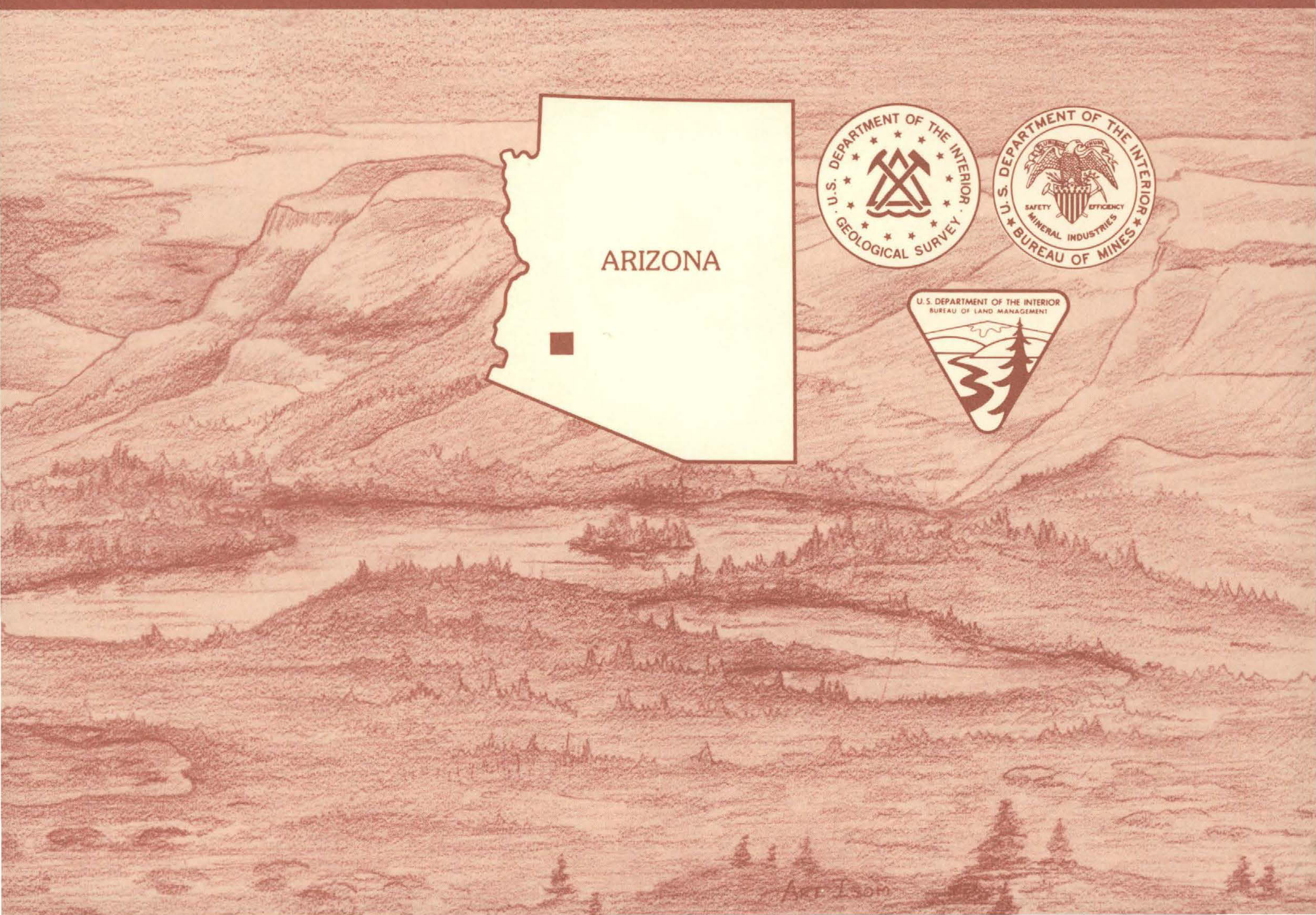
Mineral Resources of the Woolsey Peak Wilderness Study Area, Maricopa County, Arizona

U.S. GEOLOGICAL SURVEY BULLETIN 1702–F



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Chapter F

Mineral Resources of the Woolsey Peak Wilderness Study Area, Maricopa County, Arizona

By JOCELYN A. PETERSON, JERRY R. HASSEMER, DANIEL H. KNEPPER, JR., JAMES A. PITKIN, and WILLIAM F. HANNA
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U.S. GEOLOGICAL SURVEY BULLETIN 1702

MINERAL RESOURCES WILDERNESS STUDY AREAS:
SOUTHWESTERN AND SOUTH-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 on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral resource assessment of part of the Woolsey Peak Wilderness Study Area (AZ–020–142/144), Maricopa County, Arizona.

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Mineral Resources of the Woolsey Peak Wilderness Study Area, Maricopa County, Arizona

By Jocelyn A. Peterson, Jerry R. Hassemer, Daniel H. Knepper, Jr., James A. Pitkin, *and* William F. Hanna
U.S. Geological Survey

John R. McDonnell, Jr.
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SUMMARY

Abstract

The part of the Woolsey Peak Wilderness Study Area (AZ–020–142/144) requested for mineral surveys by the U.S. Bureau of Land Management encompasses 61,000 acres in southwestern Arizona. Throughout this report, reference to the Woolsey Peak Wilderness Study Area or to the study area refers only to that part of the wilderness study area requested for mineral surveys by the U.S. Bureau of Land Management. Fieldwork was carried out during the spring of 1985 and the winters of 1986 and 1987 by the U.S. Bureau of Mines and the U.S. Geological Survey to appraise the known mineral resources and to assess the mineral resource potential (undiscovered) of the study area. Inferred subeconomic resources of common variety rock and sand and gravel are present in the study area, but there are no identified locatable resources within the area even though there are some claims along its boundary. The study area has low resource potential for barite, copper, molybdenum, lead, zinc, silver, and gold in epithermal veins in the southwest and southeast corners of the study area and in a small area about 1 mi northwest of Bunyan Peak. Quartz monzonite on the northeast side of the study area has low resource potential for rare-earth elements such as lanthanum and for thorium and uranium in accessory minerals such as monazite. These rocks also have low resource potential for quartz, mica, and feldspar as well as rare-earth elements, thorium, and uranium in the numerous pegmatites that are present. The east edge of the study area has low potential for gold and platinum-group elements in placers. The entire study area has low potential for copper resources in porphyry deposits on the basis of its regional geologic setting; however, specific data suggestive of a possible porphyry copper deposit are not present. Pumiceous rocks in the southwest corner of the study area have moderate potential for resources of pumice and Apache tears, the latter being primarily a commodity sought by rock collectors. The entire study area has low potential for geothermal energy resources. The area is not considered favorable for the discovery of oil and gas.

