Mineral Resources of the Baboquivari Peak and Coyote Mountains Wilderness Study Areas, Pima County, Arizona

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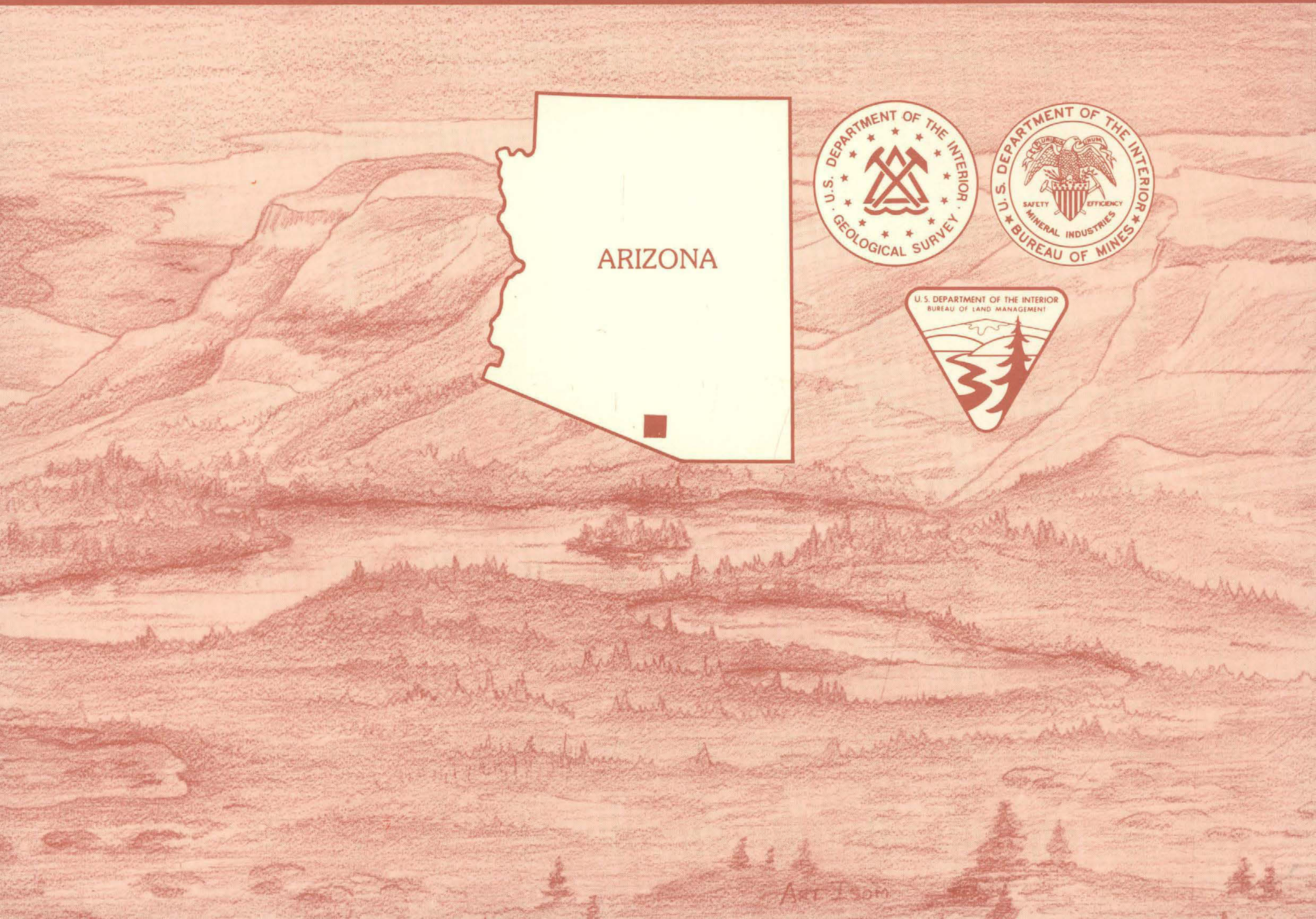

Chapter E

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

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

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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 mineral surveys of the Baboquivari Peak (AZ-020-203B) and Coyote Mountains (AZ-020-202) Wilderness Study Areas, Pima County, Arizona.

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Mineral Resources of the Baboquivari Peak and Coyote Mountains Wilderness Study Areas, Pima County, Arizona

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SUMMARY

Abstract

At the request of the U.S. Bureau of Land Management, the 2,065 acres of the Baboquivari Peak Wilderness Study Area (AZ–020–203B) and the 5,080 acres of the Coyote Mountains Wilderness Study Area (AZ–020–202) were evaluated for mineral resources (known) and mineral resource potential (undiscovered). The Baboquivari Peak and Coyote Mountains Wilderness Study Areas are located in the Baboquivari Mountains in central Pima County, Arizona. Field work for this report was conducted between 1978 and 1987.

The Baboquivari Peak Wilderness Study Area is underlain by Jurassic supracrustal (including granitoid) rocks intruded by middle Tertiary rhyolite dikes (see geologic time chart in appendixes). One gold-silver occurrence in the Baboquivari Peak Wilderness Study Area has been reported. The entire Baboquivari Peak Wilderness Study Area has high potential for resources of gold, silver, copper, lead, zinc, barium, bismuth, manganese, molybdenum, or tungsten in polymetallic veins spatially associated with felsic to intermediate intrusions. The northern part of the Baboquivari Peak Wilderness Study Area has low potential for resources of beryllium and bismuth in pegmatites or quartz veins and the entire wilderness study area has low potential for thorium resources in pegmatites. The entire Baboquivari Peak Wilderness Study Area has low potential for gold and silver resources in paleoplacer deposits. The entire Baboquivari Peak Wilderness Study Area has low potential for gold and silver resources in veins or disseminated deposits associated with the outer halo of an inferred porphyry molybdenum deposit, and the southern part of the wilderness study area has low potential for molybdenum resources based on that inferred deposit.

The Coyote Mountains Wilderness Study Area is underlain by Paleozoic metasedimentary rocks, Jurassic granitoids, and early Tertiary granite. About 20 mining claims are located in the Coyote Mountains Wilderness Study Area. Parts of the Coyote Mountains Wilderness Study Area that are underlain by Paleozoic metasedimentary rocks have high potential for resources of copper, tungsten, gold, silver, molybdenum, and zinc in skarn and polymetallic replacement deposits. The entire Coyote Mountains Wilderness Study Area has low potential for resources of thorium, niobium, uranium, and rare-earth elements, such as lanthanum and yttrium, in pegmatites. The northeastern part of the Coyote Mountains Wilderness Study Area has moderate potential for gold resources associated with a detachment fault.

The potential for oil, gas, geothermal energy, and industrial minerals is low in both wilderness study areas.

Character and Setting

The Baboquivari Peak and Coyote Mountains Wilderness Study Areas are located in the central and northern part, respectively, of the Baboquivari Mountains in central Pima County, Arizona. Baboquivari Peak forms the southwestern corner of the Baboquivari Peak Wilderness Study Area (fig. 1). The Coyote Mountains Wilderness Study Area is several miles east of Kitt Peak National Observatory (fig. 1).

Major lithologic units in the Baboquivari Peak Wilderness Study Area are Early Jurassic sedimentary, volcanic,

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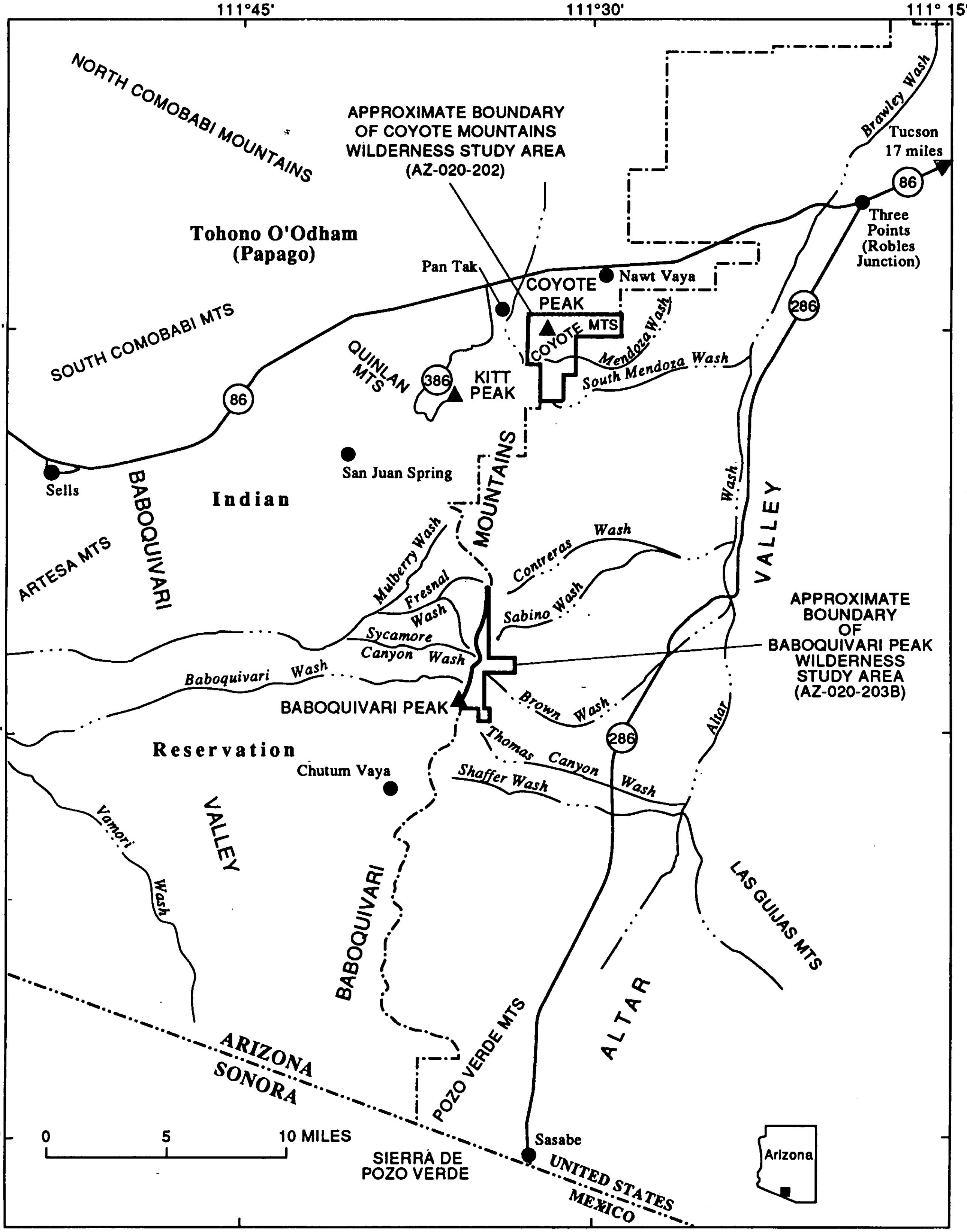

Figure 1. Index map showing location of the Baboquivari Peak and Coyote Mountains Wilderness Study Areas, Pima County, Arizona.

and hypabyssal rocks of the Pitoikam and Mulberry Wash Volcanic Formations; the Late Jurassic perthite granite of Baboquivari Peak; and the middle Tertiary rhyolite of Allison Camp. The Early Jurassic supracrustal rocks form a west-dipping homocline. The Mulberry Wash Volcanic Formation is intruded by the perthite granite of Baboquivari Peak. The rhyolite of Allison Camp intrudes the supracrustal rocks and the perthite granite as a rectilinear network of northwest- and northeast-trending dikes.

Major lithologic units in the Coyote Mountains Wilderness Study Area are Paleozoic metasedimentary rocks; Middle to Late Jurassic diorite, granodiorite, and granite units; and the early Tertiary (58 Ma, million years) Pan Tak Granite. The Pan Tak Granite underlies most of the Coyote Mountains Wilderness Study Area and is a moderately alumina-rich leucogranite. The older rocks form pendants within the Pan Tak Granite. Pegmatite dikes are abundant within the Pan Tak pluton and its wall rocks. A west-northwest-trending detachment fault is present on the north side of the Coyote Mountains.

Identified Mineral Resources

No identified mineral or energy resources are present within the Baboquivari Peak Wilderness Study Area, although several base-metal (copper, lead, zinc) and precious-metal (gold, silver) commodities have been mined or prospected nearby.

About 700 short tons of copper-silver-gold ore were shipped between 1909 and 1951 from the Bonanza mine area, which is within the boundary of the Coyote Mountains Wilderness Study Area. The ore, localized along limestone-granite contacts, averaged 10 percent copper, 1.7 troy oz silver/st (short ton), and 0.03 troy oz gold/st. Drilling records and U.S. Bureau of Mines sampling identified subeconomic inferred resources totaling 66,500 short tons averaging in excess of 5 percent copper, 1.5 troy oz silver/st, and 0.15 percent tungsten trioxide near the old workings. Resources of oil, gas, geothermal energy, and industrial minerals have not been identified.

Mineral Resource Potential of the Baboquivari Peak Wilderness Study Area

The entire Baboquivari Peak Wilderness Study Area has high potential for resources of gold, silver, copper, lead, zinc, barium, bismuth, manganese, molybdenum, or tungsten in polymetallic veins (fig. 2). Favorable criteria include presence of fracturing, middle Tertiary silicic dikes, nearby vein mineralization, and geochemical anomalies.

The northern part of the Baboquivari Peak Wilderness Study Area has low potential for beryllium and bismuth resources in pegmatites and quartz veins; the entire area has low potential for thorium resources in pegmatites (fig. 2). Beryl- and bismuth-bearing pegmatites, of Jurassic(?) age, are present 2 mi east of the Baboquivari Peak Wilderness Study Area. The Late Jurassic granite to which these pegmatites are probably related does not extend into the wilderness study area, but the possibility of isolated beryl- and bismuth-bearing pegmatite bodies within the wilderness study area cannot be precluded.

