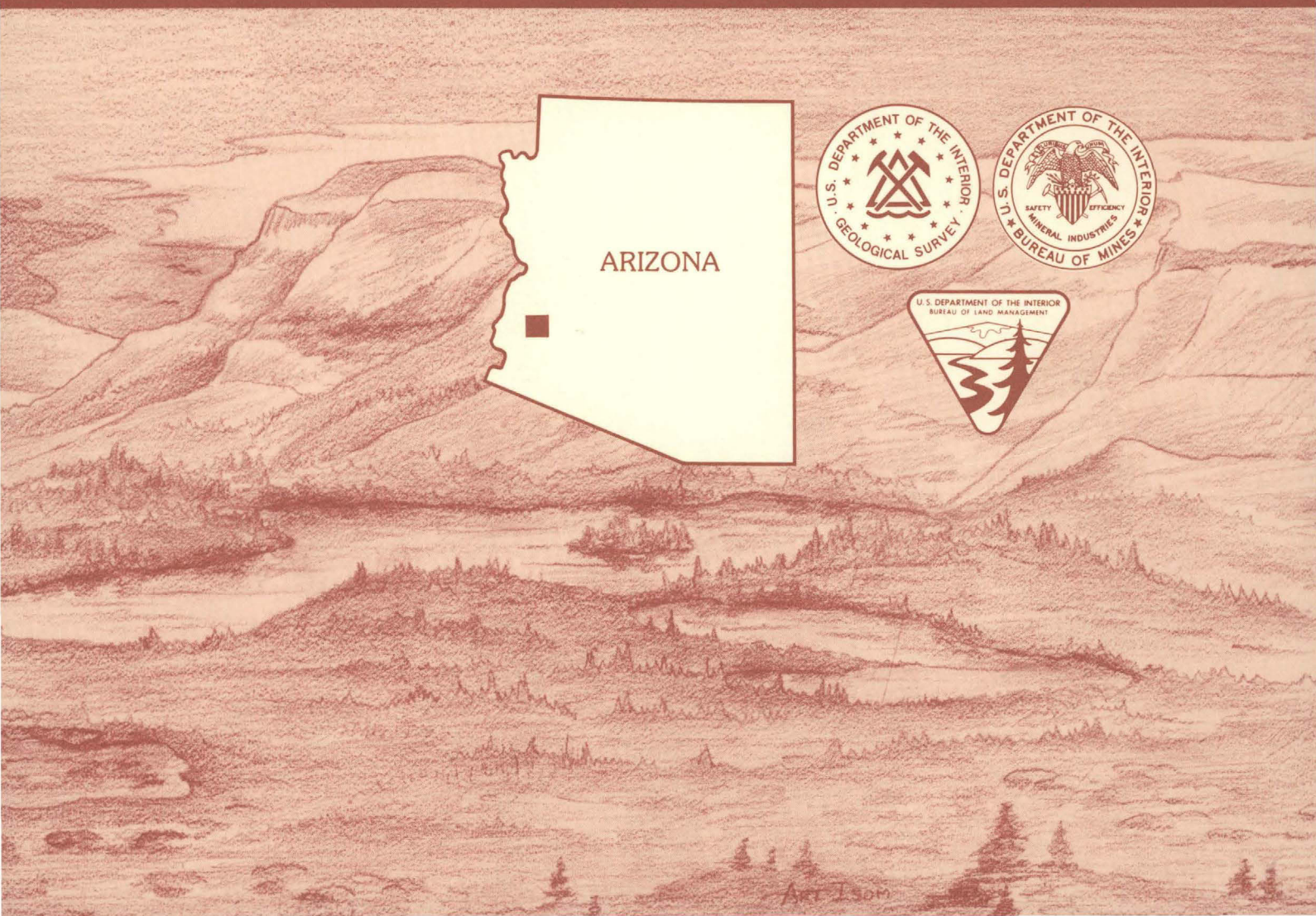
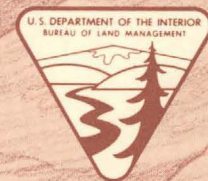


Mineral Resources of the New Water Mountains Wilderness Study Area, La Paz County, Arizona

U.S. GEOLOGICAL SURVEY BULLETIN 1702-B



AVAILABILITY OF BOOKS AND MAPS OF THE U.S. GEOLOGICAL SURVEY

Instructions on ordering publications of the U.S. Geological Survey, along with prices of the last offerings, are given in the current-year issues of the monthly catalog "New Publications of the U.S. Geological Survey." Prices of available U.S. Geological Survey publications released prior to the current year are listed in the most recent annual "Price and Availability List." Publications that are listed in various U.S. Geological Survey catalogs (see back inside cover) but not listed in the most recent annual "Price and Availability List" are no longer available.

Prices of reports released to the open files are given in the listing "U.S. Geological Survey Open-File Reports," updated monthly, which is for sale in microfiche from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225. Reports released through the NTIS may be obtained by writing to the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161; please include NTIS report number with inquiry.

Order U.S. Geological Survey publications by mail or over the counter from the offices given below.

BY MAIL

Books

Professional Papers, Bulletins, Water-Supply Papers, Techniques of Water-Resources Investigations, Circulars, publications of general interest (such as leaflets, pamphlets, booklets), single copies of Earthquakes & Volcanoes, Preliminary Determination of Epicenters, and some miscellaneous reports, including some of the foregoing series that have gone out of print at the Superintendent of Documents, are obtainable by mail from

U.S. Geological Survey, Books and Open-File Reports
Federal Center, Box 25425
Denver, CO 80225

Subscriptions to periodicals (Earthquakes & Volcanoes and Preliminary Determination of Epicenters) can be obtained ONLY from the

Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

(Check or money order must be payable to Superintendent of Documents.)

Maps

For maps, address mail orders to

U.S. Geological Survey, Map Distribution
Federal Center, Box 25286
Denver, CO 80225

Residents of Alaska may order maps from

Alaska Distribution Section, U.S. Geological Survey,
New Federal Building - Box 12
101 Twelfth Ave., Fairbanks, AK 99701

OVER THE COUNTER

Books

Books of the U.S. Geological Survey are available over the counter at the following Geological Survey Public Inquiries Offices, all of which are authorized agents of the Superintendent of Documents:

- WASHINGTON, D.C.--Main Interior Bldg., 2600 corridor, 18th and C Sts., NW.
- DENVER, Colorado--Federal Bldg., Rm. 169, 1961 Stout St.
- LOS ANGELES, California--Federal Bldg., Rm. 7638, 300 N. Los Angeles St.
- MENLO PARK, California--Bldg. 3 (Stop 533), Rm. 3128, 345 Middlefield Rd.
- RESTON, Virginia--503 National Center, Rm. 1C402, 12201 Sunrise Valley Dr.
- SALT LAKE CITY, Utah--Federal Bldg., Rm. 8105, 125 South State St.
- SAN FRANCISCO, California--Customhouse, Rm. 504, 555 Battery St.
- SPOKANE, Washington--U.S. Courthouse, Rm. 678, West 920 Riverside Ave..
- ANCHORAGE, Alaska--Rm. 101, 4230 University Dr.
- ANCHORAGE, Alaska--Federal Bldg, Rm. E-146, 701 C St.

Maps

Maps may be purchased over the counter at the U.S. Geological Survey offices where books are sold (all addresses in above list) and at the following Geological Survey offices:

- ROLLA, Missouri--1400 Independence Rd.
- DENVER, Colorado--Map Distribution, Bldg. 810, Federal Center
- FAIRBANKS, Alaska--New Federal Bldg., 101 Twelfth Ave.

Chapter B

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

By DAVID R. SHERROD, DAVID B. SMITH,
RICHARD D. KOCH, WILLIAM F. HANNA, and
JAMES A. PITKIN
U.S. Geological Survey

MICHAEL E. LANE
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1702

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

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, Jr., Secretary

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



Any use of trade, product, or firm names
in this publication is for descriptive purposes only
and does not imply endorsement by the U.S. Government

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1989

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center, Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Mineral resources of the New Water Mountains Wilderness Study Area, La Paz
County, Arizona.

(U.S. Geological Survey bulletin ; 1702-B)

Bibliography: p.

Supt. of Docs. no.: I 19.3:1702-B

1. Mines and mineral resources—Arizona—New Water Mountains
Wilderness (Ariz.) 2. New Water Mountains Wilderness (Ariz.) I. Sherrod,
David R. II. Series.

QE75.B9 no. 1702-B
[TN24.A6]

557.3 s
[553'.09791'7]

88-600429

STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys of certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and submitted to the President and the Congress. This report presents the results of a mineral survey of part of the New Water Mountains Wilderness Study Area (AZ-020-125), La Paz County, Arizona.

