Mineral Resources of the Mount Wilson Wilderness Study Area, Mohave County, Arizona

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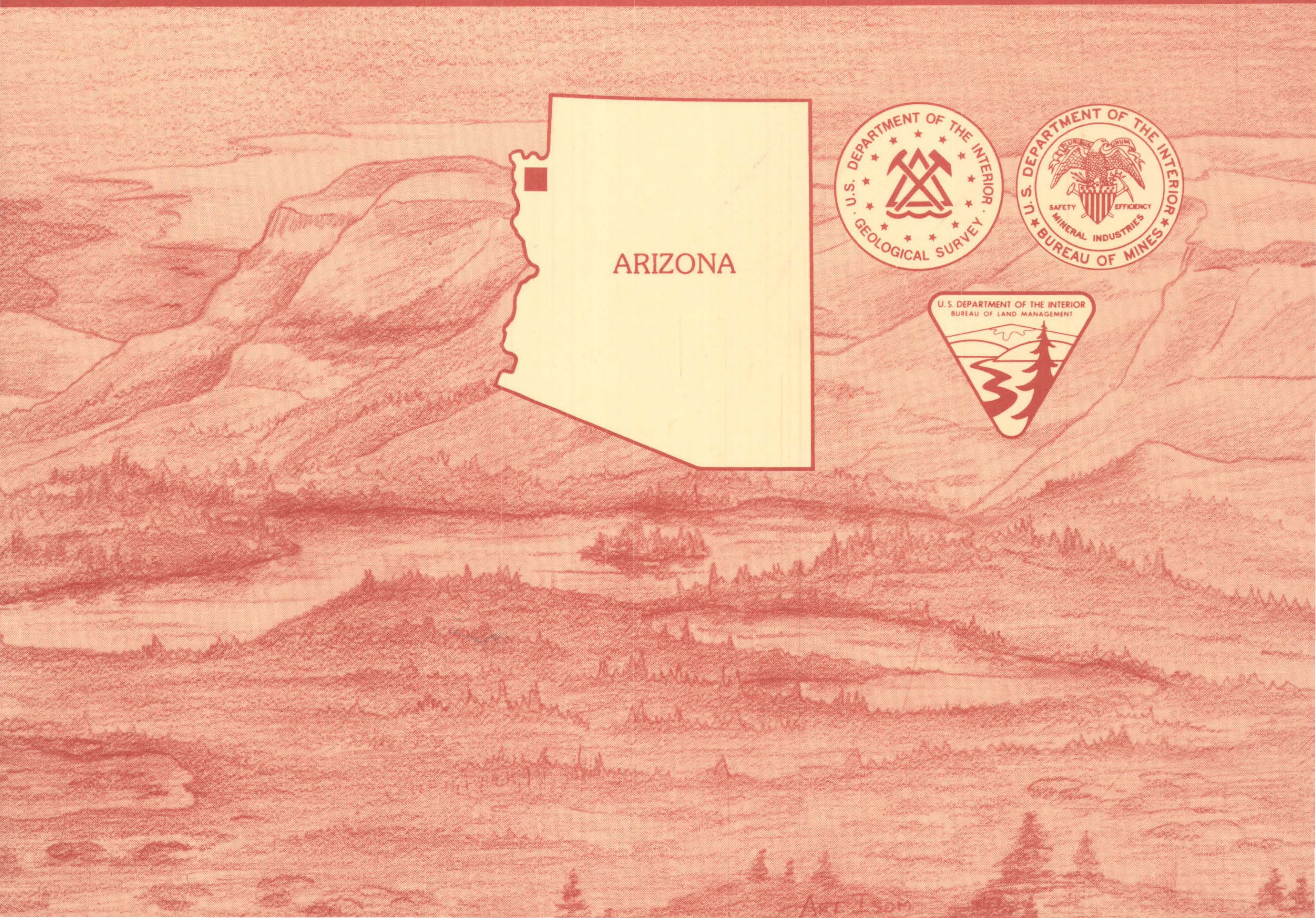

Chapter A

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U.S. GEOLOGICAL SURVEY BULLETIN 1737

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
BLACK MOUNTAINS REGION, ARIZONA

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, Jr., Secretary

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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 Mount Wilson Wilderness Study Area (AZ–020–001A), Mohave County, Ariz.

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SUMMARY

Abstract

The Mount Wilson Wilderness Study Area (AZ–020–001A) comprises 24,821 acres in Mohave County, Arizona. Reconnaissance surveys to determine identified (known) mineral resources and mineral resource potential (undiscovered) were carried out by the U.S. Bureau of Mines and the U.S. Geological Survey in 1984–87. There are no identified mineral resources in the wilderness study area. The western part of the area south of the summit of Mount Wilson has moderate mineral resource potential for lead, zinc, silver, and gold in epithermal vein deposits and low mineral resource potential for tungsten in vein deposits. A single locality within this area has a high potential for gold in vein deposits. The northern part of the study area, including the summit of Mount Wilson, has low mineral resource potential for copper, zinc, silver, and gold in epithermal vein deposits and low mineral resource potential for tungsten in vein deposits. An area just northwest of the study area has low mineral resource potential for thorium in pegmatites. The study area has no potential for geothermal energy, oil and gas, or sand and gravel resources.

Character and Setting

The Mount Wilson Wilderness Study Area lies in westernmost Arizona, directly southeast of Hoover Dam (fig. 1). It is in the Black Mountains, which are part of the Basin and Range province of western North America. The principal rock units underlying the study area are gneiss and schist of Precambrian age, overlain on the mountain flanks by fanglomerate, breccia, and basalt of Tertiary age. (See "Appendixes" for geologic time chart.) The northern part of the study area is underlain by granodiorite and granite of Tertiary age.