Manuscript approved for publication December 28, 1988.

Character and Setting

The Woolsey Peak Wilderness Study Area (AZ–020–142/144) is located about 15 mi northwest of Gila Bend, in southwestern Arizona (fig. 1). The area is in the Sonora Desert section of the Basin and Range physiographic province, a region of large mountain ranges separated by alluvium-filled valleys. The study area is underlain primarily by Tertiary volcanic rocks (see geologic time chart in appendixes) that overlie quartz monzonite and metamorphic rocks of Proterozoic or Mesozoic age. Pediments and basin margins are covered by gravels, and washes contain alluvium.

Identified Resources and Mineral Resource Potential

Other than inferred subeconomic resources of common variety rock and sand and gravel, no mineral resources were identified in the study area. Traces of gold, silver, copper, manganese, niobium, platinum, uranium, and zinc detected in quartz monzonite samples suggest that metallic-mineral concentrations could be present.

The study area has low resource potential for barite, copper, molybdenum, lead, zinc, silver, and gold (fig. 2) in epithermal veins in the volcanic rocks of the southwest and southeast corners of the study area and about 1 mi northwest of Bunyan Peak in an area underlain by pyroclastic rocks and felsic and basaltic flows. The quartz monzonite on the northeast side of the study area has a low resource potential for rare-earth elements such as lanthanum and for thorium and uranium in accessory minerals such as monazite. There is also low resource potential for quartz, mica, and feldspar and for rare-earth elements, thorium, and uranium in numerous pegmatites within quartz monzonite. Alluvium at the east edge of the study area has low resource potential for gold and platinum-group elements in placers, presumably derived from the metamorphic rocks in that area. On the basis of its regional geologic setting, the entire study area has low resource potential for copper in porphyry deposits. However, specific data suggestive of a porphyry copper deposits were not found. The southwest corner of the study area has moderate potential for resources of pumice and Apache tears, the latter being primarily a commodity sought by rock collectors, in the pumiceous rocks of Painted Rock Dam. The entire study area has low potential for geothermal energy resources because of the proximity of warm-water wells and young volcanic rocks. The area is not considered favorable for the discovery of oil and gas.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management (BLM) and is the result of a cooperative effort by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was provided by Beikman and others (1983). The USBM evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, 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

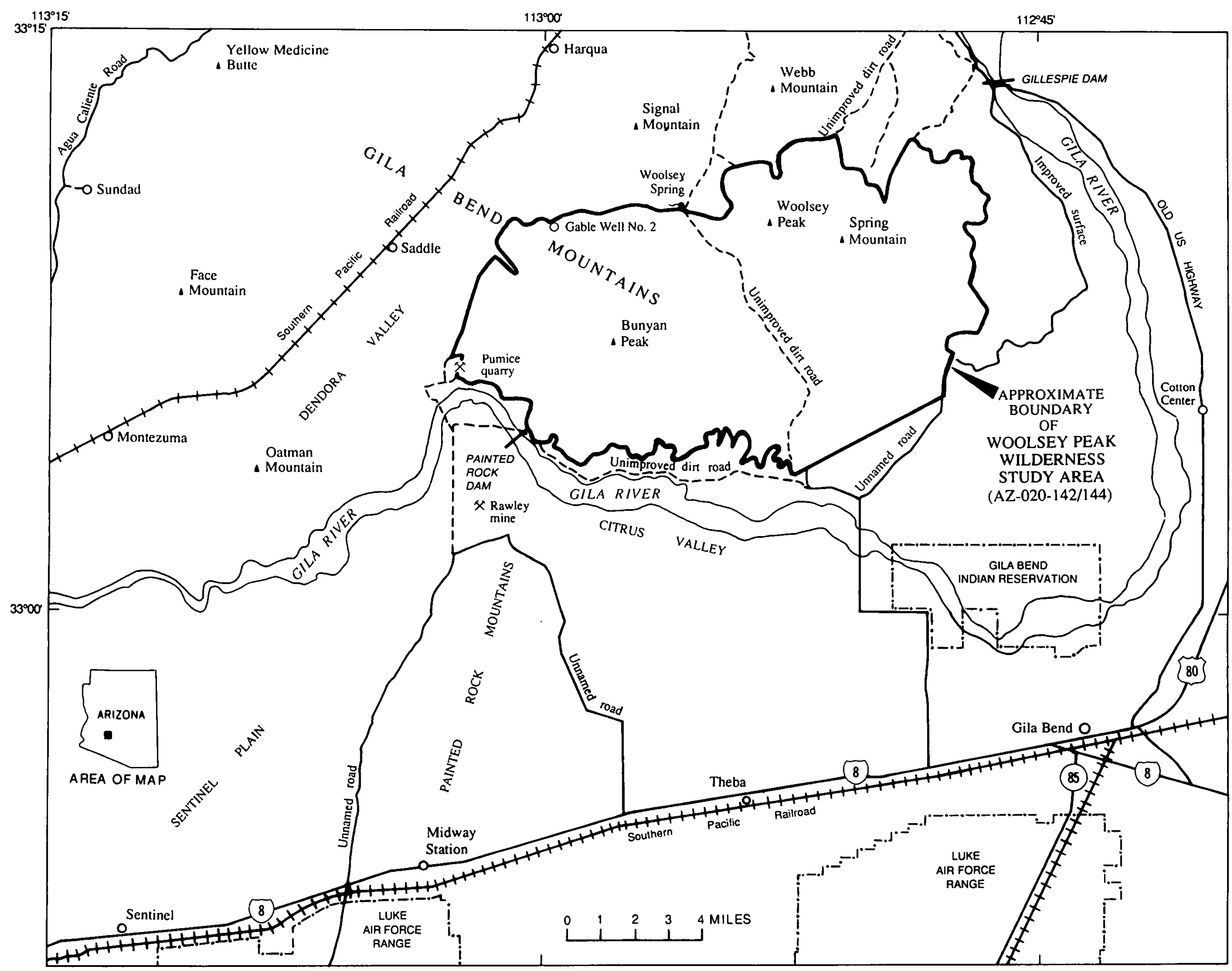

Figure 1. Map showing location of Woolsey Peak Wilderness Study Area, Maricopa County, Arizona.