CONTENTS

Summary	B1
Abstract	B1
Character and setting	B1
Identified resources	B1
Mineral resource potential of the New Water Mountains Wilderness Study Area	B2
Introduction	B3
Location and physiography	B3
Previous and present investigations	B3
Acknowledgments	B3
Appraisal of identified resources	B3
Methods of investigation	B3
History and production	B5
Mineral deposits	B5
Assessment of mineral resource potential	B5
Geology	B5
Geochemical studies	B7
Methods of investigation	B7
Summary of results	B7
Geophysical studies	B8
Gravity and aeromagnetics	B8
Gamma-ray spectrometry	B8
Electrical geophysics	B9
Mineral and energy resources of the New Water Mountains Wilderness Study Area	B9
Sedimentary-rock-hosted gold and silver	B9
Epithermal gold and silver	B10
Copper and manganese	B11
Lead and zinc	B11
Geothermal energy	B11
Oil and gas	B11
Lime	B12
References cited	B12
Appendixes	
Definition of levels of mineral resource potential and certainty of assessment	B16
Resource/reserve classification	B17
Geologic time chart	B18

FIGURES

1. Index map showing location of New Water Mountains Wilderness Study Area, La Paz County, Arizona B2
2. Map showing mineral resource potential and generalized geology of New Water Mountains Wilderness Study Area, La Paz County, Arizona B4
3. Complete Bouguer gravity anomaly map of New Water Mountains Wilderness Study Area B9
4. Aeromagnetic anomaly map of New Water Mountains Wilderness Study Area B10

TABLE

1. Sampled areas in and near the New Water Mountains Wilderness Study Area, La Paz County, Arizona B6

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

By David R. Sherrod, David B. Smith, Richard D. Koch,
William F. Hanna, and James A. Pitkin
U.S. Geological Survey

Michael E. Lane
U.S. Bureau of Mines

SUMMARY

Abstract

The New Water Mountains Wilderness Study Area (AZ-020-125) is located in La Paz County, west-central Arizona. On the basis of a preliminary request of the U.S. Bureau of Land Management, 24,120 acres of the New Water Mountains Wilderness Study Area were evaluated for mineral resources (known) and mineral resource potential (undiscovered). Throughout this report, reference to the New Water Mountains Wilderness Study Area or to the study area refers only to that part of the wilderness study area for which a mineral survey was requested by the U.S. Bureau of Land Management. Fieldwork for this report was conducted in 1984 and 1985. Although 200 claims have been located adjacent to the study area and a few claims and two prospects are located within its boundaries, there are no identified resources in the study area. Inferred subeconomic resources of stone and sand and gravel in the study area have no unique qualities and are similar to material available closer to markets.

The resource potential for gold and silver is moderate in the northwestern and northeastern parts of the study area and low in the north-central and south-central parts. The resource potential for copper and manganese is low in the northeastern part of the study area. Minor amounts of lead and zinc accompany gold, silver, copper, and manganese occurrences in the New Water Mountains Wilderness Study Area. Therefore, a low resource potential for lead and zinc is assigned to the northwestern, north-central, northeastern, and south-central parts of the study area. There is low resource potential for geothermal energy along range-bounding faults in the eastern part of the New Water Mountains Wilderness Study Area. The entire study area has low resource potential for oil and gas.

There is unknown resource potential for lime, which could be developed from inferred subeconomic resources of marble in Paleozoic rocks in the northwest part of the study area. Although inferred subeconomic resources of sand and gravel occur in the study area, these materials are abundant closer to existing markets in the region.

Character and Setting

The New Water Mountains Wilderness Study Area is in the New Water Mountains of La Paz County, Ariz., about 10 mi southeast of Quartzsite, Ariz. (fig. 1). The mountains slope gently from the surrounding alluvial plain and steepen to the 3,639-ft-high bluff of Black Mesa. The study area is underlain by steeply dipping sedimentary, volcanic, and plutonic rocks of Proterozoic, Paleozoic, and Mesozoic age (see geologic time chart in appendixes). A sequence of Tertiary volcanic and sedimentary rocks unconformably overlies pre-Tertiary rocks, and this younger sequence has been slightly to moderately tilted during basin-and-range normal faulting.

Identified Resources

No mineral resources were identified in the New Water Mountains Wilderness Study Area. Inferred subeconomic resources of stone and sand and gravel in the study area have no unique qualities. Prospecting, claim staking, and mining near the study area have been intermittent during the 20th century; U.S. Bureau of Land Management records show that about 200 claims were located adjacent to the New Water Mountains Wilderness Study Area. Ore containing 175 short tons of copper and 514 troy oz of silver was produced from mines in the New Water Mountains, but there was no recorded production from the study area.

Manuscript approved for publication October 17, 1988.

Mineral Resource Potential of the New Water Mountains Wilderness Study Area

Areas having moderate and low resource potential for gold and silver are identified for the New Water Mountains Wilderness Study Area, and areas having low resource potential for copper, manganese, lead, zinc, geothermal energy, and oil and gas are also present (fig. 2).

Paleozoic carbonate rocks crop out in the western part of the study area; similar strata outside the study area contain replacement-type gold and silver mineralization. Minor lead and zinc mineralization is associated with the gold and silver. Moderate resource potential for gold and silver and low potential for lead and zinc are assigned to these carbonate rocks in the northwestern part of the study area on the basis of geochemical anomalies in stream-sediment samples.

Northeast of the study area, some Tertiary normal faults have associated gold, silver, copper, manganese, lead, and zinc mineralization, and these faults continue into the study area. Geochemical anomalies and mineralization are associated with these faults in and near the northeastern part of the study area. The area of these anomalies has moderate resource potential for gold and silver, and it has low resource potential for copper, manganese, lead, and

zinc. Geochemical anomalies also occur along Tertiary normal faults in the south-central part of the study area but no rock alteration or mineralization was noted there. The geochemically anomalous area in the south-central part of the study area is assigned low resource potential for gold, silver, lead, and zinc.

Discontinuous, small quartz veins containing minor lead, zinc, copper, and gold are present in sedimentary rocks in the north-central part of the study area. These rocks have low resource potential for gold, silver, lead, and zinc.

The resource potential for geothermal energy is low in the study area and limited to a zone along the major range-bounding fault separating the New Water Mountains from the Ranegras Plain in the eastern part of the study area. Aquifers in the Ranegras Plain contain low-temperature geothermal waters. The resource potential for oil and gas in the study area is low on the basis of unfavorable evidence regarding the presence of hydrocarbon source rocks.

There is unknown resource potential for lime, which could be developed from inferred subeconomic resources of marble in Paleozoic rocks in the northwestern part of the study area. Although inferred subeconomic resources of sand and gravel occur in the study area, these resources are abundant closer to markets in the region.

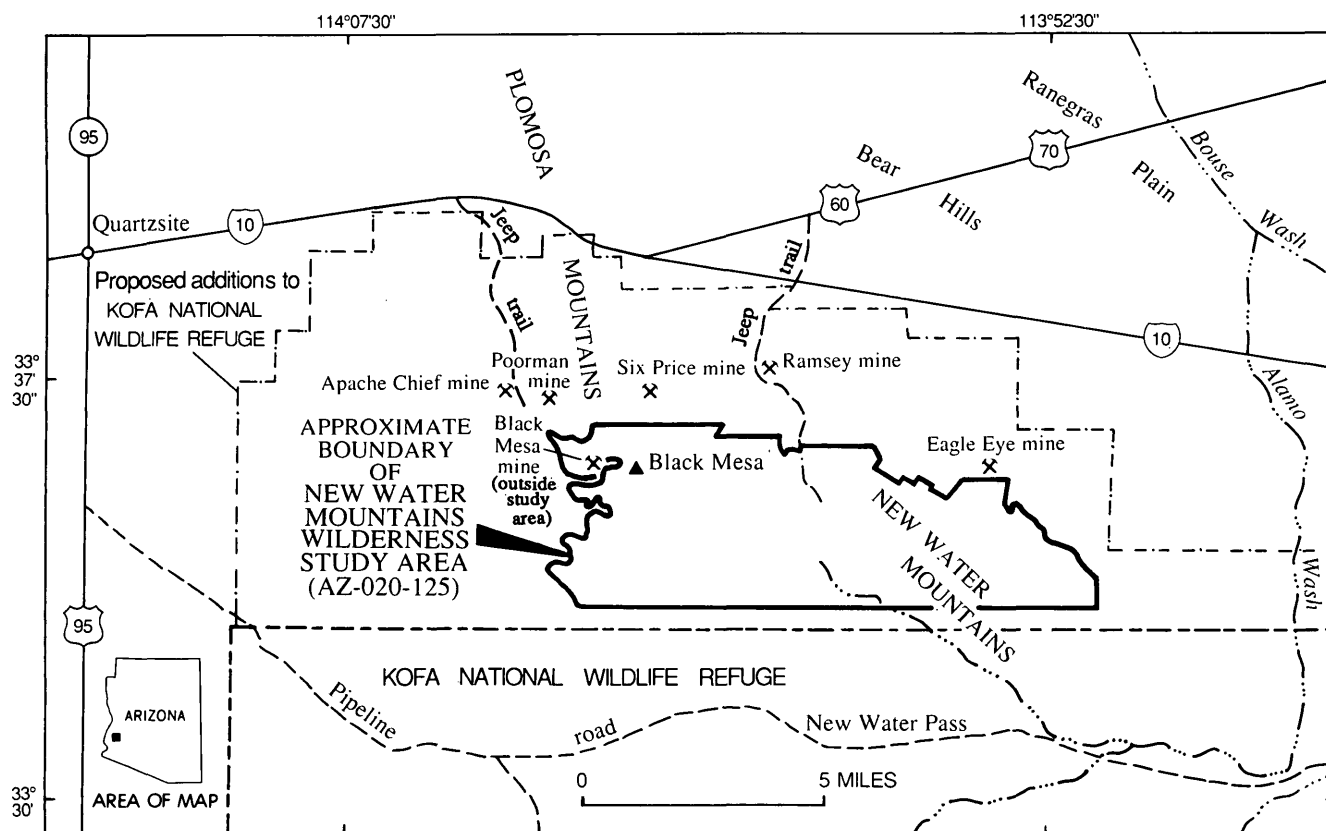


Figure 1. Index map showing location of New Water Mountains Wilderness Study Area, La Paz County, Arizona.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and represents 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 is 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 the U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey 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. Mineral assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See appendixes for the definition of levels of mineral resource potential, certainty of assessment, and resource/reserve classification.

