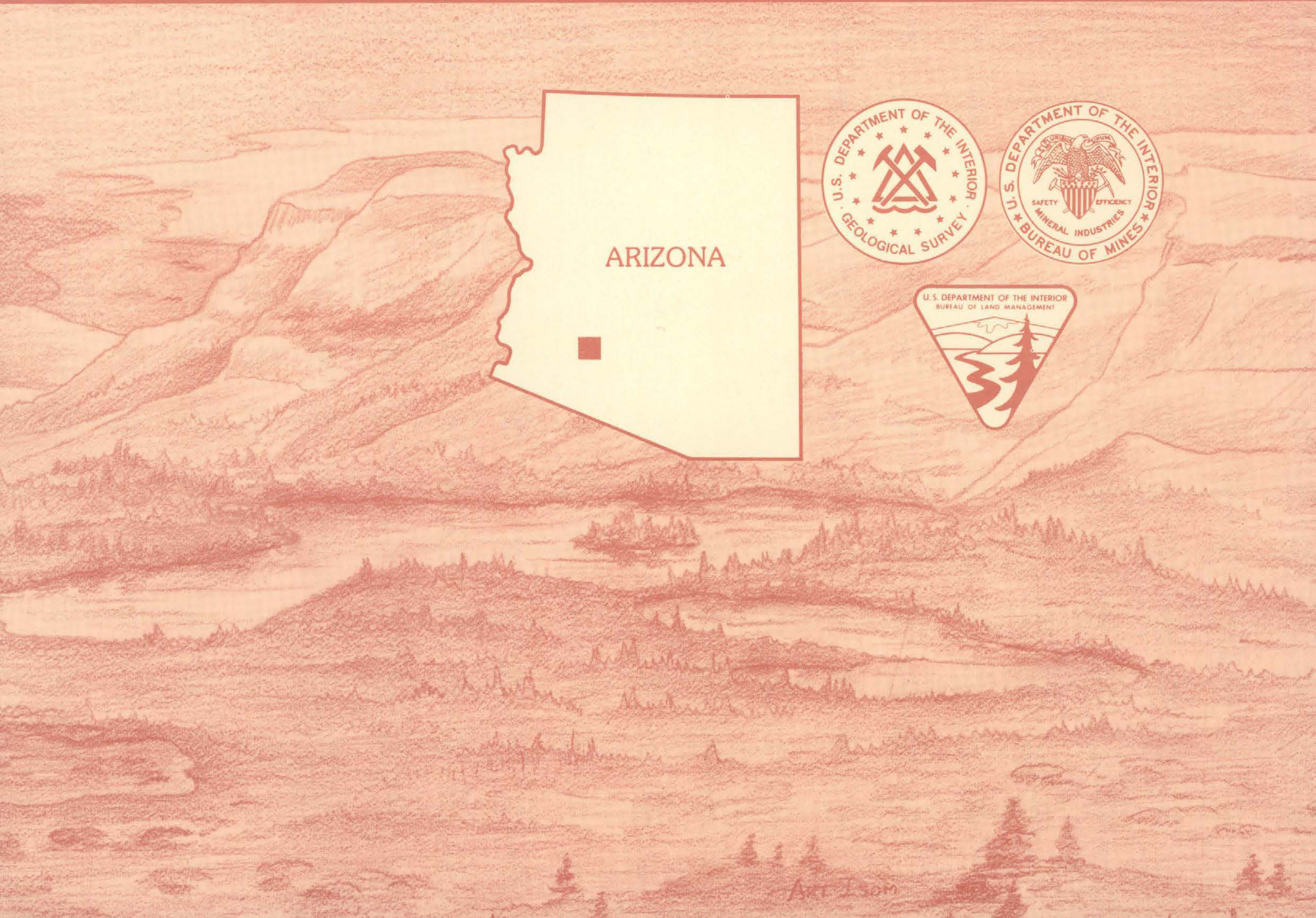
Mineral Resources of the Signal Mountain Wilderness Study Area, Maricopa County, Arizona

U.S. GEOLOGICAL SURVEY BULLETIN 1702–C



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Chapter C

Mineral Resources of the Signal Mountain Wilderness Study Area, Maricopa County, Arizona

By FLOYD GRAY, ROBERT J. MILLER, JERRY R. HASSEMER, DANIEL H. KNEPPER, JAMES A. PITKIN, and WILLIAM F. HANNA
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U.S. GEOLOGICAL SURVEY BULLETIN 1702

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
SOUTHWESTERN AND SOUTH-CENTRAL ARIZONA

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 Area

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 part of the Signal Mountain Wilderness Study Area (AZ–020–138), Maricopa County, Arizona.