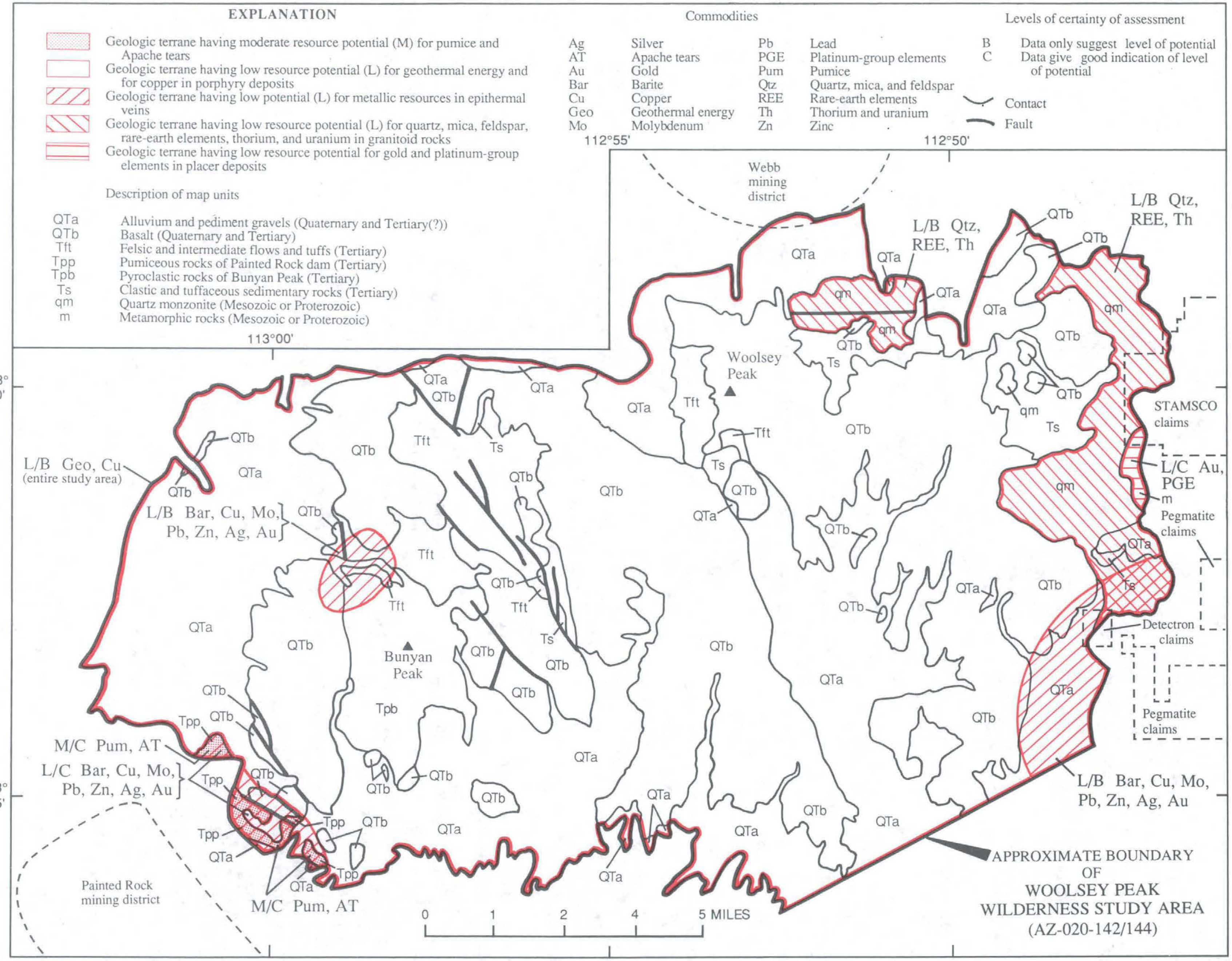

Figure 2. Generalized geology and mineral resource potential of Woolsey Peak Wilderness Study Area, Maricopa County, Arizona.

and U.S. Geological Survey (1980). USGS studies are designed to provide a scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Goudarzi (1984) discussed mineral assessment methodology and terminology as they apply to these surveys. See appendixes for the definition of levels of mineral resource potential and certainty of assessment and for the resource/reserve classification.

The BLM requested mineral surveys on 61,000 acres of the Woolsey Peak Wilderness Study Area (AZ–020–142/144) in southwestern Arizona. The area is located about 15 mi northwest of Gila Bend, Ariz. (fig. 1), in the Sonora Desert section of the Basin and Range physiographic province, where mountain ranges are separated by broad alluviated valleys. The Woolsey Peak study area is in the southeastern part of the Gila Bend Mountains. It is centered around the prominent Woolsey and Bunyan Peaks, where elevations are 3,170 and 2,418 ft, respectively. Elevations along the south boundary adjacent to the Painted Rock Dam are about 600 ft. The area can be reached by unimproved dirt roads from all sides, although access to the interior is poor. The vegetation of the study area is that of the Lower Colorado River Valley subdivision of the Lower Sonoran Desertscrub Biotic Community (Brown, 1982), the largest and most arid of the Sonoran subdivisions. The dominant shrubs in the area include creosotebush (*Larrea tridentata*), incienso (*Encelia farinosa*), and white bursage (*Ambrosia dumosa*). Widely spaced throughout the area are the small paloverde trees: Littleleaf paloverde (*Cercidium microphyllum*) and blue paloverde (*C. floridum*) and their hybrids. Saguaro (*Carnegiea gigantea*) is the dominant columnar cactus in the area; big galleta (*Hilaria rigida*) is the large common grass growing in dense clumps. The Woolsey Peak study area has local populations of wild boar, or javelina (*Dicotyles gajacu*).

Published geologic material about the study area is scant, except for generalized discussions in papers concerned primarily with the water supply of the region (Ross, 1922, 1923; Babcock and Kendall, 1948; Coats, 1952). Cheeseman (1974) reported on the mineral occurrences in the Webb mining district adjacent to the northern part of the study area. Heindl and Armstrong (1963) discussed the geology of the Gila Bend Indian Reservation southeast of the Woolsey Peak area. Concurrent with this study is a study of the Signal Mountain Wilderness Study Area directly adjacent to the north (Gray and others, in press).

