Mineral Resources of the Mohave Wash Wilderness Study Area, Mohave County, Arizona

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Chapter A

Mineral Resources of the Mohave Wash Wilderness Study Area, Mohave County, Arizona

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U.S. GEOLOGICAL SURVEY BULLETIN 1704

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
HAVASU REGION, ARIZONA

U.S. 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 Mohave Wash Wilderness Study Area (AZ–050–007C/048/020–052), Mohave County, Arizona.

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Mineral Resources of the Mohave Wash Wilderness Study Area, Mohave County, Arizona

By James G. Evans, David R. Sherrod, Randall H. Hill, *and* Robert C. Jachens
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SUMMARY

Abstract

At the request of the U.S. Bureau of Land Management, the Mohave Wash Wilderness Study Area was evaluated for mineral resources and mineral resource potential. A total of 115,453 acres was originally requested but the entire wilderness study area has since been preliminarily recommended nonsuitable for wilderness by the U.S. Bureau of Land Management. Throughout this report, "wilderness study area" and "study area" refer only to that area for which a mineral survey was requested. The U.S. Geological Survey and the U.S. Bureau of Mines conducted geological, 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. In 1988, the Bureau of Land Management changed the status of the study area to nonsuitable, but the investigation was completed to provide mineral information necessary for the Congressional wilderness process. Prospecting has occurred in and near the study area, but there was no mining activity at the time of this investigation. A subeconomic resource of gold totaling 1,550 short tons (st) was identified. One large area in the south-central part of the study area has moderate potential for gold and silver. Five small areas (four in the eastern part and one in the west-central part of the study area) have low potential for gold, and one area in the east-central part of the study area has low potential for silver. The entire study area has low potential for oil and gas. Sand and gravel are also present in the study area. The study area has no potential for geothermal resources.

Manuscript approved for publication, December 28, 1990.

Character and Setting

The Mohave Wash Wilderness Study Area is located in west-central Arizona (Mohave County) and extends to within 10 mi of Lake Havasu City, Arizona (fig. 1). The study area has a total relief of 2,480 ft and includes a varied landscape of broad washes, narrow canyons, hills of low relief, and steep ridges. It is underlain by Proterozoic granitoids and gneiss that are partly covered by volcanic, volcaniclastic, and sedimentary rocks of Miocene and Pliocene(?) age and by Quaternary sand and gravel deposits (fig. 2) (see "Appendixes" for geologic time chart). Numerous faults cut the rocks of the study area.

Identified Mineral Resources

An inferred subeconomic gold resource of approximately 1,550 st was identified. Of this amount, 1,000 st average 0.06 troy ounces per short ton (oz/st), and 250 to 550 st average 0.15 oz/st. Sand and gravel suitable for road construction are present in the study area, but sufficient sand and gravel resources exist outside the study area to supply current and foreseeable needs.

Mineral Resource Potential

A large area in the south-central part of the Mohave Wash Wilderness Study Area has moderate mineral resource potential for gold and silver. Five small areas (four in the eastern part and one in the west-central part of the study area) have low mineral resource potential for gold. The gold occurs mostly in granite and gneiss containing quartz veins and as placer deposits (low potential) in fanglomerate in one area. A small area in the east-central part of the study area underlain by partially silicified granite and gneiss has low mineral resource potential for silver. The entire study area has low potential for oil and gas and no potential for geothermal resources. Mineral resource potential is shown in figure 2.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is the result of a cooperative effort by the U.S. Geological Survey and the U.S. Bureau of Mines. An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was