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Mineral Resources of the Signal Mountain Wilderness Study Area, Maricopa County, Arizona

By Floyd Gray, Robert J. Miller, Jerry R. Hassemer, Daniel H. Knepper, James A. Pitkin, *and* William F. Hanna
U.S. Geological Survey

Terry J. Kreidler
U.S. Bureau of Mines

SUMMARY

Abstract

At the request of the U.S. Bureau of Land Management, approximately 15,250 acres of the Signal Mountain Wilderness Study Area (AZ–020–138) were evaluated. In this report, the area studied is referred to as the "wilderness study area" or simply "the study area"; any reference to the Signal Mountain Wilderness Study Area refers only to that part for which a mineral survey was requested by the U.S. Bureau of Land Management. Between 1984 and 1987 the U.S. Bureau of Mines and the U.S. Geological Survey conducted investigations to appraise the identified mineral resources (known) and assess the mineral resource potential (undiscovered) of the Signal Mountain Wilderness Study Area. These investigations revealed that basalt and sand and gravel may be identified mineral resources in the area. The mineral resource potential for copper, lead, silver, and gold is low along 2 miles of the north border of the study area. The potential is also low for oil, gas, and geothermal energy resources throughout the study area.

Character and Setting

The Signal Mountain Wilderness Study Area is located approximately 30 mi southwest of Buckeye and 15 mi south of Wintersburg, Arizona (fig. 1). The area lies within the Sonora Desert section of the Basin and Range physiographic province, a region characterized typically by large mountain chains separated by deep, alluvium-filled valleys. The study area contains many steep-walled canyons, arroyos, ridges, and sharp peaks. Elevations range from 2,182 ft at Signal Mountain to approximately 760 ft along the southwest boundary of the study area. The study area is underlain by a sequence of basalt to basaltic andesite, dacitic andesite, and minor rhyolite to rhyodacite flows, plugs, and air-fall tuffs of Miocene age (see geologic time chart in "Appendixes"). Pre-Tertiary rocks crop out less than 0.5 mi north and northeast of the study area but are not exposed in the study area. No prospects are located within the study area, but the Webb mining district is approximately 1 mi to the northeast. This district produced 27,000 lb of copper, 200 troy oz of silver, and 50 troy oz of gold between 1935 and 1951.

Manuscript approved for publication February 16, 1989.

Identified Resources and Mineral Resource Potential

Basalt and sand and gravel in the Signal Mountain Wilderness Study Area may be classified as identified mineral resources. Geochemical information from rock, stream-sediment, and panned-concentrate samples indicates that one area along the north border of the study area has low mineral resource potential for copper, lead, silver, and gold in epithermal veins (fig. 2). These metals are suggested by geochemically anomalous concentrations of molybdenum, manganese, copper, barium, arsenic, lead, and silver found in samples collected 0.25 mi north of the study area along a west-northwest-trending fault. Although Tertiary volcanic rocks are exposed on the surface, the anomalies are probably derived from the underlying basement assemblage. No geochemically anomalous suite of elements was detected within the study area.

The Webb mining district, located 1 mi northeast of the Signal Mountain Wilderness Study Area, contains