The USBM reviewed the literature related to mineral occurrences and mining activity near Woolsey Peak, examined mining claim information and land status plats from the BLM, and studied mineral information and production data obtained from USBM files and other sources. In addition, mines and prospects within 2 mi of the study area were surveyed, mapped, and sampled in 1985 (McDonnell, 1986).

The geology of the study area was mapped in 1986 and 1987 by J.A. Peterson and R.J. Miller, assisted by S.L. Jones (Peterson and others, in press); J.R. Hassemer collected stream-sediment and rock samples for geochemical analysis in 1986. Geophysical interpretations are based on published data.

APPRAISAL OF IDENTIFIED RESOURCES

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

Mining History

The Woolsey Peak Wilderness Study Area is not in any organized mining district, and no mineral production has been recorded from within its boundaries. It lies at the south boundary of the Webb mining district and is 1 mi northeast of the Painted Rock mining district (fig. 2). The Webb district produced a small amount of copper, silver, and gold from mineralized quartz veins and includes bismuth and barium occurrences. The veins are in Proterozoic schist and gneiss that were intruded by granite, diorite, and andesite. The Painted Rock district produced some copper, lead, molybdenum, silver, and gold from quartz and barite veins in Tertiary volcanic rocks. These districts are near the study area, but the mineralized veins are not known to extend into the area.

Placer and lode mining claims are north, east, and southwest of the study area and extend slightly into it along the east boundary. Although no active mining was observed during the USBM's field investigation, preparations were under way on the STAMSCO and contiguous claims (fig. 2) for exploratory drilling for gold and platinum-group elements to begin in late 1986 (Scott Hazen, claimant, oral and written commun., 1985). No activity was observed, however, during USGS field work in January 1987.

Energy Resources

No oil or gas discoveries have been reported in the vicinity, but leases on Federal land are scattered in and near the study area. According to Ryder (1983), the petroleum potential of the region surrounding the study area is "low to zero" on the basis of data from published literature. He concluded that hydrocarbons could accumulate only in the sediment-filled basins of the region and that the reservoir-rock depths are generally too shallow for maturation. The study area is underlain by plutonic and volcanic rocks, which generally do not form reservoirs. Any oil or gas accumulation in nearby sedimentary rocks would have migrated or been destroyed by tectonic and magmatic activity.

No geothermal waters or leasing activity are known in the study area. However, Witcher and others (1982) considered two nearby areas as favorable for the discovery and development of low-temperature (less than 100 °C) geothermal resources: one 4 mi to the east, and the other 12 mi to the southeast at Gila Bend. No thermal springs or wells are known in the study area.

No uranium or thorium has been produced from the study area, but geochemical reconnaissance data and nearby prospecting (McDonnell, 1986) suggest that uranium- and thorium-enriched rocks may be present. The National Uranium Resource Evaluation program collected and analyzed water and stream-sediment samples from the vicinity (Bennett, 1981). Several stream-sediment samples from drainages in the northeastern and southeastern parts of the study area contain uranium and thorium concentrations at or above the regional mean; however, the above-background levels of uranium and thorium for rocks in the eastern part of the study area are well within regional averages.

A uranium-bearing pegmatite deposit was reported by Krason and others (1982, p. 98, 198) on the Detectron and Pegmatite claims (fig. 2). The report, based on correspondence from the claimant to the BLM, includes assay values from "representative samples" of the pegmatite that range from 0.085 to 0.12 percent uranium oxide (U_3O_8) (BLM file data). Three samples collected across the pegmatite by the USBM contain 5.5–29 parts per million (ppm) (0.00055–0.0029 percent) U_3O_8.

Mineral Appraisal

Occurrences of gold, silver, lead, niobium, platinum-group elements, tantalum, thorium, titanium, uranium, and yttrium have been reported in faults, pegmatite dikes, and quartz monzonite within 1 mi of the study area's east boundary (Krason and others, 1982; BLM file data; Scott Hazen, claimant, oral and written commun., 1985).

Thirty-five chip, select, grab, and stream-sediment samples, including five from inside the study area, were collected by the USBM from workings and mineralized areas. Selected samples were analyzed by fire assay for gold and silver, by fire assay combined with inductively coupled plasma–atomic emission spectrometry (ICP) for gold, silver, palladium, and platinum, by atomic absorption spectrophotometry for lead, by X-ray fluorescence for niobium and tantalum, by ICP for copper, manganese, lead, and zinc, and by fluorimetric analysis for uranium (McDonnell, 1986). All samples were analyzed by semiquantitative optical emission spectrography for 40 elements (McDonnell, 1986). Complete analytical data are available at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

Samples from the faults and pegmatites in the quartz monzonite contain traces to low values of gold, silver, copper, lead, manganese, niobium, platinum, uranium, and (or) zinc. However, exposures were insufficient and the values too erratic to make resource estimates.

Common variety rock and sand and gravel are abundant and can be classed as inferred subeconomic resources. These commodities have no unique features and adequate resources are available closer to markets.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Jocelyn A. Peterson, Jerry R. Hassemer,
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William F. Hanna
U.S. Geological Survey

Geology

The Woolsey Peak Wilderness Study Area is underlain by volcanic rocks of Tertiary and Quaternary age and by quartz monzonite and metamorphic rocks of Proterozoic or Mesozoic age (Peterson and others, in press). Many pediments in the study area are covered by gravel and the washes contain alluvium.

Metamorphic rocks and quartz monzonite crop out primarily in the northeast quarter of the study area. The metamorphic rocks are schists derived from sedimentary and volcanic rocks. They contain mostly quartz, feldspar, and biotite and are found between the STAMSCO and Pegmatite claims (fig. 2). There has been some prospecting along copper-bearing veins in the metamorphic rocks. Fine- to coarse-grained equigranular quartz monzonite crops out extensively along the east margin of the study area and at one locality along the north margin. It is composed of plagioclase, potassium feldspar, quartz, and either biotite or muscovite locally. The quartz monzonite is intruded by numerous pegmatites and has quartz veins and epidote veinlets. The pegmatites increase in abundance to the south, and prospecting has occurred where a copper-oxide coating is seen on fracture surfaces and in small veinlets.

A poorly consolidated sequence of clastic and tuffaceous sedimentary rocks is interbedded with volcanic units in the northeast quarter of the study area and in small exposures elsewhere. The sequence consists of a heterogeneous mix of thin beds of alternating clastic and tuffaceous sedimentary rocks and includes one thin andesite flow. These rocks may correlate with the Sil Murk Formation found about 6 mi southeast of the study area (Heindl and Armstrong, 1963).

