Mineral Resources of the Harcuvar Mountains Wilderness Study Area, La Paz County, Arizona

U.S. GEOLOGICAL SURVEY BULLETIN 1701–F

Chapter F

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U.S. GEOLOGICAL SURVEY BULLETIN 1701

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
WESTERN ARIZONA AND PART OF SAN BERNARDINO COUNTY, CALIFORNIA

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 a part of the Harcuvar Mountains Wilderness Study Area (AZ–020–075), La Paz County, Arizona.

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[Plate is in pocket]

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Mineral Resources of the Harcuvar Mountains Wilderness Study Area, La Paz County, Arizona

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ABSTRACT

Two small areas in the Harcuvar Mountains Wilderness Study Area (AZ–020-075) contain inferred subeconomic resources. One area has 8,000 tons of identified resources of 1.8 percent copper, and the other has 2,000 tons of 0.030 ounce-per-short ton gold and 1.15 percent copper (fig. 1). Four separate areas that together constitute about 36 percent of the study area have a moderate resource potential for either silver, gold, copper, lead, or tungsten in small to medium-size vein or disseminated deposits. The remaining 64 percent has an unknown resource potential for gold in small to medium-size disseminated deposits. Two areas having moderate and high resource potential for gold, silver, copper, lead, and zinc are within 1 mile of the study area. The entire study area has a low potential for oil, gas, coal, geothermal resources, sand and gravel, industrial rocks and minerals, and decorative and ornamental stone. The entire study area also has a low potential for copper, zinc, lead, gold, and silver in massive sulfide deposits; a low potential for rare-earth minerals, feldspar, and mica in pegmatites; and a low potential for deposits of placer gold.

Manuscript approved for publication, September 29, 1989.

SUMMARY

As requested by the U.S. Bureau of Land Management, the U.S. Geological Survey and the U.S. Bureau of Mines studied 25,287 acres of the Harcuvar Mountains Wilderness Study Area (AZ–020–075) in the central part of western Arizona, 40–50 miles west of Wickenburg (fig. 1). The mountains are a typical desert range of western Arizona, rugged, but only moderately high. Elevation ranges from about 2,400 ft to slightly less than 5,000 ft. The Harcuvar Mountains are the central of three northeast-trending ranges, all of which trend at high angles to the more northerly and northwesterly orientation of adjacent mountains. To the southeast, McMullen Valley separates the Harcuvar Mountains from the Harquahala Mountains; to the northwest, Butler Valley lies between the Harcuvar Mountains and the Buckskin Mountains. The Atchison, Topeka, and Santa Fe Railroad and U.S. Highway 60 parallel McMullen Valley, which contains the towns of Wenden and Aquila and agricultural farms. Butler Valley is quite barren and has only a ranch road and abandoned ranch facilities. The area is accessible from trails leading away from U.S. Highway 60 and the paved road leading from Wenden to Alamo Dam on the northwest side of the range.

The study area is underlain mainly by Early Proterozoic (see geologic time chart in Appendix) amphibolite, schist, and deformed granitic rocks that are about 1.7 billion years old. These crystalline rocks are intruded by the Late Cretaceous granite of Tank Pass. Early Miocene microgabbro dikes cut the older rocks, as do northwest-trending faults and shear zones. Oligocene(?) to Miocene volcanic and sedimentary rocks are locally present on the northwest and southeast flanks of the range in the upper plate of the regionally extensive Bullard detachment fault. Crystalline rocks of the Harcuvar Mountains are arched to form a broad anticline whose axis lies about along the range crest. The detachment fault, likewise, appears to be arched about this axis and dips away from the range on all sides.

Identified Resources

Two mineralized areas in the Harcuvar Mountains Wilderness Study Area contain inferred subeconomic resources along fault zones and associated quartz veins. An inferred subeconomic resource of 600 tons of 3.3 percent copper is estimated for the Webber adit, and 8,000 tons of 1.8 percent copper is estimated for the entire fault zone of the Webber mine area. Prospects near the mouth of Happy Camp Canyon have inferred subeconomic resources of 2,000 tons of 0.030 oz (troy ounce) gold per short ton and 1.15 percent copper.

Mineral Resource Potential

Four areas have a moderate resource potential for either silver, gold, copper, lead, or tungsten in small to medium-size vein or disseminated deposits. These areas make up about 14.6 mi² (square miles), or about 36 percent of the approximately 40-mi² study area (fig. 1 and pl. 1). These areas have anomalous concentrations of metals in stream-sediment and rock samples, have favorable host rocks and structures, and three of the areas have obvious mineralized rock at the surface. Two of the areas center around mines that contain identified resources of gold and copper. The resource potential for gold in the remaining 64 percent of the study area is unknown due to lack of appropriate geochemical data.

Two areas outside the wilderness study area also have potential for undiscovered metallic resources in small to medium-size vein or disseminated deposits. Within 0.5 mi to the northeast of the study area, an area has moderate resource potential for silver, gold, and copper. Within 1 mi to the east of the study area, an area has high resource potential for gold, silver, copper, lead, and zinc.

Paleozoic or Mesozoic rocks that could act as either reservoir or source rocks for oil or gas are not present in the study area. Also, no strata are present that contain significant quantities of organic material or coal. Furthermore, if those rocks were present at depth, they would most likely be metamorphosed and would be purged of oil and gas. Therefore, the study area has low potential for oil, gas, and coal.

Geothermal energy sources are likewise not present, as there are no surface geologic indications of hot springs, nor does water from any wells in valleys adjacent to the study area have anomalous temperatures or chemistries indicative of mineral-rich hot springs. Therefore, the study area has a low potential for geothermal energy resources.

The study area contains significant amounts of sand and gravel, especially along the northwestern and southeastern borders of the Harcuvar Mountains. This material is very poorly sorted and contains many cobbles and boulders. Therefore, the study area has only a low resource potential for sand and gravel. No industrial rocks or minerals and decorative or ornamental stone (except for the gravel) are present in significant quantities in the study area. Therefore, the study area has a low potential for all industrial rocks or minerals.

Early Proterozoic amphibolite in the study area is magmatic in origin and could be part of a volcanogenic suite related to copper-, zinc-, lead-, gold-, and silver-rich massive sulfide deposits exposed near Bagdad and Prescott. However, related rhyolitic rocks that typically host these massive sulfide deposits are not present, nor are chemically precipitated rocks, such as chert or iron-formation that could indicate hydrothermal alteration. Therefore the study area has a low potential for copper, lead, zinc, gold, and silver in massive sulfide deposits.

Pegmatite bodies associated with the granite of Tank Pass are widespread throughout the study area but do not contain significant concentrations of rare-earth-element minerals, feldspar, or mica. Therefore, the study area has a low resource potential for these commodities in pegmatites.

Placer gold deposits derived from weathering of gold-bearing quartz veins could be present in the unconsolidated material along the flanks of the Harcuvar Mountains, particularly in the southern part of the study area. The resource potential for placer gold deposits in

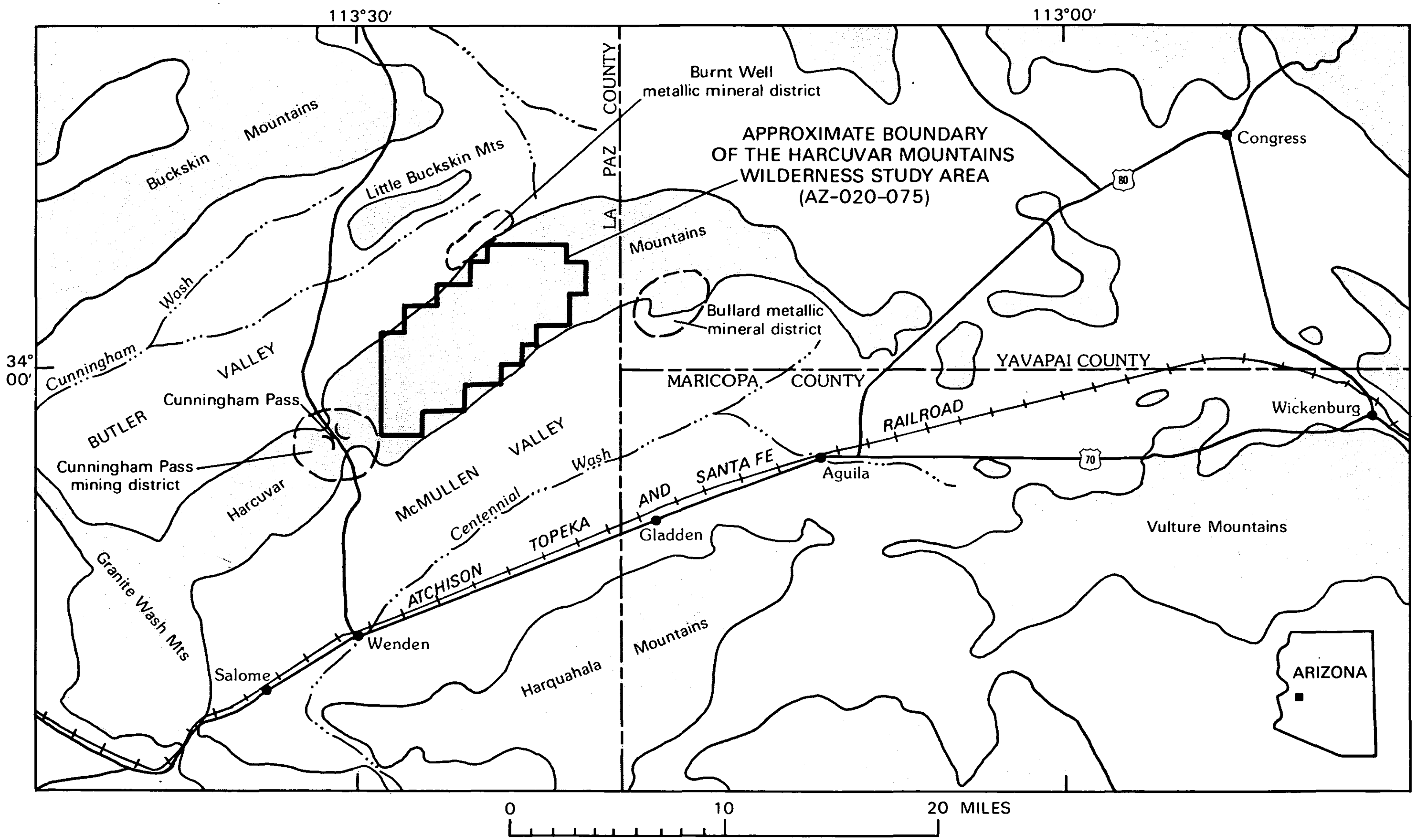


Figure 1. Index map showing location of the Harcuvar Mountains Wilderness Study Area, La Paz County, Arizona. Mountain ranges are stippled. Mining district from Keith (1978) and metallic mineral districts from Keith and others (1983).

that study area is low, however, due to the small size of known gold-bearing veins and the immature nature (insufficiently reworked) of sediments in the unconsolidated material.

INTRODUCTION

As requested by the U.S. Bureau of Land Management, the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM) studied 25,287 acres of the Harcuvar Mountains Wilderness Study Area (AZ–020–075) in west-central Arizona, appraised identified mineral resources, and determined the mineral resource potential of the area. The study area is in the eastern part of La Paz County, Arizona, a county that was only recently established from part of northern Yuma County. In this report, the Harcuvar Mountains Wilderness Study Area is referred to as the "study area."

The Harcuvar Mountains Wilderness Study Area, which is about 40–50 mi west of Wickenburg (fig. 1), is about 12 mi long and from 3 to 5 mi wide. The study area is restricted to the northeastern half of the range, north of Cunningham Pass. Topography of this part of the range is characterized by a single, fairly level main ridge having a locally wide crest. Lower flanks of this main ridge are steeper and more rugged, particularly on the southeast flank, and contain canyons and spurs. Smith Peak, the highest point in the range is 5,242 ft in elevation; elevations in the study area range from 4,957 ft in the northeast to slightly higher than 2,400 ft in the southwest, near Cunningham Pass.

Vegetation is typical of the Sonoran Desert and is characterized by palo verde, saguaro and barrel cactus, ocotillo, and mesquite. The region is characterized by low precipitation, high temperatures, and high evaporation. The only spring in the area is generally dry.

This report presents an evaluation of the mineral endowment (both the identified resources and the mineral resource potential) of the study area and is the product of several studies by the USBM and USGS. Identified resources are classified according to the system of the U.S. Bureau of Mines and the U.S. Geological Survey (1980), which is shown in the Appendix of the present report. The USBM evaluated the mines, major prospects, mineralized areas, and identified resources. Mineral resource potential is the likelihood of occurrence of undiscovered metals and nonmetals, industrial rocks and minerals, and energy resources (coal, oil, gas, and geothermal sources), and is classified according to the system of Goudarzi (1984), which is also shown in the Appendix. Geological, geochemical, remote-sensing, and geophysical studies were completed by the USGS, as was the potential for undiscovered resources.

Investigations by the U.S. Bureau of Mines

The USBM study of the mines, prospects, and mineralized areas is presented separately by Tuftin (1988) and is summarized here. Tuftin (1988) reviewed the mining literature and oil and gas lease records. Accessible mine workings were visited and sampled. Also, some alluvial sites near mineralized areas were sampled. Computations were made of identified resources.