Identified Resources and Mineral Resource Potential

There are no identified mineral resources in the wilderness study area. The western part of the study area south of the summit of Mount Wilson (fig. 2) has moderate mineral resource potential for lead, zinc, silver, and gold in epithermal vein deposits and low mineral resource potential for tungsten in vein deposits. A single locality within this area has high potential for gold in vein deposits. The northern part of the study area, including the summit of Mount Wilson, has low mineral resource potential for copper, zinc, silver, and gold in epithermal vein deposits and low mineral resource potential for tungsten in vein deposits. An area just northwest of the study area has low mineral resource potential for thorium in pegmatites. The area has no potential for geothermal energy, oil and gas, or sand and gravel resources.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management (BLM) 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

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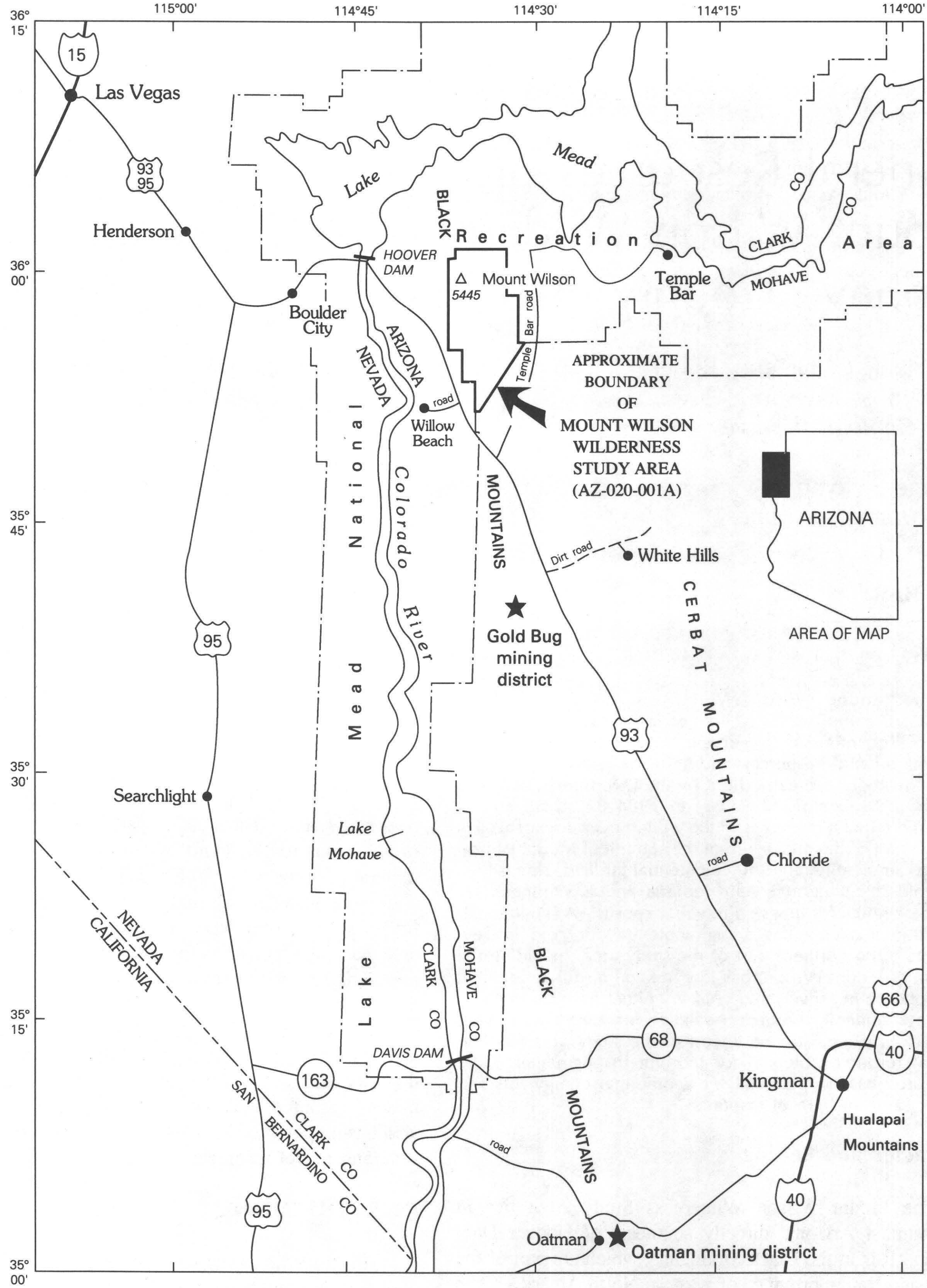

Figure 1. Map showing location of Mount Wilson Wilderness Study Area, Mohave County, Arizona.

resources at individual mines and known mineralized areas by collecting data on curent 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.

Setting

The Mount Wilson Wilderness Study Area (AZ–020–001A) is located in Mohave County, Ariz., east and south of the Colorado River and directly east of U.S. Highway 93 (fig. 1). The area is bounded on all but the southeast end by the Lake Mead National Recreation Area, and the northernmost part lies 7 mi due east of Hoover Dam. Mount Wilson (5,445 ft) is the culminating peak of Wilson Ridge, which is part of the Black Mountains, a loosely defined range that parallels the Colorado River and extends for 110 mi south from the Overton Arm of Lake Mead. From the base of Wilson Ridge at about 2,800 ft, the land slopes gently eastward to the axis of Detrital Valley and more steeply westward to the Colorado River, where the elevation is about 800 ft.

Access to the wilderness study area from the east is by two unimproved roads from the Temple Bar road north of U.S. Highway 93. Several unimproved roads, mostly dry washes, provide proximate access to the western part of the wilderness study area.

Previous Work and Present Study

Previous geologic mapping in the Mount Wilson area consists of reconnaissance work that appears on the geologic maps of Arizona (Wilson and others, 1969; Reynolds, 1988) and more detailed work on the geologic map of the Black Canyon 15-minute quadrangle (Anderson, 1978). Anderson's quadrangle map includes most of the wilderness study area, and the geology described in this report is largely based on that mapping. Before and during the construction of Hoover Dam, the U.S. Bureau of Reclamation commissioned several studies concerning rock structure near the dam site (U.S. Bureau of Reclamation, 1950). Previous mineral resources studies include those by Schrader (1909), Hewett and others (1936), Longwell (1963), and U.S. Bureau of Land Management (1983).

