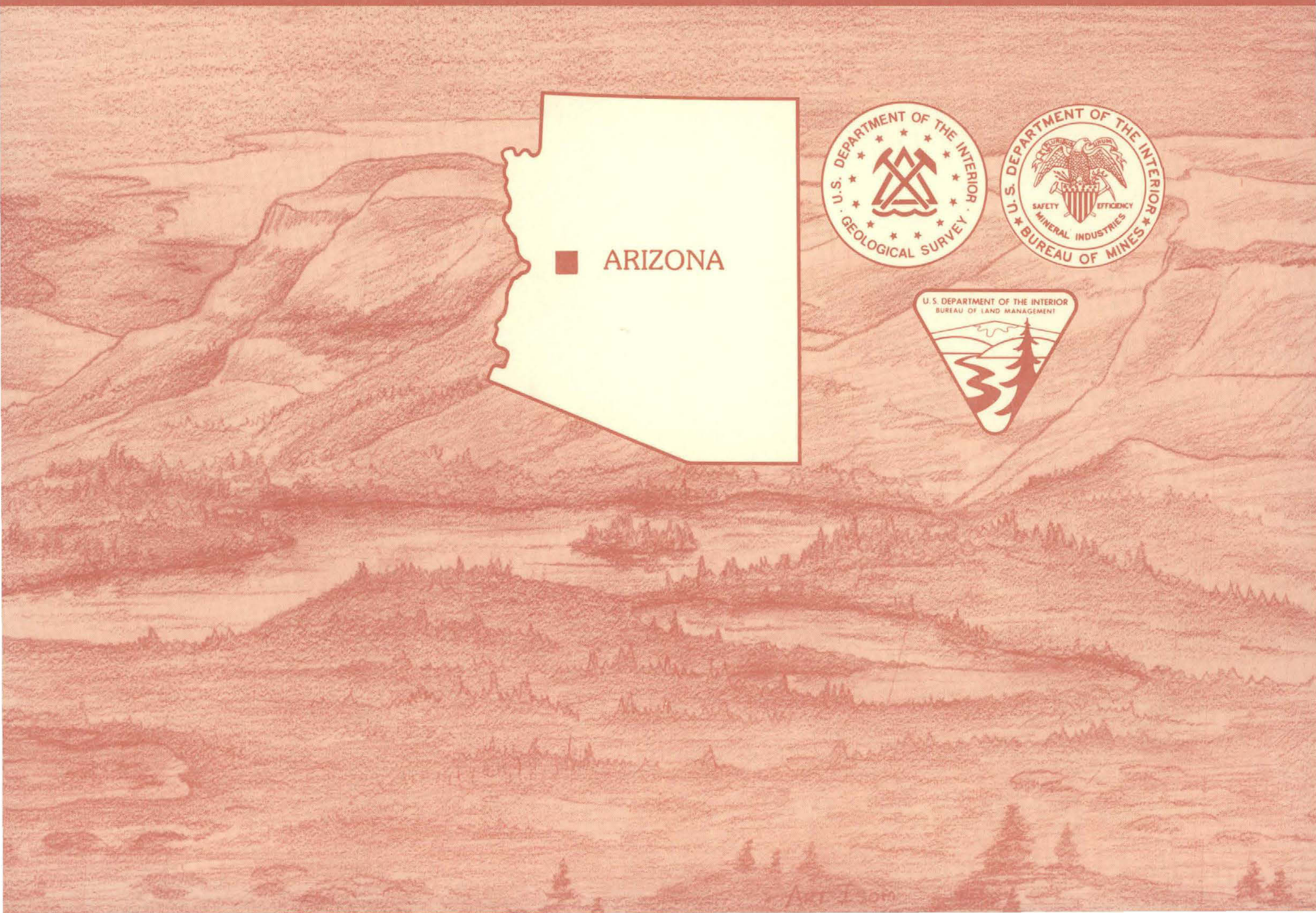
Mineral Resources of the Rawhide Mountains Wilderness Study Area, La Paz and Mohave Counties, Arizona

U.S. GEOLOGICAL SURVEY BULLETIN 1701-G



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Chapter G

Mineral Resources of the Rawhide Mountains Wilderness Study Area, La Paz and Mohave Counties, Arizona

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U.S. GEOLOGICAL SURVEY BULLETIN 1701

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
WEST-CENTRAL ARIZONA

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study 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 of certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and submitted to the President and the Congress. This report presents the results of a mineral survey of part of the Rawhide Mountains Wilderness Study Area (AZ–020–058A), La Paz and Mohave Counties, Arizona.

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Mineral Resources of the Rawhide Mountains Wilderness Study Area, La Paz and Mohave Counties, Arizona

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SUMMARY

Abstract

The Rawhide Mountains Wilderness Study area (AZ-020-058A) lies in the Rawhide Mountains and eastern Buckskin Mountains, west-central Arizona, some 40 mi east of Parker, Ariz. At the request of the U.S. Bureau of Land Management, mineral surveys of approximately 40,025 acres were done by the U.S. Geological Survey and U.S. Bureau of Mines to assess the mineral resources (known) and mineral resource potential (undiscovered) of the area. In this report, the study area refers to only that part of the wilderness study area for which a mineral survey was requested by the U.S. Bureau of Land Management.

Mining and prospecting activity has occurred in, or adjacent to, the Rawhide Mountains Wilderness Study Area in the northwest at the Big Kimble mine area, in the north-central part of the study area, in the area immediately west of Alamo Lake on the east side of the study area, in the Alamo and Lincoln Ranch mineral districts in the west-central part of the area, and in the southern part of the study area. In most areas, gold, silver, and copper occur in mylonitic gneiss and schist along northwest-striking high-angle faults or along the Buckskin-Rawhide detachment fault and its subsidiary high- and low-angle normal faults. Inferred gold, silver, and copper resources in these areas are subeconomic. Copper prospects in Tertiary conglomerates and mudstones west of Alamo Lake contain zones of hematite and thin seams of chrysocolla and malachite along shear zones related to the Buckskin-Rawhide detachment fault. Manganese occurs in Tertiary conglomerates along the southwest border of the study area on the fringe of the Lincoln Ranch mineral district. The deposits in both areas are too thin and too low grade to be economic.

The mineral resource potential for precious and base metals (gold, silver, copper) is moderate and locally high in several areas. These areas are structurally controlled by northwest-striking high-angle faults in the western and south-western parts of the study area, by high- and low-angle faults in the lower-plate terrane north of and immediately south of the Bill Williams River in the center of the study area, and by the Buckskin-Rawhide detachment fault and its upper-plate faults on the north-central and northwest parts of the area. A low mineral resource potential for precious and base metals is assigned to the southern part of the study area. Areas of moderate potential for manganese and low potential for uranium and vanadium resources occur in the limited Tertiary sedimentary and volcanic rocks in the northwestern, north-eastern, southwestern, and east-central parts of the study area. There is low potential for low-temperature geothermal water in the northeasternmost part of the study area. The entire Rawhide Mountains Wilderness Study Area has low resource potential for sand and gravel in the sparse alluvial deposits and low resource potential for oil and gas.

Manuscript approved for publication, October 16, 1989.

Character and Setting

The Rawhide Mountains Wilderness Study area (AZ-020-058A) covers approximately 40,025 acres in west-central Arizona, (fig. 1) some 40 mi east of Parker, Ariz. The study area lies astride the Bill Williams River, which divides the Rawhide Mountains on the north from the Buckskin Mountains on the south. Elevations in the study area range from about 800 ft along the Bill Williams River to 3,927 ft at the Buckskin benchmark, at the crest of the Buckskin Mountains.

The study area lies in the northwest-trending belt of metamorphic core complexes in west-central Arizona. (Rehrig and Reynolds, 1980). In these complexes, mid-crustal and deeper rocks were tectonically transported to the surface along shallow-dipping normal faults or detachment faults during a period of extensional tectonism in the late Oligocene and Miocene (Davis and others, 1980; Spencer and Reynolds, 1986a; Davis, 1988) (see "Appendixes" for geologic time chart). The Buckskin-Rawhide detachment fault of Spencer and Reynolds (1986b) crops out discontinuously along the west, north, and east borders of the study area (fig. 2). The detachment fault divides the bedrock geology of the area into two parts: an extended upper plate of Proterozoic, Paleozoic, Mesozoic, and Tertiary metamorphic, igneous, and sedimentary rocks, and a lower plate of Tertiary plutons and mylonite and mylonitic gneiss that were derived from Proterozoic, Paleozoic, Mesozoic, and Tertiary metamorphic, igneous, and sedimentary protoliths. Mylonitic deformation in the lower plate is considered to be a deeper level expression of, and slightly older than, brittle extensional faulting along the detachment fault and its upper plate (Davis, 1983; Spencer and Reynolds, 1986a; Howard and John, 1987; Davis and Lister, 1988). Syntectonic sedimentation and volcanism accompanied extension, and these rocks now crop out in the highly faulted upper-plate terrane (Davis and others, 1980; Otton, 1982; Spencer and Reynolds, 1986b).

During the last stages or after the end of the extensional deformation, high-angle faults cut the detachment terrane. The Lincoln Ranch reverse fault is the largest of these faults in the study area.