Investigations by the U.S. Geological Survey

Geologic mapping of the study area was completed, in large part, by helicopter-assisted downhill traversing of rugged and remote parts of the range in a 5-day period by Harald Drewes, Bruce Bryant, Ed DeWitt, and E.N. Hinrichs of the USGS, and S.J. Reynolds and J.E. Spencer of the Arizona Geological Survey. The remainder of the study area in lower and more accessible areas was mapped by Drewes and Hinrichs in an additional 11 days. Geochemical and petrographic samples were collected during mapping. Computer-generated maps of geochemical data were prepared by S. Azam of the Pakistan Geological Survey.

The geochemical study was conducted by R.H. Hill and was based mainly on stream-sediment and nonparamagnetic heavy-mineral-concentrate samples; some rock chip samples were used.

Remote-sensing data were analyzed by D.H. Knepper, Jr., using satellite imagery and computer-controlled color enhancement techniques that are designed to delineate areas of iron-oxide and clay-mineral alteration. The method is particularly suitable in arid regions.

Gravity and magnetic surveys of the area were analyzed by W.F. Hanna. Gravity data are in the form of a terrain-corrected Bouguer gravity anomaly map. Aeromagnetic data are in the form of a total-field magnetic anomaly map made from a survey flown about 400 ft above the ground.

APPRAISAL OF IDENTIFIED RESOURCES

S.E. Tuftin
U.S. Bureau of Mines

Two mineralized areas (A and B, fig. 2 and pl. 1) in the central and southeastern parts of the study area contain small mines and prospects situated on four northwest-striking faults. Mineralized area A is at the head of Webber Canyon near the center of the study area. The Webber adit and other workings contain abundant copper-rich minerals. Mineralized area B is near the mouth of Happy Camp Canyon and has workings in which gold and other metals are found. These two mineralized areas were the focal point for the field study by the USBM.

Methods of Investigation

Prior to field work, a literature search was conducted for minerals information pertinent to the study area. Bureau of Land Management (BLM) records were checked for current mining claims (plotted on pl. 1) and oil and gas leases (shown on fig. 3). Two USBM geologists conducted a 5-day field examination of the study area.

Twenty-five rock-chip and mine-dump samples were collected from mines and prospects in and near the study area. Gold concentrations were determined by combined fire-assay and atomic-absorption spectrometry; silver and copper concentrations were determined by atomic-absorption spectrometry. Five samples were selected for multielement analyses by inductively coupled plasma-atomic emission spectrometry. Sample analyses were conducted by Chemex Labs Inc., Sparks, Nev. Assay data and analytical results are summarized by Tuftin (1988) and are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, Colorado.

Mining History

Several prospects and small mines in the central part and along the southeastern margin of the study area have been worked, but there is no record of mineral production from them. According to BLM records, about 840 acres are covered by unpatented mining claims (pl. 1) in the study area as of May 1986.

The Cunningham Pass mining district (Wilson and others, 1934; Keith, 1978) is centered about 3 mi west of the study area on a broad northwest-trending fault zone in Early Proterozoic crystalline rocks and Cretaceous granite (Keith, 1978, p. 29–33; Keith and others, 1983). Prospecting and mining in this district began in the middle 1880's when numerous shafts and open cuts were worked for copper, gold, and silver. Total estimated and recorded production from the Cunningham Pass district through 1974 is about 9,000 tons of ore containing 773 tons of copper, 4,436 oz gold, 2,344 oz silver, and minor amounts of lead (Keith, 1978, p. 32). At May 1988 market prices of $1.04/lb (pound) copper, $451.06/oz gold, and $6.54/oz silver (Engineering and Mining Journal, 1988), these metals would have had a value of about $3.6 million.

The Bullard metallic mineral district (Keith and others, 1983) is 4 mi east of the northeastern boundary of the study area. Mineralized quartz-calcite veins in Tertiary volcanic rocks yielded about 17,000 tons of ore containing 610,000 lbs copper, 3,600 oz gold, and 6,000 oz silver (Keith and others, 1983). The Burnt Well metallic mineral district (Spencer and Welty, 1985) is one-half mile northwest of the northwestern boundary of the study area. No production is recorded from mineralized veins in Tertiary volcanic and sedimentary rocks of the area.

Identified Resources

Two mineralized areas were identified in the central part of the study area. Mineralized area A is at the head of Webber Canyon (pl. 1). Mineralized area B is near the eastern margin of the study area along Happy Camp Canyon. Fault zones and associated quartz veins in both areas generally have high concentrations of copper. One of these fault-vein systems has consistently high concentrations of gold.

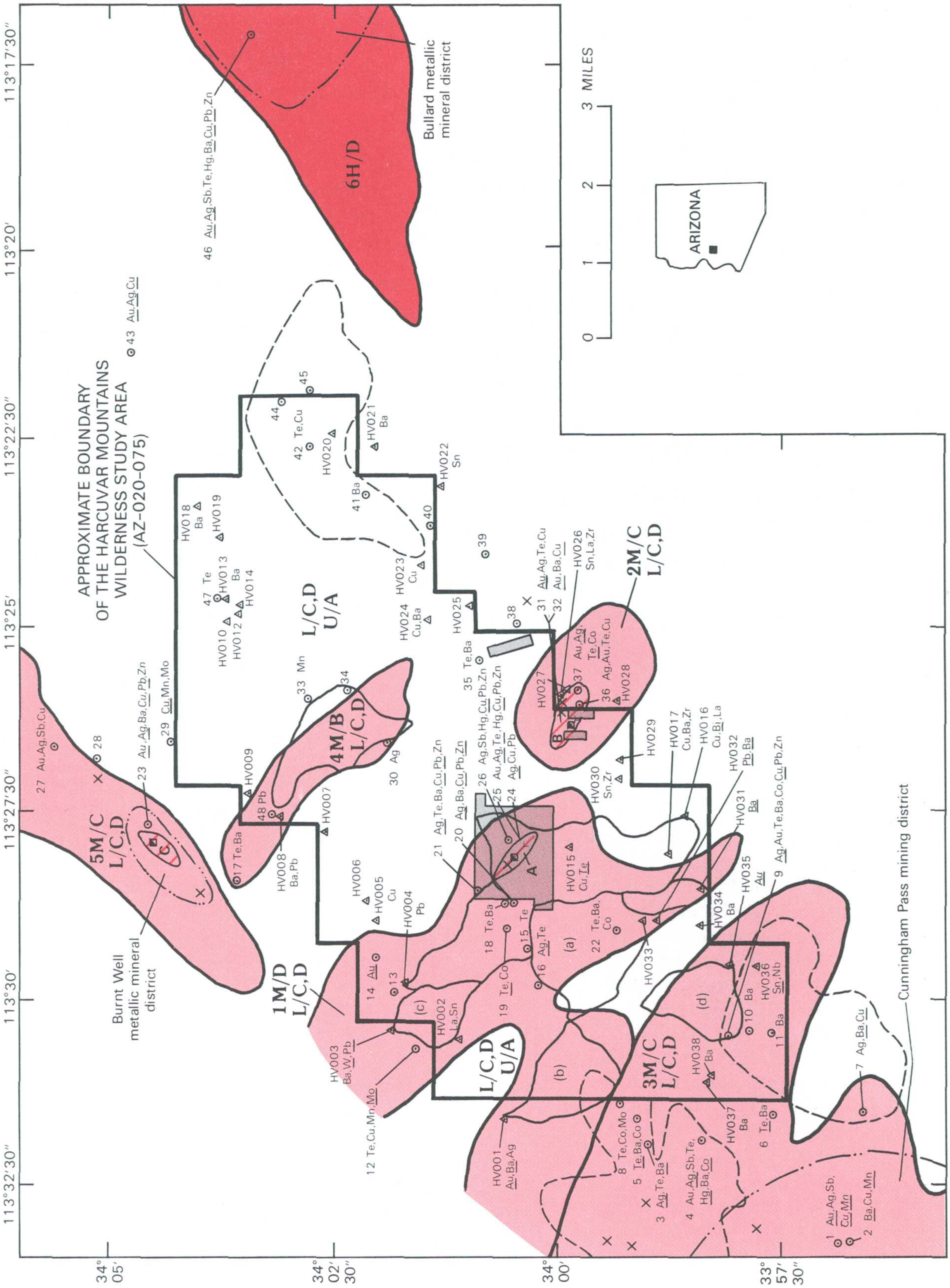
Northwest of the study area, mineralized area C contains two prospects in Tertiary sedimentary rocks (pl. 1). One sample from the area has a high concentration of copper and a trace of gold. Mineralized material in these strata is in the upper plate of the Bullard detachment fault (Spencer and Welty, 1985) and is probably related to movement and alteration along the fault.

Webber Mine Area

Mineralized area A, at the head of Webber Canyon in the central part of the study area, has workings along a northwest-striking fault in Early Proterozoic crystalline rocks and Cretaceous granite. The fault zone is characterized by breccia, gouge, silicified zones in both rock types, and limonite-coated fracture surfaces adjacent to the fault. Disseminated, green copper-oxide minerals are typically associated with the fractures, fault gouge, and silicified zones. Workings along this fault include three prospect pits, a shaft, and a 60-ft-long adit.

Five samples were taken from the adit. Samples of the fault gouge and a sample of the hanging wall contain copper ranging from 1.64 percent to 5.27 percent. Two samples of the footwall contain much less copper (0.23 percent and 0.15 percent). Maximum width of the fault gouge is 2 ft in the Webber adit (Tuftin, 1988).

An inferred subeconomic resource of 600 tons of 3.3 percent copper is estimated for the Webber adit, and an inferred subeconomic resource of 8,000 tons of 1.8 percent copper is estimated for the entire fault zone of the Webber mine area (to 50-ft depth between workings) (Tuftin, 1988).


APPROXIMATE BOUNDARY
OF THE HARCUVAR MOUNTAINS
WILDERNESS STUDY AREA
(AZ-020-075)
Bullard metallic
mineral district
Burnt Well
metallic mineral
district
Cunningham Pass mining district
6H/D
5M/C
L/C,D
4M/B
L/C,D
2M/C
L/C,D
1M/D
L/C,D
3M/C
L/C,D
L/C,D
U/A
ARIZONA
0
1
2
3 MILES
113°17′30″
113°20′
113°22′30″
113°25′
113°27′30″
113°30′
113°32′30″
34°
05′
34°
02′
30″
34°
00′
33°
57′
30″

EXPLANATION

[No terrane having high mineral resource potential for any commodity was identified within the study area]

A — **Areas having identified mineral resource**—Letters refer to areas listed here and in table on plate
- A. Copper
- B. Gold, copper
- C. Copper, gold

6 H/D — **Geologic terrane having high resource potential with certainty level D**—Number prefix refers to area listed in table 3. Numbered area may surround lettered areas; if so, lettered area has the same resource potential as numbered area

4 M/B, 2, 3, 5 M/C, 1 M/D — **Geologic terrane having moderate resource potential with certainty levels B, C, or D**—Number prefixes refer to areas listed in table 3. Numbered areas may surround lettered areas; if so, lettered area has the same resource potential as the numbered area. These areas constitute about 36 percent of the study area. Area 5 is outside the study area

L/C,D — **Geologic terrane having low resource potential with certainty level C or D**—
- For the entire study area:
- Copper, lead, zinc, gold, and silver in massive sulfide deposits (certainty level D)
- Rare-earth minerals, feldspar, and mica in pegmatites (certainty level D)
- Industrial rocks and minerals, decorative and ornamental stone, and geothermal resources (certainty level D)
- Oil, gas, coal, sand and gravel, and deposits of placer gold (certainty level C)

U/A — **Geologic terrane having unknown resource potential with certainty level A**—Gold in small to medium-size disseminated deposits; applies to entire study area except as otherwise noted

Levels of certainty
- **A** Available data not adequate to estimate potential
- **B** Data indicate geologic environment and suggest level of resource potential
- **C** Data indicate geologic environment and give good indication of level of resource potential, but do not establish activity of resource-forming process
- **D** Data clearly define geologic environment and level of resource potential and indicate activity of resource-forming processes in all or part of the area

Mining district (Keith, 1978) or metallic mineral district (Keith and others, 1983)

Unpatented mining claim (shown only in the Wilderness Study Area itself)

Shaft

Prospect pit

Adit

HV001 Sn,Nb (a) — **Stream-sediment and panned concentrate sample site and number**—Elements present in anomalous concentrations are listed with sample number; highly anomalous concentrations are underlined. See table 1 for concentrations. *Thin solid line above some sampling sites is drainage basin outline for that sample.* Letters in parentheses (a) are drainage basins discussed in text

22 Te,Ba,Co — **Rock-chip sample locality and number**—Elements present in anomalous concentrations are listed with sample number; see table 2 for concentrations. Elements present in highly anomalous concentrations listed with sample number are underlined

Areas inferred to contain anomalous concertations of iron-oxide-rich mineral (such as hematite, limonite) or hydroxyl-rich minerals (micas, clays), as evidenced from Landsat Thematic Mapper (TM) imagery

Figure 2. Summary map showing identified resources and mineral resource potential of the Harcuvar Mountains Wilderness Study Area, La Paz County, Arizona.

