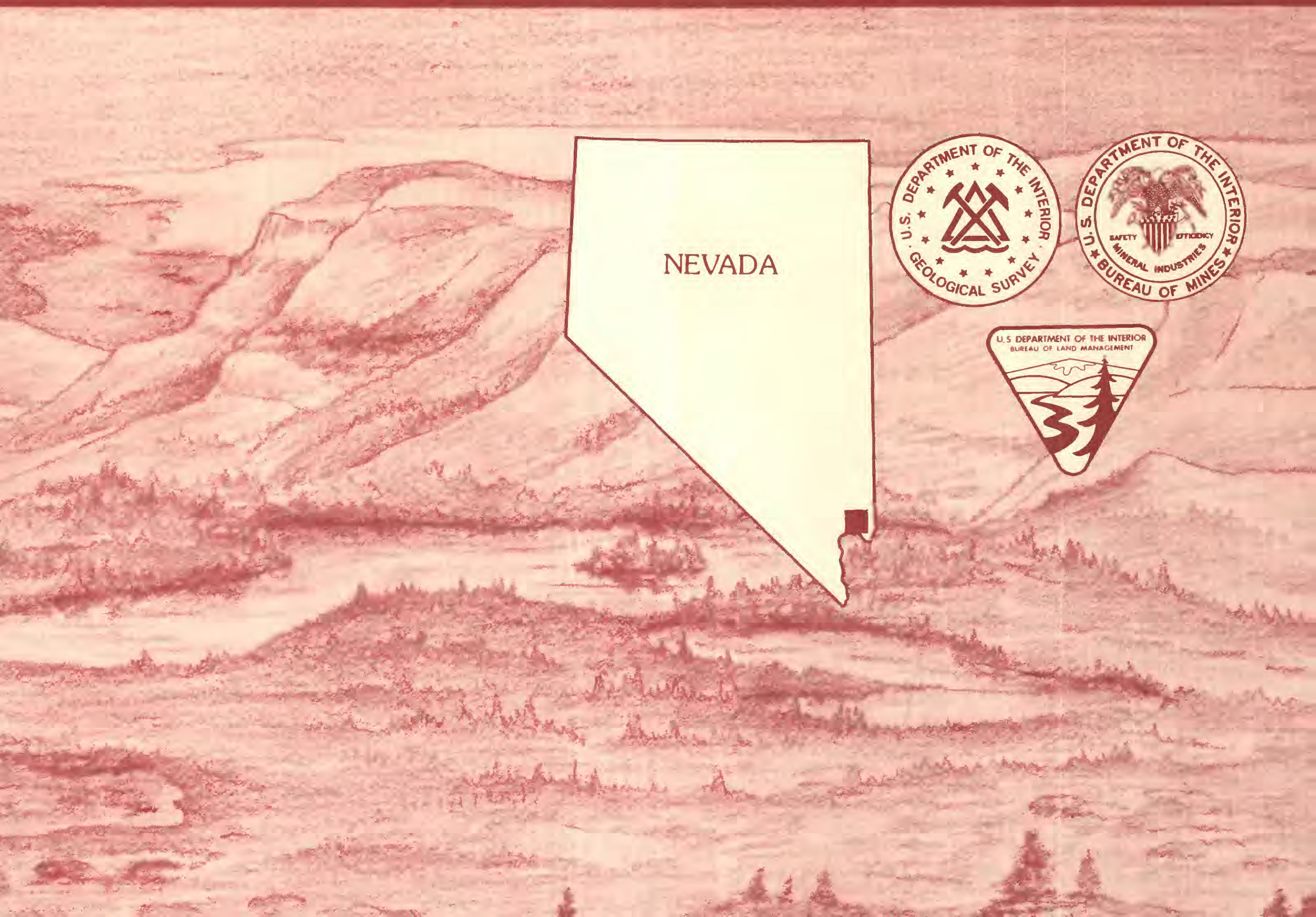
# Mineral Resources of the Lime Canyon Wilderness Study Area, Clark County, Nevada

U.S. GEOLOGICAL SURVEY BULLETIN 1730–D



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Chapter D

# Mineral Resources of the Lime Canyon Wilderness Study Area, Clark County, Nevada

By JAMES G. EVANS, GARY A. NOWLAN, and
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U.S. Geological Survey

RICHARD A. WINTERS
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U.S. GEOLOGICAL SURVEY BULLETIN 1730

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
SOUTHERN NEVADA

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

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



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## STUDIES RELATED TO WILDERNESS

### Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Lime Canyon Wilderness Study Area (NV-050-231), Clark County, Nevada.

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FIGURES

# Mineral Resources of the Lime Canyon Wilderness Study Area, Clark County, Nevada

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## SUMMARY

### Abstract

At the request of the Bureau of Land Management, the Lime Canyon Wilderness Study Area, comprising approximately 34,680 acres, was evaluated for mineral resources and mineral resource potential. Throughout this report, "wilderness study area" and "study area" refer to the 34,680 acres for which a mineral survey was requested. The U.S. Geological Survey and the U.S. Bureau of Mines conducted geologic, geochemical, and geophysical surveys to assess the identified mineral resources (known) and mineral resource potential (undiscovered) of the study area. Fieldwork for this report was carried out in 1987. The study area contains a 44-million-short ton inferred subeconomic resource of gypsum. Carbonate rock underlies 20 square miles of the study area, and sand and gravel covers 16 square miles of the study area. The eastern part of the study area has low potential for barite, copper, gold, lead, silver, and zinc resources. Nearly half of the study area has low potential for oil and gas. There is no potential for geothermal resources.