Limited reconnaissance mapping for the present report was carried out in 1986 by W.A. Lawson and R.C. Greene, mostly in the northernmost part of the area, which is not within the Black Canyon quadrangle. Geochemical sampling and interpretation of results was done by R.G. Eppinger and J.R. Hassemer, and geophysics was done by R.C. Jachens. Appraisal of identified resources by G.S. Ryan included a review of the literature, investigation of mining claim information, and field examination of the study area. Final assembly and conclusions were done by R.C. Greene.

APPRAISAL OF IDENTIFIED RESOURCES

By George S. Ryan
U.S. Bureau of Mines

Summary Statement

No mineral production has occurred, no mineral resources were identified, and no mineral leases or mining claims are present in the study area, although several prospected areas were found. Assays of 38 rock samples taken from prospected and mineralized sites during this survey indicate anomalous amounts of barium, copper, silver, and other elements. The structures in which they occur do not appear to be extensive.

Methods of Investigation

The U.S. Bureau of Mines investigation included a review of literature related to the mineral resources and mining activity in and near the Mount Wilson Wilderness Study Area. Mining claim information was checked in the BLM claim recordation files; no mining claims are present within the study area. Land status plats were obtained from the BLM State Office in Phoenix, Ariz.

Examination of the study area and vicinity by two U.S. Bureau of Mines geologists included reconnaissance by fixed-wing aircraft, four-wheel-drive vehicle, and foot traverses. Prospects and workings within and near (within 0.5 mi) the wilderness study area were surveyed and sampled.

During this study, 38 chip and grab samples were collected; 24 of them were fire assayed for gold and silver; 27 were analyzed for barium, beryllium, and copper by inductively coupled plasma–atomic emission spectrometry or X-ray fluorescence methods, and 21 were analyzed for 40 elements by the semiquantitative optical emission spectrographic method (Ryan, 1986). All testing was done by the U.S. Bureau of Mines Reno Research Center, Reno, Nev.

Mining History

Gold has been mined from Tertiary quartz-sulfide-gold veins in the Precambrian metamorphic rocks 10 to 30 mi south of the wilderness study area in the Gold Bug mining district (U.S. Geological Survey, 1968, p. A4). The highly productive Oatman mining district is in the southern part of the Black Mountains, 60 mi south of the wilderness study area. At Oatman, quartz-adularia-gold veins are found in Tertiary volcanic rocks overlying Precambrian metamorphic rocks (Bateman, 1951, p. 431). Most Tertiary volcanic rocks have been eroded from the wilderness study area, but Tertiary dikes are common.

Several prospect pits were found within and near the wilderness study area; most are along the western boundary near a hypothetical major fault along the west side of Wilson Ridge. The prospects are in the granitic rocks underlying Mount Wilson in the northern part of the wilderness study area and in the Precambrian metamorphic rocks in the southern part. Except at the Two Bs mine, the workings consist of small pits, shafts, and adits. Although no record of mineral production was found in the literature, unpublished U.S. Bureau of Reclamation records show that the Two Bs mine was started in the 1930's and work continued into the 1950's.

There has been no large-scale geophysical prospecting in the study area because of the restrictive exploration policies imposed by the administration of the Lake Mead National Recreation Area.

Appraisal of Mineral Sites Examined

Samples were taken at all of the small pits, shafts, and adits found in and adjacent to the study area. Malachite and chrysocolla were found in shear zones exposed in many prospects. Although copper minerals are readily apparent in the prospects, gold was probably the target of the early prospectors. Minor amounts of gold or silver are found in five of the samples. The highest concentrations are in a sample taken from a shaft located on a fault 1.5 mi west of Mount Wilson, outside the wilderness study area boundary (fig. 2, No. 6); the amounts are 4 parts per million (ppm) gold, 9 ppm silver, 2.13 percent barium, and 1.6 percent copper. Anomalously high values of barium (to >5,000 ppm), copper (to 15,000 ppm), gold (to 1.25 ppm), manganese, and silver (to 2 ppm) are present in many of the samples, and beryllium, chromium, nickel, strontium, tin, vanadium, and zirconium contents are higher than average crustal concentrations (Levinson, 1980, p. 43).

A 360-ft-long crosscut adit with a 184-ft-long drift is present at the Two Bs mine, 0.5 mi west of the wilderness study area (fig. 2, Nos. 19–33). The crosscut was evidently driven to intercept, at a depth of about 150 ft, a mineralized vein of variable width (2 to 10 ft) observed on the surface. The drift at the end of the crosscut follows the structure that correlates up dip with the surface outcrop. Samples 19 to 22 were taken in the crosscut adit; one sample contains 6.2 ppm silver. Samples 23 to 31 were taken along the structure exposed in the drift; one sample contains 3.8 ppm gold and 6.2 ppm silver, and another contains 5.9 ppm gold and 3.1 ppm silver. A heavy coating of copper sulfate on the walls, especially near the structure, represents the effects of the leaching of minerals from the structure and subsequent redeposition.

A 20-ft-deep shaft is located 1.5 mi east-southeast of the summit of Mount Wilson (fig. 2, Nos. 9–11). The shaft is in a highly magnetic, fine-grained igneous rock body about 200 ft^2 in area, apparently a zenolith in the granitic rocks. Two of the three samples taken from the xenolith contain 10 to 29.9 percent iron and 6.2 ppm silver. The third sample, taken from a 2-ft-wide vein that is exposed over a distance of 35 ft, contains 22.3 percent barium, 0.31 ppm gold, and 3.1 ppm silver.

A gold prospect in the south part of the study area (fig. 2, No. 34) was being drilled in March 1989. Assays of three mineralized rocks collected at the surface in two claims show 22, 25, and 31 ppm gold.