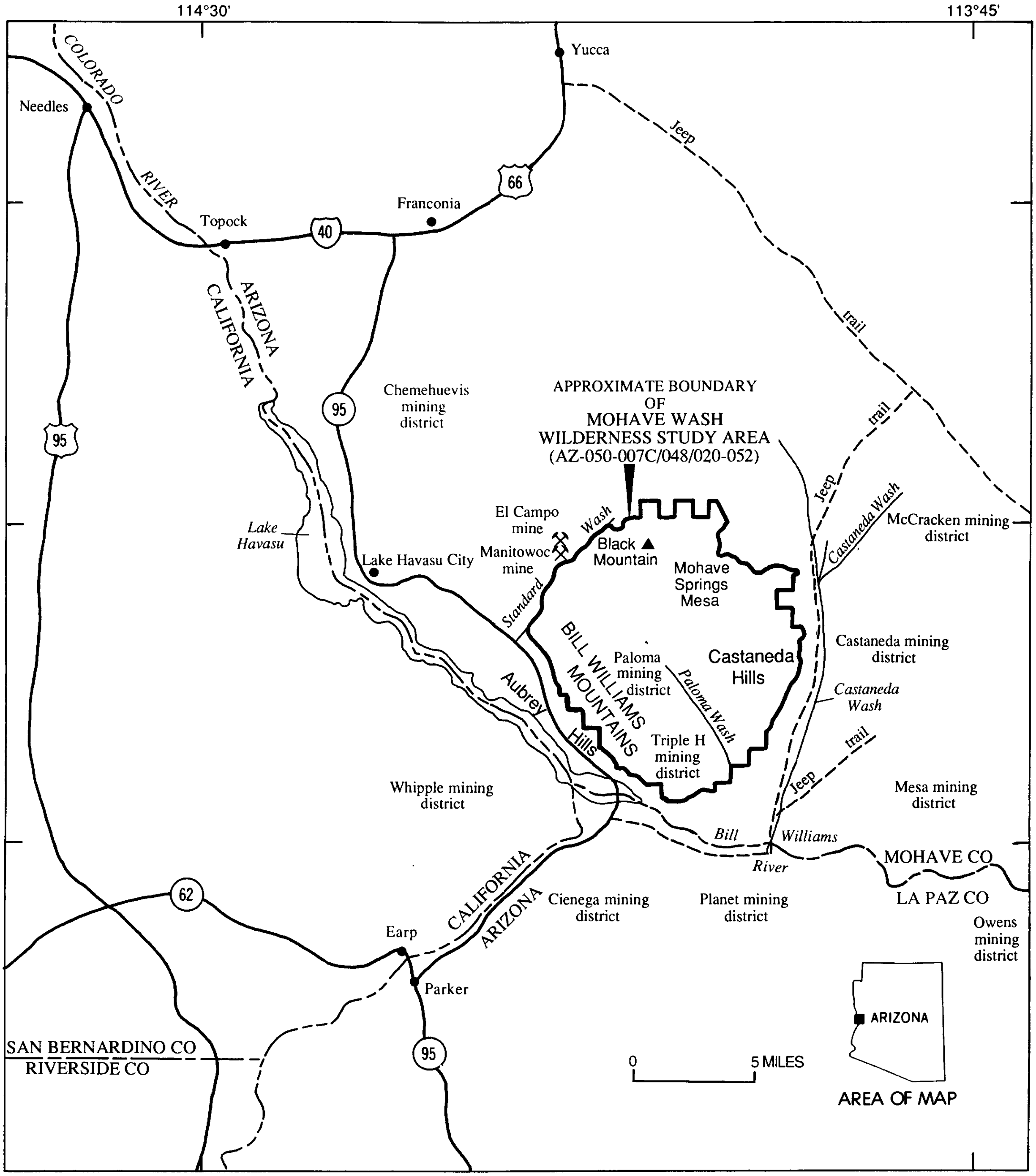

Figure 1. Index map showing location of Mohave Wash Wilderness Study Area, Mohave County, Arizona.

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 Mohave Wash Wilderness Study Area (AZ–050–007C/048/020–052) covers approximately 115,453 acres in the desert mountains east of Lake Havasu City, Ariz. (fig. 1). The terrain of the study area is generally rugged and rises from an altitude of about 480 ft on the Bill Williams River at the south margin of the study area along the boundary between Yuma and Mohave Counties to about 2,960 ft on Black Mountain in the north. The study area includes most of the Bill Williams Mountains and Castaneda Hills, Mohave Springs Mesa, and part of the Aubrey Hills. The varied landscape of the study area includes broad sandy washes, narrow twisting canyons, low hills, broad terraces, and steep rocky ridges. Although arid, the study area supports a variety of desert plants including native grasses, creosotebush, ocotillo, cactuses (several varieties ranging in size from small barrel cactus to saguaro as tall as 20 ft), and desert trees (ironwood, smoketree, catclaw, mesquite, and paloverde). Desert tortoises, coral snakes, gila monsters, numerous species of lizards, and four species of rattlesnakes inhabit the area; the desert tortoise is listed on the "Federal Register of Threatened and Endangered Species" in the "threatened" category. Wild burros, bighorn sheep, and deer are also present in the study area.

The southwest side of the study area is accessible from Arizona Highway 95. Dirt roads along Standard Wash on the northwest side and Castaneda Wash on the east provide additional access to the study area. Jeep trails follow the main washes through the study area.

Previous and Present Investigations

The geology of the study area is shown on the geologic map of Mohave County by Wilson and Moore (1959) and on the state geologic maps by Wilson and others (1969) and Reynolds (1988). The eastern part of the study area was mapped by Suneson and Lucchitta (unpub. data, 1980) and Lucchitta and Suneson (1988). The northwestern part of the study area was mapped by Howard and others (1990). Suneson and Lucchitta also studied the volcanism and tectonism of the study area and vicinity (Lucchitta and Suneson, 1977a, b, 1979; Suneson, 1980; Suneson and Lucchitta, 1978, 1979, 1983).

The U.S. Geological Survey carried out field investigations in the study area during 1987 to complete mapping and collect samples. Sherrod (1988) mapped the Monkeys Head 7.5-minute quadrangle, most of which is in the study area. Evans (unpub. data) mapped the northeastern part of the Gene Wash 7.5-minute quadrangle, which lies in the southwestern part of the study area, and studied the Proterozoic rocks of the study area. Samples of the Proterozoic rocks were collected for petrographic analysis. Geochemical data were obtained from 141 stream-sediment, 140 heavy-mineral-concentrate, and 198 rock samples (R.H. Hill, unpub. data, 1988).

Two geologists of the U.S. Bureau of Mines examined mines, prospects, and mineral occurrences in and near the study area in 1987 (McDonnell, 1989). One hundred and eighty-eight samples were collected from workings and mineralized areas.

APPRAISAL OF IDENTIFIED RESOURCES

By John R. McDonnell, Jr.
U.S. Bureau of Mines

Methods

This investigation included a review of literature related to the mineral resources and mining activity in and near the study area. Mining claim information and land status records were obtained from the Bureau of Land Management State Office in Phoenix, Ariz. Mineral information and production data were obtained from U.S. Bureau of Mines files and other sources. Mining claims and mineral occurrences were examined, and workings in the study area were surveyed by tape and compass, mapped, and sampled. All samples were analyzed for 34 elements by induced neutron activation, and they were analyzed for bismuth, copper, lead, molybdenum, and manganese by inductively coupled plasma–atomic emission spectrometry. Selected samples were also analyzed for gold by fire assay, for mercury by cold-vapor atomic absorption, and for barium by X-ray fluorescence. Analyses were performed by Bondar-Clegg, Inc., Lakewood, Colo. One sample of perlite was tested for quality by the Perlite Corp., Chester, Penn. Complete sample data are available for inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