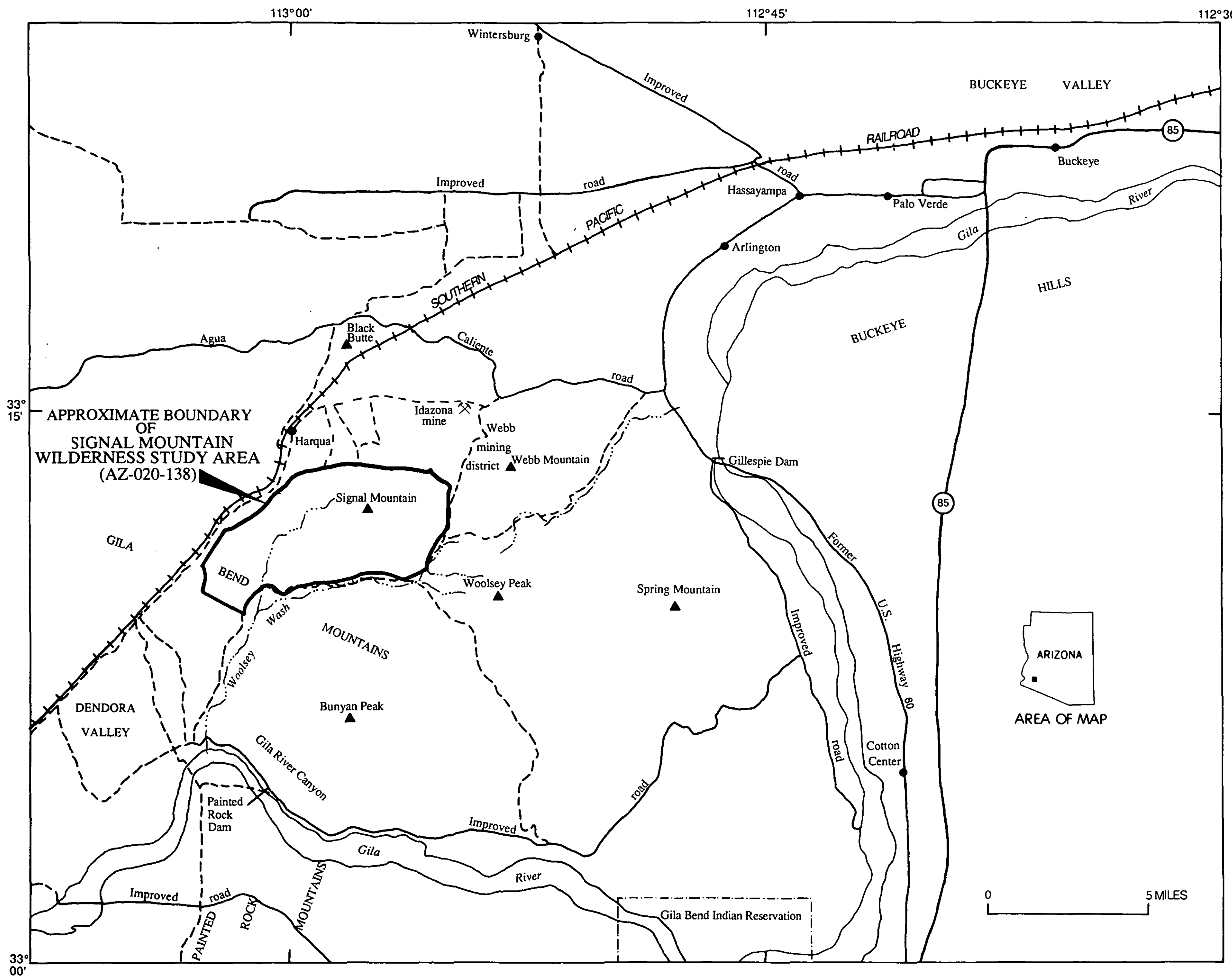


Figure 1. Index map showing location of Signal Mountain Wilderness Study Area, Maricopa County, Arizona. Dashed lines, unimproved roads.

mainly copper with byproduct silver and gold in veins within metamorphic and igneous rocks of Proterozoic to Jurassic age and in scattered skarns formed from pendants of carbonate rocks. These rocks may be displaced downward by at least two large-displacement, northwest-trending faults northeast of the study area. Geologic data indicate that the rocks of Webb Mountain may extend into the study area below the exposed Tertiary volcanic section.

Basalt from the study area could be used as aggregate and fill and may be classified as an inferred subeconomic resource, but other suitable rock is available closer to potential markets. Sand and gravel deposits in the area are small, and access to them is generally poor; sand and gravel deposits are also plentiful closer to potential markets.

The entire study area has low potential for geothermal energy resources on the basis of hot springs in adjacent ranges. The potential for oil and gas resources in the study area is low because there is no evidence of favorable hydrocarbon source rocks.

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. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was provided by Beikman and others (1983). The USBM evaluates identified resources at individual mines, prospects, and known mineralized areas by collecting data on current and past mining activities and through field examination. Identified resources are classified according to a system that is a modification of that described by McKelvey (1972) and the U.S. Bureau of Mines and U.S. Geological Survey (1980). USGS 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.

Location and Physiography

The Signal Mountain Wilderness Study Area (AZ–020–138) in southwestern Arizona is in the northern Gila Bend Mountains (fig. 1). The U.S. Bureau of Land Management requested a mineral survey of 15,250 acres of the study area in the steep, rugged mountains that include Signal Mountain, at an elevation 2,182 ft. The peripheral valley to the southwest has an elevation of approximately 760 ft.

Low-lying areas adjacent to the study area are accessible by dirt roads (fig. 1). The northern part of the study area can be reached from the Agua Caliente improved dirt road, which connects with several unimproved dirt roads that lead south into the study area. Southern access can be obtained through Woolsey Wash or an unimproved road parallel to the wash.

The arid climate supports typical southern Arizona desert fauna and flora. Paloverde, saguaro, and creosotebush are found throughout the study area's alluvial slopes and upland areas, and many varieties of desert wildflowers bloom seasonally. The washes are lined with mesquite, ironwood, acacia, and paloverde trees. Bighorn sheep, rattlesnake, and desert tortoise inhabit the area.

Procedures and Sources of Data

The USBM conducted a literature search and examined mining claim information, land-status maps, and oil- and gas-lease maps acquired from the BLM to determine the extent of mining and prospecting activity within the study area. In 1986, USBM personnel did site-specific sampling in and around the study area and carried out laboratory analyses of these samples by several spectrographic techniques (Kreidler, 1986).

