Kipushi-type deposits, (3) the high values of cobalt detected in samples from the Azure Ridge mine—0.6 percent, (4) the fact that Causey (1988) determined that two mining properties in the study area (the Esperanta and Quartz claims) have inferred subeconomic resources of copper, lead, zinc, gold, silver, cobalt, gallium, and germanium, (5) the existence of permissible, reactive host rocks in the study area, (6) the presence of structures (primarily high-angle faults) that provide paths for mineralizing fluids and a locus for mineralization, and (7) the similarity of lithology, structure, and mineralization with the Apex mine, a known Kipushi-type deposit that is about 50 mi north northeast of the study area. Therefore, the part of the study area underlain by carbonate rocks (see fig. 2 for specific location) has high potential, certainty level C, for copper, lead, zinc and lesser amounts of cobalt, gold, silver, germanium, and gallium in Kipushi-type deposits.

Sandberg (1983a, b) shows a large part of the study area as having low potential, certainty level B, for petroleum on the basis of possible presence of source rocks, reservoir rocks, and favorable areas to the north. Harris and others (1980) provide evidence from conodont color alteration index measurements that rocks within 40 mi of the study area have not been thermally overmatured. Data on color alteration of conodonts from Ordovician sedimentary rocks about 40 mi west of the study area indicate that area is permissible for petroleum. There are no known conodont data from within the study area that would provide direct evidence of the degree of thermal maturation. There are no known producing wells or shows of oil or gas in the region surrounding the study area. However, as of 1988, there were 6 oil and gas leases in or near the study area. One of these leases covers about 340 acres in the study area, and contiguous areas are covered by additional oil and gas leases (Bureau of Land Management, 1988, p. 2–35). Because of the permissible geological attributes for oil and gas and the known permissible terrane to the north and west, a large part of the study area has low potential, certainty level B, for oil and gas.

The available data indicate that there is no potential, certainty level D, for geothermal resources in the study area. The study area lies in an area of relatively low heat flow (Muffler, 1979), and there are no known warm or hot springs in the region surrounding the study area. Therefore, the study area has no potential for geothermal resources.

Limestone has a number of industrial uses and crops out extensively in the study area, although these rocks are considered by Causey (1988) to constitute an occurrence, not a resource. This classification is based on the fact that carbonate rocks in the study area are generally thin bedded, cherty, and dolomitized; these rocks also contain interbeds of sandstone, shale, and chert, which diminishes the value of the carbonate rocks for commercial purposes.

Sand and gravel in the study area likewise constitute an occurrence and not a resource (Causey, 1988). This classification is based on the presence of a commercially undesirable layer of caliche near the ground surface and the fact that other sources of sand and gravel are closer to existing markets.

## REFERENCES CITED

Anderson, R.E., Longwell, C.R., Armstrong, R.L., and Marvin, R.F., 1972, Significance of K-Ar ages of Tertiary rocks from the Lake Mead region, Nevada-Arizona: Geological Society of America Bulletin, v. 83, p. 273–288.

Anderson, R.E., 1973, Large-magnitude Late Tertiary strike-slip faulting north of Lake Mead, Nevada: U.S. Geological Survey Professional Paper 794, 18 p.

Beikman, H.M., Hinkle, M.E., Frieders, Twila, Marcus, S.M., and Edward, J.R., 1983, Mineral surveys by the Geological Survey and the Bureau of Mines of Bureau of Land Management wilderness study areas: U.S. Geological Survey Circular 901, 28 p.

Bernstein, L.R., 1986, Geology and mineralogy of the Apex germanium-gallium mine, Washington County, Utah: U.S. Geological Survey Bulletin 1577, 9 p.

Bissell, H.J., 1962, Pennsylvanian and Permian rocks of the Cordilleran area, *in* Pennsylvanian System in the United States, A symposium: American Association of Petroleum Geologists, p. 188–262.

Bohannon, R.G., 1978, Preliminary geologic map of Las Vegas 1°×2° quadrangle, Nevada, Arizona, and California: U.S. Geological Survey Open-File Report 78-670, scale 1:250,000.

———1979, Strike-slip faults of the Lake Mead region of southern Nevada, *in* Armentrout, J.M., Cole, M.R., and TerBest, Harry, Jr., eds., Cenozoic paleogeography of the western United States: Pacific Coast Paleogeography Symposium 3, Pacific Section, Society of Economic Paleontologists and Mineralogists, Los Angeles, California, p. 129–139.

———1984, Nonmarine sedimentary rocks of Tertiary age in the Lake Mead region, southeastern Nevada and northwestern Arizona: U.S. Geological Survey Professional Paper 1259, 72 p.

Bowyer, Ben, Pampeyan, E.H., and Longwell, C.R., 1958, Geologic map of Clark County, Nevada: U.S. Geological Survey Miscellaneous Field Investigations Map MF-138, scale 1:200,000.

