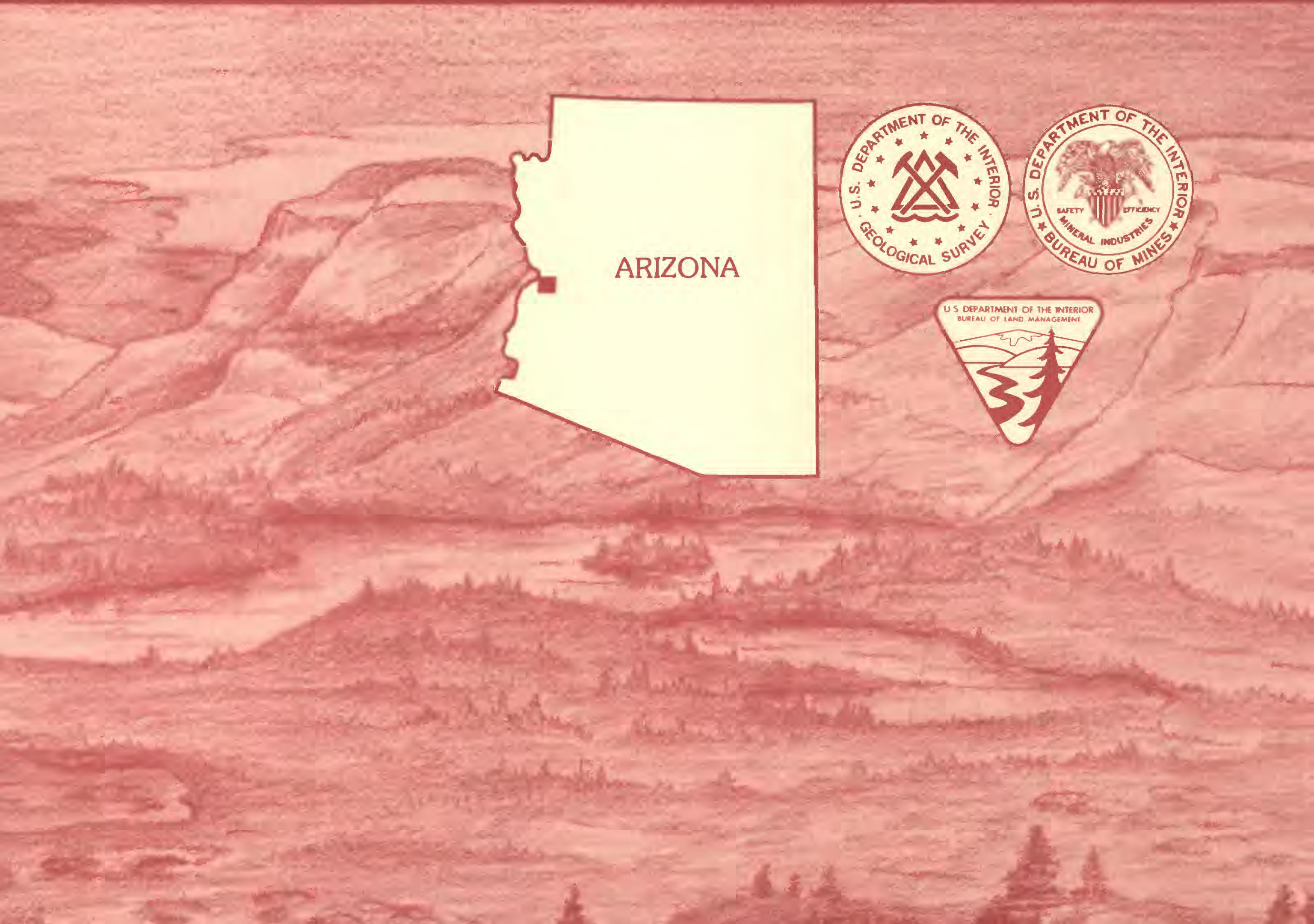
Mineral Resources of the Gibraltar Mountain and Planet Peak Wilderness Study Areas, La Paz County, Arizona

U.S. GEOLOGICAL SURVEY BULLETIN 1704-B



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Chapter B

Mineral Resources of the Gibraltar Mountain and Planet Peak Wilderness Study Areas, La Paz 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 parts of the Gibraltar Mountain (AZ–050–012) and Planet Peak (AZ–050–013) Wilderness Study Areas, La Paz County, Arizona.

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Mineral Resources of the Gibraltar Mountain and Planet Peak Wilderness Study Areas, La Paz County, Arizona

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SUMMARY

Abstract

The parts of the Gibraltar Mountain (AZ–050–012) and Planet Peak (AZ–050–013) Wilderness Study Areas for which mineral surveys were requested by the U.S. Bureau of Land Management encompass 18,807 and 16,430 acres, respectively, in west-central Arizona. Throughout this report, reference to those specific areas, or to the "study areas" refers only to those parts of the wilderness study areas for which mineral surveys were requested. Field work was carried out during the winter and spring of 1988 by the U.S. Bureau of Mines and the U.S. Geological Survey to appraise the identified (known) resources and assess the potential for undiscovered mineral resources in the study areas.

The study areas lie within a region containing well-developed detachment faults, including the Buckskin-Rawhide detachment fault that is present in and adjacent to the study areas. Numerous small hematitic copper prospects are associated with this fault, but neither study area has identified mineral resources. The region currently is of interest for gold exploration. The mineral resource potential in the Gibraltar Mountain Wilderness Study Area is high for copper, iron, and gold and low for silver, barite, manganese, and fluorite in and near the Mammon mine along the southwest edge of the study area. In the northwest corner of that study area the mineral resource potential is moderate for copper, iron, and gold and low for silver, barite, manganese, and fluorite. Basaltic rocks that cover much of the study area are probably not mineralized, but the underlying rocks may be; thus the underlying rocks have an unknown potential for copper, iron, gold, manganese, silver, barite, and fluorite resources. The mineral resource potential in the Planet Peak Wilderness Study Area is high for copper, iron, and gold and low for barite, manganese, and fluorite in those areas of exposed upper-plate rocks and is moderate for copper, iron, and gold and low for barite, manganese, and fluorite in exposed lower-plate rocks. The mineral resource potential for silver around the Pride mine is high and elsewhere is low. Areas covered by Quaternary and Tertiary alluvium have an unknown potential for all these elements except in the alluvium-covered areas along the south, southeast, and northeast margins of the study area, which have a high resource potential for copper, iron, and gold in upper-plate rocks beneath the alluvium. The study areas have no potential for oil and gas or for geothermal energy.

Manuscript approved for publication, Aug. 27, 1990

Character and Setting

The Gibraltar Mountain (AZ–050–012) and Planet Peak (AZ–050–013) Wilderness Study Areas are in west-central Arizona about 15 mi due east of Parker, Ariz., and about 25 mi southeast of Lake Havasu City, Ariz. (fig. 1). The areas lie within the Sonoran Desert section of the Basin and Range physiographic province, a region typically characterized by linear mountain ranges separated by wide, deep, alluvium-filled valleys. The Gibraltar Mountain Wilderness

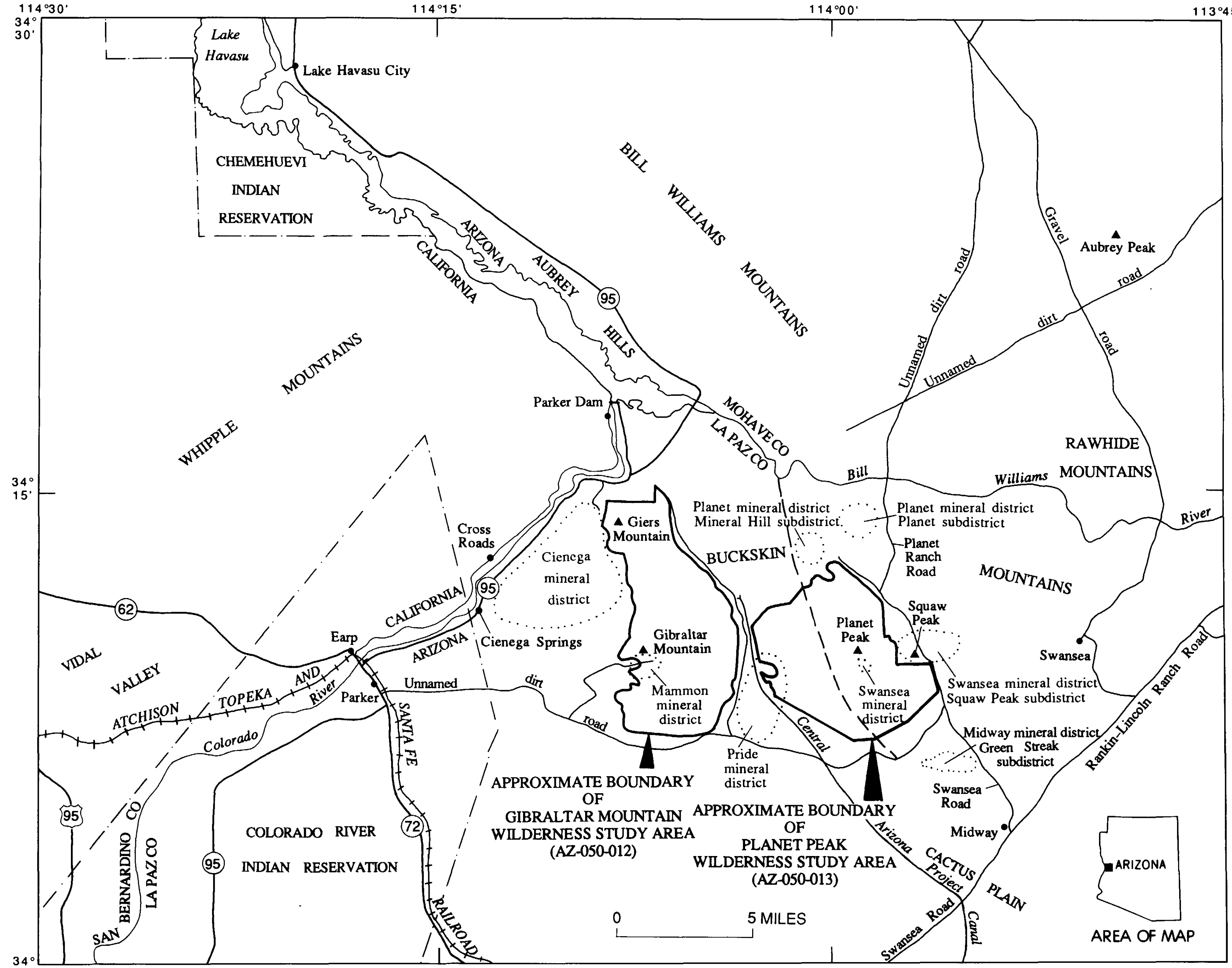


Figure 1. Index map showing location of Gibraltar Mountain and Planet Peak Wilderness Study Areas, La Paz County, Arizona. Mineral districts from Spencer and Welty (1989). Dashed line separates Cienega (left) and Santa Maria (right) mining districts. All boundaries are approximate.

Study Area is underlain primarily by volcanic rocks of Tertiary age (see geologic time chart in "Appendixes") and by minor but important outcrops of older metasedimentary, mylonitic, and granitic rocks. Most of the Planet Peak Wilderness Study Area is underlain by mylonitic rocks, and there are small exposures of Paleozoic and Tertiary sedimentary and Tertiary intrusive rocks. Alluvium is present in low-lying areas.

Identified Resources and Mineral Resource Potential of the Gibraltar Mountain Wilderness Study Area

No mineral resources were identified in the Gibraltar Mountain Wilderness study area. Mineralized rock is exposed at few localities, and extensive areas of volcanic rocks cover potentially mineralized units. The area around the Mammon mine, which is known to be mineralized, has high potential for copper, iron, and gold resources and low potential for silver, barite, manganese, and fluorite resources (fig. 2). Rocks in the upper plate of the Buckskin-Rawhide detachment fault crop out in the northwest corner of the study area and have moderate potential for copper, iron, and gold resources and low potential for silver, barite, manganese, and fluorite resources. Other rocks adjacent to the Buckskin-Rawhide detachment fault lie beneath Tertiary postdetachment basaltic and trachytic rocks and are therefore inaccessible for evaluation. However, the local geology, the nearby mineralized rocks, and the geochemical anomalies found in the basaltic terrane but possibly derived from underlying rocks all suggest that the concealed detachment-related rocks have an unknown potential for copper, iron, gold, manganese, silver, barite, and fluorite resources.

Identified Resources and Mineral Resource Potential of the Planet Peak Wilderness Study Area

Mineral resources were not identified within the Planet Peak Wilderness Study Area, and quantifying any inferred resources outside the study area at the Pride mine was not possible due to the discontinuous nature of the mineralized rocks. The study area consists of upper-plate and lower-plate rocks of the Buckskin-Rawhide detachment fault and includes local exposures of the detachment surface itself; younger Tertiary and Quaternary sediments cover much of the periphery of the study area. Because of the close association of the mineralization and the detachment surface, the exposed upper-plate rocks have high mineral resource potential for copper, iron, and gold resources, and the lower-plate rocks have moderate resource potential for these elements; rocks of both plates have low potential for barite, silver, manganese, and fluorite resources (fig. 3). The area directly surrounding the Pride mine, however, has high mineral resource potential for silver because of the known small production of this commodity from the mine. The mineral resource potential for all of these commodities is generally unknown where alluvium obscures detachment-related rocks, but it is likely to be similar to that of nearby exposed rocks. Along the south, southeast, and northeast borders of the study area, however, the alluvium covers upper-plate rocks that have high mineral resource potential for copper, iron, and gold. The study areas have no resource potential for oil and gas or for geothermal energy.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management (BLM) and is a joint effort by the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM). 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 and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, and mineralized areas. Identified resources are classified according to the system that is a modification of that described by McKelvey (1972) and U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the USGS are designed to provide a reasonable scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Mineral assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See "Appendixes" for the definition of levels of mineral resource potential and certainty of assessment and for the resource/reserve classification.

Character and Setting

The Gibraltar Mountain (AZ-050-012) and Planet Peak (AZ-050-013) Wilderness Study Areas in west-central Arizona encompass 18,807 and 16,430 acres, respectively (fig. 1). The study areas are about 10 to 20 mi east of Parker, Ariz., the nearest municipality, and about 25 mi southeast of Lake Havasu City, Ariz. The Gibraltar Mountain Wilderness Study Area includes Gibraltar and Giers Mountains, prominent peaks in the central and northwestern parts of the study area; Planet Peak dominates the topography in the Planet Peak Wilderness Study Area. Both study areas are in the western part of the Buckskin Mountains, an east-trending range bounded by the Bill Williams River on the north and Cactus Plain and Butler Valley (about 20 mi southeast of the study area) on the south. The study areas are part of the Sonoran Desert section of the Basin and Range physiographic province, an area characterized by mountain ranges separated by broad valleys.

