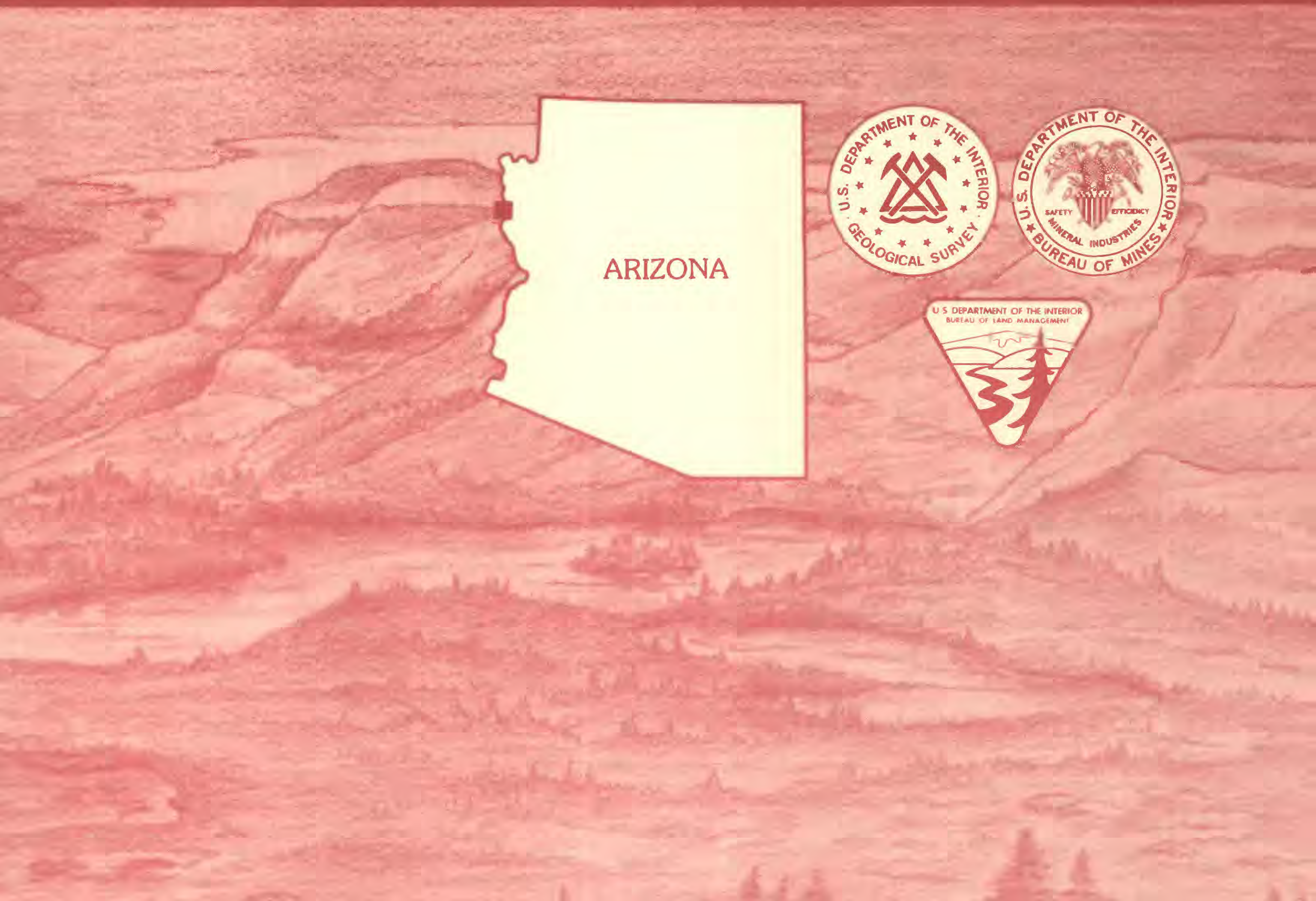
Mineral Resources of the Mount Nutt Wilderness Study Area, Mohave County, Arizona

U. S. GEOLOGICAL SURVEY BULLETIN 1737–D



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Chapter D

Mineral Resources of the Mount Nutt Wilderness Study Area, Mohave County, Arizona

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U.S. GEOLOGICAL SURVEY BULLETIN 1737

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
BLACK MOUNTAINS REGION, 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 survey of part of the Mount Nutt Wilderness Study Area (AZ–020–024), Mohave County, Arizona.

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Mineral Resources of the Mount Nutt Wilderness Study Area, Mohave County, Arizona

By Floyd Gray, Robert C. Jachens, Robert J. Miller, Robert C. Turner, Eric K. Livo, Daniel H. Knepper, Jr., *and* John Mariano
U.S. Geological Survey

Carl L. Almquist
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SUMMARY

Abstract

The Mount Nutt Wilderness Study Area (AZ–020–024) is located in the Black Mountains about 15 mi west of Kingman, Arizona. At the request of the U.S. Bureau of Land Management, approximately 27,210 acres of the wilderness study area was evaluated for mineral resources (known) and mineral resource potential (undiscovered). In this report, the area studied is referred to as the "wilderness study area" or simply "the study area;" any reference to the Mount Nutt Wilderness Study Area refers only to that part of the wilderness study area (27,210 acres) for which a mineral survey was requested. The U.S. Geological Survey and the U.S. Bureau of Mines conducted geological, geochemical, and geophysical surveys to assess the identified mineral resources and mineral resource potential of the study area. Fieldwork for this report was carried out in 1987 and 1988. A gold resource totaling at least 56,000 troy oz has been identified at two sites in Secret Pass Canyon, less than 0.5 mi north of the study area. No other metallic mineral resources were identified inside the study area. An area near the center of the study area contains fire agate, a gem stone. On the basis of tonnage, site accessibility, and current production methods, this area is considered an indicated subeconomic fire-agate resource for the foreseeable future. Sand and gravel are present in the study area. An area surrounding the Tincup mine and including a small portion of the extreme north-central part of the study area has high potential for gold and low potential for silver, lead, and mercury. Three areas in the extreme northwestern, north-central, and southwestern parts of the study area have moderate potential for gold and low potential for silver, lead, and mercury. A small area near the known fire-agate resource in the south-central part of the study area has low potential for fire agate. Large areas in the eastern and central parts of the study area have low potential for perlite and zeolite resources. The entire study area has no potential for oil and gas and no potential for geothermal resources.

Character and Setting

The Mount Nutt Wilderness Study Area is located just north of the town of Oatman, Arizona, approximately 15 mi west of Kingman, Arizona (fig. 1). It is situated between Arizona Highway 68 and old U.S. Highway 66. The study area has a total relief of about 3,000 ft; the highest points in the study area are an unnamed peak (Benchmark Nutt, 5,216 ft) and Mount Nutt (5,062 ft). The benchmark lies approximately 1 mi northeast of Mount Nutt. These peaks are surrounded by precipitous cliffs, small mesas, rough slopes, and several steep-walled canyons, the deepest of which is Grapevine Canyon. The area is underlain by Proterozoic (see "Appendixes" for geologic time chart) granite and gneiss that is overlain by or in fault contact with Tertiary volcanic rocks and Holocene sand and gravel. Small late Miocene rhyolitic intrusive bodies cut the older Tertiary rocks in several places in the study area and are typically associated with localized alteration. Volcanic rocks in the study area are cut by numerous, dominantly north-trending high-angle normal faults. Dilatant zones resulting from the intersections of these faults or from curved fault planes served to localize any hydrothermal alteration and gold mineralization that may have occurred.

Manuscript approved for publication, April 27, 1990.

Identified Mineral Resources

A gold resource totaling at least 56,000 troy oz was identified by Fischer-Watt Gold Co., Inc., at two sites in Secret Pass Canyon, one site just east of the study area and the other less than 0.5 mi north of the study area. A block of mining claims was located near the center of the study area for fire agate, a gem stone. Hand-sorted specimens, averaging $30–100 per lb and rarely $1,000 or more, have been extracted from the site. On the basis of a rough size estimate, current production methods, and site accessibility, this deposit will be an indicated subeconomic fire-agate resource for the foreseeable future. Sand and gravel in the study area have no qualities that would make them more valuable than abundant supplies available from established sources closer to existing markets.

Mineral Resource Potential

Geologic, geochemical, and geophysical studies show that the Mount Nutt Wilderness Study Area has an area with high potential for gold and low potential for silver, lead, and mercury in the north-central part of the study area. Three areas in the northwestern, southwestern, and north-central parts of the study area have moderate potential for gold and low potential for silver, lead, and mercury resources (fig. 2). That these areas are predominantly underlain by fractured, veined, and altered volcanic rocks suggests volcanic-hosted gold deposits may be present. The areas are cut by mostly north- to northwest-trending faults with localized areas of thin, irregular stockwork veins consisting of calcite and minor amounts of quartz; limonite staining and localized illitic alteration characterize the stockwork. Anomalous concentrations of elements including barium, silver, and lead and smaller concentrations of mercury and arsenic were detected in stream sediments collected from drainages in these areas. Gold was consistently detected in rock samples from shears and fault zones within Secret Pass Canyon.