### Character and Setting

The Lime Canyon Wilderness Study Area is 2 mi east of the Overton Arm of Lake Mead and 45 mi east of Las Vegas, Nev. (fig. 1). The study area's total relief of about 2,600 ft is expressed largely by several closely spaced ridges oriented generally north-south and several canyons, the deepest of which is Lime Canyon. The study area is underlain by Proterozoic granite and gneiss that is partly covered by sedimentary rocks of Paleozoic, Mesozoic, and Tertiary age and by alluvium that is as young as Quaternary (see "Appendixes" for geologic time chart). Numerous faults cut the rocks of the study area.

### Identified Mineral Resources

The wilderness study area contains an estimated 44-million-short ton (st) inferred subeconomic resource of gypsum. Carbonate rock underlies more than 20 $mi^2$ of the study area, and sand and gravel covers 16 $mi^2$ in the western part of the study area. The high-volume, low-unit-value commodities of the study area including gypsum, limestone, dolomite, and sand and gravel are not considered economic because the same commodities are available nearer to existing markets or railways.

### Mineral Resource Potential

Most of the eastern part of the Lime Canyon Wilderness Study Area has low resource potential for barite, copper, gold, lead, silver, and zinc (fig. 2). Nearly half of the study area (underlain by unit TMzPz, fig. 2) has low resource potential for oil and gas. 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.

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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). U.S. Geological Survey studies are designed to provide a 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.

## Area Description

The Lime Canyon Wilderness Study Area (NV-050-231) covers approximately 34,680 acres in the desert highlands northeast of Lake Mead (fig. 1). The terrain of the

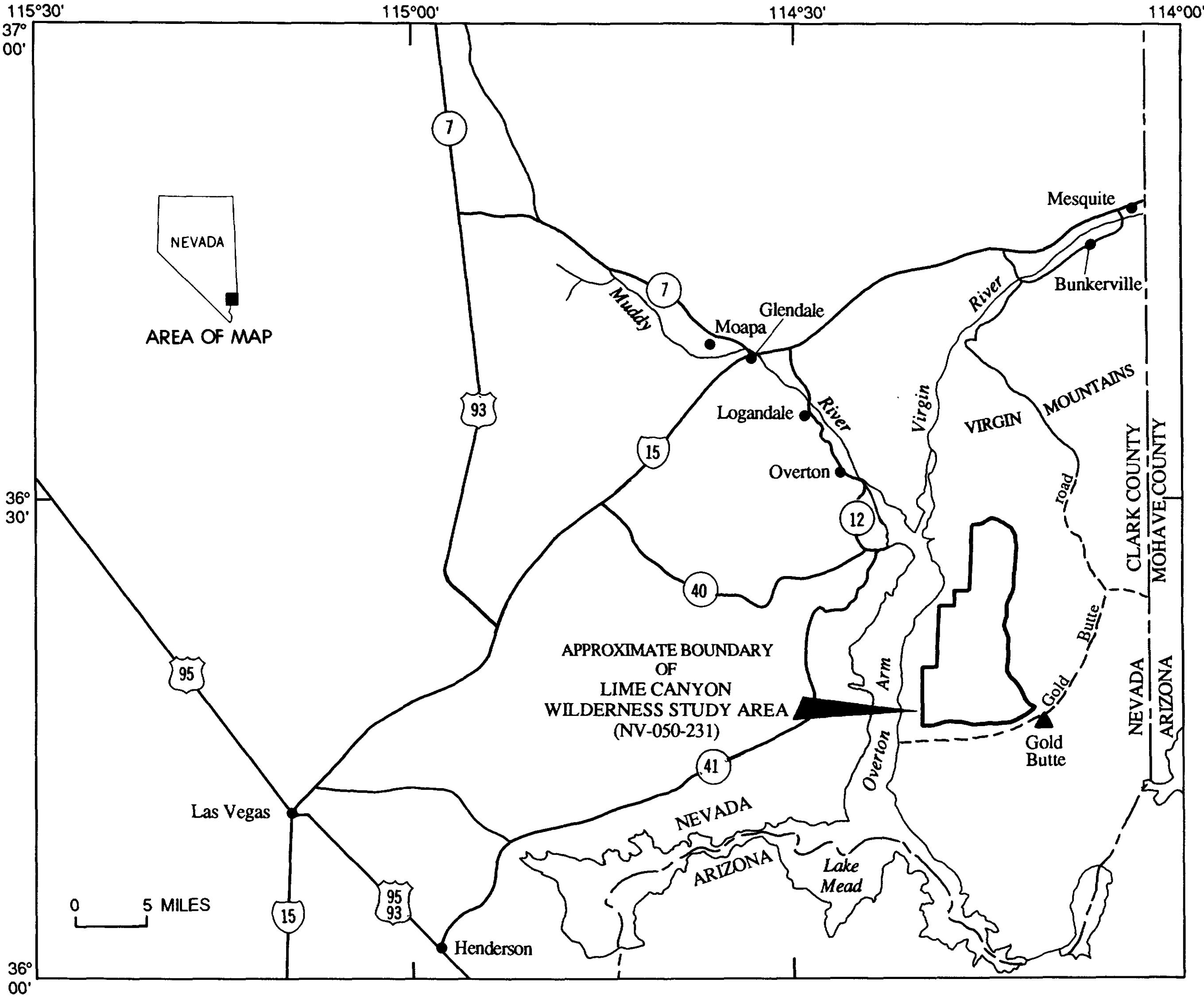



Figure 1. Index map showing location of Lime Canyon Wilderness Study Area, Clark County, Nevada.

study area is rugged; it rises from about 1,800 ft along the west side to sharp ridges above 3,000 ft in the northern part and above 4,000 ft in the southern part. The ridges are cut by a few steep rocky canyons and are separated by broad valleys. The deepest and most spectacular canyon is Lime Canyon, which is 1,200 ft deep at its east end. Although arid, the study area supports a variety of desert plants including native grasses, creosotebush, sagebrush, and joshua trees. The area contains several species of lizards, small mammals, and birds including Gambel's quail. Rattlesnakes and desert tortoises inhabit the study area; the desert tortoise is listed on the "Federal Register of Threatened and Endangered Species" in the "threatened" category. The study area lies within the Gold Butte Herd Area for wild horses and burros. Other mammals include deer, bobcats, kit foxes, cottontails, and jack rabbits. The U.S. Bureau of Land Management plans to reintroduce bighorn sheep in this region. Part of the study area is used for grazing cattle.