Access to the study areas is by numerous gravel roads that lead from State Highways 72 and 95 to the many mines and prospects peripheral to the study areas. Rugged topography within the study areas permits only foot traffic. The Central Arizona Project Canal further hinders access to the

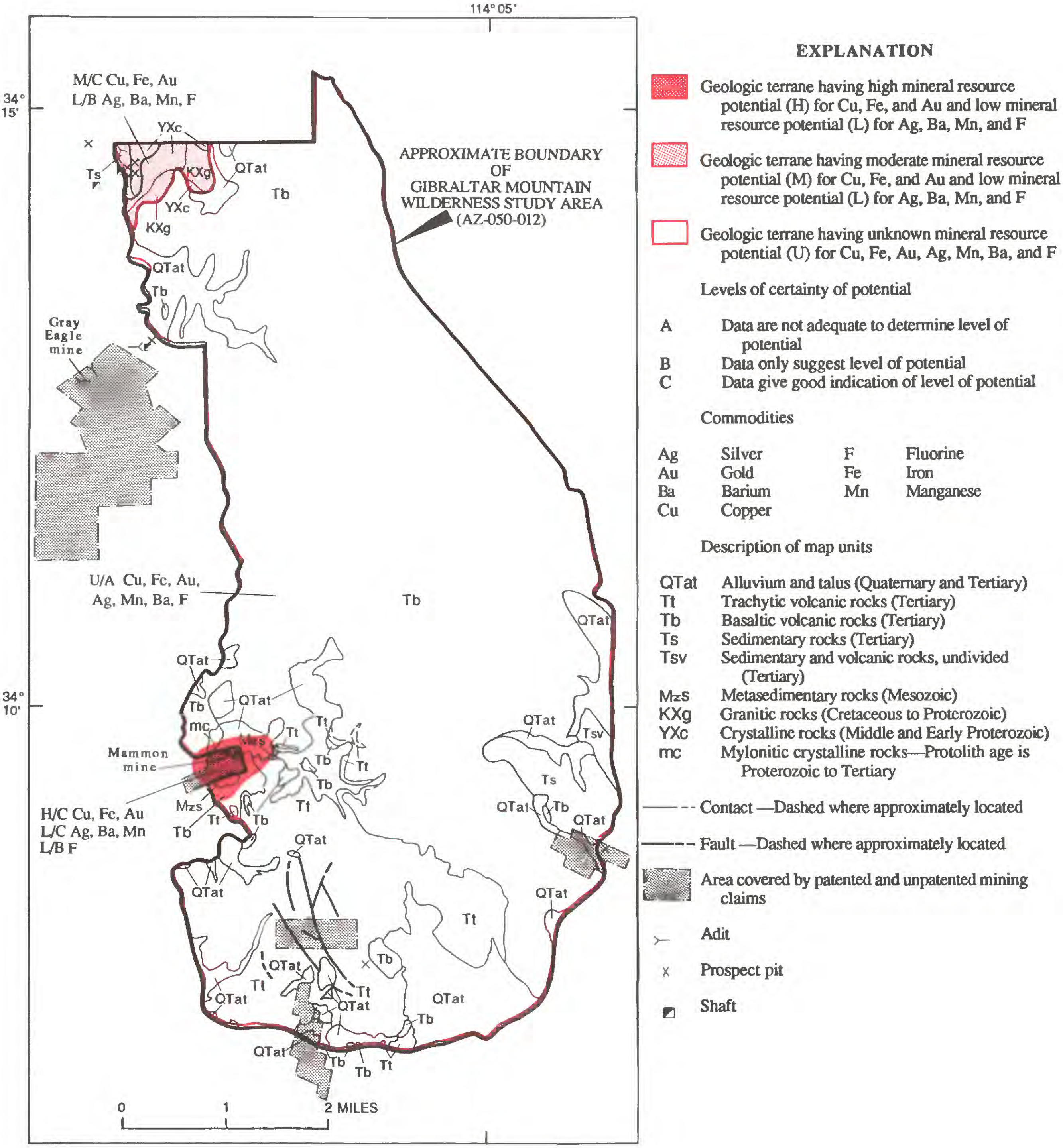
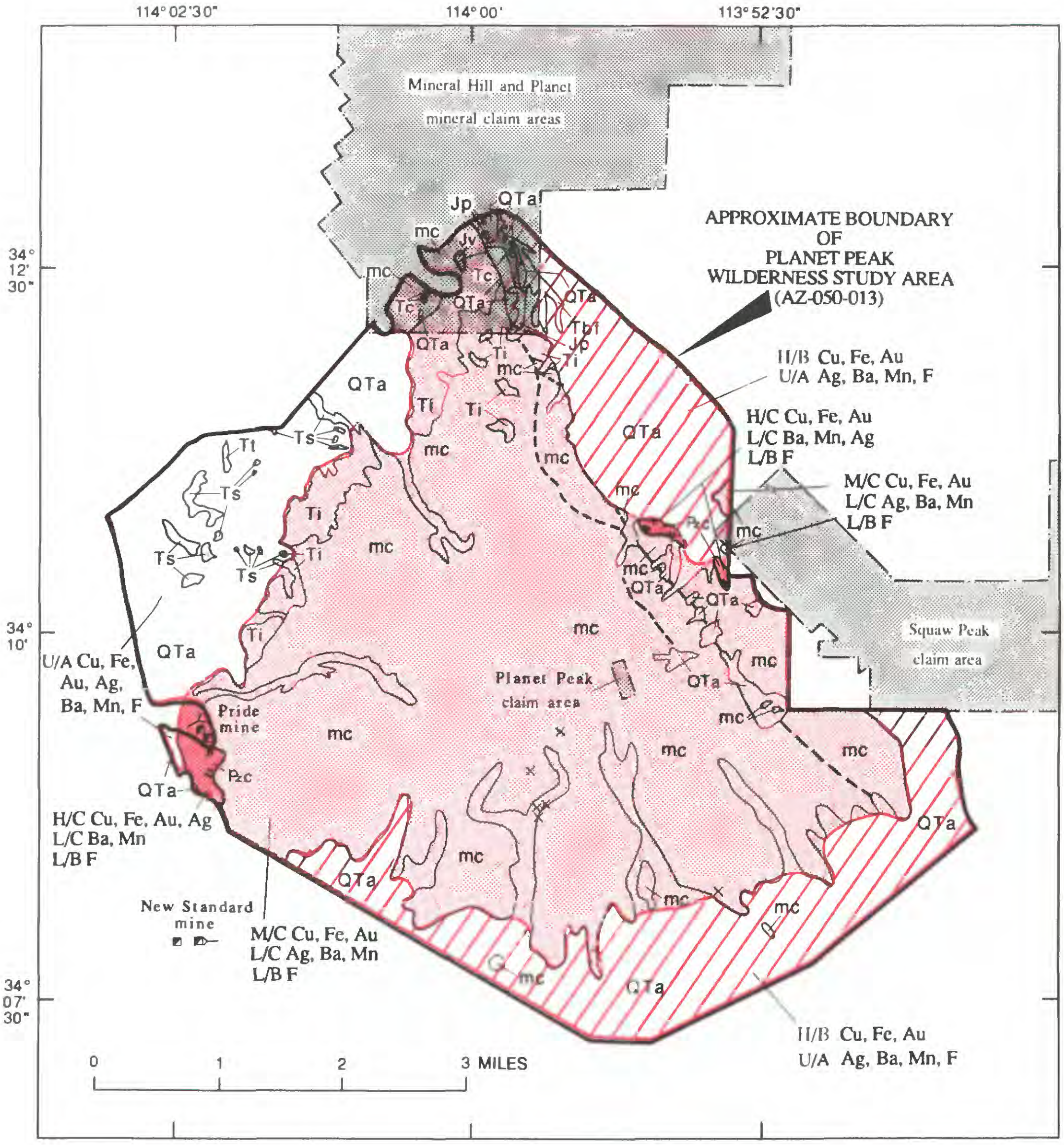


Figure 2. Mineral resource potential and generalized geologic map of Gibraltar Mountain Wilderness Study Area, La Paz County, Arizona. Geology modified from Grubensky (1989) and Spencer (1989).



EXPLANATION

Geologic terrane having high (H) and unknown (U) mineral resource potential for commodities as noted in rocks below QTa

Geologic terrane having high (H) and low (L) mineral resource potential for commodities as noted

Geologic terrane having moderate mineral resource potential (M) for Cu, Fe, and Au and low mineral resource potential (L) for Ag, Ba, Mn, and F

Geologic terrane having unknown mineral resource potential (U) for Cu, Fe, Au, and (or) Ag, Ba, Mn, and F

Levels of certainty of assessment

A	Data are not adequate to determine level of potential
B	Data only suggest level of potential
C	Data give good indication of level of potential

Commodities

Ag	Silver	F	Fluorine
Au	Gold	Fe	Iron
Ba	Barium	Mn	Manganese
Cu	Copper		

Description of map units

QTa	Alluvium (Quaternary and Tertiary)
Tbf	Basin-fill conglomerate and sandstone (Tertiary)
Tc	Replacement carbonate rocks (Tertiary)
Ts	Sedimentary rocks (Tertiary)
Tt	Air-fall tuff (Tertiary)
Ti	Intermediate to mafic intrusions (Tertiary)
Jp	Planet Volcanics of Reynolds and others (1987) (Jurassic)—Silicic to intermediate volcanic and metavolcanic rocks
Jv	Vampire Formation of Reynolds and others (1987) (Jurassic?)—Quartzite, metasandstone, and conglomerate
Pzc	Calcareous sedimentary rocks (Paleozoic)
mc	Mylonitic crystalline rocks—Protolith age is Proterozoic to Tertiary

Contact

Fault—Dashed where approximately located

Buckskin-Rawhide detachment fault—Barbs on side of lower plate

Area covered by patented and unpatented mining claims

Adit

Prospect pit

Shaft

Figure 3. Mineral resource potential and generalized geologic map of Planet Peak Wilderness Study Area, La Paz County, Arizona. Geology modified from Spencer and others (1989) and Spencer (1989).

west side of the Planet Peak Wilderness Study Area, as only one road crosses it near the south end of the study area.

Planet Peak, at an elevation of 3,141 ft, is the highest point within the study areas, whereas the alluvial plains southwest of the Gibraltar Mountain Wilderness Study Area have altitudes less than 1,000 ft. The climate is arid, and the region supports typical Sonoran Desert flora and fauna.

Previous Investigations

The earliest geologic reports of the region, in what was then northern Yuma County, described the geology and mineral deposits in the mining districts within and adjacent to the Gibraltar Mountain and Planet Peak Wilderness Study Areas (Bancroft, 1911; Blanchard, 1913). Until recently, detailed geologic mapping in the area had not been undertaken, but recognition of the significance of detachment faults and interest in mineralized areas associated with them prompted studies of the area, particularly by the University of Southern California and the Arizona Geological Survey (formerly Arizona Bureau of Geology and Mineral Technology). Shackelford (1976), working in the Rawhide Mountains east-northeast of the study areas, established the existence of what is now called the Buckskin-Rawhide detachment fault and confirmed its middle-Tertiary age. A 1:100,000-scale geologic map that includes the Buckskin Mountains was compiled by Spencer (1989). Detailed mapping by Spencer and others (1989) and by Grubensky (1989) cover the northern part of the Planet Peak and southern part of the Gibraltar Mountain Wilderness Study Areas, respectively. The mineralized areas and mines peripheral to the study areas have been described in several publications, including Keith (1978), Welty and others (1985), and Spencer and Welty (1989). Spencer and Welty (1986a) provided a regional geologic context for the mineral deposits. Further details about the work in the region, particularly related to the understanding of detachment-fault tectonics, are summarized in Spencer and Reynolds (1989). Several reports for graduate studies conducted within the region are cited in Schnabel and Welty (1986).

In the early 1980's, the Arizona Bureau of Geology and Mineral Technology developed a classification system for metallic mineral occurrences based on geologic and metallogenic criteria (Keith and others, 1983a, b), which resulted in a regrouping of deposits and occurrences into "metallic mineral districts." These mineral districts are different from the traditional mining districts, which are based on geographic and political criteria. The USBM generally uses mining districts because published literature, claim location notices, and most production figures refer to these. This paper uses the designations of Keith and others (1983a, b) as modified by Spencer and Welty (1989). Table 1 shows the relations of the metallic mineral districts to the mining districts.

Present Study

USBM personnel reviewed pertinent literature (including published reports, USBM files, and mining claims and oil and gas leases filed with the BLM) on the geology, mineralized areas, and mining activity in the region of the study areas. Discussions on the mineral resources of both study areas were held with Chuck Botdorf, district geologist in the BLM Yuma District Office, and with Pat Green, wilderness coordinator of the BLM Resource Area Office in Lake Havasu City. Field work consisted of mapping accessible mine workings by the compass-and-tape method and sampling mines and prospects in and near the study areas.

The USGS examined the geology of the areas, using geologic maps of the Arizona Geological Survey (see "Geology" below). A geochemical survey was conducted in which stream-sediment, heavy-mineral-concentrate, and rock samples were collected and analyzed by quantitative and semiquantitative methods. Geophysical data for the areas are from published gravity and magnetic investigations and preliminary radioelement studies.

Acknowledgments

Stephanie L. Jones and Cliff D. Taylor capably assisted with the field work by the USGS.

APPRAISAL OF IDENTIFIED RESOURCES OF THE GIBRALTAR MOUNTAIN WILDERNESS STUDY AREA

By David C. Scott
U.S. Bureau of Mines

Methods of Investigation

Accessible mine workings were surveyed, and 18 rock-chip samples were collected. All samples were analyzed by inductively coupled plasma–atomic fluorescence spectroscopy (total digestion) for 24 elements and by fire assay/atomic absorption spectroscopy for gold. All analyses were performed by Chemex Labs, Inc., Sparks, Nev. Data for all samples were discussed by Scott (1989). Further inquiries about sample analyses can be directed to the U.S. Bureau of Mines, Intermountain Field Operations Center, Box 25086, Denver Federal Center, Denver, CO 80225.

Mining Districts and History

The west side of the Gibraltar Mountain Wilderness Study Area is part of the Cienega mining district. It is adjacent to the Cienega mineral district and partly within the

Mammon mineral district as defined by Spencer and Welty (1989). The Planet and Pride mineral districts are east of the study area (fig. 1). Copper, gold, and silver deposits were discovered in the districts as early as 1860 (Keith, 1978, p. 129).

The Cienega mineral district is adjacent to the northwestern part of the study area. From 1870 to 1969, production from the district totaled 19,092 short tons (st) of ore that contained 1,713,533 lb of copper, 1,596 oz of silver, and 12,011 oz of gold. Mineral deposits consist of replacement bodies of silicate, carbonate, and oxide minerals and concentrations of quartz and hematite in northwest-trending shear zones, both in the upper plate of the Buckskin-Rawhide detachment fault (Spencer and Welty, 1989, p. 224).

The Mammon mineral district lies along and inside the southwestern part of the study area. Production from 1909 to 1955 totaled 841 st of ore containing 86,993 lb of copper, 142 oz of silver, and 60 oz of gold. Mineral deposits consist of chrysocolla, malachite, hematite, and calcite in northwest-trending, steeply dipping shear zones in lower-plate mylonitic gneiss of the detachment fault (Spencer and Welty, 1989, p. 224).