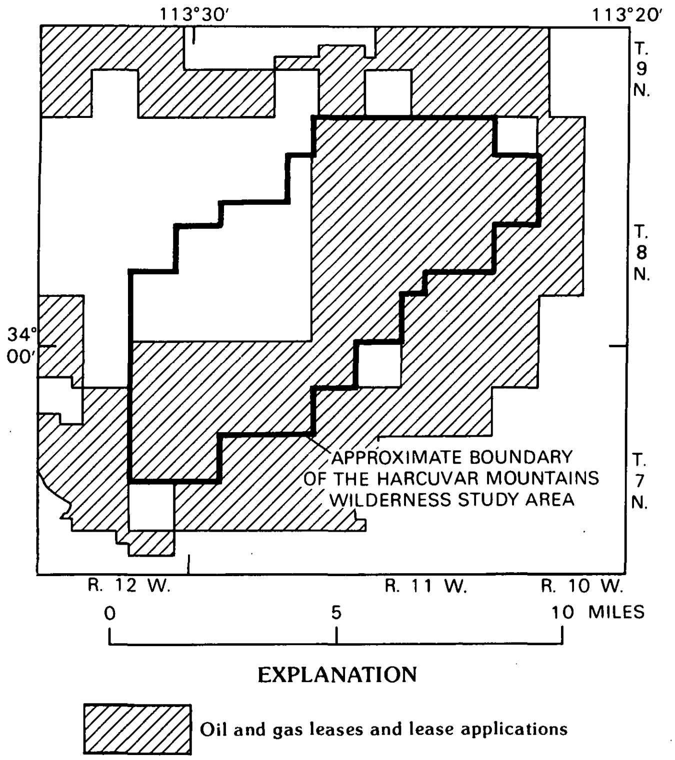


Figure 3. Index map of oil and gas leases and lease applications, Harcuvar Mountains Wilderness Study Area and vicinity, La Paz County, Arizona.

The fault and related minerals in the vicinity of these workings are in the oxidized zone. At depth, there may be a zone of supergene enrichment of copper and silver. Drilling and detailed geophysical work are needed to determine the presence of a resource at depth, but the inferred small size of the deposit probably does not warrant the expense of such investigations.

Happy Camp Canyon Area

Mineralized area B, along Happy Camp Canyon near the southeastern margin of the study area, contains workings along three northwest-trending faults that dip vertically or steeply to the northeast. The fault zones are characterized by veins and lenses of quartz, silicified zones in gneiss, breccia fragments in gouge, and fracture zones in gneiss adjacent to the faults. Quartz is commonly vuggy and contains inclusions of green copper-oxide minerals and limonite.

Workings on the western fault (inside the study area) include a 50-ft-long adit that has a 97-ft-deep winze and a 30-ft-high raise to the surface, and a prospect pit about 100 ft uphill from the portal of the adit. A vein of vuggy quartz with inclusions of limonite and secondary copper-oxide minerals parallels the strike of the fault in the vicinity of these workings.

Four samples were taken in the adit; however, the winze in this adit was not accessible. Gold is present in all samples from the adit and ranges from 0.011 to 0.073 oz/st (troy ounce per short ton). Copper concentrations are less than 1 percent for all samples in the adit.

A sample collected from the quartz vein at the top of the raise has a gold concentration of 0.029 oz/st and 1.15 percent copper. A sample taken across this vein from the prospect pit above the raise has a gold concentration of 0.025 oz/st and 4 percent copper.

An inferred subeconomic resource of 300 tons of 0.045 oz gold/st and 1.15 percent copper and an inferred subeconomic resource of 2,000 tons of 0.030 oz gold/st and 1.15 copper are determined for this structure if vein continuity to the bottom of the winze is assumed (Tuftin, 1988). Geophysical work would be needed to trace the extent of the vein.

Close to the study area boundary, two faults are exposed in two prospect pits. In the upper prospect, a sample was taken across a 2-ft-wide zone of fault gouge that had lenses of coarsely crystalline fluorite. No notable concentrations of copper or gold were detected from this sample. In a prospect about 180 ft farther down the hill, a sample taken across a 1-ft-wide quartz vein that contained inclusions of malachite and chrysocolla and 0.5 ft of gouge has 0.017 oz gold/st, and 1.1 percent copper. About 250 ft farther down the hill, an adit was driven in deformed granite—apparently to intersect this mineralized fault. Three samples taken of the wall rock in the adit contained no notable metal concentrations. The face of the adit is only a few feet away from intersecting the projection of the fault.

Veins in the vicinity of these workings are in the oxidized zone; there may be a zone of secondary enrichment of copper at depth. Drilling and geophysical work would be needed to determine the presence of ore bodies at depth, but the structures are probably too small to justify the expense of exploration.

Miscellaneous Prospects

Mineralized area C, about 2 mi northwest of the study area, has several prospects in Tertiary sedimentary rocks of the upper plate of the Bullard detachment fault. Upper-plate rocks are not present in the study area (Tuftin, 1988). The fault separates Tertiary strata from older crystalline rocks. Geology and workings in this district are summarized by Spencer and Welty (1985, p. 30–31). Two prospects were sampled about 1 mi outside the study area. A grab sample was taken from the dump of a 15-ft-deep shaft in conglomerate overlying sandstone and siltstone. Traces of green copper-oxide minerals were observed disseminated in the conglomerate; barite was noted on the dump. This grab sample contained 0.26 percent copper and 0.061 oz gold/st. A sandstone bed was sampled in another prospect about 1 mi southwest of the shaft. This sample contained only traces of copper and silver. These and several other nearby prospects are in upper plate rocks not present in the study area. Detailed sampling and exploration of these workings is not justified for this study.

A silicified zone in Early Proterozoic gneiss was sampled in a small prospect about one-half mile southeast of the study area. Only 0.014 percent copper was detected in the assay; silver and gold were not detected. The low concentration of metals and the small apparent size of this structure probably do not justify the expense of further exploration.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Harald Drewes, Ed DeWitt, R.H. Hill, W.F. Hanna, and D.H. Knepper, Jr., U.S. Geological Survey,

Assisted by Bruce Bryant and E.N. Hinrichs, U.S. Geological Survey,

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Geologic Setting

The Harcuvar Mountains Wilderness Study Area is in a region characterized by multiple deformations and metamorphisms of Proterozoic and Cretaceous age (see geologic time chart in the Appendix of this report) and a period of ductile to brittle extension during the Tertiary (Reynolds, 1980; Richard, 1988; DeWitt and others, 1988). Prior to the present study, the geology of the range was known only in reconnaissance fashion (Lee, 1908; Bancroft, 1911; Wilson, 1960). The Harcuvar Mountains are in the east-central part of a belt of mylonitic detachment terranes (so-called metamorphic core complexes) that stretch from the Whipple Mountains in California (Davis and others, 1983), through the Buckskin Mountains in Arizona (Rehrig and Reynolds, 1980; Spencer and Welty, 1986), to the Harquahala Mountains in Arizona (DeWitt and others, 1988). In these ranges, Early Proterozoic gneiss, schist, and amphibolite have been structurally interleaved with Paleozoic and Mesozoic strata along Mesozoic thrust faults. Tertiary extensional mylonitization has then been superimposed on these deformed rocks, especially around the northeast ends of the ranges.

The oldest rocks in the Harcuvar Mountains are Early Proterozoic (about 1.7 billion years old) amphibolite, pelitic schist, and minor bodies of granitic gneiss. Younger bodies of Early Proterozoic(?) granite to granodiorite cut the older rocks. All Proterozoic rocks were metamorphosed and deformed some time prior to about 1.6 Ga.

These Proterozoic metamorphic rocks were overlain by Paleozoic sedimentary rocks and Mesozoic volcanic and sedimentary strata. Beginning about 120 Ma, the stratified rocks and underlying basement were deformed, metamorphosed, and cut by thrust faults having a general southerly direction of transport in their upper plates (Reynolds and others, 1980; Reynolds, 1982; Reynolds and others, 1986; Richard, 1982, 1983; 1988; DeWitt and others, 1988). At about 90–100 Ma, the deformed rocks were intruded by the granite of Tank Pass, which was itself deformed but to a lesser degree than the stratified rocks and basement. Deformation from 120 to 90 Ma was deep seated and resulted in a ductile fabric being superimposed on the rocks. Uplift during Late Cretaceous to early Tertiary stripped the Paleozoic and Mesozoic rocks from the northern part of the Harcuvar Mountains.

In the Tertiary, at about 25 Ma, sedimentary and volcanic rocks about one-half mile thick covered the eroded crystalline rocks. Regional, low-angle normal faulting, or detachment faulting, at about 25–15 Ma (Rehrig and Reynolds, 1980; Richard, 1988; DeWitt and others, 1988) caused mylonitic fabrics to be superimposed on the crystalline rocks of the study area, especially in the northeastern Harcuvar Mountains. The resulting extension created the Bullard detachment fault (Reynolds and Spencer, 1985), which may have as much as 40 km of top-to-the-northeast offset. Tertiary strata in the upper plate of this detachment fault were tilted to the southwest and now dip into the fault.

Since about 15 Ma, the Tertiary sedimentary and volcanic rocks of the upper plate have been eroded and covered with gravel fill derived from the adjacent mountains. Recent finer grained alluvium covers the gravel deposits at greater distances from the mountain front.

Lithologic Descriptions

Early Proterozoic amphibolite, pelitic schist, and minor bodies of granite gneiss (unit Xn, undivided, pl. 1) underlie about 65–70 percent of the study area (pl. 1). Amphibolite (unit Xna) is dark greenish black and contains hornblende, plagioclase, epidote, quartz, biotite, and lesser amounts of ilmenite, sphene, apatite, allanite, and zircon. Pelitic schist (unit Xns) is light gray to silver and contains muscovite, biotite, quartz, garnet, minor sillimanite, and lesser quantities of apatite and zircon. Granitic gneiss (not separated on pl. 1) is medium gray and contains plagioclase, microcline, quartz, biotite, and lesser amounts of magnetite, muscovite, epidote, apatite, and zircon. Also included with these Early Proterozoic rocks are mylonitic gneiss (unit Xnm) and mylonitic amphibolite (unit Xnam) in lenticular masses too small to be separated. In general, individual units within unit Xn are shown only where they constitute a relatively large body at the scale of plate 1.

The amphibolite, pelitic schist, and granite gneiss are cut by Early Proterozoic(?) granodiorite to granite (unit Xng) that has been metamorphosed and deformed. The granodiorite to granite is light gray and is composed of microcline, plagioclase, quartz, biotite, traces of hornblende, and minor amounts of muscovite, magnetite, epidote, apatite, and zircon.

In many places the amphibolite, pelitic schist, and granite gneiss and granodiorite to granite are intruded by dikes, sills, and irregular masses of the granite of Tank Pass (Late Cretaceous); the resulting mixture forms a migmatite. Some migmatitic rocks may have resulted from mixing with Early Proterozoic granitic rocks, however.

Paleozoic and Mesozoic rocks present in the nearby Harquahala and Little Harquahala Mountains (Wilson, 1960; Reynolds and others, 1980; Richard, 1983, 1988; DeWitt and others, 1988), the Granite Wash Mountains and southwestern Harcuvar Mountains (Reynolds and others, 1986; Harald Drewes, unpub. data), and the Buckskin Mountains (Wilkins and Heidrick, 1982; Bruce Bryant, oral commun., 1987) are not present in the study area. They undoubtedly were deposited on Early Proterozoic crystalline rocks, but since have been stripped by erosion related to thrust faulting and uplift. One small mass of light-brown dolomitic limestone too small to be mapped is present at the base of Tertiary clastic rocks in the Burnt Well area (pl. 1). This block, about 100 ft long, is believed to be Tertiary (J.E. Spencer, oral commun., 1987) but could be a slice of Paleozoic limestone, although the probability is low. Abundant clasts of Paleozoic and Mesozoic rocks are present in Tertiary sandstone in the northern part of the study area. The fact that the nearest source area for these clasts is 24 mi to the southwest in the southern Harcuvar Mountains and Granite Wash Mountains led Reynolds and Spencer (1985) to suggest 24 mi offset on the Bullard detachment fault.

The Late Cretaceous(?) granite of Tank Pass (unit Kg), informally named for exposures in Tank Pass in the southwestern Harcuvar Mountains (Rehrig and Reynolds, 1980), underlies about 30–35 percent of the study area. This granite intrudes Early Proterozoic crystalline rocks as a large discordant mass and as many small dikes, sills, and irregular-shaped pods. Inclusions of amphibolite and pelitic schist are common in the granite. In areas of low relief, the granite disaggregates to gruss-rich colluvium. Elsewhere, the granite weathers to bouldery or blocky outcrops. Many granite bodies have sharp contacts with the Early Proterozoic crystalline rocks, but others are gradational and contain zones of mixed rocks a few feet to tens of feet wide.

The granite is medium coarse grained (0.05–0.08 in.), leucocratic, light gray to pale yellowish brown, and undeformed to slightly foliated. Where foliated, the granite may have a layered appearance due to the alteration of light- and dark-colored minerals. Foliation apparently was superimposed during or slightly after emplacement, as no post-crystallization, grain-size reduction or shearing is present. The granite is composed of subequal amounts of microcline or perthite, plagioclase, and quartz, accessory biotite, muscovite, and garnet, and lesser amounts of ilmenite, apatite, epidote, allanite and zircon.