The study area is accessible from the partly improved Gold Butte road from Mesquite on Interstate Highway 15. This road connects with jeep trails that provide access to the east side and parts of the west side of the study area.

## Previous and Present Investigations

Early interpretations of the geology of the study area were made by Longwell (1928), Intermountain Association of Petroleum Geologists (1952), Bowyer and others (1958), and Longwell and others (1965). The geologic maps covering the study area presented in these reports range in scale from 1:200,000 to 1:380,365. Morgan (1968) mapped the geology of most of the study area at a scale of 1:31,680. Volborth (1962) studied the Precambrian rocks south of the study area. These rocks were dated by Wasserberg and Lanphere (1965). The nonmarine Tertiary rocks were studied by Anderson and others (1972), Brenner and Glanzman (1979), and Bohannan (1984). The tectonics of the Lake Mead region, including the study area, were studied by Anderson (1973), Bohannan (1979), and Wernicke and others (1988).

The U.S. Geological Survey carried out field investigations in the study area during 1987. This work included geologic reconnaissance and geochemical sampling. Samples of the Proterozoic rocks were collected for petrographic analysis. Geochemical data were obtained from 60 stream-sediment, 119 panned-concentrate (McHugh and others, 1989), and 40 rock samples (J.G. Evans, unpub. data, 1988).

The U.S. Bureau of Mines conducted field investigations in 1987 that included searches for mines, prospects, claims, and mineralized geologic structures (Winters, 1988).

# APPRAISAL OF IDENTIFIED RESOURCES

*By* Richard A. Winters
*U.S. Bureau of Mines*

## Methods

Investigations by the U.S. Bureau of Mines included a search of U.S. Bureau of Mines records at the U.S. Bureau of Mines Library, Spokane, Wash., and examination of Clark County and U.S. Bureau of Land Management mining, lease, and claim records. Mineral production records of the U.S. Bureau of Mines and the State of Nevada were also examined. Aerial photographs were used in searching for mine workings and their accesses, and in determining the extent of the gypsum beds. Field studies in 1987 consisted of locating and sampling any mines, prospects, claims, and mineralized structures. Gamma-ray scintillometer readings were taken throughout the study area.

Eighty rock and 59 stream-sediment samples were collected. All samples were checked for radioactivity and fluorescence. Forty-nine rock samples were analyzed for gold by fire assay and atomic-absorption spectrophotometry and for 25 elements by inductively coupled plasma-atomic emission spectroscopy. Of the remaining 31 rock samples, 12 gypsum and 4 limestone samples were analyzed for major-element oxides by inductively coupled plasma-atomic emission spectroscopy, 12 were analyzed for uranium by neutron-activation analysis, 2 were analyzed for zeolites by X-ray diffraction, and 1 was analyzed for clay by X-ray diffraction, and 1 was analyzed for alabaster by petrographic evaluation.

Several sampling methods were used. They are (1) chip, a continuous series of rock chips taken across the measured thickness of a vein, structure, or bed; (2) random chip, rock chips taken at random intervals over a given area of apparently homogeneous exposure; (3) grab, an assortment of rock fragments; and (4) select, hand-picked chips of most altered or mineralized rock available. The stream-sediment samples, each consisting of two level 14-in. panfuls, were concentrated on a laboratory-sized Wilfley table and inspected for microscopic gold and other valuable minerals.

## Mining History

The wilderness study area is near the Gold Butte mining district, most of which is outside the southern boundary of the study area. Much of the district's mining history as presented here, is taken from Longwell and others (1965). Mining activity began in 1873 with Daniel Bonelli's discovery of mica deposits a short distance east of Gold Butte. Prior to 1900, Bonelli made several shipments of sheet mica totaling an estimated 5 short tons (st). In 1908, Frank Allsop shipped 2,500 lb of sheet mica from the same area. Later, ultramafic rocks in the vicinity were mined for vermiculite.

Metal mining began in 1905 when gold was discovered in veins in the metamorphic and granitic rocks south of Gold Butte by Frank Burgess (Vanderburg, 1936). In 1907, replacement bodies of silver-bearing copper and zinc ore were found in Paleozoic limestone north of Gold Butte (east of the wilderness study area) by Bonelli, Burgess, Syphus, and Gentry. This discovery resulted in enough mining activity in 1908 that the camp of Gold Butte was established. Small amounts of copper and zinc ore were reportedly shipped from this area between 1912 and 1918.

Since 1918, gold-bearing quartz veins in the granitic rocks have been the most valuable metallic ores in the district—see Longwell and others (1965, p. 128) and Couch and Carpenter (1943) for metal production figures. The data of Longwell and others span the years 1905-62. Total production was 2,857 troy oz of gold (less than $100,000 at $35 per oz) during this period. One gold claim is presently being worked by the Bounsall family.

There are several workings in the wilderness study area: three shafts, one adit, and other minor workings in carbonate rock and redbeds; seven patented gypsum claims; numerous uranium exploration trenches in Tertiary sediments; and current gold claims with minor workings in alluvium near Gold Butte. The gold claims may correspond with the operations referred to by Vanderburg (1936, p. 63) and Longwell and others (1965, p. 127). Two unpatented mineral surveys, at which there are no workings, are located in the study area.

As much as 56 percent of the wilderness study area has been under lease or lease application for oil and gas. As of March 1987, 37 percent of the study area was still under lease application. No drilling has been done in the study area, but drilling has been done east of the study area.