Location and Physiography

The New Water Mountains Wilderness Study Area (AZ-020-125) is in La Paz County, Ariz., about 10 mi southeast of Quartzsite, Ariz. (fig. 1). The New Water Mountains are in the Basin and Range physiographic province of southwestern Arizona, a part of the Sonoran Desert region of the southwestern United States and northern Mexico. The mountains are a southeast-trending prong of the Plomosa Mountains and are bounded on the northeast, east, and south by undissected alluvial fans of the Ranegras Plain and Alamo Wash. The study area has gentle relief except near the slopes of Black Mesa and along the range-front faults. Elevations range from about 1,400 ft at the edge of the Ranegras Plain to 3,639 ft at the summit of Black Mesa.

Access to the area consists of dirt roads that leave U.S. Interstate 10, 3 mi north of the study area, and a road that follows the El Paso natural gas pipeline right-of-way (pipeline road) on the south. The dirt roads diverge into several jeep trails that allow access along many of the arroyo floors.

Previous and Present Investigations

A large part of the study area was first mapped in detail by Miller (1966, 1970). Robison (1979, 1980) and

Davis (1985) remapped and reinterpreted some critical contacts in Mesozoic rocks of the area. Harding (1978, 1980, 1982) and Harding and Coney (1985) studied the Mesozoic McCoy Mountains Formation in the New Water Mountains and elsewhere and established the regional depositional setting for these strata. Reynolds and others (1986) assigned many of the thrust faults in the region (including those in the study area) to a belt of Late Cretaceous thrusting.

The U.S. Geological Survey mapped the geology of the study area in 1984 and 1985 (Bagby and others, 1987) and sampled stream sediment and bedrock in 1984 (Adrian and others, 1987). In 1985, the U.S. Bureau of Mines mapped and sampled mines, prospects, and mineralized areas and reviewed U.S. Bureau of Land Management mining-claim and mineral-lease records and geologic literature. Details of the sampling procedures and results are presented in Lane (1986).

Acknowledgments

We gratefully acknowledge all logistical support and advice supplied by the manager and employees of the Kofa National Wildlife Refuge (U.S. Fish and Wildlife Service) during the fieldwork for this study. The U.S. Bureau of Mines thanks claim owner Robert Muller (Mammoth, Ariz.) and geologist Don Hammer (Newmont Exploration, Ltd., Tucson, Ariz.) for assistance and information concerning the Eagle Eye mine within the Moore patented claims.

APPRAISAL OF IDENTIFIED RESOURCES

By Michael E. Lane
U.S. Bureau of Mines

Methods of Investigation

Two geologists spent 20 days examining mines and prospects inside and within approximately 1 mi of the study area boundary. Surface workings and accessible mines were surveyed, mapped, and sampled (Lane, 1986).

A total of 151 samples was taken; 2 samples were from within the study area. Chip samples were taken across geologic structures and grab samples were taken from dumps. All samples were fire assayed for gold and silver; selected samples were analyzed by semiquantitative optical emission spectrographic methods for 40 elements and by atomic-absorption spectrometry for copper (Lane, 1986). Sample data are summarized in table 1, and complete analytical data for all samples are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

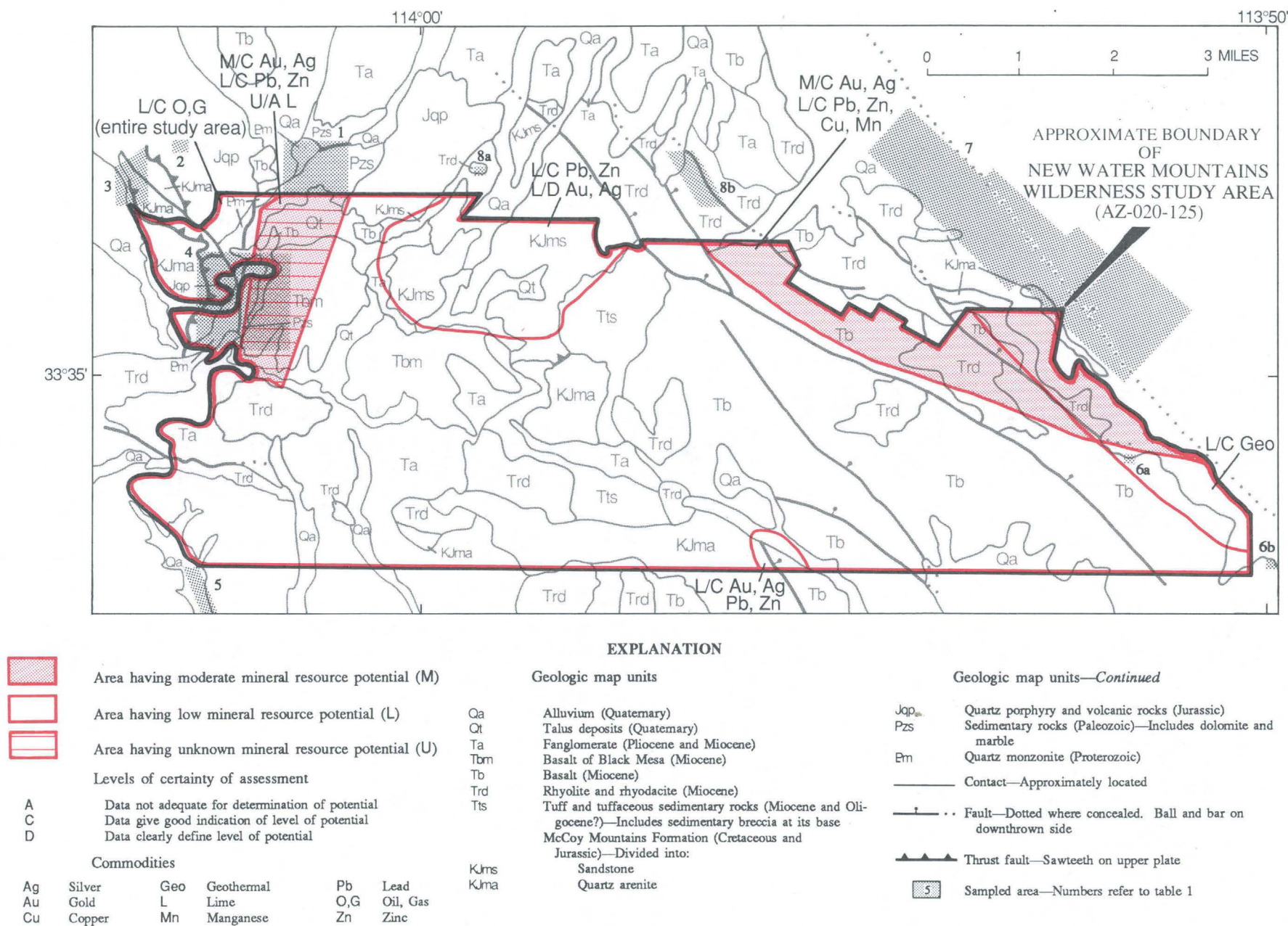


Figure 2. Mineral resource potential and generalized geology of New Water Mountains Wilderness Study Area, La Paz County, Arizona. Geology mapped by F.K. Miller, 1963–66, and by M.J. Grubensky, R.D. Koch, and D.R. Sherrod, 1984.

History and Production

Few mining claims are in the study area, according to U.S. Bureau of Land Management records. There are about 200 unpatented claims nearby but outside the study area. The 23 Moore patented claims are adjacent to the northern boundary and include the Eagle Eye mine. Keith (1978) stated that ore totaling about 518 short tons (st) and containing 175 short tons of copper and 514 troy oz of silver was produced from mines in the New Water Mountains. Production and mining activity are summarized in table 1.

Oil and gas leases are held on land about 1 mi northeast but do not extend into the study area. No geothermal leases are recorded near or in the study area. The nearest geothermal well is 8 mi north in the Ranegras Plain (Witcher and others, 1982).

Mineral Deposits

There are no identified metallic mineral resources in the New Water Mountains Wilderness Study Area. Two small pits were found in the southeast corner of the study area but analyses of samples from them showed no significant metal content.

With the possible exception of the Black Mesa mine and the Moore patented claims, there is no extension into the area of significantly mineralized occurrences or structures from outside the study area. Samples taken from the limestone-replacement deposits at the Black Mesa mine contain gold and silver—15 samples have silver contents ranging from 0.2 to 16.1 troy oz/st and 8 samples have gold contents ranging from 0.01 to 0.58 troy oz/st. The average gold content was 0.22 troy oz/st; however, if the highest content is ignored, the average gold content is only 0.09 troy oz/st. Therefore, this deposit is considered subeconomic unless large tonnages are identified by additional work. Similar mineral occurrences could exist in the marble within the boundary, but no evidence of past mining activity exists within the study area.

Near the Eagle Eye mine at the west end of the Moore patented claims, secondary copper minerals (mostly chrysocolla) are abundant in fractures and faults in rhyolite. The rhyolite extends into the study area and could be mineralized, but there is no evidence of past mining activity. Mapping, sampling, and drilling are necessary to determine the extent of any possible mineral occurrences.

Of the 18 samples taken at the west end of the Moore claims, only 1 contains a trace of gold and 11 contain silver concentrations ranging from 0.1 to 1.6 troy oz/st. All samples contain copper, and the average concentration is 1.1 weight percent; the highest value was 2.85 percent.