The Planet mineral district is 3 to 7 mi northeast of the study area. Production from the district totaled 1,090,771 st of ore that contained 19,503,012 lb of copper, 270 oz of silver, and 320 oz of gold (Spencer and Welty, 1989, p. 224). Copper carbonate, silicate, and sulfide minerals with quartz and calcite are present as disseminations and in veinlets and replacement bodies of hematite in the upper plate of the detachment fault and related northwest-trending shear zones (Spencer and Welty, 1986b, p. 196).

The Pride subdistrict within the Pride mineral district is about 2 mi east of the study area, partly within the Planet Peak Wilderness Study Area. Production from the district totaled 38 st of ore that contained 21 lb of copper, 6 oz of silver, and 78 oz of gold (Spencer and Welty, 1989, p. 224). Malachite, chrysocolla, hematite, and quartz are found in both the lower and upper plates of the detachment fault in northwest-trending, high-angle shear zones (Spencer and Welty, 1986b, p. 196).

As of March 1989, 18 claims were on file with the BLM, but no evidence of any recent mining activity was found in the study area. Cyprus Mining Co. is currently evaluating the Mammon mine area (fig. 2) as a possible copper-leaching site (Jim Jones, owner, Mammon mine, Parker, Ariz., oral commun., Jan. 1989).

Appraisal of Sites Examined

No mineral resources were identified within the study area. Copper, gold, and silver occurrences are associated with both upper- and lower-plate rocks of the Buckskin-Rawhide detachment fault. Rock-chip samples were taken from lower-plate rocks exposed at the Mammon mine and from upper-plate rocks exposed along the northwestern part of the study area. Sampled localities are discussed by geographic location.

Mammon Mine Area

Part of the Mammon mine (fig. 2) is on three patented mining claims. Several small adits and prospects were found at the mine; however, the main working is an adit about 500 ft long. The adit was driven on a shear zone striking N. 40° W. and dipping 40° SW. in an isolated outcrop of lower-plate mylonitic gneiss. The shear zone contains intensely sheared rocks that are heavily stained with limonitic iron oxide and copper carbonate, silicate, and oxide minerals; calcite and hematite are also present. Neither the shear zone nor the mylonitic gneiss can be traced into the study area; however, gneissic alluvial material was seen in drainages near the mine (R.G. Eppinger, written commun., 1989; see also "Geochemistry" below). Basalt that overlies the mylonitic gneiss is apparently not mineralized.

Two samples were collected in the study area east of the Mammon mine. A select sample, from the dump of a 48-ft-deep shaft in basalt, contains veinlets of hematite 1 to 4 in. thick. Gold was detected (5 part per billion, ppb), and high concentrations of copper (8,280 parts per million, ppm) and zinc (1,805 ppm) are present (Scott, 1989). The copper and zinc are probably associated with the hematite veinlets; no structural feature was visible in the shaft. The other sample, collected from a pit dug in oxidized basalt, contains no significant concentrations of any elements.

Gray Eagle Mine Area

A 41-ft-long adit, a shaft, and a prospect pit were found outside of but within 0.25 mi of the study area's west boundary, near the Gray Eagle mine (fig. 2). The workings are in upper-plate Paleozoic and Mesozoic limestone and shale. East- to northeast-trending high-angle faults and fractures in the limestone and shale contain azurite, calcite, chrysocolla, malachite, and hematite. These structures could not be traced outside of the workings; however, they trend toward the study area and may be present beneath the basaltic cover to the east.

Four samples were collected from the workings. Gold concentrations range from less than 5 to 1,560 ppb. The highest concentration was in a select sample from the dump of a prospect pit. Copper concentrations range from 1,790 to more than 10,000 ppm. All samples contain elevated lead (150–876 ppm), silver (2–140 ppm), and zinc (70–1,020 ppm) concentrations (Scott, 1989).

Giers Mountain Area

A cluster of workings on the northwest flank of Giers Mountain consists of four prospect pits, one shallow shaft, and one adit just inside the study area boundary (fig. 2) and one adit and one prospect pit just outside. The workings are on northwest- to northeast-striking faults in granite in the upper plate of the detachment fault. The fault gouge pinches and swells from 2 to 4 ft thick, but exposures are less than 100 ft long. Azurite, malachite, and limonite are common in the gouge.

Samples collected from the faults contain gold concentrations ranging from less than 5 to 6,400 ppb. Copper concentrations range from 42 to more than 10,000 ppm. Lead, silver, and zinc contents are generally insignificant (Scott, 1989). Similar mineralized faults containing these elements may be present beneath the basalt nearby in the study area. No resources were calculated because of the short strike lengths of the faults and sporadic element concentrations.

Miscellaneous Prospects

Two other pits within and adjacent to the southern part of the study area (fig. 2) are in basalt. No structural features were noted, and no significant metal concentrations were found in a sample from each pit (Scott, 1989).

Sand and Gravel

Sand and gravel deposits of Quaternary age are present in drainages in the study area; however, there is currently no local demand for them. Large, accessible volumes of similar sand and gravel are present outside the study area and these can satisfy any increase in local demand.

Conclusions

No mineral resources were identified in the study area. About 85 percent of the study area is covered by basalt and is apparently devoid of near-surface mineralized rock. Along the west boundary, high-angle faults and fractures in the upper and lower plates of the Buckskin-Rawhide detachment fault contain copper, gold, and silver occurrences.

APPRAISAL OF IDENTIFIED RESOURCES OF THE PLANET PEAK WILDERNESS STUDY AREA

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

Methods of Investigation

Accessible mine workings were studied, and 94 chip, grab, and select samples were analyzed for gold and 33 other elements by neutron activation and for copper and lead by atomic absorption spectrometry by Bondar-Clegg, Inc., Lakewood, Colo. Complete analytical data can be found in Kreidler (1989), available from the U.S. Bureau of Mines, Intermountain Field Operations Center, Box 25086, Denver Federal Center, Denver, CO, 80225.

Mining History

The Planet Peak Wilderness Study Area is near and includes parts of the Planet, Swansea, and Pride mineral districts of Spencer and Welty (1989). The study area also is about 1 mi northwest of the Green Streak subdistrict of the Midway mineral district (Kreidler, 1989, pl. 1). Table 1 summarizes the production history of these districts. The Planet and Swansea districts produced gold, silver, and copper from ore present as massive to lensing replacement bodies of hematite in Paleozoic carbonate rocks in the upper plate of the Bucksin-Rawhide detachment fault. Production from the Planet district alone totaled 1,009,771 st of ore that included 9,752 st of copper, 270 oz of silver, and 320 oz of gold (Spencer and Welty, 1989, p. 224). The Pride mineral district produced gold, silver, copper, and minor lead from replacement pockets in partly metamorphosed Paleozoic and Mesozoic limestone, shale, and quartzite. The Midway mineral district contained gold, silver, and copper in sporadic deposits along faults and fractures in Proterozoic to Tertiary gneiss, schist, and foliated granitoid rocks and in Paleozoic limestone. As of February 1988, the mines within 5 mi of the study area were inactive. As of January 1988, blocks of mining claims had been staked along the north and east sides of the study area; all or part of about 36 claims were staked inside the study area (Kreidler, 1989, pl. 1).

Appraisal of Sites Examined

Mineralization in the Planet Peak Wilderness Study Area occurred primarily in three areas: the Pride subdistrict of the Pride mineral district on the west border, and two parts of the Squaw Peak subdistrict of the Swansea mineral district—along a spur ridge of Planet Peak and in an area around Squaw Peak (fig. 1). In these areas, mineral occurrences along fault zones consist of veins, pods, and lenses of specular hematite and oxidized copper minerals, primarily chrysocolla, malachite, and azurite, that coat fracture surfaces. Gangue minerals include mainly hematite, quartz, and calcite. The mineralized rock is discontinuous, commonly found as near-surface pods no thicker than 2 or 3 ft. The discontinuous nature prevented quantifying of resources.

Pride Mine Area

In the Pride subdistrict of the Pride mineral district, mineralization occurred primarily at the Pride mine (fig. 3) and in an area about 1 mi to the southeast. Farther to the

Table 1. Summary of production data for mining districts in and near the Planet Peak Wilderness Study Area, La Paz County, Arizona

[Data from Keith, 1978. Mineral district names, in parentheses, are those used by Spencer and Welty (1989); NA, not applicable]

Mining district	When active	Production data				
		Gold (oz)	Silver (oz)	Copper (tons)	Lead (lb)	Other
Cienega (Cienega, Mammon and Pride mineral districts).	1880–1969 ---------	11,707	3,364	917	A few hundred.	NA
Santa Maria (Planet and Swansea mineral districts).	Intermittently since 1860's.	1,128	35,000	23,000	NA	400 tons manganese ore.
Midway ----------------	Early 1900's–late 1970's.	45	35	4.5	NA	NA

southeast, a third area of minor mineralization is defined by scattered prospects.

The Pride mine, just outside the study area boundary, is on the Buckskin-Rawhide detachment fault (Spencer and Welty, 1989, p. 246) at an elevation of about 1,250 ft. The upper-plate rocks consist of metamorphosed limestone of probable Paleozoic age; the lower plate is granitic gneiss, locally mylonitized, that underlies nearly the entire study area. Workings consist of two open cuts, an adit, two shafts, and a pit. The mine has been worked sporadically since the early 1900's, producing 38 st of ore including 78 oz of gold averaging 2.052 oz/st, 6 oz of silver averaging 0.158 oz/st, and 21 lb of copper averaging 0.28 percent (Spencer and Welty, 1989, p. 224). In the larger open cut, a massive body of specular hematite is exposed over a horizontal distance of about 100 ft and vertically for 20 to 35 ft; abundant chrysocolla, malachite, and azurite coat fracture surfaces. The hematite appears to replace limestone, although the host rock has been so intensely altered that recognition of the original rock type is difficult. The geology in the adit and at the remainder of the workings is similar. Six of nine samples taken at these workings contain gold concentrations ranging from 11 to 150 ppb and averaging 56 ppb. Average gold content for these rock types worldwide is 4 ppb (Levinson, 1980, p. 872). Copper concentrations are generally low, considering the abundance of copper minerals coating rock surfaces, ranging from trace amounts to 1.3 percent and averaging 0.66 percent. Iron concentrations range from 3.2 to 49 percent and average 26 percent. Silver was not detected in any of the samples.

About 1 mi southeast of the Pride mine, inside the study area at elevations between 1,200 and 1,300 ft, hematite and copper minerals are present in lower-plate gneiss (locally mylonitic) as near-surface pods and lenses, probably replacing tectonic slivers of carbonate rock and as narrow veins along faults with widely variable dips. Limestone fragments are found locally in some fault zones. These occurences have been explored by several shafts and pits and one adit. Fractures having low-angle dips are possibly listric faults that may or may not be associated with the detachment fault (see Wilkins and others, 1986). Of the 18 samples taken in this area, 8 contain gold above the detection limit of 5 ppb, ranging from 6 to 350 ppb, averaging 51 ppb. This average is skewed by the value of 350 ppb; without it, gold averages 9 ppb. All samples but one contain copper above trace amounts, ranging from 0.02 to 1.5 percent and averaging 0.52 percent. Iron content ranges from 2.2 to 42 percent, averaging 17.3 percent.

South and east of the Pride mine are several scattered prospects, shafts, and adits with mineral occurrences similar to those described above. Samples taken at these workings contain gold (6–23 ppb), copper (trace to 1.75 percent), and iron (5.1–62.7 percent).

Planet Peak Claim Area

Five prospect pits and three short adits are on a spur ridge on the southeast side of Planet Peak (fig. 3), at an elevation of about 2,200 ft in the Squaw Peak subdistrict of the Swansea mineral district. Mineral occurrences consist of narrow hematite veins along faults and of lenses and pods replacing slivers of carbonate rock from the upper plate; some occurrences contain secondary copper minerals. The fault zones have varying orientations and dips; fresh limestone is present in one working, and a highly altered mafic rock, possibly originally a diabase, was found in another. Of 11 samples taken in this area, 5 contain gold above the detection limit (7–20 ppb, average 12.2 ppb). The samples also contain copper (trace to 3.76 percent, average 1.2 percent) and iron (1.9–58.7 percent, average 32.4 percent).

Squaw Peak Area

Workings in the Squaw Peak area (fig. 3, Squaw Peak subdistrict of the Swansea mineral district) are less than 0.5 to 4 mi east of the study area boundary and include a large group of prospects (Kreidler, 1989, pl. 1). Squaw Peak, underlain by the detachment fault, consists of upper-plate Paleozoic sedimentary rocks, primarily limestones that are locally metamorphosed (Spencer and others, 1989). Northwest of Squaw Peak, scattered workings are found in lower-plate mylonitic gneiss. Minerals include hematite in pods and lenses and in veins in northwest- to west-striking faults having variable dips. Chrysocolla and malachite are also present locally. The discontinuous nature of the hematite veins and pods is well demonstrated in a decline north of Squaw Peak. At the surface the vein is 6 to 12 in. wide. At the face of the first level the vein has pinched out. In the lower level, lenticular pods are separated by barren fault breccia. This characteristic of the mineralized rock in the study area precludes quantifying any resources. Of the 29 samples taken in the Squaw Peak area, only 5, of which 4 are from the same mine, contain gold above the detection limit (9–24 ppb, average 13.2 ppb), 24 contain copper (0.038–4.08 percent, average 0.63 percent), and all contain iron (2.6–65.8 percent, average 28.7 percent).

Sand and Gravel

Large deposits of sand and gravel occur in the study area but have no unique qualities that make them more valuable than the vast quantities that blanket much of the desert in this region. Sand and gravel is a high-volume, low-unit-value material that must be located close to markets to be economic.

Energy Resources

About 9,500 acres of the study area are covered by oil and gas leases. However, Ryder (1983, p. C19) rates the oil and gas potential of the study area as low to zero because it is underlain by a thick sequence of metamorphic and igneous rocks that are not conducive to the formation of hydrocarbons. The leasing is probably a result of speculation that the hydrocarbon-rich overthrust belt, which contains large quantities of oil and gas in Wyoming, extends southward into Arizona (Keith, 1979, p. 10). All exploratory drilling in Arizona thus far, based on the overthrust model, has had negative results.

According to Witcher and others (1982), the study area has no known potential for geothermal resources; the nearest thermal well (130 °F) is about 4.5 mi to the northeast in Mohave County.

Comparison of Study Area to Copperstone Mine

The Copperstone mine (Cyprus Gold Co.) is about 25 mi southwest of the Planet Peak Wilderness Study Area, at the north end of the Moon Mountains in the hanging wall of the Moon Mountains detachment fault (Cyprus Gold Co., written commun., 1988). The host rock is a thick sequence of foliated to massive quartz latite tuffs of Jurassic age and Tertiary sedimentary breccias (Spencer and others, 1988). The main ore horizon lies along the contact of the breccia and the underlying quartz latite tuff. The gold occurs as small flakes ranging from 4 to 40 microns (0.00016–0.0016 in.); the most common gangue minerals are specularite (hematite), chrysocolla, barite, amethyst, calcite, and fluorite.

Reserves are 6 million st of ore having an average gold grade of 0.075 oz/st (2.57 ppm); in mid-1988 they were being mined by open-pit methods. An additional 1 million st of ore at a grade of 0.17 oz/st of gold (5.83 ppm) have been blocked out for possible future underground mining (Bill Burton, Cyprus Minerals Co., oral commun., June 1988).