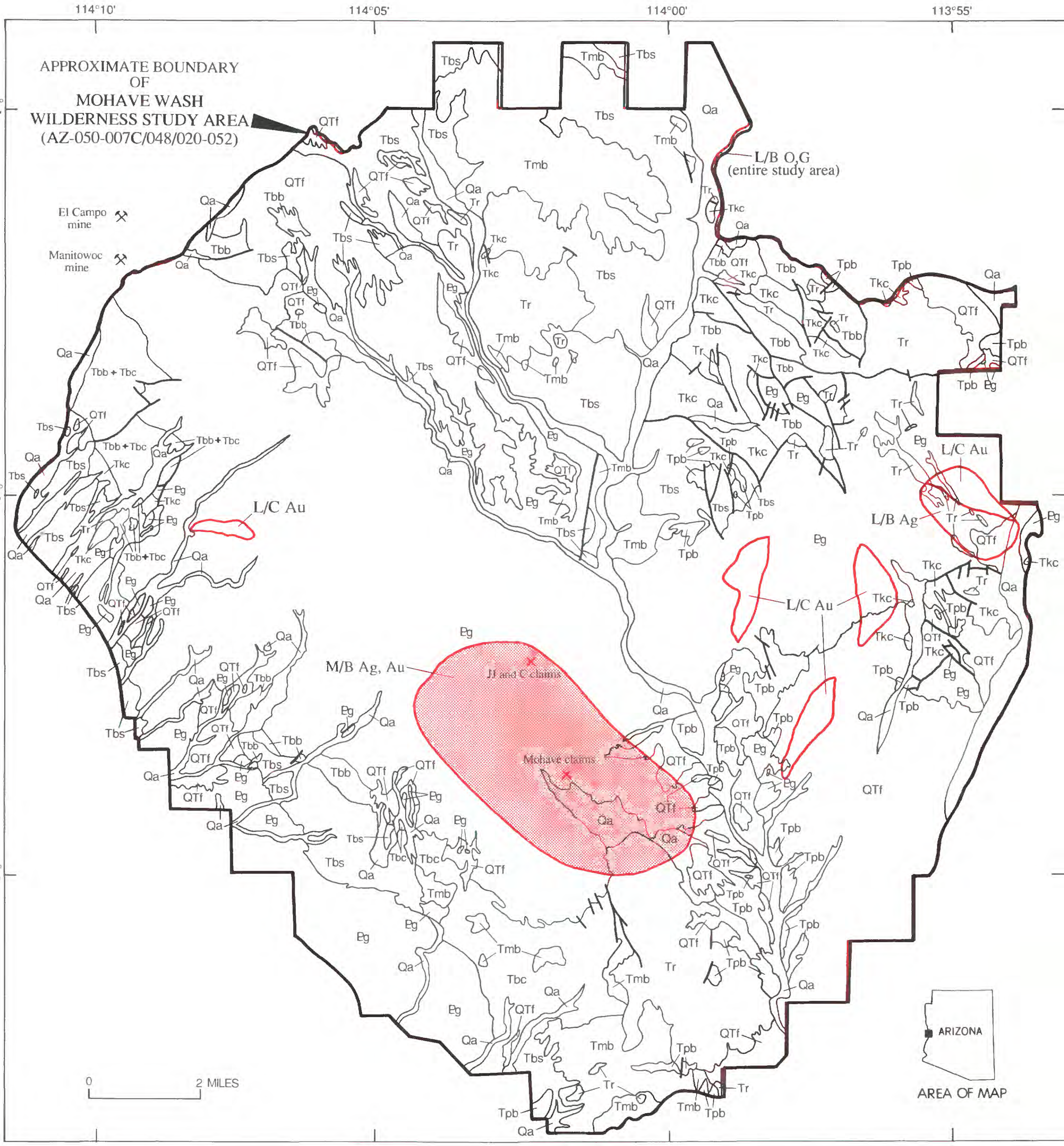

Figure 2. Mineral resource potential and generalized geology of Mohave Wash Wilderness Study Area, Mohave County, Arizona.

Mining History

Prospecting and mining have been intermittent in the study area and vicinity since the 1860's. The Paloma and Triple H mining districts lie within the study area, but neither has had recorded production. Districts within 3 to 8 mi of the study area have produced copper (Cienega, McCracken, Planet), gold (Chemehuevis, Cienega, Planet), lead (Chemehuevis, McCracken, Owens), manganese (Mesa, Planet), and silver (Chemehuevis, Cienega, McCracken, Owens, Planet) (fig. 1). Deposits in the districts formed along veins or as replacement bodies associated with fault zones (Lehman and others, 1987).

The Manitowoc and El Campo mines are just outside the northwest boundary of the study area (fig. 1). The Manitowoc mine comprises three lode claims that were patented in 1910 but have no recorded production. In a mineral resource study of the adjacent Crossman Peak Wilderness Study Area, Light and McDonnell (1983) suggested that silver and gold were the main mineral targets at the Manitowoc mine; minor amounts of lead and zinc may also have been recovered. The El Campo mine was reportedly worked during the 1930's as a placer gold deposit. No production is known, but Light and McDonnell (1983) suggested that minor amounts of gold flakes and nuggets may have been recovered. Unpatented placer and lode claims are located in the Paloma district in the south-central part of the study area. Placer claims are also scattered along the east side of the study area. No active mining operations were observed during the field investigation, but there is some prospecting and exploration activity in the study area.

No oil and gas discoveries or shows have been reported in or near the Mohave Wash Wilderness Study Area. Bureau of Land Management files show numerous oil and gas leases in the study area as of 1987. The impetus for leasing may have been speculation that the hydrocarbon-rich Idaho-Wyoming overthrust belt extends into Arizona.

EXPLANATION

[shaded box]	Area having moderate mineral resource potential (M)
[open box]	Area having low mineral resource potential (L)
×	Identified gold resource—See text for discussion
	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
O,G	Oil and gas
	Geologic map units
Qa	Alluvium (Holocene)
QTf	Fanglomerate (Pleistocene and Pliocene?)
Tpb	Porphyritic basalt (late Miocene)
Tmb	Mesa-capping basalt (late and middle Miocene)
Tr	Rhyolite (late and middle Miocene)—Flows, intrusions, and rhyolitic volcaniclastic rocks
Tbs	Breccia and sandstone (middle? Miocene)
Tbb	Basalt and basaltic andesite (middle and early Miocene)—Includes the 18-Ma Peach Springs Tuff of Young (1974)
Tkc	Arkose of Keenans Camp (middle and early Miocene)
Tbc	Breccia, conglomerate, and sandstone (early Miocene)
Ꝑg	Granitic rocks and gneiss (Proterozoic)
———	Contact
———	Fault

Figure 2.—Continued

Mineral Resources

Most of the mining and exploration activity in the study area has taken place in the Paloma district (fig. 1), which covers an area of 10 mi² underlain predominantly by Proterozoic granitoid rocks and gneiss. The rocks are faulted, and some faults served as conduits for hypogene siliceous gold-bearing solutions that deposited quartz veins containing gold and silver (Arizona Department of Mineral Resources, unpub. data, 1975). The veins are as thick as 12 ft and consist of massive white quartz; highly fractured, vuggy, silicified country rock; and quartz veinlets. During a study by the Arizona Department of Mineral Resources (unpub. data, 1975), two 100-lb samples and one 300-lb sample of vein material from unspecified localities in the Paloma district were submitted to the U.S. Bureau of Mines Research Center, Salt Lake City, Utah, for metallurgical testing. The tests showed that the veins are suitable to heap leaching of gold using a dilute cyanide solution and charcoal-in-pulp process.

Gold was detected in 127 of 146 samples during the U.S. Bureau of Mines' appraisal of workings and prospects in the Paloma district (McDonnell, 1989). Gold concentrations range from 0.005 to 28.1 ppm (0.00015 to 0.820 oz/st) and average 2 ppm. Forty-seven samples contain more than 1 ppm, and pinpoint-size gold was observed at three localities. The gold occurs in quartz veins that pinch and swell, are discontinuous in exposure, and were intermittently mineralized. The irregular nature of the veins precluded making resource estimates for most of the district, but the JJ and C and Mohave claims areas were exceptions.