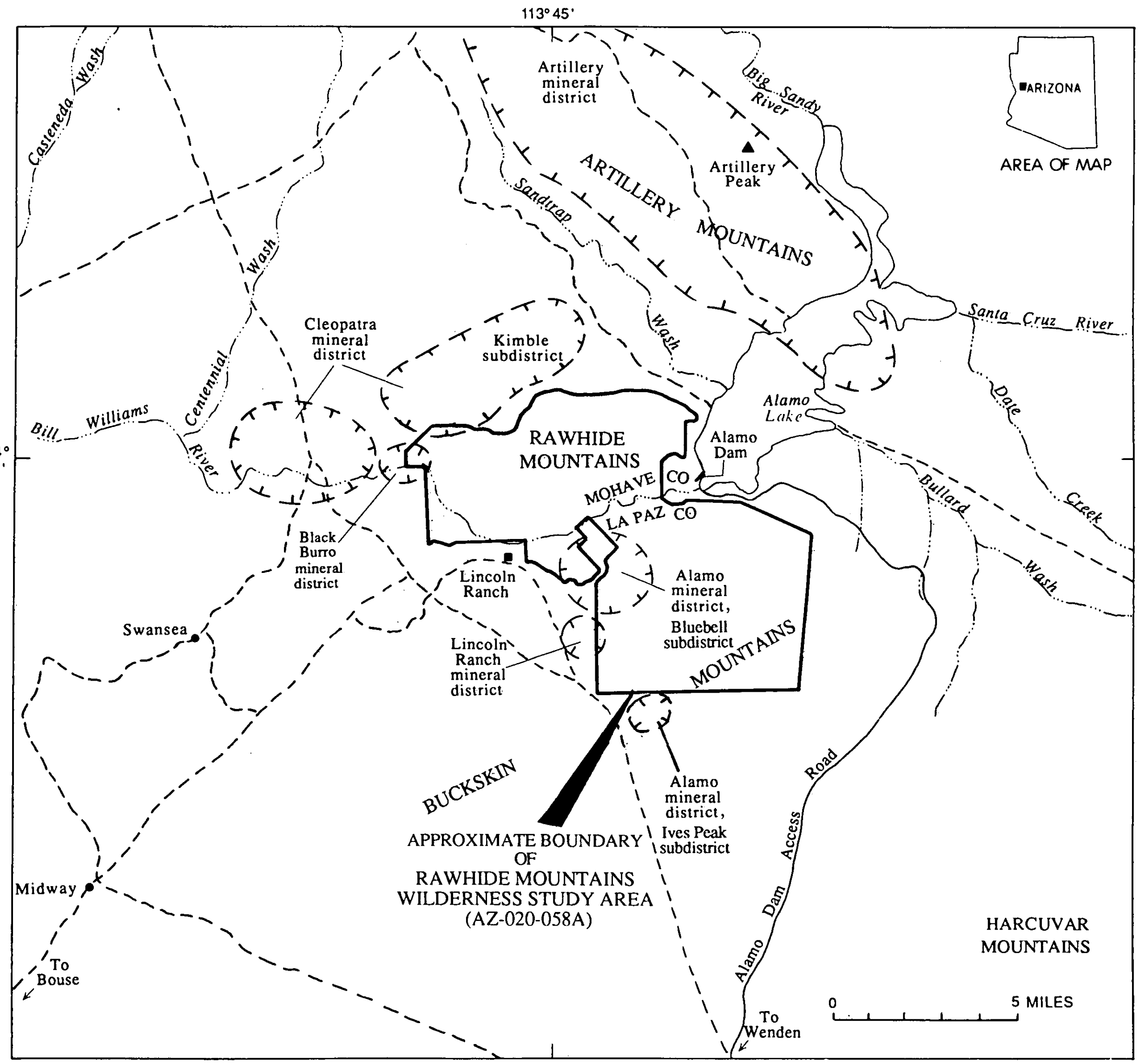

Figure 1. Index map showing location of the Rawhide Mountains Wilderness Study Area, La Paz and Mohave Counties, Arizona. Dashed hachured lines outline approximate boundaries of mineral districts adjoining the study area, as defined by Keith and others (1983a, b) and Spencer and Welty (1985, 1989). Dashed lines indicate unimproved roads.

The extensional fault system, its associated syntectonic basins, and the younger high-angle faults are important controls on the distribution of mineral resources in the study area (Spencer and Welty, 1985, 1989). Mineral exploration in western Arizona and southeastern California has focused on these geologic terranes, and some metallic deposits and prospects are known (Sherbourne and others, 1979; Wilkins and Heidrick, 1982; Lehman and others, 1987; Wilkinson and others, 1988; Spencer and others, 1988).

Identified Resources

Mining and prospecting activity has occurred in the northern, central, and southern parts of the Rawhide Mountains Wilderness Study Area (fig. 2). Low gold, silver, and copper concentrations occur in northwest-striking fault zones in mylonitic gneiss and metasedimentary rocks. Inferred subeconomic resources of 200,000 tons of 0.02 troy ounces of gold per short ton of ore (troy oz gold/st), 0.04 troy oz silver/st, and 0.2 weight-percent copper are calculated for a mineralized fault zone in the Big Kimble mine area (fig. 2, No. 3). In the north-central part of the study area, inferred subeconomic resources of 20,000 tons of 0.05 troy oz gold/st, 0.01 troy oz silver/st, and 0.4 weight-percent copper are calculated for one of the faults in the area. The southeastern part of the Bluebell subdistrict of the Alamo mineral district has an adit with inferred subeconomic resources of 20,000 tons of 0.02 troy oz gold/st, 0.05 troy oz silver/st, and 0.15 weight-percent copper (fig. 2, No. 9). A nearby fault has inferred subeconomic resources of 90,000 tons of 0.05 troy oz gold/st, 0.2 troy oz silver/st, and 0.7 weight-percent copper. The Bernard mine area (fig. 2, No. 6) has an inferred subeconomic resource of 400,000 tons of 0.07 troy oz gold/st, 0.2 troy oz silver/st, and 0.4 weight-percent copper.

Prospects in and near the study area along the southwest edge of Alamo Lake are in Tertiary sedimentary rocks that contain zones of hematite and thin seams of chrysocolla and malachite in shear zones along the Buckskin-Rawhide detachment fault. Manganese concentrations related to shear zones in the Buckskin-Rawhide detachment fault are found in Tertiary sedimentary rocks along the west border of the study area. Resources were not determined for these areas because the occurrences are small.

Mineral Resource Potential

There is moderate and locally high mineral resource potential for precious and base metals (gold, silver, and copper) in the Rawhide Mountains Wilderness Study Area (fig. 2). These areas are located along high-angle faults in the western part of the study area, along high- and low-angle faults in the lower-plate terrane north of and immediately south of the Bill Williams River, and along the Buckskin-Rawhide detachment fault and related upper-plate faults in the northeastern, northwestern, and southwestern parts of the study area. Areas of high resource potential for these elements are defined by favorable geologic, geochemical, and geophysical data and by the presence of identified mineral resources inside and immediately adjacent to the study area. The southern part of the study area has a low resource potential for precious and base-metal. Areas of moderate potential for manganese and low potential for uranium and vanadium resources occur in the limited outcrops of Tertiary sedimentary and volcanic rocks in the northwestern, southwestern, northeastern, and east-central parts of the study area.

The resource potential for oil and gas throughout the entire Rawhide Mountains Wilderness Study Area is low because of the sparsity of appropriate hydrocarbon-bearing rocks. A low potential for low-temperature geothermal waters in the northeast corner of the study area is based on (1) the presence of a buried high-angle fault that in nearby areas is the locus of low-temperature geothermal springs and (2) the lack of any known occurrence of geothermal springs in the immediately adjacent area. The potential for sand and gravel resources is low and restricted to regions throughout the study area where alluvial fans and washes are present.

INTRODUCTION

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

Location and Physiography

The Rawhide Mountains Wilderness Study Area (AZ–020–058A) covers approximately 40,025 acres in west-central Arizona (fig. 1), some 40 mi east of Parker, Ariz. The study area lies astride the Bill Williams River, which divides the southeastern Rawhide Mountains on the north from the Buckskin Mountains on the south. Alamo Lake on the Bill Williams River lies just east of the study area. Elevations in the study area range from about 800 ft along the Bill Williams River to 3,927 ft at the Buckskin benchmark, the crest of the Buckskin Mountains (fig. 2).

Access to the Buckskin Mountains south of the Bill Williams River is provided by a paved road between Wenden and the Alamo Dam. A gravel gasline road leaves the paved road and crosses the Buckskin Mountains into the Reid Valley where Lincoln Ranch is located. Access to the Rawhide Mountains north of the river is provided by dirt roads heading south from Yucca, Ariz.

The vegetation of the study areas is classified as Sonoran Desert scrub, and the main subdivision found in the study areas is the Arizona Upland subdivision (Brown, 1982). The Arizona Upland subdivision is a shrubland or low woodland of leguminous trees with open areas of shrubs and cacti. Cacti are important in this subdivision, and 20 species of cacti are largely confined to, or best represented in, the Arizona Upland subdivision. Major areas of the Lower Colorado River subdivision are also found in the study area, especially in the Buckskin Mountains. Locally common riparian areas and wetland meadows are found around seeps, streams, and washes. The dominant shrubs and cacti include many species of cholla (*Opuntia* spp.), saguaro (*Carnegiea gigantea*), creosotebush (*Larrea tridentata*), and littleleaf paloverde (*Cercidium microphylum*).

Previous work

Early descriptions of the rock types and various mineral deposits in the Rawhide and Buckskin Mountains are found in Lee (1908), Bancroft (1911), and Jones and Ransome (1920). Lasky and Webber (1949) described the manganese deposits in the adjacent Artillery Mountains. The Rawhide Mountains were mapped by Shackelford (1976, 1980). Geologists from the Arizona Bureau of Geology and Mineral Technology have studied the geologic setting of the mineral occurrences within the region (Keith and others, 1983a, b; Spencer and Welty, 1985, 1986, 1989; Welty and others, 1985; Spencer and Reynolds, 1986a, b), and their work has been invaluable during the course of this mineral resource investigation. Spencer and Welty (1985) defined mineral districts throughout the region, including the study area, and these district names are used in this report. Spencer and Welty (1989) subsequently subdivided the mineral districts into subdistricts, and these subdivisions are used where appropriate. Areas outside of the study area have been actively explored for precious-metal and uranium-vanadium deposits (Sherbourne and others, 1979; Otton, 1981, 1982; Wilkins and Heidrick, 1982; Mueller and Halbach, 1983; Wilkins and others, 1986; Lehman and others, 1987; Spencer and others, 1988), and the results of this work are applicable to the mineral resource potential of the study area.