Inferred subeconomic resources of marble in Paleozoic rocks could be developed for lime. The study area contains numerous inferred subeconomic resources of sand and gravel in dry washes. These resources have no unique

characteristics and can be found in abundance closer to existing markets in the region.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By David R. Sherrod, David B. Smith, Richard D. Koch, William F. Hanna, and James A. Pitkin
U.S. Geological Survey

Geology

The New Water Mountains, in the southwestern part of the Basin and Range physiographic province, are a late Tertiary horst of Proterozoic to Tertiary igneous and sedimentary rocks (fig. 2). A Late Cretaceous thrust fault separates the pre-Tertiary rocks into two structural plates. Tertiary volcanism commenced in the Oligocene or early Miocene. Normal faulting, characteristic of basin-and-range tectonism, began about 20 million years ago (Ma) and created the New Water and southern Plomosa Mountains.

Proterozoic quartz monzonite is the oldest rock unit exposed in the New Water Mountains Wilderness Study Area (Miller, 1970). The quartz monzonite is nonconformably overlain by Cambrian sedimentary rocks, which form the base of a northeast-striking, southeast-dipping homocline of sedimentary and volcanic strata that are Paleozoic and Mesozoic in age. The Paleozoic rocks include Devonian and Mississippian dolomite and marble that contain carbonate-replacement deposits of gold and silver at the Black Mesa and Six Price mines, outside the western and northern boundaries of the study area, respectively (fig. 1).

The pre-Tertiary rocks, which form the upper plate of the Poorman thrust (Reynolds and others, 1986), were folded, faulted, and metamorphosed to lower greenschist facies during Late Cretaceous thrusting (Harding and Coney, 1985; Reynolds and others, 1986; Sherrod and Koch, 1987). Penetrative deformation was slight, however, producing only a local, incipiently developed flat-lying cleavage. The structurally lower plate contains only Mesozoic sedimentary rocks in the study area. The Proterozoic, Paleozoic, and Mesozoic rocks were beveled during latest Late Cretaceous and early Tertiary erosion.

The oldest Tertiary rocks in the study area comprise coarse sedimentary breccia, which overlies the pre-Tertiary rocks. The unit probably marks an Oligocene(?) or early Miocene episode of faulting and deposition, as interpreted from the poorly developed bedding of the breccia, the large clast size in the beds, and the abrupt termination of the breccia against older crystalline rocks. The upper part of the sedimentary breccia is interbedded with overlying silicic volcanoclastic rocks.

Table 1. Sampled areas in and near the New Water Mountains Wilderness Study Area, La Paz County, Arizona

[Au, gold; Ag, silver; Cu, copper; Mn, manganese; Pb, lead; ppm, parts per million. Sample numbers refer to data tabulated by Lane (1986)]

Map no. (fig. 2)	Locality	Summary	Workings	Sample and production data
1	Six Price mine area	Sampled area consists of limestone, siltstone, quartzite, and granite country rock. NE- to NW-striking faults and quartz veins were sampled. All contain visible hematite, limonite, and calcite.	Inclined shaft; 3 pits; 2 shafts, 1 caved and 1 about 25 ft deep.	8 samples were collected on faults and/or quartz veins. Highest Au content is 0.04 oz/st in a chip sample collected over 1.9 ft; 4 samples contain trace Au. All samples were collected about 1/4 mi outside the study area.
2	Pooman mine area	Area consists mostly of quartzite, phyllite, and small exposures of shale and sandstone. Country rocks contain faults and/or associated quartz veins or stringers. Hematite, limonite, calcite, and minor chrysocolla and malachite are present in structures.	2 inclined shafts, 2 vertical shafts, 10 pits, 1 adit, and 1 trench.	18 samples. 9 contain trace Au, 5 contain 0.1 oz/st Ag, 1 contains 60 ppm Cu. All samples were collected about 3/4 mi outside the study area. Worked between 1909 and 1911; produced about 100 st of ore averaging 3.8 oz/st Au and 0.8 oz/st Ag (Keith, 1978).
3	Apache Chief mine area	Area consists of limestone, sandstone, quartzite, and siltstone containing faults and quartz veins. Some faults occur along bedding planes. Visible minerals include malachite, chrysocolla, hematite, gypsum, and limonite.	4 inclined shafts, 6 vertical shafts, 6 pits, 3 adits, 2 trenches.	49 samples. 3 contain Ag above 1 oz/st: 9.2 oz/st in a grab sample, 2.3 oz/st in a chip sample collected over 1.3 ft, and 7.2 oz/st in a chip sample collected over 0.4 ft. Remaining samples contain less than 0.4 oz/st Ag. The highest Au content is 0.01 oz/st in a chip sample collected over 1.3 ft. Remaining samples contain trace or undetectable Au. 3 samples contain Cu: 3.2 percent, 0.35 percent, and 0.39 percent. Samples were collected 1/4 to 1 mi outside the study area.
4	Black Mesa mine area	Samples 76-82 were collected from fault gouge and massive specularite/quartz vein, both in diabase. Samples 83-101 were in limestone. Breccia and faults contain hematite, limonite, calcite, and vugs. Keith (1978) reports presence of cerussite, anglesite, galena, chrysocolla, malachite, brochantite, native Cu, and cerargyrite.	1 vertical shaft, 5 pits, 3 adits.	26 samples. Of 6 samples collected in diabase country rock, all but 2 contain trace Au; Ag (0.20 oz/st) is contained in only 1 sample. Of 19 samples collected in limestone, the highest Au content is 0.58 oz/st in a chip sample collected over 5.5 ft, and the highest Ag content is 16.1 oz/st in a chip sample collected over 2.4 ft. 14 samples contain a trace or more Au, and 15 samples contain 0.3 oz/st or more Ag. Samples were collected just outside the study area. From 1940's to 1964, production was 51 tons of ore averaging 25 percent Pb, 13 oz/st Ag, 2 percent Cu, 0.02 oz/st Au (Keith, 1978).
5	Cave Creek area	Alluvium in wash along Cave Creek. Shafts are about 50 ft deep.	6 shafts, 1 pit	7 samples collected. None contains detectable Au, Ag, or other metals.
6a, b	Near southeast corner of study area	Samples were collected at 2 isolated pits in massive to fragmented volcanic rocks.	2 pits	2 samples collected; neither contains detectable Au, Ag, or other metals.
7	Eagle Eye mine area (Moore claims)	Area composed mostly of Tertiary andesite and rhyolite. Cu mineralization is associated with NW-trending faults. Mesozoic quartzite, shale, and siltstone crop out in small exposures near Eagle Eye mine. Cu minerals are predominantly chrysocolla, azurite, and malachite present in fractures, faults, and breccia zones.	3 vertical shafts, 2 adits, 13 pits, 1 trench.	34 samples collected. 3 contain Au (trace, trace, 0.01 oz/st). 25 samples contain Ag: the highest value is 1.6 oz/st in a chip sample collected over 2.5 ft and the lowest is 0.1 oz/st. Cu was detected in all samples; the highest value is 3.3 percent in a chip sample collected over 2.6 ft, and the lowest value is 23 ppm. Keith (1978) reported that 480 tons of 3.7-percent Cu ore were shipped from 1941-1944.
8a, b	East, west, and south of Ramsey mine	4 samples (145-149) collected across faults containing minor chrysocolla in andesite and 1 of dump material. Samples 150-151 were of sandstone dump material.	3 shafts, 3 pits	6 samples collected. 5 contain detectable Au (0.01 oz/st, 4 contain trace) and Ag (6.4 oz/st in a chip sample collected over 1 ft is the highest and 0.4 oz/st is the lowest). 4 samples contain Cu: from 5.8 percent in a chip sample collected over 1 ft to 1.48 percent.

Volcanism commenced in the New Water Mountains with the eruption of basaltic lava flows and rhyolitic domes and flows about 23–20 Ma. Pyroclastic flows were a minor part of this volcanism.

Fanglomerate overlies the volcanic sequence and all older units on the the south, east, and north sides of the study area, and it is locally overlain by Miocene basalt that caps Black Mesa. Where not overlain by the basalt of Black Mesa, the fanglomerate forms moderately dissected hills.

The basalt of Black Mesa is a sequence of lava flows that erupted about 17 Ma (Shafiqullah and others, 1980). This is the youngest volcanic sequence in the study area. Sedimentation may have continued for a while after the eruption of the basalt of Black Mesa, but the region is now being eroded and dissected by intermittent streams that connect with the Colorado River.

Northwest-trending, steep to vertical normal faults bound the northeast margin of the New Water Mountains, and most have down-to-the-northeast displacements. As a result of the faulting, the Tertiary units dip 6°–30° southwest. The range-bounding faults probably formed as part of basin-and-range extensional tectonism that affected much of southwestern Arizona (for example, Eberly and Stanley, 1978; Spencer and Reynolds, 1986). Several mines and mineralized areas are located along these faults 1–3 mi northeast of the study area.

Geochemical Studies

Methods of Investigation

A reconnaissance geochemical survey was conducted in the New Water Mountains Wilderness Study Area in 1984 as part of a U.S. Geological Survey mineral resource assessment study of the Kofa National Wildlife Refuge and its proposed additions. Minus-80-mesh stream sediments and heavy-mineral concentrates derived from stream sediments were selected as the primary sample media because they represent a composite of rock and soil exposed in the drainage basin upstream from the sample site. Chemical analysis of the sediment samples helps to identify basins containing unusually high concentrations of elements that may be related to mineral occurrences. Heavy-mineral concentrates are a useful sample medium in arid environments or in areas of rugged topography, where mechanical erosion predominates over chemical erosion (Bugrov and Shalaby, 1975; Overstreet and Marsh, 1981; Zeegers and others, 1985).