In the JJ and C claims area (fig. 3), quartz veins pinch and swell to as thick as 2 ft and follow a fault zone that strikes N. 45° E. and dips 30° to 75° SE. in gneiss. Galena, pyrite, and minor amounts of malachite are present. Gold concentrations in samples taken from the veined and mineralized fault zone range from 0.003 to 0.657

oz/st. Using a projection that assumes the mineralized zone extends 15 ft up and downdip and 30 ft along strike to the southwest, an identified resource of about 1,000 st averaging 0.06 oz/st gold was estimated. The low resource value ($24,000 at $400/oz gold) makes economic extraction unfeasible except using small-scale mining methods.

In the Mohave claims area, the location of a quartz vein is identified by prospects and float in two segments totaling 280 ft along strike and may continue along strike for as much as 600 ft beneath alluvial cover. Eight samples of the vein vary in gold concentration from 0.034 to 0.312 oz/st. Tonnage and grade calculations were made for the two traced segments (280 ft) and for the estimated total projected length of the vein (600 ft) using a downdip extension of 15 ft. Identified resources were estimated to be 250 st averaging 0.16 oz/st gold for the traced segments, and 500 st averaging 0.14 oz/st gold for the total projected length of the vein. The low resource value ($16,000–$28,000 at $400/oz gold) makes economic extraction unfeasible, except using hand-sorting methods of mining.

The presence of lode gold and gold concentrations reported in unpublished data from the Arizona Department of Mineral Resources suggest that placer gold may be present in the alluvium of the Paloma district. Information from claimants Milton Fuller (written commun., 1988) and S.E. Ashcraft (written commun., 1988) show prospecting results favorable for placer gold and silver occurrences on the east side of the study area, and four panned-concentrate samples taken by U.S. Bureau of Mines personnel from drainages in the western and eastern parts of the study area contain low concentrations of gold (9 to 35 ppb). These results suggest that placer gold occurrences could exist along the eastern and western parts of the study area.

Sand and gravel occurs in drainages throughout the study area. Sand and gravel from Standard Wash along the northwest boundary of the study area has been used for road base. The Arizona Department of Transportation dug 61 test pits along Standard Wash just outside the study area (N½ sec. 31, and SE¼ sec. 30, T. 13 N., R. 18 W.) in 1986 and evaluated the sand and gravel for possible use in rebuilding Arizona Highway 95. The material is suitable for road gravel and will be made available to the contractor who rebuilds the highway (R.W. Krohn, Arizona Department of Transportation, written commun., 1988). Inferred resources of sand and gravel of similar quality are probably present in the study area, but sufficient material exists outside the study area to supply current and foreseeable needs.

A sample was taken from a 40-ft-long, 15-ft-wide outcrop of perlite in the northeastern part of the study area near the north boundary and sent to the Perlite Corp., Chester, Penn., for testing. The sample expands uniformly (either well or poorly), contains a high proportion of unexpandable material, and could be used to make some expanded perlite end-products, but it generally would not compete favorably with other commercially available ores. Because of the small exposure of perlite, no resource was estimated.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology

The Mohave Wash Wilderness Study Area is underlain by Proterozoic granitic rock and gneiss and Miocene through Quaternary sedimentary, volcanic and volcaniclastic rock, and alluvium. Geology is generalized from N.H. Suneson and Ivo Lucchitta (unpub. data, 1980), Lucchitta and Suneson (1988), Howard and others (1990), Sherrod (1988), and Evans (unpub. data, 1988).

The oldest unit in the study area consists of granitic rock and gneiss (Pg, fig. 2). The granitic rock is medium to coarse grained, commonly porphyritic, hypidiomorphic-granular, and ranges in composition from quartz diorite to quartz alkali feldspar granite. The granite contains distinctive phenocrysts of potassium feldspar as long as 2 in. The gneiss is generally fine to medium grained and locally contains conspicuous feldspar augen as long as 4 in. The unit also includes biotite schist, muscovite schist, amphibolite, cataclasite, and mylonite. Granitic rock is most common in the northwestern and southwestern parts of the study area. Gneiss makes up most of the central and eastern parts of the study area. The composition of the gneiss is typically quartz diorite to granodiorite.

Granite that has been dated near the study area indicates an age of about 1.3 billion years before present (Ga) (Parker Dam, 2 mi southwest of the study area, 1.326±0.59 Ga; Hualapai Mountains, 30 mi north of the study area, 1.335±0.23 Ga and 1.367±0.69 Ga; Anderson, 1983). The Signal Granite (Lucchitta and Suneson, 1982), which has an age of 1.410±0.003 Ga (Gray and others, unpub. data) crops out 6 mi east of the study area.

The granite and gneiss unit is cut by numerous granitic, pegmatite, hornblendite, andesite, basalt, and rhyolite dikes. The pegmatite dikes are commonly granitic and are conspicuous because the quartz, plagioclase, and potassium feldspar grains are as much as 1 ft across. Some pegmatite dikes, which intrude muscovite schist bodies in the gneiss, lack potassium feldspar but contain lepidolite as well as 6-in.-wide muscovite books. Veins of white quartz and calcite and brown siderite are locally common in the granite and gneiss unit. Magnetite and the silicate mafic minerals in the unit that are altered to hematite give much of the rock a red-brown color. The alteration is intense in and near Tertiary fault zones and also in zones that may mark Tertiary paleodrainages.

Sedimentary breccia, conglomerate, and sandstone (Tbc, fig. 2) overlie the granitic rock and gneiss. The breccia consists of two types, polymictic and monolithologic. The polymictic breccia contains blocks of gneiss as much as 30 ft across and smaller blocks as much as 3 ft long of quartzofeldspathic schist, phyllite, limestone, quartzite, quartzite and limestone conglomerate, and granite. The monolithologic breccia is the breccia of Ester Basin of Suneson (1980) and N.H. Suneson and Ivo Lucchitta (unpub. data, 1980) that consists mostly of angular meta-andesite clasts. The breccia, which is unstratified, unsorted, and moderately to poorly indurated, is interpreted as large, possibly catastrophic landslide deposits formed during Miocene extensional faulting. The granule-to-boulder conglomerate is poorly consolidated and moderately well stratified. Clasts, mostly of the underlying granite and gneiss but including rhyolite, basalt, and quartzite, are well rounded and are locally as much as 3 ft across. The sandstone is arkosic and contains beds of grit, pebbly grit, limestone, white gypsiferous sandstone, and siltstone. These sedimentary rocks are interbedded with the oldest basalt (lower Miocene) exposed in and near the study area and are presumably of early Miocene age.