Methods of Study

The U.S. Geological Survey conducted detailed field investigations of the Rawhide Mountains Wilderness Study Area in the winters of 1986 and 1987. This work included geologic mapping at scales of 1:24,000 and 1:62,500, geochemical sampling, and the examination of outcrops for evidence of mineralization. The geochemical survey sampled rocks and stream sediments, which were analyzed for 33 elements by semiquantitative emission spectrography and for arsenic, antimony, bismuth, cadmium, gold, mercury, and zinc by atomic absorption. Regional gravity and aeromagnetic surveys were used in the assessment. Landsat thematic mapper images were interpreted for evidence of potential hydrothermal alteration in the study area. Further details on each analytical procedure undertaken for this resource assessment are given in a following section.

Acknowledgments

This work was supported by the Mineral Resource Appraisal and the National Geologic Mapping Programs of the U.S. Geological Survey. Discussions with J.E. Spencer and S.J. Reynolds of the Arizona Geological Survey improved our understanding of the geology of the area. A special thanks is extended to Diana Mangan for preparation of the figures and to Julia Thomas for patiently overseeing the final publication of the bulletin.

APPRAISAL OF IDENTIFIED RESOURCES AND KNOWN MINERALIZED AREAS

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

Summary

Most rocks in the study area are Tertiary mylonite, gneiss, and schist that were derived from Proterozoic, Paleozoic, Mesozoic, and Tertiary metamorphic, igneous, and sedimentary protoliths. These mylonitic rocks are part of a Tertiary metamorphic core complex and form the lower plate of the Buckskin-Rawhide detachment fault of middle Tertiary age. Rocks in the upper plate of the detachment fault include granite, schist, and gneiss of Proterozoic, Paleozoic, and Mesozoic age and sedimentary and volcanic rocks of Tertiary age; these rocks are sparse within the study area. Northwest-striking, northeast-dipping faults cut all the rocks and the detachment fault.

Mines and prospects occur in or near the northern, west-central, east-central, and southwestern parts of the Rawhide Mountains Wilderness Study Area (fig. 2). Mineralized zones in three areas in the study area were of sufficient size to determine available resources. These areas are (1) a fault zone in the north-central part of the study area (fig. 2, No. 4), (2) parts of the Alamo mineral district inside the study area, and (3) the Big Kimble mine area (fig. 2, No. 3), just outside the north boundary of the study area. In all these areas, the mineralization in exposed parts of fault zones is oxidized. Under these conditions silver and copper are commonly depleted in the oxidized parts of the fault zones and concentrated in a lower sulfide zone. Drilling and geophysical work are needed to determine if additional resources are present at depth.

Copper prospects along the west edge of Alamo Lake are in Tertiary conglomerates and siltstones that contain zones of hematite and thin seams of chrysocolla and malachite. These mineralized zones are adjacent to the Buckskin-Rawhide detachment fault. Copper concentrations in excess of 1 weight-percent were found in six samples from this area; however, the limited thickness and extent of the Tertiary strata in this area do not favor economic development of the minerals.

Manganese oxides coat the surfaces of clasts and form part of the matrix of Tertiary conglomerate along the west border of the study area. Only small outcrops of conglomerate extend into the study area. The manganese-bearing zones here are too thin and low grade to be economic.

Methods of Investigation

A literature search was made for minerals information pertinent to the study area. Bureau of Land Management records were checked for current mining claims and oil and gas leases. A total of 32 field days was spent in the field examination of this study area in March, April, and May 1987.

Two hundred and sixteen rock samples were collected from mines, prospects, and outcrops in and near the study area. Gold content was determined by fire assay with an atomic absorption spectrometry finish; silver and copper were determined by atomic absorption spectrometry. Of these samples, 22 were selected for multi-element analyses by inductively coupled plasma–atomic emission spectrometry. Sample analyses were conducted by Chemex Labs Inc., Sparks, Nev. Assay data and analytical results are summarized by Tuftin (1989) and are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, Co.

Mining History

The study area includes most of the Bluebell subdistrict of the Alamo mineral district and lies adjacent to the Lincoln Ranch mineral district, the Black Burro mineral district, the Cleopatra mineral district, and the Artillery mineral district (fig. 1). Spencer and Welty (1985, 1989) outlined the extent of these districts and briefly described the individual workings within them.

The Bluebell subdistrict of the Alamo mineral district lies in the west-central part of the study area (figs. 1, 2). It includes nine patented claims (the Arizona-Montana mines (fig. 2, No. 7)) outside the study area, the Mystery Hill group (fig. 2, No. 8) with workings extending into the study area, and the Bernard mine area (fig. 2, No. 6) in the southwestern part of the district (Tuftin, 1989) The district is a past producer of copper, silver, gold, and minor lead.

The claims forming the Arizona-Montana mines were located in July 1906. Mines and prospects in this group were worked intermittently until 1937 and produced approximately 170 tons of ore averaging 6 weight-percent copper, 0.8 troy oz silver/st, and 0.1 troy oz gold/st (Keith, 1978, p. 114).

The Mystery Hill group includes numerous small workings that lie east of the Arizona-Montana mines and extend inside the study area. Keith (1978, p. 115) reports that the Mystery Hill group was first worked in the late 1800's and worked sporadically through 1945, producing more than 500 tons of ore averaging about 3 weight-percent copper, 2 troy oz silver/st, 0.1 troy oz gold/st, and 0.5 weight-percent lead.

The Bernard mine area includes several prospect pits and small adits on a northwest-striking fault zone in the study area. This area was worked intermittently from 1912–1936, producing 138 tons of ore averaging about 1 weight-percent copper, 0.1 troy oz silver/st, and 0.1 gold/st (Keith, 1978, p. 114).

The Kimble subdistrict of the Cleopatra mineral district extends into the northwestern part of the study area (fig. 1). The Big Kimble mine is in the southeastern part of the Kimble subdistrict, along the north boundary of the study area. The Kimble subdistrict has produced 50 tons of ore averaging 0.412 troy oz gold/st, 0.373 troy oz silver/st, and 0.14 weight-percent copper (Spencer and Welty, 1985, p. 4).

The Lincoln Ranch mineral district is centered about 1.5 mi west of the study area (fig. 1). Almost all of the production in this district was from the Doyle mine (fig. 2, No. 11), an open-pit operation that was worked in the middle to late 1950's. The Doyle mine produced approximately 70,000 long tons of ore averaging 15–16 weight-percent manganese (Keith 1978, p. 114).

About 80 percent of the study area is covered by oil and gas leases and lease applications; however, there has been no drilling in or near the study area.

Low-temperature (less than 50 °C) geothermal waters are reported from wells and springs about 12 mi northeast of the study area along the Big Sandy River (fig. 1; Witcher and others, 1982; Stone and Witcher, 1982). There are, however, no surface indications of hot-water spring activity in the study area.

Appraisal of Identified Resources

Gold, silver, copper, and manganese occur in the Rawhide Mountains Wilderness Study Area. Gold, silver, and copper occur in northwest-striking, northeast-dipping fault zones in mylonitic rocks throughout the study area. Some of these occurrences are of sufficient size to calculate subeconomic resources. Hematite with copper minerals occur in upper-plate rocks adjacent to the Buckskin-Rawhide detachment fault west of Alamo Lake. Manganese oxides occur in the matrix in upper-plate Tertiary conglomerate adjacent to the detachment fault along the west border of the study area. Resources were not determined for the latter two areas because the occurrences are small.

Mineralization Associated with Northwest-Striking Faults

Gold, silver, and copper are found in oxidized portions of northwest-striking, northeast-dipping fault zones in lower-plate rocks in the Rawhide Mountains Study Area. Fault zones in the study area are oxidized where exposed. Silver and copper may have been depleted in the oxidized parts of the fault zones and concentrated at a previous water table (zone of secondary sulfide enrichment). Drilling and geophysical work would be needed to determine the presence of enriched zones at depth. A total of 730,000 tons of resources was determined for (1) selected structures in the north-central part of the study area, (2) parts of the Alamo mineral district in the west-central part of the study area, and (3) the Big Kimble mine area just outside the north boundary of the study area (Tuftin, 1989). In this report, resources are classified using the methods outlined by U.S. Bureau of Mines and U.S. Geological Survey (1980).

In the north-central part of the study area (fig. 2, No. 4), a small group of workings, consisting of an 18-ft-deep shaft, a 9-ft-long adit, and several pits and trenches, lies along five northwest-trending fault zones in gneiss (Tuftin, 1989). Twenty-six samples were taken from these workings and from outcrops in the area. In all but one of the fault zones, gold concentrations are very low to absent. The exception is from the eastern fault zone which contains gold concentrations ranging from 0.002 troy oz/st to 0.205 troy oz/st. Silver and copper are associated with the gold but they typically occur in very low concentrations (Tuftin, 1989). An inferred subeconomic resource of 20,000 tons of 0.05 troy oz gold/st, 0.01 troy oz silver/st, and 0.4 weight-percent copper was calculated for the eastern fault zone. This estimate assumes an average thickness of 1.3 ft, a depth of 225 ft, and a length of 450 ft for the fault zone. Metal concentrations in the other fault zones in this vicinity are very low and do not constitute a resource.

Spencer and Welty (1985, p. 5–7) define the Bluebell subdistrict of the Alamo mineral district to include the mineralized area in the west-central part of the study area (figs. 1, 2). Workings in these sections can be subdivided into smaller groups. One group lies around the Bernard mine area, which includes numerous small workings lying in the western and southern parts of the mineral district (fig. 2, Nos. 6, 9). A second group of workings, in the eastern part of the mineral district, form the Mystery Hill group of unpatented claims (fig. 2, No. 8). A third group, which includes the patented Arizona-Montana mines (fig. 2, No. 7), is outside the study area. The workings in the Alamo mineral district follow several northwest-striking, northeast-dipping fault zones in mylonitic gneiss with scattered lenses of metasedimentary rocks. Chrysocolla commonly coats fracture surfaces in the fault zones.