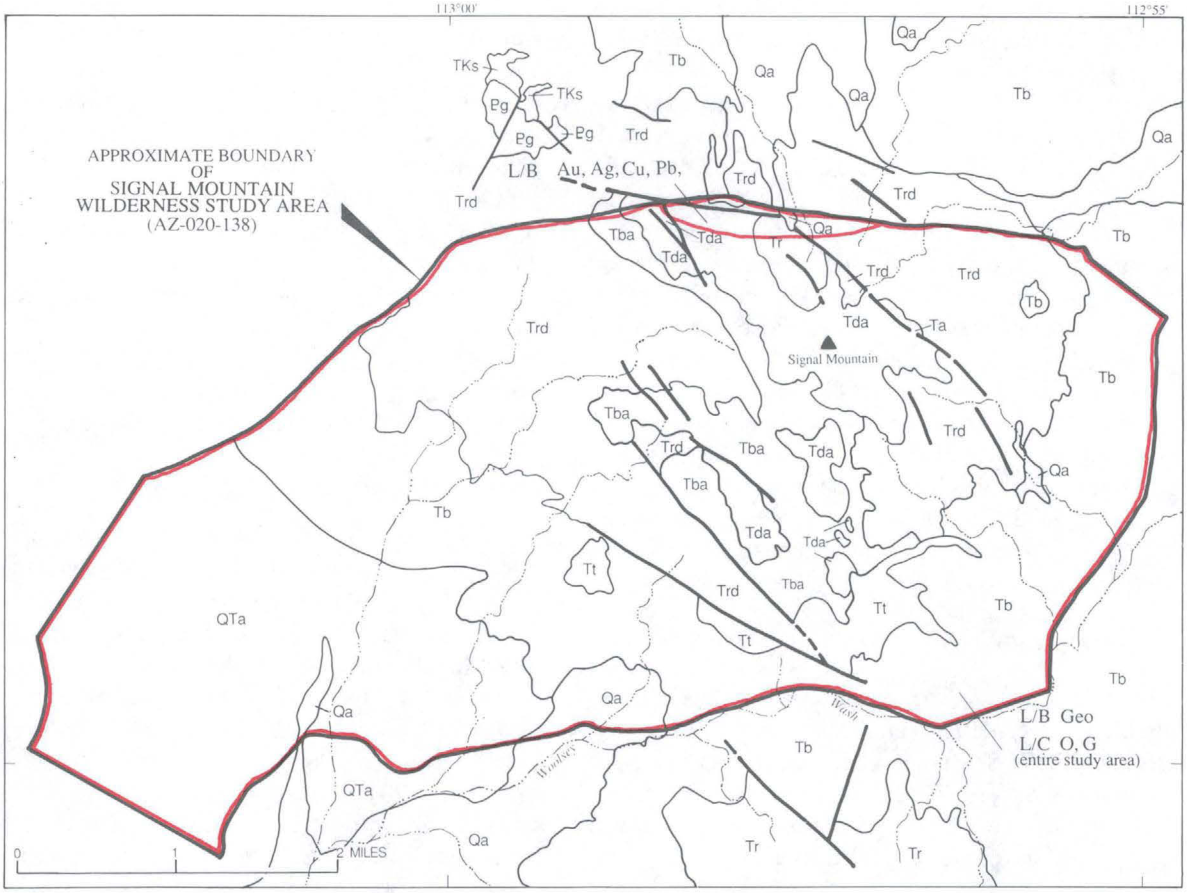
From 1984 through 1987, the USGS conducted detailed field investigations within and adjacent to the Signal Mountain Wilderness Study Area. This work included geologic mapping at scales of 1:48,000 (Floyd Gray and R.J. Miller, unpub. data), geochemical sampling, and examining outcrops for evidence of mineralization. The geochemical survey utilized rock and stream-sediment (including fine-fraction and heavy-mineral-concentrate) samples that were analyzed for 33 elements by semiquantitative emission spectrography. Gold, arsenic, antimony, cadium, mercury, zinc, and bismuth were analyzed by atomic-absorption methods, and uranium and thorium were analyzed by delayed-neutron count. Geophysical studies, based on published data, include interpretations of gravity, aeromagnetic, and gamma-ray spectrometric data. Further details on analytical procedures undertaken for this resource assessment are given in the appropriate sections that follow.

Generalized regional studies that include the wilderness study area appear in Wilson and others (1957, 1969); more recent investigations of the geology include a study of the Webb Mountain district (Cheeseman, 1974).

APPRAISAL OF IDENTIFIED RESOURCES

By Terry J. Kreidler
U.S. Bureau of Mines

USBM personnel reviewed sources of mineral information that include published and unpublished literature, USBM files, and mining claim and oil- and gas-lease records at the BLM State Office in Phoenix.



EXPLANATION

Area having low mineral resource potential (L)

Levels of certainty of assessment

B Data only suggest level of potential
C Data give good indication of level of potential

Commodities

Ag Silver
Au Gold
Cu Copper
Geo Geothermal energy
O,G Oil and gas
Pb Lead

Description of map units

Qa Alluvium (Quaternary)—Unconsolidated sand and gravel deposits

QTa Older alluvium (Quaternary and Tertiary)—Includes older gravels and minor basalt and tuff outcrops

Tr Rhyolite flows and plugs (Miocene)—Includes minor tuffs

Tt Silicic tuff (Miocene)—Primarily unwelded air-fall tuff; may include ash-flow deposits

Tda Dacitic andesite flows (Miocene)—Biotite-, hornblende-, and pyroxene-bearing cliff-forming flows

Tb Basalt flows and flow breccias (Miocene)—Thin flows and red-oxidized flow breccias; consists of olivine- and pyroxene-phenocryst-bearing basalts and minor tuffs that originated south of study area. Includes low-lying flows as well as mesa-forming basalt

Trd Rhyodacite flows and tuffs (Miocene)—Includes porphyritic volcanic rocks and minor thin silicic tuffs

Tba Basaltic andesite flows (Miocene)—Thin, olivine-pyroxene-bearing flows underlying Tda unit and interbedded with Trd unit

TKs Sandstone and conglomerate (Tertiary to Cretaceous)—Pebbly conglomerate contains quartzite and chert fragments

Ꞓg Granite (Proterozoic)—Leucocratic biotite-bearing granite

Contact

Fault—Dashed where approximately located

CORRELATION OF MAP UNITS

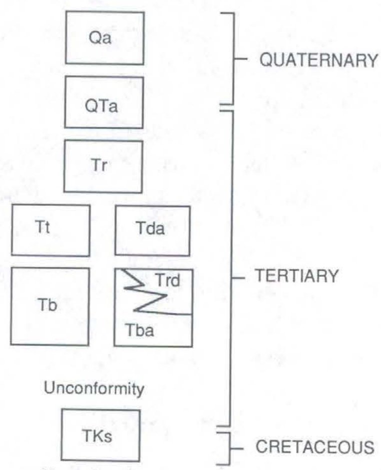


Figure 2. Mineral resource potential and generalized geology of Signal Mountain Wilderness Study Area, Maricopa County, Arizona. Geology mapped by Floyd Gray and Robert J. Miller intermittently from spring of 1984 through 1986.