The breccia, conglomerate, and sandstone unit is overlain by the Arkose of Keenans Camp (Tkc, fig. 2; Suneson, 1980; N.H. Suneson and Ivo Lucchitta, unpub. data, 1980). The lower part of the unit is a red-brown, well-stratified, locally tuffaceous, coarse-grained sandstone interbedded with pebble and cobble conglomerate that, in places, grades upward to sandstone and siltstone. The upper part of the unit is light colored, poorly consolidated sandstone with local layers of boulder conglomerate. Clasts consist of granitic rock, gneiss, basalt, metavolcanic rock, quartzite, and diabase. The Arkose of Keenans Camp interfingers with basalt and basaltic andesite dated at early to middle Miocene.

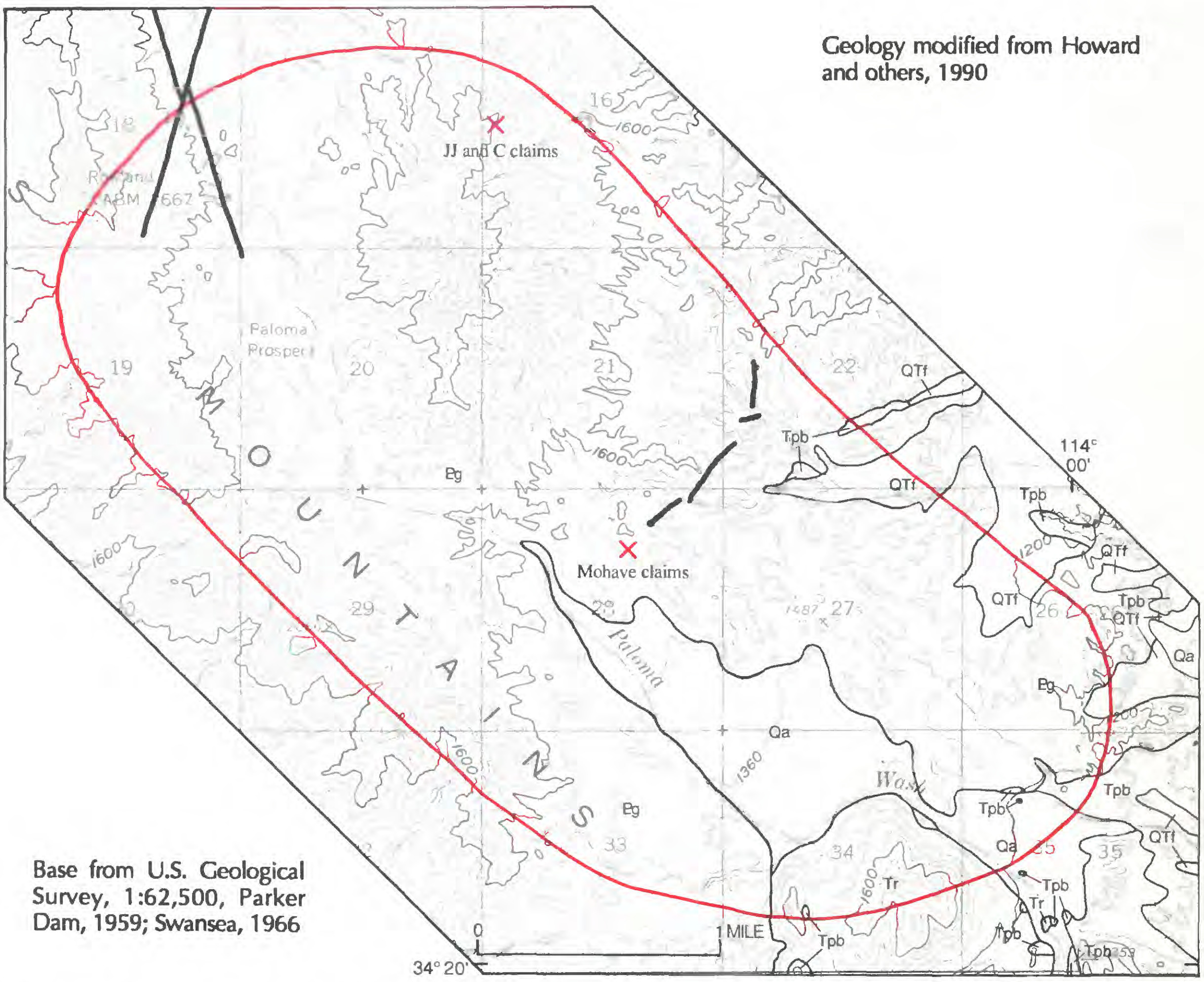

Figure 3. Generalized geology near the JJ and C and Mohave claims areas in Mohave Wash Wilderness Study Area, Mohave County Arizona. Red outline denotes moderate potential for gold and silver. See figure 2 for explanation. Contour interval 40 feet.

Basalt and basaltic andesite (Tbb, fig. 2) overlie and are locally interlayered with the sedimentary breccia, conglomerate, and sandstone unit and the Arkose of Keenans Camp. This sequence of mafic flows and flow breccia has a maximum thickness of 980 ft. Vent rocks are poorly sorted breccias of angular blocks as much as 6 ft long in a matrix of comminuted mafic debris. As mapped, the basalt and basaltic andesite unit includes thin interbeds of conglomerate, sandstone, and an unwelded biotite-bearing silicic ash-flow tuff. The unit also includes the Peach Springs Tuff of Young (1974), which conformably overlies the basalt in the southwestern part of the study area. The Peach Springs Tuff is a pale pink, moderately to densely welded ash-flow tuff with a thickness of 65 to 200 ft. The basalt in and near the study area has been dated at early to middle Miocene (K-Ar (potassium-argon) method, 18.7+0.3 million years before the present (Ma), 16.5±0.2 Ma, Suneson, 1980, p. 184). Samples of the Peach Springs Tuff from the region yield ages of 20.5±0.5 Ma to 16.2±0.4 Ma with a mean age of 18.2 Ma (K-Ar method, Glazner and others, 1986). Therefore, the basalt and basaltic andesite unit is assigned an early to middle(?) Miocene age in this report.