Occurrences of gem-quality fire agate have been reported from a locality in the south-central part of the study area within rhyolite flows, but the potential for undiscovered agate resources is low in the region surrounding the known deposit.

Zeolite and perlite occur locally in the upper part of the volcanic section associated with thick tuff intervals and rhyolite flows, flow breccias, and intrusive bodies throughout the study area. Large areas in the central and eastern parts of the study area underlain by these volcanic rocks have low potential for perlite and zeolite resources. However, the low grade and difficult access to these perlite- and zeolite-bearing beds in the study area would hinder development of these commodities.

The oil and gas resource potential of the study area was considered by Ryder (1983) to be low to zero. In this region, hydrocarbon source or reservoir rocks are limited to Tertiary and (or) Quaternary sedimentary basins that flank the mountain ranges. Within the study area, a Proterozoic schist, gneiss, and granite unit crops out or underlies expo-

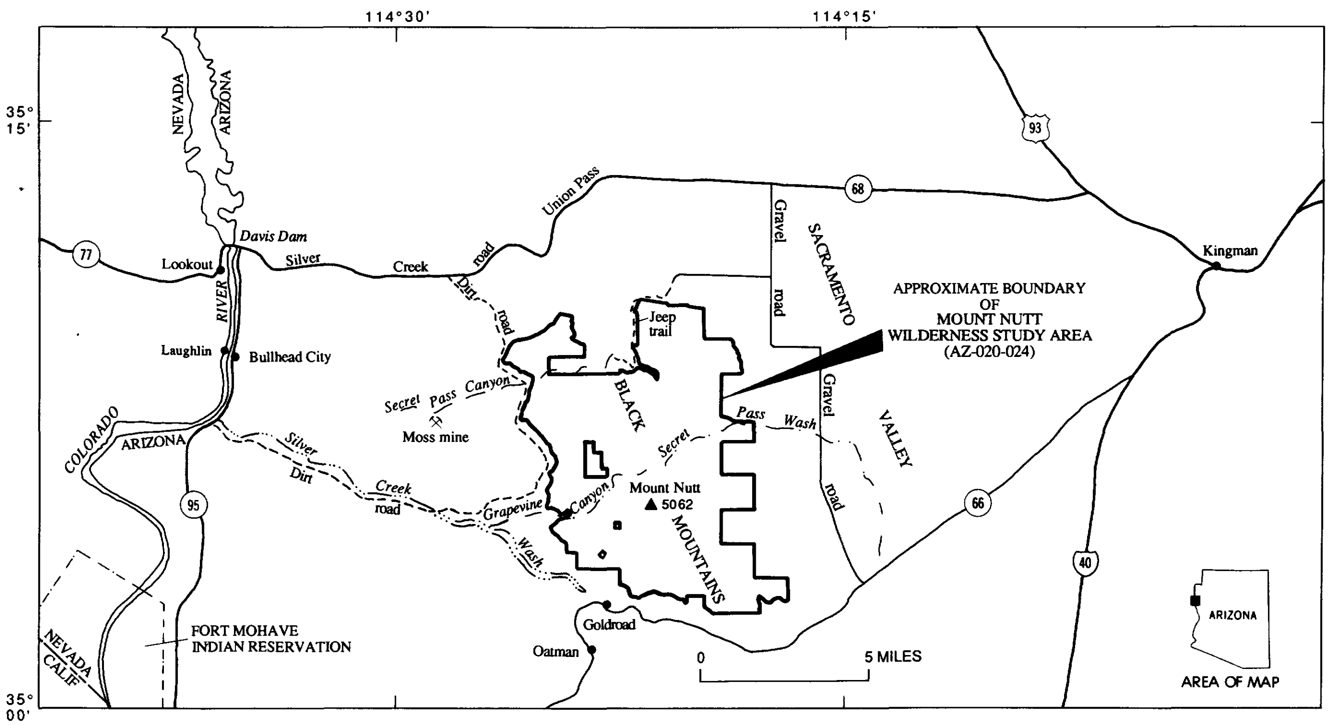


Figure 1. Index map showing location of Mount Nutt Wilderness Study Area, Mohave County, Arizona.

sures of Tertiary volcanic rock at shallow depths. Therefore, there is no resource potential for oil and gas within the study area.

There is no potential for undiscovered geothermal energy within the study area because well temperatures (approximately 30 °C) from the surrounding area are average for this region of the Basin and Range province (Bliss, 1983).

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). 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. 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.

Area Description

The Mount Nutt Wilderness Study Area (AZ–020–024) covers approximately 27,210 acres in the desert highlands 15 mi west of Kingman and 8 mi east of the Colorado River. The terrain of the study area is rugged, rising from about 2,300 ft along the west side to sharp peaks above 5,000 ft with precipitous cliffs and rocky canyons. Grapevine Canyon is the deepest and most spectacular canyon and is over 1,000 ft deep at its east end. The Mount Nutt Wildernes Study Area lies in the Mohave desertscrub biome of the Warm-Temperate Desertland Biotic Community (Brown, 1982). The vegetation of the study area is dominated by the shrubs and cacti that are typical of southwest desert biomes. However, this study area also contains local areas of the Great Basin desertscrub biome. The dominant shrubs in the study area are Mohave indicators, such as creosotebush (*Larreo tridentata*),white bursage (*Ambrosia dumosa*), brittlebush (*Encelia fairnosa*), and all-scale (*Atriplex polycarpa*); the Yucca (*Yucca* spp.) is the characteristic Mohave tree that flourishes in the study area. The Mohave desertscrub is especially rich in ephemeral plants, many of which are endemic to the biome. Cholla (*Opuntia* spp.) and other cacti are well represented in the study area and are common in the large spaces between the shrubs. Many of these cacti are endemic to the Mohave biome. Local areas of the Great Basin desertscrub biome contain California juniper (*Juniperus californica*), sagebrush (*Artemisia* spp.), and Torrey joint-fir (*Ephedra torreyana*). The area contains several species of lizards, small mammals, and birds. Rattlesnakes and desert tortoise are native to the study area. Other wildlife including deer, bobcat, kit fox, cottontail, and jack rabbit inhabit the region; the northern part of the study area contains Bighorn sheep migratory/watering routes. The study area is easily accessible in the north by gravel roads from Arizona Highway 68, from the west by dirt roads off the Silver Creek road, and from the east by roads leading into Secret Pass Canyon from Sacramento Valley.

Previous and Present Investigations

Early reports on the geology and ore deposits of the Katherine and Oatman mining districts, which include parts of the study area, were given in Ransome (1923) and Lausen (1931). Thorson (1971a) described the stratigraphy and structure of volcanic rocks in the Oatman district. Clifton and others (1980) and W.P. Durning (written commun., 1980) modified the descriptions of Thorson (1971a). Recent studies on the geology and ore-deposit characteristics of the Oatman district were conducted by Smith (1984) and Dewitt and others (1986).

The U.S. Geological Survey carried out field investigations in the study area during 1987 and 1988. This work included geologic mapping at scales of 1:48,000 and 1:24,000, geochemical sampling, geophysical surveys, and examining outcrops for evidence of mineralization. The geochemical survey used rock and stream-sediment samples (including a fine fraction and heavy-mineral concentrate) that were analyzed for 31 elements by semiquantitative emission spectrography. Arsenic, antimony, cadmium, zinc, and bismuth were analyzed by inductively coupled plasma–argon atomic-emission spectrometry. Gold was analyzed by electrothermal atomic-absorption spectroscopy and mercury by continuous-flow, cold-vapor atomic-absorption spectroscopy. Previously collected geophysical data, which resulted from regional gamma-ray, gravity, and magnetic surveys, were compiled and analyzed for this study. X-band side-looking airborne radar data and stereoscopic Landsat thematic mapper (TM) images were interpreted for structural fabric, major tectonic elements, and potential areas of hydrothermal alteration using photographic techniques. Further details on analytical procedures undertaken for this resource assessment are given in the appropriate sections that follow.