The Baboquivari Peak Wilderness Study Area has low potential for gold and silver resources in paleoplacer deposits in parts of the wilderness study area that are underlain by Early Jurassic siliciclastic strata (fig. 2). Favorable criteria in the study area include anomalous concentrations of gold and silver in panned-concentrate samples derived from stream sediments, visible gold in panned-concentrate samples, and favorable geology.

The Baboquivari Peak Wilderness Study Area has low potential for gold and silver resources in veins or disseminated deposits associated with the outer halo of an inferred porphyry molybdenum deposit. The southern part has low potential for molybdenum resources in the inferred porphyry molybdenum deposit that may be located near the south end of the wilderness study area. Favorable criteria in or near the wilderness study area include alteration, faults, middle Tertiary silicic dikes, felsic intrusive rocks, nearby polymetallic vein deposits, and geochemical anomalies.

The Baboquivari Peak Wilderness Study Area has low potential for resources of oil, gas, geothermal energy, and industrial minerals. Appropriate reservoir rocks for oil and gas are not present. No thermal springs or wells occur in the wilderness study area. Industrial minerals (sand and gravel, in this case) are present in only small quantities.

Mineral Resource Potential of the Coyote Mountains Wilderness Study Area

The part of the Coyote Mountains Wilderness Study Area that is underlain by Paleozoic metasedimentary rocks has high potential for resources of copper, tungsten, gold, silver, molybdenum, and zinc in skarn and polymetallic replacement deposits (fig. 3). Favorable criteria include known occurrences of this type, the presence of calcareous metasedimentary rocks locally altered to skarn, and geochemical anomalies.

The entire Coyote Mountains Wilderness Study Area has low potential for thorium, niobium, uranium, and rare-earth elements (such as lanthanum and yttrium) resources in mineralized pegmatites. Simple pegmatites, which are associated with an early Tertiary alumina-rich leucogranite, are abundant in the wilderness study area. Although no complex pegmatites are known, some stream-sediment samples contain anomalous concentrations of thorium, niobium, lanthanum, and yttrium and a uranium-bearing pegmatite is present east of the wilderness study area.

The northeastern part of the Coyote Mountains Wilderness Study Area has moderate potential for gold resources associated with a middle Tertiary detachment fault. Some

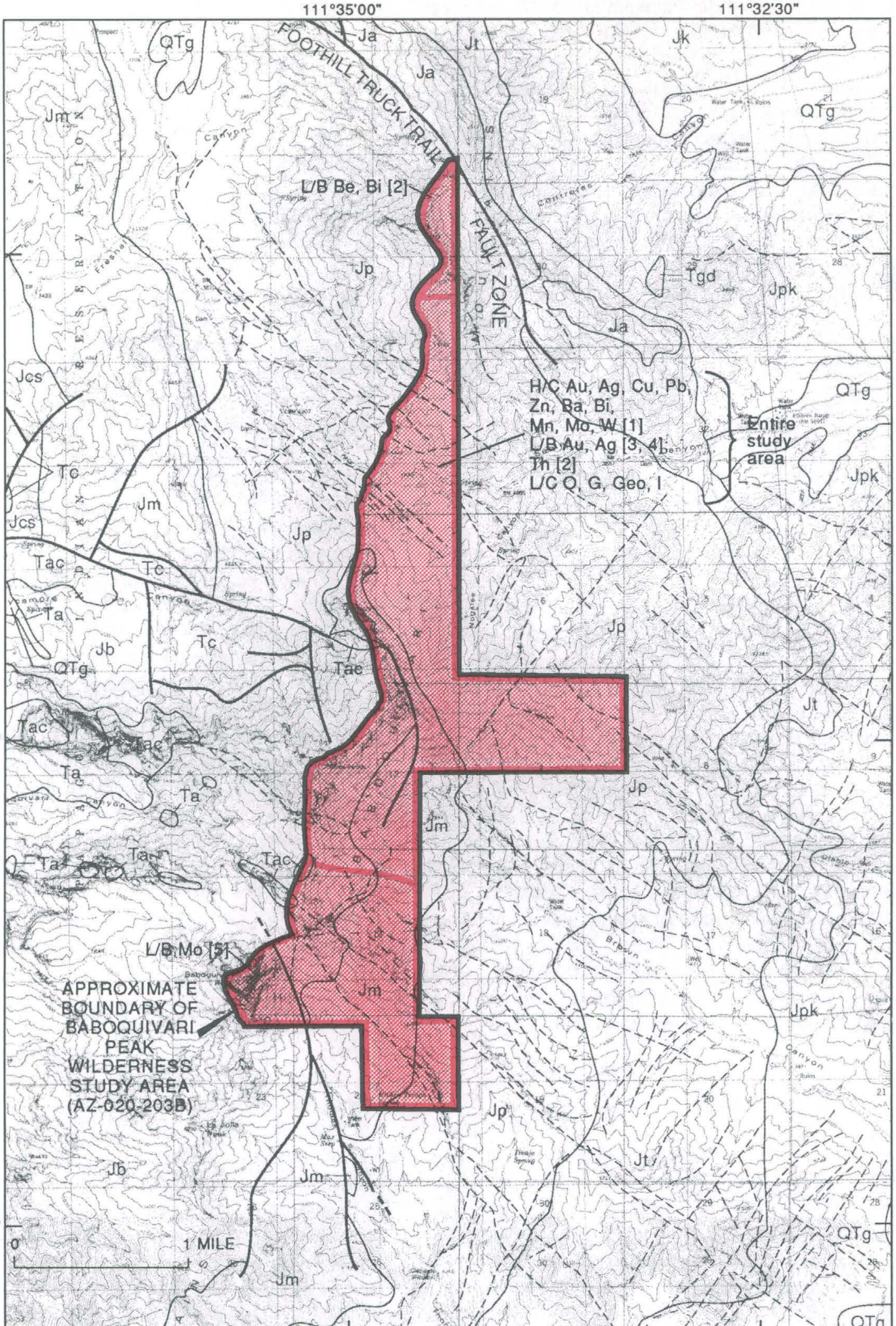

Figure 2. Mineral resource potential and generalized geology of the Baboquivari Peak Wilderness Study Area, Pima County, Arizona. Base from U.S. Geological Survey, 1979, Baboquivari Peak and Mildred Peak quadrangles. Contour interval 20 and 40 ft.

panned-concentrate samples derived from stream sediments have anomalous concentrations of gold.

The Coyote Mountains Wilderness Study Area has low potential for resources of oil, gas, geothermal energy, and industrial minerals. Appropriate reservoir rocks for oil and gas are absent. Thermal springs or wells do not occur in the wilderness study area. Only small quantities of industrial minerals (sand, gravel, and limestone, in this case) are present.

EXPLANATION

(pink shaded box)	Area with high mineral resource potential (H)
(pink outlined box)	Area with low mineral resource potential (L)
	Levels of certainty of assessment
B	Data only suggest level of potential
C	Data give good indication of level of potential
	Commodities
Ag	Silver
Au	Gold
Ba	Barium
Be	Beryllium
Bi	Bismuth
Cu	Copper
Geo	Geothermal
I	Industrial sand and gravel, limestone
Mn	Manganese
Mo	Molybdenum
O, G	Oil and gas
Pb	Lead
Th	Thorium
Zn	Zinc
[ ]	Deposit type
1	Polymetallic veins
2	Pegmatites
3	Paleoplacer gold-silver
4	Gold-silver, disseminated or in veins associated with porphyry molybdenum
5	Porphyry molybdenum
	Description of map units
QTg	Gravel and alluvium (Quaternary and late Tertiary)
Tac	Rhyolite of Allison Camp (middle Tertiary)—Intrusive rhyolite body
Tgd	Hornblende granodiorite (Tertiary)
Ta	Andesitic and dacitic flows and intrusions (Tertiary)
Tc	Conglomerate (Tertiary)
Jb	Perthite granite of Baboquivari Peak (Late Jurassic)
Jpk	Granite of Pavo Kug Wash (Late Jurassic)
Jk	Granodiorite of Kitt Peak (Middle Jurassic)
Jt	Rhyodacite porphyry of Tinaja Spring (Early Jurassic)
Jcs	Chiuli Shaik Formation (Early Jurassic)
Jm	Mulberry Wash Volcanic Formation (Early Jurassic)
Jp	Pitoikam Formation (Early Jurassic)
Ja	Ali Molina Formation (Early Jurassic)
———	Contact
———--	High-angle fault—Dashed where approximate or concealed
- - - - -	Dike of intrusive rhyolite of Allison Camp (unit Tac)—Approximately located

Figure 2. Continued.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is a joint effort by the U.S. Geological Survey and the U.S. Bureau of Mines. An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was provided by Beikman and others (1983). The U.S. Bureau of Mines evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas. Identified resources are classified according to a system that is a modification of that described by McKelvey (1972) and U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey are designed to provide a reasonable scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Mineral assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See appendixes for the definition of levels of mineral resource potential, certainty of assessment, and classification of identified resources.

Throughout this report "study area" refers to either the Baboquivari Peak Wilderness Study Area or the Coyote Mountains Wilderness Study Area or both and will include sampled areas outside but adjacent to the wilderness study areas. The term "wilderness study area" refers to terrain only within the boundaries of one or the other of the two wilderness study areas. In general, references to the Baboquivari Mountains will include the Coyote Mountains and Quinlan Mountains.

Location and Physiography

The Baboquivari Peak (AZ–020–203B) and Coyote Mountains (AZ–020–202) Wilderness Study Areas are located in Pima County, Arizona, approximately 45 and 35 mi, respectively, southwest of Tucson. Both wilderness study areas are within the Baboquivari Mountains, a chain of mountains that stretches continuously for 37 mi from the Sierra de Pozo Verde in northernmost Sonora north through the Quinlan Mountains to the Coyote Mountains (fig. 1). Kitt Peak National Observatory is situated atop the Quinlan Mountains, about 5 mi southwest of the Coyote Mountains Wilderness Study Area.

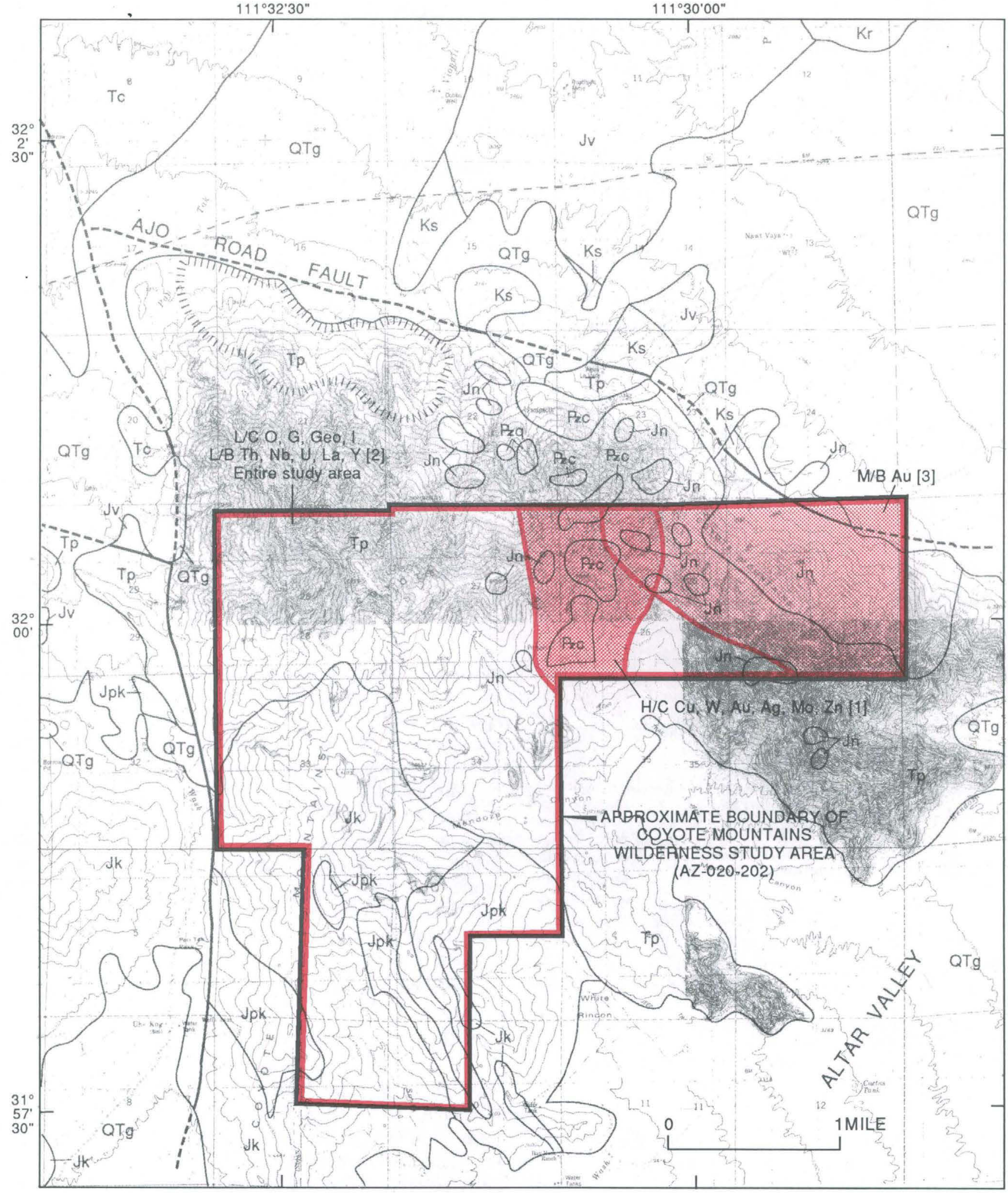

Figure 3. Mineral resource potential and generalized geology of the Coyote Mountains Wilderness Study Area, Pima County, Arizona. Base from U.S. Geological Survey, 1979, Kitt Peak, Palo Alto Ranch, Pan Tak, and San Pedro quadrangles. Contour interval 10, 20, and 40 ft.