Foliated and lineated Early Proterozoic amphibolite northeast of Cunningham Pass (pl. 1) is intensely injected by the granite of Tank Pass. A K-Ar (potassium argon) date of 70.3 Ma from hornblende of the amphibolite (Shafiqullah and others, 1980) is a minimum age for the emplacement of the granite of Tank Pass. Samples of the granite south of Cunningham Pass have K-Ar biotite dates ranging from 44 to 51 Ma (Rehrig and Reynolds, 1980; Reynolds and others, 1986). Similar granite in the Harquahala Mountains (the granite of Browns Canyon) is likewise at least 70 Ma (Richard, 1988). The geologically most reasonable age of the granite of Tank Pass is about 90 Ma.

Miocene microgabbro dikes (unit Tg), both undeformed and mylonitic, are scattered throughout the study area, but are not nearly as abundant as similar dikes in the Harquahala Mountains (Richard, 1988; DeWitt and others, 1988). The dikes are dark greenish black, fine grained, and contain sparse phenocrysts of hornblende and plagioclase set in a matrix of hornblende, epidote, plagioclase, magnetite, and biotite or chlorite. Some dikes have a diabasic texture. The dikes cut both Early Proterozoic and Late Cretaceous crystalline rocks. Sedimentary and volcanic rocks (units Ts and Ta, respectively) of Late Oligocene(?) and Miocene age crop out on the low flanks of the Harcuvar Mountains just outside the study area boundary (pl. 1). Similar rocks are also present at Black Butte, south of the Little Buckskin Mountains, and at Bullard Peak to the east of the study area.

Sedimentary rocks in this group include very pale orange, pale-yellowish-brown, grayish-red, or blackish-red conglomerate, tuffaceous sandstone, siltstone, and claystone. Except for the conglomerate beds, these rocks are poorly indurated. Sorting is moderate, and clasts, locally as much as a foot in diameter, are subangular to subrounded. Clasts include many kinds of crystalline rocks similar to those in the study area as well as many Paleozoic limestone, dolomite, and quartzite units. Also present but less abundant are clasts of unfoliated granite of unknown origin, and of Tertiary sedimentary and volcanic rocks like those on either flank of the Harcuvar Mountains.

Volcanic rocks include dark reddish-brown, K-metasomatized andesitic lava flows (Roddy and others, 1988) and flow breccias. Some andesite is porphyritic and some amygdaloidal. The andesite contains small phenocrysts of plagioclase and oxidized mafic minerals. Minor amounts of welded rhyolitic tuff is present low in the volcanic sequence north of Bullard Peak. The tuff is rich in crystals and lithic fragments and is probably similar to K-metasomatized welded tuff exposed farther east in the Harcuvar Mountains (Reynolds and Spencer, 1984; Roddy and others, 1988).

Pliocene(?) to Holocene gravel deposits (units QTg and Qg) unconformably overlie all older rocks and flank the Harcuvar Mountains. In most places, the gravel deposits form a young alluvial apron that progrades away from the mountain front. However, near Burnt Well (pl. 1) the gravel deposits are older, are at a higher elevation, and the youngest gravels lie along present drainages, which do not cut more than 30 ft below the adjacent alluvial apron surface. All deposits contain clasts ranging in size from boulders to grit in a matrix of sand-, silt-, and clay-size material. The gravels are probably thickest in McMullen Valley. Additional descriptive material about the gravels are in Demsey (1988).

Proterozoic Structural Features

Early Proterozoic amphibolite, pelitic schist, and granite gneiss have a crystalloblastic foliation (S_1) defined by the parallel alignment of hornblende and biotite in amphibolite, of biotite and muscovite in pelitic schist, and of biotite in granite gneiss. This foliation is, undoubtedly, of Early Proterozoic age, probably about 1.7 Ga, and obliterates any original depositional layers (S_0) in the rocks. Major folds associated with S_1 are not common, which may imply that the F_1 event was pervasive and isoclinal. In the central and northeastern part of the study area, where not affected by Cretaceous or Tertiary deformational events, the foliation trends northeast and dips steeply, similar to the regional foliation in Early Proterozoic rocks of central Arizona near Bagdad (Anderson and others, 1955) and Prescott (Anderson and Blacet, 1972; DeWitt, in press). Similar, northeast-trending, high-angle foliation is locally preserved in Early Proterozoic crystalline rocks in the northeastern Harquahala Mountains (Richard, 1988; DeWitt and others, 1988). Early Proterozoic(?) granodiorite to granite cuts discordantly across these foliated rocks, but is, in turn, deformed and foliated (S_2) by a younger, presumably Early Proterozoic event. No major folds (which would be F_2 folds) related to this event are recognized. No pronounced lineation is associated with either of these deformational events.

Mesozoic Structural Features

The granite of Tank Pass intrudes the Early Proterozoic crystalline rocks both discordantly and as sills along foliation planes. In thin sills and in the northern part of the study area, the granite has an exaggerated flow foliation (S_3) that gives outcrops a layered appearance. In thin section, this foliation is defined by minor compositional variations and parallel alignment of biotite and muscovite. Local, coarse-grained pegmatite bodies related to the granite also define this foliation.

Early Proterozoic crystalline rocks and the granite of Tank Pass were deformed either during emplacement of the granite or shortly thereafter, probably in the time period 100–80 Ma (Ed DeWitt, unpub. $^{40}Ar/^{39}Ar$ data). The amphibolite, pelitic schist, granite gneiss, granodiorite to granite, and granite of Tank Pass were buckled about northeast-trending axes and the crystalloblastic foliation was deformed into a number of open to closed folds (F_3) having amplitudes and wavelengths of tens of meters. Lineation formed during this event (L_3) is best developed in the central and southwestern part of the study area where amphibolite layers within the granite of Tank Pass have a hornblende lineation that plunges north to northwest. Tectonic transport during this early phase of deformation probably was southeast (Reynolds, 1982).

Mesozoic (pre-granite of Tank Pass) thrust faults that imbricate Proterozoic crystalline rocks between, above, and below slivers of metamorphosed Paleozoic and Mesozoic strata are not recognized in the study area, although they are common in adjacent ranges, such as the Harquahala and Little Harquahala Mountains and Granite Wash Mountains, and even in the southern Harcuvar Mountains (Reynolds and others, 1983; Reynolds and others, 1986; Laubach and others, 1984; Richard, 1983, 1988; Spencer and Reynolds, 1986; DeWitt and others, 1988). However, because of similar rock types and $^{40}Ar/^{39}Ar$ hornblende and muscovite thermochronology (Richard, 1988; Ed DeWitt, unpub. data, 1989), we interpret that the Early Proterozoic crystalline basement and the granite of Tank Pass appear to be in the upper plate of the Harquahala thrust. Regionally, the Harquahala thrust is the structurally highest, possibly the youngest, and one of the most continuous Mesozoic thrust faults in the area (Richard, 1988). Other thrust faults may be 100–120 Ma, but are probably not older.

A low-angle fault that dips 20°–45° to the northwest and separates upper plate mylonitic amphibolite from lower plate granite of Tank Pass is exposed in the Burnt Well area, just northwest of the study area (pl. 1). The fault is subparallel to the Bullard(?) detachment fault (discussed next), and we believe it is a Mesozoic(?) thrust fault that merges to the southwest with the Bullard(?) detachment fault by utilizing the older fault plane. Some thin mylonitic sheets in the amphibolite beneath the low-angle fault have fault-bounded northwest margins. We infer the mylonitization of these sheets to be as old as the low-angle fault, although some brittle deformation on the mylonite may be younger. The mylonitic amphibolite plate is offset by concealed northwest-trending faults, which in turn appear truncated by the Bullard(?) detachment fault. Because mylonitization in the rest of the Harcuvar Mountains is Miocene, we also speculate that this low-angle fault could have been reactivated in the Tertiary.

Tertiary Structural Features

Transposing these Early Proterozoic and Late Cretaceous crystalloblastic fabrics and locally cutting them, is a Tertiary (predominantly Miocene) mylonitic fabric characterized by planar to undulating foliation surfaces (F_4) marked by distinct lineation (L_4) and streaking of minerals, predominantly quartz, feldspars, and minor biotite. This fabric is best developed in the northern part of the study area and around the northeastern end of the Harcuvar Mountains. The degree of mylonitization increases both upward toward the highest peaks in the range and laterally toward the flanks and proximity to the Bullard detachment fault (Rehrig and Reynolds, 1980).

Mylonitic foliation is flat or dips to the northeast in the northern part of the study area, but dips to the southwest in the central and southern part of the area. Intensity of the fabric decreases from northeast to southwest. In the far north or northeast, most older fabrics are destroyed where the mylonitic foliation is developed. In the central and southwest, mylonitic foliation is expressed as minor shear bands cutting across older fabrics. Mylonitic lineation (L_4) along both the crest and flanks of the range trends N. 60°–65° E., parallel to the topographic trend of the range and parallel to anticlinal and synclinal axes defined both by F_3 folds and intersections of F_3 structures with mylonitic lineations. Locally the s–c fabrics (those defined by intersection of shear and cleavage surfaces) consistently indicate top-to-the-northeast tectonic transport during formation of the S_4 and L_4; regionally this orientation is also common (S.J. Reynolds, unpub. data, 1987; Reynolds and Spencer, 1985; this study). In areas not strongly affected by Tertiary mylonitization, s-c fabrics suggest southeast, northeast, or northwest directions of shear at various structural levels.

A combination of the Tertiary mylonitic foliation (S_4) and Late Cretaceous crystalloblastic foliation (S_3) defines an anticlinal axis parallel to the Harcuvar Mountains. In detail, the axis is a composite of several shorter en-echelon anticlines and synclines that step to the south. Near the north end of the range, beyond the area of plate 1, the anticlinal axis plunges gently northeast, and, near Cunningham Pass, it plunges 5° southwest. Foliation (a combination of S_1 and S_2 deformed by F_3 and resulting in S_3, all of which may have S_4 superimposed on them) on the flanks of the anticline normally dips no more than 20°–30°. However, low on the southeast flank foliation dips 40°–60° and gives the anticline a subtle structural asymmetry.

These folds affect the Proterozoic crystalline rocks, Paleozoic and Mesozoic strata in various Mesozoic thrust plates, and Tertiary sedimentary and volcanic rocks of the upper plate of the detachment faults in surrounding ranges. Because all these rocks are affected by the folding, the anticlinal and synclinal folds are viewed by Reynolds and Spencer (1985) as Miocene features. The complexity of the folds, as was just shown, is evidence of a polygenetic origin for the folding, which was initiated during Mesozoic time.

The Bullard detachment fault (Spencer, 1984; Reynolds and Spencer, 1985) is a major, low-angle structure that separates mylonitized lower plate crystalline rocks from rotated, normally faulted, and K-metasomatized (Roddy and others, 1988) Oligocene(?) and Miocene sedimentary and volcanic rocks and their nonmylonitic crystalline basement. In the lower plate, intensity of mylonitic foliation and lineation increases structurally upward toward the fault in most places. Superimposed on the mylonitized rocks within 100 ft of the fault is chlorite-rich breccia characterized by green, granulated, and shattered rocks that obliterate the earlier formed mylonitic fabrics. Although no nonmylonitic crystalline basement is present in the study area above the Bullard detachment fault, it is present farther east at the Bullard mine (Reynolds and Spencer, 1984, 1985).

The fault is concealed by gravel along the southeast side of the study area (pl. 1), but near Bullard Peak it is estimated to dip about 45° southeast. Discordance in attitude between the tilted Oligocene(?) and Miocene rocks and the crystalline basement gneiss requires that the fault extend as far southwest as the last outcrop of Tertiary strata; we projected the fault southwest along the range front, but it may deviate to the south and into McMullen Valley. Small high- and low-angle normal faults in the strata near Bullard Peak abut, but do not cut, the Bullard detachment fault (Reynolds and Spencer, 1984).

In the Burnt Well area along the northwest flank of the range, a similar fault, shown on plate 1 as the Bullard(?) detachment fault, dips away from the range at

20° and separates Oligocene(?) and Miocene sedimentary and volcanic rocks from crystalline rocks (Spencer and Welty, 1985). Outcrops of Tertiary strata are too minor to accurately locate small high-angle faults between tilted blocks, but steep dips among the Tertiary strata and erratic distribution of rock types suggest that such faults exist and that they do not offset the trace of the Bullard(?) detachment fault. These relationships suggest that movement along the Bullard detachment fault and its probable extensions occurred together with tilting of upper plate beds and movement along small high-angle faults.

Mylonitization in the Harcuvar Mountains took place during emplacement of northwest-trending microgabbro dikes (unit Tg, pl. 1). Similar microgabbro dikes in the Harquahala Mountains, where they make up a large, northwest-striking dike swarm, have K-Ar biotite dates of 22.1 + 1.3 Ma (Shafiqullah and others, 1980) and $^{40}Ar/^{39}Ar$ hornblende plateau dates of 22.1 + 0.4 Ma (Richard, 1988). K-Ar biotite dates of 17.5 Ma from mylonitic rocks in the northern Harcuvar Mountains (Reynolds and others, 1986) suggest that mylonitization may have been active for about 5 m.y. Movement along the Bullard detachment fault probably began no earlier than 22 Ma (volcanic rocks as old as this are in the upper plate) and likely ceased by 17 Ma (partially reset(?) fission-track dates in upper plate units) (Brooks, 1984, 1988).

Geochemical Investigation

In November 1986, a reconnaissance geochemical survey was conducted in the Harcuvar Mountains Wilderness Study Area to aid in the evaluation of the mineral resource assessment of the area. Rocks, stream sediments, and panned heavy-mineral concentrates were analyzed as the primary sample media for evaluation.