Samples were analyzed for 31 elements including antimony, barium, cadmium, cobalt, chromium, copper, gold, iron, lead, magnesium, manganese, molybdenum, nickel, silver, thorium, tin, titanium, tungsten, vanadium, and zinc by semiquantitative emission spectroscopy. This method allows the rapid and economical analysis of numer-

ous samples, but the lower limits of determination for many elements are somewhat high. Therefore, the following elements were analyzed by atomic absorption, which lowers the determination limit to less than 1 part per million (ppm) for most of them: antimony, arsenic, bismuth, cadmium, gold, mercury, silver, tellurium, thallium, and zinc.

In this study the nonmagnetic fraction of the heavy-mineral concentrates was analyzed. This fraction concentrates ore and ore-related minerals such as pyrite, galena, cassiterite, sphalerite, chalcopyrite, stibnite, free gold, barite, and scheelite to permit determination of some elements that are not easily detected in bulk stream-sediment samples.

Stream-sediment samples and heavy-mineral concentrates were collected from active alluvium in first-order (unbranched) and second-order (below the junction of two first-order) streams, as shown on U.S. Geological Survey topographic maps (scale 1:62,500). Rock samples for chemical analysis were collected both in and near the study area. Unaltered samples were collected to provide information on geochemical background concentrations, whereas samples from mines, prospects, and altered areas were collected to determine suites of elements associated with mineralization and alteration. Analytical data, sampling methods, sample preparation procedures, analytical techniques, and sampling sites are presented in Adrian and others (1987).

Summary of Results

Three anomalous areas were defined as a result of the geochemical survey. An area in the northwestern part of the study area was defined by geochemically anomalous samples from streams that drain the west half of Black Mesa. This first area was delineated on the basis of stream-sediment samples containing anomalous amounts of gold (0.068 ppm, in only one sample), silver (as much as 0.35 ppm), zinc (270 ppm in one sample), and arsenic (20–30 ppm). Nonmagnetic heavy-mineral concentrates contain anomalous amounts of silver (as much as 10 ppm), lead (as much as 10,000 ppm), and zinc (as much as 10,000 ppm). A sample of altered, limonite-bearing brecciated dolomite collected on the west flank of Black Mesa contains high concentrations of gold (0.7 ppm), silver (100 ppm), arsenic (510 ppm), antimony (650 ppm), mercury (greater than 10 ppm), bismuth (100 ppm), copper (1,500 ppm), lead (5,000 ppm), and zinc (7,000 ppm). A quartz vein sample with iron and copper stains, collected on the northern flank of Black Mesa approximately 0.5 mi north of the study area boundary, contains high concentrations of gold (0.6 ppm), silver (5 ppm), arsenic (680 ppm), antimony (greater than 1,000 ppm), tungsten (25 ppm), zinc (7,000 ppm), bismuth (200 ppm), copper (2,000 ppm), and lead (greater than 20,000 ppm). These anomalies probably indicate sedimen-

tary rock-hosted gold and silver mineralization and (or) epithermal copper, lead, zinc, gold, and silver (base- and precious-metal) mineralization. The Black Mesa and Six Price mines lie in this same anomalous area just outside the western and northern study area boundaries.

A second geochemically anomalous area lies along the south-central part of the study area and extends southeast beyond the study area boundary. This area was delineated on the basis of stream-sediment samples containing anomalous amounts of arsenic (20–30 ppm) and antimony (as much as 26 ppm), and nonmagnetic heavy-mineral concentrates containing anomalous values of arsenic (500–7,000 ppm). These anomalies suggest the presence of epithermal base- and precious-metal mineralization along middle to late Tertiary normal faults.

A third geochemically anomalous area lies in the northeast corner of the study area near the Eagle Eye mine. This area was delineated on the basis of stream-sediment samples containing low-level anomalies of arsenic (20 ppm), zinc (as much as 220 ppm), and silver (as much as 0.15 ppm) and nonmagnetic heavy-mineral concentrates containing anomalous concentrations of arsenic (500 ppm in one sample) and lead (as much as 2,000 ppm). A sample of copper-stained quartzite breccia at the Eagle Eye mine contains high amounts of silver (30 ppm), arsenic (970 ppm), antimony (180 ppm), zinc (160 ppm), copper (2,000 ppm), lead (700 ppm), and gold (0.05 ppm). As in the second area, these anomalies suggest epithermal gold, silver, copper, lead, and zinc mineralization.

Geophysical Studies

Gravity and Aeromagnetics

The New Water Mountains Wilderness Study Area is covered by regional gravity (Lyonski and others, 1980; Aiken and others, 1981; U.S. Defense Mapping Agency Aerospace Center, 1974, 1975) and magnetic (LKB Resources, Inc., 1980) surveys having sufficient resolution to define anomalies as large as or larger than several square miles. Contours of complete (terrain-corrected) Bouguer gravity anomalies are defined by about 30 stations surrounding the study area, most of which are on the Ranegras Plain to the northeast. Contours of total-field magnetic anomalies are defined by measurements made along four east-west lines and three north-south lines, all at a nominal altitude of about 400 ft above ground. Flightlines were flown about 3 mi apart and intersecting tielines were flown about 12 mi apart. Contractor-reduced data east of longitude 114° W. were reprocessed during this study to incorporate a more accurate geomagnetic reference field and to smooth the effects of flightline location errors. Contours derived from this reprocessing were later visually merged with contours west of longitude 114° W.

A prominent gravity high (fig. 3) in the Plomosa and New Water Mountains is associated with fairly dense

Proterozoic, Paleozoic, and Mesozoic metamorphosed intrusive and sedimentary rocks. Gravity anomaly values decrease gently to the southeast where Tertiary volcanic rocks of the New Water Mountains crop out and decrease more rapidly to the northeast where Tertiary and Quaternary alluvium form the Ranegras Plain. Our model of the gravity data suggests that the alluvium reaches a thickness of 600 ft adjacent to the study area, and it is likely thicker than 1,300 ft in the center of the Ranegras Plain. This model assumes a density contrast of 0.35–0.40 grams/cubic centimeter between the basin fill and bounding rocks, which is consistent with the analysis by Oppenheimer and Sumner (1980).

The aeromagnetic anomaly map (fig. 4) shows broadly northwest-trending contours that slope down to the southwest. The prominent magnetic high in the northeast corner of figure 4 corresponds to the Bear Hills (fig. 1), a northwest-trending fault block of Tertiary volcanic (chiefly basalt) and sedimentary rocks (R.D. Koch, unpublished data, 1985). Our modeling suggests that the source there could have an average total magnetization (scalar sum of induced and normally polarized remanent magnetization) of about 4.5 Amperes/meter and a ratio of remanent to induced magnetization of about 0.12—that is, about twice as magnetic as some altered basalts or unaltered basaltic andesite of southwestern Arizona (Klein and Johnson, 1983) but only half as magnetic as some unaltered basalt from other parts of Arizona and New Mexico. The aeromagnetic data suggest that the volcanic rocks of the Bear Hills extend along strike to the southeast beneath a shallow cover of alluvium in the Ranegras Plain.

The gravity and magnetic anomaly data are much too sparsely distributed to permit correlation of anomalies with mineral occurrences associated with mines and prospects adjacent to the study area. In the regional geophysical data, known mineral occurrences tend to underlie flanks of anomalies instead of the anomaly maxima or minima. Because nothing more definitive than this gross correlation can be ascertained, the regional geophysical data do not point to mineral occurrences within the study area.

Gamma-Ray Spectrometry

Knowledge of natural radioelement distribution in the New Water Mountains Wilderness Study Area is based on aerial gamma-ray spectrometry surveys of the Phoenix and Salton Sea 1° x 2° quadrangles (LKB Resources, Inc., 1980). These surveys acquired gamma-ray data along 3-mi-spaced east-west (Phoenix) and north-south (Salton Sea) flightlines at 400 ft above ground level. These flightlines provided only about 6 percent coverage of each quadrangle because a detector flown at 400 ft measures gamma radiation from an 800-ft-wide swath along a flightline. The coverage represents a reconnaissance sampling of the near-surface (0- to 1- 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.

The New Water Mountains are characterized by radioelement concentrations of 1.0–2.5 percent K, 3–5 ppm eU, and 6–12 ppm eTh. These concentrations are expected levels for the Proterozoic and Phanerozoic sedimentary and igneous rocks that crop out in the study area. Generally, the higher concentrations relate to more silicic, more radioactive igneous rocks and detritus derived from them; lower concentrations relate to less silicic, less radioactive igneous rocks and their detritus. The sparse flightline coverage of the study area precludes making a more specific assessment of the mineral resource potential from the aerial gamma-ray data.

Electrical Geophysics

Electrical (telluric) geophysical survey lines that crossed the northern boundary of the study area indicate that some faults in Tertiary rocks extend slightly beyond their inferred limits shown on figure 2 (D.B. Hoover, written commun., 1988). The data also indicate greater struc-

tural complexity than can be shown in the McCoy Mountains Formation. It is perhaps surprising that there is virtually no electrical signature of the main northwest-trending fault that separates Tertiary volcanic rocks from the McCoy Mountains Formation at the two points where the telluric lines cross the fault (D.B. Hoover, written commun., 1988). No lines traversed this fault where it is mineralized (for example, at the Ramsey mine).