## Mineral Resources

Seven patented claims cover 861 acres of gypsum beds. The beds strike north, dip 35° to 45° E., are 75 to 100 ft thick, occur in the upper Toroweap Formation, and are less resistant to weathering than the underlying limestone of the Toroweap Formation and the overlying Kaibab Limestone. The gypsum claims were located in 1924, recorded in 1928, and patented in 1933 by the McDonald Mines Co. All claims are not accurately located. Claim papers are on site. Two unpatented claims in the southern part of the study area overlap the southern part of one of the patented claims. Ten of the eleven rock samples taken from the patented claims contain 85 to 99 percent gypsum. The other sample contains 59 percent gypsum. Most samples have the gypsum content required for mine production (85 to 95 percent gypsum for most gypsum mines; Appleyard, 1983). Material containing less than 70 weight percent gypsum does not meet the standards for mining and industrial use (American Society for Testing and Materials, 1986). Alabaster, a very fine grained rock gypsum, valued by sculptors for its suitability for carving, and occasionally found in commercial deposits, crops out in the study area. A 75-lb block of white alabaster from the resource area with pink banding was judged to have good sculpting qualities by a stone cutter. A sample of alabaster, studied petrographically, contains 96 percent gypsum, 3 percent calcium carbonate, and 1 percent quartz. An estimated 44 million st subeconomic indicated resource of gypsum is present in the study area. This volume was obtained using the combined measured strike length of 29,460 ft, 75-ft thickness from Morgan (1968, p. 23), an arbitrary downdip distance of 300 ft, and a tonnage factor of 13.9 $ft^3$ (cubic feet) per st. Parts of one gypsum zone are interlayered with carbonate rock. The volume for this 5,000-ft segment was calculated using an estimated 40-ft thickness of gypsum. Gypsum interbedded with carbonate crops out near one of the unpatented mineral surveys but is considered to be subeconomic because of its location and small volume—it lies on a ridge top, has a horizontal extent of no more than 260 ft, and is less than 100 ft thick. At the present time, the gypsum in the study area cannot compete commercially with the hundreds of years of reserves of gypsum in the Las Vegas area, which are close to markets and transportation.

More than 20 $mi^2$, or about 40 percent of the wilderness study area, is underlain by 12 formations that contain limestone or dolomite (Morgan, 1968). The detailed sampling and in-depth study necessary to determine purity and volume of carbonate in the study area are beyond the scope of this investigation. Extensive mining of limestone in Clark County is primarily from the Crystal Pass Member of the Sultan Limestone. The limestone is currently being mined and abundant reserves of limestone are near markets and railroads. The abundance and availability of limestone closer to existing markets provide no incentive for further study of the limestone in the study area. Three samples of carbonate rock taken from the Horse Spring Formation (part of unit TMzPz, fig. 2) consist of high-calcium limestone suitable for cement (Harben and Bates, 1984, p. 159). However, these samples are not representative of limestone units throughout the study area.

About 16 $mi^2$ of the western part of the wilderness study area is covered by late Tertiary alluvial fans that contain millions of cubic yards of sand and gravel. Although the growth of Las Vegas and the needs of the nearby military installations and the State of Nevada Department of Transportation have accelerated the demand for sand and gravel, these materials are abundant near sites of use and transportation. Therefore, the large sand and gravel deposits in the study area are likely to be subeconomic into the foreseeable future.

The zeolite mineral clinoptilolite is contained in a 3.5-ft-thick bed in the Tertiary Horse Spring Formation but does not constitute a minable occurrence because of its small size.

Permian redbeds (sandstone or sandy shale) that may be suitable for flagstone and molding sand occur in the study area but are not economic because they are not near markets or transportation.

Gold was detected in 8 of 10 tuffaceous and granitic rocks with thin quartz veins from the southeastern part of the study area. Seven of them contain gold at values from 0.00032 to 0.012 troy oz per short ton (oz/st) (10 to 1,200 parts per billion, ppb). One grab sample of quartz from alluvium contains 0.201 oz/st (6.3 parts per million, ppm) gold. Production of gold from the Gold Butte district came from quartz veins in granite south of the study area. Gold occurrences are indicated by the data obtained in this study; the gold concentrations in the samples are low and no continuous mineralized zones or structures were found.

Forty stream-sediment samples were collected from drainages throughout the study area. Twelve contain detectable amounts of gold. Eleven samples have gold concentrations ranging from 0.0000097 to 0.00017 troy ounces per cubic yard (oz/yd$^3$) ($0.01 to $0.08/yd$^3$ based on a gold price of $450/oz). The highest value was 0.00083 oz/yd$^3$ ($0.37/yd$^3$). The source of some of this gold is the Paleozoic and Mesozoic sedimentary rocks of the study area. Eighteen alluvial samples were collected from the southeastern corner of the study area near Gold Butte. None of these samples contains detectable amounts of gold. Inasmuch as Vanderburg (1936, p. 64) reports gravel in the Gold Butte area containing as much as 0.071 oz/yd$^3$ ($32.14/yd$^3$ based on a gold price of $450/oz), the possibility exists that the alluvium samples were taken on ground from which the gold had already been extracted by mining. This conclusion is consistent with the severe ground disturbance observed during this study. The value of the highest gold concentrations in stream-sediment samples ($0.37/yd$^3$) is much less than the unit production cost of the lowest cost domestic placer gold mine known to have operated in recent times (to 1984) or $3.95/yd$^3$ at a production rate of 170,000 yd$^3$ per year (Schumacher, 1985). Therefore, there are no identified placer gold resources in the study area.