Methods of Study

About 80 percent of the drainage basins in the study area were covered by stream-sediment sampling. Thirty-five minus-60-mesh stream-sediment samples and 35 heavy-mineral, panned concentrates, derived from stream sediment, were collected from active stream alluvium. The dry stream-sediment samples were sieved through 60-mesh stainless-steel sieves. Minus-60-mesh material was retained and pulverized with ceramic plates to at least minus-100-mesh for analysis. Sediments within a drainage basin commonly represent a composite of the chemistry of rock and soil exposed upstream from the sample site. Chemical analysis of these stream-sediment samples provide data useful in identifying those basins that contain unusually high concentrations of elements that may be related to mineral deposits.

In addition, studies have shown that heavy-mineral panned concentrates derived from stream sediment are a useful sample medium in arid-semiarid environments or in areas of rugged topography where mechanical erosion predominates over chemical erosion (Bugrov and Shalaby, 1975; Overstreet and Marsh, 1981). To produce the heavy-mineral concentrate, bulk stream sediment was first sieved through a 10-mesh screen. About 25–30 pounds of the minus-10-mesh sediment were panned to remove most of the quartz, feldspar, clay, and organic material. These samples were then air-dried, passed through a 30-mesh sieve, and separated into light and heavy fractions using bromoform (heavy liquid, specific gravity 2.86). The light fraction was discarded. The material of specific gravity greater than 2.86 was separated into three fractions (highly paramagnetic, weakly paramagnetic, and nonparamagnetic) using a modified Frantz Isodynamic Magnetic Separator. The nonparamagnetic fraction was hand-ground with mortar and pestle and retained for emission spectrographic analysis. Heavy-mineral-concentrate samples provide information about the chemistry of a limited number of minerals present in rock material eroded from the drainage basin upstream from each sample site. These minerals may be rich in ore-forming and ore-related elements. The selective concentration of ore-related minerals permits determination of some elements that are not easily detected in bulk stream-sediment samples.

Twenty fresh and unaltered rock samples were collected to represent rocks exposed in the vicinity of the stream-sediment sample sites. Single grab samples from nearby outcrops were collected. Rock samples were crushed and pulverized to at least minus-100-mesh with ceramic plates for analysis. In addition, three composite mine-dump samples were collected to provide general information about mineralization in the area.

Forty-six altered and mineralized rock samples were collected from veins, shear zones, Tertiary microgabbro dikes, mylonitic zones, and small prospects in the study area. Samples were composited if they were less than ¼ mi apart. Each sample consisted of 8–15 chips, 1–2 in. across. These chips were split, composited, and one set of chip-halves was pulverized to minus-80-mesh. One part of each powder sample was then analyzed by semiquantitative emission spectrography for 31 elements and another part was analyzed by atomic absorption for gold, mercury, antimony, tellurium, and zinc.

Rock, stream-sediment, and nonparamagnetic portions of the prepared heavy-mineral concentrate samples were analyzed for 31 elements using a semiquantitative, direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). Also, arsenic, antimony, bismuth, cadmium, and zinc were analyzed by the inductively coupled plasma-argon emission spectrographic method (Crock and others, 1987). Gold and tellurium were analyzed by the electrothermal atomic absorption spectrographic method (Hubert and Chao, 1985), thallium by the atomic absorption spectrographic method (Hubert and Chao, 1985), and uranium by the fluorometric method (O'Leary and Meier, 1984). Analytical results are available from R.H. Hill (U.S. Geological Survey, Box 25046, MS 973, Federal Center, Denver, CO 80225). Finally, part of the powdered sample of the altered and mineralized rock-chip suite was tested for gold, mercury, antimony, zinc, and tellurium by the atomic-absorption method described by Viets (1978) and Ward and others (1969).

Geochemical Results

Threshold values, defined as the upper limit of normal background values, were determined for each element by inspection of frequency distribution histograms for all sample media. Anomalous and highly anomalous concentrations of elements in stream-sediment and panned-concentrate samples, defined from these threshold values, are listed in table 1. The composite mine-dump rock samples were not included in construction of the histograms. A geochemical value higher than the threshold value was considered anomalous and possibly an indicator of mineralization. Of the elements determined by emission spectrographic and wet chemical methods, gold, silver, copper, lead, zinc, mercury, antimony, tellurium, and tungsten might be related to mineralization.

Several geochemically anomalous drainage basins (pl. 1) were identified in the study area. The criterion for delineating an area as anomalous was the presence of multielement geochemical anomalies clustered within a restricted geographic region. Any future followup studies, however, should include the isolated sample localities having anomalous geochemical values. A provision defined by the scale of sampling is that moderate-size deposits could be indicated by only one sample locality, or perhaps could even be missed. The anomalous areas discussed here are referred to as drainages (a), (b), (c), and (d) on plate 1.

Drainage (a) is characterized by highly anomalous barium (5,000 ppm (parts per million)) and lead (1,000 ppm), and weakly anomalous tungsten (70 ppm) in the heavy-mineral-concentrate sample. The anomalous concentrations of metals are related to northwest-trending Tertiary microgabbro dikes or small veins or shear zones parallel to them. The anomalous concentrations of lead are important indicators of possible gold mineralization as discussed in the following section on correlation coefficient analysis.

Drainage (b) is characterized by highly anomalous gold (0.002 ppm) in the stream-sediment sample and anomalous silver (2 ppm) and highly anomalous barium (7,000 ppm) in the heavy-mineral-concentrate sample. The anomalous concentrations of metals are related to either a Tertiary microgabbro dike or shear zones and small veins related to the dike.

Drainage (c) is characterized by the same elements as drainage (a), but the anomalous values are lower in drainage (c), with the exception of tungsten. Barium is 1,500 ppm, lead is 500 ppm, and tungsten is highly anomalous at 700 ppm in the heavy-mineral-concentrate sample. These anomalous elements are related to northwest-trending shear zones, veins, or Tertiary microgabbro dikes. Again, the anomalous concentrations of lead are important indicators of possible gold mineralization.

Drainage (d) contains highly anomalous concentrations of gold (0.002 ppm) in the stream-sediment sample. The gold is probably derived from shear zones or veins similar to those suggested for drainage (b).

Other highly anomalous concentrations of barium (3,000–5,000 ppm) in the heavy-mineral-concentrate samples are scattered throughout the southwestern part of the study area (pl. 1). These anomalous concentrations are related to minor veins and shear zones that do not contain appreciable quantities of gold, silver, copper, lead, zinc, or tungsten.

One drainage basin in the northwestern part of the area (sample HV008) contains anomalous lead (100 ppm) in the minus-60-mesh stream-sediment sample, and another drainage basin north of Dripping Spring (HV004) has highly anomalous lead (300 ppm) in the heavy-mineral-concentrate sample. These lead values may indicate isolated galena-rich material in small veins that could contain anomalous concentrations of gold and silver.

Anomalous copper values are noted in two drainage basins (samples HV015 and HV016) downstream from the Webber mine, in both minus-60-mesh stream-sediment samples and heavy-mineral concentrates. These values may be enhanced by contamination from dumps at the mine. Interestingly, however, other stream-sediment samples farther north (HV023 and HV024) contain similar concentrations of copper (50 ppm) and do not have mine dumps in their drainage basins. The absence of copper in stream-sediment and panned-concentrate samples may not be totally indicative of a lack of mineralized material containing copper in the study area.

Analyses of the 46 altered and mineralized rock-chip samples are designed to characterize the types of mineralized material present in the study area. Anomalous and highly anomalous concentrations of selected elements in the samples are listed in table 2.

Anomalous concentrations of gold, silver, tellurium, copper, barium, lead, and minor amounts of tungsten, tin, manganese, mercury, and antimony are

Table 1. Anomalous and highly anomalous concentrations of selected elements in minus-60-mesh fraction of stream-sediment samples and panned concentrates from stream-sediment samples, Harcuvar Mountains Wilderness Study Area, La Paz County, Ariz.

[Concentrations in parts per million; leaders (- - -) indicate element not found in anomalous concentration in that sample; numbers below elements in heading are concentrations considered anomalous in stream-sediment samples; numbers in parentheses beneath elements in headings are concentrations considered anomalous in pannned concentrates; underlined values in table are considered highly anomalous in either stream-sediment samples or panned concentrates; all elements except Au, Te, and Tl in minus-100-mesh fraction of stream-sediment samples analyzed by semiquantitative six-step direct current emission spectrographic method by R.T. Hopkins; Au and Te analyzed by electrothermal atomic absorption spectrographic methods by R.H. Hill and T.A. Roemer; all elements in panned concentrates from stream-sediment samples analyzed by six-step spectrographic methods by Betty Adrian, Olga Erlich, and J.H. Bullock, Jr.]

Element---	Cu	Pb	Ba	Ag	Au	Bi	Te	La	Zr	Sn	W	Nb
Stream----	50	100		0.5	.002	4	.05	200	700		(500)	(200)
Panned----	(300)	(300)	(700)	(2)						(20)		
Sample No.												
HV001	---	---	(7000)	(2)	0.002	---	---	---	---	---	---	---
HV002	---	---	---	---	---	---	---	200	---	(20)	---	---
HV003	---	(500)	(1500)	---	---	---	---	---	---	---	(700)	---
HV004	---	50 (300)	---	---	---	---	---	---	---	---	---	---
HV005	50	---	---	---	---	---	---	---	---	---	---	---
HV008	---	100	(700)	---	---	---	---	---	---	---	---	---
HV013	---	---	(1500)	---	---	---	---	---	---	---	---	---
HV015	50	---	---	---	---	---	.055	---	---	---	---	---
HV016	50 (300)	---	---	---	---	4	---	200	---	---	---	---
HV017	50	---	(1500)	---	---	---	---	---	700	---	---	---
HV018	---	---	(1500)	---	---	---	---	---	---	---	---	---
HV021	---	---	(700)	---	---	---	---	---	---	---	---	---
HV022	---	---	---	---	---	---	---	---	---	(20)	---	---
HV023	50	---	---	---	---	---	---	---	---	---	---	---
HV024	50	---	(700)	---	---	---	---	---	---	---	---	---
HV026	---	---	---	---	---	---	---	200	700	(20)	---	---
HV030	---	---	---	---	---	---	---	---	1000	(20)	---	---
HV031	---	---	(5000)	---	---	---	---	---	---	---	---	---
HV032	---	(1000)	(5000)	---	---	---	---	---	---	---	---	---
HV034	---	---	(3000)	---	---	---	---	---	---	---	---	---
HV035	---	---	---	---	.002	---	---	---	---	---	---	---
HV036	---	---	---	---	---	---	---	---	---	(50)	---	(300)
HV037	---	---	(3000)	---	---	---	---	---	---	---	---	---
HV038	---	---	(2000)	---	---	---	---	---	---	---	---	---

Table 2. Anomalous and highly anomalous concentrations of selected elements in rock-chip samples, Harcuvar Mountains Wilderness Study Area, La Paz County, Ariz.

[Concentrations in parts per million; leaders (- - -) indicate element not found in anomalous concentrations in that sample; >, greater than; numbers in parentheses below elements in heading are concentrations considered anomalous in rock-chip samples; all elements except Au, Te, Sb, Hg, and Zn analyzed by semiquantitative six-step direct-current emission spectrographic method by J.H. Bullock, Jr.; Au and Te analyzed by electrothermal atomic absorption spectrographic methods by K.A. Romine; Hg analyzed by Monte Wilch; Sb and Zn analyzed by atomic absorption spectrographic methods by F.W. Tippitt]

Element---	Ag	Au	Sb	Te	Hg	Ba	Co	Cu	Mn	Mo	Pb	Zn
Anomalous-	(1.0)	(0.1)	(4)	(0.5)	(0.1)	(1,000)	(300)	(1,000)	(1000)	(70)	(200)	(500)
Highly --- anomalous	(5.0)	(0.5)		(5.0)		(5,000)	(1,000)	(5,000)		(300)	(1,000)	(2,000)
Sample No.												
1	1.0	0.9	4	---	---	---	---	10,000	3,000	---	---	---
2	---	---	4	---	---	>5,000	---	3,000	3,000	---	---	---
3	2.0	---	---	1.1	---	5,000	---	---	---	---	---	---
4	10.0	0.25	4	2.0	3.8	1,500	2,000	---	---	---	---	---
5	---	---	---	1.2	---	3,000	300	---	---	---	---	---
6	---	---	---	0.55	---	2,000	---	---	---	---	---	---
7	1.0	---	---	---	---	5,000	---	7,000	---	---	---	---
8	---	---	---	3.6	---	---	500	---	---	150	---	---
9	70.0	0.1	---	2.7	---	1,500	500	>20,000	---	---	200	1,000
10	---	---	---	---	---	3,000	---	---	---	---	---	---
11	---	---	---	---	---	2,000	---	---	---	---	---	---
12	---	---	---	3.0	---	---	---	1,000	700	300	---	---
14	---	1.9	---	---	---	---	---	---	---	---	---	---
15	---	---	---	0.5	---	---	---	---	---	---	---	---
16	5.0	---	---	1.2	---	---	---	---	---	---	---	---
17	---	---	---	1.5	---	2,000	---	---	---	---	---	---
18	---	---	---	0.9	---	1,500	---	---	---	---	---	---
19	---	---	---	5.1	---	---	700	---	---	---	---	---
20	7.0	---	---	---	---	1,000	---	20,000	---	---	1,000	10,000
21	15.0	---	---	0.5	---	1,500	---	15,000	---	---	1,000	700