The Bernard mine workings (fig. 2, No. 6) include 10 prospect pits and 6 small adits on a northwest-striking, northeast-dipping fault zone in gneiss. Twenty-eight samples were collected from the mines and prospects in this area (Tuftin, 1989). The highest gold concentration found in the Rawhide Mountains Wilderness Study Area is from a 1.3-ft chip sample taken across a silicified breccia zone with gouge in a 22-ft-long adit. This sample contained a concentration of 0.3 troy oz gold/st. Seven samples from this fault zone have concentrations of 0.1 troy oz gold/st or greater, and one contains 2.05 troy oz/st silver (Tuftin, 1989). Two samples had copper in excess of 1 weight-percent (Tuftin, 1989). The copper is present in the mineral chrysocolla, which forms thin seams and streaks in a breccia zone. An inferred subeconomic resource of 400,000 tons of 0.07 troy oz gold/st, 0.2 troy oz silver/st, and 0.4 weight-percent copper is estimated for the fault zone in the Bernard mine area using an estimated length of 1,700 ft, a depth of 850 ft, and an average thickness of 2.5 ft for the fault zone.

Unnamed workings southeast of the Bernard mine occur along a northwest-striking, northeast-dipping fault zone (fig. 2, No. 9). One adit was driven along a horizontal silicified zone in gneiss that contains lenses of fluorite and calcite crystals. The silicified zone ranges from 1 to 4 ft thick. Of 25 samples taken from this adit, 21 contained gold, with concentrations ranging from 0.003 to 0.072 troy oz/st. Silver concentrations were detected in 22 samples, with concentrations ranging from 0.01 to 0.69 troy oz/st. One sample contained copper in excess of 1 weight-percent. An inferred subeconomic resource of 20,000 tons of 0.02 troy oz gold/st, 0.05 troy oz silver/st, and 0.15 weight-percent copper are estimated for this adit, based on an estimated strike length of 345 ft, a width of 310 ft, and an average thickness of 2.1 ft (Tuftin, 1989). Six samples collected from prospects in another northwest-striking fault zone contained gold, with concentrations ranging from 0.018 troy oz/st to 0.097 troy oz/st. An inferred subeconomic resource of 90,000 tons of 0.05 troy oz gold/st, 0.2 troy oz silver/st, and 0.7 weight-percent copper estimated for this structure is based on an estimated strike length of 800 ft, a depth of 400 ft, and an average thickness of 2.3 ft (Tuftin, 1989).

Workings in the Mystery Hill group (fig. 2, No. 8) are both inside and outside the study area east of the Arizona-Montana mines. They include numerous pits, short adits, and shafts on predominantly northwest-trending, northeast-dipping fault zones in gneiss with scattered lenses of metasedimentary rock. All 53 samples from workings and outcrops along the fault zones in the area typically contain very low gold and silver concentrations; 4 samples contain at least 0.03 troy oz gold/st, 2 samples contain more than 0.5 troy oz silver/st, and 13 samples contain copper in excess of 1 weight-percent (Tuftin, 1989). The highest gold concentration found in the Mystery Hill group, 0.086 troy oz gold/st, was collected from an outcrop of silicified gneiss in the far northern part of section 20. Samples having high gold concentrations are randomly distributed in parts of the fault zones that are not noticeably different from those which have little or no gold. Because the metal concentrations in fault zones in the Mystery Hill group are low and mineralization is discontinuous, these occurrences do not constitute a resource.

Mines and prospects in the Arizona-Montana mines (fig. 2, No. 7) are privately owned. At the request of owner, analytical information relating to this area is proprietary and cannot be published.

Numerous prospect pits and several small adits and shafts are in and near the southern part of the study area, about 1 mi southwest of the Buckskin benchmark (fig. 2, No. 12). These working form the Ives Peak subdistrict of the Alamo mineral district of Spencer and Welty (1989). The workings in the area are in seven 4- to 5-ft-wide fault zones in gneiss. The fault zones have a predominantly northwest strike and dip to the northeast; however, one fault zone about 250 ft south of the study area strikes east and dips to the north. Twenty-nine samples were taken from the mines and prospects in this area. Gold was detected in 3 of these samples, and silver was detected in 16; 3 samples show more than 1 weight-percent copper (Tuftin, 1989). Although three samples contain more than 1 weight-percent copper, surface samples indicate that the average metal concentrations are too low and mineralization too discontinuous to constitute a resource.

Workings at the Big Kimble mine just outside the northwest boundary of the study area (fig. 2, No. 3) follow a northwest-trending, northeast-dipping fault zone in gneiss that was traced for about 1,000 ft. The fault zone is characterized by fractured and silicified gneiss, veins and lenses of quartz, breccia, and gouge. Limonite and chrysocolla typically coat fracture surfaces in the fault zone. Twenty-nine samples were taken from a part of the fault zone exposed by bulldozer cuts, a trench, a shaft, and three adits in the area. A sample collected from the footwall of a fault zone at the collar of an inaccessible shaft contained 0.086 troy oz/st gold (Tuftin, 1989), the highest gold concentration measured for the Big Kimble workings. Six samples from the area have gold in excess of 0.02 troy oz/st; most samples contain less than 0.01 troy oz gold/st. Silver and copper are associated with the gold, but both are of less importance. An inferred subeconomic resource of 200,000 tons of 0.02 troy oz gold/st, 0.04 troy oz silver/st, and 0.2 weight-percent copper was calculated for the fault zone in the Big Kimble mine area. This resource assumes an average thickness of 3.3 ft, a width of 500 ft, and a strike length of 1,500 ft for the fault zone. This resource is outside of the study area, but extensions of the resource project toward, and may be present in, the study area.

Mineralization Associated with the Buckskin-Rawhide Detachment Fault

Copper occurs in mid-Tertiary dark-reddish-brown conglomerates and siltstones in the upper plate of the Buckskin-Rawhide detachment fault in the northeastern part of the study area near Alamo Lake (figs. 1, 2). These sedimentary rocks occur as small and discontinuous outcrops with discontinuous zones of mineralization along bedding planes or shear zones that are typically 3 to 5 ft thick and contain abundant hematite and thin seams of chrysocolla and malachite. Eleven samples were taken from prospects in this area (Tuftin, 1989). Gold was detected in four of these samples, although the concentrations are at or near the detection limit in three of them. Silver was detected in six samples, but only in trace amounts. Six samples contained copper in excess of 1 weight-percent. Thin seams and coatings of chrysocolla occur along fracture surfaces at these sample sites, and, although some of copper concentrations are more than 1 weight-percent, the limited thickness and extent of the Tertiary strata in this area do not favor mineral concentration in economic amounts. The mineralized zones in the Alamo Lake area are of limited extent, and the gold and silver concentrations are low. A mineral resource is not identified in this area.

Manganese occurs in middle Tertiary conglomerates adjacent to the Buckskin-Rawhide detachment fault along the southwest border of the study area. These manganese occurrences are on the fringe of the Lincoln Ranch mineral district, which is centered about 1 mi west of the study area (figs. 1, 2). Manganese was mined by open-pit operations in this district, and most of the production was from the Doyle mine (fig. 2, No. 11; Keith, 1978, p. 114). The best grade mined (averaging 15–16 weight-percent manganese) was closely associated with shear zones along the Buckskin-Rawhide detachment fault. Keith (1978, p. 19) estimates that 200,000 tons or more of manganese-bearing material averaging 3 to 10 weight-percent manganese may remain around the previously operated mines. Several prospects expose Tertiary conglomerate with manganiferous lenses that range from 3 to 7 ft thick (Tuftin, 1989). The conglomerate consists of quartz and granite boulders between 2 and 8 in. in diameter. Manganese oxides coat the surface of the boulders and form part of the conglomerate matrix. Three chip samples taken from prospects near the study area boundary contain more than 1 weight-percent manganese (Tuftin, 1989). These occurrences could not exceed 3 weight-percent manganese because there is a high ratio of gangue to manganese-oxides. At least 35 weight-percent manganese is required to be ore-grade (Jones, 1985, p. 485). It is unlikely that any development of the manganese-bearing strata would occur in the study area because the manganese-bearing strata are thin, the Tertiary strata in this area are of limited extent, and there is a high ratio of gangue minerals to manganese.

Conclusions

Gold, silver, and copper concentrations occur in northwest-striking northeast-dipping fault zones in lower-plate gneiss and metasedimentary rocks in portions of the northern, central, and southern parts of the Rawhide Mountains Wilderness Study Area. An estimated total of 730,000 tons of inferred subeconomic resources was determined for several of the northwest-trending structures in the study area, from the Alamo mineral district in the west-central part, through the north-central part, to the Big Kimble mine area north of the study area. Resources of the Big Kimble mine project toward the study area and may be present in it. In all these areas, the exposed parts of the veins are too thin and low grade to be economically mined on a large scale at the present time or in the foreseeable future. Drilling and geophysical work would be needed to determine if additional resources are present at depth.

Along the northeast border of the study area, Tertiary sedimentary rocks adjacent to shear zones of the Buckskin-Rawhide detachment fault contain copper concentrations; however, the limited thickness and extent of the mineralized strata in this area do not favor economic development.

Manganese concentrations along the west border of the study area are in conglomerates adjacent to shear zones of the detachment fault. Economic development of manganese in the study area is not likely because only small outcrops of Tertiary strata extend into the study area and the manganese-bearing zones are thin, low grade, and of limited strike extent.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology

Geologic Setting

The Rawhide Mountains Wilderness Study Area lies in the northwest-trending belt of metamorphic core complexes in the Basin and Range province of west-central Arizona. (Rehrig and Reynolds, 1980). In these complexes, midcrustal and deeper rocks were tectonically transported to the surface along shallow-dipping normal faults or detachment faults during a period of extensional tectonism in the late Oligocene and Miocene (Spencer and Reynolds, 1986a). The detachment fault in the map area is known as the Buckskin-Rawhide detachment fault of Spencer and Reynolds (1986b), and it crops out discontinuously around the borders of the study area (fig. 2).