The Baboquivari Peak Wilderness Study Area is an irregular, north-south-elongate area of about 2,065 acres on the eastern slope of the Baboquivari Mountains. The west boundary of the study area is the crest of the range and is coincident with the boundary of the Tohono O'Odham (formerly Papago) Indian Reservation. The wilderness study area extends from Baboquivari Peak and the upper drainage area of Thomas Canyon Wash north 6 mi to uppermost Contreras Wash. Most of the terrain within the study area is rugged, with rocky slopes, ridges, and canyons. The summit of Baboquivari Peak (7,734 ft) is the highest point; the lowest elevations are about 5,200 ft.

EXPLANATION

Area with high mineral resource potential (H)

Area with moderate mineral resource potential (M)

Area with low mineral resource potential (L)

Levels of certainty of assessment

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

Commodities

Au	Gold	Th	Thorium
Ag	Silver	W	Tungsten
Cu	Copper	Zn	Zinc
La, Y	Lanthanum and yttrium	I	Industrial sand and gravel, limestone
Mo	Molybdenum	O, G	Oil and gas
Nb	Niobium	Geo	Geothermal
U	Uranium		

[ ] Deposit type

1	Copper skarn and polymetallic veins
2	Pegmatites
3	Gold deposits associated with detachment faults

Description of map units

QTg	Gravel and alluvium (Quaternary and late Tertiary)
Tc	Conglomerate (late Tertiary)
Tp	Pan Tak Granite (early Tertiary)
Kr	Roskruge Volcanics (Cretaceous)
Ks	Sand Wells Formation (Cretaceous?)
Jv	Volcanic rocks (Jurassic)
Jpk	Granite of Pavo Kug Wash (Late Jurassic)
Jk	Granodiorite of Kitt Peak (Middle Jurassic)
Jn	Diorite of Nawt Vaya (Middle Jurassic)
Pzq	Quartzite (Paleozoic)
Pzc	Calc-silicate schist (Paleozoic)

Contact

Fault—Dashed where approximate or concealed

Area of penetrative mylonitic foliation and lineation in Pan Tak Granite

Figure 3. Continued.

Primary access to the study area is from Arizona Highway 286 in Altar Valley on the east via dirt roads and trails up Thomas, Brown, Sabino, and Contreras Washes. The study area is also accessible from the west through Fresnal, Sycamore, and Baboquivari Washes within the Tohono O'Odham Indian Reservation.

The Coyote Mountains Wilderness Study Area includes 5,080 acres encompassing most of the higher parts of the rugged Coyote Mountains. The inverted L-shaped configuration of the wilderness study area approximates the two main ridges, one north-south and the other east-west, that comprise the Coyote Mountains. Each limb of the L is about 4 mi long. The highest point within the wilderness study area is 6,529 ft at the summit of Coyote Peak. Terrain within the wilderness study area consists of rugged and steep slopes, cliffs, narrow ridges, and steep canyons; the central part includes a number of steep-sided granitic domes. Access to much of the study area is limited due to the steep topography and some areas can be reached only by using technical climbing aids. The three principal means of access to the study area are from the east via dirt roads up Mendoza Wash, from the north via a dirt road and trail that connect with Arizona Highway 86 through the village of Nawt Vaya, and from the west via dirt roads from the village of Pan Tak or Arizona Highway 386 (the road to Kitt Peak National Observatory). The west and north boundaries of the wilderness study area are coincident with the boundary of the Tohono O'Odham Indian Reservation and access routes from the north and west cross the reservation. From the northern access route, a hiking trail through the study area leads to the summit of the Coyote Mountains.

Previous and Present Investigations

The earliest detailed geologic investigations in or adjacent to the Baboquivari Peak and Coyote Mountains Wilderness Study Areas were University of Arizona thesis studies by Wargo (1954), Kurtz (1955), Clark (1956), Wargo and Kurtz (1956), Donald (1959), Balla (1962), Fair (1965), Min (1965), and Carrigan (1971). Only the studies by Donald (1959), Balla (1962), and Carrigan (1971) deal specifically with mineral resources: beryllium occurrences near the Baboquivari Peak Wilderness Study Area and copper occurrences within the Coyote Mountains Wilderness Study Area. Broad reconnaissance geologic mapping of most of the northern part of the Baboquivari Mountains in the 1950's by L.A. Heindl of the U.S. Geological Survey was published only as a figure in a field trip guide (Galbraith and others, 1959, fig. 57). The northern part of the Coyote Mountains is within the area mapped by Keith (1976). Heindl and Fair (1965) defined several Mesozoic (Lower Jurassic) stratigraphic units in the Fresnal Canyon area, west of the Baboquivari Peak Wilderness Study Area.

A mineralized area 2 mi south of the Baboquivari Peak Wilderness Study Area was studied by Seaman (1983). Tertiary deformation in the northern Coyote Mountains and in the Sierra de Pozo Verde was studied by Davis (1980), Gardulski (1980), and Davis and others (1987). Mineral occurrences within the Baboquivari Peak and Coyote Mountains Wilderness Study Areas are included in county summaries by Keith (1974) and Schnabel and others (1986).

The entire Baboquivari Mountains north of the Sonoran border were mapped from 1978 to 1980 (Haxel and others, 1980a, 1982) as part of a mineral resource assessment of the Tohono O'Odham Indian Reservation. The geologic mapping was accompanied by uranium/lead isotopic geochronology (Wright and Haxel, 1982; Wright and others, 1981; Haxel and others, 1980a, b; Tosdal and others, 1989). Additional geologic studies within or adjacent to the Baboquivari Peak and Coyote Mountains Wilderness Study Areas were conducted in 1986 and 1987. Samples from the Coyote Mountains were included in isotopic studies by Solomon and Taylor (1981) and Farmer and Depaolo (1984) . A regional paleomagnetic study (Cohen, 1981; Cohen and others, 1981) included Lower Jurassic strata in an area a few miles northwest of the Baboquivari Peak Wilderness Study Area. Some of the Tertiary base- and precious-metal fissure veins near the Baboquivari Peak Wilderness Study Area were studied by Tosdal (1981) and Tosdal and Briskey (1981). Kluth (1980) evaluated the "uranium favorability" of the Coyote Mountains (see also Reynolds, 1980). The Sierra de Pozo Verde in northernmost Sonora was mapped by Haxel in 1982 (Haxel and others, 1984, fig. 3). Regional geologic or tectonic overviews that include the Baboquivari Mountains chain are provided by Haxel and others (1980b, 1984), and Tosdal and others (1989).

Reconnaissance geochemical studies of the Baboquivari Peak and Coyote Mountains Wilderness Study Areas were undertaken in 1986 and 1987 (Adrian and others, 1987, 1988; Nowlan, 1988). Stream-sediment samples were collected within or down drainage from the wilderness study areas. Several samples of mineralized rock were collected from dumps and adits in the Coyote Mountains Wilderness Study Area. The samples were analyzed for as many as 32 elements by semiquantitative emission spectrography, atomic-absorption spectroscopy, neutron-activation analysis, and inductively coupled plasma spectroscopy. Analyses of water from springs and dug wells on and near the Tohono O'Odham Indian Reservation are tabulated by Ficklin and others (1978, 1980). Samples of unmineralized and unaltered granite from the Coyote Mountains were analyzed as part of a regional study of the geochemistry of early Tertiary peraluminous leucogranites (Haxel, 1987).

Both wilderness study areas are covered by regional gravity (Lysonski and others, 1980; Defense Mapping Agency Aerospace Center, 1974, 1975) and by aeromagnetic surveys at 1:250,000 scale (U.S. Geological Survey, 1980). The sparseness of gravity control limits definition of Bouguer gravity anomalies to wavelengths far longer than those useful for inferring sources at the scale of the study. However, the magnetic data points are sufficiently closely spaced to define sources of 1 mi^2 or larger. The abundance of radioelements in the Baboquivari Peak Wilderness Study Area was estimated from aerial gamma-ray spectrometric data (U.S. Department of Energy, 1978a, 1978b).

Mineral investigations of the Baboquivari Peak and Coyote Mountains Wilderness Study Areas by the U.S. Bureau of Mines were carried out in 1985 and 1986 (McDonnell, 1986; Lundby, 1987). The investigations included a review of literature concerning mineral resources and mining activity; field examination of mines, prospects, and mineral occurrences in and near the wilderness study areas; mapping and sampling of mines and prospects; and collection of stream-sediment samples. Information about mining claims, oil and gas leases, and land status was obtained from the U.S. Bureau of Land Management and from Pima County records. Minerals information and production data were obtained from U.S. Bureau of Mines files and other sources.

Acknowledgments

R.G. Eppinger performed the mineralogic examination of panned-concentrate samples. We thank the following ranchers and land owners for access to their property: Roger Adams (Santa Margarita Ranch), Ray Harm, Ross Humphreys, Donald Janson, John King (Anvil Ranch), and Robert Miller (Elkhorn Ranch).

APPRAISAL OF IDENTIFIED RESOURCES

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U.S. Bureau of Mines

Baboquivari Peak Wilderness Study Area

Mining History

The Baboquivari Peak Wilderness Study Area is within the Baboquivari mining district, which extends about 33 mi northward from Mexico and includes the Baboquivari Mountains. No mining activity has been recorded within the wilderness study area, but intermittent, generally small-scale mining and limited prospecting have occurred in the surrounding area (fig. 4). In 1985, U.S. Bureau of Land Management records showed two patented mining claims about 2.5 mi south of the wilderness study area and one unpatented claim less than 1 mi east of its northern tip. The establishment of the Tohono O'Odham Indian Reservation in 1955 closed the western part of the district to mineral entry under rules of the 1872 General Mining Law.

Mining in the Baboquivari district began in the late 1800's at the Allison and Jupiter mines (Nos. 4 and 7, fig. 4). Keith (1974, p. 14–17) summarized the geology and history of the district, and estimated a total production of 57,000 short tons (st) of ore containing about 14,000 troy oz gold, 173,000 troy oz silver, 122 st copper, 12 st lead, a small amount of zinc, 24 st of tungsten concentrates, and 200 long tons of manganese ore. A small amount of placer gold was also recovered.

Most of the nearby mining activity was either west to northwest or south to southwest of the wilderness study area; activity within 3.5 mi of the boundary is summarized in table 1 and figure 4. Two groups of tungsten deposits, one 9–12 mi northwest of the study area near San Juan Spring and the other 6–8 mi southwest of the study area near Chutum Vaya (fig. 1), are not shown but have contributed to the total production reported above.

Mineral Appraisal

No mineral deposits or occurrences were found within the Baboquivari Peak Wilderness Study Area as a result of U.S. Bureau of Mines investigations, although Cruver and others (1982) and Stipp and others (1967) reported a gold-silver occurrence near the center of the wilderness study area. U.S. Bureau of Mines personnel traversed the area, but could find no gold-silver occurrence. Two stream-sediment samples were collected outside the wilderness study area from drainages in upper Brown Canyon where the occurrence was thought to be located; one of the samples assayed 42 parts per billion (ppb) gold. The samples were also assayed for silver and tungsten but both samples had concentrations below the lower detection limits (silver, 0.7 parts per million (ppm); tungsten, 0.01 percent).

Gold, silver, molybdenum, copper, lead, manganese, tungsten, and zinc have been mined or prospected at several sites near the wilderness study area (fig. 4). The occurrences generally are in quartz and quartz-calcite veins associated with a rectilinear network of rhyolite dikes. The dikes typically strike northwest and northeast and were locally intruded along pre-existing faults (Haxel and others, 1980a). The complex dike network is generally bounded by northwest-striking faults (fig. 2). The dike network includes most of the nearby mineralized occurrences and extends through the wilderness study area. Keith (1974) noted a general zoning pattern of metals in the Baboquivari mining district. Tungsten deposits are found in the north and south parts of the district and deposits of precious and base metals and molybdenum are present in the central part. Because of the zoning pattern and abundance of northwest-trending faults and dikes in the central part, Keith (1974) suggested the possibility of a porphyry-type deposit along the northwest-striking structural trend, which crosses the wilderness study area.

Beryllium occurrences have been prospected in the Contreras Canyon area 1–2 mi east of the northern tip of the wilderness study area. The beryllium concentrations are in beryl-bearing, typically northwest-striking quartz veins and pegmatites in granite. Beryllium-enriched veins and dikes may therefore be present within the northwest-striking structures that pass through the Baboquivari Peak Wilderness Study Area.

No oil or gas discoveries are reported, and no Federal leases or lease applications have been filed in the Baboquivari Peak Wilderness Study Area. Ryder (1983) evaluated the petroleum potential of wilderness lands in Arizona on the basis of geologic framework and petroleum geology derived from published literature. The evaluation rated this wilderness study area among a group that has "zero" potential because any oil or gas accumulations would have been subject to migration or destruction due to later tectonic and magmatic activity.

No geothermal waters or leasing activity are known within the Baboquivari Peak Wilderness Study Area. A statewide inventory and evaluation of geothermal resources within Arizona (Witcher and others, 1982) showed no geothermal resources near the Baboquivari Peak Wilderness Study Area.

No uranium or thorium occurrences are known within the Baboquivari Peak Wilderness Study Area. A regional uranium resource evaluation by Luning and Brouilland (1981) rated the sedimentary and volcanic rocks in the area as being unfavorable for uranium occurrences because no reductant is present. The evaluation also rated the intrusive rocks as unfavorable because they are not anomalously uraniferous, although they showed some favorable characteristics.

If industrial minerals are present, they are of such limited quantities that they do not constitute a resource.