Geochemical data from the Copperstone mine are compared with data from the Planet Peak Wilderness Study Area and with the average abundance of each element in similar rock types (table 2). Although anomalies[1] in the study area are not as high as those in rocks from the Copperstone mine, samples from the study area contain higher concentrations of the specified elements than is expected for these rock types (except for lead, in which the samples from the study area are notably deficient). These anomalies indicate that the study area may have been subject to mineralizing processes similar to those which created the Copperstone ore body. The higher concentrations of gold, however, are present only where the ground has been adequately prepared by faulting or where more reactive rock types occur. At the Copperstone mine, the breccia provided a conduit system for the circulation of hydrothermal fluids and deposition of mineral deposits. In the study area, the limestone and metacarbonate rocks of the upper plate, which have been eroded from all but a small part of the study area, supplied reactive rock for replacement.

Conclusions

With the possible exception of the Pride mine area, none of the mineralized areas in the Planet Peak Wilderness Study Area contain identified mineral resources. A detailed exploration program, including geologic mapping, geochemical and geophysical work, drilling, and trenching would be required to determine if any resources exist at the Pride mine. The large areas of sand and gravel in the study

[1]Any elemental concentration more than two times the average concentration for that rock type worldwide is considered anomalous.

Table 2. Comparison of average USBM geochemical data from the Planet Peak Wilderness Study Area and the Copperstone mine, La Paz County, Arizona

[Detection limits: gold (Au), 0.005 ppm; arsenic (As), 1 ppm; barium (Ba), 100 ppm; chromium (Cr), 50 ppm; copper (Cu), 1 ppm; iron (Fe), 0.5 percent; lead (Pb), 2 ppm; antimony (Sb), 0.2 ppm. <, less than detection limit; ND, no data. Number in parentheses beneath each element value is number of samples upon which the average is based]

Area	Au	As	Ba	Cr	Cu	Pb	Sb	Fe
				(ppm)				(percent)
Copperstone mine[1]	2.9	11.0	3,300	48	2,000	24.0	1.5	6.7
Pride mine	.056 (6)	9.2 (9)	510 (8)	76 (1)	5,935 (9)	6.3 (9)	.6 (9)	26.0 (9)
Prospects 0.6 mi south of Pride mine.[2]	.009 (7)	7.0 (18)	647 (16)	70 (8)	4,934 (18)	3.2 (5)	.5 (5)	17.34 (18)
Prospects 1.5 mi southeast of Pride mine and New Standard mine area.[2]	.012 (7)	3.7 (17)	1,111 (12)	148 (3)	3,442 (17)	3.3 (8)	.3 (9)	22.68 (17)
Planet Peak area	.012 (5)	2.3 (8)	987 (3)	<50 (11)	10,544 (11)	3.0 (2)	.4 (11)	32.45 (11)
Squaw Peak area	.013 (5)	4.3 (28)	3,443 (23)	197 (8)	5,050 (29)	9.8 (26)	.7 (25)	28.81 (29)
Average for all samples from the Planet Peak Wilderness Study Area.	.0295 (37)	4.6 (89)	1,608 (76)	128 (23)	5,938 (94)	7.6 (62)	.5 (67)	24.37 (94)
Average for similar rock types.[3]	.004	2.0	500	2	20	20	.2	ND

[1]Average element anomalies from Copperstone samples; data supplied by Bill Burton, Cyprus Minerals, June 1988.
[2]See figure 3 in Kreidler (1989) for location of prospects.
[3]From Levison (1980).

area have no more value than those that cover vast areas of the desert in this region, and thus are not likely to be developed. The area has been rated as having low to zero potential for oil and gas because it is underlain by crystalline rocks (Ryder, 1982, 1983). The area has no evidence of geothermal resources.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology

Regional Setting

The geology of the Gibraltar Mountain and Planet Peak Wilderness Study Areas is best understood in the context of the regional tectonic setting of southeastern California and western Arizona, where metamorphic core complexes are commonly exposed in the lower plates of detachment faults that extend across entire mountain ranges and project into the subsurface. The Buckskin Mountains lie within a chain of metamorphic core complexes that stretches from the Santa Catalina–Rincon Mountains east of Tucson, Ariz., to the Sacramento Mountains in California (Coney, 1980; Anderson, 1988). The metamorphic core complexes are characterized by a metamorphic basement terrane that has been overprinted with a low-angle mylonitic and gneissic fabric. Above this mylonitic terrane are unmylonitized rocks that commonly contain many low-angle faults. These low-angle faults merge into a master subhorizontal detachment fault that separates the two terranes (Coney, 1980). Some mylonitization and faulting is of Tertiary age as evidenced by deformed Tertiary plutons, but at least some of the ductile deformation is significantly older (Reynolds and Spencer, 1989). Middle-Tertiary mylonitic deformation and low-angle extensional faulting followed Late Cretaceous and early Tertiary (Laramide) compressional tectonics (Coney, 1980). The drastic changes in deformation style can be correlated with changes in the style of convergence of the North American and Pacific plates; detachment tectonics was prevalent during the transition from a subducting continental margin to a strike-slip margin (Hamilton, 1988).

Several periods of metamorphism affected rocks within the Basin and Range province of Arizona during the Mesozoic and Cenozoic eras (Reynolds and others, 1988). The most recent took place in middle Tertiary time and was largely a retrograde metamorphic event associated with mylonitization and detachment faulting. Mylonitization occurred along deeper parts of the detachment-related shear zone, whereas discrete detachment faults and associated breccias formed at shallower levels (Spencer and Reynolds, 1989; Reynolds and others, 1988). Chlorite-epidote alteration commonly accompanied brecciation. Eventually lower-plate rocks became unroofed. The Buckskin Mountains contain an unroofed mylonite that formed deep within the shear system (Rehrig and Reynolds, 1980; Spencer and Reynolds, 1989). That the Buckskin Mountains trend northeast rather than northwest, as is more typical in the Basin and Range of this region, is attributed to the development of transverse foliation arches within the huge metamorphic core complex (Spencer and Reynolds, 1989); the western one of these arches underlies the Planet Peak Wilderness Study Area (Bryant and Wooden, 1989).

Local Geology

The study areas are at the west end of the Buckskin Mountains and are geologically quite different from each other. The Planet Peak Wilderness Study Area has many excellent exposures of lower-plate mylonitic rocks and local occurrences of upper-plate rocks and the Buckskin-Rawhide detachment fault. In the Gibraltar Mountain Wilderness Study Area, however, these rocks are generally covered by postdetachment volcanic rocks. In the northwest corner of the Gibraltar Mountain study area, older granitic rocks within the upper plate are exposed. The following discussion is based on mapping by Spencer and Reynolds (see Spencer, 1989), Grubensky (1989), and Spencer and others (1989) and on interpretations from aerial photographs of unmapped areas; these were all compiled at a scale of 1:100,000 by Spencer (1989). A combination of these maps was used to compile figures 2 and 3 of this report.

Lower-plate rocks

Lower-plate mylonitic rocks in the Planet Peak Wilderness Study Area are of three types: Early Proterozoic gneissic rocks, Cretaceous granite around and including Planet Peak, and a Tertiary plutonic suite on the northwest side of the study area (Bryant and Wooden, 1989; Spencer and others, 1989). These lower-plate rocks consist of variably pegmatitic amphibolite-grade gneiss and coarse- to fine-grained intrusive rocks that are overprinted with shallow-dipping middle-Tertiary mylonitic foliation. Calc-silicate rocks, quartzite, and dolomitic-marble sheets as thick as 10 ft are locally interlayered with the crystalline rocks. Directly below the detachment fault, the rocks have been brecciated and converted to chlorite-epidote breccia and silicified microbreccia. The Cenozoic intrusive rocks consist of homogeneous, dark-gray, fine-grained diorite(?) of late Oligocene(?) to middle Miocene(?) age. Their mylonitic fabric is generally weaker than that of older crystalline rocks, and locally the foliation and lineation are weak to absent. Low-angle faults mark some contacts of these intrusions with the older crystalline rocks. The intrusions generally form sill-like bodies along the northwestern part of the Planet Peak Wilderness Study Area (fig. 3).

Upper-plate rocks

Upper-plate rocks are composed of a variety of sedimentary and volcanic rocks ranging in age from Paleozoic through Tertiary and crystalline rocks of Proterozoic to Cretaceous age (Reynolds and Spencer, 1989). In the northwest corner of the Gibraltar Mountain Wilderness Study Area (fig. 2) variably foliated granitic rocks are strongly fractured in most places. They are fine to medium grained and relatively unaltered to somewhat chloritized and epidotized in hand specimen; locally they contain minor stains of secondary copper-oxide minerals.

The Paleozoic rocks in the Planet Peak Wilderness Study Area (fig. 3) are mostly calcareous strata dominated by brown dolomitic marble containing light- to dark-brown siliceous bands several centimeters thick. At the detachment-fault surface these rocks commonly form breccia fragments within a darker brown Tertiary hydrothermal replacement carbonate that is locally vuggy and veined and has siliceous selvages. Contacts between Tertiary replacement carbonate and Paleozoic marble are generally gradational.

Undifferentiated Mesozoic rocks on the west-central edge of the Gibraltar Mountain Wilderness Study Area are composed of quartzite and phyllite, presumably of the Buckskin Formation of Reynolds and others (1987). The northern part of the Planet Peak Wilderness Study Area has several small outcrops of the Jurassic Planet Volcanics of Reynolds and others (1987) and one outcrop of the Jurassic(?) Vampire Formation of Reynolds and others (1987). The Planet Volcanics consist of schistose intermediate-composition volcanic and metavolcanic rocks containing quartz, feldspar, muscovite, and magnetite. The Vampire Formation consists of light-colored quartzite that has a basal conglomerate.

Tertiary strata are uncommon in the upper-plate rocks in the study area, but several units are present locally in the western parts of the study areas. The Gibraltar Mountain Wilderness Study Area has a unit of gently to steeply dipping, generally red to brown sandstone, siltstone, and conglomerate in the extreme northwest corner. The same unit is exposed in the western part of the Planet Peak Wilderness Study Area, and one small outcrop of air-fall tuff is interbedded with sandstone on the west side of the study area. The northern part of that study area has several small klippen of hydrothermal replacement carbonate resting on mylonite.

Postdetachment rocks

The oldest postdetachment rocks crop out in the northern part of the Planet Peak Wilderness Study Area. They are poorly sorted, matrix-supported cobble to pebble fanglomerate and sandstone; tuffaceous rocks are present locally. Clasts are composed of several Tertiary volcanic, sedimentary, and granitic units and of lower-plate mylonite and carbonate rocks.

Most of the Gibraltar Mountain Wilderness Study Area is underlain by volcanic rocks correlated with the Miocene Osborn Wash Formation (Davis and others, 1980; Grubensky, 1989). They are as thick as 900 ft near the southwest corner of the study area and locally elsewhere but are generally less than 500 ft thick. These rocks in the northern two-thirds of the study area consist of nearly flat-lying olivine-basalt flows with minor interbedded agglomerate, tuff, and sedimentary rocks. The southern one-third of the study area is composed of trachytic lava flows and pyroclastic deposits including air-fall and ash-flow tuffs and surge deposits. Erosion has exposed some plugs, and dikes are present locally. Grubensky (1989) believed that the entire trachytic sequence was likely emplaced along the flanks of a small stratovolcano, now eroded and buried. Basaltic and trachytic rocks are contemporaneous.

Alluvium ranging in age from latest Tertiary to Holocene surrounds Planet Peak and is adjacent to lava flows in the Gibraltar Mountain Wilderness Study Area. The larger stream beds also contain substantial alluvium. The alluvium consists of unconsolidated to poorly consolidated gravel, sand, and silt.

Geochemistry

Introduction

A reconnaissance geochemical survey was conducted in May 1988 as part of the mineral resource evaluation. The principal geochemical sampling media were stream sediments and heavy-mineral concentrates (HMC) collected at 41 sites within and near the Gibraltar Mountain Wilderness Study Area and at 36 sites within the Planet Peak Wilderness Study Area. The stream-sediment sample represents a composite of rock and soil exposed in the drainage basin. The nonmagnetic fraction of an HMC sample is useful in detecting mineralized areas because primary and secondary ore minerals are commonly found 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. Rock samples were collected to provide information on background metal concentrations in unaltered bedrock and to identify anomalous metal suites in mineralized areas. Stream-sediment, HMC, and rock samples were also collected in mineralized areas near the study areas to supplement data from samples collected within the study areas.

This geochemical survey was designed to locate altered, mineralized, or geochemically anomalous areas, but not to find individual mineral deposits. Detailed geochemical studies to evaluate anomalies found in this reconnaissance study have not been undertaken.

Methods

Analytical results and a full description of sampling and analytical techniques are found in Eppinger and others (1990). Stream-sediment samples were collected from active alluvial channels, generally along first-order streams. The samples were sieved with 30-mesh screens, and the minus-30-mesh fractions were pulverized for chemical analysis. HMC samples were collected at stream-sediment sites and panned until most quartz, feldspar, clay, and organic matter were removed. These samples were then sieved using 16-mesh screens. Light minerals, principally quartz and feldspar, remaining in the minus-16-mesh fractions were removed by heavy-liquid flotation (bromoform, specific gravity 2.85). The remaining portions of the HMC samples were separated with an electromagnet into magnetic, slightly magnetic, and nonmagnetic fractions. Nonmagnetic fractions were examined microscopically and by X-ray diffraction for mineral content. Both nonmagnetic and slightly magnetic fractions were pulverized for chemical analysis, whereas the magnetic fraction was archived. Rock samples were examined microscopically and then pulverized for chemical analysis.

Stream-sediment and rock samples were analyzed for 35 elements, and the slightly magnetic and nonmagnetic HMC samples were analyzed for the same 35 elements plus platinum and palladium, all by semiquantitative emission spectrography. In addition, stream sediments and rocks were analyzed by more sensitive inductively coupled plasma atomic–emission sprectrometry for arsenic, bismuth, cadmium, antimony, and zinc. Stream-sediment and rock samples were analyzed for low-level gold (detection limit is 50 ppb for stream sediments and 2 ppb for rocks) by flame and graphite-furnace atomic absorption methods, respectively.

Histograms showing the general distribution and range of the data were constructed for selected elements. Boundaries between background and anomalous concentrations of these elements were chosen by visual inspection of the diagrams and plots, by percentiles, and by average crustal abundances for elements given by Levinson (1980).

Results

Dominant lithologies in the two study areas are easily seen in the geochemical data. Abundant postdetachment Tertiary basalts in the Gibraltar Mountain Wilderness Study Area are reflected by elevated concentrations of the mafic elements nickel, cobalt, manganese, and iron. In the northwest corner of that study area, upper-plate Proterozoic granitic and Tertiary arkosic rocks are reflected by the more felsic elements lanthanum, niobium, and thorium. In the Planet Peak Wilderness Study Area, outcrops of lower-plate mylonitic granite and granitic to fine-grained felsic gneiss are common, and these rocks are reflected by the strong felsic elements lanthanum, yttrium, niobium, tin, beryllium, thorium, and barium. Sphene is the likely host mineral for most of the elements in this felsic suite, as it is known to contain lanthanum, yttrium, niobium, tin, and thorium (Deer and others, 1962) and is the dominant mineral phase, along with barite, in the HMC samples from the areas that are rich in these elements.