Peterson and others (in press) mapped six main volcanic units within the study area. Andesitic pyroclastic rocks that underlie Bunyan Peak in the west-central part of the study area form a heterogeneous sequence of large-clast flow breccia, flows, and crystal-lithic tuffs. Rhyolitic pumice breccias and minor interbedded rhyolite flows, presumably related to rocks in the Painted Rock Mountains to the south, crop out in the southwest corner of the study area. The breccias contain mostly pumice and some obsidian. In the north-central part of the study area, intermediate to felsic tuffs and flows are characterized by the presence of hornblende phenocrysts as well as feldspar and quartz phenocrysts in an aphanitic groundmass or matrix. The three basalt flows mapped by Peterson and others (in press) are combined as unit QTb in this study (fig. 2). The basalts are all similar texturally and compositionally and are distinguished primarily by stratigraphic position and degree of weathering, although weathering in the younger Tertiary basalt and the Quaternary basalt is similar. These basalts underlie much of the study area and form most of the prominent ridges.

Gravels of Tertiary(?) and Quaternary age are widespread on the pediments adjacent to the mountain ranges. In the mountains, large areas of talus flank the basalt flows. Washes contain poorly sorted alluvium.

The area has a generally northwest-trending structural grain seen in the orientations of many of the mountain crests, in the strike of many of the faults, and in the strike and dip of tilted volcanic rocks. This grain reflects the basin-and-range faulting that created the Gila Bend Mountains and other ranges of southwestern Arizona. Faults and foliation that developed in the older crystalline rocks do not follow the prominent regional trend and presumably predate its development.

Geochemistry

A reconnaissance geochemical survey of the Woolsey Peak Wilderness Study Area, conducted in 1986, includes the study area, the Webb mining district to the north, and the Painted Rock mining district to the south. The USGS collected 74 sieved stream-sediment samples, 64 nonmagnetic heavy-mineral-concentrate samples, and 19 raw-concentrate samples from first-, second-, and third-order stream drainages. Sample density was about one site for each square mile in the northwestern part of the area, where some rhyolitic intrusions are present, and in the eastern part, where Proterozoic or Mesozoic rocks crop out. In basaltic terrain, sample density was about one site for every 2 mi^2, whereas broad alluvial fans were sampled about every 4 mi^2. In addition, 22 rock and 2 water samples were collected. Data from the National Uranium Resource Evaluation (NURE) program (Bennett, 1981) were also used in the geochemical evaluation. Most samples collected in that study are from outside the study area but provide regional geochemical information for uranium and thorium.

In both the USGS and the NURE studies, stream-sediment material was seived to minus-100 mesh and the fine fraction was retained for analysis. Each nonmagnetic heavy-mineral concentrate sample was panned from a composite sample of stream sediment to an approximate composition of half dark-colored (heavy) and half light-colored minerals by using standard gold-panning techniques. This concentrate was then processed further through a heavy liquid and a magnetic separator to obtain a nonmagnetic heavy-mineral concentrate for analysis. The raw-concentrate sample was obtained by panning another, somewhat larger, sample of stream sediment until the sample was reduced to nearly 100 percent heavy minerals. The resulting raw-concentrate samples ranged from 15 to 65 grams (g) from most of the study area but were 150 to 1,200 g from the east side. A small split of sample material weighing about 0.1 g was used for spectrographic analysis; the rest of the sample was analyzed for gold and platinum. Rock samples were crushed, pulverized, and analyzed.

All sediment and rock samples were analyzed for 31 elements by a semiquantitative six-step, direct-current arc, optical emission spectrographic method (Grimes and Marranzino, 1968). Rock samples were also analyzed for arsenic, antimony, bismuth, and cadmium by an inductively coupled plasma–atomic emission spectroscopic method (Crock and others, 1987). The minus-100-mesh stream sediments were analyzed for uranium and thorium by neutron activation method (Millard and Keaton, 1982) and for 40 elements by another inductively coupled plasma–atomic emission spectroscopic method (Lichte and others, 1987). Raw-concentrate samples were analyzed for gold and platinum by atomic absorption spectroscopy (J.R. Hassemer, undocumented method modified from Thompson and others, 1968, and Swider, 1968).

Many of the elements analyzed are anomalous in one or more of the sample media. Antimony, cadmium, gold, and platinum-group elements were found in samples from mines and prospects adjacent to the study area. On the basis of geochemical data from rock samples collected at nearby mines and prospects, arsenic, barium, copper, lead, silver, and zinc are the best indicators that epithermal deposits could be anticipated in the study area.

Raw-concentrate samples contain (1) anomalous concentrations of manganese and vanadium throughout the study area, (2) weakly anomalous concentrations of copper, cobalt, chromium, and nickel in the northern and central parts of the study area, and (3) weakly anomalous concentrations of niobium in the northern part. Because these concentrations are near those determined as anomalous, little significance is given to them unless other elements, or elements in other media, are also anomalous. These near-threshold-level anomalies most likely reflect the widespread alteration and mineralization in the Proterozoic or Mesozoic rocks and the influence of rock types such as basalt.

Nonmagnetic-concentrate samples from the east boundary and outside of the study area commonly contain anomalous thorium (500–2,000 ppm), possibly in accessory thorite or monazite in the quartz monzonite, tungsten (70–1,500 ppm) in scheelite, and yttrium in an undetermined mineral, possibly monazite. These anomalies suggest that the quartz monzonite and associated pegmatites are permissive for concentrations of various metallic commodities. Samples collected from quartz monzonite within the northeastern part of the study area did not yield anomalous concentrations of these elements. Some samples from the southeast corner have anomalous barium (5,000 to more than 10,000 ppm), bismuth (200 to more than 2,000 ppm), molybdenum (10–200 ppm), lead (200–1,500 ppm), and weakly anomalous tin (10–150 ppm). One rock sample collected from that area contains 15 ppm molybdenum, 300 ppm lead, and less than 200 ppm zinc; another rock sample contains 150 ppm lead. These anomalies suggest that the crystalline rocks in the southeast corner of the study area have been overprinted by a weak hydrothermal system containing the anomalous elements. Stream-sediment samples collected just east of the study area show weakly anomalous concentrations of rare-earth elements (cerium, europium, and neodymium), which probably are contained in an accessory mineral weathered from the quartz monzonite.