22	---	---	---	2.7	---	>5,000	500	---	---	---	---	---
23	5.0	15.0	---	---	---	1,500	---	>20,000	---	---	5,000	1,650
24	1.5	---	---	---	---	---	---	15,000	---	---	200	---
25	20.0	0.1	---	8.3	2.8	---	---	>20,000	---	---	500	500
26	1.0	---	4	---	0.32	---	---	>20,000	---	---	300	1,250
27	1.0	0.15	4	---	---	---	---	5,000	---	---	---	---
29	---	---	---	---	---	---	---	20,000	1,500	70	---	---
30	1.5	---	---	---	---	---	---	---	---	---	---	---
31	1.0	1.85	---	2.3	---	---	---	3,000	---	---	---	---
32	---	0.80	---	---	---	1,000	---	5,000	---	---	---	---
33	---	---	---	---	---	---	---	---	1,000	---	---	---
35	---	---	---	0.95	---	2,000	---	---	---	---	---	---
36	1.5	0.2	---	3.6	---	---	---	5,000	---	---	---	---
37	5.0	0.2	---	5.8	---	---	500	---	---	---	---	---
41	---	---	---	---	---	5,000	---	---	---	---	---	---
42	---	---	---	3.1	---	---	---	1,000	---	---	---	---
43	20.0	11.5	---	---	---	---	---	20,000	---	---	---	---
46	30.0	4.7	6	2.2	1.2	5,000	---	20,000	---	---	3,000	1,700
47	---	---	---	0.8	---	---	---	---	---	---	---	---
48	---	---	---	---	---	---	---	---	---	---	200	---

present in northwest- to west-northwest-trending veins, shear zones, margins of microgabbro dikes, and in some low-angle mylonitic zones. Areas that have high numbers of anomalous samples are near the Webber mine, in Happy Camp Canyon, between the Webber mine and Cunningham Pass, and near the Burnt Well metallic mineral district (pl. 1). Typically, samples that have high values of base metals also have visible secondary copper minerals and galena, sphalerite, and barite.

Correlation coefficient analysis of the 46 samples reveals interesting patterns. Gold is highly correlated with lead (correlation coefficient 0.77) and less well correlated with copper (0.49) and zinc (0.46). Silver is correlated with copper (0.61), nickel (0.59), and less well correlated with antimony (0.49). Gold and silver are not highly correlated (0.19). Apparently, electrum that has a relatively constant Ag/Au ratio is not the primary gold-bearing mineral in most samples. Rather, galena that has variable concentrations of gold and silver is probably the primary precious-metal-rich mineral.

Zinc is highly correlated with copper (0.78), lead (0.77), and less well correlated with mercury (0.59). Somewhat surprisingly, tellurium is highly correlated with cobalt (0.73) and nickel (0.66), and less well correlated with iron (0.59). Also, tellurium is not correlated with gold (–0.10). Because iron is rather highly correlated with cobalt (0.68), we infer that much of the cobalt, nickel, antimony, and tellurium may be associated with pyrite that does not contain as much gold as does galena. Therefore, anomalous concentrations of lead and zinc in stream-sediments, panned concentrates, and rock-chip samples are probably the best indicators of possible high concentrations of gold in the study area.

Remote Sensing Investigation

Digital image data acquired by the Thematic Mapper (TM) system on the Landsat-4 satellite (scene I.D. 40174–17383) were analyzed to detect and map areas that may contain hydrothermally altered rocks. By analyzing ratios of the visible and near-infrared TM spectral bands, two groups of minerals can be discriminated: (1) ferric iron oxides (hematite, goethite, jarosite); and (2) hydroxyl-bearing minerals and carbonate minerals (clay minerals, micas, gypsum, alunite, calcite, dolomite). The fairly broad spectral bands of the TM data do not allow specific minerals within each group to be differentiated (see Brickey, 1986; Mouat and others, 1986). Minerals in these two groups commonly, but not exclusively, form during hydrothermal alteration or by weathering of hydrothermally altered rocks. Such alteration may provide evidence of mineralized areas. Mapping the distribution of these two mineral groups provided a method of targeting some areas of potentially hydrothermally altered rocks for additional study.

Shadows caused by a combination of rugged topography and the 25° solar elevation angle at the time the TM data were acquired limit the area of surface rocks and soils that can be evaluated for possible altered rocks. Nevertheless, anomalous concentrations of one or both of the mineral groups could be mapped in the study area.

Large parts of the study area contain pervasive ferric iron-oxide minerals that were probably derived from weathering of one or more prominent unaltered lithologic units in the region (pl. 1). Numerous small areas of both iron-oxide-bearing, hydroxyl-bearing, and (or) carbonate minerals are present randomly throughout the study area, but they do not appear to be significant alteration targets. An area at the southwestern end of the study area has a pattern of anomalies that suggests a possible hydrothermal system. This area contains pervasive ferric iron oxides within which are local concentrations of both ferric iron-oxide-bearing, hydroxyl-bearing, and (or) carbonate minerals. This tract is the one most likely to be underlain by hydrothermally altered rocks, as interpreted from the Landsat TM data.

Geophysical Investigation

The Harcuvar Mountains Wilderness Study Area is covered by regional gravity surveys (Lysonski and others, 1980; Aiken and others, 1981; Defense Mapping Agency Aerospace Center, 1974, 1975) and magnetic surveys (Western Geophysical Company of America, Aero Service Division, 1979; LKB Resources, Inc., 1980) that have sufficient resolution to define anomalies of several square kilometers (about a square mile) in area or larger. Contours of complete (terrain-corrected) Bouguer gravity anomalies are defined by about 15 isolated observation points, most of which immediately surround the study area, and by a closely spaced string of 22 observation points that extend into the northwestern part of the study area. Contours of total-field magnetic anomalies are defined by measurements made along eight east-west flight lines, five of which transect the study area, and two north-south tie lines at a nominal altitude of about 400 ft above ground. Flight lines north of latitude 34° are spaced about 1 mi apart; those south of this latitude are spaced about 3 mi apart. Tie lines are spaced about 12 mi apart.

The magnetic data (LKB Resources, 1983) were reprocessed by the USGS for purposes of incorporating a more accurate geomagnetic reference field, identifying errors in flight line locations, and smoothing the effects of location errors. The total-intensity magnetic data were gridded using a minimum curvature algorithm (Webring, 1981; Briggs, 1974) and then reduced by subtracting a gridded Definitive Geomagnetic Reference Field (DGRF) updated to the time of the survey (Peddie, 1982; International Association of Geomagnetism and

Aeronomy, 1986). The data were then contoured using linear interpolation and an algorithm for smoothing by splining under tension (Godson and Webring, 1982; Cline, 1974; Evenden, 1975). The resulting contour map displayed some large errors, presumably associated with mislocations of flight lines, which were manifested by linear anomalies along flight lines and inconsistent anomaly patterns where flight lines crossed tie lines. The data were then smoothed using an algorithm for error adjustment (Mittal, 1984). Although contours were significantly smoothed by this process, many inconsistencies in anomalies of short wavelength remained in the data. Application of many tests of low-pass filtering implied the need to further smooth the data. The resulting map, generally consistent with but slightly more detailed than those previously produced (Sauck and Sumner, 1970; Western Geophysical Company of America, Aero Service Division, 1979; LKB Resources, 1980), was generated using a Fourier filtering algorithm (Hildenbrand, 1983) that passed anomaly wavelengths greater than 10 km.

The gravity anomaly map (fig. 4) shows that the study area is covered entirely by part of a single, long-wavelength, large-amplitude, northeast-striking gravity high. This high, which is centered 2 mi southwest of the study area and which geometrically conforms to the elevated terrain of the Harcuvar Mountains, is caused by a large density contrast between an assemblage of metamorphic and igneous rocks and basin fill to the northwest and southeast. Our gravity modeling indicates that, if the average density contrast between rocks of the range and adjacent basin fill is 0.35 g/cm^3 (gram per cubic centimeter), the fill beneath that part of Butler Valley at the northwest margin of the study area is about 3,000 ft thick. If the same density assumptions are used, fill beneath that part of McMullen Valley at the southern margin of the study area is about 1.5 mi thick, about three times that of Butler Valley. These results agree with those of Oppenheimer and Sumner (1980). The modeling further suggests, on the basis of observed horizontal gradients of the gravity anomaly and assumed lateral density contrast, that the interfaces between crystalline rocks and basin fill are not as steeply dipping as we originally supposed. These interfaces appear to have a range of dips from about 45° to 75°.

Specific gravities of the Early Proterozoic crystalline rocks and the granite of Tank Pass are dramatically different. Amphibolite, which constitutes about 70 percent of the Early Proterozoic gneissic rocks, has a specific gravity of about 3.3 g/cm^3. Early Proterozoic pelitic schist, granite gneiss, and granodiorite to granite average about 2.8 (Klein and Johnson, 1983; Ed DeWitt, unpub. data., 1988). The granite of Tank Pass averages about 2.7. Therefore, coherency of the gravity high suggests that amphibolite, which predominates on the surface, must not be a major component in the subsurface or the gravity high would more closely conform to surface contacts of the amphibolite-dominated Early Proterozoic rocks. Another possibility is that the granite of Tank Pass, or Proterozoic plutonic rocks as well, is more abundant in the subsurface of the southeastern part of the range than is suggested by surface geology.

The magnetic anomaly map (fig. 5) shows that the study area is entirely on the northwest flank of a single, long-wavelength, large-amplitude, northeast-striking 140 nT (nanotesla) high. This high, which has an axis 12 mi long, extends from Cunningham Pass southwest of the study area to northeast of Smith Peak northeast of the study area. The 140-nT high parallels the southeastern margin of the study area; its crest is coincident with surface exposures of Early Proterozoic rocks. By contrast, the northwestern flank of the high is associated with the Late Cretaceous granite of Tank Pass. The very steep magnetic gradient centered over the study area suggests that the southeastern contact of the granite of Tank Pass with Early Proterozoic rocks dips rather steeply.

In order to understand which rock types are responsible for the 140-nT high, percentages of magnetite, based on hand-held magnetic susceptibility measurements, for various rock types in the study area, were measured. The results are as follows: amphibolite, 0.2 percent magnetite (by volume); granodiorite to granite, 0.6 percent; pelitic schist, 1.0 percent; granite of Tank Pass, 0.35 percent; mylonitic Tertiary microgabbro dikes, 0.15 percent (Ed DeWitt, unpub. data, 1989). Amphibolite and the granite of Tank Pass are clearly nonmagnetic; the only surface rocks that could contribute significantly to the positive anomaly are pelitic schist and granodiorite to granite. Even they appear to contain too little magnetite to produce an anomaly of such amplitude.

Because the flight-line spacing of the magnetic survey is large compared to the flight altitude above terrain, local anomalies caused by very shallow or surficial magnetic rocks cannot be contoured across the widely spaced flight traces. Thus, the 140-nT high is caused largely by a source at depth which can be modeled. Our model for this hidden source is based on an assumed total magnetization (sum of induced and remanent magnetization—dipole moment per unit volume—assuming normal polarity) of 2.25 A/m (ampheres per meter) and a ratio of remanent to induced magnetization of 0.25, both values consistent with data from southwestern Arizona (Klein and Johnson, 1983). Modeling shows that the principal part of the regional magnetic high could be caused by a magnetic source about 1 mi below sea level—that is, about 1.5 mi beneath much of the variable terrain—that is 5 mi wide, 4 mi in