Additional mineral occurrences are aligned along the trend of a hypothetical basin-and-range fault lying immediately west of the study area (not shown on fig. 2). This alignment suggests that the mineralization could have been controlled by such a structure. An apparent extension of the fault bounds the east side of the Gold Bug mining district to the south (Anderson, 1978). Nearly all mineral deposits exploited within the Black Mountains have been in either plutonic or volcanic igneous rocks or in metamorphic rocks (Longwell, 1963, p. E43). Although most of the volcanic rocks have been eroded from the northern part of the Black Mountains, the underlying Precambrian metamorphic rocks and Tertiary intrusive rocks are similar to those found in the Gold Bug and Oatman mining districts. Analyses of samples from prospects along the west side of the wilderness study area indicate that precious- and base-metal mineralization including gold and silver has occurred.

Conclusions and Recommendations

No mineral resources were identified within the Mount Wilson Wilderness Study Area. The mineral occurrences present are discontinuous, small, and of low grade. Because geological conditions are similar to those in the Gold Bug and Oatman mining districts, advanced exploration techniques such as gravimeter, induced polarization, and very low frequency electromagnetic surveys should be used to identify any near-surface veins or any massive or disseminated mineral deposits.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Robert C. Greene, Robert G. Eppinger, Jerry R. Hassemer, Robert C. Jachens, *and* William A. Lawson
U.S. Geological Survey

Geology

The Mount Wilson Wilderness Study Area includes most of Mount Wilson and Wilson Ridge. This range and the rest of the Black Mountains are part of the Basin and Range province of western North America, a region characterized by fault-block mountains with intervening alluvium-filled valleys. Wilson Ridge is underlain principally by gneiss and schist of Precambrian age, and its flanks are underlain by sedimentary and volcanic rocks of Tertiary age. Mount Wilson itself is underlain by granitic rocks of Tertiary age.

Three Precambrian rock units are distinguished on figure 2. On the east flank of Wilson Ridge, the dominant rock is hornblende-biotite gneiss (p€h), with local amphibolite or granite pegmatite. Most of the ridge is underlain by gray granite gneiss and schist (p€m) in alternating bands with granite pegmatite and darker hornblende gneiss. Highly foliated biotite schist (p€s) is present in local fault slices.

Granitic rocks underlying Mount Wilson (Tgr) include abundant hornblende-biotite granodiorite and less common biotite granite and pyroxene-biotite diorite, all of Tertiary age. Border zones are heterogeneous and contain mafic plutonic rocks, pegmatite, and aplite. Numerous felsic dikes intrude the Precambrian rocks. These are probably related to the granodiorite and may be related to mineralization.

Small areas on the flanks of Wilson Ridge are underlain by the Mount Davis Volcanics of Miocene age. The two map units in the study area include mafic lavas and flow breccias (Tdm) and rhyodacite and dacite lava and flow breccia (Tdr).

The principal rock unit flanking the sides of Wilson Ridge is the Miocene Muddy Creek Formation, which is divided into three units on figure 2. Most of the formation consists of coarse, poorly sorted fanglomerate (Tms) derived from the metamorphic and granitic rocks upslope. Exceptionally coarse debris is mapped as megabreccia (Tmm). Locally overlying or interlayered with the sedimentary rocks are flows of black olivine basalt of the Fortification Basalt Member (Tmf).

Unsorted debris of Quaternary alluvial fans and sand and gravel in stream courses (Qa) are locally mapped.

In common with most of the ranges in the Basin and Range province, Wilson Ridge is a complex horst, or uplifted block, bounded on both flanks by faults that are mostly concealed. According to Anderson (1978), the internal structure of the range is complicated by low-angle normal faults in the Precambrian rocks.

Geochemistry

Introduction and Methods

In 1987, a reconnaissance stream-sediment geochemical survey of the region including the Mount Wilson Wilderness Study Area was conducted to aid in the mineral resource evaluation; 52 stream-sediment, 41 heavy-mineral-concentrate, and 11 altered rock samples were collected and prepared. A stream-sediment sample represents a composite of rock and soil exposed in the drainage basin, whereas a nonmagnetic fraction of the heavy-mineral concentrate (HMC) derived from it is especially useful in detecting mineralized areas because primary and secondary ore minerals are commonly concentrated in this fraction. The concentration of ore and ore-related minerals in the HMC sample facilitates determination of elements that are not easily detected in bulk stream sediments. Reconnaissance geochemical studies of this nature are designed for recognition of altered or mineralized areas but not for finding individual mineral deposits. A detailed follow-up geochemical study was not undertaken for this study.

Stream-sediment samples were collected from active alluvial channels generally along first-order streams. The samples were sieved with 100-mesh screens, and the minus-100-mesh fractions were pulverized for chemical analysis. HMC samples were collected from active alluvial channels and panned until most quartz, feldspar, clay, and organic matter were removed. The HMC samples were then sieved with 16-mesh screens, and light minerals remaining in the minus-16-mesh fractions were removed by heavy-liquid flotation. The HMC samples were separated by an electromagnet into magnetic, slightly magnetic, and nonmagnetic fractions. The nonmagnetic fractions were examined by microscopic and X-ray diffraction methods to determine their mineral content and then were pulverized for chemical analysis. Magnetic and slightly magnetic fractions were not used in this study. Rocks collected from altered zones or prospects were examined microscopically and then pulverized for chemical analysis.