Discussions on the mineral resources of the study area were also held with BLM personnel at the Phoenix District Office.

Fieldwork consisted of searching for mines and prospects—none were found within the study area—and sampling sediments in washes that drain the study area. Nine samples were taken, eight from within the study area. All were analyzed for gold and silver by fire assay and for copper, lead, and zinc by inductively coupled plasma–atomic emission spectroscopy. Complete analytical data are available for inspection at the U.S. Bureau of Mines, IFOC, Building 20, Denver Federal Center, Denver, CO 80225.

Mining Activity

No evidence of mining or exploration was found within the study area. Mining has occurred in the Webb mining district 1 to 3 mi northeast of Signal Mountain. The district extends northwest from Webb Mountain to the Idazona mine. Between 1935 and 1951, copper (27,000 lb), silver (200 troy oz), and gold (50 troy oz) were produced from six mines (Keith and others, 1983). The mines follow quartz veins in Proterozoic schist and gneiss that were intruded by granite, diorite, and porphyritic dikes of andesitic composition. The andesitic rocks at Webb Mountain, which are probably correlative with those in the study area, do not host any of the mineralization.

In February and March 1986, Texasgulf Minerals and Metals Company drilled 10 exploration holes on a claim block 2 to 3 mi north of the study area near Black Butte. They were trying to delineate a gold trend following fractures and faults associated with a structural arch. The trend of the structure, N. 70° W., precludes it from intersecting the study area. The holes penetrated metamorphic and igneous rocks of probable Proterozoic age.

Mineral Resource Appraisal

Basalt and sand and gravel may be classified as inferred subeconomic resources; however, these are high-volume, low-unit-value materials that must be close to markets to be profitable. Andesite and basalt resembling that at Webb Mountain bear no signs of mineralization. Stream-sediment samples taken in the study area drainages contain insignificant amounts of gold, silver, copper, lead, and zinc (Kreidler, 1986).

Energy Resources

About 5,700 acres (37 percent) of the study area are covered by oil and gas leases; Ryder (1983), however, rates the oil and gas potential as low to zero because the rocks are volcanic. In the basins adjacent to the study area, the sedimentary rocks are no more than 5,000 ft thick, and conditions are not conducive to the accumulation of hydrocarbons. The leasing is probably based on speculation that the Wyoming overthrust belt, from which large quantities of hydrocarbons are produced, extends southward into Arizona (Keith, 1979). As of September 1986, results of all exploratory drilling to test this theory were negative. Leases in and near the study area, however, had not been tested.

Hot springs occur in adjacent ranges to the south, but none are known within the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Floyd Gray, Robert J. Miller, Jerry R. Hassemer, Daniel H. Knepper, James A. Pitkin, *and* William F. Hanna
U.S. Geological Survey

Geology

The Signal Mountain Wilderness Study Area lies on the northern edge of a southward thickening sequence of Tertiary rocks (fig. 2) that becomes approximately 1 mi thick in the study area. Approximately 0.25 to 3 mi north and northeast of the study area, these rocks unconformably overlie a pre-Miocene basement sequence that probably extends beneath the volcanic rocks in the study area. Structure in the region is dominated by numerous large northwest-trending normal faults that bound fault blocks tilted as much as 50°.

Basement rocks exposed just north of the study area, but not observed in it (fig. 2), consist of Proterozoic leucogranite and an overlying shallowly dipping sequence of Cretaceous to Tertiary coarse conglomerates and arkosic sandstones with minor interrcalated greenstone.

A middle Miocene volcanic sequence deposited unconformably on the basement complex underlies the entire study area. The basal unit of this sequence consists of basaltic andesite. Minor reworked volcaniclastic sediments and bedded cinder deposits are locally present within the basal unit. The upper part of the unit is intercalated with a widespread rhyodacite unit. Basalts probably originating from the Woolsey Peak area form the most extensive volcanic unit in the area. These rocks are overlain by more silicic rocks consisting mainly of porphyritic hornblende-biotite-bearing dacitic andesite flows and plugs and minor air-fall tuff. A major cliff-forming unit at the top of the section includes a crystal-rich dacitic tuff that underlies Signal Mountain. Rhyolite flows and plugs form the youngest Miocene unit in the area.

Four unconsolidated Tertiary and Quaternary units are present in the area, but for simplification only the two most extensive units are shown on figure 2. Flanking some of the peaks are poorly sorted, semiconsolidated to unconsolidated, locally derived terrace gravels. Closer to some of the mountains are talus slopes that obscure underlying geology. Widespread pediment surfaces are covered by older alluvium, and major drainage channels contain Quaternary alluvium.