Mineral and Energy Resources of the New Water Mountains Wilderness Study Area

Sedimentary-Rock-Hosted Gold and Silver

The Black Mesa and Six Price mines, which are near the western and northern boundaries of the study area, respectively, were excavated along polymetallic carbonate-replacement deposits developed in Paleozoic marble and dolomite (Bagby and others, 1987, domain III). These mines yielded a low tonnage of gold and silver ore with by-product lead and copper (Keith, 1978). The dolomite and

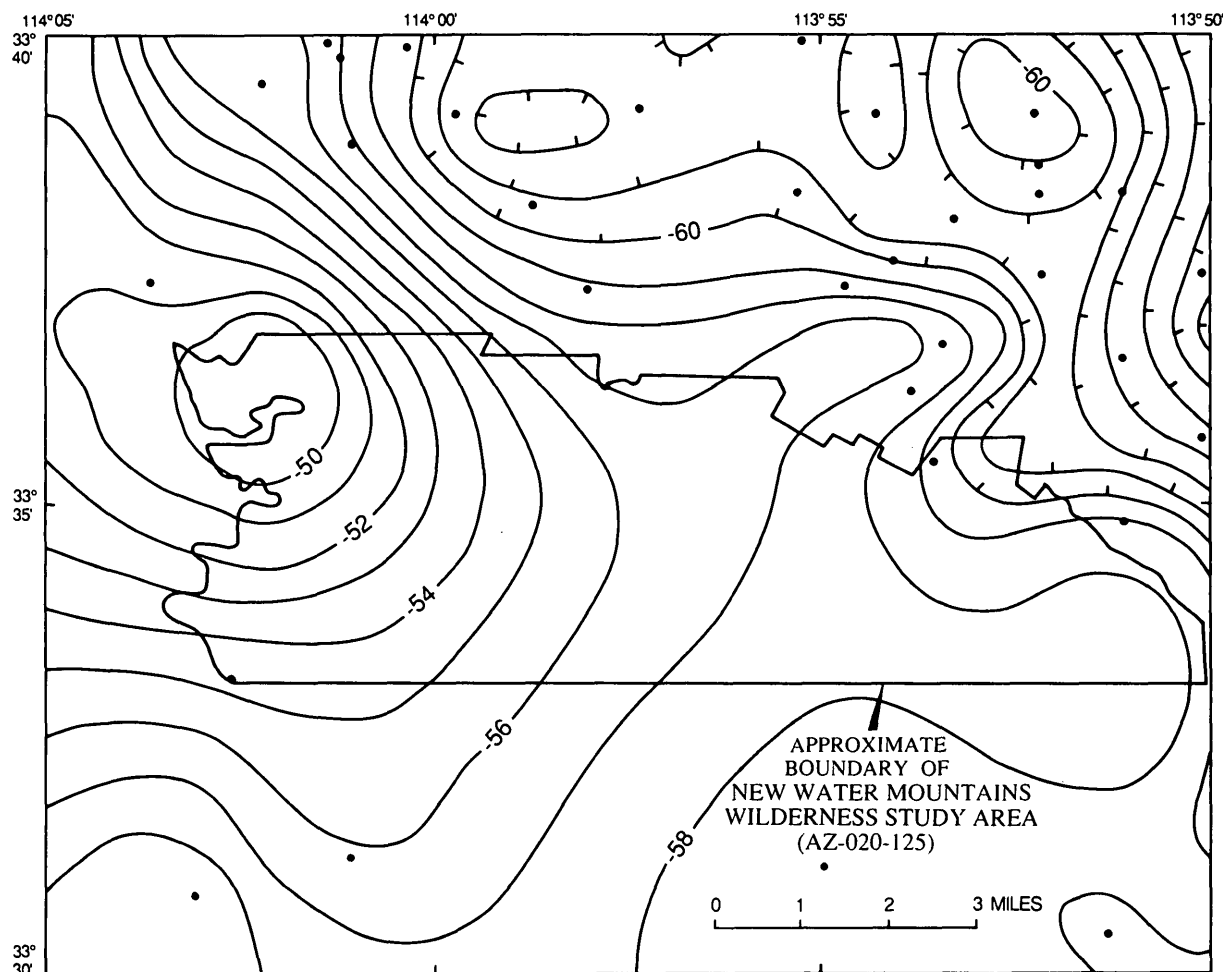


Figure 3. Complete Bouguer gravity anomaly map of New Water Mountains Wilderness Study Area. Contour interval 1 milligal. Hachures indicate area of lower anomaly values; dots indicate gravity stations.

marble extend into the western part of the study area and probably continue under Black Mesa, but they are cut off at shallow depths by the Poorman thrust, which projects to the surface on the south slope of Black Mesa (Miller, 1970; Reynolds and others, 1986; Sherrod and Koch, 1987).

The western part of the study area is defined as having anomalous gold, silver, zinc, arsenic, and lead concentrations on the basis of stream-sediment samples and heavy-mineral concentrates. Field evidence indicates that the mineralization is spotty and discontinuous at the surface (Keith, 1978; this report). A moderate resource potential, certainty level C, for sedimentary-rock-hosted gold and silver is assigned to the northwestern part of the New Water Mountains Wilderness Study Area, corresponding to the area underlain by Paleozoic carbonate rocks (fig. 2). Any deposits that are present will most likely be small and

difficult to prospect, even using sophisticated geophysical methods.

Epithermal Gold and Silver

Gold and silver mineralization is found at several places along or near range-bounding normal faults outside the northeastern boundary of the study area. These deposits are epithermal and probably formed by water-dominated geothermal systems; the faults provided avenues for the upwelling hot water (Bagby and others, 1987, domain II and unspecified domain for polymetallic veins). Geochemical anomalies and field evidence indicate that alteration and mineralization extend along faults into two parts of the study area.

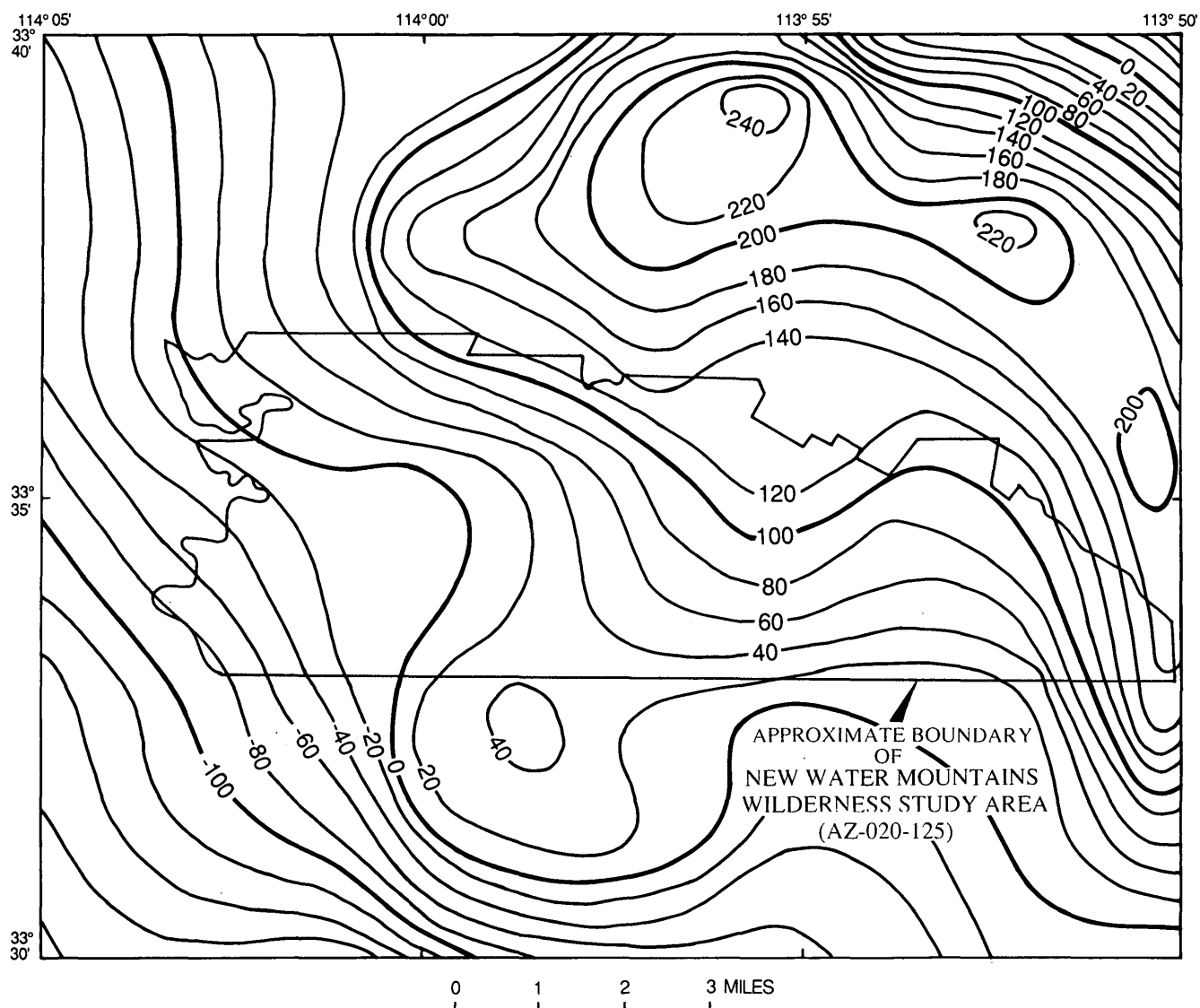


Figure 4. Aeromagnetic anomaly map of New Water Mountains Wilderness Study Area. Contour interval 20 nanoteslas.

The first area is in the northeastern part of the study area, near the Eagle Eye mine (fig. 1) (the mine is outside the study area). Sediment samples from drainages in this area have low-level anomalies for arsenic, silver, and zinc; the heavy-mineral concentrates contain anomalous concentrations of arsenic and lead. Some of the rhyolite in this area is visibly altered, and one rock sample contains anomalous concentrations of silver, arsenic, lead, manganese, and copper. The alteration forms narrow zones along normal faults. This area is assigned a moderate resource potential, certainty level C, for gold and silver (fig. 2).