Generally low-level anomalies (meaning anomalous but near the threshold value given in table 3) possibly related to mineralization are found in several places within the study areas (see figs. 4 and 5). Metals found in anomalous concentrations in and around the study areas include silver, barium, bismuth, cadmium, cobalt, copper, iron, molybdenum, manganese, lead, antimony, tin, thorium, tungsten, and zinc. Gold was detected in only a few samples from near the Pride and Mammon mines, discussed below. Table 3 lists metals found in anomalous concentrations, the ranges in concentration, and threshold values used in this study.

Samples from the Mammon mine area (fig. 4, area 1) contain anomalous concentrations of gold, cobalt, copper, and iron, and slightly anomalous concentrations of silver, barium, bismuth, molybdenum, lead, antimony, and zinc. One rock sample from this area contains 50 ppb gold. These data agree with analyses of rock samples from the Mammon mine by Scott (1989), who reported detectable gold, anomalous copper and zinc, and weakly anomalous silver and molybdenum.

Samples from one site in each of seven drainages in the Gibraltar Mountain Wilderness Study Area have weakly anomalous molybdenum and zinc (fig. 4, areas numbered 2). Other elements are found in anomalous concentrations in one or more samples from these drainages (fig. 4). Anomalous concentrations for most of these elements are near the threshold value. However, concentrations in one HMC sample from a drainage in the southern part of the study area are highly anomalous for zinc (2,000 ppm), relatively strongly anomalous for copper and molybdenum, and less anomalous for cadmium, lead, and tungsten. In that sample, hematite, trace amounts of fresh pyrite, and a single grain of sphalerite were identified. Ore and ore-related minerals were not found in any other HMC sample in areas numbered 2 on figure 4. Alluvium in all seven drainages is made up almost exclusively of postdetachment Tertiary basalt and trachyte. Lower-plate biotite-gneiss cobbles and pebbles were observed only in drainages near the Mammon mine.

Gold was found in only one sample outside of the Mammon mine area, in area 3 (fig. 4). Numerous calcite veins were observed cutting vesicular basalt in that area, and one vein sample contains 200 ppb gold. No other anomalous metal concentrations were found in that sample. One HMC sample from that drainage contains slightly anomalous manganese, and no ore or ore-related minerals were observed in that sample.

HMC samples from a drainage west of the study area (fig. 4, area 4) are highly anomalous in lead (15,000 ppm); anomalous in copper, iron, manganese, molybdenum, and antimony; and slightly anomalous in cobalt and tin. Minerals identified in the HMC samples include specularite, malachite, and fairly abundant malleable lead. Postdetachment Tertiary basalt, upper-plate metasedimentary and granitic rocks, and bull quartz with hematite-coated joint surfaces (no gold detected) were observed in stream cobbles in this area. Numerous prospects and adits are found immediately northwest of the sampled drainages (the Lion Hill mine group, Spencer and Welty, 1989).

Samples from the Pride mine area (fig. 5, area 5) contain anomalous concentrations of gold, barium, cobalt, copper, iron, and lead and slightly anomalous concentrations of silver, arsenic, manganese, molybdenum, and tungsten. Gold was found in two samples—a stream sediment (50 ppb) and a rock (200 ppb)—in amounts similar to gold reported by Kreidler (1989). Malachite, chrysocolla, and a trace of galena were identified in an HMC sample from the Pride mine.

Samples collected in the New Standard mine and Little Golden prospect areas (fig. 5, area 6) have anomalous concentrations of gold, cobalt, copper, and iron, and slightly anomalous concentrations of silver, barium, bismuth, molybdenum, lead, antimony, and tungsten. Gold was detected in five rock samples (two at 10 ppb, one at 100 ppb, and two at 200 ppb) from this area.

Several localities within the Planet Peak Wilderness Study Area have low-level anomalous concentrations of one or more elements. Samples from area 7, west of Squaw Peak (fig. 5), contain anomalous concentrations of barium, copper, and manganese and slightly anomalous concentrations of silver and molybdenum. Traces of pyrite and fluorite were observed in HMC samples, and specularite, chrysocolla, and malachite were observed locally in alluvium. Bedrock in area 7 is composed of lower-plate mylonitic gneiss. The Buckskin-Rawhide detachment fault and upper-plate metasedimentary rocks have been mapped immediately east of area 7 on Squaw Peak (Spencer, 1989), and numerous prospects are located in the vicinity.

Table 3. Summary statistics for anomalous elements from stream sediments and heavy-mineral concentrates collected by the USGS in and around the Gibraltar Mountain and Planet Peak Wilderness Study Areas, Arizona.

[n, number of samples; N, not detected; L, detected but lower than determination limit; G, greater than upper determination limit. Analyses are by emission spectrography, except for elements having an "-a" suffix (flame atomic absorption) or an "-i" suffix (inductively coupled plasma–atomic emission spectrometry). Values are parts per million unless noted otherwise]

Element (Lower determination limit)		Level of concentrates		50th percentile	Threshold	Number of samples above threshold
		Minimum	Maximum			
Nonmagnetic heavy-mineral concentrates (n = 77)						
Ag	(1)	N	L	N	L	1
Ba	(50)	150	G(10,000)	10,000	G(10,000)	37
Be	(2)	N	5	L	5	16
Co	(20)	N	500	N	200	1
Cu	(10)	N	200	L	30	3
Mo	(10)	N	100	N	L	13
Nb	(50)	N	300	100	200	8
Pb	(20)	N	15,000	20	100	12
Sb	(200)	N	200	N	L	1
Sn	(20)	N	700	20	100	4
Th	(200)	N	500	N	300	5
W	(50)	N	100	N	L	6
Y	(20)	100	700	500	700	10
Zn	(500)	N	2,000	N	L	2
Weakly magnetic heavy-mineral concentrates (n = 77)						
Co	(20)	L	500	70	200	4
Cu	(10)	10	1,000	70	150	12
Fe	(0.1%)	5	30	10	30	11
La	(100)	N	1,000	300	1,000	4
Mn	(20)	500	G(10,000)	1,500	5,000	9
Mo	(10)	N	20	L	15	5
Ni	(10)	L	500	50	150	10
Pb	(20)	N	300	30	100	4
Sn	(20)	N	50	N	30	4
Y	(20)	30	500	100	500	3
Zn	(500)	N	1,000	N	L	9
Stream sediments (n = 77)						
Ag	(0.5)	N	0.7	N	L	6
Au-a	(50 ppb)	N	50	N	50	1
Ba	(20)	100	2,000	500	1,500	2
Bi-i	(2)	N	5	N	5	1
Cd-i	(0.1)	0.1	1.2	0.25	1	4
Co	(10)	L	150	20	100	1
Cu	(5)	L	500	20	70	4
Fe	(0.05%)	1.5	10	3	7	4
La	(50)	N	200	100	150	17
Mn	(10)	100	700	300	700	6
Mo	(5)	N	5	N	5	2
Nb	(20)	L	50	L	30	10
Sb-i	(2)	N	7	N	2	3
Y	(10)	10	100	30	70	7
Zn-i	(5)	20	180	52	100	2

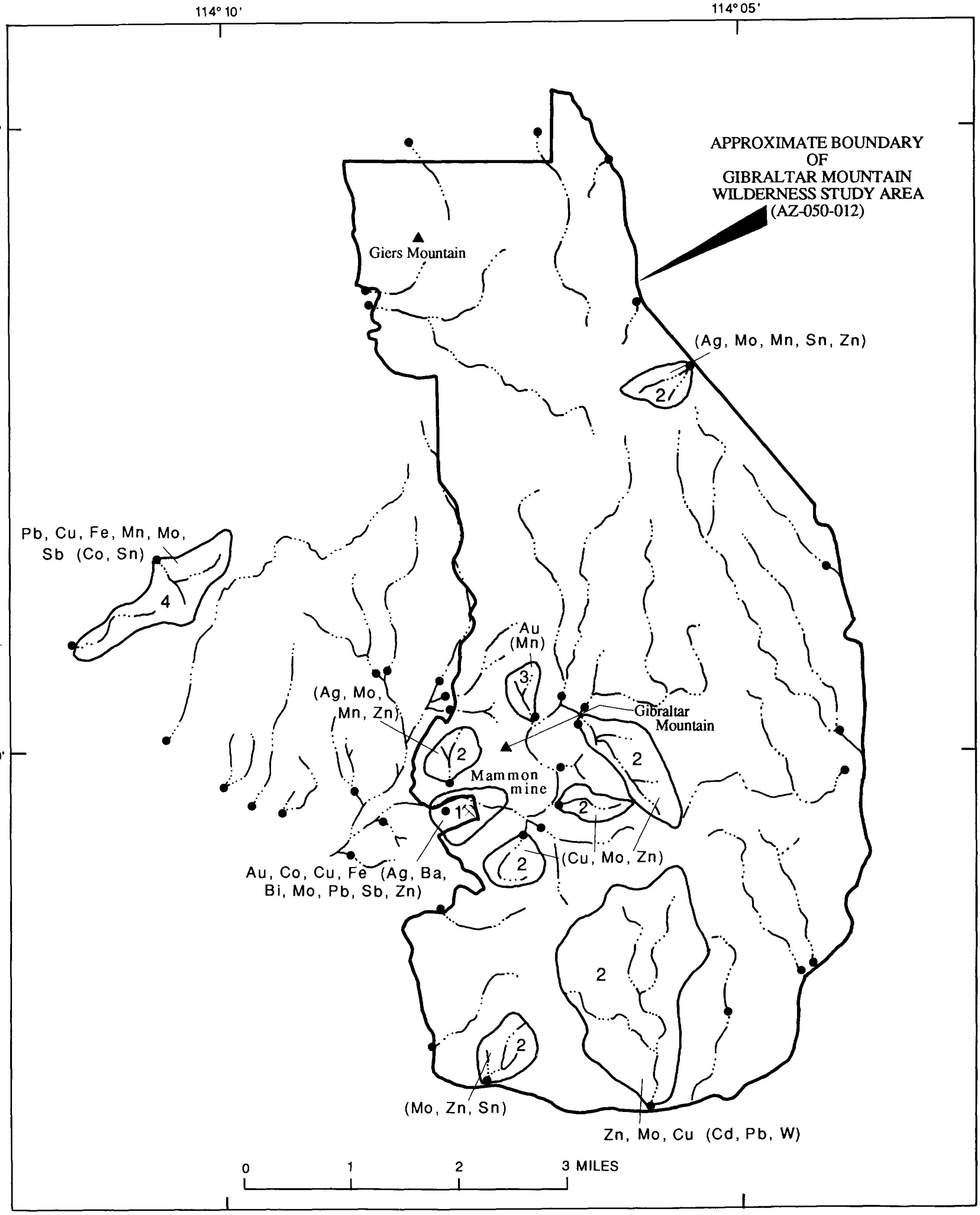

Figure 4. Stream drainages having geochemical anomalies identified from analyses of stream-sediment, heavy-mineral-concentrate, and rock samples and from ore-related minerals identified in nonmagnetic heavy-mineral concentrates collected in and near Gibraltar Mountain Wilderness Study Area, La Paz County, Arizona. Large dots are sampling sites. Parentheses indicate that elements are weakly anomalous. Numbered areas are discussed in text. Ag, silver; Au, gold; Ba, barium; Bi, bismuth; Cd, cadmium; Co, cobalt; Cu, copper; Fe, iron; Mn, manganese; Mo, molybdenum; Pb, lead; Sb, antimony; Sn, tin; W, tungsten; Zn, zinc.

Several wide-spread samples from area 8 (fig. 5) southeast of Planet Peak have low-level anomalous molybdenum. A few scattered samples in area 8 have low-level anomalous concentrations of silver, cadmium, iron, antimony, and (or) tungsten. Traces of scheelite and fluorite were observed in HMC samples. Locally, specularite, malachite, chrysocolla, and epidotized and chloritized rocks were observed in alluvium, which consists principally of locally derived mylonitic, lower-plate, coarse- to fine-grained felsic to intermediate gneisses and granite. Prospects are located in area 8 south of Planet Peak (fig. 3).

Wide-spread samples from area 9 (fig. 5) are characterized by a low-level lead anomaly, and scattered samples exhibit low-level anomalies of silver, cadmium, copper, and antimony; one HMC sample in the northern part has highly anomalous concentrations of cobalt and iron. Ore and ore-related minerals identified in HMC samples include specularite, fluorite, chrysocolla, and trace amounts of vanadinite. A trace of acanthite (Ag_2S) was identified in the cobalt-rich sample. In alluvium, specularite and epidote are common, and malachite was observed at two sites. Alluvial cobbles consist principally of mylonitic lower-plate felsic

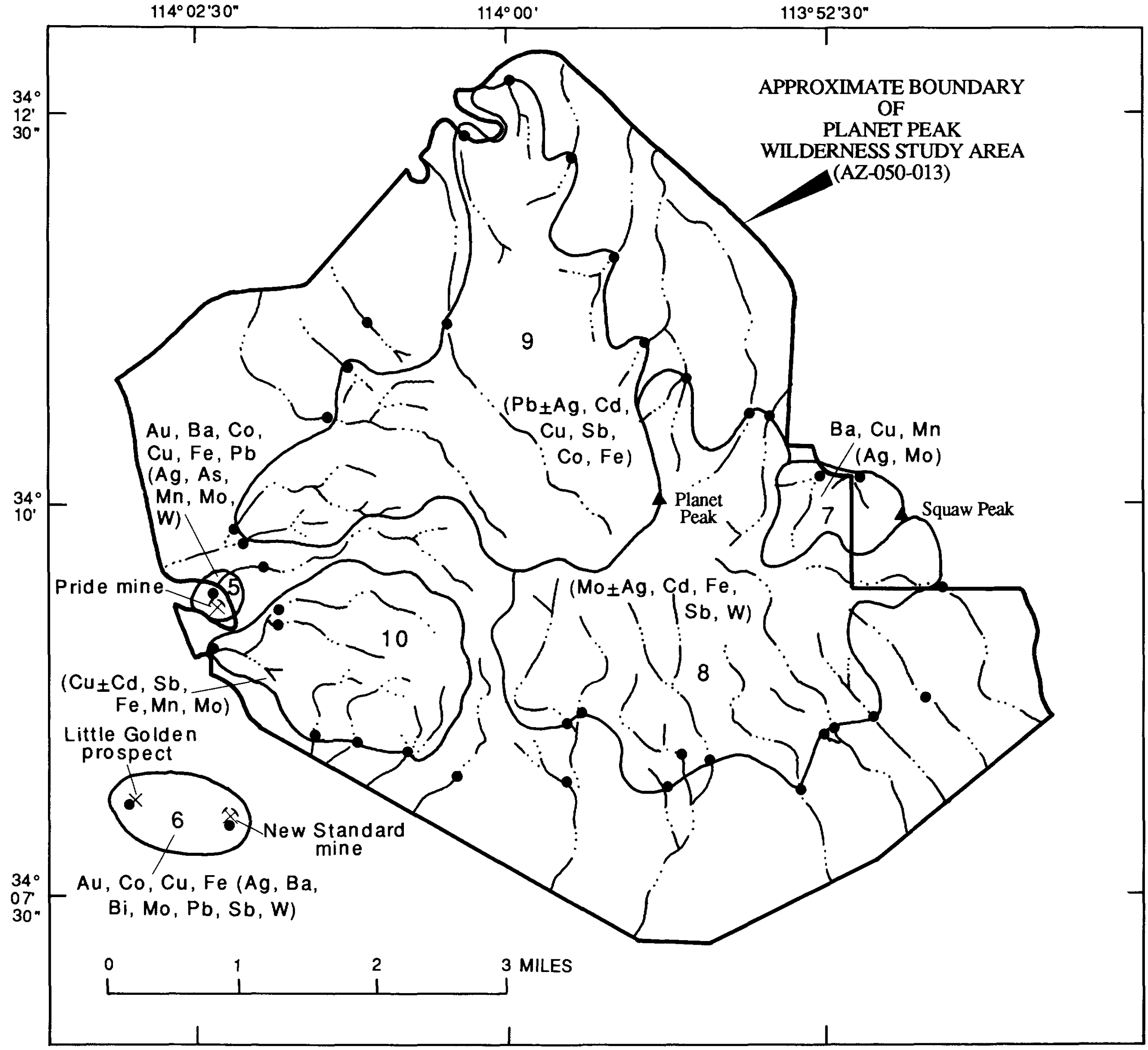

Figure 5. Stream drainages having geochemical anomalies identified from analyses of stream-sediment, heavy-mineral-concentrate, and rock samples and from ore-related minerals identified in nonmagnetic heavy-mineral concentrates collected in and near Planet Peak Wilderness Study Area, La Paz County, Arizona. Large dots are sampling sites. Parentheses indicate elements that are weakly anomalous. Numbered areas are discussed in text. Ag, silver; As, antimony; Au, gold; Ba, barium; Bi, bismuth; Cd, cadmium; Co, cobalt; Cu, copper; Fe, iron; Mn, manganese; Mo, molybdenum; Pb, lead; Sb, antimony; W, tungsten.

to intermediate gneiss. Outcrops of mylonitic lower-plate gneiss are locally chloritized; joints are commonly coated with epidote; and specularite veinlets are found locally.