Numerous high-angle, northwest-trending normal faults having large to moderate displacement are present throughout the study area. They caused significant tilting of fault-bounded blocks throughout this part of the Gila Bend Mountains. These faults are probably older than most basin-and-range faults in the region and form part of a prominent cluster of northwest-oriented structures in this part of the Basin and Range province. The faults trend principally N. 40° to 55° W., and the fault blocks tilt as much as 50°.

Geochemistry

Methods

Geochemical interpretation is based on analytical data from heavy-mineral-concentrate, stream-sediment, and whole-rock samples. In 1986 the USGS collected stream-sediment samples from 77 sites within the study area. A panned, nonmagnetic, heavy-mineral concentrate was prepared from a portion of the sediment sample collected at each site.

Stream-sediment samples represent material eroded from drainage basins upstream from the collection sites. The panned concentrate represents selectively concentrated minerals that may be related to mineralization. Chemical analyses of the minus-80-mesh and panned-concentrate fractions of stream sediments were used to identify areas of mineral resource potential. Samples were analyzed for 31 elements using a six-step direct-current arc semiquantitative emission-spectrographic method (Grimes and Marranzino, 1968); samples were analyzed for gold by an atomic-absorption method and for uranium and thorium by the delayed-neutron-counting method of Millard (1976).

Anomalous geochemical values were determined by inspection of histograms, percentiles, and enrichment of elements relative to crustal abundance. Commonly these anomalies reflect known mining activity, but in some cases they indicate the location of undisclosed or previously unrecognized metal concentrations. In general, the higher the analytical values from a sampling site, or the greater the number of anomalous elements, the more significant that site (or drainage basin) is in terms of mineral potential.

Results

The heavy-mineral-concentrate, rock, and stream-sediment samples collected within the study area contain no anomalous element concentrations and show little geochemical variation between rock types. The geochemical data give no indication of mineralization in the study area.

Several samples collected about 0.25 mi north of the study area show anomalous multi-element suites. These anomalies include molybdenum, arsenic, lead, manganese, and copper in panned-concentrate samples. The suite of elements is similar to those found in the Webb mining district and near Black Butte.

Geophysics

Gravity and Aeromagnetic Studies

The Signal Mountain Wilderness Study Area is covered by regional gravity surveys (Lysonski and others, 1980a, b; Aiken, 1976; Aiken and others, 1981) and detailed aeromagnetic surveys (U.S. Geological Survey, 1987) having sufficient resolution to define anomalies as small as a few square miles. Contours of complete (terrain-corrected) Bouguer gravity anomalies are defined by 17 observation points, all of which are at the periphery or outside of the area (fig. 3). Aeromagnetic anomalies are defined by horizontal gradiometer measurements made along 10 east-west flightlines spaced approximately 0.5 mi apart at a mean terrain clearance of 900 ft (fig. 4).

Most of the study area is covered by the south flank of a broad gravity high (fig. 3). To the northeast, north, and northwest, this high is bordered by a steep gradient that trends approximately east-west. The steepness of gradient and nearly linear trend of the contours suggest that the anomaly source has a faulted boundary to the north, a re-

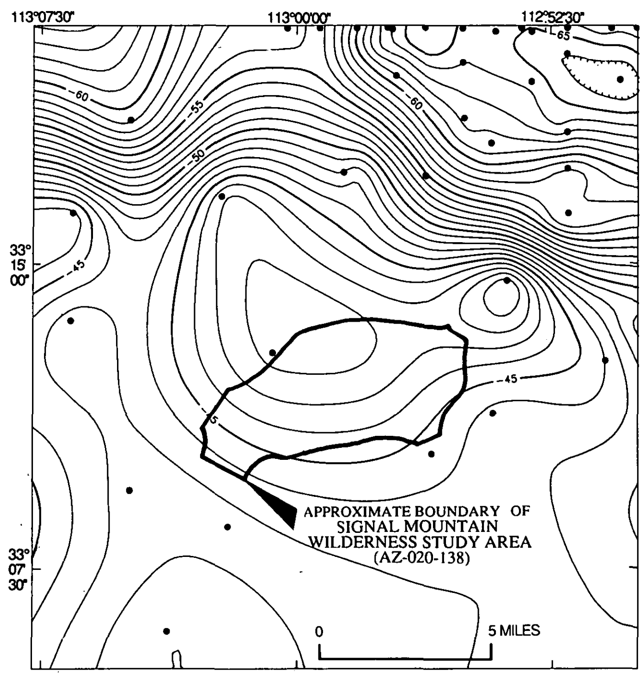


Figure 3. Bouguer gravity map of vicinity of Signal Mountain Wilderness Study Area, Maricopa County, Arizona. Contour interval 1 milligal; hachures indicate closed area of lower gravity values. Small circles represent gravity observation points.

lation commonly observed elsewhere in the Basin and Range province. To the southeast and southwest are areas of gravity lows having gentle gradients. The mushroom-shaped high, which includes a saddle-shaped extension south of the study area, conforms remarkably well to the mapped distribution of volcanic rocks. This diverse assemblage of volcanic rocks presumably overlies metamorphic rocks. Thus, the high is known to be caused in part by volcanic rocks and is presumed to be caused in part by underlying metamorphic rocks, perhaps similar to those exposed north of the study area. On the basis of simple gravity modeling, the metamorphic and volcanic rocks may have similar average densities that contrast with that of the basin fill of alluvium by about 0.5 grams per cubic centimeter (g/cm^3). Such a density contrast, if applied to a steeply faulted structure, suggests that low-density basin fill is at least 1 mi thick several miles north of the study area and less than 0.3 mi thick southeast and southwest of the study area.