Coyote Mountains Wilderness Study Area

Mining History

Most of the mining activity within the wilderness study area has taken place in the Bonanza mine (Cavillo Camp) area (No. 1, fig. 5), at the head of the north fork of Mendoza Canyon. Twenty unpatented mining claims cover the workings of the Bonanza mine area. Published information indicates that the Bonanza mine produced about 700 short tons of ore averaging 10 percent copper, 0.03 troy oz gold/st, and 1.7 troy oz silver/st between 1909 and 1951 (Keith, 1974). Although no other production has been recorded, copper minerals are exposed along rock contacts and shear

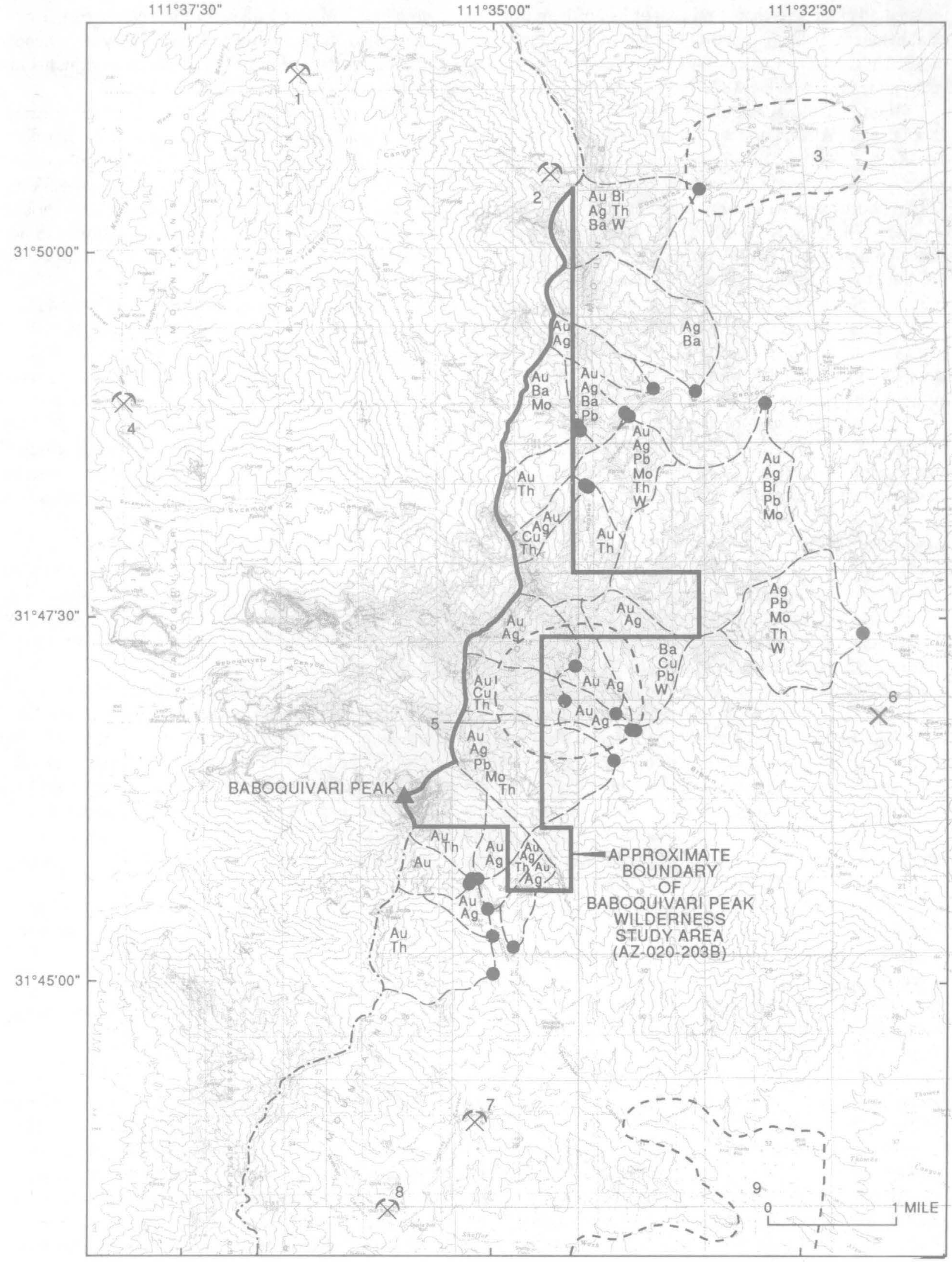

Figure 4. Location of mining and exploration activities, drainage basins, sampling sites, and elements present in anomalous concentrations in and near the Baboquivari Peak Wilderness Study Area, Pima County, Arizona.

zones in several nearby adits. In 1967, nine holes were diamond drilled for Consolidated Red Poplar Minerals Ltd. of Canada in the Bonanza mine area. Other previous mining activity includes several small prospect pits and an adit on the Tohono O'Odham Indian Reservation about 1 mi north of the Bonanza mine area (No. 4, fig. 5). Mining activity that has taken place within 3.5 mi of the wilderness study area is summarized in table 2 and on figure 5.

Mineral Appraisal

Copper and minor amounts of precious metals were mined in the Bonanza mine area. Surface cuts and underground workings were dug on contact metamorphic zones at the margins of dolomitic limestone and calcareous sandstone rocks that are probably roof pendants in early Tertiary Pan Tak Granite. Drilling records provide additional geologic information and subsurface assay data for correlation with the surface and underground workings. The copper occurrences are in the Devonian Martin Formation, a metamorphosed dolomitic limestone (Carrigan, 1971). Skarn zones, where the Martin Formation has been metasomatically altered to assemblages of epidote, garnet, and diopside, contain scheelite, copper minerals, and minor amounts of gold and silver. Copper minerals include hypogene chalcopyrite, bornite, covellite, and chalcocite in underground workings and supergene azurite, malachite, and chrysocolla near the ground surface (Carrigan, 1971). Mining or exploration took place at nine adits and declines and five prospect pits in the wilderness study area (fig. 2 of Lundby, 1987). Seventeen chip and dump samples for analysis were collected from the workings (figs. 5–7, table 2 of Lundby, 1987). One of the adits and four of the prospect pits were examined but not sampled because of lack of obvious mineral occurrences and alteration. Two samples each assayed 0.05 troy oz gold/st; the remainder of the samples assayed from nil to 0.01 troy oz gold/st. Silver assayed as much as 3.9 troy oz/st, with most of the assays below 0.7 troy oz/st. Copper assayed from 0.0166 percent to 7.2 percent, averaging about 2 percent in most of the samples. Tungsten content, which does not correlate with copper content, ranged from nil to 0.504 percent tungsten trioxide (WO_3), with 12 of the 17 samples assaying greater than 0.100 percent. The highest concentration of molybdenum was 0.0688 percent, with most of the assays averaging about 0.005 percent. Drill holes near the underground workings, however, contained considerably higher metal concentrations, with intercepts containing as much as 11.8 percent copper and 5.99 troy oz silver/st. Lundby (1987) estimated that there are inferred subeconomic resources of 66,500 short tons at a grade in excess of 5 percent copper, 1.5 troy oz silver/st, and 0.15 percent tungsten trioxide.

No oil or gas leases are recorded within 1 mi of the wilderness study area boundary and, according to Ryder (1983), the wilderness study area has no potential for oil and gas, because of the abundance of plutonic and gneissic rocks.

No geothermal waters or leasing activity are known within the Coyote Mountains Wilderness Study Area. The wilderness study area is unfavorable for the discovery and development of geothermal resources (Witcher and others, 1982).

Most of the study area is devoid of sand or gravel cover. Gravel for roadbuilding and similar uses is readily available outside of the wilderness study area. The sedimentary rocks in the wilderness study area are generally impure, metamorphosed limestones of limited quantity; thus no limestone resource is present.

EXPLANATION

4 Mine—See table 1 for description

6 Prospect—See table 1 for description

9 Mineralized area or reported mineral occurrence

Mines, prospects, and mineral occurrences

1 Black Dragon mine
2 Lost Horse(?) mine
3 Contreras Canyon area
4 Allison mine
5 Upper Brown Canyon area
6 Diablo prospect
7 Jupiter mine area
8 Gold Bullion mine
9 Edna J placer area

Drainage basin

Sampling site

Anomalous elements

Ag Silver
Au Gold
Ba Barium
Bi Bismuth
Cu Copper
Mo Molybdenum
Pb Lead
Th Thorium
W Tungsten

Figure 4. Continued.

Table 1. Mines, prospects, claims, and mineral occurrences in and near the Baboquivari Peak Wilderness Study Area, Pima County, Arizona

Map No. (fig. 4)	Name	Commodities	Geology	Workings and production	References
1	Black Dragon mine	Manganese	Discontinuous lenses, coatings, and fracture-fillings of manganese oxides in sheared and brecciated rhyolitic rocks.	Opencuts and pits; produced about 165 long tons of ore averaging 27.6 percent manganese and 19 tons of concentrate averaging 36.0 percent manganese.	Cruver and others, 1982, p. 56. Farnham and others, 1961, p. 117. Keith, 1974, p. 108. McDonnell, 1986, p. 6.
2	Lost Horse mine(?)	Molybdenum, gold, silver, copper(?)	Fracture filling in fault zone that cuts metasedimentary rocks.	About 200 ft of underground workings; no known production.	Johnson, 1972, p. 40. McDonnell, 1986, p. 6. Mining Journal, 1938.
3	Contreras Canyon area (includes Hop Sage, Shamrock, Windy, and Donna III claims)	Beryllium	Beryl-bearing quartz veins and pegmatites as thick as 3-ft in granitic rocks.	Shallow trenches and exploratory drilling; no known production.	Balla, 1982, p. 21–31. Clark, 1956, p. 10–21. McDonnell, 1986, p. 6. Meeves and others, 1966, p. 21.
4	Allison mine	Silver, gold, copper, lead, manganese	Mineralized quartz veins in shear zones in metasedimentary rocks and rhyolitic to andesitic flows and intrusions.	Several thousand feet of underground workings; mill ruins; produced an estimated 47,000 short tons of ore averaging 0.22 troy oz gold/ton, 2.7 troy oz silver/ton, and minor lead and copper.	Cruver and others, 1982, p. 56. Fair, 1965, p. 83. Keith, 1974, p. 107. McDonnell, 1986, p. 6. Wilson and others, 1934, p. 179–180. Worcester, 1931.
5	Upper Brown Canyon area	Gold(?), silver(?)	Sedimentary and silicic to intermediate volcanic rocks cut by network of rhyolite dikes.	Minor prospecting by past landowner along dike system; may be same as locality 98 listed by Cruver and others (1982, p. 64); field check by U.S. Bureau of Mines personnel in 1985 found no evidence of prospecting or production.	Cruver and others, 1982, p. 64. McDonnell, 1986, p. 6, 7.
6	Diablo prospect	Copper, molybdenum, gold, silver	Fracture zone in syenite; spatial association with andesite and rhyolite dikes.	Thirty-ft-deep shaft; no known production.	Donald, 1959, p. 34–40. McDonnell, 1986, p. 6.
7	Jupiter mine area (includes Iowana mine)	Gold, silver, lead, copper, zinc, tungsten	Discontinuous mineralized quartz-calcite in fissure veins cutting metasedimentary and granitic rocks and dioritic dikes.	Several thousand feet of underground workings; mill ruins; exploratory drilling for large-tonnage, low-grade open pit operation in 1974 yielded negative results; produced several hundred short tons of ore averaging 1 troy oz gold/ton, 16 troy oz silver/ton, and minor lead and copper.	Cruver and others, 1982, p. 45. Keith, 1974, p. 109. McDonnell, 1986, p. 6. Seaman, 1983, p. 51–52. Wilson and others, 1934, p. 181.
8	Gold Bullion mine	Gold, silver, molybdenum, copper, lead, tungsten, vanadium, zinc	Discontinuous mineralized quartz fissure veins and pegmatites as thick as 12 ft cutting metasedimentary and granitic rocks and rhyolite dikes.	Several hundred feet of underground workings; mill ruins; produced at least 3,100 tons of ore averaging about 1.0 troy oz gold/ton and 12 troy oz silver/ton; also produced several hundred short tons of high-grade molybedenum ore and minor amounts of copper, lead, tungsten, and vanadium.	Cruver and others, 1982, p. 57. Donald, 1959, p. 42–44. Joseph, 1915–1916, p. 7. Keith, 1974, p. 109. Kirkemo and others, 1965, p. E10–E11. McDonnell, 1986, p. 6. Seaman, 1983, p. 49–50. Wilson and others, 1934, p. 181.
9	Edna J placer area	Gold	Finely divided gold in a 6- to 11-ft-thick gravel bar.	Small intermittent placer operation; produced a few tens of ounces of gold.	Cruver and others, 1982, p. 45–46. Johnson, 1972, p. 39–40. Keith, 1974, p. 108. McDonnell, 1986, p. 6. Wilson, 1961, p. 81.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology

Geologic Framework of the Baboquivari Mountains

Although the Baboquivari Peak and Coyote Mountains Wilderness Study Areas have no major rock units in common, the geologic framework of both areas has been shaped by the same sequence of geologic episodes that characterizes the Baboquivari Mountains as a whole.

The oldest rocks exposed within the Baboquivari Mountains are Paleozoic metasedimentary rocks, restricted to a few small exposures in the Coyote Mountains. The oldest widespread lithostratigraphic unit in the Baboquivari Mountains comprises a thick sequence of Early Jurassic volcanic, subvolcanic or hypabyssal, and sedimentary rocks; this sequence is best preserved in the central Baboquivari Mountains. This supracrustal sequence is intruded by a Middle to Late Jurassic calc-alkaline granitoid suite and by a Late Jurassic weakly alkaline granite. The Baboquivari Mountains are a fenster (window) in the regional Late Cretaceous to early Tertiary Baboquivari thrust (Haxel and others, 1984). The thrust faulting caused regional metamorphism of supracrustal rocks during and after tectonic burial. These regionally metamorphosed rocks are exposed in the northern and southern Baboquivari Mountains. The later stages of Late Cretaceous to early Tertiary regional metamorphism were accompanied by intrusion of early Tertiary plutons of late- to post-kinematic peraluminous leucogranite, including the Pan Tak Granite in the Coyote Mountains. Middle Tertiary crustal extension formed low-angle normal faults and subjacent mylonitic shear zones at the ends of the Baboquivari Mountains—in the northern Coyote Mountains and in the Sierra de Pozo Verde (Davis, 1980; Gardulski, 1980; Wright and Haxel, 1982; Davis and others, 1987).