Copper and silver were detected in five rock samples from five sites in the east-central part of the study area (Winters, 1988). A sample from a dump adjacent to a shaft contains 0.24 percent copper and 3 ppm silver in gypsiferous sandstone and poorly cemented conglomerate. A sample of silty sandstone collected at a dump adjacent to a shaft about 300 ft from the first shaft contains 1.8 percent copper and 7.5 ppm silver. Three brecciated limestone samples from a mineralized shear zone in an adit about 1,000 ft from the two shafts contain 0.17 to 1.48 percent copper and 1 to 2 ppm silver. Two brecciated limestone samples from the southwestern part of the study area contain high values of copper, lead, silver, and zinc (Winters, 1988; copper, as much as 151 ppm; lead, as much as 950 ppm; silver, as much as 1 ppm; and zinc, as much as 1,575 ppm). On the basis of these data, there are no identified resources.

Although the Horse Spring Formation (part of unit TMzPz, fig. 2) is a favorable host for uranium accumulation in the region, airborne gamma-ray spectrometer data do not suggest uranium anomalies in the Horse Spring Formation of the study area (Aero Service Division, 1979). Garside (1973, p. 21) described one of the uranium prospects in the southeastern part of the study area as calcareous green and white clays, tuffaceous sediments, and red sandstone that contain the uranium-bearing mineral tyuyamunite(?). Another claim is in tuffaceous rock that contains very small values of gold (10 to 20 ppb). Uranium content in 25 rock samples from the southeastern part of the study area ranges from 1 to 30 ppm. Only four samples contain more than 16 ppm uranium. These concentrations are not much greater than the 2 ppm crustal abundance for uranium and are much less than the approximately 800 ppm uranium needed to make mining economically feasible (Finch and others, 1973). Scintillometer readings near the uranium claims were generally only slightly higher than a background of 30 counts per second (cps) (maximum 115 cps). No uranium resources are indicated by these data in the study area.

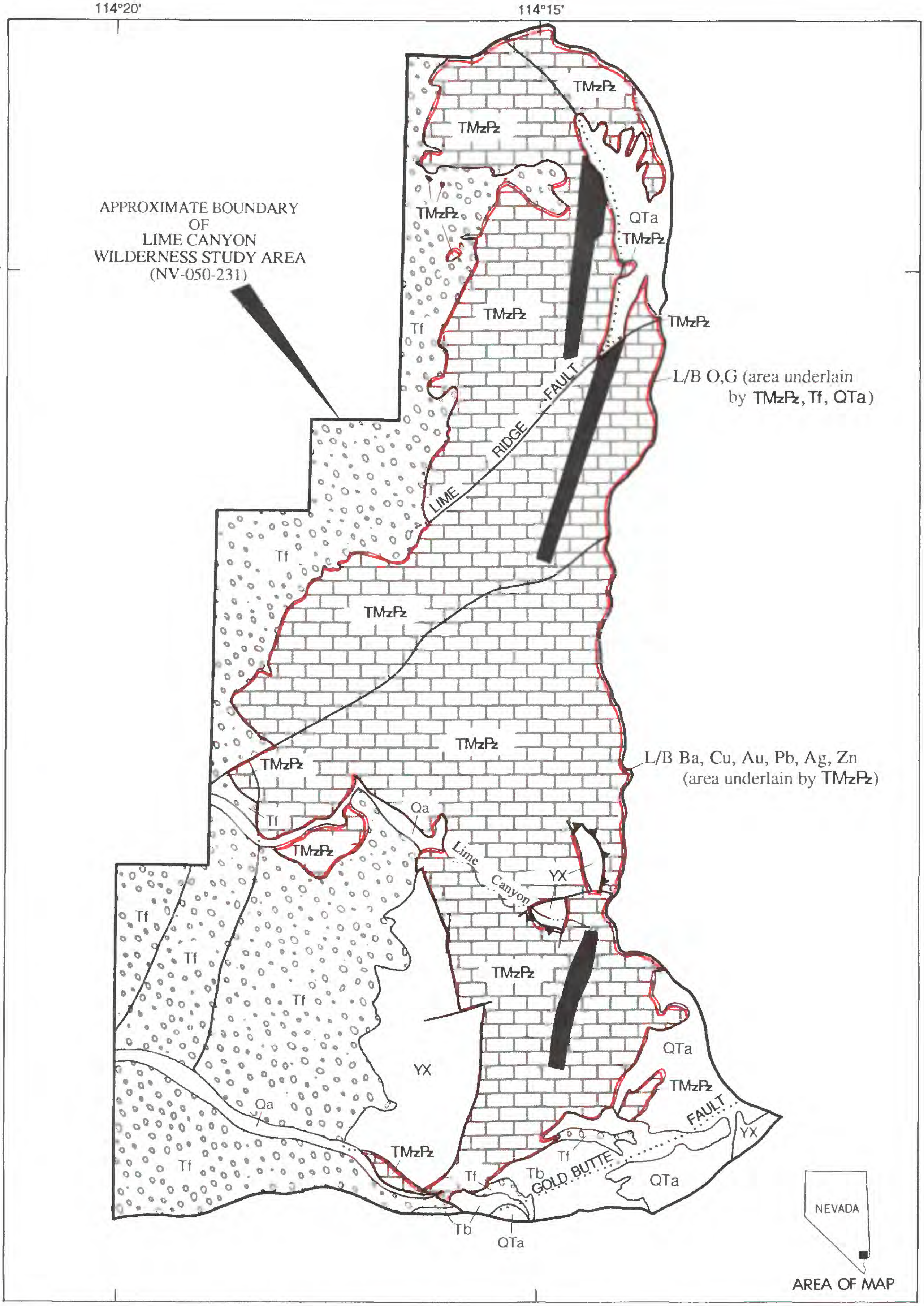
## ASSESSMENT OF MINERAL RESOURCE POTENTIAL

*By* James G. Evans, Gary A. Nowlan, *and* Joseph S. Duval
*U.S. Geological Survey*

### Geology

The Lime Canyon Wilderness Study Area is underlain by Proterozoic gneiss and granitic rocks and Paleozoic, Mesozoic, and Tertiary sedimentary rocks, Tertiary basalt and fanglomerate, and late Cenozoic alluvium. The geology shown in figure 2 is simplified from Morgan (1968) and from mapping of the northern part of the study area by J.G. Evans.