Rare-earth-element concentrations are also high in the west-central part of the study area northwest of Bunyan Peak. Anomalous arsenic (20 ppm), barium (1,400 ppm), copper (110 ppm), vanadium (220 ppm), and zinc (140 ppm) were also found in one stream-sediment sample from this area, and arsenic (10 ppm) was found in another stream-sediment sample. The samples are from drainages that erode the pyroclastic rocks of Bunyan Peak and the nearby felsic volcanic rocks. Because samples from other streams draining these units do not have anomalous element concentrations, the geochemically anomalous samples must represent localized mineralization.

Low-level arsenic (10 ppm) and lead (62 ppm) anomalies in stream sediment collected near the pumiceous rocks of Painted Rock Dam are probably related to the same hydrothermal system that formed epithermal veins in the volcanic sequence of the Painted Rock Mountains. However, in the study area these rocks are not visibly altered.

No anomalous uranium was found in stream-sediment samples. Only a few samples exceeded 5 ppm uranium and none exceeded 10 ppm. Water samples from Woolsey Spring and Gable Well No. 2 did not exceed 2 parts per billion uranium. NURE results also indicate a lack of uranium anomalies (Bennett, 1981). A weakly anomalous uranium concentration (29 ppm) was reported for a pegmatite sample (McDonnell, 1986) collected near the southeast corner of the study area; however, a NURE sample collected about 1 mi downstream showed only 2.6 ppm uranium (Bennett, 1981). Thus, geochemical data do not indicate uranium deposits in the study area.

Geophysics

Gravity and Magnetic Data

The Woolsey Peak Wilderness Study Area is covered by regional gravity (Lysonski and others, 1980a, b; Aiken, 1976; Aiken and others, 1981) and detailed aeromagnetic (U.S. Geological Survey, 1987) surveys, collectively having sufficient resolution to define anomalies of a few square miles or larger. Contours of complete (terrain-corrected) Bouguer gravity anomalies are defined by about 25 gravity stations, all of which are near the periphery of the study area (fig. 3). Contours of aeromagnetic anomalies are defined by horizontal gradiometer measurements made along 21 east-west flightlines spaced about 0.5 mi apart at a mean terrain clearance of 1,000 ft. The gradiometer data, derived from a triad of magnetometers mounted on the aircraft wingtips and tail, were used to produce a gradient-enhanced total-field aeromagnetic anomaly map (fig. 4).

The Bouguer gravity anomaly map (fig. 3) is dominated by a westward-increasing prominent gradient over the east half of the study area, a saddle-shaped high immediately west of this gradient, and a subtle low at the west end of the area. The gradient is inferred to be caused by

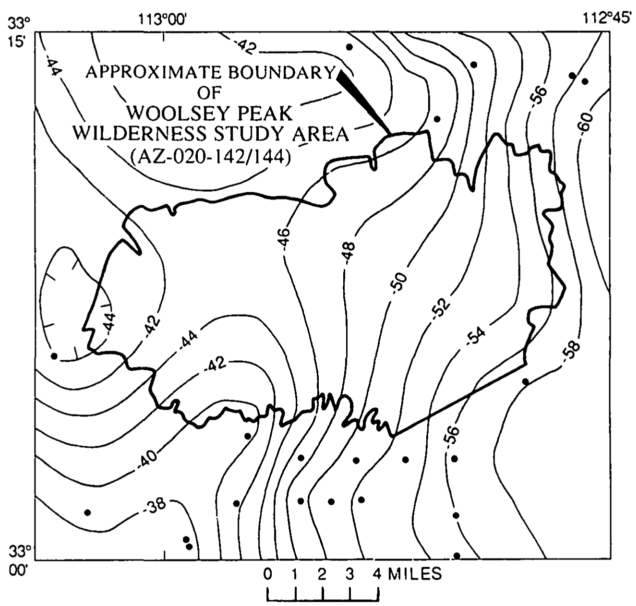

Figure 3. Bouguer gravity anomaly map of Woolsey Peak Wilderness Study Area, Maricopa County, Arizona. Contour interval 2 milligals; hachures indicate closed areas of lower anomaly values. Dots represent gravity observation points.

a crustal boundary that separates a broad terrane containing abundant low-density basin fill to the east from higher density, mostly buried metamorphic rocks to the west. The saddle-shaped high appears to be a residual anomaly, also associated with the metamorphic rocks, formed in relation to the neighboring low to the west. This low is associated with low-density gravel and alluvium.

The magnetic anomaly map (fig. 4) is dominated by several clusters of large-amplitude short-wavelength highs in the east half of the study area, one small-amplitude long-wavelength high in the southwestern part of the study area, and one large-amplitude low in the northwest corner. Magnetic measurements of nine unoriented (with respect to north) rock samples of mapped units indicate that five of the units are sufficiently magnetic to generate these anomalies.

The clusters of magnetic highs in the east half of the study area are associated principally with exposed basaltic units and quartz monzonite. The arcuate anomalies suggest a geometry commensurate with volcanic vents. In the area of Woolsey Peak, the basalt is 1,500 ft thick, estimated on geologic parameters, which agrees well with the anomaly of 1,500 nanoteslas amplitude, which is what is expected from modeling using measured magnetization. Where exposed magnetic rocks lack anomalies, we may infer one or more alternatives: the rocks may be thin and weathered and contain felsic phases, or they may be unusually magnetized (for example, a reversed magnetization may effectively cancel an induced magnetization). In the study area, we infer that the principal causes are thin volcanic rocks and felsic phases in underlying plutonic rocks. The broad magnetic high in the southwestern part of the study area is probably caused by buried basalt. The broad magnetic low in the northeast sector is enigmatic. Because of its large amplitude relative to surrounding features, it is possibly caused by reversely magnetized mafic rocks that may represent feeders to part of the basaltic pile.

Landsat Thematic Mapper Images and Interpretation

Two Landsat Thematic Mapper (TM) color-composite spectral images for evaluating potential hydrothermal alteration were prepared for this study: a color-infrared composite (CIR), and a color-ratio composite (CRC), both at approximately 1:150,000 scale. The CIR was used as an indirect measure of the albedo (brightness) of the rocks associated with potential alteration targets; the only such targets seen on the resulting map are associated with relatively bright rocks. The CRC image indicates some general mineralogical characteristics of the rocks and soils of the area.