Geology of the Baboquivari Peak Wilderness Study Area

The Baboquivari Peak Wilderness Study Area is underlain by four major rock units: the Early Jurassic Pitoikam and Mulberry Wash Volcanic Formations, the Late Jurassic perthite granite of Baboquivari Peak, and the middle Tertiary rhyolite of Allison Camp (fig. 2; Haxel and others, 1980a). Lamprophyric dikes (not shown on fig. 2) constitute a fifth, minor unit.

The Pitoikam Formation (Jp, fig. 2) comprises three members (ascending): an unnamed lower member, the Contreras Conglomerate Member, and the Chiltepines Member. The lower member consists of nonresistant interbedded conglomerate, sandstone, and siltstone; it is bounded down-section by faults and intrusions; its substrate is not exposed. The lower member underlies only the northern tip of the wilderness study area. The Contreras Conglomerate Member comprises brown and red, resistant to nonresistant, thick-bedded to massive, pebble to boulder conglomerate and breccia, with interbeds of sandstone and siltstone similar to that of the Chiltepines Member. The Contreras Conglomerate Member underlies the northern one-fourth of the wilderness study area. The Chiltepines Member consists of brown, red, and gray, nonresistant siltstone, wacke, and subordinate shale; it contains interbeds of pebble conglomerate, most common in the lower part of the member, and uncommon interbeds of tan arenite. The upper part of the Chiltepines Member includes sparse intercalated volcanic rocks similar to those in the overlying Mulberry Wash Volcanic Formation. Clasts in conglomerates of the Pitoikam Formation are largely subangular to subrounded fragments of porphyritic to aphanitic, silicic to intermediate volcanic and hypabyssal rocks; rounded quartzite clasts are less common.

The Mulberry Wash Volcanic Formation (Jm, fig. 2) is comprised of volcanic flows and flow breccias, conglomerate, sedimentary breccia, volcanic sandstone, and subvolcanic intrusions. Red, gray, brown, purple, and pink colors, mostly dark, are typical. Most of the volcanic rocks are highly altered as a result of volcanism and some are incipiently metamorphosed. Relict phenocrysts and abundances and ratios of relatively immobile trace elements (G.B. Haxel, unpub data, 1983) indicate that most of the volcanic rocks are rhyolitic to dacitic, and that some are comendites (alkali rhyolites). The comenditic volcanic rocks have anorthoclase phenocrysts. In the southern part of the outcrop area, the Mulberry Wash Volcanic Formation includes rare flows of alkaline(?) basalt. Five lithologic and stratigraphic subunits of the Mulberry Wash Volcanic Formation were mapped by Haxel and others (1980a, 1982), but only two of these subunits crop out within the wilderness study area. Both of these subunits comprise dark-brown, purple, red, and gray dacitic and subordinate comenditic flows and flow breccias; and pebble to boulder volcanic conglomerate and subordinate sandstone and sedimentary breccia. These two subunits differ only in their proportions of volcanic and sedimentary rocks, grade vertically into one another, and are shown together in figure 2.

The Pitoikam and Mulberry Wash Volcanic Formations constitute the middle and upper parts of a volcanic and sedimentary sequence with a stratigraphic thickness of about 5 mi. The lower part of the sequence does not crop out within the wilderness study area. Uranium/lead zircon analyses determined for rhyolitic volcanic and hypabyssal rocks indicate that this sequence is Early Jurassic in age, and probably spans no more than 10 million years (Wright and others, 1981; Tosdal and others, 1989).

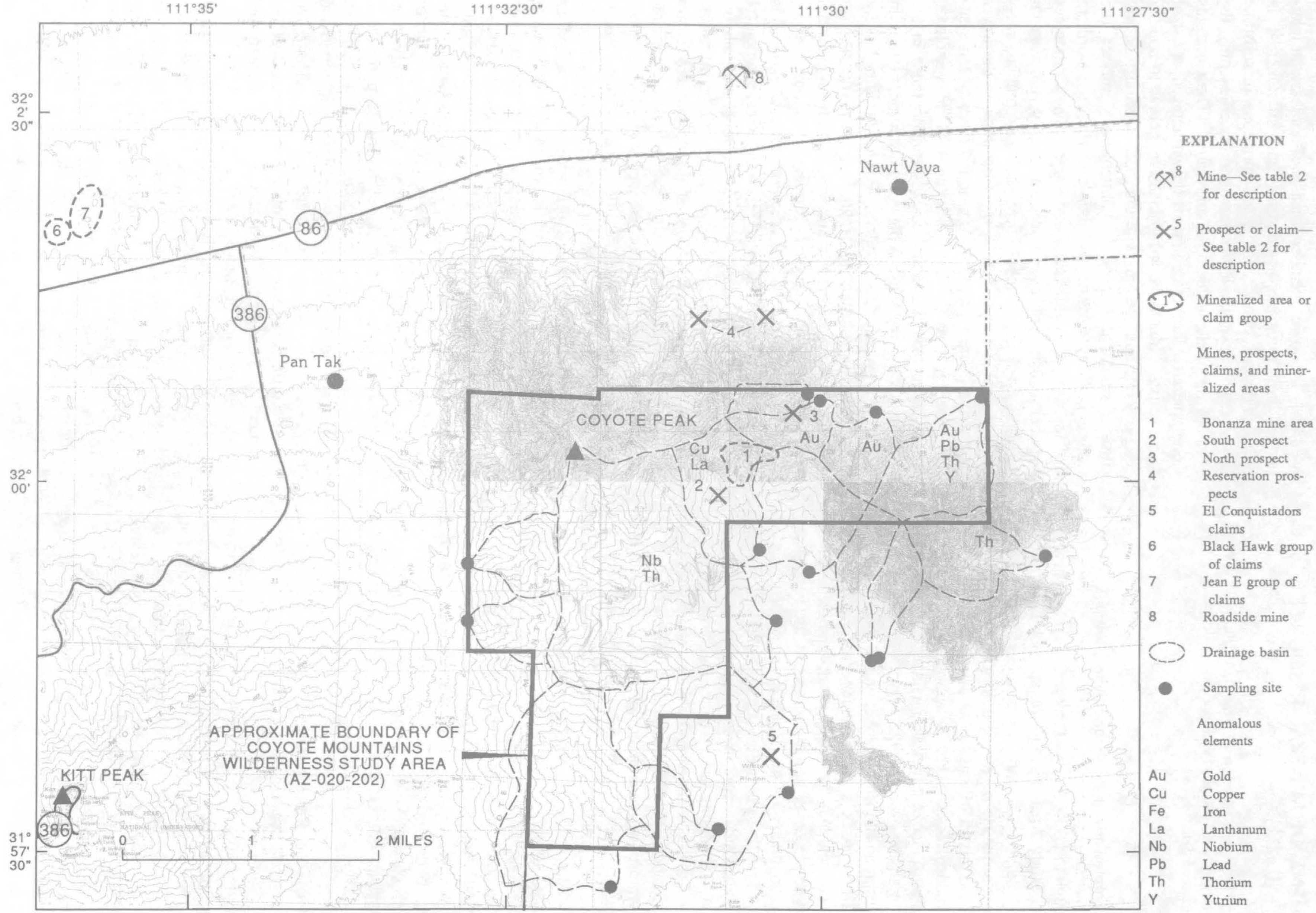

Figure 5. Location of mining and exploration activities, drainage basins, sampling sites, and elements present in anomalous concentrations in and near the Coyote Mountains Wilderness Study Area, Pima County, Arizona.

Table 2. Mines, prospects, and claims in and near the Coyote Mountains Wilderness Study Area

Map No. (fig. 5)	Name	Commodities	Geology	Workings and production	References
1	Bonanza mine area	Copper, silver, tungsten, molybdenum, zinc, gold	Contact-metamorphic deposits at margins of, and partially replacing, dolomitic limestone and calcareous sandstone blocks that are probably roof pendants in granite	Over 400 ft of underground workings; nine diamond drill holes; produced about 700 short tons of ore averaging 10 percent copper, 0.03 troy oz gold/st, and 1.7 troy oz silver/st.	Carrigan, 1971, p. 47–60. Cruver and others, 1982, p. 43–44. Keith, 1974, p. 116. Lundby, 1987, p. 6–17.
2	South prospect	Copper, silver	Skarn zone between calcareous rocks and granite.	A 35-ft-deep inclined shaft, a prospect pit, and two diamond drill holes; no known production.	Lundby, 1987, p. 17–19.
3	North prospect	Copper	Bedding-plane fault in altered metasedimentary rocks.	A 27-ft-long adit; no known production.	Lundby, 1987, p. 17–19.
4	Reservation prospects	Copper	Contact-metamorphic deposits granite-limestone contact.	Several small prospect pits and an adit; no known production.	Lundby, 1987, p. 19.
5	El Conquistadors claims	Uranium	Pegmatite in granite.	Surface workings; no production.	Cruver and others, 1982, p. 59. U.S. Atomic Energy Commission, 1970, p. 48.
6	Black Hawk group of claims	Manganese	Discontinuous narrow stringers and shattered zones containing manganese oxides; rhyolitic volcanic rocks.	At least 15 cuts and pits; produced about 46 long tons of sorted ore averaging 20 percent manganese.	Cruver and others, 1982, p. 51–52. Farnham and others, 1961, p. 116–117. Keith, 1974, p. 116.
7	Jean E group of claims	Manganese, copper, zinc	Fractures and shattered areas containing manganese oxides; rhyolitic volcanic rocks.	Several shafts and 12 or more pits and cuts; produced about 100 long tons of ore averaging about 8 percent manganese.	Cruver and others, 1982, p. 51. Farnham and others, 1961, p. 115–116. Keith, 1974, p. 116.
8	Roadside mine	Copper, silver, gold, mercury	Disseminations, streaks, and fracture fillings in shear zone cutting andesitic volcanic rocks and sandstone; aplitic or pegmatitic quartz monzonite at depth.	Shaft and diamond drilling; no reported production.	Cruver and others, 1982, p. 58. Keith, 1974, p. 117.

The Mulberry Wash Volcanic Formation is intruded by the perthite granite of Baboquivari Peak (Jb, fig. 2), which forms a small pluton exposed from the southwestern part of the wilderness study area west to the west edge of the Baboquivari Mountains. The unit consists of reddish-brown, coarse-grained, leucocratic, perthite granite and subordinate quartz perthite syenite (petrographic nomenclature of Streckeisen, 1976). Accessory minerals are biotite and amphibole (hornblende in some places and hastingsite in others), which commonly are strongly altered. Iron-oxide staining is pervasive. Interpretation of slightly discordant uranium/lead analyses of zircon suggests an age of approximately 147 Ma for these rocks (J.E. Wright, written commun., 1982).

The Pitoikam and Mulberry Wash Volcanic Formations and the perthite granite of Baboquivari Peak are intruded by dikes and stocks of the rhyolite of Allison Camp (Tac, fig. 2). Within and adjacent to the wilderness study area, this rhyolite forms a rectilinear network of northwest- and northeast-trending dikes. These dikes range from a few to 70 ft thick and as much as 4 mi long. A particularly prominent dike dominates the northwest-trending ridge between upper Brown and Thomas Canyons. This unit comprises yellowish-weathering, sparsely to strongly porphyritic rhyolite containing phenocrysts of quartz, alkali feldspar, and, in most rocks, plagioclase and (or) altered biotite; subordinate trachydacite dikes, without quartz phenocrysts, are less abundant but widespread (volcanic rock nomenclature of LeBas and others, 1986). Some dikes have flow banding along their margins. In a few places, for example, the west side of the central part of the wilderness study area, rhyolite dikes evidently were intruded along pre-existing faults. The dikes commonly contain hematite pseudomorphs after pyrite in the Jupiter Canyon area, south of the area shown on figure 2 (Seaman, 1983). Interpretation of potassium/argon ages and discordant uranium/lead zircon ages indicates that the ages of the rhyolite of Allison Camp and related volcanic rocks are 24±2 Ma (R.M. Tosdal, written commun., 1982; J.E. Wright, written commun., 1981).

Dikes and small irregular intrusions of nonresistant, typically dark-gray, mesocratic to locally melanocratic lamprophyre or, less commonly, microdiorite are widely scattered throughout most of the Baboquivari Mountains (unit not shown on fig. 2). Dikes are typically 3 to 16 ft thick. The few lamprophyric intrusions within the wilderness study area apparently have no preferred orientation and are too small and poorly exposed to map. In several outcrops, the lamprophyric intrusions are consistently and sharply intruded by dikes of the rhyolite of Allison Camp. One of the clearest and most accessible of these outcrops is located in upper Sabino Canyon, along the trail about 70 ft east of the wilderness study area. Although no isotopic ages have been determined directly for the lamprophyric intrusions in the Baboquivari Mountains, regional geologic relations (Riggs, 1985, 1987; G.B. Haxel, unpub. data, 1987) suggest that they are middle Tertiary in age and probably approximately the same age as the rhyolite of Allison Camp.

The geologic map (fig. 2) includes geologic map units that are outside the Baboquivari Peak Wilderness Study Area. The additional units are the Early Jurassic Ali Molina Formation, the Early Jurassic Chiuli Shaik Formation, the Early Jurassic rhyodacite porphyry of Tinaja Spring, the Middle Jurassic granodiorite of Kitt Peak, the Late Jurassic granite of Pavo Kug Wash, Tertiary conglomerate, Tertiary andesitic and dacitic flows and intrusions, Tertiary intrusions of hornblende granodiorite, and upper Tertiary and Quaternary gravel and alluvium. Descriptions of these units are modified from Haxel and others (1980a, 1982).