A clastic sedimentary unit composed principally of poorly to moderately bedded, poorly to moderately sorted breccia and sandstone (Tbs, fig. 2) overlies the Peach Springs Tuff, basalt, and basaltic andesite. The clastic unit locally contains well-sorted eolian sandstone and is well cemented by calcite in places. Local angular unconformities within the clastic unit indicate syntectonic deposition.

Numerous small rhyolitic lava flows, domes, dikes, and silicic pyroclastic and other volcaniclastic rocks (Tr, fig. 2) intrude and overlie the basalt and basaltic andesite unit. The pyroclastic rocks consist of well-stratified to massive ash to lapilli tuff, thick-bedded air-fall tuff, and minor amounts of ash-flow tuff. Other volcaniclastic rocks in the unit are principally tuffaceous sandstone. Age range of the rhyolite in the Castaneda Hills quadrangle is 15.1±0.1 to 10.3±0.1 Ma (Suneson and Lucchitta, 1979). Samples from the wilderness study area are 13.1±0.1 to 10.3±0.1 Ma, or middle to late Miocene.

Mesa-capping basalt (Tmb, fig. 2) forms flows that are 3 to 15 ft thick and breccia 3 to 10 ft thick. The basalt contains as much as 10 percent phenocrysts of plagioclase and olivine altered to iddingsite; the rock also contains xenocrysts of quartz. Ages of three of these basalts from the study area are middle to late Miocene (13.1±0.2, 13.0±0.5, and 9.2±0.2 Ma, K-Ar method, Suneson and Lucchitta, 1979).

Porphyritic basalt, the youngest basalt unit of the study area (Tpb, fig. 2), contains conspicuous phenocrysts of plagioclase as much as 1 in. across and minor amounts of plagioclase megacrysts as long as 3 in. Other phenocrysts include clinopyroxene, olivine, spinel, and magnetite. Samples of the unit have been dated at 7.7±0.5 to 6.8±0.2 Ma; two samples, both dated at 7.5±0.2 Ma were taken from the study area (K-Ar method, Suneson and Lucchitta, 1979). On the basis of these K-Ar ages, the basalt is assigned a late Miocene age.

The porphyritic basalt and older rocks are overlain by fanglomerate that consists of poorly to moderately indurated, poorly bedded to massive, poorly sorted sand, gravel, cobbles, and boulders that underlie pediment slopes and fill the present basins (QTf, fig. 2). The deposits include inactive stream channels and are 5 to 100 ft thick. Soil horizons are locally developed on top, and thin tuff beds are present in places. The unit is mostly Pleistocene in age, but some of the older, higher (more uplifted) deposits may be Pliocene.

Alluvium (Qa, fig. 2) consists of unconsolidated silt, sand, gravel, cobbles, and boulders of active stream channels, narrow stream terraces throughout the study area that are less than 3 ft above stream channels, and floodplain deposits along the Bill Williams River. The alluvium is Holocene in age.

Structure

The entire study area is in the upper plate of the low-angle Rawhide detachment fault that is exposed in the Rawhide Mountains 5 mi south of the study area. The upper plate moved northeast (Shackelford, 1980). The study area is in the 60-mi-wide Colorado River extensional corridor across which slip on all faults is estimated to total about 30 mi (Howard and John, 1987). Inception of movement was during the Tertiary, but the precise age is not known. Suneson and Lucchitta (1983), however, suggest that most movement on the Rawhide detachment fault and related listric faults occurred after eruption of the oldest basalts in the region (18.7 and 16.5 Ma) and ceased by 14 Ma. The period of detachment faulting was succeeded by development of steep normal faults, most of which strike northwest. The normal faults may have been active until about 7 Ma, as suggested by the undeformed porphyritic basalts dated at about 7 Ma, which lie 7 mi west of the study area. Several steep northeast-striking faults offset the northwest-striking normal faults.

The southeast margin of the study area is on the northeast flank of the Bill Williams River fault zone, a feature that extends along the Bill Williams River and the Aubrey Hills for about 15 mi. It is a right-lateral strike-slip fault zone that cuts intensely fractured pre-Tertiary and Tertiary rocks in the Aubrey Hills. Cumulative right-lateral separation of about 0.6 mi on the fault zone probably occurred between late Miocene and latest Pliocene time.

Geochemical Studies

A reconnaissance geochemical survey conducted in the Mohave Wash Wilderness Study Area consisted of the collection and analysis of stream sediments, panned concentrates, and of fresh and altered rock samples. The sample media consisted of 141 minus-60-mesh stream-sediment samples collected from active alluvium and 140 heavy-mineral panned concentrates derived from stream sediment. Rock samples include 80 fresh, unaltered rock samples representative of units exposed in the study area, 115 samples of altered Proterozoic rock to determine the kind of mineralization, if any, that may be related to the alteration; 3 mine-dump samples were also collected to provide some general information on mineralization.

Stream sediments represent a composite of rock and soil exposed upstream from the sample site. Heavy-mineral concentrates represent a concentration of ore-forming and ore-related minerals that permits determination of some elements that are not easily detected in bulk stream sediments. Studies have shown that heavy-mineral concentrates derived from stream sediments are a useful sample medium in arid and semiarid environments or in areas of rugged topography where mechanical erosion is more prevalent than chemical erosion (Bugrov and Shalaby, 1975; Overstreet and Marsh, 1981).

The stream sediments, nonmagnetic heavy-mineral concentrates, and rocks were analyzed for 31 elements using a semiquantitative direct current arc emission spectrographic method (Grimes and Marranzino, 1968). In addition, rock and stream-sediment samples were analyzed for arsenic, antimony, bismuth, cadmium, and zinc by flame atomic–absorption spectroscopy (O'Leary and Meier, 1984). Rock samples were analyzed for gold by flame atomic–absorption spectroscopy. Stream-sediment samples were analyzed for gold by electrothermal atomic–absorption spectroscopy (Hubert and Chao, 1985). Uranium analyses were done by a fluorimetric method (O'Leary and Meier, 1984).

The study area contains anomalous concentrations of several elements, of which arsenic, barium, copper, gold, silver, tin, tungsten, and zinc were judged to be related to possible mineralization. Threshold values, defined as the upper limit of normal background values, were determined for each element by inspection of histograms for all sample media except the mine-dump and altered Proterozoic rock samples. A geochemical value higher than the threshold value is considered anomalous and may indicate mineralization.