Because much of the bedrock in the quadrangle is volcanic, many of the potential alteration targets may be associated with local volcanic processes or weathering rather than with mineralization. Areas of silicic alteration cannot be detected using this technique.

Potential alteration targets occur in two clusters in the northern part of the study area. The westernmost cluster is associated with a pattern distinctive of limonite; the targets represent apparent local concentrations of limonite. The eastern cluster, about 1 mi east of Spring Mountain (fig. 1), shows the presence of limonite and minerals of the clay group. Field examination of these targets indicated that most of them lie within or enclose outcrops of clastic and tuffaceous sedimentary rocks that have not been hydrothermally altered. The TM spectral-image data did not locate any unknown potentially mineralized areas within the study area.

Aerial Gamma-ray Spectrometry

Aerial gamma-ray spectrometry measures the near-surface (less than 2 ft deep) distribution of 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 understanding of geologic processes.

The spectrometry data were obtained between 1974 and 1981 for the NURE program of the U.S. Department of Energy (1979). Four flightlines, 400 ft above ground level, covered the study area: lines approximately along the north and south borders and two lines between them. Spectrometry data that include the study area are presented on radioelement contour maps and color-composite image maps (Duval, 1983) at scales of 1:500,000 and 1:1,000,000. The data described below were derived from the NURE report for the Phoenix 1° by 2° quadrangle (U.S. Department of Energy, 1979).

Radioelement maps that include the Woolsey Peak Wilderness Study Area show two distinct regions. In the eastern one-third of the study area, concentrations of 3 to 3.5 percent K, 6 to 8 ppm eU, and 9 to 10 ppm eTh reflect the more radioactive quartz monzonite and metamorphic rocks. Concentrations of 1 to 1.5 percent K, 2 to 3 ppm eU, and 2 to 6 ppm eTh in the western two-thirds of the area are related to the less radioactive volcanic rocks and alluvial material. The concentrations are not anomalous for the rocks in the study area. Mapping of any concentrations is controlled by the location of the NURE flightlines, and the sparse flightline coverage of the study area precludes deriving specific information on mineral resource potential from the aerial gamma-ray data.

Mineral and Energy Resources

Several types of mineral deposits are adjacent or close to the study area, including copper, silver, and gold veins of the Webb mining district directly north of the area, copper-lead-molybdenum-barite epithermal vein deposits in

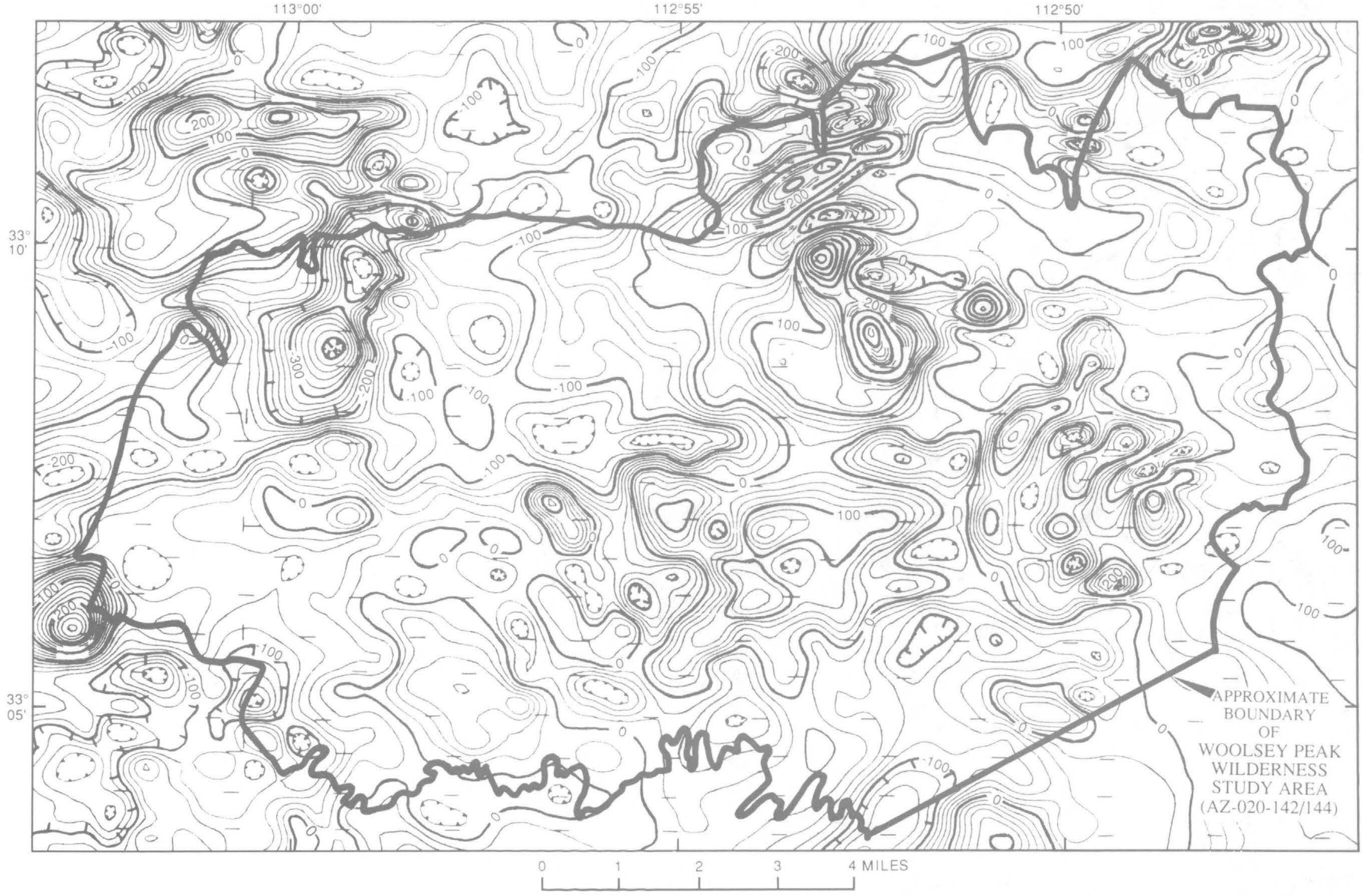

Figure 4. Aeromagnetic anomaly map of Woolsey Peak Wilderness Study Area, Maricopa County, Arizona. Contour intervals 20 (light) and 100 (bold) nanoteslas; hachures point toward closed areas of lower magnetic intensity. Dashed lines represent flightline traces.

the Painted Rock Mountains south of the area, and pegmatites and placer claims east of the area. Geologically similar parts of the study area are permissive for such deposits, but abundant mineralization was not seen during the reconnaissance field studies.