The second area parallels a normal fault in the south-central part of the study area. This area is not visibly altered, but sediment and concentrate samples from several drainages that cross the fault have geochemical anomalies for arsenic and silver, as discussed in the "Geochemistry" section. Because the area lacks visible signs of alteration or mineralization, it is assigned a low potential, certainty level C, for gold and silver (fig. 2).

A third area is delineated on the basis of stream-sediment samples containing anomalous concentrations of gold, silver, zinc, and arsenic. This area lies in the northwestern part of the study area, and has moderate potential for gold and silver, certainty level C.

A fourth area was delineated on the basis of copper-stained quartz veins distributed sporadically in the Mesozoic McCoy Mountains Formation south of the Ramsey mine (fig. 1). Shallow prospecting holes have been dug along veins containing small amounts of pyrite, galena, sphalerite, and copper-bearing minerals; the pyrite may be auriferous. The veins could be either epithermal or metamorphic in origin (Bagby and others, 1987, domain II or VII) and are probably the source of the geochemical anomalies in sediment and concentrate samples collected from the area. Minus-80-mesh sediment from this area contains slightly anomalous amounts of arsenic and zinc; some of the heavy-mineral concentrates contain lead. Gold was detected in trace amounts in one sample of sediment. These veins are small, irregular, and discontinuous. A low resource potential for gold and silver, certainty level D, is assigned to the area underlain by the McCoy Mountains Formation northeast of Black Mesa (fig. 1), in the north-central part of the study area (fig. 2).

Copper and Manganese

Copper mineralization in and near the study area is spotty and scattered but it locally forms small high-grade chimneys of ore-grade copper deposits in fracture veins and pipes in the Tertiary volcanic rocks just beyond the north and east margins of the study area and in the northeastern corner of the study area (Keith, 1978; this report). Sooty manganese oxides coat many fracture surfaces in this area but form small deposits. The northeastern part of the study area is assigned a low resource potential, certainty level C, for copper and manganese (fig. 2).

Lead and Zinc

Lead and zinc, chiefly in galena and sphalerite, respectively, are present in very small amounts with the gold, silver, copper, and manganese mineralization of the study area. Anomalous concentrations of lead and zinc are contained in sediment samples and heavy-mineral concentrates from many gulleys that drain mineralized areas. The mineralized areas are small and discontinuous. For these reasons, a low resource potential for lead and zinc, certainty level C, is assigned to those parts of the study area that have resource potential for gold, silver, copper, and manganese (fig. 2).

Geothermal Energy

The New Water Mountains are in the Basin and Range physiographic province, which is characterized by high regional heat flow. Heat-flow values of 101 milliwatts per square meter (mW/m^2) were measured 20 mi west of the study area and values of 100–150 mW/m^2 were measured 80 mi east (Muffler, 1979). The Ranegras Plain, which borders the New Water Mountains on the northeast, is considered "favorable for the discovery and development of local sources of low-temperature (less than 90 °C) geothermal water" (Sammel, 1979). The Ranegras Plain contains no thermal springs, but shallow wells (80- to 1,000-ft deep) have tapped water with temperatures of 27–35 °C. The water, heated during deep circulation, probably rises along range-bounding faults. Water of such low temperature could be used in space heating, agriculture, and perhaps industry. No igneous-related geothermal systems occur within 100 mi of the study area (Muffler, 1979).

Thermal aquifers of the Ranegras Plain lie chiefly in Tertiary and Quaternary alluvial fill and are outside the study area. The major range-bounding fault along the northeast margin of the study area conceivably may have thermal fluids convecting near it on the basis of its proximity to the Ranegras Plain. Therefore, a low potential, certainty level C, for geothermal energy is assigned to the area northeast of that fault along the eastern boundary of the study area (fig. 2).

Oil and Gas

The New Water Mountains Wilderness Study Area is in a part of the Basin and Range physiographic province that is considered to have low or zero potential for oil and gas (Ryder, 1983). There are no tar or oil seeps, black shales, or other evidence of hydrocarbon source beds in the exposed sedimentary strata of the study area. The Paleozoic marine rocks exposed there are thin and structurally disrupted by the thrust faults of the Maria fold belt (Reynolds and others, 1986). The Mesozoic rocks, though chiefly deposited subaerially, include lacustrine rocks as well. The lacustrine strata contain some fossil sponges,

fish scales, and gastropod remains (Miller, 1966; Sherrod and Koch, 1986), but they are not notably fossiliferous and are also structurally disrupted. The Tertiary alluvial fill of Ranegras Plain may have limited potential for oil or gas, but these rocks about the New Water Mountains and do not extend beneath them.

Oil plays would be based on the possibility of pre-Tertiary source rocks underlying the thrust faults in the study area, for which there is no geologic or geophysical evidence. Therefore, the New Water Mountains Wilderness Study Area has low potential, certainty level C, for oil and gas resources (fig. 2).

Lime

Lime (from limestone or marble) is used for agricultural purposes and for the production of cement, but its bulk and low unit value limit the distance over which it can be transported economically. Also, the purity of lime is an important consideration to its resource potential.

Dolomite and marble form part of the Paleozoic sedimentary sequence exposed in the northwest part of the study area. They were not analyzed for this study. Therefore, there is unknown resource potential, certainty level A, for lime assigned to the northwestern part of the study area (fig. 2). Regardless of purity, the dolomite and marble are subeconomic at this time.

REFERENCES CITED

- Adrian, B.M., Smith, D.B., Hill, R.H., Roemer, T.A., Vaughn, R.B., and Delaney, T.A., 1987, Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, and rock samples from the New Water Mountains Wilderness Study Area, La Paz County, Arizona: U.S. Geological Survey Open-File Report 87-339, 22 p.
- Aiken, C.L.V., Lysonski, J.C., Sumner, J.S., and Hahman, W.R., 1981, A series of 1:250,000 complete residual Bouguer gravity anomaly maps of Arizona: Arizona Geological Society Digest, v. 13, p. 31-37.
- Bagby, W.C., Haxel, G.B., Smith, D.B., Koch, R.D., Grubensky, M.J., Sherrod, D.R., and Pickthorn, L.G., 1987, Mineral resource assessment of the Kofa National Wildlife Refuge, Arizona: U.S. Geological Survey Open-File Report 87-609, 71 p.
- Beikman, H.M., Hinkle, M.E., Frieders, Twila, Marcus, S.M., and Edward, J.R., 1983, Mineral surveys by the Geological Survey and the Bureau of Mines of Bureau of Land Management Wilderness Study Areas: U.S. Geological Survey Circular 901, 28 p.
- Bugrov, V.A., and Shalaby, I.M., 1975, Geochemical prospecting in the eastern desert of Egypt, in Elliott, I.L., and Fletcher, W.K., eds., Geochemical exploration, 1974: Rexdale, Ontario, Association of Exploration Geochemists, p. 523-530.
- Davis, G.M., 1985, Geology of the southern Plomosa Mountains: Tempe, Ariz., Arizona State University, M.S. thesis, 158 p.
- Eberly, L.D., and Stanley, T.B., Jr., 1978, Cenozoic stratigraphy and geologic history of southwestern Arizona: Geological Society of America Bulletin, v. 89, no. 1, p. 921-940.
- Goudarzi, G.H., 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-787, 51 p.
- Harding, L.E., 1978, Petrology and tectonic setting of the Livingston Hills Formation, Yuma County, Arizona: Tucson, Ariz., University of Arizona, M.S. thesis, 57 p.
- 1980, Petrology and tectonic setting of the Livingston Hills Formation, Yuma County, Arizona, in Jenney, J.P., and Stone, Claudia, eds., Studies in western Arizona: Arizona Geological Society Digest, v. 12, p. 135-145.
- 1982, Tectonic significance of the McCoy Mountains Formation, southwestern Arizona: Tucson, Ariz., University of Arizona, Ph.D. dissertation, 197 p.
- Harding, L.E., and Coney, P.J., 1985, The geology of the McCoy Mountains Formation, southeastern California and southwestern Arizona: Geological Society of America Bulletin, v. 96, no. 6, p. 755-769.
- Keith, S.B., 1978, Index of mining properties in Yuma County, Arizona: Arizona Bureau of Geology and Mineral Technology Bulletin 192, 185 p.
- Klein, D.P., and Johnson, G.R., 1983, Density, porosity, and magnetic properties of rock specimens from southwestern Arizona: U.S. Geological Survey Open-File Report 83-808, 31 p.
- Lane, M.E., 1986, Mineral investigation of a part of the New Water Mountains Wilderness Study Area (AZ-020-125), La Paz County, Arizona: U.S. Bureau of Mines, Mineral Land Assessment Open-File Report 57-86, 25 p.
- LKB Resources, Inc., 1980, National Uranium Resource Evaluation aerial gamma-ray and magnetic reconnaissance survey, Colorado/Arizona area, Salton Sea, El Centro, Phoenix, Ajo, and Lukeville quadrangles-Final report: U.S. Department of Energy Grand Junction Office Report GJBX 12-80, v. 2, scale 1:500,000.
- Lysonski, J.C., Sumner, J.S., Aiken, C.L.V., and Schmidt, J.S., 1980, Complete residual Bouguer gravity anomaly map of Arizona: Arizona Bureau of Geology and Mineral Technology, scale 1:500,000.
- McKelvey, V.E., 1972, Mineral resource estimates and public policy: American Scientist, v. 60, p. 32-40.
- Miller, F.K., 1966, Structure and petrology of the southern half of the Plomosa Mountains, Yuma County, Arizona: Stanford, Calif., Stanford University, Ph.D. dissertation, 107 p.
- 1970, Geologic map of the Quartzsite quadrangle, Yuma County, Arizona: U.S. Geological Survey Geologic Quadrangle Map GQ-841, scale 1:62,500.
- Muffler, L.J.P., ed., 1979, Assessment of geothermal resources of the United States—1978: U.S. Geological Survey Circular 790, plate 1.
- Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range province, Arizona: Tucson, Ariz., University of Arizona Laboratory of Geophysics, scale 1:500,000.
- Overstreet, W.C., and Marsh, S.P., 1981, Some concepts and techniques in geochemical exploration, in Skinner, Brian, ed., Economic Geology 75th Anniversary Volume: New Haven, Conn., p. 775-805.
- Reynolds, S.J., Spencer, J.E., Richard, S.M., and Laubach, S.E.,