The aeromagnetic anomaly map of the study area is characterized by magnetic anomalies of highly variable amplitude and wavelength (fig. 4), which correlate principally with volcanic rocks or their deeper seated equivalents of highly variable composition. Many of the magnetic lows appear to be generated by mafic rocks that show remanent magnetization of much greater magnitude than their induced magnetization. These remanent magnetic lows correlate spatially with their source rocks much more precisely than do other types of lows that commonly are paired with an adjacent anomaly, both being produced by a single source. These prominent anomalies correlate only in part with exposed rocks that are expected to be very strongly magnetic, especially the basalt. This lack of total correlation implies that subsurface hypabyssal feeders may underlie the basalt or that the basalt thickens preferentially over some ancient terranes. Finally, anomalies in the study area appear to coincide with those of a region where anomalies trending one direction change to a perpendicular direction.

Areas of greatest geophysical significance are shown in figure 4. Region I is nonmagnetic, correlating mainly with a tract mapped as rhyodacite and related volcanic rocks. This region might serve as a window to magnetic basement rocks that underlie the volcanic rock pile, thus permitting an estimate of the volcanic rock thickness. We

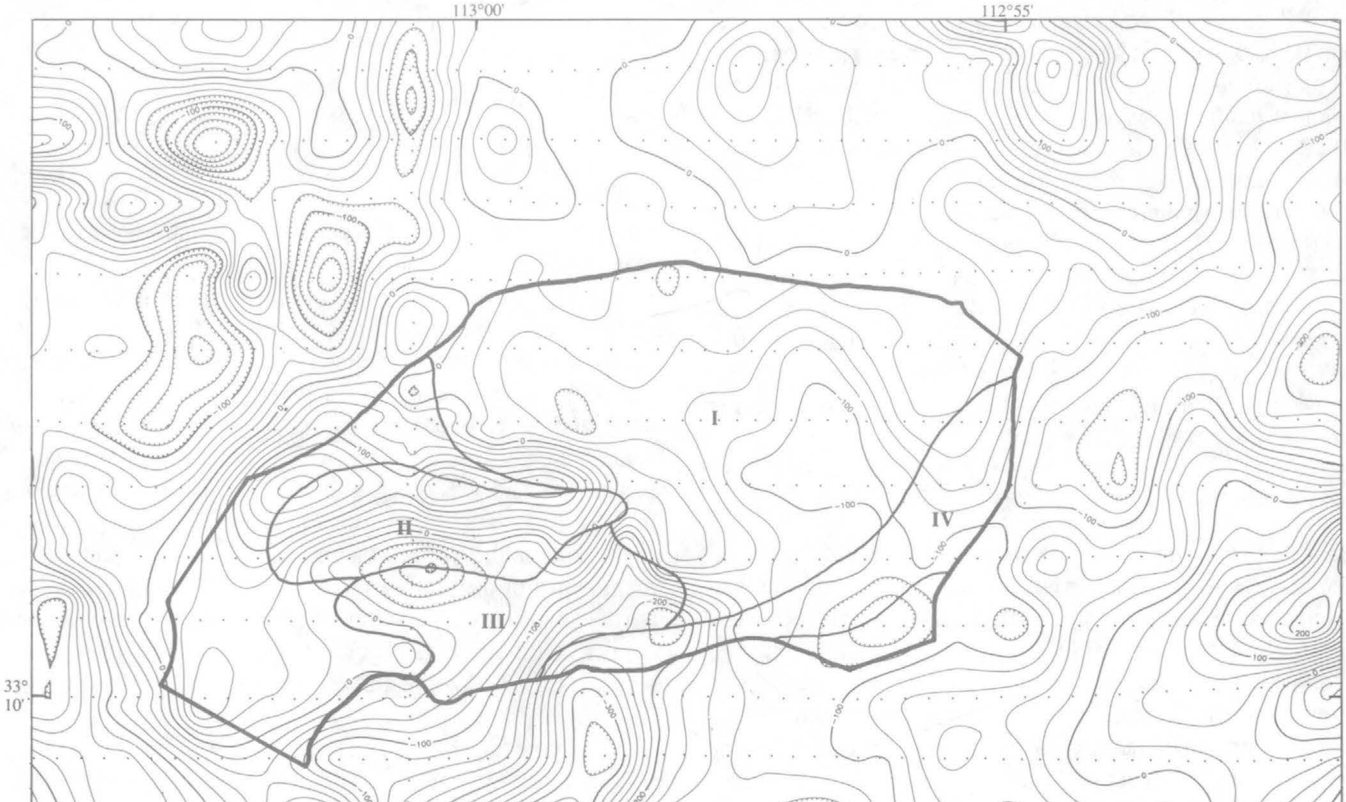


Figure 4. Aeromagnetic map of vicinity of Signal Mountain Wilderness Study Area, Maricopa County, Arizona (bold outline). Contour intervals 20 and 100 nanoteslas; hachures indicate closed areas of lower values. Numbered regions of geophysical significance discussed in text: I, nonmagnetic rocks; II, normally magnetized mafic rocks; III, rocks having short wavelengths; IV, reversely magnetized rocks.

tentatively infer a volcanic rock thickness here of about 1 mi.