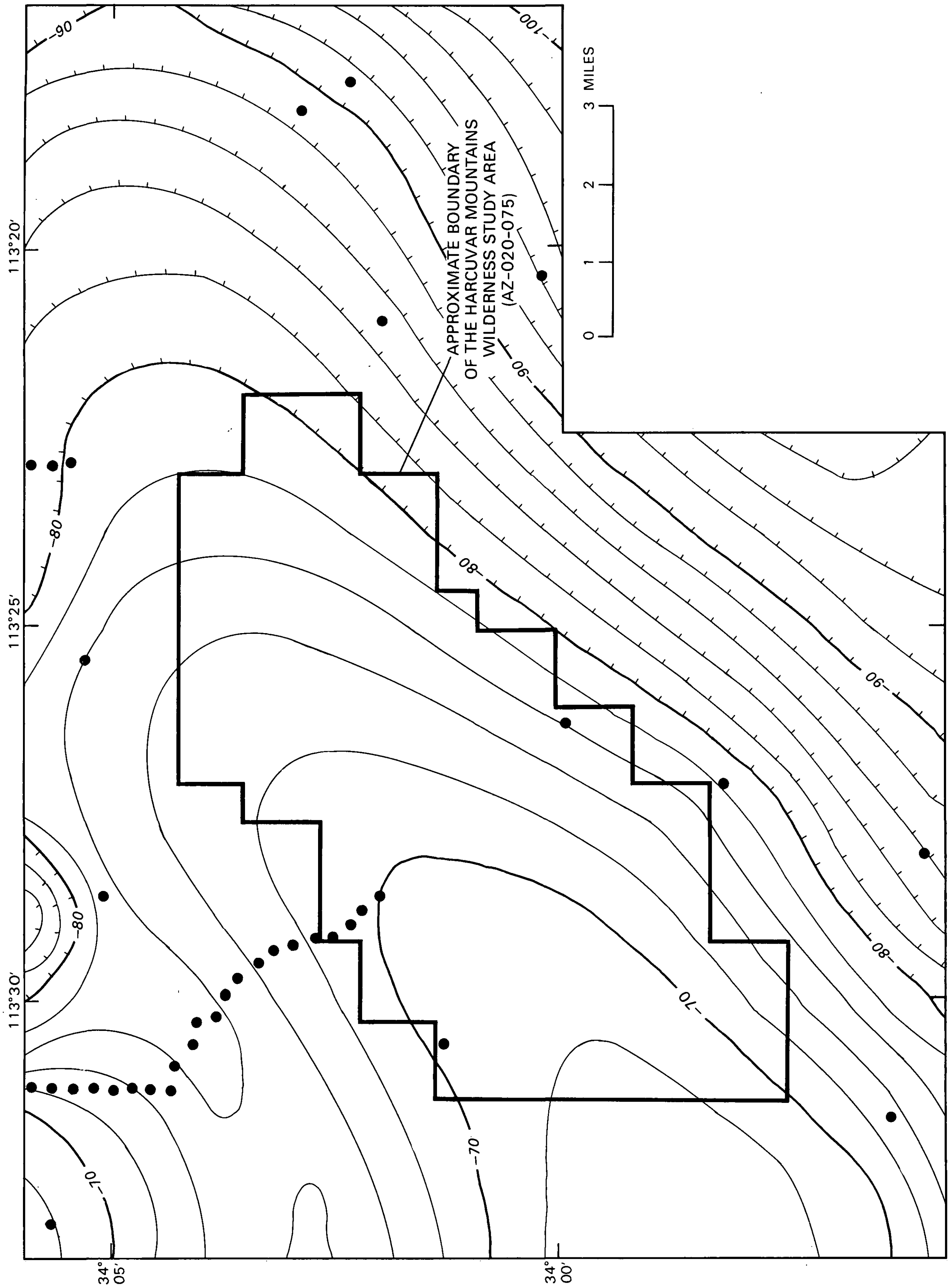

Figure 4. Bouguer gravity anomaly map of the Harcuvar Mountains Wilderness Study Area and vicinity, La Paz County, Arizona. Contour interval, 2 mGal (milligal). Solid circles, gravity observation points. Hachures indicate values of −80 mGal or less.

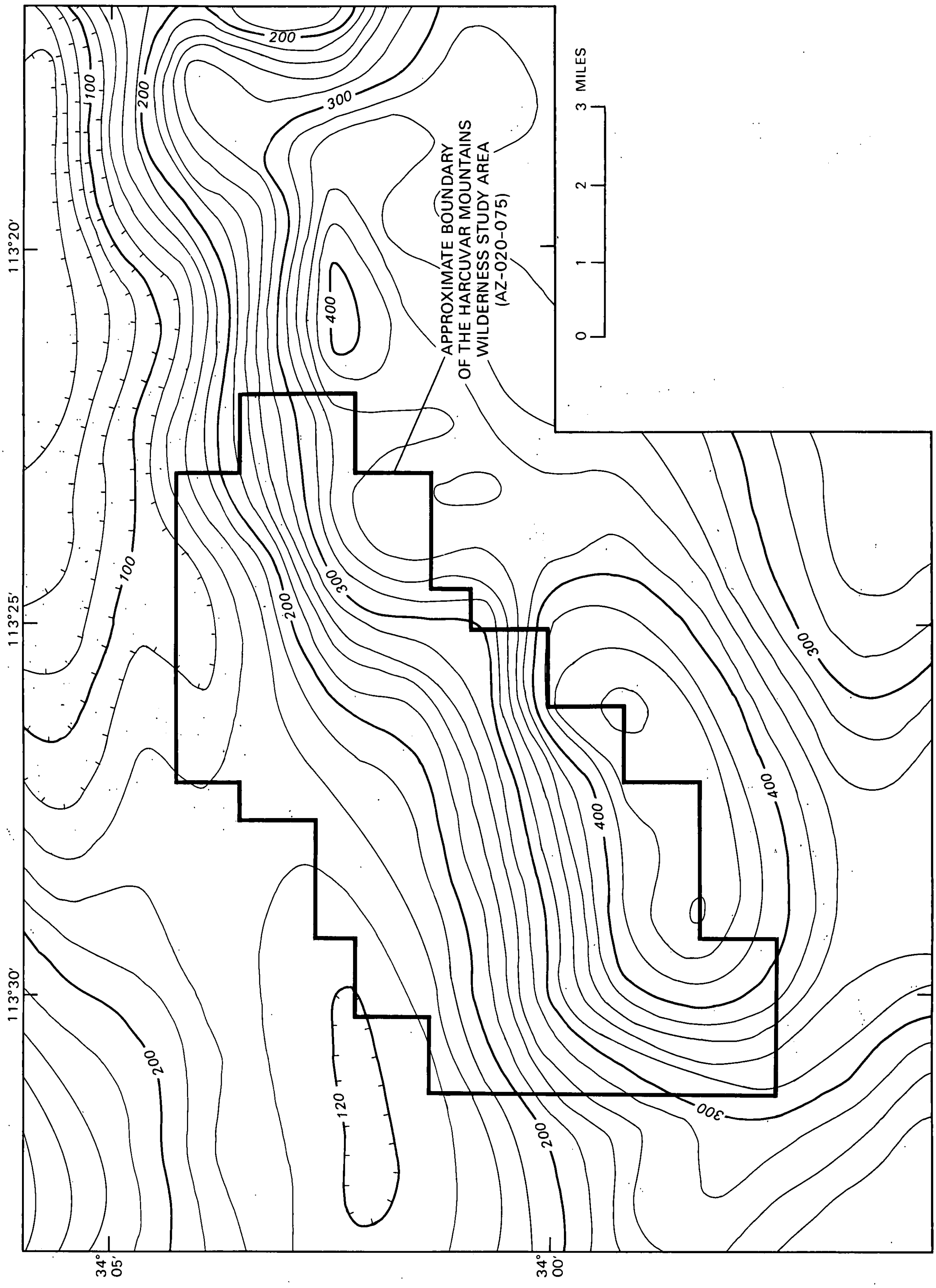

Figure 5. Magnetic anomaly map of the Harcuvar Mountains Wilderness Study Area and vicinity, La Paz County, Arizona. Contour interval, 20 nT (nanotesla). Hachures indicate values of 120 nT or less.

strike length, and 5 mi thick. These gross geometric characteristics simply confirm that most of the anomaly source is large, strongly magnetized, and at significant depth.

Quite possibly, the buried source may be a rock type not present in quantity on the surface. That rock could be a Proterozoic granite containing in excess of 1.0 percent magnetite, such as the granite of Blue Tank Canyon or the granite of Harquahala Mountain (6 percent and 2 percent magnetite, respectively) in the Harquahala Mountains (DeWitt and others, 1988; Ed DeWitt, unpub data, 1989). Also, and possibly more likely, the anomaly could be caused by a large mass of Tertiary microgabbro dikes (10 percent magnetite) or underlying body of gabbro similar to the one proposed to explain a magnetic anomaly of similar proportions in the Harquahala Mountains (DeWitt and others, 1988).

Also worth noting is that the Webber and Centroid mines (pl. 1) in and southwest of the study area, respectively, are beneath widely separated parts of the flank of the magnetic high at about the same anomaly value level of 275 nT. The modeled magnetic body associated with the regional magnetic high lies beneath the Webber mine but not the Centroid mine. Although cursory examination of other regions along strike of this magnetic gradient might be merited, no genetic relationship is known to suggest that other mineral prospects will be found in this way.

Mineral and Energy Resource Potential

About 36 percent of the study area (areas 1–4, table 3; pl. 1) has a moderate potential (certainty levels B, C, or D) for silver, gold, copper, lead, or tungsten in small to medium-size vein or disseminated deposits (table 3). In addition, two areas (5 and 6, pl. 1) having metallic mineral resource potential are within 1 mi of the study area. The entire study area has a low potential (certainty level C) for oil, gas, coal, sand and gravel, and placer gold. The entire study area also has a low potential (certainty level D) for geothermal resources, sand and gravel and other industrial rocks and minerals, decorative and ornamental stone, copper, lead, zinc, gold, and silver in massive sulfide deposits, and rare-earth minerals, feldspar, and mica in pegmatites.

The 64 percent of the study area outside areas 1–4 also has an unknown potential for gold in small to medium-size disseminated deposits similar to those near Carlin, Nev. (Radtke and others, 1980) and the deposit at the Mesquite mine in southeastern California (Willis, 1986). These deposits are characterized by very low grades of gold (1 ppm or less constitutes ore), much of which is very fine grained to microscopic in size. Ideally, a split of the panned concentrate from a stream-sediment sample should be analyzed for gold by atomic absorption techniques in order to evaluate the potential for this type of deposit. However, these analyses were not completed for the geochemical investigation. Because drainage basins and areas in the Harquahala Mountains to the southeast have been shown to contain highly anomalous concentrations of gold (DeWitt and others, 1988; J.E. Hassemer, unpub. data, 1986) even though favorable rock types and structures were not apparent, we do not believe that an assessment other than "unknown" can be made for this area.

Copper, Silver, Gold, Lead, or Tungsten Related to Formation of Northwest-Trending Shear Zones, Veins, and Microgabbro Dikes

Most of the mines and prospects in the study area are localized along northwest- to west-northwest-trending shear or fault zones, quartz veins, or margins of microgabbro dikes of early Miocene age. Shear zones and veins are more numerous than dikes, and microgabbro dikes in the Harcuvar Mountains are much less numerous than similar dikes in the Harquahala Mountains (DeWitt and others, 1988). Most quartz veins either parallel shear or fault zones or formed on the margins of dikes. Veins may have silver greatly in excess of gold (Ag/Au ratio about 100) or silver only slightly in excess of gold (Ag/Au about 2) (Welty and others, 1985; Ed DeWitt, unpub. data, 1986) and highly variable concentrations of copper and much lower concentrations of lead. Barite is a common gangue. Much of the mineral resource potential of the area is controlled by the distribution of shear zones, veins, and microgabbro dikes.

Area 1 (about 9.2 mi^2 or 23 percent of the study area), an elongate area trending northwest that includes the area of the Webber mine (pl. 1), has a moderate potential (certainty level D) for copper, silver, gold, lead, and tungsten in medium-size vein or shear zone deposits (table 3) similar to those at the Webber mine mineralized area (see section on "Appraisal of identified resources"). Known veins and mineralized shear zones in this area trend northwest, contain highly variable concentrations of copper (from 2,000 ppm to 4 percent) and low grades of silver (0.02–0.35 oz/st) and gold (less than 0.003 oz/st). Other veins and fracture zones away from the Webber mine may contain similar concentrations of metals. Stream sediments from drainages in area 1 contain anomalous to highly anomalous concentrations of copper, lead, gold, silver, and barium (table 1 and pl. 1). Rock-chip samples from area 1 contain anomalous to highly anomalous concentrations of copper, silver, gold, tellurium, antimony, mercury, lead, zinc, barium, cobalt, and molybdenum (table 2 and pl. 1). Northwest-trending quartz veins and shear zones west of the Webber mine, such as those sampled at rock-chip locality 16, probably are representative of the mineralized material causing

Table 3. Summary of areas that have mineral resource potential in and adjacent to the Harcuvar Mountains Wilderness Study Area, La Paz County, Ariz.

[Level of potential/level of certainty explained on plate 1; commodities listed in order of relative importance; commodities not underlined are considered to be byproducts or trace metals that could be recovered if deposits containing gold were mined; where variable sizes of deposits are shown, the most probable size is listed first; size of deposits listed below; <, less than]

Map area	Name	Resource potential	Level of potential/ level of certainty	Commodities (listed in order of importance)	Size, type of deposit
1	Webber------------	Moderate---	M/D	Cu, Ag, Au, Pb, W	Medium, vein.
2	Happy Camp Canyon-	Moderate---	M/C	Au, Ag, Cu	Small, vein.
3	Cunningham Pass,-- North	Moderate---	M/C	Ag, Au, Cu, Pb	Small-medium, vein; and medium, disseminated.
4	Northern----------	Moderate---	M/B	Ag, Au, Pb,	Small, vein.
5	Burnt Well--------	Moderate---	M/C	Au, Cu, Ag	Medium, vein or disseminated.
6	Bullard-----------	High-------	H/D	Au, Ag, Cu, Pb, Zn	Medium, vein or disseminated.

Small vein deposit = <10,000 tons.
Medium-size vein deposit = 10,000-250,000 tons.
Medium-size disseminated deposit = 200,000-10,000,000 tons.

anomalous concentrations of metals in stream-sediment sample HV001. Stream-sediment sample HV003 has the only significant tungsten anomaly in the study area; the source of the tungsten is unknown.

Area 2 (about 1 mi² or 2 percent of the study area), northwest-trending and centered on the workings in lower Happy Camp Canyon (pl. 1) has a moderate potential (certainty level C) for gold, silver, and copper in small shear zone and quartz vein deposits similar to those in area 1. Quartz veins containing abundant vugs have variable grades of gold (0.01–0.03 oz/st), low grades of silver (about 0.02 oz/st), and highly variable concentrations of copper (from 1,800 ppm to 4 percent). Rock-chip samples from the area contain anomalous concentrations of gold, silver, and copper as well as anomalous concentrations of tellurium and cobalt. Mineralized material in area 2 does not appear to extend northwest into area 1, as stream-sediments from the intervening area (HV027, HV029, and HV030) do not contain anomalous concentrations of most of the metals just listed for area 2.