- 1986, Mesozoic structures in west-central Arizona, *in* Beatty, Barbara, and Wilkinson, P.A.K., eds., *Frontiers in geology and ore deposits of Arizona and the southwest*: Arizona Geological Society Digest, v. 16, p. 35–51.
- Robison, B.A., 1979, Stratigraphy and petrology of some Mesozoic rocks in western Arizona: Tucson, Ariz., University of Arizona, M.S. thesis, 154 p.
- 1980, Description and analysis of Mesozoic "Red Beds," western Arizona and southeastern California, *in* Jenney, J.P., and Stone, Claudia, eds., *Studies in western Arizona*: Arizona Geological Society Digest, v. 12, p. 147–154.
- Ryder, R.T., 1983, Petroleum potential of wilderness lands in Arizona, *in* Petroleum potential of wilderness lands in the western United States: U.S. Geological Survey Circular 902, p. C1–C22.
- Sammel, E.A., 1979, Occurrence of low-temperature geothermal waters in the United States, *in* Muffler, L.J.P., ed., *Assessment of geothermal resources of the United States—1978*: U.S. Geological Survey Circular 790, p. 86–131.
- Shafiqullah, M., Damon, P.E., Lynch, D.J., Reynolds, S.J., Rehrig, W.A., and Raymond, R.H., 1980, K-Ar geochronology and geologic history of southwestern Arizona and adjacent areas: Arizona Geological Society Digest, v. 12, p. 201–260.
- Sherrod, D.R., and Koch, R.M., 1987, Structure and stratigraphy of Mesozoic sedimentary and volcanic rocks in the New Water Mountains, southwestern Arizona, *in* Dickinson, W.R., and Klute, M.A., eds., *Mesozoic rocks of southern Arizona and adjacent areas*: Arizona Geological Society Digest, v. 18, p. 81–90.
- Spencer, J.E., and Reynolds, S.J., 1986, Some aspects of the middle Tertiary tectonics of Arizona and southeastern California, *in* Beatty, Barbara, and Wilkinson, P.A.K., eds., *Frontiers in the geology and ore deposits of Arizona and the southwest*: Arizona Geological Society Digest, v. 16, p. 102–107.
- 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, 5 p.
- U.S. Defense Mapping Agency Aerospace Center, 1974, World relative gravity reference network, North America, pt. 2: U.S. Defense Mapping Agency Aerospace Center Reference Publication 25, with supplement updating gravity values to the International Gravity Standardization Net 1971, 1635 p.
- U.S. Defense Mapping Agency Aerospace Center, 1975, Holding, storage, and retrieval of gravity data: U.S. Defense Mapping Agency Aerospace Center Publication RP-75-003, 33 p.
- Witcher, J.C., Stone, Claudia, and Hahman, W.R., Sr., 1982, Geothermal resources of Arizona: Arizona Bureau of Geology and Mineral Technology, scale 1:500,000.
- Zeegers, H., Al Shanfari, S.M., Al Muflehi, Y.A., and Letalenet, J., 1985, Aspects of regional geochemical prospecting in desert conditions, *in* *Prospecting in areas of desert terrain*: London, The Institution of Mining and Metallurgy, p. 131–140.

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
↑ LEVEL OF RESOURCE POTENTIAL	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 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		Probability Range	
	Measured	Indicated	Inferred	Hypothetical
ECONOMIC	Reserves			+
MARGINALLY ECONOMIC	Marginal Reserves			
SUB-ECONOMIC	Demonstrated Subeconomic Resources			
	Inferred Reserves			
	Inferred Marginal Reserves			
	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		
	Mesozoic	Cretaceous		Late	96	
				Early		138
		Jurassic	Late	205		
			Middle		~240	
		Early	290			
		Triassic		Late	~330	
	Middle			360		
	Early	410				
	Paleozoic		Permian		Late	435
		Early	500			
		Carboniferous Periods		Pennsylvanian	Late	~570
Middle			900			
Early		1600				
Mississippian			Late	2500		
		Early	3000			
Devonian		Late		3400		
Silurian		Middle	4550			
Ordovician		Early				
Cambrian						
Proterozoic	Late Proterozoic					
	Middle Proterozoic					
	Early Proterozoic					
Archean	Late Archean					
	Middle Archean					
	Early Archean					
pre-Archean ²					(3800?)	

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

²Informal time term without specific rank.

SELECTED SERIES OF U.S. GEOLOGICAL SURVEY PUBLICATIONS

Periodicals

- Earthquakes & Volcanoes (issued bimonthly).
- Preliminary Determination of Epicenters (issued monthly).

Technical Books and Reports

Professional Papers are mainly comprehensive scientific reports of wide and lasting interest and importance to professional scientists and engineers. Included are reports on the results of resource studies and of topographic, hydrologic, and geologic investigations. They also include collections of related papers addressing different aspects of a single scientific topic.

Bulletins contain significant data and interpretations that are of lasting scientific interest but are generally more limited in scope or geographic coverage than Professional Papers. They include the results of resource studies and of geologic and topographic investigations; as well as collections of short papers related to a specific topic.

Water-Supply Papers are comprehensive reports that present significant interpretive results of hydrologic investigations of wide interest to professional geologists, hydrologists, and engineers. The series covers investigations in all phases of hydrology, including hydrogeology, availability of water, quality of water, and use of water.

Circulars present administrative information or important scientific information of wide popular interest in a format designed for distribution at no cost to the public. Information is usually of short-term interest.

Water-Resources Investigations Reports are papers of an interpretive nature made available to the public outside the formal USGS publications series. Copies are reproduced on request unlike formal USGS publications, and they are also available for public inspection at depositories indicated in USGS catalogs.

Open-File Reports include unpublished manuscript reports, maps, and other material that are made available for public consultation at depositories. They are a nonpermanent form of publication that may be cited in other publications as sources of information.

Maps

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

Geophysical Investigations Maps are on topographic or planimetric bases at various scales; they show results of surveys using geophysical techniques, such as gravity, magnetic, seismic, or radioactivity, which reflect subsurface structures that are of economic or geologic significance. Many maps include correlations with the geology.

Miscellaneous Investigations Series Maps are on planimetric or topographic bases of regular and irregular areas at various scales; they present a wide variety of format and subject matter. The series also includes 7 1/2-minute quadrangle photogeologic maps on planimetric bases which show geology as interpreted from aerial photographs. Series also includes maps of Mars and the Moon.

Coal Investigations Maps are geologic maps on topographic or planimetric bases at various scales showing bedrock or surficial geology, stratigraphy, and structural relations in certain coal-resource areas.

Oil and Gas Investigations Charts show stratigraphic information for certain oil and gas fields and other areas having petroleum potential.

Miscellaneous Field Studies Maps are multicolor or black-and-white maps on topographic or planimetric bases on quadrangle or irregular areas at various scales. Pre-1971 maps show bedrock geology in relation to specific mining or mineral-deposit problems; post-1971 maps are primarily black-and-white maps on various subjects such as environmental studies or wilderness mineral investigations.

Hydrologic Investigations Atlases are multicolored or black-and-white maps on topographic or planimetric bases presenting a wide range of geohydrologic data of both regular and irregular areas; principal scale is 1:24,000 and regional studies are at 1:250,000 scale or smaller.

Catalogs

Permanent catalogs, as well as some others, giving comprehensive listings of U.S. Geological Survey publications are available under the conditions indicated below from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225. (See latest Price and Availability List.)

"**Publications of the Geological Survey, 1879-1961**" may be purchased by mail and over the counter in paperback book form and as a set of microfiche.

"**Publications of the Geological Survey, 1962-1970**" may be purchased by mail and over the counter in paperback book form and as a set of microfiche.

"**Publications of the U.S. Geological Survey, 1971-1981**" may be purchased by mail and over the counter in paperback book form (two volumes, publications listing and index) and as a set of microfiche.

Supplements for 1982, 1983, 1984, 1985, 1986, and for subsequent years since the last permanent catalog may be purchased by mail and over the counter in paperback book form.

State catalogs, "List of U.S. Geological Survey Geologic and Water-Supply Reports and Maps For (State)," may be purchased by mail and over the counter in paperback booklet form only.

"**Price and Availability List of U.S. Geological Survey Publications**," issued annually, is available free of charge in paperback booklet form only.

Selected copies of a monthly catalog "New Publications of the U.S. Geological Survey" available free of charge by mail or may be obtained over the counter in paperback booklet form only. Those wishing a free subscription to the monthly catalog "New Publications of the U.S. Geological Survey" should write to the U.S. Geological Survey, 582 National Center, Reston, VA 22092.

Note.--Prices of Government publications listed in older catalogs, announcements, and publications may be incorrect. Therefore, the prices charged may differ from the prices in catalogs, announcements, and publications.