Region II is underlain by normally magnetized mafic rock and transects mapped contacts between basalt, a mixture of silicic tuff and basalt, and Quaternary units. It is not known how much of this feature is directly attributable to surficial basalt, but, because the feature trends across mapped boundaries, it may be caused mainly by a subvolcanic unit, possibly 0.7 mi thick, most of which is buried to a depth of about 2,100 ft. This hypabyssal unit may be similar to the assumed basement rocks of region I. This prominent magnetic high has a distinctive east-west trend and separates northwest-trending anomalies to the northwest from northeast-trending anomalies to the southeast.

Region III is characterized by short-wavelength features directly associated with surficial basalt. If the basalt of this region has magnetic properties similar to the basalt a few miles to the southeast, its thickness ranges from less than 30 to about 75 ft. Some of the small circular features occur directly over mapped basalt while others occur over an area of Tertiary and Quaternary alluvium mixed with silicic tuff and basalt.

Region IV is underlain mostly by reversely magnetized mafic rock mapped as basalt. This region is represented by a northeast-trending belt of magentic lows that extends almost continuously northeastward to a small low associated with mapped Jurrasic diorite at Webb Mountain, about 1.7 mi northeast of the map area. The lows within region IV may be accounted for by basalt about 75 ft thick if its magnetic properties are similar to those of basalt a few miles to the southeast. However, the apparent continuity of this belt of lows to the region of diorite at Webb Mountain suggests the possibility that the belt of lows might represent a narrow zone of weakness through which intrusion or extrusion, or both, has recurred throughout a long period of geologic time.

Aerial Gamma-Ray Spectrometry

Aerial gamma-ray spectrometry measures the near-surface (0- to 20-in. depth) distribution of the natural radioelements potassium (K), equivalent uranium (eU), and equivalent thorium (eTh). Because this distribution is controlled by geologic processes, aerial gamma-ray measurements can be used in geologic mapping, mineral exploration, and understanding of geologic processes. Calibration of aerial systems at sites of known radioelement concentrations permits survey results to be reported in percentage for K and parts per million (ppm) for eU and eTh.

The spectrometry data discussed in this report were obtained by the NURE program of the U.S. Department of Energy (LKB Resources, 1979). NURE data acquistion was keyed to 1° by 2° topographic quadrangles, and flightline spacing was usually at 3-mi and 6-mi intervals. The coarse spacing means that the data are suitable for producing maps at scales of only 1:500,000 and smaller. All flight altitudes were 400 ft above ground level, which permits an aerial gamma-ray system to effectively detect terrestrial gamma radiation from a swath 800 ft wide along the flightline.

NURE data for Arizona and adjacent parts of California and New Mexico have been compiled and processed to produce sets of maps at scales of 1:500,000 and 1:1,000,000. They include contour maps and composite color-image maps, the latter produced as described by Duval (1983). Spectrometric data described in this report were derived from the NURE report for the Phoenix 1° by 2° quadrangle (LKB Resources, 1979).

The Signal Mountain Wilderness Study Area is characterized by radio-element concentrations of 1 to 1.5 percent K, 2 to 3 ppm eU, and 4 to 6 ppm eTh. These concentrations are determined from three NURE flightlines that transect the study area and provide sufficient control for defining radioelement distribution for the area. The concentrations detected are not anomalous for the Tertiary and Quaternary sedimentary and volcanic rocks that occur in the study area. The sparse flightline coverage of the study area, however, precluded deriving information on mineral resource potential from the aerial gamma-ray data.

CONCLUSIONS

Basalt and sand and gravel in the Signal Mountain Wilderness Study Area may be classified as inferred subeconomic resources for aggregate and fill, but other suitable material is available closer to potential markets.

There are no direct indications of mineral or energy resource potential, even though the area lies near an area characterized by hydrothermal vein or skarn (in carbonate-rich rock) deposits that contain silver, copper, lead, manganese, and gold. Geologic studies, geochemical sampling, examination of mines and prospects, and review of mine production and ore types indicate that these deposits are mainly associated with northwest-trending, high-angle faults that cut the Webb Mountain area. Because multi-element suites of anomalous elements occur in rocks 0.25 mi north of the study area, a low mineral resource potential for copper, lead, silver, and gold resources, certainty level B, was asssigned along 2 mi of the north boundary of the study area (fig. 2).

The potential for oil and gas resources in the study area is low, certainty level C. This evaluation is based on the absence of organic-rich rocks that might be a source of hydrocarbons and on the lack of suitable reservoir rocks.

Although hot springs occur in adjacent ranges to the south, no evidence of geothermal activity was seen in or near the study area. No geothermal leases exist in the Signal Mountain Wilderness Study Area. The area has low potential, certainly level B, for geothermal energy resources.

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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	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
UNKNOWN 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:

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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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Gray; others—MINERAL RESOURCES, SIGNAL MTN. WILDERNESS STUDY AREA, MARICOPA CO., ARIZ.—U.S. Geological Survey Bulletin 1702–C