All samples were analyzed for 31 elements (antimony, arsenic, boron, barium, beryllium, bismuth, cadmium, calcium, chromium, cobalt, copper, gold, iron, lanthanum, lead, magnesium, manganese, molybdenum, nickel, niobium, scandium, silver, strontium, thorium, tin, titanium, tungsten, vanadium, yttrium, zinc, and zirconium) by semiquantitative emission spectrography. The HMC and rock samples were also analyzed for gallium, germanium, palladium, phosphorous, platinum, and sodium by the same method. Stream sediments were analyzed for arsenic, bismuth, cadmium, antimony, and zinc, and rocks for gold, all by atomic-absorption methods. Analytical results and a

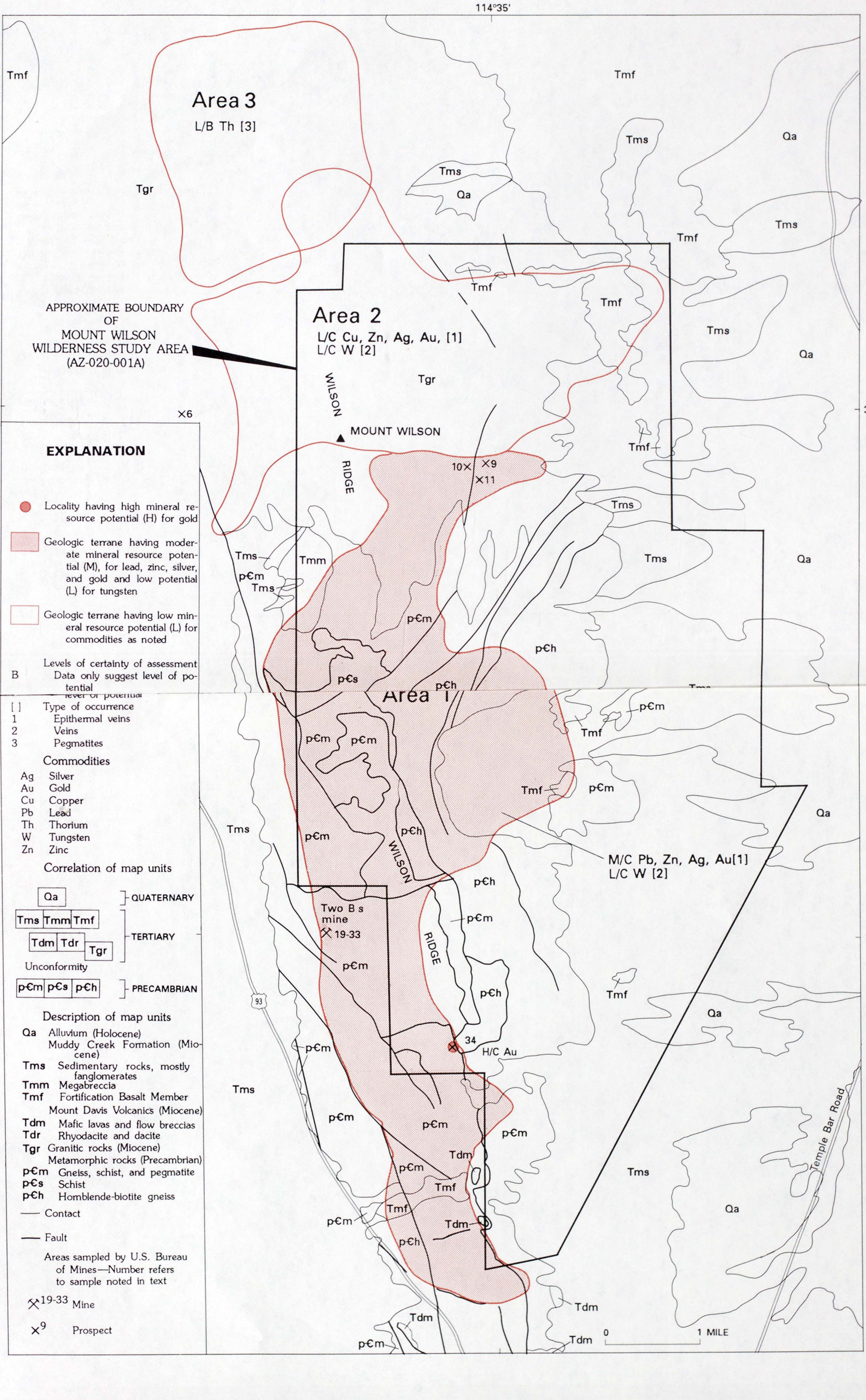

Figure 2. Mineral resource potential and generalized geology of Mount Wilson Wilderness Study Area, Mohave County, Arizona.

description of sampling and analytical techniques were supplied by B.M. Adrian (written commun., 1988).

Frequency distribution diagrams (histograms) were constructed for most elements, showing the general distribution and range of the data. Boundaries between background and anomalous element concentrations were chosen by inspection of histograms, percentiles, and average crustal abundances for elements given by Levinson (1980).

Results

Anomalous concentrations of several elements are locally found in samples derived from exposed crystalline rock in and adjacent to the wilderness study area. Summary statistics for these elements are provided in table 1. Three general areas, defined by clusters of samples having unique geochemical associations, are shown on figure 2. (1) Numerous samples from a large area extending from the west central to the southwestern part of the study area contain highly anomalous concentrations of lead, tungsten, zinc, and molybdenum. (2) Samples from an area in the northern part of the study area are weakly anomalous in copper, vanadium, tin, and molybdenum. (3) Samples from outside and immediately northwest of the wilderness study area have anomalous amounts of thorium.

Area 1 contains 21 stream-sediment and HMC sample sites. Anomalous concentrations of elements are found in HMC samples as follows: lead (11 samples, 300 to 5,000 ppm), tungsten (12 samples, 150 to 5,000 ppm), molybdenum (7 samples, 10 to 500 ppm), vanadium (2 samples, 500 and 1,000 ppm), and antimony (1 sample, 300 ppm). Silver, gold, and bismuth occur in one HMC sample (70 ppm, greater than 1,000 ppm, and 700 ppm, respectively) from a site draining prospects in the southern part of the area. Two small isolated HMC sample sites along the eastern edge of the area contain single-element anomalies, one for silver (70 ppm) and the other for arsenic (1,000 ppm). Stream-sediment samples from area 1 have anomalous values of zinc (10 samples, 65 to 125 ppm), molybdenum (1 sample, 5 ppm), copper (1 sample, 100 ppm), and lead (1 sample, 100 ppm). The highest cadmium concentrations are in stream-sediment samples from area 1, but all are less than 1 ppm. Gold was detected in three rock samples (0.04, 0.05, and 1.25 ppm) from the vicinity of the Two Bs mine. Other anomalous concentrations of elements in rock samples from area 1 include molybdenum, copper, tungsten, arsenic, vanadium, and barium. Trace amounts of several ore and ore-related minerals were observed in HMC samples from area 1, including scheelite, pyrite, malachite, wulfenite, vanadinite, cinnabar, gold, and possibly arsenopyrite. Native lead was also observed in four HMC samples.