The Buckskin-Rawhide detachment fault divides the bedrock geology of the map area into two parts: an extended upper plate of Proterozoic, Paleozoic, and Mesozoic igneous and sedimentary rocks and Tertiary volcanic and sedimentary rocks, and a lower plate of Tertiary plutons and mylonitic rocks derived from Proterozoic, Paleozoic, Mesozoic, and Tertiary igneous, metamorphic, and sedimentary protoliths (fig. 2). Mylonitic deformation in the lower plate is considered to be a deeper level expression of, and slightly older than, brittle extensional faulting along the detachment fault and its upper plate (Davis, 1983; Spencer and Reynolds, 1986a; Howard and John, 1987; Davis and Lister, 1988). Syntectonic sedimentation and volcanism accompanied extension, and these rocks now crop out in the highly faulted upper-plate terrane (Davis and others, 1980; Spencer and Reynolds, 1986b). K-Ar, $^{40}Ar/^{39}Ar$, and fission-track geochronologic data indicate that deformation ceased by the middle Miocene (Otton, 1982; Spencer and Reynolds, 1986a; Bryant and Naessar, 1987).

During the last stages or after the end of the extensional deformation, high-angle faults cut the detachment terrane. The Lincoln Ranch reverse fault is the best known of these faults. Post-detachment rocks include sandstones, conglomerates, and unconsolidated sediments that have accumulated in scattered areas throughout the region.

Lower-Plate Terrane

The rocks units of the lower-plate terrane are characterized by a subhorizontal mylonitic foliation and an accompanying northwest-trending elongation lineation. This fabric was superposed on all the lower-plate rock units during Tertiary extensional deformation, and it overprints any older metamorphic fabric. The following description of these rocks deals only with the protoliths of the Tertiary mylonites.

The oldest protolith in the lower-plate terrane is a heterogeneous Proterozoic gneissic terrane consisting of augen gneiss, layered hornblende-bearing mafic gneiss, metagranite, quartzofeldspathic migmatites, and pegmatites. Most of these rocks have been deformed several times.

Marbles, quartzites, calc-silicate rocks, phyllites, and schist are interleaved with the Proterozoic gneissic rocks. These rocks are considered equivalent to Paleozoic and lower Mesozoic cratonal sedimentary rocks and Jurassic volcanic rocks that crop out in the upper plate of the Buckskin-Rawhide detachment fault and also on the Colorado Plateau, about 80 mi to the northeast (Shackelford, 1976; Reynolds and others, 1987). The tectonic interleaving of the Proterozoic, Paleozoic, and Mesozoic rocks probably occurred in the late Mesozoic during contractional deformation similar to that documented in the upper plates of the detachment faults in the region and in adjacent ranges to the southeast (Reynolds and others, 1986; Spencer and Reynolds, 1987; Bryant and Wooden, 1989).

Leucocratic garnet-bearing mylonitic granite gneiss and associated aplite and pegmatite gneiss intruded the older terrane prior to the mylonitic deformation. These granitic gneiss occur as sills, dikes, and small plutons. The rocks are lithologically similar to the granite of Tank Pass of Rehrig and Reynolds (1980) in the Harcuvar Mountains, some 20 mi to the southeast. There, the granite is assigned a Late Cretaceous age, on the basis of an unpublished Rb-Sr isochron (Reynolds and others, 1983).

A heterogeneous assemblage of medium- to coarse-grained igneous rocks of the Swansea plutonic suite (Bryant and Wooden, 1989) is the youngest rock unit in the lower-plate terrane. Rock types include gabbro, diorite, porphyritic granodiorite, and leucocratic granodiorite. Parts of this suite have been previously mapped as Mesozoic diorite and quartz monzonite by Shackelford (1976). Most of the rocks are variably mylonitized and metamorphosed, but some rocks of the plutonic suite are interpreted to have intruded the lower-plate terrane synkinematically with the mylonitic deformation (Shackelford, 1976; Bryant and Wooden, 1989). A U-Pb zircon age of 21.6±1.5 Ma from a granodiorite outside of the map area (Bryant and Wooden, 1989) indicates an early Miocene age for the younger part of the suite. In the study area, the Swansea plutonic suite underlies much of the Rawhide Mountains.

Upper-Plate Terrane

Upper-plate rock units are typically fault bounded and commonly intensely brecciated and fractured. For the most part, upper-plate rocks lie outside the study area. The following description includes rock units outside of the study area but within the map area shown on figure 2.

Intensely brecciated granite, layered gneiss, and minor diorite dikes that occur west of the study area in the Reid Valley (Lincoln Ranch area) may be the oldest rocks in the upper plate. According to Spencer and Reynolds (1986a), these rocks could be either Proterozoic or Mesozoic.

Weakly to moderately metamorphosed marble, schist, phyllite, and quartzite occur in Reid Valley and in the Rawhide Mountains. Shackelford (1976) and Spencer and Reynolds (1986a) correlate these rocks with other cratonal Paleozoic rocks found in the region and on the nearby Colorado Plateau. The relation of these rocks to the Proterozoic or Mesozoic granitic rocks is unknown, as they occur in separate fault blocks.

Tertiary sedimentary and volcanic rocks unconformably overlie the crystalline and metasedimentary rocks. The sedimentary rocks consist of reddish sandstone, conglomerate, breccia, siltstone, mudstone, and grey limestone. The volcanic rocks consist of basaltic, andesitic, and latitic flows, flow breccias, and agglomerates; silicic tuffs are minor. All the rocks dip moderately to steeply. Previous workers in the region (Shackelford, 1976; Spencer and Reynolds, 1986a) correlated these rocks to the Chapin Wash and Artillery Formations and to the Sandtrap conglomerate of Lasky and Webber (1949). K-Ar dates from the interbedded volcanic rocks in the region indicate that these rocks are of Miocene age (Otton, 1982).

Post-Detachment Rocks

Post-detachment rocks are sparse in the map area. The rocks are divided into three broad units. The oldest unit consists of subhorizontal conglomerate and sandstone that filled structural depressions in the detachment terrane after the cessation of extensional deformation. Detritus in these rocks is locally derived. Clasts of upper-plate rocks are more abundant than are those of mylonitic rocks of the lower-plate terrane.

The younger units consist of unconsolidated to poorly consolidated sandstone and conglomerate and alluvium that unconformably overlies all older rock units. Mylonitic rocks of the lower plate are a major detrital component. The sandstone and conglomerate occur in moderate dissected alluvial fans and as terrace gravels above the modern washes. Alluvium occurs in the modern washes and fills larger valleys such as Reid Valley near Lincoln Ranch.

Structure

The major structure within the study area is the Buckskin-Rawhide detachment fault. The regionally subhorizontal normal fault superposes high-crustal-level rocks, including syntectonic sedimentary rocks, onto rocks that were at mid-crustal depths prior to extension. Presently the detachment dips off the edges of the mylonitic rocks in its lower plate. Other low-angle normal faults structurally below the detachment fault are abundant in the Rawhide Mountains. All of the low-angle faults cut the regionally shallow dipping and undulating mylonitic fabrics.

Brittle high- and low-angle faults in the upper-plate rocks formed contemporaneously with the detachment fault. Intense brecciation and fracturing along these faults are important to the deposition of metallic minerals by hydrothermal fluids circulating along the structures (Wilkins and Heidrick, 1982; Spencer and Welty, 1986; Beane and others, 1986). Many small mines in and adjoining the study area are located along the faults in the upper-plate terrane.

The Lincoln Ranch reverse fault cuts the mylonitic lower plate and the Buckskin-Rawhide detachment fault. The Lincoln Ranch fault dips steeply northeast in the center of the map area but dips shallowly northeast in the Rawhide Mountains (Shackelford, 1976). Other subparallel high-angle faults cut the lower-plate mylonitic rocks. Numerous base- and precious-metal mines are located along the smaller high-angle faults (fig. 2).

Geochemistry

Methods of Study

A total of 73 minus-60-mesh stream-sediment samples collected from active stream alluvium and 73 heavy-mineral, panned concentrates derived from stream sediment were selected as primary sample media. These sediments are thought to represent a composite of the chemistry of rock and soil exposed in the drainage basin upstream from the sample site. Chemical analysis of these stream-sediment samples provides data useful in identifying those drainages which contain unusually high concentrations of elements that may be related to mineral occurrences. In addition, studies have shown that heavy-mineral panned concentrations derived from stream sediments are a useful sample medium in arid and semiarid environments or in areas of rugged topography, where mechanical erosion dominates over chemical erosion (Bugrov and Shalaby, 1975; Overstreet and Marsh, 1981). The heavy-mineral-concentrate samples provide information about the chemistry of a limited number of minerals present in the rock material eroded from the drainage basin upstream from each sample site. This selective concentration of ore-related minerals permits determination of some elements that are not easily detected in bulk stream-sediment samples.

To represent the rocks exposed in the vicinity of the sample sites, 65 fresh and unaltered rock samples were collected. In addition, seven composite mine-dump samples were collected to provide some general information on the mineralization present in the area. All samples were analyzed for 31 elements using a semiquantitative direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). In addition, the rock and stream-sediment samples were analyzed for arsenic, antimony, bismuth, cadmium, zinc, gold, tellurium, and thallium by wet chemical and atomic absorption techniques.

Geochemical Results

Of the elements analyzed by emission spectrography and wet chemical analysis, barium, copper, lead, molybdenum, tellurium, tungsten, and zinc were deemed to be related to possible mineralization. Threshold values, defined as the upper limit of normal background values, were determined for each element by inspection of frequency distribution histograms for all sample media. The composite mine-dump rock samples were not included in construction of the histograms. A geochemical value higher than the threshold value is considered anomalous and worthy of scrutiny as a possible indicator of mineralization.

Three anomalous areas were identified in the study area on the basis of the presence of multi-element anomalies clustered within a restricted geographic region. Several other isolated sites contained single or multi-element anomalies. Future follow-up studies in the area should re-examine all anomalies, particularly since the scale of sampling for this compilation would allow a moderate-sized deposit to be identified by only one sample locality.

An area on the west-central boundary of the study area exhibits strongly anomalous values of barium, copper, lead, molybdenum, tungsten, and zinc in heavy-mineral-concentrate samples and copper, cobalt, nickel, tellurium, and zinc in the minus-60-mesh stream-sediment samples. The source of these anomalies is the epithermal quartz veins and mine dumps at the Arizona-Montana mines, Bluebell mine, and other mines and prospects in the area. The mineralization here is localized along high-angle faults that cut the mylonitic rocks of the lower plate of the Buckskin-Rawhide detachment fault. The faults are parallel to, and probably related to, the high-angle Lincoln Ranch fault, located about a mile to the west.