Samples from area 10 (fig. 5) contain weakly anomalous copper; a few scattered samples have low-level anomalous concentrations of cadmium and antimony and single-site anomalies for iron and manganese. One sample contains anomalous iron, copper, and molybdenum and slightly anomalous silver. Minerals identified in HMC samples from area 10 include abundant barite and anatase, small amounts of fluorite, and traces of scheelite. Cobbles in alluvium consist of mylonitic granite, biotite gneiss, and felsic gneiss. Specularite, epidote, malachite, and chrysocolla were observed locally in alluvium. Mylonitic-gneiss and granite bedrock is locally chloritized, coated with epidote on joints, and, in one area, cut by specularite veinlets. Hematite pseudomorphs after pyrite were observed locally along joint surfaces. Prospects in mylonitic gneiss and granite in the southern part of area 10 contain pods and lenses rich in specularite and chrysocolla.

Interpretation

A common suite of elements found in anomalous concentrations is evident in analyses of stream-sediment, HMC, and rock samples from around the Pride, Mammon, and New Standard mines, the Little Golden prospect, and prospects near Squaw Peak. Anomalies are relatively strong for copper and iron, relatively weak for silver, barium, bismuth, molybdenum, lead, and tungsten, and variable for gold, arsenic, cobalt, manganese, antimony, and zinc. East of the Planet Peak Wilderness Study Area, strongly to weakly anomalous concentrations, generally of this same suite of elements along with tin, vanadium, and thorium, were found in samples from mineralized areas in the Swansea Wilderness Study Area (Tosdal and others, 1990a). South of Cactus Plain, the same general suite, along with strontium, was found in samples from the Plomosa mining district (Tosdal and others, 1990b).

The numerous single-site anomalies for molybdenum and zinc with or without silver, copper, manganese, and tin in the Gibraltar Mountain Wilderness Study Area (fig. 4, areas numbered 2) are difficult to assess. Most of these are weak anomalies in samples from generally basaltic terrain where ore-related minerals were not found in HMC samples. Locally high manganese and iron content in samples throughout much of this study area suggests that adsorption of metals by manganese oxide and iron oxide minerals may be the reason for the anomalous metal concentrations. The adsorbed metals may have been derived from fluids leaking along fractures or joints in basalt from possible underlying concealed mineral deposits related to the detachment fault. Any concealed deposits would likely be similar to those in the Mammon mine area.

A notable exception to metal adsorption is the HMC sample from a drainage in the southern part of the Gibraltar Mountain Wilderness Study Area, where a suite of strongly anomalous zinc, molybdenum, copper, cadmium, lead, and tungsten is found in samples that contain traces of fresh pyrite and of sphalerite, the likely host mineral for the zinc and cadmium. This metal suite and the presence of fresh sulfide minerals suggest that exposed sulfide deposits may be present in the drainage. Follow-up work would be necessary to ascertain whether the metals in this drainage are from deposits that are related to the Buckskin-Rawhide detachment fault, which are common to the region, or from some other type of deposit.

Similarly, the gold-bearing calcite veins cutting basalt in area 3 (fig. 4) need more detailed study to determine whether the detection of gold in calcite can be repeated and, if so, to determine the extent and nature of the anomalous gold. The lack of associated anomalous metals in area 3 is problematic and suggests that the 200-ppb gold value in calcite is spurious. However, further evaluation is warranted because many deposits in the Cienega mining district were relatively rich in gold (Spencer and Welty, 1986a, 1989).

The highly anomalous lead concentrations in area 4 (fig. 4) probably have a human origin. The malleable lead fragments from the HMC sample were generally irregular pieces and fine shavings, a characteristic of lead shot found in HMC samples by Griffitts and others (1984). Anomalous antimony, a commonly used hardener in lead shot, was also found in one of the samples. However, other anomalous metals found in area 4 (copper, cobalt, iron, manganese, and molybdenum), the presence of malachite and specularite in HMC samples, and the presence of hematite-coated bull quartz in drainage cobbles are all favorable evidence for mineralization in the area. Any mineral deposits in area 4 are most likely similar to known deposits immediately to the northwest of the area, where milky-quartz-bearing veins in adits and prospects are found locally along faulted upper-plate rocks (sites G, H, and I in fig. 2 of Spencer and Welty, 1989).

Samples from most of the Planet Peak Wilderness Study Area exhibit low- to moderate-level anomalies for many of the elements found in anomalous quantities (noted above). However, scattered single-site anomalies for one to three of the elements are most common; samples having large anomalous multi-elemental suites are rare. This information, coupled with numerous observations of cobbles, pebbles, and veins of specularite, chrysocolla, hematite after pyrite, epidote, and chlorite, along with fluorite and traces of pyrite, vanadinite, and acanthite in HMC samples throughout the study area, suggests that mineralizing proccesses were widespread in the area. Mines and prospects west and south of Planet Peak are attributed to mineralization related to the Buckskin-Rawhide detachment fault, in the lower-plate rocks and along the detachment fault (Spencer and Welty, 1989). The numerous samples having anomalous metals and the ore-related minerals in samples throughout the study area most likely reflect replacement or fracture-filling in lower-plate rocks along high-angle structures below and locally along the detachment surface, as depicted at sites A, B, and F in figure 2 of Spencer and Welty (1989). These deposits are typically small compared to deposits in upper-plate rocks (Spencer and Welty, 1986b). Thus, the geochemical anomalies in the Planet Peak Wilderness Study Area probably reflect numerous small sporadic copper-iron occurrences, rather than a large concealed deposit.

A subtle metal zonation, also exhibited in the Planet Peak Wilderness Study Area, results from slightly molybdenum-rich rocks to the south and slightly to moderately lead-rich rocks to the north. This zonation may reflect local chemical variation in the large-scale detachment-related mineralization of the region. Spencer and Welty (1989) reported that copper- and iron-sulfide minerals formed early in the genesis of many of the Buckskin-Rawhide detachment related deposits. A reduced chemistry for early mineralizing fluids is suggested by the presence of trace amounts of fresh pyrite (several occurrences), galena (Pride mine), and acanthite (north end of the Planet Peak Wilderness Study Area) and by the more common observation of hematite pseudomorphs after pyrite in samples throughout the study area.

Geophysics

Aeromagnetic and Gravity Data

Aeromagnetic and gravity data for a region encompassing the Gibraltar Mountain and Planet Peak Wilderness Study Areas have been compiled and examined for possible indications of geologic features that may have a bearing on mineral resource evaluations. No new geophysical field work has been performed for the present investigation.

Two sources of aeromagnetic data were used: a survey of the Prescott 1° by 2° quadrangle, Ariz., flown for the National Uranium Resource Evaluation (NURE) program, and a survey of the Needles 1° by 2° quadrangle, Calif. and Ariz., flown for the USGS. The Prescott traverses were made on east-west headings at spacings of 1 mi and at a nominal height of 400 ft above ground (Western Geophysical Company of America, Aero Service Divison, 1979). The Needles traverses were similarly on east-west headings but at 0.5-mi spacings and a nominal drape height of 1,000 ft (U.S. Geological Survey, 1981). Gravity data were obtained from files of the Defense Mapping Agency (DMA) through the National Center for Solar-Terrestrial and Geophysical Data (Boulder, CO 80303) and from J.D. Hendricks of the USGS (Flagstaff, AZ 86001).

A map of the residual total-intensity aeromagnetic field was computed by removal of the International Geomagnetic Reference Field and merging of the two data sets. This map (fig. 6) reveals a striking contrast in magnetic expression of the postdetachment- and the detachment-related rocks. Postdetachment volcanic rocks, chiefly basalts, produce intense short-wavelength anomalies, while the detachment-related mylonitic crystalline rocks produce anomalies that are much more subdued and of longer wavelength. The boundary between these two magnetic domains traces an arc of a circle centered near the southeast corner of the map (fig. 6) and suggests broad domal uplift. Antiforms and synforms of the folded (corrugated) detachment terrane correspond roughly to long-wavelength, northeast-trending anomaly highs and lows east of the boundary within the circle. The Planet Peak Wilderness Study Area is characterized by such anomalies, in contrast to the Gibraltar Mountain Wilderness Study Area, which is characterized by the short-wavelength postdetachment-related anomalies. Because gradients of anomalies over alluviated areas imply only slightly greater depths to source as compared to those over bedrock, the alluvium is most likely rather thin. The broad anomalies associated with the detachment terrane cannot be traced through the belt of short-wavelength anomalies produced by postdetachment volcanic rocks concealed beneath Cactus Plain, southwest of the study areas.

An area of strong field disturbances on the south margin of the map (fig. 6) includes outcropping Phanerozoic granitic rocks and extensive alluvium. These disturbances may reflect the presence of a largely concealed granitic pluton. Proterozoic crystalline rocks of the upper plate exposed in the northwestern and northeastern parts of the mapped region have an aeromagnetic expression intermediate between that of postdetachment volcanic rocks and the lower-plate mylonites in wavelength and intensity of anomalies. Upper-plate rocks such as these are probably present beneath the alluvium north of Bill Williams River near long 113°55' W.

The complete-Bouguer gravity anomaly field (fig. 7) was computed from about 235 stations of the DMA plus Hendricks regional set and additional stations of two detailed Pacific Arizona Crustal Experiment profiles. All data reductions and terrain corrections employed a standard Bouguer density of 2.67 grams per cubic centimeter and followed conventional USGS procedures (see, for example, Cordell and others, 1982).

The map reveals a non-uniform decrease in anomaly levels from a maximum of about –41 milligals (mGal) in the extreme southwest corner to a minimum of about –93 mGal near the northeast corner. This overall gradient is associated with a first-order structural grain and is accompanied by a mild northeasterly increase in average topographic elevation. Superimposed on the regional gradient are broad lows of about 10-mGal amplitude that roughly correspond to areas of outcrop of postdetachment volcanic rocks. No lows of more than a few milligals amplitude are found anywhere on Cactus Plain. This confirms that no great thickness of alluvial fill is present and suggests that the buried postdetachment volcanic rocks inferred from magnetic data have thinned southward. Estimates of depth to basement made for this region on the basis of gravity data generally yield depths less than 1,000 ft except for a small area near the southwest corner of the map, where the depth of fill may be as great as 2,500 ft (Oppenheimer and Sumner, 1980).

Landsat Thematic Mapper Images and Interpretation

Background

A digitally processed Landsat Thematic Mapper (TM) color-ratio composite image was used to discern the location and distribution of spectral reflectance characteristics that suggest the presence of selected minerals commonly associated with hydrothermally altered rocks in the Gibraltar Mountain and Planet Peak Wilderness Study Areas (figs. 8, 9). The spectral bands of the TM system are too broad to allow individual mineral species to be identified; however, anomalous areas of two spectrally different groups of minerals (groups 1 and 2) can be distinguished (Knepper, 1989).

Group 1 minerals consist of the common ferric iron oxide, hydroxide, and sulfate minerals hematite, goethite, lepidocrocite, and jarosite. These minerals commonly form during the weathering of pyrite and, consequently, are generally associated with weathered, hydrothermally altered rocks. The group 1 minerals are not, however, diagnostic of hydrothermally altered rocks because they can also form from the oxidation of iron-bearing minerals in unaltered rocks (Knepper, 1989, p. 13). Areas having concentrations of the group 1 minerals commonly indicate that the rocks have been altered and are said to have group 1 anomalies.