The distribution of anomalous concentrations of arsenic, barium, copper, gold, molybdenum, silver, tin, tungsten, and zinc is irregular; few patterns are clear. Barium tends to occur in anomalous concentrations in the southern part of the study area that is mostly underlain by Tertiary sedimentary and volcanic rocks. Because these rocks are devoid of bedded barite deposits, the barium must be derived from either barite veins or authigenic barite in the clastic rocks, or from barite reconcentrated as a result of Holocene erosion and transportation.

Gold was detected in minus-60-mesh stream-sediment samples from five drainages in the study area. Four of the drainages are in the east-central part of the study area. Three of these drainages are underlain mostly by Proterozoic rocks; the fourth drainage is underlain by Tertiary fanglomerate. The fifth drainage in which gold was detected is in the west-central part of the study area in Proterozoic rock. Although the gold concentrations in the samples are low (0.006 to 0.026 ppm), these values are above crustal abundance (Simons and Prinz, 1973) and indicate the presence of rocks containing more than average gold content in the four drainages underlain by Proterozoic rock and placer deposits in the drainage underlain by fanglomerate. The gold in the drainages underlain by Proterozoic rock is associated with anomalous concentrations of one or more of the following elements: barium, lead, tin, and tungsten.

The Paloma district (fig. 1) has veins containing gold and silver in Proterozoic rock (gold as much as 28.1 ppm and silver as much as 654 ppm; maximum values from U.S. Bureau of Mines samples). No stream-sediment or panned-concentrate samples from the district contain gold or silver. A panned concentrate from outside the district at the mouth of Paloma Wash contains 0.4 ppm gold, which probably reflects the gold eroded from the district. Areas in the Paloma district are anomalous in one or more of the following elements: barium, lead, tin, and tungsten. The district also contains rocks that have anomalous concentrations of arsenic, copper, molybdenum, and zinc.

Most samples containing gold and silver are from the Proterozoic rock unit. One sample of fractured Miocene basalt containing calcite amygdules on the west edge of the study area, however, contains 0.23 ppm gold, as well as 20,000 ppm copper and 20 ppm molybdenum. Geochemical data do not suggest widespread gold or other mineralization elsewhere in Tertiary volcanic or other rocks.

Silver concentrations as high as 15 ppm occur in silicified Proterozoic rock and siderite veins in the east-central part of the study area (fig. 2). The silicified Proterozoic rock occurs at the contact with the Tertiary(?) and Quaternary fanglomerate and may be part of a broader zone of silicification that is buried. The silver in the silicified rock is associated with high concentrations of copper (greater than 20,000 ppm). Other rocks containing silver also contain anomalous concentrations of one or more of the following elements: lead, tungsten, and zinc.

Silver also occurs in rock samples from scattered isolated localities along the south and west boundaries of the study area. Most of these samples are from the Proterozoic rock unit. A few are from the Tertiary conglomerate. Geochemical data do not indicate widespread silver mineralization near these anomalous samples.

Geophysical Studies

Gravity and magnetic data from western Arizona were compiled and examined to aid in the assessment of the mineral resource potential of the Mohave Wash Wilderness Study Area. Limited gravity data useful for addressing the regional structural and tectonic setting of the study area are available, but they are inadequate for delineating mineral deposits that may be present.

Gravity data for the Mohave Wash Wilderness Study Area and vicinity were obtained from Mariano and others (1986), and J.D. Hendricks (written commun., 1987). Gravity stations are scattered at 1- to 3-mi intervals in the vicinity of the study area, and about 50 stations are within the study area boundary. The observed gravity data, based on the International Gravity Standardization net datum (Morelli, 1974), were reduced to free-air gravity anomalies using standard formulas (Telford and others, 1976). Bouguer, curvature, and terrain corrections (to a distance of 103.6 mi from each station) at a standard reduction specific gravity of 2.67 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 related to the near-surface geology but also deep-crustal density distributions that support the topography in a manner consistent with the concept of isostasy. To isolate that part of the gravity field arising 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 crust-mantle interface assuming Airy-type isostatic compensation (Jachens and Griscom, 1985).

The residual gravity field over the study area is dominated by a curvilinear high, about 6 mi wide, that trends roughly east-west and is centered over the large exposure of Proterozoic granitic and gneissic rock that occupies the central part of the study area. Gravity values are not uniformly high over outcrops of Proterozoic rock but rather decrease by as much as 10 milligals (mGal) both north and south of the central high. The lowest gravity value in the study area occurs over the mesa-capping basalt on Black Mountain (Tmb) near the north boundary of the study area. Other low gravity values occur over nearby Tertiary volcanic rocks and form a roughly circular, 6-mi-diameter low that is open to the northeast. Total gravity relief is about 20 mGal.

The curvilinear gravity high primarily reflects density distributions within the crystalline basement and could indicate a central zone of dense Proterozoic gneiss flanked on the north, south, and east by less dense Proterozoic granitoids. The volcanic rock in the northern part of the study area causes part of the northward decrease in gravity but probably contributes no more than 5 mGal to the total relief.

The regional context of the gravity high over the study area suggests that it may be partly caused by sources other than the Proterozoic rock. This high lies at the south end of a long narrow gravity high that follows the Colorado River trough northward for a distance of more than 125 mi. This high culminates over many of the metamorphic core complexes along the river. Extensive density sampling across this feature at three locations north of the study area indicates that density variations within the main mass of crystalline country rock are not adequate to explain the gravity anomalies at these places. However, mafic dikes of probable Tertiary age occur beneath the axis of the high with densities sufficiently high that large concealed volumes of this material could account for the observed anomaly.

Detailed aeromagnetic data are available along profiles spaced about 0.5 mi apart for that part of the study area west of long. 114° W. (Prescott 1° by 2° quadrangle) and along profiles spaced about 1 mi for the rest of the area (Needles 1° by 2° quadrangle). An aeromagnetic survey of the Prescott quadrangle was flown in 1977 and compiled by Western Geophysical Company of America under contract to the U.S. Department of Energy as part of the National Uranium Resource Evaluation (NURE) program (U.S. Department of Energy, 1979). Total-field magnetic data over the study area and surrounding areas of Arizona were collected along east-west flightlines spaced approximately 1 mi apart and at a nominal height of 400 ft above the ground surface. Corrections were applied to the data to compensate for diurnal variations of the Earth's magnetic field, and the International Geomagnetic Reference Field (updated to the month that the data were collected) was subtracted to yield a residual magnetic field that primarily reflects the distribution of magnetite in the underlying rocks.