The oldest rock unit in the study area contains medium- to coarse-grained granitic rocks and medium-grained gneiss, schist, and quartzite. The granitic rocks are commonly porphyritic with feldspar phenocrysts as much as 2 in. long. Some of these rocks resemble the rapakivi-type granite in the Gold Butte area described by Volborth (1962). The granitic rocks are hypidiomorphic granular and consist mostly of potassium feldspar (40 to 60 percent orthoclase, perthite, and microcline), plagioclase (15 to 35 percent), and quartz (10 to 35 percent) and have composi-



114°20'
114°15'
36° 25'
36° 15'
APPROXIMATE BOUNDARY
OF
LIME CANYON
WILDERNESS STUDY AREA
(NV-050-231)
TMzPz
QTa
Tf
LIME RIDGE FAULT
L/B O,G (area underlain by TMzPz, Tf, QTa)
L/B Ba, Cu, Au, Pb, Ag, Zn (area underlain by TMzPz)
Qa
Lime Canyon
YX
GOLD BUTTE FAULT
Tb
NEVADA
AREA OF MAP

tions ranging from granite to quartz monzonite. They contain as much as 6 percent biotite and 5 percent amphibole, and they also contain minor amounts of magnetite and sphene. The metamorphic rocks consist mostly of plagioclase (10 to 65 percent), potassium feldspar (0 to 50 percent), and quartz (5 to 30 percent for rocks other than quartzite). The gneiss and schist also contain as much as 20 percent pyroxene, as much as 10 percent biotite, as much as 28 percent amphibole, and as much as 2 percent opaque minerals; they also contain minor amounts of sphene and zircon. The feldspars in the granitoids, gneiss, and schist are moderately altered to sericite, contain some muscovite, and are slightly saussuritized. The biotite is slightly altered to chlorite, mafic minerals are slightly to very altered to hematite, and some rocks show minor carbonate replacement. Wasserburg and Lanphere (1965) reported rubidium-strontium ages for the metamorphic rocks near Gold Butte, just south of the study area, at 1,700 million years before present (Ma) (Early Proterozoic). They also dated the granitic rocks near Gold Butte at 1,060 Ma (Middle Proterozoic). The age of the granitic and metamorphic rocks is considered to be Early and Middle Proterozoic.

The Paleozoic, Mesozoic, and Miocene sedimentary rocks that overlie the Proterozoic rocks are combined into one unit in this report. The stratigraphic nomenclature is from Morgan (1968). This unit includes the following Paleozoic formations that have a total stratigraphic thickness of 6,800 ft: Prospect Mountain Quartzite, Pioche Shale, Lyndon Limestone, Chisholm Shale, Peasley Limestone, and an unnamed dolomite, all of Cambrian age; unnamed dolomite and sandstone of Cambrian or Ordovician age; the Devonian Muddy Peak Limestone; the Mississippian Monte Cristo Limestone; the Pennsylvanian Callville Limestone; and the Pakoon Limestone, Queantoweap Sandstone, Hermit Formation (sandstone), Coconino Sandstone, Toroweap Formation (gypsum, sandstone, limestone), and Kaibab Limestone, all of Permian age. The unit also includes the following Mesozoic formations that have a combined stratigraphic thickness of 3,700 ft: the Moenkopi Formation (gypsum, gypsiferous shale, limestone) and Chinle Formation (sandstone) of Triassic age, and the Aztec Sandstone of Triassic(?) to Jurassic age. The unit includes the following Miocene formations that may have a combined stratigraphic thickness of more than 2,500 ft: an unnamed fanglomerate, the Horse Spring Formation (limestone, andesite, tuff, sandstone, magnesite, shale, gypsum), and the Muddy Creek Formation (gypsiferous sandstone and siltstone).

Unconsolidated fanglomerate that crops out along the west side of the study area is interbedded with basalt along the southeast boundary near Gold Butte. The rocks are younger than the Muddy Creek Formation and may be Pliocene in age.

Older alluvium, probably ranging in age from Pliocene to Holocene is present in the northeastern and southeastern parts of the study area. Holocene alluvium occupies the bottoms of two canyons in the southern part of the study area.

The study area is cut by numerous faults, only a few of which, possibly the most significant ones, are shown in figure 2. The Lime Ridge and Gold Butte faults are part

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**EXPLANATION**

Area of low mineral resource potential (L)

Levels of certainty of assessment
- B — Data only suggest level of potential

Commodities
- Ag — Silver
- Au — Gold
- Ba — Barium
- Cu — Copper
- Pb — Lead
- Zn — Zinc
- O,G — Oil and gas

Identified resources
- Indicated resources of gypsum—See text for discussion
- Inferred resources of carbonate rock (area underlain by TMzPz)—See text for discussion
- Inferred resources of sand and gravel (area underlain by Tf)—See text for discussion

Geologic map units
- Qa — Alluvium (Quaternary)
- QTa — Older alluvium (Quaternary and Pliocene)
- Tf — Fanglomerate (Pliocene)
- Tb — Basalt (Pliocene)
- TMzPz — Sedimentary rocks (Miocene, Mesozoic, and Paleozoic)
- YX — Granitoid and gneiss (Middle and Early Proterozoic)

Contact

Fault—Dotted where concealed

Thrust fault—Sawteeth on upper plate

◄ **Figure 2.** Mineral resource potential and generalized geology of Lime Canyon Wilderness Study Area, Clark County, Nevada.