Brenner, E.F., and Glanzman, R.K., 1979, Tertiary sediments in the Lake Mead area, Nevada, *in* Newman, G.W., and Goode, H.D., eds., Basin and Range Symposium and Great Basin Field Conference: Rocky Mountain Association of Geologists, Denver, Colorado, p. 313–323.

Bureau of Land Management, 1988, Draft environmental impact statement, Preliminary wilderness recommendations for Nevada contiguous lands: Department of Interior, Bureau of Land Management, Ely, Las Vegas, and Winnemucca Districts, 291 p.

Causey, J.D., 1988, Mineral resources of the Million Hills study area, Clark County, Nevada: U.S. Bureau of Mines Mineral Land Assessment Open-File Report MLA-34-88, 29 p.

Chao, T.T., and Theobald, P.K., Jr., 1976, The significance of secondary iron and manganese oxides in geochemical exploration: Economic Geology, v. 71, p. 1,560–1,569.

Cordell, L.E., Geller, G.R., and Hildenbrand, T.G., 1982, Complete Bouguer gravity anomaly map of the Rio Grande rift, Colorado, New Mexico, and Texas: U.S. Geological Survey Geophysical Investigations Map GP-949, scale 1:1,000,000.

Couch, B.F., and Carpenter, J.A., 1943, Nevada's metal and mineral production (1859–1940, inclusive): Nevada Bureau of Mines and Geology Bulletin 38, no. 4, 159 p.

Cox, D.P., and Bernstein, L.R., 1986, Descriptive model of Kipushi Cu-Pb-Zn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 227.

Engineering and Mining Journal, 1993, Prices: Engineering and Mining Journal, v. 194, no. 6, p. 92.

Goudarzi, G.H., 1984, Guide to the preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-787, 51 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.

Harris, Anita G., Wardlaw, Bruce R., Rust, Claude C., and Merrill, Glen K., 1980, Maps for assessing thermal maturity (conodont color maturation index maps) in Ordovician through Triassic rocks in Nevada and Utah and adjacent parts of Idaho and California: U.S. Geological Survey Miscellaneous Investigations Series Map I-1249, 2 sheets, scale 1:2,500,000.

Hecla Mining Company, 1990, Hecla Mining Company 1989 Annual Report: Hecla Mining Company, 6500 Mineral Drive, Coeur d'Alene, Idaho, 32 p.

———1993, Hecla Mining Company 1992 Annual Report: Hecla Mining Company, 6500 Mineral Drive, Coeur d'Alene, Idaho, 32 p.

Heikes, V.C., 1913, Nevada, *in* Mineral resources of the United States, calendar year 1912: U.S. Geological Survey, p. 773–818.

———1914, Gold, silver, copper, lead, and zinc in Nevada in 1913, *in* Mineral resources of the United States, calendar year 1913, part I—metals: U.S. Geological Survey, p. 803–844.

———1916, Gold, silver, copper, lead and zinc in Nevada in 1914, *in* Mineral resources of the United States, calendar year 1914, part I-metals: U.S. Geological Survey, p. 655–716.

———1917, Gold, silver, copper, lead, and zinc in Nevada in 1914, *in* Mineral resources of the United States, calendar year 1915, part I-metals: U.S. Geological Survey, p. 613–754.

———1919, Gold, silver, copper, lead, and zinc in Nevada, *in* Mineral resources of the United States, calendar year 1916, part I-metals: U.S. Geological Survey, p. 457–500.

———1921a, Gold, silver, copper, lead, and zinc in Nevada, *in* Mineral resources of the United States, 1917, part I-metals: U.S. Geological Survey, p. 253–298.

———1921b, Gold, silver, copper, lead, and zinc in Nevada, *in* Mineral resources of the United States, 1918, part I-metals: U.S. Geological Survey, p. 217–264.

Hewett, D.F., Callaghan, Eugene, Moore, B.N., Nolan, T.B., Rubey, W.W., and Schaller, W.T., 1936, Mineral resources of the region around Boulder Dam: U.S. Geological Survey Bulletin 871, 197 p.

Hill, J.M., 1916, Notes on some mining districts in eastern Nevada: U.S. Geological Survey Bulletin 648, 214 p.

Intermountain Association of Petroleum Geologists, 1952, Guidebook to the geology of Utah; No. 7, Cedar City, Utah to Las Vegas, Nevada: 165 p., plate 1 scale 1:380,365.

Kirk, W. S., 1985, Cobalt *in* Mineral Facts and Problems, 1985 Edition: U. S. Bureau of Mines Bulletin 675, p.171–183.

Ledbetter, M.T., 1970, A Pennsylvanian-Permian shelf to craton transition, Azure Ridge, Clark County, Nevada: Memphis, Tenn., Memphis State University, M.S. thesis, 96 p.