The Mount Nutt Wilderness Study Area geologic map is generalized from mapping in the southern half by Thorson (1971a) and Clifton and others (1980) and the northern half from mapping done during the course of this

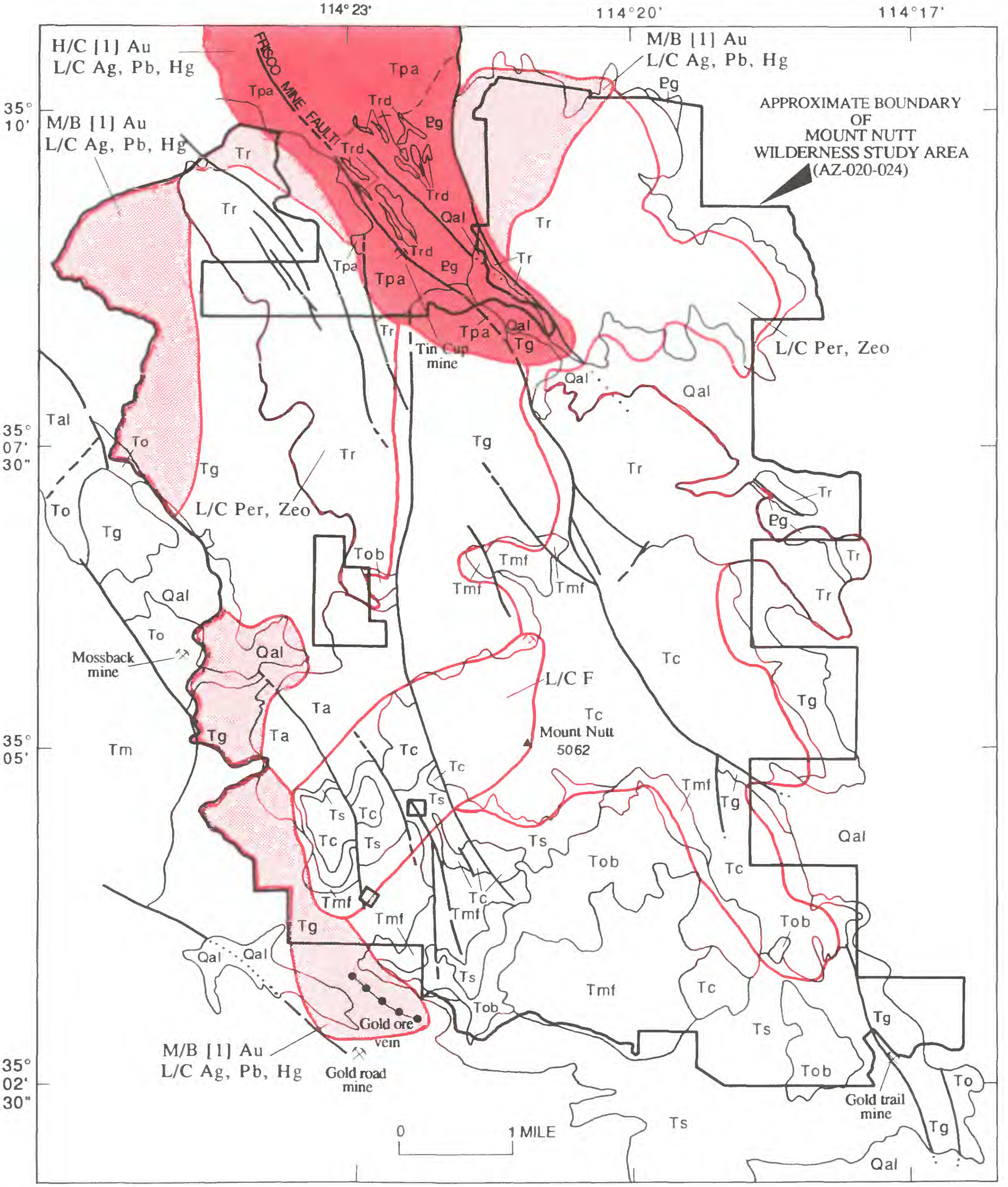


Figure 2. Mineral resource potential and generalized geology of Mount Nutt Wilderness Study Area, Mohave County, Arizona.

study (Floyd Gray and R.J. Miller, unpub. data, 1988; Gray and others, 1987). Altered and mineralized areas in the northern half were mapped in detail to characterize the extent and effect of hydrothermal activity in the study area.

The U.S. Bureau of Mines carried out field investigations in 1987, including searches for mines, prospects, claims, and mineralized geologic structures (Almquist, 1989). Ninety-two chip, grab, and select samples and one panned-concentrate sample were collected.

Acknowledgments

The authors would like to thank Robert Harrison of the U.S. Bureau of Land Management and Perry Durning of Fischer-Watt Gold Co., Inc., for their information regarding the geology and mining activity in the study area. In addition, the staff of the Kingman, Arizona Resource Area Office of the U.S. Bureau of Land Management provided logistical support, equipment, and facilities.

EXPLANATION

Area having high resource potential (H)

Area having moderate resource potential (M)

Area having low resource potential (L)

Mine having identified fire-agate resource—See text for discussion

Levels of certainty of assessment

B — Data only suggest level of potential

C — Data give good indication of level of potential

Commodities

Au	Gold
Ag	Silver
F	Fire agate
Hg	Mercury
Pb	Lead
Per	Perlite
Zeo	Zeolites

[ ] Deposit type

1 Epithermal gold deposits in volcanic and volcaniclastic rock

Map units

Qal **Alluvial deposits (Quaternary)**—Mostly stream sand and gravel; includes fanglomerate; also includes minor amounts of eolian and lacustrine sediment. May also include scattered low-lying bedrock outcrops

Tob **Olivine basalt (Tertiary)**—Medium-grained, gray, granular to ophitic basalt with 1- to 3-mm phenocrysts of iddingsite (altered olivine)

Tmf **Meadow Creek and Flag Spring Trachytes, undivided (Tertiary)**—Alkalic to subalkalic quartz latite flows, agglomerates, and flow breccias

Tr **Rhyolite (Tertiary)**—Rhyolitic flows, massive domes, plugs, and associated breccias and tuffs

Tc **Cottonwood unit of Thorson (1971a) (Tertiary)**—Rhyolite to alkali rhyolite flow domes and flow breccias. May be correlative with unit Tr

Ts **Sitgreaves Tuff (Tertiary)**—Volcaniclastic sedimentary rock including conglomerate and air-fall tuff

Tm **Moss Porphyry (Tertiary)**—Rhyolite to rhyodacite porphyry stock. Contains phenocrysts of feldspar, quartz, and minor amounts of altered biotite. Intrudes the Alcyone Formation of Thorson (1971a, b) on west side of study area

Trd **Rhyodacite dikes and intrusive rocks (Tertiary)**—Argillically altered, limonite-stained intrusive rocks; commonly contains altered plagioclase and quartz phenocrysts

Ta **Antelope quartz latite unit of Thorson (1971a) (Tertiary)**—Rhyodacite to rhyolite flows and domes

Tpa **Porphyritic andesite (Tertiary)**—Porphyritic, plagioclase-rich andesite flows and flow breccias

Tg **Gold Road Latite (Tertiary)**—Andesitic to dacite flows, flow and vent breccias, and minor amounts of lithic air-fall tuff

To **Oatman latite unit of Thorson (1971a) (Tertiary)**—Dacite to andesitic basalt flows, tuffs, and flow breccias

Tal **Alcyone Formation of Thorson (1971a,b) (Tertiary)**—Flows, tuffs, and breccias of quartz latitic composition

Pg **Granite, schist, and gneiss (Proterozoic)**

Contact—Dashed where approximately located

Fault—Dashed where approximately located; dotted where inferred

APPRAISAL OF IDENTIFIED RESOURCES

By Carl L. Almquist
U.S. Bureau of Mines

Methods

In March 1987 the U.S. Bureau of Mines conducted a mineral investigation of the Mount Nutt Wilderness Study Area. This investigation included a review of literature, unpublished U.S. Bureau of Mines and U.S. Bureau of Land Management files, mining claim, and land-status records; contact with mineral interest holders; a field examination of the study area and vicinity; and an evaluation of sample analyses. Two U.S. Bureau of Mines geologists spent nine days in the study area and collected 92 chip, grab, and select samples and 1 panned-concentrate sample. The samples were analyzed by Chemex Labs, Inc., Sparks, Nevada. Gold content was determined by fire assay and neutron activation. Silver, arsenic, antimony, bismuth, cadmium, gallium, tellurium, copper, lead, zinc, and molybdenum contents were determined by inductively coupled plasma–atomic emission spectrometry. All analytical data are reported in Almquist (1989).

Mining and Mineral Exploration History

The Oatman mining district, Arizona's third largest gold producer, extends into the southwestern part of the study area. In the early 1860's, a gold-bearing ore shoot was discovered in a prominent quartz vein outcrop 2.5 mi west of the study area at the Moss mine (Almquist, 1989, pl. 1). Shortly after this discovery, other gold-bearing veins were located nearby to the east and southeast, but nearly 30 years passed before the largest gold mines of the Oatman district were opened. In the early 1900's, development work was started at the Tom Reed, United Eastern, and Gold Road mines, which were by far the most productive in the district. Ore production peaked in 1920 and then sharply declined in 1924 as gold ore grades decreased. Mining activity stagnated in the late 1920's, was revived in 1933 when the gold price increased to $35 per oz, and ceased in 1942 (Ransome, 1923; Lausen, 1931; and Durning and Buchanan, 1984). Recorded production, from 1870 to 1980, is 1,966,000 troy oz of gold, 1,147,000 troy oz of silver, and 60,000 lb of copper from 4,073,000 short tons (st) of ore (Keith and others, 1983, p. 38–39). All the past-producing mines in the Oatman district are outside the study area.

More gold-bearing veins are present in the Union Pass mining district, which extends into the northern part of the study area at the mouth of Secret Pass Canyon. Discoveries in the district followed the Moss mine discovery at Oatman by about ten years, and mining activity coincided with the main period of activity at Oatman, but on a smaller scale. The most productive past-producing mines in the district are all northwest of the study area. Recorded production, from 1868 to 1943, is 128,000 troy oz of gold and 313,000 troy oz of silver from 704,000 st of ore (Keith and others, 1983, p. 52–53).