Eleven HMC samples from area 2 exhibit weakly anomalous concentrations of the following elements: copper (6 samples, 20 to 30 ppm), tin (6 samples, 30 to 50 ppm), vanadium (3 samples, 300 ppm), and molybdenum (3 samples, 10 to 20 ppm). Anomalous elements in stream sediments from area 2 include vanadium (5 samples, 300 to 500 ppm), zinc (2 samples, 60 ppm), and copper, tin, and silver (1 sample each; 200 ppm, 20 ppm, and 2 ppm, respectively. Rock samples from area 2 contain anomalous amounts of copper and barium and detectable amounts of tungsten, silver, arsenic, gold, molybdenum, and vanadium. No ore or ore-related minerals were observed in HMC samples from area 2.

Area 3 encompasses five sample sites northwest of, but adjacent to, the wilderness study area boundary. All HMC samples from the sites have anomalous thorium, concentrations ranging from 300 to 2,000 ppm. Thorite was observed in two of the HMC samples. Other anomalous elements in HMC samples include arsenic (1 sample, 2,000 ppm), molybdenum (2 samples, 10 and 50 ppm), and tungsten (1 sample, 150 ppm). Two stream-sediment samples in area 3 contain detectable thorium.

Anomalous lanthanum and barium are also found in numerous samples in the study area. Anomalous lanthanum is generally confined to areas exposing Tertiary plutonic rocks in the northern part of the study area, where HMC samples contain 1,500 ppm to greater than 2,000 ppm. A strong correlation is found in HMC samples between anomalous lanthanum and the occurrence of yellow sphene, a rare-earth-element-bearing mineral (Deer and others, 1962) and an abundant accessory mineral in Tertiary plutonic rocks in the study area (Anderson, 1978). Anomalous amounts of niobium also occur in yellow-sphene-bearing HMC samples from the study area. Deer and others (1962) report niobium substituting for titanium in the sphene lattice.

In contrast to lanthanum, anomalous concentrations of barium are found throughout the study area in samples derived from rock types of diverse composition and age. Barium concentrations are greater than 1 percent in more than half of the HMC samples, and barite is commonly observed. Some of the barite in HMC samples from the central and northern parts of the study area appears to be vein fragments, exhibiting alternating bands of barite, quartz, and hematite. Barite, quartz, and specularite are found in and near veins and shear zones at the mine and prospects hosted by both Precambrian and Tertiary rocks in the study area (Ryan, 1986). If the barium in the study area is due largely to vein barite cutting Precambrian to Tertiary rocks, then the abundance of barite found in HMC samples suggests that barite veins are widespread throughout the study area. Conversely, the barite may come both from veins and from crystalline rocks, although barite is not mentioned as an accessory mineral in rock units in the study area (Anderson, 1978).

Interpretation

The lead-zinc-copper-molybdenum-antimony-gold-silver-bismuth-arsenic suite of elements identified in stream-sediment, HMC, and rock samples from area 1 is a suite

Table 1. Summary statistics for anomalous elements from the Mount Wilson Wilderness Study Area, Mohave County, Arizona

[Analyses are by semiquantitative emission spectrography, except for elements with "-aa" suffix, which are by atomic-absorption methods. Analysts: B.M. Adrian and F.W. Tippitt. Lower limits of analytical determination are shown in parenthesis. Values are in parts per million. n, number of samples; N, not detected; L, detected but lower than determination limit]

Element	Minimum	Maximum	50th percentile	Anomalous threshold	Number of times detected above threshold
Heavy-mineral concentrates (n=41)					
Silver (1)	N	70	N	N	2
Arsenic (500)	N	2,000	N	N	3
Gold (20)	N	>1,000	N	N	1
Barium (50)	70	>10,000	>10,000	[1]—	[1]—
Bismuth (20)	N	700	N	N	1
Copper (10)	L	30	L	15	7
Lanthanum (100)	L	>2,000	300	1,000	15
Molybdenum (10)	N	500	N	L	13
Niobium (50)	N	300	N	100	5
Lead (20)	N	5,000	N	150	12
Antimony (200)	N	300	N	N	1
Tin (20)	N	50	N	20	8
Thorium (200)	N	2,000	N	200	8
Vanadium (20)	L	1,000	100	200	5
Tungsten (50)	N	5,000	N	100	10
Stream sediments (n=52)					
Silver (0.5)	N	2	N	N	1
Copper (5)	7	200	30	70	2
Molybdenum (5)	N	5	N	N	2
Lead (10)	15	150	N	70	2
Tin (10	N	20	N	N	1
Thorium (100)	N	200	N	N	3
Vanadium (10)	70	500	100	200	10
Zinc (200)	N	300	N	N	4
Zinc-aa (5)	10	125	45	60	9
Rocks (n=11)					
Silver (0.5)	N	2	N	N	1
Arsenic (200)	N	L	N	N	2
Gold-aa (0.02)	L	1.25	L	L	5
Barium (20)	20	>5,000	150	3,000	3
Copper (5)	L	15,000	50	500	3
Molybdenum (5)	L	20	5	L	7
Vanadium (10)	10	300	50	150	2
Tungsten (20)	N	50	L	L	3