In the western part of the study area along the north side of the Bill Williams River, five drainage basins are all characterized by anomalous concentrations of barium, copper, lead, vanadium, and zinc in the heavy-mineral concentrates; one drainage basin also has anomalous concentrations of tungsten. Scattered, weakly anomalous concentrations of copper, cobalt, lead, molybdenum, and zinc are identified in the minus-60-mesh stream-sediment samples. These anomalies are probably related to hydrothermal alteration along the Buckskin-Rawhide detachment fault or to unidentified epithermal mineralization along the Lincoln Ranch fault.

In the northwest part of the study area, strongly anomalous concentrations of barium in heavy-mineral-concentrate samples and moderately anomalous concentrations of arsenic, copper, lead, and zinc in the minus-60-mesh stream-sediment samples have been identified in five drainage areas. Two sources for these anomalies are suggested. One source is contamination from a stratiform manganese prospect north of the study area in combination with the fault-controlled epithermal veins at the Big Kimble mine. A second source is the hydrothermal alteration along the detachment fault in the immediate area.

Scattered throughout the study area are sites whose heavy-mineral-concentrate samples contain only a few anomalous elements. Barium or barium and lead anomalies occur downstream from the Swansea plutonic suite in the Rawhide Mountains. Isolated sites containing only anomalous concentrations of barium in the heavy-mineral concentrates are found in the southern Buckskin Mountains and may be related to contact zones between Late Cretaceous mylonitic granite gneiss and the Proterozoic country rocks. The lack of other anomalous elements in these samples suggests that these anomalies might not be related to hydrothermal mineralization.

Just north of the Bill Williams River in the central part of the study area, a drainage basin contains strongly anomalous concentrations of barium, lead, and molybdenum in a heavy-mineral-concentrate sample. Weakly anomalous concentrations of copper in the minus-60-mesh stream-sediment sample are found at the same site. Epithermal veins and mine dumps upstream from the sample site in the north-central area are considered to be the source of the anomaly.

Two areas show anomalous concentrations of molybdenum in minus-60-mesh stream-sediment samples. One site in the extreme south-central part of the study area is also associated with moderately anomalous concentrations of copper. The other molybdenum anomaly occurs in the southeast part of the study area.

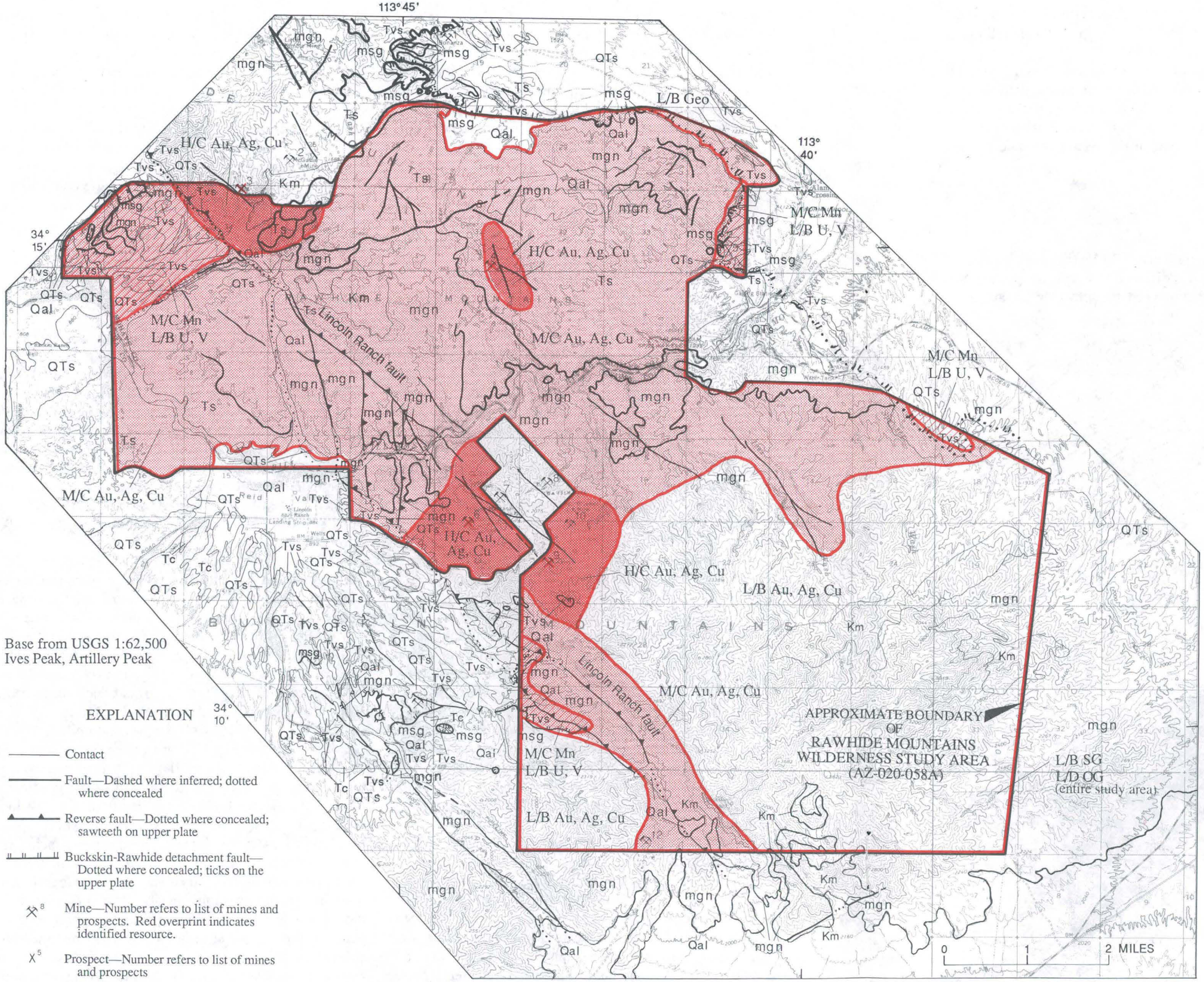
Three other sites are immediately south of the Bill Williams River in the Buckskin Mountains. One stream-sediment sample site from Ives Wash contains anomalous concentrations of copper. Less than 1 mi to the west, anomalous concentrations of gold were detected in a single stream-sediment sample. A stream-sediment sample from near Alamo Dam contains high concentrations of tungsten. All locations are close to faults and may reflect local epithermal mineralization.

Geophysical studies

Gravity and Magnetic Data

The study area is covered by regional gravity (Aiken and others, 1981; Defense Mapping Agency Aerospace Center, 1974, 1975) and aeromagnetic (Western Geophysical Company of America, Aero Service Division, 1979) surveys having sufficient resolution to define anomalies of about 2 mi^2 in area or larger. Contours of complete (terrain-corrected) Bouguer gravity anomalies are defined by 13 gravity stations within or near the study area. Contours of total-field magnetic anomalies are defined by measurements made along 11 east-west flightlines spaced 1 mi apart at a nominal height of 400 ft above terrain.

The gravity anomaly map (fig. 3) shows that the study area and surrounding region are transected by a uniform gradient which is steep north of the area and gentle over the area, with anomaly values increasing toward the south. The steep part of the gradient appears to be caused by the strong density contrast and nearly vertical edge of a block of mylonitic Proterozoic, Paleozoic, Mesozoic, and Tertiary rocks which underlies the Rawhide Mountains and the Buckskin Mountains immediately to the south. A northwest-trending fault in Sandtrap Wash along the northeast boundary of the study area probably forms the edge of the the mylonitic rocks. Superposed on the gentle part of the gradient are a small-amplitude high, in the form of a north-facing nose over the western part of the area, and a small-amplitude low in the form of a southwest-facing nose over the eastern part of the area. The high is mainly associated with the Tertiary Swansea plutonic suite which contains diorite of high density. The influence of the diorite on the high is inferred to be small, however, because the magnetic anomaly data do not indicate a subsurface abundance of this mafic rock. The low is not associated with specific terranes of mapped rocks, and its source is unknown. Possible sources of the low are a low-density quartzofeldspathic or granitic mylonite or a nonmagnetic low-density felsic body intruding the mylonite at shallow depth.



EXPLANATION

Area having high mineral resource potential (H) for gold, silver, and copper

Area having moderate mineral resource potential (M) for gold, silver, and copper

Area having moderate mineral resource potential (M) for manganese and low mineral resource potential (L) for uranium and vanadium

Area having low resource potential (L) for commodities as indicated

Level of certainty of assessment

- B Data only suggest level of potential
- C Data give good indication of level of potential
- D Data clearly define level of potential

Commodities

- Ag Silver
- Au Gold
- Cu Copper
- Mn Manganese
- U Uranium
- V Vanadium
- Geo Geothermal
- OG Oil and gas
- SG Sand and gravel

Mines and prospects

1. Bonanza mine
2. McGuffie mine
3. Big Kimble mine
4. Unnamed mines and prospects in north-central area
5. Unnamed prospects by Alamo Lake
6. Bernard mine
7. Arizona-Montana mines
8. Mystery Hill group
9. Unnamed mines in sections 19 and 20
10. Bluebell mine
11. Doyle mine
12. Unnamed mines and prospects southwest of Buckskin benchmark

Geologic map units

Post-detachment rocks

- Qal Alluvial deposits (Quaternary)
- QTs Sandstone and conglomerate (Quaternary and Late Tertiary)
- Tc Conglomerate and sandstone (Late Tertiary)

Upper-plate rocks

- Tvs Sedimentary and volcanic rocks (Miocene and Oligocene?)
- msg Metasedimentary and granitic rocks (Mesozoic, Paleozoic, and Proterozoic)

Lower-plate rocks

- Ts Swansea plutonic suite (Miocene)
- Km Mylonitic granite (Late Cretaceous)
- mgn Mylonitic gneiss (Tertiary, Mesozoic, Paleozoic, and Proterozoic)

Figure 2. Mineral resource potential and generalized geology of the Rawhide Mountains Wilderness Study Area, La Paz and Mohave Counties, Arizona. Geology of Reid Valley and Lincoln Ranch area modified from Spencer and Reynolds (1986a). Geology of Rawhide Mountains modified from Shackelford (1976) and modified by Bruce Bryant (1986 to 1987). Geology of Buckskin Mountains by Bruce Bryant (1986 to 1987) and R.M. Tosdal (1987).