An unknown tonnage of gold ore, reportedly containing from 0.43–0.57 oz/st, was produced from the Tin Cup mine, which is in Secret Pass Canyon less than 0.5 mi north of the study area (Almquist, 1989, pl. 1; Westervelt, written commun., 1987). Recent exploration work (1984–1988) by Santa Fe Pacific Mining, Inc., and Fischer-Watt Gold Company, Inc., which included drilling, resulted in the identification of approximately 460,000 st of ore with a grade of 0.110 troy oz gold/st at the Tin Cup mine and approximately 108,000 st of ore with a grade of 0.053 oz gold/st at a nearby site, a total resource of about 56,000 troy oz gold. As of early 1988, Fischer-Watt Gold Company was continuing its exploration efforts in the Secret Pass area (F.L. Hillemeyer, Fischer-Watt Gold Company, Inc., Kingman, Ariz., oral commun., 1988).

Mines and Prospects, Mining Claims and Leases

There are numerous prospect pits, shallow shafts, and adits inside the study area but no mines with a history of metallic mineral production. Large blocks of unpatented mining claims, located on gold-bearing vein deposits in the Oatman and Union Pass mining districts, extend from the north, west, and south into the study area (Almquist, 1989, pl. 1). Mining claims have also been located on a gemstone resource northeast of Mount Nutt, where fire agate was being mined on a small scale during the U.S. Bureau of Mines investigation.

Ryder (1983, p. 19) rated the study area as having zero to low potential for the occurrence of petroleum, on the basis of prevalent Proterozoic crystalline rocks and Tertiary volcanic rocks. Approximately 5,160 acres were under lease for oil and gas at the time of the U.S. Bureau of Mines investigation (Almquist, 1989, pl. 1).

Reserves and Identified Resources

Host rocks, structures, and some types of alteration associated with gold deposits in the Oatman mining district are present in the southern and western parts of the study area. Although these characteristics suggest the presence of ore deposits and there has been some prospecting in the study area, no ore deposits have been discovered. Element concentrations that could indicate the presence of metallic mineral resources were not detected in U.S. Bureau of Mines samples from prospects and altered outcrops inside the study area (Almquist, 1989, table 1 and appendix), but these findings are not conclusive. In the Oatman mining district, most past-producing ore shoots are not exposed; their only surface expression is altered volcanic rock that gives no distinct geochemical anomaly (Durning and Buchanan, 1984).

The gold ore deposits recently identified by drilling in the Secret Pass Canyon area are on the Frisco Mine fault, which is traceable for more than 2 mi into the study area (Almquist, 1989, pl. 1; fig. 2). Gold was detected in all U.S. Bureau of Mines samples collected from workings in the Secret Pass Canyon area, with concentrations as high as 0.880 and 0.354 oz/st (Almquist, 1989, table 1), but there are no known gold-bearing deposits in the study area.

Deposits that were mined on the Mossback, Gold Ore, and Gold Trail mine veins are not traceable at the surface into the study area (Almquist, 1989, pl. 1). The northwest-trending Mossback vein dips about 80° SW and appears to be fault-terminated at a point near the east boundary. The Gold Ore and Gold Trail mine veins trend toward the study area, but their trace is obscured by volcanic cover.

A block of mining claims near the center of the study area was located for fire agate. Hand-sorted specimens, valued at $30–$100 per lb, are packed out from the remote site and sold in small quantities. Exceptional individual specimens reportedly sell for $1,000 or more (Tom Dodge, claimant, oral commun., 1987). On the basis of a rough size estimate, current production methods, and site accessibility, this deposit will be a subeconomic indicated fire-agate resource for the foreseeable future. Inferred subeconomic resources of sand and gravel in the study area have no qualities that make them more valuable than abundant supplies available from established sources closer to existing markets. Therefore, development is unlikely. No other industrial-mineral commodities are present in the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Floyd Gray, Robert C. Jachens, Robert J. Miller, Robert C. Turner, Eric K. Livo, Daniel H. Knepper, Jr., *and* John Mariano
U.S. Geological Survey

Geology

Stratigraphy

The Mount Nutt Wilderness Study Area is underlain by Proterozoic granite, schist, and gneiss and Tertiary volcanic and volcaniclastic rocks. Rhyolitic to rhyodacitic porphyries intrude the basement rocks and the lower to middle parts of the volcanic section. The geology shown in figure 2 is modified from Thorson (1971a), Ransome (1923), Clifton and others (1980), Dewitt and others (1986), and Floyd Gray and R.J. Miller (unpub. data, 1988).

Proterozoic rocks are exposed in scattered areas along the east side of the Mount Nutt Wilderness Study Area and in a northwest-trending fault-bounded block as much as 2 mi wide in the Secret Pass Canyon area. These rocks consist of medium- to coarse-grained biotite granite to quartz monzonite, weakly foliated gneiss, and schist. The granitic rocks are commonly porphyritic with feldspar phenocrysts as large as 2 in. in diameter; some rocks have a rapakivi texture. The granitic rocks are hypidiomorphic-granular and consist of potassium feldspar (approximately 55 percent), plagioclase (approximately 25 percent) and quartz (approximately 20 percent). They contain as much as to 6 percent biotite and nearly an equal amount of amphibole; they also contain minor amounts of magnetite and sphene locally. The feldspars in the granite, gneiss, and schist are slightly saussuritized, and they are typically altered to sericite and muscovite. Biotite is slightly altered to chlorite, and mafic minerals are partially replaced by iron oxide. The eastern contact of the Proterozoic rocks with the volcanic rocks is a depositional unconformity with the volcanic rocks dipping approximately 25–35° W. The western contact of the basement rocks and the overlying volcanic rocks is exposed just north of the study area and is an east-dipping low-angle normal fault.

The oldest volcanic rocks of the study area are basalt and basaltic volcaniclastic rocks within the Alcyone Formation of Thorson (1971a, b), a sequence of mainly andesite and trachyandesite (subalkalic quartz latite) flows exposed just inside the west boundary of the study area (fig. 2). The trachyandesite flows are typically dark porphyritic rocks consisting of 65 percent groundmass and 35 percent phenocrysts of sanidine, plagioclase, and biotite and minor amounts of pyroxene and quartz.

The middle volcanics unit of Thorson (1971a) unconformably overlies the Alcyone Formation. Units comprising the middle volcanics unit include the Oatman latite unit of Thorson (1971a) and the Gold Road Latite. The Oatman latite unit ranges in composition from dacite to andesitic basalt, but its average composition is subalkalic latitic andesite (Dewitt and others, 1986). The unit is composed of flows, flow breccias, and minor amounts of tuff and is exposed in the western part of the study area. The Gold Road Latite conformably overlies the Oatman latite unit and is composed of porphyritic subalkalic to alkalic flows and vent breccias; this unit is exposed throughout the study area.

The middle volcanics unit is intruded by the Moss Porphyry, a small stock exposed west of the study area (Thorson, 1971a). The unit's composition ranges from porphyritic tonalite and monzodiorite to granodiorite. Numerous silicic, porphyritic northwest-trending dikes and small sills similar to the Moss Porphyry are exposed in the northern part of the study area and suggest a more widespread intrusive episode that may include separate high-level plutonic bodies (Floyd Gray and R.J. Miller, unpub. data, 1988).

The upper volcanics unit of Thorson (1971a) unconformably overlies the middle volcanics unit and consists of the Antelope quartz latite unit of Thorson (1971a), Cottonwood unit of Thorson (1971a), Flag Spring Trachyte, Meadow Creek Trachyte, and the dominantly volcaniclastic Sitgreaves Tuff. In the north half of the study area, the upper volcanics unit is correlated with a thick sequence of rhyolite flows and domes, welded tuffs, and small silicic plugs. The Antelope quartz latite and Cottonwood units are dominantly flows and domes of subalkalic rhyodacite to rhyolite and rhyolite to alkalic rhyolite, respectively (Dewitt and others, 1986). The Flag Spring Trachyte and Meadow Creek Trachyte are quartz latite flows, agglomerates, and flow breccias. The Sitgreaves Tuff is a volcaniclastic unit that contains conglomerate and air-fall tuff with abundant lithic fragments derived from the upper volcanics unit.

The upper volcanics unit is unconformably overlain by flat-lying to gently east-dipping olivine basalt flows and interbedded conglomerate and silicic ash.

Although ages are available for several units in and near the study area, the details of the timing of Tertiary volcanic events remains unclear. Thorson (1971a) reported conventional potassium-argon (K-Ar) ages of 18.6±0.9 Ma (million years before present) and 19.2±0.9 Ma for the Gold Road latite and Antelope quartz latite, respectively. This apparent inversion of the stratigraphy can be accounted for in the analytical uncertainty of the ages or by assuming that one or both represent minimum ages. Dewitt and others (1986) obtained an Ar-Ar age of 18.8±0.1 Ma on hornblende from the Moss Porphyry. This body intrudes the Alcyone (lower unit) and is chemically similar to the Cottonwood unit. DeWitt and others (1986) suggested that the Moss Porphyry may be coeval with the upper volcanics unit. A uranium-lead age of 18±4 Ma for the Moss Porphyry (DeWitt and others, 1986) suggested that the intrusion was coeval with the main period of volcanism and not late Miocene, as was suggested by Thorson (1971a).