of the Lake Mead fault system (Bohannan, 1979, 1984); both show about 6 mi of left-lateral separation that occurred between 17 and 13 Ma. Cross sections by Morgan (1968) of the Virgin Mountains (fig. 1) show a low-angle normal fault beneath much of the study area. Part of this fault is exposed at the east end of Lime Canyon. This fault affected the unnamed fanglomerate and Horse Spring Formation and, therefore, must have been active during the Miocene after about 12 Ma. Block faulting from 12 to 6 Ma tilted strata (Bohannan, 1984). As much as 40 mi of left-lateral slip may have taken place on the Lake Mead fault system (Anderson, 1973; Bohannan, 1979). The study area is near the eastern end of a zone of late Tertiary to Holocene crustal deformation that extends from the southern Sierra Nevada to the Colorado Plateau. This zone has undergone as much as 150 mi west-northwest extension (Wernicke and others, 1988).

## Geochemical Studies

A reconnaissance geochemical survey was conducted in the Lime Canyon Wilderness Study Area. Minus-80-mesh stream sediments, panned concentrates derived from stream sediments, and rocks were collected during this study. Samples of stream sediment and panned concentrates were collected at 60 sites. Forty altered rock samples were collected, mostly from the Proterozoic rocks in the southern part of the study area, to determine the suite of elements associated with any mineralization that may have occurred in the area. Twelve unaltered samples of Proterozoic rock were taken for petrographic analysis.

Stream-sediment samples were collected from alluvium in active stream channels. Stream sediments represent a composite of the rock and soil exposed upstream from the sample site. The panned-concentrate samples represent a concentration of minerals that may be ore forming or ore related and permit determination of some elements that are not easily detected in bulk stream sediments. Two panned-concentrate samples were collected at each site. One sample was further concentrated by a series of steps using bromoform and magnetic separations to produce a "nonmagnetic heavy-mineral-concentrate sample." The other sample was analyzed for gold without further treatment and is termed a "raw panned-concentrate sample."

The stream sediments were analyzed for 35 elements, and the rock samples were analyzed for 31 elements using a semiquantitative direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). Nonmagnetic heavy-mineral concentrates were analyzed for 37 elements by the same method. In addition, samples were analyzed for certain elements by more sensitive methods. Stream-sediment samples were also analyzed for gold by graphite furnace atomic absorption (Meier, 1980; O'Leary and Meier, 1986), for uranium by ultraviolet fluorimetry (Centanni and others, 1956; O'Leary and Meier, 1986), and for antimony, arsenic, bismuth, cadmium, and zinc by inductively coupled plasma-atomic emission spectroscopy (Crock and others, 1987). The raw panned-concentrate sample was analyzed for gold by flame atomic absorption (Thompson and others, 1968; O'Leary and Meier, 1986). Rock samples were also analyzed for gold, mercury, and uranium by methods mentioned above (gold, Thompson and others, 1968; O'Leary and Meier, 1986; mercury, Crock and others 1987; uranium, Centanni and others, 1956; O'Leary and Meier, 1986). These analyses were used to identify drainages containing anomalous concentrations of elements indicative of mineralization. Anomalous concentrations in the stream-sediment, panned-concentrate, and rock samples were determined for each element by statistical examination of the data, by comparison of the data from the study area with data from nearby wilderness study areas (El Dorado, Ireteba Peaks, and Million Hills, McHugh and others, 1989 a, b), and by comparison to element concentrations in rocks listed by Rose and others (1979).

The study area contains anomalous concentrations of several elements, of which arsenic, barium, copper, gold, lead, molybdenum, silver, thorium, tin, tungsten, and zinc possibly resulted from mineralization. Areas underlain by rocks containing anomalous concentrations of some of these elements are shown in figure 2.

Samples collected in most drainages underlain by Paleozoic, Mesozoic, and Miocene sedimentary rocks are rich in barium; the values detected in heavy-mineral-concentrate samples are greater than 10,000 ppm and suggest the possibility that bedded barite deposits crop out in the study area (fig. 2).

Samples from three small areas adjacent to the areas having samples anomalous in barium also contain anomalous amounts of gold (0.33 to 0.65 ppm in raw panned-concentrate samples). These areas are near sites at which the U.S. Bureau of Mines took stream-sediment samples that contain minute amounts of gold. Rock samples containing barium and gold collected on the east side of the study area also contain small amounts of copper, lead, silver, and zinc. The gold in this area may be related to the mineralization event during which these metals were concentrated. The two areas from which samples containing barium and gold were collected on the north and west sides of the study area are in largely unaltered sedimentary rock. This gold may be syngenetic or could have been deposited in or near faults by hydrothermal solutions.

Silver (0.5 to 1.5 ppm) occurs in samples of altered Proterozoic rocks and silicified carbonate rocks in the south-central part of the study area, where it is associated with lead (100 to 1,000 ppm) and zinc (200 to 1,500 ppm). A raw panned-concentrate sample from a small drainage at the south end of the study area contains an anomalous value of gold (0.1 ppm). The drainage contains the rock types that nearby have anomalous concentrations of silver, although silver was not detected in samples collected from that drainage.

Very small amounts of gold (0.02 to 0.04 ppm) were detected in panned concentrates from sediments in canyons that cut through the Proterozoic and carbonate rocks and Tertiary fanglomerate in the southwestern part of the study area.

High concentrations of lead (as much as 2,000 ppm) are found in heavy-mineral-concentrate samples from drainages in a band across the central part of the study area. Some of these samples also have high concentrations of barium (greater than 10,000 ppm) and zinc (as much as 3,000 ppm), and some have no anomalous concentrations of lead, barium, zinc, or any other elements.