In the area of figure 2, the Early Jurassic Ali Molina Formation (Ja, fig. 2) consists of schistose metaconglomerate, quartzite, and metamorphosed rhyodacite flows, flow breccia, and welded tuff.

The Early Jurassic Chiuli Shaik Formation (Jcs, fig. 2) rests unconformably on the Early Jurassic Mulberry Wash Volcanic Formation. The unit is composed of rhyodacite tuff, andesite flows, volcanic breccia, conglomerate, sandstone, and rare limestone lenses.

The Early Jurassic rhyodacite porphyry of Tinaja Spring (Jt, fig. 2) is an intrusive porphyry with a fine-grained, crystalline groundmass containing phenocrysts of plagioclase, potassium feldspar, quartz, altered biotite, and magnetite. The unit is commonly silicified and iron oxide stained in the area represented by figure 2.

In the area of figure 2, the Middle Jurassic granodiorite of Kitt Peak (Jk, fig. 2) comprises medium- to coarse-grained hornblende-biotite and biotite granodiorite and subordinate monzogranite. It is uniformly porphyritic, with potassium feldspar phenocrysts 1–2 in. long. Sphene is locally present.

The Late Jurassic granite of Pavo Kug Wash (Jpk, fig. 2) is fine- to coarse-grained, equigranular, leucocratic, biotite monzogranite and syenogranite, typically containing conspicuous greasy-gray quartz. Quartz veins are locally common. The unit intrudes the granodiorite of Kitt Peak along mapped contacts and as north-northwest-trending dikes.

Unit Tc (fig. 2) consists mainly of pebble to boulder conglomerate unconformably overlying the Chiuli Shaik Formation. Clasts of the Late Jurassic perthite granite of Baboquivari Peak are locally abundant. Northwest of the corner of the area represented by figure 2, the unit includes conglomerate with subordinate sedimentary breccia and friable, thoroughly weathered basal conglomerate interpreted by Fair (1965, p. 29) to represent in situ weathering of underlying source rocks.

Unit Ta (fig. 2) includes andesitic and dacitic volcanic flows, flow breccia, tuff, dikes and other small intrusions, and intrusive breccia. Locally it rests nonconformably on the perthite granite of Baboquivari Peak.

Tertiary hornblende granodiorite (Tgd, fig. 2) consists of scattered small intrusions and unmapped dikes of fine- to medium-grained, equigranular to porphyritic hornblende and biotite-hornblende granodiorite and monzogranite. This rock type typically contains hornblende laths 0.1–0.2 in. long. In the area represented by figure 2, the intrusions are most common near Contreras and Sabino Canyons.

Unit QTg (fig. 2) includes unconsolidated and weakly consolidated gravel, sand, and minor silt along washes, on pediments, in alluvial fans, and forming low hills adjacent to the mountains.

The structure of the Baboquivari Peak Wilderness Study Area is relatively simple. Overall, the Pitoikam Formation and the overlying Mulberry Wash Volcanic Formation dip homoclinally westward. Dips range generally from 20° to 60° northwest to southwest. Channels and crossbeds in conglomerates and sandstones uniformly indicate units are younger to the west. Along the intrusive contact of the perthite granite of Baboquivari Peak with the Mulberry Wash Volcanic Formation, the granite is locally finer grained than elsewhere and the volcanic rocks are locally hornfelsic. Small dikes of granite in the volcanic rocks are rare. Three mapped high-angle faults, marked by gouge zones as much as 8 ft wide, are present in the wilderness study area. A small fault passes through the saddle northeast of Baboquivari Peak. A more important fault in Sycamore Canyon extends into, and dies out within, the central part of the study area. The northernmost tip of the study area lies within the Foothill Truck Trail fault zone. This major fault extends northwest-southeastward for about 12 mi within and along the west edge of the Baboquivari Mountains and separates the metamorphosed Early Jurassic supracrustal rocks of the higher Baboquivari Mountains from the largely unmetamorphosed Pitoikam Formation of the Fresnal Canyon area. The Foothill Truck Trail fault probably has had Tertiary movement although it probably originated in Early Jurassic time (G.B. Haxel and J.E. Wright, written commun., 1984).

Geology of the Coyote Mountains Wilderness Study Area

The Coyote Mountains (fig. 3) are a crudely triangular range bounded on the west by a middle or late Tertiary high-angle fault with the east side upthrown; on the north by a composite north-dipping fault (the Ajo Road fault) consisting of a middle Tertiary detachment fault modified by a younger high-angle normal fault, and on the southeast by Tertiary and Quaternary alluvium in Altar Valley.

The Coyote Mountains Wilderness Study Area is underlain by five major rock units: Paleozoic metasedimentary rocks, Middle Jurassic diorite of Nawt Vaya, Middle Jurassic granodiorite of Kitt Peak, Late Jurassic granite of Pavo Kug Wash, and the early Tertiary Pan Tak Granite (fig. 3; Haxel and others, 1980a; Wright and Haxel, 1982). Lamprophyre dikes, similar to those in the Baboquivari Peak Wilderness Study Area, constitute a sixth, minor unit (not shown on fig. 3). The Pan Tak Granite forms a small pluton, partially exposed in the northern and central Coyote Mountains, that intrudes the Paleozoic and Jurassic rocks. The Paleozoic rocks underlie a relatively small area and form thin "rafts" shallowly underlain by the Pan Tak Granite. These rafts are discontinuous remnants of a single body in the north-central part of the Pan Tak pluton.

The Paleozoic metasedimentary rocks comprise two map units: calc-silicate schist and quartzite (Pzc and Pzq, respectively, fig. 3). The calc-silicate schist unit contains calc-silicate schist and granofels, quartzofeldspathic schist, quartzite, and schistose marble; accessory minerals in the unit include diopside, garnet, wollastonite, hornblende, clinohumite, and phlogopite. Most of the quartzite unit is micaceous. The calc-silicate schist is locally altered to diopside or garnet skarn that contains minor idocrase. The quartzite is derived from the Cambrian Bolsa Quartzite and the calc-silicate unit from the Cambrian Abrigo Formation and Devonian Martin Formation (Carrigan, 1971).

The diorite of Nawt Vaya (Jn, fig. 3) comprises mesocratic, compositionally and texturally heterogeneous biotite-hornblende quartz diorite and tonalite, and subordinate hornblende-phenocrystic hornblende diorite and augite hornblendite. In contrast to the heterogeneity of these dioritic rocks, the granodiorite of Kitt Peak (Jk, fig. 3) is rather homogeneous throughout the Baboquivari Mountains. The granodiorite of Kitt Peak consists of medium- to coarse-grained, sphene-bearing hornblende-biotite granodiorite and subordinate monzogranite and quartz monzodiorite. Lenticular, fine-grained, biotite-rich monzodioritic enclaves are common. The unit commonly contains potassium feldspar phenocrysts. The granodiorite of Kitt Peak is intruded by the granite of Pavo Kug Wash (Jpk, fig. 3), coarse- to fine-grained, equigranular, texturally heterogeneous, leucocratic biotite monzogranite and syenogranite, typically containing greasy-gray quartz. In most of their extensive outcrop areas in the Quinlan Mountains and northern and central Baboquivari Mountains, these granitoids are unfoliated. In the Coyote Mountains and western Quinlan Mountains, where these granitoids were metamorphosed (see below), they commonly are foliated. In some places, the diorite of Nawt Vaya was converted to biotite-rich schist. The granodiorite of Kitt Peak and granite of Pavo Kug Wash yielded Middle to Late Jurassic concordant uranium/lead zircon ages (J.E. Wright, written commun., 1981). Field relations and petrologic data suggest that the diorite of Nawt Vaya forms the mafic end-member of a compositional series with the granodiorite and granite units; a Middle Jurassic age for this unit is therefore inferred. The petrology and regional relations of these Jurassic granitoids are discussed by Tosdal and others (1989).

The Pan Tak Granite (Tp, fig. 3) is a high-silica (73–77 weight percent silica), moderately alumina-rich (1 to 3 percent normative corundum) leucogranite characterized by various combinations of the accessory minerals biotite, muscovite, and garnet. In general, the granite consists of two intrusive phases that are intermixed on the scale of feet to hundreds of feet: an older phase of reddish-weathering, leucocratic, medium-grained granite and a younger phase of whitish-weathering, highly leucocratic (alaskitic), medium-grained to pegmatitic granite. Pegmatite in some places grades into and in other places intrudes the younger granite phase. Overall, the two phases appear nearly equal in abundance. Garnet typically is more common in the younger phase. Textural relations (in thin section) indicate that muscovite is a primary, magmatic mineral.

The geologic map (fig. 3) includes geologic map units in addition to the ones that underlie the wilderness study area. The additional units are Jurassic volcanic rocks, the Cretaceous(?) Sand Wells Formation, the Cretaceous Roskruge Volcanics, late Tertiary conglomerate, and late Tertiary and Quaternary gravel and alluvium.

Unit Jv (fig. 3) comprises volcanic rocks similar to rocks in the Baboquivari Mountains and has been assigned a Jurassic age (Wright and Haxel, 1982; Tosdal and others, 1989). The Cretaceous(?) Sand Wells Formation (Ks, fig. 3) is composed of sandstone, siltstone, conglomerate, mudstone, and volcanic breccias and flows of intermediate composition (Haxel and others, 1980b; Wright and Haxel, 1982). The Roskruge Volcanics (Kr, fig. 3) are made up of a series of brightly colored ash flows and volcanic breccias that are primarily quartz latite to rhyodacite in composition (Bikerman, 1967, 1968). Unit Tc (fig. 3) comprises consolidated or semiconsolidated conglomerates (Wright and Haxel, 1982) that in some cases have probably been offset by Tertiary faults. Unit QTg (fig. 3) includes unconsolidated and weakly consolidated gravel, sand, and minor silt along washes, on pediments, and in alluvial fans.

Contacts between the Pan Tak Granite and country rocks consistently are sharply intrusive. The granite is not migmatitic, neither in the sense of outcrop-scale injection or granitization of its country rocks, nor in the sense of origin by in situ anatexis of the country rock. The granite is conspicuously free of enclaves. In most areas of the Coyote Mountains, the country rocks of the Pan Tak Granite are intruded by swarms of pegmatite dikes. These dikes typically are 1 to 15 ft thick and dip gently east-southeastward. Pegmatite dikes are most abundant in the re-entrant on the southwest side of the pluton, and decrease in abundance southward away from the pluton and northward and northeastward into the center of the pluton. Rugged topography in the northwestern and central parts of the Pan Tak pluton is controlled by a prominent set of widely spaced, moderately east-northeast-dipping joints. The uranium/lead zircon crystallization age of the Pan Tak Granite is 58±2 Ma (Wright and Haxel, 1982).

Two metamorphic fabrics were imposed on the Pan Tak Granite and its country rocks. The older of these fabrics, defined by moderately west-southwest-dipping foliation and subordinate southwest-plunging lineation, is a regional metamorphic fabric broadly contemporaneous with the intrusion of the Pan Tak Granite (Wright and Haxel, 1982; Haxel and others, 1984). This fabric is widespread in the Jurassic granitoid rocks, ubiquitous in the Paleozoic calc-silicate schist, and fairly common in the older phase of the Pan Tak Granite. The younger phase of the granite generally crosscuts this fabric. On the northern slope of the Coyote Mountains, both phases of the Pan Tak Granite and many of the rafts or inclusions of quartzite or diorite in the granite are variably overprinted by a moderately north-northeast-dipping mylonitic foliation accompanied by a strong north-plunging lineation. This post-Pan Tak Granite fabric is penetrative in the northwestern Coyote Mountains. Elsewhere on the northern slope of the Coyote Mountains, the mylonitic fabric is variably and sporadically developed in tabular or lensoidal domains that decrease in size and abundance southward. The mylonitic fabric is essentially absent south of the ridge that trends east from Coyote Peak. Thus, the Tertiary mylonitic fabric is present only in the northwestern part of the Coyote Mountains Wilderness Study Area (fig. 3).

Geochemistry

Reconnaissance geochemical surveys of the Baboquivari Peak and Coyote Mountains Wilderness Study Areas were conducted in 1986. Samples of drainage sediment were collected at 10 sites near the Baboquivari Peak Wilderness Study Area (fig. 4) and at 15 sites near the Coyote Mountains Wilderness Study Area (fig. 5). In addition, nine samples of mineralized rock were sampled from dumps and adits at two sites in the Coyote Mountains Wilderness Study Area. Because many of the samples from near the Baboquivari Peak Wilderness Study Area contained anomalous concentrations of gold and silver, samples of drainage sediment were collected at 14 additional stream sites in 1987.

Stream-sediment samples and panned-concentrate samples derived from stream sediments were chosen as the routine sample media for this reconnaissance study because they represent a composite of material eroded from the drainage basin of the stream sampled. Both wilderness study areas occupy areas of high relief where streams locally are only incipiently developed. This is especially true of the Baboquivari Peak Wilderness Study Area, where all sampling sites are 300 ft to 1.3 mi outside its boundaries. Stream-sampling sites are located both inside the Coyote Mountains Wilderness Study Area and as much as 1.1 mi outside its boundaries.

Three samples were collected at each stream site. One of the samples was air dried and then sieved through a 30-mesh stainless-steel sieve. A 30-mesh sieve was used rather than the more conventional 80-mesh to lessen the possible dilution effects windblown material might have in this desert environment. The two additional samples each consisted of 20 lb of stream sediment that were panned until about 1.5 oz or less remained. One of these panned-concentrate samples was further concentrated by a series of steps involving heavy liquids and magnetic separations to produce a "nonmagnetic heavy-mineral concentrate." The other panned concentrate received no further treatment before chemical analysis for gold and was termed a "raw panned concentrate."