Ages from volcanic rocks in the northern part of the study area, correlated with the upper volcanic unit, are somewhat younger than the age reported by Thorson (1971a). Biotite from two samples of porphyritic andesite (unit Tpa, fig. 2) produced ages of 18.2±0.5 Ma and 18.4±0.5 Ma (R.J. Miller, unpub. data, 1989). A silicic dike, tentatively correlated with the upper part of the upper volcanic unit, has a K-Ar biotite age of 17.1±0.5 Ma (R.J. Miller, unpub. data, 1988) suggesting that the upper volcanic unit may represent as much as 2 million years of volcanic activity. A brief quiescent period may have preceded eruption of mesa-capping basalts. This basalt is much thicker and more areally extensive south of the study area and has been dated by whole-rock K-Ar methods at 15.8±0.5 Ma (R.J. Miller, unpub. data, 1988). No volcanic units overlie this basalt in the southern Black Mountains.

Quaternary units unconformably overlie Tertiary volcanic and older crystalline rocks. Flanking some of the peaks are poorly sorted, semiconsolidated to unconsolidated locally derived terrace gravels. Closer to some of the mountains are talus slopes that obscure underlying geology. Widespread pediment surfaces are covered by older alluvium, and major drainage channels contain Quaternary alluvium.

Structure

Rocks within the study area are intensely faulted and tilted as a consequence of late Tertiary deformation related to extensional tectonism. The faults are generally north- to northwest-trending high-angle normal faults. The study area is divided into two areas that have different structural configurations. The south half of the study area (roughly from Mount Nutt south) is dominated by a large circular structural feature inferred to be a volcanic depression (Thorson, 1971a; Clifton and others, 1980; Dewitt and others, 1986; Gray and others, 1987). This feature is older than the north- to northwest-trending fault set and is offset along them (Gray and others, 1987). The north half of the study area is dominated by north- to northwest-trending normal faults. The Tertiary volcanic cover is thinner in the northern part of the study area where a more closely spaced set of parallel faults is exposed. The general structural pattern suggests a faulted, southward-plunging horst cored by Proterozoic granitic rocks.

Brecciation and Alteration

Brecciation and localized alteration are coincident with Tertiary fault and fracture systems. The fault and fracture systems possibly served as conduits for circulating hydrothermal fluids driven by proximal rhyolitic magmatism. Zones of intensely brecciated rocks from 5 ft to about 150 ft wide characterize most faults. Weak to moderate propylitic alteration is evident along more prominent normal faults with irregular zones of illitic alteration; minor silicification is locally present along these faults. Alteration is mainly present in the lower part of the volcanic section; young bedded air-fall tuff, silicic breccias, and rhyolite plugs are virtually unaltered. Near the Frisco Mine fault, propylitic alteration is common adjacent to the fault in both granitic and volcanic rocks. The granitic rocks are intensely fractured near the fault and host an irregular stockwork vein system consisting of quartz, calcite, and minor amounts of fluorite. Volcanic rocks near the fault are propylitically altered and also are argillically altered in irregular patches.

Rhyolitic to rhyodacitic dikes in the northern part of the study area are limonite stained and pervasively argillically altered; the alteration resulted from acid fluid associated with the breakdown of pyrite. The dikes are bleached white with irregular reddish brown to yellowish tan patches created by limonite staining.

Moderate to intense argillic alteration is predominant in the eastern margin of the Moss Porphyry west of the study area. This silicic, high-level intrusion is typically bleached white to yellowish-brown or pinkish-white in this region.

Geochemical Studies

Methods

A reconnaissance geochemical survey was conducted in the Mount Nutt Wilderness Study Area in the fall of 1986 and the spring of 1987. Reconnaissance surveys allow the evaluation of large areas for evidence of mineralization. Reconnaissance surveys are not designed to find individual deposits, rather the spacing of samples allows large areas to be subdivided rapidly at low cost into zones of favorable geochemical provinces and mineralized tracts. Minus-80-mesh stream sediments, heavy-mineral concentrates derived from stream sediments, and rocks were selected as the sample media in this study. Fifty-three sites were sampled for stream sediments and heavy-mineral concentrates and 27 rock samples were collected at 25 sites.

The stream-sediment samples were collected from the active alluvium in the stream channel length of approximately 50 ft. The stream sediments were sieved through an 80-mesh screen and pulverized to a fine powder before analysis. The heavy-mineral concentrates were sieved through a 10-mesh screen and then panned until most of the quartz, feldspar, clay-sized material and organic matter were removed. The remaining light minerals were separated from the heavy minerals with heavy liquid (bromoform, specific gravity 2.8). Magnetite and ilmenite were removed from the resultant heavy-minerals fraction with a Franz Isodynamic electromagnetic separator; the remainder was separated into nonmagnetic and slightly magnetic fractions. The nonmagnetic fractions, which were used in this study, were ground to a fine powder before analysis. Stream sediments represent a composite of the rock and soil exposed upstream from the sample collection site. The heavy-mineral concentrate represents a composite of the heavy-mineral components of the rocks exposed in the drainage basin, which could include ore-forming and ore-related minerals. Analyses of the nonmagnetic fraction of the concentrate permits determination of the concentration of some elements that are not easily detected in bulk stream sediments. Rocks were collected from mineralized and unmineralized outcrops and stream float. Samples that appeared fresh and unaltered were collected to provide information on background geochemical values. Altered samples were collected to determine the suite of elements associated with the observed alteration or mineralization. The rocks were crushed and pulverized to a fine powder before analysis.

The heavy-mineral concentrates, stream sediments, and rocks were analyzed for 31 elements by direct-current arc, semiquantitative, emission spectrographic analysis (Grimes and Marranzino, 1968; Crock and others, 1983). The rocks were also analyzed for antimony, arsenic, bismuth, cadmium, and zinc by inductively coupled argon plasma–atomic emission spectroscopy (O'Leary and Viets, 1986); for gold by atomic absorption (Thompson and others, 1968); and for mercury by cold-vapor atomic-absorption methods (Koirtyohann and Khalil, 1976). Analytical data and a description of the sampling and analytical techniques were compiled by J. Bullock (written commun., 1989).

Results

A plot of the anomalous values from the minus-80 mesh stream-sediment samples delineated an anomalous zone in the northwestern part of the study area. This zone is characterized by anomalous values for mercury (0.1–0.6 parts per million, ppm), gold (0.05–0.1 ppm), arsenic (10–18 ppm), lead (as high as 200 ppm), zinc (as high as 250 ppm), and barium (2,000–3,000 ppm). A second zone, in the southeastern part of the study area, is characterized by anomalous values for mercury (8–16 ppm) and molybdenum (as high as 15 ppm). A third zone delineated from this sample medium is in the east to northeast part of the study area and is characterized by anomalous values of mercury (as high as 12 ppm) and zinc (230–250 ppm).

Rock samples collected from altered volcanic rocks and altered silicic dikes in and adjacent to the north-central part of the study area yielded anomalous precious metal values (table 1). The rocks are characterized by anomalous values for gold of as much as 10 ppm (average value being approximately 1.43 ppm), silver (as high as 30 ppm), and mercury (as high as 84 ppm). Arsenic concentrations are weakly anomalous but low compared to the Sleeper and Buckhorn gold deposits (table 1).

Weakly anomalous concentrations of trace elements, (mercury, arsenic, antimony, and molybdenum) were detected in scattered, altered rocks in and adjacent to the northwestern part of the study area.

Geophysical Studies

Three types of geophysical data from western Arizona (magnetic, gravity, and radiometric) were compiled and examined to aid in the assessment of the mineral resource potential of the Mount Nutt Wilderness Study Area, Arizona. Detailed aeromagnetic and radiometric data are available along profile lines spaced about 1 mi apart. The sparsely distributed nature of the gravity data and the wide separation between aeromagnetic and radiometric profile lines make these data adequate for addressing the regional structural and tectonic setting of the study area but do not permit detailed statements about mineral resource potential at the deposit scale.

Aeromagnetic Data

An aeromagnetic survey of the study area and vicinity was flown in 1977 and compiled by Western Geophysical Company of America under contract to the U.S. Department of Energy as part of the National Uranium Resource Evaluation (NURE) program (U.S. Department of Energy, 1979). Total-field magnetic data were collected along east-west flightlines spaced approximately 1 mi apart at a nominal height of 400 ft above the ground surface. Corrections were applied to the data to compensate for diurnal variations of the Earth's magnetic field, and the International Geomagnetic Reference Field (updated to the month data were collected) was subtracted to yield a residual field that primarily represents the distribution of magnetite in the underlying rocks.

The magnetic field of the Mount Nutt Wilderness Study Area is dominated by numerous short-wavelength (1–3 mi in width), high amplitude (200–400 nanoteslas) anomalies that are characteristic of areas of rugged relief in magnetic volcanic rocks. The mafic volcanic rocks that primarily underlie regions of rugged terrain within the study area appear to be strongly magnetic and cause large anomalies. These anomalies result both from lateral variations of induced and remanent magnetization within the volcanic rocks and from variable separation between the magnetic sensor and the underlying rocks because a constant flight elevation could not be maintained above the ground surface. In contrast, the tuff units and rhyolitic rocks appear to be much less magnetic and cause magnetic lows. Most of these anomalies do not directly contribute to an understanding of the mineral resource potential of the study area.