The aeromagnetic anomaly map (fig. 4) is dominated by a northwest-trending region of highs, marked by nonhachured contours above 200 nanoteslas (nT). An isolated east-west trending high above the 200 nT contour occurs over the western part of the area. Most of the large region of highs in the Rawhide and Buckskin Mountains correlates with the exposures of the Swansea plutonic suite (fig. 2) and in the southeast part of the study area with outcrops of mafic gneisses in the lower-plate terrane. In the absence of further subsurface information, it is inferred that much of the region of the high is underlain by the Swansea plutonic complex. The isolated east-west high has an unknown source, but it also correlates with outcrops of the Swansea plutonic suite (fig. 2). This latter high clearly is not associated with the exposed magnetic diorite phase of the plutonic suite to the south because, in agreement with gravity anomaly data, this diorite is insufficient in vertical extent to generate a significant anomaly.

The most significant conclusion drawn from the combined gravity and magnetic anomaly data is that normal-density, magnetic, felsic intrusive rocks underlie significant parts of the study area. High-density, magnetic diorite in the western part of the area is thin and limited areally.

Remote Sensing

Digital image data acquired by the Thematic Mapper (TM) system on the Landsat-4 satellite (image No. 40174–17383) were analyzed to detect and map areas

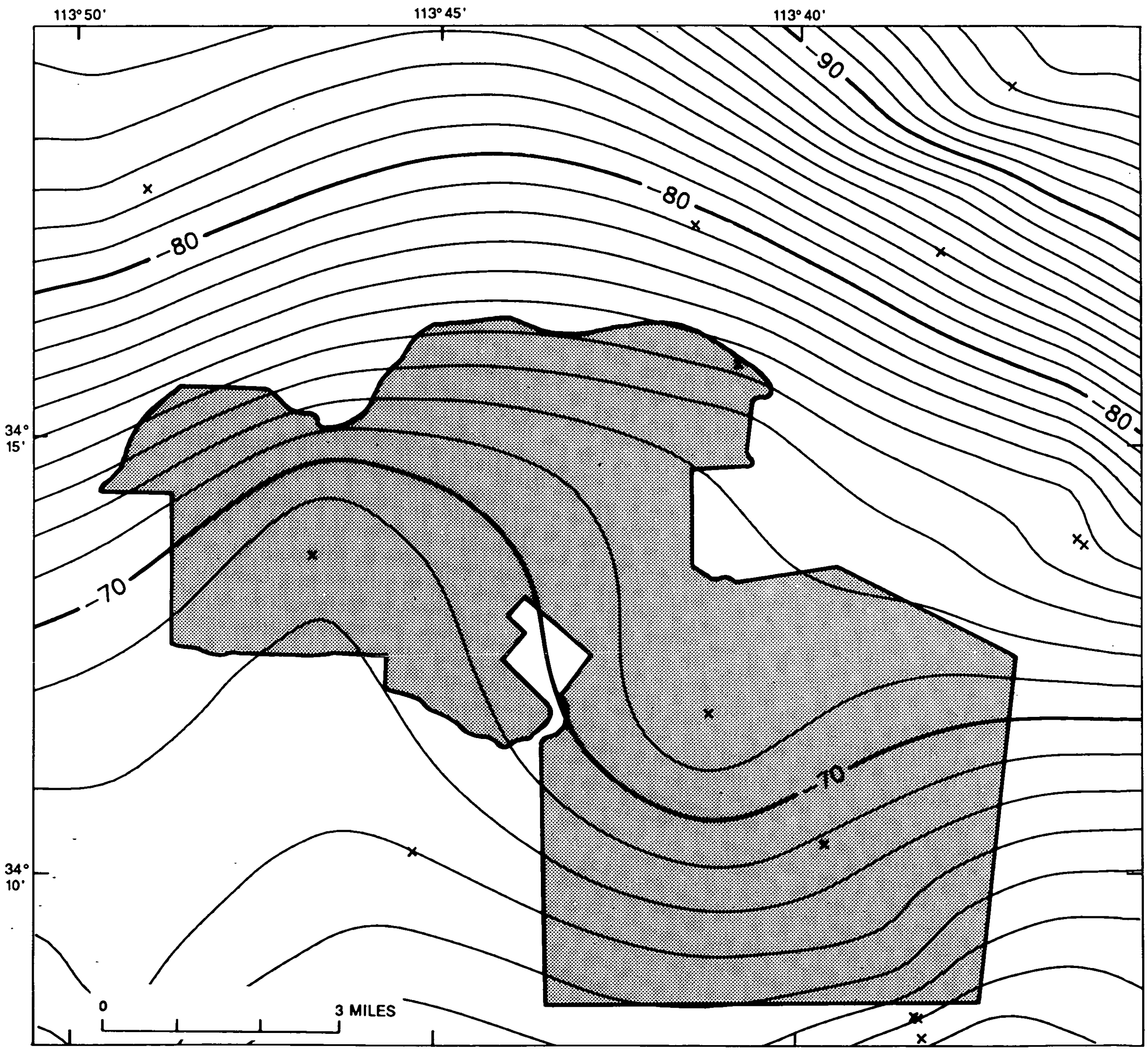


Figure 3. Bouguer gravity anomaly map of the Rawhide Mountains Wilderness Study Area (shaded), La Paz and Mohave Counties, Arizona. Contour interval 1 milligal; gravity stations denoted by x.

that may contain hydrothermally altered rocks. The six visible and near-infrared bands of image data were digitally processed to enhance spectral characteristics of minerals that often accompany alteration or are derived from the weathering of altered rocks. Visual interpretation of a vegetation-masked TM color-ratio composite consists of identifying areas having concentrations of limonite (group 1), areas of hydroxl-bearing and/or hydrated minerals (group 2), and areas where both groups of minerals occur together (group 3). Identification of the different groups is based on the spectral responses of the different limonitic minerals in the TM bands (Hunt and Salisbury, 1971, Raines, 1977; Hunt and Ashley, 1977).

On the basis of the TM images, areas of the different limonite-group minerals occur in the Rawhide Mountains Wilderness Study Area. Areas of alluvial deposits and Tertiary sedimentary rocks were excluded from this analysis. Moderate to dense vegetation obscures the rocks and soils of much of the study area and hinders the interpretation of the TM images. Furthermore, the rugged topography in the study area, combined with the relatively low solar-elevation angle at the time the TM data were acquired, results in a significant part of the study area being in deep to moderate shadow on the TM data. Vegetation and shadows have, therefore, greatly limited the area of surface rocks and soils that could be spectrally analyzed for evidence of possible alteration

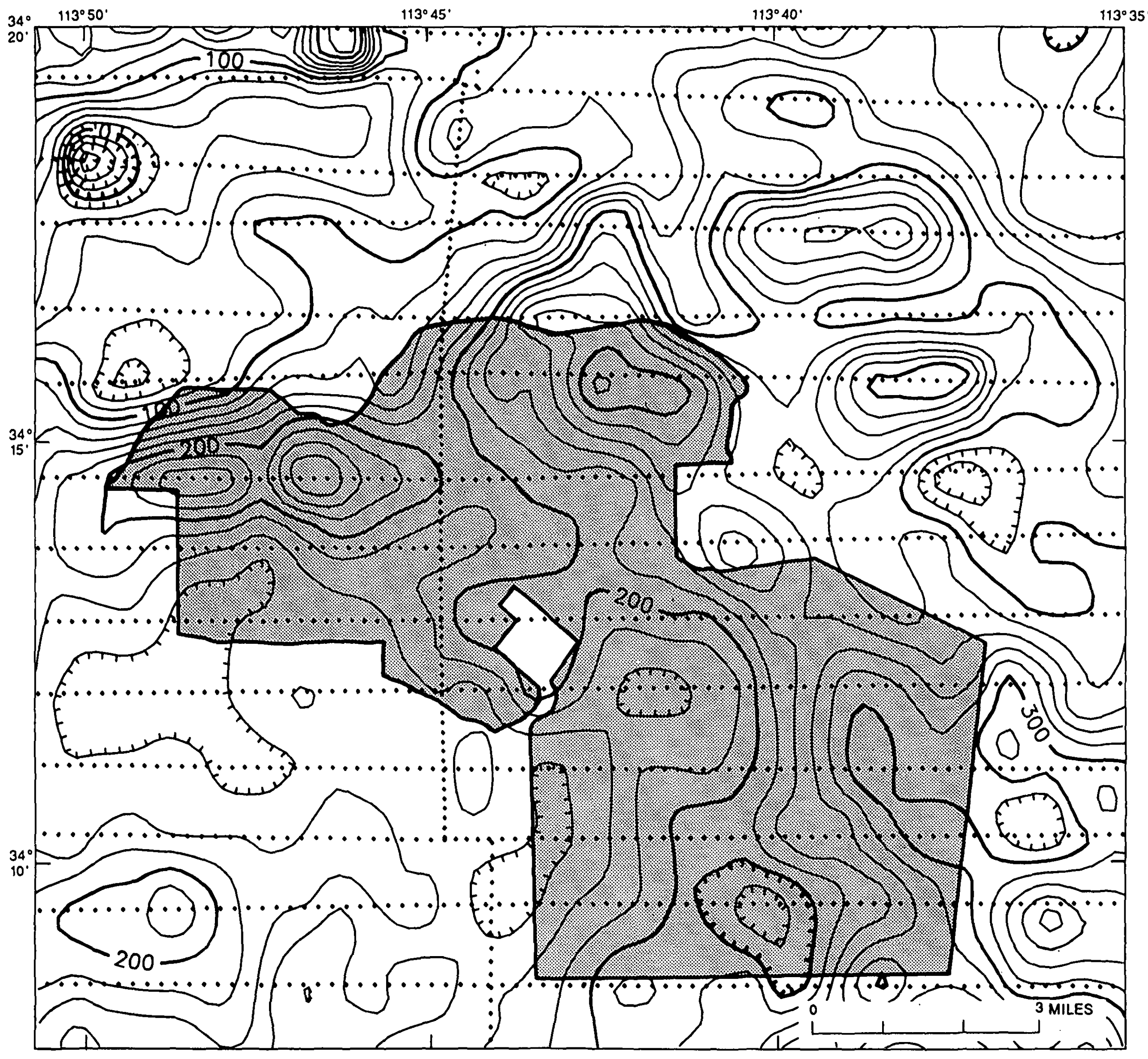


Figure 4. Aeromagnetic anomaly map of the Rawhide Mountains Wilderness Study Area (shaded), La Paz and Mohave Counties, Arizona. Contour interval 20 nanoteslas; hachures indicate closed areas of lower values. Dotted lines show flightlines.

minerals. Because of these masking effects, the areas of identified anomalies may represent only portions of more extensive areas.