Lincoln, F.C., 1923, Mining districts and mineral resources of Nevada: Nevada Newsletter Publishing Company, Reno, Nevada, 295 p.

Longwell, C.R., 1921, Geology of the Muddy Mtns., Nevada, with a section on the Grand Wash Cliffs in Western Arizona: American Journal of Science, v. 201, p. 39–62.

———1928, Geology of the Muddy Mountains, Nevada: U.S. Geological Survey Bulletin 798, 152 p.

———1974, Measure and date of movement of Las Vegas Valley shear zone, Clark County, Nevada: Geological Society of America Bulletin, v. 85, p. 985–990.

Longwell, C.R., Pampeyan, E.H., Bowyer, Ben, and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin 62, 218 p., 16 plates.

Luedke, R.G., and Smith, R.L., 1981, Map showing distribution, composition, and age of late Cenozoic volcanic centers in California and Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-1091-C, scale 1:1,000,000, 2 plates.

McHugh, J.B., Bullock J.H., Jr., Briggs, P.H., and Nowlan, G.A., 1989, Analytical results and sample locality map for stream-sediment and panned-concentrate samples from the Million Hills Wilderness Study Area, Clark County, Nevada: U.S. Geological Survey Open-File Report 89-25, 21 p.

McHugh, J.B., and Nowlan, G.A., 1989, Analytical results and sample locality maps for 12 water samples from springs and domestic wells near the El Dorado, Lime Canyon, and Million Hills Wilderness Study Areas, Clark County, Nevada: U.S. Geological Survey Open-File Report 89-301, 10 p.

McKelvey, V.E., 1972, Mineral resource estimates and public policy: American Scientist, v. 60, no. 1, p. 32–40.

McNair, A.H., 1951, Paleozoic stratigraphy of part of northwestern Arizona: American Association of Petroleum Geologists Bulletin, v. 35, no. 3, p. 503–541.

Morgan, J.R., 1968, Structure and stratigraphy of the northern part of the South Virgin Mountains, Clark County, Nevada: M.S. thesis, University of New Mexico, Albuquerque, New Mexico, 103 p.

Moyle, P.R., and Buehler, A.R., 1990, Site-specific investigation of a cobalt/manganese occurrence in the Million Hills [Wilderness] Study Area, Clark County, Nevada: U.S. Bureau of Mines Mineral Land Assessment Open-File Report MLA-3-90, 41 p.

Muffler, L.J.P., 1979, Assessment of geothermal resources of the United States—1978: U.S. Geological Survey Circular 790, prepared in cooperation with the Department of Energy, 163 p., accompanying maps, scale 1:1,000,000, 1:2,500,000, 1:5,000,000.

Naramore, Chester, 1911, Nevada, *in* Mineral resources of the United States, calendar year 1909, part I-metals: U.S. Geological Survey, p. 386–430.

Naramore, Chester, and Yale, C.G., 1909, Nevada, *in* Mineral resources of the United States, calendar year 1908, part I-metallic products: U.S. Geological Survey, p. 462–506.

Petkof, Benjamin, 1985, Gallium, *in* Mineral facts and problems, 1985 edition: U.S. Bureau of Mines Bulletin 675, pp. 291–296.

Plunkert, P.G., 1985, Germanium, *in* Mineral facts and problems, 1985 edition: U.S. Bureau of Mines Bulletin 675, pp. 317–322.

Rose, A.W., Hawkes, H.E., and Webb, J.S., 1979, Geochemistry in mineral exploration, 2nd ed.: London, Academic Press, 657 p.

Sandberg, Charles A., 1983a, Petroleum potential of wilderness lands in Nevada, *in* Miller, B.M., ed., Petroleum potential of wilderness lands in the western United States: U.S. Geological Survey Circular 902-H, 11 p.

———1983b, Petroleum potential of wilderness lands, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-1542, 11 p., 1 sheet, scale 1:1,000,000.

Smith, P.L., and Tingley, J.V., 1983a, A mineral inventory of the Esmeralda-Stateline Resource area, Las Vegas District, Nevada: Nevada Bureau of Mines and Geology Open-File Report 83-11, 176 p.

———1983b, Results of geochemical sampling within Esmeralda-Stateline Resource area, Esmeralda, Clark, and southern Nye Counties, Nevada (portions of Death Valley, Goldfield, Kingman, Las Vegas, Mariposa and Tonopah 2° sheets): Nevada Bureau of Mines and Geology Open-File Report 83-12, 176 p.

U.S. Bureau of Mines, 1993, Mineral Commodity Summaries: U.S. Bureau of Mines, 202 p.

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.

U.S. Geological Survey, 1972, Aeromagnetic map of the Gold Butte–Chloride area, Arizona and Nevada: U.S. Geological Survey Geophysical Investigations Map GP-757, scale 1:62,500.