Two pronounced magnetic lows, one lying mostly outside the study area along its southwest edge and another that straddles the northwest corner of the study area, suggest mineralization may have occurred. The southwestern low lies over the Oatman mining district and extends less than 1 mi into the study area (anomaly 1, fig. 3). This low covers more than 15 mi^2 and includes most of the deposits and claims in the district. The rocks encompassed by this low are significantly less magnetic than the igneous rocks in the surrounding area, probably as a result of hydrothermal alteration that destroyed the magnetite in the rocks. The northwestern low (anomaly 2, fig. 3) is situated over exposures of rhyolite that include a group of rhyolite plugs. This low may be related to alteration associated with the intrusion of the rhyolite plugs, but it also partly indicates the magnetic character of the rhyolite that elsewhere in the study area appears to be only weakly magnetic.

Gravity Data

Gravity data in the vicinity of Mount Nutt Wilderness Study Area were obtained from Mariano and others (1986). Gravity stations are scattered at 1–3 mi intervals outside the study area, but only 12 stations are located within the study area boundary and most are aligned along a northeast-trending profile that crosses the center of the study area. The observed gravity data, based on the International Gravity Standardization Net datum (Morelli, 1974), were reduced to free-air gravity anomalies using standard formulas (Telford and others, 1976). Bouguer, curvature, and terrain corrections (to a distance of 103.6 mi from each station) at a standard reduction density of 2.67 g/cm^3 (grams per cubic centimeter) were made at each station to determine complete Bouguer gravity anomalies.

The Bouguer gravity field over the study area and surrounding region shows shallow-density distributions related to near-surface geology and deep-crustal density distributions that correlate with topography in a manner consistent with the concept of isostasy. To isolate that part of the gravity field that arises from near-surface density distributions, an isostatic residual gravity map was constructed from the Bouguer gravity data. The method used was removal of a regional gravity field computed from a model of the crust-mantle interface that assumes Airy-type isostatic compensation (Jachens and Griscom, 1985).

Measurements were made on hand samples collected from outcrops in or near the study area to determine the densities of the major rock types. Fifteen samples of Proterozoic basement rock yielded an average density of 2.72±0.06 g/cm^3. Twenty-six samples of unaltered Tertiary volcanic rocks yielded an average of 2.51±0.12 g/cm^3, although this average should be used with caution because the density measurements on the volcanic rock samples showed considerable scatter.

The gravity field in the vicinity of the Mount Nutt Wilderness Study Area primarily shows the thickness of low-density Cenozoic deposits that overlie higher density Proterozoic basement rock. An elongate gravity low about 4 mi wide and 6 mi long that is centered on Mount Nutt covers most of the study area. This low, which culminates

Table 1. Analyses of altered rock samples in and near Mount Nutt Wilderness Study Area, Mohave County, Arizona

[All samples are either from altered volcanic rocks in fault and fracture zones or from altered, hematite-stained silicic dikes. Analyses by J. Bullock and B. Anderson. N, not detected at detection limit (given in parentheses). --, not analyzed for. All element concentrations measured in parts per million unless otherwise indicated. Au, gold; Ag, silver; Hg, mercury; As, arsenic; Sb, antimony; Cd, cadmium; Pb, lead; Zn, zinc; Mo, molybdenum]

Sample Number	Au	Ag	Hg	As	Sb	Cd	Pb	Zn	Mo
WGT-3	3.10	1.5	72	12	<2	0.7	30	24	N(5)
WGT-13	5.45	1	28	33	<2	0.6	50	54	<5
WGT-15	1.60	1.5	0.06	27	<2	0.8	20	39	N(5)
WGT-21-7	0.60	0.5	0.52	50	<2	1.2	20	62	<5
WGT-30	0.40	2	0.02	48	<2	0.6	50	38	N(5)
WGT-34	0.15	10	0.12	65	2	0.6	70	40	N(5)
WGT-35	0.75	0.5	0.02	70	<2	0.5	30	48	<5
WGT-37	0.05	2	0.06	45	15	0.2	50	36	N(5)
7M136A	0.40	0.7	0.08	39	<2	0.4	<10	42	15
7M136B	<0.05	N(0.5)	<0.07	120	<2	1.8	N(10)	31	N(5)
7M136C	0.10	1	1.1	21	<2	0.7	<10	36	7
7M136D	0.10	<0.5	0.12	72	<2	0.9	20	64	10
7M136F	<0.05	N(0.5)	<0.02	<5	<2	0.2	<10	26	N(5)
7M137	0.45	0.5	0.04	96	4	1.9	50	87	N(5)
7M137B	<0.05	<0.5	0.38	27	<2	0.7	10	31	<5
7M137C	6.55	5	0.08	9	2	0.7	N(10)	<2	20
7M137D	<0.05	N(0.5)	0.04	16	<2	0.7	50	12	N(5)
7M137E	0.10	2	0.06	8	<2	0.1	20	7	15
7M137F	0.05	1.5	0.72	12	<2	0.7	N(10)	31	N(5)
7G105-1	0.55	0.7	24	10	<2	0.7	50	26	N(5)
7G105-2	0.25	1	0.96	<5	<2	0.1	20	14	<5
7G105-3	3.35	1	0.02	21	<2	0.1	15	24	N(5)
7G105-4	0.20	N(0.5)	0.20	39	<2	0.2	15	27	N(5)
7G105-5	<0.05	N(0.5)	<0.02	<5	<2	0.8	30	71	N(5)
7G106-1	4.30	10	84	11	<2	0.4	20	39	<5
7G106-3	0.40	0.7	0.12	47	<2	1.2	30	63	N(5)
7G106-4	2.30	15	0.06	44	<2	0.7	50	55	N(5)
7G106-5	1.65	<0.5	0.02	44	<2	0.4	20	47	N(5)
7G106-6	0.25	1	0.08	57	<2	0.5	30	53	N(5)
*7G102-1	2.10	5	2.9	38	<2	0.8	100	100	100
*7G102-2	2.30	20	9.2	<5	<2	<0.1	10	5	50
*7G102-3	1.10	1.5	0.48	19	<2	<0.1	100	92	20
*7G102-4	10	5	1.2	8	<2	<0.1	10	6	<5
*7G103	0.07	30	0.12	10	<2	<0.1	50	7	100
Deposits									
[1]Sleeper	0.25	27	--	340	130	--	7	25	--
Analyses in parts per billion (ppb)									
[2]Buckhorn 3	51.25	8.48	567.50	55.75	8.35	--	3	803.75	2
Buckhorn 4	327.86	3.19	334.29	142.86	10.97	--	6.86	29.71	3.43
Buckhorn 5	1686.67	2.52	271.67	227.67	101.77	--	6.67	283	2
Buckhorn 6	1581.11	16.06	3002.22	1017.67	48.29	--	5.67	9.78	35.78
Buckhorn 14	201.67	5.40	490	151.00	11.80	--	8	55.33	14.33

*Sample from rhyodacite dikes in study area.

[1]Means of surface-rock chemistry from Wood (1988, p. 300)

[2]Average values of altered basaltic andesite (3-6 samples) and silicified fanglomerate (14 samples) from Monroe and others (1988)

in values lower than –30 milligals (mGal), is bounded on the northeast by a gravity ridge having highest values of about –12 mGal and on the south and southwest by gravity highs of about –10 mGal. These highs are centered over outcrops of Proterozoic basement rock. Proterozoic basement rock is also exposed along the north boundary of the study area, an area where gravity values reach only about -18 mGal. An area with gravity values of about -22 mGal that bounds the low on the west is not associated with any Proterozoic basement exposures.

A northeast-southwest trending structural trough is implied by low gravity values and, on the basis of modeling, may contain as much as 1.5 mi of volcanic rock. Using a density contrast of 0.2 g/cm³ between Proterozoic basement and Tertiary volcanic rock, gravity-modeling results indicate that the structural trough is bounded on the northeast by a Proterozoic surface that dips gently southwest and on the southwest by a near-vertical interface. Northwest-trending faults have been mapped in Tertiary rock immediately above the inferred near-vertical southwest boundary and these faults parallel the gravity gradient that defines the edge of the trough. Although the gravity data are sparse and do not accurately define the extent of the inferred vertical boundary, it appears to lie within the deepest part of the magnetic low over the Oatman mining district.