Barite, Copper, Molybdenum, Lead, Zinc, Silver, and Gold in Epithermal Veins

Two different kinds of epithermal vein deposits are present adjacent to the study area. The Webb district contains copper, silver, and gold veins in pre-Tertiary metamorphic rocks. The epithermal vein deposits in the Painted Rock Mountains are found in Tertiary volcanic rocks. Largest of the veins is at the Rawley mine where molybdenum, lead, and barite have been the primary commodities produced (Stewart and Pfister, 1960). Veins similar to those of the Webb district could be present in both the quartz monzonite and metamorphic rocks within the study area, and several veins containing chrysocolla are known to be present in the area. Geochemical evidence indicates that a hydrothermal system may have affected the southeast corner of the area, which is underlain by quartz monzonite. This area has a low resource potential for barite, copper, molybdenum, lead, zinc, silver, and gold, certainty level B. Rocks of the Painted Rock Mountains consist of rhyolitic pumice breccias and are exposed in the southwest corner of the study area. Although there was no visual evidence of epithermal veins, these rocks have a low resource potential for barite, copper, molybdenum, lead, zinc, silver, and gold in epithermal vein deposits, certainty level C, because of weak geochemical anomalies for lead and arsenic. An area about 1 mi northwest of Bunyan Peak has geochemical anomalies indicative of hydrothermal activity, so the area has low resource potential, certainty level B, for barite, copper, molybdenum, lead, zinc, silver, and gold in epithermal deposits.

Commodities Associated with Quartz Monzonite

Pegmatite dikes form pronounced light-colored linear features in the quartz monzonite in and southeast of the study area. They are composed primarily of quartz with subordinate muscovite and rarely feldspar. Some of the pegmatites elsewhere in Arizona have been mined for these minerals (Keith, 1974). This study area is south of the main region of pegmatites in Arizona, where complex and rare minerals have been found. Nevertheless, nearby prospects for uranium (McDonnell, 1986) suggest that the pegmatites or accessory monazite in the host quartz monzonite may contain anomalous amounts of uranium, thorium, and (or) rare-earth elements. The aerial gamma-ray data also suggest the presence of slightly higher concentrations of uranium and thorium in quartz monzonite on the northeast side of the study area. Therefore, in the northeastern part of the study area the resource potential is low for quartz, mica, and feldspar in pegmatites within the quartz monzonite, certainty level B, and is also low, certainty level B, for uranium, thorium, and rare-earth elements in both the pegmatites and the enclosing quartz monzonite.

Placer Gold and Platinum-group Elements

Placer claims adjacent to the study area are inactive, although there were plans to begin a drilling operation on one of them (McDonnell, 1986). There does not appear to have been production from any of these claims. Analyses of samples collected at claims east of the study area show low levels of gold, silver, niobium, platinum-group elements, and uranium. These elements probably weathered out of the quartz monzonite and metamorphic rocks adjacent to the placer accumulations. The source of the platinum is uncertain; it may have been derived from metasedimentary rocks that received the platinum as a depositional product from an unknown source. Numerous pediments in the study area are covered by a thin layer of gravel. Most of these gravels are derived from basaltic rocks, but, along the east border of the study area, pediment gravel and alluvium that are underlain by or adjacent to quartz monzonite could possibly contain minor accumulations of these elements. Therefore, pediments adjacent to older rocks along the east border of the study area have a low resource potential for gold and platinum-group elements in placer deposits, certainty level C.

Other Commodities

The Woolsey Peak Wilderness Study Area lies northwest of the major porphyry copper deposits of Arizona, but in recent decades new deposits have been found beneath pediments. No alteration characteristic of porphyry copper deposits was seen in the study area, but the crystalline rocks do have small copper occurrences. The study area is permissive, then, for a buried porphyry copper deposit on the basis of the regional geologic setting and has a low potential, certainty level B, for copper in porphyry copper deposits.

Three of the rock units within the study area contain pumice lapilli, at least locally, although the pumice usually constitutes only a small amount of the total rock volume. Isolated occurrences of nearly 100 percent pumice are present in exposures of the clastic and tuffaceous sedimentary rocks (Ts) and the pumiceous rocks of Painted Rock Dam (Tpp) units. Small amounts of pumice from the pumiceous rocks of Painted Rock Dam have been removed from a pit just outside the southwest boundary of the study area. The rocks within this unit have a moderate potential for pumice, certainty level C.

In addition to pumice, the rocks by Painted Rock Dam locally contain Apache tears, which are sought by rock collectors. According to several rock collectors we talked to at the site, most of these particular Apache tears are rather small, but occasionally larger ones can be found. They are only known from one outcrop, but they may be present in other parts of the unit where obsidian is abundant. The pumiceous rocks of Painted Rock Dam (Tpp) have a moderate resource potential for Apache tears, certainty level C.

Energy Resources

The Woolsey Peak study area is surrounded by four sedimentary basins that contain warm-water wells and springs. These include the large Agua Caliente-Hyder area about 25 mi to the west, an area north of Cotton Center about 5 mi to the east, an area north of Gillespie about 15 mi to the north, and a small area centered in Gila Bend (Witcher and others, 1982). Such sedimentary basins, however, are not in the study area. The relatively recent eruption of basalt from Woolsey Cone (Peterson and others, in press) suggests that above-average temperatures may be present beneath the area. Because there are no known hot springs or basins in the study area, however, the resource potential for geothermal energy is low, certainty level B.

Although the area has some oil and gas leases (McDonnell, 1986), there have been no discoveries near the study area and Ryder (1983) rates the area as having low to zero potential. Because the study area is underlain by crystalline rocks and basalt, it has no potential for oil and gas resources, certainty level D.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

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

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

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

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

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

LEVELS OF CERTAINTY

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

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 →

Abstracted with minor modifications from:

Taylor, R.B., and Steven, T.A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268-1270.
Taylor, R.B., Stoneman, R.J., and Marsh, S.P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40-42.
Goudarzi, G.H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-0787, p. 7, 8.

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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U. S. DEPARTMENT OF THE INTERIOR

March 3, 1849

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