Group 2 minerals are diverse, including hydroxyl-bearing and (or) hydrated minerals (clay minerals, micas, gypsum, alunite, and jarosite) and carbonate minerals (calcite

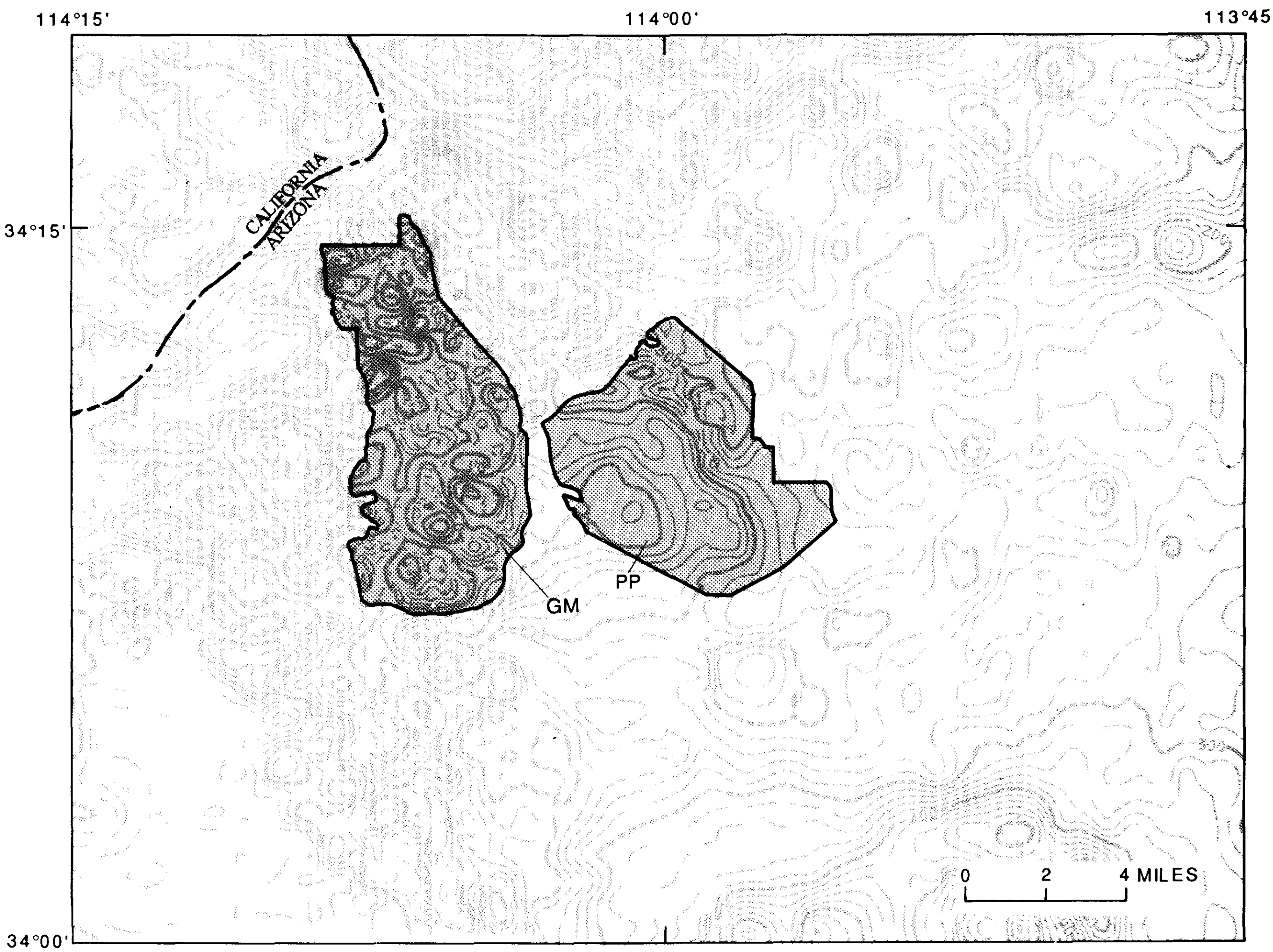

Figure 6. Residual total-intensity aeromagnetic map of region including Gibraltar Mountain (GM) and Planet Peak (PP) Wilderness Study Areas, California and Arizona. Contour interval 20 nanoteslas; hachures indicate closed areas of lower values.

and dolomite), all of which are spectrally similar in the TM bands. Jarosite shares common spectral characteristics with both group 1 and group 2 minerals and is included in both classes. Although the group 2 minerals are not restricted to altered rocks, they are commonly important constituents of altered rocks or are derived from the weathering of altered rocks (Knepper, 1989). Areas indicating group 2 minerals are said to have group 2 anomalies.

In some places, spectral characteristics indicate that areas of group 1 minerals overlap those of group 2 minerals such that both groups of minerals may be present. Such areas are said to have group 3 anomalies and to contain group 3 minerals.

Interpretive Methods

Interpretation of potentially hydrothermally altered rocks on the TM color-ratio composite image consists of visually outlining distinct areas of unique colors related to group 1, group 2, or group 3 minerals (Knepper, 1989, p. 17). Areas clearly related to unaltered rocks or sediments were excluded from the analysis. The remaining areas are considered anomalous and may reflect local exposures of hydrothermally altered rocks. Additional field studies would be necessary to document thoroughly the nature of any altered rocks associated with the anomalies and to eliminate possible false anomalies.

Light to moderate vegetation obscures parts of the study area. Because of the rugged topography, combined with the relatively low solar elevation angle at the time the TM data were acquired (25°), a significant part of the study area is in deep to moderate shadow on the TM image. The Mammon mining district in particular is partially covered by deep shadows. Vegetation and shadows, then, have obscured some areas of surface rocks and soils that could otherwise be spectrally analyzed for evidence of possible

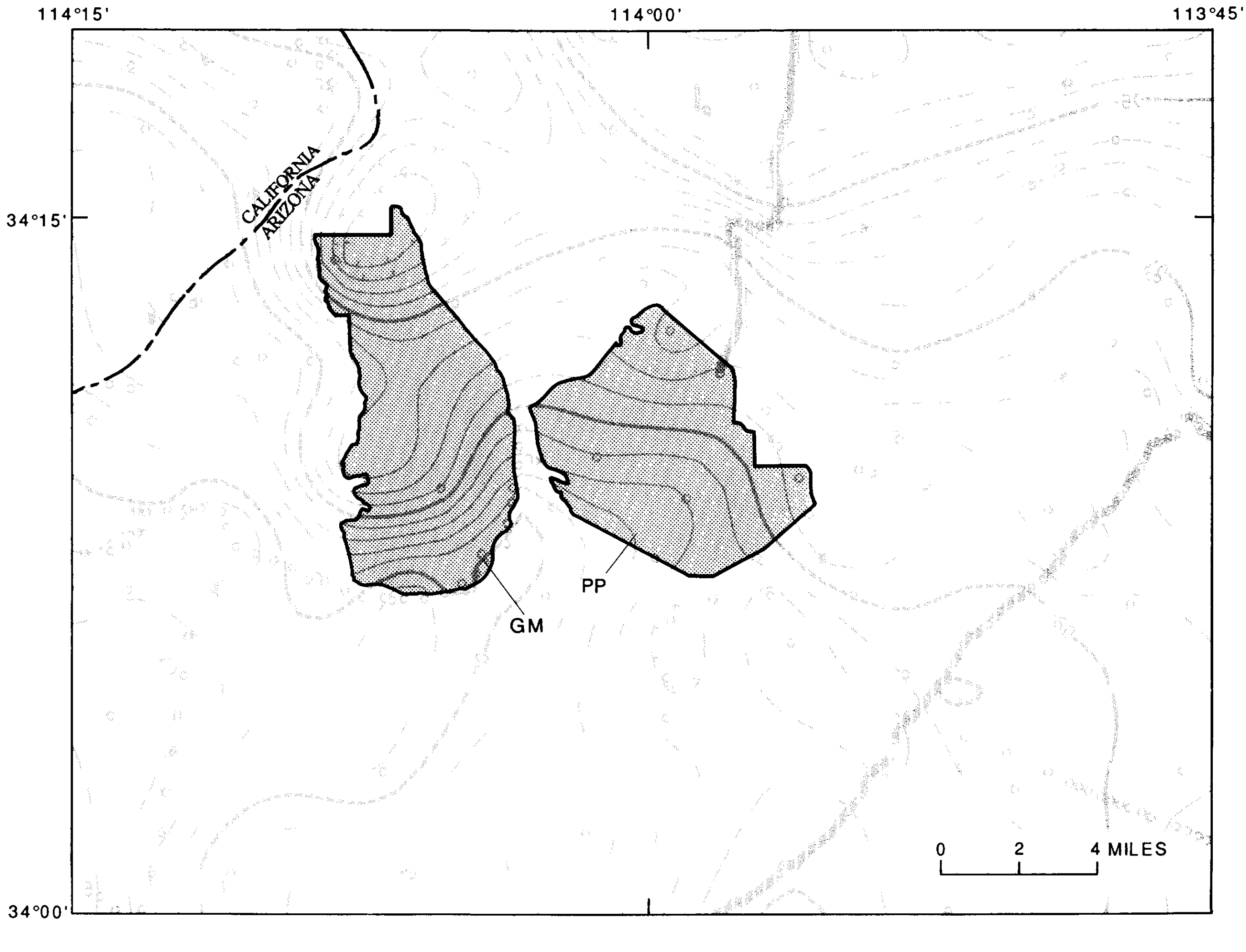

Figure 7. Complete-Bouguer gravity anomaly map of region including Gibraltar Mountain (GM) and Planet Peak (PP) Wilderness Study Areas, California and Arizona. Contour interval 2 milligals; hachures indicate closed areas of lower values. Open circles represent gravity stations.

alteration minerals. Even so, several anomalous areas were identified (figs. 8, 9); these anomalies, because of the masking effects of vegetation and shadows, may represent only parts of more extensive areas.

Possible Areas of Hydrothermally Altered Rocks

The Cienega mineral district west of the Gibraltar Mountain Wilderness Study Area is clearly anomalous in group 1, group 2, and group 3 minerals (fig. 8). The anomalies in this district appear to reflect altered host rock at least partly contained in mine dumps and tailings. Within the study area, two large areas of iron oxide (group 1) anomalies are present along with smaller local anomalies of group 1, group 2, and group 3 minerals. The large areas of iron oxide (group 1) anomalies appear to reflect unaltered bedrock. The large anomaly in the southern part of the study area is mostly associated with the trachytic rocks. The large anomaly along the northeast side of the study area has spectral characteristics that suggest iron oxide anomalies within basin sediments, but the area is primarily underlain by basalt. These large anomalies are probably due to weathering of the underlying rock but could indicate subtle large-scale hydrothermal alteration, although such alteration was not seen in the field. The small anomalies labeled 1v appear to be caused by iron oxide alteration formed through weathering of basalt outcrops. The remaining anomalies, representing hydrothermal alteration and mapped from the TM color-ratio composite image, are in a variety of rock types throughout the study area; these may mark small areas of previously unrecognized hydrothermally altered rocks. Note the group 3 anomaly in the southern part of the study area. All group 2 anomalies and the northernmost group 1 anomaly east of the study area possibly represent dispersed anomalies or disturbed ground. Further study, beyond the scope of this assessment, would be needed to evaluate these areas.

Near the north edge of the Planet Peak Wilderness Study Area are areas clearly anomalous in group 3 minerals (fig. 9). These anomalies appear to reflect altered host rock in and near the Mineral Hill and Planet subdistricts of the Planet mineral district. Within the study area, two moderate-sized and several small iron oxide (group 1) anomalies are very localized. The anomaly northwest of Squaw Peak lies just west of mined ground. One small group 3 anomaly is near the north border of the study area. No group 2 anomalies were detected, and no strong group 1 anomalies were found in the study area by using Landsat TM data.

Aerial Gamma-ray Spectrometry

Natural radioelement distribution in the study areas was evaluated by examining available data from aerial gamma-ray spectrometry surveys of the Needles and Prescott 1° by 2° quadrangles (Geodata International, Inc., 1979, and Western Geophysical Company of America, Aero Service Division, 1979, respectively). These surveys acquired the data along east-west flightlines 400 ft above ground level at intervals of 3 mi (Needles) and 1 mi (Prescott). The three flightlines that cross the Gibraltar Mountain Wilderness Study Area, which is wholly within the Needles quadrangle, provide about 5-percent coverage of the study area because an aerial gamma-ray survey at 400 ft above ground level effectively measures terrestrial gamma radiation from a swath 800 ft wide along each flightline. The Planet Peak Wilderness Study Area is approximately split between the Needles and Prescott quadrangles. No flightlines cross the Needles part of the study area, and seven flightlines cross the Prescott part. Resulting coverage for the Planet Peak study area is about 7.5 percent, all within the east half of the study area. For each study area, coverage represents a reconnaissance sampling of the near-surface (0- to 18-in. depth) distribution of the natural radioelements potassium (K), uranium (eU), and thorium (eTh). The prefix e (for equivalent) denotes the potential for disequilibrium in the uranium and thorium decay series.

Preliminary, relatively small-scale radioelement contour maps that include the Gibraltar Mountain Wilderness Study Area indicate that it is characterized by the relatively low concentrations of 1.2 percent K, 2.5 ppm eU, and 5 ppm eTh. Generally, in terranes where igneous rocks predominate, higher radioelement concentrations relate to more silicic, more radioactive rocks and to detritus derived from them, whereas lower concentrations relate to less silicic, less radioactive rocks and their detritus. Low concentrations within the Gibraltar Mountain Wilderness Study Area, reflect the abundant Miocene olivine-basalt flows that dominate the northern two-thirds of the study area. Relatively more silicic and alkalic trachytic volcanic rocks, present in the southern one-third of the study area, would be expected to have higher radioelement concentrations than the basalts to the north; however, the reconnaissance coverage for the study area precludes detection of these lithologic contrasts.

Radioelement concentrations derived from relatively small-scale contour maps that include the Planet Peak Wilderness Study Area are 2 to 3 percent K, 4 to 5 ppm eU, and 10 to 15 ppm eTh. Higher concentrations of 3 percent K, 5 ppm eU, and 15 ppm eTh in the northern part of the study area may reflect the presence of silicic rocks of the Planet Volcanics and sedimentary rocks, whereas lower concentrations of 2 to 2.5 percent K, 4 ppm eU, and 10 to 12.5 ppm eTh to the south are more characteristic of the mylonite. The concentrations measured in both study areas are thought of as normal (not anomalous) levels for the rocks present in these areas, and the widely spaced reconnaissance flightline coverage precludes deriving any direct information on mineral resource potential from the aerial gamma-ray data.

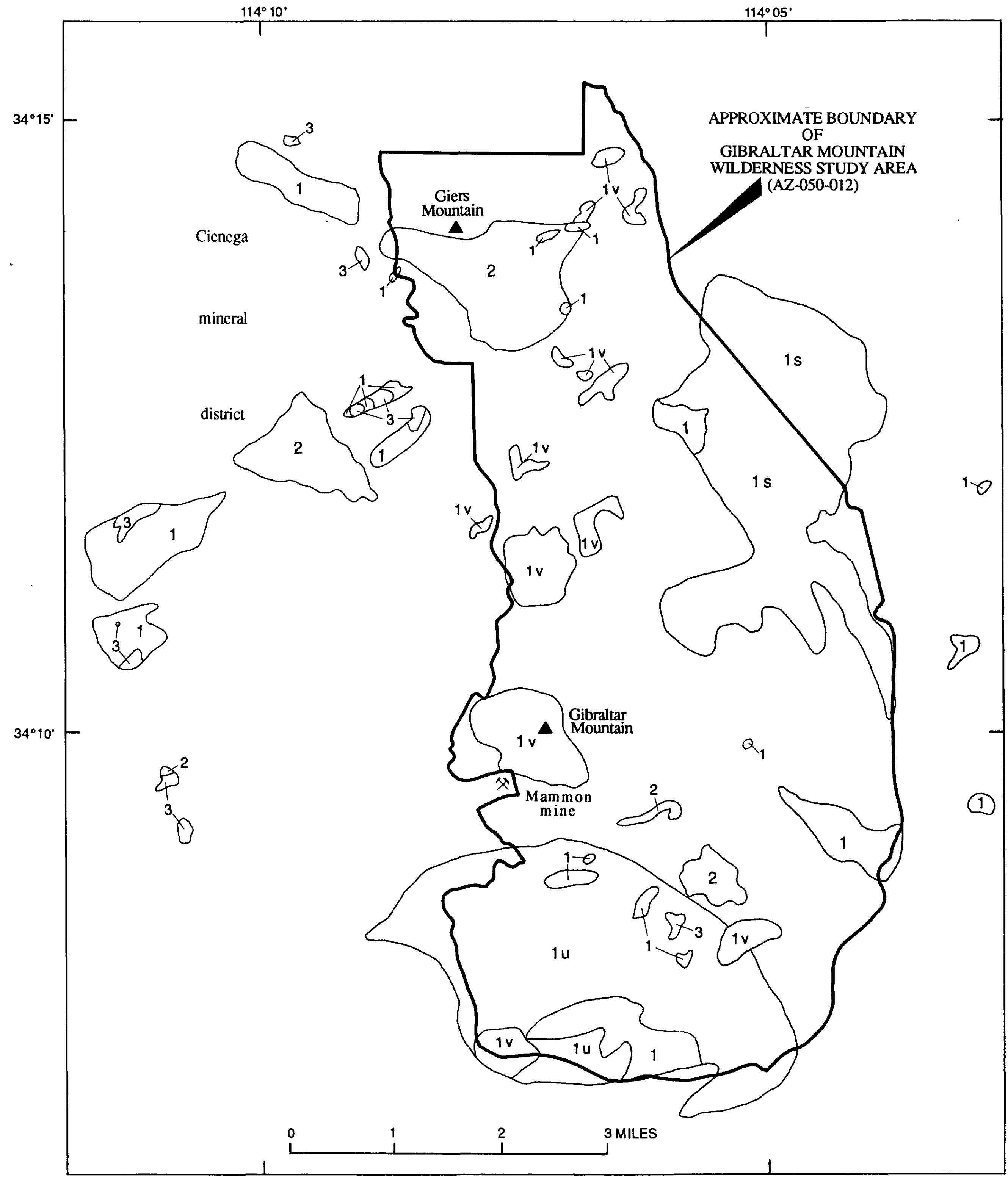

Figure 8. Distribution of potentially hydrothermally altered areas in and near Gibraltar Mountain Wilderness Study Area, Arizona, based on interpretations of Landsat Thematic Mapper color-ratio composite images. Numbered areas (1-3) contain various combinations of spectrally different mineral groups (see text): 1, group 1 minerals; 2, group 2 minerals; 3, groups 1 and 2 minerals. Suffixes: v, probable iron oxide alteration from weathering of basalt; s, iron oxide anomalies associated with spectral characteristics of basin sediments; u, iron oxide anomalies associated with trachytic rocks.