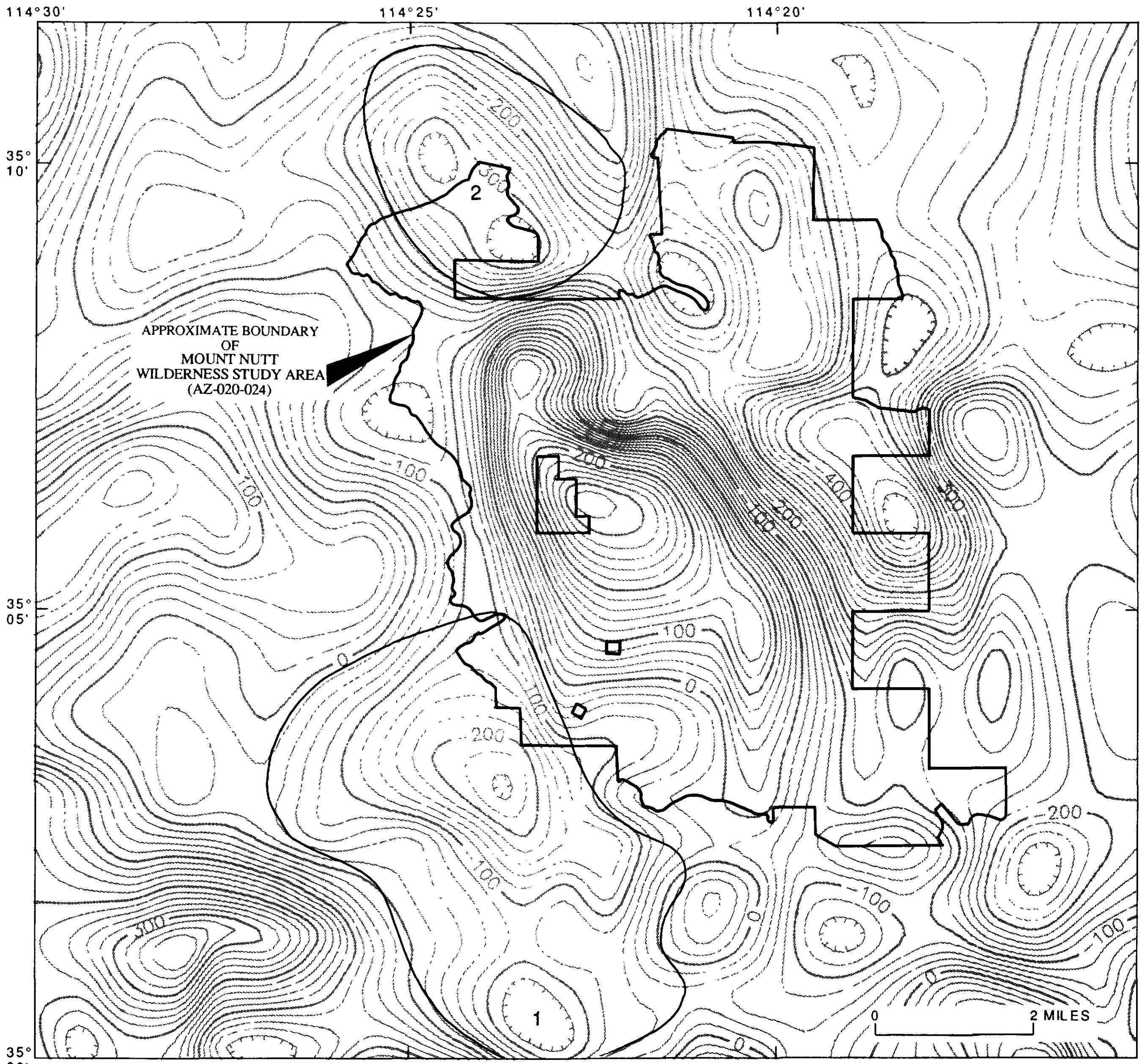


Figure 3. Aeromagnetic anomalies of Mount Nutt Wilderness Study Area, Mohave County, Arizona. Contour interval, 20 nanoteslas; hachured in direction of magnetic low; anomalies labeled 1 and 2 are discussed in text.

Radiometric Data

Knowledge of natural radioelement distribution in the Mount Nutt Wilderness Study Area is based on an aerial gamma-ray spectrometry survey (U.S. Department of Energy, 1979) of the Kingman 1- by 2-degree quadrangle. The survey acquired gamma-ray data along 1-mi-spaced east-west flightlines at 400 ft above the ground for the eastern part of Kingman quadrangle. The line spacing represents about 15 percent coverage for the study area because an aerial gamma-ray system flown 400 ft above the ground effectively detects terrestrial gamma radiation from a swath 800 ft wide along a flightline. The coverage represents a reconnaissance sampling of the near-surface (0- to 18-in. depth) distribution of the natural radioelements potassium (K), uranium (eU), and thorium (eTh). The prefix "e" (for equivalent) denotes the potential for disequilibrium in the uranium and thorium decay series.

Examination of 1:500,000 and smaller scale radioelement maps made from the aerial-gamma-ray data for the eastern part of the Kingman quadrangle indicates that the study area is characterized by radioelement concentrations of 2.0 to 3.6 percent K, 2.5 to 3.5 ppm eU, and 12.5 to 20.0 ppm eTh. Relatively lower concentrations of 2.0 to 2.4 percent K, 2.5 to 3.0 ppm eU, and 12.5 ppm eTh are present in the southern part of the study area, and relatively higher concentrations of 2.4 to 3.6 percent K, 2.5 to 3.0 ppm eU, and 15 to 20 ppm eTh are present in the northern part. These concentrations likely reflect the distribution of the Proterozoic and Tertiary igneous rock that composes most of the bedrock of the study area. Generally, higher radioelement concentrations relate to more silicic rock, and detritus derived from it. The study area includes part of the Oatman mining district at its southwest side and part of the Union Pass mining district (fig. 2) at the northeast side of Secret Pass Canyon (fig. 1). The southwest side of the study area is in the area of lower radioelement concentrations, and the northeast side is in the area of higher radioelement concentrations. There is no evidence that these concentrations relate to the mineralization that occurred in the mining districts.

Remote Sensing

Digital image data acquired by the thematic mapper (TM) system on the Landsat-4 satellite (Scene I.D. 40174–17383) were analyzed to detect and map areas that may contain hydrothermally altered rocks. The six bands of image data in the visible and near-infrared spectral bands were digitally processed to enhance spectral characteristics of minerals that commonly accompany alteration or are derived from the weathering of altered rocks. Those areas that have spectral characteristics suggesting the presence of alteration minerals were visually mapped on 1:62,500-scale Applicon color ink-jet plots of the processed data.

The broad bands of the TM data allow two groups of minerals to be identified, but the minerals *within* each group cannot be distinguished from each other. Group 1 minerals consist of the limonite minerals, particularly hematite, goethite, and jarosite. Hematite and goethite are not diagnostic of hydrothermal alteration because they are common weathering products of iron-bearing minerals in altered and unaltered rocks alike. However, concentrations of hematite or goethite that crosscut lithologic units do suggest alteration. Jarosite is diagnostic of hydrothermal alteration, regardless of whether or not it crosscuts lithologic units.

Group 2 minerals include the hydroxyl-bearing and (or) hydrated minerals (clay minerals, micas, gypsum, alunite, jarosite) and carbonates (calcite, dolomite). Although the minerals in Group 2 are not restricted to altered rocks, they are commonly important constituents of altered rocks or are derived from the weathering of altered rocks. Alteration halos of Group 2 minerals (micas and clay minerals), which can extend as far as 200 ft laterally from vein systems, (Durning and Buchanan, 1984) can be detected with remote sensing.

Interpretation

Visual interpretation of the masked TM color-ratio composite consists of identifying concentrations of Group 1, Group 2, and jarosite (included in both Group 1 and Group 2 minerals) in the study area. In general, areas of alluvium identified on the basis of outcrop patterns in available geologic maps and photo interpretation of the images were excluded from consideration. The areas of potentially hydrothermally altered rocks were manually outlined by visual interpretation of the color-ratio composite image and the outlines were transferred to a 1:62,500-scale base map of the wilderness study area, which was used to compile figure 4.

Results

Areas that may depict hydrothermally altered rocks taken from the masked TM color-ratio composite image are shown in figure 4. Areas containing only Group 1 minerals are labeled "1"; those containing only Group 2 minerals are labeled "2;" and those containing both Group 1 and Group 2 minerals (and (or) jarosite) are labeled "3". Areas of widespread, apparently low concentrations of minerals of these groups are labeled "D" for dispersed. Another area (labeled "A") may represent an illitically altered area (Durning and Buchanan, 1984). Mine dumps, mill tailings, and (or) discharge in nearby stream beds are labeled "d."

No pronounced alteration patterns within the central Oatman mining district just south of the wilderness study area are visible on the TM data. Traces of veining (through linear alignment of mine dumps) can be seen, but they were not plotted on figure 4. Ransome (1923), Lausen (1931), and Durning and Buchanan (1984) described the variability of the veining and surrounding alteration halos; surface expression of some of the most productive veins is very limited. However, the Mossback mine is associated with area "A" on the TM image. Propylitic alteration in the Oatman district is also associated with Group 1 elements (limonite) due to weathering of pyrite.

Vegetation obscures only a small part of the rocks and soil in the study area. The areas of rugged topography in the study area, combined with the relatively low solar-elevation angle at the time the TM data were acquired (25 degrees), results in a small part of the study area being in deep to moderate shadow on the TM data. Vegetation and shadows, then, have only modestly limited the area of surface rocks and soil that could be spectrally analyzed for alteration minerals. A number of anomalous areas were identified and these anomalies, because of the masking effects of vegetation and shadows, may represent a part of slightly more extensive areas.

Four types of potential dispersed alteration were delineated within the study area. Within the dispersed anomalies, locally more intense concentrations are present.