[1]Threshold not determined for barium; 27 samples contained >10,000 ppm barium

expected for epithermal base-metal and precious-metal deposits, such as those described by Berger (1982). The presence of mercury (in cinnabar, a mercury sulfide), arsenic, and antimony in area 1 suggests low-temperature epithermal deposits. The mine and prospects in area 1 are commonly found along local barium-rich quartz veins occupying shear zones (Ryan, 1986). Thus, the anomalous metals found in this study may be derived from low-temperature epithermal deposits of similar form. Wulfenite, a secondary lead-molybdenum mineral, and vanadinite, a secondary lead-vanadium mineral, suggest that oxidized parts of the deposits are exposed. Native lead identified in four HMC samples from area 1 may have a similar natural secondary origin or may be a man-made contaminant. Several of the HMC samples containing native lead were collected adjacent to an abandoned part of U.S. Highway

93; they may be contaminated. Nevertheless, two of the samples containing native lead also contain wulfenite, and another contains pyrite. While native lead is reported to be extremely rare in nature (Palache and others, 1951, p. 102), it has appeared in numerous HMC samples from streams draining oxidized lead deposits in the southwestern United States (P.K. Theobald, written commun., 1988).

The source of anomalous concentrations of tungsten and scheelite in samples from area 1 is unknown. Scheelite was found only in HMC samples from sites draining Precambrian metamorphic rocks that locally contain amphibolite and hornblende gneisses (Anderson, 1978). The scheelite and associated tungsten-anomalous samples may come from disseminated scheelite similar to that found in Precambrian amphibolite and calc-silicate gneisses in Colorado (Tweto, 1960), or they may be related to tungsten veins similar to those described by Cox and Bagby (1986, model 15a). The presence of anomalous concentrations of molybdenum is compatible with either possibility.

Samples from area 2 contain weak concentrations of a suite of elements: copper-tin-vanadium-molybdenum, with local anomalous zinc, silver, arsenic, and tungsten. The low levels for the anomalous elements, coupled with the lack of ore or ore-related minerals in HMC samples from the area, make this suite difficult to evaluate. All HMC samples from the area contain abundant sphene. The substitution of some tin and appreciable vanadium for titanium in the sphene lattice (Deer and others, 1962) may account for the tin and vanadium anomalies in the area. Remaining elements in the suite from area 2 are similar to the precious-metal and base-metal epithermal suite identified in area 1. Mineralized quartz, drusy quartz, and chalcedony veins containing barium, copper, lead, zinc, silver, and gold, found along shear zones identified at prospects in area 2, lend support to epithermal base-metal deposits as sources for the metal suite in area 2.

Because thorite occurs chiefly as a primary mineral in pegmatites (Frondel, 1958), the high concentrations of thorium and the thorite identified in area 3 may be derived from pegmatites along the border of the Tertiary granitic rocks (Anderson, 1978). Arsenic and molybdenum in area 3 may be related to the epithermal deposits described above. However, each of these elements is anomalous only in a single sample, and no associated mineral phases were identified in HMC samples; hence, assignment of these elements to a deposit type would be speculative.

Geophysics

Three types of geophysical data from western Arizona (magnetic, gravity, and radiometric) were compiled and examined to aid in assessment of the mineral resource potential of the Mount Wilson Wilderness Study Area. Detailed aeromagnetic and radiometric data are available along profiles spaced about 1 mi apart. Gravity data coverage is adequate for addressing the regional structural and tectonic setting of the study area but is too sparse to permit detailed interpretations about mineral resource potential at deposit scale.

Aeromagnetic Data

An aeromagnetic survey of the Kingman and Las Vegas 1° by 2° quadrangles, Calif., Nev., and Ariz., was flown in 1977 and compiled by Western Geophysical Company of America (1979) under contract to the U.S. Department of Energy as part of the National Uranium Resource Evaluation program. Data in the Kingman quadrangle were subsequently merged with aeromagnetic data in adjacent areas by Mariano and Grauch (1988). Total-field magnetic data over the study area and surrounding areas of Arizona were collected along east-west flightlines spaced approximately 1 mi apart in the Kingman quadrangle and 3 mi apart in the Las Vegas quadrangle, at a nominal height of 400 ft above the ground surface. Corrections were applied to the data to yield a residual magnetic field that reflects the distribution of magnetization in the underlying rocks.

The magnetic field over the study area is characterized by a large elongate north-trending magnetic high of 300 to 500 nanoteslas in amplitude and about 3 mi wide that is roughly centered over the crystalline basement rocks exposed in the west half of the study area. The magnetic high is well expressed along profiles that cross both the Tertiary granitic rocks (Tgr) exposed at the north end of the study area and the Precambrian rocks (p-Ch and p-Cm) exposed to the south. This high forms part of a major discontinuous linear magnetic high that lies adjacent to and follows the Colorado River trough southward for a distance of more than 125 mi (Mariano and Grauch, 1988).

The source rocks for this magnetic anomaly are ambiguous, but three lines of evidence suggest that the high primarily reflects Tertiary granitic rocks (Tgr). First, the detailed form of the magnetic anomaly itself suggests a source in the Tertiary granitic rocks. Profiles that cross parts of the study area where the Tertiary granitic rocks crop out show, in addition to the broad magnetic high, many short-wavelength anomalies that can only be generated by magnetic sources that lie close to the sensor, effectively at the ground surface. Although the long-wavelength magnetic high persists on profiles to the south where only Precambrian rocks are exposed, the short-wavelength anomalies are progressively subdued with increasing distance southward. This behavior is consistent with a magnetic source exposed at the north end of the study area and becoming progressively more deeply buried toward the south. Second, measurements of the magnetic susceptibility of rock samples show that the average susceptibility of five samples of Tertiary granitic rocks is about twice as large as the average susceptibility of 30 specimens of

Precambrian rock. Within each group, however, the values show considerable scatter, and each group contains individual specimens that have susceptibilities large enough to account for the anomaly. Third, the form of the geologic contact between the Precambrian rocks and Tertiary granitic rocks where this contact crosses ridges and canyons along the southwest edge of the exposed Tertiary body (Anderson, 1978) suggests that this body continues southward beneath the Precambrian rocks.