General Discussion of Mineral and Energy Resources

Deposits Near Detachment Faults

As indicated previously, several mineral districts lie adjacent to or partly within the study areas—the Cienega, Mammon, Midway, Planet, Pride, and Swansea. These districts and their subdistricts produced copper, gold, and silver and contain deposits characterized by specularite (hematite) and copper carbonate, silicate, and oxide minerals accompanied by quartz, barite, fluorite, chlorite, manganese oxides, and relict (oxidized) pyrite (Spencer and Welty, 1989). Ore deposits are found in several settings in both

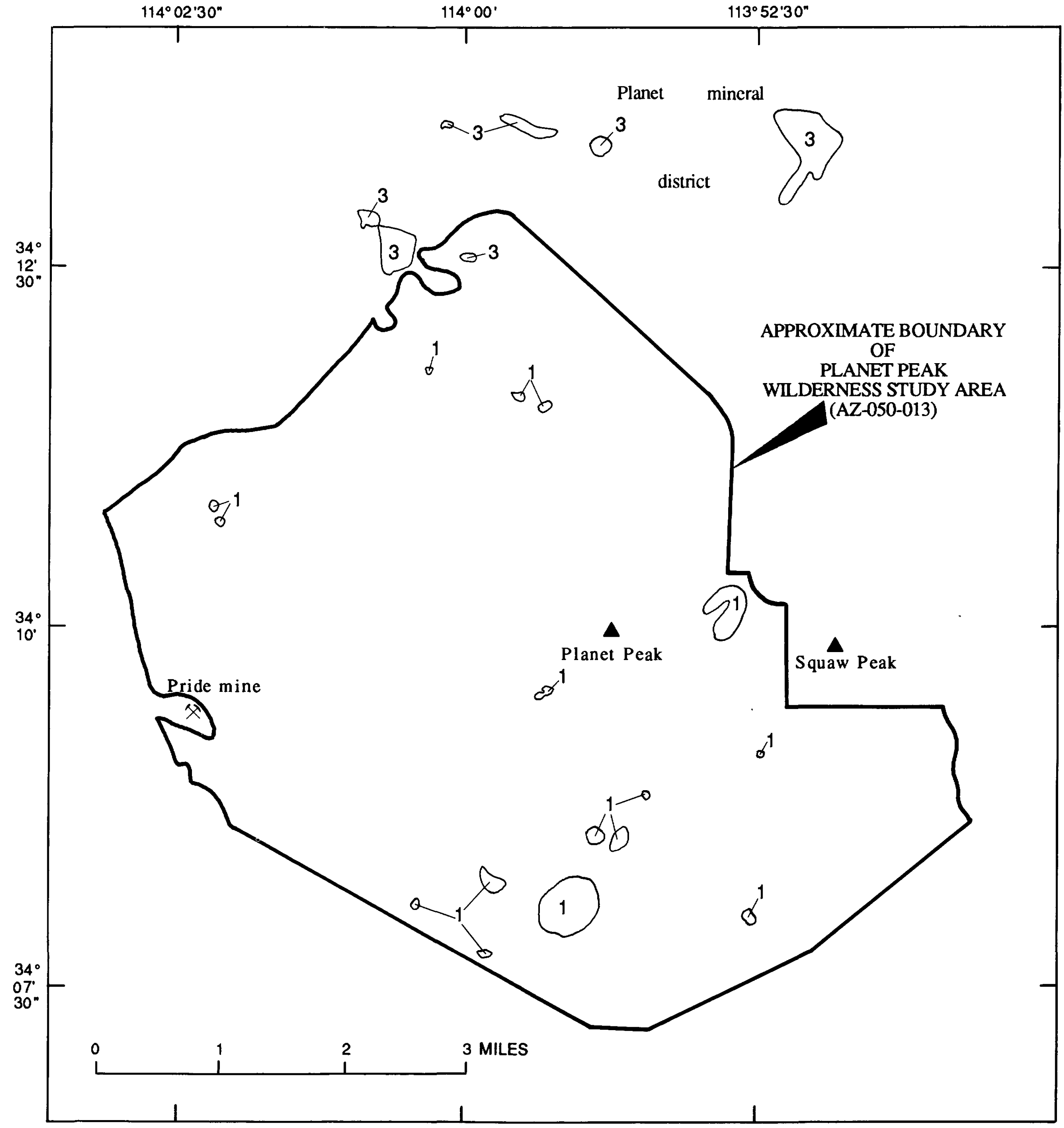

Figure 9. Distribution of potentially hydrothermally altered areas in and near Planet Peak Wilderness Study Area, Arizona, based on interpretations of Landsat Thematic Mapper color-ratio composite images. Numbered areas (1-3) contain various combinations of spectrally different mineral groups (see text): 1, group 1 minerals; 2, group 2 minerals; 3, groups 1 and 2 minerals.

lower- and upper-plate rocks of the Buckskin-Rawhide detachment fault: (1) as massive replacements in carbonate slices within the lower plate, (2) as fracture fillings and possible local replacements in shear zones in lower-plate crystalline rocks, (3) as massive replacements in upper-plate metasedimentary rocks adjacent to the fault, (4) as fracture fillings and possible replacements in silicified, iron-stained, and brecciated rocks within and adjacent to the detachment fault, and (5) as fracture fillings and local replacements in high-angle shear zones in upper-plate rocks (Spencer and Welty, 1989). The ore deposits of the Cienega mineral district contain more gold than other deposits of the Buckskin Mountains, are more than 1,000 ft above the detachment fault, and are spatially associated with Mesozoic thrust faults.

Deposits similar to those in the Buckskin Mountains are found farther west in the Whipple Mountains (Ridenour and others, 1982; Wilkins and Heidrick, 1982). However, some deposits that may be associated with detachment faults contain primarily gold without copper or hematite (Frost and Watowich, 1987; Drobeck and others, 1986). Although both gold and copper-iron types of deposits are spatially associated with detachment faults, the exact relation between the two remains somewhat obscure. It is thought that the major function of the detachment fault was to serve as conduits for hydrothermal fluids. Most copper-hematite mineralization appears to have been contemporaneous with movement along the fault (Wilkins and others, 1986; Spencer and Welty, 1986b) and to have consisted of early development of copper and iron sulfide minerals, followed by deposition of hematite, and then by formation of copper oxide, silicate, and carbonate minerals (Spencer and Welty, 1986b). The mineralizing process most likely resulted from the movement of metal-rich basinal brines out of the basins during detachment faulting (Wilkins and others, 1986). Frost and Watowich (1987) suggested that copper concentrations formed in deeper parts of a detachment system, whereas the gold seems to have been localized in the uppermost crustal levels where brittle deformation was predominant. These authors suggested that the copper deposits generally lack economic amounts of gold and that the two types of deposits (gold and copper-iron) probably represent end members of the types of deposits that could form along detachment faults. In other words, the deposits are zoned on a regional scale such that copper-iron deposits formed in the deepest parts of the detachment system, whereas gold deposits formed near the surface close to the headwalls of the detachment faults.

The above assertions about the distribution of gold and copper-iron deposits, if correct, and the occurrence of gold in the Cienega district well above the detachment surface could indicate that the copper-hematite deposits in the immediate vicinity of the study areas are unlikely to contain significant amounts of gold. However, the production of small amounts of gold from the Mammon and Pride mines and the presence of gold in several of the geochemical samples suggest that gold may indeed be present at the detachment surface as well as in rocks well above the fault plane. Therefore, undiscovered copper-iron deposits containing small amounts of gold could be present, but in the Gibraltar Mountain Wilderness Study Area, except near the Mammon mine, they would be covered by Tertiary volcanic rocks correlated with the Osborn Wash Formation. Although the copper and iron in these deposits as well as the small amounts of barite, fluorite, and manganese-oxide minerals found locally are not currently of great interest as minable commodities, changes in the Nation's economy or in technology could make some of them attractive again in the future.

Energy Resources

Western Arizona has several localities designated as favorable for low-temperature geothermal resources within 50 mi of the study areas (Witcher and others, 1982), and one thermal well is about 4.5 mi northeast of the Planet Peak Wilderness Study Area. The designated geothermal resource areas all lie within intermontane basins rather than in mountainous terrain like that of the study areas. Similarly, in California, known geothermal wells near the study areas are in basins rather than in mountain ranges (Higgins, 1980). Because inferred geothermal resources near the study areas are in a different geologic setting, it is doubtful that the study areas would have substantial, if any, geothermal resources.

Ryder (1982, 1983) designated the region around the study areas as having low to zero potential for oil and gas because most of the mountain blocks are composed of crystalline and volcanic rocks rather than sedimentary rocks suitable for reservoirs. The Tertiary sedimentary rocks in the intervening basins are generally less than 5,000 ft thick but could provide traps for hydrocarbons. However, the study areas extend only a short distance basinward and are, thus, unlikely candidates for petroleum resources.

Mineral and Energy Resources of the Gibraltar Mountain Wilderness Study Area

The high mineral resource potential, certainty level C, for copper, iron, and gold in the Mammon mine area of the Gibraltar Mountain Wilderness Study Area is based on the known production of the commodities from the mine, on the abundant hematite in the case of iron, and on the geochemical anomalies for these elements in that area. The area also has low potential, certainty level C, for silver, barite, and manganese and low potential, certainty level B, for fluorite on the basis of the presence of these elements in geochemical samples from the area. Production of small quantities of silver is known from some deposits related to detachment faults. Although fluorine analyses were not performed during this study, the presence of fluorite in some geochemical samples and at nearby prospects suggest that some parts of the study area have low potential for fluorite resources.

The northwest corner of the study area, where upper-plate Proterozoic rocks crop out, has moderate mineral resource potential, certainty level C, for copper, iron, and gold and low resource potential, certainty level B, for silver, barite, manganese, and fluorite because of small prospects in these rocks and because of the appropriate geologic environment for detachment-related deposits. USBM rock samples collected in the prospects of that area yielded anomalous gold and copper, but USGS stream sediments collected from the area do not contain any anomalous elements; therefore any mineralization probably is very sporadic and localized.

The remainder of the detachment-related rocks in the study area are buried below basalts and trachytes correlative with the Osborn Wash Formation or below Quaternary alluvium and, therefore, cannot be directly evaluated. The expected proximity of these buried rocks to the detachment surface and their presumed similarity to nearby exposed rocks suggest that they may contain copper, iron, and gold with accompanying silver, manganese, barite, and fluorite. Low-level geochemical anomalies in drainage samples from the basalts and trachytes may be derived from leakage halos from possible underlying mineralized rocks. These geochemically anomalous elements include gold, molybdenum, zinc, silver, manganese, lead, tin, tungsten, and cadmium. Without detailed examination, the mineral resource potential of these buried rocks is unknown, certainty level A, for copper, iron, gold, silver, manganese, barite, and fluorite.

The study area has no potential for energy resources such as geothermal waters or for oil and gas because the geological environment is unsuitable for the accumulation of these commodities.

Mineral and Energy Resources of the Planet Peak Wilderness Study Area

Exposed rocks of the Planet Peak Wilderness Study Area consist of lower- and upper-plate rocks near the Buckskin-Rawhide detachment-fault surface, which is exposed locally. Because rocks adjacent to the detachment surface are known to be mineralized, the mineral resource potential of the exposed upper-plate rocks is high and that of exposed lower-plate rocks is moderate, both certainty level C, for copper, iron, and gold. Although iron has never been mined from these deposits, its ubiquitous presence in hematite must be considered. The area directly around the Pride mine, where a small amount of silver was produced, also has a high resource potential, certainty level C, for silver, while the rest of the exposed upper- and lower-plate rocks have low resource potential, certainty level C, for silver.

Geochemical anomalies for manganese and barium in various parts of the study area and for manganese in nearby prospects indicate that the study area has low potential, certainty level C, for manganese and barite resources in the upper- and lower-plate rocks. Similarly, fluorite found in HMC samples from the study area and in nearby prospects suggests that the resource potential is low, certainty level B, for fluorite in the same areas.

Rocks of the lower and upper plates of the detachment fault continue beneath the alluvium along the edges of the study area. Along the northwest border the mineral resource potential is unknown, certainty level A, for copper, iron, gold, silver, barite, manganese, and fluorite because the rocks below the alluvium are part of the lower plate of the detachment fault. However, along the south, southeast, and northeast boundaries the mineral resource potential is high, certainty level B, for copper, iron, and gold and is unknown, certainty level A, for silver, barite, manganese, and fluorite because the rocks below the alluvium are part of the upper plate.

Because the geology of the study area is not conducive to the accumulation of oil or gas or for geothermal energy resources, the study area has no resource potential for these commodities.

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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.

<table>
<tr><th></th><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td rowspan="4">LEVEL OF RESOURCE POTENTIAL ↑</td><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.
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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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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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Miscellaneous Field Studies Maps are multicolor or black-and-white maps on topographic or planimetric bases on quadrangle or irregular areas at various scales. Pre-1971 maps show bedrock geology in relation to specific mining or mineral-deposit problems; post-1971 maps are primarily black-and-white maps on various subjects such as environmental studies or wilderness mineral investigations.

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Eppinger; others—MINERAL RESOURCES, GIBRALTAR MOUNTAIN, PLANET PEAK WILDERNESS STUDY AREAS, ARIZONA—U.S. Geological Survey Bulletin 1704-B