U.S. Geological Survey, 1983, Aeromagnetic map of part of the Las Vegas 1°×2° quadrangle, Nevada: U.S. Geological Survey Open-File Report 83-729.

Vanderburg, W.O., 1937, Reconnaissance of mining districts in Clark County, Nevada: U.S. Bureau of Mines Information Circular 6964, 81 p.

Volborth, Alex, 1962, Rapakivi-type granites in the Precambrian complex of Gold Butte, Clark County, Nevada: Geological Society of America Bulletin, v. 73, no. 6, p. 813–831.

Wasserburg, G.J., and Lanphere, M.A., 1965, Age determinations in the Precambrian of Arizona and Nevada: Geological Society of America Bulletin, v. 76, no. 7, p. 735–758.

Welsh J. E., 1959, Biostratigraphy of the Pennsylvanian and Permian Systems in southern Nevada: Salt Lake City, Utah, University of Utah, Ph.D. dissertation, 106 p.

Wernicke, Brian, Spencer, J.E., Burchfiel, B.C., and Guth, P.L., 1982, Magnitude of crustal extension in the southern Great Basin: Geology, v. 10, no. 10, p. 499–502.

Yale, C.G., 1906, Nevada, *in* Mineral resources of the United States calendar year 1905: U.S. Geological Survey, p. 259–275.

———1907, Nevada, *in* Mineral resources of the United States, calendar year 1906: U.S. Geological Survey, p. 287–300.

———1908, Nevada, *in* Mineral resources of the United States, calendar year 1907, Part 1—Metallic products: U.S. Geological Survey, p. 337–398.

# APPENDIXES

# DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

## LEVELS OF RESOURCE POTENTIAL

H **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 t least part of the area.

M **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 reasonable likelihood for resource accumulation, an (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

L **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 permissive. This broad category embraces areas with dispersed but insignificantly mineralized rock, as well as areas with little or not indication of having been mineralized.

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

U **UNKNOWN** mineral resource potential is assigned to areas where information is inadequate to assign a low, moderate, or high level of resource potential.

## LEVELS OF CERTAINTY

A Available information is not adequate for determination of the level of mineral resource potential.
B Available information only 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.

LEVEL OF RESOURCE POTENTIAL ⟶

| A | B | C | D |
|---|---|---|---|
| U/A | H/B HIGH POTENTIAL | H/C HIGH POTENTIAL | H/D HIGH POTENTIAL |
| | M/B MODERATE POTENTIAL | M/C MODERATE POTENTIAL | M/D MODERATE POTENTIAL |
| UNKNOWN POTENTIAL | L/B LOW POTENTIAL | L/C LOW POTENTIAL | L/D LOW POTENTIAL |
| | | | N/D NO POTENTIAL |

LEVEL OF CERTAINTY ⟶

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

| | IDENTIFIED RESOURCES | | | UNDISCOVERED RESOURCES | |
|---|---|---|---|---|---|
| | Demonstrated | | Inferred | Probability Range | |
| | 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 McKelvey, V.E., 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 by the U.S. Geological Survey in this report

| EON | ERA | PERIOD | | EPOCH | AGE ESTIMATES OF BOUNDARIES IN MILLION YEARS (MA) |
|---|---|---|---|---|---|
| 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 | |
| | | 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 | [1]~570 |
| 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 Ma also called Precambrian, a time term without specific rank.
[2]Informal time term without specific rank.

# Mineral Resources of Wilderness Study Areas: Southern, Nevada

This volume was published as separate chapters A–E

U.S. GEOLOGICAL SURVEY BULLETIN 1730

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

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[Letters designate the separately published chapters]

(A) Mineral Resources of the La Madre Mountains Wilderness Study Area, Clark County, Nevada, by James E. Conrad, Harlan N. Barton, and David A. Lipton.

(B) Mineral Resources of the Mt. Stirling Wilderness Study Area, Clark and Nye Counties, Nevada, by Raul J. Madrid, Robert Turner, David W. Brickey, H. Richard Blank, and Martin Conyac.

(C) Mineral Resources of the South McCullough Mountains Wilderness Study Area, Clark County, Nevada, by Ed De Witt, J.L. Anderson, H.N. Barton, R.C. Jachens, M.H. Podwysocki, D.W. Brickey, and T.J. Close.

(D) Mineral Resources of the Lime Canyon Wilderness Study Area, Clark County, Nevada, by James G. Evans, Gary A. Nowlan, Joseph S. Duval, and Richard A. Winters.

(E) Mineral Resources of the Million Hills Wilderness Study Area, Clark County, Nevada, by Joel R. Bergquist, Gary A. Nowlan, H. Richard Blank, Jr., and J. Douglas Causey.

* U.S. GOVERNMENT PRINTING OFFICE: 1994-583-048/10003

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U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849