On the basis of this evidence and the steepness of the gradients on the flanks of the broad magnetic high, we interpret the magnetic data to indicate that the entire study area is underlain by Tertiary granitic rocks, exposed at the north end and buried at a depth of a mile or more near the south end.

Gravity Data

Gravity data in the vicinity of the Mount Wilson Wilderness Study Area were obtained from Mariano and others (1986) and supplemented by 13 new observations collected during the spring of 1987. Fourteen gravity measurements are from localities within the study area, and detailed profiles exist along the roads that border the area to the east and west. The observed gravity data are based on the International Gravity Standardization Net datum formulas (Telford and others, 1976). Bouguer, curvature, and terrain corrections (to a distance of 103.6 mi from each station) at a standard reduction density of 2.67 grams per cubic centimeter (g/cm^3) were made at each station to determine complete Bouguer gravity anomalies.

The Bouguer gravity field over the study area and surrounding regions reflects not only shallow density distributions but also deep sources that support the topography in a manner consistent with the concept of isostasy. To isolate that part of the gravity field that arises from near-surface density distributions, an isostatic residual gravity map was constructed from the Bouguer gravity data by removing a regional gravity field computed from a model of the crustal-mantle interface assuming Airy-type isostatic compensation (Jachens and Griscom, 1985).

The residual gravity field over the study area forms a large gravity high of about 20 milligals that has a shape, length, and width similar to the magnetic high discussed above. The elongate gravity high extends north-south the entire length of the study area. Like the corresponding magnetic anomaly, it forms part of an extensive linear gravity high that follows the Colorado River trough southward for a distance of more than 125 mi. However, the gravity anomaly is more continuous.

The close spatial correlation between the magnetic and gravity anomalies, their similarity in shape, and their great length suggest that both anomalies have the same source or closely related sources. The highest gravity value occurs at a station on the exposed Tertiary granitic body, which is consistent with a Tertiary granitic source for the gravity anomaly as well as for the magnetic anomaly. However, the average density of five samples of the Tertiary pluton is 0.07 g/cm^3 lower than the average density of 30 samples of the Precambrian rocks. This apparent contradiction could result if the small number of samples of the Tertiary pluton are not representative of the entire body, or it could be resolved if the Tertiary pluton increases in density with depth. Simpson and others (1986) identified mafic Tertiary igneous rocks as the source of the continuation of this gravity anomaly 90 mi farther south in the Mohave Mountains.

Radiometric Data

Radiometric data for the study area were collected at the same time and from the same aircraft as the magnetic data. Recordings were made of gamma-ray flux indicative of radioactive isotopes of potassium, thorium, and uranium. No consistent anomalies indicative of thorium or uranium having count rates exceeding one standard deviation above mean background fluctuations were detected along the profiles crossing the study area (Western Geophysical Company of America, 1979), thus suggesting that no large deposits of these elements exist in the very near surface beneath the profiles. However, because gamma rays are strongly attenuated during passage through Earth materials, these data do not preclude significant concentrations of these elements buried more than about 2 ft beneath the ground surface or between the 1-mi-spaced profiles.

Mineral and Energy Resources

Area 1 (fig. 2) along the western part of the study area contains strongly anomalous concentrations of lead, tungsten, molybdenum, and zinc in heavy-mineral concentrate and stream-sediment samples and weaker anomalous concentrations of other elements, including silver and gold, as indicated above. Area 1 is also located on the north-trending magnetic and gravity highs, features that suggest the presence of Tertiary intrusive rocks at shallow depths south of the exposures. Numerous Tertiary dikes probably are border phases of the shallow intrusive rocks and may be conduits for hydrothermal solutions. Veins containing copper-, silver-, and gold-bearing minerals are present at the Two Bs mine, and a large production of gold and silver has come from the Gold Bug and Oatman mining districts to the south. Therefore, area 1 has a moderate mineral resource potential, certainty level C, for lead, zinc, silver, and gold in epithermal deposits and a low mineral resource potential, certainty level C, for tungsten in vein deposits.

Strongly anomalous concentrations of gold in rock samples collected in part of area 1 (fig. 2, No. 34) indicate that this locality has a high potential, certainty level C, for vein deposits of gold.

Area 2 contains weakly anomalous concentrations of copper, tin, vanadium, and molybdenum and some zinc, silver, arsenic, and tungsten. The magnetic and gravity highs of area 1 extend through area 2 also. Area 2 is underlain by Tertiary plutonic rocks with numerous dikes. It has a low mineral resource potential, certainty level C, for copper, zinc, silver, and gold in epithermal veins and a low mineral resource potential, certainty level C, for tungsten in vein deposits.

Area 3 has yielded heavy-mineral concentrates containing anomalous amounts of thorium and grains of thorite, but it has no thorium radiometric anomaly. Area 3 has a low mineral resource potential, certainty level B, for thorium deposits in pegmatites.

There are no known warm springs along Wilson Ridge and no volcanic or intrusive rocks of Quaternary age. However, there are several warm springs in the canyon of the Colorado River about 6 mi west of the study area. That area is underlain by the Patsy Mine Volcanics of Miocene age, a unit that does not extend into the study area. Because evidence for sufficiently high temperatures for geothermal power is lacking, even near warm springs, the study area has no resource potential for geothermal energy, certainty level D.

Because the wilderness study area is underlain by high-grade metamorphic and intrusive rocks with a thin mantle of volcanic and continental sedimentary rocks on the flanks, the area has no mineral resource potential for oil and gas (Ryder, 1983, p. C19), certainty level D.

Such deposits of sand and gravel as exist in stream courses on the flanks of Wilson Ridge are small, of poor quality, and far from potential markets. Therefore, the wilderness study area has no mineral resource potential for sand and gravel, 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	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	[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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