(1) Group 2 and Group 3 elements are widespread on the west edge of the study area (fig. 4). Area "A" is described as a large area of illitic alteration by Durning and Buchanan (1984). The area just to the north appears to be a similar, though less intense, area of alteration possibly attributable to the underlying Moss Porphyry.
(2) Moderate to strong potentially altered areas (Group 1 and Group 2) were delineated within the southern one-third of the study area (fig. 4). Some of the areas contain Group 2 cores. In general, the areas are located on south-facing slopes; shadows mask any characteristics of these elements on north-facing slopes.
(3) Group 1 elements are widespread in the northern one-quarter of the study area (fig. 4). Weathering of one or more volcanic lithologic surfaces (volcanic flow rock?) possibly could be generating nonhydrothermal Group 1 products. However, Group 3 elements are also present in this area.
(4) Combinations of type 2 and type 3 anomalies (above) occur in the middle of the study area (fig. 4). Areas of Group 1, Group 2, and combinations of Group 1 and Group 2 elements are localized within the more dispersed alteration. Local high concentrations of Group 2 and Group 1 and Group 2 elements are present within the north-central region excluded from the study area.

The relative importance of any one of the mapped anomalies is difficult to evaluate; however, proximity to areas of known alteration or mineralization is probably a good method for assessing the anomalies.

Mineral and Energy Resource Potential

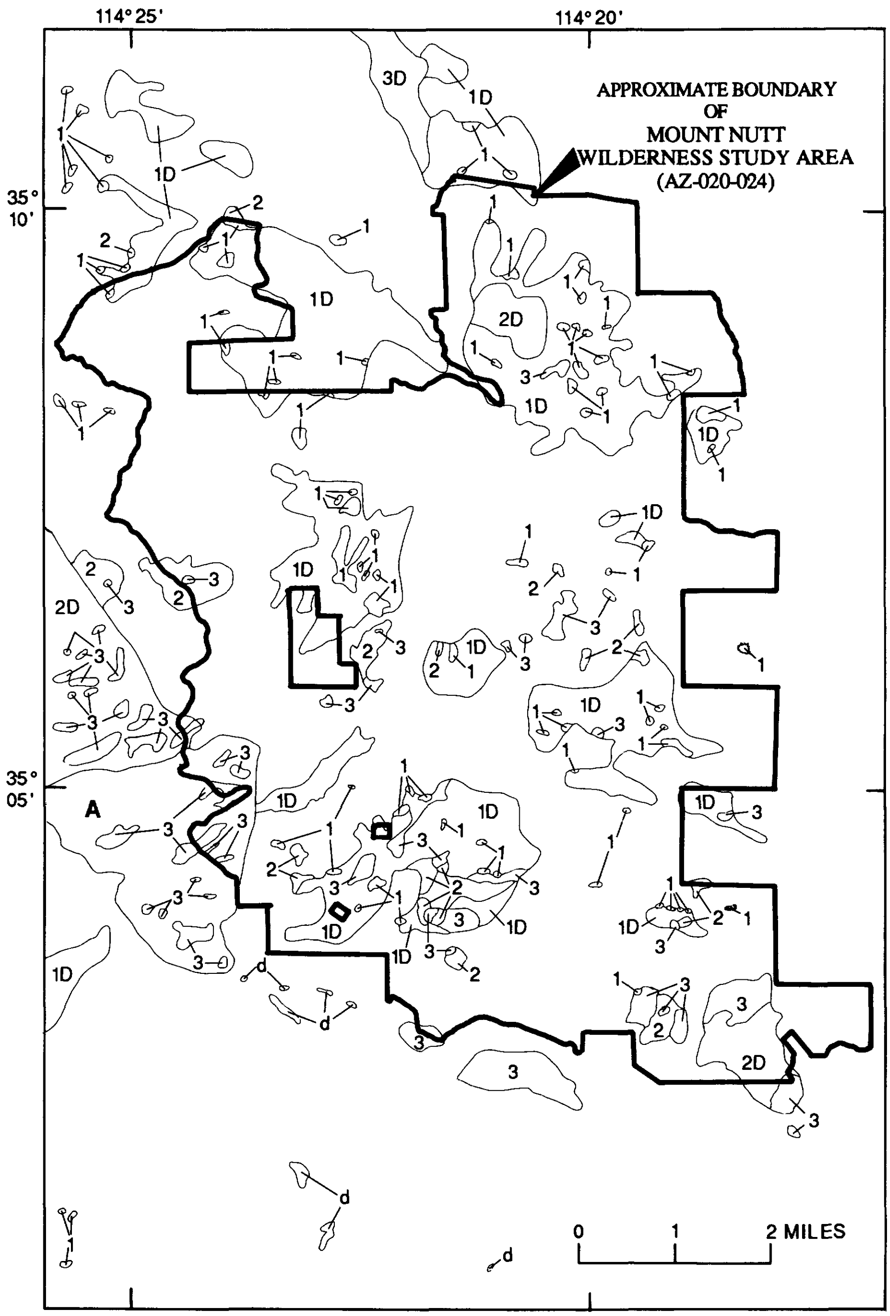
An area in the extreme north-central part of the Mount Nutt Wilderness Study Area has high resource potential for gold and low resource potential for silver, lead, and mercury with a C certainty level. Three areas in the north-central, northwestern, and southwestern parts of the study area have moderate resource potential for gold with a B certainty level. These areas also have low potential for silver, lead, and mercury with a certainty level C. A small area in the south-central part of the study area has low potential, certainty level C, for fire agate. Large areas in the central and eastern parts of the study area have low potential for perlite and zeolite resources with a certainty level of C. The entire study area has no potential for oil and gas, certainty level D, and no potential for geothermal resources, certainty level D.

The results of this study show that there is high mineral resource potential for gold in the extreme north-central part of the study area (fig. 2). A gold resource totaling at least 56,000 troy oz has been identified at two sites in the Secret Pass Canyon area. The main site (Tincup mine) is less than 0.5 mi outside the study area; the second site lies approximately 500 ft north of the study area. Most of the area is underlain by intensely faulted and fractured rocks that also extend into the wilderness study area. The fault structure is visible in the study area for over 2 mi. Altered, mineralized rocks exposed north of the study area are also present in the study area and are covered by unaltered silicic tuff and flows. The thickness of this unaltered cover increases southward. Geochemical data suggest that the area is characterized by low but anomalous levels of arsenic and mercury in stream sediments and lead and silver in heavy-mineral concentrates. The potential is interpreted to be high because composite chip material and rock samples of altered rocks consistently yield anomalous concentrations of gold and low but detectable concentrations of gold suite elements (table 1) (see Berger, 1986). A certainty level C is assigned to the area because the fault trace is generally well exposed, and the geochemical data suggest that mineralization occurred in the area. Moderate resource potential for gold exists in three areas in the extreme northwestern, northeastern, and southwestern parts of the study area (fig. 2). This potential is suggested by anomalous concentrations of mercury, lead, barium, and arsenic. Scattered anomalous concentrations of gold, molybdenum, and zinc detected in stream sediments suggest that mineralization occurred. The potential is moderate because alteration patterns defined by remote sensing, faulting, and the anomalous trace-element suite are similar to the known gold deposits in the area. A certainty level of

B is assigned to the areas because either potential host rocks are poorly exposed or examination of their surficial appearance suggests that they are only weakly altered and mineralized. Each of the areas mentioned above has a low potential for silver, lead, and mercury resources, certainty level C. The concentrations of these three elements are not large enough clearly to suggest the occurrence of potential resources of these commodities even as byproducts.

Perlite and zeolite minerals occur in the upper part of the volcanic sequence associated with welded tuff sequences and small rhyolitic plugs. This part of the sequence has a low potential for zeolite and perlite, certainty level C. Low grade and the lack of access to perlite and zeolite-bearing beds in the study area would hinder development of these commodities.

Ryder (1983) assessed the oil and gas potential of the study area as zero to low on the basis of extensive occurrences of Proterozoic schist and gneiss which make up the basement rocks of the wilderness study area and which are unsuitable hydrocarbon source or reservoir rocks. There is no resource potential for oil and gas, certainty level D, in the study area.



EXPLANATION

- **1** Group 1 minerals are hematite, goethite, and jarosite—See text for discussion
- **2** Group 2 minerals are hydroxyl-bearing and (or) hydrated minerals (including clay minerals, micas, gypsum, alunite, and jarosite) and carbonates (calcite and dolomite)—See text for discussion
- **3** Group 1 and 2 minerals
- **A** Illite (Durning and Buchanan, 1984)
- **D** Dispersed occurrence of mineral group
- **d** Mine dumps and mine tailings

Figure 4. Areas of alteration minerals in Mount Nutt Wilderness Study Area, Mohave County, Arizona.

No geothermal resources were observed in or adjacent to the study area (Witcher and others, 1982; Muffler, 1979). Although the study area contains numerous rhyolite and basalt intrusions and the study area is in a region judged to have undergone greater than normal heat flow during the Miocene to early Pliocene, the Miocene intrusions in the study area are small and the entire region had most likely cooled to near ambient temperatures by the early Pliocene. Therefore, there is no potential for geothermal 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 UNKNOWN POTENTIAL	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH 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:

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RESOURCE/RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

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

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

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

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