Fairly high values of tungsten (100 to 300 ppm) and barium are contained in heavy-mineral-concentrate samples from the east edge of the study area. Examination of nonmagnetic heavy-mineral-concentrate samples from the southeastern part of the study area under ultraviolet light shows the tungsten-bearing minerals scheelite and powellite (molybdenum-bearing scheelite) in approximately equal quantities. Scheelite and powellite occur in granitic dikes that cut Proterozoic rocks 13 mi southeast of the study area (Longwell and others, 1965). These minerals may have been deposited by hydrothermal fluids moving upward along faults from sources deep in Proterozoic rock.

Thorium occurs in fairly high concentrations (700 to 5,000 ppm) in heavy-mineral-concentrate samples from the southeastern corner of the study area. The thorium-bearing minerals may have come from Proterozoic rocks in the study area and/or from reworked alluvium derived from Proterozoic rocks south of the study area.

## Geophysical Studies

Aerial gamma-ray spectroscopy is a technique that provides estimates of the near-surface (to a maximum depth of about 20 in.) concentrations of percent potassium (K), ppm equivalent uranium (eU), and ppm equivalent thorium (eTh). Because the uranium and thorium measurements include radioactive daughter nuclei that are chemically distinct from the parent nuclei, the uranium and thorium data are described as equivalent concentrations. These data (K, eU, eTh) provide a partial geochemical representation of the near-surface materials. For a typical aerial survey, each measurement reflects average concentrations for a surface area of about 645,000 square feet to an average depth of about 12 in.

From 1975 to 1983, the U.S. Department of Energy contracted for aerial gamma-ray surveys that covered almost all the conterminous United States and much of Alaska. The flightline spacings of these surveys vary from 1 mi (rare) to 10 mi and are, in general, only suitable for producing regional-scale maps.

As part of a state mapping project, the data for Nevada and New Mexico were compiled and processed to produce a series of 1:1,000,000-scale maps. These maps include composite-color maps by Duval (1983). These maps were examined to estimate the K, eU, and eTh concentrations for each of several wilderness study areas, including the Lime Canyon Wilderness Study Area, and the occurrence or absence of anomalous radioelement concentrations were noted. The definition of an anomaly requires that the element concentration as well as its ratios to the other two elements all be high values in the context of the map.

The Lime Canyon Wilderness Study Area has overall low radioactivity with values of 0-1.2 percent K, 1-2 ppm eU, and 0-6 ppm eTh. No radioactivity anomalies exist within the boundaries of the study area or in the immediate vicinity. The uranium composite-color map suggests slight enrichment of uranium relative to potassium and thorium, but such enrichment is characteristic of the carbonate rocks in the southern part of Nevada, and the absolute concentrations of uranium are low.

## Mineral and Energy Resource Potential

Geological and geochemical data indicate that the part of the study area underlain by Paleozoic, Mesozoic, and Tertiary rocks has low resource potential for barium, copper, gold, lead, silver, and zinc with a B certainty level (fig. 2). Anomalous concentrations of these six elements occur in rock, stream-sediment, and panned-concentrate samples. These elements, along with molybdenum, tin, and tungsten, may indicate local hydrothermal alteration. The close association of most high barium concentrations in panned-concentrate samples with apparently unaltered sedimentary rocks suggests that bedded barite deposits may be present. The presence of anomalous concentrations of copper, lead, silver, and zinc in the three sample types and the occurrences of these elements studied by the U.S. Bureau of Mines suggest that carbonate replacement deposits similar to the ones along Tramp Ridge, 2 mi east of the study area (Longwell and others, 1965), may be present. The low level of potential is suggested by the lack of deposits found in the well-exposed rocks of the study area that have been mapped in detail (Morgan, 1968). The certainty level B is assigned because the data only suggest the level of resource potential.

Thorium occurs in fairly high concentrations in heavy-mineral-concentrate samples from the southeastern part of the study area. The thorium is probably from Proterozoic rocks in and/or south of the study area and these concentrations do not suggest that resources of thorium are present in the study area.

The oil and gas potential of the study area is low based on nearby oil and gas shows and recent exploratory drilling just north of the study area (Sandberg, 1983). Since 1983 much of the study area has come under lease or application for oil and gas and drilling has been done 2 mi east of the study area. The resource potential for oil and gas is low, certainty level B, for the part of the study area underlain by Paleozoic, Mesozoic, and Miocene sedimentary rocks. Some of the fanglomerate and older alluvium in the study area is underlain by these sedimentary rocks and, therefore, has been included in the part of the study area that has low potential for oil and gas.

No geothermal resources were found in or adjacent to the study area (Muffler, 1979). Although the study area contains Tertiary basalt at its south end and is in a region that probably underwent greater than normal heat flow during the Miocene to early Pliocene, the entire region has most likely cooled to near ambient temperatures since the early Pliocene. Therefore, no potential exists for geothermal resources, certainty level D.

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# 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 at 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, and (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 no 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 UNKNOWN POTENTIAL | H/B HIGH POTENTIAL | H/C HIGH POTENTIAL | H/D HIGH POTENTIAL |
| | M/B MODERATE POTENTIAL | M/C MODERATE POTENTIAL | M/D MODERATE 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.
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## 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<br>Early | 96<br>138 |
| | | Jurassic | | Late<br>Middle<br>Early | 205 |
| | | Triassic | | Late<br>Middle<br>Early | ~240 |
| | Paleozoic | Permian | | Late<br>Early | 290 |
| | | Carboniferous Periods | Pennsylvanian | Late<br>Middle<br>Early | ~330 |
| | | | Mississippian | Late<br>Early | 360 |
| | | Devonian | | Late<br>Middle<br>Early | 410 |
| | | Silurian | | Late<br>Middle<br>Early | 435 |
| | | Ordovician | | Late<br>Middle<br>Early | 500 |
| | | Cambrian | | Late<br>Middle<br>Early | [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.

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U. S. DEPARTMENT OF THE INTERIOR
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