A fairly uniform distribution of group-1 (limonite) minerals occurs over the southern, western, central, and northwestern parts of the study area. Because of the size of these areas, it is believed that they are probably related to the distribution and weathering of one or more prominent rock units and do not suggest that large scale hydrothermal alteration has occurred in the area. Within the study area, other potential-alteration anomalies of groups 1 and 3 are moderately abundant. Concentrations of group-2 minerals only are rare within the study area. Concentrations of group-3 minerals are spatially associated with clusters of shafts and adits at the known mineral occurrences in the Alamo mineral district (figs. 1, 2, Nos. 6, 7, 8, 9, 10) and around the Bonanza, McGuffie, and Big Kimble mines (fig. 2, Nos. 1, 2, 3) north of the study area. Other concentrations of groups 1 and 3 are scattered throughout the study area and are not clearly related to areas of known altered rocks or mineralization. Several areas of minerals of groups 1 and 3 lie in the southern Buckskin Mountains where the Late Cretaceous mylonitic granite crops out. No known mineral occurrence is known within the area, although anomalous barium concentration was detected in one stream-sediment sample from the area.

Mineral Resource Asssessment

The assessment of the mineral resource potential of the Rawhide Mountains Wilderness Study Area draws upon different and diverse sets of geologic data. Included in these data are the regional geology, geochemistry, geophysics, mineral occurrence maps, mining claim records, and the available ore deposit models that are applicable to the geologic terrane in the study area. These data were used to delineate favorable tracts within the study area, and an estimate of the level of resource potential and degree of certainty for each tract were made by using the criteria outlined in the "Appendixes." Throughout this discussion, mineral resource potential refers only to undiscovered mineral resources.

Areas of resource potential for gold, silver, copper, manganese, uranium, and vanadium minerals are present in the study area. These are outlined on figure 2 and are discussed below. Applicable metallic ore deposit models for the study area include detachment fault-related base- and precious-metal deposits (Wilkins and Heidrick, 1982; Wilkins and others, 1986; Spencer and Welty, 1986; Spencer and others, 1988), stratabound and fault-controlled manganese deposits (Cox and Singer, 1986; Spencer and Welty, 1985), and stratabound uranium and vanadium deposits (Sherbourne and others, 1979; Otton, 1981; Spencer and Welty, 1985). One small area has resource potential for low-temperature geothermal waters. The entire study area has a low potential for oil and gas and deposits of sand and gravel.

Base and Precious Metals

Base- and precious-metal mines and prospects in and adjacent to the Rawhide Mountains Wilderness Study Area have been worked intermittently since the late 1800's and have produced approximately 2,000 tons of ore containing 34 tons of copper, 157 tons of lead, 11.5 tons of zinc, about 10,000 oz of silver, and less than 200 oz of gold (Keith, 1978; Keith and others, 1983a, b). The mineral occurrences are epithermal in character. The mines are developed in the high-angle faults cutting the mylonitic lower-plate rocks (Alamo mineral district), in replacement deposits in carbonate rocks, in epithermal veins in faults, and as veins and replacement minerals in low-angle structures in and above the Buckskin-Rawhide detachment fault (Welty and others, 1985). Low-angle normal fault systems in adjoining ranges are also sites of these types of epithermal deposits (Wilkins and Heidrick, 1982; Spencer and others, 1988).

On the basis of known mineral occurrences within the entire region, all areas along the high- and low-angle faults, particularly where reactive (carbonate) rocks are present, are assigned a moderate mineral resource potential with a certainty level of C for gold, silver, and copper. These areas are in the north half and part of the southwest corner of the study area (fig. 2). Geochemical and thematic mapping data support this assignment. Areas of high resource potential with a certainty level of C for gold, silver, and copper are assigned to areas adjoining known mineral occurrences and including those areas where subeconomic resources have been identified. These areas include those parts of the Alamo mineral district within the west-central part of the study area, the area immediately south of the Big Kimble mine in the northwestern part of the study area, and an area in the north-central part of the study area (fig. 2). Most of the southern part of the study area is assigned a low resource potential with a certainty level of B for gold, silver, and copper.

Manganese

Mines in the Lincoln Ranch mineral district to the west and the Artillery mineral district to the northeast of the Rawhide Mountains Wilderness Study Area, have significant production of manganese (Keith, 1978; Keith and others, 1983a, b). The deposits are along high-angle faults cutting the unmetamorphosed upper-plate rocks or are stratabound in Tertiary sedimentary rocks (Lasky and Webber, 1949; Spencer and Welty, 1985). Upper-plate Tertiary sedimentary rocks occur only in small areas in the study area. Areas located in the southwestern, east-central, northwestern, and northeastern parts of the study area are assigned a moderate resource potential for manganese with a certainty level of C (fig. 2).

Uranium and Vanadium

The Anderson uranium-vanadium mine is located in the Date Creek Basin 15 mi east of the Rawhide Mountains Wilderness Study Area. The deposit occurs in fine-grained sedimentary and volcanic rocks assigned to the middle Tertiary Chapin Wash Formation (Sherbourne and others, 1979; Otton, 1981; Spencer and Welty, 1985). These rocks extend in the subsurface to the northeast edge of the study area and crop out locally there. Volcanic and sedimentary rocks that crop out in the northwestern and southwestern parts of the study area are also broadly correlative with the Chapin Wash Formation. Although there is no known evidence to indicate any uranium or vanadium mineralization, the presence of the appropriate rock units and structures requires that these areas be assigned a low resource potential for uranium and vanadium with a certainty level of B (fig. 2).

Oil and Gas

Despite the presence of a significant number of oil and gas leases or lease applications, the entire Rawhide Mountains Wilderness Study Area is assigned a low resource potential with a certainty level of D for oil and gas. This resource potential level is justified because of the general lack of the usual hydrocarbon-bearing rocks, because the generally thin sections of unmetamorphosed rock are structurally bounded at shallow depths and are underlain by mid-crustal mylonitic rocks, and because much of the exposed terrane is underlain at the surface by the mid-crustal mylonitic rocks.

Geothermal Water

A low resource potential with a certainty level of B is assigned for low-temperature (less than 50 °C) geothermal waters in the northeast corner of the Rawhide Mountains Wilderness Study Area. This designation is based on the presence of geothermal wells and springs about 12 mi northeast of the study area along the Big Sandy River (fig. 1; Witcher and others, 1982; Stone and Witcher, 1982). These springs occur along high-angle faults where waters that have circulated to depths in the crust and were warmed by the normal geothermal gradients come back to the surface under normal hydrologic circumstances (Stone and Witcher, 1982, p. 368). Similar geothermal springs could occur adjacent to the northeast corner of the study area where a buried fault occurs along Sandtrap Wash. There are, however, no surface indications of hot water spring activity in the study area.

Sand and gravel

No known commercial sand and gravel deposits are located near the Rawhide Mountains Wilderness Study Area. In addition, areas of unconsolidated to poorly consolidated alluvial deposits are relatively scarce within the study area. However, a low resource potential with a certainty level of B is assigned to the entire area for sand and gravel.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

- H **HIGH** mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data support mineral-deposit models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.
- M **MODERATE** mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate reasonable likelihood for resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.
- L **LOW** mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics define a geologic environment in which the existence of resources is permissive. This broad category embraces areas with dispersed but insignificantly mineralized rock, as well as areas with little or no indication of having been mineralized.
- N **NO** mineral resource potential is a category reserved for a specific type of resource in a well-defined area.
- U **UNKNOWN** mineral resource potential is assigned to areas where information is inadequate to assign a low, moderate, or high level of resource potential.

LEVELS OF CERTAINTY

- A Available information is not adequate for determination of the level of mineral resource potential.
- B Available information only suggests the level of mineral resource potential.
- C Available information gives a good indication of the level of mineral resource potential.
- D Available information clearly defines the level of mineral resource potential.

LEVEL OF RESOURCE POTENTIAL →

<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td rowspan="4">U/A
UNKNOWN POTENTIAL</td><td>H/B
HIGH POTENTIAL</td><td>H/C
HIGH POTENTIAL</td><td>H/D
HIGH POTENTIAL</td></tr>
<tr><td>M/B
MODERATE POTENTIAL</td><td>M/C
MODERATE POTENTIAL</td><td>M/D
MODERATE POTENTIAL</td></tr>
<tr><td rowspan="2">L/B
LOW POTENTIAL</td><td rowspan="2">L/C
LOW POTENTIAL</td><td>L/D
LOW POTENTIAL</td></tr>
<tr><td>N/D
NO POTENTIAL</td></tr>
</table>

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:

Taylor, R.B., and Steven, T.A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268–1270.

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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
	Paleozoic	Triassic		Late Middle Early	~ 240
		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.

Mineral Resources of Wilderness Study Areas: West-Central Arizona

This volume was published as separate chapters A–G

U.S. GEOLOGICAL SURVEY BULLETIN 1701

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

CONTENTS

[Letters designate the separately published chapters]

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Maps

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

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