An aeromagnetic survey of the Needles quadrangle was flown in 1980 and compiled by Applied Geophysics, Inc., under contract to the U.S. Geological Survey (U.S. Geological Survey, 1981). Total-field magnetic data were collected along east-west flightlines spaced approximately 0.5 mi apart and at a nominal height of 1,000 ft above the ground surface. These data were processed in a manner similar to the data from the Prescott quadrangle to yield a residual magnetic field.

The residual magnetic map indicates that although both Proterozoic crystalline rock and Tertiary volcanic rock cause magnetic anomalies over the study area, the strongest anomalies occur over outcrops of Proterozoic rock. The magnetic data over the extensive exposure of Proterozoic rock reflect a well-defined boundary between weakly magnetic rock to the north and strongly magnetic rock in the central and southern parts of the study area. The magnetic body is spatially correlated with the gravity high in the eastern and western parts of the study area but lies to the south of the high in the central part. The magnetic boundary extends outside the study area to the northwest where it passes beneath part of the Chemehuevis mining district and within 1 mi of the Manitowoc and El Campo mines. Within the study area, the boundary passes beneath the Paloma district. No magnetic anomalies clearly associated with other nearby mining districts (McCracken, Owens, Mesa, and Castaneda) project into the study area.

Mineral and Energy Resource Potential

The results of geochemical sampling suggest that there is low mineral resource potential for gold in four areas in the eastern part and one area in the west-central part of the study area (fig. 2). This potential is suggested by anomalous concentrations of gold in minus-60-mesh stream-sediment samples. The potential is low because no rocks containing gold were found in these areas. A certainty level of C is assigned because the rocks are generally well exposed.

A small area in the east-central part of the study area has low mineral resource potential for silver. This potential is suggested by nine altered rock and vein samples that contain anomalous amounts of silver. A certainty level of B is assigned because, although the rocks are well exposed, altered rock is projected to underlie Tertiary and Quaternary units on the east side of the area of potential. Therefore, the rock samples only suggest the level of potential.

A moderate resource potential for gold and silver is suggested for the Paloma district (fig. 1) in the south-central part of the study area beyond the claims at which resources were identified. The potential is suggested by numerous rock samples containing gold and silver. The potential is moderate because the gold- and silver-bearing quartz veins and similar quartz veins that were not sampled are locally abundant in the district. A certainty level of B is assigned because the analyses of rock samples only suggest the level of potential.

The anomalous amounts of arsenic, barium, copper, lead, molybdenum, tin, tungsten, and zinc that accompany some of the gold and silver suggest epithermal alteration, but they do not form concentrations sufficiently large to suggest the possibility of deposits.

Ryder (1983) assessed the oil and gas potential of the study area as zero to low because the Proterozoic crystalline rocks underlying much of the wilderness study area are not conducive to the accumulation of hydrocarbons. The resource potential for oil and gas is low, certainty level B, for the entire study area.

No geothermal resources were found in or adjacent to the study area (Witcher and others, 1982; Muffler, 1979). Although the study area contains numerous rhyolite and basalt intrusions and the study area is in a region judged to have undergone greater than normal heat flow during the Miocene to early Pliocene, the Miocene intrusions in the study area are small and the entire region has most likely cooled to near ambient temperature since the early Pliocene. Therefore, there is no potential 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 ↑

<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td rowspan="4">U/A

UNKNOWN POTENTIAL</td><td>H/B
HIGH POTENTIAL</td><td>H/C
HIGH POTENTIAL</td><td>H/D
HIGH POTENTIAL</td></tr>
<tr><td>M/B
MODERATE POTENTIAL</td><td>M/C
MODERATE POTENTIAL</td><td>M/D
MODERATE POTENTIAL</td></tr>
<tr><td rowspan="2">L/B
LOW POTENTIAL</td><td rowspan="2">L/C
LOW POTENTIAL</td><td>L/D
LOW POTENTIAL</td></tr>
<tr><td>N/D
NO POTENTIAL</td></tr>
</table>

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.

SELECTED SERIES OF U.S. GEOLOGICAL SURVEY PUBLICATIONS

Periodicals

Earthquakes & Volcanoes (issued bimonthly).
Preliminary Determination of Epicenters (issued monthly).

Technical Books and Reports

Professional Papers are mainly comprehensive scientific reports of wide and lasting interest and importance to professional scientists and engineers. Included are reports on the results of resource studies and of topographic, hydrologic, and geologic investigations. They also include collections of related papers addressing different aspects of a single scientific topic.

Bulletins contain significant data and interpretations that are of lasting scientific interest but are generally more limited in scope or geographic coverage than Professional Papers. They include the results of resource studies and of geologic and topographic investigations; as well as collections of short papers related to a specific topic.

Water-Supply Papers are comprehensive reports that present significant interpretive results of hydrologic investigations of wide interest to professional geologists, hydrologists, and engineers. The series covers investigations in all phases of hydrology, including hydrogeology, availability of water, quality of water, and use of water.

Circulars present administrative information or important scientific information of wide popular interest in a format designed for distribution at no cost to the public. Information is usually of short-term interest.

Water-Resources Investigations Reports are papers of an interpretive nature made available to the public outside the formal USGS publications series. Copies are reproduced on request unlike formal USGS publications, and they are also available for public inspection at depositories indicated in USGS catalogs.

Open-File Reports include unpublished manuscript reports, maps, and other material that are made available for public consultation at depositories. They are a nonpermanent form of publication that may be cited in other publications as sources of information.

Maps

Geologic Quadrangle Maps are multicolor geologic maps on topographic bases in 7 1/2- or 15-minute quadrangle formats (scales mainly 1:24,000 or 1:62,500) showing bedrock, surficial, or engineering geology. Maps generally include brief texts; some maps include structure and columnar sections only.

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Miscellaneous Investigations Series Maps are on planimetric or topographic bases of regular and irregular areas at various scales; they present a wide variety of format and subject matter. The series also includes 7 1/2-minute quadrangle photogeologic maps on planimetric bases which show geology as interpreted from aerial photographs. Series also includes maps of Mars and the Moon.

Coal Investigations Maps are geologic maps on topographic or planimetric bases at various scales showing bedrock or surficial geology, stratigraphy, and structural relations in certain coal-resource areas.

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Hydrologic Investigations Atlases are multicolored or black-and-white maps on topographic or planimetric bases presenting a wide range of geohydrologic data of both regular and irregular areas; principal scale is 1:24,000 and regional studies are at 1:250,000 scale or smaller.

Catalogs

Permanent catalogs, as well as some others, giving comprehensive listings of U.S. Geological Survey publications are available under the conditions indicated below from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225. (See latest Price and Availability List.)

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