Area 3 (about 3.5 mi² or 9 percent of the study area), north and east of Cunningham Pass, has a moderate potential (certainty level C) for silver, gold, copper, and lead in small to medium-size vein deposits similar to those in the Cunningham Pass mining district to the southwest. Veins and margins of Tertiary microgabbro dikes in the Cunningham Pass district contain chalcopyrite, bornite, pyrite, electrum, and minor galena in a gangue of hematite, calcite, barite, and quartz (Tovote, 1918; Keith, 1978). The veins and dikes range in strike from west to north, but average northwest, and dip at variable angles. Mineralized material of this type is noted in area 3 in chip samples 3, 4, 6, 7, and 9 (pl. 1), which have anomalous to highly anomalous concentrations of silver, gold, tellurium, mercury, barium, copper, cobalt, and lead. Stream-sediment sample HV035 contains anomalous concentrations of gold. Structural controls of mineralization in area 3 include mapped northwest-trending shear zones and faults and inferred, west-northwest-trending fracture or fault zones, especially the ones present in sections 5, 6, 7, 8, 9, and 15, T. 7 N., R. 12 W. (pl. 1).

Area 3 also has a moderate potential (certainty level C) for gold, silver, copper, and lead in medium-size disseminated deposits. In such a deposit, not only quartz veins and margins of microgabbro dikes but also adjacent wallrock would contain lower grades of gold but much larger tonnages of ore than in the vein-type deposits. In the southwestern United States, disseminated deposits representative of this type include the Mesquite mine (Epler, 1985; Willis, 1986) and the Picacho mine (Van Nort and Harris, 1984; Drobeck and others, 1986) in southeastern California. The possibility of disseminated deposits in the study area is suggested by the number of rock-chip samples that contain anomalous concentrations of gold and silver, by the potentially altered area in sections 9 and 10, T. 7 N., R. 12 W., identified by Thematic Mapper (TM) imagery, and by the fact that the only stream-sediment samples that contained measurable gold (by the analytical techniques used) were found in area 3 (HV035) and immediately to the north in area 1 (HV001).

Area 4 (about 1 mi² or 2 percent of the study area), southeast of the Burnt Well metallic mineral district (Spencer and Welty, 1985), has a moderate potential (certainty level B) for silver, gold, and lead in small vein deposits related to northwest-trending fault zones of Tertiary microgabbro dikes. Stream-sediment sample HV008 contains anomalous concentrations of lead and barium, and rock-chip samples 30 and 48, both of which are in the drainage basin southeast of HV008, contain anomalous concentrations of silver and lead, respectively. Although the exact source of the mineralized material is unknown, we suspect that northwest-trending veins or margins of microgabbro dikes in the drainage basin contain minor amounts of galena or other silver-rich minerals.

Silver, Gold, Copper, Lead, and Zinc Related to the Bullard Detachment Fault

Tertiary volcanic and sedimentary rocks, both north of the study area near the Burnt Well metallic mineral district and east of the study area near the Bullard mining district and metallic mineral district (pl. 1), are in the upper plate of the Bullard detachment fault. The detachment fault is a low-angle structure that juxtaposes mylonitic Early Proterozoic and Cretaceous rocks in the lower plate and rotated and normally faulted Tertiary strata in the upper plate. In the Rawhide and Buckskin Mountains, northwest of the Harcuvar Mountains, a distinctive assemblage of massive hematite, chrysocolla, malachite, gold, and silver is in veins, shear zones, and replacement bodies in upper-plate units, and both along the detachment fault, and locally as disseminated deposits in some lower-plate units (Spencer and Welty, 1985, 1986). Potassium metasomatism of upper-plate units, characteristic of this type of mineralization, is noted at the Bullard mine, east of the study area (Roddy and others, 1988). This type of mineralization apparently took place during and slightly after detachment faulting (Wilkins and Heidrick, 1982; Wilkins and others, 1986). Also, bedded and disseminated deposits (whose mineralization may have taken place during sedimentation before detachment faulting) and vein-type manganese mineral deposits are locally abundant in upper-plate units, as in the Artillery Mountains north of the study area (Wilson and Butler, 1930; Lasky and Webber, 1949).

Area 5, centered on the Burnt Well metallic mineral district, has a moderate potential (certainty level C) for gold, copper, and silver in medium-size vein or disseminated deposits in the upper plate of the Bullard(?) detachment fault. Although area 5 is outside the study area, its boundaries are within 0.5 mi of the study area, and minor amounts of mineralized material could extend into the study area. Because area 5 is outside the study area, stream-sediment samples were not collected to see whether mineralized material extended into the study area. Vein deposits in area 5 would be similar to vein and replacement deposits mentioned earlier, and could extend far to the southwest along the trace of the Bullard(?) detachment fault. Disseminated deposits in area 5 would be similar to those deposits suggested for area 3, north of Cunningham Pass. Anomalous concentrations of gold, silver, copper, lead, antimony, zinc, and barium are noted in rock-chip samples (samples 23 and 27) from area 5. Most upper plate strata in and near area 5 is covered by thin deposits of gravel (units QTg and Qg), which could be penetrated by shallow drill holes or explored by use of geophysical techniques.

Area 6, surrounding the Bullard mining district and extending to the southwest along the Bullard detachment fault, has a high potential (certainty level D) for gold, silver, copper, lead, and zinc in medium-size veins or disseminated deposits related to movement along the fault. Although area 6 is outside the study area, uncertainty in the location of the detachment fault along the southeast flank of the Harcuvar Mountains suggests that mineralized material from area 6 could be as close as 1 mi to the study area. Tertiary sedimentary and volcanic rocks in the upper plate of the detachment fault near Bullard Peak (pl. 1) are cut by many generations of normal faults, some of which contain veins of quartz, calcite, copper carbonate minerals, chalcopyrite, electrum, and minor galena. Deposits in the Bullard metallic mineral district (Welty and others, 1985; Keith and others, 1983) are characteristically gold-rich, having Ag/Au ratios of 0.2–2.0 (Ed DeWitt, unpub. data, 1986). Vein deposits in area 6 would be similar to those in the Bullard mining district; disseminated deposits would be similar to those suggested for area 3, north of Cunningham Pass. Because most upper-plate rocks in area 6 are covered by gravel deposits, and because the trace of the Bullard detachment fault southwest of Bullard Peak can only be approximately located, we cannot define the southwestern boundary of area 6 with certainty and show it queried(?) on plate 1. As with area 5, the thin cover of gravel in and southwest of area 6 could be penetrated by shallow drill holes or prospected by geophysical techniques.

Oil, Gas, Coal, and Geothermal Energy

Paleozoic or Mesozoic rocks that could act as either reservoir or source rocks for oil or gas are not present in the study area. Also, no strata are present that contain significant quantities of organic material or coal. Furthermore, if those rocks were present at depth in the lower plate of the Harquahala thrust (as discussed in the section on structure), they would most likely be metamorphosed to at least greenschist facies as they are in the adjacent Harquahala Mountains to the southeast (DeWitt and others, 1988; Richard, 1988) and the Buckskin Mountains to the northwest (B.H. Bryant, unpub. data, 1988; Reynolds and others, 1988) and would be purged of oil and gas. Therefore, the study area has a low potential (certainty level C) for oil, gas, and coal.

Geothermal energy sources are likewise not present, as there are no surface geologic indications of hot springs, nor does water from any wells in valleys adjacent to the study area have anomalous temperatures or chemistries indicative of mineral-rich hot springs. Therefore, the study area has a low potential (certainty level D) for geothermal energy resources.

Other Commodities and Deposit Types

The study area contains significant amounts of sand and gravel, especially along the northwestern and southeastern borders of the Harcuvar Mountains. This material is very poorly sorted and contains many cobbles and boulders. Therefore, the study area has only a low resource potential (certainty level C) for sand and gravel.

No industrial rocks or minerals and decorative or ornamental stone (except for the gravel just mentioned) are present in significant quantities in the study area. Therefore, the study area has a low potential (certainty level D) for all industrial rocks or minerals.

Early Proterozoic amphibolite (unit Xna) could be volcanic in origin and part of a volcanogenic suite related to copper-, zinc-, lead-, gold-, and silver-rich massive sulfide deposits exposed near Bagdad (Anderson and others, 1955; Conway and others, 1986) and Prescott (Anderson and Creasey, 1958; Anderson and Nash, 1972; Donnelly and Hahn, 1981; DeWitt, 1983; DeWitt and Waegli, 1986). However, related rhyolitic rocks that typically host these massive sulfide deposits are not present, nor are chemically precipitated rocks, such as chert or iron-formation that could indicate hydrothermal alteration. Therefore the study area has a low potential (certainty level D) for copper, lead, zinc, gold, and silver in massive sulfide deposits.

Pegmatite bodies associated with the granite of Tank Pass (unit Kg) are widespread throughout the study area but do not contain significant concentrations of rare-element minerals, feldspar, or mica. Therefore the study area has a low resource potential (certainty level D) for these pegmatite minerals.

Placer gold deposits derived from weathering of gold-bearing quartz veins could be present in the unconsolidated material (unit Qg) along the flanks of the Harcuvar Mountains, particularly in the southern part of the study area. The resource potential for placer gold deposits in the study area is low (certainty level C), however, due to the small size of known gold-bearing veins and the immature (insufficiently reworked) nature of sediments in the unconsolidated material.

Recommendations for Further Study

In order to appraise the potential for disseminated deposits having very low grades of gold in the area, panned-concentrate samples should be analyzed for gold by atomic absorption methods. In the Harquahala Mountains to the southeast, highly anomalous concentrations of gold and silver were found in drainage basins that did not contain obvious indicators of mineralization. The same could be true for drainages in the Harcuvar Mountains, especially in the area northeast of the Webber mine.

The trend of fracture(?) zones and major faults in area 3, north and northeast of Cunningham Pass, is more westerly (west-northwest) than most shear zones, faults, and microgabbro dikes in the Harcuvar and Harquahala Mountains (northwest). The importance, extent, and age of these west-northwest-trending structures should be investigated, especially in light of the mineralized material in the Cunningham Pass mining district and the moderate potential for gold, silver, copper, and lead in area 3.

More and better gravity data are needed to locate precisely the crest of the Bouguer anomaly on the southeastern side of the study area. Also, better magnetic data, especially south of latitude 34° N. are needed to model the size and configuration of the magnetic body at depth that causes the magnetic anomaly. These data are especially important if the body turns out to be buried Tertiary microgabbro dikes or their plutonic equivalent, as much of the mineral resource potential in the study area is linked to the emplacement and deformation of these rocks.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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 unlikely. This broad category embraces areas with dispersed but insignificantly mineralized rock as well as areas with few or no indications of having been mineralized.

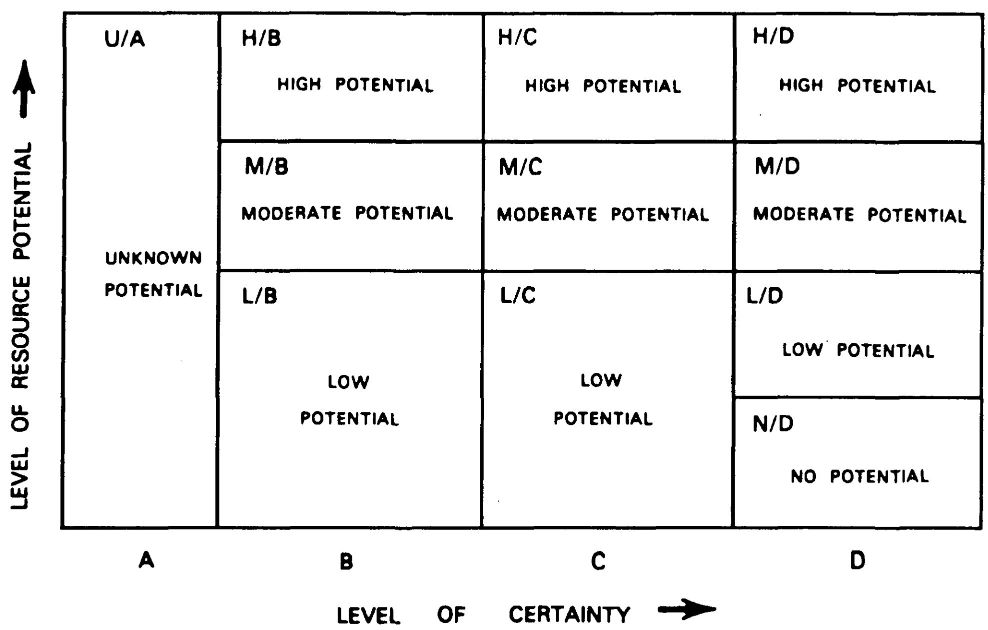
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

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.

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

NO mineral resource potential is a category reserved for a specific type of resource in a well-defined area.

Levels of Certainty



A. Available information is not adequate for determination of the level of mineral resource potential.
B. Available information 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.

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RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	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, 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 in this report

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
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	~ 570[1]
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 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.

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