The minus-30-mesh stream-sediment samples and nonmagnetic heavy-mineral-concentrate samples were analyzed by emission spectrography for iron, magnesium, calcium, titanium, manganese, silver, arsenic, gold, boron, barium, beryllium, bismuth, cadmium, cobalt, chromium, copper, lanthanum, molybdenum, niobium, nickel, lead, antimony, scandium, tin, strontium, vanadium, tungsten, yttrium, zinc, zirconium, and thorium. In addition, the minus-30-mesh stream-sediment samples were analyzed for gold by atomic absorption, for arsenic, bismuth, cadmium, antimony, and zinc by inductively coupled plasma spectroscopy, for mercury by atomic absorption, and for uranium and thorium by delayed neutron-activation analysis. The raw panned-concentrate samples were analyzed for gold by atomic absorption. Tabulations of the analytical results, descriptions of methods of sample preparation, and descriptions and references for the analytical methods are given by Adrian and others (1987, 1988).

Geochemistry of the Baboquivari Peak Wilderness Study Area

Minus-30-mesh stream-sediment results were compared with results for 971 samples of minus-30-mesh stream sediment from the nearby Ajo 1° by 2° quadrangle

(Theobald and Barton, 1983). These comparisons revealed no anomalous minus-30-mesh stream-sediment samples near the Baboquivari Peak Wilderness Study Area except that silver and copper are each weakly anomalous in samples from three sites.

Results from nonmagnetic heavy-mineral concentrate samples were compared with results from 952 samples collected in the Ajo 1° by 2° quadrangle (Theobald and Barton, 1983). In contrast to the minus-30-mesh stream-sediment results, results from nonmagnetic heavy-mineral concentrate samples revealed striking gold-silver anomalies and also showed that anomalous concentrations of barium, bismuth, lead, molybdenum, thorium, and tungsten are present. Gold analyses of raw panned-concentrate samples confirmed the presence of a strong gold anomaly.

No detectable gold was measured in 952 samples of nonmagnetic heavy-mineral concentrate from the Ajo 1° by 2° quadrangle (Theobald and Barton, 1983, table 2). The lower limit of determination is 20 ppm. Twelve of the 24 samples from the study area contain detectable gold, ranging from 20 ppm (0.58 troy oz/st) to more than 1,000 ppm (29 troy oz/st). The median value for the 12 samples containing detectable gold is 250 ppm (7.3 troy oz/st).

Gold analyses of raw panned-concentrate samples have several advantages over gold analyses of nonmagnetic heavy-mineral-concentrate samples. They have the advantages of larger sample size and thus greater homogeneity; minimal sample preparation and thus fewer handling steps; and sensitivity that is less than crustal abundance (approximately 0.002 ppm) if the gold concentration of the raw panned-concentrate sample is converted to the concentration of the original stream sediment. The analytical method will detect as little as 0.05 ppm gold in a 10-gram sample. We consider concentrations of 0.3 ppm (0.009 troy oz/st) or greater to be anomalous; this is a conservative level and might be as low as 0.1 ppm (0.003 troy oz/st). Twenty of the 24 raw panned-concentrate samples contain anomalous concentrations of gold. The highest concentration of gold in any raw panned-concentrate sample from the study area is 52 ppm (1.5 troy oz/st), which converts to approximately 0.16 ppm gold (0.005 troy oz/st) in the original unpanned stream sediment.

The analyses of nonmagnetic heavy-mineral-concentrate samples show that gold and silver are present in equal amounts and that concentrations of the two metals vary sympathetically. Examination of the samples under microscope revealed no silver or probable silver-bearing minerals other than gold. Samples from all four of the major canyon systems draining the wilderness study area (Contreras, Sabino, Brown, and Thomas) contain anomalous amounts of gold and silver (fig. 4).

In addition to anomalous gold and silver, samples of nonmagnetic heavy-mineral concentrate from the study area have anomalous concentrations of barium, bismuth, lead, molybdenum, thorium, and tungsten (fig. 4). Barium is anomalous in about one-half of the samples. Bismuth is anomalous in one-sixth of the samples. Lead is anomalous in one-fourth of the samples. Molybdenum is anomalous in one-third of the samples and tungsten in one-half. One-half of the samples contain anomalous concentrations of thorium.

Geochemical patterns indicate that gold and silver concentrations are largely independent of the concentrations of the other anomalous elements. However, microscopic examination shows a correspondence between visible gold and pyrite. Thorium concentrations are independent of the other elements except that they tend to be negatively correlated with barium concentrations. Barium, bismuth, lead, molybdenum, and tungsten appear to be complexly interrelated.

Geochemistry of the Coyote Mountains Wilderness Study Area

Results were compared with results from the Ajo 1° by 2° quadrangle (Theobald and Barton, 1983), as described under Baboquivari Peak Wilderness Study Area results. Three raw panned-concentrate samples from the northeastern part of the Coyote Mountains Wilderness Study Area contain anomalous concentrations of gold (fig. 5); evidence of prospecting in this part of the study area is almost nonexistent. The nonmagnetic heavy-mineral concentrate samples from the easternmost of these three sample sites contains an anomalous concentration of lead. The minus-30-mesh stream-sediment sample collected about 0.8 mi downstream from the Bonanza mine area (fig. 5) contains anomalous concentrations of copper and lanthanum. Thorium concentrations are anomalous in several samples of stream sediment and nonmagnetic heavy-mineral concentrate. The average niobium concentration in nonmagnetic heavy-mineral-concentrate samples is about 55 ppm, which is higher than the less than 50 ppm average in the Ajo 1° by 2° quadrangle. The yttrium concentration is anomalous in one stream-sediment sample.

Geophysics

Aeromagnetics

The Baboquivari Peak and Coyote Mountains Wilderness Study Areas are covered by a single aeromagnetic survey (U.S. Geological Survey, 1980) having sufficient resolution to define anomalies about 1 mi^2 or larger. Total-intensity magnetic anomalies are defined by east-west traverses spaced about 1 mi apart at a nominal altitude of 4,000 ft above sea level but draped over higher topography.

The Baboquivari Peak Wilderness Study Area is transected by two prominent magnetic anomalies: a large-amplitude low in the center of the wilderness study area and a small-amplitude high in the southern part of the wilderness study area. The high is probably caused by dacitic to andesitic flows and flow breccias of the Mulberry Wash Volcanic Formation. The low is enigmatic: it is spatially associated with the perthite granite of Baboquivari Peak, but this granite is undoubtedly too deficient in magnetic minerals to be the source of a large-amplitude anomaly. One possible although unlikely explanation is that the low is the dipole effect of the volcanic rocks causing the high to the south. If so, the volcanic rocks must carry a strong total magnetization (average dipole moment per unit volume) having a post-tectonic direction upwardly and northwardly inclined—neither normal nor reversed but between these two polarities. Another, more likely, possibility is that the exposed granite is underlain by reversely magnetized, intermediate to mafic igneous rocks. The low is similar in character to a low associated with Tertiary basalt 6 mi west of the wilderness study area. Thus, the low in the Baboquivari Peak Wilderness Study Area may be caused by buried mafic subvolcanic rocks that perhaps fed andesitic or basaltic flows now eroded or displaced.

The Coyote Mountains Wilderness Study Area is characterized by low magnetic gradients forming flanks of two highs separated by a low. A broad high covering the northeastern part of the wilderness study area is associated with a variety of mapped rock units but is probably caused largely by the diorite of Nawt Vaya, which is inferred to be more extensive in the subsurface than at the surface. A small-amplitude high at the southern margin of the wilderness study area appears to be caused by a lobe of the granodiorite of Kitt Peak, which extends eastward from the main mass of the pluton. The main mass of the pluton is associated with a large-amplitude high. The intervening low, forming the southeastern nose of a feature centered over Jurassic volcanic rocks 4 mi northwest of the wilderness study area, has an unknown source. This low, covering the northwestern part of the wilderness study area, may be caused by reversely magnetized subvolcanic rocks extending in the subsurface southeastward from the terrane of volcanic rocks. A second possibility is that the low may be caused by either a decrease in magnetic mineral content or an increase in domain size of magnetic minerals in exposed felsic intrusive rocks. A third possibility is the existence of altered intermediate to mafic rocks in the subsurface.

Aerial Gamma-ray Spectrometry

Aerial gamma-ray spectrometry measures the near-surface (0 to 18 in.) distribution of the natural radioelements potassium (K), uranium (eU), and thorium (eTh). The "e" (for equivalent) prefix denotes the potential for disequilibrium in the uranium and thorium decay series. Because the distribution of these elements is controlled by geologic processes, aerial gamma-ray measurements can be used in geologic mapping, mineral exploration, and the understanding of geologic processes.

The spectrometry data used for this report were obtained between 1974 and 1981 for the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy. Flightline spacing was usually at 3- and 6-mi intervals, which yields data suitable for producing contour and other maps only at scales of 1:500,000 and smaller. All NURE flight altitudes were 400 ft above ground level, allowing the effective detection of terrestrial gamma radiation from a swath 800-ft wide along the flightline.

NURE data that include the Baboquivari and Coyote Mountains Wilderness Study Areas are presented on contour maps and color composite image maps (Duval, 1983) at scales of 1:500,000 and 1:1,000,000. Spectrometric data described below were derived from the NURE reports for the Nogales and Tucson 1° by 2° quadrangles (U.S. Department of Energy, 1978a,b).

The Baboquivari Peak Wilderness Study Area is characterized by radioelement concentrations of 2.0 to 2.5 percent K, 4 to 6 ppm eU, and 10 to 15 ppm eTh. These concentrations are determined from two NURE flightlines that cross the wilderness study area and provide sparse control for defining radioelement distribution for the area. These concentrations are reasonable (not anomalous) for the Mesozoic and Cenozoic crystalline rocks that are present in the wilderness study area. The sparse flightline coverage of the study area precludes deriving any direct information on mineral resource potential from the aerial gamma-ray data.

The Coyote Mountains Wilderness Study Area is characterized by radioelement concentrations of 2.3 to 2.7 percent K, 5 to 7 ppm eU, and 10 to 12 ppm eTh. These concentrations are determined from two NURE flightlines that cross the study area and provide sparse control for defining radioelement distribution. Within the study area, K concentrations are locally 2.7 to 3.0 percent east of Coyote Peak. These concentrations possibly reflect the presence of the Pan Tak Granite (Wright and Haxel, 1982) within the study area; whether they have any significance to copper, silver, and tungsten mineralization in the Coyote Mountains Wilderness Study Area (Lundby, 1987) is not known. A limited area of 8 to 9 ppm eU lies east and outside of the wilderness study area, north of 32° latitude. This occurrence is in the area of the Ajo Road detachment fault (Wright and Haxel, 1982, fig. 2) and could be the "anomaly" mentioned in a report on uranium favorability of metamorphic core complexes; this report concludes that "...the Coyote Mountains probably have very low favorability for uranium occurrence..." (Kluth, 1980, p. 595). For the Coyote Mountains Wilderness Study Area, the radioelement concentrations are reasonable (not anomalous) for the Mesozoic and Cenozoic crystalline rocks that are present in the wilderness study area. The sparse flightline coverage of the wilderness study area precludes deriving any direct information on mineral resource potential from the aerial gamma-ray data.

Mineral Resource Potential of the Baboquivari Peak Wilderness Study Area

No known mineral deposits or occurrences are within the Baboquivari Peak Wilderness Study Area. However, the study area lies within the Baboquivari mining district, which has produced gold, silver, copper, lead, zinc, manganese, tungsten, and molybdenum from polymetallic veins that are spatially associated with high-angle faults and Tertiary felsic-to-intermediate dikes. Most of the vein deposits are small, but a major past producer is 3 mi west of the wilderness study area. Small amounts of placer gold have been recovered within 3 mi. Small amounts of beryl and bismuth are present in scattered simple pegmatite/quartz veins that are within 2 mi of the wilderness study area. High concentrations of gold and silver in stream-sediment and panned-concentrate samples and visible gold in panned-concentrate samples from streams in the study area are nearly ubiquitous. The source of these high amounts of gold and silver may be polymetallic veins similar to those nearby or the precious metals may be from types of deposits not known in the area but for which there is permissive evidence as discussed below.

Polymetallic Vein Deposits

The entire Baboquivari Peak Wilderness Study Area has high potential, certainty level C, for resources of gold, silver, copper, lead, zinc, barium, bismuth, manganese, molybdenum, or tungsten in polymetallic veins. Favorable criteria for polymetallic vein deposits listed by Cox (1986) are present in and within about 3 mi of the wilderness study area. Nearby mineral deposits interpreted to be polymetallic vein deposits include the Allison mine, the Black Dragon mine, the Diablo prospect, the Gold Bullion mine, the Jupiter and Iowana mines, and the Lost Horse mine(?) (table 1 and fig. 4).

In a study of geology and ore potential near the Jupiter mine (fig. 4), Seaman (1983) suggested that the base- and precious-metal mineralization probably preceded the intrusion of the rhyolite dikes. Evidence for the suggestion is the pervasive phyllic and propylitic alteration in the area around the Jupiter mine that presumably accompanied mineralization but is found only in pre-Tertiary rocks. However, the spatial association of mineralized rocks and dikes suggests that Tertiary mineralization cannot be ruled out. If the nearby mineral deposits formed in the Mesozoic, favorable criteria for polymetallic veins include known vein deposits, extensive faulting, brecciation, presence of at least one small granitic intrusion (Seaman, 1983, p. 28), and strong geochemical anomalies for gold, silver, barium, bismuth, lead, molybdenum, and tungsten in panned-concentrate samples derived from stream sediment. If the nearby mineral deposits formed in the Cenozoic, favorable criteria, in addition to the above, include an association with Tertiary rhyolite dikes and the intrusion of those dikes into sedimentary and metamorphic terrain. Although mineralized rocks have not been definitively recognized within the wilderness study area, bedrock geology and favorable structures spatially associated with nearby mineral deposits extend into the wilderness study area.

Beryllium- Bismuth- and Thorium-Bearing Pegmatites

The northern part of the Baboquivari Peak Wilderness Study Area has low potential, certainty level B, for beryllium and bismuth resources in pegmatites or quartz veins and the entire wilderness study area has low potential, certainty level B, for thorium deposits in pegmatites. Beryl and the bismuth minerals, bismuthinite, bismutite, and native bismuth are found in pegmatites 1–2 mi northeast of the wilderness study area (Clark, 1956, p. 19); anomalous bismuth concentrations in some panned-concentrate samples from the middle to northern part of the study area suggest that similar pegmatites may be present there. Anomalous thorium concentrations in panned-concentrate samples from throughout the study area may be evidence of pegmatites throughout the entire wilderness study area.

Paleoplacer Gold-Silver Deposits

The entire Baboquivari Peak Wilderness Study Area has low potential, certainty level B, for resources of gold and silver in placers in the Early Jurassic Pitoikam Formation and Mulberry Wash Volcanic Formation. The lack of correlation between gold-silver concentrations and concentrations of barium, bismuth, molybdenum, lead, and tungsten in samples from streams in the study area suggests that the source of the gold and silver may be different than that of the other five metals. Consistent gold-silver ratios argue that a single mineralizing event accounts for the precious metals. The existence of paleoplacer gold-silver deposits is presented here as one of two permissive, but speculative, mineral-deposit models that might explain the anomalous gold and silver.

Samples containing anomalous concentrations of gold and silver are not limited to any general part of the sampled area. Therefore, if mineralization is limited to a particular rock unit, that unit must be widespread. In addition to the network of dikes formed by the middle Tertiary rhyolite of Allison Camp, the unit common to most of the sampled area is the Early Jurassic Pitoikam Formation, which is comprised of conglomerate, sandstone, siltstone, and minor mudstone or shale (Haxel and others, 1980a). The uppermost part of the formation includes volcanic conglomerate and dacitic flows. Overlying the Pitoikam Formation within the sampled area is the Early Jurassic Mulberry Wash Volcanic Formation (Haxel and others, 1980a). Subunits of the Mulberry Wash Volcanic Formation within the wilderness study area are composed of volcanic debris and dacitic (or andesitic) flows, flow breccia, and dikes.

Nearby subunits of the Mulberry Wash Volcanic Formation, not exposed in the sampled area, are composed of rhyodacite, latite, and andesite flows and rhyodacite volcanic conglomerate. The geologic setting is one of volcanic activity that could have been accompanied by precious-metal mineralization with subsequent formation of precious-metal placer deposits that are now being eroded and carried into present-day streams. The separation of gold-silver from the other anomalous elements in the sampled area could result from this recycling of gold and silver.

Gold-Silver Deposits Associated with an Inferred Porphyry Molybdenum Deposit

The entire Baboquivari Peak Wilderness Study Area has low potential, certainty level B, for gold and silver resources as veins or disseminated deposits in the outer halo of an inferred molybdenum deposit. The southern part of the wilderness study area has low potential, certainty level B, for molybdenum resources in that inferred porphyry molybdenum deposit. This mineral-deposit model is the other permissive, but speculative, model presented here as a possible explanation for anomalous gold and silver in samples from streams of the study area. This model is closely related to the model for polymetallic vein deposits discussed earlier but differs in that the veins or disseminated deposits are inferred to be part of a porphyry system, especially the outer part of a porphyry system. Therefore, the following will discuss evidence for the presence of a porphyry molybdenum deposit near the wilderness study area even though primary emphasis is on the potential for gold-silver deposits.

Gold is not characteristically associated with Climax-type porphyry molybdenum deposits (Ludington, 1986) and the Climax-type model will not be considered here even though favorable criteria are present near the wilderness study area. The presence of a porphyry copper deposit cannot be completely excluded, either, because many of the characteristics of a porphyry copper system are the same as for a low-fluorine porphyry molybdenum system. However, the Baboquivari Mountains lie within what has been termed southern Papago terrane (Haxel and others, 1984), which is outside of the southern Arizona porphyry-copper province (Schmitt, 1966; Titley, 1982) and lacks many of the geologic characteristics of the porphyry-copper province.

The presence of a porphyry molybdenum deposit near Jupiter Canyon, about 2 mi south of the Baboquivari Peak Wilderness Study Area, was suggested by Seaman (1983). This suggestion was based on the existence of pervasive phyllic and propylitic alteration in bedrock, the presence of felsic intrusive rocks, and anomalous molybdenum, tungsten, and fluorine concentrations in samples from adits, dumps, and pits (Seaman, 1983, p. 5). Samples of water from springs and shallow wells 3 to 5 mi southwest of Jupiter Canyon contain highly anomalous concentrations of molybdenum (Ficklin and others, 1978, 1980). A hole drilled to about 500 ft in Jupiter Canyon in the Early Jurassic rhyodacite porphyry of Tinaja Spring (fig. 2) penetrated only propylitic and phyllic alteration (Seaman, 1983, p. 39–43, 84); thus if a porphyry molybdenum deposit exists, it is probably 1,500–3,000 ft below the surface (Seaman, 1983, p. 84–86) and (or) laterally displaced from Jupiter Canyon.

Favorable criteria for low-fluorine porphyry molybdenum deposits (Theodore, 1986) in the study area include pervasive propylitic and phyllic alteration in the Jupiter mine area (No. 7, fig. 4), presence of felsic intrusive rocks, Mesozoic or Tertiary age of mineralization, numerous faults, strong geochemical anomalies for gold, silver, barium, bismuth, lead, molybdenum, or tungsten in panned-concentrate samples, tungsten in the form of scheelite in panned-concentrate samples from streams draining the wilderness study area, and presence of polymetallic vein deposits of gold, silver, copper, lead, zinc, and manganese in the Jupiter Canyon area.

Although speculative, this model of gold-silver deposits associated with an inferred porphyry-molybdenum system warrants consideration.

Other Commodities

The Baboquivari Peak Wilderness Study Area has low potential, certainty level C, for resources of oil, gas, geothermal energy, and industrial minerals for the reasons presented in the section "Mineral appraisal of the Baboquivari Peak Wilderness Study Area."

Mineral Resource Potential of the Coyote Mountains Wilderness Study Area

The Coyote Mountains Wilderness Study Area lies within the Coyote mining district. Most of the production of the district came from the Bonanza mine (No. 1, fig. 5), which is located within the wilderness study area. Production from the Bonanza mine area was from small copper skarn and polymetallic replacement deposits. A uranium-bearing pegmatite is near the wilderness study area and simple pegmatites are common throughout the wilderness study area. In the northeastern part of the wilderness study area there is permissive evidence (discussed below) for gold deposits associated with a detachment fault.

Copper Skarn and Polymetallic Replacement Deposits

An area of the Coyote Mountains Wilderness Study Area underlain by Paleozoic metasedimentary rocks has high potential, certainty level C, for resources of copper, tungsten, gold, silver, molybdenum, and zinc in skarn and polymetallic replacement deposits. Favorable criteria for copper skarn (Cox and Theodore, 1986) and polymetallic replacement deposits (Morris, 1986) within the wilderness study area include an intrusive contact between granitic rocks and calcareous or carbonate-bearing rocks, altered and mineralized rocks at the contact, an association between copper-bearing skarn and polymetallic replacement deposits, and anomalous concentrations of gold in panned-concentrate samples from streams draining areas peripheral to the central, copper-dominated mineralized area.

In addition to copper, tungsten, gold, and silver, minor amounts of zinc and molybdenum were produced from the Bonanza mine area. Mineralized and altered samples from adits, dumps, and prospects in the Bonanza mine area contain concentrations of 1,000 ppm or greater of barium, silver, and zinc (Adrian and others, 1987; Lundby, 1987). Some samples contain greater than 20,000 ppm copper or greater than 10,000 ppm tungsten and as much as 150 ppm tin. Mineralization resulted from the intrusion of the early Tertiary Pan Tak Granite into Paleozoic metasedimentary rocks. Mineralized zones are present along the contact between the intrusion and metasedimentary rocks or as replacements in limestone (Carrigan, 1971). Most of the production came from replacement zones associated with skarn; in some cases, specific limestone beds were replaced without the development of skarn. Despite high concentrations of copper and tungsten in mineralized rock samples, the copper concentration is anomalous in only one drainage sample from the study area—a stream sediment downstream from the Bonanza mine area; no drainage samples contain anomalous concentrations of tungsten (fig. 5).

Skarn minerals in the Bonanza mine area include epidote, garnet, diopside, and magnetite (Carrigan, 1971, p. 47–60). Altered and mineralized zones are confined to the metasedimentary rocks except for minor zones of argillic and sericitic alteration and oxide copper in the granite where the granite is in contact with skarn. Because copper is the predominant metal in the skarn, it is classified as a copper skarn (Einaudi and others, 1981, p. 320, 330).

Mineralized Pegmatites

The entire Coyote Mountains Wilderness Study Area has low potential, certainty level B, for resources of thorium, niobium, uranium, lanthanum, and yttrium in pegmatites. Favorable criteria include abundance of pegmatites, anomalous concentrations of thorium, niobium, yttrium, and lanthanum in drainage samples, and occurrence of a mineralized pegmatite less than 1/2 mi southeast of the wilderness study area.

Elements often associated with late granitic differentiates tend to be present in anomalous or above-average concentrations in stream-sediment or panned-concentrate samples from streams in the study area (fig. 5). No complex pegmatites have been recognized within the wilderness study area. However, anomalous concentrations of thorium, niobium, yttrium, and lanthanum in samples of drainage sediment and the occurrence of uranium in a pegmatite southeast of the wilderness study area (No. 5, fig. 5, and table 2) suggest that complex pegmatites could be present.

Gold Deposits Associated with Detachment Faults

The northeastern part of the Coyote Mountains Wilderness Study Area has moderate potential, certainty level B, for gold resources in deposits associated with the Ajo Road detachment fault. Panned-concentrate samples from the northeastern part of the wilderness study area contain anomalous concentrations of gold. The gold anomaly is mild compared to the Baboquivari Peak area, but proximity to the Ajo Road detachment fault gives added significance to the anomaly and suggests that the detachment-fault model (Spencer and Welty, 1986) may be applicable. The following discussion attempts to show that the geologic setting is favorable for the formation of detachment-fault-related mineral deposits and that known deposits near the detachment fault may indeed be related to the fault.

Favorable criteria for the detachment-fault model include anomalous concentrations of gold in panned-concentrate samples, existence of manganese deposits in the upper plate of the Ajo Road detachment fault 3 mi northwest of the wilderness study area, and occurrence of base and precious metals in the upper plate 2.5 mi north of the wilderness study area.

Some base- and precious-metal mineral deposits are associated with detachment faults in western Arizona and southeastern California (Spencer and Welty, 1986). These deposits are characterized by early copper and iron sulfides, later specular hematite and manganese oxides, and still later chrysocolla and malachite. According to the model, redox gradients with depth along the detachment fault can result in the separation of oxides of manganese from oxides of iron. Also, the interface between reduced and oxidized fluids moves as movement takes place along the fault and can result in the deposition of both reduced and oxidized forms of copper, iron, and probably other metals in the same deposit. Mineralization associated with the Ajo Road detachment fault may be represented by known copper, silver, gold, mercury, and manganese mineralization in fault zones in the upper plate. At the Roadside mine (No. 8, fig. 5) native copper, copper carbonates and oxides, sparse copper sulfides, tetrahedrite, mercurian tetrahedrite, cinnabar, and native mercury are present in a fault zone in volcanic and sedimentary rocks as disseminations, streaks, and fracture fillings (Keith, 1974, p. 117). Information on the Roadside mine is sparse, but perhaps what has been interpreted as deep (800 ft) oxidation in the mine actually represents primary deposition of oxidized forms of copper. If so, the Roadside mine fits the detachment-fault model where oxidized and reduced forms of copper are deposited at the same place but at different times. At the Black Hawk and Jean E localities (Nos. 6 and 7, fig. 5), manganese oxides fill fractures in high-angle fault zones in volcanic rocks (Farnham and others, 1961, p. 115–116; Keith, 1974, p. 116). These deposits of manganese oxides fit the detachment-fault model of separation of manganese oxides from iron oxides.

Other Commodities

The Coyote Mountains Wilderness Study Area has low potential, certainty level C, for resources of oil, gas, geothermal energy, and industrial minerals for the reasons presented under "Mineral Appraisal of the Coyote Mountains Wilderness Study Area."

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

H **HIGH** mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data support mineral-deposit models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.

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

L **LOW** mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics define a geologic environment in which the existence of resources is permissive. This broad category embraces areas with dispersed but insignificantly mineralized rock, as well as areas with little or no indication of having been mineralized.

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

U **UNKNOWN** mineral resource potential is assigned to areas where information is inadequate to assign a low, moderate, or high level of resource potential.

LEVELS OF CERTAINTY

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

B Available information only suggests the level of mineral resource potential.

C Available information gives a good indication of the level of mineral resource potential.

D Available information clearly defines the level of mineral resource potential.

A	B	C	D
U/A	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
UNKNOWN POTENTIAL	M/B MODERATE POTENTIAL	M/C MODERATE POTENTIAL	M/D MODERATE POTENTIAL
	L/B LOW POTENTIAL	L/C LOW POTENTIAL	L/D LOW POTENTIAL
			N/D NO POTENTIAL

LEVEL OF RESOURCE POTENTIAL →

LEVEL OF CERTAINTY →

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RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from McKelvey, V.E., 1972, Mineral resource estimates and public policy: American Scientist, v. 60, p. 32-40; and U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

Terms and boundary ages used by the U.S. Geological Survey in this report

EON	ERA	PERIOD		EPOCH	AGE ESTIMATES OF BOUNDARIES IN MILLION YEARS (Ma)
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	[1]~570
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				(3800?)
pre-Archean[2]					4550

[1]Rocks older than 570 Ma also called Precambrian, a time term without specific rank.
[2]Informal time term without specific rank.

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March 3, 1849

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